SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

SCHEDULE 6

SPECIFICATIONS AND DRAWINGS

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

SCHEDULE 6

SPECIFICATIONS AND DRAWINGS

SP1 SPECIFICATIONS

1.1 Specifications

The following documents (the “**Specifications**”) are incorporated into and included with this Schedule 6 [Specifications and Drawings] by reference:

(a) Appendix 6-1 [General Specifications (SPGS)];

(b) Appendix 6-2 [General Technical Specifications (SPGT)];

(c) Appendix 6-3 [Turbine Specifications (SPT)];

(d) Appendix 6-4 [Governor System Specifications (SPGOV)];

(e) Appendix 6-5 [Generator Specifications (SPG)]; and

(f) Appendix 6-6 [Excitation System Specifications (SPEXC)].

1.2 Read Together

The Specifications are complementary and will be read and interpreted together and what is required by any one Specification will be deemed to be required by all Specifications.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-1

GENERAL SPECIFICATIONS (SPGS)

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-1

GENERAL SPECIFICATIONS (SPGS)

SPGS1 DEFINITIONS AND INTERPRETATION

1.1 Definitions

In this Appendix 6-1 [General Specifications (SPGS)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Apex Reports**" has the meaning set out in SPGS 12.10;

"**As-Built Drawings**" has the meaning set out in SPGS 7.2.12(d);

"**BC Hydro Drawing Border**" has the meaning set out in SPGS 7.2.19(a)(v);

"**BC Hydro Title Block**" has the meaning set out in SPGS 7.2.13(a);

"**Bill of Materials**" or "**BoM**" has the meaning set out in SPGS 7.3.3;

"**Block Diagrams**" has the meaning set out in SPGS 7.2.10;

"**Cable Schedule**" has the meaning set out in SPGS 7.3.5(a);

"**Calculation**" has the meaning set out in SPGS 7.3.2(a);

"**Commissioning Report**" has the meaning set out in SPGS 6.13.1;

"**Completion Design**" has the meaning set out in SPGS 5.2(c);

"**Construction Revision Drawing**" has the meaning set out in SPGS 7.2.12(b);

"**Contractor's Title Block**" has the meaning set out in SPGS 7.2.13(b);

"**Design Change Notice**" or "**DCN**" has the meaning set out in SPGS 5.4.1;

"**Design Commitment**" has the meaning set out in SPGS 8.4;

"**Design Review**" has the meaning set out in SPGS 8.2.1;

"**Design Submittals**" means any Drawings, Explanatory Documents and other information required to be prepared by the Contractor and submitted to Hydro's Representative under the Specifications;

"**Detailed Design**" has the meaning set out in SPGS 5.2(b);

"**Detailed Design Drawings**" has the meaning set out in SPGS 7.2.4;

"**Drawing**" has the meaning set out in SPGS 7.2.1;

"**Drawing List**" has the meaning set out in SPGS 7.2.14(b);

"**Drawing Number**" has the meaning set out in SPGS 7.2.14(a);

"**Electrical Load Schedule**" has the meaning set out in SPGS 7.2.11;

"**Electrical Schematics**" has the meaning set out in SPGS 7.2.8;

"**Electrical Wiring Diagrams**" has the meaning set out in SPGS 7.2.9;

"**Explanatory Documents**" has the meaning set out in SPGS 7.3.1;

"**Final Design**" has the meaning set out in SPGS 5.2(d);

"**General Arrangement Drawings**" has the meaning set out in SPGS 7.2.3;

"**Group A**" has the meaning set out in SPGS 2.3;

"**Group B**" has the meaning set out in SPGS 2.4;

"**Group C**" has the meaning set out in SPGS 2.5;

"**Group D**" has the meaning set out in SPGS 2.6;

"**Group E**" has the meaning set out in SPGS 2.7;

"**Group F**" has the meaning set out in SPGS 2.8;

"**Group H**" has the meaning set out in SPGS 2.10;

"**Group I**" has the meaning set out in SPGS 2.11;

"**Group J**" has the meaning set out in SPGS 2.12;

"**Group K**" has the meaning set out in SPGS 2.13;

"**Group L**" has the meaning set out in SPGS 2.14;

"**Group M**" has the meaning set out in SPGS 2.15;

"**Hazard Log**" has the meaning set out in SPGS 7.3.4;

"**Initial Design**" has the meaning set out in SPGS 5.2(a);

"**Issued for Construction Drawings**" or "**IFC Drawings**" has the meaning set out in SPGS 7.2.12(a);

"**Issued for Record Drawings**" or "**IFR Drawings**" has the meaning set out in SPGS 7.2.12(e);

"**ITP Register**" has the meaning set out in SPGS 6.5;

"**LaSalle Report**" means the report prepared by the LaSalle Consulting Group setting out the results of the model test(s) of the Site C Dam;

"**Major Component**" means each Turbine, Governor System, Generator or Excitation System, as applicable;

“**Major Sub-Component**” means significant, large, complex or key components of the Equipment, such as the Turbine or Generator embedded components, Turbine runner, Turbine wicket gates, Governor hydraulic unit, Generator stator frame, Generator stator core, Generator stator winding, Generator rotor spider, Generator rotor rim, Generator rotor poles, Exciter transformer and Exciter rectifier;

“**Manufacturer Kick-Off Meeting**” has the meaning set out in SPGS 6.2;

“**Mechanical Schematics**” has the meaning set out in SPGS 7.2.7;

“**Operations and Maintenance Manual**” or “**Manual**” has the meaning set out in SPGS 7.3.12;

“**Organizational Chart**” has the meaning set out in SPGS 3.1.1;

“**Others**” means BC Hydro’s own forces or a separate person, firm or corporation having a contract with BC Hydro to carry out work related to the Project;

“**Parts List**” has the meaning set out in SPGS 7.3.3;

“**Photos**” has the meaning set out in SPGS 7.3.13(a);

“**Procedure**” has the meaning set out in SPGS 7.3.8;

“**Quality Release**” has the meaning set out in SPGS 6.11;

“**Redline Drawing**” has the meaning set out in SPGS 7.2.12(c);

“**Reliability Centred Maintenance Sheet**” or “**RCM Sheet**” has the meaning set out in SPGS 7.3.6(b);

“**Report**” has the meaning set out in SPGS 7.3.11;

“**Risk Management Plan**” or “**RMP**” has the meaning set out in SPGS 4.2;

“**Risk Register**” has the meaning set out in SPGS 4.2(b)(iv);

“**Safety by Design Plan**” or “**SbDP**” has the meaning set out in SPGS 4.5;

“**Shop Drawings**” has the meaning set out in SPGS 7.2.6;

“**Site C Component Hierarchy**” has the meaning set out in SPGS 7.2.16(b);

“**Technical Submittal Schedule**” has the meaning set out in SPGS 8.3.2;

“**Tetra Tech Report**” has the meaning set out in SPGS 12.10; and

“**Three Dimensional Drawing**” has the meaning set out in SPGS 7.2.5(a).

1.2 Interpretation

In all of the Specifications, including this Appendix 6-1 [General Specifications (SPGS)]:

(a) the descriptions of the scope of Work set out the minimum requirements for the Work and will not be interpreted in any way as including the complete details of the Work required to be performed by the Contractor, but, as the context allows, will be interpreted in accordance with SPGT 3 of Appendix 6-2 [General Technical Specifications (SPGT)] and interpreted to include those details that an experienced manufacturer and supplier of equipment similar to the Equipment would provide in the supply of such equipment;

(b) wherever the words “directed”, “required”, “permitted”, “approved”, “approval”, “specified”, “accepted” or “acceptance” are used, such words, as the context allows, will be deemed to be followed by the words “by Hydro’s Representative”;

(c) wherever the words “submit”, “submitted” or “submission” are used, such words, as the context allows, will be deemed to be followed by the words “to Hydro’s Representative”;

(d) wherever the words “one Unit” are used, such words, as the context allows, will be read as “each Unit”;

(e) except as may be expressly permitted under the Contract Documents, the Contractor may not deviate from the Specifications unless such deviations are approved by BC Hydro and such deviations are equal to or better than as specified;

(f) an Equivalent may not be incorporated into the Work unless and until the Contractor receives a written amendment to the applicable Specification or Drawing, as the case may be, identifying the approved substitution from Hydro’s Representative;

(g) any reference to “Ministry of Highways and Transportation Representative” will be deemed to be a reference to Hydro’s Representative;

(h) no revision of any Specification or Drawing that has been issued or approved by Hydro’s Representative will be valid unless and until the revision is approved by Hydro’s Representative in writing;

(i) any requirement for Work on Site to be approved or accepted by BC Hydro, including Hydro’s Representative, before proceeding will be deemed to be a Hold Point; and

(j) any reference to the Work or the performance of the Work will be deemed to include Work to be performed by a Subcontractor.

1.3 Abbreviations

Where the context allows, wherever the following abbreviations and technical terms appear in the Specifications, they will have the corresponding meanings shown below:

Abbreviation	Full Term
AGMS	Airgap Monitoring System
APEGBC	Association of Professional Engineers and Geoscientists of British Columbia
ANSI	American National Standards Institute
ASHRAE	American Society of Heating Refrigeration and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CEA	Canadian Electrical Association
CEMA	Canadian Electrical Manufacturer’s Association
CGSB	Canadian General Standards Board

Abbreviation	Full Term
CSA	Canadian Standards Association
CT	Current Transformer
EEMAC	Electrical and Electronic Manufacturers’ Association of Canada
ES	BC Hydro’s Engineering Standards
HMI	Human Machine Interface
HPU	Hydraulic Power Unit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers Inc.
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
MOV	Metal Oxide Varistor
MSDS	Material Safety Data Sheet
NBCC	National Building Code of Canada
NCR	Non-conformity Report
NERC	North American Reliability Council
OSH	BC Hydro’s Occupational Safety Health Standards
PD	Partial Discharge
PDMS	Partial Discharge Monitoring System
PLC	Programmable Logic Controller
PSS	Power System Stabilizer
QA	Quality Assurance
SPR	BC Hydro’s Safety Practice Regulations
SSMP	Site Safety Management Program
SSPC	Steel Structures Painting Council
VT	Voltage Transformer
WCB	WorkSafeBC (formerly Workers Compensation Board)
WHMIS	Workplace Hazardous Materials Information System
WPP	BC Hydro’s Work Protection Practices
WSCB	WorkSafeBC

Abbreviation	Full Term
A	ampere
BHP	brake horsepower
α	Resistivity Temperature Coefficient
dB	decibel
cm	centimetre
°C	degree Celsius

Abbreviation	Full Term
El.	The elevation in metres based on Canadian Geodetic Survey Datum
ft	foot
in	inch
H	stored energy constant
Hz	hertz (cycles per second)
J	joule
kg	kilogram
km	kilometre
kPa	kilopascal
kVA	kilo volt-ampere
kW	kilowatt
L	litre
lb	pound
lm	lumen
lx	lux
M	metre
min	minute
mm	millimetre
MVA	mega volt ampere
N	Newton
Ω	Ohm
Pa	Pascal
ppm	parts per million
rms	root mean square
r/min	revolutions per minute
s	Second
S	Siemens
t	tonne = 1000 kg
V	Volt
W	Watt

SPGS2 <u>SUBMITTALS</u>

2.1 <u>General</u>

(a) The Contractor will, for all components of the Work and without exception, submit complete and thorough design justification and documentation, including detailed Drawings and Explanatory Documents.

(b) Without limiting the requirements of any other provision of the Contract Documents relating to Submittals, including Design Submittals, the Contractor will deliver to BC Hydro the level of detail and documentation that a prudent owner would customarily receive for equipment similar to the element or component of the Equipment in accordance with Good Industry Practice.

(c) Hydro's Representative may request additional Drawings or Explanatory Documents, including Calculations, pertaining to specific details of the Equipment that Hydro's Representative may require in order to confirm or clarify details of the design, and the Contractor will provide such Drawings or Explanatory Documents without delay so as not to adversely affect the progress of the Work.

(d) If, under these Specifications, including this Appendix 6-1 [General Specifications (SPGS)], a Submittal is required to be submitted in hardcopy format, the following will apply:

(i) the Contractor will submit that Submittal electronically in accordance with Schedule 5 [Submittals Procedure];

(ii) after that Submittal has been endorsed "Accepted" or has been deemed to have been endorsed "Accepted" in accordance with Schedule 5 [Submittals Procedure], the Contractor will, in addition to SPGS 2.1(d)(i) and within 30 days of a request from Hydro's Representative, submit that Submittal in hardcopy format; and

(iii) for certainty, Hydro's Representative may defer the making of a request under SPGS 2.1(d)(ii) for any reason, including if Hydro's Representative considers, in its sole discretion or after consultation with the Contractor or Others, that any Drawing or Explanatory Document in that Submittal may for any reason require further revision and resubmission.

2.2 Technical Submittal Summary Table

The information set out in Table 2.2 below is set out for convenience only, and if there is any conflict between the information set out in Table 2.2 and any other part of the Specifications, including this Appendix 6-1 [General Specifications (SPGS)], then the Specifications will govern.

Table 2.2 – Submission Summary Table

Group (if applicable)	Group Name (if applicable) or Name of SPGS Heading Requiring Submittals	Due Date (Cross Reference)
	Contractor Management	SPGS3
	Project Planning	SPGS4
	Site Construction Requirements	SPGS11
	Infrastructure and Services at Site	SPGS13
	Infrastructure and Services within the Powerhouse	SPGS14
A	Design Interface 1 – Preliminary Version	SPGS 2.3
A	Design Interface 1 – Final Version	SPGS 2.3

B	Design Interface 2	SPGS 2.4
C	Design Interface 3	SPGS 2.5
	Design Reviews and Design Submittals	SPGS8
	Design Change Notice	SPGS 5.4
D	Initial Design	SPGS 2.6
E	Detailed Design	SPGS 2.7
F	Completion Design	SPGS 2.8
G	[Not Used]	[Not Used]
	Issued for Construction Drawings	SPGS 7.2.12(a)
H	Assembly and Installation Procedures – Preliminary Version	SPGS 2.10
I	Commissioning Procedures – Preliminary Version	SPGS 2.11
J	Operations and Maintenance Procedures and Manuals – Preliminary Version	SPGS 2.12
K	Quality, Inspection and Testing	SPGS 2.13
	Construction Revision Drawings	SPGS 7.2.12(b)
H	Assembly and Installation Procedures – Final Version	SPGS 2.10
	Shipping	SPGS12
I	Commissioning Procedures – Final Version	SPGS 2.11
	Commissioning Data, Test Results and Reports	SPGS 6.13.2
	Operations and Maintenance Procedures and Manuals – Final Version	SPGS 2.12
	Redline Drawings	SPGS 7.2.12(c)
	Issued for Record Drawings	SPGS 7.2.12(e)
L	Final Design Report	SPGS 2.14
M	Final Quality Explanatory Documents	SPGS 2.15
	Photos	SPGS 7.3.13(c)

	Training Materials	SPGS 10.3
	Final Drawings and Explanatory Documents	SPGS 2.16

2.3 Group A – Design Interface 1

"**Group A**" refers to all Drawings and Explanatory Documents required by Others to:

(a) layout and design the Powerhouse;

(b) define the overall arrangements for the Equipment;

(c) define the design criteria for the Equipment;

(d) define the principal features of Interface points, including the penstock coupling, concrete block out locations and piping and electrical interfaces; and

(e) layout and design the Balance of Plant equipment.

The Contractor will, not later than 30 days after the Effective Date, submit preliminary versions of Group A, which preliminary versions may be submitted in the Contractor's format.

The Contractor will, not later than 120 days after the Effective Date, submit final versions of Group A, formatted in accordance with the Contract Documents.

Group A will include:

(f) General Arrangement Drawings;

(g) water passage Drawings, including:

- (i) geometry of spiral case and draft tube;
- (ii) location of pier nose cap;
- (iii) the dimensions for the access passages to the Turbine Pit, draft tube door and draft tube elbow door; and
- (iv) penstock couplings;

(h) dimensioned concrete outline Drawings, including:

- (i) equipment embedments (pier nose cap, anchors, foundation bolts, piping, etc.) in first stage concrete pours;
- (ii) blockouts in first stage concrete pours for later equipment placement;
- (iii) equipment embedments (draft tube elbow, draft tube platform supports, spiral case, Turbine Pit liner, doors, anchors, foundation bolts, piping, cable conduits, base plates, etc.) in second stage concrete pours; and
- (iv) blockouts in second stage concrete pours for later equipment placement;

(i) layout and dimensions for all Major Components and Major Sub-Components, including panels and cabinets;

(j) foundation loads, including magnitude, location and direction of all static and dynamic forces transferred from the Equipment to the foundation (including load combinations);

(k) the first iteration of the Three Dimensional Drawing;

(l) preliminary nameplates for all Major Components;

(m) approximate weights of Major Sub-Components;

(n) overall single line and system block diagrams;

(o) the preliminary Electrical Load Schedule; and

(p) installation schedule.

2.4 Group B – Design Interface 2

"**Group B**" refers to all Drawings and Explanatory Documents required by Others for final layout and design of the Powerhouse.

The Contractor will, not later than 180 days after the Effective Date, submit Group B.

Group B will include:

(a) installation Procedures for all embedded parts and piping details for the Equipment required to allow placement of second stage concrete work;

(b) a list of all locations the Contractor will require Others to perform concrete backfilling and/or grouting of the Equipment;

(c) specifications and Procedures for concrete backfilling and/or placement of grout;

(d) Mechanical Schematics for piping that show the location of the Interface points for equipment provided by Others including for the:

  (i) Cooling Water System;

  (ii) Generator heat recovery system;

  (iii) Equipment drainage systems;

  (iv) Generator brake air, Governor System air and Turbine air admission systems;

  (v) Turbine air depression and air exhaust systems;

  (vi) Generator deluge systems; and

  (vii) ventilation system for the Turbine wicket gate bushing access gallery;

(e) design and performance criteria, including pipe material, pipe diameter, range of flow rates, pressure ratings, pressure drop Calculations and range of supply water temperatures as applicable for the:

(i) Cooling Water System;

(ii) Generator heat recovery system;

(iii) Equipment drainage systems;

(iv) Generator brake air, Governor System air and Turbine air admission systems;

(v) Turbine air depression and air exhaust systems;

(vi) Generator deluge systems; and

(vii) Equipment ventilation systems and/or ductwork for the ventilation systems;

(f) an updated Equipment Three Dimensional Drawing; and

(g) Drawings of Generator Stator, Generator Rotor and Turbine Shaft Lifting Devices and the preliminary version of the lifting Procedures.

2.5 Group C – Design Interface 3

"**Group C**" refers to all Drawings and Explanatory Documents required by Others for detailed design of the Powerhouse and for Interface points between the Contractor's Work and the work of Others.

The Contractor will, not later than 360 days after the Effective Date, submit Group C.

Group C will include:

(a) details of embedded and non-embedded piping, pipe sleeves, conduits, ducts and cable trays, including the location, size, length and standard and special details of supports, brackets and seismic bracing;

(b) electrical Enclosure locations;

(c) Electrical Schematics for all Enclosures with wiring that will interface with equipment provided by Others;

(d) Exciter Transformer iso-phase bus layout design and performance requirements, Interface points and connection details for electrical bus that will interface with equipment provided by Others;

(e) Generator main and neutral terminal, design and performance requirements, Interface points and connection details for electrical bus that will interface with equipment provided by Others;

(f) an updated Equipment Three Dimensional Drawing;

(g) the preliminary Cable Schedule; and

(h) technical requirements for Generator bus voltage and current transformers.

2.6 Group D – Initial Design

"**Group D**" refers to all Drawings and Explanatory Documents prepared for the Initial Design stage for each Major Component.

The Contractor will, not later than 180 days after the Effective Date, submit the Group D Submittals associated with each Major Component.

Group D will include preliminary versions of the:

(a) Calculations;

(b) Hazard Log;

(c) Detailed Design Drawings;

(d) Three Dimensional Drawing;

(e) Mechanical Schematics;

(f) Electrical Schematics;

(g) Electrical Load Schedule;

(h) Block Diagrams;

(i) Software Design Plans; and

(j) Application Configuration Files.

2.7 Group E – Detailed Design

"**Group E**" refers to all Drawings and Explanatory Documents prepared for the Detailed Design stage for each Major Component.

The Contractor will, not later than 360 days prior to the commencement of manufacture or the purchase of an Equipment component, submit the Group E Submittals associated with that Equipment component.

Group E will include:

(a) updates or additions to the Submittals listed in SPGS 2.6;

(b) additional Detailed Design Drawings; and

(c) Electrical Wiring Diagrams.

2.8 Group F – Completion Design

"**Group F**" refers to all Drawings and Explanatory Documents prepared for the Completion Design stage for each Major Component.

The Contractor will, not later than 180 days prior to the commencement of manufacture or the purchase of an Equipment component, submit the Group F Submittals associated with that Equipment component.

Group F will include updates or additions to the Submittals listed in SPGS 2.6 and SPGS 2.7, and all other Drawing Submittals that are required for procurement, manufacturing, assembly and installation of the Equipment component including:

(a) field interconnection and termination Electrical Wiring Diagrams;

(b) detailed installation Drawings, showing among other things dimensions, allowable tolerances, weld preparation, field welding details and field painting;

(c) field-run piping and conduit arrangement Drawings;

(d) list of any layout of the equipment Enclosures, instruments, cables, trays and conduits;

(e) expected noise levels for valves and fans;

(f) noise level Calculations;

(g) the Software to be provided with the Equipment; and

(h) the preliminary spare Parts List (both optional and mandatory spare parts), prepared in accordance with SPGT 2.22.1(d) of Appendix 6-2 [General Technical Specifications (SPGT)].

2.9 Group G – Not Used

2.10 Group H – Assembly and Installation Procedures

"**Group H**" refers to all Explanatory Documents that will be used to assemble and install the Equipment and all Drawings referred to in such Explanatory Documents, and includes assembly, installation and test Procedures.

The Contractor will, with or prior to submitting related Group C Submittals, submit preliminary versions of Group H.

The Contractor will, not later 60 days prior to commencement of assembly and installation of a Unit, submit final versions of Group H Submittals related to that Unit.

2.11 Group I – Commissioning Procedures

"**Group I**" refers to all Explanatory Documents that will be used to commission the Equipment and all Drawings referred to in such Explanatory Documents, and includes commissioning Procedures.

The Contractor will, with or prior to submitting related Group C Submittals, submit preliminary versions of Group I.

The Contractor will, not later 60 days prior to commencement of the commissioning of a Unit, submit final versions of Group I Submittals related to that Unit.

2.12 Group J – Operations and Maintenance Procedures and Manuals

"**Group J**" refers to all Procedures and Manuals that will be used to operate, inspect, test, maintain, assemble, disassemble and replace each Major Component, and includes (for each Major Component):

(a) the Operations and Maintenance Manual, prepared in accordance with SPGS 7.3.12;

(b) the Reliability Centred Maintenance Sheets;

(c) any special Procedures required to maintain the Equipment during the Warranty Period (if there are different requirements than what is required by the Operations and Maintenance Manual); and

(d) Drawings that are referred to in the Explanatory Documents set out in SPGS 2.12(a) through SPGS 2.12(c).

The Contractor will, with or prior to submitting related Group E Submittals, submit preliminary versions of Group J for each Major Component.

The Contractor will submit final versions of Group J Submittals related to each Major Component in accordance with the schedule set out under SPGS 7.3.12.

2.13 Group K – Quality, Inspection and Testing

"**Group K**" refers to Quality Assurance Drawings and Explanatory Documents required for the Equipment or generated as part of the Work in accordance with SPGS6 and Schedule 8 [Quality Management].

Group K includes:

(a) material safety data sheets (MSDS);

(b) Procedures for special processes, such as welding, brazing and NDE as requested;

(c) Inspection and Test Plans (ITPs);

(d) Inspection and Test Records;

(e) test equipment and instrumentation lists and calibration Reports;

(f) non-conformity reports (NCRs);

(g) Design Change Notices;

(h) Quality Progress Reports;

(i) Quality Releases;

(j) Final Quality Reports;

(k) commissioning inspections, measurements, test data, test results Reports;

(l) Photos; and

(m) Drawings that are referred to in the Explanatory Documents set out in SPGS 2.13(a) through SPGS 2.13(l).

2.14 Group L – Final Design Report

"**Group L**" refers to, for each Major Component, a complete set of all previously submitted design Explanatory Documents, including Calculations, Hazard Logs and design-related Reports produced as part of the Work, which will include the most up-to-date revision of each such Explanatory Document, bound together into a master design Report.

The Contractor will, not later than 60 days after completion of the commissioning of last Unit, submit Group L.

The Contractor will submit ten hardcopies of Group L.

2.15 Group M – Final Quality Explanatory Documents

"**Group M**" refers to a complete set of all previously submitted Group K Submittals, which will include the most up to date version of each Group K Submittal and be bound together into a master Report.

The Contractor will, not later than 60 days after completion of the commissioning of the last Unit, submit Group M.

The Contractor will submit ten hardcopies of Group M.

2.16 Final Drawings and Explanatory Documents

In addition to any requirement under the Specifications to provide hardcopies of any Submittal, no less than 90 days after completion of the commissioning of the last Unit, the Contractor will as part of the Work submit the most recent version of each Drawing and Explanatory Document that was endorsed "Accepted" or deemed to have been endorsed "Accepted" in accordance with Schedule 5 [Submittals Procedure].

A minimum of two hardcopies of each such Drawing and Explanatory Document will be submitted.

SPGS3 CONTRACTOR MANAGEMENT

3.1 Organizational Charts

3.1.1 General

The following organizational charts (each an "**Organizational Chart**") will be submitted:

(a) not later than 30 days after the Effective Date:

(i) an Organizational Chart describing the overall management structure for the performance of the Work, including the positions set out in SPGS 3.2; and

(ii) an engineering Organizational Chart describing the management and performance of the design of the Work and including what involvement design personnel will have in manufacturing and Work at Site;

(b) not less than 30 days prior to commencing procurement required in the performance of the Work, a procurement Organizational Chart describing the management and performance of the procurement and manufacturing Work;

(c) not less than 60 days prior to commencing any Work at Site, an Organizational Chart describing the management and performance of the Work at Site; and

(d) not less than 60 days prior to commencing testing and commissioning of any of the Work, including any of the Equipment, a commissioning Organizational Chart illustrating the management and performance of the commissioning Work.

3.1.2 Content

Organizational Charts will include:

(a) the names of Key Individuals and positions;

(b) reporting structure; and

(c) a description of the responsibility and authority of each person included in the Organizational Chart.

3.1.3 Curriculum Vitaes

The Contractor will provide the names of and the curriculum vitaes for the:

(a) Project Manager and other managers proposed for the Work, including the qualifications and relevant experience of each manager proposed, and references;

(b) design managers and designers proposed for the design Work, including the qualifications and relevant experience of each person proposed, and references;

(c) Site Managers proposed for the Work at Site, including the qualifications and relevant experience of each person proposed, and references.

3.2 Contractor's Management Positions

3.2.1 Management Functions

The Contractor will, not later than 30 days after the Effective Date unless expressly required otherwise in this Appendix 6-1 [General Specifications (SPGS)], submit the names and qualifications of all management personnel that are proposed for the Work, including the persons who will have responsibility for the following roles:

(a) Project Manager;

(b) Senior Design Manager;

(c) Design Engineer for the Turbine;

(d) Design Engineer for the Generator;

(e) Design Engineer for the Exciter;

(f) Design Engineer for the Governor;

(g) Commercial Manager;

(h) Procurement Manager;

(i) Quality Manager;

(j) Sourcing Quality Manager;

(k) Qualified Environmental Professional;

(l) Authorized Site Representative;

(m) Site Construction Manager;

(n) Site Technical Supervisor;

(o) Site Quality Management Representative;

(p) Site Safety Coordinator; and

(q) Lead Test Engineer.

The Contractor will identify any additional persons and functions that the Contractor plans to have a senior management role in the performance of the Work.

All persons in a management position will be fluent in the English language, both orally and in writing.

Once a person in a management position has been accepted by Hydro's Representative, the Contractor may only change such person following delivery for Review of a request justifying the change, the date the change will take effect and curriculum vitae details of the replacement.

Hydro's Representative may require the replacement of any person in a Contractor's management position who Hydro's Representative, acting reasonably, advises does not have appropriate qualifications and experience for the position, or is not performing as reasonably required to meet the Contractor's obligations under the Contract Documents

The Contractor has complete responsibility for the appointment of management personnel required for the performance of the Work. BC Hydro assumes no responsibility for the selection or performance of any of the Contractor's management personnel. By accepting a management person, or not objecting to a person's performance, BC Hydro will not be interpreted in any way to have accepted any such responsibility.

3.2.2 <u>Project Manager</u>

The Contractor will appoint a person to be the project manager who will:

(a) either be, or have immediate access to, the Contractor's Representative so as to facilitate efficient and effective communication with Hydro's Representative;

(b) have a minimum of ten years' hydroelectric or equivalent projects experience in the design, manufacturing, installation and commissioning of equipment similar to the Equipment;

(c) be the Contractor's senior manager to direct, coordinate and be responsible for all aspects of the Work including services to be provided for the Work and the timely supply of all components and aspects of the Work;

(d) provide the lead and impetus necessary to properly achieve Work objectives, key intermediate and completion milestone dates and all other Contract obligations;

(e) coordinate and direct the development and management of the overall plan for the complete performance of the Work including the design, procurement, manufacturing, delivery, installation, testing and commissioning of the Equipment and approve the individual Work component schedules;

(f) coordinate all Subcontractors;

(g) monitor the Contractor's and Subcontractors' progress with authority to decide corrective action and resolve problems that adversely affect Project objectives and Contract commitments;

(h) establish department priorities based on the Contract obligations and commitments; and

(i) have management responsibility for all project plans and Procedures required for the performance of the Work in accordance with the Contract Documents including those relating to safety, environmental protection, quality, risk and design management.

3.2.3 Design Engineers

The Contractor will appoint design engineers (DEs), including the Turbine design engineer, the Governor design engineer, the Generator design engineer and the Exciter design engineer, as follows:

(a) each will be a qualified Professional Engineer with a minimum of six years' hydroelectric or equivalent experience in the relevant discipline;

(b) each will be available as required for the uninterrupted performance of the Work, including as necessary by providing services to the Site;

(c) have responsibility to:

  (i) lead the design;

  (ii) prepare the technical concept in collaboration with the design specialists;

  (iii) provide input for the overall schedule and work breakdown structure;

  (iv) specify system components for subcontracting;

  (v) negotiate with vendors together with purchasing;

  (vi) schedule and expedite system components;

  (vii) call the design kick-off and design review meetings (design steering);

  (viii) prompt reports and documentation on quality deviations to the appropriate Key Individuals;

  (ix) provide technical inputs for claim management;

  (x) provide measures to mitigate impacts from deviations;

  (xi) ensure contractual requirements are met;

  (xii) coordinate control of supplies;

  (xiii) create of the supply plan in collaboration with the Contractor's quality management;

  (xiv) perform supplier quality control if required in supply plan;

  (xv) provide notification of ready for shipment to customer; and

  (xvi) organize customer training at the facility;

(d) coordinate with Hydro's Representative any Site visits that may be required under SPGS 3.2.3 of this Appendix 6-1 [General Specifications (SPGS)];

(e) during the performance of the Work at the Site, for each Unit, visit the Site to review the progress of the Work at all installation points key to confirm performance of the Work in accordance with the design and the Contract Documents;

(f) for each Unit, visit the Site as often as the design engineer deems required in his or her professional opinion to monitor the implementation of design, but not less than once during the assembly of each Major Component, and any other Major Sub-Component, during the course of the installation Work, and once at or near the completion of the Work, to review any deficiencies with Hydro's Representative; and

(g) for each Unit, verify to BC Hydro that the Work was carried out in accordance with the design engineer's design by preparing and submitting written Site visit Reports summarizing the design engineer's observations and any directions and modifications to the design approved by the design engineer.

3.2.4 Sourcing Quality Manager

The Contractor will appoint a sourcing quality manager (CSQM) who will:

(a) have a minimum of eight years' hydroelectric or equivalent experience with sourcing of similar Equipment;

(b) manage the Contractor's sourcing quality program and ensure a quality supply of Equipment in accordance with the requirements of the Contract Documents, including Schedule 8 [Quality Management];

(c) at all times during the course of the Work, be present at manufacturer's facilities for attendance of the Contractor's Witness Points and Hold Points (if applicable) or arrange for suitable backup personnel who have qualifications acceptable to Hydro's Representative;

(d) review all Equipment inspection and quality control documentation, non-conformity reports, manufacturer-requested changes and other documentation before submission as required by the Contract Documents;

(e) interface with Hydro's Representative or authorized delegate, for quality management regarding quality issues;

(f) attend a monthly quality review meeting with Hydro's Representative;

(g) review and confirm that all inspections, tests, non-conformance issues, factory changes and other quality issues are properly documented in accordance with the Contractor's sourcing quality program; and

(h) collect manufacturing history records to release supply.

3.2.5 Site Quality Management Representative

The Contractor will appoint a site quality representative (CSQR) who will:

(a) have a minimum of six years' hydroelectric or equivalent experience with similar installations;

(b) manage the Contractor's Site quality program and ensure a quality installation in accordance with the Contract Documents, including Schedule 8 [Quality Management];

(c) at all times during the course of the Work, be on Site, or arrange for suitable backup personnel who have qualifications acceptable to Hydro's Representative;

(d) deliver any oral and/or written communication regarding quality matters to each of Hydro's Representative for Review and to the Contractor, at the same time and without delay, including the distribution of any quality documentation, and cooperate with Hydro's Representative to verify that such communication does occur;

(e) observe and review all test and inspection activities, schedules and reporting;

(f) not carry out testing and inspection on behalf of the Contractor, even if requested by the Contractor's representatives, and leave all required testing and inspection to others appointed by the Contractor for that purpose;

(g) review all inspection and quality control and assurance documentation, non-conformity reports, field changes and other documentation before submission as required by the Contract Documents;

(h) remain independent from the front line personnel doing the assembly and installation Work;

(i) interface with Hydro's Representative, or authorized delegate, regarding quality issues;

(j) submit a monthly progress Report on Site quality management;

(k) attend a monthly quality review meeting with Hydro's Representative;

(l) independently report any observed variances or non-conformance issues directly to Hydro's Representative;

(m) review and confirm that all inspections, tests, non-conformance issues, field changes and other quality issues are properly documented in accordance with the Contractor's Site quality program; and

(n) maintain and submit updated quality documents and records.

3.2.6 Site Safety Coordinator

The Contractor will appoint a Contractor's Site safety coordinator (CSSC) who will:

(a) have a minimum of five years' experience with equivalent projects of a similar scale;

(b) be responsible to manage the Contractor's obligations for safety as set out in the Contract Documents including Schedule 10 [Safety];

(c) be familiar with the applicable occupational safety and health Laws;

(d) provide daily on-Site inspections;

(e) review Contractor's proposed work programs from a safety perspective;

(f) submit a weekly safety Report;

(g) review the Contractor's Work Procedures to ensure that qualified persons have addressed the specific Site hazards;

(h) ensure that training in necessary safety Procedures is properly conducted;

(i) participate in Contractor's tailboards;

(j) when required, conduct and document regular Site safety coordination meetings;

(k) conduct regular Site inspections with project safety coordinator;

(l) accompany WorkSafeBC on Site inspections and post the results of such inspections; and

(m) inform all safety representatives of the hazards and risks that arise at the worksite as the Work progresses.

3.2.7 Site Environmental Manager

The Contractor will appoint a Contractor's Site environmental manager (CSEM) who will perform the functions of an Environmental Monitor as set out under Schedule 7 [Environmental Obligations] and in addition to any other qualifications required under Schedule 7 [Environmental Obligations], will;

(a) have a minimum of five years' experience with equivalent projects of a similar scale;

(b) be a Qualified Environmental Professional;

(c) provide overall management of the Contractor's obligations regarding the environment as set out in the Contract Documents, including Schedule 7 [Environmental Obligations] and be familiar with the applicable environmental Laws and the Contract Documents;

(d) provide daily on-Site inspections;

(e) submit weekly Reports on environmental compliance;

(f) monitor the effectiveness of the environmental protection measures in place and ensure that the Contractor is following the environmental Procedures as required by applicable Laws and the Contract Documents;

(g) ensure that the Contractor is taking care to avoid unnecessary damage or disturbance to the environment and that any damage caused is corrected; and

(h) participate in the Contractor's tailboards.

3.2.8 Site Construction Manager

The Contractor will appoint a Contractor's Site Construction manager (CSCM) who will:

(a) have a minimum of eight years' hydroelectric or equivalent experience in the installation of equipment similar to that which is called for in the Contract;

(b) oversee all activities of Work at the Site. The installation trades personnel will report directly to the CSCM;

(c) prepare, on an ongoing basis, general layout and work schedule for laydown, assembly and installation areas;

(d) on a daily basis, review and establish the composition of trades personnel for specific aspects of the Work including varying crew sizes to meet the requirements of the Contract Documents;

(e) direct disciplinary action, if necessary;

(f) coordinate the Work with the work of Others that have Interfaces with the Work, including as described in Appendix 4-8 [Interface Requirements];

(g) provide scheduling and tracking information on a daily basis and participate in the preparation of look ahead schedules and crane utilization schedules as required by the Contract Documents including Schedule 4 [Work Program and Schedule];

(h) ensure each trades personnel meets minimum qualifications as specified in the Contract;

(i) establish training with support from the Contractor's Site technical supervisor, as necessary;

(j) ensure Contract materials are onsite, recorded and stored properly;

(k) ensure proper installation Procedures are being followed;

(l) ensure consumables and installation tools, equipment and materials are in adequate supply;

(m) ensure all safety, health and environmental responsibilities and requirements are fulfilled;

(n) be responsible for the overall risk management on Site as related to the Contractor's activities; and

(o) participate in Site meetings with Hydro's Representative to discuss issues, provide updates on the progress of the Work and identify risks related to imminent Work and Work in progress.

The CSCM or a delegate who has qualifications acceptable to Hydro's Representative will be present at the Site during day shifts or other shifts when Work is in progress, and will be available on the Site at all reasonable times upon request made by Hydro's Representative. As required for the proper performance of the Work, the CSCM will receive assistance from competent personnel.

3.2.9 Site Technical Supervisor

The Contractor will appoint a Contractor's Site technical supervisor (CSTS) who will:

(a) have a minimum of six years' hydroelectric or equivalent experience in the installation of similar types of equipment as specified in the Contract;

(b) have a functional reporting relationship to the Contractor's design office, independent of Site personnel;

(c) take technical direction from the Contractor's design engineers;

(d) have the authority and responsibility to stop the Work if the Work at Site is not in accordance with the design engineer's requirements or the requirements of the Contract Documents;

(e) provide technical support to the installation trades personnel including:

  (i) training of the trades personnel in special Procedures that may be required to assemble, install and test the Equipment, and components of Equipment, supplied under the Contract;

  (ii) carry out inspection of the Work to ensure that the drawings, and the installation and testing Procedures are being followed;

(iii) make sure that quality assurance is being properly conducted;

(iv) write and distribute progress Reports, as required under the Contract Documents;

(v) ensure that general planning and layout of the Work are being timely and properly performed; and

(vi) carry out performance evaluation of the installation trades personnel, and ensure that technical training as necessary is properly conducted; and

(f) except where SPGS 3.2.9(j) applies, be present at the Site at all times when Work is scheduled to be performed at the Site.

Several CSTSs may be used to assist with workload or to provide specialized expertise for specific assembly and installation activities provided that:

(g) the CSTSs each have the experience required under SPGS 3.2.9(a); and

(h) there is a clearly established hierarchy for the CSTSs such that one CSTS is ultimately responsible;

If several CSTSs are used:

(i) the Contractor will provide to Hydro's Representative the name, qualifications and scope of responsibilities of each CSTS; and

(j) at least one CSTS will be present at the Site when Work is scheduled to be performed at the Site, which CSTS will have specialized expertise in connection with the assembly and installation activities to be performed at that time.

Arrangements for any emergency Work that may be required will be made and submitted for Review.

3.2.10 Lead Test Engineer

The Contractor will appoint a lead test engineer (CLTE) who will:

(a) have a minimum of six years' hydroelectric or equivalent experience with similar installations;

(b) lead the acceptance and commissioning testing for the Equipment;

(c) prepare test Procedures, and direct testing at the manufacturing and installation phases of the Works;

(d) develop staged test plans and teams for the testing of various components of the Equipment and the completed Work;

(e) direct all test activities, schedules and reporting;

(f) review and approve all test Reports;

(g) remain independent from the personnel doing the assembly and installation Work;

(h) interface with Hydro's Representative, BC Hydro testing and commissioning personnel and other BC Hydro personnel regarding commissioning test Procedures and schedules; and

(i) ensure all tests are properly documented.

Different Contractor's test engineers (CTEs) may be appointed with responsibility to lead the acceptance and commissioning testing for each Major Component, provided that:

(j) the CTEs each have the experience required under SPGS 3.2.10(a); and

(k) there is a clearly established hierarchy for the CTEs such that the CLTE is ultimately responsible.

If several CTEs are used, the Contractor provide to Hydro's Representative the name, qualifications and scope of responsibilities of each CTE.

SPGS4 PROJECT PLANNING

4.1 Project Management Plan

The Contractor will submit not later than 60 days after the Effective Date the project management plan for the Work that:

(a) conforms to the internationally recognized standards and guidelines in project management practices;

(b) describes how the Work will be executed, monitored, controlled and closed;

(c) integrates and coordinates all subsidiary project plans including scope, schedule, quality, change control, document control, environmental, safety, risk and procurement;

(d) describes the project monitoring and control processes that will be used for the Work; and

(e) describes the Contractor's project management procedures and company regulations including:

  (i) the basics of integrated project controlling with regards to schedule, progress and costs/resources;

  (ii) the process and tools used for handing claims and in particular Change Order; and

  (iii) the documentation management principles and in particular project documents management within Contract.

4.2 Risk Management Plan

The Contractor will submit not later than 90 days after the Effective Date the risk management plan for the Work (the "**Risk Management Plan**" or "**RMP**") that:

(a) identifies, addresses and manages risks related to safety, health, environment, cost, schedule and quality during the design, manufacturing, assembly, installation and commissioning phases of the Work;

(b) includes the following features:

  (i) a flowchart of the organizational structure showing the personnel assigned to the project risk management, including outside resources;

  (ii) roles and responsibilities of risk team members;

(iii) include all Work performed by Subcontractors ;

(iv) a risk register (the "**Risk Register**") that captures all details required to monitor identified risks. Risk assessments and recommended prevention and/or mitigation measures will be formally documented in the Risk Register. An action log will be included that documents decisions and follow-up actions to be taken for each identified risk. The Risk Register will be updated in accordance with the Risk Management Plan and will be submitted monthly along with other reporting requirements specified within Schedule 2 [Design and Construction Protocols]; and

(v) the formal process to be followed during Work execution, with regards to the risk assessment approach and frequency for updating the Risk Register; and

(c) is based on the following principals:

(i) all risks will be identified and captured in the Risk Register;

(ii) all risk scenarios will be evaluated for elimination or mitigation through appropriate measures;

(iii) all higher and medium risk scenarios and associated risk management strategies will be communicated to and accepted by the appropriate level of the Contractor's management; and

(iv) results of formal risk assessments will be considered in the preparation or review of emergency response plans and Procedures.

Where appropriate, Hydro's Representative will be invited to observe and/or participate in risk assessments performed by Contractor. The results of risk assessments related to the Work will be submitted upon completion of any of the assessments identified within the Contractor's Risk Management Plan. Any involvement of BC Hydro in such assessments will not relieve the Contractor of any of its duties and obligations under the Contract.

The Contractor will:

(d) perform risk assessments using qualified and knowledgeable personnel;

(e) participate in risk assessments conducted by either Hydro's Representative or Others when these risk assessments relate to activities for which Interfaces exist with the Work or where Contractor is involved; and

(f) not be entitled to any additional compensation or extension of time for the management and mitigation of risks associated with the different activities related to the Contract.

4.3 <u>Fire Response Management Plan</u>

The Contractor will submit not later than 90 days after the Effective Date the Fire Response Management Plan (FRMP) for the Work that lists, tracks and records on a Site map the place of installation for all potentially fire-producing equipment and materials used on the Site.

Others will provide firefighting capability for fires that, in order to be extinguished, require the use of means other than fire extinguishers.

4.4 Design Management Plan

The Contractor will submit not later than 60 days after the Effective Date a design management plan (DMP) that:

(a) provides a general description of the Contractor's design team, size, location and capabilities and identifies what Work if any will be subcontracted;

(b) describes the management and performance of the design Work and a description of the responsibility and authority delegated to the Contractor's design engineers and others including what involvement design staff will have in manufacturing and work at Site;

(c) describes process to ensure that the design Work will be performed on schedule, to recognized design standards in accordance with accepted safety and risk management plans by personnel with the level of expertise and experience required for the duration of the Work;

(d) describes how engineering design changes will be reviewed, approved, managed and communicated within the Contractor's team;

(e) describes the quality control process to be used for the design Work including identifying the Contractor's designers, checkers, reviewers, and sign and seal roles for Drawings and Explanatory Documents;

(f) provides a flowchart of the organizational structure showing the personnel assigned to the design quality management, including outside resources;

(g) describes how design conducted by the Contractor's design engineers is communicated to and reviewed by the Subcontractors;

(h) describes how design conducted by the Subcontractors is reviewed and accepted by the Contractor's design engineers;

(i) describes how the Contractor's design engineers will review NCRs from both manufacturing and Site Work;

(j) describes how the results of design quality management will be documented and communicated in accordance with Schedule 8 [Quality Management];

(k) allows Hydro's Representative the option to audit the design quality elements and documentation;

(l) describes how often and when the Contractor's internal design reviews and external design reviews with BC Hydro in accordance with SPGS8 will be performed throughout the design process; and

(m) allows for a minimum of three external design reviews with BC Hydro during the design stage to be organized and conducted by the Contractor with reasonable notice at appropriate intervals in accordance with SPGS8.

4.5 Safety by Design Plan (Human Factors Engineering Plan)

The Contractor will submit not later than 90 days after the Effective Date the safety-by-design plan (the "**Safety by Design Plan**" or "**SbDP**") that:

(a) demonstrates the design and installation methodology for the temporary and permanent works that conforms to Good Industry Practice, similar but not limited to, ANSI/ASSE Z590.3-2011

Prevention through Design – Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes;

(b) includes a methodology for the systematic identification of hazards and failure modes and the elimination or reduction of safety risks to workers and the public;

(c) describes a procedure for the selection of design alternatives based on regulatory requirements safety risk tolerance criteria and other design requirements;

(d) ensures that safety is embedded into the design of the Equipment over its full lifecycle considering the following criteria:

(i) the Equipment being designed;

(ii) how the Equipment will be constructed or installed;

(iii) how testing and commissioning will be performed;

(iv) how operation and maintenance will be performed; and

(v) how the Equipment will be replaced when it has reached end-of-life;

(e) describes how safety assessments will be conducted and documented in the design process;

(f) identifies the qualifications and experience of the key individuals involved in the safety assessment and verification process; and

(g) describes how to incorporate a safety and environmental methodology in its design approach in developing the final design solution to assist the designers to foresee, evaluate, eliminate, or control hazards and risks for the Equipment throughout the lifecycle of the Equipment, including during manufacturing, installation, commissioning, operation, maintenance and replacement. This must be a dynamic process with a repeated sequence of identifying, assessing and mitigating hazards. The purpose of this design approach is to intentionally “design out” or minimize temporary or permanent safety and environmental hazards that may occur over the Equipment lifecycle.

Safety-by-design Submittals are required in addition to other Safety related Submittals as safety-by-design is a deliberate and intentional initiative to identify all potential hazards specific to the Equipment with a view to eliminate or mitigate the risks associated with them. Hazards will be documented in accordance with SPGS 7.3.4.

4.6 <u>Procurement, Manufacturing and Shipping Plan</u>

The Contractor will submit not later than 90 days after the Effective Date a procurement, manufacturing and shipping plan (PMSP) that:

(a) describes the Contractor’s proposed procurement process that will be used for the proper performance of the Work including the procedures for selecting Subcontractors, if any, and material suppliers;

(b) describes the management and performance of procurement and manufacturing Work, and a description of the responsibility and authority delegated to the procurement manager and key resources;

(c) describes the schedule tracking and quality control processes that will be used for procurement and manufacturing;

(d) identifies the location and size of manufacturing facilities for the Major Sub-Components;

(e) identifies what foundries and casting facilities will be used to provide the materials for the Equipment;

(f) provides a manufacturing time frame for the Major Sub-Components;

(g) provides a preliminary shipping plan that identifies the dependencies and risks to the timely delivery of Major Sub-Components;

(h) identifies the dimensions and weights of all large components and the planned shipping method and route from the manufacturing facility to the Site of these components;

(i) defines roles and responsibilities for control of supplies and manufacturing supervision at Subcontractors' facilities;

(j) defines the way the Contractor will assess the Subcontractors' or material suppliers' performance; and

(k) defines roles and responsibilities for ensuring quality of the materials that are used to fabricate the Equipment.

4.7 Construction Management Plan

The Contractor will submit not later than 180 days after the Effective Date its construction management plan that:

(a) describes the quality, safety, environmental, risk management, document and change control process to be used for the Work at Site;

(b) identifies the estimated Site labour force loading requirements for the Site Work indicating the size of the labour force by trade for each major activity on a month-to-month basis;

(c) includes a Site layout and materials handling plan identifying:

- (i) Site office(s);
- (ii) lunch room(s);
- (iii) laydown area(s);
- (iv) fabrication and storage facilities;
- (v) flow materials to the Site; and
- (vi) Powerhouse service bay utilization in a phased sequence of assembly; and

(d) identifies the type, size and distribution of services required to support the Work at the Site, including electrical power, water, drainage and compressed air in conformity with the Contract Documents.

4.8 Commissioning Plan

The Contractor will submit not later than 180 days prior to commencement of commissioning a commissioning plan that:

(a) describes the management and performance of the commissioning Work and a description of the responsibility and authority delegated to the Contractor's lead test engineer;

(b) for the commissioning of each Major Component, identifies the:

- (i) reason for the test(s);
- (ii) test steps;
- (iii) sequence;
- (iv) duration; and
- (v) description of test points; and

(c) identifies the test Procedures to be carried out.

SPGS5 DESIGN

5.1 LaSalle Report

The Contractor will, applying Good Industry Practice, take into account any relevant information provided in the LaSalle Report in undertaking the design of the Equipment. The Contractor assumes all risks relating to the water intake and conveyance characteristics of the Site C Dam with respect to the Contractor's Turbines, including:

(a) the risk that the actual conditions at the Site C Dam in the intake structures through to the Turbine inlets are not the same as the water intake and conveyance characteristics as described in the LaSalle Report; or

(b) the risk that the actual conditions at the Site C Dam in the intake structures through to the Turbine inlets are not the same as the Contractor assumed in preparing its design of the Equipment, or at the time of entering into this Agreement; or

(c) the risk that the actual water flow conditions at the Site C Dam interfere with the efficiency of the Contractor's Turbines,

and the Contractor expressly waives any and all Claims against BC Hydro and releases BC Hydro from any and all liability (including liability arising out of negligence) arising out of or in connection with the failure of the Turbines or the Turbine Model to perform as guaranteed in the Contract on the basis of actual water flow conditions at the Site C Dam.

5.2 Progressive Design

The Contractor will undertake the design of each Major Component in progressive phases as set out in this SPGS 5.2, capturing the information and detail of a previous phase, and the Contractor will not progress to the next phase until the Contractor has submitted Submittals fully describing the design of the phase, except as otherwise may be agreed to in writing by BC Hydro.

The following terms describe the key design phases for each Major Component:

(a) "**Initial Design**" or 30% design means the point in the design process at which the major design features of the Major Components and Major Sub-Components are ready to be finalized. Finalization of such major design features is required because they form the basis of detailed design work required for the Major Components and Major Sub-Components going forward, and changes to such major design features at a later phase in the design process may not be possible, may require rework, or may result in a delay to the scheduled design work.

For illustration, at Initial Design, the General Arrangement Drawings related to layout and Interfaces to equipment supplied by Others will be complete, the Turbine runner and water passage dimensions will be complete, the Generator electrical characteristics will be mostly finalized and design Calculations for the Major Components will be complete.

(b) "**Detailed Design**" or 70% design means the point in the design process at which the design features for all of the Equipment components, sub-components, parts, etc., have been developed in sufficient detail that it is possible for a high-level review of the design to be undertaken to verify that the design of the Equipment meets the Contractor's internal requirements and to verify that the design meets the requirements of the Specifications.

For illustration, at Detailed Design, most of the detailed design for the Major Sub-Components will be complete, the General Arrangement Drawings will be complete, the Calculations will be complete, most of the Electrical and Mechanical Schematics will be complete, and Parts Lists will have been started.

(c) "**Completion Design**" or 90% design means the point in the design process that is just before the point at which the Shop Drawings and IFC Drawings are ready to be created, Wiring Diagrams will be complete, and where a final comprehensive review of the design may be undertaken to verify that the design of the Equipment meets the Contractor's internal requirements and to verify the design meets the requirements of the Specifications. A final review to confirm that the present design has correctly incorporated the feedback, comments or deficiencies identified during the high-level review conducted at Detailed Design is also usually undertaken at this point in the design process.

(d) "**Final Design**" means the point in the design process at which the final comments, revisions and final design details are incorporated into the Drawings and Explanatory Documents for the Equipment in preparation for these documents to be Issued for Construction.

5.3 BC Hydro Design Revisions

The following will apply to BC Hydro's requests for revisions to a design of an element or component of the Equipment: revisions to Drawings, Explanatory Documents, specifications, equipment and additional design requested by BC Hydro under the processes described in SPGS 5.2 of this Appendix 6-1 [General Specifications (SPGS)] are not Changes and will be completed at the Contractor's cost (except to the extent that any such requested revision would constitute a material change to a provision of Schedule 6 [Specifications and Drawings] in which event the terms of Schedule 12 [Changes] will apply and such revision will not be implemented except pursuant to the terms of Schedule 12 [Changes]).

5.4 Design Change Notices

5.4.1 Design Change Notices

The Contractor may request Hydro's Representative to approve a proposed change to the design of an element or component of the Equipment that deviates from what is described in the Contract Documents or the Contractor's design documents, but will not make such a change without first submitting a "**Design Change Notice**" or "**DCN**" as set out in this SPGS 5.4.1.

Without limiting anything in Schedule 2 [Design and Construction Protocols] and, specifically, Section 3.2(f) of Schedule 2 [Design and Construction Protocols], the Contractor will:

(a) assign a classification to each DCN that indicates whether the proposed design change:

(i) deviates from the Contract Documents; or

(ii) complies with the Contract Documents but deviates from the Contractor's design documents;

(b) submit for Consent each DCN for a proposed design change that deviates from the Contract Documents;

(c) submit for Review each DCN for any proposed design change that complies with the Contract Documents but deviates from the Contractor's design documents; and

(d) submit Drawings or Explanatory Documents in support of the proposed design.

For certainty, if a proposed design change contains any proposed Equivalent, that proposed design change will be considered to deviate from the Contract Documents, and the DCN for that proposed design change will be submitted for Consent pursuant to Section 5.4.1(b) of this Appendix 6-1 [General Specifications (SPGS)].

5.4.2 Purpose of Design Changes

The Contractor acknowledges that it understands all of the technical and performance requirements for the Equipment as set out in the Contract Documents as of the Effective Date and that it is not the purpose of Section 5.4.1 of this Appendix 6-1 [General Specifications (SPGS)] to facilitate design changes that materially affect those technical and performance requirements.

5.4.3 Consideration of Design Changes

In considering any DCN, BC Hydro may consider whether the proposed design will or may materially deviate from the technical or performance requirements for the Equipment as set out in the Contract Documents as of the Effective Date.

[redacted]

SPGS6 QUALITY, INSPECTION AND TESTING

6.1 Testing of Equipment and Materials

The Work includes:

(a) all testing required by any applicable codes and standards for the Equipment and any other specific tests specified in Schedule 6 [Specifications and Drawings]; and

(b) all testing required by any applicable codes and standards for any materials used by the Contractor in respect of the Work and any other specific tests specified in Schedule 6 [Specifications and Drawings].

6.2 Manufacturer Kick-off Meeting

Prior to commencing the manufacture of the Equipment, the Contractor will hold meetings (each, a "**Manufacturer Kick-Off Meeting**") to review quality requirements and the quality plan with each manufacturer for each Major Component, as determined by mutual agreement between BC Hydro and the Contractor. The Contractor's sourcing quality manager will participate in each Manufacturer Kick-Off Meeting with other participants as necessary from the Contractor's engineering and sourcing teams. The Contractor will develop a detailed agenda and invite Hydro's Representative to attend all Manufacturer Kick-Off Meetings. The Contractor will prepare and deliver minutes of meeting for each Manufacturer Kick-Off Meeting to Hydro's Representative for information. Participants in the Manufacturer Kick-Off Meetings will attend in person.

6.3 Inspection During Manufacturing

The Contractor will undertake the manufacture of the Equipment, including the manufacture of any element or component of the Equipment, so as to permit BC Hydro to carry out any inspections of an element or component of the Equipment as permitted by the Contract Documents.

6.4 Manufacture and Delivery in Sequence

The Contractor will manufacture and deliver the Equipment in a sequence as required for orderly and efficient installation and commissioning at the Site, across the Units, with completion and commissioning of early installed Units proceeding while others are being installed.

6.5 Inspection and Test Plans (ITPs)

Without limiting anything in Schedule 8 [Quality Management], the Contractor will establish and implement Inspection and Test Plans (ITPs) that include all inspections and tests within the scope of the Work including, as applicable, material procurement and acceptance, equipment manufacturing, shop assembly, testing, shipping and delivery, storage, installation and commissioning.

The Contractor will monitor the progress of all ITPs and record the ITPs in a register (the "**ITP Register**"). The Contractor will submit a copy of the ITP Register monthly, along with the Quality Progress Report in accordance with Schedule 8 [Quality Management].

6.6 Quarterly Progress Meetings

The Contractor will facilitate and hold a quarterly progress meeting with BC Hydro at the Contractor's Canadian office to review the Work progress made in the last quarter and foresee progress, any actions and risks for the upcoming quarter. The Contractor will propose a routine agenda, specific agenda and attendees for each meeting to be mutually agreed by Hydro's and the Contractor's Representatives. The Contractor will invite its Subcontractors to the meetings as the Work progresses or facilitate and hold sub-meetings as needed at Subcontractor's facility to enable the Subcontractor to participate in and benefit from the discussion between the Contractor and BC Hydro. The quarterly progress meeting may be combined with any Design Review, Manufacturer Kick-Off Meeting, or other meeting to maximize benefits for both parties. Participants in the quarterly progress meetings will attend in person.

6.7 Notice of Witness Points and Hold Points

For electrical tests that have Witness Points or Hold Points and that do not occur on Site, the Contractor will give BC Hydro at least 30 days' written notice prior to such tests carried out in Canada and at least 60 days' prior written notice for tests carried out outside Canada.

For other activities that have Witness Points or Hold Points and that do not occur on Site, the Contractor will give BC Hydro at least 14 days' prior written notice.

The Contractor will include in each Witness or Hold Point Notice the following information:

(a) the Project name;

(b) ITP number and name;

(c) Unit number;

(d) ITP step or sequence number;

(e) date of notification;

(f) date of inspection;

(g) start time;

(h) address of the facility; and

(i) name of the contact person and cell phone number.

For activities that have Witness Points or Hold Points and that occur on Site, the requirements of Schedule 8 [Quality Management] apply.

6.8 Hold Points

The Contractor will identify Hold Points based on the Contractor's ITPs, the Contractor's design, the Contractor's experience with the manufacturer or supplier, the Contractor's assessment of the manufacturer's or supplier's capability, capacity and schedule, and any other factors that may impact conformity of the Work.

As a minimum, the Contractor will include the following BC Hydro Hold Points in the applicable inspection and test plans:

Equipment	Hold points
Turbine	
Runner	Stamping on test coupons attached on runner castings including blades, band and crown.
	Repair of major defects in runner castings including non-destructive examination (NDE) on excavation and completed weld.
	Verification of crown and band hydraulic profile.
	Initial assembly set-up including crown, band and minimum of the first three blades and verification of blade hydraulic profile of one random blade.
	Final acceptance test including review and witness of data book, surface quality, NDE, dimension and geometry, balance and stress measurement.

Equipment	Hold points
Headcover	Mechanical test results of pressure steel plates including Charpy V-notch impact test and tensile tests.
	NDE of welds after post-weld heat treatment.
Stay ring	NDE of welds after post-weld heat treatment.
Tower assembly	Distributor assembly fit-up and clearance measurement in factory.
Wicket gates	Stamping on test coupons attached on wicket gate castings.
	Repair of major defects in wicket gate castings including NDE on excavation and completed weld.
	Final acceptance test including review and witness of data book, surface quality, NDE, dimension and geometry.
Servomotor	Cylinder hydraulic and leakage test in factory.
Shafts	NDE and mechanical tests of shaft forgings after rough machining.
Generator	
Stator bar	Design tests in a lab on prototype bars.
	Routine electrical tests and all test Reports before shipping.
Stator core	Stator core lamination factory tests.
Stator frame	Trial assembly of sections in factory.
	NDE after post-weld heat treatment, if applicable.
	Dimensional inspection with minimum first two layers of stator core sheets installed in factory.
Rotor pole	Routine electrical tests and all test Reports before shipping.
Current transformer	Routine electrical tests (first transformer) and all test Reports before shipping.
Governor System	
Accumulator Tank	Accumulator hydraulic test.
Governor control system	Factory integration tests and test Reports before shipping.
Excitation System	
Exciter control system	Factory integration tests and test Reports before shipping.
Exciter rectifier	Rectifier heat run and burn-in tests.
Exciter transformer	Transformer design tests, if applicable, and production tests (first transformer), and all test Reports before shipping.

The Contractor will include such additional Hold Points as Hydro's Representative may, acting reasonably, direct from time to time.

6.9 Witness Points

The Contractor will identify Witness Points based on the Contractor's ITPs, the Contractor's design, the Contractor's experience with the manufacturer or supplier, the Contractor's assessment of the manufacturer’s or supplier’s capability, capacity and schedule, and any other factors that may impact conformity of the Work.

As a minimum, the Contractor will include the following inspection and test steps as potential BC Hydro’s Witness Points in the applicable Inspection and Test Plans:

(a) material verification:

   (i) review of material certificates provided by the material suppliers, e.g., mill certificate for ASTM A516 steel plates;

   (ii) material tests conducted by the manufacturers, e.g., Charpy V-notch impact test for ASTM A516 Grade 70 S5 steel plates;

   (iii) surface radioactivity measurement of runner and wicket gate castings;

   (iv) material visual inspection; and

   (v) validity of material shell life, e.g., validity date for paints;

(b) material traceability control, e.g., stamping on casting coupons;

(c) verification of measurement instruments and tools verification, e.g., validity date of a micrometer; and

(d) special process qualification:

   (i) welding process and performance qualification;

   (ii) NDE personnel qualification and NDE procedures;

   (iii) heat treatment procedures;

   (iv) coating inspector qualification and coating procedures; and

   (v) brazing process and performance qualification;

(e) special process verification:

   (i) welding process monitoring;

   (ii) first pass, if applicable, and final weld inspection;

   (iii) NDEs;

   (iv) heat treatment graph; and

   (v) coating process verification and coating inspection;

(f) design or type tests for electrical equipment, e.g., electrical tests on prototype stator bars;

(g) production tests for electrical equipment, e.g., electrical tests on stator bars;

(h) final product verification:

 (i) dimensions and geometry, e.g., water passage surface profile;

 (ii) volumetric quality, e.g., discontinuity within a casting;

 (iii) surface finish quality, e.g., roughness, discontinuity and hardness;

 (iv) assembly fitting, e.g., assembly of stator frame sections; and

 (v) coating and protection, e.g., coating thickness and adhesion;

(i) data book review;

(j) product packing, packaging and loading;

(k) monitoring of equipment during transportation, e.g., installation and setup of impact recorders on a Turbine runner; and

(l) contractor's quality releases.

The Contractor will include such additional Witness Points as Hydro's Representative may, acting reasonably, direct from time to time.

6.10 Non-Conformity Report

The Contractor will assign a classification for each Non-conformity Report (NCR) that indicates whether the non-conformity is not conforming to the Contract Documents, or conforming to the Contract Documents but not conforming to the Contractor's design documents.

The Contractor will submit the NCRs not conforming to the Contract Documents for Consent and the NCRs conforming to the Contract Documents but not conforming to the Contractor's design documents for Review.

6.11 Quality Release

The Contractor's Quality Manager will control the shipping of all Equipment supplied to the Site by using a release (each, a "**Quality Release**") to certify the following in respect of each component:

(a) all inspection and tests have been performed and accepted;

(b) all DCNs and NCRs are closed;

(c) all Quality Documentation in respect of such component and piece of Equipment is valid and complete; and

(d) the protection, packaging and loading are adequate for shipping.

The Contractor will submit a copy of the Quality Release before shipping.

6.12 Final Quality Reports

6.12.1 General

The Contractor will submit Final Quality Reports for each Unit.

Each Final Quality Report will include all the records indicated on the ITPs, and any other additional test data requested by Hydro's Representative. The Final Quality Reports will be a compilation of all the Quality Documentation produced during and in connection with the performance of the Work, including the following, as applicable:

(a) a copy of all completed ITPs with signatures and dates for each step;

(b) closed NCRs;

(c) design change completion Reports;

(d) Equipment calibration certificates;

(e) welding or brazing Procedures;

(f) welder qualification records;

(g) certificates of compliance;

(h) mill test certificates for all materials;

(i) dimensional inspection Reports;

(j) non-destructive testing Reports;

(k) heat treatment Reports;

(l) surface roughness, coating Procedures and coating inspection Reports;

(m) type and design test Reports;

(n) sampling and production test Reports;

(o) acceptance test Reports;

(p) acceptance memoranda;

(q) quality releases;

(r) shipping inspection Reports;

(s) torqueing records;

(t) completed Procedures, checklists and Reports;

(u) all interim and final records required by the Procedures and any other records that help to illustrate the installation sequence or any problems that may have occurred during the Work;

(v) red-line mark-ups to become IFR Drawings;

(w) a copy of all technically relevant correspondence between Contractor and Hydro's Representative;

(x) embedded Photos to illustrate or assist in the understanding of the installation or to identify key steps or specific problems; and

(y) progress Photos.

Each quality record included in a Final Quality Report will indicate the component or sequence of the Work to which such records relates.

6.12.2 Format

Final Quality Reports will meet the requirements for Explanatory Documents as specified in SPGS 7.3.

6.12.3 Inclusion of Final Quality Reports in Technical Submittal Schedule

The Contractor will monitor and control the release of the Final Quality Reports to BC Hydro. The Contractor will include in the Technical Submittal Schedule the schedule for delivery of the Final Quality Reports.

6.13 Commissioning Reports

6.13.1 General

The Work includes provision of a comprehensive commissioning Report for each Major Component. Each commissioning Report (the "**Commissioning Report**") will summarize the results of the Equipment commissioning tests and will include all of the commissioning:

(a) Procedures;

(b) inspection records;

(c) measurements;

(d) test data;

(e) test results;

(f) Calculations used to manipulate the test data; and

(g) test equipment used and their calibration certificates.

6.13.2 Submittal Schedule for Commissioning Data, Test Results and Reports

The commissioning data, test results and Reports for the Equipment will be submitted in accordance with the following schedule:

(a) for inspection records, measurements, test data and test results, in accordance with SPGS 7.3.9(b);

(b) for an early preliminary version of the Commissioning Report, not later than 30 days after completion of commissioning of each Unit; and

(c) for the final version of the Commissioning Report, not later than 90 days after completion of commissioning of each Unit.

The Contractor will submit ten hardcopies of the final Commissioning Report required under SPGS 6.13.2(c) of this Appendix 6-1[General Specifications (SPGS)].

SPGS7 DRAWINGS AND EXPLANATORY DOCUMENTS

7.1 General

The Work includes all Drawings and Explanatory Documents required to enable workers to assemble, install, inspect, test, commission, operate, maintain, disassemble, repair, refurbish, modify or replace any components of the Equipment throughout its Design Life. Drawings and Explanatory Documents include:

(a) Drawings;

(b) Calculations;

(c) Parts Lists and Bills of Materials;

(d) Hazard Logs;

(e) Cable Schedules;

(f) Reliability Centred Maintenance (RCM) Sheets;

(g) Inspection and Test Plans (ITPs);

(h) Inspection and Test Records;

(i) Non-conformity Reports;

(j) Design Change Notices;

(k) Requests for Information;

(l) Quality Progress Reports;

(m) Final Quality Reports;

(n) Procedures;

(o) inspection records, measurements, test data and test results;

(p) test equipment and instrumentation;

(q) Reports;

(r) Operation and Maintenance Manuals; and

(s) Photos.

All supporting documentation referenced by Drawings or Explanatory Documents will be supplied with and will be considered part of the Drawing or Explanatory Documents, except for recognized Canadian and international codes and standards, including those listed in Appendix 6-2 [General Technical Specifications (SPGT)].

7.1.2 Sufficient Detail

Drawings and Explanatory Documents will show the design, method of fabrication (if applicable) and arrangement of the Work in sufficient detail to enable Hydro's Representative to observe whether the Contractor's design is in general conformity with the Contract Documents. Notwithstanding anything to the contrary in this Appendix 6-1 [General Specifications (SPGS)], if for a proper understanding of the Contractor's Drawings or Explanatory Documents, Hydro's Representative determines that an examination of any other drawings, design notes, calculations, reports, inspection records, measurements, test data, specifications, samples, patterns and models that are used by the Contractor in respect of the Work, the Contractor will, upon Hydro's Representative's request, make such other drawings, design notes, calculations, procedures, reports, inspection records, measurements, test data, specifications, samples, patterns and models available for Review.

7.1.3 General Format

All Drawings and Explanatory Documents will:

(a) be clear and sharp;

(b) be in colour;

(c) utilize English for all text. For Drawings, if the Contractor chooses to work in another language, non-English text will be shown in brackets next to the English text;

(d) utilize the International System of Units (the “SI” system, commonly referred to as the metric system) for all dimensions and measurements. If it is significantly more efficient for a contractor or manufacturer to use non-SI units of measure in select sections within a Drawing or Explanatory Document, it is acceptable to show the equivalent measure in non-SI units in square brackets (for example, “[XXXXX]”) next to the SI measure;

(e) utilize metric engineering unit prefixes (i.e., a power of ten that is an integer multiple of three, such as “micro”, “milli”, “kilo”, “mega”, etc.);

(f) have a title block or cover page that includes the:

    (i) customer name (BC Hydro);

    (ii) Project (Site C Clean Energy Project);

    (iii) document title;

    (iv) version and purpose of that version (e.g., issued for comments); and

    (v) date;

(g) utilize metric paper sizes as defined in ISO 216;

(h) generally minimize the use of abbreviations. Where abbreviations are used or where it is Good Industry Practice to use abbreviations, abbreviations will be in accordance with BC Hydro ES 10-A0425 and ES 10-N0020;

(i) where symbols are used, be in accordance with BC Hydro ES 10-A0425; and

(j) where calendar dates are used, be numerical and be in year, month, day (YYYY-MM-DD) format.

7.1.4 Electronic Format

Drawings and Explanatory Documents submitted in electronic format will:

(a) be in the latest version of the Adobe Acrobat [.pdf] file format;

(b) be electronically produced from the Contractor's original electronic master (as opposed to being scanned into Adobe Acrobat [.pdf] format);

(c) be keyword searchable throughout;

(d) have no restrictions on:

   (i) the number of copies that can be printed;

   (ii) the ability to print a single page or a group of pages;

   (iii) content copying;

   (iv) content copying for accessibility;

   (v) page extraction; or

   (vi) the use of commenting tools;

(e) be stand-alone with no reference files attached (i.e., all appendices, figures, etc., will be combined into one file);

(f) be electronically rotated to the correct orientation for viewing (i.e., a Drawing will appear on the display such that the BC Hydro Title Block is located on the lower right, and for Explanatory Documents, the pages and text will be the right way up;

(g) for documents with:

   (i) one page size, have ISO A4 as the maximum page size when the Adobe Acrobat [.pdf] file is created;

   (ii) multiple page sizes, have ISO A3 as the maximum page size when the Adobe Acrobat [.pdf] file is created;

(h) have the correct paper size type chosen such that the contents of the document fills the entire page; and

(i) be formatted for easy printing on a standard office printer or photocopier with a minimum of paper sizes required.

7.1.5 Hardcopy Format

Where a hardcopy of Drawings and Explanatory Documents is required as a Submittal, the hardcopy will be produced from the Contractor's original electronic master.

7.1.6 Professional of Record

(a) General: In addition to and without limiting any requirements in Schedule 5 [Submittal Procedures] with respect to sealing Drawings and Explanatory Documents, all final Drawings and all final Explanatory Documents will be submitted with an original seal. A scanned version of a Drawing or Explanatory Document sealed with an ink seal is not acceptable;

(b) Civil Structures and Elements: Drawings for all civil structures or for civil structural elements, including walkways, platforms and guardrails of the Equipment will be signed and sealed by a Professional of Record who has the "Struct. Eng." endorsement from the Association of Professional Engineers and Geoscientists of British Columbia.

7.1.7 Revisions to Drawings or Explanatory Documents

(a) Verification of Revisions: Each set of revisions made to a Drawing or Explanatory Document will be clearly identified to enable a reviewer to quickly find the revisions made in comparison to the previous version of the Drawing or Explanatory Document and, at a minimum:

(i) a revision to a Drawing will be encircled with a cloud marking, and each cloud mark will have an associated revision number identifier next to it; and

(ii) a revision to an Explanatory Document will be identified using a different colour of text or by use of a software's revision tracking tool (e.g., Microsoft Word's track changes tool).

(b) Revisions Made During a Warranty Period: If the Contractor for any reason wishes to revise or amend any of the Drawings and Explanatory Documents during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols], the Work includes promptly submitting the revised or amended documents in the same electronic and hardcopy formats and quantities as previously required for the last Submittal for those Drawings or Explanatory Documents.

(c) Revisions of Hardcopies: Where a hardcopy of an Explanatory Document needs to be revised, if the Explanatory Document is bound in such a way that it easy to replace the affected pages (e.g., 3-ring binder format), it is acceptable to submit replacement pages instead of re-submitting a full copy of the revised Explanatory Document. If replacement pages will be submitted, a revision instruction page will also be submitted, which will be formatted to be inserted into the front of the Explanatory Document and will contain complete instructions explaining which pages will be substituted with those replacement pages. If the Explanatory Document is bound in such a way that it is not easy to replace the affected pages, the Contractor will re-submit a full copy of the revised Explanatory Document.

7.2 Drawings

7.2.1 General

Each drawing submitted under the Contract Documents showing the Work or a portion of the Work (each a "**Drawing**") will use a combination of:

(a) graphical projections and views of the Equipment of portion of the Equipment (including scaled orthographic projections, and scaled plan, section and detail views);

(b) symbolic representations of the Equipment (including schematic symbols, block diagrams, etc.);

(c) annotative symbols (such as dimensions, bill of material reference bubbles, etc.); and

(d) text,

to provide a complete description of the Equipment, such that the Drawings convey a complete description of:

(e) how the Equipment is fabricated, manufactured, constructed, shipped erected and installed;

(f) how the components of the Equipment are physically arranged and assembled to form the in-service configuration (examples include general arrangement, outline and wiring/connection drawings);

(g) how the components of the Equipment are functionally connected to form the in-service configuration (examples include piping, hydraulic and electrical schematic diagram drawings, as well as block diagram drawings); and

(h) the manufacturer, distributor and part number of each component of the Equipment, to allow replacement parts to be procured.

7.2.2 Drawing Types

Drawings prepared as part of the Work includes the following types (at the Contractor’s request BC Hydro will provide examples of each to the Contractor):

(a) General Arrangement Drawings;

(b) Detailed Design Drawings;

(c) Three Dimensional Drawings;

(d) Shop Drawings;

(e) Mechanical Schematics;

(f) Electrical Schematics;

(g) Electrical Wiring Diagrams;

(h) Block Diagrams; and

(i) Electrical Load Schedule,

however for clarity, BC Hydro does not expect Shop Drawings to be submitted.

7.2.3 General Arrangement Drawings

General arrangement Drawings, including overview, plan, cross-section, layout diagrams, etc. (the “**General Arrangement Drawings**”), are Drawings that show the overall size, arrangement or assembly of the Equipment and will include:

(a) front, top and side orthographic projections the Equipment;

(b) internal view(s) of the Equipment;

(c) sectional views of the Major Components;

(d) overall dimensions, tolerances, clearances, weights, mounting/attachment points, major lifting points, major access panels/doors and Major Sub-Components;

(e) a drawing scale;

(f) alphanumeric identifiers for devices shown;

(g) Parts List(s); and

(h) any other information required in order to detail the physical size, arrangement and assembly of the Equipment.

The General Arrangement Drawings will be drawn to scale and the scale will be clearly stated and shown on such Drawings. For illustration, a General Arrangement Drawing might show a cross-section of the complete Generator or Turbine.

7.2.4 Detailed Design Drawings

Detailed design Drawings (the "**Detailed Design Drawings**") are Drawings that show the detailed design features, arrangement or assembly of one or more components of the Equipment and will include:

(a) front, top and side orthographic projections the component;

(b) detail and section views as required;

(c) anchoring complete with first and second stage anchor details;

(d) details of embedded and non-embedded piping, ducts and cable trays including: connections, and standard and special details of supports, brackets and seismic bracing;

(e) machining details;

(f) weld sizes and weld specifications;

(g) surface finishes and protective coatings;

(h) mounting/attachment points (including bolt torques) and Lifting Points;

(i) details of sub components/devices;

(j) materials, dimensions, tolerances, fits, clearances, weights, alarm levels and trip levels;

(k) access panels/doors;

(l) lighting fixture, devices and distribution panel layouts;

(m) Enclosure Wiring Diagrams showing all components, devices and terminal blocks;

(n) standard details for electrical work including: grounding, cable tray fill and installation, colour-coding, conductor connection and termination, and installation details;

(o) standard details for miscellaneous metal including: ladders, stairs, removable and fixed handrails, kick plates, anchor bolts and expansion anchors, hatch covers, grating and frames, and Lifting Eyes;

(p) a drawing scale;

(q) alphanumeric identifiers for devices;

(r) Lifting Devices and Special Tools;

(s) Parts Lists; and

(t) any other information or detail necessary for workers to understand how to assemble, install, inspect, test, commission, operate, maintain, disassemble, repair, refurbish, modify or replace any components of the Equipment throughout its entire Design Life.

The Detailed Design Drawings typically will be drawn to scale and the scale will be clearly stated and shown on such Drawings. For illustration a Detailed Design Drawing might show the detailed design of the shaft coupling studs and nuts, a bearing pad, a stator bar, or a rotor pole body core assembly.

7.2.5 Three Dimensional Drawings

(a) General: A three dimensional Drawing (a "**Three Dimensional Drawing**") is a Drawing that shows the Equipment in an three dimensional electronic file format and will include all of the dimensional information for the Equipment required by Others to:

(i) layout and design the Powerhouse;

(ii) define the overall arrangements for the Equipment;

(iii) define the design criteria for the Equipment;

(iv) define the principal features of Interface points such as the penstock coupling, concrete block out locations, and piping and electrical Interfaces; and

(v) layout and design the Balance of Plant equipment.

The typical dimensional information that will be shown on the Three Dimensional Drawing includes:

(vi) water passage dimensions including the:

(A) geometry of spiral case and draft tube;

(B) location of pier nose cap;

(C) dimensions for the access passages to the: Turbine Pit, draft tube door, and draft tube elbow door; and

(D) penstock couplings;

(vii) dimensioned concrete outline details including:

(A) equipment embedments (pier nose cap, anchors, foundation bolts, piping, etc.) in first stage concrete pours;

(B) blockouts in first stage concrete pours for later equipment placement;

(C) equipment embedments (draft tube elbow, draft tube platform supports, spiral case, Turbine Pit liner, doors, anchors, foundation bolts, piping, cable conduits, base plates, etc.) in second stage concrete pours; and

(D) blockouts in second stage concrete pours for later equipment placement;

(viii) layout and dimensions for all Major Components and Major Sub-Components including panels and cabinets;

(ix) piping details that show the location of the Interface points for equipment provided by Others including for the:

(A) Cooling Water Systems;

(B) Generator heat recovery system;

(C) Equipment drainage systems;

(D) Generator brake air, Governor System air, and Turbine air admission systems;

(E) Turbine air depression and air exhaust systems;

(F) Generator deluge systems;

(G) ventilation system for the Turbine wicket gate bushing access gallery;

(x) Exciter Transformer iso-phase bus layout and Interface points for electrical bus that will interface with equipment provided by Others;

(xi) Generator main and neutral terminal Interface points for electrical bus that will interface with equipment provided by Others; and

(xii) Raceways.

(b) Drawing Scale: The Three Dimensional Drawing will be drawn to scale and the scale will be clearly stated and shown on the Drawing.

(c) Intended Use by BC Hydro: BC Hydro intends to import the Contractor's Three Dimensional Drawing into its Powerhouse three dimensional Autodesk Revit model from time to time to facilitate the efficient design of the Powerhouse and to check for potential mismatches between Interface points.

(d) Expected Level of Detail: BC Hydro expects the development of the Three Dimensional Drawing will be an iterative process with the level of detail increasing with each iteration and generally be coincident with the Initial Design, Detailed Design, Completion Design and Final Design phases of the design process.

Piping and electrical conduit shown in the Three Dimensional Drawings will have sufficient detail so as to enable the visualization of the final routing of the piping and electrical conduit and to allow for the use of the software based clash detection tools. The 3D model representation of these components do not need to be so detailed as to include each length of piping or electrical conduit nor does the detail of the piping or electrical conduit need to be much more than a line with some basic properties associated with that line unless the dimensional details of the piping is materially important for visualization purposes (e.g., the piping for the Governor System).

(e) Submission Format: BC Hydro would prefer the Three Dimensional Drawings be submitted in a 2014 Autodesk Revit [.rvt] file format, but if this is not possible, the Contractor will work with BC Hydro to find a method of exporting the Contractor's three dimensional file in a file format that is compatible for import into BC Hydro's Revit model of the Powerhouse.

7.2.6 Shop Drawings

Shop Drawings (the "**Shop Drawings**") are Drawings that are typically created from the Detailed Design Drawings by a fabrication or manufacturing Subcontractor and used to fabricate or manufacture the sub-components or individual pieces of the Equipment.

For illustration, Shop Drawings might include:

(a) a set of Drawings that show the detail of each of the plate steel pieces that will be welded together to form one section of the Generator stator frame;

(b) spool Drawings;

(c) plate cutting and bending Drawings; or

(d) numerical data used for manufacturing.

7.2.7 Mechanical Schematics

Mechanical schematic Drawings (the "**Mechanical Schematics**") are Drawings that:

(a) illustrate how mechanical components including: pneumatic, hydraulic, lubrication, cooling, piping, etc., components are functionally connected as part of the Equipment;

(b) are not the Drawings that describe the physical locations and configurations of the Equipment; and

(c) will:

(i) be separate from General Arrangement Drawings;

(ii) be separate from Detailed Design Drawings;

(iii) accurately reflect the functional connection of the Equipment;

(iv) include schematic symbols representing devices and their interconnections, and that match the interconnections shown on the Drawings;

(v) include pipe sizes, design flow rates, and design operating pressures;

(vi) include alphanumerical device names and terminals for each device, that match the device name and terminal identifiers shown on the Drawings;

(vii) be colour-coded to differentiate hot from cold, high-pressure from low-pressure, inflow from outflow, etc., where appropriate;

(viii) include directional markers indicating process flows;

(ix) include cross-references to other Mechanical Schematics;

(x) include, where applicable, a description of any interconnections to non-mechanical components, together with a description of the function of the interconnection;

(xi) include device calibration and settings; and

(xii) include any other information required in order to illustrate how the mechanical components of the Equipment are functionally connected.

Mechanical Schematics will be accompanied by valve and instrumentation data sheets. The valve data sheets will describe in detail the valve and application, and contain all relevant design and operating parameters.

7.2.8 Electrical Schematics

Electrical schematic Drawings (the "**Electrical Schematics**") are Drawings that:

(a) illustrate how electrical components are functionally connected to form electric circuits that are included as part of the Equipment;

(b) illustrate how equipment is controlled by or controls other equipment components;

(c) show the input and output contacts, registers and their function (e.g., data input, data output, alarm, trip, indication and control);

(d) show the alarm levels and trip levels;

(e) are not the Drawings that describe the physical locations and configurations of the Equipment; and

(f) will:

(i) accurately reflect the electrical connection of the Equipment;

(ii) be separate from and not include reference to Electrical Wiring Diagrams;

(iii) include schematic symbols representing devices and their interconnections, and that match the interconnections shown on the corresponding Electrical Wiring Diagrams;

(iv) include alphanumerical device names and terminals for each device, that match the device name and terminal identifiers shown on the corresponding Electrical Wiring Diagrams;

(v) include an alphanumeric location identifier (that matches the Site C Component Hierarchy) beside each device (indicating where the device is physically located, such as a particular Enclosure);

(vi) include alphanumerically identified electrical nodes that match the corresponding wire names shown on the Electrical Wiring Diagrams;

(vii) include a full contact/terminal development for all (i.e., both used and unused) contacts/terminals of each relay, switch, pushbutton or other device shown;

(viii) include cross-references to other Electrical Schematics;

(ix) include, where applicable, a description of any interconnections to non-electrical components, together with a description of the function of the interconnection;

(x) not include terminal blocks, terminal block identifiers, wire colours, or names/numbers of devices' unconnected terminals (except for contact developments as specified above);

(xi) for logic systems, have voltage ranges corresponding to logical “1” and to logical “0”;

(xii) include device calibration and settings; and

(xiii) include any other information required in order to illustrate how the electrical components of the Equipment are functionally connected.

Electrical Schematics will:

(g) where applicable, be accompanied by device and instrumentation data sheets;

(h) for PLC or microprocessor based systems, be accompanied by logic block-diagrams illustrating the control function and sequence of the circuit; and

(i) for sub-module blocks included in schematics, be accompanied by a complete description of the blocks, including internal schematics, component layouts and component lists.

7.2.9 Electrical Wiring Diagrams

Electrical wiring diagrams (the “**Electrical Wiring Diagrams**”) are Drawings that:

(a) illustrate how electrical components of the Equipment are physically arranged and connected to form electric circuits included as part of the Equipment;

(b) describe the physical locations and configurations of the Equipment; and

(c) will:

(i) accurately and visually reflect the electrical configuration of the Equipment;

(ii) be separate from Electrical Schematics;

(iii) not include cross-references to Electrical Schematics;

(iv) utilize a grid-reference wiring method, whereby the Drawing is divided into a grid, with each grid section identified by a letter denoting the row and a number denoting the column, and electrical connections between devices made via referencing the appropriate grid section within parentheses;

(v) include a graphical representation of each device (including terminal blocks) and all of its terminals (to which connections are or may be made), positioned within grid sections that the arrangement of each device on the Drawing relative to other elements on the Drawing are shown to closely approximate the actual position of the device within the Equipment;

(vi) show electrical interconnections that match the electrical interconnections shown on the corresponding Electrical Schematics;

(vii) include alphanumerical device names and terminals for each device (including terminal blocks), that match the device name and terminal identifiers shown on the Electrical Schematics;

(viii) include alphanumerically identified wire names that match the corresponding electrical node identifiers shown on the Electrical Schematic Diagrams;

(ix) include cross-references to other Electrical Wiring Diagrams;

(x) include the alphanumeric identifier denoting the colour of each wire;

(xi) include wire size information, with the majority of the information being covered by a descriptive note;

(xii) include a label for each end of each cable shown in the Electrical Wiring Diagram. This label will:

(A) be included only on the Electrical Wiring Diagram that depicts the Equipment that the cable terminates in;

(B) show the cable's number, type and destination (to match the Cable Schedule);

(C) include a Drawing cross-reference to one other Electrical Wiring Diagram (the diagram that depicts the Equipment that the cable's other end terminates in); and

(D) be located on the Electrical Wiring Diagram in a location that to correspond to the physical location of the cable's entry into the Equipment;

(xiii) include any other information required in order to illustrate how the electrical components of the Equipment are physically arranged and connected.

7.2.10 Block Diagram

Block diagrams (the "**Block Diagrams**") are Drawings that illustrate the high-level mechanical arrangement, electrical arrangement, sequence of operation, or process flow of a system to describe the functionality and connectivity at the system level (as distinct from the detailed connectivity and functionality of the various components of the systems).

Block Diagrams will include schematic symbols representing major system components (hardware and/or software), process flow and interconnections that affect high-level functionality of the system. Representations of system components may be simplified, so as to not present detailed information that is not directly relevant to high-level functionality of the system. Interconnections shown will match the more detailed interconnections shown on the Schematic Diagrams.

Where necessary to facilitate the readability of the Block Diagram, Block Diagrams may be nested. For example, a block on one drawing may be shown in more detail on another Block Diagram.

7.2.11 Electrical Load Schedule

Electrical load schedule Drawings (the "**Electrical Load Schedule**") are Drawings that show a listing of all electrical loads, and will be provided as an Excel [.xlsx] spreadsheet during the design and installation stages and as a Drawing upon completion of the acceptance and commissioning tests. The Electrical Load Schedule will include:

(a) version information (date, revision number, etc.);

(b) function or designation (such as lift-pump motor, governor pump #1 motor);

(c) type of load (such as motor, starter, heater, lighting, power receptacle);

(d) physical location in accordance with the Site C Component Hierarchy;

(e) rating (including number of phases, voltage, current, power and power factor);

(f) if applicable, recommended type of electrical protection (e.g., fuse or breaker); and

(g) if applicable, recommended rating for the electrical protection.

If the load is a motor, the following additional information will be included:

(h) speed;

(i) starting current;

(j) maximum permissible locked rotor time;

(k) maximum number of starts allowable per hour; and

(l) enclosure type.

7.2.12 Contractor Drawings

At a minimum, except for Shop Drawings and Drawings that are prepared by BC Hydro, the following types of Drawings will be submitted with respect to all elements of the Work for each Unit:

(a) Issued for Construction Drawings: All Drawings issued by the Contractor or by Hydro's Representative for use by the Contractor to manufacture, construct, install or commission a component of the Work, including the Equipment (each, an "**Issued for Construction Drawing**" or "**IFC Drawing**"). The Contractor will submit an IFC Drawing not later than 60 days before commencement of the manufacturing, construction, installation or commissioning of the component of the Work to which that Drawing applies;

(b) Construction Revision Drawing: A revision to an IFC Drawing made during the manufacturing, construction, installation, or commissioning phase of the Work to record changes to be made to the Work after the Issued For Construction Drawing has been issued but before the Work has been manufactured, constructed, installed, or commissioned (each a "**Construction Revision Drawing**").

The Contractor will prepare, to the satisfaction of Hydro's Representative acting reasonably, Construction Revision Drawings as required to reflect any changes to be made to the Work and submit such Drawings as soon as practicable;

(c) Redline Drawings: Drawings that have been marked up by hand by the Contractor to record changes that have been made to the Work after the Issued For Construction Drawings have been issued or after Construction Revision Drawings have been issued. Changes recorded on Redline Drawings must be incorporated into the As-Built Drawings or the Record Drawings (each a "**Redline Drawing**"). The Contractor will submit a Redline Drawing not later than 15 days after the completion of commissioning of the Unit to which that Drawing applies;

(d) As-Built Drawings: Drawings that are prepared from measurements taken at the factory or on Site to describe accurately the actual location, actual sizes, actual state, etc., of elements of the Work. As-Built Drawings will indicate variations from the Issued for Construction Drawings that occurred during manufacture, construction, installation or commissioning phases of the Work (each, an "**As-Built Drawing**"). The Contractor will submit As-Built Drawings not later than 15 days after the completion of the applicable Work; and

(e) Issued for Record Drawings: Drawings that represent the final state of the Equipment as closely as practicable following the manufacture, assembly, installation and commissioning phases of the Work and that incorporate all such items as approved Change Orders, approved DCNs and other modifications made during the Work (each, an "**Issued for Record Drawing**" or "**IFR Drawing**"). Variations from the Contract Documents may be noted, where appropriate, with remarks or comments. The Contractor will submit an IFR Drawing not later than 60 days after the completion of commissioning of the Unit to which that Drawing applies.

Unless explicitly stated otherwise and in accordance with SPGS 7.2.17, all of the Drawing types described above will be Unit specific Drawings.

7.2.13 <u>BC Hydro Title Block and Contractor's Title Block</u>

(a) A standard BC Hydro title block (the "**BC Hydro Title Block**") is included in the lower right corner of the BC Hydro Drawing Border, and includes areas indicating the Drawing title, Drawing number, revision number, revision date and personnel involved in producing the Drawing.

(b) An area directly above the BC Hydro Title Block is designated for a separate title block (the "**Contractor's Title Block**") for use by the Contractor. The Contractor's Title Block will include:

(i) the name of the Contractor's company;

(ii) the Contract number for the Contract between BC Hydro and the Contractor;

(iii) if the Equipment shown on the drawing is provided to the Contractor by a Subcontractor, the name of the Subcontractor's company;

(iv) any information internal to the Contractor or its Subcontractors, that the Contractor wishes to include and/or track on each Drawing (this might include drawing numbers, personnel and revision tracking information internal to the Contractor's own processes);

(v) the drawing scale; and

(vi) the Contractor will not include its own drawing border placed within the BC Hydro Drawing Border. If a Subcontractor cannot provide Drawings using BC Hydro's Drawing Border, the Contractor will ensure that the Subcontractor's Drawing must be placed inside the BC Hydro Drawing Border and the elements of the Drawing must be to scale when the Drawing is printed in ISO A0 format.

7.2.14 <u>Drawing Numbering</u>

(a) Each Drawing will include a unique BC Hydro drawing number (the "**Drawing Number**"), indicated in the designated drawing number area of the BC Hydro Drawing Border, and formatted as 1016-W04-XXXXX-YZZZ, where:

(i) 1016 is the BC Hydro station code for Site C;

(ii) W is substituted with the BC Hydro drawing type (as appropriate depending on the content of the Drawing), and may be C (civil), E (electrical), M (mechanical) or H (protection and control), e.g., all Turbine Drawings will be M drawings, all Governor System Drawings will be M drawings, all Generator Drawings will be E drawings and all Excitation System Drawings will be E drawings;

(iii) 04 is the BC Hydro subject designation code indicating the powerhouse;

(iv) XXXXX is substituted with the drawing serial number, which will include leading zeroes such that all Drawing serial numbers are five digits long (e.g., 00142 for the 142nd drawing); and

(v) if multiple sheets are utilized, Y is substituted with the text "SH." (sheets may be used to group Drawings with similar subject matter under a single serial number);

(vi) if multiple sheets are utilized, ZZZ is substituted with the Drawing sheet number, and will include leading zeroes such that all Drawing sheet numbers are three digits (e.g., 001 for the first sheet, and 014 for the 14th sheet).

(b) The Drawing type and number will be assigned within a master list (the "**Drawing List**") that follows a pre-designed framework (the framework will be designed by BC Hydro in collaboration with the Contractor to provide an orderly, efficient and intuitive method of numbering Drawings, and will also allow for future expansion/modification of the Drawing List). The Drawing List will be developed as follows:

(i) before any Drawings are produced, the Contractor will submit a proposed list of Drawings;

(ii) BC Hydro will assign Drawing Numbers to each of the Contractor's proposed Drawings. This will form the first draft of the Drawing List, which will be sent to the Contractor; and

(iii) the Contractor will collaborate with BC Hydro to revise and update the Drawing List as the Work progresses, in order to ensure additions, deletions and modifications to the Drawing List respect the pre-designed numbering framework.

7.2.15 Drawing Revision Tracking

(a) The revision number of each Drawing will:

(i) be indicated in the designated revision number field within the BC Hydro Title Block;

(ii) utilize letters to indicate pre-construction Drawing revisions submitted to BC Hydro (for example, revision A is submitted to BC Hydro, BC Hydro returns the Drawing with comments, the Contractor incorporates the comments and re-submits the Drawing to BC Hydro as revision B);

(iii) utilize numbers to indicate Drawings that are to be Issued For Construction (starting with revision 0); and

(iv) utilize a number and a letter to indicate Drawings that are submitted to BC Hydro in between Issued For Construction revisions (for example, after revision 0 is Issued For Construction, revisions 1A, 1B, and 1C may be submitted before the final Issued For Construction revision 1 is issued after the Drawing has been endorsed Accepted or deemed to have been endorsed Accepted.

7.2.16 Drawing Titles and Terminology

(a) The BC Hydro Title Block contains a six-line field for the Drawing title, listed as follows from the top line (line 0) to the bottom line (line 5):

(i) *Line 0 – Facility name*: This line will contain the text shown here between the quotes: "SITE C CLEAN ENERGY PROJECT".

(ii) *Line 1 – Main feature*: This line will contain text that indicates the Unit number, as appropriate and as follows: "POWERHOUSE UNIT 01" through "POWERHOUSE UNIT 06".

(iii) *Line 2 – Specific feature*: This line will contain text indicating the specific feature or subsystem of each Unit that the Drawing shows. Examples of text that might be used in this line include: “TURBINE”, “GOVERNOR”, “GENERATOR” and “EXCITER”.

(iv) *Line 3 – Subcomponent or subsystem of the specific feature described in Line 2*: Examples of text that might be used in this line include: “RUNNER”, “HYDRAULIC POWER UNIT”, “BRUSHGEAR” and “DC BREAKER”.

(v) Line 4 -- *Subcomponent or subsystem of the specific feature described in Line 3*: Examples of text that might be used in this line include: “CROWN”, “BAND” “DISTRIBUTING VALVE”, “COLLECTOR RING” and “CONTACTS”.

(vi) *Lines 5 – Description of information shown*: These lines will contain text that describes what type of information about the Equipment is shown on the Drawing. Examples of text that might be used in these lines include: “CROWN”, “PIPING”, “CONTACTS”, “CONCRETE OUTLINE”, “GENERAL ARRANGEMENT”, “BRUSH HOLDER”, “AC SCHEMATIC”, “WIRING DIAGRAM”, “PLAN AT EL. 420.0”.

(b) BC Hydro will provide the Contractor with a hierarchical list (the “**Site C Component Hierarchy**”) of the various components (areas, structures, equipment, systems, subsystems, etc.) of the Project. The intent of the Site C Component Hierarchy is to ensure that naming is consistent across the entire Project. Terminology (including titles) used on Drawings will follow the Site C Component Hierarchy. BC Hydro invites collaboration by the Contractor on development/modification of the Site C Component Hierarchy, in order to ensure it is accurate and reflective of the Equipment.

7.2.17 Unit Specific Drawings

(a) A complete set of Drawings, with unique Drawing Numbers, will be provided for each Unit. For clarity:

(i) regardless of whether Equipment specific to each Unit may be identical to other Units in terms of design and construction, a Drawing will not represent Equipment for more than one Unit; and

(ii) regardless of whether Equipment within a specific Unit may be identical to other Equipment within that Unit in terms of design and construction, each piece of Equipment will be represented uniquely on the Drawings.

7.2.18 Drawing Cross-Referencing

Drawings will include full two-way cross-referencing to other Drawings, using the Drawing Numbers, where Equipment described on part of a Drawing is continued on another Drawing, or where it connects to Equipment described on another Drawing.

(a) Cross-reference Drawing Numbers will be listed in the designated “references” area of the BC Hydro Drawing Border, along with an associated reference number (1, 2, 3, 4, etc.) within the Drawing. Cross-references shown within a Drawing will not refer directly to another Drawing Number, but instead will refer to the reference number assigned to the appropriate Drawing Number within the designated “references” area of the BC Hydro Drawing Border (e.g., REF 1, REF 2, etc.).

(b) If it is convenient for a Contractor to use their own internal drawing numbers for cross-referencing, these numbers will be shown in brackets next to the cross-reference Drawing Number in the designated references area of the BC Hydro Drawing Border.

7.2.19 Drawing Format

(a) General: The Drawings will:

(i) be produced using computer-aided design and drafting software tools;

(ii) utilize the ISO A0 page size;

(iii) utilize a minimum text height of no less than 3.0 mm;

(iv) in addition to any express requirement in the Specifications, including this Appendix 6-1 [General Specifications (SPGS)], with respect to the electronic format for specific Drawings, be provided electronically in Adobe Acrobat [.pdf] file format with one file provided for each Drawing; and

(v) utilize the standard BC Hydro drawing border (the "**BC Hydro Drawing Border**"), which will be provided electronically by BC Hydro (in AutoCAD [.dwg] format, ISO A0 size) to the Contractor.

(b) Electronic Format: Each Drawing submitted electronically will:

(i) utilize an electronic name for each file that matches the Drawing Number (including sheet number, if used) and revision number (preceded with a leading "R") depicted within the BC Hydro Title Block, with each field separated by a dash (for example, 1016-C04-00142-002-R00C.pdf and 1016-C04-00142-002-R00C.dwg are submitted for drawing 1016-C04-00142, sheet 002, pre-construction revision 00C);

(ii) for Drawings submitted in Adobe Acrobat [.pdf] file format, contain the same information as the original CAD Drawing;

(iii) for all final Issued for Construction Drawings, Construction Revision Drawings and Issued for Record Drawings, be provided electronically in both Adobe Acrobat [.pdf] file format and AutoCAD 2014 [.dwg] file format (and include any external reference files or "xrefs" used) with one file of each type provided per Drawing; and

(iv) for AutoCAD Drawings, be stand-alone with no xrefs attached (i.e., there will be one drawing per file with the xrefs combined into the same file).

(c) Hardcopy Format: Each hardcopy Drawing submitted will:

(i) be a sealed Drawing;

(ii) include one set of:

(A) ISO A4 Drawings; and

(B) ISO A3 Drawings;

(iii) be printed on white 90 g/m^2 bond paper; and

(iv) be accompanied by a scanned electronic copy of the signed and sealed hardcopy Drawing, in Adobe Acrobat [.pdf] format, with "–HS" added to the end of the filename (denoting "hand signature").

7.3 Explanatory Documents

7.3.1 General

Explanatory documents (the "**Explanatory Documents**") are all Submittals required to be submitted by the Contractor under this Appendix 6-1 [General Specifications (SPGS)] other than Drawings. Explanatory Documents will:

(a) be printable on any commonly available laser printer with paper sizes including ISO A4 and ISO A3;

(b) have a minimum 25 mm margin on the left side to enable printed copies to be bound;

(c) have a cover page that, in addition to the requirements set out in SPGS 7.1.3(f), includes:

- (i) the names of the author, reviewer and PoR;
- (ii) for final Submittals, the PoR's seal;
- (iii) for Reports and Manuals:
  - (A) the Contractor's name, address and contact information;
  - (B) Contractor's document reference number;
  - (C) equipment type and serial number(s);
  - (D) applicable BC Hydro Contract and Contract Order numbers;
  - (E) the applicable BC Hydro Equipment Designation Number(s);
  - (F) if different from the Contractor, the manufacturer's name, street addresses, postal address, and contact information including landline phone number, cell phone number, email address, and web address; and
  - (G) if different from the Contractor, the manufacturer's reference number(s);

(d) have a:

- (i) revision page for Reports and Manuals; and
- (ii) revision log for all other Explanatory Documents,

that shows the revision history, including the revision, purpose of the revision, the date issued, a high-level description of the revision;

(e) have on each page, the customer name, project, contract number; report title, version and the page number; and

(f) for Reports and Manuals, have a table of contents.

7.3.2 Calculations

(a) General: The Work includes provision of calculations (each a "**Calculation**") that demonstrate or support the basis for the Equipment design. Calculations will include enough information for BC Hydro to independently verify the results of the calculation including:

(i) a description of calculation methods used;

(ii) the formulas for all calculations steps and intermediate and final results;

(iii) any assumptions made for calculations; and

(iv) discussion of results and comparison with the specification requirements.

A typical Calculation that BC Hydro may request be submitted is one that demonstrates how information or a value listed in a Technical Data Information Form was determined.

(b) Stress and Deflection Analysis: The use of modern methods of stress and deflection analysis, such as finite element methods will be utilized; however, Hydro's Representative may request that their use be accompanied by full documentation of the method used and data showing correlation between the results obtained with the method and experimental data. Also required is a comparison of the results obtained by modern methods of stress and deflection analysis and by traditional methods used on previous Equipment designs currently in service. For the Turbine hydraulic components, the loads required for stress analysis will be determined based on the use of:

(i) steady-state and non-steady-state CFD methods; or

(ii) measurements of pressure on the Model hydraulic surfaces, such as the runner or stay vanes, and subsequent scaling of measured Model pressures to the Prototype conditions; or

(iii) other techniques submitted for Consent and accepted by Hydro's Representative.

Liberal safety factors will be used throughout the design. The Contractor's design stresses, deflections, and material selection will be supported by its conventional successful practice on similar work. The Contractor will demonstrate, through its successful experience on similar work, recognized industry standards, experimental or test data, or any acceptable means, that the design safety factors, and elastic stability and deflection criteria, that the Contractor proposes to use, are both conservative and consistent with all the requirements and intent of Schedule 6 [Specifications and Drawings].

The degree of conservatism in the design of all components will also consider the risk and consequences of failure, access or lack of access to repair, maintain or inspect, high dynamic loading or vibration, stress reversal and uncertainty in static or dynamic loading conditions.

(c) Finite Element Analysis:

(i) Finite element stress analysis including fatigue and life cycle analysis for the Equipment will include: the effects of stress concentration, residual stresses in the welds and heat affected zones and both static and dynamic loading on major Equipment components such as the, Turbine runner, Turbine headcover, Generator stator and Generator rotor. The level of residual stresses used by the Contractor for the purpose of stress calculations and also for fatigue analysis will be submitted for Consent.

(ii) Where applicable, separate calculations will be provided for the component static stresses and dynamic stresses. The method to be used by the Contractor for assessing the dynamic stresses during the design stage will be submitted for Consent.

(iii) Where finite element methods are used for the calculation of deflection and stresses, special attention will be given to the selection of calculation domain (full component or one segment only), applied loading distribution, boundary conditions and quality of calculation mesh. The Contractor will test the sensitivity of the calculation results to critical or key input data, boundary conditions and alternative meshing.

(iv) Where finite element methods are used for the calculation of deflections and stresses, the Contractor will demonstrate the sensitivity of the calculation results to critical or key input data, boundary conditions and alternative meshing. The Contractor will demonstrate a convergence of the results within 5%. If due to the nature of the analysis 5% is not a practical convergence criterion then the proposed alternate criterion will be submitted for Consent.

(d) Fatigue Analysis: Fatigue analysis to be performed by the Contractor during the design stage and based on calculated static and dynamic stresses will consider the cumulative effect of all significant loading cycles expected in service including but not limited to those at normal operating conditions and transient conditions as specified in SPGT 2.7.5 of Appendix 6-2 [General Technical Specifications (SPGT)].

(e) Seismic: Calculations of stresses and deflections for the Major Components resulting from superimposing the Equipment design earthquake loads on the normal operating steady state loads and/or transient loads expected in service. The most adverse combination of the Equipment design earthquake loads, steady state loads and transient loads will be clearly identified together with the resulting stresses and deflections in Major Sub-Components.

Recognizing there are large uncertainties inherent in the assessment of seismic hazards and seismic design standards could potentially change in the future, the Contractor will evaluate the seismic performance of the Equipment for earthquakes larger than the most adverse combination of loads to test their robustness and their sensitivity to larger earthquakes and submit the results of the evaluation.

(f) Bearing Performance: Calculations of all bearing (guide and thrust) temperature rises and stresses for all operating requirements and operating conditions specified in Appendix 6-2 [General Technical Specifications (SPGT)] including thrust bearing seizing.

(g) Bearing Stresses: Calculations of bearing stresses for all bearing and wear surfaces.

(h) Fastener Stresses: Calculations of fastener stresses for major or critical joints (such as runner and rotor coupling, headcover, rotor rim and stator core studs etc.), including pre-load, deflection/stretch, torque, and stresses in the fasteners.

(i) Transient Analysis: Calculations of the spiral case pressure rise and Unit speed rise on a load rejection for the most adverse operating condition.

(j) Shaft Critical Speed: Calculations of the torsional and flexural critical speed of the main shaft, and shaft stresses under extreme loading conditions, such as the Generator short-circuit condition and out-of-phase synchronization condition.

Calculations of the shaft critical speeds will be provided for the full range of the Generator and Turbine guide bearing stiffness starting from zero stiffness and up to sufficiently high values of stiffness exceeding the expected bearing stiffness. These Calculations will demonstrate that at all expected values of guide bearing stiffness the following requirements will be met:

(i) minimum shaft critical speed will be at least 30% higher than maximum Turbine runaway speed;

(ii) shaft resonance in bending or torsional vibration mode will not be excited during Unit operation within the full range of specified operating regimes.

(k) Cooling and Piping Systems: Calculations for the sizing, pressure drop, noise, and flow requirements for all cooling and piping systems, including valves.

(l) List of Calculation Submittals: The Contractor will include a list of the Calculations it will submit in the Technical Submittal Schedule, in addition to the Calculations required to be submitted under the Specifications.

(m) Calculation Reports: Each Calculation will be submitted in a Report and will:

(i) be presented in a clear, easy to follow format;

(ii) include the electronic file of the raw calculation, in the latest version of the MathCAD [.mcd] file format or another format acceptable to Hydro's Representative; and

(iii) be organized in a logical manner; and

(n) contain the following items or equivalent:

(i) introduction;

(ii) description of input data;

(iii) basis or standard justifying the use of the calculation or the calculation methodology;

(iv) design/modelling assumptions and, if FEA analysis is used, the convergence criteria;

(v) load cases and/or design cases;

(vi) If FEA or CFD, descriptions of software, methods and the model and the various inputs and boundary conditions;

(vii) results from the calculations;

(viii) comparison of methodology and results to the specified technical requirements of the Contract;

(ix) conclusions; and

(x) references.

7.3.3 Parts Lists and Bill of Materials

Each part, piece and material that comprises each component or subsystem of the Equipment will be listed in a parts list or a bill of material (each a “**Parts List**” or “**Bill of Materials**” or “**BoM**”) and will:

(a) have a unique number which will be cross referenced to the applicable Drawing or Explanatory Document;

(b) include part numbers, quantities, manufacturer’s or supplier’s names, sizes, materials, ASTM or other specifications or standard designations for the part materials;

(c) be shown in table format, and will include the following fields: “PARTS LIST ITEM#” or BoM ITEM, “QTY”, “DESCRIPTION”, “UNIT WEIGHT”, “MANUFACTURER”, “MANUFACTURER PART# / PART”, “CATALOG #” (if different from the PART# / PART), “DIMENSIONS”, “EST COST” and “REF DWG#”. Parts Lists for piping, valves, instrumentation and fittings will include the additional fields: “BC HYDRO’S TAG NUMBER”, (cross-referenced with the Contractor’s tag number, if applicable), “SIZE”, “FINISH” and “STANDARD” (ASTM or other specification or standard designations);

(d) where applicable, show the ratings of each part in the Parts List or BoM “DESCRIPTION” field (e.g., for capacitors and resistors: size, type of material, manufacturer and part number, along with voltage ratings for capacitors and power ratings for resistors); and

(e) be shown on the Drawings or Explanatory Document as follows:

    (i) the Parts List for a particular component or subsystem of the Equipment will be shown on the General Arrangement Drawing for that subsystem or part of the Equipment, if it is reasonably practicable to do so; otherwise, the Parts List will:

        (A) be shown on the last sheet of the Drawing; or

        (B) if the Parts List cannot be shown on the last sheet of a Drawing, be included as an Explanatory Document and include a Drawing number cross reference for each part in the list;

    (ii) each Drawing that includes a Parts List will, as much as possible, be designed such that all parts, components and materials listed in the Parts List are shown on that Drawing. For clarity, the number of references a Parts List makes to other Drawings will be minimized; and

    (iii) for each part shown on a Drawing, the part will include a numbered Parts List reference bubble next to graphical element in the Drawing that represents its corresponding part, component, or material listed in the Parts List; and

(f) be submitted with the relevant Drawings if included as an Explanatory Document pursuant to SPGS 7.3.3(e)(i)(B).

Parts Lists and Bills of Materials will be updated promptly and re-submitted as revisions occur. A complete as-constructed Parts Lists and Bills of Materials will be provided immediately after completion of the Work.

In addition to the Contractor’s own identification, Hydro’s Representative will provide alphanumeric valve and instrumentation tag numbers.

7.3.4 Hazard Logs

Hazard logs (each a “**Hazard Log**”) will be created for each Major Component. The Hazard Logs will document the outcome of the Safety by Design Plan described in SPGS 4.5 and the human factors engineering requirements described in SPGS9, and at a minimum, will contain the information set out in the Hazard Log template, which can be found in the electronic data site described in Section 6.35 of Schedule 2 [Design and Construction Protocols].

Hazard Logs will be submitted in Excel [.xlsx] file format.

7.3.5 Cable Schedule

(a) General: A master list of all electrical cables supplied as part of the Equipment (the “**Cable Schedule**”) will be provided. Information about each cable will include the:

(i) length;

(ii) type;

(iii) number of conductors;

(iv) size of conductors;

(v) purpose;

(vi) two locations where the cable is terminated; and

(vii) route between the terminal locations.

Each cable will be assigned within the Cable Schedule that follows a pre-designed framework (the framework will be designed by BC Hydro in collaboration with the Contractor to provide an orderly, efficient and intuitive method of numbering cables, and will also allow for future expansion/modification of the Cable Schedule).

Each cable supplied as part of the Equipment will be shown once in the Cable Schedule.

Naming of cable terminal locations within the Cable Schedule will follow the Site C Component Hierarchy.

(b) Development: The Cable Schedule will be developed as follows:

(i) before any related Drawings are produced, the Contractor will submit a proposed list of cables using a purpose-built template that will be provided by BC Hydro to the Contractor;

(ii) BC Hydro will assign cable numbers to each of the Contractor’s proposed cables. This will form the first draft of the Cable Schedule, which will be sent to the Contractor; and

(iii) the Contractor will collaborate with BC Hydro to revise and update the Cable Schedule as the Work progresses, in order to ensure additions, deletions and modifications to the Cable Schedule respect the pre-designed numbering framework.

7.3.6 Reliability Centred Maintenance (RCM) Sheets

(a) Failure Mode and Effects Analysis: The Work includes completing failure mode and effects analysis for each component of (or system in) the Equipment, including identification of:

(i) the critical components of the Equipment;

(ii) the failure modes and the effects of the failure for each component;

(iii) the failure category (e.g., economic, safety, environment);

(iv) the expected root cause for each failure mode;

(v) the expected mean time between failures;

(vi) the typical warn time for the failure (e.g., days, weeks or months);

(vii) the indicators of a pending failure;

(viii) the characteristics of the failure (e.g., definitive life/wear out characteristics, random (constant probability of failure), general degradation to failure, or hidden);

(ix) the consequences of failure (e.g., total stoppage, part stoppage or quality, no immediate effect, or no effect);

(x) the recommended maintenance required for each component of the Equipment;

(xi) the recommended maintenance frequency including the frequency minimum interval and maximum interval bounds;

(xii) the recommended maintenance strategy (e.g., condition-based maintenance, fixed time maintenance, or operate to failure);

(xiii) the recommended method to monitor (online), inspect, or test for each failure mode;

(xiv) the recommended spare parts and the recommended number of spare parts to have on hand;

(xv) the estimated person hours required to complete the maintenance required to prevent the failure;

(xvi) the estimated resources (trades type and number) required to complete the recommended maintenance;

(xvii) the estimated cost of the materials required to complete the maintenance needed to prevent the failure from occurring;

(xviii) the estimated person hours required to correct the failure should the failure occur while the Equipment is in service;

(xix) the estimated resources (trades type and number) required to complete the repairs should the failure occur while the Equipment is in service; and

(xx) the estimated cost of the materials required to repair the Equipment should the failure occur while the Equipment is in service.

(b) Reliability Centred Maintenance Sheets: The Work includes preparation of reliability centred maintenance sheets (the "**Reliability Centred Maintenance Sheets**" or "**RCM Sheets**") for each component of the Equipment. Each RCM Sheet will document the conclusions to the points listed in SPGS 7.3.6(a)(ii) for each Equipment component.

(c) Equipment Inspection, Test and Maintenance Program: The Work includes incorporation of the results and conclusions from the failure mode and effects analysis of the Equipment into:

(i) the recommended inspection, test and maintenance program for the Equipment; and

(ii) the Operations and Maintenance Manual for each Major Component.

(d) RCM Turbo Software: BC Hydro will enter the results from the failure mode and effects analysis into BC Hydro's RCM Turbo maintenance frequency optimizer tool. Sample screen snap shots of the RCM Turbo data entries for a Peace Canyon G.S. Excitation System component and for a Peace Canyon G.S. Governor System component, which can be found in the electronic data site described in Section 6.35 of Schedule 2 [Design and Construction Protocols]. The data entry fields shown in those screen snap shots from the RCM Turbo tool are completed using the data documented in the RCM Sheets.

7.3.7 Inspection and Test Records

All inspection and test records produced for the Work, including during manufacturing, assembly, installation and commissioning, will include the following details:

(a) the Unit number;

(b) component or part identification;

(c) type of inspection or test;

(d) reference to the applicable ITP;

(e) dates of sampling, inspection, testing and reporting;

(f) personnel involved;

(g) location of the inspection or test;

(h) specified requirements and standards;

(i) inspection or test standard reference;

(j) acceptance/rejection limits;

(k) test equipment with calibration data;

(l) inspection or test results (complete with units of measure);

(m) remarks regarding conformance with the Contract; and

(n) inspection or test witness, if any.

In addition to the above, non-destructive examination (NDE) records will include:

(o) the job number;

(p) Drawing number;

(q) NDE area map or weld map of the examined or radiographed areas;

(r) weld number, if applicable;

(s) welder identification, if applicable;

(t) exposure date;

(u) detail of findings;

(v) exact location and size of defects;

(w) disposition, including any re-examination results and conclusions;

(x) examiner's or radiographer's name and certificate(s); and

(y) a copy of the Non-Destructive Examination Procedure, in sufficient detail that the same Non-Destructive Examination may be readily duplicated.

7.3.8 Procedures

The Work includes provision of written procedures (each a "**Procedure**") that describe in detail how each component of the Equipment is assembled, installed, inspected, tested, commissioned, operated, isolated, maintained, disassembled, repaired, refurbished and replaced, and that include:

(a) an introductory description of the Procedure, including the purpose of the Procedure and the component of the Equipment it applies to;

(b) the equipment nameplate information;

(c) the estimated number of people required to perform the Procedure, including their roles and required skill sets;

(d) the estimated time (duration in hours) to complete the Procedure;

(e) a list, including quantity, of the commonly available tools and equipment required;

(f) a list, including quantity and description, of all the specialized tools and equipment required;

(g) a list, including quantity, of any consumables required;

(h) a list of spare or replacement parts required to perform the Procedure including part numbers and acceptable substitutes, spare, or replacement parts;

(i) the weight of any components over 15 kg that need to be lifted or moved;

(j) safety precautions required including isolation requirements, required personal protective clothing, etc.;

(k) specialized safe work Procedures including confined space Procedures, Worker rescue Procedures, etc.;

(l) a step-by-step description of how to perform the Procedure complete with:

- (i) exploded views of the equipment or component the Procedure applies to;
- (ii) how the Equipment or component is to be configured if the configuration is different from what it would be for normal operation (including changes to software or protection settings);
- (iii) the pre-checks to be performed prior to execution of the Procedure and what to look for;
- (iv) the checks to be performed during execution of the Procedure and what to look for;
- (v) what the expected data results are (if applicable);
- (vi) what post checks are to be performed after completion of the Procedure;
- (vii) required assembly adjustments, design clearances and torque specifications;
- (viii) diagrams, flow charts, checklists;
- (ix) reference Drawings; and
- (x) references to relevant Quality documentation;

(m) detailed acceptance criteria;

(n) checklists or data collection forms to be used with the Procedure; and

(o) a troubleshooting guide to facilitate diagnosis of problems that commonly occur during the performance of the Procedure or of problems commonly identified during the performance of the Procedure.

Where an acceptance criterion is not simply a pass or fail, the acceptance criterion must specify the allowable tolerance/deviation from the desired value.

At a minimum, the following information will be included in the checklists or data collection forms to be used with the Procedure:

(p) date;

(q) Unit number;

(r) Equipment component or assembly the Procedure applies to;

(s) relevant environment conditions;

(t) relevant information about the equipment or instrumentation used in the performance of the Procedure such as, make, model, calibration date;

(u) the as-found settings;

(v) the as-found readings (if applicable);

(w) what out-of-tolerance conditions or problems, if any, were encountered and what the correction was;

(x) interim settings (if applicable);

(y) interim readings (if applicable);

(z) the as-left settings;

(aa) the as-left readings (if applicable);

(bb) printed name and sign-off by the person(s) responsible for executing the Procedure;

(cc) printed name and sign-off by the person(s) responsible for accepting the Procedure; and

(dd) printed name and sign-off by the PoR.

Checklists or data collection forms will be arranged such that they can easily be converted to allow the data to be collected electronically

Procedures will be complete, thorough and sufficiently detailed that they may be used as a reference document for, and to assist in any future work on the Unit by, BC Hydro throughout the Design Life of the Equipment.

7.3.9 Inspection Records, Measurements, Test Data and Test Results

(a) Format: All inspection records, measurements, test data and test results generated during the Work, including during manufacturing, in-lab or in-factory testing, quality control or assurance, Site assembly, Site installation and Site acceptance and commissioning tests performed by the Contractor will be recorded and submitted for Review.

The Contractor will make every effort to record test data electronically using electronic data collection tools, or to record low-frequency or low-volume data manually in a Word [.docx] or Excel [.xlsx] format. Where this is deemed by Hydro's Representative unnecessary or impractical, test data will be recorded manually and tabulated in a neat, methodical manner.

Hydro's Representative may request additional inspections, measurements or tests if the results of any inspections, measurements or tests are inconsistent or deemed to be inadequate.

(b) Submittal Schedule: All inspection records, measurements, test data and test results:

(i) that occur as part of the manufacturing, in-lab or in-factory testing phase of the Work, or for quality control or assurance will be submitted in accordance with the Specifications, including this Appendix 6-1 [General Specifications (SPGS)]; and

(ii) that occur as part of the Work at Site, will be submitted in accordance with the following schedule:

(A) for the raw inspection records, measurements, test data and test results, as soon as reasonably practicable after each test has been completed but not later than two days after each inspection, measurement or test has been completed;

(B) for the preliminary processed inspection records, measurements, test data and test results, as soon as reasonably practicable after each test has been completed but not later than seven days after each inspection, measurement or test has been completed; and

(C) for the final inspection records, measurements, test data and test results, as soon as reasonably practicable after each test has been completed but not later than 15 days after each inspection, measurement or test has been completed.

7.3.10 Measuring Equipment and Instrumentation

(a) General: The Work includes submission of all documentation for each piece of measuring equipment and instrumentation used for the quality control or assurance Work and for the Work at the Site. Such documentation will include:

(i) the make and model of the measuring equipment or instrument;

(ii) the manufacturer's specifications including rated accuracy and resolution, maximum range, sensitivity to temperature or other environmental factors;

(iii) certified copies of the latest calibration records; and

(iv) sufficient manufacturer's documentation or manuals to demonstrate the measuring equipment or instrument is suitable for the intended application.

(b) Submittal Schedule: The documentation for each measuring equipment and instrument will be submitted not later than 60 days prior to the date it is first scheduled to be used. The calibration recertification documentation for this equipment will be submitted not later than 30 days prior to when the equipment is first scheduled to be used after recalibration.

(c) Suitability: If in the opinion of Hydro's Representative the proposed measuring equipment or instrumentation or test equipment is for any reason not suitable or appropriate for the intended task the Contractor will be required to propose and obtain alternative measuring equipment and instrumentation. This includes such devices as torque wrenches, meters, pressure gauges, etc.

(d) Permanently Installed Instrumentation: The Work includes submission of the calibration documentation for the permanently installed instrumentation for the Equipment in accordance with SPGS 7.3.10(a). The documentation will be submitted not later than 30 days after the instrumentation has been calibrated.

7.3.11 Reports

Reports (each a "**Report**") summarize the outcome of engineering activities such as calculations, studies or investigations, or Site activities such as installation, commissioning, inspection or maintenance. Reports will include, at a minimum, the following information:

(a) For engineering activities:

(i) an introductory description of the Report including:

(A) the equipment or component it applies to; and

(B) the purpose of the activity;

(ii) the background or introduction to the activity;

(iii) the methodology used in the activity;

(iv) a discussion about the results obtained;

(v) the conclusions reached as a result of the activity;

(vi) any recommendations based on the results of the activity; and

(vii) additional and supporting information included as a appendices such as:

(A) Calculations;

(B) reference information;

(C) flowcharts;

(D) Photos;

(E) diagrams; and

(F) Drawings.

(b) For Site activities:

(i) an introductory description of the Report including:

(A) the equipment or component it applies to; and

(B) the purpose of the activity;

(ii) the actual number of workers required to perform the activity including their skill sets;

(iii) the actual elapsed time to complete the activity;

(iv) a list, including quantity, of the tools and equipment that were required to complete the activity;

(v) a list, including quantity, of any consumables used;

(vi) a list of spare or replacement parts that were used during the performance of the activity;

(vii) a list of previously unidentified safety precautions that were required;

(viii) a step- by-step description of how the activity was performed complete with:

(A) flow charts;

(B) check lists;

(C) diagrams;

(D) exploded views of the equipment or component the activity applies to; and

(E) Drawings;

(ix) detailed acceptance criteria;

(x) completed check lists and data collected during the performance of the activity;

(xi) a description of problems occur during the performance of the activity and the steps that were taken to correct for the problem;

(xii) activity results;

(xiii) conclusions; and

(xiv) recommendations for next time the activity is performed including:

(A) lessons learned;

(B) residual hazards that need to be added to the Hazard Log;

(C) ways in which Procedures should be revised; and

(D) ways in which Operations and Maintenance Manuals should be revised.

7.3.12 Operations and Maintenance Manuals

The Work includes submission of comprehensive operations and maintenance manuals (each an "**Operations and Maintenance Manual**" or a "**Manual**") for each Major Component prepared in accordance with Good Industry Practice and to the level of detail reasonably required by BC Hydro for the operation, inspection, testing, maintenance, disassembly, reassembly, repair and replacement of the Equipment.

Manuals will be submitted in accordance with the following schedule:

(a) As-Shipped Manuals: Prior to shipping the first item of the applicable Major Component for each Unit, the Contractor will submit the Manual for the Major Component that reflects the state of the Equipment as it will be shipped to Site.

(b) Issued for Record Manuals: Not later than 60 days after completion of commissioning of each Unit, the Contractor will submit the issued for record Manual for each Major Component that reflects the state of the Equipment as it was left following commissioning.

(c) Final Issued for Record Manuals: Not later than 60 days after completion of commissioning of the last Unit, the Contractor will submit the final issued for record Manual for each Major Component. Each Manual will apply to all Equipment of the same type and will clearly identify any unique requirements for a particular Unit should the Equipment not be identical. i.e., there does not need to be a final issued for record Manual for each Unit. The Contractor will submit ten hardcopies of the final issued for record Manuals.

Each Manual will be divided into sections and subsections in a manner that permits intuitive and convenient navigation, and that includes the following:

(d) Table of Contents: a listing of Manual sections and page and reference numbers. Each section in the Manual will include detailed table of contents and page references for the section.

(e) Section 1 - Equipment Description: This section will include the following information:

(i) an introductory description of the Manual, including the Equipment or component it applies to, and the purpose of the Manual;

(ii) technical specifications, characteristics and design data for all components of the Equipment;

(iii) a description of the system and how each component operates within that system;

(iv) a description of each component of the Equipment, its function and operation;

(v) a table of weights for each component of the Equipment over 15 kg that needs to be removed to facilitate inspection, testing, maintenance or repair;

(vi) Lifting Points and Lifting Devices for the Equipment; and

(vii) equipment or component identification numbers.

(f) Section 2 – Technical Data, Information Forms, Setting Sheets and Software: This section will include the as-commissioned:

(i) versions of the Technical Data and Information Forms that reflect the as-commissioned data and information for the Equipment;

(ii) for all applicable Equipment components:

(A) control set-points and alarm and trip thresholds;

(B) protection and control instrumentation setting sheets; and

(C) instrumentation calibration records;

(iii) documentation of all Software associated with the system, including:

(A) a complete description of the Configuration Tool Software, and its specific version number, used to create the Application Configuration Files;

(B) a complete printout of the source code, memory map, input/output mapping, and configuration settings for the Application Configuration Files;

(C) a complete printout of help files and Explanatory Documents for the Contractor's function blocks and algorithms used in the Application Configuration Files;

(D) a complete printout of the Event List, Alarm list, and Target list associated with the Application Configuration Files; and

(E) any other Explanatory Document associated with the Application Configuration Files; and

(iv) the final copy of the Software in its native file format.

(g) Section 3 – Summary of Requirements during Warranty Period: This section will include a summary of all of the necessary operations, inspection, and maintenance requirements as they relate to the Warranty for the Equipment including:

(i) the contact information for the Contractor's Representative during the Warranty Period including:

(A) Contractor's Representative's name and title;

(B) full legal company name;

(C) full name of company division or department;

(D) street address;

(E) postal address;

(F) landline phone number;

(G) cell phone number (if applicable);

(H) email address; and

(I) web address (if applicable).

(ii) the contact information for the Contractor's product and spare parts support department(s) and/or suppliers including:

(A) full legal company name;

(B) full name of company division or department;

(C) street address;

(D) postal address;

(E) landline phone number;

(F) cell phone number (if applicable);

(G) email address; and

(H) web address (if applicable).

(iii) a table that summarizes the key dates as they relate to the Warranty Period for the Equipment including: Major Component, in-service date, materials and workmanship warranty end date, and design warranty end date. An example of such table is provided immediately below;

Major Component	In-service Date	Materials and Workmanship Warranty End Date	Design Warranty End Date
Generator 01	2022-12-01	YYYY-MM-DD	YYYY-MM-DD

(iv) a table that summarizes the inspection, maintenance, and operational requirements for the Equipment during the Warranty Period including:

(A) Major Sub-Component;

(B) Equipment sub-sub-component (if applicable);

(C) task (one item per line in the table);

(D) frequency;

(E) cross reference to applicable Procedure(s) including any special Procedures identified under SPGS 2.12(c); and

(F) cross reference to applicable Drawing(s) (if not already referred to in the reference Procedure); and

An example of such table is provided immediately below:

Major Sub-Component	Equipment sub-sub-component	Task	Frequency						Reference Procedure	Reference Drawing
			Continuous	Monthly	Annually	After 1 Year	After X Years	Interval		
Rotor	Poles	Check inter-pole connections				X		6 Years		

(v) any other information a prudent owner/operator would customarily receive for equipment similar to the Equipment and which would assist BC Hydro's operations and maintenance personnel to meet the requirements of the Warranty.

(h) <u>Section 4 – Operations</u>: This section will include all the Procedures and any other information required to operate the Equipment.

(i) <u>Section 5 – Preventative Maintenance</u>: This section will include the Procedures for all Equipment components that are to be inspected, tested and maintained, the acceptance criteria for each task, and the recommended intervals for each task including:

(i) completed RCM Sheets for each component of the Equipment;

(ii) a list of the Equipment components that are meant to be operated to failure or that do not require inspection, testing or maintenance;

(iii) all inspection, testing, maintenance and minor repair or replacement Procedures required to meet the requirements of the Warranty and to ensure the Equipment achieves its Design Life and that are in addition to those tasks that has been identified in the RCM Sheets;

(iv) adjustment Procedures and clearances;

(v) lubrication requirements, including:

(A) lubrication Procedures;

(B) a list of recommended lubricants;

(C) oil and grease operating and maintenance bulletins for all components of the Equipment;

(D) information on probable points of wear; and

(E) recommended service life between lubrications;

(vi) exploded views of the Equipment to show disassembly and assembly details of the components and parts;

(vii) all disassembly/reassembly Procedures required to disassemble and assemble the Equipment;

(viii) lifting Procedures;

(ix) cleaning Procedures including accepted cleaners;

(x) MSDS for all chemicals and materials, such as lubricants, greases, solvents, paints and cleaners supplied by the Contractor;

(xi) dry-out Procedures;

(xii) specialized safe work Procedures including confined space Procedures, Worker rescue Procedures, etc.;

(xiii) all pertinent bulletins, Procedures and Manuals prepared by the various manufacturers of each component of the Equipment, suitably annotated to indicate clearly those items that form part of the complete assembly, including cross references to Parts Lists;

(xiv) a table that summarizes the inspection, maintenance, and operational requirements for the Equipment after expiration of the Warranty Period including:

(A) Major Sub-Component;

(B) Equipment sub-sub-component (if applicable);

(C) task (one item per line in the table);

(D) frequency;

(E) cross reference to applicable Procedure(s); and

(F) cross reference to applicable Drawing(s) (if not already referred to in the reference Procedure); and

An example of such table is provided immediately below:

Major Sub-	Equipment sub-sub-	Task	Frequency	Reference	Reference

Component	component		Continuous	Monthly	Annually	After 1 Year	After X Years	Interval	Procedure	Drawing
Rotor	Poles	Check inter-pole connections				X		6 Years		

(xv) any other information a prudent owner/operator would customarily receive for equipment similar to the Equipment and which would assist BC Hydro's operations and maintenance personnel to operate, inspect, and maintain the Equipment.

(j) Section 6 – Major Overhaul, Repair and Replacement Procedures: This section will include Procedures for all reasonably expected major overhaul, repair and replacement tasks that may be required over the Design Life of the Equipment including:

(i) all major overhaul, repair and refurbishment tasks for the Equipment along with applicable material requirements, Drawings, and spare parts and material specifications;

(ii) specialized assembly and dismantling Procedures; and

(iii) all replacement Procedures for the Equipment.

(k) Section 7 - Routine Test Reports: This section will include two extra copies of each checklist or data collection forms for each Procedure included in the Manual.

(l) Section 8 – Spare Parts: This section will:

(i) include a spare Parts List prepared in accordance with Appendix 6-2 [General Technical Specifications (SPGT)], including at a minimum the information shown in the BC Hydro Spare Parts List template described under that Appendix;

(ii) include a recommended Parts List for spare parts, if additional spare parts are recommended over and above those included as part of the Work; and

(iii) meet the documentation requirements for spare parts in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

(m) Section 9 – Component Manuals: This section will include the original Manuals for components of the Equipment that are not custom made by the Contractor. Examples might include:

(i) level, pressure or flow instrumentation;

(ii) control buttons, switches and relays;

(iii) display screens;

(iv) motor control starters, breakers and relays;

(v) valves and regulators; and

(vi) assembly, safety or operating bulletins.

(n) Section 10 - Miscellaneous: This section will include any additional and miscellaneous information required in order to completely describe the Equipment for the purposes of the Manual.

(o) Section 11 – Drawings*:* This section will include:

(i) a complete indexed list of all the Drawings for the subject Equipment that includes both BC Hydro's Drawing number and the Manufacturer's Drawing number; and

(ii) a complete set of Drawings for the subject Equipment.

7.3.13 Photos

(a) General: In addition to the requirements in Schedule 9 [Communication Roles], the Work includes provision of photographs (the "**Photos**") that provide a documentary and visual record of the progress of the Work and will:

(i) be taken using a digital camera, programmed with the correct date;

(ii) be in colour;

(iii) have a resolution of not less than 8 megapixels;

(iv) be clear, legible, high-contrast and suitable for the purpose intended;

(v) be taken with sufficient lighting provided, in order to ensure features of the subject of the photograph are not obscured by shadows and that the content is not blurry;

(vi) each be digitally stored in JPEG file format, with a compression quality ratio (Q factor) of not less than 75;

(vii) each be dated; and

(viii) each be uniquely numbered in such a way that the Photos automatically sort sequentially in a sequence that is logical with respect to the context for the purpose of taking the Photos.

Special preparation of Equipment (such as painting or cleaning) is not required before taking Photo unless otherwise required to produce a clear legible, high-contrast photograph.

(b) Quantity: A sufficient number of Photos of the Equipment components will be taken such that workers have a sufficient visual record to be able to assemble, install, inspect, test, commission, operate, maintain, disassemble, repair, refurbish, modify, or replace any components of the Equipment throughout its entire Design Life without access to Drawings or Parts Lists.

(c) Submission: Photos will be submitted electronically at least once a week, with progress Reports and any special reporting requirements. Within 30 days of the completion of each significant stage in the Work where applicable, the Contractor will submit the complete set of Photos electronically on an acceptable media. All the Photos will be made available at any time during the Work to Hydro's Representative upon request. BC Hydro reserves the right to use the Photos provided by the Contractor without restriction.

(d) Organization: All Photo Submittals will be sorted and organized in electronic folders generally in accordance with the following hierarchy:

(i) Unit;

(ii) Major Component;

(iii) Major Sub-Component;

(iv) Equipment sub-sub-component (e.g., Turbine runner crown, Turbine runner blade, Turbine runner crown); and then

(v) stage of the Work when the Photo was taken (e.g., manufacturing, assembly, delivery, installation, testing, commissioning, disassembly, inspection, maintenance).

The folder hierarchy and the folder name will be the same as the Site C Component Hierarchy.

(e) Labelling: All Photo Submittals will be accompanied with an Excel [.xlsx] file that provide a listing of and label for each Photo. The information included in the label for each Photo will be sufficient such that it possible for a Worker to understand the subject of and intent for taking the Photo in decades into the future and will include:

(i) the unique filename of each Photo;

(ii) the date each photograph was taken;

(iii) the name of the Equipment component that is the subject of the Photo;

(iv) a unique caption that describes the subject of each Photo;

(v) the reason the Photo was taken (if other than to simply document general progress);

(vi) the stage of the Work when the Photos was taken (e.g., installation, commissioning, inspection, testing, or maintenance);

(vii) the direction of the camera's view, if appropriate; and

(viii) the photo information embedded in Metadata in both EXIF and IPTC format.

Where a series of Photos are taken that are of the same subject and/or taken for the same intent, the listing and labelling can be generalized to apply to the series of Photos provided the Photos are sorted and grouped in the same electronic folder.

(f) Manufacturing Photos: The Work includes provision of Photos that document the manufacturing of the Equipment before it is shipped to Site, including:

(i) start of manufacturing, such as moulding, material staging, cutting and dispatching;

(ii) casting, forging and machining;

(iii) shop assembly;

(iv) shop inspection and testing;

(v) visual defects and associated remedial works; and

(vi) the final state of the Equipment immediately after it has been inspected and accepted by the Contractor prior to preparation for shipment.

(g) Shipping Photos: The Work includes provision of Photos of the shipment progress (preparation, loading, transport, delivery, unloading and storage) of Equipment components that require a Shipping Plan, including:

(i) how the Equipment is prepared;

(ii) loading and securing on transport vehicles;

(iii) state of the Equipment when it is received at Site or at the Contractor's storage area; and

(iv) unloading and storage at the Contractor's storage area or at Site.

(h) Site Work Photos: The Work includes provision of Photos that document performance of the Work at Site, including:

(i) assembly;

(ii) adjustment and alignment;

(iii) instrumentation and measurement;

(iv) welding, brazing and non-destructive examinations;

(v) engineered lifts;

(vi) pressure testing;

(vii) functional testing and other early commissioning testing; and

(viii) commissioning testing.

7.3.14 Explanatory Documents Format

(a) Electronic Format: Explanatory Documents submitted in electronic format will:

(i) have a table of contents;

(ii) have embedded page numbers;

(iii) be fully indexed, complete with a hierarchy of dynamic electronic bookmark links to each section and subsection and that matches the table of contents;

(iv) utilize an electronic file name for each file that conveys the applicable Unit number, contents of the file and version;

(v) if the format for an Explanatory Document is not otherwise expressly specified, be submitted in an electronic format acceptable to Hydro's Representative;

(vi) with the exception of Photos, be submitted in Adobe Acrobat [.pdf] file format in addition to the electronic format specified for each type of Explanatory Document; and

(vii) for final submission of Explanatory Documents in Excel [.xlsx] format, also be submitted in Excel [.csv] format.

(b) Hardcopy Format: Where a hardcopy of an Explanatory Document is required as a Submittal, the hardcopy will:

(i) be bound in a robust ISO A4 size presentation binders with clear plastic on the front and spine to form a pouch in which the cover page is inserted;

(ii) utilize the ISO A3 page size for Drawings, and the ISO A4 page size for all other pages with all Drawings folded twice (Z-folded) so that they have an ISO A4 footprint and the Drawing Number can be seen without having to unfold them;

(iii) be printed on white 75 g/m^2 bond paper;

(iv) have tabbed index dividers, labeled on both sides to match the corresponding section number in the table of contents; and

(v) for Reports and Manuals, have on their spines the same information as the cover page section.

7.4 Request for Variations to Protocols

If the Contractor's practice for the design or installation stages is different from the protocols as set out in the Specifications then the Contractor may submit a request to alter the protocols for Consent.

SPGS8 DESIGN REVIEWS AND DESIGN SUBMITTALS

8.1 Reviewed Drawings and Specifications

8.1.1 Review Procedure

Subject to SPGS 5.2 of this Appendix 6-1 [General Specifications (SPGS)], before commencing detailed design or fabrication of a particular element of the Equipment, the Contractor will submit for Consent all necessary Design Submittals as BC Hydro may reasonably require, including any design Reports and Calculations, reasonably necessary for BC Hydro to conduct an appropriate review to confirm that the design described in the Design Submittal conforms to the requirements of the Contract Documents, including Schedule 2 [Design and Construction Protocols], Schedule 6 [Specifications and Drawings] and [redacted]

If the Contractor proceeds with any design or fabrication phase in advance of an "Accepted" or deemed "Accepted" endorsement on the necessary Design Submittals by Hydro's Representative then Hydro's Representative may require the Contractor to make changes to such design or completed fabrication to the extent permitted under the Contract, which the Contractor will undertake at its own cost.

8.2 Design Reviews

8.2.1 General

The Work includes the opportunity for Hydro's Representative to have separate design reviews (each a "**Design Review**") for each Major Component as set out in this Appendix 6-1 [General Specifications (SPGS)] at each of the major stages of design. Design Reviews will be held so as to permit both the parties in a timely way to confirm with each other that the design of the Equipment complies with the requirements of the Contract Documents. The parties will cooperate to facilitate productive and useful Design Reviews.

8.2.2 Intent of Design Reviews

Design Reviews are not intended to be a substitute for or replacement of the Contractor’s internal design review and quality control processes, or to alter or amend the parties obligations with respect to design of the Equipment as described in the Contract Documents. Design Reviews are intended to assist the Contractor with improving on and optimizing the Final Designs of the Work, including by:

(a) being a co-operative systematic evaluation of the design in comparison to the requirements in the Contract Documents including considerations such as:

  (i) compliance with the Contract;

  (ii) feasibility;

  (iii) risks;

  (iv) completeness;

  (v) plausibility/correctness;

  (vi) clearness, comprehensibility;

  (vii) cost effectiveness;

  (viii) constructability, maintainability and operability;

  (ix) safety-by-design requirements (human factors engineering) and Hazard Log;

  (x) quality control requirements;

  (xi) environmental requirements (customer requirements and legal requirements); and

  (xii) health and safety requirements (customer requirements and legal requirements);

(b) being a way to identify lessons learned and experiences from other similar work that could be incorporated into the design;

(c) providing an opportunity for BC Hydro to provide the Contractor with a maintenance and operations perspective of their design including helping to incorporate safety-by-design features into the design of the Equipment; and

(d) providing a forum for the early detection of defects in design.

8.2.3 Design Review Process

The procedure for each Design Review will be as follows:

(a) prior to the Design Review the Contractor will:

  (i) submit design information, including design memorandum, Drawings, Calculations and other design information, relevant to the Equipment Component and the stage of design being considered; and

(ii) submit a list of the Contractor's personnel who will participate in the Design Review, their job title and their role within the project;

(b) the Contractor will have the design personnel participate who are responsible for the design being covered by the Design Review participate in that Design Review, and BC Hydro will use reasonable efforts to have BC Hydro team members who are qualified to comment on and consider the Contractor's design participate in that Design Review;

(c) the Design Reviews will be informal, and no minutes will be prepared or circulated; however each participant can take notes for their own reference. Nothing said or agreed to at a Design Review, and no requests for information submitted by either party after a Design Review for the purpose of seeking clarifications or confirmation regarding any discussion at a Design Review, will be binding on either party unless otherwise confirmed in writing in accordance with the requirements of the Contract Documents;

(d) the parties will have candid conversation with respect to the design under consideration for the purpose of making the design process, and the Contractor's performance of the Work, efficient and without error; and

(e) for certainty, Hydro's Representative's Consent as required under SPGS 8.2.1 may not be inferred from informal communications that may occur during a Design Review, such Consent to be delivered expressly and separately, with respect to specific Design Submittals.

Either party may request that additional matters or issues be included in a Design Review.

8.2.4 Timing of Design Reviews

The Contractor will plan and include in its Technical Submittal Schedule Design Reviews at a minimum at the following points in the overall design process for each component of the Equipment:

(a) at the Initial Design, Detailed Design and Completion Design stages;

(b) when the preliminary versions of the:

(i) Software Design Plan;

(ii) Application Configuration Files;

(iii) assembly and installation Procedures;

(iv) commissioning Procedures;

(v) operations and maintenance Procedures;

(vi) replacement Procedures;

(vii) Operations and Maintenance Manual;

(viii) confined space and Worker rescue Procedures; and

(ix) Reliability Centred Maintenance Sheets,

have been completed for each Major Component. Preliminary versions of these Explanatory Documents will be completed prior to the design activities reaching the Completion Design stage for the Equipment component to which the preliminary version applies, so as to enable the

Contractor to incorporate feedback received from BC Hydro into the Final Design of the Equipment;

(c) at each point a Software Meeting is required as set out in Appendix 6-2 [General Technical Specifications (SPGT)]; and

(d) when either the Contractor or BC Hydro believes the most expedient way to ask questions, provide feedback, or share information with respect to requirements in the Contract Documents or a particular Design Submittal or Design Commitment.

8.2.5 Design Review Meeting Topics

The following topics, as a minimum, will be included in one or more Design Reviews:

(a) Integration of the Equipment to the Powerhouse, including:

  (i) Equipment layout, system engineering and interface definitions; and

  (ii) review of Interface points between the Contractor and Others.

(b) Turbine design, including:

  (i) hydraulic design of runner & water passage components (i.e., CFD analysis);

  (ii) mechanical analysis of Major Sub-Components (i.e., FEA, fatigue analysis);

  (iii) design of shaft seal water supply and control system;

  (iv) detailed mechanical design;

  (v) detailed electrical design and associated Drawings (i.e., system, network and interface architecture Drawings, instrumentation, schematics and wiring diagrams);

  (vi) related Drawings and Explanatory Documents; and

  (vii) review of the Hazard Log for the Turbine.

(c) Generator design, including:

  (i) electro-magnetic design;

  (ii) mechanical analysis of Major Sub-Components;

  (iii) stator bar design;

  (iv) detailed mechanical design;

  (v) detailed electrical design and associated Drawings (i.e., system, network and interface architecture Drawings, instrumentation, schematics and wiring diagrams);

  (vi) related Drawings and Explanatory Documents; and

  (vii) review of the Hazard Log for the Generator.

(d) Governor System design, including:

(i) electronic governor hardware, software and interface design;

(ii) Governor hydraulic and actuating systems;

(iii) detailed mechanical design;

(iv) detailed electrical design and associated Drawings (i.e., system, network and interface architecture drawings, instrumentation, schematics and wiring diagrams);

(v) other related Drawings and Explanatory Documents; and

(vi) review of the Hazard Log for the Governor.

(e) Excitation System design, including:

(i) power and control components, hardware, software and interface design;

(ii) detailed electrical design and associated Drawings (i.e., system, network and interface architecture drawings, instrumentation, schematics and wiring diagrams);

(iii) other related Drawings and Explanatory Documents; and

(iv) review of the Hazard Log for the Exciter.

(f) Assembly and installation, including:

(i) constructability;

(ii) sequencing and overall coordination of Equipment installation;

(iii) coordination with the installation of equipment installed by Others;

(iv) coordination of the installation schedule, sequence, Procedures, resourcing, etc.; and

(v) preparation of the documents for installation Procedures and test plans.

(g) Acceptance and commissioning tests including:

(i) planning and overall coordination of the Equipment acceptance and commissioning tests;

(ii) coordination with the equipment acceptance and commissioning tests performed by Others;

(iii) coordination of the acceptance and commissioning test schedule, sequence, Procedures, resourcing, etc.;

(iv) coordination of preparation of the documents for acceptance and commissioning Procedures and test plans; and

(v) review of special cases such as special precautions for commissioning of the first Unit or type tests such as the sudden short circuit test, efficiency test, etc.

In each Design Review meeting, and with respect to each of the above topics, the following topics will be considered, as applicable:

(h) the recommended frequency for each task;

(i) the risk level of each task; and

(j) the consumables required to perform each task.

8.2.6 Design Review Meeting Format

The format of a Design Review meeting can be:

(a) in person with all required members of each party present;

(b) via conference call and desktop sharing; or

(c) a combination of SPGS 8.2.6(a) and SPGS 8.2.6(b) of this Appendix 6-1 [General Specifications (SPGS)].

The format of each Design Review will determined by agreement between the parties. If the parties cannot agree on the format for a Design Review meeting, then that meeting will be in person as described in SPGS 8.2.6(a) of this Appendix 6-1 [General Specifications (SPGS)].

Notwithstanding the above, the following Design Review meetings will be in person:

(d) The first Design Review for each Major Component. These Design Reviews will be held at the Contractor's design facilities.

(e) The Design Reviews for the:

(i) assembly and installation Procedures;

(ii) commissioning Procedures;

(iii) operations and maintenance Procedures; and

(iv) Operations and Maintenance Manual,

will be held at the Contractor's facilities or BC Hydro's offices; whichever location will enable the largest number of technical specialists to participate.

(f) The first safety-by-design (Human Factors Engineering) Design Review will be held at the Peace Canyon Generating Station that will be used as a proxy facility to Site C.

8.3 Technical Submittal Schedule

8.3.1 Overview

Both parties will act in a timely way so as to facilitate the efficient completion of the design of the Equipment and accordingly:

(a) the Contractor will use reasonable efforts to plan Design Submittals related to the design, manufacture, installation, commissioning and operation of the Work so as to permit BC Hydro to meet the review time periods as set out in the Schedule 5 [Submittals Procedure], considering factors such as the nature, scope, number and timing of Design Submittals;

(b) BC Hydro will use reasonable endeavours to respond to Design Submittals quickly, notwithstanding the time periods set out in Schedule 5 [Submittals Procedure], particularly if BC Hydro's response will be that BC Hydro requires additional information;

(c) if at any time BC Hydro identifies that it cannot respond to a Design Submittal within time periods set out in Schedule 5 [Submittals Procedure], BC Hydro will promptly notify the Contractor and the parties will cooperate to identify and implement steps the parties will take to avoid any delay to the Work Program and Schedule while facilitating BC Hydro's review of the Design Submittal;

(d) the Contractor will use reasonable efforts to plan Design Review meetings to occur after BC Hydro has had sufficient time to review the Design Submittals that will form the topics of discussion at the Design Review meetings; and

(e) notwithstanding the above requirements, the Contractor will provide to BC Hydro a minimum of:

    (i) 21 days notification for Design Review meetings conducted in Canada and the United States; and

    (ii) 42 days notification for Design Review meetings conducted elsewhere.

8.3.2 <u>Technical Submittal Schedule</u>

In addition to the Submittal Schedule required to be submitted under Schedule 5 [Submittals Procedure], the Contractor will prepare and submit a separate technical submittal schedule (the "**Technical Submittal Schedule**") setting out and describing:

(a) a complete listing of all Submittal Items associated with each Submittal required under Schedule 6 [Specifications and Drawings];

(b) each Design Submittal the Contractor anticipates it will submit under SPGS 8.1.1 of this Appendix 6-1 [General Specifications (SPGS)], including:

    (i) the subject matter and scope of design of the Equipment to be addressed in each Design Submittal; and

    (ii) the type of each Design Submittal (for example, Drawings, Calculations, Procedures);

(c) the order and scheduling requirements of each Design Submittal in relation to the Work Program and Schedule (or the updated Work Program and Schedule as applicable) including the submission date, review period(s) and finalization date;

(d) the Design Reviews for each Major Component; and

(e) an indication of the anticipated Design Commitments that will be sought by the Contractor during the design process.

The Contractor:

(f) will prepare and submit a draft Technical Submittal Schedule within 30 days of the Effective Date, and the parties will cooperate to finalize and agree to the Technical Submittal Schedule within 60 days of the Effective Date;

(g) may use a modified version of the form of Submittal Schedule set out in Appendix 5-1 [Form of Submittal Schedule] to prepare the Technical Submittal Schedule; and

(h) will, in addition to the Submittal Schedule content requirements set out in Schedule 5 [Submittals Procedure]:

(i) take into account the requirements for particular Submittals as set out in SPGS 2.3 through SPGS 2.16 of this Appendix 6-1 [General Specifications (SPGS)], in the preparation of the Technical Submittal Schedule; and

(ii) provide as part of the Technical Submittal Schedule specific Drawing or Explanatory Document information including the:

(A) title of the Drawing or Explanatory Document;

(B) type of Submittal (Drawing, Calculation, Procedure, Report, etc.);

(C) Contractor's revision number;

(D) BC Hydro's document number;

(E) BC Hydro's revision number; and

(F) if applicable, Contractor Drawing type (IFC Drawing, Redline Drawing, IFR Drawing, etc.).

8.3.3 Technical Submittal Schedule Updates

The parties will cooperate and agree to update the Technical Submittal Schedule as required, but at a minimum every 120 days, including to address any adjustments to the Work Program and Schedule made pursuant to Schedule 4 [Work Program and Schedule].

8.3.4 Compliance with Technical Submittal Schedule

The Contractor will submit Submittals in accordance with the Technical Submittal Schedule, as may be updated from time to time in accordance with SPGS 8.3.3 of this Appendix 6-1 [General Specifications (SPGS)].

If the Contractor fails to do so, and if as a result BC Hydro receives more Submittals at one time than BC Hydro should have received and as indicated by the most recently updated Technical Submittal Schedule for that time, such that BC Hydro does not have the capacity to review, comment on and return the Submittals within the time periods set out in that Technical Submittal Schedule, then BC Hydro, after consulting with the Contractor, will establish a priority list for review of Submittals, taking into account the resources of BC Hydro and the requests of the Contractor. BC Hydro will then use reasonable efforts to review the Submittals on that priority list in the order of priority assigned to them, which may result in lower priority Submittals taking more time to review than required under Schedule 5 [Submittals Procedure].

8.4 Design Commitments

Notwithstanding that the Contractor will at all times remain responsible for all aspects of the design of the Equipment, at any time during the design process, the Contractor may request that BC Hydro make a commitment to an aspect or portion of the design (a "**Design Commitment**") confirming that such aspect or portion of design is acceptable to BC Hydro with the intention that the Contractor will be entitled to proceed with the design based on such commitment. BC Hydro will co-operate with the Contractor to consider and make appropriate commitments at appropriate stages of the design process as required for logical progression of the design of the Equipment. To facilitate BC Hydro's review and comment on Design Submittals and BC Hydro's consideration of requests by the Contractor for Design Commitments, the following will apply:

(a) the Contractor will:

(i) include with each Design Submittal:

(A) a clear description of the nature of the Design Submittal and any aspects or components of the Design Submittal that the Contractor wishes BC Hydro to review and comment upon; and

(B) if any Design Commitments are sought by the Contractor, a clear description of each Design Commitment sought, together with appropriate background information as necessary for BC Hydro to properly assess the requested Design Commitment; and

(ii) within five days before delivering a Design Submittal, make a presentation to BC Hydro to explain the content of the Design Submittal, any aspects or components that the Contractor wishes BC Hydro to review and comment upon, and any Design Commitments that the Contractor seeks from BC Hydro;

(b) the Contractor and BC Hydro will co-operate to arrange, within 15 days of the date BC Hydro receives the Design Submittal, an interim meeting at which BC Hydro may ask questions about the Submittal and provide preliminary comments for the Contractor's consideration and response;

(c) within 20 days of the date BC Hydro receives a Design Submittal, BC Hydro will provide any comments it has regarding the Design Submittal, and, with respect to the requested Design Commitment(s), if any, BC Hydro will notify the Contractor that BC Hydro:

(i) grants the Design Commitment as described in BC Hydro's notice; or

(ii) refuses to make the requested Design Commitment because the design does not comply with the requirements of the Contract Documents; or

(iii) refuses to consider making the requested Design Commitment because the design is not sufficiently developed, or because the Contractor has not provided appropriate background information, as necessary for BC Hydro to properly assess the requested Design Commitment.

8.5 <u>Amendments and Additions to the Design of the Equipment</u>

Throughout the completion of the detailed design of the Equipment, the Contractor will have further consultations with BC Hydro where there has been a material amendment or addition to the Reviewed Drawings and Specifications which would have an impact on the BC Hydro.

SPGS9 SAFETY BY DESIGN (HUMAN FACTORS ENGINEERING)

9.1 Human Factor Design Principles

The Contractor will apply the following principles into the design and installation methodology for the temporary works and permanent works:

(a) design and lay out the Equipment as to positively impact, and to minimize the potential for adverse impacts on, the safety and well-being of the workers at the Site;

(b) take into account the interactions between workers and engineered systems, and consider human behaviours and response patterns in the design and layout of the Equipment;

(c) optimize safety, environmental, reliability and operational performance of the Equipment throughout the full life cycle of the Project; and

(d) apply a systematic approach to identifying and mitigating safety and environmental hazards between workers and systems interactions.

9.2 Intent of BC Hydro's Safety by Design

The intent of BC Hydro's safety-by-design is for the Contractor to:

(a) define the intended and foreseeable uses for the Equipment, including supply, installation, use and maintenance through to replacement and/or decommissioning and disposal, including considerations for temporary facilities required to carry out the Work; and

(b) assess any hazardous situations that could occur during the various states and uses of the Equipment.

The Contractor is required to identify, communicate and mitigate potential safety hazards (if any) of the equipment purchased. For each hazardous situation, until the goal of adequate hazard reduction is achieved, the following questions will be considered:

(c) Is the hazard avoidable and can it be designed out?

(d) Is risk reducible by the design modifications?

(e) Is safeguarding possible (i.e., adding barriers, etc.)?

(f) Does adding any of the proposed barriers pose additional hazards?

(g) Is safety adequate (i.e., warning signs, etc.)?

9.3 Minimize Human Impact on Safety

When designing systems, the allocation of safety actions between humans and technology will be substantiated and dependence on human action to maintain a safe state will be minimised.

A systematic approach will be taken to identifying human actions that can impact on safety.

This principle includes defining the safety actions of personnel responsible for monitoring and controlling plant and responding to faults and equipment malfunctions, and of personnel carrying out maintenance, testing and calibration activities. It also includes considering the impact on safety of other workers who may not directly interact with plant and equipment.

Analysis will be carried out of tasks important to safety to determine demands on personnel in terms of perception, decision making and action.

The analysis will address the actions identified above and include consideration of physical, psychological and cognitive factors that could impact human performance.

The analysis will demonstrate the feasibility of these actions within the available timescales and inform the way the actions are designed and supported to achieve reliable task performance. The analysis will be sufficiently detailed and demonstrably employed, to provide a basis for developing user interfaces, procedures and job aids, as well as defining operator roles and responsibilities, staffing levels, personnel competence and training needs, communication networks and workspace design.

The workload of personnel required to fulfill safety related actions will be analysed and demonstrated to be reasonably achievable. Wherever possible, this demonstration will form part of the commissioning and training Work.

Workspaces in which the Workers perform inspection, testing, maintenance and operations activities will be designed to support reliable task performance, by taking account of human perceptual and physical characteristics and the impact of environmental factors.

User interfaces, comprising controls, indications, recording instrumentation and alarms will be provided at appropriate locations on the Equipment and will be suitable and sufficient to support effective monitoring and control of the Equipment during all normal operational and fault conditions.

This principle applies to central control rooms, local control stations and emergency locations that will remain habitable during foreseeable facility emergencies. It also applies to provisions for maintenance and testing.

The user interface provisions will encompass normal operation, abnormal operation and postulated fault conditions including, where practicable, severe accidents.

The user interface will:

(a) enable the operator to determine the Equipment status, including availability and status;

(b) provide a conspicuous early warning of any safety related changes in Equipment status;

(c) provide the means of confirming that any safety related response systems have operated and identifying, initiating and confirming necessary safety actions;

(d) support effective diagnosis of Equipment status changes; and

(e) enable the operator to determine and execute appropriate safety actions, including actions to overcome failures of any automated safety related response systems or to reset a safety related response system after its operation.

The user interface will be designed to ensure compatibility with human psychological and physical characteristics and to facilitate reliable human performance. Interfaces and equipment will be clearly labelled.

A systematic approach to the identification and delivery of personnel competence will be applied.

The process for identifying and delivering competence will encompass the phases of:

(f) job analysis;

(g) identification of competence requirements;

(h) training needs analysis;

(i) training program design and implementation; and

(j) formal assessment and evaluation of competence.

The process will be applied to all those whose actions could have an impact on safety. Management will be included in the process. Appropriate supervision and monitoring will be maintained until individuals are demonstrably competent to perform their tasks.

Procedures will be produced to support reliable human performance during activities that could have an impact on safety. Procedures will be accurate, clear and presented in a format that is compatible with the needs of the Workers and suitable for the task they are designed to support. Risk assessments will identify and analyse human actions or omissions that might have an impact on safety.

Assessments will include the examination of:

(k) precursor errors, such as the introduction of unrevealed errors during maintenance;

(l) actions that contribute to initiating events;

(m) post-fault responses; and

(n) long-term recovery actions.

The selection and application of probability data for human errors will be:

(o) derived from operational experience data and/or through the application of recognised human reliability assessment techniques. Use of either approach will be justified and its relevance for the task and context demonstrated; and

(p) underpinned by task analysis and reflect the influence of human performance shaping factors, making due allowance for uncertainty.

9.4 Constructability

The Contractor will apply safe design principles to the construction of the temporary and permanent Work. The Contractor will carefully consider how the design will translate through to manufacture, installation and completion and will evaluate any reasonable design modification options and, where practicable, will implement such reasonable design modifications as necessary to facilitate safety during installation.

9.5 Operability and Maintainability

The Contractor will design the Equipment and components for safe access during operation and maintenance activities. The Contractor will place all Equipment and components such that disassembly and maintenance can be performed with minimal need for extensive disassembly or removal of other equipment.

The Contractor will use a recognized human engineering or human factors standards to demonstrate that operations and maintenance interfaces have been evaluated and designed to minimize safety hazards, human error and incorrect operation. The Contractor will integrate ergonomic principles in the design of the temporary Work and the permanent Work. The Contractor will ensure that the Equipment conforms to the human factors design principles described in SPGS9.

SPGS10 TRAINING FOR BC HYDRO PERSONNEL

10.1 General

The Work includes a minimum of three training sessions at Site for each Major Component as required to fully instruct BC Hydro's workers in the content of all Procedures and Manuals provided as part of the Work. The Contractor will provide the services of qualified and competent instructors who will give full instruction to designated BC Hydro workers in the system theory, adjustment, operation and maintenance, including pertinent safety requirements, of all aspects and components of the Equipment. Each training session will also include:

(a) explanation of all Equipment components, their function and their location;

(b) a review of all Procedures and Manuals for the Equipment;

(c) hands on demonstration of the routine maintenance and test Procedures for the Equipment, including the online checks, the annual offline tasks, the three year offline tasks and the six year offline tasks;

(d) troubleshooting hints and tips; and

(e) a review and hands on demonstration of any special inspection, test and maintenance requirements during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols].

10.2 Format

Each training sessions will:

(a) be a minimum of 24 hours;

(b) be suitable for up to 20 people per session;

(c) comprise the complete course;

(d) be conducted in English;

(e) consist of lectures, demonstrations, practical or hands on work, and written course materials; and

(f) be recorded in DVD format.

10.3 Materials

Training materials will be submitted, and the Contractor grants an irrevocable, fully paid up and royalty-free licence to BC Hydro to reproduce the training materials and to record the training for BC Hydro's own future use. The Contractor will provide one hardcopy of the training materials for each student, and an additional two hardcopies.

A preliminary version of the training materials will be submitted not later than 120 days prior to commencement of commissioning of the first Unit.

10.4 Schedule

The first training sessions for each Major Component will be scheduled to occur prior to completion of the acceptance and commissioning tests on the first Unit, at a time that is convenient for BC Hydro, having regard to the availability of BC Hydro personnel. BC Hydro intends to schedule the other training sessions to occur during acceptance and commissioning of a subsequent Unit, and after the last Unit commences Commercial Operation, at a time that is convenient for BC Hydro, having regard to the availability of BC Hydro personnel. If operational requirements dictate, BC Hydro reserves the right to change the date of the training with 14 days' prior notice.

10.5 Training During Acceptance and Commissioning of the Equipment

BC Hydro intends to have operations personnel participate in the installation, acceptance, and commissioning of the Equipment, such as:

(a) the facility managers;

(b) the regional maintenance engineers;

(c) communications, protection and control technologists;

(d) electricians;

(e) mechanics; and

(f) other personnel with a technical background in the inspection, testing and maintenance of hydro-electric equipment.

The Work includes:

(g) allowing BC Hydro workers to observe as the Contractor completes the installation, acceptance and commissioning tests for the Equipment; and

(h) answering questions that BC Hydro workers may have.

10.6 Demonstration of Contractor's Procedures

10.6.1 General

Without limiting SPGS 10.5 of this Appendix 6-1 [General Specifications (SPGS)], the Work includes demonstrations of how to complete all Procedures provided as part of the Work including: disassembly, assembly, inspection, testing, maintenance, repair, refurbishment, operation, confined space and Worker rescue Procedures except where explicitly stated otherwise. These demonstrations will occur during outages for inspection, testing and maintenance of the Equipment that occur during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols]. These demonstrations will:

(a) demonstrate that the Procedure can be performed as described; and

(b) be used to train BC Hydro's workers.

If a demonstration shows that the Procedure cannot be performed as written, the Work includes:

(c) revision of the Procedure if the deficiency is related to the clarity of the Procedure itself;

(d) modification or replacement of the Equipment components if the performance of the Procedure identifies a deficiency in the design of the Equipment that results in:

(i) an increase to the:

(A) inspection, test, or maintenance interval of the Equipment, by any amount;

(B) number of personnel required to perform the Procedure, by more than one Worker; or

(C) estimated duration (time) to complete the Procedure, by more than 5%; or

(ii) the inability to adequately complete a Worker rescue in a reasonable amount of time with a reasonable amount of effort.

10.6.2 Excluded Procedures

The following Procedures do not need to be demonstrated by the Contactor unless the inspection, test, or maintenance activity occurs during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols]:

(a) Generator upper bracket removal and installation;

(b) Generator rotor removal and installation;

(c) Generator stator bar removal and installation;

(d) Turbine headcover removal and installation;

(e) Turbine runner removal and installation;

(f) Turbine servomotor removal and installation; and

(g) Turbine wicket gate removal.

10.7 Contractor's Representative during Inspection, Testing and Maintenance Outages

The Work includes having at least one technical representative of the Contractor present for the duration of all inspection, testing and maintenance tasks specified in the Operations and Maintenance Manual for the Equipment and scheduled to be performed during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols], with the exception of tasks that occur at a frequency of greater than once per year. This technical representative will:

(a) be a subject matter expert for the type of inspection, testing, or maintenance activity to be performed;

(b) provide technical direction to BC Hydro workers tasked with performing the scheduled inspection, testing or maintenance activity;

(c) provide hands-on training to BC Hydro workers tasked with performing the scheduled inspection, testing, or maintenance activity; and

(d) prepare and submit an inspection, testing and maintenance Report at the completion of each inspection, testing and maintenance outage. The Report will:

(i) explicitly state the representative's assessment of BC Hydro's compliance with the Contractor's Warranty requirements;

(ii) detail any deficiencies found and include recommended corrective actions; and

(iii) if applicable, provide recommendations for changes to equipment maintenance and operational practices, improvements to equipment maintenance and operational practices or corrective actions that need to be taken to become compliant with the Warranty requirements.

A preliminary copy of this Report will be provided to the Plant Manager and Plant Maintenance Engineer for the facility prior to the end of the maintenance outage or prior to the Contractor's representative leaving the facility, whichever comes first. A final copy of this Report will be submitted not later than 60 days after the Contractor's technical representative leaves the facility.

SPGS11 SITE CONSTRUCTION REQUIREMENTS

11.1 Drilling, Coring or Cutting Into Concrete

The Contractor will:

(a) submit, no less than seven days prior to drilling, coring or cutting into concrete, a drilling, coring or cutting plan and a permit to the Prime Contractor for acceptance and to Hydro's Representative for Consent;

(b) include a silica exposure prevention plan as part of the drilling, coring or cutting plan;

(c) in cases where the Work may potentially drill, core or cut into anything embedded in the concrete, incorporate into its drilling, coring or cutting plan the use of ground penetrating radar to ensure that embedded materials, including reinforcement, are avoided;

(d) take all reasonable steps to avoid embedded materials, including reinforcement; and

(e) if it is not possible to avoid embedded materials, including reinforcement, obtain Consent from Hydro's Representative and acceptance from the Prime Contractor.

11.2 Electrical Equipment

All construction electrical wiring and equipment for power, light, heat or communication purposes will be installed and operated in accordance with the applicable provisions of Canadian Electrical Code.

Electrical equipment will be maintained in a safe condition and free from damage. Damaged equipment and cords will be removed from service and tagged until rendered safe.

11.3 Temporary Heating Equipment

Temporary heating devices will be installed in accordance with Site standards and manufacturers' recommended installation requirements.

All temporary heating equipment will be operated, maintained, serviced and refueled according to the manufacturer's recommendations and Site safety Procedures with key focus on the following:

(a) utilizing qualified, trained operators and maintenance personnel;

(b) minimum clearances maintained to combustible material, equipment or other construction risks;

(c) proper ducting and air quality monitoring and management; and

(d) proper fuel handling, usage and storage.

11.4 Work Near Ancillary Powerhouse Equipment or Operating Units

As the Units and ancillary equipment in the Powerhouse are commissioned, the Contractor will:

(a) no longer be permitted to perform any Work near the operating equipment, on any floor, without the express permission of Hydro's Representative;

(b) no longer be permitted to perform any grinding on or near Generators that:

  (i) are having their stator cores stacked;

  (ii) have their stator windings exposed;

  (iii) rotor windings exposed; or

  (iv) are considered to be operational including when online, offline, isolated for maintenance or being commissioned;

(c) at all times contain all contaminants, such as dust, debris, dirt, particulate, fumes, silica, generated by grinding, sand blasting, painting, cleaning, welding, drilling or any other activity that could generate contaminants, in the performance of the Work that could:

  (i) enter the Units or ancillary equipment;

  (ii) enter the Powerhouse ventilation system; or

  (iii) damage sensitive operating equipment; and

(d) submit containment plans for any activities that could generate contaminants not later than 30 days prior to commencement of such activities. Where possible, Work that has the potential to generate contaminants will be located in a fully contained environment or outside the Powerhouse.

Should the Contractor accidentally release any contaminants in the Powerhouse, the Contractor will:

(e) immediately notify Hydro's Representative of the location, type and approximate quantity of contaminants released; and

(f) immediately mitigate the resulting contamination.

11.5 Cleanliness

11.5.1 General

The Contractor will maintain the Work Area in a tidy condition, free from the accumulation of waste products and debris generated by the performance of the Work.

The Work includes taking all reasonable steps in accordance with Good Industry Practice required to keep:

(a) the Equipment provided as part of the Work; and

(b) the Powerhouse auxiliary equipment,

clean during the storage, assembly, installation, commissioning and operation of the Equipment by preventing objectionable dust and fumes including welding, brazing, soldering, sand blast abrasives, sand blast residues, paint, paint overspray, sanding, grinding, concrete work, engine/compressor lubricant, fuels, etc., generated by the Work from escaping into the Powerhouse atmosphere or environment through the use of preventative measures including installation, maintenance and operation of:

(c) containment and collection systems;

(d) negative pressure systems;

(e) dust or fume barriers;

(f) hording;

(g) temporary walls;

(h) heavy duty shrink wrap; and

(i) localized air extraction.

At a minimum, the indoor air quality in the Powerhouse and the cleanliness of the Powerhouse during the Work must not be worse than the conditions present after completion of the second stage concrete work for the first Unit.

11.5.2 Baseline Air Quality and Cleanliness Measurements

Upon completion of the Powerhouse second stage concrete work for the first Unit, BC Hydro will take a series of Powerhouse air quality and Powerhouse cleanliness measurements. These measurements will:

(a) be used to form a baseline of acceptable levels of both air quality and cleanliness during construction;

(b) form the existing Powerhouse current conditions; and

(c) be made available to all contractors on Site.

11.5.3 Air Quality and Cleanliness Measurements During the Work

BC Hydro will take routine air quality and cleanliness measurements within the Powerhouse at the discretion of Hydro's Representative during the Work. These measurements will be:

(a) compared to the baseline acceptable levels; and

(b) made available to the Contractors on Site.

The Contractor will:

(c) take routine air quality and cleanliness measurements in accordance with the Contractor's air monitoring and cleanliness testing plan. These measurements will be:

  (i) compared to the baseline acceptable air quality levels and cleanliness measurements; and

  (ii) made available to the Prime Contractor and Hydro's Representative within three days.

11.5.4 Compliance and Remediation

If the Work at Site results in a failure to keep the air quality in the Powerhouse or keep Powerhouse cleanliness within acceptable limits, this failure it will be cause for immediate remediation by the Contractor to the satisfaction of Hydro's Representative. Repeated measurements of air quality or plant cleanliness above acceptable limits will be cause for cessation of the Work at the Contractor's expense until remedial measures are implemented to the satisfaction of Hydro's Representative.

11.5.5 Remediation of Contaminated Equipment or Surfaces

If the Equipment provided as part of the Work, any Powerhouse auxiliary equipment or the Powerhouse itself is contaminated by dust or fumes generated by the Work, the Work includes complete restoration of the contaminated Equipment and any other equipment or surfaces to their pre-contaminated states or replacement of the Equipment or other equipment if restoration is not possible.

11.6 Materials and Equipment Handling

The Work includes provision of adequate personnel with properly scheduled equipment to unload and handle materials and equipment.

The Prime Contractor will coordinate and the Contractor will:

(a) cooperate with the overall materials and equipment handling program for the Site; and

(b) incorporate the following items into the Contractor's materials and equipment handling plan for the Site:

  (i) directional signage and gates;

  (ii) Site checkpoint to coordinate deliveries, hoisting, debris removal and cleanup;

  (iii) paging or radio communication system to allow voice communication by Contractors' management personnel and BC Hydro;

  (iv) advance notice of deliveries;

(v) hoist log and schedule;

(vi) traffic control, vehicular access, parking and snow removal;

(vii) temporary Site office and storage facilities;

(viii) concrete placement operations;

(ix) proper identification, labelling and disposition of materials and equipment;

(x) proper recycling of construction debris with designated dumpsters; and

(xi) time allocated in weekly Site coordination meetings to discuss materials and equipment handling and coordination issues.

11.7 Site Restoration Upon Completion of the Work

Except as otherwise permitted by Hydro's Representative, within 30 days of completion of the Work at Site, the Work includes:

(a) decommissioning, removal and disposal of all construction infrastructure installed at Site by the Contractor including:

(i) warehouses;

(ii) temporary structures and enclosures;

(iii) construction offices infrastructure;

(iv) communications equipment;

(v) electrical equipment, including illumination;

(vi) mechanical equipment, including water supplies, sanitary and waste disposal facilities, heating and ventilation equipment, compressed air systems and fire protection equipment;

(vii) safety and dust barriers; and

(viii) temporary works; and

(b) restoration of the Contractor's Work Areas to the same or better condition than the Contractor's Work Areas were found at the commencement of the Work.

11.8 Safety Practice Regulations Training

Further to the safety requirement for work connected to the electrical grid described in Schedule 10 [Safety], BC Hydro will commence providing WPP training one month prior to the date the equipment is scheduled to be connected to the electrical grid. The training will be offered once per week. The Contractor will:

(a) allow a minimum of 15 hours for WPP training for each person who requires this training;

(b) submit a list of people who will be taking the training; and

(c) ensure that the WPP training for each person that requires such training is refreshed every two years.

11.9 Limits of Approach

The Contractor will maintain Limits of Approach for all its employees and agents and Subcontractors' employees and agents, and for their associated work, including use of all equipment, tools and materials, based on the standards set in Rule 400 of BC Hydro's SPRs.

SPGS12 SHIPPING

12.1 General

(a) The Contractor will:

(i) be responsible for informing itself concerning space and load limitations on access roads to and on the Site and space limitations in the Powerhouse;

(ii) prepare the materials and equipment for shipment in such a manner as to protect such materials and equipment from damage and weather while in transit and to facilitate off loading, handling and installation at the Site;

(iii) ship and receive all equipment required for the Work to Site including unloading it, placing it in temporary storage, if required, and delivering it to the installation location;

(iv) provide adequate equipment and personnel for unloading and handling of materials;

(v) provide seven days written notice prior to arrival on Site of any significant deliveries that may require coordination with other contractors or BC Hydro;

(vi) if required, submit a transportation logistics plan for any materials and equipment in accordance with this Appendix 6-1 [General Specifications (SPGS)] not later than 120 days prior to the shipment of such materials and equipment;

(vii) not be permitted to store materials long-term in the Powerhouse. Long term storage will be provided by in locations designated by Hydro's Representative;

(viii) ensure materials arrive in the installation sequence in which they will be utilized and installed. In cases of large quantities, exterior storage, to be provided by the Contractor, must be utilized; and

(ix) ensure material placement and storage areas do not interfere with job progress or with the Work of Others.

(b) Hoisting equipment must be scheduled in a detailed and accurate fashion and only the time needed to efficiently unload and hoist materials will be provided.

If proper arrangements have not been made, or the delivery does not arrive as scheduled, the delivery may be subject to lower priority, at the Contractor's expense, to other hoisting activities. Late deliveries adversely affecting the scheduled work of Others may cause a delay claim against the Contractor.

If the Contractor arranges for Others to perform this work the Contractor will still be fully responsible for all aspects of this work.

(c) Equipment and materials that could potentially be stored outside must be suitably packaged to enable storage outside in all seasons.

(d) Equipment and materials are not to be consigned under any circumstances to BC Hydro.

(e) Spare parts will be packed in boxes separate from other equipment supplied under the Contract and be clearly labelled “Spare Parts”.

12.2 Delivery Checkpoint

Others will provide a common checkpoint for all deliveries for the purposes of coordination and traffic control on Site access roads. All materials entering the Site are to be registered through this checkpoint by the Contractor.

The Contractor will coordinate deliveries to the Powerhouse with Hydro’s Representative and Others prior entering this area.

12.3 Delivery Schedule

The Contractor will:

(a) submit a detailed delivery schedule that identifies milestone delivery dates and the time range materials and equipment are to arrive at Site, not later than 180 days prior to the shipment of the first materials and equipment to the Site; and

(b) as soon as possible, establish exact delivery dates and times for on Site coordination of the shared lifting equipment.

The material placement and storage areas are not to interfere with the job progress or with the work of Others.

12.4 Labelling

12.4.1 Shipping Vessels

Shipping vessels including crates, containers, packages and bundles will:

(a) have the following be clearly and indelibly marked on the outside:

- (i) Contractor c/o - (Handling Contractor);
- (ii) delivery point address;
- (iii) contract number;
- (iv) Purchase Order (PO) number;
- (v) parcel number;
- (vi) gross shipping weight;
- (vii) Lifting Points;
- (viii) shipping dimensions; and

(ix) type of storage at Site, i.e., outdoor, outdoor covered, indoor, indoor heated;

(b) have a packing slip securely attached on the outside. The packing slip will include a brief description of the contents of the container and the area in which the Equipment and Material is to be used.

Each individual part or assembly of parts forming a shipping component will be identified by a unique number. This number will appear on a shipping tag, firmly fastened to the shipping component.

12.4.2 Materials and Equipment with a Limited Shelf-life

Materials with a limited shelf-life, such as adhesives, paint, etc., will:

(a) be properly labelled as such; and

(b) have attached to their vessels:

(i) current Material Safety Data Sheet information; and

(ii) instructions for handling and storage.

12.5 Hazardous Materials and Controlled Products

The Contractor will, no less than 14 days prior to a Hazardous Material or controlled product arriving on Site, prepare a plan, complete with a copy of a current Material Safety Data Sheets (MSDS), for the handling, storage and use of that Hazardous Material or controlled product, for acceptance by the Prime Contractor.

12.6 Components Containing Oil

Components that normally contain oil, such as servomotors, piping, reservoirs, accumulators, etc., will not contain oil during shipping. If oil is required to minimize corrosion on unprotected surfaces of fully assembled components, such as servomotors, then the unprotected surfaces may be covered in a thin film of oil and the component completely sealed such that there is no risk of oil leakage during shipping. Any oil used during shipping, for any purpose, will not be re-used in final assembly.

12.7 Tracing and Expediting

The Contractor will:

(a) be responsible for tracing and expediting all shipments and for obtaining all clearances;

(b) establish and maintain an inventory management system for the Work at Site;

(c) notify itself of all delivery of equipment, materials and parts to Site; and

(d) submit a copy all shipping notices and slips.

12.8 Shipping Damage

The Contractor will, at its cost, repair or replace any and all equipment damaged by delivery to the Site. All repairs are subject to acceptance by Hydro's Representative.

12.9 Components Dimensions

To enable transport into the Powerhouse, the dimensions of Equipment components will be limited to the Site C Powerhouse access door opening.

12.10 Transportation Plan for Certain Equipment

No later than 24 months prior to the date the Contractor anticipates delivering to the Site any load that, because of its dimensions or weight, require permits or approvals under applicable Laws, the Contractor will submit for Consent a transportation logistics plan describing the proposed transportation logistics and route for each such load, including each of the matters listed in the reports prepared for BC Hydro by Apex Industrial Movers (the "**Apex Reports**") and the report prepared for BC Hydro by Tetra Tech EBA (the "**Tetra Tech Report**"), all of which can be found in the electronic data site described in Section 6.35 of Schedule 2 [Design and Construction Protocols].

12.11 Transportation

Notwithstanding anything contained in the Apex Reports and the Tetra Tech Report and notwithstanding any other provision in the Contract, including any "Accepted" or "Proceed Except As Noted and Re-Submit" endorsement given by Hydro's Representative with respect to the transportation logistics plan described in SPGS 12.10 of this Appendix 6-1 [General Specifications (SPGS)], the Contractor will be fully responsible for all transportation and transportation logistics of the Equipment to the Site, including for all risks and costs associated with such transportation.

12.12 Notification of Packaging

In addition to its obligations under SPGS 12.11 of this Appendix 6-1 [General Specifications (SPGS)], the Contractor will treat as a Witness Point the time at which any of the Major Sub-Components are to be packaged for shipment. Prior to shipping a Major Sub-Component, the Contractor will give BC Hydro written notice of the date of delivery to the Site in accordance with the Contract and, where applicable, the type of transport used and the name and address of the carrier, freight forwarder and/or agent.

12.13 Packaging

The Contractor will take steps as required so that all the Equipment is properly prepared for shipment and securely packaged in such packing and containers or otherwise which will in every way be adequate and sufficient to withstand exposure to the elements and rough handling or impacts during shipment. Such packing will be sufficient to ensure safe arrival at the Site and to fully cover hazards, including extreme temperature. Any Equipment loss, damage or repair cost resulting from inadequate or defective packing will be the Contractor's sole responsibility.

12.14 Monitoring Equipment

Where a component of the Equipment is particularly sensitive to the elements, rough handling, impacts, etc., monitoring equipment will be installed and used during transportation, e.g., installation and setup of impact recorders on a Turbine runner. The specifications and calibration documentation for the monitoring equipment and the allowable limits for the Equipment component will be submitted not later than 60 days prior to shipment of the Equipment.

SPGS13 INFRASTRUCTURE AND SERVICES AT SITE

13.1 Site Access

13.1.1 General Site Access

The Site can be accessed from the north (left bank) of the Peace River. Access to the north side of the dam site area from Fort St. John for the construction period will be via Highway 97 and existing provincial and municipal public roads including Old Fort Road. 269 Road will not be used except for the portion of that road between 240 Road and the regional landfill site.

Access to the Site will be controlled 24 hours a day, seven days a week throughout the construction period, so that only authorized traffic will be able to access the Site.

13.1.2 Use of Public Roads

BC Hydro will not be responsible for any delays incurred by the Contractor resulting from any restrictions or limitations imposed or caused by:

(a) the BC Ministry of Transportation and Highways;

(b) any municipality;

(c) other lawful authority in the use of public or private roads; or

(d) weather including: snow storms, avalanches, floods, wash outs, or other weather related conditions including seasonal loading restrictions.

The Contractor will:

(e) comply with the requirements of the *Highway Act* and amendments thereto, and with all applicable safety and traffic regulations, load limitations and clearances;

(f) create a minimum of interference and inconvenience to Others and the public; and

(g) plan and schedule its traffic in accordance with such restrictions and limitations.

Notwithstanding any other provision of this SPGS 13.1.2, the Contractor is restricted from hauling material and equipment using commercial vehicles (weights exceeding 11,759kg) to and from the Site via Old Fort Road, 240 Road, 269 Road, 271 Road or 85th Avenue on school days to avoid scheduled school bus pick-up and drop-off times. This school bus schedule is typically in effect Monday to Friday, excluding statutory holidays, between the hours of 7:15am and 8:15am, and 2:30pm and 3:30pm. BC Hydro will confirm the school bus schedule with School District 60's Transportation Supervisor at the start of each school year, and request that the school district provide updates to BC Hydro if changes occur during the school year. BC Hydro will share the current school bus schedule with the Contractor so that the Contractor can include it in its supporting role traffic management plan required under Schedule 9 [Communications Roles]. The Contractor will also include, in that supporting role traffic management plan, an outline of how it will communicate the restricted hauling period to its employees and suppliers. The Contractor will demonstrate, at BC Hydro's request, its compliance with this requirement.

13.1.3 Site Access Roads

BC Hydro will require the Prime Contractor to:

(a) from time to time, restrict access on Site roads to allow critical equipment deliveries to pass. The Contractor is to abide by the decision of the Prime Contractor in the use of the Site access roads; and

(b) be responsible for the maintenance of the common Site access roads.

The Prime Contractor will not be responsible for any claims or delays brought about by the joint use of the Site roads or maintenance on these roads.

Others will:

(c) construct the Site access roads to the Contractor's Work Areas.

The Contractor will:

(d) be entitled to the use the main site access roads to the Powerhouse and designated laydown area during the course of Work and for all proper purposes in connection with the Work;

(e) comply with all traffic control measures and safety regulations in effect with respect to roads at the Site;

(f) be responsible for the upgrade and maintenance of Site access roads to its Contractor's Work Areas; and

(g) be responsible for all snow clearing required to gain access to its temporary laydown and storage areas.

13.1.4 Rail Access

In addition to the road access, an existing Canadian National (CN) rail line on the south (right bank) of the Peace River will be available for the transportation of construction materials or equipment. These materials or equipment will arrive at Septimus Siding. From there, the materials or equipment can be transported to Site via Septimus Siding Access Road. The Contractor is responsible for making arrangements and for any costs associated with shipping materials or equipment via the CN rail line.

BC Hydro may construct or cause to be constructed a second rail line to the north of the existing CN rail line, which will be designated for the use of Others. If that second rail line is constructed, the Contractor may from time to time apply to use portions of that rail line that may be designated for the use of the GSS Contractor by submitting a written request to Hydro's Representative no less than six months prior to the time that the Contractor plans to use such portions.

13.1.5 Worker Transportation

BC Hydro will designate ten parking stalls to the Contractor at the Powerhouse for the duration of the Contract.

The Contractor will:

(a) provide bus transportation between the Worker Accommodations facilities and the Contractor's Work Areas; and

(b) submit any additional requirements for parking stalls outside of the Powerhouse.

Personal vehicles, including bikes, scooters and skateboards, will not be allowed on Site.

13.2 Designated Work Areas

BC Hydro will designate the Contractor's Work Areas including laydown, staging and storage areas to the Contractor for use during the course of the Work at the Site. BC Hydro will:

(a) designate laydown areas as shown on Appendix 4-5 [Site Plan Overmarked with Proposed Laydown Areas], which will be available as follows:

  (i) for turbine first stage imbeds (pier nose, draft tube access door, primary anchors, embedded pipes, etc.) in Laydown Area 24, to be available November 1, 2017;

  (ii) for Site offices, Laydown Area 32 close to the Powerhouse service bay, with the final location to be coordinated with the GSS Contractor, to be available August 1, 2019;

  (iii) for the Contractor's warehouse and fenced yard in Laydown Area 24, to be available November 1, 2019; and

  (iv) for temporary storage of large components:

    (A) joint use of Laydown Area 30, to be coordinated with MCW contractor;

    (B) joint use of Laydown Area R6 not before October 1, 2019, for runner storage only, to be coordinated with GSS contractor; and

    (C) Laydown Area 31, to be available after July 1, 2021;

(b) permit access to the Contractor's Work Areas in those areas shown on Appendix 4-5 [Site Plan Overmarked with Proposed Laydown Areas];

(c) permit access to the Powerhouse service bay, for joint use by the Contractor and Others, on August 1, 2019;

(d) inspect and audit, on a scheduled basis, to ensure that the fire abatement equipment and fire abatement strategies in place are adequate for the equipment and material stored in the laydown area. Inspections will be documented, and a formal Report kept of findings and any corrective actions recommended and actioned; and

(e) not be responsible for any claims or delays brought about by the joint use of the working and assembly areas with Others.

Others will:

(f) level and grade the Contractor's Work Areas.

The Work includes all work necessary to upgrade, maintain and operate the Contractor's Work Areas. The Contractor will:

(g) if the Contractor requires use of any land outside the designated areas, submit a proposal for Consent not later than 90 days prior to the estimated date the Contractor requires such land;

(h) make its own arrangements for the use of land outside of BC Hydro's property;

(i) clearly define the limits of the Work;

(j) provide barriers for restricted areas of the Site as directed;

(k) ensure no vehicles are operated or parked in areas not designated for this purpose;

(l) be responsible for snow removal from the Contractor’s Work Areas;

(m) not restrict BC Hydro’s or its agents access to the Contractor’s Work Areas;

(n) obtain prior written permission from Hydro’s Representative or Others, as applicable, to access areas in which the Work is not regularly performed;

(o) provide adequate fire mitigation and abatement equipment for all laydown areas that are associated with the Work and Contractor’s Work Areas;

(p) ensure materials are separated by a clear space so that manual fire-fighting equipment can access and respond effectively to a fire situation;

(q) ensure access is provided and maintained to all fire-fighting equipment, including fire hoses, extinguishers and hydrants;

(r) ensure storage of materials in the laydown area do not restrict or limit access to any fire mitigation and abatement equipment; and

(s) submit for Consent plans for any temporary structures for fabrication, assembly or storage, not later than 90 days prior to the estimated date such structures are required.

The Contractor’s Work Areas, including the Powerhouse working and assembly areas, are shown on the Drawings supplied as part of the Reference Information.

13.3 Warehouse

For the duration of the Contract, Others will provide laydown space of approximately 10,000 square metres, including 1,400 square metres of heated space for storage, sorting and preassembly of materials and equipment. The storage area will be provided to the Contractor free of charge, on an “as is, where is” basis.

The Contractor will:

(a) ensure Equipment components, including spare parts, are stored in a suitable location or a suitable warehouse;

(b) only construct storage facilities in areas designated to Contractor and acceptable to Hydro’s Representative;

(c) be responsible for providing security;

(d) any required upgrades to the allocated space subject to approval; and

(e) leave the space upon the completion of the Work in a condition that is acceptable to Hydro’s Representative.

13.4 Temporary Structures and Enclosures

The Work includes all temporary enclosures and structures required for the Work. The temporary structures and enclosures will:

(a) not interfere with the general access or work of Others;

(b) be submitted for Review;

(c) if they exceed 9.3 m^2 in area, be protected in accordance with the requirements of the British Columbia Building Code and British Columbia Fire Code. BC Hydro will consider alternative fire-suppression methods for temporary enclosures and structures on a case-by-case basis, subject to the Contractor submitting for Review a written plan that adequately addresses the fire risk-profile of the enclosure or structure and that includes consideration of function, location, flammability of contents, proximity to adjacent structures, accessibility, access/egress, proposed fire detection and suppression method, etc.;

(d) be constructed of non-combustible panels, flame-resistant tarpaulins, or approved materials of equivalent fire-retardant characteristics. Any other fabrics or plastic films used will be certified as conforming to the requirements of Test Method #2 contained in NFPA 701, Standard Methods of Fire Tests for Flame Propagation of Textiles and Films; and

(e) be equipped with a minimum of one fire extinguisher suitable for all classes of fires that are expected inside the enclosure. Fire extinguishers will be located so that travel distance to a fire extinguisher does not exceed 15 metres.

13.5 Contractor's Site Office

The Work includes provision of all Site office infrastructure required for the Work including:

(a) Site offices;

(b) lunchroom(s);

(c) locker/change room(s); and

(d) sanitary facilities.

This infrastructure will be:

(e) no greater than 600 total square metres in size; and

(f) installed in the location designated by Hydro's Representative.

13.6 Communications

13.6.1 General

The Contractor will be responsible for the provision of all Site voice and data communication facilities it requires for the Work. The Contractor will submit for Review its plans for voice and data communications before having these facilities brought onto the Site.

BC Hydro's office facilities and equipment will not be available for use by the Contractor.

13.6.2 Telephone Connection

Others will provide up to a total of 15 telephone lines to the Contractor's office facilities.

The Contractor will:

(a) make its own arrangements with a service provider for connection of these services under the Contractor's name;

(b) be responsible for all costs for the use of this phone service; and

(c) be responsible for the cabling and equipment necessary to operate the communications equipment.

13.6.3 Internet Connection

Others will provide up to a total of 30 internet connections to the Contractor's office facilities with a minimum download speed of 5 MB/s (megabytes per second).

The Contractor will:

(a) make its own arrangements with a service provider for connection of these services under the Contractor's name;

(b) be responsible for all costs for the use of this internet service; and

(c) be responsible for the cabling and equipment necessary to operate the communications equipment.

13.6.4 Cellular Mobile Service

Others will provide Telus 3G cellular service at the Site.

The Contractor will:

(a) make its own arrangements with a service provider for connection of these services under the Contractor's name; and

(b) be responsible for all costs for the use of this service.

13.6.5 Radio Communication

BC Hydro will provide the Contractor access to the BC Hydro TETRA radio communication system.

The Contractor will provide five Sepura STP8000 TETRA radios to enable effective communicate with BC Hydro and with other Contractors at Site.

13.7 Electrical Power

Others will:

(a) provide a 400 kVA power supply for the Contractor's designated laydown area;

(b) provide a three phase, 600 V, 200 A power supply for the Contractor's Site office and lunchroom;

(c) provide a three phase, 600 V disconnect at the point of interconnection to each power supply;

(d) provide a three phase power meter; and

(e) not be responsible for any delays to the Contractor in the event of an interruption in the power supply provided.

The Contractor will:

(f) be responsible for connection to the power supply and all labour, equipment and materials for the downstream power distribution required for the Work;

(g) be responsible at all times for the protection of BC Hydro's distribution system against any damage resulting from contractor's construction operations;

(h) enter into a separate contract with Others to take and pay for electric power. Power usage will be metered at the current and applicable BC Hydro tariff;

(i) submit one-line diagrams depicting the electrical arrangement being used at each location. These one-line diagrams will be submitted and at least seven days prior to any change; and

(j) if required, be responsible for the provision of its own back-up power supply.

Hydro's Representative will act as arbitrator where a conflict exists related to the use of an electrical power supply that cannot be resolved between Contractor and Others. Hydro's Representative will allot the use of power supply to each contractor in the manner which Hydro's Representative considers best serves the interest of the overall Project.

13.8 Illumination

The Work includes all lighting equipment, labour and materials to ensure adequate illumination for all of the Contractor's Work Areas. Adequate illumination will be construed as the minimum lighting required to:

(a) meet the requirements of WorkSafeBC;

(b) provide sufficient light to permit the Work to be performed in accordance with the requirements of the Contract; and

(c) permit complete inspection of the Work.

13.9 Water Supply

13.9.1 Untreated Water Supply

Untreated water will be provided:

(a) outside the Powerhouse, at a centrally located valved outlet;

(b) within the Powerhouse at several centrally located valved outlets; and

(c) at a rate of 50 L/min at 690 kPa.

The Work includes all additional piping, valves, pumps, fittings, hose, pressure regulators, etc., for the distribution of water beyond the supplied outlets.

All materials, equipment and Work in connection with the Contractor's extension and distribution facilities for water will be submitted for Review. The Contractor will maintain its installation in a safe and serviceable condition for the duration of the Contract.

The Contractor will be prepared, from time to time, to share the water outlets with BC Hydro.

13.9.2 Disposal of Water

The Contractor will make all arrangements, which are satisfactory to Hydro's Representative, to ensure that any waste water from its operation is disposed of in accordance with the safety, environmental and Work management plans; and will not damage or otherwise interfere with the Work or operations of Others.

13.9.3 Treated Water

Treated water will not be available. The Work includes providing potable water for the Contractor's requirements.

13.9.4 Additional Water Supplies

If the Contractor requires additional water, the Work includes supply of this water including:

(a) if the water is trucked to the Site, means to store the water;

(b) if the water is pumped from the Peace River or from a well:

  (i) the well; and

  (ii) intake works including intake screening devices;

(c) obtaining and submitting the necessary permits;

(d) submission for Consent of a water distribution system plan;

(e) all piping, valves, pumps, fittings, hose, pressure regulators, etc.; and

(f) marking all outlets dispensing non-potable water as water unfit for drinking.

13.10 Sanitary Facilities and Waste Disposal

The Work includes provision of sanitary facilities and waste disposal for all of the Contractor's Work Areas. All sanitary services and waste disposal required by the Contractor will:

(a) be supplied and maintained in accordance with applicable Laws;

(b) remove and dispose of all sewage from the Site as soon as possible in in accordance with all applicable Laws;

(c) not discharge untreated sewage into any water course; and

(d) immediately report to Hydro's Representative any leakage, spill or discharge from any sewage and waste fluid disposal.

Without limiting the generality of the following, the Contractor will remove and dispose of all waste materials in accordance with:

(e) the current Province of British Columbia *Environmental Management Act*;

(f) the current *Transportation of Dangerous Goods Act* and *Regulations*; and

(g) the CEMP.

13.11 Material Recycling and Disposal

The Work includes:

(a) removal and disposal of all waste brought in by the Contractor but not required for the Work or accepted by Hydro’s Representative as spares in the Work including construction materials, paints, solvents, lubricants, fuels, liquids, hazardous wastes, sand blast abrasives, sand blast residue, compostables, recyclables, wrappings, cardboard, wood, metals and other such debris associated with the Work, etc., from the Site on a daily basis and in accordance with the requirements of the safety, environmental and waste management plans;

(b) provision of wheeled trash bins in sufficient quantity for the proper segregation of the waste flow to facilitate the placement materials in designated recycling bins;

(c) recycling and disposal of all waste as soon as possible in a safe and environmentally sound manner in accordance with all applicable Laws; and

(d) obtaining disposal authorization from the appropriate municipal, provincial or federal authorities prior to disposal of any waste materials. The Contractor will submit to Hydro's Representative a written copy of these disposal authorizations.

13.12 Fuel Supply

The Contractor will provide fuel supply for the duration of the Work.

13.13 Temporary Works

The Work includes the provision of all temporary works and equipment including ramps, platforms, scaffolding, stairs and ladders, handrails, barriers, access enclosures, floor and/or wall protection, hatch covers, rigging, blocking, shims, supports, etc., required in the execution of the Work. The location of such temporary works will not interfere with the general access or work of Others and will be submitted for Consent.

13.14 Basic Lifting and Handling Equipment

13.14.1 Cranes and Hoists

With the exception of the two Powerhouse bridge cranes the Contractor will be responsible for providing all other cranes and hoists required to perform the Work, including:

(a) boom trucks;

(b) forklifts;

(c) mobile cranes; and

(d) portable hoists.

13.14.2 Hoisting Accessories

With the exception of the lifting beam used to perform a tandem lift with the two Powerhouse bridge cranes the Contractor will be responsible for providing all other hoisting accessories and lifting equipment required to perform the Work such as:

(a) component-specific Lifting Devices;

(b) any general use spreader bars or lifting beams; and

(c) all rigging such as slings, eyebolts, turnbuckles, shackles, etc.

13.14.3 Hoisting of Components in the Penstock Coupling Chamber

To allow installation of the penstock spool piece section, flexible coupling and the closure section, BC Hydro intends to provide temporary access hatches, at each Unit, on the transformer and exciter floors to the penstock coupling chamber. The Contractor will install these components through the hatches using a mobile crane.

The Contractor will sequence the installation of the penstock spool piece sections, flexible couplings and the closure sections, taking into account Interface Milestone Dates for the installation of the Equipment and the space available in the penstock coupling chamber.

Road access to the area upstream of the Powerhouse for use by the mobile crane and component delivery truck will be provided by Others. The Contractor will submit its specific access requirements no later than 180 days prior the scheduled installation date for the installation of the first of these components.

The Contractor will be responsible for providing the mobile crane and trade certified personnel to operate the mobile crane and component delivery trucks for installation of the Equipment. Any temporary roof/hoarding/safety barriers over and around the openings required for the Work will also be the responsibility of the Contractor.

SPGS14 INFRASTRUCTURE AND SERVICES WITHIN THE POWERHOUSE

14.1 Restricted Areas

Except as accepted, the Contractor will not be permitted access to restricted areas in the Powerhouse, including:

(a) the control room;

(b) active power system boundaries, as defined in the System and Local Operating Orders, by any WPP isolation in effect, and the Safety Practice Regulations;

(c) Others' work areas; and

(d) other restricted areas as defined from time to time by Hydro's Representative.

Any unauthorized individual found in a restricted area will, unless otherwise directed by Hydro's Representative, be immediately removed from the Project.

14.2 Powerhouse Working and Assembly Areas

BC Hydro will require the Prime Contractor to designate the Contractor's Work Areas within the Powerhouse for the use of the Contractor.

The Contractor will:

(a) protect the Powerhouse floors with plywood or other suitable materials. Any floor and wall finishes damaged as a result of the Contractor's operations will be repaired at the Contractor's own expense and to the satisfaction of Hydro's Representative;

(b) not exceed the maximum floor loadings as stated in SPGS 14.4 and will provide at the Contractor's own expense any temporary blocking or support necessary to attain acceptable floor load distribution. This requirement will apply to all working and assembly areas; and

(c) not use equipment assembly areas, such as the Powerhouse service bay, for the storage of equipment, tools, materials or other things unless such use has been submitted for Consent and accepted by Hydro's Representative.

14.3 Contractor's Site Office

If required, the Work includes provision of a temporary Site office for installation in the Powerhouse service bay in an area designated by Hydro's Representative. The Contractor's Site office will be no greater than 40 square metres in size.

14.4 Maximum Floor Loadings

The following uniformly distributed floor loadings, pertaining to structures by Others, will not be exceeded:

(a) main floor of Powerhouse service bays and Unit bays, EL. 420.0 m: 75 kPa;

(b) generator floor of Powerhouse service bays and Unit bays, EL. 413.0 m: 25 kPa; and

(c) walkways, platforms and stairs: 5 kPa.

The location and blocking for all components will take into account the permissible floor loadings.

14.5 Powerhouse Bridge Cranes

14.5.1 General

The two Powerhouse bridge cranes and the lifting beam used to perform a tandem lift with the two cranes will be supplied by Others. The main hoist on each Powerhouse bridge crane will have a swivel mounted rams horn hook with either a central hole in the hook or a hook block with a retractable pin for connection to Lifting Devices for components such as shaft and runner.

The lifting beam supplied with the Powerhouse bridge cranes will:

(a) connect the main hooks of the two Powerhouse bridge cranes for large capacity lifts such as the Generator rotor; and

(b) have a centrally mounted lifting shaft supported on a pivot that allows the lifting shaft to hang vertical independent of the relative elevation of the two hooks. The lifting shaft will have a thrust bearing that allows the lifting shaft and lifted load to be rotated independently of the lifting beam. The bottom end of the lifting shaft will contain a groove and split ring (or similar device) for coupling the lifting shaft to lifting fixtures such as the rotor Lifting Device provided by the Contractor.

14.5.2 Capacity

Each Powerhouse bridge crane will have one auxiliary hoist with a capacity of approximately 30,000 kg and one main hoist with a capacity that will be determined by Others. The cranes will be capable of operating either singly or jointly. The combined capacity of the two Powerhouse bridge cranes and lifting beam will be based on the weight of the fully assembled Generator rotor and Lifting Device as provided in [redacted].

14.5.3 Jurisdiction and Contractor Use

The Powerhouse bridge cranes will be under the sole jurisdiction of the Prime Contractor.

The two Powerhouse bridge cranes will be made available for the joint use of the Contractor and Others working in the Powerhouse. No contractor will have exclusive use of either Powerhouse Bridge crane. The Contractor is expected to work with Others to determine a schedule for the joint use of the two cranes that is mutually agreeable to all parties. Should it develop at any time that the joint use of these cranes is not proceeding in a satisfactory manner or for the best interests of BC Hydro acting as Prime Contractor, then Hydro's Representative may require the Contractor and Others to submit at the end of each shift, a time schedule of its Powerhouse bridge crane requirements for the following shift. Hydro's Representative will thereupon review these requirements and allot the periods of time to each contractor which it considers will best serve the interests of BC Hydro and its decision thereon will be final and binding on each contractor.

When BC Hydro is Prime Contractor, Hydro's Representative may at any time require the use (for BC Hydro work, maintenance, repairs, emergencies, etc.) of either or both Powerhouse bridge cranes that are being used by the Contractor and in this event the Contractor will immediately return the Powerhouse bridge crane(s) to Hydro's Representative. BC Hydro's use of the Powerhouse bridge cranes will take precedence over the Contractor's needs.

14.5.4 Responsibilities of Others

Others will:

(a) be responsible for the maintenance of the Powerhouse bridge cranes in accordance with the WorkSafeBC Regulations, including routine cleaning, lubrication, mechanical repairs, electrical repairs and adjustments. The frequency of such maintenance may depend on the cumulative hours or nature of usage of the Powerhouse cranes by all contractors and the WorkSafeBC Regulations;

(b) supply, free of charge, the electric power required for the operation of the Powerhouse bridge cranes;

(c) not be responsible for any costs associated with delays that are caused by Others use, repair, or maintenance of the Powerhouse bridge cranes; and

(d) not be responsible for any claims or delays brought about by the joint use of these Powerhouse bridge cranes or the imposed scheduled use.

14.5.5 Contractor's Responsibilities

The Contractor will:

(a) be responsible for providing qualified, trade certified personnel to operate the Powerhouse bridge cranes to satisfy all its needs;

(b) submit for Consent a list of the names and qualifications of Contractor's proposed Powerhouse bridge crane operators. BC Hydro may conduct testing to verify the proposed operator qualifications. Only accepted operators will allowed to operate the Powerhouse bridge cranes. The accepted list will be revised and kept up to date at all times;

(c) be responsible for all lifts performed by the Contractor, or any of its Subcontractors;

(d) be responsible for repairs for any damage to BC Hydro property, including the cranes, resulting from the Contractor's use of the Powerhouse bridge cranes and lifting equipment;

(e) be responsible for non-routine maintenance and repairs resulting from Contractor's misuse of the Powerhouse bridge cranes;

(f) be responsible for daily inspections of the Powerhouse bridge cranes and will immediately report to BC Hydro if any problems are found during these inspections or when in use. Daily inspections are to be recorded in the crane log book;

(g) be responsible for the preparation of lift plans and Procedures when necessary to meet WorkSafeBC regulations; and

(h) operate the Powerhouse bridge cranes in accordance with operating manuals supplied by BC Hydro or as otherwise required for satisfactory operation of the cranes.

14.5.6 Transporting Loads Over Personnel or Equipment

All crane loads travelling over operating Generators must be approved by Hydro's Representative. Under no circumstances will any personnel be allowed to be under a crane load.

14.6 Electrical Power

14.6.1 During Initial Phase of Installation

During the initial phase of installation, construction power will be provided by Others including:

(a) provision of a three phase, 600 V source with 450 A circuit breaker at each Unit bay; and

(b) provision of a three phase, 600 V source with 600 A circuit breaker in the Powerhouse service bay.

BC Hydro will:

(c) not be responsible for any claims or delays brought about by the joint use of the power supplies; and

(d) not be responsible for any claims or delays to the Contractor as a result of an interruption in the construction or permanent power supply provided.

The Contractor will:

(e) submit not less than 90 days prior to mobilizing to Site its power requirements for inside the Powerhouse. The power requirements will cover the duration of the Work;

(f) be responsible for connection to the power supply and all labour, equipment and materials for the downstream power distribution required for the Work;

(g) submit one-line diagrams depicting the electrical arrangement being used at each location. These one-line diagrams will be submitted and at least seven days prior to any change; and

(h) if required, be responsible for the provision of its own back-up power supply.

14.6.2 During Acceptance and Commissioning Testing

During the acceptance and commissioning stage of the Work, the installation progress of the permanent power distribution switchgear within the Powerhouse may be sufficiently advanced to allow some of this switchgear to be energized. Use of power supply from these permanent power distribution switchgear will be subjected to their availability and approval by Hydro’s Representative.

14.7 Illumination

During the initial phase of construction, the Powerhouse and surrounding areas will not have permanent lighting systems installed and operational and therefore the Work includes all lighting equipment required to provide adequate lighting for the Work.

At the latter phases of construction, permanent lighting system within the Powerhouse will be operational. The illumination level will be adequate for general illumination, but the Contractor will retain any task lighting required for the Work to be performed in accordance with the requirements of the Contract, and to permit complete inspection of the Work.

The lighting equipment will be supplied from the temporary construction distribution switchgear.

14.8 Heating and Ventilation Equipment

14.8.1 General

The permanent Powerhouse heating and ventilation system will not be available during the performance of the Work. Others will provide basic heating and ventilation equipment required to facilitate the construction of the Powerhouse, but this equipment will not be designed to meet the Contractor’s needs for its Work.

For overall temperature ambience control, there will be a need to have temperature regulation and some partitioning between the work locations and the operating floor areas to mitigate dust ingress and significant temperature variations. The Contractor will cooperate with BC Hydro in regulating movement of its materials and forces into and out of the Powerhouse to avoid unbalancing temporary HVAC systems.

14.8.2 Scope of the Work

The Work includes all heating and ventilation equipment required for the Work including:

(a) review of the Powerhouse construction heating and ventilation and control systems and general ventilation system planning to be provided by Others;

(b) preparation of and submission of a specific Site work heating and ventilation plan to the Prime Contractor for acceptance and to Hydro's Representative for Review, not later than 90 days prior to commencement of the scope of the related Work, that:

(i) describes how the Contractor will ensure that indoor air quality and air balance in the Powerhouse will be maintained in compliance with WorkSafeBC Regulations and ensure that all equipment and personnel in the Powerhouse will not be affected by contaminated air;

(ii) identifies the type, size and number of welding exhaust equipment; and

(iii) describes how the heating and ventilation system will satisfy all heating and ventilation requirements for the Work in accordance with WorkSafeBC Regulations, current building codes, health and safety standards, and complies with SPGS 11.5 and SPGS 14.8;

(c) provision of any required equipment to connect to the general construction heating and ventilation system, according to the accepted design and maintain in good working order throughout construction; and

(d) submit an air monitoring and cleanliness testing plan to the Prime Contractor for acceptance and to Hydro's Representative for Review, not later than 90 days prior to commencement of the scope of Work at the Site.

14.8.3 <u>Not Included in the Scope of the Work</u>

The following will be provided by Others:

(a) a general construction heating and ventilation system for the Powerhouse; and

(b) maintenance of the general construction heating and ventilation system.

If any of the Contractors' installations include cementitious materials, temperature sensitive epoxy, or similar synthetic products, temperatures necessary to maintain quality of storage and installation will remain the responsibility of the Contractor for these items and installations, as they are considered localized.

14.8.4 <u>Heating and Ventilation Equipment Requirements</u>

The heating and ventilation equipment will:

(a) comply with current regulations including WorkSafeBC and ASHRAE Standard 60.1, federal and provincial building codes and industrial ventilation regulations for a construction Site environment;

(b) be capable of providing adequate heating for the Work in the Contractor's localized work areas;

(c) if required, be capable of providing adequate cooling to counteract any additional heat dissipation caused by the Work;

(d) be capable of creating slight negative pressure in the vicinity of non-construction areas so as to prevent objectionable dust and fumes from migrating to spaces other than the Contractor's localized work areas in the Powerhouse;

(e) be capable of adequately dissipating, outside the Powerhouse, objectionable fumes from operations, including welding, brazing or concrete grinding, carried out by the Contractor;

(f) be capable of adequately filtering and scrubbing the air in the Contractor's localized work areas in order to remove all dust, debris and other contaminants use air cleansing units at all times; and

(g) protect any operating Units from construction dust or coatings fume.

14.9 Compressed Air

Compressed air will not be available in the Powerhouse during construction. The Contractor will be responsible for providing all equipment and materials required for a compressed air supply if required for the Work.

14.10 Water Passage Cleanliness and Water Accumulation

Others will be responsible for:

(a) the removal of water accumulated in the draft tube elbow; and

(b) the final cleaning of the interior of the penstock and draft tube elbow water passage components.

The Contractor will:

(c) create barriers to prevent contaminants or contaminated water from entering the draft tube elbow; and

(d) be responsible for final cleaning of the components in the water passages supplied as part of the Work.

If, due to the Work, the water in the draft tube elbow is deemed by Hydro's Representative, acting reasonably, to be contaminated, then, subject to Schedule 14 [Dispute Resolution Procedure], the Contractor will be responsible for the cost to pump and dispose of the contaminated water.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-2

GENERAL TECHNICAL SPECIFICATIONS (SPGT)

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-2

GENERAL TECHNICAL SPECIFICATIONS (SPGT)

SPGT1 GENERAL

1.1 Definitions and Interpretation

1.1.1 Definitions

In this Appendix 6-2 [General Technical Specifications (SPGT)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Access Route**" has the meaning set out in SPGT 2.9.3;

"**Advanced Programming Techniques**" has the meaning set out in SPGT 2.13.5(b);

"**Alarm**" has the meaning set out in SPGT 2.13.7;

"**Application Configuration Files**" has the meaning set out in SPGT 2.13.2;

"**Auxiliary Unit Equipment Hatch**" has the meaning set out in SPGT 2.9.11;

"**Balance of Plant**" or "**BOP**" has the meaning set out in SPGT 2.9.7;

"**Cart**" has the meaning set out in SPGT 2.9.4;

"**Configuration Tool Software**" has the meaning set out in SPGT 2.13.3;

"**Confined Space**" has the meaning set out in Part 9.1 [Confined Spaces, Definitions] of the WorkSafeBC OHS Regulation;

"**Cooling Water System**" has the meaning set out in SPGT 2.7.7;

"**Critical Cyber Assets**" or "**CCAs**" has the meaning set out in SPGT 2.17.4;

"**Crouching**" has the meaning set out in SPGT 2.9.2;

"**Design Life**" has the meaning set out in SPGT 2.6.3(c);

"**Double Block and Bleed**" has the meaning set out in SPGT 2.10.7(c);

"**Double Valve and Drain**" has the meaning set out in SPGT 2.10.7(d);

"**Enclosure**" has the meaning set out in SPGT 2.17.2(a);

"**Equipment-Specific Unit Hatch**" has the meaning set out in SPGT 2.9.11;

"**Event**" has the meaning set out in SPGT 2.13.6;

"**Event Buffer**" has the meaning set out in SPGT 2.13.6;

“**Event Data Structure**” has the meaning set out in SPGT 2.13.6;

“**Event List**” has the meaning set out in SPGT 2.13.6;

“**Hazard**” means an object or condition (source or situation) that may expose a person to a risk of injury or Occupational Disease;

“**Lifting Device**” has the meaning set out in SPGT 2.20.2(a);

“**Lifting Point**” has the meaning set out in SPGT 2.20.3;

“**Limits of Approach**” or “**LOA**” has the meaning set out in BC Hydro SPR Rule 401;

“**Main Unit Equipment Hatch**” has the meaning set out in SPGT 2.9.11;

“**Maximum Cooling Water Supply Temperature**” has the meaning set out in SPGT 2.7.6(a);

“**Minimum Cooling Water Supply Temperature**” has the meaning set out in SPGT 2.7.6(b);

“**Musculoskeletal Injury**” or “**MSI**” has the meaning set out in Part 4.46 [Ergonomics (MSI) Requirements, Definitions] of the WorkSafeBC OHS Regulation;

“**Occupational Disease**” means any disease mentioned in Schedule B of the Workers Compensation Act, plus any other diseases that WorkSafeBC may designate or recognize as an occupational disease (by regulation of general application, or by order dealing with a specific case). Disease includes disability from exposure to contamination;

“**Patient**” means a Stretcher and Worker that have been prepared together according to the Procedures specified by the manufacturer of the Stretcher, by other Workers, for the purpose of evacuation;

“**Powerhouse**” means the Site C powerhouse together with the associated intake structure, penstocks, and tailrace;

“**Production Run**” has the meaning set out in SPGT 4.4.2;

“**Production Test**” has the meaning set out in SPGT 4.4.1(b);

“**Prone**” has the meaning set out in SPGT 2.9.2;

“**Protection Target**” or “**Target**” has the meaning set out in SPGT 2.13.7;

“**Raceway**” has the meaning set out in SPGT 2.17.9(a);

“**Rated Speed**” has the meaning set out in SPGT 2.7.3(a);

“**Rescue Operation**” means an activity during which Workers prepare, manipulate, and evacuate a Patient, in as near a horizontal position as possible, from any area of the Unit (including Access Routes), to one of the Powerhouse floors;

“**Resistance Temperature Detectors**” or “**RTDs**” has the meaning as set out in SPGT 2.12.3(a);

“**Software**” has the meaning set out in SPGT 2.13.1;

“**Software-Adjustable**” has the meaning set out in SPGT 2.13.8(a);

“**Software Design Plan**” has the meaning set out in SPGT 2.13.5(f);

“**Software-Driven Device**” has the meaning set out in SPGT 2.13.4;

“**Software Meeting**” has the meaning set out in SPGT 2.13.5(f);

“**Special Cart**” has the meaning set out in SPGT 2.20.1(e);

“**Standing**” has the meaning set out in SPGT 2.9.2;

“**Supine**” has the meaning set out in SPGT 2.9.2;

“**Type Test**” has the meaning set out in SPGT 4.4.1(c);

“**Unit**” means a Turbine and its respective Generator, Exciter, and Governor that are interconnected and function as a single unit;

“**Unit Control Board**” or “**UCB**” means the panel group for a Unit (usually located immediately adjacent to the Unit) that provides the local operator interface to the Unit, including automatic and manual control (including synchronizing), electrical and non-electrical protection (including vibration), monitoring/indication (including airgap), metering, sequence of events recording and alarm annunciation, DC power distribution, and supervisory control/monitoring interface;

“**Unit Equipment Hatches**” has the meaning set out in SPGT 2.9.11;

“**Work at Height**” has the meaning set out in SPGT 2.10.8;

“**Worker**” has the meaning set out in SPGT 2.9.2; and

“**Worker-Adjustable**” has the meaning set out in SPGT 2.13.8(b).

1.1.2 Interpretation

The information set out in Appendix 11-6 [Technical Data and Information Forms] will be deemed to be included as a technical requirement of the Equipment to which the information applies.

In the case of an inconsistency between the information set out in Appendix 11-6 [Technical Data and Information Forms] and the Specifications:

(a) if any of the information set out in Appendix 11-6 [Technical Data and Information Forms] when applied to the design of the Equipment would provide a greater benefit to BC Hydro, including with respect to such matters as quality, functionality and Design Life of the Equipment, when compared with the technical requirements set out in the Specifications, then the Contractor will supply Equipment that complies with the information set out in Appendix 11-6 [Technical Data and Information Forms]; and

(b) in any other case, the Contractor will supply Equipment that complies with the Specifications.

1.2 Scope

1.2.1 Scope of the Equipment

Six identical Units are required for the Project, together with related Work, as follows:

(a) six identical Turbines as described in Appendix 6-3 [Turbine Specifications (SPT)];

(b) six identical Governors as described in Appendix 6-4 [Governor System Specifications (SPGOV)];

(c) six identical Generators as described in Appendix 6-5 [Generator Specifications (SPG)];

(d) six identical Exciters as described in Appendix 6-6 [Excitation System Specifications (SPEXC)]; and

(e) the ancillary equipment and materials described in this Appendix 6-2 [General Technical Specifications (SPGT)].

Unless otherwise expressly specified in the Contract Documents, the Work related to the Equipment includes the design, manufacture, fabrication, supply, testing, delivery to Site, installation, commissioning, training, and warranty inspections.

1.2.2 Scope of Related Work

The Work related to the Equipment includes:

(a) any Work described in Appendix 6-1 [General Specifications (SPGS)];

(b) any Work described in this Appendix 6-2 [General Technical Specifications (SPGT)];

(c) interfacing between the Equipment components and the systems that are included within the scope of this Contract;

(d) interfacing between the Equipment components and the systems that are included within the scope of this Contract and equipment or systems provided by Others;

(e) foundation bolts, anchors, embedded parts, sole plates, piping, and other components to be embedded in first and second stage concrete;

(f) supervision of the installation by Others of Contractor-supplied embedded parts and piping in first stage concrete;

(g) supervision and quality control of all foundation construction that provides for installation or permanent support;

(h) true and proper setting out of components including items to be embedded in concrete and/or grout;

(i) provisions for Others to backfill with concrete and/or grout components such as the Generator sole-plates, equipment bases, concrete voids behind Turbine or Generator embedded components, etc.;

(j) provision of supervision of Others during backfilling with concrete and/or grouting of Equipment components;

(k) auxiliary equipment to support start-up, shutdown and operation of the Units;

(l) lubricants, grease and oil;

(m) spare parts;

(n) acceptance and commissioning tests on the Equipment;

(o) design Work required to accommodate the change in the power exit location from the downstream side of the Powerhouse to the upstream side of the Powerhouse;

(p) except only as expressly stated otherwise in the Contract Documents, the supply of Drawings and Explanatory Documents that completely describe the Equipment as may be required for BC Hydro to operate and maintain the Equipment over its Design Life; and

(q) things necessary for the complete and proper performance of the Work in accordance with the Contract.

The Contractor will be responsible for the complete design of all Equipment, for its manufacture and installation, and for its proper functioning during operation and any tests specified in the Contract Documents.

1.2.3 Work Not Included

The following work will be performed by BC Hydro or by Others:

(a) placement of first and second stage concrete around embedded parts;

(b) backfilling with concrete and/or grouting that is identified in the Contract Documents as work to be performed by Others;

(c) Balance of Plant equipment;

(d) penstock and Powerhouse civil work; and

(e) provision of the various facilities and services at the Site expressly excluded in the Contract Documents.

1.3 Submittals

Not used.

SPGT2 GENERAL TECHNICAL DATA AND REQUIREMENTS

2.1 Common Data

Not used.

2.2 Turbine Data

Not used.

2.3 Governor Data

Not used.

2.4 Generator Data

Not used.

2.5 Exciter Data

Not used.

2.6 General Design Criteria

2.6.1 General

The design of the Equipment will:

(a) be such that excessive deflections and vibrations do not occur. In particular, Equipment will be designed and installed such that coincidence of natural frequencies of Equipment and of the assembly with rotational, hydraulic and electric excitation frequencies does not occur. If, in the opinion of Hydro’s Representative, any of the excitation and natural frequencies may interact, the Contractor will be required to either modify the design to eliminate the interaction or demonstrate to the satisfaction of Hydro’s Representative that these frequencies will in fact not interact;

(b) be such that long-term geometrical stability is maintained;

(c) be such that the Equipment is capable of safely withstanding any possible kinetic and electric transient stress caused by speed and voltage regulation under full load rejection;

(d) be such that all components of the Equipment, at a minimum, incorporate long life and low maintenance features and to withstand all static and dynamic loads, electrical and mechanical stresses that could be experienced during the Design Life of the Equipment, including unusual events such as seismic activities, terminal short circuits, maximum over-speed conditions at maximum temperature, short circuits of one-half of the field winding, and runaway conditions;

(e) minimize the risk of fire and consequential damage;

(f) prevent ingress of vermin, dust and dirt; and

(g) prevent accidental contact with electrically energized or moving parts.

2.6.2 Operating Conditions for the Equipment

For any NSHE within the Normal Turbine Operating Range and when the Equipment is operating in accordance with the requirements of Schedule 6 [Specifications and Drawings], the Equipment components will be designed to operate over the component’s Design Life in the most adverse combination of the following conditions:

(a) Annual Operation:

- (i) 3,000 hours per year in the synchronous condenser mode and the remainder of the year (5,760 hours) in generation mode; or

- (ii) 8,760 hours per year in the generation mode in Operating Zones 2 and 3.

(b) Speed-no-load Operation:

- (i) 200 hours per year at speed-no-load.

(c) Start-Stop Cycles:

(i) 730 starts from standstill to generation mode per year, assuming a complete thermal cycle from ambient to maximum operating temperature per cycle;

(ii) 730 stops from generation mode to standstill per year, assuming a complete thermal cycle from maximum operating temperature to ambient per cycle; and

(iii) 365 transitions per year from the generation mode to synchronous condenser mode and back to generation mode.

(d) Time to Generator Rated Output:

(i) A maximum time of 10 minutes between:

(A) initiation of the start sequence with the Unit offline and speed at 0 RPM; and

(B) online operation at Generator Rated Output.

(e) Time to Standstill:

(i) A maximum time of 10 minutes between:

(A) initiation of the stop sequence with the Unit at Generator Rated Output; and

(B) a normal shut down to Unit offline and speed at 0 RPM.

(ii) Slow coast down of the Unit in the event that the brakes fail to be applied.

(f) Other Operating Requirements: Each Unit will be capable of withstanding without damage or loss of operational reliability other transient and unusual operating conditions, including the following conditions:

(i) four load rejections per year for the most adverse combination of NSHE and Turbine and Generator Unit power output;

(ii) 10 runaway speed cycles over the 80 year Design Life, each cycle lasting seven minutes at maximum Turbine runaway speed;

(iii) over the 80 year Design Life operating an average of 876 hours per year, in Operating Zone 1 at the durations given in Appendix 6-3 [Turbine Specifications (SPT)] for each operating region within Operating Zone 1;

(iv) four terminal short circuits over the 80 year Design Life for any combination of phases (i.e., A to B to C, A to B, B to C, C to A);

(v) four short circuits of one half of the Generator field winding over the 80 year Design Life;

(vi) ten 180 degrees out-of-phase synchronizations over the 80 year Design Life;

(vii) continuous operation in the Minimum Reservoir Operating Range for reservoir filling as specified in SPGT 2.6.14, and potential emergency reservoir draw down requirements;

(viii) continuous operation in the Flood Reservoir Operating Range and corresponding Tailwater Levels at the maximum output the Turbine and Generator are capable of producing at the available head;

(ix) operation at a tailwater as low as elevation 408.2 m during a complete plant outage. After such an outage one or more Units will be restarted. After Unit restart the tailwater level will increase and normal tailwater levels will be achieved approximately 10 minutes after restart; and

(x) one full-flow intake gate closure test per year.

2.6.3 Design Life

Each component of the Equipment will be designed to operate to meet the conditions as described in SPGT 2.6.2:

(a) without measureable deterioration of the structural or mechanical integrity of the component;

(b) without measureable deterioration of the reliability of the component; and

(c) without measureable increase in the maintenance requirements of the component, over, at a minimum, the duration (the "**Design Life**") as set out in Table 2.6.3.

If a Design Life is not specifically provided in Table 2.6.3 for a particular component, then the Design Life for that component will have a Design Life of 80 years unless it can be demonstrated that a shorter design life for that component is acceptable by Good Industry Practice for heavy industrial use.

Table 2.6.3 – Design Life

Component	Design Life
Turbine mechanical components (including: embedded parts, headcover, spiral case, stay vanes, wicket gates, runner, bottom ring, discharge ring, draft tube liner, pier nose liners, operating ring, wicket gate linkages, servo motors, shaft, Turbine guide bearing, oil coolers, cooling water piping, and hoists)	80 years
Generator mechanical components (including: embedded parts, stator frame, stator core, rotor hub, rotor spider, rotor rim, rotor pole body, Generator thrust bearing, Generator guide bearing, upper bracket, lower bracket, and top covers, oil coolers, air coolers, cooling water piping, collector rings, deluge piping, brake cylinders, and brake track)	80 years
Generator components including: stator winding, stator circuit rings, rotor field winding, exciter field leads, main and neutral leads, current transformers	50 years
Excitation System (Refer to Note 1)	50 years
Governor System (Refer to Note 1)	50 years
Seals, gaskets, bushings, and other wearable components which are only accessible during a major disassembly (i.e., runner removal)	40 years
Electrical protection systems, electronic control systems, instrumentation systems, fire protection electronic systems	30 years
Turbine shaft seal stainless steel wear face	25 years
Other easily maintainable components not otherwise described above (such as ancillary mechanical and electrical systems)	25 years
Turbine shaft seal replaceable seal ring	10 years
Generator brake pads	5 years

Component	Design Life
Collector ring brushes	2 years
Oil filters, air filters, water filters	1 year

Note:

1 This Design Life covers the principal components of the Excitation System and Governor System. Where parts of the Excitation System and Governor System are listed in other parts of this table (seals, gaskets, electronic control systems, etc.) those parts will meet the Design Life requirements specific to those components.

2.6.4 Expected Inspection, Maintenance, and Test Intervals

Not including warranty inspections, scheduled Equipment outages will be as follows:

(a) every three years for routine maintenance, inspection, and testing that does not require dewatering of the water passages; and

(b) every six years for routine maintenance, inspection and testing activities that require dewatering of the water passages.

In case of system operation requirements, these outages could be deferred a year.

No component will require maintenance or replacement in less than a three year interval with the exception of Turbine shear pins, consumables (such as oil filters, air filters, water filters, and Generator brushes) or parts that require routine cleaning such as washable air filters or strainers. With the exception of the Turbine shear pins and Generator brushes, it will be possible to replace consumables or maintain these components while the Equipment is in operation.

2.6.5 Major Overhaul

The Equipment will be designed and constructed to achieve 40 years of operation without a major overhaul. BC Hydro’s intention is to disassemble the Equipment once, after 40 years of operation for an overhaul (i.e., the upper bracket, rotor, lower bracket, headcover and runner removed).

2.6.6 Ambient Conditions

The Equipment will be operable under the following estimated ambient conditions. In the design of the Equipment these conditions will be taken into account by the Contractor:

(a) an outdoor air temperature range from -50°C to 40°C;

(b) an air temperature range within the Powerhouse from 2°C to 40°C;

(c) a relative humidity within the Powerhouse of up to 100%; and

(d) the altitude that will be used for the design of 420 m.

2.6.7 Ozone Exposure

All Equipment and materials will be suitable for long-term ozone exposure, except for Turbine components that are not, from a practical point of view, normally exposed to the atmosphere such as servo-motor seals, wicket gate bushing seals, Turbine shaft seals, O-rings between bolted flanges, etc.

2.6.8 Noise Levels

(a) General: Under all conditions, the Equipment will comply with the WorkSafeBC noise exposure limits in accordance with Part 7 of the OHS Regulation.

(b) Peak Sound Levels: Peak sound levels outside of the:

(i) Exciter Enclosure(s);

(ii) Brushgear Housing (if above of the Generator Top Covers);

(iii) Generator Enclosure (with the access doors closed); and

(iv) Turbine Pit (with the access doors closed),

with the Equipment operating will not exceed a sound pressure level of 75 dBA measured 1 m from the Equipment and 1.4 m above the floor.

(c) Peak Sound Levels: Peak sound levels, outside of the Governor HPU, with the Governor operating will not exceed a sound pressure level of 94 dBA, measured 1 m from the Governor HPU and 1.4 m above the floor, provided that the Governor HPU component creating the high noise level is operating less than 10% of the time otherwise the requirements in SPGT 2.6.8(b) apply.

(d) Measurement: Measurements of sound levels will use a sound level meter that meets at least the Type 2 requirements of ANSI S1.4 or IEC 61672, used on an A-weighting network and on slow response.

(e) Noise Abatement: Measures taken to meet these noise level requirements, including inclusion of sound dampening enclosures, acoustic insulation, etc., will be designed such that they do not impede Workers from performing all inspection and maintenance tasks that are intended to be performed while the Equipment is in service. It is acceptable to require Workers to wear hearing protection during the performance of these specific inspection and maintenance tasks.

2.6.9 Walkways, Platforms, Stairs, Ladders and Guardrails

(a) General: Walkways, platforms, stairs, ladders, guardrails and other miscellaneous structures will be designed in accordance with the National Building Code of Canada (limit states design). All walkways, platforms and guardrails will include kick plates.

(b) Floor Loadings: Walkways, platforms, stairs, and other miscellaneous structures subject to occupancy loadings will be designed to withstand a minimum uniform live load of 5 kPa except as otherwise specified. Higher loading will be considered if such structures are subject to additional loads (i.e., if required to support Unit components permanently or during assembly and dismantling).

(c) Ladders: Ladders will be designed to comply with ANSI A14.3.

(d) Guardrails: Guardrails will be designed to comply with the National Building Code of Canada (loading and geometry).

(e) Swing Gates: Suitable swing gates will be provided at openings in guardrails at the top of stairs and ladders which connect to through walkways or landings, from which a Worker may be at risk of falling. The swing gates will have latches for both the open and closed positions.

2.6.10 Allowable Concrete Bearing Pressures

Unless otherwise specified, bearing pressures on concrete will not exceed:

(a) 9 MPa during normal operating conditions; and

(b) 11 MPa during unusual operating conditions.

2.6.11 Seismic Requirements

(a) General: The Equipment will be designed to withstand resultant forces due to a seismic event with 0.250 g horizontal and 0.182 g vertical accelerations. The Equipment and all primary operational and control systems required for safe operation of the Equipment will be designed to be capable of operating immediately after the seismic event.

Horizontal and vertical ground accelerations will be combined together as required to provide a robust, conservative design.

(b) Design: The design of the Equipment will ensure that internal components and anchors/mounts are capable of withstanding:

(i) accelerations imposed on the Equipment without damage or deformation; and

(ii) movement due to the cyclically imposed seismic motion.

(c) Equipment Anchors: All concrete anchors, anchor points, and Equipment and Enclosure baseplates will:

(i) be of a type that the anchor manufacturer certifies as acceptable for use in seismic applications; and

(ii) have a design capacity that exceeds the combined operational loads and seismic loads.

2.6.12 Adjustability of Equipment Alignment for Powerhouse Movement

The shale bedrock beneath the roller compacted concrete buttress on which the Powerhouse substructure is supported is expected to move over time and may result in a shift to the verticality of the Powerhouse of up to 1:2000. For this reason the Equipment will be designed to allow for realignment of verticality of not less than 1:2000. The design will allow for adjustability of components such as the Generator soleplates, the Generator thrust bearing support, Turbine and Generator guide bearings, etc., in both the lateral and vertical directions.

2.6.13 Black Start Capability

The Site C Generating Facility will be designated a black start facility. The Equipment will be designed to enable a Unit to be started without any power sources available except for a 125 V dc battery source that will have enough capacity to:

(a) provide power to the electronics in control systems; and

(b) be used as field flash source for the Excitation System.

Prior to black start the Governor HPU is assumed to be pressurized.

2.6.14 Commissioning of the Equipment During Reservoir Filling

For spillway discharges greater than 1100 m^3/s the total dissolved gas content in the water may exceed environmental limits. To keep the total dissolved gas content within allowable limits, the first Unit must be used to pass any additional flow that is greater than 1100 m^3/s and therefore:

(a) all dry acceptance and commissioning tests for a minimum of one Unit will be scheduled for completion prior to the reservoir elevation reaching 452.0 m;

(b) the wet acceptance and commissioning tests for the first Unit will commence when the reservoir first reaches elevation 452.0 m. The specific focus of these tests will be to complete the acceptance and commissioning tests necessary such that once the reservoir elevation reaches 460.0 m, the Unit can be placed temporarily into continuous service at a block load point. The filling of the reservoir from elevation 452.0 m to 460.0 m is expected to take two months; and

(c) the Unit placed temporarily into service will be capable of continuous operation in the Normal Reservoir Operating Range and the Low Reservoir Operating Range at this block load point that results in a discharge from the Turbine that is at or above 400 m^3/s until such time that all acceptance and commissioning tests have been completed on a second Unit and the second Unit has been placed into Commercial Operation. Once the second Unit has been placed into Commercial Operation, the first Unit can be taken out of service to complete outstanding acceptance and commissioning tests.

Typical dry and wet acceptance and commissioning tests are detailed in SPGT6.

Operation of the Equipment to meet these requirements will not shorten the Design Life of the Equipment and will not void any provisions of any warranty required to be provided under this Contract. The Work includes provision of any Contractor personnel the Contractor believes is necessary to supervise and/or monitor the operation of the Unit placed temporarily into service to satisfy itself that these two requirements are met.

2.7 Mechanical Design Criteria

2.7.1 Configuration

The configuration of the Unit will be vertical.

2.7.2 Direction of Rotation

The direction of rotation will be clockwise when looking down on the Unit.

2.7.3 Speed

The speed of the Unit will be as follows:

(a) Rated Speed: The rated synchronous speed (the "**Rated Speed**") of the Unit will be determined by the Contractor.

(b) Runaway Speed: The runaway speed of the Unit will be determined by the Contractor.

(c) Critical Speed: The critical speed of the shaft system will be greater than 1.3 times the runaway speed.

2.7.4 Unit Inertia Constant

The Unit inertia constant (H_{GT}) for the Turbine and Generator rotating components will be not less than 4.0 MW ·s/MVA at Generator Rated Output.

2.7.5 Allowable Stresses

(a) General: The following will apply to the calculation of allowable stresses and bearing pressures:

(i) unless otherwise specified, stresses are defined to be the equivalent (combination by Von-Mises methodology) stresses determined using Finite Element Analysis (FEA) defined in accordance with ASME BPVC, Section VIII, Div. 2. Primary Stress, Secondary Stress, and Peak Stress are Von-Mises equivalent stresses as defined in ASME BPVC, Section VIII, Div. 2;

(ii) a convergence criterion of not greater than 5% will be used for the FEA of locations of localized high stress (concentrated stress);

(iii) for the Turbine components indicated in SPT, the fatigue analysis will be in accordance with ASME BPVC, Section VIII, Div. 2;

(iv) stresses in cast steel will be limited to 80% of the allowable stresses for plate steel unless otherwise specified;

(v) instantaneous stress refers to a time-based stress value of a component:

(A) for steady-state operating conditions, the maximum instantaneous stress, at each location, is the peak value of stress (in tension or compression) captured during sampling over a minimum time interval of 60 seconds; and

(B) for transient conditions, such as Unit start up or a load rejection, a longer sampling period may be required by Hydro’s Representative for capturing the maximum instantaneous stress, at each location;

(vi) the design will consider the anticipated dynamic and instantaneous stresses when determining stress levels. As described in Appendix 6-3 [Turbine Specifications (SPT)] strain gauge testing of critical Turbine components such as the runner will be carried out at Site to measure the stresses at critical locations;

(vii) static stress, at each location, is the mean value of local stress over the time intervals specified in SPGT 2.7.5(a)(v); and

(viii) extreme operation refers to transient conditions such as Unit start up, runaway, worst case short-circuit, faulty synchronization, and similar transient conditions. Such operating conditions may result in high instantaneous stresses in certain parts of the Unit. These instantaneous stresses will be evaluated as specified in SPGT 2.7.5(a)(v).

(b) Static Stress limits in Turbine Component Materials:

(i) *Steady-State Operation*: At all required steady-state operating conditions at all specified gross heads (including normal operational load changes between zero flow (standstill) and maximum unit power output, synchronous condenser operation, and the unit dewatered) and also at the Spiral Case Design Pressure or when subject to governor oil design pressure, the static stress in the material will not exceed the limits specified in

Table 2.7.5(b) (or lower limits as may be specified by the Contractor), unless indicated otherwise.

Table 2.7.5(b)– Static Stress limits in Turbine Component Materials					
Maximum Allowable Stresses					
Material	**Stress Classification** (in accordance with ASME BPVC, Section VIII, Div. 2)				
	General Primary Membrane (P_M)	**Local Primary Membrane (P_L)**	**Local Primary Membrane plus Primary Bending ($P_L + P_B$)**	**Total Equivalent, Primary plus Secondary plus Peak ($P_L + P_B + Q + F$)**	**Other**
a) Headcover base material and weld material	S, where S = minimum of ($0.4*\sigma_y$, $0.2*\sigma_u$)	1.5*S	1.5*S	minimum of (2.0*S, σ_y)	-
b) Spiral Case and Stay Ring base material and weld material	S, as specified in ASME BPVC, Section VIII, Div. 1 for P-No. 1 steels For materials not covered above, S = minimum of ($0.5*\sigma_y$, $0.25*\sigma_u$)	1.5*S	1.5*S	minimum of (2.0*S, σ_y) For load rejection only: 3.0*S	For the hydrostatic pressure test only: Stresses will not exceed the limits of Section 4.1.6.2 of ASME BPVC, Section VIII, Div. 2 – 2013, or lower as specified by the Contractor
c) Materials for other components, such as Wicket Gates, Operating Ring, Bottom Ring, Discharge Ring, except otherwise specified	S, as specified in ASME BPVC, Section VIII, Div. 1 for P-No. 1 steels For materials not covered above, S = minimum of ($0.5*\sigma_y$, $0.25*\sigma_u$)	1.5*S	1.5*S	minimum of (2.0*S, σ_y)	-
d) Forged or plate steel for Turbine shaft(s)	Maximum equivalent stress ≤ S, where S = minimum of ($0.4*\sigma_y$, $0.2*\sigma_u$) At stress concentration locations (fillets at shaft sleeve, at flange edges, etc.): Maximum equivalent stress ≤ minimum of (2.0*S, σ_y) Torsional shear stress calculated by empirical methods not to exceed 42 MPa.				
e) Runner base material and weld material	At crown and band blade outlet transitions: Maximum equivalent stress ≤ S, where S = minimum of ($0.3*\sigma_y$, $0.16*\sigma_u$) At other locations: Maximum equivalent stress ≤ S, where S = minimum of ($0.5*\sigma_y$, $0.25*\sigma_u$)				

(ii) *Extreme Operation*:

(A) Stresses in Rotating Parts (runner): For the runner, the maximum instantaneous equivalent stress due to transient conditions (start up, load change, load rejection, etc.), runaway speed, or emergency torque on the shaft will not exceed ⅔ of the minimum yield stress of material.

(B) Stresses in Rotating Parts (except runner): For the rotating parts of the Turbine, the maximum instantaneous primary general membrane stress (P_m=S) due to the runaway speed or due to emergency torque on the shaft will not exceed ⅔ of the minimum yield stress of material. The maximum instantaneous equivalent stress will not exceed 2 x S.

(C) Stresses in Wicket Gates/Operating Mechanism: At the breaking point of the shear pin or the breaking link, the maximum instantaneous primary general membrane stress (P_m=S) in the operating mechanism, including the wicket gates and wicket gate stems, wicket gate levers and links, etc., will not exceed ⅔ of the minimum yield stress of the material. The maximum instantaneous equivalent stress will not exceed 2 x S, or 80% of the tensile strength, whichever is less.

(c) Static Stress limits in Generator Component Materials: Stress levels specific to the Generator are defined as follows:

(i) Nominal stress is defined as the equivalent stress derived from normal, bending, and shear stresses resulting from the loads. It is typically not local. It is not self-limiting. It can be calculated from analytical or FEA methods.

(ii) Peak stress is defined as the equivalent stress resulting from the loads. It is locally restricted, self-limiting maximum stress, calculated from FEA method based on elastic material law. Use of analytical methods for rare cases is subject to Consent. If the peak stress of any load case exceeds the specified limit, a fatigue analysis will be required.

(iii) Stress levels will not exceed the maximum peak stress cap under any circumstances.

(iv) *Plate steel and forgings (Generator)*: For plate steel and forgings the equivalent stress, determined by the FEA, will not exceed the limits specified in Table 2.7.5(c)(iv) below (or lower limits as may be specified by the Contractor):

Table 2.7.5(c)(iv) -- Plate steel and forgings (Generator) limits

<table>
<tr><th colspan="4">Generator Rotating Components</th></tr>
<tr><th>Condition</th><th>General Primary Membrane
(P_M)</th><th>Total Equivalent, Primary plus Secondary plus Peak
(P_L + P_B + Q + F)
(1)</th><th>Total Equivalent, Primary plus Secondary plus Peak
(P_L + P_B + Q + F)
(2)</th></tr>
<tr><td>a) Normal operation and standstill</td><td>not to exceed 1/3 of the specified minimum yield point of the material
(1/3 * σ_y)</td><td>not to exceed 60% of the specified minimum yield point of the material
(0.6 * σ_y)</td><td rowspan="2">specified minimum yield point or 3/4 of specified minimum tensile strength, whichever is less Minimum of (σ_y or 3/4 * σ_u)</td></tr>
<tr><td>b) Standstill – compression load due to rim shrink</td><td>not to exceed 1/2 of the specified minimum yield point of the material
(1/2 * σ_y)</td><td>not to exceed 66.7% of the specified minimum yield point of the material
(2/3 * σ_y)</td></tr>
</table>

Generator Rotating Components			
Condition	**General Primary Membrane** (P_M)	**Total Equivalent, Primary plus Secondary plus Peak** ($P_L + P_B + Q + F$) (1)	**Total Equivalent, Primary plus Secondary plus Peak** ($P_L + P_B + Q + F$) (2)
c) Runaway speed	not to exceed 2/3 of the specified minimum yield point of the material ($2/3 * \sigma_y$)	not to exceed 1.5 times the specified minimum yield point of the material ($1.5 * \sigma_y$)	2.5 times the specified minimum yield point or 2 times the specified minimum tensile strength, whichever is less Minimum of ($2.5 * \sigma_y$ or $2 * \sigma_u$)
d) Worst of short circuit or faulty synchronization	not to exceed 3/4 of the specified minimum yield point of the material ($3/4 * \sigma_y$)		

(1) Above this value a fatigue analysis is mandatory.

(2) Total Equivalent, Primary plus Secondary plus Peak stress limits will not be exceeded under any circumstances, regardless of the results of the fatigue analysis.

Generator Non- Rotating (fixed) Components		
Condition	**General Primary Membrane** (P_M)	**Total Equivalent, Primary plus Secondary plus Peak** ($P_L + P_B + Q + F$)) (above this value a fatigue analysis is mandatory)
a) Normal operation and standstill	not to exceed 1/3 of the specified minimum yield point of the material ($1/3 * \sigma_y$)	not to exceed 60% of the specified minimum yield point of the material ($0.6 * \sigma_y$)
b) Standstill – compression load due to rim shrink	not to exceed 1/2 of the specified minimum yield point of the material ($1/2 * \sigma_y$)	not to exceed 66.7% of the specified minimum yield point of the material ($2/3 * \sigma_y$)
c) Runaway speed	not to exceed 2/3 of the specified minimum yield point of the material ($2/3 * \sigma_y$)	not to exceed 1.5 times the specified minimum yield point of the material ($1.5 * \sigma_y$)
d) Worst of short circuit or faulty sync	not to exceed 3/4 of the specified minimum yield point of the material ($3/4 * \sigma_y$)	

(v) *Copper parts:* The maximum stress in operating and runaway condition will not exceed 60 MPa in copper parts that are subject to heating, annealing or stress relief in the fabrication or installation process.

(d) Dynamic Stresses: Dynamic stress is the fluctuating component of local stress, which is characterized by its peak-to-peak amplitude. The peak-to-peak amplitude of the local dynamic stress is defined as the peak-to-peak value using the methodology of IEC Publication 60193, Clause 1.3.3.10.8 of the IEC Publication 60193.

At all steady-state operating conditions between the speed-no-load and maximum Unit power output at each NSHE, the peak-to-peak amplitude of dynamic stress in the material of all Turbine and Generator components will not exceed the limits specified below (or lower limits as may be specified by the Contractor):

Material	Stress Limit
Steel plate	The peak-to-peak amplitude of the equivalent stress not to exceed 50 MPa or 15% of the specified minimum yield point of the material, whichever is less.
Cast carbon steel and cast stainless steel	Same as steel plate requirement.
Weld material for component welded joints	The peak-to-peak amplitude of the equivalent stress not to exceed 45 MPa or 13.5% of the specified minimum yield point of the material, whichever is less.

(e) Seismic Design: The resulting maximum primary membrane stress (P_m=S), when superimposing the loads resulting from the specified seismic design requirements on the normal operating loads, will not exceed 2/3 of the minimum yield strength of the material. The maximum equivalent stress will not exceed 130% of the specified minimum yield point or 80% of the specified minimum tensile strength of the material, whichever is less.

(f) Residual Stresses: Maximum equivalent residual stress in the welds and heat affected zones of major Unit components (in particular for the Turbine runner) after post-weld heat relief will not exceed 25% of the specified minimum yield point of the material.

(g) Miscellaneous Structures: All miscellaneous structures such as supports, frames and attachments used for permanently mounted Equipment or for dismantling and assembly during erection and maintenance, or other ancillary equipment not specifically addressed elsewhere in the Specifications, will be designed according to CSA S16 and will include in their design a minimum impact factor of 25% without exceeding the allowable stresses.

(h) Bushing Stresses: Bearing pressures on Turbine wicket gate bushings, wicket gate operating mechanism wear-strips, and pin bushings will not exceed 20 MPa or lower pressures if recommended by the Contractor or required for the bushing material. Bearing pressures on Turbine link pin bushings and wicket gate bushings may exceed 20 MPa in extreme loading conditions such as Turbine shear pin failure provided that these bushing loads do not exceed the normal allowable design loads provided by the bushing manufacturer.

2.7.6 Water Analysis at the Site C Dam Site

(a) Maximum Water Temperature: The maximum expected temperature of the water of the Peace River at the Site C dam site (the “**Maximum Cooling Water Supply Temperature**”) is expected to be 18ºC.

(b) Minimum Water Temperature: The minimum expected temperature of the water of the Peace River at the Site C dam site (the “**Minimum Cooling Water Supply Temperature**”) is expected to be 0ºC.

(c) Water Quality: A chemical analysis of the water of the Peace River at the Site C dam site can be found in Volume 2: Assessment Methodology and Environmental Effects Assessment, Section 11: Environmental Background, Sub-section 11.5-Water Quality of BC Hydro’s Environmental Impact Statement.

(d) Suspended Sediment: An analysis of the suspended sediment in the Peace River at the Site C dam site can be found in Volume 2: Assessment Methodology and Environmental Effects Assessment, Section 11: Environmental Background, Sub-section 11.8-Fluvial Geomorphology and Sediment Transport Regime of BC Hydro’s Environmental Impact Statement.

2.7.7 Cooling Water System

The Work includes the Cooling Water System. A take-off from the respective Turbine spiral case will primarily supply the cooling water requirements for each Unit, as well as contributing flow into the Powerhouse raw water header for ancillary purposes (cooling water for other Units, service water, domestic water, HVAC cooling, fire protection water and Unit transformer). In the event that a Unit's cooling water strainer has been isolated, the Powerhouse raw water header (fed via adjacent Units) will provide an alternative supply of cooling water. The raw water header will be provided by Others. All cooling water will be strained raw water.

All individual return lines from each cooling system will be combined together into a single return line for the Unit and connected to the tailrace cooling water discharge line that is provided by Others. A head loss of 5 m water column will be allowed for in the discharge line. The location for this connection will be considered as adjacent to each unit.

The cooling water system (the "**Cooling Water System**") means all components such as: spiral case take-off nozzles, nozzle gratings, piping, piping system supports, valves, fittings, strainer(s) and filter(s), oil coolers, air coolers, pressure regulators (where required), seal lubrication systems, insulation, instrumentation, interface to the Powerhouse control systems, etc., required for the Equipment cooling, water lubricated systems, branched supplies to the Powerhouse raw water header, and the connections to the cooling water discharge line.

The Interface points and diameters for the Powerhouse raw water header and the cooling water discharge line will be mutually agreed upon with Hydro's Representative. Interface points will be flanged.

(a) Thermal Performance: The temperature for determining the thermal performance of Cooling Water System heat transfer equipment and sizing of heat transfer equipment will be the Maximum Cooling Water Supply Temperature. The Cooling Water System will also be designed to operate satisfactorily at the Minimum Cooling Water Supply Temperature.

(b) General Design Criteria: The Cooling Water System will:

(i) have, as a minimum, the same design pressure as the Spiral Case Design Pressure;

(ii) be designed in accordance with ASME B31.1 or the ASME BPVC, Section VIII, Div. 1 as applicable;

(iii) be sized to provide adequate flow and pressure from the reservoir via the spiral case inlet with reservoir level at the Minimum Normal Reservoir Level while discharging into the Maximum Flood Design Tailwater Level;

(iv) be designed to have the cooling water flow required for the Equipment cooling and water lubricated systems completely shut off by automatic actuation of a control valve when the Unit is stopped, without shutting off the supply of water from the Unit spiral case to the Powerhouse raw water header;

(v) provide strained raw water to the Powerhouse raw water header and to the Equipment including, the Turbine and Generator bearings, the Generator air coolers, the Turbine shaft seal and the runner seals (runner seal cooling water flow only required during synchronous condenser operation), and any other system as necessary. The branch to the raw water system will be located upstream of the Unit cooling water control valve and the isolating valve on the downstream side of the strainer;

(vi) be sized for each Unit as follows:

(A) all aspects of the system common to the supply of the Unit's cooling water requirements, as well as contributing to the Powerhouse raw water header (i.e., from the Turbine spiral case to upstream of the split between dedicated cooling water and including the branch connecting to the Powerhouse raw water header), will provide not less than 250% of the cooling water requirements for one Unit;

(B) all aspects of the system specific to the supply of the Unit's cooling water requirements (i.e., downstream of the branch connecting to the Powerhouse raw water header), will provide not less than 150% of the cooling water requirements for one Unit; and

(C) all aspects of the system specific to the supply and receipt of flow from the Powerhouse raw water header (i.e., the branch connecting to the Powerhouse raw water header), will provide not less than 188% of the cooling water requirements for one Unit;

(vii) have a removable stainless steel wedge wire grating with stainless steel fasteners, designed to withstand full blockage without damage, at the inlet from the Turbine spiral case with a clear spacing between wedge wires not exceeding 25 mm. The free area of the grating will be not less than 1.25 times the area of the outgoing pipe. The location of the grating will minimize the potential for debris to enter the system;

(viii) have a manual simplex basket strainer on the inlet from the Turbine spiral case that meets the following requirements:

(A) have 3 mm perforations or less;

(B) be designed for a differential pressure of at least 200 kPa without damage;

(C) the free area of the strainer will be not less than 3 times the area of the incoming pipe;

(D) the pressure differential of each strainer, when clean, will be less than 14 kPa at a flow rate equivalent to 250% of a Unit's cooling water demand;

(E) have a painted steel body with a stainless steel basket strainer;

(F) have a valved drain line routed to an appropriate Powerhouse drain; and

(G) have permanent lifting facilities to facilitate basket removal for cleaning purposes, including an integral davit arm for the cover;

(ix) have lockable isolation valves such that each part, component or device of the Cooling Water System can be isolated for maintenance (including instrumentation, air bleed vents, sampling ports, strainers, oil coolers, air coolers), with specific requirements as follows:

(A) for the Cooling Water System strainer; a triple off-set butterfly valve will be supplied on the upstream side, and will also serve as isolation from the Turbine spiral case. A butterfly valve will be supplied on the downstream side, with a check valve immediately upstream of it;

(B) for isolating the branch connecting to the Powerhouse raw water header; a triple off-set butterfly valve will be supplied; and

(C) for isolating the singular cooling water discharge pipe, a butterfly valve will be supplied immediately ahead of connection to the cooling water discharge line;

(x) have a power actuated butterfly control valve to shut off the cooling water flow when the Unit is not operating;

(xi) have a flow control device on the outflow of each cooler;

(xii) incorporate design features to ensure negligible corrosion or fouling;

(xiii) have automatic air bleed vents where air pockets may form;

(xiv) not be pressure regulated (except if required for the Turbine shaft seal);

(xv) be designed to allow for the presence of debris in the water such as wood chips, leaves, etc., without damage to the Equipment; and

(xvi) have additional connections, joints, tees, pressure taps, sections with removable insulation, thermal wells, etc., as required to perform all commissioning tests such as Generator efficiency tests, flow meter verification/calibration, flow balancing, etc.

(c) Instrumentation: The Cooling Water System will have the following instrumentation:

(i) a differential pressure transducer on all strainers and filters;

(ii) an RTD and dial temperature gauge (each in thermal wells), pressure transducer, and pressure gauge on the main cooling water line just downstream of the Turbine spiral case take-off;

(iii) an RTD and dial temperature gauge (each with thermal wells), pressure transducer, and pressure gauge on the main inflow connecting the plant heat recovery system to the heat recovery system heat exchangers;

(iv) a pressure transducer and pressure gauge downstream of the Generator cooling water flow regulating valve;

(v) RTDs and dial temperature gauges (each in thermal wells) on the outflow of each group of coolers (Turbine guide bearing, Generator bearing, Generator air coolers, and heat recovery system heat exchangers);

(vi) flow meters for each group of coolers (Turbine guide bearing, Generator bearing, Generator air coolers, and heat recovery system heat exchangers) located on the downstream side (to be located on the upstream side only if there is insufficient back pressure on the downstream side to maintain the flow meters under pressure at all times);

(vii) flow meters for each Turbine runner seal cooling water supply; and

(viii) a pressure transducer and pressure gauge on the discharge line.

2.7.8 Powerhouse Service Air

Compressed air will be available at a nominal pressure of 690 kPa from the Powerhouse service air system. Equipment requiring compressed air from the Powerhouse service air system will be capable of operating down to a minimum pressure of 550 kPa except where otherwise expressly noted.

2.7.9 Brake and Process Air

Brake and process air will be provided from the Powerhouse service air system via a single, dedicated brake and process air header running the length of the Powerhouse with branches to each Unit that terminate near the Governor System HPU. There will be a central Brake and process air receiver in the Powerhouse connected to the service air system via a check valve and a priority valve arrangement.

The Contractor will connect to the brake and process air system after the Interface point at each Unit; with one branch supplying air to the Contractor's Generator brake air system and another branch supplying process air to all of the Contractor's pneumatically operated equipment. Each branch will have Double Block and Bleed.

The Contractor will provide any other devices, such as pressure regulators, dryers, and particulate and coalescing filters, etc., which the Contractor requires for protection of its equipment. These can either be at point of use, or in a common line.

2.7.10 Air Quality

Powerhouse service air will be to a minimum of ISO 8573-1:2010 [7,4,X(25)].

Compressed air supplied by BC Hydro for the synchronous condenser air depression system will be completely untreated.

2.7.11 Pressure Vessels

Accumulators, air receivers, and pressure containing tanks or vessels will:

(a) be provided in accordance with ASME BPVC Section VIII, Division 1;

(b) made of carbon steel construction with a minimum corrosion allowance of 3.2 mm;

(c) be certified by the BC Safety Authority, complete with a Canadian Registration Number; and

(d) undergo Production Tests prior to shop painting.

2.7.12 Air Receivers

Except where specified elsewhere in the Contract Documents each air receiver will be equipped with:

(a) an instrument header with an isolation valve, pressure gauge, a spare port (suitably plugged), and a test port;

(b) Double Block and Bleed isolation valves;

(c) by-pass arrangements designed such that each individual receiver can be isolated, and removed if necessary while still allowing the associated compressed air system to remain in-service;

(d) appropriate provisions for handling and lifting;

(e) support legs/skirts/base plate complete with anchor bolt holes;

(f) a pressure relief valve mounted on the top of the receiver;

(g) separate inlet and outlet lines where it is functionally advantageous to do so;

(h) a drain valve at the lowest point in the receiver;

(i) a spare connection port;

(j) a 50 mm x 50 mm copper (or stainless steel) electrical grounding pad;

(k) an access hatch with a minimum size of 600 x 400 mm and located approximately 1 m off the floor if the air receiver size permits, otherwise an inspection port measuring 300 mm, or the diameter of the air receiver, whichever is less. A Worker will not be required to carry the weight of the hatch or port in order to open the access hatch; and

(l) an auto condensate drain on systems where the air is not dried sufficiently to prevent condensation in the receivers for all ambient conditions.

2.7.13 <u>Air Compressors</u>

Air compressors provided as part of the Work will:

(a) for high-volume, 690 kPA rated compressors, be Atlas Copco rotary screw type;

(b) for high-pressure (piston style) compressors, be Ingersoll Rand; and

(c) include an acoustic enclosure that limits the peak sound pressure level.

2.7.14 <u>Shaft Couplings</u>

The shaft coupling flanges will be designed by the Contractor in accordance with Good Industry Practice and will include:

(a) all torque transmission via fitted fasteners or shear sleeves/dowels. Torque transmission by friction will not be permitted;

(b) fasteners (coupling bolts or studs) that are designed to be pre-stressed by either Superbolt® tensioners manufactured by Superbolt Inc. or by a hydraulic tensioning device stretching. Pre-stressing by torqueing or heating will not be permitted;

(c) fasteners that are provided with a hollow core and threaded at both ends with plugs for the purpose of measuring elongation;

(d) fasteners that are mechanically locked with a fitted locking plate that is held in place with fasteners (welding will not be used for locking purposes). If Superbolts are provided, the jackbolts will be locked by means of corrosion resistant wire passing through the head of each jackbolt; and

(e) match marking and have high/low spots on coupling faces identified.

2.8 Turbine and Generator Bearings

The Turbine guide bearing, Generator guide bearing, and the Generator thrust bearing will be oil-lubricated and meet the following requirements:

2.8.1 Operating Conditions

The bearings will be capable of operating without damage:

(a) continuously at any speed from 50% up to 110% of synchronous speed, with cooling water applied and lift pump not operating;

(b) for seven minutes at maximum runaway speed, with cooling water applied;

(c) for 60 min at 10 RPM and then coming to a standstill, with cooling water applied and lift pump operating;

(d) throughout any operating condition or scenario, such as loss of cooling water, which leads to high bearing oil and/or high bearing metal temperatures, and ultimately a Unit trip and emergency shutdown to a standstill state (i.e., there will be sufficient thermal capacity in the bearing to withstand an emergency shutdown without damage);

(e) over the full range of axial movement including during jacking of the rotor; and

(f) with the Unit slow rolling in the reverse direction during maintenance activities with the lift pump operating.

2.8.2 Bearing Pressures

The average bearing pressures on babbitt surfaces of bearings in steady state operation will not exceed 4,500 kPa.

2.8.3 Guide Bearing Pads

The Generator and Turbine guide bearing pad design will:

(a) be of the segmented, babbitted, self-lubricating type;

(b) be self-lubricating without requiring the use of auxiliary pumps for normal operation;

(c) be individually adjustable by the centering and radial adjusting screws mounted on the bearing support or alternatively be individually adjustable by adjustable taper wedges. Shims or spacers will not be permitted. The means for locking the radial adjusting screws, if used, will be a SuperBolt® or equivalent method that does not require torqueing of the adjustment screws;

(d) allow easy adjustment and measurement of the bearing clearances with a minimum amount of effort; and

(e) allow easy and safe removal for inspection and maintenance, without disassembly of other components.

2.8.4 Guide Bearing Arrangement

The arrangement of the Generator and Turbine guide bearings will, without the need to drop the level of oil in the bearing oil reservoir, allow a Worker to:

(a) inspect the guide bearings; and

(b) measure and adjust the guide bearing clearances.

2.8.5 Bearing Oil Coolers and Bearing Cooling Water Piping

(a) General: The bearing oil coolers will be water-cooled heat exchangers. The bearing oil coolers and cooling water piping will:

(i) be sized to keep the Equipment bearing oil temperatures within the allowable limits for all specified operating conditions;

(ii) be connected to the Cooling Water Supply System;

(iii) have heat exchange tubes made of 90/10 copper/nickel, seamless, soft annealed, ASTM B111 UNS C70600 Temper O61;

(iv) have lockable isolation valves on the inlet and outlet piping to the oil cooler;

(v) be arranged such that it is possible to isolate individual oil coolers if they start leaking while leaving the remaining oil coolers in service;

(vi) have a manual balancing valve, if required by the Design, on the discharge piping from the oil cooler; and

(vii) include tools or equipment required to remove and exchange a cooler without dismantling other parts of the Turbine and Generator.

(b) Arrangement: The bearing oil cooler system will:

(i) be an internal oil cooler of the submerged cooling coil(s) type or be an external bearing oil cooler of the double tube sheet, leak detecting type, self-pumping design without oil circulation pumps;

(ii) ensure all connections are made outside the oil reservoir and in such a manner that water from a leaky connection or from condensation cannot drip into either the bearing or the oil reservoir;

(iii) have a water detection system to indicate any leakage of water from the cooler tubes;

(iv) use a mounting system that does not consist of any material that could potentially degrade over the Design Life of the Unit;

(v) be designed such that the oil coolers and connecting piping can be easily removed with bolted connections and mounts for all components; and

(vi) be designed such that all cooler surfaces in contact with oil can be easily inspected and cleaned.

2.8.6 Bearing Lubricating Oil Reservoirs

The bearing lubrication oil reservoirs will:

(a) be a stationary design;

(b) have the necessary piping and fittings for filling and draining the oil reservoir including two isolation valves on each fill and drain line – one immediately adjacent to bearing reservoirs, and one just before the Interface point;

(c) have separate piping for filling and draining oil from the reservoir;

(d) have fill and drain piping that is at least 50 mm in nominal diameter, and which is identical in diameter for all bearing reservoirs and to the Governor sump tank;

(e) have a reservoir oil drain connection that is placed at a level that ensures that oil and/or foreign liquid will drain out of the reservoir;

(f) be designed in a manner that the dirt/metal particles in the reservoir will be flushed out during oil filtering process;

(g) have fill and drain connections that are in diametrically opposite positions at the bottom of the reservoir;

(h) have drain and fill lines that are routed to a location that allows for ease of access;

(i) have a 13 mm oil sampling port suitably located such that the oil sampled is representative of the oil actively lubricating the bearing (i.e. the port will not be situated in a location where the oil is relatively stagnant); and

(j) have a design that minimizes the possibility of oil spills and releases (including the drain and fill piping).

The Work includes all piping and fittings from the oil reservoirs to Interface points outside the Generator Enclosure and Turbine Pit. The Interface points will be flanged and their location will be submitted for Consent.

2.8.7 Bearing Top Cover(s)

The bearing lubricating oil reservoir top cover(s) will:

(a) have removable top cover plates with an appropriate seal (felt, brush, etc.) around the shaft to prevent dirt or foreign matter entering the bearing. It will be possible to adjust the seals without the need to remove the top covers;

(b) have at least three observation openings of minimum 200 mm diameter with clear robust plastic covers on top of the cover plates;

(c) be lightweight and easily removable by one Worker without the use of lifting equipment and without requiring any significant disassembly of other components; and

(d) not have any conduit or piping or any other equipment mounted on it with the exception of instrumentation specifically for the bearing.

2.8.8 Maintainability and Access

Arrangement and design of the Generator and Turbine bearings, their support structures, their cooling systems, and other related components will:

(a) minimize the number of locations where bearing lubricant or cooling water leaks can occur;

(b) minimize the effort, complexity, and cost of maintaining the bearings over their Design Life;

(c) have the ability to remove any guide bearing pad, for inspection or replacement, without significant disassembly; and

(d) be possible to safely access the vibration detectors and oil-level sight glass with the Unit operating.

2.8.9 Bearing Oil Mist and Leak Control

The bearings will be designed to have no oil leaks during their Design Life and to prevent oil mist from escaping the bearing lubricating oil reservoirs under all Unit operating conditions. The bearing oil lubricating reservoirs and oil piping will:

(a) have sufficient capacity, oil flow, turbulence and temperature control to avoid any oil leaks under all Unit operating conditions;

(b) have redundant seals for all normally submerged joints/connections;

(c) have internal baffles as necessary to minimize turbulence and the potential for creating mist;

(d) have a bearing stove pipe that has labyrinth, or equivalent seal to prevent oil overtopping the stove pipe. It is strongly encouraged that redundant seals are used for the locations normally submerged in oil;

(e) have fully machined sealing faces; and

(f) if necessary, have a passive system for oil mist control.

If oil leakage or misting occurs, the Work includes:

(g) repairing or redesigning the bearing lubricating oil reservoir and piping; and

(h) repairing and cleaning all equipment that has been contaminated by the oil leakage or mist.

2.8.10 Bearing Oil

The bearing lubricating oil will be in accordance with SPGT 3.3.12.

Bearing oil will be filtered during filling and draining of the reservoirs.

2.8.11 Manufacturer and Assembly of the Bearing Pads

During manufacture and assembly of the Generator and Turbine bearing pads:

(a) the bearing pad surfaces to which the babbitt adheres will be thoroughly cleaned and tinned;

(b) the degree of bonding between the babbitt and the bearing pad material will be 90% or better with no individual un-bonded area exceeding 300 mm^2 in size;

(c) the bond at the edges of the babbitt and the bearing pad material, and adjacent to any ports or grooving, will be 100%; and

(d) the Contractor's ultrasonic and penetrant testing techniques will be in accordance with SPGT 4.4.8.

2.8.12 Bearing Instrumentation

(a) Bearing RTD's: The Turbine and Generator bearings will:

(i) have RTDs installed in not less than 50% of the guide bearing pads and spaced equally around the circumference of the bearing. The RTDs will be removable without draining the oil from the bearing oil reservoir and will be accessible by only removing the bearing top cover;

(ii) if the RTDs are in dry wells, have RTDs installed in not less than 50% of the thrust bearing pads and spaced equally around the circumference of the bearing or, if not in dry wells, have RTDs installed in all of the thrust bearing pads;

(iii) have the RTDs located in the hottest part of the bearing pads;

(iv) have provisions for installation of RTDs in all pads;

(v) have two RTDs installed in dry wells in each bearing oil reservoir and spaced 90 degrees apart;

(vi) have RTDs that are positively retained by some means (threaded, spring loaded, etc.) to ensure good thermal contact;

(vii) have the RTD leads routed such that all leads exit the oil reservoirs above the maximum oil level and located in such a manner that the potential for oil leaks are minimized;

(viii) not have RTDs installed in inspection hatches or view ports;

(ix) have measures to prevent stray current from circulating from the rotating components to the stationary components through the bearings; and

(x) be terminated in such a manner as to allow for easy removal and replacement.

(b) Bearing Oil Level: The bearing oil reservoirs will each have:

(i) one oil level transmitter;

(ii) one sight level gauge for visual indication of the oil level routed to a location that can be viewed by a Standing Worker when the Unit is in operation. The gauge will be graduated in millimetres with the normal bearing oil level being zero and lower than normal will be indicated as negative; and

(iii) a permanent means to visually demark the expected oil level in the bearing during the following conditions:

(A) when the oil temperature is at the ambient temperature of the Powerhouse with the Unit shut down. Assume for this purpose that the ambient temperature is 18 C;

(B) when the Generator is operating at Rated Operating Conditions;

(C) the high oil level alarm point;

(D) extreme high oil level;

(E) the low oil level alarm point; and

(F) extreme low oil level.

It will be possible to adjust these visual indicators.

2.8.13 Labelling

All bearing pads will be permanently marked, such as by the use of punched numbers, with their position number. The markings will be easily visible to a Worker upon removal of the access covers to the bearing pads.

2.9 Maintainability and Access

2.9.1 General

The Equipment will be designed such that dismantling and reassembly are as simple as possible, requires a minimum compliment of Workers and minimum duration. Considerations include: safety, isolation of hazardous energy sources, required Worker complements, service bay logistics (laydown), and Powerhouse bridge crane logistics.

The layout and arrangement of the Equipment will ensure ease of conducting routine testing, inspection, and maintenance tasks in accordance with manufacturer's requirements and recommendations for all Equipment components. Ease of conducting routine testing, inspection, and maintenance means minimizing:

(a) obstructions to the work (overhead items such as cable trays or piping; proximity to walls or other fixed items; other co-located equipment such as instrumentation and/or wiring);

(b) work in restricted access areas (including work involving ladders, items within a Confined Space or within areas not safely accessible during Unit operation in accordance with BC Hydro WPP);

(c) work in areas requiring additional personal protective equipment, use of fall protection, special access or safety devices (bosun chair, fall restraint systems);

(d) working outside 'ergonomic zone' (i.e., high reach, very low, far reach);

(e) requirements for portable or off-site devices (hoists, lights);

(f) the number of isolation points or isolation activities required prior to removal; and

(g) the number of disconnections required for removal.

In addition to the above, the layout and arrangement will also facilitate ease of major maintenance tasks including major component removal or repair by:

(h) minimizing number of lifts/load transfers required from start to finish;

(i) considering suitable, load-rated laydown area available in Powerhouse footprint;

(j) minimizing restricted access (including ladders involved, items beyond worker reach, items within Confined Spaces or within areas not safely accessible during Unit operation in accordance with BC Hydro WPP); and

(k) minimizing obstructions for visibility and means of communication to safely complete all maintenance and construction activities.

The design of the Equipment will incorporate layout and arrangements to facilitate ease of isolation where ease of isolation means minimizing:

(l) the number of devices required to achieve each isolation scenario;

(m) the distance travelled and time required for completion of isolation by one Worker;

(n) any obstructions to visual verification (beyond worker height, requiring aids such as mirror or flashlight);

(o) the need to enter areas of restricted access (including work involving ladders, items within Confined Spaces or within areas not safely accessible during Unit operation in accordance with BC Hydro WPP);

(p) areas requiring additional personal protective equipment, use of fall protection, special access or safety devices (bosun chair, fall restraint systems); and

(q) isolation devices located outside 'ergonomic zone' (i.e., high reach, very low, far reach).

The layout, device selection, and arrangement will minimize the time required for obtaining Generating Unit isolation for work on rotating components.

The Contractor will demonstrate that adequate access and clearance is provided to perform routine and emergency repair activities for all the Equipment by performing 3D computer modelling.

2.9.2 Worker

A worker (a "**Worker**") means a 115 kg person that, when in the standing position ("**Standing**"), requires a minimum clearance height of 2050 mm, a minimum clearance width of 710 mm, and a minimum clearance depth of 610 mm. In the prone ("**Prone**") or supine ("**Supine**") position, a Worker requires a minimum clearance height of 610 mm, a minimum clearance width of 710 mm, and a minimum clearance length of 2050 mm. In the crouching ("**Crouching**") position, a Worker requires a minimum clearance height of 1400 mm, a minimum clearance width of 760 mm, and a minimum clearance depth of 910 mm.

In all cases where Worker access is required (including use of Access Routes by Workers), such access will be designed so that Workers are able to perform activities such as inspections or removals, in an ergonomically correct way, without causing Worker injury or Occupational Disease.

2.9.3 Access Route

An access route (an "**Access Route**") permits access and passage of Workers (together with any applicable tools, equipment, Carts, Special Carts, and vehicles) as required to undertake inspections, maintenance, emergency egress, and Rescue Operations with respect to the Equipment.

2.9.4 Carts

Equipment access will accommodate a wheeled cart (a "**Cart**") that will be supplied by BC Hydro, to be used by Workers to transport tools and equipment or to transport a Patient during a Rescue Operation. A Cart has deck size 610 mm (w) x 1220 mm (l), vertical dimension 203 mm (h), load capacity 910 kg, and wheel size 150 mm (dia) x 50 mm (w). An example of a cart is Acklands Grainger part number DHMEPT2448-95.

2.9.5 Powerhouse Main Floor Layout

The Contractor's Unit bay design will accommodate a Powerhouse main floor layout that allows for a minimum clear distance from the Generator Top Covers to the downstream Powerhouse wall/columns of 3175 mm. This clear distance will to span the length of the Powerhouse and will be free of any obstructions including hatches and temporary guard rails that will be installed around open hatches, as these would encroach onto the clear distance when in use.

This clear distance is intended to accommodate forklifts, pallet jacks, equipment set up for Generator testing, Unit or BOP equipment on Carts, or other vehicles to traverse the length of the Powerhouse without travelling on Generator Top Covers.

2.9.6 Powerhouse Generator Floor Layout

(a) The Contractor's Unit bay design and proposed equipment layout (including Equipment located on the Generator floor) will accommodate a clear Access Route for Workers on the Generator floor, such that the Access Route:

    (i) runs the length of the Powerhouse; and

    (ii) has a minimum clear width of 2100 mm that is free of any obstructions including hatches and temporary guard rails that will be installed around open hatches, as these would encroach onto the clear distance when in use.

(b) For the purposes of the Contractor's Unit bay design and proposed equipment layout, the dimensions of the Generator circuit breaker will be assumed to be as follows:

    (i) Width (x direction): 5600 mm;

    (ii) Length (y direction): 3700 mm; and

    (iii) Height (z direction): 2300 mm.

(c) For the purposes of the Contractor's Unit bay design and proposed iso-phase bus layout, the Isophase bus ducts will have at least 250 mm clearance between the floor above (the ceiling) and the top of the iso-phase bus ducts to accommodate anchor brackets and hangers, etc. Similar clearance above the Excitation System transformer cubicle is also required.

2.9.7 Balance of Plant Systems

Balance of plant systems (the "**Balance of Plant**" or "**BOP**") includes Powerhouse equipment and systems outside the scope of this Contract.

BC Hydro intends to examine BOP considerations with regard to Powerhouse layout, and may provide the Contractor with some guidance on possible constraints or requirements.

Notwithstanding any guidance that BC Hydro may provide to Contractor with regard to BOP systems, BC Hydro will examine how the Contractor's design may affect and influence future design of BOP systems. Although BOP systems do not fall within the scope of this Contract, Unit and Unit bay designs put forward by the Contractor will have a fundamental influence on Powerhouse arrangement, functionality, maintainability, access, safety, and cost. As such, the Contractor will give consideration to how their Unit and Unit bay designs will influence and affect future design of BOP systems for the Project.

2.9.8 Segregation of Electrical and Water/Oil Systems

Design of the Unit bay will aim to achieve as much segregation between electrical systems and liquid systems (such as oil and water systems) as possible.

2.9.9 Excitation System Equipment Placement

Placement of the Excitation System equipment will minimize Hazards presented to Workers and nearby equipment, if a component of the Excitation System fails catastrophically.

Failure (such as a short circuit producing arcing, combustion products, and flying debris) of an Excitation System component will not:

(a) impede Worker emergency egress;

(b) expose Workers standing at the Unit Control Board to Hazards before the Workers can complete emergency egress; or

(c) damage the Unit Control Board or station service distribution panels. These panels will be located on the downstream side of the Powerhouse on the same floor on which the Generator Enclosure is accessed.

If the location of the Excitation System equipment requires the use of a barrier system to meet the above requirements, the barrier system will:

(d) accommodate ventilation and cooling requirements of the Excitation System, assuming convection cooling;

(e) withstand pressure generated by an Excitation System failure (which may include use of directed venting features);

(f) not allow flying debris generated by an Excitation System failure to pass through it;

(g) withstand exposure to combustion products;

(h) not impede the ability for Workers to perform required maintenance on the Excitation System equipment;

(i) not impede Worker emergency egress; and

(j) allow for the replacement of the Excitation System equipment with minimal disassembly of the barriers.

The Excitation System equipment will not be located on the Powerhouse main floor.

2.9.10 Staircases

(a) General: The Work includes, within each Unit bay, one or more sets of staircases that allow Workers to travel from the Powerhouse main floor, down to the floor that allows access to the Turbine draft tube cone and Wicket Gate Bushing Gallery, with access provided to every floor in between.

It is acceptable for a set of staircases to be located within the flexible coupling chamber upstream of the Unit.

All staircases are considered an Access Route.

A set of staircases within each Unit bay is needed to help ensure Workers have multiple emergency egress routes available at all times, in case a route becomes unavailable.

Notwithstanding the above requirements, it is acceptable for the staircase access to the Draft Tube Elbow Access Gallery and Door for each Unit to be shared between two Unit bays.

(b) Dimensions: For consideration during preliminary Powerhouse layout/arrangement activities that the Contractor may undertake, the following minimum staircase dimensions will be assumed:

(i) a minimum clear height of 2.14 m between any stair tread and any overhead obstruction;

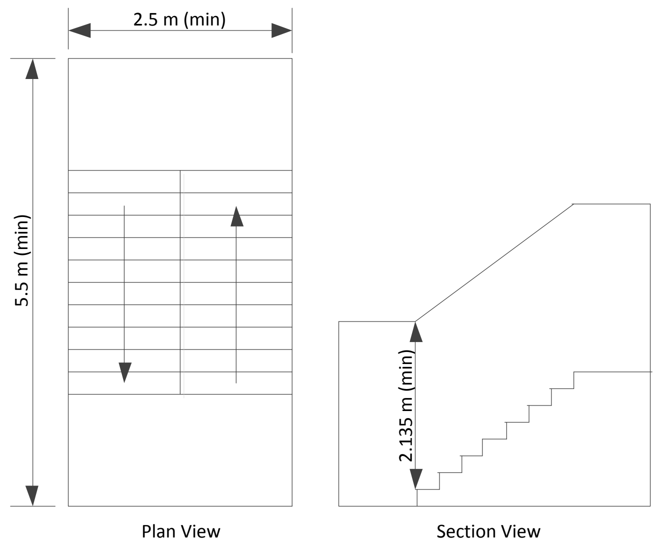
(ii) a minimum clear width of 2.5 m, inside-to-inside of stairwell walls, for multi-floor Powerhouse staircases;

(iii) a minimum clear width of 1.12 m for Turbine and Generator access staircases; and

(iv) a minimum length of 5.5 m, inside-to-inside of stairwell walls, may be assumed for the multi-floor Powerhouse staircases in preliminary layouts, however the length of all staircases is dependent on floor elevations.

For clarity, these minimum staircase dimensions are illustrated in Figure 2.9.10.

Figure 2.9.10 – Powerhouse minimum staircase dimensions (not to scale).



2.9.11 Unit Equipment Hatches

Equipment hatches (the "**Unit Equipment Hatches**") are required within each Unit bay in order to permit use of the Powerhouse bridge crane to hoist heavy and/or large Unit equipment between different floors of the Powerhouse. Unit Equipment Hatches include Main Unit Equipment Hatches, Auxiliary Unit Equipment Hatches, and Equipment-Specific Unit Equipment Hatches.

Unit Equipment Hatches will:

(a) be located such that the auxiliary hooks of the Powerhouse bridge cranes can be positioned via crane travel so that the hook centreline aligns vertically with the centre point of each hatch. Although BC Hydro does not currently have crane travel information available, this requirement is raised for consideration and collaboration as necessary;

(b) be sized to accommodate the largest Equipment component expected to be hoisted through it; and

(c) include a minimum clearance of 150 mm on all sides between the hatch and any Equipment being hoisted through it.

The Contractor's design will accommodate a set of main Unit equipment hatches (each a "**Main Unit Equipment Hatch**") within each Unit bay, as follows:

(d) all hatches vertically–aligned to permit the Powerhouse bridge crane to access all of the hatches, and hoist Equipment components directly between the turbine floor (if a turbine floor exists) and the main floor;

(e) a hatch on the main floor above the generator floor, sized to accommodate the largest Equipment component (including the Excitation System components and Governor System components) to be hoisted between the main, generator, and turbine floors (if a turbine floor exists);

(f) a hatch on the generator floor above the turbine floor (if a turbine floor exists), sized to accommodate the largest Equipment components (including the Governor System components) to be hoisted between the turbine floor (if a turbine floor exists) and the main floor; and

(g) hatch location outside of the perimeter of the Generator Enclosure (i.e., it will not be necessary to remove a Generator Top Cover when hoisting a piece of equipment through the hatches). This allows the Main Unit Equipment Hatches to be used while the Unit is running.

The Contractor's design will also accommodate a set of auxiliary equipment hatches (each an "**Auxiliary Unit Equipment Hatch**") within each Unit bay, as follows:

(h) all hatches between the main Powerhouse floor and draft tube cone floor(s) vertically–aligned (necessary to permit the Powerhouse bridge crane to access all of them). The hatch used to hoist equipment between the draft tube cone and draft tube elbow floors is not required to be vertically-aligned with the hatches above it;

(i) each hatch of minimum dimension 1530 mm by 1300 mm (sized to allow scaffolding, a welder, or any other required tools and equipment to be hoisted between powerhouse floors);

(j) one hatch per Powerhouse floor. As an example, at BC Hydro's Peace Canyon generating station there is a set of vertically-aligned hatches, with one hatch located on each of the following floors: main, generator, turbine, spiral case, draft tube cone upper, and draft tube cone lower; and

(k) hatch location outside of the perimeter of the Generator Enclosure (i.e., it will not be necessary to remove a Generator Top Cover when hoisting a piece of equipment through the hatches). This allows the Auxiliary Unit Equipment Hatches to be used while the Unit is running.

It is permissible for the Main Unit Equipment Hatches discussed above to also function as Auxiliary Unit Equipment Hatches (i.e., a single set of vertically-aligned hatches may include both the Main Unit Equipment Hatches and Auxiliary Unit Equipment Hatches).

It is acceptable for the Contractor to propose equipment-specific hatches (each an "**Equipment-Specific Unit Hatch**") in addition to the Main Unit Equipment Hatches and Auxiliary Unit Equipment Hatches, in order to allow for a more optimized design. Additional equipment-specific hatches may be located within the perimeter of the Generator Enclosure if they are intended to be used to hoist equipment that the Unit must be out of service to remove. As an example, the Contractor may decide that it is advantageous to have an additional hatch specific to servomotors. In this case, it would be acceptable for this hatch to require removal of a Generator Top Cover, since the Unit must be out of service in order for a servomotor to be removed.

The Contractor's design will rely on Unit bay specific hatches to hoist Unit-specific equipment between floors, and will not propose or rely on service bay or other powerhouse hatches for the purpose of hoisting Unit-specific equipment between floors.

2.9.12 <u>Component Weight</u>

Equipment weighing more than 15 kg will be:

(a) reachable by either the Powerhouse bridge crane or a permanent hoist provided as part of the Work; or

(b) provided with some means for removal and transport such as lifting equipment, carts, special tooling, etc.

2.10 Safe Design

2.10.1 Eliminating or Minimizing Hazards

Where hazards cannot be practicably avoided, extra actions will be taken to minimize them by:

(a) mitigating rotating and moving part hazards by provided guards to protect against accidental contact by a Worker with moving parts and/or pinch points (such as motor couplings);

(b) mitigating electrical hazards by providing, barriers or guards to prevent against accidental contact by a Worker;

(c) mitigating fall hazards by providing guardrails, stairs, work platforms, ladders, and/or anchor points for personal fall protection systems;

(d) rounding sharp edges off or by providing covers over sharp or protruding components to mitigate injury risk to Workers; and

(e) mitigating other slip and trip hazards by providing non-slip work surfaces (such as textured flooring) and/or by providing for portable or permanent lighting.

2.10.2 Hazards During Testing

The Equipment will include design features as required, including the provision for installation of temporary barriers and danger signs, to guard against hazards to Workers or property during performance of acceptance, commissioning, or maintenance tests.

2.10.3 Design of Pressurized Systems

The design of pressurized systems will be in accordance with WorkSafeBC Regulations and BC Hydro OSH Standards 209 and 303 to enable isolation of hazardous energy for confined space entry.

2.10.4 Confined Spaces

The Contractor will, wherever possible and reasonably practicable and in accordance with all Laws, avoid the creation of Confined Spaces. When the creation and use of Confined Spaces cannot be practicably avoided, extra actions will be taken to minimize the hazards associated with these spaces including:

(a) Limiting Need to Access Confined Space: Ensuring no control equipment or gauge that requires regular operation or monitoring is located in such space, otherwise remote operation, monitoring, and/or inspection system will be provided; and

(b) Maintaining a Safe Atmosphere: Providing:

  (i) permanent natural and/or mechanical ventilation to avoid build-up of contaminants and/or combustible atmospheres. All maintenance of mechanical ventilation equipment will be performed outside of the space; and

  (ii) more than one means of entry and exit to the space, with each entry and exit properly designed to provide safe and adequate access, including performing a Rescue Operation. The design of the entries and exits will take into consideration that the Workers may be required to wear personal protective equipment, breathing apparatus, and protective clothing.

For each instance of Confined Space, the design will:

(c) demonstrate that all reasonably practicable non-Confined Space design solutions have been exhausted;

(d) clearly identify the type of work to be performed inside the space and the associated Confined Space hazards, and demonstrate that these hazards can be eliminated or minimized to as low as reasonably practicable so that the work can be performed in a safe manner;

(e) identify maximum occupancy, ventilation requirements, rescue Procedures, and limitations on work to be performed within the Confined Space; and

(f) be in accordance with WorkSafeBC OHS Regulation Part 9 “Confined Spaces” requirements.

2.10.5 Isolation and Lockout

Equipment will be designed in accordance with the requirements for safe isolation and lockout, published in WorkSafeBC OHS Regulation Part 10, De-energization and Lockout, in conjunction with BC Hydro OSH 204, BC Hydro OSH 206, OSH 209, and BC Hydro SPR Rule 700.

If the unexpected energization or start-up of machinery or equipment or the unexpected release of a hazardous energy source could cause injury, the energy source must be able to be isolated and effectively controlled, grounded/bonded, and/or blocked, and locked out.

The design of the Equipment will:

(a) include provisions for isolating, bonding/grounding, and/or blocking devices to allow proper isolation and lockout during operation, maintenance, and repair activities;

(b) provide means in the isolating, bonding/grounding, and/or blocking devices to allow visual confirmation and/or positive verification of the isolation of the hazardous energy; and

(c) ensure and demonstrate that all isolating, bonding/grounding, and/or blocking devices are accessible.

2.10.6 Isolation of Confined Spaces

(a) General: Isolation of Confined Spaces will be provided in accordance with most stringent requirements of WorkSafeBC regulations and BC Hydro OSH 209 and 303.

(b) When Hazardous Substances Are Present: For isolating hazardous substances the isolation options, in order of preference, are disconnecting, blanking, and Double Block and Bleed.

2.10.7 Isolation of Mechanical Apparatus

(a) General: The design of the Equipment will be in accordance with BC Hydro OSH 209 for isolation of mechanical apparatus.

(b) Mechanical Blocking: Mechanical blocking will be:

    (i) provided at any location where the movement (linear, rotary, gravity, etc.) of any piece of equipment could create a hazard directly (for example a hydraulic cylinder) or indirectly (for example a valve or switch) regardless whether the source of energy to that piece of equipment has itself been isolated;

(ii) designed and tested to 150% of the worst-case combination of loads that could be applied to the blocking; and

(iii) clearly identified on the Drawings and that its intended purpose is to be used as a means for mechanical blocking for the purposes of isolating the equipment as a form of Worker protection.

(c) Double Block and Bleed Isolating Valves: A double block and bleed ("**Double Block and Bleed**") valve arrangement consists of two designated isolating valves in the piping and an open designated drain valve located in between the two designated isolating valves. The drain line must be the same diameter as the line being isolated. The drain line routing will allow for local visual inspection of any flow in the drain line.

(d) Double Valve and Drain Isolating Valves: A double valve and drain ("**Double Valve and Drain**") valve arrangement consists of two designated isolating valves in the piping and an open designated drain valve located in between the two designated isolating valves. The drain line can be less than the diameter of the line being isolated, but will be no less than 10% of the diameter of the supply line. If a drain size has been stated, or implied, elsewhere in the Specifications the more stringent condition will apply. The drain line routing will allow for local visual inspection of any flow in the drain line.

2.10.8 Work at Height

In accordance with WorkSafeBC OHS Regulation Part 11, Fall Protection, when a Worker is required to work at a height from which a fall of 3 m or more may occur, or where a fall from a height of less than 3 m involves a risk of injury greater than the risk of injury from the impact on a flat surface ("**Work at Height**"), a fall protection system will be used.

The design of the Equipment will:

(a) avoid the requirement for Workers to Work at Height and eliminate or significantly minimize all fall hazards;

(b) avoid fall hazards greater than 7.6 m;

(c) ensure equipment, including gauges, actuators, valves, controls, and other items that require periodic operation, maintenance, inspection, and/or repairs are located at or close to grade level; and

(d) follow the human factors design criteria in SPGT 2.11 or an equivalent or substantially similar human factors standard.

To the extent reasonably practicable, the Contractor will minimize the need to perform any Work at Height. When it is unavoidable or impracticable in the design to avoid the need for Workers to Work at Height, the design of the Equipment will ensure that routine Work at Height, which is defined as any work at height (including operation, maintenance, and/or inspection) that needs to be performed more than once a year, is engineered with a proper fall protection system (i.e., railings) that does not require the use of a personal fall protection system (i.e., personal fall protection harnesses). If the fall protection system is temporary in nature, it will be marked with its intended use and be provided with a storage location near the location it is intended to be used.

In addition, for Work at Height (for routine or non-routine work), the Contractor will:

(e) demonstrate that all reasonably practicable design solutions that avoid the need to Work at Height have been exhausted;

(f) clearly identify the work height/elevation level, the frequency of the work, the duration of the work, and the nature of the work (i.e., specific work activities, tools and training requirement) in the Hazard Log;

(g) demonstrate that careful consideration has been given to provide safe access and adequate fall protection (where required) to ensure work activities at height can be performed safely for each applicable design/situation; and

(h) demonstrate that careful consideration has been given to facilitate a Worker Rescue Operation.

2.10.9 Limits of Approach (LOA)

The design of the Equipment will:

(a) allow Workers to maintain Limits of Approach (LOA) for their qualifications during any planned or unplanned operation, maintenance, inspection, and/or repair activities; and

(b) minimize the need for Workers to shut-down or barricade Equipment components when performing normal operations, maintenance, and inspections, to the extent reasonably practicable.

In addition, for each instance of design that requires work at Column 2 of Table 401 Limits of Approach in the SPR (for routine or non-routine work), the Contractor will:

(c) demonstrate that all reasonably practicable design solutions that avoid the need to work at Column 2 limits have been exhausted;

(d) clearly identify the work requirements, the frequency of the work, the duration of the work, and the nature of the work (i.e., specific work activities, tools, and training requirement) in the Hazard Log; and

(e) demonstrate that careful consideration has been given to provide safe access and adequate protection for work activities at Column 2 limits for each applicable design/situation.

2.10.10 Electric Shock and Arc Flash

All electrical equipment will comply with CSA C22.1. The design of the Equipment will avoid arc flash hazards to workers or bystanders. Arc flash hazards will be limited to Category 2 or less.

Electrical equipment such as switchboards, panel boards, industrial control panels, meter socket enclosures, motor control centres, and other equipment that requires examination, adjustment, servicing, or maintenance while energized will be permanently marked in accordance with the template in the IEEE 1584 to warn persons of potential electric shock and arc flash hazards. This marking will be located so that it is clearly visible to persons before working on the equipment.

All equipment and/or systems that can pose arc flash hazards to workers or bystanders will be adequately mitigated, properly identified and labelled with information in accordance with CSA Z462, IEEE 1584, and BC Hydro ES 44-Z1101 including:

(a) Arc Flash Hazard Boundary;

(b) Incident Energy (expressed in Cal/cm^2);

(c) working distance (expressed in metres);

(d) Hazard Category; and

(e) Associated PPE required.

2.11 Human Factors Design Criteria

The following establishes general human factors design criteria for the Equipment. The design of the Equipment will meet or exceed these requirements where applicable.

The objective is to achieve effective, efficient, reliable and safe system operation and maintenance through the successful integration of human factors into the system.

These criteria are to be applied to the design of all Equipment systems, subsystems, components, and all areas of the Equipment, including temporary works required for construction.

2.11.1 Ergonomics Requirements

In accordance with WorkSafeBC OHS Regulation Part 4, Sections 4.46 to 4.53, risks of Musculoskeletal Injury (MSI) to Workers must be either eliminated, or if that is not practicable, minimized.

All the risk factors identified in the WorkSafeBC OHS Regulations will be reviewed to ensure human and system design interfaces are optimized to eliminate or minimize the risk of MSI to Workers.

Risk factors include:

(a) the physical demands of work activities, including:

   (i) force required;

   (ii) repetition;

   (iii) duration;

   (iv) work postures; and

   (v) local contact stresses;

(b) aspects of the layout and condition of the workplace or workstation, including:

   (i) working reaches;

   (ii) working heights;

   (iii) seating; and

   (iv) floor surfaces;

(c) the characteristics of objects handled, including:

   (i) size and shape;

   (ii) load condition and weight distribution; and

   (iii) container, tool, and equipment handles;

(d) environmental conditions, including hot and cold temperatures; and

(e) the following characteristics of the organization of work:

(i) work-recovery cycles;

(ii) task variability; and

(iii) work rate.

Risk assessments using tools and techniques similar to WorkSafeBC MSI Risk Factor Assessment Worksheet B will be performed.

2.11.2 Vibration

In accordance with WorkSafeBC OHS Regulations Part 7, Division 2, Sections 7.10 to 7.16, the design of the Equipment is required to select tools and equipment, to the extent practicable, to minimize Workers from exposure to vibration in excess of the limits specified by WorkSafeBC.

This applies to both "hand-arm vibration" (meaning vibration that is transmitted from vibrating surfaces of objects, such as hand tools, through the hands and arms) and "whole-body vibration" (meaning vibration that is transmitted to a Worker's body from vibrating surfaces on which a Worker stands or sits.

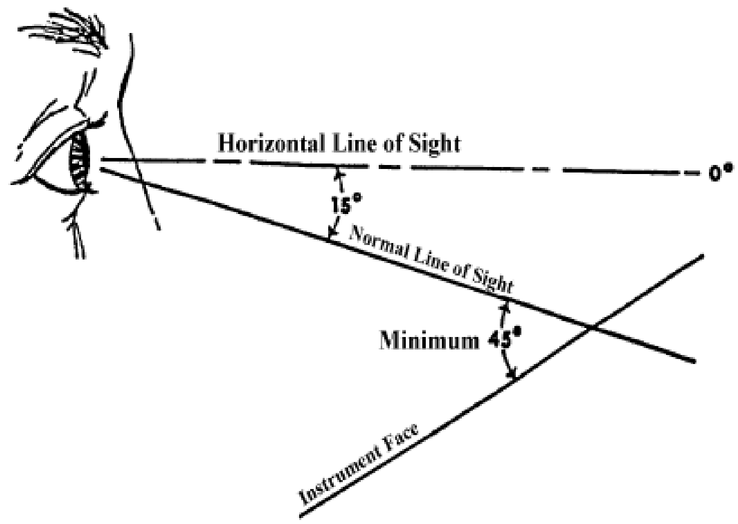
2.11.3 Display Locations

Displays, including devices such as gauges, sight glasses, linear and rotary scales, etc., will be located and designed so that they may be read to the required degree of accuracy by Workers in their normal operating or servicing position without need to assume uncomfortable, awkward, or unsafe postures.

Displays will be visually accessible without resorting to use of ladders, flashlights, or other special equipment to view the display.

Display faces will be perpendicular to the Workers' normal line of sight whenever feasible and will be not less than 45° from normal line of sight as shown in Figure 2.11.3(a).

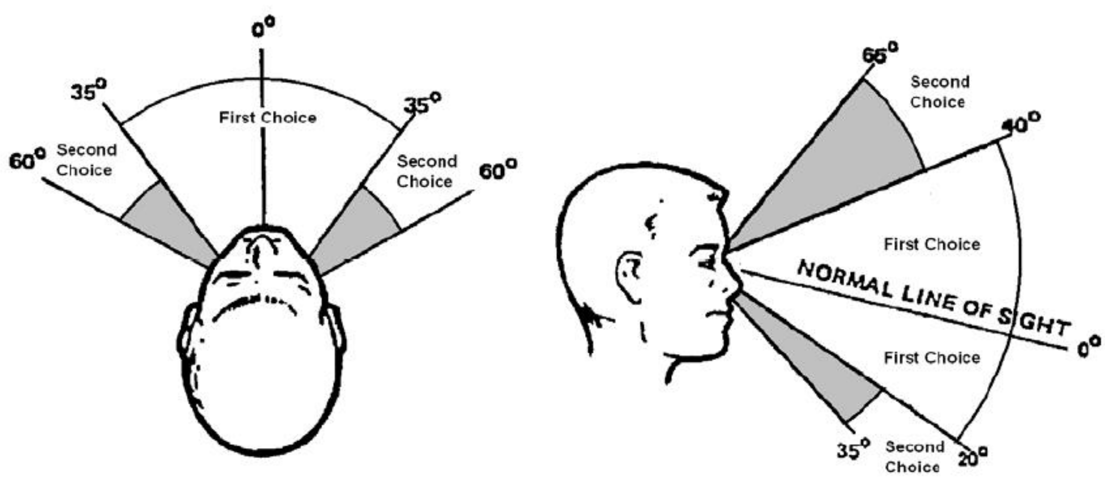
Figure 2.11.3(a) – Display elevation with respect to a Worker.



Displays will be located so that the Worker is not required to rotate their head more than 60° left or right from centre as shown in Figure 2.11.3(b) below as viewed from the expected viewing position.

Displays will be located so that the Worker does not need to rotate their head more than 65° up or 35° below their normal line of sight as specified figure below while at the expected viewing distance.

Figure 2.11.3(b) – Display position with respect to a Worker.



Glare will not interfere with the reading of the display.

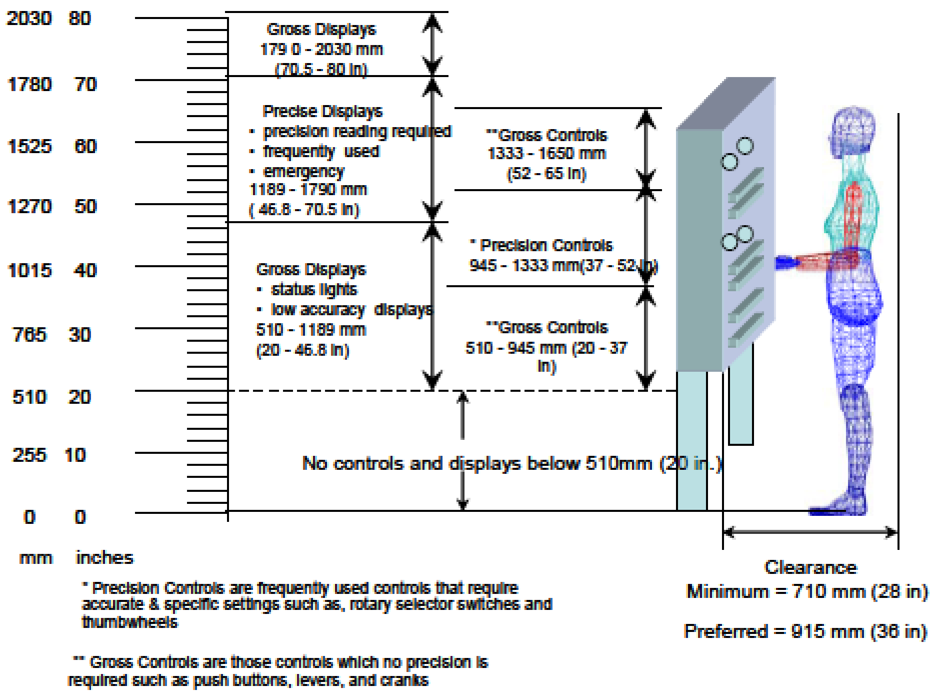
2.11.4 Controls Locations

Local displays will be located above and in clear relationship with their associated controls. If it is not possible to locate the displays above their controls, the displays may be located to the left of the controls.

In the event that the above cannot be met, then the displays will be located so that they are visible from the controls.

For standing operations, important controls, i.e., those requiring precise, frequent or emergency activation, will be located at a height of between 945 mm and 1333 mm as in Figure 2.11.4, and at a maximum distance of 500 mm either side of the body centerline.

Figure 2.11.4 – Control locations with respect to a Worker.



Controls will be located so that they are not susceptible to being moved accidentally or inadvertently, particularly critical controls where such operation might cause equipment damage, Worker injury or system performance degradation.

Controls which are operated in a task-driven sequence or which are operated together will be grouped together along with their associated displays. When several steps of a sequence are selected by one control, the steps will be arranged by order of occurrence to minimize control movements and prevent cycling through unnecessary steps. Cycling through the control's on/off position will be avoided.

Where sequential operations follow a fixed pattern, controls will be arranged to facilitate operation (e.g., a left-to-right and top-to-bottom pattern, as on a printed page).

The arrangement of functionally similar or identical primary controls will be consistent from panel to panel throughout the Equipment.

The size, shape, and location of controls will be designed to ensure that the operation of any one control will not interfere with the Worker's ability to use other controls and to perform other duties.

Spacing between controls will be increased for operation with protective hand wear, when such protective gear is required.

2.11.5 Controls Design

Control movement will be consistent with the related movement of an associated display, equipment component. In general, moving a control forward, clockwise, to the right, up, or pressing a control, will turn the equipment or component on, increase a quantity, or move equipment or component to forward, clockwise, to the right, or up.

Stops will be provided at the beginning and end of the range of control positions if the control is not to be operated beyond the indicated end positions or specified limits.

Discrete controls will be designed so that they display positive indication that the control has activated, i.e., indication light or large displacement of a switch.

Controls that are to be installed outdoors and require frequent use by Workers will be large enough to be operated with gloved hands.

Controls will be designed so that they do not slip from the grasp of a Worker, e.g., use knurled knobs.

If a control must be protected from accidental actuation, one or more of the following methods will be used:

(a) locate and orient the control so that the Worker is not likely to strike or move it accidently in the normal sequence of control movement;

(b) use of recess, shield, or otherwise surround the control by physical barriers. The control will be entirely contained within the recess or barrier envelope;

(c) use of covers or guards for the control. Safety or lock wire will not be used;

(d) interlock the control so that extra movement (e.g., a side movement out of a detent position or a pull-to-engage clutch) or the prior operation of a related or locking control is required;

(e) provide the control with movement resistance (e.g., viscous or coulomb friction, spring-loading, or inertia) so that definite or sustained effort is required for actuation;

(f) lock the control to prevent its quickly passing through a position when strict sequential activation is necessary (i.e., the control is moved only to the next position, then delayed); and

(g) design the control for operation by rotary action.

Dead man controls, which will result in system shut-down to a non-critical operating state when force or input is removed, will be utilized wherever Worker incapacity can produce a critical system condition.

2.11.6 Display Design

All instrumentation that is used to display information to a Worker will include permanent, highly readable, visual clues to help a Worker assess the status of the process being monitored at a glance such as:

(a) the use of green, yellow, and red colours to respectively indicate if the process is in an acceptable, marginal, or unacceptable, or dangerous state;

(b) the use of mechanical tabs or markers to indicate normal, high, low, and alarm and trip set-points;

(c) positioning the indicating device such that it points up when in the normal or safe condition; and

(d) the use of “zebra” stripe backgrounds to enhance readability of sight glasses.

2.11.7 Human Machine Interface (HMI) Colours

The colour of HMI devices, including push buttons, control devices indicating lights, selector switches, alarm lights, annunciation lights, status lights, will be:

(a) the colour RED for active state. i.e., breaker closed, intake gate open, and valve open, etc.;

(b) the colour GREEN for an inactive state as described in BC Hydro DP 45-Z0043;

(c) the colour YELLOW for power available indication;

(d) a flashing YELLOW for warning or alarm; and

(e) the colour BLACK for other functions as labeled.

2.11.8 Physical Accommodation

The Equipment will be designed to ensure physical accommodation, compatibility, operability, and maintainability by the Workers. Physical accommodation is defined as having adequate:

(a) reach, strength, and endurance necessary to perform all physical tasks;

(b) clearance for movement, to ingress/egress work area, and perform all required tasks;

(c) internal and external visibility to perform all required operations; and

(d) fit of personal protective equipment to successfully perform all duties while receiving optimal protection from adverse environmental threats and conditions.

Many anthropometric data sets are available. Design will take advantage of these data to meet the above requirements. For general design guidance, see dimensions for the standing body, seated body, depth and breadth, circumferences and surfaces, hands and feet in MIL-HDBK-759. MIL-HDBK-743 will be consulted for more extensive data.

2.11.9 Design for Maintenance

The Equipment will be designed to:

(a) facilitate rapid and positive fault detection and isolation of defective items to permit their prompt removal and replacement; and

(b) incorporate error-proofing in equipment mounting, installing, interchanging, connecting and operating.

The Equipment will be:

(c) replaceable as modular packages and will be configured for removal, and replacement; and

(d) capable of being removed, replaced, repaired, assembled and disassembled in its operational environment by Workers wearing any clothing and equipment appropriate to the environment and maintenance concept.

The Equipment will be designed and installed to provide complete visual and physical access and a favourable working level for all parts of a system on which maintenance is performed.

2.11.10 Valves

All valves that could reasonably be used for routine operation, isolation or maintenance of the Equipment, will be located so that they are accessible from grade or platform.

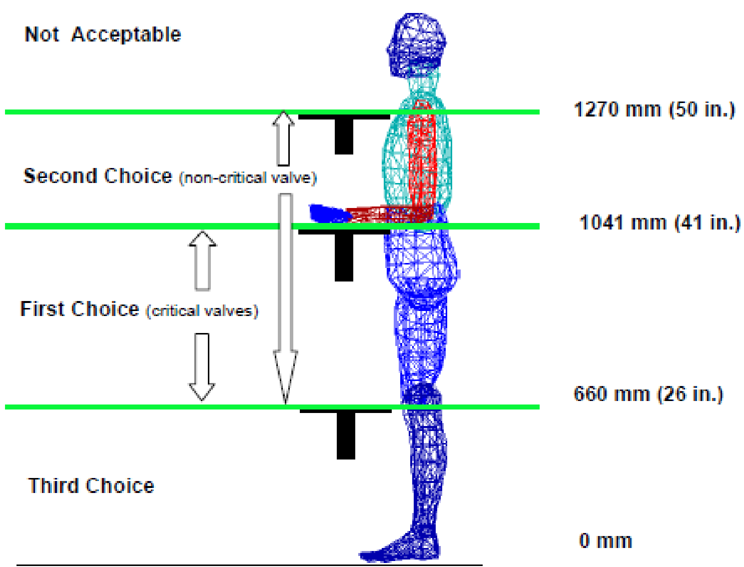
Hand-operated valves will be capable of being opened and closed against their maximum design pressure, fully unbalanced, with a force at the hand-wheel not exceeding 200 N.

All valves will be located so that Workers do not have to stand on equipment, guardrails or pipe work to access them.

Workers will not have to reach beyond 500 mm of a platform to a valve.

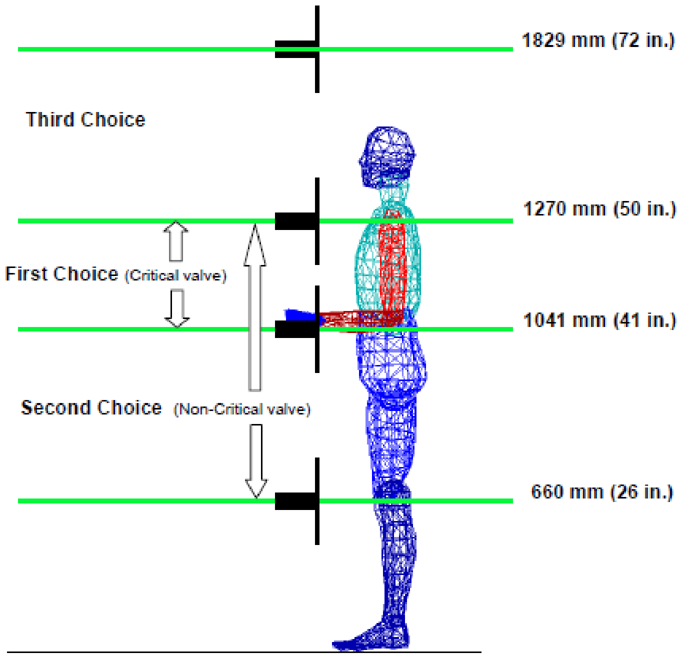
Operator handles for vertical stem valves will not be placed above the shoulder height of 1270 mm and will be placed as recommended in Figure 2.11.10(a).

Figure 2.11.10(a) – Operator handle height for vertical stem valves.



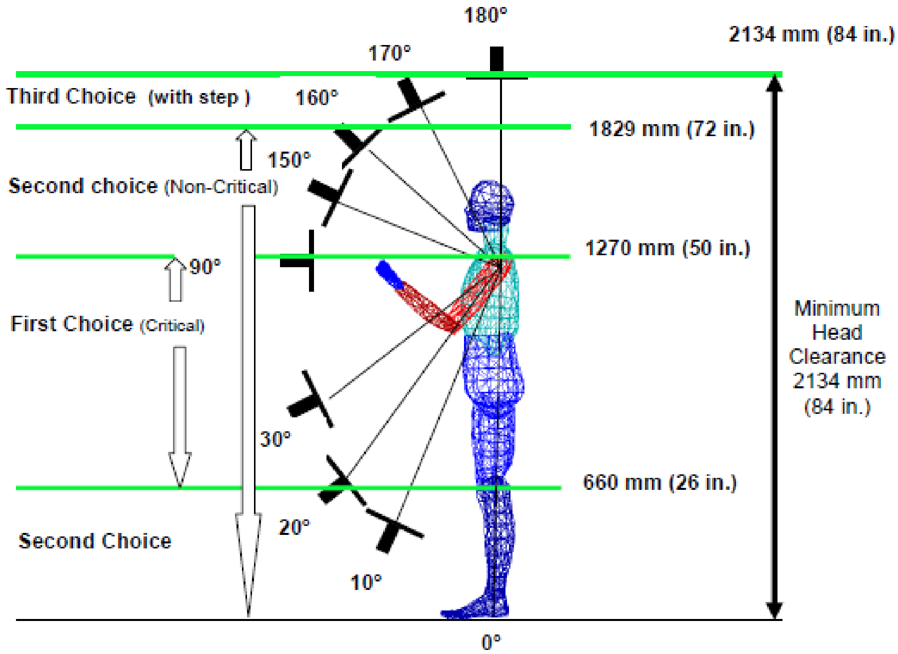
Operator handles for horizontal stem valves of size 51 mm or greater will not be placed below the knee height of 660 mm and will be placed in recommended location as shown in Figure 2.11.10(b).

Figure 2.11.10(b) – Operator handle height for horizontal stem valves.



Operator handles for angled stem valves will be placed in the recommended locations as shown in Figure 2.11.10(c). Gate and globe valves 203 mm and larger, if installed above 1270 mm will not be angled downwards. Overhead valves will not be installed lower than 2134 mm above grade or platform.

Figure 2.11.10(c) – Operator handle height for angled stem valves.



2.12 Instrumentation

2.12.1 General

All instrumentation will:

(a) have a dynamic frequency response appropriate for the application;

(b) be sized such that the range and display are appropriate for the application;

(c) be calibrated;

(d) if there are provisions for adjustment, have a fine-enough adjustment mechanism such that it is possible to easily adjust the set-point in increments of not more than 5% of the total range; and

(e) have their locations clearly identified on the Drawings for the Equipment.

2.12.2 Limit Switches

All limit switches will:

(a) be Allen Bradley heavy-duty oil-tight, plug-in type with slow or snap action contact operating mechanisms as determined by application;

(b) use water and oil-tight type limit switches;

(c) not include any electronics; and

(d) have, at a minimum, two form C contacts.

2.12.3 Resistance Temperature Detectors (RTDs)

(a) General: All resistance temperature detectors ("**Resistance Temperature Detectors**" or "**RTDs**") will:

(i) be 3-wire, platinum, 100 Ω at 0°C, α = 0.003855;

(ii) be of sufficient accuracy to enable their use for the Generator calorimetric testing in accordance with IEEE 115;

(iii) if the RTD cannot be safely or conveniently removed while the Unit is in service, contain two sensing elements (referred to as a "dual-element RTD");

(iv) have Teflon insulated leads that are at least 2000 mm long;

(v) have shielded conductors (leads) to prevent the flow of stray current; and

(vi) be calibrated in degrees Celsius.

(b) Installation: All RTDs will:

(i) with the exception of the stator winding RTDs, be located for convenient removal;

(ii) with the exception of the stator winding RTDs and the Generator air cooler air inlet RTDs, be installed in such a manner that they can be replaced without the need to disassemble the Equipment or the need to drain the cooling water or oil from the Unit; and

(iii) have the leads sufficiently clamped and have external protection to prevent mechanical damage particularly when exposed to oil or air movement such as in a bearing or exposed to stator air flow.

(c) Termination: All RTDs, with the exception of the stator winding, stator core, and stator frame RTDs will:

(i) be terminated in water- and oil-proof connection heads; and

(ii) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit.

(d) Thermal Wells: To improve the transfer of thermal energy across the metal-to-metal interfaces between the detector head and the well, RTDs assemblies installed in thermal wells will:

(i) use a thermal joint compound with a thermal conductivity of at least 0.00745 W/(cm ·°C);

(ii) be coated with thermal joint compound;

(iii) have well voids filled with thermal joint compound; and

(iv) be installed in a threaded pipe-mounted thermo well.

(e) Cabling and Wiring: RTDs will:

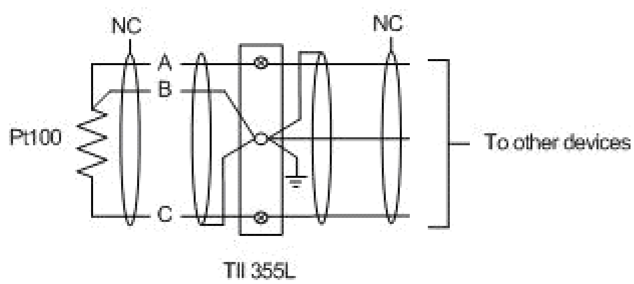
(i) be connected to the appropriate Equipment terminal cabinet using a twisted triad cable with an overall shield that is grounded only at the terminal cabinet end;

(ii) for dual-element RTDs, have the leads for both elements wired to the appropriate terminal cabinet;

(iii) for any RTD element that is not in service, have all of the leads grounded at the Equipment terminal cabinet; and

(iv) be wired to Tii Network Technology 355L Station Protector Modules if there is a possibility of inadvertent energization to a voltage greater than 600 Vac or as otherwise required by the Contract Documents. The centre terminal of the 355L will be solidly grounded and will also be connected to the “B” conductor of the RTD in accordance with Figure 2.12.3.

Figure 2.12.3 – Wiring diagram for a Tii Network Technology 355L Station Protector Module.



Refer to BC Hydro DP 45-Z0034.

2.12.4 Level Measurement, Control, and Indication Devices

The Work includes one level transducer and direct-reading sight glass for each liquid containing reservoir, pressure vessel, or holding tank. The transducer and sight glass are to be located in a stilling well.

(a) Transducer Type: Level transducers will:

(i) be of the guided wave radar type, 4-20 mA, 24 Vdc, two-wire output, loop-powered and capable of HART communications;

(ii) be Magnetrol or Rosemount;

(iii) have a local display at the transducer;

(iv) be rated for the design pressure of the measured fluid; and

(v) have over-range protection to 30% above the maximum pressure to which they may be exposed.

(b) Sight Glass: Each sight glass will:

(i) be rated for the design pressure of the measured fluid including consideration for the worst-case transient conditions;

(ii) have over-range protection to 30% above the maximum pressure to which they may be exposed;

(iii) be fed from the top and bottom of the same stilling well provided for the level transducer;

(iv) have sufficient mechanical protection to prevent damage that may occur from Workers or Carts bumping into the sight glass;

(v) have a scale of sufficient length to indicate the liquid level at all ambient and operating temperatures;

(vi) be located near the reservoir, pressure vessel, or holding tank in an accessible location where it can be readily and safely read by a Worker when the Equipment is in service; and

(vii) have their own isolating and drain valves in addition to the stilling well.

In locations where a sight glass may be impractical (for example, the Turbine guide bearing) a float gauge may be submitted for Consent.

For the Governor, the accumulator sight glass will be a magnetic semaphore flag device.

(c) Stilling Well: Each stilling well will:

(i) have flanged connections to the primary sump/reservoir/vessel/tank;

(ii) have a flanged cover at both ends to facilitate stilling well clean out;

(iii) have isolating valves, a drain, and a vent, so that the stilling well can be isolated and used to independently calibrate the level transducer using the sight glass; and

(iv) if used for water, use stainless steel for all components.

(d) Installation: Each level transducer and sight glass combination will:

(i) be installed in its own stilling well;

(ii) have a guided wave radar sensing element that is long enough so that the sensing element tip remains in liquid until the reservoir, pressure vessel, or holding tank is below its minimum operable level;

(iii) be located/orientated so that the transducer can be independently calibrated of the liquid level in the sump/reservoir/vessel/tank without being removed;

(iv) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit; and

(v) be wired to the appropriate Equipment terminal cabinet.

2.12.5 Water-in-Oil Contamination Detector

The Work includes water-in-oil contamination detectors in all oil containing reservoirs or sumps that are water-cooled. The water-in-oil contamination detectors will:

(a) be a 4-20 mA, 24 Vdc, two-wire output, loop-powered devices capable of capturing a minimum of 100 full range samples per second with a minimum accuracy of 2%, and capable of HART communications;

(b) continuously measure the build-up of water in the oil;

(c) be installed in the location within the oil reservoir or sump that is most likely to accumulate water. If the reservoir or sump has more than one low point, then detectors will be installed in each low point; and

(d) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit.

2.12.6 Digital Flow Measurement, Control, and Indication Devices

Flow measurement, control and indication devices will:

(a) be a 4-20 mA, 24 Vdc, two-wire, loop-powered devices capable of capturing minimum of 100 full range samples per second, and a minimum accuracy of 1%;

(b) be capable of HART communications;

(c) be a magnetic flow meter type from Magnetrol, Rosemont, Foxboro, or ITT BARTON;

(d) be rated for the design pressure of the measured fluid;

(e) have over-range protection to 30% above the maximum pressure to which they may be exposed;

(f) be located to maximize the length of straight pipe upstream and downstream of the device with a minimum straight length of 5 diameters upstream and 2 diameters downstream, or have the length recommended by the equipment supplier, whichever is greater;

(g) have a programmable digital display capable of displaying the flow in both metric and imperial units. Viewing will be possible from a normal standing position for a Worker; and

(h) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit.

2.12.7 Digital Pressure Measurement, Control, and Indication Devices

Pressure measurement, control, and indication devices will:

(a) be a 4-20 mA, 24 Vdc, two-wire, loop-powered devices capable of capturing minimum of 100 full range samples per second, and a minimum accuracy of 0.25%;

(b) be capable of HART communications;

(c) be Rosemont;

(d) be rated for the design pressure of the measured fluid;

(e) have over-range protection to 30% above the maximum pressure to which they may be exposed;

(f) have a programmable digital display capable of displaying the pressure in both metric and imperial units. Viewing will be possible from a normal standing position for a Worker;

(g) be located such that the pressure-measuring pipe is self-draining;

(h) include a calibration tee(s) with valves to enable calibration of the instrument without removal;

(i) include a quarter-turn isolation ball valve(s) and drain facilitate device removal and testing;

(j) have 3-valve balancing manifolds for differential pressure transducers;

(k) have automatic air bleeds where the accuracy and/or the usefulness of pressure measurement could be compromised by the presence of air; and

(l) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit.

2.12.8 Analog Gauges and Process Switches

(a) General: All analog gauges and process switches will:

- (i) be rated for the design pressure of the measured fluid;
- (ii) have over-range protection to 30% above the maximum pressure to which they may be exposed;
- (iii) be located such that viewing will be possible from a normal standing position for a Worker;
- (iv) have a dual metric and imperial range with metric being the primary range; and
- (v) be supplied with electrical connection heads capable of accepting standard ½ inch NPT threaded conduit.

(b) Pressure Gauges: Pressure gauges will:

- (i) have pressure snubbers;
- (ii) be located such that the pressure-measuring pipe is self-draining;
- (iii) have a liquid-filled, dial-type gauge that is a minimum of 100 mm in diameter with a safety glass lens and white background with black numerals;
- (iv) have units in kPa and psi with kPa being the primary range;
- (v) if the pressure gauge cannot be installed in the same common isolation line as a digital pressure measurement device, include a test instrument tee with valve to enable testing of the instrument without removal; and
- (vi) include a quarter-turn isolation ball valve and drain to facilitate device removal and testing.

(c) Pressure Switches: Each pressure switch will:

(i) include an adjustable range sufficient to cover all reasonable pressure variations expected;

(ii) include a minimum of two form C contacts;

(iii) include a hysteresis appropriate for the application;

(iv) include pressure snubbers or other form of damping if required to prevent chattering contacts;

(v) not include any electronics;

(vi) be located such that the pressure-measuring pipe is self-draining;

(vii) if the pressure switch cannot be installed in the same common isolation line as a digital pressure measurement device, include a test instrument tee with valve to enable testing of the instrument without removal; and

(viii) include a quarter-turn isolation ball valve and drain to facilitate device removal and testing.

(d) Flow Switches: Each flow switch will:

(i) include an adjustable range sufficient to cover all reasonable flows variations expected;

(ii) include a minimum of two form C contacts;

(iii) include a hysteresis appropriate for the application;

(iv) not include any electronics; and

(v) not be used in locations where accurate metering/monitoring of the flow is required.

(e) Dial Temperature Gauges: Dial temperature gauges will:

(i) have a minimum of 100 mm in diameter liquid filled, safety glass lens, white background and black numerals dial gauge type; and

(ii) have units in degrees Celsius.

2.12.9 Vibration Monitoring System Probes

(a) General: The Work includes:

(i) one eddy current probe, driver, and matched cable, for use as a keyphasor, mounted on the upstream side of the Turbine shaft;

(ii) a matching keyphasor target of suitable material will be permanently fixed to the Turbine shaft, circumferentially located in-line with the centre of Generator rotor pole number 1; and

(iii) four eddy current probes, drivers, and matched cables to monitor shaft vibration on each guide bearing.

(b) Sensor Requirements: Eddy current probes will:

(i) be type CMSS68 eddy current probes, with type CMS958 matched coaxial cables and type CMSS668 drivers, each as supplied by SKF;

(ii) have a range equal to at least four times the normal bearing clearance;

(iii) have the drivers mounted in a suitably rated NEMA Enclosure outside of each bearing pot; and

(iv) be wired to the Generator Terminal Cabinet or the Turbine Pit Panel.

(c) Probe Location: The location of the eddy current probes on each guide bearing will be as follows:

(i) one probe on the upstream side;

(ii) one probe on the downstream side; and

(iii) the remaining two probes located at 90 degrees from the upstream and downstream probes.

(d) Probe Mounting: Eddy current probes will be:

(i) installed on mounting brackets that allow convenient radial adjustment of the distance between the probe tip and the bearing journal or shaft without twisting the probes;

(ii) conveniently accessible by Workers for purposes of inspection and adjustment:

(A) while the Unit is in operation; and

(B) without disassembly of any bearing components; and

(iii) mounted in such a way:

(A) to minimize any thermal effects of the bearing warming up;

(B) that the probe measures the total movement of the bearing journal (i.e., the probe itself will not move in the radial direction); and

(C) to minimize the vibration of the probe mount.

(e) Applicable Codes and Standards: The probes, drivers and cables supplied for this application will be designed and installed in accordance with API-670.

(f) Vibration Monitoring System: The vibration monitoring system will be a Bentley Nevada 3500 continuous monitoring system. Others will supply and install the Bently Nevada 3500 vibration monitoring rack and the Bently Nevada input/output modules.

2.12.10 Instrumentation Protection

All instrumentation that could be affected by water spray, brake dust, water or oil leakage or mist will be protected so that, subsequent to an exposure to contamination, the instrumentation remains in an operational state.

No instrumentation will be damaged or otherwise made inoperative when high-voltage electrical tests are conducted on the Generator stator or rotor windings.

2.12.11 Operational Information (OI) System

BC Hydro will have a low-speed data acquisition system (OI) permanently installed to record all significant operational parameters for the Equipment. Examples of information that will be recorded are: operating mode, times at each mode and operating regime, power, gate setting, temperatures, and instantaneous vibration levels, tailwater and headwater levels, etc. Any information recorded by this system, needed specifically for warranty or commissioning purposes, will be made available to the Contractor and will be provided by Hydro's Representative at the appropriate times. Requests by the Contractor for any additional information will be made in writing to Hydro's Representative who will have final say on what and how much information can be released to the Contractor.

2.12.12 Measurement and Display Units

Measurement of process quantities and associated displays on the Equipment will utilize the International System of Units (SI).

Display of process quantities will be in engineering units (i.e., if a scientific notation prefix is required, it will be in units such as giga-, kilo-, mega-, micro, etc.).

A table of sample process variables and associated measurement and display units is included below:

Process Variable	**Units**
Current	milliamperes (mA) Amperes (A) kiloamperes (kA)
Voltage	millivolts (mV) Volts (V) kilovolts (kV)
Power	megavolt-amperes (MVA) megawatts (MW) megavolt-amperes reactive (MVAr)
Frequency	Hertz (Hz)
Resistance	milliohms (mΩ) Ohms (Ω) megaohms (MΩ)
Temperature	degrees Celsius (^{o}C)
Flow	Litres per minute (L/m) cubic metres per second (m^3/s)
Pressure	kilopascals (kPa)
Liquid Level	millimetres (mm) metres (m)
Rotational Speed	revolutions per minute (rpm) percent (%)

2.13 Software and Software-Driven Devices

2.13.1 General

"**Software**" includes Application Configuration Files and Configuration Tool Software.

All Software provided with the Equipment will:

(a) not be copy-protected;

(b) not require BC Hydro to use authentication codes/keys in order to activate the Software with each use;

(c) be provided on unlimited corporate-wide license for BC Hydro use;

(d) be compatible with the latest version of the Microsoft Windows personal computer operating system at the time of Equipment delivery; and

(e) be supplied in CD ROM format, clearly labelled, and complete with all applicable Explanatory Documents, including instruction manuals and help files.

The Work includes, at no additional cost, any available Software upgrades or enhancements, along with documentation, during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols].

2.13.2 Application Configuration Files

For each Software-Driven Device that is provided as part of the Equipment, the Work includes provision of all software files, library files, and configuration data files (the "**Application Configuration Files**") that contain information necessary to achieve intended operation of the Equipment according to the Specifications, including:

(a) source code that defines the control logic, sequence, and strategy for the device;

(b) settings data to be assigned to device configurable parameters;

(c) device firmware or built-in operating system (BIOS) data; and

(d) graphics for human-machine interface (HMI) display devices.

If the Contractor wishes to use any passwords for accessing, viewing, or modifying any Application Configuration Files, the passwords will be provided to BC Hydro, and will allow the highest level of access (i.e., "administrator" access) to the Application Configuration Files. Any passwords used will be subject to approval.

Application Configuration Files will be provided to BC Hydro in a manner that allows BC Hydro to modify all aspects of them.

Application Configuration Files will be designed such that when printed from within the associated Configuration Tool Software, content will fit on 8.5"x11" or 11"x17" sheets and be easily and conveniently readable on hard copy (for example, function blocks, text and connection lines will not be truncated by page borders, and minimum text height will be no less than 1 mm on hard copy);

2.13.3 Configuration Tool Software

The Work includes provision of all software application packages, tools, and development kits (the "**Configuration Tool Software**") used to:

(a) create, modify, and configure Application Configuration Files associated with the Equipment;

(b) upload and download Application Configuration Files to the Equipment;

(c) view and trend real-time values of software variables as the Application Configuration Files are executing within the Equipment;

(d) capture and review records of Events that occur within the Equipment; and

(e) compare and highlight individual differences between Application Configuration Files stored in the Equipment, with Application Configuration Files stored on a laptop computer.

Configuration Tool Software will include:

(f) a function block style of programming language - i.e., a programming language that relies primarily on graphical (as opposed to text-based) representation of source code, so as to simplify design of Application Configuration Files. This will be the primary programming language used by the Contractor, and will include:

(i) a large group of available function block types, with no limit imposed on the number of instances of each block that may be used (other than those based on memory limitations of the supporting hardware), including:

(A) Laplace integrator;

(B) Laplace proportional control;

(C) Laplace differentiation;

(D) Laplace summing junction;

(E) saturated limit (both positive and negative with fixed limits);

(F) saturated limit (both positive and negative with controllable limits);

(G) binary delay ON/OFF;

(H) binary bistable latch - RS type and JK type;

(I) logical OR, AND, NOT, XOR;

(J) first-order low-pass filter;

(K) hysteresis;

(L) threshold detector (window comparator);

(M) output drivers, binary and analog;

(N) input scanners, binary and analog; and

(O) data type conversion (e.g., word-to-bit, bit-to-word, floating-point-to-integer);

(ii) capacity to interconnect function blocks at the will of the user, including connection of blocks in closed-loop feedback configuration;

(iii) the ability for the user to define new function block types that include embedded user-defined source code, as well as a user-defined input and output interfaces; and

(iv) a user interface that includes an on-screen description of each function block and parameter (a help file is an acceptable method of providing this functionality);

(g) a method of comparing the Application Configuration Files stored in the Equipment with those stored on a laptop computer, with individual differences identified and easily distinguished;

(h) capability to password–protect changes to device settings; and

(i) provisions to ensure that CPU utilization is well within its processing capacity, including:

(i) a warning when CPU utilization is greater than approximately 50% of its maximum capacity; and

(ii) the ability to display, in real time, the logic scan time, the CPU utilization, and memory utilization in percent of full capacity.

2.13.4 Software-Driven Devices

A "**Software-Driven Device**" is a device, provided as part of the Equipment, that contains a microprocessor and volatile memory (i.e., memory that requires power to retain its data), which is used during the device's operation.

(a) Data Storage Back-Up: Each Software-Driven Device provided by the Contractor will include storage back-up to ensure device data is retained when external power is removed from the device. Upon restoration of external device power, the Software-Driven Device will automatically load required data from its internal storage back-up source into its volatile memory, and begin operation.

For information and reference and without limiting this requirement, an example of an acceptable method of storage back-up would be use of non-volatile flash memory to store a Software-Driven Device's data. When power is restored to the device, the device would then load all data required for operation from non-volatile flash memory into its volatile memory.

(b) Software Setting Modifications: Modification of Software-Driven Device settings (including gains, time constants, threshold values, etc.) will only be possible from a laptop computer, communicating with the Software-Driven Device using Configuration Tool Software.

All adjustable parameters will be available for uploading to a laptop computer from each Software-Driven Device and for downloading to each Software-Driven Device from a laptop computer, when the Unit is running and when the Unit is stopped.

(c) Code Execution Frequency: The ability to process different blocks or sections of code at two or more different rates will be provided. Application Configuration Files will be designed so that there are no erroneous operations due to time or memory limitations.

The Contractor will utilize this functionality to ensure that:

(i) source code sections that are required to be processed often (in order to ensure intended Equipment operation) are adequately serviced by the Software-Driven Device's CPU; and

(ii) source code sections that do not need to be executed often do not encroach onto the Software-Driven Device's processing capability in a manner that may adversely impact operation of the Equipment.

For information and reference and without limiting this requirement, an example of where this practice may be utilized is a source code section that processes temperature data, which would likely not need to be executed as often as source code sections that process the Equipment's main control loop algorithm.

2.13.5 Software Design

(a) General: Application Configuration Files will be designed in accordance with BC Hydro DP 45-Z0010. Where DP 45-Z0010 and this SPGT disagree, this SPGT will govern.

Application Configuration Files will be designed to ensure that any device memory or processing speed limitations will not cause detrimental or unintended operation of the Equipment.

(b) Advanced Programming Techniques: Application Configuration Files will be designed to balance readability, simplicity, and computational efficiency, with readability being the most valued by BC Hydro. Use of advanced techniques ("**Advanced Programming Techniques**") to design Application Configuration Files, including techniques listed below, will be limited to only where necessary (i.e., where it would be disproportionately complex or inefficient to not use these techniques), or where specified in the Specifications:

(i) nested software structures or subroutines;

(ii) interrupt-driven software routines;

(iii) custom software functions (i.e., functions that are not provided with the manufacturer's Configuration Tool Software);

(iv) custom data communication protocols; and

(v) any other functionality within the manufacturer's Configuration Tool Software that is not immediately evident to a user viewing Application Configuration File source code within its associated Configuration Tool Software.

(c) Commenting and Embedded Documentation: In addition to commenting requirements outlined in BC Hydro DP 45-Z0010, additional commenting within Application Configuration Files will be provided where Advanced Programming Techniques are used by the Contractor, so as to clearly, concisely, and completely reveal and describe the algorithms and techniques used by the Contractor. The audience is a BC Hydro user who is knowledgeable with regard to the Configuration Tool Software, but not with regard to the Contractors' Advanced Programming Techniques used to design the Application Configuration Files.

(d) Modularity: Software will be designed in a modular manner, by dividing code into logical sections and function blocks, in order to improve readability for users, and to allow code sections to be standardized and used throughout the program.

Modules will be as generic and small as possible, in order to support user-friendly (readable), verifiable, deterministic design.

Module interfaces (i.e., inputs and outputs to other modules) will be designed to be as simple as possible, to provide good traceability of connections to other modules.

(e) Fault Tolerance and Failsafe Behaviour: Software will be designed to be highly deterministic and predictable when error conditions, including unexpected error conditions, are encountered during program execution. The software will identify off-nominal conditions, and cause its associated Software-Driven Device and/or system to go to a failsafe state.

(f) Software Design Plan and Software Meetings: The Contractor will prepare, before design of Application Configuration Files begins, and a minimum of 180 days before the scheduled date that the first component of the Equipment will be shipped to the Site, one or more Software design plans (each a "**Software Design Plan**"), which, for each Software-Driven Device or subsystem of the Equipment that will use Application Configuration Files, will describe:

(i) a block diagram showing:

(A) inputs from other devices and systems;

(B) intended program structure, modularity, and execution order;

(C) performance requirements of each code section; and

(D) outputs to other devices and systems;

(ii) algorithms to be used;

(iii) intended naming techniques and data types for variables and constants;

(iv) any custom Software functions to be used (including custom structured variables and data communications functionality), along with documentation;

(v) examples of source code to be delivered (source code sections from the Contractor's past projects are acceptable to submit as an example), illustrating presentation and commenting;

(vi) a list of planned variables (including structured variables), constants, alarms, targets, and any other data planned to be utilized in the Application Configuration Files;

(vii) memory addressing plan;

(viii) screen concepts for HMIs, including menu design indicating screens to be provided, and data to be shown on each screen; and

(ix) any other information that the Contractor determines is relevant.

At the request of Hydro's Representative, the Contractor will make its Application Configuration File designers for each Software-Driven Device available for one or more meetings (each a "**Software Meeting**") with BC Hydro, to discuss the Application Configuration Files, the Software Design Plan, and Hydro's Representative's feedback on both.

When determining whether Application Configuration Files submitted by the Contractor are acceptable or whether they require further revision and refinement by the Contractor before it is accepted, BC Hydro will consider the adequacy of commenting, documentation, as well as the Contractor's use of Advanced Programming Techniques. The intent of both the Software Design Plan and the Software Meetings is to minimize the amount of revision that will be required by the Contractor before Application Configuration Files are submitted. BC Hydro welcomes any additional collaboration that the Contractor may wish to have with BC Hydro with regard to design of Application Configuration Files.

2.13.6 Events

An "**Event**" is a change of discrete status detected by a Software-Driven Device.

An "**Event List**" is a list of Events that have been designated, within Application Configuration Files for a Software-Driven Device, to be monitored and recorded because they are deemed operationally relevant by the Contractor or by BC Hydro.

Event Lists are required for Software-Driven Devices where specified in the Specifications, and will be developed collaboratively between the Contractor and BC Hydro until the first Unit is placed in full Commercial Operation.

BC Hydro's standardized plant monitoring systems utilize a custom structured variable type (the "**Event Data Structure**") to record data about Events (when they occur) in a standardized manner, at BC Hydro generating stations. The Event Data Structure includes the following elements:

(a) Message number: A unique number (can be 0 to 9999) denoting the message number associated with an Event. BC Hydro maintains a list of standardized event message text and associated message numbers, which will be provided to the Contractor by BC Hydro.

(b) Category: Used to denote the type of Event as follows:

(i) *1*: change of status only;

(ii) *2*: change of status designated as an Alarm; and

(iii) *3*: change of status designated as a Target.

(c) State: Used to denote the state of the Event as follows:

(i) *0*: de-asserted (off); and

(ii) *1*: asserted (on).

(d) Supervisory group: The plant supervisory alarm group to which the Alarm belongs (can be 1 to 128 or 0 if the Event is not an Alarm).

(e) Year: Year the event occurred (four-digit number).

(f) Month: Month of the year the event occurred (can be 1 to 12).

(g) Day: Day of the month the event occurred (can be 1 to 31).

(h) Hour: Hour of the day the event occurred (can be 0 to 23).

(i) Minute: Minute of the hour the event occurred (can be 0 to 59).

(j) Second: Second of the minute the event occurred (can be 0 to 59).

(k) Millisecond: Millisecond of the second the event occurred (can be 0 to 999).

BC Hydro's standardized plant monitoring systems also utilize a custom structured variable type (an "**Event Buffer**"), used to store, in a 1000-element time-sorted circular buffer, Events that have been detected by various generating station devices, for communication between devices. Where specified in the Specifications, certain devices provided as part of the Work includes a similar Event Buffer, and capability to communicate Events to other devices using a custom communication protocol (details of which will be provided to the Contractor by BC Hydro).

2.13.7 Alarms and Targets

An "**Alarm**" is an Event that is designated to cause visual and audible alerts to operations personnel (via HMI devices, horns, and other annunciation equipment), indicating an associated degree of urgency or operational importance. An Event is designated as an Alarm within the Event Data Structure by designating it as a category 2 Event.

A "**Protection Target**" or "**Target**" is an Event that is designated to cause visual display indicating that a protective device has operated and initiated a Unit shutdown or trip. An Event is designated as a Target within the Event Data Structure by designating it as a category 3 Event.

2.13.8 Adjustable Settings

Certain Software-Driven Devices will include functionality to allow adjustment of each of their settings via one of the following two methods:

(a) "**Software-Adjustable**" settings will be adjustable by a Worker using a laptop computer and Configuration Tool Software to communicate with the Software-Driven Device; or

(b) "**Worker-Adjustable**" settings will be adjustable by:

(i) a Worker using the HMI associated with the Software-Driven Device, when the system associated with the Software-Driven Device is in local control mode; or

(ii) a device external to the Software-Driven Device, when the system associated with the Software-Driven Device is in remote control mode.

All Worker-Adjustable settings will also be Software-Adjustable.

2.14 Lighting

2.14.1 General

The lighting systems for the Equipment will:

(a) meet the requirements of BC Hydro ES 44-Z0040 for energy efficiency for lighting systems in generating stations;

(b) be permanent, shrouded, industrial class lighting fixtures;

(c) be of the low-energy type such as florescent tube or LED type;

(d) have industry standard power supplies and connections for the bulb(s);

(e) have light switches located at all entrances – multiple-way if there is more than one entrance;

(f) ensure lighting levels throughout the Equipment are appropriate for Workers to safely and efficiently conduct operation, inspection, maintenance, and emergency response activities with minimum requirements for additional task lighting;

(g) have emergency lights, that will operate during a power outage, along all egress routes with minimum illumination level of 50 Lux on the face of the light. Emergency lights will be wired to their own dedicated circuit(s) so they can be connected to the Powerhouse station service emergency ac bus power source. Emergency lights powered by localized batteries are not permitted;

(h) have means for safely accessing, maintaining, and replacing lighting fixtures or lamps;

(i) have fixtures that are seismically stabilized. The swing and shaking of lighting fixtures will be prevented;

(j) be designed to ensure maintenance of the lighting can be completed while maintaining Column 4 LOA to exposed energized conductors or equipment (except for lighting located within the Generator Enclosure); and

(k) ensure all circuit wiring is terminated in the designated Enclosures for each work area with all circuits clearly identified.

2.14.2 Illumination Levels

Illumination levels throughout the Equipment including, Brushgear Housing, Generator Enclosure, Generator Pit, Turbine Pit, and Turbine Lower Wicket Gate Bushing Access Gallery will be in compliance with all applicable WorkSafeBC illumination requirements or have an illumination level of 300 Lux (whichever is greater).

2.14.3 Lighting Panels

All cabling and wiring for lighting provided as part of the Work will be terminated in dedicated lighting panels. Lighting panels will meet the requirements for Enclosures.

The number and location of lighting panels will be submitted, but generally for one Unit it is expected that there will be one lighting panel in the Generator Enclosure, one panel recessed into the Turbine Pit liner, and one panel outside the Lower Wicket Gate Bushing Access Gallery.

It is acceptable for lighting panels to be combined with power receptacle panels.

Others will provide the cabling and Raceways to connect the lighting panels to the Powerhouse station service distribution panels.

2.15 Power Receptacles

2.15.1 General

All areas of the Equipment including the Brushgear Housing, Generator Enclosure, Generator Pit, Turbine Pit, and Turbine Lower Wicket Gate Bushing Access Gallery will have power receptacles provided for portable tools and work lights. Power receptacles will also be provided anywhere a movable work platform is expected to be used.

120 Vac power receptacles will be:

(a) single phase, 3-prong (hot, neutral, and ground terminals), 20 A duplex receptacles; and

(b) be of the ground fault interrupting type for receptacles located below elevation 413 m, in damp areas, or in areas subjected to flood such as the Penstock Coupling Chamber or Turbine Pit.

600 Vac power receptacles will be:

(c) 60 A, three phase, three-wire (ground via receptacle body), Crouse Hinds AR 1037:

  (i) surface mount: will include a back box with adaptor Crouse Hinds AJ 57 or AJ 57C; or

  (ii) embedded: will include a 15 degree angle adaptor suitable for AJ 57 on box cover;

(d) connected to a safety disconnect; and

(e) protected by a Class A ground fault circuit interrupter where installed below elevation 413 m, in damp areas, or in areas subject to flood such as the Penstock Coupling Chamber or Turbine Pit.

2.15.2 Power Receptacle Panels

All cabling and wiring for power receptacles provided as part of the Work will be terminated in dedicated power receptacle panels. Power receptacle panels will meet the requirements for Enclosures.

The number and location of power receptacle panels will be submitted, but generally it is expected there will be one power receptacle panel in the Generator Enclosure, one panel recessed into the Turbine Pit liner, and one panel outside the Lower Wicket Gate Bushing Access Gallery.

It is acceptable for power receptacle panels to be combined with lighting panels.

Others will provide the cabling and Raceways to connect the power receptacle panels to the Powerhouse station service distribution panels.

2.16 Electrical Power

2.16.1 Power Supplies

The Equipment will be designed to be capable of operating continuously with the Powerhouse station service electrical power supplies indicated below. The Work includes the provision of power supplies for equipment requiring voltages other than those indicated.

(a) 600 Vac, 60 Hz, 3-phase, 3-wire from motor control centres (MCC);

(b) 347/600 Vac, 60 Hz, 3-phase, 4-wire from distribution panels (intended to be used for lighting only);

(c) 120/208 Vac, 60 Hz, 3-phase, 4-wire from distribution panels; and

(d) 125 Vdc from distribution panels (intended to be used as a power source for control electronics and instrumentation only).

Of the above power supplies, only the 125 Vdc power source will be uninterruptable (the power source is a dual redundant 125 Vdc battery bank). All other power supplies may be momentarily interrupted during facility maintenance such as during a break-before-make transfer of the station service power source or to facilitate equipment isolation.

2.16.2 Surge Protection and Short Circuit Level

(a) All electrical equipment connected to the station service power systems at the facility will have Basic Insulation Level (BIL) per ANSI/IEEE C37.20.2, C37.20.3, C57.12.00, and C57.12.01.

(b) Where required, electrical and/or electronic components will be provided with surge suppression devices.

(c) The power system short circuit level in the facility will be as follows:

(i) 600 Vac – 65 kA rms;

(ii) 347/600 Vac – 65 kA rms; and

(iii) 120/208 Vac – 10 kA rms.

2.16.3 Power Quality

Voltage and frequency variation of the power supply will normally be ±5% nominal voltage and ±1% nominal frequency. However, the frequency of the Powerhouse station service AC electrical power supplies may rise to approximately 50% over-frequency (90 Hz) within 10 seconds after a Unit load rejection event, and will return to approximately 5% over-frequency (63 Hz) within 60 seconds and may remain there indefinitely.

All Equipment provided as part of the Work including, control solenoids, relays, power supplies, instruments, motors, or other such equipment that is connected to the Powerhouse AC station service will be capable of operating continuously within the above voltage ranges and durations.

2.16.4 Loss of Power Supplies

With only the 125 Vdc power source available for the Equipment control system electronics and instrumentation, the Equipment will be designed to:

(a) operate satisfactorily at a constant load set-point for up to 1 hour; and

(b) be able to be shutdown and come to a complete standstill in a normal manner.

BC Hydro does not foresee a need to localized uninterruptable power supplies or localized batteries to meet these requirements. If the Equipment needs a power source other than the powerhouse 125 Vdc power source to meet these requirements, the Work includes provision of the required power source(s) which power source(s) will be submitted for Review.

2.16.5 Power Supplies for Specialized Equipment Tests

The Work includes any power supplies including cabling, Enclosures, protective devices, fittings, adaptors, control panels, etc., required for specialized testing equipment.

2.17 Electrical Equipment and Devices

2.17.1 General

The Work includes all the electrical equipment, components, and devices including: motors, switches, contactors, motor control centres (MCCs), magnetic starters, relays, instrumentation, protection and control devices, wiring, cables, terminal boxes, Enclosures, electrical metallic tubing, rigid conduit, Raceways, cable and wire terminations, etc., required for the Equipment except where expressly otherwise noted.

The Work also includes:

(a) supply, installation, and termination of all cables and wiring inside the Generator Enclosures and Turbine Pits to the designated Interface points;

(b) supply, installation, and termination of all cables and wiring between the Contractor's supplied Equipment to the designated Interface points;

(c) supply, installation, and termination of all cables and wiring between the separate components of the Contractor's supplied Equipment;

(d) supply and installation of all Raceways, included embedded Raceways, required for the:

  (i) installation of all electrical cables and wiring entering into, exiting from, and in the Generator Enclosures and Turbine Pits regardless of who supplies the cable or wire; and

  (ii) installation of all electrical cables and wiring between any two pieces of Contractor supplied equipment outside the Generator Enclosures and Turbine Pits regardless if Raceways are also used by Others;

(e) enabling Others to install and terminate cables and wiring to terminal blocks in the Contractor's Equipment;

(f) installation of all electrical cables and wiring in the Generator Enclosures and Turbine Pits in the Contractor supplied and installed Raceways and Enclosures regardless of who supplies the cable or wire;

(g) being responsible for coordinating with Others the cable installation and termination, and the exchange of termination information; and

(h) submitting the cable and wire termination information.

The electrical Work and all electrical equipment, devices, and components will comply with the Specifications and with the applicable codes and standards in SPGT 3.2.

Electrical equipment and devices will be designed and arranged in an acceptable manner.

Electrical equipment and devices that are stand-alone in nature, such as the Generator lift pump, will be mounted on rigid corrosion-protected steel skid such that the equipment can easily be moved around as a package using a forklift, pallet jack, or overhead crane.

2.17.2 Electrical Enclosures

(a) General: Electrical enclosures (each an "**Enclosure**") include indoor or outdoor wall-mounted or free-standing equipment panels, cubicles, cabinets, and control consoles that house electrical and electronic equipment components and wiring devices. Enclosures also include junction and termination boxes.

All control, protection, and instrumentation equipment and systems will be installed in suitable Enclosures.

(b) Location: Enclosures that may be required to be accessed by Workers for inspection or maintenance more than once a year will be positioned in locations that are accessible by Workers while the Equipment is in service.

(c) Component Arrangement: Electrical and electronic equipment, components, and wiring devices within Enclosures will be arranged such that they easily accessible for maintenance and replacement.

(d) Types: Enclosure will:

(i) for full-height Enclosures, be free-standing and floor mounted;

(ii) for half-height Enclosures, have a panel support and be floor mounted;

(iii) for half-height or smaller Enclosures, be wall-mounted;

(iv) have a NEMA 2 rating for equipment requiring openings or grills for cooling air;

(v) have a NEMA 2 rating for dry indoor locations;

(vi) have a NEMA 4 rating for outdoor, wet, or moist locations including locations where the Enclosure may be subject to spray from a deluge or sprinkler system;

(vii) have a NEMA 12 rating for equipment in locations where oil or oil mist may be present; and

(viii) be suitably rated for use in the environment it has been placed in if the Enclosure has been placed in a hazardous location.

All conduit and cable fittings for Enclosures will be rated for the same environment as the Enclosure.

(e) Construction: Enclosures will:

(i) generally be of dead front, rigid and self-supporting heavy-duty construction with minimum 14 gauge steel frame and side steel panels made of zinc coated cold-rolled sheet steel with continuously welded seams;

(ii) for Enclosures with a footprint larger than 500 x 500 mm, be constructed of 12 gauge or heavier cold-rolled steel with continuously welded construction used throughout and will be mounted on a solid steel frame. The Enclosure construction will form a completely enclosed, rigid, free-standing structure that is suitably braced, stiffened, and reinforced to withstand, without damage, all stresses incidental to shipping, installation, and operation;

(iii) use panel supports (to raise half-height Enclosures to working height) that are welded with heavy-duty galvanized steel channels;

(iv) have a structural shell in accordance with CAN/CSA G40.21 M or equivalent ASTM material;

(v) have welds that are in accordance with the requirements of CSA W59;

(vi) have continuous welds that are ground to give a smooth appearance and in no case will exposed surfaces be made unsightly with welds;

(vii) have hinged doors for easy access to all Equipment expected to be accessed more than once every 3 years;

(viii) have means to enable the use of keyed padlocks supplied by BC Hydro to secure doors or access panels in the closed position to prevent unauthorized access to the equipment within the Enclosure;

(ix) have means to prevent unauthorized access to: controls, control input or output ports, or communications ports or data ports mounted on the front of Enclosures;

(x) have provisions for top and bottom cable/conduit entry (no top entry for NEMA 4 enclosures) including removable gland plates or a series of conduit knockouts to accommodate cables and conduits;

(xi) be designed to prevent water ingress due to discharge of sprinklers from the fire protection system and be provided with drip shields at the top of the Enclosure;

(xii) have drain holes and plugs;

(xiii) if required, be suitably ventilated to provide adequate circulation of air;

(xiv) not be drilled or welded for attaching internal electrical devices and components including: wires, terminal strips, resistors or switchboard devices, etc., where such holes or fastenings will be visible from the front of the Enclosure;

(xv) not be drilled or welded for attaching internal wiring devices and components. Removable 12 gauge steel sub panel(s) for mounting electrical and electronic equipment, components and wiring devices will be provided;

(xvi) include lock washers or other locking devices for all screws and bolts used for mounting electrical and electronic equipment, components, and wiring devices on the sub panel; and

(xvii) have Lifting Points provided for easy handling for large or full-height Enclosures and for Enclosures that weigh more than 20 kg.

(f) Provision for External Cables: External cables supplied by Others may enter an Enclosure from an overhead cable tray system, through floor slots or pipe sleeves from a tray system on the floor below, or from an embedded or surface conduit system. Enclosures will be furnished with suitable removable gland plates or a series of conduit knockouts to accommodate these cables. The final design requirements will be established with the Contractor when the powerhouse design and equipment layout has been completed.

(g) Ventilation: If an Enclosure requires ventilation, the Enclosure will:

(i) have screened and filtered openings to prevent the entrance of rodents or foreign materials and to minimize the entrance of dust when ventilation for natural or forced air circulation of air is provided; and

(ii) use pleated filters when forced air circulation is provided. The filters will be designed in so they may be removed easily for cleaning/replacing with the Equipment in operation.

(h) Infrared Inspection Ports: Where an Enclosure encloses high-voltage or medium-voltage equipment, uninsulated current-carrying buswork, or components carrying greater than 60 A, the

Enclosure will enable a Worker to inspect all DC and low-voltage AC bus connections using an infrared camera.

(i) Protection against Vibration: Where an Enclosure may be subjected to vibration or shock during normal operation, instruments and relays will be mounted on fixed panels and protected against shock and vibration.

(j) Doors: Enclosures doors will:

(i) have single or double doors as specified or required by the design;

(ii) be front opening and, if required, rear opening;

(iii) be neat, matching and uniform in appearance;

(iv) have continuous, fully concealed hinged doors with stiffeners and the appropriate NEMA rating oil resistant gaskets;

(v) for all full-height Enclosures, have top and bottom non-locking latches and a zinc die case or chromium plated "T" type handle;

(vi) open not less than 120 degrees from the closed position and have stops to limit the swing, prevent damage to hinges or adjacent equipment, and keep the doors open during maintenance or testing;

(vii) ensure the clearance between any edge of a hinged door, when closed, and the adjacent panel is uniform and does not exceed 5 mm;

(viii) for termination/junction boxes doors, be held down with screw lock tabs; and

(ix) be electrically bonded to the Enclosure frame.

(k) Plinths and Panel Supports: Free-standing full-height and half-height Enclosures will be provided with a plinth or mounting base, and panel support respectively. The plinth will:

(i) be a 50 mm high channel base of 3 mm thick cold-rolled sheet steel;

(ii) be designed to support the weight of the populated Enclosure and to withstand the lateral forces including seismic forces; and

(iii) have pre-drilled holes for anchor bolts.

Half-height free standing Enclosures will:

(iv) be welded or bolted to a steel support frame with drilled base plate(s) for anchoring to the floor; and

(v) have a steel support frame that is designed to support the weight of the populated Enclosure and to withstand the lateral forces including seismic forces.

Wall or surface-mounted Enclosures will be designed with four mounting tabs for bolting to steel channels anchored to the wall.

(l) Finishes: Enclosures will:

(i) have coatings on the surface of all metal parts except non-ferrous metal, galvanized steel, finished or machined surfaces;

(ii) be phosphatized and finished with a smooth semi-gloss ANSI 61 gray coating on the exterior, including the Enclosure plinth or mounting base, and glossy white powder coating in the interior and subpanel; and

(iii) use a powdered paint coating that is applied electrostatically then baked on to the metal.

(m) Size: The Enclosure will:

(i) have a 2.3 m maximum height not including the plinth or mounting base;

(ii) be sized as specified or as required by the number of internal components, wiring devices and the expected number of wires and cables to be terminated at the Enclosure by the Contractor;

(iii) include sufficient terminals to terminate wiring and cables required by the Contractor and Others (including spares); and

(iv) be designed to accommodate an additional 30% spare wire and cable terminal blocks of each size.

The Work includes the supply and installation of the spare terminal blocks in the Enclosures and the termination of spare contacts / devices to spare terminals.

(n) Dimensions and Clearances within an Enclosure for Insulated Components: Generous space and clearances will be allowed inside the Enclosure for easy and unobstructed access to the terminal blocks, devices and wiring channels. In general, there will be:

(i) at least 75 mm clearance between each individual device and termination strips; between the device and wiring channels, and on both sides of the wiring channels;

(ii) at least 75 mm clearance on both sides of the terminal strips;

(iii) at least 100 mm clearance above and/or below the terminal strips, devices, and wiring channels for routing of incoming wires;

(iv) barriers that separate circuits of different voltage ratings; and

(v) at least 50 mm clearance between the wiring devices in the Enclosure and the devices and wiring on the Enclosure door.

CT and VT Enclosures will:

(vi) be generously sized for the number and gauge of terminating wires; and

(vii) allow at least 100 mm between terminal blocks; between terminal blocks and ground bus; and between ground bus/terminal blocks and edge of boxes.

(o) Dimensions and Clearances within an Enclosure for Uninsulated Components: All uninsulated components operating at 301 V phase-to-phase or above will:

(i) maintain a minimum clearance of 100 mm from all other components operating at 301 V or above; and

(ii) maintain a minimum clearance of 190 mm from the nearest part of:

(A) the Enclosure;

(B) any door or component mounted thereon; or

(C) ground.

Equipment will be insulated in areas where this requirement is not possible.

(p) Components and Wiring: Refer to SPGT 2.17.3 and SPGT 2.17.6 for panel wiring for devices and equipment and Enclosure wiring requirements.

(q) Power Supplies to Enclosures: BC Hydro will provide:

(i) 120 Vac 60 Hz interruptible station service power to Enclosures; and

(ii) 125 Vdc uninterruptible station service power to Enclosures.

The Work includes provision of:

(iii) suitable terminal block type fusing on the load side of the 120 Vac and 125 Vdc supplies to use for power supply termination; and

(iv) an estimate of the current (A) and power (kW) input the Equipment or Enclosure requires.

(r) Lighting and Receptacles: All Enclosures larger than 500 x 500 mm and containing control, protection, or instrumentation devices will include:

(i) switched fluorescent tube or LED fixture for general illumination. The light(s) will:

(A) be suitable for operation at 120 Vac;

(B) provide adequate illumination for inspection and maintenance activities; and

(C) be operated by a switch mounted next to the door opening inside the Enclosure; and

(ii) at least one 120 Vac receptacle in each area of the Enclosure accessible by a door.

The light switch and receptacles will be industrial grade devices mounted in industrial type steel utility boxes with stainless or galvanized steel covers.

(s) Heaters: All Enclosures containing devices which are sensitive to moisture, located below elevation 413 m, or located in damp areas, or located in areas subject to flooding (such as the Penstock Coupling Chamber, Turbine Pit, or outside) will have a 120 Vac anti-condensation heater. The anti-condensation heater will:

(i) be of the self-regulating type;

(ii) be thermostatically controlled;

(iii) be of the safe-touch convection type; and

(iv) DIN rail mounted.

The power requirement for the heater will be calculated according to the location and size of the Enclosure and the expected lowest ambient temperature.

(t) Inter-Enclosure Wiring: Where an Enclosure will be shipped in split sections, terminal blocks for inter-section wires will be provided at one side of the split only. The connecting wires from one section will be sufficiently long to reach terminal blocks in the other shipping section when installed, and will be bundled, coiled and tied for shipping. After installation, the inter-section wire bundle(s) will be uncoiled, pulled through the connected shipping sections, and terminated in the designated terminal blocks.

The inter-section wires will be tagged ready for inserting into similarly tagged terminal blocks.

(u) External Grounding: Provisions for connection to an external ground to the Powerhouse station ground grid will be provided in accordance with BC Hydro ES 45-U0093 and BC Hydro ES 45-U0094.

(v) Internal Grounding System: A grounding system will be installed within the Enclosure in accordance with BC Hydro ES 45-U0093 and BC Hydro ES 45-U0094. In addition, the ground bus will be made continuous between shipping sections by connecting between the ground bus in each shipping section a length of bare stranded copper conductor having the same ampacity as the copper bus.

Subject to acceptance, small Enclosures may be provided with a ground stud in lieu of a ground bus.

2.17.3 Requirements for Electrical Components and Devices Within Enclosures

(a) General: Panel-mounted components and devices including pushbuttons, selector switches, indicating lights, HMI displays, auxiliary relays, timer relays, terminal blocks, etc., will:

(i) if mounted through the Enclosure door or side panels, be industrial type and match the NEMA enclosure type;

(ii) be rated for operation in an hazardous environment if located in a hazardous area and if they penetrate the Enclosure walls or door;

(iii) be rated for 120 Vac 60 Hz or 125 Vdc continuous operation;

(iv) have spare contacts for use with other control and protection equipment supplied by Others, and

(v) be electrically bonded to the Enclosure.

(b) Hazardous Environments: Devices that are located entirely inside an Enclosure that is rated for hazardous operation do not need to be rated for operation in a hazardous environment provided all power to the Enclosure can be disconnected. The switches used to disconnect the power will be located outside the Enclosure and in their own Enclosure that is rated for that hazardous environment, or the switches will be located outside the hazardous area.

(c) Pushbuttons: General use pushbuttons will be the flush-type with maintained or momentary type as required by the design. Emergency pushbuttons will be latching type with a mushroom head cap and pull-action reset (unlatch). Each pushbutton will:

(i) activate at least four form C output contact blocks with provision to add more blocks in the future;

(ii) be of the momentary-contact type when used with starter seal-in and control circuits;

(iii) be of the maintained- or latched-contact type as dictated by the intended control function; and

(iv) have cap colors in accordance with SPGT 2.11.7;

(d) Selector Switches: Selector switches will be rotary type with number of positions as specified in the Equipment specification or contact development diagram on the Drawings. Each switch position will activate four form C output contact blocks with provision to add more blocks in the future.

Key-lockable selector switches will not be used.

(e) Indicating Lights: Indicating lights will be 30 mm color LED type with an integrated test switch.

Light colors will be in accordance with SPGT 2.11.7;

In lieu of integrated test switch, all indication lights will be wired in a test circuit activated by a momentary test pushbutton.

(f) Auxiliary and Timer Relays: A relays will:

(i) be self-contained, plug-in (ice cube relays), electromechanical type with multi-pin base for surface mounting inside equipment Enclosures;

(ii) be secured to the base by a clip or latch;

(iii) be Releco relays with at least three form C output contacts each; and

(iv) have operating coils that are rated for 120 Vac or 125 Vdc operation as required.

Timer relays will be electronic with adjustable timing range as required.

(g) Gold Plated Edge Connectors: All printed circuit card edge connectors will have gold plating.

(h) Wiring Terminal System Devices: Wiring devices offered with the wiring termination system such as rail-mounted fuse blocks and signal conditioners may be used as required to simplify installation and wiring.

2.17.4 NERC CIP-006 Physical Security Requirements

In accordance with NERC CIP-006, access to programmable electronic devices and communication networks ("**Critical Cyber Assets**" or "**CCAs**"), including hardware, software, and data that are essential to the reliable operation of the Unit, is required to be restricted and controlled. The Work includes:

(a) lockable, six-wall Enclosures around CCAs, to prevent unauthorized access;

(b) for CCA devices (such as an HMI) that are accessible from outside an Enclosure, a lockable, hinged cover, with Lexan window and manually-operated open/close handle; and

(c) provisions to allow Others to install an access card scanner (of dimensions 85 mm x 122 mm x 28 mm), associated power and data cables, and a physical key-operated override device at each CCA access point to control and log access to CCAs.

2.17.5 Conductor Termination

(a) General: All conductors from external cables and all interconnecting wiring inside an Enclosure will terminate in terminal blocks. Except where explicitly noted otherwise, the wiring termination system including terminal blocks and related accessories will:

(i) be in accordance with BC Hydro ES 45-V0371, except that DIN 3 symmetrical (TS35) type rails will be used (instead of DIN 1 type);

(ii) have terminal blocks and terminal block accessories shown on the following BC Hydro drawings: 1006-H04-03160-001, 1006-H04-03131-001, 1006-H04-03131-002, 212 H04 01528-002, 212 H04 01528-003, and 212 H04 01528-004 which will be utilized instead of parts intended for similar application which are listed in Tables 1, 2, and 3 in BC Hydro ES 45-V0371;

(iii) include one wire label affixed to each end of each conductor at its termination point, clearly depicting the conductor's wire name as it is shown on the corresponding Electrical Wiring Diagram;

(iv) be provided in sufficient quantity for termination of the required conductors; and

(v) be located to suit the incoming cables so that neat and orderly routing and termination of wires can be made and so that all cables and wires can be adequately tagged with cable tags and wire numbers.

(b) Terminal Blocks: Terminal blocks will:

(i) be industrial type, screw clamp wire type, single-level termination;

(ii) be complete with end-plates and end-clamps;

(iii) have their terminal markers clearly labeled to match the terminal block number shown on the corresponding Electrical Wiring Diagram;

(iv) if used to terminate RTDs or 4-20 mA instrumentation inputs or outputs, be of the disconnecting type;

(v) be suitable for terminating two wires under one screw (i.e., in one hole), and sized to accept a range of wire sizes that includes the size of the wires that are to be terminated; and

(vi) use partition plates to separate power terminal blocks from other control and instrument wiring blocks in the same terminal strip.

Spring loaded case clamp-style terminal blocks will not be used.

(c) Terminal Block Arrangement: Terminal blocks in Enclosures larger than 500 x 500 mm will be arranged in vertical strips of not more than 100 terminal blocks. Terminal blocks in smaller Enclosures may be arranged in vertical and horizontal strips of not more than 100 blocks.

(d) Terminal Block Identification: Each terminal block strip will be identified by a terminal strip number (e.g., TB1, TB2, etc.) that corresponds to the terminal strip number shown on the corresponding Electrical Wiring Diagram.

(e) Other Wiring Termination System Devices: With the exception of auxiliary and timer relays, for functions other than only wire termination, use of manufacturer-supplied rail-mounted devices, such as fuse blocks, miniature circuit breakers, surge protection, PLC interfaces, industrial bus, small power supplies, and signal conditioners will be used.

(f) Test and Isolation Facilities: Test and isolation facilities will be in accordance with BC Hydro ES 45–X0010 and ES 45-X0011.

Detailed requirements for mounting location, orientation, and wiring for isolation and test facilities will be submitted prior to implementation.

(g) Grounding: Each terminal mounting DIN rail included in the Equipment will be grounded according to BC Hydro ES 45-V0371.

A minimum of 20% spare ground terminals will be provided within each Enclosure.

2.17.6 Equipment and Enclosure Wiring

(a) General: Internal Equipment and Enclosure wiring and wiring design will:

(i) be in accordance with BC Hydro DP 45-Z0019 and BC Hydro DP 45-Z0004;

(ii) utilize plastic wire channels or ducts that have a minimum size of 40 mm x 40 mm, that

(A) are sized for the expected number of wires to be routed plus 25% spare capacity; and

(B) that are located to route wires between the terminal blocks and devices;

(iii) be neatly routed and clamped to side panels or wiring channels/ducts;

(iv) exit wiring channels/ducts neatly through gaps in the channels/ducts;

(v) be tied in bundles that allow for some slack in the wiring (so as to not stress any connection), and are sized and arranged to allow manual wire tracing by a Worker during troubleshooting, and to not impede other wiring, cabling, or devices;

(vi) utilize separately routed channels/ducts for circuits that operate above 120 Vac or 125 Vdc;

(vii) where wiring passes over a hinged Enclosure door, utilize wires bundled in a U-shaped loop, as long as possible, with the bottom of the U facing down, with the bundle anchored on each side of the hinge using screws or bolts (no adhesive), and with a plastic sleeve or spiral wrap installed over the bundle between the anchor points;

(viii) not use connections made with wire nut (Marrett) or Marr-type connectors (except for lighting and receptacle circuits); and

(ix) be verified and tested by the Contractor, in accordance with section 4 of BC Hydro DP 45-Z0019 (where “Designer or BC Hydro representative” is replaced with “Contractor”).

(b) Major Equipment Wiring: Large or major pieces of Equipment with multiple separate Enclosures and components such as sub-system equipment, loose instruments, and devices will be wired as follows:

(i) loose instruments and devices that are: part of the Equipment or Enclosure, mounted on a skid, or installed in inaccessible areas of the equipment will have the wires brought out to a nearby Enclosure or a centralized marshalling panel (usually an Interface point);

(ii) all connections between components and between components and Enclosures will be made with cables in cable trays, rigid galvanized steel conduit, or flexible metallic conduit;

(iii) all wiring and conduit that connect fixed equipment components to removable components will be designed and installed to permit easy and convenient removal of the parts with minimal disassembly and re-assembly; and

(iv) the location and adequacy of Enclosures will be subject submitted for Review. Where feasible, tray systems may be substituted for conduit and will be submitted for Consent.

Wiring on Equipment that needs to be connected at Site will be pre-formed and will have tagging and wire numbers affixed prior to shipment to the Site.

(c) Current Transformer, Voltage Transformer and Test Block Identification: Current transformer (CT) and voltage transformer (VT) winding designations and test block designations will be in accordance with BC Hydro ES 45-A0065.

(d) Enclosure Wire Colour Coding: Protection, control, and instrumentation Enclosure wiring will follow the colour scheme listed in BC Hydro DP 45-Z0004.

The neutral as well as phase conductors of current transformer and voltage transformer circuits will be colour coded yellow and red respectively.

Green coloured wire will be used only for ground conductors.

All other general electrical wiring in Enclosures such as MCCs, starters, or other off-the-shelf equipment will follow the CSA electrical code colours.

(e) Wires Terminated on Studs: Where wiring is terminated on studs, a ring tongue terminal lug with insulated ferrule will be used (T&B Sta-kon – e.g., Cat. RB14 10 and 14RB 10) on each wire. All terminal studs will have contact nuts and locking nuts or lock washers. Spade type terminals will not be used.

(f) Enclosure Wire Types: Wiring used in Enclosures will be in accordance with SPGT 2.17.7.

(g) Analog Signals: Shielded cable will be used for all analogue signals. Cable specifications will be similar to that used for RTDs except that a lower insulation class is acceptable.

A grounded test terminal in accordance with BC Hydro ES 45–X0010 will be provided.

2.17.7 Cables and Wiring

(a) General: The design and rating of the cables will be in accordance with Schedule 6 [Specifications and Drawings].

Cables will incorporate low-acid gas evolution jackets where possible.

(b) Cable and Wiring Types:

(i) General: All cables and wiring used at Site and that will remain part of the permanent Work including cables and wiring used for communications, general purpose and control, panel wiring, analogue, metering, instrumentation, fibre optic, coaxial, network, etc., will be in accordance with BC Hydro DP 45-Z0004 unless explicitly stated otherwise.

(ii) Cables and Wiring with BC Hydro Part Numbers: Where BC Hydro DP 45-Z0004 specifies a BC Hydro part number instead of a manufacturer's part number, BC Hydro will provide the cable or wire specifications to the Contractor upon submitted request. BC Hydro will also consider requests to supply cables and wires with a BC Hydro part number at cost to the Contractor, provided the Contractor submits its request 180 days prior to the date the cable or wire is required at Site.

(iii) Medium Voltage Power Cables: Medium voltage power cables will be single conductor, 15 kV class or higher as required by the design, rated FT-4, incorporate XLPE 133% insulation, and rated for 90°C. The conductor will be stranded copper and shielded.

(iv) Low Voltage Power Cables: Low voltage power cables will be 600 Vac, tray type, XLPE insulation, bare copper ground conductor, individual conductor shields, and fire-retardant FT-4 rated PVC jacket. The cables will have copper conductors of size as specified or a minimum size of 12 AWG.

(c) Installation: Cable installation methodology will be as follows:

(i) cables 600 V phase-to-phase and above will occupy dedicated raceways;

(ii) cables less than 600 V phase-to-phase may occupy the same cable trays (but not conduits) as protection, control, and instrumentation cables provided that a separation barrier is installed;

(iii) all cabling will be run in cable trays, galvanized steel rigid conduit, or electrical metallic tubing except where otherwise expressly required;

(iv) cabling that is to be run via direct burial in soil or embedment in concrete will be installed in PVC conduit;

(v) cables from separate devices will be marshalled to collection Enclosures and grouped on terminal blocks for connection to outgoing multi-conductor cables to minimize the number of individual cable runs;

(vi) cables from separate devices will be marshalled into collection Enclosures as required and grouped for pulling through a single, larger conduit to facilitate neatness and to minimize the number of individual conduit runs;

(vii) wiring termination and intermediate Enclosures will be used to marshal and terminate cables as required to facilitate ease of equipment removal;

(viii) splices in cable and wiring are not permitted. Where a cable or wiring splice is required, it will be made within an Enclosure using terminal blocks;

(ix) cable runs will be kept as short as possible;

(x) devices requiring extension cables such as RTDs leads and analog devices, will be terminated in Enclosures before connecting to other cables; and

(xi) all conductors of a cable including spare conductors will be terminated on consecutive terminals.

Individual, loose, or otherwise unprotected wires will not be run in cable trays or ducts.

(d) Ground Shield: Cable ground shields will:

(i) for cables with spiral shields, be grounded in accordance with BC Hydro ES 45–U0096; or

(ii) for each cable or wire pair/triad shield conductor, be terminated on a grounded terminal block.

In all cases, terminal blocks will be provided for terminating cable shield drain wires.

(e) Cable and Conductor Colour Codes and Tagging: All cables will:

(i) be in accordance with the colour codes in BC Hydro DP 45-Z0004;

(ii) be labelled with the cable numbers as listed in the Cable Schedule; and

(iii) be tagged at each end.

2.17.8 Bolted Electrical Connections

Bolted electrical connections including bus-to-bus and bus-to-cable will:

(a) be designed to ensure that the bolted connection remains tight over the Design Life of the Equipment;

(b) have at least 85% contact between the two surfaces;

(c) utilize hardware that;

(i) is a minimum of two bolts deep per connection; and

(ii) for cable crimp lugs, are of the double-crimp type (i.e. utilizes crimp barrels that are two crimps deep);

(d) use the appropriate bolting hardware for the installation considering the bus and connector material, current carrying capacity, location, and environment;

(e) use materials that limit ferromagnetic heating of the bolting hardware to an operating temperature that is lower than adjacent bus;

(f) not use a combination of stainless bolts with stainless steel nuts;

(g) not require lubricant for bolt threads;

(h) use flat or Belleville washers on the bus and connectors between bolt-head and nut;

(i) have means for ensuring that the bolted connection hardware remains tight, such as lock washers or preferably locknuts; and

(j) be cleaned immediately prior to making the connection.

Generally, unless otherwise specified, the bolted-connection hardware will be reusable so that the hardware removed during joint disassembly can be reused for connection reassembly.

2.17.9 Raceways

(a) General: Raceway ("**Raceway**") means an open or closed channel designed to hold electrical cables and wires. Raceways include rigid and flexible metallic conduits, electrical metallic tubing, cable trays, and Polyvinyl chloride (PVC) conduits or ducts. Raceways will:

(i) be installed in a neat and tidy manner;

(ii) have smooth and even bends where bends are required;

(iii) have bends that are not greater than 90 degrees and with a radius of sufficient diameter that a Worker can easily pull cables without the use of cable lube;

(iv) be level in the horizontal direction;

(v) be plumb in the vertical direction;

(vi) for conduit and duct banks, be left with pull strings installed;

(vii) be designed and braced to withstand expected mechanical stresses that result from vibration and thermal cycling; and

(viii) where practicable, have evenly spaced supports.

Cables and wires in Raceways will be in accordance with CSA C22.1 conduit / tray fill and ampacity derating requirements.

All cable runs external of the Equipment will be made using Raceways unless otherwise indicated.

(b) Rigid Conduits: Rigid conduit will be made of heavy-duty galvanized thick-wall steel tubing and used with threaded fittings.

(c) Flexible Conduits: Flexible conduits will:

(i) be made of interlocking ribbed steel or aluminum tubing;

(ii) be used to isolate vibration from Equipment or in areas where use of rigid conduits may be impractical;

(iii) be installed for short sections of cables (e.g., between the lighting transformer and distribution panel or where cable trays cannot be used); and

(iv) have a waterproof plastic covering or jacket.

(d) Electrical Metallic Tubing: Electrical metallic tubing will:

(i) be made of thin wall steel tubing and used with clamped fittings; and

(ii) be used for lighting and telephone cable runs only and where mechanical protection is not required, e.g., surface runs on ceilings and walls. Sections of conduits below a height of 3 m will be rigid galvanized conduits.

(e) Cable Trays: Cable trays will:

(i) be galvanized steel ventilated ladder type, NEMA load class 12B;

(ii) be capable of carrying the weight of Workers as required by construction and maintenance activities; and

(iii) have provisions for appropriate fall arrest, if required.

(f) PVC Ducts: PVC ducts will:

(i) be designed for direct burial in soil or embedment in concrete;

(ii) be tagged at each end and at each intermediate junction box;

(iii) range from 50 mm to 150 mm in diameter with cable or wire percent fill in accordance with CSA C22.1; and

(iv) be installed with PVC elbows and fittings to provide bends of not greater than 90 degrees.

Stub-ups above ground will be proud of concrete floor and protected with at least a 300 mm length of rigid metallic conduit over the duct, or alternately encased in a concrete cover of at least 100 mm around the ducts and 300 mm high.

(g) Raceway Supports: Raceway supports will:

(i) be of heavy gauge rust-proof material or steel with rust-resisting finish equivalent to sherardizing or cadmium-zinc plating; and

(ii) have plastic end caps installed on the ends of all supports.

(h) Bus Ducts: Bus ducts will:

(i) have copper bus;

(ii) have means to support and secure the bus at regular intervals using insulated spacers and clamps;

(iii) be naturally cooled, non-phase segregated, metal-enclosed, high-current carrying type;

(iv) be of non-magnetic extruded aluminum construction with a rigid self-supporting enclosure assembled and installed at Site; and

(v) include all necessary supports and installation hardware.

2.17.10 Electrical Contacts

(a) General: All contacts will:

(i) be rated for, as a minimum, 120 Vac 60 Hz and 125 Vdc operations for all discrete output contacts from Equipment, devices, switches, and relays;

(ii) be heavy duty;

(iii) be corrosion resistant;

(iv) be ungrounded;

(v) be electrically isolated if required for BC Hydro's circuitry;

(vi) if the contacts have adjustable closing or opening positions, be adjustable to within ±1% of full travel unless otherwise specified herein; and

(vii) if used for annunciation and trip contacts, close to alarm except where explicitly expressed otherwise.

(b) Current Ratings: Current ratings of all contacts will be coordinated with the ratings of their respective loads and will be rated to energize, carry, and de-energize loads according to the following schedule:

(i) *Electronic relay circuit*: 120 Vac or 125 Vdc and not less than 2.0 A (resistive).

(ii) *Protective relay (tripping) circuit*: 120 Vac or 125 Vdc and not less than 1.0 A non-inductive interrupt, make and carry 10 A.

(iii) *Control (non-motor-starter), Shutdown, or Trip circuit*: 120 Vac or 125 Vdc and not less than 5 A (inductive).

(iv) *Motor starter circuit*: 120 Vac and not less than 10 A (inductive).

(v) *Annunciation, Status, Indication, or Alarm*: 125 Vdc and not less than 0.25 A (non-inductive).

(c) Type of Contacts: Contacts are defined as:

(i) form A – normally open (NO);

(ii) form B – normally closed (NC); or

(iii) form C – SPDT (1 NO and 1 NC contact with common return).

(d) Number of Contacts:

Except where explicitly noted otherwise, each electronic device and each Software-Driven Device will include a minimum of one form C contact that is configured to be operated by the device to indicate that the device is healthy (i.e., if the device self-diagnoses that it is unhealthy, or experiences a critical failure such as a power failure, the contact will reset to indicate the device's unhealthy state).

Each auxiliary relay provided will include a minimum of:

(i) two unused form C contacts; or

(ii) two unused form A contacts and two unused form B contacts.

2.17.11 Electric Motors

(a) Electric motors supplied for driven equipment will:

(i) have power and torque characteristics that are matched to the function and duty of the driven equipment;

(ii) where possible, be mounted on a common base with the driven equipment;

(iii) where possible, be direct-connected to the driven equipment;

(iv) be in accordance with EEMAC, NEMA and ANSI standards;

(v) exceed the NEMA premium motor efficiency guidelines or at a minimum, meet or exceed the Canadian Energy Efficiency Regulations for electric motors rated 1- 500 HP;

(vi) have a NEMA design B motor unless otherwise specified by the supplier of the equipment driven by the motor;

(vii) be 600 Vac, three phase, 60 Hz squirrel-cage induction-type;

(viii) be totally-enclosed and fan-cooled;

(ix) have a minimum service factor of 1.15;

(x) be designed for full-voltage across-the-line starting;

(xi) not exceed 600% of rated current for the locked rotor current at rated voltage and frequency;

(xii) have windings with moisture- and oil-resistant insulation;

(xiii) have Class F non-hygroscopic insulation;

(xiv) ensure the temperature rise does not exceed a Class B temperature rise under continuous operation at full rated load and voltage, and ambient temperature of 40°C;

(xv) for motors larger than 3 hp, have re-greasable anti-friction bearings; and

(xvi) have a closed terminal box.

Electric motors rated 1.5 kW or less for equipment such as exhaust fans, motorized louvers may be rated at 120 Vac, single-phase, 60 Hz operation. Fractional horsepower motors for motorized valves will be rated 600 Vac, three-phase, 60 Hz.

(b) Over-Frequency Rating: All electric motors and their driven devices will be capable of withstanding the stress due to an impressed terminal frequency equivalent to that experienced during a full-load rejection over-speed of the Unit together with a 10% rise in terminal voltage. The period of the frequency and voltage rise will not exceed 60 seconds.

(c) Power Terminations and Connections: The motor termination box will have a minimum 90°C temperature rise rating. All termination boxes, connectors, and fittings will be liquid-tight NEMA 4 type.

Terminal points for electric motors will, unless otherwise indicated, be as follows:

(i) 600 V, 3-phase motors – be in the motor terminal box;

(ii) 120 Vac motors – on the terminal blocks in the local control panel; and

(iii) 125 Vdc motors – on the terminal blocks in the local control panel.

(d) Drawings: The following information will be included on the Drawings for all electric motors:

starting current with load	(A)
starting time with load	(s)
locked rotor current	(A)
maximum starts per hour	
power factor	
power	(kW)
number of poles	
speed	(r/min)
running current	(A)
voltage	(V)
phase	

2.17.12 Motor Starters

(a) General: The Work includes all motor control centers (MCCs), including motor starters, contactors, local breakers, and fused disconnects, required for the Equipment. In general:

(i) motor starters will be full-voltage across-the-line starting, reversible or non-reversible type;

(ii) variable frequency drives will not be used except for HVAC and crane/hoist applications;

(iii) motor starters for small 120 V equipment such as small fans, motorized louvers, and other equipment that required manual, automated, or remote control, may be open-type motor starters installed inside the Contractor supplied Enclosures;

(iv) manual mode only on-off equipment with manual switches in suitable NEMA Enclosures are acceptable;

(v) supply, installation, and termination of cables required to connect the starters and MCCs to the Powerhouse station service will be by Others; and

(vi) branch circuit protection for the motor circuits will be supplied and installed by Others.

(b) Type 1 Starter: Type 1 motor starters will:

(i) be heavy-duty combination motor starter in an Enclosure located in the proximity of the Equipment;

(ii) be of a standard NEMA size with ratings suitable for the current and horsepower of the electric motor;

(iii) be provided with a MAN-OFF-AUTO (manual, off, automatic) three-position maintained-style selector switch;

(iv) have a mushroom-head type latching EMERGENCY STOP pushbutton;

(v) each consist of a non-automatic moulded case air circuit breaker, a reversible or non-reversing full-voltage magnetic contactor, complete with electronic overload protection in all three phases to protect against thermal overload, prevent operation upon loss of one phase, phase unbalance, and ground fault;

(vi) have contactors with heavy-duty welding and arc-erosion resistant contacts designed for repeated operations at maximum horsepower ratings at rated voltage;

(vii) be provided with a 600 V to 120 V single phase fused control transformer to supply the starter control circuit. The control circuit will include a control power supervisory relay;

(viii) have auxiliary contacts pre-wired for seal-in circuits, starter status indicating lights, and reversible contactor interlocks;

(ix) have six additional auxiliary form C contacts and two form C control power supervisory contacts for external interlocking and/or annunciation circuits;

(x) have a disconnecting means to isolate the starter from its power source. It will be possible for a Worker to:

(A) visually verify the starter has been isolated from its power source (i.e., a Worker can see a physical break); and

(B) lockout the starter in the isolated state;

(xi) have all components sized for a maximum rms symmetrical fault current of 10,000 A on the 120/208 V three phase system; and

(xii) have all components sized for a maximum rms symmetrical fault current of 65,000 A on the 600 V three-phase system.

For Equipment with 120 V motors, open-type motor starters may be mounted inside local control panels.

(c) Type 2 Starter: Type 2 motor starters will:

(i) meet all of the Type 1 motor starter requirements;

(ii) be provided with mechanically-interlocked, latching START and STOP pushbuttons, enabled only when the MAN-OFF-AUTO selector switch is in MAN, mounted on the front door of the starter panel door, and individually identified with nameplates;

(iii) may include the following as required for the control of the Equipment:

(A) momentary type pushbutton for jogging and other functions enabled only when button is pushed; and

(B) a non-resettable elapsed time meter for measuring motor running time.

(d) Drawings: The following information will be included on the Drawings for all motor starters:

NEMA size	
control transformer	(VA)
peak contactor coil current	(A)
nominal contactor coil current	(A)

2.17.13 Dry-Type Transformers

Dry-type transformers including power and control transformers will:

(a) have a design in accordance with CSA C9-02;

(b) be high-efficiency;

(c) be air-cooled;

(d) have copper windings and coils that are cast or resin encapsulated coils;

(e) have cores that are constructed using electrical-grade steel laminations;

(f) have Class 220°C insulation; and

(g) have a maximum temperature rise of 115°C given an ambient temperature of 40°C.

With the exception of the Exciter transformer, transformers with capacities greater than 15 kVA will come with 2 x ± 2.5% taps on the primary side.

2.17.14 Electrostatic Control

(a) General: All electronic components and printed circuit boards will be handled using adequate methods for the control of static electricity. As a minimum, the following static control procedures will be used:

(i) any finished printed circuit boards and subassemblies that are loose shipped (i.e., not mounted in their final equipment locations) will be contained and sealed in antistatic shielding bags (3M 2100);

(ii) all electronic components will be stored in antistatic containers during the preassembly stage; and

(iii) all test and assembly staff will use securely grounded antistatic wrist straps, table mats and floor mats at all times when handling electronic components and printed circuit boards.

(b) Requirements: A detailed description of electrostatic control Procedures for the assembly, testing and general handling of both the in house and outside manufactured printed circuit boards and subassemblies will be provided with the Equipment.

2.17.15 Surge Protection

The Work includes all devices necessary to protect electronic equipment that it supplies against high-voltage “spikes” or “noise” which may occur in the external operating power supplies.

All inductive devices, such as relays and solenoids, which are energized by a DC source will be provided with free-wheeling diodes rated at 5000V PIV. The rated continuous current of the free-wheeling diode will be equal to, or greater than, that of the inductive device to which it is connected. The energy rating of the free-wheeling diodes will be at least four times the discharge energy of the coil. The method of surge suppression across relays will vary depending on the application according to BC Hydro DP 45-Z0006:

(a) non-time critical DC relay application will use diodes;

(b) time critical DC relay applications will use metal oxide varistors; and

(c) AC relay applications will use metal oxide varistors.

2.17.16 Transient Immunity

(a) External to the Equipment: The Equipment control, protection, and instrumentation systems will be free from false operation or failure for all magnitudes of transients that can occur in the control circuitry and power supplies external to these systems. To reduce the transients, cables with shielding by spiralled 5 mil copper bands grounded at both ends and surge suppressers on inductive devices (relays, etc.) will be supplied by Others. The Contractor will assume however that high voltage transients will persist in the control circuitry and power supplies external to the Equipment.

(b) Internal to the Equipment: To limit transients that may be generated by switching off inductive devices within the Equipment control, protection, and instrumentation systems, surge protection for all inductive devices such as relays and solenoids will be provided in accordance with SPGT 2.17.15. Care will be taken in the location of the devices to assure failure of the surge devices does not create a hazard.

2.18 Grounding

2.18.1 General

All Equipment provided as part of the Work including Turbine embedded components, Turbine components, Generator embedded components, Generator components, the Excitation System, the Governor System, and exposed non-current carrying conductive materials capable of becoming energized due to either insulation failure or building up of a static or induced potential, will be grounded to an equipment ground bus for connection to the Powerhouse ground grid in accordance with BC Hydro ES 44–Z1010.

The following references to BC Hydro ES 44–Z1010 will also be considered:

(a) BC Hydro 01.20.MTCE.03;

(b) BC Hydro OSH 206;

(c) BC Hydro ES 44–G0020;

(d) BC Hydro ES 44–Z0320;

(e) BC Hydro ES 44–G0310-01; and

(f) CSA 22.1.

The Work includes identification of the locations for all Ground pads that need to be embedded in concrete walls for the convenient connection of equipment, test apparatus, and safety grounding.

2.18.2 Maintenance Ground Studs

All metal clad switchgear rated 600 V and above and all medium-voltage and high-voltage equipment will be lockable in the isolated position and all exposed live parts will be provided with ground ball studs accessible for worker protection grounds. Sufficient number of ground ball studs will be provided on all normally live components requiring grounding, such that a minimum of two ground ball stud sets are available during maintenance. One “set” consists of three ball studs, one for each phase for a 3-phase device. One set will be installed on each of the source and load sides of the equipment.

The grounding studs will be ball type (Maclean Power Systems type HC-30029-1.5) and will be permanently installed at locations and at angles convenient for clamping by a person standing at the floor level, using a socket type grounding clamp.

The studs will withstand the rated dynamic forces and short-time current for a minimum of three seconds following a ground fault.

If required, the insulating boots of the grounding studs will be designed for easy removal and reattachment. They will have durability proven in service and will require no special operating tools.

2.19 Equipment Identification

2.19.1 General

All Equipment and Equipment components, including valves, piping, electronic equipment, motors, contactors, protection and control devices, switches, relays, terminal boxes, instrumentation, Raceways, cables, wires, Enclosures, MCCs, control panels, fire protection equipment, mechanical equipment, gauges, floor control stations, equipment shown on piping and instrumentation diagrams, major Equipment components, Lifting Devices, Lifting Points, etc., will:

(a) be identified with nameplates, tagging and/or colour codes;

(b) for electrical equipment, use identification that complies with BC Hydro labelling and colour codes as provided in BC Hydro ES 44-P0010-01, BC Hydro ES 44-P0012-01, BC Hydro ES 44-P0013-01, and BC Hydro ES 44-P0061-01;

(c) have a nameplate provided for each phase of a multiphase, standalone piece of equipment;

(d) have one unique identifier nameplate for each equipment component. This identifier will:

  (i) be same as the component identifier used in all Drawings, Manuals, Procedures, and in any documentation involving the component;

  (ii) include unique identification as to which system it is associated with, e.g., Unit 01, Unit 02, Station Service, etc.; and

  (iii) clearly identify its association with equipment systems such as Units; and

(e) in the absence of BC Hydro standards, have nameplates attached to electrical equipment in accordance with CSA C22.1, Rule 2-100.

Enclosures will be provided with identification nameplates showing equipment numbers and a short description of the equipment/Enclosure.

Blocks of unique identification numbers will be assigned by Hydro's Representative for the Contractor's use.

Equipment identification will be submitted for Consent.

Unless otherwise noted, Equipment identification requirements apply to all electrical and mechanical equipment, including instrumentation and control systems, supplied as part of the Work.

2.19.2 Design Principles

The purpose of using nameplates, tagging, and/or colour codes is to uniquely identify the Equipment and its components to facilitate the operation, inspection and maintenance of each item and to provide a means of clearly identifying isolation points that will be used for the purpose of worker protection, in full compliance with BC Hydro's SPR and OSH standards. The design principle that will be achieved is means used for Equipment identification are to be consistent with BC Hydro adopted standards and to facilitate:

(a) consistency across BC Hydro owned and operated facilities;

(b) compliance with BC Hydro's SPR and WPP rules;

(c) tracking and managing maintenance records;

(d) standardization of nameplate information; and

(e) uniform identification methodology.

2.19.3 Abbreviations

Except as otherwise specified in this Schedule 6 [Specifications and Drawings], abbreviations, designations and letter symbols for units and decimal prefixes will be in accordance with BC Hydro ES 45-A0082.

2.19.4 High-Voltage Equipment

(a) General: Identification of high-voltage station equipment including station buses for all AC voltage classes will be as described in BC Hydro ES 44-A0158.

(b) Phase Designations: Aluminum plate and decal details for phase designations will be in accordance with BC Hydro ES 44-P0012 and BC Hydro ES 44-P0013.

2.19.5 Enclosures and Electrical Equipment,

Nameplates for Enclosures and Electrical Equipment will be:

(a) in accordance with BC Hydro ES 45-U0541;

(b) affixed on every door or access panel;

(c) black lamacoid with engraved white letters; and

(d) secured to the Equipment or Enclosure with metal screws.

2.19.6 Devices On or Within Enclosures

All devices and components mounted on or within Enclosures and all Enclosure wiring devices will:

(a) each be suitably identified by lamacoid or anodized aluminum nameplates in accordance with BC Hydro ES 45-U0541; and

(b) show, as a minimum, the device identification number.

Nameplates will:

(c) be located 10 mm under the device or component if located within the Enclosure;

(d) be located on both the outside and inside of the Enclosure wall, cover or door if the device or component protrudes through the Enclosure; and

(e) be secured to the panel with metal screws. No adhesives will be used to secure the nameplates.

2.19.7 Electrical / Protection and Control Equipment

IEEE C37.2 device function numbers in accordance with BC Hydro ES 45-A0084 will be used for electrical / protection and control equipment identification. Device identification will be placed on or adjacent to each device, on both front and back of the panel where the equipment is installed.

2.19.8 Powerhouse Instrumentation

Instrumentation tagging will be in accordance with BC Hydro DP 45-Z0035.

2.19.9 Raceways

Nameplates for Raceways will:

(a) each be suitably identified by lamacoid or anodized aluminum nameplates in accordance with BC Hydro ES 45-U0541;

(b) show, as a minimum, the device identification number;

(c) be secured with metal screws. No adhesives will be used to secure the nameplates; and

(d) be oriented outwards and towards the point of view.

2.19.10 Valves

The Valve identification convention will be submitted to the Contractor by Hydro's Representative.

Tags for valves will be:

(a) black lamacoid with engraved white letters in accordance with Section 4(a) of BC Hydro ES 31 Q0020 Piping Systems – Valve Tag Numbering; and

(b) secured to the Equipment with industrial gauge ball chain (minimum of gauge #13 (6.3 mm)).

Where remote controls for valve actuators are wall mounted, these tags will be secured to the walls with screws.

Where valve body markings (valve type, pressure-temperature class rating) aren't clearly and readily visible, these particulars will be included on an independent tag, exactly as they appear on the valve itself. This independent tag will be identical in nature to the valve identification tag, and secured immediately adjacent to it.

2.19.11 Mechanical Equipment

The convention for Mechanical equipment identification will be submitted to the Contractor by Hydro's Representative.

Tags for mechanical equipment will be:

(a) black lamacoid with engraved white letters per Section 4(a) of BC Hydro ES 31-Q0020 Piping Systems – Valve Tag Numbering;

(b) secured to the Equipment with screws; and

(c) secured to the Equipment with industrial gauge ball chain (minimum of gauge #13 (6.3 mm), where (b) isn't practical.

2.19.12 Piping

On drawings and other design documentation, the convention for identification of piping will be submitted to the Contractor by Hydro's Representative.

Installed piping systems will be physically identified in accordance with the requirements of BC Hydro ES 31-Q0021 Piping Systems – Piping Identification. For this purpose, piping will be defined as pipes, valves, gauges, pressure vessels, tanks, receivers, pipe supports, etc.

2.19.13 Cranes and Hoists

All cranes and hoists will:

(a) be permanently identified by the legible display of the manufacturer's name, model and serial number on the structure;

(b) have their rated capacity permanently indicated on the superstructure, hoist, and load block of the crane or hoist;

(c) have each major interchangeable structural component of a crane or hoist uniquely identified and legibly marked to enable confirmation that the component is compatible with the crane or hoist;

(d) be provided with a securely fastened corrosion resistant nameplate showing the:

  (i) manufacturer's name;

  (ii) model and serial number;

  (iii) year of manufacture; and

  (iv) main characteristic data of the respective equipment as specified in the applicable standards or necessary for the proper identification of the equipment involved;

(e) have the limits of travel clearly marked on the crane structure or building;

(f) have markings on the crane structure or building, visible to the Worker, clearly indicating the direction of hook, bridge and trolley motions compatible with those marked on the controls for cranes or hoists operated by a pendant or remote control; and

(g) have the rated capacity of a monorail crane permanently marked on the hoist and at intervals not exceeding 10 m on the monorail beam.

2.19.14 Cranes and Hoist Load Chart

A load chart must be permanently posted on each crane or hoist, or must be issued to the crane or hoist operator who must keep it available at all times when operating the crane or hoist if the rated capacity of a crane or hoist is affected by either of the following:

(a) the position of a load supporting trolley; or

(b) the use or position of outriggers to increase the stability of the structure.

The load chart must indicate the rated capacity for the crane or hoist for the working positions and configurations in use and must be in a legible condition.

2.19.15 Identification of Rigging, Lifting Devices, and Lifting Points

All rigging, Lifting Devices, and Lifting Points, will be clearly marked in a permanent, fade resistant and waterproof fashion such as with punched lettering or a permanent etched nameplate, with the following information:

(a) name;

(b) purpose and short description (e.g., used for fall protection or equipment, equipment it can be used on, configuration, restrictions, etc.);

(c) rated load; and

(d) reference Procedure, Manual and/or Drawing number(s).

2.19.16 Hatches and Removable Platforms

Equipment and access hatches and removable platforms will be marked with:

(a) the weight of the hatch or platform (or platform components); and

(b) the static load bearing capacity of the hatch or platform.

The marking(s) will be:

(c) permanently affixed;

(d) durable, fade resistant, and waterproof; and

(e) visible by a Worker without the need to remove the hatch or platform.

2.19.17 Direction Markers

The Turbine Pit, Generator Pit and Generator Enclosure walls will be clearly marked with highly visible, permanent, durable, fade resistant, and waterproof directional signage as follows:

(a) “U/S” for upstream;

(b) “D/S” for downstream;

(c) “L” for left; and

(d) “R” for right.

Upstream and downstream are defined by the direction the water flows through the Powerhouse. The left and right sides of the Powerhouse is as viewed when looking downstream.

2.19.18 Nameplate Placards for Major Equipment Components

The Turbine, Governor, Generator, and Exciter will each be provided with a nameplate placard that will be a minimum of 430 mm high and 610 mm wide. The nameplate placard will have raised nickel plated lettering and border, and a depressed background painted with black enamel. The lettering will be round Gothic. The nameplate placard will be not less than 3 mm thick including the thickness of the raised lettering. A photo-etched nameplate placard is acceptable.

2.20 Tooling, Lifting Devices, and Lifting Points

2.20.1 Tooling

(a) General: In addition to the tooling specified elsewhere, the Work includes a complete set of high-quality tools, and all speciality or custom tools and equipment, which are necessary or convenient for the installation, maintenance and testing of the Equipment, including:

 (i) one set of standard tools and accessories including socket wrenches and accessories, standard and oversize wrenches, torque wrenches (click type), torque multipliers, general hand tools, lubricating devices, etc.;

 (ii) three complete sets of specialty tools including jigs, adapters, fasteners, custom measuring tools, custom wrenches, gauges, hydraulic wrenches and associated sockets/adapters, hydraulic jacks, etc.;

 (iii) two sets of hydraulic hand pumps and hydraulic power units for use with the tools above;

 (iv) two sets of standard rigging such as slings, shackles, turnbuckles, and any other standard lifting accessories;

 (v) two sets of tools and devices used to install and remove any rack-in/rack-out type Equipment; and

 (vi) minimum of two sets, or sufficient quantities for multiple uses, of all parts or consumable items used with/for the tooling such as fasteners, seals/packings, adapters, jigs, lubricates, hydraulic oil, repair kits, etc.

All Equipment tooling will be delivered to the Site a minimum of 30 days prior to completion of the Work on the first Unit.

(b) Storage: All tooling will be supplied with the appropriate heavy-duty wheeled storage boxes, cabinets, toolboxes and/or mounting panels. Tooling required for major assembly and disassembly will be protected for long-term storage.

(c) Labelling: All tooling will be labelled. The label will:

(i) include a description including its intended purpose, equipment it will be used on, etc.;

(ii) include the manufacturer’s Drawing and part number;

(iii) include, for storage boxes, cabinets, toolboxes, and/or mounting panels, a photo of the contents;

(iv) be permanently affixed to the storage container for the tooling; and

(v) be durable, fade resistant, and waterproof.

(d) Use: The Contractor will not use any of the tooling for assembly of the Equipment without the written permission of Hydro’s Representative. If used, the tooling will be returned to BC Hydro upon completion of the work in an as-new condition. If the tooling returned to BC Hydro is not in as-new condition, BC Hydro may direct the Contractor to repair or replace the tooling.

(e) Special Carts: The Work includes three, special wheeled carts (each, a “**Special Cart**”) suitable to be used by Workers to transport Turbine Pit Maintainable Components or Generator Pit Maintainable Components.

(f) Hydraulic Tensioning System: If Superbolts® are not used in all of the locations listed below, the Work includes a hydraulic tensioning system for the installation and removal of the:

(i) Generator rotor to Generator thrust block coupling;

(ii) Generator thrust block to Turbine shaft coupling;

(iii) Turbine shaft to Turbine runner coupling; and

(iv) Turbine headcover to stay ring.

The tensioning system will include:

(v) three sets of high-pressure hoses, hydraulic tensioners, pressure gauges, manifolds, sockets, wrenches, etc.; and

(vi) two sets of hydraulic power units.

(g) Shaft Pull Up System: If a hydraulic tensioning system is not provided or cannot be used to raise and lower the Turbine runner and shaft assembly to couple to the Generator, then the Work includes a separate hydraulic shaft pull up system that can be used for this purpose. This system will include:

(i) one complete set of high-pressure hoses, hydraulic jacks, pressure gauges, manifolds, any required tensioning components such as specialty components such as fasteners, threaded rods, etc.;

(ii) one hydraulic power unit necessary to perform the coupling operation; and

(iii) one extra of each individual component.

(h) Moveable Work Platforms: If moveable work platforms are provided as part of the permanent Work they will:

(i) be designed in accordance with Part 13 of the WorkSafeBC OSH Regulations;

(ii) have a minimum lift capacity of 225 kg (two Workers plus equipment);

(iii) be moveable while the platform is elevated using controls in the work platform; and

(iv) be electric.

2.20.2 Lifting Devices

(a) General: A lifting device ("**Lifting Device**") is any device connected between a hoist hook and an Equipment component that must be custom fabricated or cannot be readily purchased at an industrial supply store in British Columbia. Lifting Devices will:

(i) be provided for all Equipment components requiring a Lifting Device for assembly, inspection, maintenance, overhaul, or replacement;

(ii) be turned over to Hydro's Representative upon completion of the Work; and

(iii) be in an "as new" condition when turned over to Hydro's Representative.

(b) Design, Fabrication and Testing: Lifting Devices will:

(i) be designed and load tested to a minimum of 125% of rated capacity except as otherwise noted;

(ii) be designed to not introduce a hazard to Workers and/or be designed to be easily removable or stowed when not in use;

(iii) be certified and marked in accordance with WorkSafeBC Regulations for under-hook lifting devices;

(iv) meet the requirements of ASME B30.20 – Below-the-Hook Lifting Devices;

(v) be designed to enable Workers to perform the lift without the need for Workers to stand on or under the load while the lift is in progress;

(vi) include on the Drawings the load capacity, test load, and all information and instructions for use;

(vii) have a lifting Procedure; and

(viii) have a lifting diagram.

The Work includes the weights and equipment required to complete the load tests.

For Lifting Devices with a capacity in excess of 50 tonnes, and where the Contractor does not consider load testing the Lifting Device to be practical, the Contractor will submit for Consent a proposed alternative certification process. This certification process will also include all design and manufacturing documentation for the Lifting Device and any associated equipment and justification why load testing the Lifting Device is not practical. If the proposed alternative certification process is accepted, then at first use, the Contractor will be required to lift the heaviest component that the Lifting Device is designed for, unload the Lifting Device, and perform a thorough inspection of the Lifting Device prior to using the Lifting Device for installing the component. Implementation of this alternative certification process is at the Contractor's sole risk and discretion.

BC Hydro reserves the right to request the Contractor to re-certify any Lifting Devices in questionable condition.

(c) Quantity of Lifting Devices: If the quantity of a Lifting Device has not been specified elsewhere the Work includes:

(i) three complete sets of all Lifting Devices that have capacities equal to or less than 50 tonnes; and

(ii) one complete set of all Lifting Devices that have capacities in excess of 50 tonnes.

(d) Sling Materials: Wherever practicable slings will be composed of synthetic materials and not wire rope. For maintenance applications where the slings would be exposed to more frequent use, such as for generator top covers and rotor poles, or where there is the possibility of abrasive damage, wire rope slings may be used.

2.20.3 Lifting Points

Lifting points (a "**Lifting Point**") are all points on the Equipment, or on the Powerhouse structure, that a Lifting Device, hoist hook, shackle, or sling is connected to enable lifting the Equipment. All Equipment lifting points installed for use during assembly, inspection, maintenance, or overhaul will:

(a) be designed in accordance with all applicable standards; and

(b) have the lifting point locations and their load capacity on the Equipment Drawings.

The Lifting Points will take into account the type of hoist – such as the Powerhouse bridge crane, Turbine Pit Hoist, etc. – that will be used to lift the Equipment component and the need for clearance between the Lifting Point used and other Equipment components not included in the lift.

The Contractor will re-certify any Lifting Points Hydro's Representative considers to be in questionable condition.

2.21 Cranes and Hoists

2.21.1 General

(a) The Work includes the design, fabrication, supply, installation, assembly, delivery, testing and commissioning of any hoisting equipment provided as part of the Work.

(b) Hoisting equipment will meet the applicable referenced standards.

(c) As a minimum each hoist will have a rated lift capacity equal to 110% of the heaviest Maintainable Component for which the hoist is designated to lift, including allowance for any Lifting Devices.

(d) Each hoist will have sufficient vertical lift, and travel (where applicable) to hoist each Maintainable Component and place them at an acceptable location.

(e) To the maximum extent possible hoisting equipment will be designed to move components in a single lift and to minimize re-rigging or transferring of the load.

(f) For cranes and hoists that have one or more electric motors have a single pendant that allows a Worker to operate all motors.

(g) Hoists will be installed at a height above the adjacent floor to provide a safe clearance such that a Worker will not bump into any component of the hoist.

(h) The hoist will be located such that any trolley or bridge travel does not interfere with other equipment, ladders or lighting.

(i) Where a bridge is provided, the end trucks will be rigidly connected to the bridge and aligned such that the bridge travels freely with no binding.

(j) Where the trolley or bridge track is curved there will be some positive means of preventing the components from coming off the track.

(k) Three complete sets of any special tooling required to maintain the hoisting equipment will be provided.

(l) Three of each type of portable hoist will be provided.

(m) All crane and hoist functions will be capable of being operated by One Worker.

(n) Means of securing and storing all chains will be provided.

(o) Rail restraints for top running bridge and trolley equipment will be provided, and will be designed to prevent bridge and trolley equipment from coming off its associated rails during a seismic event.

2.21.2 Hoists

For hoists 1 tonne or less, the hoist will be electric or be manual chain operated. If the capacity of the hoist exceeds 1 tonne, the hoist will be powered electrically.

Where an electric hoist is required it will meet the following requirements unless specifically stated elsewhere in the Specifications:

(a) be designed to use a 600 V or 120 V power supply;

(b) if power is provided by a power cord then suitable receptacles will be provided located adjacent to the work area and provision provided for storing of the power cord;

(c) have a hoist motor capable of 3 m per minute for the raising and lowering of the load. If the capacity of the hoist exceeds 1 tonne the hoist motor will have variable speed;

(d) have a hoist motor with overload protection to prevent the operator from picking up a load that exceeds the crane's capacity; and

(e) have a hoist with an upper non-rotary limit switch, and lower lift limit switch, that automatically stops the hoist.

2.21.3 Trolleys

Where a trolley is required it will have the following requirements:

(a) if the capacity of the hoist is 500 kg to 1 tonne, the trolley will be electric or manual chain operated;

(b) if the capacity of the hoist exceeds 1 tonne, the trolley will be powered electrically; and

(c) where electrically powered, the trolley will have a:

  (i) travel speed such that it would take no more than 2 minutes to travel the full distance, but with a speed no less than 3 m per minute and no more than 9 m per minute; and

  (ii) festoon system to power all motors at all points along the travel.

2.21.4 Bridge Girders

Where a bridge girder is required it will have the following requirements:

(a) if the capacity of the hoist is less than 1 tonne the bridge girder will be electric or manual chain operated;

(b) be powered electrically if the capacity of the hoist is 1 tonne or greater; and

(c) if electrically powered incorporate drive motors at both ends of the bridge girder capable of driving the bridge at 9 m per minute.

2.21.5 Portable Hoists

Where portable hoists are proposed they will be submitted for Review.

Portable hoists will:

(a) only be used where it is impractical to install a permanent hoist;

(b) only be used where they have a rating of 1 tonne or less;

(c) require no more than two Workers to install;

(d) be operable by one Worker; and

(e) if the hoist is required to be mounted, then the location that the hoist is to be used requires permanent mounting points. This may be in the form of concrete anchors, embedded or attached sockets, pre-threaded holes, etc. Mounting points are to be protected when not in use.

2.21.6 Shop Work

As a minimum, the shop work will consist of the following:

(a) all electrical and control panels will be shop assembled and tested;

(b) hoist and trolley, and where practical bridge, components fully assembled and fully functionally tested; and

(c) load tested where practical.

2.21.7 Site Testing

All site testing will be performed after final assembly of all components. The Work includes any special tools, test weights, or other equipment required to perform the site testing.

Regardless what testing has been performed in the shop, as a minimum, the following site tests will be carried out:

(a) testing the hoist at 100% and 125% of its rated capacity over the entire travel ranges of the hoist, trolley, and bridge;

(b) checking power draw during any load tests and during simultaneous operations;

(c) testing/calibrating of any overload devices or limit switches;

(d) ensuring hoist, trolley, and bridge travels are smooth and free from any binding when loaded or unloaded; and

(e) checking the effort required operate any manual hoisting or travel devices.

2.22 Spare Parts and Interchangeability

2.22.1 Spare Parts

(a) General: The Work includes spare parts for the Equipment. All spare parts for the Equipment will be:

- (i) complete;
- (ii) identical to the corresponding part for the Equipment;
- (iii) interchangeable with the corresponding parts on the Equipment;
- (iv) of the same materials and workmanship as the corresponding parts of the Equipment;
- (v) machined to their final dimensions unless otherwise specified;
- (vi) dimensionally identical whenever possible;
- (vii) delivered to Site a minimum of 30 days prior to completion of the Work on the first Unit;
- (viii) adequately protected in leak-proof plastic for indefinite storage in an unheated storage space;
- (ix) packaged individually such that a spare part can be used without damaging the protection on other spare parts (exception – stator winding components which can be packaged in bundles); and
- (x) stowed on shelves in an unheated storage space to be provided by Others.

(b) Labelling: Labels will be provided on all spare part packages. The labels will:

- (i) include a description;

(ii) state the shelf-life and expiry date (if applicable);

(iii) include the manufacturer's drawing and part number;

(iv) include a photo of the contents;

(v) be permanently affixed to the packaging for the spare part; and

(vi) be fade resistant and waterproof.

(c) Documentation: The Work includes complete documentation for the spare parts that contains, as a minimum:

(i) Manuals and Drawings for the spare parts;

(ii) a complete description of the part;

(iii) a photo of the part;

(iv) part numbers;

(v) the name of original manufacturer of part;

(vi) storage instructions;

(vii) the shelf-life and expiry date (if applicable) of the part;

(viii) the cost for each part, by order of magnitude ($0.10, $1.00, $100, $1,000, etc.);

(ix) complete information for ordering all devices and replacement parts; and

(x) parts bulletins and brochures.

(d) BC Hydro's Spare Part List: The Work includes filling in the data fields in BC Hydro's Spare Parts List template for all spare parts provided for the Equipment. BC Hydro's Spare Parts List template can be found in the electronic data site described in Section 6.35 of Schedule 2 [Design and Construction Protocols]. The final spare Parts List will be submitted not later than 60 days before commencement of commissioning of the Equipment.

(e) Recommended Spare Parts: The Work includes providing a list of recommended spare parts. The recommendations will take into consideration:

(i) what spare parts will be required for normal operation of the Equipment over the Design Life of the Equipment;

(ii) what spare parts may have a reasonable likelihood of failing over the Design Life of the Equipment;

(iii) the difficulty of finding a spare part in North America on short notice (e.g., long lead time parts, custom made parts, or parts that are only available from one source);

(iv) the likelihood a spare part will be easily available at the time it may be required (e.g., will the spare part be considered obsolete or have been discontinued with no equivalent replacement); and

(v) the results of the failure mode and effects analysis conducted for each Equipment component in accordance with Appendix 6-1 [General Specifications (SPGS)].

The recommended spare parts, and corresponding prices, will be entered into Table Appendix 11-7 A through Table Appendix 11-7 E of Appendix 11-7 [Equipment Spare Parts Lists].

2.22.2 Interchangeability

All Equipment components in a Unit will be interchangeable with the components in the other Units.

Similar components within a Unit will be interchangeable, one with the other, so as to enable substitution or replacement from spare parts to be made easily and quickly.

2.23 Embedded Parts

(a) General

All embedded parts will be clean and free of oil, grease, loose rust, and scale when installed and ready for concreting.

Any temporary supports, to be permanently embedded in concrete, for embedded parts that contain large internal cavities (e.g., hollow structural section, pipes, etc.) to be permanently embedded in concrete, will have provisions for filling with grout. As a minimum, one grout inlet hole and one air release hole will be provided as close as practical to the top of each temporary support. Grouting will be carried out by Others prior to concreting.

The Contractor is responsible for cross-checking the installation work performed by Others by survey both before and after the concrete placement.

(b) Embedded Parts in First Stage Concrete

The Work includes the supply of all anchors, foundation bolts, piping, and any other parts to be embedded in first stage concrete.

An additional 10% length of tie-down material to permit placing of the first stage anchors and foundation bolts will be provided.

(c) Embedded Parts in Second Stage Concrete

The Work includes the supply and installation of all anchors, foundation bolts, piping and conduit, and any other parts to be embedded in second stage concrete, except for the installation of the: stator sole plate anchors, upper bracket sole plate anchors, lower bracket sole plate anchors and anchors for embedded supports for the top covers, which will be installed by Others.

SPGT3 STANDARDS, MATERIALS, STANDARD ITEMS, AND WORKMANSHIP

3.1 Design Standards

All Equipment and Equipment components will be designed:

(a) to comply with all applicable Laws;

(b) to meet all requirements and standards specifically set out in Schedule 6 [Specifications and Drawings], including in SPGT 3.2;

(c) in accordance with Good Industry Practice;

(d) to comply with codes and standards that are not specifically referred to in Schedule 6 [Specifications and Drawings] if required to meet Good Industry Practice or other specified codes and standards;

(e) to meet the more stringent of the requirements in the industry codes and standards or BC Hydro's codes and standards; and

(f) to comply with the latest editions or revisions thereof of the standards and codes listed in SPGT 3.2, including any amendments or supplements in effect as at the Effective Date, except as expressly set out otherwise in the Contract Documents.

If one or more of the above standards is applicable, then the most stringent of such standards will apply.

3.2 Codes and Standards

Table 3.2A – Codes and Standards

Standard	Description
ANSI/FCI 70-2	Control Valve Seat Leakage
ANSI S1.4	Specification for Sound Level Meters
ANSI/UL 467	UL Standard for Safety Grounding and Bonding Equipment
API 598	Valve Inspection and Testing
API 670	Machinery Protection Systems
ASME B1.1	Unified Screw Threads
ASME B1.13M	Metric Screw Threads: M Profile
ASME B1.20.1	Pipe Threads, General Purpose (Inch)
ASME B16.1	Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.10	Face-to-Face and End-to-End Dimensions of Valves
ASME B16.11	Forged Fittings, Socket-Welding and Threaded
ASME B16.21	Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.22	Wrought Copper and Copper Alloy Soldier Joint Pressure Fittings
ASME B16.24	Cast Copper Alloy Pipe Flanges and Flanged Fittings Class 150, 300, 600, 900, 1500, and 2500
ASME B16.34	Valves—Flanged, Threaded, and Welding End
ASME B16.5	Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	Factory-Made Wrought Buttwelding Fittings
ASME B18.2.1	Square, Hex, Heavy Hex, and Askew Head Bolts and Hex, Heavy Hex, Hex Flange, Lobed Head, and Lag Screws (Inch Series)
ASME B18.2.3 series	Metric Screws and Bolts
ASME B18.2.6M	Metric Fasteners for Use in Structural Applications
ASME B30.11	Monorails and Underhung Cranes
ASME B30.16	Crane and Hoist Standards

Standard	Description
ASME B30.17	Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)
ASME B30.20	Below-the-Hook Lifting Devices
ASME B31.1	Power Piping Code
ASME B31.3	Process Piping
ASME B31E	Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems
ASME B36.10	Welded and Seamless Wrought Steel Pipe
ASME B36.19	Stainless Steel Pipe
ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Div. 1 and Div. 2.	Rules for Construction of Pressure Vessels
ASME HST-1	Performance Standard for Electric Chain Hoists
ASME HST-2	Performance Standard for Hand Chain Manually Operated Chain Hoists
ASME HST-4	Performance Standard for Overhead Electric Wire Rope Hoists
ASME PCC-1	Guidelines For Pressure Boundary Bolted Flange Joint Assembly
ASME PTC 29	Speed Governing Systems for Hydraulic Turbine Generator Units
ASTM A27	Steel Castings, Carbon, for General Application
ASTM A105	Carbon Steel Forgings for Piping Applications
ASTM A106	Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A108	Steel Bar, Carbon and Alloy, Cold-Finished
ASTM A123	Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153	Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A176	Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip
ASTM A181	Carbon Steel Forgings, for General Purpose Piping
ASTM A182	Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A193	Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
ASTM A194	Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
ASTM A213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
ASTM A234	Piping Fitting of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A240	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A27	Steel Castings, Carbon, for General Applications
ASTM A276	Stainless Steel Bars and Shapes
ASTM A285	Pressure Vessel Plates, Carbon Steel, Low-and Intermediate-Tensile Strength
ASTM A307	Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

Standard	Description
ASTM A312	Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A325	Structural Bolts, Steel, Heat-Treated, 120/105 ksi Minimum Tensile Strength
ASTM A343	Standard Test Method for Alternating Current Magnetic Properties of Materials at Power Frequencies using Wattmeter - Ammeter - Voltmeter Method and 25-CM Epstein Test Frame
ASTM A36	Carbon Structural Steel
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A380	Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
ASTM A388	Standard Practice for Ultrasonic Examination of Steel Forgings
ASTM A490	Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
ASTM A403	Wrought Austenitic Stainless Steel Piping Fittings
ASTM A48	Gray Iron Castings
ASTM A488	Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
ASTM A516	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM A53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A609	Standard Practice for Castings, Carbon Low-alloy, and Martensitic Stainless Steel, Ultrasonic Examination thereof
ASTM A641M	Zinc-Coated (Galvanized) Carbon Steel Wire
ASTM A653M	Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A668	Steel Forgings, Carbon and Alloy, for General Industrial Use
ASTM A677	Non-oriented Electrical Steel Fully Processed Types
ASTM A717	Standard Test Method for Surface Insulation Resistivity of Single-Strip Specimens
ASTM A743	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A780	Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A815	Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings
ASTM A924M	General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM A967	Chemical Passivation Treatments for Stainless Steel Parts
ASTM B111	Copper and Copper Alloy Seamless Condenser Tubes and Ferrule Stock
ASTM B169	Aluminum Bronze Sheet, Strip, and Rolled Bar
ASTM B221	Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B23	White Metal Bearing Alloys (known commercially as “Babbitt Metal”)
ASTM B308	Aluminum-Alloy 6061-T6 Standard Structural Profiles
ASTM B49	Copper Rod Drawing Stock for Electrical Purposes

Standard	Description
ASTM B584	Copper Alloy Sand Castings for General Applications
ASTM B632	Aluminum-Alloy Rolled Tread Plate
ASTM B75	Seamless Copper Tube
ASTM B875	Aluminum Diffusion Coating Applied by Pack Cementation Process
ASTM B88	Seamless Copper Water Tube
ASTM C547	Mineral Fiber Pipe Insulation
ASTM C795	Thermal Insulation for Use in Contact with Austenitic Stainless Steel
ASTM D1868	Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems
ASTM E125	Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings.
ASTM E186	Standard Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings
ASTM E23	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E280	Standard Reference Radiographs for Heavy-Walled (4 ½ to 12-in. (114 to 305-mm)) Steel Castings
ASTM E446	Standard Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
ASTM E814	Standard Test Method for Fire Tests of Penetration Firestop Systems
ASTM F593	Stainless Steel Bolts, Hex Cap Screws, and Studs
ASTM F594	Stainless Steel Nuts
ASTM F855	Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment
ASTM-D3276	Recommended Practice Guide for Paint Inspectors
ASTM-D3359	Method for Measuring Adhesion by Tape Test
AWS A2.4	Standard Symbols for Welding, Brazing, and Nondestructive Examination
AWS A5.10	Welding Consumables
AWS D1.6	Structural Welding Code— Stainless Steel
AWS QC1	Standard for AWS Certification of Welding Inspectors
BCICA QSMIM	Quality Standards for Mechanical Insulation Manual
CAN/CGSB 48.9712	Non-destructive testing - Qualification and certification of NDT personnel
CAN/CSA 60044-1	Instrument Transformers – Current Transformers
CAN/CSA 60044-2	Instrument Transformers – Inductive Voltage Transformers
CAN/ULC-S102	Standard Method Of Test For Surface Burning Characteristics Of Flooring, Floor Coverings, And Miscellaneous Materials And Assemblies
CAN3-C108.3.1	Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems
CAN4	Standard Method Of Fire Tests Of Firestop Systems
CCH 70-3	Specification for Inspection of Steel Castings of Hydraulic Machines

Standard	Description
CEATI Report No. T052700-0329 Part I	Hydroelectric Turbine-Generator Units Guide for Erection Tolerances and Shaft System Alignment – Part I: Definitions
CEATI Report No. T052700-0329 Part II	Hydroelectric Turbine-Generator Units Guide for Erection Tolerances and Shaft System Alignment – Part II: Vertical Shaft Units with Francis Turbines or Reversible Pump-Turbines
CEMA 2Y-1	Standard for CEMA Light Grey Colour for Indoor Switchgear
CGSB	Various Cleaning and Paint Specifications
CMAA 74	Electric Overhead Travelling Cranes
CSA A23.1	Concrete Materials and Methods of Concrete Construction
CSA A23.2	Test methods and standard practices for concrete
CSA A23.3	Design of Concrete Structures
CSA A23.5M	Supplementary Cementing Materials
CSA A5	Portland Cements
CSA B167	Overhead travelling cranes — Design, inspection, testing, maintenance, and safe operation
CSA C22.1	Canadian Electric Code Part I - Safety Standards for Electrical Installations
CSA C22.2	General Requirements - Canadian Electrical Code, Part II
CSA C22.2.31 M	Switchgear Assemblies
CSA C22.2.75 M	Thermoplastic Insulated Wires and Cables
CSA C60044	Instrument Transformers
CSA C88	Power Transformers and Reactors
CSA C9	Dry Type Transformers
CSA G40.21	Structural Quality Steel
CSA S157	Strength design in aluminum
CSA S16	Design of steel structures
CSA W178.1	Certification of welding inspection organizations
CSA W178.2	Certification of welding inspectors
CSA W47.1	Certification of Companies for Fusion Welding of Steel
CSA W47.2	Certification of Companies for Fusion Welding of Aluminum
CSA W48	Filler Metals and Allied Materials for Metal Arc Welding
CSA W59	General Specification for Welded Steel Construction (Metal Arc Welding)
CSA W59.2	Welded Aluminum Construction
CSA Z107.56	Procedures for the Measurement of Occupational Noise Exposure
CSA Z462	Workplace electrical safety
DIN EN 10106	Cold rolled non-oriented electrical steel sheet and strip delivered in the fully processed state
EEMAC Y1 2	Performance Specification for Finishing Systems for Outdoor Electrical Equipment
EN 61000-4-3	Electromagnetic compatibility (EMC) -- Part 4-3: Testing and measurement techniques- Radiated, radio-frequency, electromagnetic field immunity test

Standard	Description
EN 61000-4-5	Electromagnetic compatibility (EMC) -- Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 60034-1	Rotating Electrical Machines – Part 1: Rating and Performance
IEC 60041	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
IEC 60193	Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests
IEC 60308	International Code for Testing of Speed Governing Systems for Hydraulic Turbines
IEC 60545	Guide for Commissioning, Operation and Maintenance of Hydraulic Turbines
IEC 60609-1	Hydraulic turbines, storage pumps and pump-turbines Cavitation pitting evaluation Part 1: Evaluation in reaction turbines, storage pumps and pump-turbines
IEC 61672	Electroacoustics - Sound Level Meters
IEC 62097	Hydraulic machines, radial and axial - Performance conversion method from model to prototype
IEEE 100	Dictionary of IEEE Standards Terms
IEEE 1043	Recommended Practice for Voltage-Endurance Testing of Form-Wound Bars and Coils
IEEE 1095	Guide for Installation of Vertical Generators/Motors for Hydroelectric Applications
IEEE 115	Test Procedures for Synchronous Machines, Part 1
IEEE 1207	Guide for the Application of Turbine Governing Systems for Hydroelectric Generating Units
IEEE 1246	Guide for Temporary Protective Grounding Systems Used in Substations
IEEE 125	Recommended Practices for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators
IEEE 1310	Recommended Practice for Thermal Cycle Testing of Form-Wound Stator Bars and Coils for Large Rotating Machines
IEEE 1553	Standard for Voltage-Endurance Testing of Form-Wound Coils and Bars for Hydrogenerators
IEEE 1584	Guide for Performing Arc-Flash Hazard Calculations - Includes Access to Additional Content
IEEE 1799	Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings
IEEE 286	Recommended Practice for Measurement of Power-Factor Tip-up of Rotating Machinery Stator Coil Insulation
IEEE 315 and 315A	Graphic Symbols for Electrical and Electronics Diagrams
IEEE 421.1	Standard Definitions for Excitation Systems for Synchronous Machines
IEEE 421.2	Guide for Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems
IEEE 421.3	Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines

Standard	Description
IEEE 421.4	Guide for the Preparation of Excitation System Specifications
IEEE 421.5	Recommended Practice for Excitation System Models for Power System Stability Studies
IEEE 43	Recommended Practice for Testing Insulation Resistance of Rotating Machinery
IEEE 492	Guide for Operation and Maintenance of Hydro-Generators
IEEE 522	Guide for Testing Turn Insulation on Form Wound Stator Coils for AC Electric Machines
IEEE 693	Recommended Practice for Seismic Design of Substations
IEEE 802	Standard for Local and Metropolitan Area Networks: Overview and Architecture
IEEE 810	Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Runout Tolerances
IEEE 95	Recommended Practice for Insulation Testing of Large AC Rotating Machinery (2300 Vac and Above) with High Direct Voltage
IEEE 98	Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials
IEEE 99	Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment
IEEE C37.102	Guide for AC Generator Protection
IEEE C37.110	Guide for the Application of Current Transformers Used for Protective Relaying Purposes
IEEE C37.13	Low-Voltage AC Power Circuit Breakers Used in Enclosures
IEEE C37.18	Enclosed Field Discharge Circuit Breakers for Rotating Electric Machinery
IEEE C37.2	Electrical Power System Device Function Numbers and Contact Designations
IEEE C37.20.2	IEEE Standard for Metal-Clad Switchgear
IEEE C37.20.3	IEEE Standard for Metal-Enclosed Interrupter Switchgear (1kV-38kV)
IEEE C37.90.1	Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C50.12	Salient Pole Synchronous Generators and Generator/Motors for Hydroelectric Turbine Application Rated 5 MVA and Above
IEEE C57.110	Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability when Supplying Non Sinusoidal Load Currents
IEEE C57.116	Guide for Transformers Directly Connected to Generators
IEEE C57.12.01	Standard General Requirements for Dry-Type Distribution and Power Transformers, Including Those with Solid-Cast and/or Resin Encapsulated Windings
IEEE C57.12.01	General Requirements for Dry Type Distribution and Power Transformers
IEEE C57.12.51	Requirements for Ventilated Dry-type Power Transformers, 501kVA and larger, Three-Phase with High-Voltage 601 to 34,500 Volts, Low Voltage 208Y/120 to 4160 Volts
IEEE C57.12.56	Test Procedure for Thermal Evaluation of Insulation Systems for Ventilated Dry-Type Power and Distribution Transformers

Standard	Description
IEEE C57.12.57	Requirements for Ventilated Dry Type Transformers 2500 kVA and Below, Three-Phase, with High-Voltage 34 500 Volts and Below, Low-Voltage 216Y/125 and 480Y/277 Volts
IEEE C57.12.60	Guide for Test Procedures for Thermal Evaluation of Insulation Systems for Solid-Cast and Resin-Encapsulated Power and Distribution Transformers
IEEE C57.12.91	Test Code for Dry Type Distribution and Power Transformers
IEEE C57.124	Recommended Practice for the Detection of Partial Discharge and the Measurement of Apparent Charge in Dry Type Transformers
IEEE C57.13	Requirements for Instrument Transformers
IEEE C57.18.10	Practices and Requirements for Semiconductor Power Rectifier Transformers
IEEE C57.94	Recommended Practice for Installation, Application, Operation and Maintenance of Dry Type General Purpose Distribution and Power Transformers
IEEE C57.96	Guide for Loading Dry-Type Distribution and Power Transformers
IEEE C57.98	Guide for Transformer Impulse Tests
IEEE P1207	Working Group Draft Application of Turbine Governing System
IEEE C37.1	Definition, Specification and Analysis of Systems Used for Supervisory Control, Data Acquisition and Automatic Control
ISO 1940-1	Mechanical vibration — Balance quality requirements for rotors in a constant (rigid) state — Part 1: Specification and verification of balance tolerances
ISO 216:2007	Writing paper and certain classes of printed matter -- Trimmed sizes -- A and B series, and indication of machine direction.
ISO 4032	Hexagon regular nuts (style 1) — Product grades A and B
ISO 4386-1	Plain Bearings-Metallic Multi-layer Plain Bearings - Part 1: Non-destructive Ultrasonic Testing of Bond of thickness greater than or equal to 0,5 mm
ISO 4386-2	Plain bearings - Metallic multilayer plain bearings - Part 2: Destructive testing of bond for bearing metal layer thicknesses greater than or equal to 2 mm
ISO 4386-3	Plain bearings - metallic multi-layer plain bearings - Part 3: Non-destructive Penetrant Testing
ISO 4406	Hydraulic Fluid Power - Fluids - Method for Coding the Level of Contamination by Solid Particles
ISO 7919-1	Mechanical Vibration of Non-Reciprocating Machines - Measurements on Rotating Shafts and Evaluation Criteria - Part 1: General Guidelines Second Edition
ISO 7919-5	Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts - Part 5: Machine sets in hydraulic power generating and pumping plants
ISO 8573-1	Compressed air — Part 1: Contaminants and purity classes
ISO 9000	International Quality Standards (series)
ISO 9712	Non-destructive testing - Qualification and certification of NDT personnel
ISO 10816-5	Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts – Part 5: Machine sets in hydraulic power generating and pumping plants
MIL HDBK 743	Anthropometry Of U.S. Military Personnel

Standard	Description
MIL HDBK 759	Human Engineering Design Guidelines
MIL-STD-1472F	Department of National Defense Design Criteria Standard Human Engineering, 1999
NACE SP 0188	Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
NBCC	National Building Code of Canada
NEMA 107	Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus
NEMA ICS 2	Industrial Control and Systems Controllers, Contactors and Overload Relays Rated 600 V
NEMA MG1	Motors and Generators
NEMA TR 1	Transformers, Regulators and Reactors
NERC CIP-006	Physical Security of Critical Cyber Assets
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SMACNA	Seismic Restraint Manual: Guidelines for Mechanical Systems
SSPC-PA1	Shop, Field and Maintenance Painting of Steel
SSPC-PA2	Procedure for Determining Conformance to Dry Film Thickness Measurements
SSPC-SP1	Solvent Cleaning
SSPC-SP10	Near White Metal Blasting Cleaning
SSPC-SP11	Power Tool Cleaning - To Bare Metal
SSPC-SP2	Hand Tool Cleaning
SSPC-SP3	Power Tool Cleaning
SSPC-SP6	Commercial Blasting Cleaning
SSPC-SP7	Brush-off Blast Cleaning
SSPC-SP8	Pickling
UL 1561	UL Standard for Safety Dry-Type General Purpose and Power Transformers
UL 94	Tests for Flammability of Plastic Materials for Parts in Devices and Appliances
US Federal Standard 595B	Federal Standard 595B Colors used in Government Procurement

Table 3.2B – BC Hydro Technical Documents

BC Hydro Technical Documents	Description
BC Hydro DP 45-Z0004	P&C Cable and Wire – Selection Guide
BC Hydro DP 45-Z0006	Generation Engineering – Application of Surge Suppression on Auxiliary Relay Coils
BC Hydro DP 45-Z0007	Generation Engineering – Design Documents Outline of Requirements.
BC Hydro DP 45-Z0010	Generation Engineering – Software Design Practice
BC Hydro DP 45-Z0019	Generation Engineering – Panel Wiring Requirements
BC Hydro DP 45-Z0031	Generation Engineering – Hydro Electric Unit Protection Overview

BC Hydro Technical Documents	Description
BC Hydro DP 45-Z0034	Generation Engineering – Stator RTD Terminal Cabinet (SRTC)
BC Hydro DP 45-Z0035	Generation Engineering – Unit Instrumentation
BC Hydro DP 45-Z0043	Generating Engineering – Plant Central Control Human Machine Interface
BC Hydro ES 10-A0425	Abbreviations and Symbols – Designations and Letter Symbols for Units and Decimal Prefixes
BC Hydro ES 10-N0020	Electrical – Station Layouts – Station Electrical CAD Cell Naming Conventions
BC Hydro ES 31-Q0020	Piping Systems Valve Tag Numbering
BC Hydro ES 31-Q0021	Piping Systems Piping Identification
BC Hydro ES 31-Z0002	Headcover Fastener Design
BC Hydro ES 44-A0158	Identification of High Voltage Station Equipment Including Station Buses For all AC Voltage Classes
BC Hydro ES 44-G0020	Outdoor Grounding Design Principles & Detailed Procedure For Station Design
BC Hydro ES 44–G0310-01	Typical Grounding Details Indoor Stations
BC Hydro ES 44-P0010-01	Letters And Numbers for Station Signs
BC Hydro ES 44-P0012-01	Decal Sign for Phase Designation A-B-C 100 X 75
BC Hydro ES 44-P0013-01	Aluminum Plate for Phase Designation A-B-C 200 X 165
BC Hydro ES 44-P0061-01	Decal Sign for Three Phase Equipment Designation
BC Hydro ES 44-Z0040	Energy Efficiency for Lighting Systems in Generating Stations
BC Hydro ES 44–Z0320	Generator Neutral Grounding
BC Hydro ES 44-Z0330	Airgap Monitoring System Design Practise
BC Hydro ES 44–Z0510	Current and Voltage Transformers Guideline
BC Hydro ES 44-Z1010	Generating Station Grounding
BC Hydro ES 44-Z1101	Arc Flash Hazard Analysis
BC Hydro ES 45-A0065	CT and VT Winding Designations and Test Block Designation on P&C Documentation and Panels
BC Hydro ES 45-A0082	List of Abbreviations, Designations and Letter Symbols for Units and Decimal Prefixes
BC Hydro ES 45-A0084	Device Function Numbers
BC Hydro ES 45-U0041	Colour Code for Low Voltage Cables and Wires
BC Hydro ES 45–U0093	Grounding and Bonding Associated with P&C Modular Type Panels
BC Hydro ES 45-U0094	Grounding and Bonding Associated with Major Equipment Control Cabinets
BC Hydro ES 45–U0096	Grounding of Shields on Spirally Shielded Control Cables
BC Hydro ES 45-U0123	Securing Facility for Low Voltage Cables Entering Switchboards, Cubicles, etc.
BC Hydro ES 45-U0541	Nameplating for Switchboards, Cubicles, etc.
BC Hydro ES 45-V0371	Sectional Rail Mounted Terminal Blocks (600V) and Related Accessories
BC Hydro ES 45-X0007	Protection and Control Cable Termination Panel Design and Practice
BC Hydro ES 45–X0010	Isolation and Test Facilities Before 1997
BC Hydro ES 45-X0011	Isolation and Test Facilities Within P&C Panels, 1997

BC Hydro Technical Documents	Description
BC Hydro MS 01.20.MTCE.03	Recommended Grounding Practices for the Maintenance Work, Major Repair, Refurbishment and Testing of Large Synchronous Generators
BC Hydro MS 01.20.TEST.01	Insulation Resistance and Polarization Index
BC Hydro MS 01.20.TEST.02	DC Hipot Step Test
BC Hydro MS 01.20.TEST.03	Partial Discharge Test
BC Hydro MS 01.20.TEST.04	Corona Probe Test – Stator Winding
BC Hydro MS 01.20.TEST.05	Pole Drop Test – Salient Pole Field Winding
BC Hydro MS 01.20.TEST.06	Embedded Winding RTD Test
BC Hydro MS 12.17-01-3	Lubricating and Hydraulic Oil Field Sampling and Laboratory Testing
BC Hydro OSH 204	Personal Lockout
BC Hydro OSH 206	Worker Protection Grounding/Bonding
BC Hydro OSH 209	Isolation of Mechanical Apparatus
BC Hydro OSH 303	Confined Spaces
BC Hydro Report	BC Hydro MICA Switchgear HF Engineering Design Standard
BC Hydro Report	BC Hydro Safety Principles for Engineered Systems, BMT Isis / BC Hydro, Apr 10, 2008
BC Hydro SPR Rule 700	Isolation and Lockout: Generating Stations (also known as WPP)
BC Hydro TS 01.20.SPEC.01	Generator Fire Protection

Table 3.2C – BC Hydro Reference Drawings

BC Hydro Drawings	Description
212-H04-01528-002	Revelstoke G.S. – Powerhouse-Unit 5 – Primary & Standby Protection – UCB Panel R1 – Layout Diagram
212-H04-01528-003	Revelstoke G.S. – Powerhouse-Unit 5 – Primary & Standby Protection – UCB Panel R1-Bill of Materials – Layout Diagram
212-H04-01528-004	Revelstoke G.S. – Powerhouse-Unit 5 – Primary & Standby Protection – UCB Panel R1-Nameplates – Layout Diagram
1006-H04-01031-001	GM Shrum G.S. – Powerhouse-Unit 4 – Stator RTD Terminal Cabinet (SRTC) – Layout
1006-H04-01031-002	GM Shrum G.S. – Powerhouse-Unit 4 – Stator RTD Terminal Cabinet (SRTC) – Wiring Diagram
1006-H04-03131-001	Gordon M. Shrum G.S. – Powerhouse-Unit 3 – Auxiliary Controls – UCB Panel F3 – Layout Diagram
1006-H04-03131-002	Gordon M. Shrum G.S. – Powerhouse-Unit 3 – Auxiliary Controls – UCB Panel F3-Bill of Materials – Layout Diagram
1006-H04-03160-001	GM Shrum G.S. – Powerhouse-Unit 3 – Protection Alarm & Metering (PAM) – UCB Panel F2 -- Layout
G417-H14-B9	Exciter Protection Schematic

3.3 Materials

3.3.1 General

The materials to be furnished as part of the Work which are specified by reference to standard specifications or codes will be in compliance with the latest editions or revisions thereof, including any amendments or supplements in effect as at Effective Date, unless otherwise specified in the Contract Documents.

3.3.2 Materials

Without limiting Section 6.29 of Schedule 2 [Design and Construction Protocols], the materials throughout will be the best of their respective kinds and, except as otherwise specified, all materials will be in accordance with the latest edition of the applicable standards. The ultimate strength, yield point, ductility, hardness, etc., will be determined from test pieces obtained as described in the specification for the material in question. Where no definite specifications are given, test pieces will be obtained as required by Hydro's Representative. The Work includes all test pieces, blanks, etc., cut and machined to the sizes, shapes and dimensions as directed.

3.3.3 Mill Orders and Certificates

At least 30 days prior to commencing manufacturing, the Contractor will submit mill orders and mill certificates for the material to be used in the work. Mill orders will list the heat or melt numbers, physical and chemical properties of the metal, and show which components and production lots have been fabricated from such heat or melt.

3.3.4 Threads, Screws, Bolts, etc.

All threads, screws, bolts and nuts will be in accordance with ASME B1.13M dimensions, ASME B18.2.3M Series and to ASME B18.2.4M Series.

Bronze and stainless steel fasteners will be used where necessary to ensure that the Equipment can be readily dismantled after a long period of service.

Threaded fasteners supplied will be identified as to specification, including type or grade, as applicable, by:

(a) mill test certificates satisfactorily correlated to the materials or products to which they pertain; and

(b) legible markings on the material or product made by its producer in accordance with the applicable material or product standard.

All pipe threads will be in accordance with ANSI/ASME B1.20.1 - American National Standard Taper Pipe Threads (NPT).

Counter-sunk bolt heads will not be used without being submitted for Consent and accepted by Hydro's Representative.

All fasteners will be locked unless specifically specified elsewhere. Locking methods will be submitted for Review and could consist of locking tabs, lock wires, cotter pins, adhesive thread lockers, double nuts, and wedge type lock washers such as Nord-Lock®. Use of split-ring type lock washers or serrated lock washers is not acceptable.

Acceptable lock washers may be submitted for consideration where plain washers have been specified in these Specifications.

Large fasteners will be marked to facilitate determining if movement has occurred.

3.3.5 Drilled Concrete Anchors

Drilled anchors for the mounting of any equipment on concrete surfaces will be one of the following:

(a) Hilti HSLG-R Heavy Duty Expansion Anchors;

(b) Hilti HSL-3 Heavy Duty Expansion Anchors;

(c) Hilti HAD Undercut Anchors; or

(d) Hilti Kwikbolt TZ Expansion Anchors.

3.3.6 Locating Dowels

The dowels supplied to locate or align the Equipment components during installation, and that are not required to transmit load when the Unit is operating, will be the standard taper pin design with 1:50 taper.

The dowels supplied to locate or align the Equipment components during installation, to transmit load when the Unit is operating, and where the relative location of the two doweled components does not change after reaming of the holes, will be standard taper pin design with 1:50 taper. If cylindrical pins are proposed they will be submitted for Consent.

The dowels supplied to locate or align the Equipment components during installation, to transmit load when the Unit is operating, and where the relative location of the two doweled components can change (such as between wicket gate arms and stems), will be cylindrical pins.

All dowels will be provided with some means of extraction such as threaded ends with nuts and washers or threaded holes.

All dowels left in place after installation will be positively retained.

3.3.7 Patching, Etc.

No patching, plugging or other such means of covering defects, discrepancies, or errors will be carried out without the prior written permission of Hydro’s Representative.

3.3.8 Tolerances and Fits

As minimum requirements, the Work will be carried out in accordance with ASME Y14.5 - Dimensioning and Tolerancing. The class of fit will be noted on the Drawings submitted.

3.3.9 Material Standard Specifications

Unless otherwise specified, materials will be equal to, or better than, the following standard specifications, ASTM standards or CSA standards:

Component	Description	Material Specification
Flexible coupling	Steel plate	ASTM A516 Grade 70, S5
Closure section	Steel plate	ASTM A516 Grade 70, S5
Spiral case	Steel plate	ASTM A516 Grade 70, S5
Stay ring	Steel plate	ASTM A516 Grade 55, S5 and S8

Component	Description	Material Specification
Bottom ring	Steel plate Cast steel	ASTM A516 Grade 60, S5 and S8 ASTM A27 Grade 65-35
Discharge ring	Steel plate Stainless steel	ASTM A516 Grade 60, S5 ASTM[2]
Draft tube and pit liner	Steel plate	CSA G40.21M Grade 260WT
Runner	Cast stainless steel Plate stainless steel	ASTM A743 Grade CA-6NM[1] ASTM A240 Grade S4150
Runner stationary seal rings	Stainless steel	ASTM A176 Type 410 or ASTM A240 Type 304L
Turbine and Generator Shaft	Forged steel Forged steel (if welded) Steel plate	ASTM A668 Class D, S6, S7 ASTM A668 Class D, S4, S6, S7 ASTM A516 Grade 70, S5
Headcover	Cast steel Steel plate	A27 Grade 65-35, S10 ASTM A516 Grade 55, S5, S8
Regulating ring	Steel plate	ASTM A516 Grade 55, S5
Wicket gates	Cast stainless steel Plate stainless steel	ASTM A743 Grade CA-6NM[1] ASTM A240 Grade S4150
Servomotors	Steel plate Cast steel	ASTM A285 Grade B ASTM A27 Grade 65-35
Pins	Stainless steel	ASTM A276 Type 410
Turbine and Generator guide bearings and Generator thrust bearing	Babbitt	ASTM B23 Grade 2 or 3[4]
Turbine shaft sleeve/runner plate for water seal	Stainless steel	ASTM A176 Type 410 or ASTM A240 Type 410
Shafting	Cold rolled steel	ASTM A108
Bolts and nuts	Carbon steel	ASTM A193 Grade B7 and ASTM A194 Grade 2H
Generator hub and rotor spider	Steel plate	CSA Specification G40.21 Grade 300W
Stator frame	Steel plate	CSA Specification G40.21 Grade 300W
Current carrying components including: Generator stator winding, Generator rotor winding, Excitation System buses, and Excitation System transformer winding	Electrolytic tough pitch copper	ASTM B187 or better
Corrosion resistant bolts and nuts	Stainless steel	ASTM F593 and F594 ASTM B6 and B8
Miscellaneous	Cast iron Cast steel Forged steel	ASTM A48 Class 30 ASTM A27 Grade 65-35 ASTM A668
Miscellaneous structural steel	Bars, channels, angles and plates	CSA G 40.21M Grade 300W
Miscellaneous structural steel	Shapes and hollow sections	CSA G 40.21M Grade 350W

Component	Description	Material Specification
Guardrails	Steel pipe	ASTM A53 Type E/Grade B
Stainless Steel Clad Plate		ASTM[3]
Miscellaneous stainless steel		ASTM[3]

Notes:

[1] The casting for the runner and wicket gates will satisfy the requirements of ASTM A743M grade CA6NM with the following supplementary requirements:

(i) Chemical requirements for heat analysis:

(A) C < 0.035%

(B) Si < 0.6%

(C) P < 0.025%

(D) S < 0.015%

(E) P + S < 0.03%

(F) Cu < 0.3%

(G) Residual elements including Cu < 0.5%.

Product analysis tolerances in accordance with ASTM A484M Table 1.

(ii) Supplementary requirements of ASTM A743M:

(A) S13 = Post Weld-Heat Treatment;

(B) S14 = Hardness Test.

(iii) Supplementary requirements of ASTM A781M:

(A) S1 = Magnetic Particle Examination;

(B) S2 = Radiographic Examination;

(C) S3 = Liquid Penetrant Examination;

(D) S4 = Ultrasonic Examination;

(E) S5 = Examination of Weld Preparation;

(F) S6 = Certification;

(G) S7 = Prior Approval of Major Weld Repairs;

(H) S8 = Marking;

(I) S9 = Charpy Impact Test (Minimum average value of 50 joules at 0 (zero) °C and interpretation in accordance with ASTM A370);

(J) S12 = Test Report;

(K) S14 = Tension Test from Castings.

(iv) Welding process and filler metal will produce a fully homogeneous weld with low diffusible hydrogen.

[2] Refer to Appendix 6-3 [Turbine Specifications (SPT)] regarding stainless steel required portions of the discharge ring.

[3] The grade, ASTM Specification number, chemical composition and the thickness of the alloy cladding metal will be submitted for Review.

[4] The bearing pads will be cast from the original bars or ingots received from babbitt foundry. The Contractor will not reuse melted and solidified babbitt for bearing pad casting.

3.3.10 Checker Plate and Gratings

(a) Checker Plate: Checker plate will be of an accepted raised pattern in steel or aluminum. All edges of plates will be planed and the joints will be cut to maintain continuity of pattern where possible. Checker plate pattern will be ground off, where floor flanges occur, to ensure even bearing.

(b) Grating: If aluminum or steel grating is used instead of checker plate, it will be manufactured by Fisher and Ludlow (Canada) Ltd. The grating will be installed in accordance with the manufacturer's written recommendations.

3.3.11 Stainless Steel

(a) The Work includes development and provision of storage, handling, fabrication, welding, and installation Procedures to eliminate carbon steel contamination (or other material contamination) of stainless steel and to maintain the surface integrity of the stainless steel.

(b) Where stainless steel components are being shop fabricated and welded, the shop performing the Work will be submitted for Consent and will have Procedures in place to eliminate the carbon steel contamination of stainless steel. The Procedures will include the use of dedicated stainless steel tools and equipment for preparing welds (including wire brushes, chisels, files, hammers, clamps), the separation of areas used to fabricate carbon steel from areas used to fabricate stainless steel to prevent contamination by shavings and dust, and methods to prevent tools or equipment (such as gloves, grinding wheels) used on carbon steel from being used on stainless steel.

(c) Tools and equipment used for stainless steel will be marked "Stainless Steel".

(d) Only 300 series stainless steel brushes will be used on austenitic stainless steels.

(e) All products (for example marking crayons, solvents, cutting fluids, adhesives, oils, greases) coming into contact with stainless steel will be chlorine free.

3.3.12 Bearing and Governor Oil

(a) General: The oil used in the Generator bearing, Turbine Bearing and Governor System will:

- (i) be Teresso 46 lubricating mineral oil as produced by Esso Petroleum Canada;
- (ii) be provided in clean, sealed containers;
- (iii) be new; and
- (iv) be filtered prior to first use in the shop and at Site.

(b) Use and Replacement: BC Hydro does not routinely replace the oil. If the oil is drained during a maintenance outage the oil may be stored in a common sump with other oil of the same type.

(c) Testing and Treatment: BC Hydro periodically samples and tests oil in accordance with BC Hydro MS 12.17-01-3. If the oil tests below BC Hydro's minimum standards, the oil is typically filtered and reused unless the filtering, or other treatment, cannot restore the oil to BC Hydro's minimum standards.

(d) Oil Used for Testing and Flushing: Any oil used for testing, such as pressure tests, shop tests, leak tests, or used for flushing, will not be re-used in the final assembly of the Unit.

(e) Filtration: Bearing and Governor System oil will be filtered to a cleanliness level that is required by the most stringent component in the system but no less than an ISO 4406 cleanliness level of 17/15/12.

3.4 Steel for Pressure Vessel Purposes

Unless otherwise specified, all plate steel used for fabrication of the flexible coupling section, closure section, spiral case, stay ring, headcover, runner, other major Turbine components and for all pressure vessels will be classified in the P. No. 1 group of steels in the ASME BPVC, Section VIII, Division 1.

For Turbine components, representative samples of the steel will be impact tested. The tests will be conducted in accordance with ASTM E23.

The allowable limits for the energy value (Charpy "V" notch impact test) at -18°C will not be less than 34 J average and 27 J minimum for any one specimen.

3.5 Castings

3.5.1 General

All castings will be true to pattern, of workmanlike finish and uniform quality, free from blow-holes, porosity, hard spots, shrinkage defects, cracks, or other injurious defects, and will be satisfactorily cleaned for their intended purpose. The surfaces of the castings that do not undergo machining will be suitable for their intended use and will be free from foundry irregularities, such as projections, ridges, hollows, honey-combing, pock marks, or chip marks.

3.5.2 Repairs

Iron castings will not be repaired, plugged or welded. Steel castings may be repaired by welding, provided that the Procedure is submitted for Review. Such acceptance will be permitted only when defects do not adversely affect the strength or the machinability of the castings.

The repair Procedure to be submitted will generally be in accordance with ASTM A488 and in addition will include the following information:

(a) description of the Work to be repaired;

(b) type of welding process proposed;

(c) type and size of electrode to be used;

(d) methods of edge preparation;

(e) methods to inspect that the defect has been completely removed prior to repair welding;

(f) methods to control distortion and shrinkage; and

(g) methods of preheating and stress relieving repair welds.

Under no circumstances will welds in excess of 20 mm be applied after stress relieving or final annealing.

3.5.3 Impurities

Excessive segregation of impurities or alloys at critical points in a casting will be cause for its rejection. The largest fillets compatible with the design will be incorporated wherever a change in section occurs.

3.5.4 Mechanical Testing

The mechanical properties of all castings will be determined from specimen and by methods in accordance with ASTM A370. The number, size and location of the test coupons will be submitted.

3.5.5 Test Coupons

Test coupons from which test specimens are prepared will be attached to all castings weighing 220 kg or more. The number, size and location of the test coupons will be submitted for Consent.

3.5.6 Iron Castings

Iron castings will be in accordance with ASTM Specification A48, Class 30, or better.

3.5.7 Steel Castings

Steel castings will be in accordance with ASTM Specification A27, Grade 70-36, or better and fully heat treated as required by this standard.

3.5.8 Stainless Steel Castings

Stainless steel castings will be fully heat treated when required by the grade used. The grade, composition and ASTM Specification number will be submitted for Review.

3.5.9 Non-Destructive Testing

Castings of all principal parts including all parts subject to water pressure will be inspected at the foundry after cleaning and removal of defects. Proposed repair by welding will be submitted for Consent prior to the repair. Castings will also be inspected after repairs, heat treatment and machining have been completed.

Radiography will be in accordance with ASME BPVC Section V, Article 2. For each casting and material thickness, the Contractor will submit a proposed acceptance standard. The acceptance standard will be based on ASTM E-446, E-186 or E-280 whichever is applicable for the material thickness being examined. The Contractor will specify the proposed severity level for each type of defect. Any crack in any casting is not acceptable.

Magnetic particle examination will be used for checking for surface defects.

Ultrasonic examination or radiography will be used for checking for subsurface defects.

For ultrasonic examination, the Contractor will submit Drawings showing the areas proposed to inspect on major castings. The proposed Procedure and basis for acceptance quality level will be stated in terms of ASTM A609 and will be submitted for Review.

3.5.10 Identification

All castings will be clearly stamped with the heat number in a location that can be readily observed when the casting is assembled in a complete unit.

3.5.11 Radioactivity

All castings will be non-radioactive as measured on the surface by a Geiger Muller detector. The radiation dose at the surface will not exceed 0.5µSv/h on any casting.

3.6 Forgings

3.6.1 General

If flanges are to be welded to the Turbine shaft, the carbon content will be limited to 0.35%, or alternatively steel in accordance with ASTM A668 Class D S4 may be used.

3.6.2 Ingots

The ingots from which the forgings are made will be cast in metal moulds. Forgings will be free from defects affecting their strength and durability, including seams, pipes, flaws, cracks, scales, fins, porosity, hard spots, tool marks, excessive non-metallic inclusions and segregations.

3.6.3 Machining and Finishing

The largest fillets compatible with the design will be incorporated wherever a change in section occurs. Tool marks or tearing of the metal by the finishing tool will not be permitted on the surface of the fillets. Grinding or polishing will be required to remove such marks if they occur. All finished surfaces will be smooth and free from tool marks.

3.6.4 Identification

All forgings will be clearly stamped with the heat number, in a location that can be readily observed when the forging is assembled in a complete unit.

3.6.5 Inspection

Forgings of all principal parts including all parts subject to water pressure will be inspected at the forging plant in the ingot stage, and after forming, cleaning and removal of defects but prior to any repair welding. The forgings will also be inspected after repairs, heat treatment, and machining have been completed.

For Ultrasonic Examination (UT), the test sensitivity will be in accordance with the ASME BPVC, Section V, Article 23, SA-388 and also will be the basis for the acceptance quality levels which will be submitted for Review.

3.6.6 Radioactivity

All forgings will be non-radioactive as measured on the surface by a Geiger Muller detector. The radiation dose at the surface will not exceed 0.5µSv/h on any forging.

3.7 Piping and Valves

3.7.1 General

(a) Piping systems will be designed, supplied and installed in accordance with ASME B31.1 Power Piping Code.

(b) Pipe dimensions will be based on ASME B36.10 or ASME B36.19, as applicable. Tubing will have nominal inch dimensions. Metric piping, tubing, fittings, valves, etc., will not be used.

(c) The Work includes determining the design pressure of a piping system considering such things as: worst case combination of operating conditions, pressure rises due to water hammer or other transient events, relief valve settings, thermal effects, and an allowance for an additional 10% pressure.

(d) Piping conveying water will be sized to keep:

(i) the fluid flow velocity to less than 3 m/s; and

(ii) friction losses below 0.5 kPa per 1 m length of pipe.

(e) Piping conveying gases will be sized to keep:

(i) the fluid flow velocity to less than 15 m/s; and

(ii) friction losses below 0.06 kPa per 30 m length of pipe, during steady state operating conditions.

During short term transient events, such as initial draft tube water depression, these values may be exceeded.

(f) The piping system will be designed such that high loads are not introduced in the piping system where the piping is connected to equipment subject to vibration, thermal expansion and contraction, or other movement.

(g) Dielectric couplings, or a functionally equivalent isolation system, will be provided between different metallic materials to prevent galvanic corrosion and for situations where electrical isolation is required.

(h) Piping systems will include provisions for gravity draining of the pipes.

(i) Automatic vents or (combination) air relief valves, as appropriate will be provided at high points and where air pockets may form in the piping.

(j) Piping will be installed parallel to, or at right angles to, walls and partitions except where accepted. Piping will be arranged such that it does not interfere with or restrict Worker access to other equipment.

(k) A sufficient number of isolation valves will be provided such that it is possible to replace or maintain equipment with minimal disruption to the operation of Equipment and adjacent Units.

(l) Practical and efficient means of removing pumps, valves, compressors, and other equipment that will have to be regularly removed for overhaul will be provided. Where flexible couplings, flanged elbows or Victaulic connections do not facilitate removal of such equipment, removable spool pieces such as dismantling joints or tied flange adaptors will be provided.

(m) Where connection between two components (pipe, fitting, valve couplings etc.) cannot be confirmed to comply with ANSI/UL Standard 467 “Grounding & Bonding Equipment” or ES 44-Z1010 to maintain electrical continuity for the purposes of electrical grounding, a bonding strap will be installed across the connector.

(n) No pipe unions will be used as part of the Work.

(o) Threaded joints will only be used for auxiliary connections to items such as pressure gauges, instrumentation, pipe plugs, etc., and localized unpressurized drain line branches.

3.7.2 <u>Seismicity</u>

(a) Piping systems will be supported and seismically restrained to meet the requirements of ASME B31E.

(b) Compressed air and pressurized oil piping, and piping passing directly above the Generator, will be classified as ‘critical’ per ASME B31E. The remainder of piping will be classified as ‘noncritical’ per ASME B31E.

(c) In addition to position retention, ‘critical’ (leak tight) piping will achieve inconsequential leakage during seismic events, and zero leakage immediately following seismic events.

(d) Normal Unit operation conditions will be considered concurrent with the seismic load.

3.7.3 Material and Dimensions

(a) General:

(i) Diameters described below are nominal.

(ii) Pressure and temperature ratings listed below are the minimum requirements. If the pressure and temperature ratings listed below will not be sufficient, the Contractor will submit alternatives.

(b) Air Admission and Synchronous Condenser Air Exhaust Piping:

(i) *Embedded Piping*:

Piping	
50 mm (2”) and less	Stainless steel, schedule 40S, ASTM A312 TP304L with ends for socket welding.
Over 50 mm (2”)	Stainless steel, schedule 40S, ASTM A312 Grade TP304L with ends for butt welding.
Fittings	
50 mm (2”) and less	Forged stainless steel, socket welded, Class 3000 ASTM A182 Grade F304L, ASME B16.11.
Over 50 mm (2”)	Wrought stainless steel, butt welded, schedule 40S, ASTM A403 Grade WP304L, ASME B16.9.

(ii) *Exposed Piping*:

Piping	
19 mm (3/4”) and less	Stainless steel, seamless tubing, plain ends, ASTM A213 grade TP304, 0.049” wall thickness up to 13 mm (½”), 0.065” wall thickness up to 19 mm (3/4”), fully annealed, suitable for field bending and flaring. Hardness of 90HRB (200 HV) or less.
25 mm (1”) to 50 mm (2”)	Stainless steel, schedule 10S, ASTM A312 TP304L, with ends for socket-welding.
Over 50 mm (2”)	Stainless steel, schedule 10S, ASTM A312 Grade TP304L with ends for butt-welding.

Fittings

19 mm (3/4") and less	Swagelok system, compression type for tube to fitting connections, and threaded type for fitting to fitting connections, Stainless steel 316, ASTM A276 (bar stock) or ASTM A182 (forged).
25 mm (1") to 50 mm (2")	Forged stainless steel, socket welded, Class 3000 ASTM A182 Grade F304L, ASME B16.11.
Over 50 mm (2")	Wrought stainless steel, butt welded, schedule 10S, ASTM A403 Grade WP304L, ASME B16.9.

Flanges

25 mm (1") to 50 mm (2")	Stainless steel, socket weld, ASTM A182, Gr. F304L, forged, Class 150, ASME B16.5.
Over 50 mm (2")	Stainless steel, weld neck, ASTM A182, Gr. F304L, forged, Class 150, ASME B16.5.

Valves

19 mm (3/4") and less	Swagelok stainless steel valves.
25 mm (1") and over	Flanged valves, ASME B16.5, ASME B16.34. ASME B16.10. Class 150.

For the above systems, and where piping (embedded and exposed) is immune from exposure to water under any operating condition, carbon steel piping systems, and alternative connections, may be proposed by the Contractor and submitted for Review.

(c) Cooling Water, Pressure Tap, Unpressurized Drainage and Pressurized Drainage Piping:

(i) *Embedded Piping*:

Piping

50 mm (2") and less	Stainless steel, schedule 40S, ASTM A312 TP304L with ends for socket welding.
Over 50 mm (2")	Stainless steel, schedule 40S, ASTM A312 Grade TP304L with ends for butt welding.

Fittings

50 mm (2") and less	Forged stainless steel, socket welded, Class 3000, ASTM A182 Grade F304L, ASME B16.11.
Over 50 mm (2")	Wrought stainless steel, butt welded, schedule 40S, ASTM A403 Grade WP304L, ASME B16.9.

(ii) *Exposed Piping*:

Piping

19 mm (3/4)" and less	Stainless steel, seamless tubing, plain ends, ASTM A213 grade TP304, 0.049" wall thickness up to 13 mm (½"), 0.065" wall thickness up to 19 mm (3/4"), fully annealed, suitable for field bending and flaring. Hardness of 90 HRB (200 HV) or less.
25 mm (1") to 40 mm (1-½")	Stainless steel, schedule 10S, ASTM A312 TP304L with ends for socket welding.

50 mm (2”) to 150 mm (6”)	Stainless steel, schedule 10S, ASTM A312, Grade TP304L with Victaulic grooved ends using Victaulic RX rolls.
Over 150 mm (6”)	Stainless steel, schedule 10S, ASTM A312 Grade TP304L with ends for butt-welding.

Fittings

19 mm (3/4”) and less	Swagelok system, compression type for tube to fitting connections, and threaded type for fitting to fitting connections, Stainless steel 316, ASTM A276 (bar stock) or ASTM A182 (forged).
25 mm (1”) to 40 mm (1½”)	Forged stainless steel, socket welded, Class 3000, ASTM A182 Grade F304L, ASME B16.11.
50 mm (2”) to 150 mm (6”)	Victaulic stainless steel grooved end fittings with Victaulic couplings style 89 (Grade E ‘EPDM’ gaskets).
Over 150 mm (6”)	Wrought stainless steel, butt welded, schedule 10S, ASTM A403 Grade WP304L, ASME B16.9.

Flanges

25 mm (1”) to 50 mm (2”)	Stainless steel, socket weld, ASTM A182, Gr. F304L, forged, Class 150, ASME B16.5.
Over 50 mm (2”)	Stainless steel, weld neck, ASTM A182, Gr. F304L, forged, Class 150, ASME B16.5.

Valves

19 mm (3/4”) and less	Swagelok stainless steel valves.
Greater than 19 mm to 150 mm (6”)	Flanged valves, ASTM A351 Gr. CF8M stainless steel
over 150 mm (6”)	Flanged valves, ASME B16.5, ASME B16.34. ASME B16.10. Class 150.

Minimum size is 75 mm (3”) for embedded pressurised drainage piping and 100 mm (4”) for embedded unpressurised drainage piping.

(d) <u>Compressed Air System Piping (nominal design pressure up to 690 kPa; including Synchronous Condenser Air Depression, Service Air, Process Air, and Brake Air)</u>:

(i) *Embedded Piping*:

Piping

50 mm (2”) and less	Stainless steel, schedule 40S, ASTM A312 TP304L seamless with ends for socket welding.
Over 50 mm (2”)	Stainless steel, schedule 40S, ASTM A312 Grade TP304L seamless with ends for butt welding.

Fittings

50 mm (2”) and less	Forged stainless steel, socket welded, Class 3000 ASTM A182 Grade F304L, ASME B16.11.
Over 50 mm (2”)	Wrought stainless steel, butt welded, schedule 40S, ASTM A403 Grade WP304L, Class S, ASME B16.9.

(ii) *Exposed Piping*:

Piping

19 mm (3/4") and less	Stainless steel, seamless tubing, plain ends, ASTM A213 grade TP304, 0.049" wall thickness up to 13 mm (½"), 0.065" wall thickness up to 19 mm (3/4"), fully annealed, suitable for field bending and flaring. Hardness of 90HRB (200 HV) or less.
25 mm (1") to 50 mm (2")	Stainless steel, schedule 10S, ASTM A312 TP304L, seamless, with ends for socket-welding.
Over 50 mm (2")	Stainless steel, schedule 10S, ASTM A312 TP304L, seamless, with ends for butt-welding.

Fittings

19 mm (3/4") and less	Swagelok system, compression type for tube to fitting connections, and threaded type for fitting to fitting connections, Stainless steel 316, ASTM A276 (bar stock) or ASTM A182 (forged).
25 mm (1") to 50 mm (2")	Forged stainless steel, socket welded, Class 3000 ASTM A182 Grade F304L, ASME B16.11.
Over 50 mm (2")	Wrought stainless steel, butt welded, schedule 10S, ASTM A403 Grade WP304L, Class S, ASME B16.9.

Flanges

25 mm (1") to 50 mm (2")	Stainless steel, socket weld, ASTM A182 F304L, forged, Class 150, ASME B16.5.
Over 50 mm (2")	Stainless steel, weld neck, ASTM A182 F304L, forged, Class 150, schedule 10S bore, ASME B16.5.

Valves

19 mm (3/4") and less	Swagelok stainless steel valves.
25 mm (1") and over	Flanged valves, ASME B16.5, ASME B16.10, ASME B16.34 Class 150.

(e) <u>Governor High Pressure Oil and Governor High Pressure Compressed Air Piping</u>:

(i) *Embedded Piping*: None expected. If required, embedded piping systems will be submitted for Consent.

(ii) *Exposed Piping*:

Piping

19 mm (3/4") and less	Stainless steel, seamless tubing, plain ends, ASTM A213 TP304, 0.049" wall thickness up to 13 mm (½"), 0.065" wall thickness up to 19 mm (3/4"), fully annealed, suitable for field bending and flaring. Hardness of 90HRB (200 HV) or less.
25 mm (1") to 50 mm (2")	Seamless steel, extra strong, ends for socket welding, black, ASTM A106, Grade B.
65 mm (2-1/2") to 200 mm (8")	Seamless steel, extra strong, ends for butt welding, black, ASTM A106, Grade B.

Fittings

19 mm (3/4”) and less	Swagelok system, carbon steel, ASTM A108 (bar stock). Compression type for tube to fitting connections, and threaded type for fitting to fitting connections,
25 mm (1”) to 50 mm (2”)	Forged steel, socket welding, black, ASTM A105, Class 3000, ASME B16.11.
65 mm (2-½”) to 200 mm (8”)	Wrought steel, extra strong, butt welding, black, ASTM A234, Grade WPB, ASME B16.9.

Flanges

25 mm (1”) to 50 mm (2”)	Forged steel, socket weld, ASTM A105, Class 600, ASME B16.5.
Over 50 mm (2”)	Forged steel, welding neck, ASTM A105, Class 600, ASME B16.5.

Valves

19 mm (3/4”) and less	Swagelok stainless steel valves.
25 mm (1”) and over	Flanged valves, ASME B16.5, ASME B16.34. ASME B16.10. Class 600.

If piping larger than 200 mm (8”) is required the proposed piping system will be submitted for Review.

Instead of seamless steel piping, stainless steel piping systems may be proposed by the Contractor and submitted for Consent.

(f) Generator Thrust Bearing High Pressure Oil Injection System, and Rotor Jacking System Piping:

(i) *Embedded Piping*: None expected. If required, embedded piping systems will be submitted for Review.

(ii) *Exposed Pressure Piping*:

Piping

19 mm (3/4”) and less	Stainless steel, seamless tubing, plain ends, ASTM A213 grade TP304, rated working pressure not less than 20 MPa (-28 to 37 degrees Celsius). Fully annealed, suitable for field bending and flaring. Hardness of 90HRB (200 HV) or less.

Fittings

Swagelok system, compression type for tube to fitting connections, and threaded type for fitting to fitting connections, Stainless steel 316, ASTM A276 (bar stock) or ASTM A182 (forged).

Valves

Swagelok stainless steel valves.

(iii) *Exposed Return Piping*:

Piping	
19 mm (3/4") and less	Stainless steel, seamless tubing, plain ends, ASTM A213 grade TP304, rated working pressure not less than 20 MPa (-28 to 37 degrees Celsius). Fully annealed, suitable for field bending and flaring. Hardness of 90HRB (200 HV) or less.
25 mm (1") to 50 mm (2")	Stainless steel, schedule 10S, ASTM A312 TP304L, with ends for socket-welding
Fittings	
19 mm (3/4") and less	Swagelok system, compression type for tube to fitting connections, and threaded type for fitting to fitting connections, Stainless steel 316, ASTM A276 (bar stock) or ASTM A182 (forged).
25 mm (1") to 50 mm (2")	Forged stainless steel, socket welded, Class 3000 ASTM A182 Grade F304L, ASME B16.11.
Flanges	
25 mm (1") to 50 mm (2")	Stainless steel, socket weld, ASTM A182 Gr. F304L, forged, Class 150, ASME B16.5.
Valves	
19 mm (3/4") and less	Swagelok stainless steel valves.
25 mm (1") to 50 mm (2")	Flanged valves, ASME B16.5, ASME B16.34. ASME B16.10. Class 150.

(g) Bearing Oil Reservoir Fill and Drain Piping:

(i) *Embedded Piping*: None expected. If embedded piping is required, embedded piping systems will be submitted for Consent.

(ii) *Exposed Piping*:

Piping	
25 mm (1") to 50 mm (2")	Stainless steel, schedule 10S, ASTM A312 Grade TP304L with ends for socket welding.
Fittings	
25 mm (1") to 50 mm (2")	Forged stainless steel, socket welded, Class 3000, ASTM A182 Grade F304L, ASME B16.11.
Flanges	
25 mm (1") to 50 mm (2")	Stainless steel, socket weld, ASTM A182 Gr. F304L, forged, Class 150, ASME B16.5.
Valves	
25 mm (1") to 50 mm (2")	Flanged valves, ASME B16.5, ASME B16.34. ASME B16.10. Class 150.

(h) Fire Protection/Deluge Piping: Fire protection and deluge piping will be in accordance with Generation Technical Specification 01.20.SPEC.01 Generator Fire Protection.

3.7.4 Embedded Piping and Sleeves

(a) Embedded pipe sleeves through walls and floors will be supplied and installed by Others.

(b) Routing of piping through wall and floors may also be done through block outs or trenches, instead of pipe sleeves.

(c) With the exception of drainage piping, the use of embedded piping will be minimized. Where piping is embedded in concrete, it will be set to the required lines and grades and securely braced and held so that no movement can occur during concreting operations and it will be placed to minimise the impact on other embedments and reinforcing steel.

(d) Where pipes less than 75 mm (3") are required to be embedded in concrete, they will be protected from concrete contact with suitable sleeves. Small-bore piping such as pressure tap and control piping which cannot practically be routed through sleeves may only be embedded if mechanical protection is provided.

3.7.5 Valves

(a) General:

(i) Valves are generally classified as three types: isolating valves, control valves, and regulating valves:

Isolating valves:	isolating, or isolation, valves are primarily in the fully-open or fully-closed positions, and can be manually or power actuated. Where power actuated, they typically can only be opened and closed locally except for applications, such as difficult access, or protection against flooding, where remote activation would improve safety.
Control valves:	primarily are in the fully-open or fully-closed positions, and are power actuated. They are typically controlled remotely by a control system.
Regulating valves:	are used to regulate flow and typically can be operated at any opening from fully-open to fully-closed, and can be manually or power actuated. Where power actuated they are typically controlled remotely by a control system.

(ii) Valves, other than compression fitting, will conform to ASME B16.10 and ASME B16.34.

(iii) All requirements in SPGT 3.7.5 also apply to specialty valves such as 3-way valves, check valves, air bleeds, and vacuum breaks unless explicitly specified elsewhere.

(iv) Valves will be in accordance to the pressure-temperature ratings for the applicable Class of flanges as specified in ANSI B16.5 except where explicitly specified elsewhere.

(v) Isolation valves are to be of the same size as the pipe run in which they are installed except where explicitly specified otherwise.

(vi) Valves will be installed so that they are easily removable without significant disassembly of other equipment or cutting of pipe or welds.

(vii) Flanged valves will be used for the following applications:

(A) where specified in SPGT 3.7.3;

(B) where the valve is the closest valve to an Interface point; and

(C) where the valve is located immediately adjacent to a tank, sump, receiver, accumulator, reservoir, or other fluid containing vessel;

(viii) Non-flanged valve connections:

(A) If other types of valve connections are proposed, such as wafer style check valves, they will be submitted for Consent.

(B) Where butterfly valves are permitted, lug style butterfly valves may be used instead of flanged style. Lug style valves will be suitable for dead end service.

(b) Isolating Valves: Isolating valves will:

(i) only be used in the fully-open or fully-closed position;

(ii) be lockable, in both the open and closed position, by an acceptable method. The locking method will permit visual checking of the position of the valve while locked;

(iii) be installed at all locations necessary to operate and maintain equipment, and any other additional locations required to protect Workers during maintenance or assembly/disassembly of equipment;

(iv) for valves 75 mm (3") and less, be ball valves and for larger valves be either ball valves or eccentric butterfly valves; and

(v) be tested and "bubble tight" in accordance with API 598 for seat closure tests.

Location of isolating valves will be submitted for Review.

(c) Drain Valves: Drain valves will:

(i) be considered isolating valves;

(ii) be located at each low point in piping systems to permit draining of the piping systems by gravity;

(iii) be located downstream of each isolating valve for the purpose of both verifying the isolation valve is not leaking, and to provide safe isolation to workers;

(iv) be at multiple points in long runs;

(v) as a minimum, for piping 100 mm (4") diameter and larger have a drain and vent size that is 25 mm (1") and for piping less than 100 mm (4") diameter have a the drain and vent size that is one fourth the pipe size with a minimum size of 13 mm (½"), or the pipe size, whichever is smaller. Where drain and vent sizes have been specifically stated elsewhere, or the drain valve is part of Double Block and Bleed or Double Valve and Drain systems, the more stringent condition will apply;

(vi) for drain lines from drain valves, be routed to the nearest suitably sized drainage piping, floor drain, or oil-water separator as appropriate; and

(vii) for drain valves on oil and compressed air piping, include NPT plugs.

A common valve may be used for the low point drain and the drain valve for safe isolation to Workers.

(d) Control Valves:

(i) Control valves will be capable of repetitive operation based on a very conservative estimate of the frequency of operation.

(ii) Valves 75 mm (3”) and less will be ball valves and for larger valves be either ball valves or eccentric butterfly valves.

(iii) Control valves will be tested and “bubble tight” in accordance with API 598 for seat closure tests.

(e) Regulating Valves:

(i) Regulating valves will:

(A) be capable of continuous operation at the full range of operating conditions without cavitation or other damage;

(B) be high-quality of the globe, needle, eccentric plug, or V-ball type;

(C) not be relied upon to fully close or isolate any system; and

(D) be provided with seat leakage values in accordance with Class I of ANSI 70-2.

(ii) Regulating valves used for flow control for bearings and runner seals will have some form of precise indexing such that the regulating valve opening can be accurately determined.

(f) Ball Valves:

(i) Ball valves 25 mm (1”) and larger will have a split or 3-piece body.

(ii) Ball valves 19 mm (3/4”) and less will be Swaglok series 60 (stainless steel 316) with RPTFE seats.

(g) Materials: Unless specified explicitly elsewhere the valve materials will be as follows:

Valve bodies:		
	greater than 75 mm (3”)	Materials and corrosion protection suitable for long life in the operating environment
	75 mm (3”) and less	Stainless steel
Ball/disks/stems:		Stainless steel
Seat/seals:		As recommended by the valve manufacturer for the application

(h) Valve Operators and Position Indication:

(i) Valves will be provided with a manual operator, whether power actuated or not.

(ii) Where required, chain operators will be stainless steel, and will be supplied with hooks to secure them in convenient, acceptable locations.

(iii) Where solenoid operators are used, they will be powered by 125 Vdc unless otherwise specified.

(iv) Where pneumatic operators are provided they will be spring return such that if there is a loss of compressed air the valve moves to the safest position.

(v) Where electric or solenoid operators are used to perform a control function they will be spring loaded such that upon loss of power the valve moves to the safest position.

(vi) Valve actuators will be sized based on the worst-case operating condition, including:

(A) the maximum torque capacity of the valve. Bearing surfaces in the body yoke and cover will be designed to eliminate side thrust on the valve stem; and

(B) ensuring the valves do not get stuck due to effects of corrosion or silting, but will not damage the valve when extra force is required to open/close the valve.

(vii) Where isolating valves are to be power-actuated, electric operators will be provided.

(viii) Isolating and control valves that are power actuated will have adjustable limit switches to indicate both the open and closed positions.

(ix) Where regulating valves are to be power actuated, pneumatic or electric operators will be provided.

(x) Operators will have indicators that clearly indicate valve fully open and valve fully closed positions.

(xi) Regulating valves that are power actuated will:

(A) be controlled by a 4-20 mA position input signal, using a 24 Vdc power supply, scaled such that if there is a power loss the valve moves to the safest position;

(B) have a 4-20 mA position transducer scaled such that 0% to 100% open corresponds to the full 4-20 mA output range; and

(C) have a visual position indication scale.

(xii) In addition to the power actuated valves specified elsewhere, as a minimum, the following valves will be power actuated:

(A) Unit cooling water control valve (on the water supply feed to the Unit cooling system);

(B) Generator cooling water flow regulating valve(s);

(C) Synchronous condenser main depression and maintenance air valves;

(D) Synchronous condenser exhaust air valve;

(E) Turbine air admission valve(s);

(F) Runner seal cooling water valve(s);

(G) 3-way valves for the generator heat recovery system;

(H) Generator deluge valve; and

(l) Large penstock drain valve.

A complete listing for power actuated valves will be submitted.

3.7.6 Pipe and Valve Support Systems

(a) The Work includes provision of pipe and valve support systems and concrete anchors.

(b) Pipe and valve support systems will be of corrosion-resistant material, and will be galvanically isolated where the support system and associated piping are of dissimilar materials.

(c) Unistrut will be used for supporting piping systems where the loading is within the Unistrut capability.

(d) Unistrut will be installed flush in the concrete surface where practical.

(e) Unistrut Unicushion isolation material will be placed between the pipe or valve and any pipe or valve support or anchor at the point of contact.

(f) Support systems, including auxiliary members and accessories, will be hot dip galvanized.

3.7.7 Flanged Joints

(a) For carbon steel flanges, bolting will consist of heavy hexagonal ASTM A193 B7 Class bolts and heavy hexagonal ASTM A194 2H nuts.

(b) Fasteners and washers will be stainless steel if one or both flanges are stainless steel.

(c) Two Type A plain washers will be used for each bolt and the washer material will be the same as the flange material.

(d) Bolted flange joint assemblies will be installed in accordance with ASME PCC-1, Guidelines for Pressure Boundary Bolted Flange Joint Assembly.

(e) Fasteners for flange-bolted connections will appropriately tightened using calibrated equipment. As a minimum, a torque wrench will be used.

(f) Flanges will be of the raised face type. Bolt holes will straddle centrelines.

(g) Bolts, studs and nuts will be lubricated.

(h) For stainless steel nuts and bolts, an anti-seize compound, specifically manufactured for use on stainless steel fasteners to eliminate galling, will be used.

3.7.8 Threaded Joints

Where threaded joints occur, such as for pressure gauges, instrumentation, pipe plugs, etc., they will meet the following requirements:

(a) pipe threads will be NPT;

(b) pipe threads will be cut full and will be free from torn or ragged surfaces;

(c) minimum thread engagement will be according to ASME B1.20.1;

(d) threaded joints will be made up with joint compound. Stainless steel threaded joints will be made using an accepted anti-seize compound specifically manufactured for use on stainless steel pipe threads to eliminate galling; and

(e) the use of thread cement or caulking of threaded joints to stop or prevent leakage is not acceptable.

3.7.9 Compression Fitting Joints

(a) Fittings for stainless steel tubing will be Swagelok. Fitting materials will be as recommended by Swagelok. No substitutions are permitted.

(b) The preparation of tubing will be in accordance with the recommended Procedures of the manufacturer of the fittings. Tube ends will be cleaned thoroughly to remove foreign matter before assembly.

(c) Tube bending is preferred; elbow fittings will only be used where tube bending is not possible. Bending will be done in accordance with manufacturer's instructions.

3.7.10 Victaulic Couplings

(a) Only Victaulic® Style 89 couplings will be used.

(b) Victaulic flange adapters or similar will not be used.

(c) Victaulic couplings will only be used for pipe to pipe connections and fittings.

(d) Victaulic couplings are not permitted for valves or equipment connections.

(e) Victaulic coupling will be either stainless steel or galvanized steel.

(f) When selecting Victaulic couplings, the pressure rating of the installed coupling will be equal or greater than the test pressure of the system in which it is installed.

(g) Pipe and fitting ends will be grooved in accordance with Victaulic's current listed fabrication Procedures considering the pipe material, wall thickness, pressure, size, and method of joining.

(h) Mechanical couplings, fittings, piping items, and materials will be installed in accordance to Victaulic Field Installation Handbook.

(i) Pipe fitters/installers will be certified by Victaulic in the correct method of grooving and installing pipe for use with the specific coupling system to be used.

(j) Grooved joints will be measured and inspected to ensure compliance with the grooved piping dimensions in the Victaulic Field Installation Handbook. Note that, "off the shelf" Victaulic fittings/components come pre-grooved with Victaulic proprietary groove dimensions and do not need to be re-measured at Site.

(k) Shop and Site fabricated grooves of pipe are to be measured and documented prior to installation. Out of tolerance grooved piping and fittings will not be installed.

(l) Grooving machine roll sets used for roll grooving on stainless steel pipe will be specified by Victaulic for use on stainless pipe. These roll sets will not be used on non-stainless pipe.

(m) Hydraulic roll cutters are not to be used for cutting light wall stainless pipe unless specifically designed for this service.

(n) Victaulic couplings will not be used for any piping above the Generator.

(o) The Work includes:

(i) submission installation and QA Procedures prior to the start of any work on Victaulic couplings.

(ii) providing the tools required for grooving the pipe. The tools will meet the requirements of Victaulic for acceptable grooving as found in the Victaulic Field Installation Handbook.

3.7.11 Gaskets

(a) Gasket thickness will not exceed 2 mm.

(b) Full-face gaskets will be used for flat-faced flanges in accordance with ANSI/ASME B16.21.

(c) Flat ring-type gaskets will be used for raised-face flanges in accordance with ANSI/ASME B16.21.

(d) Gasket materials for flanged connections will be suitable for the temperature, pressure, and corrosiveness of the fluid conveyed in the pipeline.

(e) Grooved joint gasket materials will be as recommended by the coupling manufacturer for the temperature, pressure, and corrosiveness of the fluid conveyed in the pipeline. Unless otherwise specified, flush seal type gaskets will be provided for grooved-joint systems.

3.7.12 Piping Execution, Prefabrication, and Site Connections

(a) Prior to assembly, all piping materials and items will be clean and free from foreign matter. Care will be taken to prevent foreign matter from entering the piping during installation. When sections of pipe are not actively being worked on, open ends will be plugged or otherwise closed. Pipe ends for connection at a later date will be safely protected and secured by providing pressure-rated and air-tight caps, covers, plugs, or blind flanges until the connections are made.

(b) The Work includes taking such measurements as are necessary to verify the Work does not interfere with other equipment and structures. In the case of conflicts with work by Others, Hydro’s Representative will decide which contractor has precedence.

(c) Piping systems will be shop fabricated into assemblies to the extent permitted by shipping and installation limitations. Welding in the Powerhouse will be minimized, but only so much as to not adversely affect constructability of the system.

(d) After cutting, pipes will be reamed, burrs and burns removed, and there will be no distortion or necking of the pipe due to the cutting process.

(e) Prior to shipment:

(i) flange faces will be protected with a plastic insert or plywood cover to protect the face from damage;

(ii) pipe openings will be plugged or covered to protect from contamination or damage; and

(iii) any uncoated steel pipe will be internally and externally treated with a rust-inhibiting coating.

(f) Temporary supports for use during installation will be clearly marked for removal before start up.

3.7.13 Anti-Condensation Insulation

(a) Exposed raw water piping, cooling water supply and return piping, drainage piping that has continuous flow, and associated piping equipment, such as fittings, flanges, valves, strainers and filters, flow meters, etc. will be covered with anti-condensation insulation and as recommended by the insulation manufacturer, except for:

(i) Generator air cooler piping inside the temperature regulated area of the Generator Enclosure and providing it does not pass over any electrical equipment; and

(ii) Turbine bearing and Turbine shaft seal cooling water piping located inside the headcover.

(b) All materials will be listed in the BCICA Quality Standards for Mechanical Insulation Manual (QSMIM) as acceptable materials for application on piping.

(c) Insulation will be pre-formed pipe insulation with integral vapour barrier. Mineral fibre or fibre glass type materials are acceptable.

(d) The minimum insulation material thickness will be the greater of the thickness expected to prevent condensation under all expected ambient conditions in the powerhouse or the following:

(i) up to and including 75 mm (3”) pipe 12 mm thick; and

(ii) 100 mm (4”) pipe and larger 25 mm thick.

(e) Insulation for fittings and flanges will be pre-formed moulded insulation.

(f) Insulation for valves will be pre-formed sections as far as practicable.

(g) Service jackets will be complete with integral self-seal lap.

(h) Jackets will be pre-coloured PVC, minimum 0.76 mm (30 mils) thickness. Colours will be in accordance with BC Hydro ES 31-Q0021.

(i) As a minimum, insulation will meet the requirements of ASTM C547 Type 1 (up to 454 ^{o}C (850 F)).

(j) Insulation applied over stainless steel will comply with the requirements of ASTM C795.

(k) Insulation materials, including jackets, mastic, tape, vapour retarder, will meet or exceed fire hazard classification 25/50 for flame spread/smoke developed. Flame spread rating and smoke developed classification of a material will be determined in accordance with CAN/ULC-S102.

(l) Where banding is used for attachment of insulation, the bands will be stainless steel 12.7 mm (0.5 inch) wide by 0.48 mm (0.019 inch) thick.

3.7.14 Anti-Condensation Insulation Installation

(a) The Work includes:

(i) applying a PVC jacket over the pipe insulation using fasteners and jacket finishing tape. Installation will achieve a 100% vapour closure. No PVC jacket will be applied without the prior written confirmation of Hydro’s Representative following inspection of the insulation installation; and

(ii) insulation of valve bodies and bonnets with fitted over-sized pipe covering or mitred blocks to thickness of adjacent pipe covering with every joint sealed.

(b) Insulation will be applied after all installation and testing Work has been completed and accepted.

(c) Insulation materials will be applied in accordance with BCICA QSMIM 1501 C for Cold Piping Cold Application and manufacturer’s requirements and the Specifications.

(d) Insulation will be applied with all joints fitted to eliminate voids.

(e) At pipe supports, the insulation will be fitted and sealed to the supports. Pre-formed insulation will be neatly cut to accommodate pipe supports.

(f) There will be a minimum of 25mm (1.0 inch) clearance between the outside of the insulation and any adjacent piping, equipment, walls, ceilings or other obstructions.

(g) For strainers, filters, flow meters, valves, and valve bonnets, the insulation will be installed, secured and sealed such that it is easily removable and provides access for maintenance without the necessity of removing the insulation on the adjacent piping.

(h) Removable sections of insulation will be provided in the cooling water piping system, at locations to be determined by Hydro's Representative, for the purpose of independent flow measurement, by BC Hydro, using a portable ultrasonic flow meter, and for inspection of the piping. The insulation will be able to be removed without damage.

(i) The equipment identification will be visible without removing the insulation.

3.8 Welding

3.8.1 General

(a) Standards:

(i) Subject to SPGT 3.8.1(a)(ii) and SPGT 3.8.1(a)(iii), welding will be in accordance with ASME BPVC Section VIII Division 1, ASME B31.1, or CSA Standard W59 as applicable to the Equipment and as submitted.

(ii) For structural welding of stainless steel, not including Turbine components covered by the above standards (such as the runner), AWS D1.6/AWS D1.6M will apply.

(iii) Welding of aluminum will be in accordance with CSA Standard W59.2.

(b) Symbols: Welding symbols will be as shown in AWS A2.4.

(c) Preparation for Coatings: Welds subject to coating will be thoroughly cleaned and present a smooth surface free from weld spatter and sharp edges.

3.8.2 Pipe Welding

(a) Welding of branches, headers, bends, etc., will be done in the shop to the extent possible.

(b) Temporary attachments made at Site will be fastened by fillet or butt welds and these welds will meet the same quality requirements as the main welds. Tack welds will only be permitted if they are incorporated in the main welds.

(c) Welds will be thoroughly cleaned and present a smooth surface free from weld spatter.

(d) Piping buttwelds will be full penetration. Backing rings will not be used for piping buttwelds.

(e) Stainless steel welds will:

(i) be pickled and passivated in accordance with ASTM A380 and ASTM A967 to the extent possible;

(ii) prior to any pickling or passivation treatment, oil, grease and other contaminants will be removed from stainless steel parts;

(iii) after sufficient pickling time has elapsed, the treated surface will be cleaned of acids by thoroughly rinsing with deionised water; and

(iv) any weld that cannot be pickled and passivated will be approved.

3.8.3 Welding Specifications

The Work includes submittal of welding specifications for all Equipment provided as part of the Work. The welding specifications will include:

(a) specifications for welding in the Contractor’s facilities (and the Contractor’s sub-Contractor’s facilities if applicable);

(b) specifications for welding on Site;

(c) requirements for:

(i) materials;

(ii) process and performance qualification;

(iii) monitoring of process, repair, non-destructive testing;

(iv) and quality records to assure the quality of the welding; and

(d) justification for any exclusion from the applicable codes or standards.

3.8.4 Welding Techniques

(a) General: The Contractor will be responsible for determining and developing proper techniques to be used in its welding operations, including preheating and any special welding techniques that may be necessary to ensure that the mechanical properties of the steel and weld metal in the welded and stress relieved condition are the same as for un-welded steel. The welding sequence will be designed to keep shrinkage and residual stresses to the minimum possible values.

(b) Weld Procedure Qualifications: Welding Procedure qualification tests will include impact tests if impact tests are required for base metals. The weld Procedure qualification will include impact (Charpy) test in accordance with ASTM E23 and A370. The average energy at -18°C will not be less than 34 Joules with a minimum of 27 Joules for any specimen.

BC Hydro may witness weld Procedure qualification tests.

(c) Inclement Weather: The Procedures for inclement weather recommended in paragraph UW 30 of the ASME BPVC Code, Section VIII, Division 1, and Sections 5.1.1 and 5.1.2 of CSA W59 will be mandatory. For welding of aluminum, the Procedures for inclement weather and cleaning required in Sections 5.1.5 and Appendix C5 of CSA W59.2 will be mandatory.

No welding will be conducted when the ambient temperature is below 10°C unless all surfaces with a radius of 75 mm of the area to be welded are pre-heated to a minimum of 38°C and maintained at the temperature during the rest of the operation.

3.8.5 Welding Procedures, Operators and Welders

Each welding operator and welder will have up to date welding certificates for the various techniques and positions used in the Work. For welding according to CSA W59, welding procedures and personnel will be qualified in accordance with CSA W47.1. For welding according to CSA W59.2, welding procedures and personnel will be qualified in accordance with CSA W47.2.

If, in the opinion of Hydro's Representative, the Work of any operator or welder appears questionable, such operator or welder will be required to pass another qualification test. If the Work of any operator or welder is shown to be repeatedly unsatisfactory by radiographic or other inspection, the Contractor will replace him with a qualified operator or welder.

3.8.6 Welding Materials

(a) Stainless Steel: Stainless steel members will be welded with stainless steel electrodes.

(b) SMAW Process: For SMAW processes, low hydrogen welding rods will be used. Flux will remain in its sealed bag in a dry environment prior to use. If moisture is suspected of being absorbed, then either discard or bake flux on shallow trays at 400°C for a minimum of one hour.

(c) Aluminum: For welding of aluminium, welding filler materials will be in accordance with AWS Standard A5.10.

3.8.7 Temporary Welds

Temporary attachments made at Site will:

(a) be fastened by fillet or butt welds; and

(b) meet the same requirements as the permanent welds.

Tack welds will only be permitted if they are incorporated in the main welds or completely removed later.

3.8.8 Welded Joints

Full penetration welds will be:

(a) back gouged to sound metal;

(b) inspected by magnetic particle or liquid penetrant; and

(c) back welded to achieve full penetration.

3.8.9 Records

The Contractor will retain welding records in accordance with applicable codes of the Equipment to confirm that the welding is conducted according to welding specifications and the quality of welding is achieved. Upon request by BC Hydro, the Contractor will submit the welding records. If a Welding Procedure Specification (WPS) is specifically requested, the Contractor will also submit the corresponding Procedure Qualification Record (PQR) and a weld map to show the location of the weld that the WPS applies to.

All welding records will be included in the Final Quality Report submitted.

3.8.10 Repairs

Where repair by welding is required, a repair weld Procedure will be submitted. Weld repair for piping will be performed in accordance with ASME B31.1.

Welding imperfections for which corrective treatment is required will be repaired to the satisfaction of Hydro's Representative.

Unacceptable defects in welds will be gouged out to sound metal and magnet particle or liquid penetrant tested in order to ensure that the defect has been completely removed prior to making the repair.

Repaired welds will be ground to eliminate any abrupt changes in surface or contour.

Where grinding is employed, the surface imperfections will be removed by grinding in such a manner as to provide smooth contours with a curvature of not less than 10 mm radius in either the convex or concave direction. Care will be taken to prevent local overheating of the metal during grinding.

3.8.11 Post Welding Treatment

(a) Stress Relief: Stress relief heat treatment will be executed on pressure components or large machined weldments unless otherwise not recommended by codes and material standards.

3.8.12 Welding Inspection

(a) General: The Contractor will be responsible for welding inspection, including visual inspection and non-destructive examination (NDE).

NDE will:

(i) subject to SPGT 3.8.12(a)(ii), be conducted in accordance with codes and standards as required by ASME BPVC, Section VIII, Division 1, ASME B31.1, CSA Standard W59, or AWS D1.6, as applicable to the Equipment;

(ii) for aluminum, be conducted in accordance with Section 7.4 of CSA W59.2; and

(iii) be conducted after final heat treatment of the Equipment.

The Contractor will submit NDE Procedures and Reports.

The extent of weld inspections will be based on each welding operator.

(b) Inspection and Test Plans: Welding inspection and testing, including any non-destructive tests, will be specified in specific equipment Inspection and Test Plans (ITPs).

(c) Weld Inspection: Weld inspection will be conducted, as a minimum, in accordance with the following requirements unless otherwise specified. The location of such inspection will be at the discretion of Hydro's Representative:

	Type of Weld	Type of Inspection	Extent of Inspection
A	Groove weld on butt joint (for pressure vessels and the following water passage components: spiral case, stay ring, closure section, flexible coupling, and penstock spool piece)	Radiographic	100%
B	Groove weld on tension butt joint (for components not listed in A or otherwise specified elsewhere)	Ultrasonic	100%
C	Groove weld on compression butt joint (for components not listed in A or otherwise specified elsewhere)	Ultrasonic	10%
D	Groove weld on joints not suitable for radiographic inspection	Ultrasonic	100%
E	All other welds	Magnetic Particle or liquid penetrant	20%
F	All welds	Visual	100%

(d) Piping Weld Inspection

(i) Visual inspection: Welds will be visually inspected in addition to the requirements below.

(ii) Full penetration welds: Full penetration welds on piping will be subject to radiographic examination in accordance with the table below:

Type of Weld	Type of Inspection	Extent of Inspection
Carbon steel and stainless steel butt welds, welded in position during installation	Radiographic	100%
Carbon steel and stainless steel field modified pipe (example: field fabricated wye or tee connections)	Radiographic	100%
Carbon steel (shop welded)	Radiographic	20%
Carbon steel (field welded)	Radiographic	20%
Stainless steel (shop welded)	Radiographic	25%
Stainless steel (field welded)	Radiographic	40%
Compressed air lines	Radiographic	100%

(iii) Fillet welds: Fillet welds will be inspected by:

(A) magnetic particle examination on ferromagnetic materials, and

(B) liquid penetrant examination on non-ferromagnetic materials.

(iv) Extent of inspection on fillet welds:

(A) on non-compressed air piping a minimum of 25% of fillet welds will be inspected.

(B) on compressed air piping all fillet welds will be inspected.

(v) Inspection of welds on piping that was not pressure tested: Welded connections that cannot be hydrostatically tested or leak tested in accordance with SPGT 5.3.3 will be subject to 100% examination by the methods listed above.

(e) Inspection before Delivery to Site: For welding inspection during fabrication before the Equipment is delivered on Site, visual inspection will be conducted by a minimum Level 2 inspector qualified to CSA W178.2, or AWS QC1, NDE will be conducted by a minimum Level 2 NDE Operator qualified to CAN/CGSB 48.9712, or ISO9712.

(f) Inspection at Site: Welding inspection on Site will:

(i) be performed by an independent company certified to CSA W178.1 that is engaged by the Contractor and accepted;

(ii) for visual inspections, be conducted by a minimum Level 2 inspector qualified to CSA W178.2;

(iii) for NDE inspections, be conducted by a minimum Level 2 NDE Operator qualified to CAN/CGSB 48.9712;

(iv) for butt welds on the Turbine spiral case, Turbine flexible coupling, closure piece, and penstock spool piece installed in position on Site, be radiographed with 100% coverage, and;

(v) for welds on the Turbine stay ring, be radiographed or otherwise checked by non-destructive testing with coverage, method and acceptance criteria to be submitted;

(g) Visual Inspection Reports: Visual inspection Reports will be prepared to confirm that all welds have been 100% visually inspected in accordance with applicable codes and standards.

(h) Non-conformances: Where weld inspection reveals a defect during the random examination of a portion of welds, then the Progressive Sampling for Examination procedure in ASME B31.3 will be followed.

For welds previously inspected by the Contractor and deemed to conform, will subsequent random and independent inspection identify non-conformances, BC Hydro reserves the right to increase the level of NDE surveillance. The costs for the additional NDE inspections will be incurred by the Contractor.

3.9 Painting and Protective Coatings

3.9.1 General

(a) Scope: The Work includes all materials, equipment, skilled labour and work supervision for the surface preparation, painting (including touch-up), protection and drying of all Equipment supplied under this Contract and in accordance with this Appendix 6-2 [General Technical Specifications (SPGT)].

(b) Grade: Except as otherwise provided, the Contractor's standard coating system will be acceptable for commercial grade equipment (non-customer designed) such as: fractional horsepower motors, contactors, gauges, pressure switches, etc., provided the dry film thickness of the finish coat will be at least 50 µm.

(c) Surface Preparation and Application: All surface preparation and coating applications will be inspected by a minimum Level II NACE certified coatings inspector with records retained to verify conformance with this Appendix 6-2 [General Technical Specifications (SPGT)].

(d) Safety and Health: For safety and health requirements associated with coatings, Schedule 10 [Safety] applies.

(e) Environment: For environmental requirements associated with coatings, Schedule 7 [Environmental Obligations] applies.

3.9.2 Coating Specifications

The Work includes submission of coating specifications for all Equipment provided as part of the Work. The coating specifications will consider Equipment design and operational conditions, required service life, a minimum of fifteen (15) years durability of the coating before the first major maintenance, and protection of the Equipment from corrosion during handing, shipping, and storage. The coating specifications will include:

(a) specifications for all coatings for custom designed Equipment;

(b) specifications for all coatings applied on Site;

(c) applicable:

 (i) codes and standards;

 (ii) coating systems, including finish coats (and colour samples);

 (iii) coating schedules for the Equipment;

 (iv) inspection and testing requirements; and

 (v) requirements for quality documentation.

3.9.3 Standards and Codes

The following standards and codes apply:

SSPC-PA1	Shop, Field and Maintenance Painting of Steel
SSPC-PA2	Procedure for Determining Conformance to Dry Film Thickness Measurements
SSPC-SP1	Solvent Cleaning
SSPC-SP2	Hand Tool Cleaning
SSPC-SP3	Power Tool Cleaning
SSPC-SP6	Commercial Blasting Cleaning
SSPC-SP7	Brush-off Blast Cleaning
SSPC-SP8	Pickling

SSPC-SP10	Near White Metal Blasting Cleaning
SSPC-SP11	Power Tool Cleaning - To Bare Metal
NACE SP 0188	Discontinuity (Holiday) testing of Protective Coatings
ASTM-D3276	Recommended Practice Guide for Paint Inspectors
ASTM-D3359	Method for Measuring Adhesion by Tape Test

3.9.4 Materials

(a) General: All materials used for coatings, including thinners, will be from the same manufacturer and same batch. Materials for the primer and top coats will be compatible in accordance with the paint manufacturer specification. The materials will not have exceeded their shelf life or 1 year since the date of manufacture, whichever is less.

(b) Blast Cleaning Abrasives: All proposed abrasives will be submitted for Review and be capable of producing a 50 μm (2.0 mils) to 75 μm (3.0 mils) high-density angular profile and meet SSPC-SP10 (near white metal) requirements for degree of surface cleanliness.

(c) Markings: All paint materials will be delivered in the manufacturer's original containers marked with the:

(i) manufacturer's name;

(ii) designated name of the product;

(iii) colour;

(iv) date of manufacture; and

(v) batch number.

Such information will be legible at the time the material is used.

(d) Storage: All materials will be properly stored and protected from detrimental exposure.

(e) Acceptable Coating Materials: The following are acceptable coating materials:

International Paints:	
Primer:	Interseal 670HS Intergard 264 Interline 925 Interzinc 52
Topcoat:	Interthane 990
ICI Devoe:	
Primer:	Cathacoat 313 Bar-Rust 233, 235 and 236
Topcoat:	Bar-Rust 233HS Devthane 379 UVA

Carboline:	
Primer:	Carbomastic 90 Carboguard 890
Topcoat:	Carbothane 134 Carboguard 890

Acceptable coatings for oil immersion service are:

International Paints:	Interline 850
ICI Devoe:	Bar-Rust 236 Devchem 253
Carboline:	Plasit 9060

Acceptable coatings for carbon steel piping exterior are:

International Paints:	Primer: Interseal 670HS Topcoat: Interseal 670HS
ICI Devoe:	Primer: Bar Rust 236 Topcoat: Bar Rust 236
Carboline:	Primer: Carboguard 890 Top Coat: Carboguard 890

Acceptable removable rust preventative shop coatings are:

(i) for runners and wicket gates: Rust Veto 342 or 344 from Houghton.

For all other applications, removable rust preventative shop coatings will be submitted for Review.

(f) Other Coatings Systems: Other coating systems proposed by the Contractor will be submitted for Review.

3.9.5 Execution

(a) General: The application of all coating materials will be performed in accordance with SSPC-PA1 for shop and Site painting. All coatings will:

(i) be applied in accordance with the manufacturer's data sheets;

(ii) be thinned only when necessary for proper application and then only in accordance with the manufacturer's recommendations; and

(iii) not be applied over damp steel or over previous coats that have not sufficiently dried.

The dried film will be smooth and continuous, free from overspray, sags, runs, pinholes and other film defects. Dry spray will be kept to a minimum by using proper spray practices. Excessive dry spray will be removed.

(b) Temperature: The ambient air temperature and steel substrate temperature will be not less than 5°C or the lowest temperature recommended by the paint manufacturer (whichever is higher) and the substrate temperature will be at least 3.0°C above the dew point.

(c) Relative Humidity: The relative humidity will be less than 85% during coating application and curing.

(d) Pot Life: The coating manufacturer's recommended pot life will not be exceeded. If the pot life is exceeded, the remaining material will be discarded and a new paint batch prepared.

(e) Surfaces Not to be Painted: The following surfaces will not be coated and will be protected by appropriate and adequate masking during the cleaning and painting of adjacent areas.

(i) stainless steel surfaces;

(ii) rotating or sliding machined surfaces;

(iii) metal surfaces in contact with concrete except for the spiral case; and

(iv) plastic and other non-metallic components.

(f) Treatment of Surfaces Not to be Painted: Unless otherwise noted, all unpainted surfaces (including stainless steel surfaces) not in contact with concrete, will be protected with a rust preventative compound for protection during shipment and storage but removable during installation.

(g) Surface Preparation:

(i) *Solvent Washing*: All grease and oil will be removed from surfaces to be coated by solvent washing or other suitable methods, in accordance with SSPC-SP1, prior to abrasive blast cleaning.

(ii) *Abrasive Blast Cleaning*: All weld splatter, sharp edges, protrusion, and delamination will be removed by grinding or chipping before blast cleaning. Surface features that are difficult to properly protect by paint alone such as deep pits and rivets may require filling with a 100% solid epoxy filler prior to coating. Once the filler has adequately dried, the surface will be abrasive blasted prior to coating.

All compressed air used for blasting and spray application will be free of moisture and oil. Suitable air filters and traps will be installed on all blasting pots and spray equipment to completely remove oil and water.

All abrasive medium will be free of grease. Samples from each lot must be immersed in clean water to test for grease. Oil on the water surface will be cause for rejection of that lot of blasting medium.

All surfaces to be painted will be cleaned to a SSPC-SP6 finish for non-immersion service environments and to a SSPC-SP10 finish for immersion in oil or water, and for all pressure vessels. The resulting surface profile will be 50 μm (2.0 mils) minimum to 75 μm (3.0 mils) maximum.

(h) Coating Application:

(i) *Priming*: Prior to coating application, all dust and residual blast cleaning abrasive will be removed by dry compressed air blast and/or vacuuming. All nuts, bolt heads, sharp edges, and welds will first be stripe coated by brush to ensure complete coverage. The coating will be applied into all crevices and corners, and all runs and sags will be brushed out in order to ensure no air pockets, voids, or excessive build-up. All coats of paint will be applied within the maximum recoat interval as specified by the manufacturer's datasheets.

The first priming coat will be applied as soon as possible after blast cleaning. The prepared surface may be left uncoated as long as no surface contamination or rust bloom occurs. Any areas that show signs of rusting or contamination will be re-blasted or re-cleaned to the specified standard.

Measurements of the primer Dry Film Thickness (DFT) will be taken to confirm the required amount of coating has been applied prior to top-coating application.

(ii) *Priming of Site Welded Joints*: To facilitate the welding required at Site, primer application will be stopped approximately 75 mm from the edge of the plates prepared for welding. This unpainted portion will be protected by application of the specified removable rust preventative.

(iii) *Top-coating*: Once the priming has been completed and accepted, all areas to be top-coated will be conducted in accordance with painting schedule. All edges, bolts, nuts, corners, etc., will be stripe coated before application of the spray body coat.

The Contractor will ensure the topcoat is applied within the primer overcoat window as specified in the manufacturer's datasheets.

(iv) *Site and Touch up Painting*: All surfaces required to be coated at Site including unpainted welded and bolted Site joints as well as any damaged painted areas, will be restored by painting to the same degree as the original coating or adjacent coating.

Any damaged coatings will be removed back to where the original paint is well adhered. The edge between the intact and damaged area will be feathered by sanding with 80 grit sandpaper to provide a rough patch for the new coating. Sanding of the intact coating will extend a minimum of 13 mm onto intact coating and the area solvent-wiped prior to coating application. If the substrate has corroded, the exposed steel will be cleaned of all corrosion products to bare steel in accordance with SSPC-SP2, SP3 and/or SP11. Power wire wheel will not be used as a final method because doing so will leave a polished finish. The coatings applied will be as stipulated in this Appendix 6-2 [General Technical Specifications (SPGT)].

Galvanizing touch-up will be in accordance with ASTM A780. Any damaged coating areas will be mechanically cleaned before the galvanizing touch-up can be applied.

(i) <u>Surfaces Exposed to Water</u>: The following requirements will apply for surfaces continuously or intermittently exposed to water including such areas as the spiral case, penstock spool piece section, closure section and flexible coupling, draft tube liner, or the headcover:

(i)	First coat:	zinc-rich primer:	DFT:	50-75 µm (2-3 mils);
(ii)	Second coat:	high-solid epoxy:	DFT:	150-200 µm (6-7.5 mils);
(iii)	Third coat:	high-solid epoxy:	DFT:	150-200 µm (6-7.5 mils).

The painting of the water passages of the spiral case, penstock spool piece section, closure section and flexible coupling, draft tube liner, and stay ring will be conducted after assembly welding is completed on Site.

(j) Surfaces Exposed to Oil: The interior of oil piping will be pickled in accordance with SSPC-SP8. For other surfaces continuously or intermittently exposed to oil including such areas as the bearing oil reservoir, bearing cover, and oil tank, the following requirement will apply: 2 to 3 coats of high-solid epoxy for total DFT of 250-350 µm (10-14 mils).

(k) Carbon Steel Piping Exterior: The following requirements will apply for the exterior of carbon steel piping:

(i) First coat: high-solid epoxy: DFT: 100-150 µm (4-6 mils);

(ii) Top coat: high-solid epoxy: DFT: 100-150 µm (4-6 mils).

(l) Spiral Case Surfaces Embedded in Concrete: For spiral case surfaces embedded in concrete, the following requirements will apply:

(i) First coat: metallic zinc-rich epoxy primer: DFT: 50-75 µm (2-3 mils).

(m) Surfaces Exposed to an Indoor Environment: For surfaces exposed to an indoor environment, such as the Generator stator frame, Generator rotor spider, etc., the following requirements will apply:

(i) First coat: high-solid epoxy: DFT: 50-75 µm (2-3 mils);

(ii) Second coat: high-solid epoxy: DFT: 150-200 µm (6-7.5 mils).

(n) Surfaces Exposed to an Outdoor Environment (the Weather): For surfaces exposed to and outdoor environment (the weather), the following requirements will apply:

(i) First coat: zinc-rich primer: DFT: 50-75 µm (2-3 mils);

(ii) Second coat: high-solid epoxy: DFT: 150-200 µm (6-7.5 mils); and

(iii) Third coat: Urethane: DFT: 75-125 µm (3-4.5 mils).

(o) Concrete Floors: Floor coatings will be water-based low-odour epoxy.

(p) Concrete Walls: Walls coatings will be water-based acrylic system.

(q) Surfaces Hot-Dip Galvanized:

(i) Surface preparation prior to galvanization will be to SSPC-SP8 or SSPC-SP6;

(ii) unless specifically mentioned to the contrary, iron and steel will be galvanized in the factory after shop fabrication is completed. The zinc coating will be uniform, clean, smooth and as free from spangle as possible;

(iii) galvanizing will:

(A) follow ASTM A 641M for steel wires;

(B) be hot-dip zinc coated following ASTM 653M, commercial grade (CS), Type B, coating designation G90 for doors and door frames; and

(C) follow ASTM A123 or A153 as applicable for all other parts;

(iv) the preparation for galvanizing and the galvanizing itself will not distort or adversely affect the mechanical properties of the materials;

(v) special treatment during galvanizing will be applied to prevent the formation of “white rust” during shipment or storage; and

(vi) all hot-dip galvanized metal surfaces to be painted will be solvent cleaned, including abrasive cleaning of welds, and a second solvent cleaning performed if necessary prior to finish coat application. All surfaces will be inspected prior to coating application.

3.9.6 Colour

The colour of the finish coats will be provided by BC Hydro. The Contractor will provide colour samples for all finish coats prior to the start of painting.

Where multiple coats are applied, each coat will have a different shade.

Colour code for piping will be in accordance with BC Hydro ES 31–Q0021.

The colour of the coating for all components within the water passage, including the underside of the Turbine headcover will be off white.

3.9.7 Inspection and Testing

(a) Inspection and Test Plans: The Contractor will submit Inspection and Test Plans (ITPs) for all Equipment coated prior to shipment to Site and will submit separate ITPs for all coatings applied to the Equipment on the Site. The plans will include or cover the following:

(i) surfaces and locations of the components to be painted;

(ii) painting schedule;

(iii) surface preparation;

(iv) ambient and surface conditions;

(v) mixing of paint;

(vi) thickness measurement for each paint coat;

(vii) visual inspection to verify that the coating is free from pinholes, sags runs and other coating defects;

(viii) adhesion check;

(ix) holiday test, if applicable; and

(x) test methods and frequencies, acceptance criteria.

(b) Surface Preparation: At the request of Hydro's Representative, the Contractor will submit satisfactory evidence that the surface preparation blast profile meets the requirements of the Specifications. This evidence may be presented using commercially available surface texture measuring Testex tape.

(c) Inspection of Completed Work: Inspection of the completed Work will be made with the use of a suitable magnetic type film thickness gauge in accordance with SSPC-PA2 and a Holiday detector for immerged surfaces in accordance with NACE SP 0188 section 4 High-Voltage Spark Testing. Thickness measurements will be performed over the entire painted surface of the Work.

(d) Defects: Defects will be repaired to the satisfaction of Hydro's Representative. If more than five coating defects are found in 10 square metres, Hydro's Representative may require recoating of the entire defective area. If necessary, removal of the previous coating may be required at the expense of the Contractor.

(e) Spot Checks: At the discretion of Hydro's Representative occasional small spot checks for adhesion will be performed. These checks will be made in accordance with ASTM Standard D-3359, method A or B, as applicable. Level 3 is the minimum acceptance level for this test. Such test areas will be repaired as part of the Work.

3.10 Fire Stopping and Fire-Resistance Ratings

The Work includes fire stopping for all penetrations in the Generator Enclosure and Turbine Pit. All fire stopping will have a minimum fire-resistance rating of:

(a) two hours for fire stopping located in the walls, floors, ceiling, and bolt on closures; and

(b) two hours for ventilation fire dampers.

Generator Enclosure and Turbine Pit access doors will include a minimum fire-resistance rating of 90 minutes.

Penetrations, other than access doors, will:

(c) be protected by bolted-on closures that:

- (i) are easily removed and replaced without being damaged;
- (ii) seal the entire opening; and
- (iii) have suitable cut-outs in the closure for any pipes, conduits, etc., that pass through the penetration; and

(d) use fire dampers in penetrations that are required for ventilation.

Notwithstanding the above, gross openings smaller than 0.25 m^2 will be fire stopped by Others.

3.11 North American Parts Availability

Mechanical and electrical equipment, devices, components, and parts including piping, valves, pumps, fans, filters, strainers, motors, switches, control and instrumentation devices, PLCs, etc., provided as part of the Work will:

(a) as much as practicable, be of a design that is compatible with North American design norms;

(b) be normally stocked by at least one third-party distribution mechanical or electrical equipment sales distribution company with distribution centres, sales offices, and sales representatives located in North America; and

(c) have customer service support personnel based in North America.

3.12 Proprietary Equipment

No Equipment or Equipment components provided as part of the Work will contain any proprietary design aspects that would:

(a) preclude future replacement of mechanical or electronic parts such as piping, valves, pumps, fans, filters, strainers, motors, lighting, switches, control and instrumentation devices, PLCs, etc., with similar parts from a different manufacturer; and

(b) preclude BC Hydro personnel from understanding the detailed design of the Equipment.

SPGT4 INSPECTION AND TEST REQUIREMENTS

4.1 Calibration of Measuring Equipment and Instrumentation

All permanently installed instrumentation for the Equipment including protection and control devices, current transformers, voltage transformers, transducers, meters, detectors, gauges, etc., and all measurement devices used for the Work at Site such as torque wrenches, meters, pressure gauges, etc., will:

(a) be calibrated to a traceable standard by a methodology that is consistent with the manufacturer's recommended calibration procedure;

(b) for instrumentation where it is desirable to calibrate in situ or where it may not be feasible to calibrate to a traceable standard (such as for oil level measurement devices), have an alternative calibration Procedure submitted; and

(c) whenever practicable, be field calibrated either immediately before or immediately after it has been installed in its permanent location to confirm the calibration has not changed since the instrument was calibrated by either the instrument manufacturer or by the Contractor prior to shipment to Site.

4.2 Equipment Inspection and Test Plan

The Work includes the preparation of any inspection and test plans for manufacturing and shop assembly for the Equipment.

4.3 Non-Destructive Examination (NDE)

4.3.1 General

Unless otherwise specified, the Work includes Non-Destructive Examination (NDE) conducted in accordance with SPGT 4.3.

4.3.2 Operator Qualifications

NDE operators will be fully qualified to do the NDE on which they are engaged. Upon request, the Contractor will provide Hydro's Representative with proof of such qualifications. Hydro's Representative may have an operator replaced if the results of that operator's examination are found to be repeatedly unsatisfactory.

4.3.3 Acceptance Criteria

NDE acceptance criteria will be in accordance with the most stringent of:

(a) Schedule 6 [Specifications and Drawings], where specified;

(b) applicable material standards;

(c) ASME BPVC Section VIII Division I for pressure vessels and components in the water passage;

(d) ASME B31.1 for piping; and

(e) CSA W59 for steel structures.

4.4 Shop Inspection and Tests

4.4.1 General

(a) General: The Work includes performance of sufficient shop inspections and tests, and other additional shop tests as may be required by Hydro's Representative, acting reasonably, that are performed on the Equipment to:

  (i) verify compliance with all applicable standards and the requirements of Schedule 6 [Specifications and Drawings]; and

  (ii) to demonstrate the correct function of Equipment.

(b) Production Test: A production test (a "**Production Test**") is performed at the Contractor's or other suitable facility, on each and every item produced, regardless of the fact that items produced may be identical in design.

(c) Type Test: A type test (a "**Type Test**") is performed at the Contractor's or other suitable facility, on at least one item out of a group of identical items produced, and the test results are taken to be representative of the group of identical items.

If the Contractor has, for a different project, already conducted a Type Test on a component of the Equipment that requires a Type Test, the Contractor may submit for Consent a request for an exemption to this Type Test. This Submittal will be accompanied with Explanatory Documents that demonstrate that this Type Test has been performed in accordance with the Schedule 6 [Specifications and Drawings] and that the Equipment has satisfactorily passed the test. Notwithstanding the above, BC Hydro will not exempt Generator stator winding and Generator stator core Type Tests.

4.4.2 Production Run

A production run (a "**Production Run**") occurs when a component of the Equipment, comprised of many very similar or identical parts including Generator stator bars, Generator stator core laminations, Generator rotor rim plates, Generator rotor poles, Turbine shear pins, Turbine headcover bolts, Turbine wicket gates, Turbine runner blades, Excitation System silicon controlled rectifiers, etc., and components thereof, are manufactured continuously from the same batch of materials, and using the same process. If there is a discontinuity in any of these items, then a new Production Run has begun.

Each Production Run is required to undergo the applicable tests specified in Schedule 6 [Specifications and Drawings] including the lab, factory, manufacturing, Quality Assurance, Quality Control, Site tests, etc.

If the Production Run parts fail any of the tests, then the Production Run will be subject to quarantine until the failure cause is determined, the number of parts affected is determined, and remedial action carried out. Remedial action may include replacement of all affected parts.

4.4.3 Materials

(a) General: Materials that contain defects may be rejected by BC Hydro at any stage of the Work regardless if the materials were previously accepted.

(b) Castings: Castings of all principal parts will be inspected at the foundry, after cleaning and removing of defects. The castings will also be inspected after any repairs, heat treatment, and machining have been completed.

(c) Structural and Lamination Steel: Copies of all mill test reports will be submitted upon request.

(d) Forging: Forging of all principal parts will be inspected at the forging plant in the ingot state, and after forming, cleaning, and removal of defects but prior to any repair welding. The forging will also be inspected after repairs, heat treatment, and machining have been completed.

4.4.4 Electronic Equipment Noise, Transient, and Surge Immunity

(a) Tests: As part of the Work, all electronic devices supplied with the Equipment will undergo the following Type Tests, that are to be performed prior to shipment to Site, and with the Equipment powered up and operating normally (if the Contractor can provide documented proof satisfactory to Hydro’s Representative that the equipment supplied conforms to these requirements, these Type Tests may not be required):

(i) *Surge Withstand Capability (SWC) and Fast Transient Tests*: The Equipment electrical systems and devices will be tested for Surge Withstand Capability (SWC) in accordance with IEEE C37.90.1 and EN 61000-4-5. All connections including: power supply connections, input connections, output connections, but excluding communication links and 4-20 mA analogue signals, will withstand the test signal applied both in the transverse and common modes. These system components will be identified and indelibly marked as being SWC tested.

(ii) *Radiated Radio Frequency Wave Test*: This test simulates a “worst case” industrial noise environment consisting of high-voltage relays operating in close proximity to solid-state equipment. The Equipment will be tested to determine the sensitivity of the equipment to radiated high-frequency wave interference coupled from nearby radio transmitters in accordance with EN 61000-4-3. The equipment enclosure (chassis) that acts to shield the solid state portions of the Equipment electrical systems will be in the normal in-service condition, then the radio antenna will be brought within 1 m of the exposed operating circuits. Each radio transmitter will be operated continuously for 10 seconds and intermittently by turning it on and off once per second at least five times. Continuous and intermittent testing will be performed with the radio antennae oriented vertically, horizontally, and pointed directly at the circuit under test. The tests will be performed with the Enclosure doors open. The Equipment will be subjected to transmission from each of the following output frequencies:

(A) a VHF radio transmitter - nominal 47 MHz to 48 MHz - rated 15 W minimum RF output to antenna;

(B) a VHF radio transmitter - nominal 158 MHz to 173 MHz - rated 10 W minimum RF output to antenna;

(C) a UHF radio transmitter - nominal 450 MHz to 470 MHz - rated 5 W minimum RF output to antenna; and

(D) a UHF radio transmitter - nominal 832 MHz - rated 0.6 W minimum RF output to antenna (cellular phone region).

(b) Acceptance Criteria: These tests will be considered successful when functional testing is subsequently performed, and it is confirmed that the Equipment operates properly, including:

(i) no erroneous output or intermittent operation is present;

(ii) no component failure occurs; and

(iii) no change in calibration occurs exceeding normal tolerances.

An erroneous output is one that presents false information on any form of display, relay contact output, analog or digital signal output including communication outputs. These will include:

(iv) erroneous indications;

(v) erroneous relay contact output operations;

(vi) erroneous, missing or unwanted additional digital data bits;

(vii) synchronization errors; and

(viii) errors in any types of analog outputs including isolated control signals and 4-20 mA input/outputs.

Momentary variations up to ±10% in the visually displayed operating parameter values will be acceptable.

The Work includes performing all necessary modifications to remedy deficiencies identified and repair test damage caused by these tests.

4.4.5 Electrical Equipment and Device Functional Tests

(a) Individual Component Tests: Prior to system integration, the Contractor will subject individual components, including racks, power supplies, modules, printed circuit boards, instruments, switches, meters, LEDs, and other indications, gauges, solenoids and transducers, etc., to its routine Production Tests to prove the quality and uniformity of the workmanship and the materials used in the manufacture of the Equipment.

(b) System Integration Tests: System integration tests are Production Tests that will be performed to prove the total functionality of the Equipment and compliance with the requirements of Schedule 6 [Specifications and Drawings]. These tests will:

(i) be performed before preparation for shipment, to confirm that the Equipment operates correctly and that no changes or corrections will be required after installation at Site;

(ii) simulate the actual Site installation conditions as much as reasonably possible by setting up in the factory the maximum reasonable interconnection of the Equipment; and

(iii) include testing of all communication equipment used to integrate the separate components of the Equipment. Typical test inputs and outputs will be used to confirm functionality of each type and to prove compatibility with BC Hydro's Unit Control Board PLC.

(c) Communications Tests: Production Tests of all communications links used to communicate with equipment provided by Others will be performed. Only verification of Read/Write functionality via modbus is required. The Contractor will show or document how to setup modbus address and any other programming within the Equipment to set up modbus to TC/PIP over Ethernet port.

(d) Continuity Tests: Continuity tests are Production Tests that will be performed, noting that in some cases, functional testing may demonstrate continuity.

(e) Controls and Instrumentation Tests: Operational tests are Production Tests that will be conducted on controls and instruments to demonstrate that the Contract requirements have been met. As a minimum the following test will be provided:

(i) all discrete inputs will be connected to suitably labelled test switches;

(ii) all discrete outputs will be connected to suitably labelled lamps;

(iii) all analog outputs, analog inputs, and panel mounted meters will be operated throughout their ranges;

(iv) demonstration of communication links. The testing will be performed in the factory using communications test equipment supplied by BC Hydro; and

(v) all VT and CT inputs will be connected to suitable test sources.

(f) Changes to Electrical Equipment and Devices: Once electrical equipment and device functional testing has been completed, no further changes will be made to the Equipment hardware and Software prior to shipping.

4.4.6 Motor Tests

Motors will undergo Production Tests as follows:

(a) dielectric test of winding insulation at 1500 V, 60 Hz for 1 minute;

(b) running current at rated voltage measurement;

(c) locked rotor current at rated voltage measurement; and

(d) resistance of winding measurement corrected to 15°C.

4.4.7 Bearing Oil Cooler Tests

All oil coolers used in the bearings for the Equipment will undergo hydrostatic Production Tests. They will be free of leaks after 2 hours when hydrostatically tested to 1.5 times the Cooling Water System design pressure. If any leaks are found, they will be repaired and subjected to a retest.

4.4.8 Bearing Pad Tests

The Work includes Production Tests of every bearing pad using ultrasonic and penetrant testing techniques to determine the characteristics of bonding between the babbit and the backing material. The non-destructive testing Procedures will be in accordance with ISO 4386-1, test class 3 and ISO 4386-3.

4.5 Shop Assemblies Before Shipment

(a) Machining and Assembly Dimensions: The Contractor will check and record all pertinent machining and assembly dimensions in the shop as part of the Production Tests. These checks may be witnessed by Hydro’s Representative as required in the manufacturing inspection plan and copies of all records will be submitted upon completion of the checks.

(b) Assembly and Dimensional Checks: All assembly and dimensional checks and other tests that may be required to demonstrate accuracy of workmanship, oil-tightness, water-tightness, and satisfactory operation will be performed by the Contractor to the satisfaction of Hydro’s Representative as part of the Production Tests. Such tests will simulate normal operating conditions as closely as is practicable.

4.5.2 Devices Requiring Adjustment

All devices requiring adjustment will be checked as part of the Production Tests for range of adjustment so that a minimum of further adjustment will be required after assembly at the Site. Hydro’s Representative may, at its option, inspect the entire Equipment during fabrication and before shipment, and witness the regular shop tests after trial assembly.

4.5.3 Match Marking and Doweling

All components will be identified and properly match-marked and/or doweled, before disassembly if the components were shop assembled, to ensure ease and accurate assembly at the Site.

4.5.4 List of Finished Weights

Upon completion of the work in the shop, a detailed list of finished weights of all important Equipment sub-components will be submitted. The list will also state the total weight of the completed:

(a) Generator;

(b) Exciter;

(c) Turbine; and

(d) Governor.

4.5.5 Shaft Runout Checks

The degree of shaft runout on Equipment will be checked as part of the Production Tests in the Contractor’s shop by rotating the finished shaft in a lathe or aligning device.

The amount of runout, determined by a stationary indicator, will not exceed the following tolerances, or such lesser tolerances as the Contractor may deem necessary.

(a) Cylindrical surface of all turbine and generator bearing journals, including bearing top cover sealing surfaces — 50 µm

(b)	Shaft seal surface	50 µm
(c)	Male or female portion of coupling spigots as applicable	25 µm
(d)	Face of coupling at rotor end of coupling flange	20 µm
(e)	Face of coupling at runner end of turbine shaft	25 µm
(f)	Outside cylindrical surface of couplings	50 µm
(g)	Concentric control surfaces	25 µm
(h)	Balance of shaft exclusive of indicated points	250 µm

SPGT5 SITE WORK

5.1 General

5.1.1 General

Work at Site will include the Site assembly of all components and subassemblies, and performance of all the testing of the Equipment as required by the Specifications to allow for the Unit to be operational.

5.1.2 Responsibilities

The Contractor will be responsible for:

(a) the true and proper setting out of the Work;

(b) the correctness of the location, grades, dimensions, and alignment of all components of the Work that it undertakes to supply and install and provision of all instruments, appliances, materials and labour required in connection therewith; and

(c) the supply of all skills, special tools, fixtures and material required, unless otherwise specified, to complete the Work.

5.1.3 Errors

If at any time during the progress of the Work any error appears or arises in the location, grades, dimensions, or alignment of any part of the Work, the Contractor will rectify such error to the satisfaction of Hydro's Representative. This work will be carried out at the Contractor's expense unless such error is based on incorrect data supplied in writing by Hydro's Representative, in which case the expense of rectifying the error will be borne by BC Hydro.

5.1.4 Assistance

The Contractor will afford all reasonable facilities and assistance to Hydro's Representative for checking/verifying dimensions, elevations, reference points and lines established or required by the Contractor. Any work performed by Hydro's Representative will not in any way relieve the Contractor of its responsibility for the correctness thereof.

5.1.5 Reference Points

The Contractor will be responsible for protecting and preserving all reference points, benchmarks, and all other survey markers. If any such survey marker is disturbed by the Contractor it will, if so required by Hydro's Representative, be replaced as part of the Work.

5.2 Assembly of the Turbine and Generator Bearings

During assembly of the Turbine and Generator bearings the Contractor will ensure that the bearings are kept as clean as possible including building a "clean" room around the bearings. Prior to final closing up of the reservoirs, the bearings will be inspected and accepted.

5.3 Cleaning, Testing, and Flushing of Piping Systems

5.3.1 General

All piping systems supplied by the Contractor including compressed air piping, oil containing piping, reservoirs, cooling water piping, air coolers, oil coolers, and oil containing equipment will be cleaned, hydrostatically tested, and flushed as specified herein or at other times as directed by Hydro's Representative in accordance with Good Industry Practice, who may witness any or all piping system tests.

The exterior surfaces of all piping system components will be cleaned after all installation has been completed regardless of whether they are to be painted, insulated, covered in any way, or left bare.

The cleaning, hydrostatic testing, and flushing Work includes:

(a) all fluids required for cleaning, testing and flushing;

(b) all filling equipment, fluid handling equipment, pumps, test gauges, storage reservoirs, valves, temporary piping, flushing filters and any other necessary equipment and instrumentation required to monitor, clean, test, flush, drain and dry the piping;

(c) adherence with the handling Procedures described in these Contract Documents; and

(d) temporary storage, removal and disposal of all cleaning, testing and flushing fluids in accordance with these Contract Documents.

The Contractor may submit for Consent alternative Procedures for cleaning, testing, and flushing piping systems.

5.3.2 Cleaning

Cleaning of piping systems will be as specified below. Immediately following the cleaning work, all piping system elements will be protected to prevent future contamination during transportation and installation work.

(a) Cleaning of Carbon Steel Oil Containing Piping: After trial installation and subsequent dismantling, carbon steel piping systems will be chemically cleaned to remove residual oil, grease, mill scale, rust and weld spatter from the interior surfaces. Where possible, piping will be chemically cleaned in the manufacturing facility and securely sealed for shipping to Site. Where chemical cleaning is performed on Site, such cleaning will be performed external to the powerhouse or as agreed with Hydro's Representative.

Chemical cleaning will be carried out by the Contractor as follows:

(i) *Pre-cleaning Preparation*:

(A) install high point vents, low point drains and blind end bleed-off connections;

(B) hydrostatically test the piping system; and

(C) install temporary piping as required to control flow through the piping system and test for leaks at sufficient pressure to ensure tightness during cleaning; and

(ii) *Cleaning Procedure for Carbon Steel Pipe*:

(A) disconnect all piping to be chemically cleaned. Remove or isolate from the system to be cleaned, all parts constructed from materials which are subject to corrosion attack by the cleaning medium. Extreme care will be taken to prevent the entry of any chemical into associated equipment;

(B) use high-pressure air, steam, or water to mechanically clean the interior of the pipe to assure removal of loosely held scale and other particles. Accessible areas will be wire brushed;

(C) circulate a degreasing solution through the pipe for approximately 2 hours at 70°C. The degreasing solution will be: 3% by mass of sodium hydroxide; 0.01% by mass of wetting agent;

(D) flush with water until the degreasing solution has been completely removed, verifying removal by a litmus paper test;

(E) pickle the system to bare metal by circulating: 15% by mass of inhibited hydrochloric acid for 4 to 6 hours at 60°C;

(F) rinse with water;

(G) circulate neutralizing solution through the system for a period of 30 minutes at 80°C, and then drain. This solution will have the following composition:

(I) 0.25% by mass of monosodium phosphate;

(II) 0.25% by mass of disodium phosphate;

(III) 0.25% by mass of sodium hydroxide; and

(IV) 0.25% by mass sodium nitrite; and

(H) thoroughly dry piping prior to flushing.

(b) Cleaning of Stainless Steel Oil Containing Piping: Clean and descale in accordance with ASTM A380. Strong fibre cellulose (no textiles) materials will be used for removal of oils and greases. Passivate in accordance with ASTM A967. A passivation paste will be used to re-passivate around site welds.

(c) Cleaning of Other Piping Systems: All other piping systems, except as otherwise noted, will be thoroughly cleaned internally. All oils, greases and other contaminates, will be removed from the piping. The Contractor will submit for Consent the methods it proposes to clean these piping systems.

5.3.3 Hydrostatic Testing

All piping systems, except as otherwise noted, will be given a hydrostatic test. The piping system will be completely assembled and include all components such as valves, coolers, filters, strainers, etc. Hydrostatic testing of piping systems will:

(a) be performed prior to, and also after embedment in concrete;

(b) be for a period of at least 4 hours with no loss in pressure or visible leaks. Any components that are not designed to withstand the test pressure will be disconnected during the test or otherwise isolated during the tests;

(c) have a system test pressure that is 150% of design (gauge) pressure except for:

  (i) gravity drainage piping, which will be tested at 70 kPa (gauge);

  (ii) fill and drain piping will be tested at 70 kPa (gauge) or 150% design pressure (gauge), whichever is greater; and

  (iii) air lines that are only subject to atmospheric pressure or partial vacuum, which will be tested at 70 kPa (gauge), or 150% design pressure (gauge), whichever is greatest;

(d) except as expressly otherwise provided in this Appendix 6-2 [General Technical Specifications (SPGT)], the purity of the test fluid will be at least equal to that of the system operating fluid; and

(e) be repeated if any remedial work is performed.

Any leaks or other defects will be corrected by the Contractor to the satisfaction of Hydro's Representative, including the cleaning and flushing of any affected areas.

Following completion of all cleaning, hydrostatic testing, flushing and final assembly of the Governor HPU oil piping, a second hydrostatic test will be performed with oil on all the pressure lines up to the isolation valve to the accumulator.

Potable/domestic water can be used for hydrostatic testing of all air systems, and immediately following hydrostatic testing, air systems will be air blown to remove residual moisture. Acceptance criteria will be no moisture in the service air, process air, brake air, and governor high pressure compressed air piping systems.

Where BC Hydro has accepted that hydrostatic testing is impractical then additional weld inspections will be performed according to SPGT 3.8.12.

5.3.4 Flushing of Piping Systems

(a) Flushing of Oil Containing Piping: After satisfactory completion of cleaning and initial hydrostatic testing, the piping systems containing oil will be flushed with clean oil to ensure that all traces of foreign material are removed. The oil used for flushing will:

  (i) be of the same type of oil that will be used when the Equipment is in operation;

  (ii) be filtered during filling process; and

(iii) not be re-used for any other purpose.

The following procedure will be followed during the flushing process:

(iv) components that can be damaged by the high velocities or by moisture and particles will be isolated from the flushing circuit and cleaned individually;

(v) components that restrict the flow rate, and thereby detrimentally increase the pressure loss, will be isolated from the flushing circuit and cleaned individually;

(vi) manifolds, blocks, pumps, reservoirs, assemblies and components will be delivered clean according to the submitted Procedure. The Work includes provision of a cleanliness certificate attesting to the cleanliness of these components. If not clean, they will be flushed separately;

(vii) the following will also be cleaned separately:

(A) Reservoirs: All reservoirs will be cleaned manually.

(B) Hydraulic cylinders: Where manual cleaning is not practical, the cylinders will be operated through their full stroke at their maximum operational rate for a minimum of 10 cycles using filtered oil, in accordance with SPGT 5.3.4(a)(i) through (iii).

(C) Accumulators: All accumulators will be cleaned manually.

(D) Oil Coolers: The surface of the cooler in contact with oil will be thoroughly cleaned in a manner appropriate for their design. If the oil is in contact with the fin side of the cooler then the coolers will be steam cleaned or submerged in a suitable parts cleaner. If the fins are external to the oil then the coolers will be cleaned using the same methods specified for piping;

(viii) system filters will not be used as flushing filters. Specific flushing filters will be provided;

(ix) jumper pipes complete with drain valve(s) will be used to form a temporary flushing loop in series;

(x) each flushing circuit will be configured to achieve the following:

(A) a Reynolds Number of at least 120% of the maximum Reynolds Number encountered during normal system operation, and which is a minimum of 4,000;

(B) flushing velocity of at least 3 m/s in all parts of the system;

(C) system pressure controlled to a minimum of 300 to 500 kPa (gauge), measured downstream of the flushing circuit, before the return line filter and sampling port; and

(D) the coldest part in the flushing loop will have a minimum temperature of 50°C. The minimum temperature in the system will be used in calculations/analysis to ensure the required Reynolds Number is achieved.

Where the planned flushing pressure and temperature combinations exceed the rating of that of any part of a piping system, alternative arrangements will be submitted for Review;

(xi) the sampling port will be connected upstream of the flushing filters. To obtain a more representative oil sample, sampling will be taken dynamically with the oil in continuous flow in the loop, and with the sample extracted mid-stream;

(xii) for the governor system; after three consecutive samples from the system indicate that an ISO 4406 minimum cleanliness level of 16/14/11 or better has been achieved, flushing will then be continued for at least 30 more minutes;

(xiii) for the remainder of systems; after three consecutive samples from the system indicate that an ISO 4406 minimum cleanliness level of 17/15/12 or better has been achieved, flushing will then be continued for at least 30 more minutes;

(xiv) after completion of flushing, the cleanliness levels will be verified by an independent third party;

(xv) for each flushing process, test documentation will be submitted; and

(xvi) when all flushing is complete:

(A) the flushing oil will be drained;

(B) filters and strainers will be checked for cleanliness, and inspected for failure or damage; and

(C) systems will be sealed completely to prevent future contamination.

(b) Flushing of Fire Protection/Deluge, Pressure Tap, and Cooling Water Piping Systems: The fire protection/deluge, pressure tap, and cooling water piping systems will be flushed after hydrostatic testing. Connections adjacent to mechanical equipment will be broken and the system will be flushed to remove all dirt and foreign matter. The following procedure will be followed during the flushing process:

(i) each flushing circuit will be configured to achieve the following:

(A) the purity of the flush water will be at least equal to that of the system operating fluid;

(B) breaks will be provided at suitable points within the system to reduce the length of pipe being cleaned. Wherever possible, flushing water will not be directed from regions of high velocity into regions of low velocity, such as headers, heat exchangers, pressure vessels, etc.; and

(C) cleanliness will be verified by examining flush cloths that filter the exit flush water. Flushing will be for a minimum period of 5 minutes;

(ii) when all flushing is complete:

(A) the flushing water will be drained;

(B) filters and strainers will be checked for cleanliness, and inspected for failure or damage; and

(C) systems will be sealed completely to prevent future contamination.

(c) Flushing of Service Air, Process Air, Brake Air, and Governor High Pressure Compressed Air Piping Systems: The service air, process air, brake air, and governor high pressure compressed air piping systems will be flushed after hydrostatic testing. The following procedure will be followed during the flushing process:

(i) The piping systems will be flushed/blown free of particulate contamination. Where practical, blowdown will commence as close as possible to the system pressure source and proceed outward to the system extremities. The purity of the flush air will be at least equal to that of the system operating air. Cleanliness will be evaluated by holding a flush cloth in the exit air stream for a minimum period of 5 minutes. Acceptance criteria will be based on no visible particulate contamination.

(d) No flushing is required for the following piping systems:

(i) Air Admission;

(ii) Synchronous Condenser Air Depression;

(iii) Synchronous Condenser Air Exhaust;

(iv) Pressurized Drainage; and

(v) Unpressurized Drainage.

5.3.5 Preparation for Service

After cleaning, hydrostatic testing, and flushing of the piping systems, but prior to entering service for the first time, all valves and appurtenances will be lubricated as required, all gauges and regulators will be adjusted, all filters and strainers will be inspected and cleaned, and the piping systems will be given an operational test.

The Work includes the filling and the priming of all piping and associated equipment, including air piping, oil containing piping, reservoirs, cooling water piping, air coolers, oil coolers, oil containing equipment, with the appropriate fluid supplied by the Contractor.

The systems will be made complete and ready for operation in all respects to the satisfaction of Hydro’s Representative.

5.4 Site Measurements

Site measurements of the Equipment will be taken during installation and testing of the Equipment. For the Turbine and Generator the number of readings to be taken will be generally in accordance with CEATI Report No. T052700-0329 or as specified herein.

The location of every component will be verified by measurement and compared to the applicable Drawing, installation Procedure, or as required by this Appendix 6-2 [General Technical Specifications (SPGT)].

5.5 Site Assembly Checks, Alignment and Rotational Tests

5.5.1 General

In addition to, and notwithstanding any requirements covered elsewhere in the Contract Documents, Hydro’s Representative may carry out, if it so desires, a complete verification and independent check of the Site assembly of all the parts regarding their levels, clearances, pertinent fits and alignments.

5.5.2 Tolerances and Definitions

The Contractor will be guided by the tolerances and definitions contained in the latest version of the CEATI Report No. T052700-0329 Part I and Part II. The final installation tolerances will not exceed those contained in the CEATI Report No. T052700-0329 Part II, or as contained elsewhere in the Contract Documents. The actual tolerances listed in the Contractor's Installation Procedure may be less.

5.5.3 Unit Centreline Tolerances

The Unit vertical centreline will be within 6 mm of the intersection of Unit longitudinal and transverse centrelines.

The Unit horizontal centreline of the distributor will be within 6 mm of the required elevation of the centreline of the distributor.

5.5.4 Dimensional Checks for Embedded Part Assembly

Immediately prior to concreting, the Contractor will verify that the location and geometry of all components to be embedded are within the accepted tolerance, and that the embedded parts are adequately braced against movement while placing the concrete, regardless of who is placing the concrete. The Contractor will be responsible for monitoring the concrete placement and the position of all components during the concrete placement and will take appropriate action will any movement, or other problems, be detected.

5.5.5 Shaft Couplings

(a) General: The Contractor will be responsible for the following:

(i) machining in the shop the shaft flange coupling bolt holes;

(ii) marking in the shop any reference points and high spots on the shaft flanges;

(iii) correcting any alignment problems;

(iv) assembling, fitting and aligning the shaft couplings;

(v) finish reaming or boring the shaft coupling bolt holes to size as required; and

(vi) supplying the coupling bolts, nuts and locking plates and all special equipment and tooling necessary to assemble and align the shaft coupling.

The relative positions of the pieces for best overall alignment will be determined and the flanges will be match marked and permanently stamped to preclude the possibility of error during any future reassembly. Locking plates, or other devices, will be fitted but not welded.

(b) Elevations: Elevations of the Turbine and Generator centre-lines will be checked and corrected as required prior to any further alignment work. If the elevation(s) are out of tolerance, the Contractor will identify and resolve the problem and perform whatever remedial work is required. The elevations will be re-checked at the completion of all alignment work.

(c) Remedial Work: If a subsequent alignment or vibration problem occurs that is, in the opinion of Hydro's Representative, caused, or correctable, by remedial work to the coupling, the Contractor will perform and bear all costs associated with the remedial work. The remedial work Procedure will be submitted. Any required remedial work will be performed immediately upon direction of Hydro's Representative.

5.5.6 Alignment and Rotational Tests

The Turbine and Generator assembly will be rotated and run-out and plumb measurements taken. The Contractor will perform, witness, and submit, all required documentation for this Work. The Procedure used to measure run-outs and plumb will be submitted.

If, in the opinion of Hydro's Representative, excessive Turbine or Generator vibration and/or noise is present, the Contractor will undertake corrective measures or produce acceptable evidence that comparable Turbines or Generators with the same vibration and/or noise are operating satisfactorily.

5.6 Concrete Backfilling and Grouting

When backfilling and/or grouting is required, the Work includes:

(a) provision of Procedures and Drawings;

(b) provisions to enable Others to access to the locations requiring grouting (including scaffolding, if required);

(c) surface preparation including drilling and tapping of holes for concrete backfilling and/or grouting of Equipment components or voids and for venting. The holes will be threaded with a minimum diameter of 25 mm; and

(d) final finishing including plugging of holes with material the same as the base material, welding and/or seal welding, and coatings.

5.7 Cable Insulation and Continuity Tests

Insulation resistance tests will be performed for one minute on all conductors individually in all cables except for 120 V lighting and receptacle branch circuits. Cables will:

(a) if rated 600 V and above, be tested at 1000 Vdc;

(b) if rated less than 600 V, be tested at 500 Vdc;

(c) be tested after they have been completely installed but before termination on equipment; and

(d) be tested to ground with all the other conductors not under test, and all shields, grounded.

After cable installation, continuity tests will be performed on each conductor of each cable.

SPGT6 SITE ACCEPTANCE AND COMMISSIONING TESTS

6.1 General

Site acceptance and commissioning tests as specified herein will be performed by the Contractor to determine the performance characteristics of Equipment and to determine whether the requirements stated in the Contract have been met.

Note that some of the Equipment tests may require operating the Turbine at speed-no-load for significant periods of time.

6.1.1 Testing Schedule and Co-ordination

BC Hydro will perform the overall coordination and scheduling for all the Site acceptance and commissioning tests.

The Contractor will work cooperatively with BC Hydro on a day-to-day basis and in an efficient manner to schedule tests, and coordinate access. If any disputes arise, Hydro's Representative will make a final ruling on both the testing priorities and responsibilities.

BC Hydro will be permitted to witness or participate in any of the Contractor's tests. Such participation by BC Hydro will not relieve the Contractor of any responsibility under the Contract.

6.1.2 Test Equipment and Instrumentation

The Work includes all things required for the Site acceptance and commissioning tests including, bus bars, connectors, flexible links, shorting bars, high-voltage cables, transducers, measurement equipment, test instruments, data acquisition equipment, Software, temporary wiring, spare parts and other required appurtenances except where explicitly noted otherwise.

The test equipment and instrumentation used will be of high quality and precision, and will be suitably designed for the test to be performed.

The test equipment and instrumentation will be calibrated within the one year prior to the scheduled acceptance test completion and after completion of the tests.

6.1.3 Tests Performed by BC Hydro

During the acceptance and commissioning tests, BC Hydro may perform independent and/or additional tests, some of which may be performed in parallel with the tests performed by the Contractor.

All data collected by BC Hydro's Operational Information system as well as any other test data independently collected by BC Hydro related to the Equipment can be made available to the Contractor upon request to Hydro's Representative.

If any testing is taking place on the Equipment that does not directly involve the Contractor, the Contractor will nevertheless provide a representative(s) to witness such tests to ensure that the Equipment is operating satisfactorily.

6.1.4 Non-conformances, Defects, and Deficiencies

In addition to Section 24.4 of Schedule 2 [Design and Construction Protocols]:

(a) if the results of any of the tests, including tests performed during the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols], do not meet the requirements of, or any applicable standards referenced in, the Specifications, then the Contractor will immediately report to Hydro's Representative with the following information:

    (i) a description of the problem and how it occurred;

    (ii) additional testing, if any, required; and

    (iii) risk to continued testing or operation including supporting documentation.

    As soon as practicable thereafter, an action plan and schedule for problem correction will be submitted for Consent. This action plan will include a description of how the Contractor will correct the problem so as to remedy the root cause. Upon acceptance of the action plan by Hydro's Representative, the Contractor will immediately commence the corrective action. Upon successful completion of the corrective action, the Contractor will submit for Review a Report detailing all the Work carried out; and

(b) any non-conformances, defects, or deficiencies that develop or are discovered in the Equipment during testing, commissioning or the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols] will be forthwith corrected, at no cost to BC Hydro, and the tests will be continued or repeated until the Equipment is demonstrated to be in good working order in compliance with the Contract.

6.2 Equipment Commissioning Tests by the Contractor

6.2.1 Pre-Operational Tests

Pre-operational tests will generally be in accordance with IEC 60545.

6.2.2 Pre-Rotational Checks and Tests

After assembly of the Equipment has been completed, but before initial operation, the Contractor will check all components of the Equipment and perform all pre-rotational checks and tests necessary to demonstrate to the satisfaction of Hydro's Representative that all components have been properly assembled, and correctly adjusted, and are in proper working order. Pre-commissioning checks and tests will include:

(a) verification that all installation documentation has been completed and that the Unit is safe to operate with whatever deficiencies are remaining;

(b) anchor and bolt checks to confirm the Equipment is appropriately secured to floors, walls, other Equipment, or other structures. This will include confirmation of appropriate anchoring force (e.g., bolt torques);

(c) grounding and bonding resistance tests to confirm that all parts of grounded Equipment are bonded to ground. The Work includes confirmation of grounding and bonding of Equipment, Enclosures, terminal rails, terminal blocks, and device terminals;

(d) high-current resistance testing will be performed on all ground connections made between Equipment and the facility ground grid;

(e) checks of all wiring and cabling to control systems, equipment, and devices supplied and installed by the Contractor, including:

  (i) checks to confirm adequate harnessing and stress-relief has been applied to cables and wires;

  (ii) insulation resistance tests for all cables;

  (iii) checks to confirm wires and cable conductors are securely attached at their connection terminals ("tug test"); and

  (iv) continuity tests to confirm equipment terminals are connected in accordance with the corresponding Electrical Schematic Diagrams;

(f) insulation resistance tests for all motors;

(g) device checks to confirm functionality of each device within the Equipment prior to system-level integration checks. This includes power-up testing and operational checks to confirm individual devices operate correctly; and

(h) system integration checks to confirm functionality of subsystems and systems within the Equipment, and their connections to systems outside the Equipment. This includes checks to confirm devices are communicating correctly, appropriate settings are entered into the Equipment, that protections, indications, and controls are functional, and that the Equipment is ready for commissioning testing.

Any deficiencies or problems discovered during the pre-commissioning checks and tests will be corrected prior to the commissioning tests unless the Contractor and Hydro’s Representative mutually agree that the remedial work can be deferred.

6.2.3 Commissioning Checks and Tests

(a) Mechanical Runs and Overspeed Tests: Mechanical runs and overspeed tests will be performed on each Unit including:

(i) bump test and slow roll;

(ii) bearing temperature-rise runs at steps of 25%, 50%, 75%, and 100% of Rated Speed;

(iii) overspeed test at full-load rejection speed; and

(iv) overspeed test at 5% above the full-load rejection speed to confirm operation of the protection system.

During these tests there will be:

(v) no unusual noises or smells coming from the Equipment;

(vi) no unusual movement of the Generator or Turbine components; and

(vii) confirmation that the bearing temperatures are in accordance with that temperature rise limits stated in the Generator TDIF and in the Turbine TDIF.

At completion of the tests the following work will be done:

(viii) complete inspection of the entire Unit;

(ix) inspect and verify the tightness of every electrical connection on the rotor;

(x) verify the tightness on all pole keys by whatever means was used during installation;

(xi) inspect all rim keys and rim guidance systems;

(xii) re-measurement of the shape, concentricity and circularity of the rotor (using the air gap monitoring system is acceptable);

(xiii) verification that the balancing is still acceptable, and if the balance has changed, investigate cause before attempting to re-balance; and

(xiv) perform a high-potential test on the stator and rotor windings in accordance with Appendix 6-5 [Generator Specifications (SPG)].

(b) Runaway Test: Runaway testing will be performed as follows:

(i) if so directed by Hydro’s Representative, the runaway speed tests will be performed on a minimum of one Unit at no additional cost to BC Hydro. If the test is not considered successful by Hydro’s Representative, the test will be repeated on the same Unit and/or additional Units as required by Hydro’s Representative;

(ii) test preconditions will be as follows:

(A) overspeed tests in accordance with SPGT 6.2.3(a) will be completed. If the balancing changed during the overspeed testing, the cause will be investigated and the balance corrected before proceeding;

(B) the Contractor will perform a complete inspection of the entire Unit immediately prior to the runaway speed test;

(C) the gross head for the tests will be as close the maximum head as is practical; and

(D) the bearing cooling water flow rates will be set to their respective design values;

(iii) the runaway tests will be conducted to 100% physical stroke of the servomotors;

(iv) ramping and timing for the runaway speed test will be as follows:

(A) the ramp-up time from 100% rated speed to full runaway speed is at the discretion of the Contractor;

(B) the time at full runaway speed will not be less than 30 seconds; and

(C) the ramp-down time and final speed is at the discretion of the Contractor subject keeping the pressure rise in the spiral case and penstock within the limits specified in Appendix 6-3 [Turbine Specifications (SPT)]. However, the Contractor will obtain a vibration signature at 100% speed before complete shutdown of the Unit;

(v) during speed ramp up the Contractor will monitor all aspects of the Unit performance to determine whether to continue the test, and in particular the vibration and air gap to determine whether the Unit will be re-balanced before proceeding to the final runaway speed;

(vi) as a minimum the following post runaway testing and work will be performed:

(A) complete inspection of the entire Unit;

(B) inspect and verify the tightness of every electrical connection on the rotor;

(C) verify the tightness on all pole keys by whatever means was used during installation;

(D) inspect all rim keys and rim guidance systems;

(E) NDE of any welds on the rotor that are deemed critical by the Contractor or by Hydro’s Representative;

(F) verification of the torque on a sample of fasteners of each type on the rotor;

(G) re-measurement of the shape, concentricity and circularity of the rotor (using the air gap monitoring system is acceptable);

(H) verification that the balancing is still acceptable, and if the balance has changed, investigate cause before attempting to re-balance; and

(I) perform a high-potential test on the stator and rotor windings in accordance with Appendix 6-5 [Generator Specifications (SPG)].

(c) Guide Bearing Run-out: The run-out of the guide bearings will be measured. The bearing run-outs, when the Generator is at Generator Rated Output and Generator Rated Operating Conditions, will be in accordance with that stated in Appendix 6-5 [Generator Specifications (SPG)] and in the Turbine TDIF.

(d) Load Rejection Tests: Load rejection tests will be performed at steps of 25%, 50%, 75%, and 100% of rated load.

During each test, vibration, Governor on-line gain performance, pressure rise, speed rise, and voltage rise will be measured.

During each test the Exciter will be operated in manual control.

(e) Noise Levels: The noise levels outside of the Equipment will be measured.

(f) Load Testing: As a minimum, the following load tests will be performed to determine Unit operating characteristics over the entire operating range, including determining the:

(i) extent of rough-load zone operation;

(ii) equipment vibrations and abnormal noise;

(iii) bearing vibrations; and

(iv) turbine stability (including hydraulic pressure fluctuations, and air admission requirements).

(g) Synchronous Condenser Testing: As a minimum, testing and commissioning of the synchronous condenser system will consist of the following:

(i) testing of the compressed air system if supplied by the Contractor (if such system is supplied by BC Hydro or Others BC Hydro will test);

(ii) testing the air depression system with the Unit at a standstill to verify function of depression system, maintenance air system, level control system, exhaust system, and the compressed air system;

(iii) testing and balancing of the cooling water supply to Turbine runner seals; and

(iv) online testing of the complete synchronous condenser system including all protection and control functions, maintenance air requirements, level control, compressed air system cycling.

(h) Hydraulic Thrust Measurement on the Prototype Turbine: The Work includes measurement of the prototype hydraulic thrust over the full operating range of the Turbine. The test Procedure will be submitted. The test will be carried out on a minimum of 2 Units.

(i) Turbine Servomotor Differential Pressure Test: The servomotor differential pressure tests will be performed to verify and document the wicket gate hydraulic and friction forces, and to compare against the governor capacity.

6.3 Equipment Commissioning Tests by BC Hydro

The tests as specified herein may be performed by BC Hydro. All test instruments and data acquisition equipment will be supplied by BC Hydro. The Contractor will make provision in the test schedule for these tests to be performed at no additional cost to BC Hydro.

6.3.1 Unit Tests

Unit tests including:

(a) start, stop, and synchronization tests;

(b) on-line power system tests;

(c) bearing vibration monitoring tests; and

(d) bearing temperature monitoring tests.

6.3.2 WECC Tests

Testing to verify that the Equipment performance meets the requirements of the Western Electricity Coordinating Council (WECC) Test Guidelines for Synchronous Unit Dynamic Testing and Model Validation will be conducted by BC Hydro. These tests will include:

(a) Excitation System automatic and manual voltage regulator step-response tests;

(b) open-circuit and short-circuit Generator saturation tests;

(c) over-excitation and under-excitation limiter tests;

(d) reactive current compensation test;

(e) direct-axis transient open-circuit time constant validation test (field breaker trip test);

(f) PSS step-response tests;

(g) PSS performance tests;

(h) direct-axis parameters (VAR rejection) test;

(i) quadrature-axis parameters (MW rejection) test;

(j) load rejection test;

(k) Governor System frequency step-response test;

(l) water starting-time constant test;

(m) volts per hertz limiter tests;

(n) online measurements tests; and

(o) reactive power capability tests.

6.3.3 Prototype Power Output Testing

(a) General

(i) The prototype power output testing may either be performed by BC Hydro during or after the completion of the Contractor's commissioning tests or BC Hydro may use the information obtained as part of the Contractor's commissioning tests.

(ii) During the prototype power output testing the power output will be measured at the Generator terminals.

(iii) Water levels and pressures for these tests will be measured according to IEC 60041 using either the Contractor's or BC Hydro's equipment, whichever has the lowest evaluated uncertainty.

(iv) If required the power output will be scaled according to IEC 60041 to account for differences between the measured NSHE occurring during the test and the NSHE required for the test.

(v) If required NSHE for these tests will be measured and calculated according to IEC 60041 using either the Contractor's or BC Hydro's equipment, whichever has the lowest evaluated uncertainty and the flow for the calculation will be determined from the model test data from the Independent Laboratory.

(b) Operating Condition A: During the site acceptance and commissioning tests the power output at Operating Condition A will be determined as follows:

(i) testing will be performed as close as possible to the tailwater level required by Operating Condition A;

(ii) the ability of the Turbine to operate continuously at the power output stated in the Turbine TDIF for Operating Condition A will be verified; and

(iii) for any Unit which is not capable of continuous operation at Operating Condition A, testing will be done to determine the highest power output that the Unit is capable of continuous operation while not exceeding a flow of 423.3 m^3/s.

(c) Operating Condition B: During the site acceptance and commissioning tests the power output at Operating Condition B will be determined as follows:

(i) three Units will be operated at their maximum achievable continuous power output with all other Units shut down and no discharge from the spillway;

(ii) the above test will be repeated a minimum of three times with at least one common Unit in each pair of tests;

(iii) if there is a variation in the power output between Units or between tests on a Unit that exceeds 1 MW these tests may be repeated at BC Hydro's discretion with different combinations of three Units; and

(iv) the achieved power output for Operating Condition B for each Unit will be deemed to be the lowest power output measured for Operating Condition B based on the above tests.

(d) Operating Condition C (Prototype Minimum Turbine Output): During the site acceptance and commissioning tests the power output at Operating Condition C will be determined as follows:

(i) three Units will be operated at their Prototype Minimum Turbine Output with all other Units shut down and no discharge from the spillway;

(ii) the above test will be repeated a minimum of three times with at least one common Unit in each pair of tests;

(iii) if there is a variation in the power output between Units or between tests on a Unit that exceeds 1 MW these tests may be repeated at BC Hydro's discretion with different combinations of three Units; and

(iv) the highest minimum Unit output measured on a Unit from these tests will be deemed to be the Prototype Minimum Turbine Output for each Unit.

6.4 Other Tests Performed by BC Hydro

BC Hydro may, at its own expense and for its own information perform any or all of the following tests during the acceptance and commissioning tests. The results from these tests will be used to assess the performance of equipment by Others. The Contractor will make provision in the test schedule for these tests to be performed at no additional cost to BC Hydro. These tests for each Unit may include:

(a) filling of the draft tube and penstock to verify sealing of intake gate and draft tube maintenance gates; and

(b) a full-flow intake gate closure test. The test consists of closing the intake gate with the Unit operating at maximum output. During the test the wicket gates are maintained at the opening required to obtain maximum Unit output until the intake gate is fully closed at which time the Unit is tripped off line.

6.5 Baseline Tests by BC Hydro

BC Hydro may, at its own expense and for its own information, perform any or all of the tests specified in the Specifications upon completion of the Work. The results from these tests may be used as baselines for future tests.

6.6 Equipment Inspection and Testing After Commercial Operation

BC Hydro intends to inspect the Equipment approximately every 12 months during the first two to three years of the warranty periods described in Sections 24.1 and 24.2 of Schedule 2 [Design and Construction Protocols]. These outages may include testing including any or all of the tests listed in the Specifications. The purpose of these inspections is to evaluate the furnished Equipment. The results obtained will be used, among other things, for acceptance or rejection of the Work. The Work includes the Contractor's participation in these inspections and witnessing of the testing and such participation and witnessing will be at the Contractor's cost.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-3

TURBINE SPECIFICATIONS (SPT)

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-3

TURBINE SPECIFICATIONS (SPT)

SPT1 TURBINE INFORMATION AND REQUIREMENTS

1.1 Definitions and Interpretation

In this Appendix 6-3 [Turbine Specifications (SPT)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Actual Operation Period**" has the meaning set out in SPT 4.4.2(d)(i);

"**Actual Permitted Thresholds**" has the meaning set out in SPT 4.4.2(e);

"**Actual Warranty Assessment Periods**" has the meaning set out in SPT 4.4.2(e);

"**Additional Prototype Low-End Operating Range**" has the meaning set out in SPT 3.3.2(c);

"**Cavitation Frosting**" has the meaning set out in SPT 4.4.4(e);

"**Cavitation Protection Margin**" has the meaning set out in SPT 2.2.1;

"**Cavitation Warranty Assessment Period**" has the meaning set out in SPT 4.4.2(b);

"**Flood Reservoir Operating Range**" has the meaning set out in Table 3.1.3;

"**Gross Head**" has the meaning set out in Table 3.3.3;

"**Guaranteed Plant Annual Energy**" has the meaning set out in SPT 3.3.3(b);

"**Independent Laboratory**" has the meaning set out in SPT 2.1.2(f);

"**Independent Turbine Model Test**" has the meaning set out in SPT 2.1.2(f);

"**Initial Operating Period**" has the meaning set out in SPT 4.4.2(a);

"**Intake and Penstock Head Losses**" has the meaning set out in SPT 3.1.7(a);

"**Low Reservoir Operating Range**" has the meaning set out in Table 3.1.3;

"**Minimum Reservoir Operating Range**" has the meaning set out in Table 3.1.3;

"**Model Regimes**" has the meaning set out in SPT 2.2.4;

"**Net Specific Hydraulic Energy**" or "**NSHE**" has the meaning set out in SPT 3.1.7(c);

"**Normal Reservoir Operating Range**" has the meaning set out in Table 3.1.3;

"**Normal Turbine Operating Range**" has the meaning set out in SPT 3.2.1;

"**Operating Condition A**" has the meaning set out in SPT 3.2.2(a);

“**Operating Condition B**” has the meaning set out in SPT 3.2.2(b);

“**Operating Condition C**” has the meaning set out in SPT 3.2.2(c);

“**Operating Zone 1**” has the meaning set out in SPT 3.2.3(a);

“**Operating Zone 2**” has the meaning set out in SPT 3.2.3(b);

“**Operating Zone 3**” has the meaning set out in SPT 3.2.3(c);

“**Other Operating Conditions**” has the meaning set out in SPT 3.2.2(d);

“**Plant Annual Energy**” has the meaning set out in SPT 3.3.3;

“**Plant Annual Energy Calculation**” has the meaning set out in SPT 3.3.3;

“**Prototype Design Drawings**” has the meaning set out in SPT 4.6.1;

“**Prototype Minimum Turbine Output**” has the meaning set out in SPT 3.3.2(b);

“**Prototype Tailwater Curve**” has the meaning set out in SPT 3.1.5(b);

“**Prototype Tailwater Levels**” has the meaning set out in SPT 3.1.5;

“**Reference Minimum Turbine Output**” has the meaning set out in SPT 3.3.2(a);

“**Reference Sections**” has the meaning set out in SPT 2.4.1(c);

“**Reference Section 1**” has the meaning set out in STP 2.4.1(c)(i);

“**Reference Section 2**” has the meaning set out in STP 2.4.1(c)(ii);

“**Reference Turbine Model**” has the meaning set out in SPT 2.4.2(a);

“**Servomotors**” has the meaning set out in SPT 4.25.1;

“**SHE**” has the meaning set out in SPT 3.1.7(c)(i);

“**Spiral Case Design Pressure**” has the meaning set out in SPT 4.3.4;

“**Stated Periods**” has the meaning set out in SPT 4.4.2(c);

“**Stated Thresholds**” has the meaning set out in SPT 4.4.4;

“**Tailwater Curve**” has the meaning set out in SPT 3.1.4(b);

“**Tailwater Levels**” has the meaning set out in SPT 3.1.4;

“**Turbine**” has the meaning set out in SPT 1.2.2(b);

“**Turbine Model**” or “**Model**” has the meaning set out in SPT 2.1;

“**Turbine Model Test**” has the meaning set out in SPT 1.2.1;

“**Turbine Model Test Report**” has the meaning set out in SPT 2.5.1;

“**Turbine Operating Condition**” has the meaning set out in SPT 3.2.4;

“**Turbine Pit**” has the meaning set out in SPT 4.26.1;

“**Turbine Pit Maintainable Components**” has the meaning set out in SPT 4.26.5(b);

“**Turbine Pit Terminal Panel**” has the meaning set out in SPT 4.30;

“**Turbine Rated Output**” has the meaning set out in SPT 3.3.1;

“**Warranty Assessment Periods**” has the meaning set out in SPT 4.4.2(b);

“**Weighting Regime**” has the meaning set out in SPT 3.3.3; and

“**Wicket Gate Leakage**” has the meaning set out in SPT 4.5.3.

1.2 Scope of this Specification

1.2.1 Scope of Work for Turbine Model Test

The principal items of the scope of work for the turbine model test (the "**Turbine Model Test**”) include:

(a) perform the turbine hydraulic studies as a part of the model design;

(b) design and manufacture a Turbine Model;

(c) carry out development work and Turbine Model tests in the Contractor's hydraulic laboratory;

(d) prepare and submit the Turbine Model Test Report;

(e) transport and deliver the Turbine Model to and from the Independent Laboratory for the model test and supply all necessary information to permit the installation of the Turbine Model in the Independent Laboratory; and

(f) provide the services of technicians and witnesses at the Independent Laboratory during the Turbine Model Test.

1.2.2 Scope of Work for the Turbines

Six identical turbines are required for the Project, together with related Work, as follows:

(a) transport the Turbine Model to BC Hydro after completion of the Independent Turbine Model Test; and

(b) each turbine (a “**Turbine**”) includes the draft tube cone, draft tube elbow, flexible coupling, penstock spool piece, closure section, pier nose cap(s), and turbine components, including spiral case, stay ring and stay vanes, wicket gates, bottom ring, discharge ring, Francis runner, turbine shaft and coupling devices, shaft seal, headcover, wicket gate servomotors, wicket gate operating mechanisms, turbine guide bearing, cooling systems, and instrumentation.

1.2.3 Scope of Related Work

The Work related to each Turbine includes:

(a) Governor high pressure oil piping between servomotors and the Governor System;

(b) piping for synchronous condenser operation, and all related appurtenances;

(c) provision of representative(s) to supervise the installation of Turbine embedded parts and piping in first stage concrete;

(d) if delivered in multiple pieces, assembly of the pier nose cap pieces at Site;

(e) supply, install, and removal of spiral case inlet and stay ring bulkheads and associated piping for the spiral case hydrostatic tests and pressurized embedment;

(f) temporary draft tube closure devices; and

(g) provision of representative(s) to witness the Turbine tests performed by BC Hydro and cavitation inspections.

1.2.4 Work Not Included

The scope of Work for each Turbine does not include:

(a) performance of model test in the independent hydraulic laboratory;

(b) construction of the foundation and related concrete work for the Turbine for support and embedment of Turbine components;

(c) installation of Turbine embedded parts in first stage concrete;

(d) performance of spiral case hydrostatic tests;

(e) insulation of exposed water passage components (spiral case inlet, flexible coupling, penstock spool piece, penstock, draft tube, lower wicket gate bushing gallery, and spiral case); and

(f) performance of the Turbine tests at Site performed by BC Hydro as indicated in SPT 7.1.

1.3 Submittals

1.3.1 Turbine Calculations

For the Turbine hydraulic components, the loads required for stress analysis will be determined based on the use of steady state and non steady state CFD methods.

Turbine Calculations for submission include:

(a) Calculations stresses and deflections occurring during the spiral case hydrostatic pressure tests and subsequent spiral case embedment under internal water pressure as specified in SPT 6.3 for the spiral case, the stay ring, and the bulkheads for the spiral case and stay ring.

(b) For embedded parts, calculations of buoyancy, stresses, deflections and displacement during their concreting.

(c) Evaluation of hydraulic excitation frequencies together with torsional and bending natural frequencies of the runner, stay vanes, and wicket gates and to demonstrate that resonance conditions on the prototype components will not occur.

(d) Numerical dynamic and modal analysis of the runner (using Finite Element Methods or other submitted techniques). This analysis will be supported by the experimental data demonstrating validity of the methods used and providing satisfactory evidence of similarity with previously analysed runners, which were supplied by the Contractor and are presently in operation.

The runner dynamic and modal analysis will include:

(i) evaluation of the predominant excitation frequencies to be expected during operation of the Unit, such as buffeting, blade passage frequency, blade gate interaction frequency, blade vortex shedding frequency, wicket gate passage frequency, draft tube vortex frequency and torsional excitation frequencies from the Generator;

(ii) numerical analysis of the runner natural frequencies and modes of vibration in air and in water together with comparison to the experimental data relating the vibration frequencies in air and water; and

(iii) analysis of the correlation of analytically predicted modal results for the natural frequencies of the runner in water, with the external excitation frequencies that could be reasonably expected to occur.

This analysis will demonstrate sufficient margins between the runner natural frequencies in water and expected in service excitation frequencies to avoid runner resonance conditions.

(e) To exclude resonance of the stay vanes and wicket gates due to flow induced excitations (including Von Karman vortex excitations), calculations of the natural frequencies in air and in water will be submitted along with a CFD analysis of the flow through the stay vane/wicket gate cascade. These calculations will confirm that for all operating conditions, possible hydraulic excitation frequencies do not coincide with the natural frequencies of the stay vanes and wicket gates in water and the safety margin is sufficient to avoid resonance.

(f) Fatigue:

(i) The fatigue analysis and Design Life calculations will incorporate all of the operating requirements, the operating conditions for Equipment, and the design life specified in Appendix 6-2 [General Technical Specifications (SPGT)].

(ii) For the fatigue analysis of the Turbine operating in Operating Zone 1 the following durations will be used:

Condition	Annual duration (hours)	Flow range (m^3/s)	
Speed no load	183	Q1	
Region 1	183	Q1 to	Q1+INC
Region 2	122	Q1+INC to	Q1+2*INC
Region 3	61	Q1+2*INC to	Q1+3*INC
Region 4	122	Q1+3*INC to	Q1+4*INC
Region 5	207	Q1+4*INC to	Q2

Where:

Q1 = Speed no load flow

Q2 = the discharge at the Reference Minimum Turbine Output or Prototype Minimum Turbine Output as applicable

INC = (Q2-Q1)/5

(iii) In addition to the frequencies and durations specified above and in Appendix 6-2 [General Technical Specifications (SPGT)] ,the fatigue analysis will include the condition of the Turbine operating in the Normal Turbine Operating Range for 8,760 hours of operating time per year at the operating condition where the highest fatigue damage occurs. The total annual hours used in the fatigue analysis and Design Life Calculation will exceed 8760 hours.

(g) Calculations of the hydraulic downthrust during normal operating conditions.

(h) Calculations of the hydraulic downthrust and upthrust for the most adverse transient conditions.

(i) Calculations for synchronous condenser operation including:

(i) required air volume for initial water depression, residual pressure, and time to depress the water to just below the runner and time to depress the water to the final level;

(ii) make up air requirements;

(iii) sizing of depression air piping, including pressure drop calculations; and

(iv) runner seal cooling water flow rates.

SPT2 TURBINE HYDRAULIC DESIGN AND MODEL

2.1 General

A turbine model (a “**Turbine Model**” or “**Model**”) means a scale physical model (including spiral case, stay vanes, wicket gates, runner, headcover, draft tube cone, and draft tube elbow) of the Contractor’s proposed Turbine.

2.1.1 Homology and Test Requirements

The Turbine Model mechanical design, homology, and test requirements and also definitions of the hydraulic performance parameters set out in SPT2 will be in accordance with the International Code for Model Acceptance Tests of Hydraulic Turbines, IEC Publication 60193, except as may be specifically noted herein.

2.1.2 Elements of the Turbine Model Development and Testing Program

The main elements of the Turbine Model development and testing program are as follows:

(a) Hydraulic Design and Turbine Model Development: Perform theoretical analysis, including application of computational fluid dynamics (CFD) methods, and physical modelling and testing.

The hydraulic design and Turbine Model development will take into account Powerhouse optimization considerations.

(b) Design Analysis: Prepare a detailed design analysis demonstrating that the prototype hydraulic design does not exceed the allowable stresses specified in Appendix 6-2 [General Technical Specifications (SPGT)], and will also achieve the specified Design Life.

For the Turbine hydraulic components, the loads required for stress analysis will be determined based on the use of steady-state and non-steady-state CFD methods.

Perform an analysis of static and dynamic stresses in the prototype runner, wicket gates, and stay vanes and ring, in accordance with the analysis requirements in SPT 1.3.1 to demonstrate that the design criteria specified or referenced in this Appendix 6-3 [Turbine Specifications (SPT)] and Appendix 6-2 [General Technical Specifications (SPGT)] are not exceeded, including safety factors that meet Good Industry Practice.

Perform analysis to evaluate hydraulic excitation frequencies and natural frequencies of the runner, stay vanes, and wicket gates and to demonstrate that resonance conditions on the prototype components will not occur.

Perform a dynamic and modal analysis of the runner including:

(i) evaluation of the predominant excitation frequencies to be expected during operation of the Turbine, such as buffeting, blade passage frequency, blade-gate interaction frequency, blade vortex shedding frequency, wicket gate passage frequency, draft tube vortex frequency, and any torsional excitation frequencies from the Generator; and

(ii) analysis of the analytically predicted runner natural frequencies in air and in water with comparison against the external excitation frequencies expected to occur.

Perform a runner fatigue analysis, in accordance with the analysis requirements in SPT 1.3.1, based on the calculated static and dynamic stresses, and considering the cumulative effect of all significant loading cycles expected in service. The fatigue analysis will consider the effects of residual stresses.

Where finite element methods are used for the calculation of deflections and stresses, the Contractor will demonstrate the sensitivity of the calculation results to critical or key input data, boundary conditions, and alternative meshing. The Contractor will demonstrate a convergence of the results within 5%.

(c) Turbine Model Manufacture: Manufacture a complete Turbine Model that meets the requirements of Schedule 6 [Specifications and Drawings].

(d) Turbine Model Tests: Turbine Model testing will be performed to meet the requirements of SPT 2.3.

The Turbine Model test results will permit the determination of the discharge, mechanical power of the runner, hydraulic efficiency, cavitation limits, and pressure fluctuation amplitudes/frequency in all Turbine water passages. Additional information such as the runaway characteristics, hydraulic thrust characteristics, wicket gate torque and balance point, as well as the draft tube vortex phenomena will also be determined.

BC Hydro may require that representatives of BC Hydro have the opportunity to witness the testing of the Turbine Model in the Contractor's laboratory prior to delivery to the Independent Laboratory.

(e) Turbine Model Test Report: Prepare a Turbine Model Test Report in accordance with the requirements outlined in SPT 2.5.

(f) Independent Turbine Model Test: BC Hydro may require that the Contractor's Turbine Model be tested by an independent laboratory (the "**Independent Turbine Model Test**"). BC Hydro has selected the following laboratory to perform independent testing: École Polytechnique Fédérale de Lausanne – Laboratoire de Machines Hydrauliques in Lausanne, Switzerland (the "**Independent Laboratory**").

The design of a final Turbine Model will comply with the requirements of the Independent Laboratory for Turbine Model installation and testing.

The Turbine Model will permit performance tests in the Independent Laboratory to be conducted at the Reynolds number of $Re_{ref}=7 \times 10^6$ +/-20% for the water temperature not exceeding 20°C.

If BC Hydro directs that a Contractor's Turbine Model be delivered to the Independent Laboratory then the Contractor will at its own cost deliver the Turbine Model to and from the Independent Laboratory.

The Contractor will at the Contractor's own cost provide the services of technicians and witnesses at the Independent Laboratory as required by the Independent Laboratory during the independent testing.

The Contractor will preserve their Turbine Model and the components without alteration from the Effective Date and will not use the Turbine Model for other studies or projects or purposes without the prior written approval of BC Hydro.

The Contractor will preserve its Turbine Model, following the completion of testing by the Independent Laboratory, and make the Turbine Model available following execution of the Contract for purposes as may be defined in the Contract such as with respect to the cavitation warranty. For such purposes the Contractor will deliver the Turbine Model to BC Hydro at the Site no later than 60 Days after the expiration of the cavitation warranty.

(i) *Verification of Turbine Model Dimensions*: The Independent Laboratory will, with the assistance of the Contractor, perform certain dimensional checks of the Turbine Model as directed by BC Hydro. A Contractor will cooperate fully with the Independent Laboratory in the carrying out of the dimensional checks.

If the Independent Laboratory finds discrepancies in comparison to the Contractors' measurements, which exceed the uncertainty of the measuring device, then the Contractor will be responsible for the costs incurred to have the Independent Laboratory fully measure the Model.

(ii) *Verification of Turbine Model Roughness*: The Independent Laboratory will perform roughness measurements of the Turbine Model. The Contractor will cooperate fully with the Independent Laboratory in the carrying out of the measurements. Details of the measurement requirements are indicated in SPT 2.4.4(b).

If the Independent Laboratory finds the arithmetic average roughness measurements, Ra, to exceed the limits indicated in SPT 2.4.3(a), then the Contractor may be required to bring the deviating roughness measurements, Ra, into compliance prior to the start of independent testing.

The Independent Laboratory will use a Hommel Tester T1000, or equivalent, for the roughness measurements.

(iii) *Report*: The report from the Independent Laboratory will be used to establish the Contractor's Turbine performance levels, the Guaranteed Plant Annual Energy determined by the methodology given in SPT 3.3.3, and also to verify that the performance requirements specified in SPT 2.2 will be achieved by the Contractor's Turbine.

2.2 Performance Requirements

2.2.1 Cavitation Protection Margin

The cavitation protection margin, defined as the difference between the reference plant Thoma number (σ_P) and critical Thoma number (σ_1) when converted to metres (the "**Cavitation Protection Margin**"), will be not less than 3.0 m over the full range of prototype power outputs and operating NSHEs. For all operating conditions, the reference plant Thoma number will be calculated based on the tailwater level for the minimum facility discharge of 390 m^3/s. The tailwater curve is specified in SPT 3.1.4.

2.2.2 Inlet Cavitation Protection Margin

The Contractor will demonstrate that an appropriate inlet edge cavitation protection margin will be provided with reference made to similar prototype Francis turbines which have been operating without inlet cavitation problems. Inlet edge cavitation protection margin will be defined and demonstrated as the minimum difference in N_{ED} (metres) at fixed Q_{ED} values between operating points of the incipient runner inlet edge cavitation and the Normal Turbine Operating Range, when measured on the Turbine Model hill chart.

2.2.3 Wicket Gate Torque

The wicket gate balance point and the closing tendency of the wicket gates will comply with the requirements of SPT 4.22.3(a).

2.2.4 Hydraulic Pressure Fluctuations

Within the Normal Turbine Operating Range, the maximum peak-to-peak amplitude of the 97% probability distribution time signal of pressure fluctuations in Model water passages will not exceed the following percentages of the test NSHE multiplied by the density of the water:

(a) for the draft tube elbow pressure taps: 14%; and

(b) for all other pressure taps: 10%.

Within the full range of Turbine Model operating regimes (the "**Model Regimes**") corresponding to the specified prototype Gross Head range and plant Thoma number range, the maximum peak-to-peak amplitude of the 97% probability distribution time signal of pressure fluctuations in all Model water passages will be compared with the following percentages of the test NSHE multiplied by the density of the water:

(c) 10% for Model Regimes with corresponding prototype power outputs in Operating Zone 1;

(d) for Operating Zone 2, a straight line connecting a 10% limit at the beginning of Operating Zone 2 to a 3% limit at the start of Operating Zone 3; and

(e) 3% for Model Regimes with corresponding prototype power outputs in the Operating Zone 3 at the respective prototype NSHEs.

For the pressure fluctuations measurements located in the draft tube, in accordance with SPT 2.3.7(a), (e), the reference elevation for the calculation of plant Thoma will be the bottom of the runner.

For the purpose of the Turbine Model tests, the peak-to-peak amplitude of pressure fluctuations is defined as the peak-to-peak value in accordance with Clause 1.3.3.10.8 of the IEC Publication 60193. The 100% time signal will be presented for information purposes.

2.3 Turbine Model Test

The reference elevation for calculation of the Thoma number for all Turbine Model testing will be the centreline of the distributor, except as stated in SPT 2.2.4.

The water temperature will be recorded throughout the tests and will not exceed 20°C.

All Model hydraulic efficiencies will be presented at a Reynolds number of $Re_{ref} = 7 \times 10^6$. To minimize the correction to the Model efficiency, the tests will be run as close as possible to that Reynolds number. Adjustment of the Model efficiency for presentation at $Re_{ref} = 7 \times 10^6$ will be in accordance with SPT 2.4.2. The range of test Reynolds numbers during the Model performance testing will not exceed 7×10^6 +/-20%.

2.3.1 Turbine Model Hill Chart

A minimum of 300 individual test points will be used to generate the hill chart of the Turbine Model and prototype Turbine.

Performance tests will be carried out for the Model speed factor range corresponding to an operating range of prototype Turbine NSHEs, which extends from not less than 50 m^2/s^2 below the minimum to not less than 50 m^2/s^2 above the maximum NSHE values indicated by the Contractor. Test information will be sufficient to permit interpolation from zero speed factor to runaway speed factor. The tests will be made in suitable increments of the wicket gate opening from the gate position corresponding to approximately speed-no-load at maximum NSHE up to and including 120% of the maximum gate opening of the Turbine.

The tests used to generate the hill chart data may be performed at high Thoma number values if, within the uncertainty of the test stand, the efficiency is shown to be independent of Thoma number over the range of Thoma numbers for the facility. If the above condition is not met then the hill chart will be measured at plant Thoma.

2.3.2 Turbine Model Hydraulic Efficiency Tests

Turbine Model hydraulic efficiency tests will be carried out at the Turbine Model speed factor range corresponding to the range of NSHE.

For each specified Weighting Regime in Table 3.3.3, the prototype Turbine efficiency inputs into the Plant Annual Energy Calculation will be verified at the plant Thoma numbers. The following method will be used for these points:

(a) Step 1: Establish the full range of plant Thoma numbers for each Weighting Regime used for calculation of the Plant Annual Energy and listed as Weighting Regime “No. i”:

  (i) minimum plant Thoma number at each individual Weighting Regime will be calculated based on the tailwater level with one unit running at the Turbine discharges specified in Table 3.3.3 for the above Weighting Regime. The tailwater level for each Weighting Regime will be determined by linearly interpolating the tailwater levels at low plant discharges as specified in SPT 3.1.4; and

(ii) maximum plant Thoma number at all Weighting Regimes will be calculated based on the tailwater level corresponding to the rated discharge of six Units in accordance with SPT 3.1.4.

(b) Step 2: For each Weighting Regime "No. i" determine the following characteristics:

(i) minimum level of Model hydraulic efficiency at $Re_{ref} = 7 \times 10^6$ within the full range of plant Thoma numbers (between minimum and maximum Thoma numbers described in Step 1) at the above Weighting Regime; and

(ii) plant Thoma number value σ_i, at which the minimum level of Model hydraulic efficiency was achieved.

(c) Step 3: For each Weighting Regime "No. i" complete measurements of the Model hydraulic efficiency at the fixed plant Thoma number σ_i (determined in Step 2) at least two times, and transfer the measured efficiencies to $Re_{ref} = 7 \times 10^6$. Measurements for each NSHE at the Weighting Regimes will be performed in a cyclic manner, so that each cycle comprises the efficiency measurements for all weighting regimes at the above NSHE as follows:

(i) start efficiency measurements at the Weighting Regime with the minimum wicket gate opening, then proceed to other Weighting Regimes in the direction of the gate opening increase, and continue measurements until the Weighting Regime with the maximum gate opening is reached; and

(ii) after efficiency measurements at the Weighting Regime with the maximum gate opening are completed, move in the opposite direction, i.e., proceed to the next weighting regime with smaller gate opening, and continue until the Weighting Regime with the minimum wicket gate opening is reached.

The scatter of the individual efficiency measurement data (adjusted to $Re_{ref} = 7 \times 10^6$) at any of the weighting regimes will not exceed the total band of 0.3%.

(d) Step 4:

(i) For each Weighting Regime determine the mean arithmetic value of all Model efficiency measurements completed in Step 3 for this Weighting Regime and adjusted to $Re_{ref} = 7 \times 10^6$ and to the Reference Turbine Model roughness. The number of efficiency measurements carried out by the Contractor to derive the mean efficiency will be sufficient to ensure that random uncertainty of the mean Model hydraulic efficiency for each Weighting Regime does not exceed ±0.1%.

(ii) As per SPT 2.4.2(b), scale the above mean reference Model hydraulic efficiencies at the Weighting Regimes to the prototype efficiencies. These calculated prototype efficiencies will then be used for calculation of the prototype Turbine outputs in accordance with Table 3.3.3.

If pressure fluctuations in the Model water passages exceed the levels specified in SPT 2.2.4, then air will be admitted into the Model to reduce pressure fluctuations to the acceptable level, and Model efficiencies used for calculation of the Plant Annual Energy will be determined with the influence of air admission taken into account and applying the process described in Steps 1 - 4 above.

As part of its Model testing program, the Contractor will carry out additional performance tests for the Model Regimes corresponding to the prototype maximum and minimum NSHEs determined using the data provided in this Appendix 6-3 [Turbine Specifications (SPT)]. The tests for each of these two NSHEs will cover the full range of wicket gate openings between approximately speed-no-load at maximum

NSHE and 120% of the maximum gate opening, and will be carried out using the following procedures of adjusting the wicket gate openings for measurement of the Model performance characteristics:

(e) Firstly: Start at the minimum wicket gate opening and adjust the gate position by increasing the gate opening until the desired gate opening is reached, proceed in this manner up to 120% of the maximum wicket gate opening.

(f) Secondly: Start at 120% of the maximum gate opening and adjust the wicket gate position by decreasing the gate opening over the whole range of required wicket gate openings.

The tests with adjustment of the gate openings, as described in SPT 2.3.2(e) and SPT 2.3.2(f), will be carried at high Thoma number values and at the reference plant Thoma number calculated based on the tailwater level at rated discharge of one unit. The difference in the Model hydraulic efficiency measured based on Methods 1 and 2 at any tested Model Regime with fixed speed factor, wicket gate opening and Thoma number will not exceed 0.3% after transferring the measured efficiencies to $Re_{ref} = 7 \times 10^6$.

2.3.3 Cavitation Tests

Cavitation tests will include tests of Turbine Model performance as a function of Thoma number as well as visual observations of cavitation. These tests will be performed to allow the following assessments to be made:

(a) potential for cavitation erosion on the prototype Turbine;

(b) the Turbine setting relative to minimum tailwater level; and

(c) potential operating restrictions for the Turbine within the Normal Turbine Operating Range.

Cavitation tests will be carried out over the Model speed factor range corresponding to the Normal Turbine Operating Range.

Cavitation curves will be derived for the Model Regimes by operating the Turbine Model at constant speed, test NSHE and wicket gate opening, and varying the draft tube outlet pressure while measuring the Turbine Model discharge and power. For the operating conditions indicated below, cavitation curves will be produced for a range of Model wicket gate openings, including the wicket gate opening corresponding to the maximum prototype power output at the indicated operating condition, and also 95%, 105%, 110%, and the lesser of 115% of this wicket gate opening or the maximum physical wicket gate opening for the Turbine Model:

(d) Maximum NSHE within the Normal Turbine Operating Range;

(e) Operating Condition B;

(f) within the Normal Turbine Operating Range, the operating condition which produces the highest Turbine discharge (may coincide with Operating Condition B);

(g) Minimum NSHE within the Normal Turbine Operating Range; and

(h) any other operating point where the Turbine may approach the Cavitation Protection Margin.

Each cavitation curve will include the uncertainty bandwidths for the measurements, the plant Thoma line and the Critical Thoma line.

The test results will be plotted as curves of discharge factor, power factor, and hydraulic efficiency versus the Thoma number. From these curves the critical Thoma number (σ_1) will be determined, where Critical

Thoma number (σ_1) is defined herein as the value of the Thoma number for which a drop of 1% in hydraulic efficiency or any other Model characteristic (i.e., power factor or discharge factor) is attained when compared with the non-cavitation performance at high Thoma numbers, where cavitation curves are not sloped (Figures 4 a) b) c) of IEC Publication 60193).

Thoma number for incipient cavitation will be the value of the Thoma number associated with the beginning of visible bubbles adhering to the runner surface of two blades.

Visual observations of the Model cavitation phenomena and the draft tube rope will also be made over the specified operating of NSHEs (as determined by the Contractor using data in this Appendix 6-3 [Turbine Specifications (SPT)]) and the full range of plant Thoma numbers, at which the prototype Turbine will operate. A borescope, or equivalent optical device(s), will be used for visualization of cavitation in inaccessible areas such as the blade leading edges between crown and band. The results of observations, including those through the borescope will be recorded on digital photographs and sketches. Visual observations will confirm that no cavitation bubbles adhere to the blades and any other surfaces of the proposed Model runner at the Model Regimes representing the full range of prototype power outputs, operating NSHEs, and tailwater levels for Normal Turbine Operating Range.

2.3.4 Runaway Speed Tests

Turbine Model runaway speed tests will be carried out to determine the maximum runaway speed under Turbine Model test conditions corresponding to the prototype NSHE range and the required range of wicket gate openings. The Turbine Model runaway speed tests will cover the full range of wicket gate openings between the minimum position of the wicket gates and 120% of the maximum wicket gate opening of the Turbine, in increments of 2 degrees.

The effect of the Thoma number upon the runaway speed characteristics will be investigated for the maximum runaway speed.

2.3.5 Wicket Gate Torque Tests

(a) Synchronized Wicket Gates: Wicket gate hydraulic torques in relation to gate opening and speed factor respectively will be measured at the speed factor corresponding to the maximum prototype NSHE. Wicket gate hydraulic torques will also be measured along the runaway speed curve. Tests will be performed at gate openings from the minimum gate opening to 120% of maximum gate opening of the Turbine in increments of 2 degrees, and additionally at the point corresponding to speed-no-load.

Wicket gate hydraulic torques will also be measured along the runaway speed curve from the minimum gate opening to 120% of maximum gate opening of the Turbine in increments of at least 3 degrees.

The wicket gate balance point and the closing trend of the wicket gates will be determined.

Wicket gate torque tests for synchronized gates will be performed on at least four gates located 90^o apart with one gate located at the spiral case inlet.

(b) Desynchronized Wicket Gates: Wicket gate hydraulic torque tests for desynchronized gates will be performed with three gates at the wicket gate location where the maximum synchronized wicket gate torque was measured. For the desynchronized wicket gate testing, one desynchronized gate will be between two synchronized gates.

Wicket gate hydraulic torques for desynchronized gates will be measured at the speed factor corresponding to the maximum prototype NSHE. The desynchronized wicket gate will be positioned from the minimum gate opening to 120% of maximum gate opening in increments of 5 degrees for each torque test. The synchronized gates will be positioned from the minimum gate opening to 120% of maximum gate opening in minimum increments of 2 degrees for each torque test, and will identify the angle associated with the peak torque. Gate torques will be measured on three gates for all combinations of the desynchronized and synchronized gate positions.

2.3.6 Hydraulic Thrust Tests

Testing will be carried out to determine the Turbine Model hydraulic thrust for the range of operation specified in SPT 3.2 and during runaway conditions.

2.3.7 Pressure Fluctuation Tests

Pressure fluctuations related to flow instabilities or vortices in the Turbine Model will be measured by use of pressure transducers and pressure taps located in the water passages, including:

(a) draft tube elbow (two transducers – lower transducer in the elbow on the Unit centerline, and an upper transducer on the downstream side of the elbow aligned to a line approximately 45 degrees above the horizontal passing through the lower transducer);

(b) spiral case;

(c) between the headcover and runner crown;

(d) between the discharge ring/bottom ring and runner band (one transducer);

(e) four points around the draft tube inlet at a distance below the runner band exit that is equal to approximately the Model runner outlet (reference) diameter multiplied by 0.3; and

(f) the locations of the draft tube cone access doors. If the draft tube cone access door locations are included within the requirement of SPT 2.3.7(e), then no additional taps are required.

The Model hydraulic pressure fluctuations will be recorded such that their unfiltered peak-to-peak amplitude and frequency are defined throughout the entire operating range of NSHEs power outputs and plant Thoma numbers, and a frequency analysis will be made. Within the Turbine Normal Operating Range, the maximum pressure fluctuations for all pressure taps will be identified. As a minimum, the following operating points will be tested:

(g) throughout the range of Turbine discharges at minimum NSHE;

(h) Operating Condition B; and

(i) throughout the range of Turbine discharges at maximum NSHE.

If naturally aspirated air admission is required for mitigation of hydraulic pressure fluctuations, additional tests will be carried out to determine the effect of air admission on the pressure fluctuations and Turbine Model efficiency and also to determine the optimum air flow rate.

2.4 Technical Requirements

2.4.1 Turbine Model Manufacturing and Homology

(a) General: The upstream boundary of the Turbine Model will be the location where the Contractor's spiral case inlet terminates and is connected to the penstock.

The draft tube cone will have a section made from a transparent material and a window at the bottom of the elbow to allow observation of cavitation and the draft tube rope.

(b) Model Runner: The Turbine Model will be rigid enough to minimize deformation during testing under the most adverse loading conditions so that results of the tests will not be affected by Model deformation. The components of the Model runner and other critical Model components will be fully machined and the runner blades will be machined on a five axis numerically controlled machine tool.

The Model runner outlet (reference) diameter will be not less than 350 mm and not more than 370 mm.

Manufacturing features such as gaps or abrupt steps in the Model runner due to fabrication and/or assembly methods will be avoided. Any remaining gaps or steps will be prepared to a smooth profile so as to avoid the creation of incidental cavitation bubbles and without compromising homology between Model and prototype. The definition of incipient cavitation is provided in SPT2.3.3, and cavitation bubbles occurring as a result of gaps, abrupt steps, etc., may be considered when determining incipient cavitation at the Independent Laboratory.

(c) Reference Sections: The Turbine Model high pressure and low pressure measuring sections (“**Reference Sections**”) will coincide with the respective Model Reference Sections, which will be homologous to the prototype Reference Sections defined as follows:

(i) The high pressure reference section (“**Reference Section 1**”), as defined in Clause 1.3.3.1.1 of the IEC Publication 60193, will be located 2350 mm upstream of the centerline of the flexible coupling, as measured on the prototype.

(ii) The low pressure reference section (“**Reference Section 2**”), as defined in Clause 1.3.3.1.2 of the IEC Publication 60193, is the area of the draft tube normal to the direction of the average discharge flow velocity located upstream of the outlet of the draft tube. At least four pressure taps per draft tube channel will be used. Reference Section 2 will be located as close to draft tube outlet as possible, while meeting the requirements of IEC Publication 60193.

(iii) The rate of expansion of the draft tube will be constant upstream and downstream of Reference Section 2. There will be no sudden expansion or flaring of the draft tube downstream of Reference Section 2.

(d) Homology: The Turbine Model will be homologous to the prototype in all the water passages between the high pressure and low pressure Reference Sections, including all details of the main and peripheral water passages, except as may be approved by BC Hydro in advance of the manufacture of the Turbine Model. The scaling factor will be the ratio of the Turbine Model runner to prototype runner outlet diameters (Reference Diameter, D, as defined in Clause 1.3.3.2.6 of the IEC Publication 60193).

BC Hydro recognizes that for some features of the Turbine Model other than the main water passages it may be difficult to maintain 100% homology. If a non-homology arises, a description of the proposed non-homology(s) will be delivered in writing to BC Hydro, accompanied by appropriate justification, supporting information, modifications, rationale, and any proposed analytical Procedures to account for each non-homology. BC Hydro may request additional supporting information, data, and documentation it considers necessary to make a decision with respect to the proposed non-homology. If BC Hydro decides in its sole discretion to accept the non-homology, then BC Hydro will provide written confirmation of such acceptance to the Contractor. Acceptance of a non-homology by BC Hydro does not constitute an endorsement nor a recommendation of the non-homology. BC Hydro will not be obligated to review or accept any proposed non-homology. Except as specifically approved by BC Hydro in advance, the Contract will require 100% homology between the Turbine Model and the prototype.

The following will be homologous between the Turbine Model and prototype:

(i) runner fillets will be homologous to the prototype;

(ii) net area of balancing holes in the Turbine Model runner will be homologous to the net area of the balancing holes in the prototype; and

(iii) the axial gap between the runner and the discharge ring will be homologous with the prototype.

Within the limitations of the Turbine Model design, the following non-homologies between the Turbine Model and the prototype may be acceptable:

(iv) the wicket gate fillets will be as homologous as possible within the limitations caused by the geometrical differences between Turbine Model and prototype wicket gate shaft diameters;

(v) the stay vane fillets;

(vi) shaft length, shaft diameter, and shaft seal geometry;

(vii) the drains (penstock, spiral case, draft tube);

(viii) the flexible coupling;

(ix) the cooling water take off nozzle on the spiral case;

(x) the access doors or the small gaps around the access doors (spiral case, draft tube cone, draft tube elbow); and

(xi) the draft tube platform pockets in the draft tube cone.

The direction of Turbine Model rotation may be the same as the prototype (clockwise when looking down on the Turbine Model) or reversed relative to the prototype if the reverse rotation is beneficial for the Contractor’s Turbine Model development.

In addition to the above, the Contractor will submit any and all geometric differences that may occur between the Model and prototype Turbines, accompanied by appropriate justification, supporting information, modifications, rationale, and any proposed analytical Procedures to account for each geometric difference. A geometric difference is defined as a physical difference occurring between the scaled up Model and the prototype Turbine, regardless if the difference is within the allowable limits of the definition of homologous as indicated in IEC 60193 and/or SPT.

(e) <u>Draft Tube Gate Slots</u>: The Turbine Model draft tube construction will include homologous draft tube gate slots. The opening at the top of the draft tube gate slots will be included in the Turbine Model with a suitable hydraulically smooth cover which can be removed for additional optional tests by BC Hydro.

If the proposed draft tube has one draft tube pier, the gate slots will be modeled in accordance with the anticipated prototype dimensions listed below.

Slot dimensions at draft tube side walls: 1200 mm wide x 500 mm deep

Slot dimension at top of draft tube: 1800 mm wide

Minimum thickness of draft tube pier 2400 mm

2.4.2 Hydraulic Efficiency Scaling

(a) Turbine Model to Reference Turbine Model Scaling: The scaling of Turbine Model efficiency will be performed in accordance with the methodology and formulae of IEC Publication 62097, Edition 1.0, 2009, except as may be specifically noted herein. The rescinded spreadsheet associated with IEC 62097 will not be used. No scaling of Model efficiency will be made for the scale effect of leakage loss due to non-homologous runner seals between the Model and prototype.

For the purposes of normalizing the measured Turbine Model performance to a standard condition (the "**Reference Turbine Model**"), the following parameters will be used:

(i) Reference Reynolds number, $Re_{ref} = 7 \times 10^6$

(ii) Reference model water density, $\rho_{ref} = 1000\ kg/m^3$

(iii) Reference arithmetical mean roughness, Ra_{ref}, of Turbine Model components:

Spiral case	0.8 µm
Stay vane channels	0.8 µm
Wicket gate channels	0.4 µm
Runner blade, crown, and band (inner surfaces)	0.4 µm
Runner crown and band (outer surfaces)	0.8 µm
Draft tube	0.8 µm
Stationary parts (headcover, discharge/bottom ring) facing the runner outer surfaces	0.8 µm

Normalization of the Turbine Model test data to the Reference Turbine Model condition, including the transposition of tested Turbine Model hydraulic efficiency to the hydraulic efficiency at the Reference Turbine Model condition will be in accordance with the methodology and scale effect formulas of IEC 62097. However, the shift in the values of N_{ED} and Q_{ED} as specified in IEC 62097 as a condition of hydraulic similarity between the Turbine Model and homologous prototype is to be disregarded.

The calculation of arithmetic average roughness measurements will be in accordance with IEC 62097.

(b) Reference Turbine Model to Prototype Scaling: Scaling to the prototype efficiency will be performed in two distinct steps, from the Turbine Model as-measured to the Reference Turbine Model condition, and then from the Reference Turbine Model condition to the prototype condition.

The roughness values used for the prototype will meet the requirements of SPT 2.4.3(b).

For the purpose of scaling the Model hydraulic efficiency to the prototype Reynolds number the temperature of water for the prototype conditions will be assumed to be 8°C.

2.4.3 Roughness

(a) Turbine Model Roughness: Turbine Models will be manufactured with the roughness, Ra, of the Model components within the following ranges:

Spiral case	0.4 – 1.6 µm
Stay vane channels	0.4 – 1.6 µm
Wicket gate channels	0.2 – 0.8 µm
Runner blade, crown, and band (inner surfaces)	0.2 – 0.8 µm
Runner crown and band (outer surfaces)	0.4 – 1.6 µm
Draft tube	0.4 – 1.6 µm
Stationary parts (headcover, discharge/bottom ring) facing the runner outer surfaces	0.4 – 1.6 µm

Notwithstanding the requirements of SPT 2.1.2(f)(ii), if a component arithmetic average roughness measurement, Ra, is found to exceed the upper limit of the above allowable ranges, the roughness value of the affected component(s) used for the efficiency scaling calculation (SPT 2.4.2(a)) will be assigned the upper limit of the above allowable ranges for the specific component. No adjustment will be made for a roughness value which is lower than the above ranges.

(b) Prototype Roughness: For the efficiency step up from Turbine Model to prototype, the Contractor will use the prototype roughness values stated in the Turbine TDIF. The prototype roughness values used for the step up calculation will become a minimum requirement for the manufactured prototype. The Contractor will not use roughness values less than the following (the upper limits on prototype roughness are specified in SPT 4.12.2, 4.17.3 and 4.22.2):

(i) the minimum surface roughness (arithmetical mean value) of the runner blades, including the blade fillets at the crown and band will be 1.6 µm;

(ii) for other runner surfaces exposed to the water flow, including those of peripheral water passages, such as seals and outer surfaces of runner band and crown, the minimum surface roughness (arithmetical mean value) will be 3.2 µm;

(iii) for wicket gate surface exposed to the water flow, the minimum surface roughness (arithmetical mean value) will be 1.6 µm;

(iv) for unpainted stationary parts exposed to the water flow, the minimum surface roughness (arithmetical mean value) will be 3.2 µm; and

(v) for painted stationary parts exposed to the water flow, the minimum surface roughness (arithmetical mean value) will be 6.3 µm.

2.4.4 Turbine Model Measurements

(a) Dimensional Measurements: All dimensions of the final Turbine Model will be measured immediately after completion of Model testing and will meet the uniformity requirements of Table 2.4.5.

For hydraulic profiles (runner blades, stay vanes, and wicket gates) the Contractor will measure a number of surface points and, by the use of software programs, compare them to the design. A minimum of 50 surface points per runner blade surface will be measured. The distribution of the measured surface points will be guided by the curvature of the surface. Additional minimum six points will be measured on each of the blade edges. The measurement data for hydraulic profiles can be in tabular form and for the Turbine Model runner no less than 50% of the runner blades will be measured after assembly of the blades into the crown and the band. In all cases the design dimensions and allowable deviations from the design will be noted in the dimensional tabulation form.

All measurements will be properly documented and submitted with the Turbine Model Test Report. Prior to submittal, the Model measurements will be analyzed by the Contractor and those areas out of tolerance will be highlighted and the corrective action indicated.

The measurement reports will document compliance of the Turbine Model with the uniformity and homology requirements and tolerances contained in Table 2.4.5.

(b) Roughness Measurements: Measurement of the Turbine Model roughness for Contract purposes will be measured at the Independent Laboratory, prior to the start of independent testing, as indicated in SPT 2.1.2(f)(ii).

The surface roughness will be measured at the following sample points:

Spiral case	Nine points; at three radial sections: entrance, middle and end of casing
Stay vane channels	Two channels, with six points per channel; two points per side of the vane, one point on the top of the channel, one point on the bottom of the channel
Wicket gate channels	Two channels, with 10 points per channel between two wicket gates; six points on the inner side of the wicket gate, two points on the outer side of the wicket gate, one point on the top of the channel, one point on the bottom of the channel
Runner blade channels	Two channels, with 10 points per each blade side, three points on the runner crown, and three points on the runner band within one channel
Runner crown and band (outer surfaces)	Five points on each of the outside surface of the crown and band
Draft tube	10 points, with seven points located upstream of the bend
Stationary parts (headcover, discharge/bottom ring) facing the runner outer surfaces	10 points at the areas facing to the runner band and crown outer surface measurement points

2.4.5 Turbine Model Uniformity Requirements

Table 2.4.5 - Model Uniformity and Homology with Prototype Requirements

Dimensions	Permissible maximum deviation of individual value from average value
Principal dimensions of hydraulic passages	
Spiral case, draft tube, etc.	±0.5%
Stay ring diameters	±0.25%
Length of wicket gates and stay vanes	±0.5%
Maximum thickness of wicket gates and stay vanes	±1.0%
Distributor height	±0.3%

Dimensions	Permissible maximum deviation of individual value from average value
Wicket gate pitch circle diameter Wicket gate profile Stay vane profile Relative angular position between wicket gates and stay vanes Wicket gate opening for the nominal 50% and 100% positions	±0.1% ±1.0%T ±2.5%T ±0.5° ±1.0%a
Runner dimensions Blade profiles Inlet pitch Inlet and outlet opening Inlet and outlet diameter and other runner dimensions Runner seal length Runner seal diameter	 ±0.1%D ±0.1%D ±2.0%a ±0.2%D ±2.0% ±0.2%
Clearances Runner seal clearances Wicket gate end clearances Headcover/runner crown Discharge ring/runner band	 ±30% ±30% ±2.0% ±2.0%

D - Runner outlet diameter
T - Maximum thickness (wicket gate, stay vane)
a - Opening between two adjacent blades or wicket gates

Notes:
- Wicket gate profile includes both sides of the gate over the full gate length.
- Stay vane profile includes both sides of the vane over the full vane length.
- Blade profile includes both sides of the blade over the full blade length.
- Blade profile is measured after runner assembly.

2.5 Turbine Model Test Report

2.5.1 General

All turbine model test reports (each a "**Turbine Model Test Report**") will be prepared in accordance with Clause 2.3.3.5 of the IEC Publication 60193, augmented as detailed below. Each Turbine Model Test Report will describe in detail all hydraulic studies and Turbine Model development work and as a minimum will include the results of Turbine Model testing.

2.5.2 Description of Hydraulic Laboratory

The laboratory, in which the Turbine Model tests were performed, will be described. Details will be provided of the measuring instruments and their calibration.

2.5.3 Calibration Records and History

All instrument pre-test calibrations and post-test verifications of calibrations will be documented. Relation of the calibrations to recognized primary standards will be clearly traced.

Calibration records will include the calibration history of the individual measuring instruments to permit assessment of the long-term stability of the instruments. The history will include at least six calibrations done prior to these tests or cover a period of at least one year.

2.5.4 Hydraulic Study, Turbine Model Development Results, and Design Analysis

Detailed calculation Reports and analysis for the hydraulic design and Turbine Model development theoretical analysis and design analysis work identified in SPT 2.1.2(a) and SPT 2.1.2(b).

The calculation Reports and analyses will include supporting information regarding the hydraulic design and Turbine Model development. The supporting information will present any distinguishing features or optimizations made regarding:

(a) Runner:

(i) number of runner blades, blade length, and hydraulic profile;

(ii) runner band and crown hydraulic profiles;

(iii) length, clearance, type, and configuration of upper and lower runner seals;

(iv) location, number, and size of runner crown pressure relief holes; and

(v) thickness and shape of blade trailing edges to avoid Von-Karman vortex induced resonance.

(b) Spiral Case and Stay Ring:

(i) hydraulic profile of the spiral case and stay ring, including stay vanes and stay ring shrouds; and

(ii) thickness and shape of stay vane trailing edges to avoid Von-Karman vortex induced resonance.

(c) Draft Tube:

(i) hydraulic profile of the draft tube.

(d) Wicket Gates:

(i) hydraulic profile of the wicket gates.

2.5.5 Turbine Model Performance Curves

Hydraulic performance characteristics of the Turbine Model at the reference Reynolds number of $Re_{ref} = 7 \times 10^6$ will be shown on the following curves:

(a) Turbine Model performance hill chart developed in accordance with SPT 2.3.1, consisting of speed factor and discharge factor as its axes will indicate:

(i) lines of constant hydraulic efficiency of the Turbine Model at the reference Reynolds number of $Re_{ref} = 7 \times 10^6$;

(ii) lines of constant wicket gate opening;

(iii) lines of constant power factor;

(iv) lines of constant critical Thoma number (σ_1);

(v) line of Cavitation Protection Margin;

(vi) specified operating range;

(vii) rope free zone at reference plant Thoma number;

(viii) runner blade face side cavitation limit;

(ix) runner inflow and outflow cavitation limits; and

(x) runner blade inter-channel vortices limit.

(b) Curves of Turbine Model hydraulic efficiency and discharge factor at speed factors (corresponding to the range of NSHEs) plotted against wicket gate openings.

(c) Curves of power factor, discharge factor and hydraulic efficiency at each wicket gate opening tested, plotted against the speed factor, starting at zero and extending up to runaway speed factor.

(d) Curves of Turbine Model hydraulic efficiency plotted against the power factor for the range of NSHEs.

(e) Curves of speed factor and discharge factor at the runaway conditions for the range of wicket gate openings between closed position of the gates and 120% of maximum achievable prototype gate angle.

If naturally aspirated air admission is required, the curves of Turbine Model hydraulic efficiency showing the effects of air admission, with efficiency plotted against the power factor for the range of NSHEs will also be included.

2.5.6 Cavitation Test Data

Results of cavitation tests will be shown as curves of discharge factor, power factor and hydraulic efficiency versus the Thoma number for various speed factors corresponding to the operating range of NSHEs and tested range of Turbine Model wicket gate openings. These curves will clearly show vertical lines for the following values of the Thoma number:

(a) reference plant Thoma number;

(b) critical Thoma number (σ_1);

(c) Thoma number corresponding to the Cavitation Protection Margin; and

(d) Thoma number for incipient cavitation.

Curves of critical Thoma number versus discharge factor for the range of NSHEs will also be plotted.

In addition, sketches and digital photographs taken during visual observations of the cavitation phenomenon at the tested Model Regimes will be presented.

2.5.7 Expected Prototype Performance Curves

Prototype hydraulic efficiency will be scaled from the Turbine Model hydraulic efficiency in accordance with SPT 2.4.2.

Prototype performance hill charts will be generated (from the Turbine Model performance hill chart results), consisting of NSHE and MW power output as its axes and will indicate:

(a) lines of constant hydraulic efficiency of the prototype;

(b) lines of constant wicket gate opening;

(c) lines of constant discharge;

(d) lines of constant critical Thoma number (σ_1);

(e) line of Cavitation Protection Margin;

(f) operating range for normal operating conditions;

(g) rope free zone at reference plant Thoma number;

(h) runner blade face side cavitation limit;

(i) runner inflow and outflow cavitation limits; and

(j) runner blade inter-channel vortices limit.

Curves of expected prototype hydraulic efficiency, power output, and discharge plotted against wicket gate openings scaled-up from the results of the Turbine Model performance tests.

Curves of prototype runaway speed showing the relationship of prototype runaway speed to wicket gate opening for the range of NSHEs.

If naturally aspirated air admission is required, the Report will include the curves showing relationship of the pressure fluctuations, prototype hydraulic efficiency, power output, discharge and wicket gate opening for the range of NSHEs, with the effects of air admission indicated on these curves.

2.5.8 Sample Calculations

Sample calculations for the Turbine Model hydraulic efficiency, cavitation, runaway speed tests and other tests of the Turbine Model will be presented.

Sample calculations of the prototype hydraulic efficiency calculation for the proposed Site C Turbine in accordance with the methodology and formulas of IEC 62097 and as specified herein will be presented.

2.5.9 Turbine Model and Prototype Hydraulic Efficiency Data

For each Weighting Regime the scaled-up prototype hydraulic efficiency of the Turbine will be calculated for the Weighting Regimes specified in Table 3.3.3.

2.5.10 Wicket Gate Torque Test Data

Wicket gate torque test results will be provided with the balance point clearly identified.

2.5.11 Hydraulic Thrust Data

Hydraulic thrust measurement results and calculations of the thrust for the prototype will be presented.

2.5.12 Pressure Fluctuation Test Data

Expectations of pressure fluctuations on the prototype relative to those observed on the Turbine Model and requirements for naturally aspirated air admission to reduce pressure fluctuations will be provided.

2.5.13 Comparison of Specified Limits

Comparison of the Turbine Model Test results with the following will be presented:

(a) Cavitation Protection Margin;

(b) Turbine Model pressure fluctuation limits; and

(c) all other performance requirements.

2.5.14 Test Uncertainties

Calculations of the systematic and random uncertainty in the tested hydraulic efficiency of the Turbine Model will be presented in the Turbine Model Test Report together with an assessment of the uncertainties for other Turbine Model Test results, including the cavitation protection margin, the amplitudes of pressure fluctuation, and the Turbine Model wicket gate torque and hydraulic thrust uncertainties.

The aggregate of all test uncertainty for Turbine Model efficiency measurements will not exceed ±0.25%.

2.5.15 Non-homologies

A descriptive list of Turbine Model non-homologies, complete with figures if appropriate, will be included in the Turbine Model Test Report.

2.5.16 Turbine Model Dimensions and Drawings

As-built Turbine Model drawings and as-measured Turbine Model dimensions and surface roughness will be included in the Turbine Model Test Report.

As-built Turbine Model drawings will include all Turbine hydraulic components and peripheral water passages required for verifying homology with the prototype.

For all water passage components, as-built Turbine Model drawing revisions will be based on actual Turbine Model measurements (Turbine Model dimensions will be revised on as-built Turbine Model drawings if the average value of a dimension deviates from the design value by 0.2% or more). The as-built Turbine Model water passage drawings will form the basis for the prototype design drawings.

SPT3 HYDRAULIC DATA

3.1 Specific Hydraulic Energy (SHE) Variations

3.1.1 General

The intent of SPT3 is to describe the hydraulic design criteria and the Plant Annual Energy Calculation for the Units.

The Equipment will be designed to meet the requirements of the Contract while operating over the range of reservoir and tailwater levels, and the resulting NSHE's set out in this Appendix 6-3 [Turbine Specifications (SPT)].

3.1.2 Reservoir Levels

The Site C reservoir levels for operation of the dam and the Powerhouse are defined as follows:

(a)	Maximum Reservoir Flood Level[1]	El. 466.3 m
(b)	Maximum Normal Reservoir Operating Level	El. 461.8 m
(c)	Normal Reservoir Operating Level	El. 461.7 m
(d)	Minimum Normal Reservoir Operating Level	El. 461.2 m
(e)	Minimum Normal Reservoir Level	El. 460.0 m
(f)	Minimum Reservoir Level	El. 451.5 m

Note:

(1) The Maximum Reservoir Flood Level corresponds with the Maximum Flood Tailwater Level specified in SPT 3.1.4.

3.1.3 Reservoir Operating Ranges

The Site C reservoir operating ranges for operation of the dam and generating plant are as follows:

Table 3.1.3 - Reservoir Operating Ranges

Description	Lower Reservoir Elevation (m)	Upper Reservoir Elevation (m)
Flood Reservoir Operating Range	461.8	466.3
Normal Reservoir Operating Range[1]	461.2	461.8
Low Reservoir Operating Range	460.0	461.2
Minimum Reservoir Operating Range[2]	451.5	460.0

Notes:

(1) For the purposes of Schedule 6 [Specifications and Drawings] only, the Normal Reservoir Operating Range of the Site C reservoir will be 0.60 m and between the Maximum Normal Reservoir Operating Level and the Minimum Normal Reservoir Operating Level.

(2) Applicable to commissioning of the first Unit and for possible future emergency reservoir draw down.

3.1.4 Preliminary Tailwater Levels

Tailwater levels (the "**Tailwater Levels**") are defined as follows:

(a) Maximum Flood Design Tailwater Level at El. 419.5 m; and

(b) Intermediate tailwater levels (the "**Tailwater Curve**") will be determined by linear interpolation between the closest tailwater levels set out in Table 3.1.4.

Table 3.1.4 - Tailwater Curve

Facility Discharge (m^3/s)	Tailwater Level (m)
0	408.4
390	408.9
500	409.1
1,000	409.9
1,500	410.6
2,000	411.2
2,500	411.7
3,000	412.2

(c) This Tailwater Curve will be used for:

(i) determining sigma values as described in SPT 2.3.2 for use in the Plant Annual Energy; and

(ii) measurement of cavitation curves in the Model test and the determination of the cavitation safety margin from those curves in accordance with SPT 2.2.1.

3.1.5 Prototype Tailwater Levels

Prototype tailwater levels predicted for the Project (the "**Prototype Tailwater Levels**") are defined as follows:

(a) Maximum Flood Design Tailwater Level at El. 419.5 m; and

(b) Intermediate tailwater levels (the "**Prototype Tailwater Curve**") will be determined by linear interpolation between the closest tailwater levels set out in Table 3.1.5.

Table 3.1.5 - Prototype Tailwater Curve

Facility Discharge (m^3/s)	Tailwater Level (m)
0	408.2(1)
390	408.7(2)
500	408.8
1,000	409.7
1,500	410.4
2,000	411.0
2,500	411.5
3,000	412.0

Notes:

(1) In extreme conditions (such as a complete plant outage) tailwater may fall as low as elevation 408.2 m.
(2) Each Unit must be capable of continuous operation with a minimum facility discharge of 390 m^3/s with a tailwater level of 408.7 m.

(c) This Prototype Tailwater Curve will be used for:

(i) determining the Turbine Rated Output;

(ii) determining all prototype operating conditions including the Normal Turbine Operating Range and Other Operating Conditions;

(iii) determining the performance at Operating Condition C from the Turbine Model Testing; and

(iv) cavitation warranty purposes in accordance with SPT 4.4.

3.1.6 Penstock Dimensions

The penstock internal diameter will be optimized in the future by Others based on a project cost/benefit analysis. It is anticipated that the penstock diameter will be between 9.8 m and 10.5 m. The Equipment will be designed to operate safely and reliably with a penstock internal diameter in the range of 9.8 m to 10.5 m.

Penstock dimensions may be assumed to be the following:

(a) approximate length of intake to start of penstock: 35 m;

(b) approximate length of steel penstock to flexible coupling: 80 m; and

(c) penstock internal diameter at flexible coupling: determined by the Contractor.

3.1.7 Intake and Penstock Head Losses and Net Specific Hydraulic Energies

(a) Intake and Penstock Head Losses: For all performance testing, including the determination of the Plant Annual Energy, the total head losses from the intake at the reservoir to the penstock/spiral case flexible coupling (the "**Intake and Penstock Head Losses**") will be calculated as follows:

Head loss = $k*Q^2$ where:

D_1	K_1	Notes
9.8	$2.40 * 10^{-6}$	For use to establish Turbine operating head range
10.2	$2.11 * 10^{-6}$	To be used for Plant Annual Energy Calculation and where otherwise noted
10.5	$1.94 * 10^{-6}$	For use to establish Turbine operating head range

K_2	=	$(4.13 * 10^{-3}) * [(1/D_1^4) + (1/D_2^4)]$
Q	=	Selected Turbine Discharge in m^3/s
D_1	=	inside diameter of the penstock upstream of the lower reducing elbow
D_2	=	inside diameter of the spiral case inlet at the flexible coupling between the spiral case and penstock (the above head loss calculation, k, is valid for D_2 between 7.0 - 10.0 m)
k (head loss coefficient)	=	$K_1 + K_2$

(b) Outlet Head Loss: For all performance testing, including the determination of the Plant Annual Energy, the outlet (draft tube exit) head loss will be calculated as follows:

DE	=	Clear height of the draft tube outlet
DW	=	Clear width of the draft tube outlet in plan (if a central pier is used this will be the clear width of the two outlets combined)
ko (outlet head loss coefficient)	=	$1/(2*g)/(DE*DW)^2$
Outlet Head Loss	=	$ko* Q^2$

(c) Net Specific Hydraulic Energies (NSHE): "**Net Specific Hydraulic Energy**" or "**NSHE**" is defined as the difference between:

(i) the total Specific Hydraulic Energy ("**SHE**") at the Turbine high pressure reference section (Reference Section 1) determined as the aggregate of the potential SHE plus the pressure SHE plus the velocity SHE;

and:

(ii) the total SHE at the Turbine low pressure reference section (Reference Section 2) determined as the potential SHE at the elevation of the tailwater level plus the velocity SHE.

NSHE and SHE will be calculated as local acceleration due to gravity times head. Local acceleration due to gravity at the elevation of the distributor centreline is deemed to be 9.8149 m/s^2.

3.1.8 Reference Operating Heads

The variation in net head will be determined by the Contractor using the information described in SPT 3.1 above in general and specifically considering the range of penstock dimensions shown in SPT 3.1.6 and Intake and Penstock Head Losses indicated in SPT 3.1.7(a).

3.2 Operating Conditions and Operating Zones

3.2.1 Normal Turbine Operating Range

The Normal Turbine Operating Range comprises operation within the Normal and Low Reservoir Operating Range with the tailwater levels corresponding to plant discharges from 390 m^3/s to 2540 m^3/s.

Together with Operating Zones 2 and 3, the following Operating Conditions A, B, C and the Other Operating Conditions define specific evaluation and operating conditions which will collectively be referred to as the "**Normal Turbine Operating Range**". The Equipment will be capable of continuous operation at any operating point within the Normal Turbine Operating Range while meeting all requirements of Schedule 6 [Specifications and Drawings].

3.2.2 Unit Operating Conditions

Each Unit will be capable of continuous operation under the following conditions, considering the range of penstock dimensions indicated in SPT 3.1.6:

(a) Operating Condition A: Operating Condition A ("**Operating Condition A**") is determined as follows:

(i) all six Turbines discharging 423.33 m^3/s (total plant discharge 2,540 m^3/s);

(ii) reservoir at the Minimum Normal Reservoir Operating Level;

(iii) the tailwater level corresponding to a facility discharge of 2,540 m^3/s; and

(iv) rated power factor of 0.95 (over excited).

(b) Operating Condition B: Operating Condition B ("**Operating Condition B**") is determined as follows:

(i) three Turbines operating at maximum discharge(1) (maximum Turbine discharge and Generator output for this Operating Condition B to be determined by the Contractor);

(ii) reservoir at the Minimum Normal Reservoir Operating Level;

(iii) the tailwater level for a facility discharge corresponding to three Turbines at maximum discharge; and

(iv) rated power factor of 0.95 (over excited).

Note:

(1) With less than full plant operation, Turbine discharge will be permitted to exceed 423.33 m^3/s. The Environmental Impact Statement (EIS) restricts total plant discharge to 2,540 m^3/s but does not limit the discharge of an individual Unit.

(c) Operating Condition C: Operating Condition C ("**Operating Condition C**") is determined as follows:

(i) each Unit operating at the discharge associated with the Prototype Minimum Turbine Output as determined during commissioning;

(ii) reservoir at the Maximum Normal Reservoir Operating Level;

(iii) the tailwater level for a facility discharge corresponding to the Prototype Minimum Turbine Output discharge from three Turbines; and

(iv) rated power factor of 0.95 (over excited).

Note:

Operating Condition C has been defined for the purposes of evaluating any future Additional Prototype Low-End Operating Range. The low-end operating range will be assessed relative to the Reference Minimum Turbine Output.

(d) Other Operating Conditions: the other operating conditions (the “**Other Operating Conditions**”) described below define other operating requirements for the Normal Turbine Operating Range:

(i) *Low Head, High Flow*: A Turbine operating at maximum achievable discharge associated with this head; with the reservoir at Minimum Normal Reservoir Level (460.0 m) and the tailwater at the level associated with a facility discharge of 2,540 m^3/s. If the maximum achievable Turbine discharge at this condition is less than 423.33 m3/s, then the tailwater level used will be the level associated with the total discharge of the maximum achievable discharge for six Turbines.

(ii) *Low Head, Low Flow*: A Turbine operating at the Prototype Minimum Output; with the reservoir at Minimum Normal Reservoir Level (460.0 m) and the tailwater at the level associated with a facility discharge of 2,540 m^3/s (or the tailwater at the level associated with the total discharge of the maximum achievable discharge for five Turbines plus one Turbine discharge at the Prototype Minimum Output, if this total discharge is less than 2,540 m^3/s).

(iii) *High Head, High Flow*: A Turbine operating at an output between the minimum facility discharge (390 m^3/s) and the Rated Turbine Output; with the reservoir at Maximum Normal Reservoir Operating Level (461.8 m) and the tailwater at the levels associated with discharges for one Turbine operating between the minimum facility discharge (390 m^3/s) and the Rated Turbine Output.

(iv) *High Head, Low Flow*: A Turbine operating at the Prototype Minimum Output; with the reservoir at Maximum Normal Reservoir Operating Level (461.8 m) and the tailwater at the level associated with the discharge of two Turbines operating at the Prototype Minimum Output.

3.2.3 Operating Zones

The following Operating Zones are used in Schedule 6 [Specifications and Drawings] for the purposes of defining service and performance requirements within the Normal and Low Reservoir Operating Range.

(a) Operating Zone 1: The range of Turbine outputs between speed no load and Operating Zone 2 (“**Operating Zone 1**”). The upper limit of Operating Zone 1 is determined by the smaller of the wicket gate opening at either the Reference Minimum Turbine Output or the Prototype Minimum Turbine Output.

(b) Operating Zone 2: The range of Turbine outputs from the upper limit of Operating Zone 1 up to the wicket gate opening for the Turbine operating at Weighting Regime “B” in Table 3.3.3 (“**Operating Zone 2**”). The wicket gate opening determined for Weighting Regime “B” will be fixed for all other net heads for determining the boundary of Operating Zones 2 and 3.

(c) Operating Zone 3: The range of Turbine outputs from the wicket gate opening corresponding to Weighting Regime “B” in Table 3.3.3 (as described in Operating Zone 2 above) to the Turbine Rated Output (“**Operating Zone 3**”).

3.2.4 Turbine Operating Conditions

A Turbine operating condition (the “**Turbine Operating Condition**”) is an operating point defined by NSHE and discharge in the required range of Turbine operation.

3.3 Turbine Rating and Energy Calculation

3.3.1 Turbine Rated Output

The Turbine rated output (the "**Turbine Rated Output**") is the highest achievable Turbine power output that can be delivered continuously to the Generator from the Turbine through the Turbine shaft while meeting all requirements of Schedule 6 [Specifications and Drawings]. The Contractor is to determine the Turbine Rated Output.

The Turbine will be designed to achieve the Turbine Rated Output at Operating Condition A. The Turbine will also achieve the Turbine Rated Output for the range of net heads determined from the reservoir levels within the Normal Reservoir Operating Range and the Prototype Tailwater Levels corresponding to one to six Units in operation.

If a higher Turbine Rated Output is determined by the Contractor to be beneficial to the Project, while still complying with the requirements of Schedule 6 [Specifications and Drawings], then, as a minimum, the Equipment will be sized to deliver this higher Turbine Rated Output at Operating Condition B. The Turbine will also achieve this higher Turbine Rated Output for the range of net heads determined from the reservoir levels within the Normal Reservoir Operating Range and the Prototype Tailwater Levels corresponding to one to three Units in operation.

The Turbine Rated Output will be the higher of the Turbine power in megawatts as determined for Operating Conditions A and B.

The Turbine Rated Output will be determined with consideration of the range of potential penstock dimensions indicated in SPT 3.1.6 and SPT 3.1.7.

3.3.2 Minimum Turbine Output

(a) Reference Minimum Turbine Output: The reference minimum Turbine output (the "**Reference Minimum Turbine Output**") is defined by the Turbine Model wicket gate opening for the Turbine operating at Weighting Regime "A" in Table 3.3.3.

The wicket gate opening determined for Weighting Regime "A" will be fixed to determine the minimum Turbine discharges for all other net heads within the Normal and Low Reservoir Operating Ranges. The range of Turbine outputs in megawatts measured at the Generator terminals at these minimum Turbine Discharges will define the Reference Minimum Turbine Outputs.

The Reference Minimum Turbine Output will be determined considering the range of penstock dimensions indicated in SPT 3.1.6.

(b) Prototype Minimum Turbine Output: If it is determined at Site, after completion of all Equipment start-up and commissioning tests, that the prototype Turbine is capable of continuous operation at a fixed wicket gate opening that is smaller than the wicket gate opening associated with the Reference Minimum Turbine Output at Operating Condition C, then a revised minimum output (the "**Prototype Minimum Turbine Output**") may be determined provided that the Equipment is capable of continuous operation in the range of wicket gate openings between this Prototype Minimum Output and the Reference Minimum Turbine Output, and meets all requirements of Schedule 6 [Specifications and Drawings] within the Normal Turbine Operating Range.

The Prototype Minimum Turbine Output value will be measured at the Generator terminals. The Contractor will submit a Report for Consent documenting the Prototype Minimum Turbine Output complete with supporting information such as successful experience on similar work, experimental or test data, calculations, or other means, to demonstrate that the Unit is capable of operating continuously at the Prototype Minimum Turbine Output.

(c) Additional Prototype Low-End Operating Range: The additional prototype low-end operating range (the "**Additional Prototype Low-End Operating Range**") is the difference (as determined at the Generator terminals) between the Reference Minimum Turbine Output and the Prototype Minimum Turbine Output at Operating Condition C.

3.3.3 Plant Annual Energy Calculation

The average annual energy (the "**Plant Annual Energy**") generated by the Units will be determined for each Weighting Regime, from the Turbine Model scaled-up efficiency as specified in SPT 2.4.2. The scaled-up efficiencies for the prototype Turbine, along with the Gross Head and Turbine discharges listed in Table 3.3.3 will be used to calculate the Plant Annual Energy in accordance with the operating hours and formulae (the "**Plant Annual Energy Calculation**") shown in Table 3.3.3.

If air admission is required, the Model efficiencies using air admission will be used for verification against the Contract requirements and guarantees as described in this Appendix 6-3 [Turbine Specifications (SPT)]. The scaled-up efficiencies entered into Table 2.19 of the Turbine TDIF will include air admission when applicable.

All weighting regimes shown in Table 3.3.3 (each a "**Weighting Regime**") will be located in Operating Zone 2 or 3.

The Plant Annual Energy Calculation will be submitted in accordance with the following subsections:

(a) Contractor's Turbine Model Test Report: The Plant Annual Energy data as set out in [redacted]

The Intake and Penstock Head Losses for the Plant Annual Energy Calculation will be calculated for a 10.2 m diameter penstock.

(b) Independent Turbine Model Test: Table 2.19 of the Turbine TDIF, updated by BC Hydro with the turbine efficiencies measured at the Independent Laboratory, is the guaranteed plant annual energy (the "**Guaranteed Plant Annual Energy**").

The Intake and Penstock Head Losses for the Plant Annual Energy Calculation will be calculated for a 10.2 m diameter penstock.

(c) Generator Losses Testing: The prototype Generator performance, as measured during Site acceptance and commissioning testing, will be used to update the Plant Annual Energy Calculation which will be evaluated against the Guaranteed Plant Annual Energy to determine whether there is any shortfall.

Table 3.3.3 - Plant Annual Energy Calculation

Constants and operating conditions to be used in performance calculations:

Reservoir Level (H_{res})	$461.7\ m$	Local gravitational acceleration (g)	$9.8149\ ^{m}/_{s^2}$	Gross Head $(H_g = H_{res} - H_{tr})$	$51.2\ m$
Tailwater Level (H_{tr})	$410.5m$	Density of water (p)	$1000\ ^{kg}/_{m^3}$	Frequency (f)	60 Hz

Weighting Regime	Turbine Discharge	Head Losses	Net Head	NSHE	Scaled up Prototype Turbine Efficiency	Turbine Output	Generator Losses[1,2]	Generator Output	Operating Hours (annual, 6 units)	Energy (annual, 6 units)
	$\left(^{m^3}/_{s}\right)$	(m)	(m)	$\left(^{m^2}/_{s^2}\right)$	$(\%)$	(kW)	(kW)	(kW)	(h)	(GWh)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		$(k + ko) \cdot (1)^2$	$H_g - (2)$	$(3) \cdot g$		$\frac{(1) \cdot (4) \cdot (5) \cdot p}{10^3}$		$(6) - (7)$		$\frac{(8) \cdot (9)}{10^6}$
A	**260**								**2,000**	
B	**310**								**1,500**	
C	**320**								**3,000**	
D	**330**								**3,500**	
E	**340**								**3,500**	
F	**350**								**3,500**	
G	**360**								**3,500**	
H	**370**								**3,000**	
I	**380**								**2,500**	
J	**390**								**2,500**	
K	**400**								**2,000**	
L	**410**								**500**	
Synchronous Condenser Operation[3]						0			**4,000**	
									Plant Annual Energy (GWh):	

Notes:

1 Generator losses for this calculation are for the Generator operating at a power factor of 0.95, except as noted in note 3 below.

2 Generator losses for this calculation are to include Generator thrust bearing losses, including hydraulic thrust from the Turbine, Generator guide bearing losses, and Turbine guide bearing losses.

3 Generator losses for this calculation are for the Generator operating under-excited with a reactive power output in kVAr measured at the Generator terminals equal to 50% of the Generator Rated Output (kVA). Turbine windage will not be included for this presentation of synchronous condenser energy consumption.

SPT4 TURBINE TECHNICAL DATA AND REQUIREMENTS

4.1 General

The design and operation of the Turbines will not adversely impact structural integrity of the Unit penstock. Proper consideration will be given to any limitations of structures and design loads of these structures will not be exceeded at all required operating conditions of the Turbine.

4.2 Turbine Data

Not used.

4.3 Design Criteria

4.3.1 Hydraulic Pressure Fluctuations

Within the full range of steady-state operating regimes of the prototype Turbine, the maximum peak-to-peak amplitude of the 97% probability distribution time signal of pressure fluctuations in the prototype water passages will not exceed the following percentage of the test NSHE multiplied by the density of the water.

The measured prototype pressure fluctuations will not exceed the hydraulic pressure fluctuations measured at the Independent Laboratory in any Operating Zone by more than 3% of the test NSHE multiplied by the density water. Where the Turbine discharge, at which the maximum pressure fluctuations in the prototype occur, differs from the equivalent Turbine Model discharge at which maximum Model pressure fluctuations occur, the evaluation will compare the difference between the maximum hydraulic pressure fluctuations in the Turbine Model and the prototype for each Operating Zone independent of Turbine discharge.

For the purpose of the evaluation of hydraulic pressure fluctuations at the steady-state operating regimes, the peak-to-peak amplitude of the pressure fluctuations is defined in accordance with Clause 1.3.3.10.8 of the IEC Publication 60193. The 100% time signal will be presented for information purposes. Aperiodic pressure spikes resulting from localized cavitation bubbles collapsing on the draft tube wall may be excluded from the evaluation of hydraulic pressure fluctuations if the Contractor submits such proposed exclusion for Consent.

4.3.2 Shaft Runout

The indicated shaft runout is defined as the maximum vibratory peak-to-peak displacement of the Turbine shaft in accordance with the Standard ISO 7919-5.

For all steady-state operating regimes within the range of NSHE, the total indicated shaft runout referenced to the Turbine guide bearing support or bearing housing and combining the synchronous and asynchronous runouts, will not exceed the following limits:

(a) 0.25 mm in Operating Zone 1;

(b) 0.2 mm in Operating Zone 2; and

(c) 0.175 mm in Operating Zone 3.

The guide bearing clearance selected by the Contractor will allow for a minimum 0.1 mm instantaneous oil film thickness between the rotating shaft and guide bearing pads at the operating conditions with the highest runout and/or eccentricity of the shaft within the bearing.

The synchronous shaft run out at the Turbine guide bearing for all steady state operating conditions will not exceed the limits specified in the CEATI International Report No. T052700-0329 Hydroelectric Turbine Generator Units Guide for Erection Tolerances and Shaft System Alignment – Part II – Table 10.

In addition to the above requirements, the non-rotating parts will meet the requirements of ISO 10816-5 evaluated for Zone A based on displacement measurements.

4.3.3 Loading Conditions

The Contractor will design the Turbine components and auxiliaries for the most adverse combination of the loading conditions listed below and described in Schedule 6 [Specifications and Drawings], plus any other loading conditions which the Contractor considers necessary, all without exceeding the specified allowable stresses. The Turbine and all auxiliary equipment will remain intact and functional after a seismic event specified in Appendix 6-2 [General Technical Specifications (SPGT)] has occurred.

The minimum loading conditions are listed below. The Contractor will add additional degrees of conservatism as its experience and best practice dictate.

(a) Spiral Case Design Pressure;

(b) Maximum runaway speed of Turbine;

(c) Maximum hydraulic downthrust;

(d) Maximum hydraulic uplift;

(e) Normal operation at all operating conditions specified in Appendix 6-2 [General Technical Specifications (SPGT)] including load changes at any rate within the hydraulic limits specified elsewhere in the Appendix;

(f) Load rejections from all gate positions;

(g) Mass of concrete, Turbine and Generator parts;

(h) Governor oil system design pressure; and

(i) Generator short circuit and out-of-phase synchronization.

4.3.4 Spiral Case Design Pressure

The maximum pressure occurring in the spiral case during a full load rejection will not exceed 707 kPa at the distributor centerline elevation.

The design pressure to which the spiral case is designed to withstand (the “**Spiral Case Design Pressure**”), as determined at the distributor centerline elevation, will be equal to or greater than 707 kPa.

Each Unit will be designed for the fastest wicket gate opening and closing times possible, while still respecting the requirements of this Appendix 6-3 [Turbine Specifications (SPT)] and the Spiral Case Design Pressure.

4.3.5 Water Passage Components

The: flexible coupling, closure section, penstock spool piece, spiral case, bottom ring and/or discharge ring that form part of the lower wicket gate bushing access gallery, stay ring, headcover and all spiral case nozzles/drains/openings will:

(a) be designed for, as a minimum, the Spiral Case Design Pressure;

(b) assume no support from the surrounding concrete; and

(c) be designed and fabricated in accordance with ASME BPVC.

The flexible coupling, closure section, penstock spool piece, and spiral case will have a minimum corrosion allowance of 2 mm thickness included in the design.

4.3.6 Turbine Weight Requirements

The total combined weight of the Turbine runner coupled to the Turbine shaft, with the Turbine shaft and runner Lifting Device attached will not exceed the lifting capacity of the main hook of one Powerhouse bridge crane.

4.4 Cavitation Warranty

4.4.1 General

The design and installation of the Turbine will be such that cavitation damage will be kept to a minimum. Such damage, if it does occur, will not impair the strength of the runner or other parts of the Turbine, and will not measurably contribute to any decrease in the efficiency or power output of the Turbine.

4.4.2 Warranty Details

(a) Initial Period: There is an initial operating period of 8,000 Operating Hours for each prototype Turbine (the "**Initial Operating Period**") in generation mode (i.e., time spent in synchronous condenser mode is not taken into account in this 8,000 hours). The Initial Operating Period commences right after the Commissioning Notice to Operate is released. During the Initial Operating Period certain inspections may be performed as provided in SPT 4.4.3(b) and the provisions of SPT 4.4.3(c) will apply in respect of any cavitation damage arising.

(b) Cavitation Warranty Assessment Period: After the Initial Operating Period of 8,000 hours, the cavitation warranty assessment period (the "**Cavitation Warranty Assessment Period**") starts and will have a duration of 10,000 operating hours in generation mode (i.e., time spent in synchronous condenser mode is not taken into account in these 10,000 hours). The successive Cavitation Warranty Assessment Periods that will each be of a duration of 10 000 operating hours for the Turbine (collectively, the "**Warranty Assessment Periods**") will not commence until the Initial Operating Period and any obligations arising pursuant to SPT 4.4.3(c) have been completed.

(c) Stated Periods: The Initial Operating Period and the Warranty Assessment Periods are herein collectively referred to as the stated periods (the "**Stated Periods**").

(d) Warranty Inspection Outage Timing: The Contractor acknowledges and agrees that it may not be feasible to shut-down operation of the subject generating Unit such that the total hours of commercial operation in generation mode of the subject Unit match exactly the Stated Periods, since Shut-Down will have to take into account, among other things, BC Hydro system requirements. Although the parties will endeavour to have the shut-down occur as close as practicable to the Stated Periods, the deviation (the Deviation) from these Stated Periods, if any, is not to exceed:

(i) 20% of the applicable Stated Period, where the actual total operating hours (the "**Actual Operation Period**") are in excess of the Stated Period; or

(ii) 15% of the Stated Period, where the actual operating hours are less than the Stated Period.

(e) Actual Thresholds: For each of the Actual Operation Periods determined for the Warranty Assessment Periods (the "**Actual Warranty Assessment Periods**"), the Stated Thresholds will be adjusted if there is a Deviation (but in any event whether or not required to be adjusted will hereafter be referred to as the actual permitted thresholds (the "**Actual Permitted Thresholds**" and each an "**Actual Permitted Threshold**"), in accordance with the following formula:

A = B * (C/D)^E

Where:

A = the particular Actual Permitted Threshold (in kg for total material loss, in mm for pitting depth and in m^2 for frosted area) at the time of cavitation damage examination, as the case may be.

B = the applicable Stated Threshold (in kg for total material loss, in mm for pitting depth and in m^2 for frosted area) for D.

C = the Actual Operation Period.

D = the reference duration of commercial operation in generation mode of the subject Turbine, being 10,000 hours.

E = 1.3 for calculation of the Actual Permitted Threshold for total material loss (kg) or for pitting depth (mm) and 1.0 for calculation of the Actual Permitted Threshold for cavitation frosting (m^2).

(f) Cavitation Warranty: The Contractor guarantees that, for each Turbine, over the range of minimum to maximum NSHE's as determined by the Contractor using the data provided in this Appendix 6-3 [Turbine Specifications (SPT)] and under the conditions set out in SPT 4.4.3(a), the damage to the runner and non-rotating parts due to cavitation during the Cavitation Warranty Assessment Period, will not exceed the limits for material loss or damages stated in SPT 4.4.4.

4.4.3 Conditions, Inspections, Reports and Remedy

(a) Cavitation Warranty Conditions: The warranty will be based on the following conditions:

(i) over the range of minimum to maximum NSHE's as determined by the Contractor using the data provided in this Appendix 6-3 [Turbine Specifications (SPT)], the Turbine operation will be limited as follows:

(A) during the Stated Periods and also during the Actual Operating Periods, each Turbine will not be operated for more than 5% of its total aggregated operating time in generation mode, above the following Turbine outputs:

(I) the maximum Generator Output associated with a specific net head (as indicated by the limit of the operating range, Turbine hill chart, Turbine

Rated Output, or other as applicable) over the range of net heads guaranteed by the Contractor;

(B) during the Stated Periods and also during the Actual Operating Periods, each Turbine will not be operated for more than 10% of its total aggregate operating time in generation mode in Operating Zone 1;

(C) during the Initial Operating Period one or two Units may be operated for more than 5% of its total aggregate operating time in generation mode in the Minimum Reservoir Operating Range for the duration that it takes to fill the reservoir from the Minimum Reservoir Level of 451.5 m up to the Minimum Normal Reservoir Level of 460.0 m. Refer to Appendix 6-2 [General Technical Specifications (SPGT)] regarding the commissioning of the first Unit; and

(ii) for at least 99% of operating time, the minimum Prototype Tailwater Level at each of the Turbine discharges will be not lower than the level determined for single Unit operation with the Prototype Tailwater Curve in Table 3.1.5.

(b) <u>Inspections</u>: BC Hydro will dewater the Unit to allow the Contractor to carry out inspections of the Turbine and all Turbine water passages. There will be at least one inspection before the expiry of the Initial Operating Period and one inspection as close to the expiry of the Initial Operating Period as practicable. The Contractor will be given at least 30 Days advanced notice and 15 Days' notice of the Unit shutdown and will be allowed a period of up to 24 consecutive hours to carry out each inspection. The timing of the Unit shutdown will be determined by Hydro's Representative to suit BC Hydro's system requirements.

(c) <u>Site Reports</u>: If cavitation damage to the Turbine is found during any inspection in respect of any of the Stated Periods, the Contractor will prepare a site inspection Report to be submitted, which defines the extent and causes of the cavitation damage and will outline the proposed procedure and time required to carry out the necessary remedial work, modifications and cavitation repairs. Damage is defined as any "frosted" (see definition in SPT 4.4.4) or pitted surface. The site inspection Report will be complete with photographs, precise measurement of all the damaged areas, and recommendations concerning the need and urgency of carrying out remedial work, modifications and cavitation repairs. Within these recommendations the Contractor will indicate one of the following:

(i) remedial work, modifications and cavitation repairs will be made immediately. In such case, the Contractor will investigate immediately to find the causes of the cavitation severity; or

(ii) remedial work, modifications and cavitation repairs can be carried out at a later date, (but if in respect of the Initial Operating Period prior to the start of the Cavitation Warranty Assessment Period) when the generating Unit can be taken out of service without affecting BC Hydro's system.

(d) <u>Initial Operating Period Remedy</u>: Prior to start of the Cavitation Warranty Assessment Period, the Contractor will carry out such remedial work and modifications to the Turbine as required to remove the causes of cavitation damage, so that cavitation damage of the Turbine does not exceed the Actual Permitted Thresholds, and also at this time the Contractor will repair all cavitation damage irrespective of its importance, either immediately, or at a later date as agreed with Hydro's Representative. A period of up to 14 Days will be allowed for this work, and the Warranty Assessment Periods will not commence until this initial remedial work, modifications and repairs are accepted.

If there is any cavitation damage found during, or at the end of the Initial Operating Period, that could reasonably be expected to be present and in excess of the Stated Thresholds during the Cavitation Warranty Assessment Period, then the Contractor will proceed with the required CFD analysis and testing of the revised Turbine Model as indicated in SPT4.4.5. This CFD analysis and Turbine Model testing will commence immediately following the discovery of the cavitation damage.

(e) Hydraulic Design Expert: The inspections and supervision of the remedial work, modifications and repairs described above will be carried out by the Contractor's hydraulic design experts in the finishing of water passages.

4.4.4 Limits of Cavitation Damage

Cavitation thresholds for the Turbine (the "**Stated Thresholds**") that are permitted during any Cavitation Warranty Assessment Period is as follows, where Dth is defined as the throat diameter of the Turbine runner in metres:

(a) no loss of material, pitting, or cavitation frosting is permitted in the runner inlet area;

(b) the total volume of material removed will not exceed:

(i) runner 20 x Dth^2 cm^3;

(ii) for each runner water passage between two adjacent blades 3 x Dth^2 cm^3;;

(iii) all non-rotating parts of the Unit 10 x Dth^2 cm^3;

(c) the maximum depth of any pit will not exceed:

(i) runner 2 x $Dth^{0.4}$ mm or more than 1/3 of the material thickness at the location of the pit;

(ii) all non-rotating parts of the Unit 1 x $Dth^{0.4}$ mm;

(d) the actual loss of material from the runner and Turbine non-rotating parts, will be determined by an accepted Procedure in accordance with IEC Publication 60609 with material loss volume calculated after all areas damaged by cavitation have been ground to solid metal in preparation for welding. BC Hydro also requires the following:

(i) the total area of "Cavitation Frosting" will not exceed 2% of the total hydraulic area of each component including the runner, discharge ring and draft tube cone. No cavitation will be allowed on the spiral case, the stay ring, the stay vanes, the bottom ring, the headcover and the wicket gates, etc.; and

(ii) for each runner water passage between two adjacent blades, the area of cavitation frosting as defined below will not exceed 0.2 m^2;

(e) for the purpose of the Contract Documents, the areas of Cavitation Frosting (the "**Cavitation Frosting**") will be defined as those areas where the depth of damage is less than 0.5 mm and where the surface roughness (arithmetical mean value) has deteriorated due to cavitation to a value of 12.5 µm or larger value for the runner and /or to a value of 50 µm or larger value for other Turbine components affected by frosting;

(f) any continuous area on the surfaces of the runner and Turbine non-rotating parts, where the depth of cavitation pitting is 2 mm or more, will not exceed an area of 25 cm^2; and

(g) wear due to erosion by suspended material in the water or corrosion caused by the chemical composition of the water is not included in the evaluation of the cavitation damage.

4.4.5 Repair Under Warranty

(a) General: If the Turbine fails, or is expected to fail to meet the warranty requirements for material loss or other cavitation damage as stated in SPT 4.4.4, the Contractor will, at an acceptable time, modify and repair pitted areas of the Turbine by welding and grinding in an acceptable manner. The Contractor will carry out such modifications as required to remove the cause of the cavitation erosion, subject to SPT 4.4.5(b), SPT 4.4.5(c) and SPT4.4.5(d). For repairs to the stainless steel runner the Contractor will use state of the art material exhibiting resistance to cavitation superior to that of the base runner material. The proposed materials and the manner of application will be submitted for Consent.

The Contractor will provide all the necessary tools, materials and labour for performing remedial work, and will be responsible for the costs of dismantling, transportation and reassembly necessitated by cavitation pitting modifications and repairs.

(b) Computational Fluid Dynamics: Without in any way limiting the Contractor's obligations set out in SPT 4.4.5(a), the Contractor will, at its own expense, perform computational fluid dynamics (CFD) simulations on the Turbine to predict the effectiveness of the proposed solution for removing the cause of the cavitation damage to the extent required under the Contract. The Contractor will promptly perform the CFD and submit a detailed Report of the CFD results. BC Hydro may, in its sole and absolute discretion, decide whether or not to proceed with the remedial solution modification proposed by the Contractor, even if the proposed modification does not involve exceeding the tolerance in Table 4.6.5.

(c) Model Turbine: If the proposed remedial solution is accepted and would involve any portion of the Turbine exceeding the tolerance in Table 4.6.5, BC Hydro may require that the Contractor modify the Turbine Model to reflect the modifications for the proposed. The Contractor will pay all costs and expenses associated with the modifications to the Turbine Model and testing of the Turbine Model in its own hydraulic laboratory. BC Hydro may require the Turbine Model to be submitted to an Independent Laboratory for testing in accordance with SPT2. The Contractor will pay all expenses associated with transporting and testing the Turbine Model at the Independent Laboratory. BC Hydro may decide to witness the test in the Contractors own laboratory and in the Independent Laboratory and would then pay for its own transportation and accommodation costs only.

(d) Remedial Solution: Upon BC Hydro's receipt of the Turbine Model new test results from the Independent Laboratory, BC Hydro may, in its sole and absolute discretion, decide whether or not to proceed with the remedial solution modification proposed by the Contractor as tested. If accepted, all of the repair work, remedial work and/or implementation of remedial solution modifications to the Turbine, will be done at the Contractor's sole cost and expense, including, without limitation, all materials, labour, Subcontractors and equipment.

(e) Services Provided by BC Hydro: For the purposes of inspections, remedial work, modifications and repairs in accordance with the requirements of SPT 4.4, BC Hydro will isolate and dewater the Unit, install the draft tube platform and provide electric power free of charge to the Contractor.

(f) Renewed Warranty: Any cavitated areas repaired under SPT 4.4 will be subject to a maximum of two renewals of the Cavitation Warranty Assessment Period for further periods of 10 000 operating hours (i.e., three times 10 000 hours, including the first Cavitation Warranty Assessment Period). Under any renewal warranty the Contractor warrants that over the range of minimum to maximum NSHE determined by the Contractor using data in this Appendix 6-3 [Turbine Specifications (SPT)], the damage on the runner and non-rotating parts due to cavitation will not exceed the limits stated in SPT 4.4.4 under the conditions set out in SPT 4.4.3. The warranty will be renewed each time cavitation damage on the Turbine exceeds the Stated Thresholds.

4.5 Runaway Speed, Hydraulic Thrust, and Wicket Gate Leakage

4.5.1 Runaway Speed

The maximum runaway speed will not exceed the value stated in the Turbine TDIF. The maximum runaway speed will be determined for the Turbine under operating conditions corresponding to the range of NSHE's determined by the Contractor using data in this Appendix 6-3 [Turbine Specifications (SPT)]. The maximum runaway speed will not be exceeded at any of the required range of wicket gate openings.

If so directed, the maximum runaway speed of the Turbine will be confirmed by the Site testing of the prototype Turbine.

4.5.2 Hydraulic Thrust

The Turbine maximum hydraulic thrust (downthrust or upthrust) within required range of steady-state operating regimes and also during transient conditions, including runaway speed conditions, Unit start-up, load rejections, etc., will be as follows:

(a) hydraulic upthrust will be less than the magnitude of thrust due to the weight of rotating parts of the Turbine and Generator.

If the achieved hydraulic thrust in the prototype exceeds the values stated in the Turbine TDIF, proposed modifications to correct the achieved hydraulic thrust will be submitted for Consent, and subsequently implemented by the Contractor.

4.5.3 Wicket Gate Leakage

The Contractor will minimize the wicket gate leakage (the "**Wicket Gate Leakage**") when the gates are closed and Unit is shut down or operates in the synchronous condenser mode. The Contractor will guarantee the wicket gate leakage at the following conditions:

(a) Unit shut down and watered-up;

(b) spiral case is under full headwater pressure; and

(c) average reservoir and tailwater operating levels that are indicated in Table 3.3.3.

4.6 Prototype Homology, Uniformity and Surface Condition Requirements

4.6.1 General

All water passages of the prototype Turbine will be homologous to the water passages of the Model. To this end, Drawings showing all the Turbine water passages will be prepared for the prototype based on the verified Model dimensions and as-built Model water passage Drawings as outlined in SPT 2.4.4 and SPT 2.5.16.

The above Drawings to be known as the prototype design drawings ("**Prototype Design Drawings**") will show the prototype dimensions scaled from the Model dimensions. The scaling factor will be as specified in SPT 2.4.1(d). No deviation between the scaled Model dimension and the corresponding prototype design dimension will be permitted.

All Turbine manufacturing detail Drawings will conform to these Prototype Design Drawings where the component's shape is part of the hydraulic passage.

Checking for homology, uniformity of the prototype dimensions and the surface condition (surface finish, waviness and local discontinuities) of hydraulic passages will be done during the manufacture of the individual components and where appropriate after full assembly of all components. Checks will include but are not limited to the following:

(a) principal dimensions of the spiral case, the stay ring, the wicket gates, the draft tube, the space between the headcover and the runner crown and the space between the discharge ring/bottom ring and the runner band;

(b) number of runner blades, wicket gates and stay vanes;

(c) length and clearance of the runner seals and the end clearances of wicket gates;

(d) roughness and waviness of all hydraulic components of the Unit;

(e) principal dimensions of the runner including inlet and outlet diameters and inlet height of the runner;

(f) profiles and main dimensions of the runner crown and band;

(g) location of the runner inlet edges in at least four locations on each blade and location of the runner outlet edges in at least five locations on each blade;

(h) inlet pitch between the runner blades in at least four locations on each blade;

(i) outlet width between the runner blades in at least five locations on each blade;

(j) profiles of the runner blades, wicket gates and stay vanes including the profile of the runner blade inlet edges at four locations, the profile of the runner blade outlet edges at five locations, as well as the maximum thickness of the runner blades, stay vanes and wicket gates;

(k) height of the distributor at the location of each wicket gate; and

(l) relative angular position of the stay vanes and the wicket gates.

4.6.2 Permissible Deviation in Geometric Similarity and Uniformity of Prototype

Any deviation of the final prototype dimensions from the design dimensions that are greater than the permissible tolerances shown in Table 4.6.5 will be submitted for Consent. If suitable documentation is not made available to confirm that the proposed deviations will not have negative impact on the Turbine performance or and not detrimental to BC Hydro, then the Contractor will retest its Model, incorporating such deviations as part of the Work. BC Hydro may require the Turbine Model to be submitted to an Independent Laboratory for testing in accordance with SPT2. The Contractor will pay all costs and expenses associated with transporting and testing the Turbine Model at the Independent Laboratory.

During manufacture of the prototype, all component dimensions affecting the water passages will be subject to the uniformity tolerances also shown in Table 4.6.5. Any deviation exceeding the permissible uniformity tolerances will be corrected. Any non-compliance remaining after the Contractor's attempts at correction of uniformity tolerances will be submitted for Consent as outlined in the preceding paragraph.

4.6.3 Application to Hydraulic Profiles

The application of the permissible tolerances of Table 4.6.5 to hydraulic profiles such as runner blades, wicket gates and stay vanes will be done by the Contractor using direct measurements of surface points (target points), together with a computer based comparison program as outlined in SPT 4.6.3(a), (b), and (c) below. The Contractor may use templates to check local profiles such as inlet edge profiles and to check repeated components such as the profile of wicket gates and stay vanes. All templates used in manufacturing of the Turbine will become the property of BC Hydro.

If the Contractor wishes to use a Procedure for the homology assurance program of the hydraulic profiles that is different from the procedure outlined herein, such Procedure will be submitted for Consent. Such a Procedure will be at least as effective and accurate in assuring compliance with the homology requirements as the methods outlined below.

(a) Measurement Procedures: The measurement Procedure proposed by the Contractor, to be submitted, will be one of the following:

    (i) optical method to obtain direct measurements using computerized survey theodolites (minimum of two theodolites), which convert measured angles into a set of Cartesian coordinates;

    (ii) direct readout of surface points on the numerical console (also recorded on computer media) of a multi-axis machine tool. This method will, however, require a calibration to be acceptable;

    (iii) mechanical “measuring arm” which uses the measured relative rotation of a number of swivel joints to calculate the distance from a base (reference) position; or

    (iv) laser technology which uses fringe counts and angle measurements to determine the location of the target point relative to a base (reference) position.

(b) Surface Points (Target Points): The use of direct measurements requires establishing target points on the surface of the profile to be checked. These points will be the design points on the surface of the profile.

A minimum of 100 points but no less than one point for every 400 cm^2 of the surface will be designated as target points per each runner blade surface. The distribution of the target points will be guided by the curvature of the surface. Additional minimum 10 target points but no less than 1 point for every 20 cm of length will be designated for all blade edges. The number of target points for checking of other profiles will be submitted.

The target points will be permanently marked at the beginning of the machining process and will remain marked until completion of the process (in the case of runner blades until the runner has been completely finished).

(c) Comparison with Design Data: In order to compare the measurements of the target points obtained in an arbitrary coordinate system, with the design data usually available in the design coordinate system, the Contractor will supply a computer program that transforms the measurements into the design coordinate system. The Contractor will submit the measurements of target points and their deviations from design points.

The vector difference in location of the target points from the design points will not exceed the permissible maximum deviations of Table 4.6.5.

4.6.4 Surface Condition

The surface roughness and waviness of the hydraulic surfaces of the stay ring, the runner, and the wicket gates will be as specified in SPT 4.12.2, 4.17.3 and 4.22.2 respectively. For other hydraulic passages of the prototype Turbine the surface roughness will not exceed the limits specified in Clause 2.2.3.3 of IEC Publication 60193 or lower limits if recommended by the Contractor.

The maximum size of local surface discontinuities of the prototype Turbine water passages, such as protruding welds or steps caused by misalignment of hydraulic surfaces, will be submitted for Consent.

4.6.5 Permissible Maximum Deviations in Geometric Similarity and Uniformity of the Prototype Turbine

Table 4.6.5 – Permissible Maximum Deviations in Geometric Similarity and Uniformity of Prototype Turbine

Dimensions	Uniformity of individual value to average value for prototype	Prototype average value to scaled Model average value
Principal dimensions of hydraulic passages		
Metallic and concrete passages (spiral case, draft tube, etc.)	±0.5%	±0.5%
Stay ring diameters	±0.5%	±0.5%
Length of wicket gates and stay vanes	±1.0%	±1.0%
Maximum thickness of wicket gates and stay vanes	±2.0%	±1.0%
Distributor height	±0.2%	±0.1%
Wicket gate pitch circle diameter	±0.1%	±0.1%
Relative angular position between stay vanes and wicket gates	±0.5°	±0.5°
Wicket gate and stay vane profile	±2.0%T	±1.0%T
Wicket gate opening at 50% and 100% position	±1.0%a	≥0%a
Runner dimensions		
Blade profiles	±3 mm	±2 mm
Inlet pitch	±6 mm	±2 mm
Outlet opening	+3%a to -2%a	+1%a to -1%a
Inlet and outlet diameter and other runner dimensions	±6 mm	±6 mm
Runner seal length	±2%	≥0%
Clearances		
Runner seal clearances	±30.0%	≤0%
Wicket gate end clearances	±30.0%	≤0%
Headcover/runner crown	±2.0%	±2.0%
Discharge ring/runner band	±2.0%	±2.0%

D - Runner outlet diameter

T - Maximum thickness

a - Opening between two adjacent blades or wicket gates

Notes:

1. Individual tolerances will not be combined.
2. Wicket gate profile includes both sides of the gate over the full gate length.
3. Stay vane profile includes both sides of the vane over the full vane length.
4. Blade profile includes both sides of the blade over the full blade length.
5. Blade profile is measured after runner assembly.

The difference between the prototype average value and the scaled Model average value is represented as a percentage of the prototype average. For example, if the prototype average value = a; prototype to Model scale factor = f; Model average value = b; So, C=a-f*b will be no greater ($\leq$) or no less ($\geq$) than zero percent of a.

4.7 Turbine Embedded Parts

4.7.1 General

The Turbine embedded parts will be designed to withstand a maximum differential concrete level of 0.5 m in any part of the concrete placement.

The Turbine embedded parts will be designed to withstand a maximum fluid concrete depth as follows:

Component	Maximum fluid concrete depth (m)	Approximate concrete placement rate, depending on concrete temperature and other variables (m/hr)
Pier nose cap, and miscellaneous embedded components	2.5	1.0
Draft tube liner	2.0	0.75
Turbine pit liner and lower wicket gate bushing gallery liner	1.2	0.4
Spiral case	Average 1.2	0.4

All Turbine embedded parts will be in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

4.7.2 In First Stage Concrete

All Turbine embedded parts in first stage concrete will be in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

4.7.3 In Second Stage Concrete

All Turbine embedded parts in second stage concrete will be in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

After placement and set-up of the second stage concrete around and to embed the draft tube liner, the Contractor and Hydro’s Representative will jointly perform inspection to determine if there are any voids in the concrete behind the draft tube liner. If required, grouting will be carried out by Others.

4.7.4 Embedded Piping

At the locations where embedded piping will be connected to the embedded parts, such as the spiral case, the draft tube liner or the stay ring, the piping will be covered with foam, to permit movement of the components without applying any significant load to the embedded piping. The foam will completely cover the pipe from the pipe junction with the component for a length of ten times the pipe diameter or one metre, whichever is greater.

4.8 Flexible Coupling

4.8.1 General

Each Unit will be equipped with one flexible coupling located between the penstock spool piece and the closure section.

The flexible coupling will have zero leakage.

At the upstream end the flexible coupling will have an inside diameter matching the penstock diameter at this point. Location of the upstream end of the flexible coupling will be located in the coupling chamber and will be sufficiently far from the upstream and downstream walls to allow future dismantling of the flexible coupling.

The flexible coupling will consist of a flexible coupling joining the closure section and the penstock spool piece so assembled as to provide a coupling allowing for an angular movement of not less than ½°, 40 mm of longitudinal movement at the centre of the circumferential joint, and 7 mm of lateral movement, in addition to the cumulative dimensional deviations of the closure section, the penstock spool piece, and the flexible coupling.

Seal clamp rings will be segmented to facilitate local adjustment of the seal at any location around the perimeter of the pipe independently.

4.8.2 Fabrication

The flexible coupling will be fabricated from steel plate by welding, and sectionalized as necessary for handling and shipment.

4.8.3 Installation

The flexible coupling will be installed to ensure that the maximum flexibility is fully available for any subsequent differential movement between the penstock encasement and the powerhouse.

4.9 Closure Section

4.9.1 General

The closure section will be fitted and welded between the flexible coupling and the spiral case inlet. The inner diameter of the closure section at its upstream end will match the inner diameter of the downstream end of the penstock spool piece. Tolerances and installation will be in accordance with the requirements specified in SPT 4.8.

4.9.2 Fabrication

The closure section will be shop assembled and welded commensurate with shipping limitations. Sufficient additional length of plate will be included on the closure section to trim and fit for Site assembly and welding.

Special attention will be given to crating the pieces for shipment to prevent distortion in transit to the Site, and provision made for internal bracing during erection.

4.9.3 Installation

The downstream end of the closure section will be aligned and welded by the Contractor to the spiral case inlet.

The flexible coupling will be rigidly held when the closure section is fitted and welded into position.

After Site welding of the closure section, the Contractor will remove all internal bracing, including the bracing in the closure section, and grind flush any irregularities on the surface. These surfaces will be examined by liquid penetrant test and repaired if necessary.

4.10 Penstock Spool Piece

4.10.1 General

The penstock spool piece will be fitted and welded between the flexible coupling and the penstock. The inner diameter of the penstock spool piece at its downstream end will match the inner diameter of the upstream end of the closure section. The inner diameter of the penstock spool piece at its upstream end will match the inner diameter of the downstream end of the penstock. The penstock spool piece section will be cylindrical to allow it and the adjacent penstock section (supplied by Others) to be used for flow measurement using an acoustic flow meter. The penstock spool piece section will extend 2500 mm upstream of the centerline of the flexible coupling. Tolerances and installation will be in accordance with the requirements specified in SPT 4.8.

4.10.2 Fabrication

The penstock spool piece section will be shop assembled and welded commensurate with shipping limitations. Sufficient additional length of plate will be included on the penstock spool piece section to trim and fit for Site assembly and welding.

Special attention will be given to crating the pieces for shipment to prevent distortion in transit to the Site, and provision made for internal bracing during erection.

4.10.3 Penstock Flow Meter

BC Hydro intends to be able to install an 18 path acoustic flow meter in two penstock spool pieces and/or penstock for efficiency testing of one or two Turbines. The Contractor will bore and spot-face (on the inside surface, perpendicular to a radial line) the 36 holes (diameter and locations to be determined by Hydro's Representative) into each Turbine. The Contractor will provide all the means of access necessary to perform the work. The Contractor will supply and install threaded type 316L stainless steel plugs, complete with nuts and seals, to seal the holes when the flow meter probes are not being used.

4.10.4 Installation

The penstock steel liner will be an ASME P1 steel suitable for penstock use. The actual material will be selected by the penstock supplier. The penstock will be fabricated to tolerances, in accordance with Good Industry Practice, and will include bracing near the interface location. The Contractor will be responsible for fitting the penstock spool piece to the penstock.

The Contractor will trim, fit, and prepare the upstream end of the penstock spool piece and will weld the penstock spool piece and the penstock pieces at the Site.

The penstock spool piece will be rigidly braced when being welded to the penstock.

The flexible coupling will be rigidly held when the penstock spool piece is fitted and welded into position.

After Site welding of the penstock spool piece, the Contractor will remove all internal bracing, and if directed one spider in the penstock. The Contractor will grind flush any irregularities on the surface. These surfaces will be examined by liquid penetrant test and repaired if necessary.

The Contractor will be responsible for all painting of exposed steel, as well as any required touch up painting, including the weld and the weld heat affected zones located on both sides of the weld.

If directed, the Contractor will be responsible for all painting of exposed steel on the penstock.

4.11 Spiral Case

4.11.1 General

The spiral case will be of the spiral type, built up by welding steel plates, but may also include specific sections made of cast steel.

The circumferential joints will be designed to give a strength equivalent to that of the longitudinal joints.

Longitudinal joints in the spiral case will be shop-welded, if the transportation limits allow. Spiral case welds will be stress relieved where required by the ASME BPVC.

The Contractor will provide all supports and bracing necessary to support the spiral case and stay ring during assembly and welding.

Concrete support saddles will be provided by Others, including the placement of grout in between the saddle and the spiral case. Any protection required between the spiral case and the support saddles will be supplied and installed by the Contractor.

After Site welding of the spiral case has been completed and before the spiral cases are embedded in concrete, the Contractor will remove all extraneous lugs, brackets, etc., attached to the case and will grind flush any irregularities or protuberances left on the surface of the spiral case, and perform touch-up painting. After the concrete encasement is cured, the Contractor will remove all internal bracing and grind flush any irregularities on the surface. These surfaces will be examined by liquid penetrant test and repaired if necessary.

4.11.2 Inlet

The spiral case inlet will have an inner diameter matching the inner diameter of the downstream end of the closure section. Sufficient additional length will be included on the inlet edge of the plate to trim and fit for Site welding to the test bulkhead and subsequently to the closure section as part of the Work. The spiral case inlet will be in a vertical plane, and the axis will be concentric with the axis of the penstock spool piece, the flexible coupling, the closure section and the penstock.

A circumferential thrust ring, or rings, will be supplied to absorb the axial thrust produced by the maximum pressure acting on an area equal to the entrance of the spiral case. This will be designed such that the maximum bearing stress at the surrounding concrete is in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

4.11.3 Cooling Water Supply

The cooling water supply nozzle and associated piping will be in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

4.11.4 Bulkheads

The Work includes two spiral case inlet bulkheads and two stay ring bulkheads. The Contractor will install the spiral case and stay ring bulkheads for the hydrostatic testing and embedment of the spiral case under pressure. The Contractor will also remove the spiral case and stay ring bulkheads after the hydrostatic testing and the spiral case concreting.

The spiral case inlet bulkheads will be of the elliptical dished type suitable for welding to the inlet of the spiral case. A 100 mm water inlet connection, flanged on the interior and exterior of each bulkhead will be located on the top of the spiral case bulkhead. A 150 mm flanged drain connection will be located on the bottom of each spiral case bulkhead. Threaded connections will also be provided for an air release valve and pressure gauge.

The stay ring bulkheads will be of the barrel type and will allow for the grouting of the stay ring and discharge ring if applicable, while the spiral case is embedded under water pressure.

4.11.5 Tie-down Bars, Turnbuckles, Jacks, Anchors, Foundation Bolts

Tie-down bars, turnbuckles, jacks, anchors, temporary supports, and foundation bolts will be as specified in SPT 4.7.

4.11.6 Penstock Drains

(a) The Contractor will provide two drain pipes for draining the penstock and to accommodate fish salvage operations, as follows:

   (i) one of not less than 400 mm (16”) diameter, and which is located with the invert of the drain at an elevation of 300 mm above the lowest point in either the spiral case or closure section and will be located downstream of the flexible coupling; and

   (ii) one of not less than 150 mm (6”) diameter, and which is located at the lowest point in either the spiral case or penstock spool piece and will be located downstream of the flexible coupling.

   After their respective isolation valves (described in SPT 4.11.6(c) and SPT 4.11.6(d) below), the drains will be merged together for a common discharge into the draft tube, below the elevation of the draft tube platform.

(b) Each drain inlet will have a removable stainless steel wedge wire grating with stainless steel fasteners, designed to withstand full blockage without damage, with a mesh size not exceeding 25 mm. The free area of the grating will be not less than 1.25 times the area of the outgoing pipe.

(c) The 400 mm (16”) drain pipe will contain an actuated ball valve with the following features:

   (i) lockable in open and closed positions;

   (ii) the valve will be a Velan Memory Seal SB150, full port ball valve to ANSI class 150, rated 285 Psig at 100°F with raised face flanged, carbon steel body, 316 SS ball, 316 SS stem, PTFE seat, and graphite packing, or equivalent;

   (iii) the valve actuator will be conservatively sized for 1380 kPa (200 psi) differential on valve plus an additional 15% (minimum) output torque for water carrying fine silt; and

   (iv) the valve actuator will be a Rotork electric worm gear actuator type IQ complete with de-clutchable manual over-ride (lockable), double O-ring sealed and water tight to NEMA

6 – IP68 Enclosure; 600 V, 3 phase induction motor; integrated reversible motor starter; actuator derived 120 V for control; lockable oil-tight Local/Remote selector switch and Open/Close controls; LCD display; four (4) open/close limit switches, and torque switches; remote indication and control facilities; and Modbus communication.

(d) The 150 mm (6”) drain pipe will contain a manually operated ball valve with the following features:

(i) lockable in open and closed positions;

(ii) the valve will be a Velan Memory Seal SB150, full port ball valve to ANSI class 150, rated 285 Psig at 100°F with raised face flanged, carbon steel body, 316 SS ball, 316 SS stem, PTFE seat, and graphite packing, or equivalent; and

(iii) The valve manual actuator will be conservatively sized for 1380 kPa (200 psi) differential on valve plus an additional 15% (minimum) output torque for water carrying fine silt.

(e) The embedded portion of the drain pipe(s) in first stage concrete will be installed by Others, and the Contractor will supervise the installation. Both ends of the embedded portion of the pipe(s) will have adequate trim allowance to accommodate any misalignment. The Contractor will make the connections between the embedded components and the non-embedded components.

4.11.7 <u>Maintainability and Access</u>

(a) <u>Spiral Case Access Gallery:</u> The Contractor’s design will propose a Turbine spiral case access gallery to provide Workers with level access to the Turbine spiral case access door. The Turbine spiral case access gallery will:

(i) be as a minimum, accessible by staircase;

(ii) have a landing area outside the Turbine spiral case access door that is located just below the elevation of the Turbine spiral case access door bottom flange;

(iii) be located and arranged such that tools and equipment (such as a welder) can be hoisted to and from the gallery through an Auxiliary Unit Equipment Hatch using the Powerhouse bridge crane;

(iv) be sized to accommodate Workers conducting a Rescue Operation; and

(v) be sized to accommodate staging for typical maintenance activities inside the spiral case (for example, inspection, welding, painting and installation of the Turbine spiral case access stairs).

Ladder access into the Turbine spiral case access gallery is not permitted.

(b) <u>Spiral Case Access Door</u>: One watertight Turbine spiral case access door, used to access the interior of the Turbine spiral case, will be provided. The Turbine spiral case access door will:

(i) have an access opening cross-section that is as large as practicable but of minimum clear dimensions 1250 mm high by 1000 mm wide (considering any space required for the door hinge);

(ii) have a sill located a minimum of 400 mm above the lowest point in the spiral case;

(iii) have sufficient additional reinforcement in the area surrounding the opening of the door to compensate for the metal removed from the Turbine spiral case to accommodate the door;

(iv) be hinged to open horizontally, and inwards into the spiral case;

(v) be capable of opening to at least 120 degrees (the objective being that when open, the door does not impede access, work, a Rescue Operation, or installation of the Turbine spiral case access stairs);

(vi) have an inner surface that is flush and fitted with the inside surface of the spiral case to give a maximum gap of 10 mm when in the closed position;

(vii) have stainless steel door hinge pins and have sufficient clearance to permit the door to be bolted watertight against the O-ring seal without restraint from the hinge pins;

(viii) have blind holes tapped into the door flange to permit using jackscrews;

(ix) have bolted connections consisting of high strength bronze or stainless steel cap screws;

(x) use an O-ring or equivalent reusable door seal; A gasket type seal is not permitted;

(xi) have provisions for the alignment of the flange bolt holes; and

(xii) have two anchor points, rated to 2300 kg, provided just beside the access door frame, to be used for a Rescue Operation and fall protection purposes.

(c) Test Cock: A stainless steel test cock will be provided in the spiral case adjacent to the Turbine spiral case access door at an elevation slightly lower than the bottom of the door opening. The test cock will:

(i) have a threaded stainless steel end cap;

(ii) have a pressure gauge with isolation valve located adjacent to the test cock; and

(iii) have lockable valves.

The test cock will be used to confirm there is no water behind the door prior to opening the door.

(d) Spiral Case Temporary Access Stairs: Removable Turbine spiral case access stairs complete with guardrails on both sides of the stairs will be provided, to allow a Worker to safely pass through the open Turbine spiral case access door, and descend to the bottom of the Turbine spiral case. The Turbine spiral case access stairs will:

(i) be designed, sized and arranged to allow for convenient installation and removal, considering the size of the Turbine spiral case access door;

(ii) be installed and removed from outside the spiral case (i.e., it will not be necessary to have someone inside the spiral case to facilitate installation or removal of the Turbine spiral case access stairs);

(iii) be securely attached to the frame of the Turbine spiral case access door when in the installed position;

(iv) include durable anti-slip surface material on all stairs and on the stair support feet that come into contact with the spiral case;

(v) be rated to handle the maximum loads expected over their lifetime (considering loads from personnel, tools, and equipment); and

(vi) be designed to allow a Rescue Operation of a Worker on a Stretcher.

Ladder access into the Turbine spiral case is not permitted.

4.12 Stay Ring

4.12.1 General

The stay ring will be of cast steel, welded plate steel, or combined cast steel and plate steel welded construction, heat treated before final machining to relieve locked up casting or fabrication stresses and sectionalized as necessary for handling and shipping. It will consist of upper and lower rings, rigidly held together by stay vanes. Fully machined flanges will be provided for bolted connections between the radial sections of the stay ring, between the stay ring and the headcover, bottom ring and discharge ring. Shims, machined spacers, or levelling screws, will not be permitted. All bolted connections will be suitably doweled. There will be no discontinuities in the water passages between radial sections of the stay ring.

For the purpose of grouting the stay ring while the spiral case is under internal water pressure, a minimum of 16 grout inlet and air release holes will be provided in the lower ring of the stay ring as required.

Drainage ducts will be provided in at least two stay vanes to remove leakage water from the headcover as specified in SPT 4.19.5. If drainage through the stay vanes is not feasible, an alternative drainage arrangement will be proposed.

4.12.2 Water Passages

The stay vanes will be shaped to give minimum obstruction and head loss to the flow of the water.

Hydraulic surfaces of the stay ring including welds between the stay vanes and upper and lower rings will be smooth, without humps, hollows or edges in any contour. The maximum surface roughness (arithmetical mean value) of the stay vanes and upper and lower rings in contact with water will not exceed 6.3 μm.

Surface waviness of the stay vanes and upper and lower rings will be checked using a 600 mm length of flexible wooden spline, and the maximum allowable gap under the spline in the direction of flow will not exceed 3.2 mm.

4.12.3 Design

The stay ring will be designed to support the superimposed loads of the concrete, Generator, Turbine and the hydraulic forces resulting from the operation of the Unit under the complete range of net specific hydraulic energies without the assistance of the Turbine pit liner. The stay ring will also be designed to withstand the forces transmitted to it from the spiral case under the Spiral Case Design Pressure together with the above loads without exceeding the allowable stresses specified in Appendix 6-2 [General Technical Specifications (SPGT)].

The transition between the stay ring and the spiral case will be designed to avoid excessive stress concentration and permit gradual change in stress from the stay ring to the spiral case plate. The transition plate will be shop welded to the stay ring with full penetration welds. The Site welded stay ring to spiral case connections will be such that there is minimal thickness difference between the two components and that all Site welded connections can be tested by radiography.

The design of the stay vanes will be such that none of the potentially excitable natural frequencies of the stay vanes in water coincides with the Von-Karman vortex shedding frequency or other hydraulic excitation frequencies and the margin is sufficient to avoid resonance at all required operating conditions.

The stay vanes will be welded to the stay ring with full penetration welds.

4.12.4 Tie-down Bars, Turnbuckles, Jacks, Anchors, Foundation Bolts

Tie-down bars, turnbuckles, jacks, anchors and foundation bolts will be as specified in SPT 4.7.

4.13 Bottom Ring

4.13.1 General

The bottom ring will be of cast steel or welded plate steel sectionalized as necessary for handling and shipping and will be of heavy, rugged construction. All necessary cap screws, dowels and bolts will be supplied to facilitate assembly and to bolt and dowel the bottom ring to the discharge ring. All dowels and fasteners will be stainless steel. The bottom ring will be designed such that it can be removed in the future if necessary. It will seat on fully machined surfaces. The use of shims, machined spacers, or levelling screws will not be permitted.

4.13.2 Bearings for Lower Wicket Gate Stems

The bottom ring will be provided with bearings for the lower stems of the wicket gates.

The bottom ring bearings for the wicket gate lower stems will be as specified in SPT 4.24. The bushings for the lower wicket gate stem bearings will be contained within a removable cartridge to facilitate removal and replacement of the bushings from the lower wicket gate bushing access gallery, in accordance with SPT 4.14.4, without major disassembly of the Turbine components.

4.13.3 Bottom Ring Surface

The upper surface of the bottom ring that is adjacent to the wicket gates will be protected by stainless steel of hardness compatible with the adjacent material on the wicket gates. It will be machined to provide a smooth water passage.

This protection may be provided by welded overlay in stainless steel or stainless steel clad plates fastened by suitable bolts and dowels. The stainless steel will not be less than 5 mm thick after machining and will cover an annulus at least equal in area to that of the closed wicket gates. The stainless steel material will be chosen to minimize the risk of galling in case of contact between the ends of the wicket gates and the headcover surface.

4.13.4 Renewable Runner Seal

A renewable seal ring or rings at the running clearance with the runner band will be attached to the bottom ring or if required, the discharge ring. The seal ring will be of corrosion and abrasion resistant material and will be assembled of no more than two segments.

The mounting face for the seal will be machined concentric with the axis of rotation and will permit replacement of the seal without any subsequent machining.

The seal ring will be at least 40 points Brinell hardness less than the adjacent runner seal. All fasteners used for the attachment of the renewable seals will be bronze or stainless steel.

4.13.5 Wicket Gate Seals

For details of the wicket gate seals to be provided by the Contractor in the bottom ring, refer to SPT 4.22.4.

4.14 Discharge Ring

4.14.1 General

The discharge ring will be of plate steel, sectionalized as necessary to facilitate shipment and it will be secured to the stay ring by bolting or welding. It will be of heavy construction, ribbed to prevent distortion. The horizontal surface adjacent to the bottom of the runner band and also the surface extending 250 mm down from the top of the lower discharge ring flange will be covered with stainless steel to a minimum finished thickness of 5 mm.

The water passages of the discharge ring will be hydraulically smooth with no abrupt changes in geometry and obstructions to the water flow that could cause flow disturbance and instability. The space between the runner band and the discharge ring will be profiled to minimize disc friction losses and secondary flows behind the runner band.

4.14.2 Placement of Concrete and Grouting

Where best suited, concrete placement holes, grout inlet holes, and air release holes will be provided in the discharge ring and/or the lower wicket gate bushing gallery outer wall to facilitate concrete placement and pressure grouting (by Others) below the lower stay ring while the spiral case is under internal water pressure. Concrete placements holes will be equally spaced and 170 mm diameter. Each concrete placement hole will be provided with a plug that contains a centrally threaded grout inlet/air release hole that will allow pressure grouting below the lower stay ring. The Contractor will weld the plugs for the concrete placement holes after completion of the concrete placement. Threaded steel pipe plugs will be supplied to seal all grout inlet and air release holes. The Contractor will install and seal weld these plugs after grouting has been completed.

The location and quantity of the concrete placement holes will be submitted.

4.14.3 Tie-down Bars, Turnbuckles, Jacks, Foundation Bolts

Tie-down bars, turnbuckles, jacks and foundation bolts will be as specified in SPT 4.7.

4.14.4 Lower Wicket Gate Bushing Access Gallery

(a) General: A lower wicket gate bushing access gallery will:

   (i) be provided around the entire circumference of the discharge ring;

   (ii) be sized and arranged to allow all lower wicket gate bushings to be inspected, maintained, and replaced by Standing Workers, and will not be less than 0.75 m clear width (radial direction); and

   (iii) the outer wall will be a steel liner.

(b) Drainage: Not used

(c) Ventilation: The lower wicket gate bushing access gallery will have provisions for fresh air ventilation system with fresh air entering the lower wicket gate bushing access gallery from a 200 mm pipe embedded below the Turbine spiral case in second stage concrete and exiting the lower wicket gate bushing access gallery via the access hatch. The pipe for the fresh air ventilation system will:

(i) have an opening (the outlet of the embedded pipe) located at mid elevation of the gallery wall and located 180 degrees in plan from the access hatch;

(ii) originate at a suitable location on the Draft Tube Cone Access Floor and be routed through the concrete under the Turbine spiral case. The pipe entrance will be flanged; and

(iii) minimize changes in direction of the pipe.

Ventilation air requirements will be provided by a portable blower or permanent supply fan supplied by Others.

(d) Maintainability and Access: An Access Route to the lower wicket gate bushing access gallery from the Draft Tube Access Gallery that requires use of a ladder is permissible provided:

(i) the ladder extends into the lower wicket gate bushing gallery far enough to allow a Worker to conveniently and safely mount and dismount the ladder;

(ii) an unobstructed clearance for Worker access around the entire length of the ladder is included, sized to allow a Worker to climb the ladder and access the lower wicket gate bushing access gallery;

(iii) a hinged access hatch is provided at the top of the ladder to facilitate access to the lower wicket gate bushing access gallery by a Worker;

(iv) immediately next to the hinged access hatch, a removable deck will be included, sized and arranged to facilitate hoisting equipment into and out of the lower wicket gate bushing access gallery, as well as to allow two Workers to conduct a Rescue Operation involving a Patient inside the lower wicket gate bushing access gallery. The design of this deck will be such that it can be removed quickly by one Worker to facilitate an efficient Rescue Operation;

(v) an anchor point rated to 2300 kg is located above but in the approximate center of the removable deck for use as a fall arrest anchor point and an anchor point during a Rescue Operation;

(vi) an anchor point rated to 2300 kg is located above the top of the ladder, for use as both a fall arrest anchor point and a Rescue Operation;

(vii) an anchor point rated to 2300 kg is located above the top of the ladder, for use as an anchor point for lifting equipment; and

(viii) sizing, access to, and arrangement of the lower wicket gate bushing access gallery allows Workers to conduct a Rescue Operation involving a Patient inside the lower wicket gate bushing access gallery.

(e) Lighting and Receptacles: The lower wicket gate bushing access gallery will:

(i) have permanent waterproof light fixtures. The number and arrangement of light fixtures required will be such that:

(A) the illumination requirements of Appendix 6-2 [General Specifications (SPGS)] are met in all areas of the lower wicket gate bushing access gallery; and

(B) the chances of a Worker hitting a light while walking in the access gallery is minimized; and

(ii) have a minimum of one 120 V receptacle every 180 degrees, with waterproof covers.

(f) Runner Band Seal Clearance: Provision will be made for measuring the clearance at the runner lower seal at four points equally spaced.

4.15 Draft Tube and Pier Nose Cap

4.15.1 General

The draft tube will be of the elbow type with at least one intermediate pier.

4.15.2 Draft Tube Liner

The draft tube liner will be plate steel and will extend to the point where the average axial water discharge velocity at the maximum Turbine discharge, defined in Operating Condition B, is less than 6 m/s. The hydraulic profile of the draft tube liner will be such that hydraulic losses are minimized. It will be ribbed externally to ensure rigidity and have sufficient anchorage to secure embedment in the concrete.

The upper section of the liner will be not less than 25 mm thick and will extend downwards a minimum of 4.5 m below the bottom of the runner. The lower section will be not less than 20 mm thick. The liner will be completely pre-assembled and match-marked in the shop with all ribs accurately fitted. To facilitate Site installation, the liner will be shipped in as few pieces as shipping limitations will allow.

Plate steel ribs will be welded to the liner on the four sides of each draft tube access door and around the circumference about 150 mm from the lower edge. These ribs will be located so that they will be embedded in the second stage concrete placed around the liner. The minimum width of the ribs will be 150 mm. Perforations will be provided in the ribs, except in the downstream most rib, to improve local concrete placement. To prevent water seepage between the concrete and the draft tube liner, a deformable seal material, approximately 12 mm thick, will be supplied and bonded by Others to the most downstream rib. Obstructions on or near the downstream most rib will be minimized for easier bonding of deformable seal material.

For the purpose of grouting the draft tube liner the Contractor will provide 20 grout inlet and air release holes in the draft tube liner. The location of these grout holes will be determined on Site after the second stage concrete has been placed.

For stainless steel required at the throat of the draft tube liner refer to SPT 4.14.1.

4.15.3 Pier Nose Cap

A steel nose cap will be supplied for the pier, which will extend 3 m downstream from the pier nose. The steel plate will be at least 20 mm thick and ribbed to ensure rigidity. Consideration will be given to the location of stiffeners and ribs to allow for adequate access for placement of reinforcement within the pier nose.

4.15.4 Tie-down Bars, Turnbuckles, Jacks, Anchors, Foundation Bolts

Tie-down bars, turnbuckles, jacks, anchors and foundation bolts will be as specified in SPT 4.7.

4.15.5 Drain Pipe Connections

An inlet for a 6 inch drain will be located approximately 500 mm below the draft tube platform elevation. The inlet will have a removable stainless steel grating that mounts to a stainless steel face with stainless steel fasteners, and is designed for full blockage. The free area of the grating will be not less than 1.25 times the area of the outgoing pipe. The Contractor will connect this drain to the drain piping that was embedded in first stage concrete by Others.

4.15.6 Maintainability and Access

(a) Draft Tube Cone Access Galleries: The Contractor's design will propose two draft tube cone access galleries to provide Workers with level access to each of the draft tube cone access doors. Each of the draft tube cone access doors will:

   (i) be as a minimum, accessible by staircase;

   (ii) be sized to accommodate Workers conducting a Rescue Operation;

   (iii) have a landing area outside the draft tube cone access door that is located just below the elevation of the draft tube cone access door bottom flange; and

   (iv) ensure the floor elevation of the draft tube platform is approximately the same as the floor elevation of the landing outside the draft tube cone access doors.

   One of the draft tube cone access door will be:

   (v) located and arranged such that tools and equipment (such as a welder) can be hoisted to and from the gallery through an Auxiliary Unit Equipment Hatch using the Powerhouse bridge crane; and

   (vi) sized to accommodate staging for typical maintenance activities inside the draft tube cone (for example, inspection, welding, painting and installation of the draft tube platform).

   Ladder access to the draft tube cone access door is not permitted.

(b) Draft Tube Cone Access Doors: Two watertight draft tube cone access doors, used to access the interior of the Turbine draft tube cone section immediately below the discharge ring, will be provided. Each draft tube cone access door will:

   (i) have an access opening cross-section that is as large as practicable but of minimum clear dimensions 1500 mm high by 1000 mm wide;

   (ii) be located in diametrically opposite positions in the draft tube liner;

   (iii) have sufficient additional reinforcement in the area surrounding the opening of the door to compensate for the metal removed from the Turbine draft tube to accommodate the door;

   (iv) be hinged to open horizontally, and outward into the draft tube access gallery;

(v) be capable of opening to at least 120 degrees (the objective being that when open, the door does not impede access, work, a Rescue Operation or installation of the draft tube platform);

(vi) have an inner surface that is flush and fitted with the inside surface of the draft tube liner to give a maximum gap of 10 mm when in the closed position;

(vii) have stainless steel door hinge pins and have sufficient clearance to permit the door to be bolted watertight against the O-ring seal without restraint from the hinge pins;

(viii) have blind holes tapped into the door flange to permit using jackscrews;

(ix) have bolted connections consisting of high strength bronze or stainless steel cap screws;

(x) use an O-ring or equivalent reusable door seal. A gasket type seal is not permitted;

(xi) have provisions for the alignment of the flange bolt holes; and

(xii) have two anchor points, rated to 2300 kg, provided just beside the access door frame, to be used for a Rescue Operation and fall protection purposes.

(c) Draft Tube Elbow Access Gallery: The Contractor’s design will propose a draft tube elbow access gallery to provide Workers with level access to the draft tube elbow access door. The draft tube elbow access gallery will:

(i) be as a minimum, accessible by staircase;

(ii) be sized to accommodate Workers conducting a Rescue Operation;

(iii) be sized to accommodate staging for typical maintenance activities inside the draft tube elbow (for example, inspection, installation of scaffolding, and concrete repairs);

(iv) have a landing area outside the draft tube elbow access door that is located just below the elevation of the draft tube elbow access door bottom flange; and

(v) ensure the landing floor elevation is as close as possible to the same elevation as the bottom radius point of the draft tube elbow.

Ladder access to the draft tube elbow access gallery is not permitted.

(d) Draft Tube Elbow Access Door: One watertight access draft tube elbow access door, used to access the interior of the Turbine draft tube elbow, will be provided. The draft tube elbow access door will:

(i) have an access opening cross-section that is as large as practicable but of minimum clear dimensions 1500 mm high by 1000 mm wide (considering any space required for the door hinge);

(ii) have the door sill located a minimum of 400 mm above the lowest point in the draft tube;

(iii) have sufficient additional reinforcement in the area surrounding the opening of the door to compensate for the concrete removed from the Turbine draft tube elbow to accommodate the door;

(iv) be hinged to open horizontally, and inwards into the draft tube elbow;

(v) be capable of opening to at least 120 degrees (the objective being that when open, the door does not impede access, work, or a Rescue Operation);

(vi) have an inner surface that is flush and fitted with the inside surface of the draft tube elbow to give a maximum gap of 10 mm when in the closed position;

(vii) have stainless steel door hinge pins and have sufficient clearance to permit the door to be bolted watertight against the O-ring seal without restraint from the hinge pins;

(viii) have blind holes tapped into the door flange to permit using jackscrews;

(ix) have bolted connections consisting of high strength bronze or stainless steel cap screws;

(x) use a recessed O-ring or equivalent reusable door seal; a gasket type seal is not permitted; and

(xi) have provisions for the alignment of the flange bolt holes.

(e) Test Cocks: Stainless steel test cocks will be provided in the draft tube adjacent to each draft tube cone access door and adjacent to the draft tube elbow access door at an elevation slightly lower than the bottom of the door openings. The test cocks will:

(i) have a threaded stainless steel end cap;

(ii) have a pressure gauge with isolation valve located adjacent to the test cock; and

(iii) have lockable valves.

The test cocks will be used to confirm there is no water behind the door prior to opening the door.

4.16 Draft Tube Platform

4.16.1 Scope

The Contractor will design, supply and install removable draft tube platforms including roller systems for storage, launching and retraction of the main beams. The design and fabrication of the draft tube platforms will be in accordance with relevant design standards, including the requirements of CSA S16 and/or CSA S157.

Roller systems, main beams and associated parts will be provided for all six Units. Two complete sets of secondary beams, decking panels, and associated parts will be provided to allow the draft tube platforms to be simultaneously installed in two Units. The Contractor will provide all tooling required to safely install and remove the draft tube platforms. Roller systems will include fixed and vertically adjustable roller supports.

If the distance from the draft tube platform to the lowest point on the runner exceeds 2.0 metres then a secondary means of accessing the runner will be provided. This secondary access may consist of a higher level platform supported on the main draft tube platform, a scaffolding type system specifically designed for this use, a portable man-lift(s), or a platform independent of the main draft tube platform. A secondary platform or scaffolding access system, if it does not cover the entire main draft tube platform, will cover at least 25% of the draft tube platform area, and be easily movable. The secondary platform or scaffolding access system will have the same design requirements as the main draft tube platform. If a portable main-lift(s) is provided it will have a capacity for at least two Workers including appropriate tooling and equipment. If secondary access is being provided the main draft tube platform will be designed to accommodate any additional incremental loading imposed by this secondary access in addition to the main draft tube platform design loads. The design/configuration of this secondary means of access will be submitted for Consent.

4.16.2 Design Requirements

(a) Purpose: The purpose of the draft tube platform is to provide:

(i) a working surface for all necessary inspection and maintenance activities below the runner during Unit shutdowns. The design of the draft tube platforms will accommodate the following inspection and maintenance activities:

(A) runner inspection (cavitation, cracking, NDE, etc.);

(B) welding repairs on the runner, discharge ring; and

(C) access to the runner coupling bolts if they project through the runner;

(ii) support for all necessary Workers, tools, and light equipment to perform the necessary inspection and maintenance activities. The Contractor will select appropriate Design Life loading criteria for the draft tube platforms based on the required usage, but at a minimum will maintain the following:

(A) a uniformly distributed live load of 5 kPa over the entire draft tube platform working surface;

(B) any dead loads applied by secondary access platforms, scaffolding, man-lifts, tooling or lifting equipment located on the draft tube platform, will be considered simultaneously in the design of the draft tube platform with SPT 4.16.2(a)(ii)(A);

(C) if a man-lift is to be used on the platform, then any lateral loads that the man-lift might impose will be considered simultaneously in the design of the draft tube platform with SPT 4.16.2(a)(ii)(A) and (B); and

(D) if a hoist is to be used on the platform, then any hoisting loads imposed will be considered simultaneously in the design of the draft tube platform with SPT 4.16.2(a)(ii)(A) and (B).

(b) Materials:

(i) Materials utilized for the draft tube platforms will be in accordance with the requirements of the relevant design standards, including the applicable CSA or ASTM standards for structural steel, aluminum alloys and/or stainless steel.

(ii) Combustible products such as wood will not be utilized for the draft tube platforms.

(iii) All structural shapes, bars, plates, bolts, nuts and washers will be based on metric sizes.

(iv) Steel components will be hot dip galvanized.

(v) Stainless steel fasteners will be used for all removable components. Fasteners and concrete anchors for permanent components will be corrosion resistant.

(c) Configuration and Details:

(i) Main beams will be stored on fixed roller supports at either side of the draft tube cone access doors.

(ii) Pairs of fixed and vertically adjustable roller supports will be used to launch the main beams through openings in the draft tube liners. Sufficient range in the vertically adjustable roller supports will be provided to ensure main beam seating in the beam pockets of the draft tube liners on both ends of the beams.

(iii) The draft tube platforms will be located below the runners within the draft tube liners and will approximately coincide with the draft tube cone access doors, in accordance with SPT 4.15.6(a)(iv).

(iv) Installation and removal of all components of the draft tube platforms will only require two Workers.

(v) Components which are to be handled manually by one Worker will weigh less than approximately 20 kg. Components which are to be handled manually by two Workers will weigh less than approximately 35 kg.

(vi) Portable lifting equipment may be provided as necessary to allow for the installation and removal of secondary beams and/or decking panels. Weights of individual components could exceed the requirements indicated above with the assistance of portable lifting equipment.

(vii) All roller supports will have bearings to permit frictionless launching and retraction of the main beams.

(viii) All draft tube platform components will be permanently marked with identification numbers to coincide with the assembly drawing(s). Identification numbers will also differentiate between each set of draft tube platforms.

(ix) The top surface of decking panels will be slip resistant (i.e., checker plate).

(x) Decking panels will be secured to the supporting beams as necessary where overturning may occur.

(xi) Removable locking devices will be provided to secure the main beams in the draft tube liners upon installation.

(xii) All necessary connections to facilitate installation and removal will be bolted.

(xiii) Appropriate isolation will be provided between dissimilar metals, as required, to prevent galvanic corrosion.

4.16.3 Assembly

The Contractor will fully shop assemble each draft tube platform, simulating as much as is practical the main beams and draft tube configuration, in the presence of Hydro's Representative prior to delivery to the Site.

Each of the draft tube platforms will be installed and subsequently removed at the Site in a minimum of three Units to demonstrate fit and operation in each Unit to Hydro's Representative.

4.16.4 Tooling and Related Equipment

The vertically adjustable roller support will incorporate a removable, hand-pumped, single acting hydraulic cylinder. Sufficient hydraulic cylinders and hand pumps will be provided for two Units plus a complete set of spares. The hydraulic cylinder type will be common for all vertically adjustable roller supports.

Two complete sets of any tooling required to facilitate the safe installation and removal of the draft tube platforms. This includes any lifting equipment required for the installation of the side beams and decking panels, come-a-longs, etc., to facilitate installation of the main beams, temporary supports/beams, etc.

Each draft tube platform will come with one (or more if required) cart(s) with storage racks to easily move all the draft tube platform components from Unit to Unit.

One full-size, laminated set of Issued for Record Drawings for the draft tube platform will be mounted on a moisture resistant panel and installed adjacent to the main beams at the draft tube cone access door for each Unit.

4.16.5 Pockets for Draft Tube Platform

All pockets and openings in the draft tube liner to support the beams of the draft tube platform will be provided together with cover plates where the main beams pass through the draft tube liner. Beam pockets and openings will be contoured to conform to the draft tube profile preventing cavitation damage to these areas. The plates used in the construction of the pockets and openings will be welded to the draft tube liner from both sides and will be the same thickness as the liner.

The cover plates will be of aluminum to reduce their mass. Each cover plate will be supplied with a reusable O ring or accepted equivalent.

The pockets will have provision for the leveling of the main and side beams. This leveling will be permanently done once for each unit so that no adjustments are required when installing the draft tube platforms in any of the Units.

4.16.6 Use During Site Installation Work

The Contractor will be permitted to use the draft tube platforms during the Site installation subject to the design live load limitations and availability of the platforms. The Contractor will be responsible for protecting the draft tube platforms from damage while in use, and will deliver the platforms in as-new condition at the completion of the installation Work at the Site.

4.17 Runner

4.17.1 General

The runner will be of the fabricated Francis type with the individual components fully machined by numerically controlled machine tools on all hydraulic surfaces before fabrication. The runner blades will be machined on a 5 axis numerically controlled machine tool. The individual parts will be manufactured from stainless steel castings or stainless steel rolled or pressed plates. The runner blades will be identified by a number stamped in such a position that the markings are readily visible when the runner is assembled in the Unit and will not be obliterated by erosion or pitting. An integral or separate runner cone will be provided to guide the water as it leaves the runner, if the runner cone proves to be beneficial for the Turbine performance and/or stability of operation.

All runner welds will be full penetration welds, using a martensitic stainless steel filler metal

The balancing of pressure between the space above the runner crown and the draft tube will be through the runner balance holes. These holes will be designed to prevent cavitation around the holes and not to impact adversely the Turbine performance.

4.17.2 One-Piece Runner

The runner will be a one-piece fabricated runner.

4.17.3 Hydraulic Surfaces

The hydraulic surfaces of the runner will be ground to a smooth finish without humps or hollows in any contour. Any irregularities which might be conducive to cavitation will be corrected by welding and/or chipping and grinding.

The hydraulic water passages will be divided into two areas, those areas subject to cavitation or to incipient cavitation and other areas. Surface waviness will be checked using a 600 mm length of flexible wooden spline with the maximum permissible gap under the spline in areas subject to cavitation or to incipient cavitation not to exceed 0.4 mm. For other areas the gap under the spline will not exceed 0.6 mm.

The maximum surface roughness (arithmetical mean value) of the runner blades including the blade fillets at the crown and band will not exceed 3.2 μm.

For other runner surfaces exposed to the water flow including those of peripheral water passages, such as seals and outer surfaces of runner band and crown, the surface roughness will not exceed 6.3 μm.

4.17.4 Balance

The runner will be balanced statically.

The runner out-of-balance will not exceed the limits of balance quality grade G6.3 in accordance with the Standard ISO 1940/1.

4.17.5 Vertical Clearances

Vertical movement of the runner will be restricted to not more than 20 mm by a machined contact surface on the underside of the headcover. The Contractor will design this clearance to allow the adjustment and the dismantling of the Generator thrust bearing.

To facilitate assembly and dismantling the coupling of the Turbine shaft and the generator rotor flanges, the clearance between the bottom of the runner band and the discharge ring will be not less than 30 mm.

4.17.6 Strength

The runner will have sufficient strength to support both its own mass and that of the Turbine shaft when disconnected from the Generator rotor coupling flange and resting either on the floor or on the discharge ring. It will be designed to safely withstand the loads specified in SPT 4.3 without exceeding the specified allowable design stresses in Appendix 6-2 [General Technical Specifications (SPGT)].

4.17.7 Residual Stresses

To confirm the level of runner residual stresses including those in the blade fillet welds and heat affected zones, the Contractor will measure residual stresses in at least five locations on the runner surfaces. Measurements will be performed after post-weld heat treatment of the runner and submitted in a Report.

4.18 Turbine Shaft

4.18.1 General

The Turbine main shaft will:

(a) be forged or fabricated of forged or plate steel components;

(b) be in one piece between the Turbine runner and the Generator thrust block coupling flange;

(c) be designed to safely withstand the loads specified in SPT 4.3 without exceeding the specified allowable stresses in Appendix 6-2 [General Technical Specifications (SPGT)]; and

(d) have full penetration welding.

4.18.2 Machining

The shaft will be machined all over and be provided with coupling flanges at both ends for connection to the runner and to the thrust block coupling flange.

Three 50 mm wide machined and polished bands will be provided on the outside diameter of the shaft concentric with the bearing journal. Two of these bands will be as far apart as possible and accessible when the Unit is assembled for use in shaft alignment. The third band will be used for the shaft vibration detectors at the Turbine guide bearing.

If the Toothed-Wheel Speed Sensing System is attached to the Turbine shaft then there will be a step machined in the shaft to support the device vertically and the surface finish, runout, and finished diameter of the shaft at this location will meet the requirements of the Toothed-Wheel Speed Sensing System.

The shaft surfaces will be finished to the following minimum requirements:

(a)	Bearing surface	0.4 μm;
(b)	Shaft surface	3.2 μm;
(c)	Spigot surface	0.8 μm; and
(d)	Alignment bands	0.4 μm.

Refer to Appendix 6-2 [General Technical Specifications (SPGT)] for shaft runout checks.

4.18.3 Hollow Bore

The shaft will have a finished hollow bore. The diameter of the hole will be sufficiently large for the purpose of the shaft inspections including NDT inspections, and also for the purpose of air admission if the Contractor recommends the air admission through the shaft. Suitable covers will be furnished at the top and bottom ends of the shaft.

The upper and lower 50 mm of the shaft internal bore will be machined concentric with the bearing journal and polished for use in the shaft alignment. These 50 mm machined bands may be located on the inside diameter of the shaft top and bottom coupling flanges if these areas are readily accessible. The machined band on the flange inside diameter at the runner end will be adequately protected against corrosion.

4.18.4 Stainless Steel Runner Plate

The shaft will be provided with a wear-resistant runner plate for the shaft seal. The horizontal runner plate arrangement will be mounted on the runner crown or shaft coupling flange. The runner plate will be made in sections to facilitate removal with the Turbine assembled, and will be securely fastened to the shaft.

The running surface will be polished to give a finish not to exceed 0.4 µm.

4.18.5 Deflector

A water deflector will be provided on the shaft between the main guide bearing and the shaft seal.

4.18.6 Balance

The shaft static unbalance will not exceed the limits of balance quality grade G6.3 in accordance with the Standard ISO 1940/1. The Procedure proposed by the Contractor for verification and if required correction of the shaft static unbalance will be submitted. Balancing is not required for fully machined shafts.

4.18.7 Bolt and Nut Guard

The Contractor will supply and install a robust guard for protection of nuts or any other parts of the coupling bolt assembly at the runner end of the shaft flange connection, for protection against corrosion and cavitation, if applicable.

In locations where the coupling bolt assembly is immersed in water, the cover(s) will be water tight and be designed to avoid cavitation.

4.19 Headcover

4.19.1 General

The headcover will be of welded plate or combined cast and plate steel welded construction. It will be sectioned as necessary to facilitate shipment. Water passages at the bottom of the headcover will not contain obstructions to the water flow. The space between the bottom of the headcover and the runner crown will be profiled to minimize disc friction losses and avoid hydraulic instability above the runner crown.

4.19.2 Fasteners

The headcover will be bolted and dowelled to the stay ring flange and will have holes tapped and plugged to permit jackscrews to be used. No shimming, spacers or levelling screws will be allowed at the outer flange to level the headcover.

The design of the headcover fasteners and the associated headcover and stay ring joint will, as a minimum, comply with the requirements of BC Hydro Engineering Standard ES31 Z0002, Headcover Fastener Design.

4.19.3 Strength and Rigidity

The rigidity of the headcover will be sufficient to eliminate the possibility of interference with the wicket gates or binding of the wicket gate stems. Conservative design features will be incorporated into the headcover design and the headcover stresses will not exceed the allowable limits specified in Appendix 6-2 [General Technical Specifications (SPGT)].

4.19.4 Bearings for Upper Wicket Gate Stems

The headcover will be provided with bearings for the upper stems of the wicket gates.

The bearings for the wicket gate upper stems in the headcover will be as specified in SPT 4.24. All self-lubricated bushings for these bearings will be removable and replaceable without major disassembly of the Turbine components.

4.19.5 Drainage

The headcover drainage system will be composed of two sub-systems, a gravity drainage system and a pumped drainage system. The two systems will be designed to minimize the standing water at any location on the headcover. To the extent possible, the headcover will be designed to be drained primarily by the gravity system, with minimal low points, and use the pumping system only for areas where it is not possible to drain by gravity under normal operating conditions. Water collecting on the headcover bolts will not be permitted.

All parts of the drainage system will be capable of being cleaned out in the event of a plugged drain. This would require extending the drain line above the drainage point to a higher point on the Turbine pit liner to achieve a straighter access for drain cleaning equipment. This higher access point will have a suitable cover and will be either flush or recessed into the pit liner.

The Contractor will supply and connect the gravity drainage and pumped drainage piping from the headcover to the drainage headers supplied by Others (the terminal points will be outside of the Turbine Pit, and/or below the stay ring, and will be determined by Hydro’s Representative).

(a) Gravity Drainage:

(i) The gravity drainage system will be composed of two sub-systems; one that comprises two perimeter drains located around the Turbine Pit as symmetrically as possible, and the second that is a single dedicated drain for the Turbine shaft seal. It is expected that these three drains will go through ducts in the stay vanes or baffle vane.

(ii) The Turbine Pit perimeter drainage system will be conservatively sized such that in the event of pumped system failure, and a plugged Turbine shaft seal drain, that the water level in the headcover will not rise high enough to damage any equipment in the Turbine Pit or get into the Turbine guide bearing.

(iii) If practical, leakage from the wicket gate seals will be directed into the perimeter drainage system.

(iv) The perimeter drainage system will have accessible, corrosion resistant, and removable debris screens placed over the inlets of the drains.

(b) Pumped Drainage:

(i) The pumped drainage system will consist of at least one pump to transfer excess drainage/leakage water to the Powerhouse drainage system. The pumped drainage system will be complete with strainers, check valves, isolating valves, air release valves and air vacuum valves (if required), pressure gauges, piping and fittings, as necessary, and all parts will be accessible for maintenance without dismantling of other parts of the Unit.

(ii) The pumped drainage system pump(s) will be either submersible or self-priming and be resistant to debris, such as rags, in the water. The pump(s) will be sized to handle 200%

of all Turbine shaft seal and wicket gate seal leakage assuming inoperability of all gravity drainage. The pump(s) will be designed to discharge the design flow to the Maximum Flood Design Tailwater with an allowance for not less than 4 metres for head loss in the piping system between the pump and tailrace.

(iii) For control and alarm purposes the following levels will be instrumented (from low to high level):

(A) pump(s) stop;

(B) pump #1 start;

(C) pump #2 start (if applicable);

(D) high level alarm; and

(E) extreme high level alarm (possible Unit trip).

(iv) The three pump control levels will be implemented using an oil resistant electronic level transducer such as wave guided radar. The two alarm levels will be implemented with two independent float-operated limit switches.

(v) The pump(s) controls will be located in the Turbine Pit Terminal Panel and provide:

(A) external communication to the facility control and monitoring systems and provide status of pumps, level, alarms;

(B) HAND OFF AUTO transfer switch for each pump including a dry contact to raise an alarm if not in AUTO position;

(C) absolute head cover water level indication;

(D) level switch status; and

(E) power status for each pump.

4.19.6 Lower Headcover Surface

The lower surface of the headcover that is adjacent to the wicket gates will be protected by stainless steel of a hardness compatible with the material on the wicket gates. It will be machined to provide a smooth water passage.

This protection may be provided by welded in stainless steel or stainless steel clad plates, or by stainless steel weld overlay. In all cases the stainless steel will not be less than 5 mm thick after machining and will cover an annulus at least equal in area to that of the closed wicket gates. The stainless steel material will be chosen to minimize the risk of galling in case of contact between the ends of the wicket gates and the headcover surface.

4.19.7 Wicket Gate Seals

For details of the wicket gate seals to be provided by the Contractor in the headcover, refer to SPT 4.22.4.

4.19.8 Renewable Runner Seal

A renewable seal ring at the runner clearance with the runner crown will be attached to the headcover. The seal ring will be of corrosion and abrasion resistant material and will be assembled of no more than two segments.

The mounting face for the seal will be machined concentric with the axis of rotation and will permit replacement of the seal without any subsequent machining.

The seal ring will be at least 40 points Brinell hardness less than the adjacent runner seal. All fasteners used for the attachment of the renewable seals will be bronze or stainless steel.

4.19.9 Bearing for the Operating Ring

The headcover will be provided with a bearing surface for the operating ring. The bearing will be fitted with self-lubricated wear strips. The bearing for the operating ring and material of the wear strips will be as specified in SPT 4.24. The design will be such that the bearing and self-lubricated wear strips are easily renewable.

4.19.10 Headcover Joint Seal

A rubber O-ring seal, or other accepted sealing method, will be incorporated in the joint between the sections of the headcover to make the joint water tight.

4.19.11 Maintainability and Access

The design of the headcover will permit easy access and dismantling of Turbine components for inspection and repair, without removal of the Generator rotor.

(a) Turbine Shaft Seal Access: The headcover design will incorporate as many access ports as possible with steps/ladders for convenient and safe access inside the headcover for inspection and maintenance (including replacement) of the shaft seal and other components. Access ports will be arranged as follows:

  (i) each access port will be a minimum of 610 mm x 460 mm;

  (ii) to allow manipulation and removal of Turbine shaft seal components via the Turbine shaft seal access ports;

  (iii) to allow convenient access and maintenance of all Turbine shaft seal components by a Worker, using required tools and equipment; and

  (iv) sized to accommodate Workers conducting a Rescue Operation through a Turbine shaft seal access port in as a horizontal direction as practicable during a rescue operation.

  Available working space inside the headcover will accommodate the largest component that may have to be removed without major headcover or Turbine guide bearing disassembly, by the number of Workers required to perform the removal, using necessary tools and equipment, and considering worker safety, ergonomics, fatigue, strain, and repetitive stress.

(b) Runner Crown Seal Clearance Measurement: Provisions will be made to allow for the measurement, from the top side of the headcover, the runner crown seal clearance at four points spaced 90° apart.

An effective means will be provided to prevent the screwed plugs (if applicable) for the crown seal clearance holes from loosening during the Unit operation.

(c) Runner Crown Inspection Ports: Four inspection ports, each 500 mm minimum diameter and spaced 90° apart, will be provided in the headcover to view the space between the headcover and the runner crown.

(d) Runner/Shaft Nut Guard Inspection Ports: If applicable, four ports will be provided in the headcover to allow for the inspection of the guard for the runner to shaft coupling bolt assemblies (refer to SPT 4.18.7) if the above guard is provided in the space between the headcover and runner crown.

4.20 Turbine Shaft Seal

4.20.1 General

A concentric axial type Turbine shaft seal will be provided below the Turbine guide bearing to limit the leakage of water into the Turbine Pit. The Turbine shaft seal housing will be bolted to the headcover and will be so arranged that the Turbine shaft seal components can be removed from the Turbine Pit for servicing and without disturbing the Turbine guide bearing or other Turbine components.

The sealing ring(s) will be composed of a carbon material that is not a proprietary design and can be sourced from, and machined by multiple suppliers. Other components of the seal, including bolts, nuts and screws, will be fabricated from a corrosion resistant material such as stainless steel or bronze. The replaceable seal wear face will consist of a hardened, corrosion resistant surface that may be composed of a proprietary alloy.

The Turbine shaft seal will be provided with readily accessible, and easy to read, visual wear indicators for each sealing ring.

The Turbine shaft seal will be designed to accommodate the maximum axial movement required, plus some reserve, due to Unit operation, Generator jacking, and any movement necessary to uncouple the rotor.

Turbine shaft seal components will be sized such that they can be assembled by one to two Workers. If the size or weight of a component exceeds the requirements of Appendix 6-2 [General Technical Specifications (SPGT)], the Contractor will provide the tools and lifting equipment required to perform the work.

The sealing rings will be lubricated and cooled using water from the Unit cooling water system. The water will be uniformly distributed around the Turbine shaft seal to ensure all wear faces are properly cooled and lubricated. The cooling water will be provided under sufficient pressure and flow to maintain sufficient seal cooling and a clean water barrier against the river water but not high enough to cause unnecessary seal wear.

The Turbine shaft seal will have a drainage system that captures and routes the majority of the leakage directly to the headcover drains including guards/deflectors as necessary to limit splashing.

All components required for flow control, regulation, flow and pressure indication, and other instrumentation will be provided on a single panel to be located in the Turbine Pit.

4.20.2 Water Filtration

The Contractor will supply any additional water filtration required beyond the raw water strainer. This filtration system will meet the following requirements:

(a) the Turbine shaft seal of each Unit will have its own independent filtration system;

(b) the Turbine shaft seal filtration system will not use mechanical contact to clean the filtration surface;

(c) the filtration system will be a redundant, fully automatic, self-cleaning style;

(d) the Contractor will provide references for and demonstrate that it is a proven design that has been successfully applied in water filtration systems for shaft seals of similar size and specific speed Turbines;

(e) the filtration system will be installed outside the Turbine Pit by the Contractor;

(f) the redundant filtration system will be mounted in parallel with isolating valves to enable maintenance or replacement of any component (except the isolating valves) of the filtration system while maintaining a continuous supply of cooling water flow to the Turbine shaft seal;

(g) if the Turbine shaft seal requires a continuous supply of filtered water when the Unit is not operating then the filtration system will source water from upstream of the unit cooling water control valve. The selected location will allow the water to be sourced from both the spiral case and station raw water header, either independently or combined,

(h) the filtration system will be designed such that the pressure and flow required by the Turbine shaft seal are maintained:

    (i) during a cleaning cycle;

    (ii) while an entire filtration path has been isolated, and;

    (iii) during a cleaning cycle and while an entire filtration path is isolated;

(i) if the filtration system has periodic cleaning cycles, the system will be capable of operating and cleaning in fully automatic mode and in a manual mode, and the controller will have the following modes of operation:

    (i) automatic operation based on head loss across filter (adjustable);

    (ii) automatic operation by adjustable timer; and

(j) if the cleaning cycle produces high level of discharges, Hydro’s Representative may require the individual drain lines from the self-cleaning process to be combined together into a single drain line and connected to the draft tube elbow approximately 500 mm below the draft tube platform elevation. The individual drain lines will each have a check valve, with an isolation valve immediately downstream. The single combined drain line will be provided with an isolation valve.

4.20.3 Piping and Accessories

The piping system will be designed and installed such that it can be easily removed for maintaining the Turbine shaft seal components.

The cooling water flow to the Turbine shaft seal will be regulated to ensure the appropriate differential pressure is applied to each component. The regulators will be stainless steel or bronze.

4.20.4 Instrumentation and Controls

The Contractor will supply instrumentation and controls necessary for the proper functioning of the Turbine shaft seal. Each shaft seal water supply will have flowmeters, pressure transducers, and pressure gauges.

Pressure transducers will be used instead of pressure switches. Mechanically operated instrument or control devices will not be used.

Provision will be made to allow for instrumenting the vertical motion of the Turbine shaft Seal during operation.

Instrument and control wiring will be supplied by the Contractor from the Equipment within the Turbine Pit to a termination point outside the Turbine Pit.

4.21 Turbine Guide Bearing

4.21.1 General

The Turbine guide bearing will be designed and constructed in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

4.21.2 Bearing Support

The bearing support will be made of cast steel or welded plate steel of heavy construction designed to support the bearing rigidly under the most extreme operating conditions and to transmit the bearing loads to the Turbine headcover. On final assembly the bearing support will be dowelled to the Turbine headcover.

4.22 Wicket Gates and Wicket Gate Seals

4.22.1 General

The wicket gates will be stainless steel, fully machined and will have two stems at the top and bottom of the gate to distribute the imposed loads to the wicket gate stem bearings in the bottom ring and the headcover. The wicket gates will be uniform in shape and hydraulically profiled to direct the water with uniform acceleration and minimum friction and hydraulic disturbance. The gate surfaces exposed to the water flow will be finished to a smooth hydraulic profile. The wicket gates will be interchangeable and will not include any internal drains or pressure relief holes.

The gate clearances with the adjacent surfaces of the headcover and bottom ring will be adjustable from above the headcover.

4.22.2 Wicket Gate Hydraulic Surfaces

The maximum surface roughness (arithmetical mean value) of the wicket gate hydraulic surfaces will not exceed 3.2 μm.

Surface waviness of the wicket gate profiles will be checked using a 600 mm length of flexible wooden spline, and the maximum allowable gap under the spline in all directions will not exceed 1.6 mm.

4.22.3 Wicket Gate Design Requirements

(a) The wicket gates should be in hydraulic balance for a wicket gate opening between the speed no load position and approximately 20% opening, and at higher openings the wicket gate hydraulic torque should act on the gates in closing direction.

(b) In order to minimize the gate leakage (refer to SPT 4.5.3), the contact surfaces of the wicket gates will be fully machined to ensure that they are parallel over the entire height of the gates and to provide an adequate gate to gate contact area when the gates are in closed position. The contact surface at the nose of the gate will have slightly raised face to permit future grinding if the face becomes damaged. The wicket gates will be carefully fitted along the line of contact during shop assembly within 0-mm clearance to ensure minimal leakage when they are closed against headwater pressure (Servomotor squeeze on).

(c) The design of the wicket gates will be such that neither of the potentially excitable natural frequencies of the gates in water coincides with the Von-Karman vortex shedding frequency or other hydraulic excitation frequencies and the margin is sufficient to avoid resonance at all required operating conditions.

(d) The top and bottom surfaces of the wicket gates will have hardness compatible with the headcover and bottom ring surface material, so that if there is a contact, galling will not occur.

(e) Each upper gate stem will be provided with a thrust bearing to support the mass of the gate and/or to withstand the hydraulic lift forces. The thrust bearing will be as specified in SPT 4.24.

4.22.4 Wicket Gate Seals

Brass seals will be provided in the headcover and bottom ring in the clearance at the top and the bottom of the wicket gates. These seals are required to prevent leakage during a normal shut down and during the synchronous condenser operation, and wire-drawing on the adjacent parts when the gates are closed. The seals will be designed so as to permit replacement without removing the wicket gates.

The design of the wicket gate seals will consider the inclusion of suitable precautions for preventing damage to the seals, which could be caused by wood chips and other debris that may be present in the water. The wicket gate seals will withstand damage due to operation of the wicket gates, without the need to lubricate the wicket gate seals, when the Turbine is dewatered during a maintenance outage. The wicket gate seals will have a minimum life expectancy of 12 years.

4.23 Wicket Gate Operating Mechanism

4.23.1 General

The wicket gates will be connected through levers and links to the operating ring, which in turn is connected by rods to the Servomotors. The components of the wicket gate operating mechanism will be of steel construction. The moving parts will be provided with wear strips on the headcover for the operating ring and bushing for the wicket gate link pins as specified in SPT 4.24.

The wear strips for the operating ring will be provided with seal/wiper elements to prevent the ingress of foreign material onto the wear strips during operation or maintenance.

4.23.2 Operating Ring

The operating ring will distribute the Servomotor forces and movements to all of the wicket gates simultaneously. It will be designed to receive the wicket gate Servomotor connecting rods and pins and the wicket gate links and pins. It will be of rigid construction and will be supported from and guided by the headcover. It will be sufficiently rigid so that there is minimal deflection for any combination of fully unbalanced Servomotor loading.

The design of the attachment of the connecting rods and the wicket gate links to the operating ring will make allowances for wear during operation of the operating ring wear strips mounted on the headcover and not cause undue stresses or deflections in these attachments. Provision will be made for measuring the wear in these strips. The operating ring will be designed to allow replacement of the wear strips with a minimum of dismantling.

4.23.3 Connecting Rods

The connection between the wicket gate Servomotors and the operating ring will be made with rods equipped with pins mounted in the bushings. The bushings for the Servomotor rod pins will be as specified in SPT 4.24.

4.23.4 Links and Levers

The mechanism will consist of a lever (or levers) mounted on each wicket gate and links connecting the lever to the operating ring. A double link will be used to connect the gate lever to the operating ring. The connections between the operating ring and the links, and between the links and levers, will be made with pins.

4.23.5 Wicket Gate Thrust Mechanism

The wicket gate thrust mechanism will be designed to accommodate the worst case hydraulic up and down thrust for all operating conditions. All bolting will be stainless steel or high strength bronze. The thrust mechanism will prevent contact of the wicket gates with the headcover and bottom ring surfaces, taking into account all deflections for all loading conditions. The thrust ring will be as specified in SPT 4.24. The allowable bearing pressures on the thrust ring will be 75% of those permitted for the headcover and bottom ring wicket gate bushings in accordance with Appendix 6-2 [General Technical Specifications (SPGT)]. The vertical adjustment of the thrust mechanism will be designed in such a way to permit easy adjustment of the clearances, and any special tooling required to perform these adjustments will be provided to BC Hydro as part of the Work. The wicket gate vertical movement will be verified at Site.

The wicket gate thrust mechanism will have a seal to prevent dirt ingress into the thrust mechanism and upper wicket gate stem bearing.

4.23.6 Link Pins

The link pins in the operating ring will be of the eccentric type to allow adjustment of the gate contact when in the closed position. The design will be such that repairs and replacements can be easily made with minimum dismantling of the Turbine. The locking mechanism for the link pins will be designed to resist rotation for at least 200% of the worst case loading including shear pin breakage.

4.23.7 Protective Devices

(a) Shear Pin and Friction Device: The wicket gate levers will be equipped with a combination of shear pins (or other suitable breaking device) and friction devices to protect all components of the wicket gate operating mechanism from damage in case one or more of the wicket gates become blocked. The shear pins will be designed to withstand the maximum forces applied for all normal operating conditions but sized to break the shear pins under the application of excessive forces either in the closing or opening direction. The friction device will be sized such that operation of the Unit can continue for short periods of time after a shear pin has broken and permit realigning of the wicket gate lever and stem by opening or closing against the stops. The design of the shear pins and friction device will avoid cascade failure of the shear pins for all normal operating conditions and if one or more shear pins has already failed.

Replacement of a shear pin will be readily accomplished with minimum dismantling of the linkage and with the penstock dewatered and draft tube watered up. The shear pins will have provisions to facilitate easy removal, i.e., threaded holes and edges prepared to prevent galling holes. All tooling required to replace a shear pin will be provided to BC Hydro as part of the Work.

The shear pins will have only one shear plane. Each shear pin will consist of two parts with two different diameters, the lower part having the smaller diameter of the two. This will ensure that dismantling of the linkage can be accomplished without serious damage to other components.

(b) Stops: Substantial stops will be provided on the headcover to limit the angle of movement of the wicket gate when a shear pin is sheared and so to prevent the loose wicket gate from interfering with the runner and the operation of the other wicket gates.

As a further precaution against damage, the stops will be provided with replaceable cushion to mitigate the effect of the shock.

4.23.8 Wicket Gate Labelling

All of the major components of the wicket gate assembly including the wicket gate, the wicket gate levers, the wicket gate linkage assemblies, etc., will be permanently marked with their position number. If the means used to permanently mark the wicket gates is such that a Worker cannot see the markings when standing on the Turbine pit walkway, then each wicket gate assembly will have a number permanently marked on them in a visible location. Wicket gate number one will be the upstream wicket gate and the wicket gates will be numbered in the direction of rotation.

4.24 Wicket Gate and Wicket Gate Operating Mechanism Bearings

4.24.1 General

The bearings for the wicket gate stems in the headcover and bottom ring will be fitted with self-lubricated bushings. These bushings will be provided with acceptable mechanical means of preventing bushing rotation in the bores. The use of “grub” screws alone will not be permitted.

The upper stem bearings adjacent to the main water passage will be provided with a chevron type seal and a gland, or equivalent, to prevent leakage from the water passage. These seals will be designed to be replaced without disassembly of any other components. These seals will last for the Design Life of the bushings. All bolts, studs, and nuts for the seals will be of bronze or stainless steel.

All bearings adjacent to the water passages will be provided with lip type seals/wiper elements, or equivalent, to prevent the ingress of foreign material into the bearings during operation or maintenance. These seals will last the life of the bearings.

The bearings in the wicket gate operating mechanism will be fitted with:

(a) self-lubricated bushings for wicket gate link pins and Servomotor rod pins;

(b) self-lubricated thrust rings for wicket gate thrust mechanisms; and

(c) self-lubricated wear strips for operating ring.

All self-lubricated bushings, thrust rings, and wear strips will operate against stainless steel bearing surfaces and will be positively retained to prevent their rotation or other movement.

4.24.2 Self-Lubricated Material

The Contractor will offer self-lubricated bushings, thrust rings and wear strips for which it can demonstrate extensive experience in similar size and head Turbines. Within the basic arrangement, the Contractor may propose the same self-lubricated material for all wicket gate and wicket gate operating mechanism bearings, or different self-lubricated materials depending on the bearing location, accessibility, and operating and maintenance requirements. Self-lubricated materials will be Orkot TXM Marine.

4.25 Wicket Gate Servomotors

4.25.1 General

The Turbine will be provided with two or more oil-pressure operated double-acting hydraulic cylinders (the "**Servomotors**") having a combined capacity sufficient to supply the force necessary to operate and hold closed the wicket gates against the highest loads encountered, at the minimum oil pressure.

The operating and design pressures will be in accordance with the requirements for the Governor high pressure oil system as specified in Appendix 6-4 [Governor System Specifications (SPGOV)].

The Servomotors will be capable of moving the wicket gates from a fully closed position to a fully open position and vice versa under the worst case operating conditions with at least 25% reserve capacity. Each Servomotor will consist essentially of a cast steel or fabricated plate steel cylinder of rigid construction and a cast iron or steel piston connected to a steel piston rod.

Provision will be made to perform levelling and alignment of the Servomotors during installation. No shimming is allowed for the Servomotor alignment except with the use of a single machined plate appropriately fixed in place. Each Servomotor will be adjusted such that all Servomotors simultaneously reach their end of travels in the wicket gate opening and closing directions.

There will be no external oil leaking from the Servomotor and its connections.

4.25.2 Location

The Servomotors will be located on and rigidly supported from the stay ring on pedestals or from the Turbine pit liner.

If the Servomotors are to be mounted on the headcover, they will be located in such a way as to minimize interference with other components and to allow access to all areas of the headcover for maintenance. It will not be necessary to remove a Servomotor to perform maintenance on any component of the wicket gate operating mechanism, including shear pin replacement. The Servomotors will not block access to the Turbine guide bearing or shaft seal.

Consideration will be given to the likely need for one or more concrete columns placed between the Servomotors, in the Servomotor pit liner recess, to transfer the loads from the Generator lower bracket into the stay ring. In addition to this, convenient means will be provided to move the Servomotors to a location accessible by the Turbine pit hoist. The Servomotors will be recessed sufficiently to permit removal of the headcover without removal of the Servomotors and they will not block access to any other components.

A clear space of not less than 300 mm width will be provided for concrete and reinforcing steel between the servomotor blockouts and the spiral case.

4.25.3 Cylinder

The Servomotor cylinder will be designed and located so that the force for moving the wicket gates will be divided approximately equally between the cylinders and will be applied in substantially equal magnitude to opposite sides of the wicket gate operating ring and tangentially to the ring.

The inner surface of the cylinder will be bored to a uniform diameter and will have a surface of 0.40 µm arithmetical mean roughness, or better, to allow the piston to traverse freely and smoothly and to reduce oil leakage past the piston to an absolute minimum.

4.25.4 Piston

Each piston will be fitted with suitable synthetic composite piston rings shaped to give close contact and uniform pressure on the cylinder walls. In addition to the piston rings, Teflon rider rings will be used to minimize piston wear caused by excessive piston to cylinder contact. As an alternative design, the Contractor may submit another method to hold oil leakage past the piston to a minimum.

The pistons will be overlaid with aluminum bronze or equivalent. The piston will have a seal at the piston to rod connection.

The allowable leakage past the piston at 100% design pressure on one side of the piston while the opposite side is vented to atmosphere, in either direction will not exceed 0.5 L per hour.

4.25.5 Piston Rod, Bushings and Seals

(a) Rod Design: Material of the piston rods will be hardened steel or chrome plated steel. The rods will be designed to permit easy rotation for adjustment. The rod end will allow for continuous length adjustment with a suitable locking mechanism and will not be dowelled. The rod will be sized to prevent buckling at the most adverse combination of the loading conditions, including but not limited to the following:

(i) maximum possible misalignment;

(ii) supporting the full weight of the operating mechanism; and

(iii) maximum test pressure for the system.

(b) Rod Seals and Bushings: The rod bushing and bearing design will allow minimizing the sag at the rod end with the rod fully extended and the maximum forces acting on the rod end.

The rod seal will be of the double seal arrangement. The primary seal will be capable of sealing against the full test pressure and its design will take into consideration the maximum deflection of the rod when the rod is fully extended with the maximum load on the rod end. The preferred primary seal is a chevron packing type. The leakage through the primary seal will be zero during the warranty period. The secondary seal will seal against any incidental primary seal leakage that may occur as the seals wear in the long term, and route this leakage to an appropriate collector. The secondary seal will also be used to prevent debris/liquids entering the primary seal from the exterior of the cylinder and will not be relied upon for sealing under pressure.

4.25.6 Bypass and Piping Connections

Bypass connections equipped with orifices and/or adjustable needle valves will be provided on the Servomotors to slow the rate of closure of the wicket gates from within two-thirds of the speed-no-load position to the fully-closed position. The bypass connections will be fitted with check valves which will prevent sluggish movement on opening the wicket gates from the fully-closed position.

The Servomotor cylinders will be provided with flanges for connection to the oil piping. Connections will be provided at each end of each Servomotor cylinder with the necessary piping and valves for the following items that will be supplied and installed by the Contractor:

(a) pressure gauges;

(b) air release; and

(c) low point drains.

Isolation valves will be provided for each oil pipe connection immediately adjacent to the Servomotor.

Orifices will to be provided at both Servomotor pipe flange connections for all Servomotors, to limit the speed of the Servomotor in the extreme event of a break in the oil piping. The Servomotor timing associated with this extreme event is expected to be slightly faster than the normal design timing.

4.25.7 Wicket Gate Locking and Stroke Limiting Devices

(a) General: All wicket gate locking and stroke limiting devices will be capable of withstanding without damage, the most adverse loading that can be applied to them including loading during the Servomotor tests specified in SPT 5.3.4. The devices will also be designed for use as isolating devices to safely protect workers performing maintenance work at all locations in the Turbine Pit and Turbine water passages.

There will be two types of locking devices as described in SPT 4.25.7(b) and (c) below. All locking devices will be capable of being manually locked with a “padlock” in either the engaged or disengaged positions.

The wicket gate locking devices will be mounted external to the Servomotor. The locking devices will be designed such that the position of the component that actually performs the locking function can be directly verified visually.

(b) Automatic Lock: A wicket gate locking device will be provided on the operating ring or at one Servomotor and will be applied and released automatically at the closed gate position, by a hydraulically operated mechanism. The design will incorporate safety features which positively preclude porting oil to the opening side of the Servomotor until the lock is fully released.

The wicket gate locking device will be applied whenever the turbine Governor complete shutdown sequence is initiated, but will lock the wicket gates only after they have reached the fully closed position (i.e., the “squeeze” position). The wicket gate locking device will retain a minimum of 60% of the squeeze on the Wicket Gates to keep them closed in the absence of oil pressure in the servomotors. Release of the wicket gate locking device will automatically occur as part of the turbine Governor starting sequence and will be accomplished by hydraulic means in combination with electrical interlocks. The design will be such that, upon loss of the DC control voltage, the gate lock will be applied correctly following Unit shutdown, with no damage occurring to the operating ring, Servomotors or wicket gate locking device.

The wicket gate locking device will be provided with the following electrically independent limit switches for use by Others:

(i) gate lock fully released;

(ii) gate lock fully released;

(iii) gate lock not fully applied; and

(iv) gate lock fully applied.

Provision will be made in the Turbine Pit for manually blocking the hydraulic lines to the release mechanism of the automatic lock.

If the wicket gate locking device is to be applied to a Servomotor then the locking device will be designed to minimize damage to the Servomotor rod in the event that the lock is inadvertently engaged before the Servomotor is fully retracted.

(c) Manual Locks: To provide safety during maintenance, provision will be made in the Turbine Pit for manually locking the Servomotors in the fully open and fully closed positions. These locking devices will be applied on the operating ring or at one of the Servomotors. The devices will be permanently mounted on the Servomotors or operating ring and be capable of being conveniently installed by a Worker. The device to manually lock the Servomotors in the closed position can be incorporated into the design of the automatic lock described in (b) above.

(d) Stroke Limiting Device: The set of suitable machined steel blocks, or horse-shoe rings will be provided for limiting the Servomotor stroke primarily during Site testing of the Unit. The stroke limiting device may also be used for maintenance purposes to safely block the Servomotors at some intermediate position. The blocks will be provided for use on the operating ring or one of the Servomotors and be graduated in thickness to permit limiting the Servomotor stroke in the opening direction from 10% to full stroke in increments of 1%. To minimize the number of blocks, 1% increment requirement may be achieved by combinations using blocks in different number and size. Each block will have a number and will have the block thickness stamped on it. The blocks, if used on the Servomotor rods, will have a soft lining to prevent damage to the Servomotor rod. For maintenance purposes the blocking will be capable of being installed to block movement in either opening or closing directions.

4.26 Turbine Pit

4.26.1 Turbine Pit

The turbine pit (the "**Turbine Pit**") is the space located above the headcover but below the Generator Pit and encircled by the Turbine pit liner.

4.26.2 Turbine Pit Liner

The Turbine pit liner will:

(a) be of plate steel, 20 mm minimum thickness;

(b) extend up to the floor accessing the Generator thrust bearing;

(c) be adequately ribbed and have sufficient anchors to provide proper anchorage in the concrete;

(d) either be welded to the stay ring with full penetration welds or provided with a flange machined and drilled for dowelling and bolting to the stay ring;

(e) if required, have suitable provision for supporting the Servomotors and transmission of the Servomotor reaction forces through the Turbine pit liner to the surrounding concrete; and

(f) have additional Turbine pit liner anchors in the vicinity of the Servomotor mountings to ensure adequate support.

4.26.3 Lighting and Receptacles

The Turbine Pit will:

(a) have permanent light fixtures. The number and arrangement of light fixtures required will be such that:

(i) the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] are met in all areas of the Turbine Pit; and

(ii) if they are mounted on the Turbine pit liner, they do not need to be removed or altered to enable removal of the headcover; and

(b) have 600 V and 120 V receptacles located every 3 m along the inside walls of the Turbine pit liner. The receptacles will be arranged such that they do not need to be removed or altered to enable removal of the headcover.

4.26.4 Tie-down Bars, Turnbuckles, Jacks, Anchors, Foundation Bolts

Tie-down bars, turnbuckles, jacks, anchors and foundation bolts will be as specified in SPT 4.7.

4.26.5 Maintainability and Access

(a) Raceway, wiring, cabling, Piping and Equipment in Pit: All Raceway, piping and equipment mounted in the Turbine Pit, will be located in such a way as to minimize disassembly requirements during major disassembly of the Turbine. All conduits and piping will be routed in recesses in, or passages behind, the Turbine pit liner, such that removal of the headcover or other major components requires only joints to be broken or short stub sections to be removed. Terminus of conduits and routing of conductors will be arranged to minimize the amount that conduits have to be “pulled back” during disassembly. Wiring and cabling will be run in Raceway, and routing will be such that wires and cables are kept as short as possible.

(b) Turbine Pit Maintainable Components: Each maintainable component within the Turbine Pit (the “**Turbine Pit Maintainable Components**”) will be designed and will have a Procedure for moving it between its respective in-service position and a location outside of the Turbine Pit via the Turbine Pit Access Passage without removal of the Generator rotor. The Procedure will include a consideration of the necessary tools, equipment, Worker complement, and lifting equipment. The key objective will be to eliminate all manual transfers and manipulation of any Turbine Pit Maintainable Component by a Worker from the location where the component was removed to where it is set down on a Cart or other device.

The Turbine Pit Maintainable Components include any Unit components installed in the Turbine Pit that may require maintenance activities performed on them at any point during their Design Life, as required by the Contractor’s Equipment design and Equipment maintenance schedule. Turbine Pit Maintainable Components will include:

(i) complete Servomotor assembly (without oil), complete with locking device and yoke;

(ii) Turbine guide bearing components, including the bearing cover, bearing pads and coolers;

(iii) shaft seal maintainable/replacement components;

(iv) headcover drainage pump(s);

(v) operating mechanism components, including link, wicket gate lever, shear lever, wicket gate bushing cartridge;

(vi) all Turbine pit walkway components; and

(vii) Generator Pit Maintainable Components, if applicable.

There will be no need to lift a wicket gate.

(c) Turbine Pit Walkway: A permanent Turbine Pit access platform will be provided in the Turbine Pit, near its periphery, and will span the entire circumference of the Turbine Pit. Note that the Turbine pit walkway is part of an Access Route.

The Turbine pit walkway will be sized and arranged such that a Standing Worker can enter the Turbine Pit via the Turbine Pit Access Passage and walk around the entire circumference of the Turbine pit walkway in as ergonomically correct a position as possible, considering any equipment, piping, or structural member of the Turbine pit hoist and the fully raised and stowed hook positions.

The Turbine pit walkway will be arranged to allow a Standing Worker on the walkway, to visually inspect the wicket gate shear pins, and wicket gate links and levers. The Turbine pit walkway will be designed so that it does not obscure visual inspection of the wicket gate links and levers, and so that shear pins, and that shear pin replacement can be conducted without removing any part of the Turbine pit walkway.

The Turbine pit walkway will be provided with removable guardrails. Vertical posts for the guardrails will fit into sockets in the Turbine pit walkway, such that the guardrail sections can be quickly and easily installed or removed.

The Turbine pit walkway will be designed with anti-slip surfaces that are conveniently and easily removable in sections. Turbine pit walkway sections will be designed such that their size and weight will permit Workers to conveniently remove and manipulate the sections, without the aid of lifting equipment.

The Turbine pit walkway will be sized and arranged to accommodate a means for moving all Turbine Pit Maintainable Components as required, including allowances for use of, including any specialized tooling, Carts, anchors, lifting equipment, and Procedures, by Workers.

(d) Turbine Shaft and Guide Bearing Access: A Turbine shaft and guide bearing access walkway or access platform will be provided, near the Turbine guide bearing and shaft and will span the entire circumference of the Turbine guide bearing and shaft. The Turbine bearing access walkway may be an installed platform, or a surface of the headcover if applicable. Note that the Turbine bearing access walkway is part of an Access Route.

The Turbine bearing access walkway will be arranged such that a Worker can walk around its entire circumference while in the Standing position.

Access to the Turbine bearing access walkway from the Turbine pit walkway will be provided in at least two locations: one directly aligned with the Turbine Pit Access Passage, and the other located either diametrically opposite, or between Servomotor cylinders. The Turbine bearing access walkway will be arranged such that a Standing Worker can move from the Turbine pit walkway to the Turbine bearing access walkway.

The design of the Turbine bearing access walkway will incorporate the following:

(i) non-slip low maintenance surfaces;

(ii) removable or hinged hatches to allow access to the shaft seal access ports;

(iii) if a platform is used, it will be easily removable for maintenance purposes;

(iv) if a fall Hazard exists, removable guardrails will be provided. Vertical posts for the guardrails will fit into sockets in the platform, such that the guardrail sections can be quickly and easily installed or removed;

(v) consideration of necessary tools, equipment, and Worker crew complement; and

(vi) accommodation of means to transport Turbine Pit Maintainable Components.

(e) Heavy and Oversize Component Management: The specialized tooling, carts, anchors, lifting equipment, and Procedures required to move all Turbine Pit Maintainable Components between the Turbine Floor and the in-service position, will be designed to eliminate all transfers and manipulation of heavy components by a Worker is moved to the final point where it is to be placed on a cart for movement around the Turbine Floor or into its in service position.

4.26.6 Turbine Pit Hoist

(a) General: Each Turbine will have a motorized Turbine pit hoist and overhead monorail system comprised of a circular monorail around the perimeter of the Turbine Pit and around the perimeter of the Turbine shaft with a spanning beam across the pit for a motorized hoist to travel along. The spanning beam end trucks will both travel on the circular monorails.

The Work includes provision of power to the hoist from one or more receptacles located around the Turbine Pit including determining the number, location and size (rated voltage and current) of the receptacles.

(b) Design Criteria: The Turbine pit hoist and overhead monorail system will:

(i) allow the Turbine pit hoist to travel around the circumference of the Turbine Pit in either direction;

(ii) have a rated lift capacity in accordance with Appendix 6-2 [General Technical Specifications (SPGT)], or 5 tonnes whichever is higher; and

(iii) have sufficient vertical lift to pick a Turbine Pit Maintainable Component up from the lowest point in the Turbine Pit.

The arrangement of the Turbine pit hoist will be such that a Worker can walk around the entire circumference of the Turbine pit walkway in the Standing position, considering any structural member of the hoist. The hoist hook assembly – in the fully raised or stowed hook position – will be included in this requirement if the hoist hook assembly cannot be stowed in a position that does not interfere with a Standing Worker walking on the Turbine pit walkway.

4.26.7 Turbine Pit Door

A Turbine pit access door(s), complete with frame and any necessary accessories will be provided.

The Turbine pit access door will:

(a) not require more than 15 kg to open or close when the Unit is operation;

(b) be equipped with a damper system to prevent slamming of the door;

(c) have a sill flush with the adjacent concrete floor;

(d) have a clear opening when the door(s) is open;

(e) have a hinge or hinge mechanism which allows the door to open flush against the walls of the Turbine Pit Access Passage;

(f) be equipped with a mechanism to enable it to be latched in the fully-open position during prolonged maintenance periods; and

(g) have means to latch the door when closed. It will be possible for a Worker to unlatch the door from either side of the door.

In addition to the above, a removable barrier that can be installed across the Turbine Pit access way opening during prolonged maintenance periods will be provided. The barrier will have a hinged gate(s) with spring return sized to allow Workers and Special Carts to pass through.

4.26.8 Not Used

4.27 Air Admission

4.27.1 General

An air admission system is required for each Unit. All necessary equipment and material including non-embedded and embedded piping, drain piping, silencer, isolating valves, check valves, control valves, and controls and wiring required for the complete installation and operation of the air admission system will be provided.

The air admission system will:

(a) be based on a design proven as being successful in operation for similar size and head Turbines;

(b) be through the Turbine shaft or the headcover;

(c) be routed and connected to the terminal point, where the piping will draw air from outside of the Powerhouse with the inlet located above the Maximum Flood Design Tailwater Level;

(d) be controlled in such a way as to minimize degradation to the performance of the Unit. Air admission will be regulated and will be shut-off when it is not required. Unnecessary or excessive air admission will not be accepted;

(e) ensure no water or other lubricants used in the air admission system will leak or drain out of the air admission system into the Powerhouse or onto any equipment including the Generator and the adjacent Units under any operating conditions; and

(f) have control and instrumentation wiring terminated in the Turbine Pit Terminal Panel and/or Generator Terminal Cabinet.

4.27.2 Compressed Air

If during commissioning it is determined that compressed air is required for smooth operation of a Unit, the Work includes all air compressors or blowers, controls and embedded and non-embedded piping.

The hydraulic thrust at the operating conditions where air admission or injection of compressed air is required, will not be increased beyond the maximum allowable hydraulic thrust.

4.27.3 Direct Air Admission

In addition to the above air admission system, embedded piping in second stage concrete for direct air admission into the draft tube will be provided. This piping will be connected to the draft tube liner to allow future installation of air admission devices will this be found necessary for smooth operation of the Unit. The piping will terminate at a flanged connection, with a blind flange installed, on the downstream wall of the Turbine on the spiral case access floor.

4.27.4 Modifications Made During Commissioning or Operation

Any apparatus or device inserted into the water passage, which was not included in the original Turbine Model Test, to allow for smooth operation of the Unit will be submitted for Consent and will be subject to the Contractor's demonstration by Turbine Model Tests of the effect of these devices on the hydraulic performance of the Unit.

4.28 Synchronous Condenser System

4.28.1 General

The synchronous condenser air depression system will be designed to operate all six Units in synchronous condenser mode and be capable of operating between one and three Units in synchronous condenser mode. The Work includes:

(a) three Units with synchronous condensing operation capability (the specific three Units will be determined by Hydro's Representative);

(b) three Units with suitable connections and embedded parts to allow for future connection as synchronous condensers; and

(c) be capable of depressing the water in one Turbine with the air depression system compressed air supply initially at 90% of nominal design pressure.

Additional requirements include:

(d) if the design of the synchronous condenser system requires components to be installed on top of the Generator, the synchronous condenser system will:

  (i) ensure no water or other lubricants used in the synchronous condenser system can leak onto adjacent equipment;

  (ii) provide a leakage sump and associated drains and piping to route any leakage away from the Equipment; and

  (iii) make every reasonable attempt to minimize air leakage and ensure that if any air leakage does occur it does not have a detrimental effect on adjacent equipment;

(e) for the three Units that are not fully configured for synchronous condenser operation all contractual interfaces between piping systems will be terminated with bolted on blind flanges;

(f) electrical panel configurations will be the same for all Units regardless if the Units are fully configured for synchronous condenser operation or not;

(g) cooling water piping configurations will be designed to allow for all Units to have the same piping and valve configuration in the future regardless if the Units are fully configured for synchronous condenser operation or not; and

(h) all piping and equipment required to exhaust the air into the air admission header system, and sized to fully exhaust the depression air within 5 minutes.

The synchronous condenser air depression system will be a previously proven design supplied through the headcover, through the Turbine shaft or through an air inlet in the draft tube liner.

The Work also includes any additional equipment required for the air admission system or synchronous condenser air depression system to prevent any leakage or miss operation of either the air admission system or synchronous condenser air depression system including:

(i) additional pneumatically operated control valves for the air admission actuated by a solenoid valves;

(j) check valves; and

(k) any other electrical or mechanical interlocks, instrumentation, control logic, etc., deemed necessary.

4.28.2 <u>Air Depression System Compressed Air Supply (Supplied by Others)</u>

The compressed air supply will be supplied by Others and will:

(a) terminate at a flanged isolation valve adjacent to all six Units at a mutually agreeable location;

(b) have a piping system that is sized to ensure rapid initial depression of the water level in the draft tube (runner clear of water);

(c) have a nominal design pressure of 690 kPa;

(d) be comprised of a piping system that consists of:

  (i) a main compressed air header running the length of the Powerhouse;

  (ii) piping interconnecting air compressors to main header;

  (iii) piping interconnecting air receivers to main header;

  (iv) piping up to the isolation valves in SPT4.28.2(a);

  (v) flanged connections adjacent to every major piece of equipment, in the main header at least at every Unit, and at other appropriate locations to facilitate disassembly and removal of piping; and

  (vi) all fittings, additional isolation valves where required, drain valves, and other components needed to complete the Work;

(e) have a minimum of two air compressors including: filters, check valves, condensate drains, pressure relief valves, individual isolation and bleed valves, motor starters, controls, etc. The combined capacity of the compressors will be capable of re-pressurizing the air receivers after the water level in one Unit has been depressed to nominal system pressure in 30 minutes while supplying makeup air to two units operating in synchronous condense mode. Individual compressors will have sufficient capacity to maintain three Units in synchronous condenser operation continuously; and

(f) have air receivers with a total volume of 265 m^3. The air receivers will also have access ports for Workers, drain valves, and automatic water drains.

Depending on the final Powerhouse layout, there may be other requirements such as additional embedded piping, additional isolation/drain points to accommodate construction sequence, etc.

4.28.3 Components Common to Each Unit

The Work includes the following components for each Unit:

(a) the embedded piping required to route compressed air from the location of the control valves into the Turbine including either piping to the draft tube, and/or to the Turbine Pit, and/or to the Generator Enclosure as required for the Contractor’s design;

(b) the embedded piping required to route exhaust air out of the Turbine to the air admission header. This includes embedded piping to the air admission piping, embedded piping to the Unit, or both;

(c) the embedded piping required for providing cooling water to the runner seals;

(d) a connection in the Cooling Water System to supply cooling water to the runner seals; and

(e) the embedded or exposed piping and connections to the draft tube required for draft tube water level measurement.

4.28.4 Unit Specific Components

For the three Units that will be initially configured to operate in synchronous condenser mode the Work includes:

(a) compressed air supply piping components consisting of:

    (i) exposed piping and fittings required to connect from main header isolation valve to the Unit including drain valves at low points that are also sized to also be suitable for bleed valves for isolation;

    (ii) isolating valve as close to the Unit as is practical and a check valve just upstream of it;

    (iii) a main air depression control valve and a maintenance air control valve that are both pneumatically operated using solenoid valves;

    (iv) all piping and associated equipment required to connect from the compressed air system to the control valves; and

    (v) pressure transducer and pressure gauge on the supply side of the control valves and a pressure gauge on the Unit side of the control valves;

(b) exhaust air system consisting of:

(i) exposed piping, valves, and fittings required to connect the embedded exhaust air piping, Unit, and air admission together including an isolation valve adjacent to the Unit and drain valves in the piping; and

(ii) an exhaust air control valve that is pneumatically operated using a solenoid;

(c) runner seal cooling water components consisting of:

(i) cooling water piping to connect from the cooling water system take off to the embedded piping including: piping and fittings, isolation valve at the connection, check valves for each seal branch, isolating valves at most downstream ends of the exposed piping for each seal branch, drain valves in each branch of the piping, and balancing valves in each seal branch;

(ii) a pneumatically or electrically operated cooling water supply valve;

(iii) one flow meter for each runner seal; and

(iv) any additional cooling water filtration that is required by the Contractor's design; and

(d) water level measuring components consisting of a water level transducer, sight glass, and a stilling well. The assembly will be located and designed such that it is possible to service/replace the water level transducer without removing the well and such that its performance is not influenced by vibration.

4.28.5 Synchronous Condenser Operation Controls

The control logic for the synchronous condenser air depression system will reside in the Governor PLC for each Unit as specified in Appendix 6-4 [Governor System Specifications (SPGOV)]. All Units will be configured the same except the control logic will be installed but disabled in the three Units that are not fully configured for synchronous condenser operation.

4.29 Instrumentation

4.29.1 General

(a) For clarity some instrumentation descriptions/requirements are located in other sections of the technical specifications.

(b) Unless specified elsewhere all instrumentation wires will be terminated on terminal blocks in the Turbine Pit Terminal Panel.

4.29.2 Pressure Taps

(a) Pressure taps in the Turbine water passages will be designed and installed in accordance with the requirements of IEC Publication 60041.

(b) Pressure tap piping will be at least 12 mm in nominal diameter.

(c) The pressure taps upstream of the spiral case, in the spiral case, and draft tube liner, will have stainless steel inserts at least 100 mm diameter.

(d) Pressure taps installed in concrete water passages will have a have stainless steel inserts, round or rectangular, with a minimum dimension of at least 300 mm and be mounted flush with the wall. Inserts will also have sufficient concrete anchors.

(e) Location of the pressure taps will be homologous to that on the Turbine Model where they have been included on the Turbine Model.

(f) Location of the pressure taps that were not included on the Turbine Model will be submitted.

(g) Each pressure tap pipe will have a separate isolation valve. If the pressure tap piping is not permanently connected to instrumentation the pressure tap piping will be terminated with a threaded plug after the valve.

(h) Where permanently connected to instrumentation each pressure tap pipe will have a drain/flushing line the same size as the pressure tap pipe with an isolation valve with the drain/flushing line routed to a gravity drain. Where more than one pressure tap is connected to a common manifold the drain/flushing pipe may be common to that manifold.

(i) The Contractor will develop a Procedure for cleaning the pressure taps and pressure tap piping, and include a description of any required equipment, fittings, and connections.

(j) Pressure tap piping is to be routed to a location indicated on a submitted drawing.

(k) Embedded pressure tap piping will be covered up to 300 mm downstream of the first elbow adjacent to the spiral case and draft tube liner, to prevent bonding of the piping to the concrete. The cover will be Aero Tube as manufactured by Manson or Equivalent.

(l) The pressure tap piping will also be protected by structural steel members against damage during concreting. Welding of these members to the spiral casing will not be allowed. Where the pressure tap piping is installed by Others, the piping and protection will be prefabricated so that minimal assembly is required at Site.

4.29.3 Reference Section 1 - Inlet Head Pressure Taps

Four pressure taps spaced at 45° from vertical will be provided in the penstock spool piece section 2350 mm upstream of the centerline of the flexible coupling for Reference Section 1 for measuring inlet pressure to the Turbine. Pressure tap piping on the exterior of the penstock spool piece section will be readily removable to permit cleaning of the lines. The pressure tap piping will be routed to a common manifold at a floor to be determined by Hydro’s Representative. One indicating pressure gauge reading from 0 to 1000 kPa and a pressure transducer will be provided on the manifold.

4.29.4 Winter-Kennedy Pressure Taps

A total of three pressure taps will be provided in the spiral case that terminate at a location adjacent to the inlet head pressure taps.

4.29.5 Discharge Ring Pressure Taps

A minimum of two pressure taps will be provided on the discharge ring to measure pressure and its fluctuations in the space between the runner band and discharge ring/bottom ring. The pressure taps will be located in one vertical plane at different elevations. The pressure tap piping will be routed to a common manifold located nearby the draft tube access doors. The manifold will be provided with one indicating vacuum-pressure gauge reading from -100 kPa to +500 kPa and a pressure transducer.

4.29.6 Draft Tube Pressure Measurements

(a) Pressure taps will be provided at Reference Section 2 to measure outlet pressure for the Turbine. On two units the number of the pressure taps and locations will be homologous to the Turbine Model. For the remaining four units there will be a minimum of two pressure taps per outlet installed mid height in the walls in a plane homologous to the Turbine Model. The pressure tap piping will be routed to a common manifold to a location nearby the draft tube access doors. The manifold will be provided with one indicating vacuum-pressure gauge reading from -100 kPa to +500 kPa and a pressure transducer. The Units that will have the fully homologous pressure taps will be determined by Hydro's Representative.

(b) Pressure taps will be provided on the draft tube elbow to measure pressure and pressure fluctuations. The pressure tap piping will be routed to a location nearby the draft tube access doors.

(c) Pressure taps will be provided on the draft tube cone to measure pressure and pressure fluctuations. The pressure tap piping will be routed to a common manifold to a location nearby the draft tube access doors. The manifold will be provided with one indicating vacuum-pressure gauge reading from -100 kPa to +500 kPa and a pressure transducer.

4.29.7 Headcover Pressure Taps

A minimum of four pressure taps will be provided on the headcover to measure pressure and pressure fluctuations in the space between the underside of the headcover and the runner crown and also on the outside of the upper runner seal. The pressure taps will be located on a single radial line at different radii. The headcover pressure tap piping will be routed to a common manifold located on the Turbine Pit wall adjacent to the shaft seal instrumentation. The manifold will have a pressure transducer and one indicating vacuum-pressure gauge reading from -100 kPa to +1000 kPa.

4.29.8 Wicket Gate Broken Shear Pin Indication

Each shear pin will be fitted with an electrically conductive breaking element (or Equivalent) which would indicate when and which shear pin has failed. Limit switches will not be provided as sensing devices. The breaking element will be maintenance free, require no adjustments, and operate reliably in a wet or oil soaked environment.

The connection between each shear pin and stationary parts will be highly flexible and robust, it will not interfere or rub on any other components, and will be routed so as to minimize bending.

Each breaking element will be rated for 24 and 125 Vdc operation, and will have each of its two terminals wired to the Turbine Pit Terminal Panel.

A red indicating LED for each breaking element will be provided in Turbine Pit Terminal Panel, and will be connected such that it will extinguish to indicate whenever a shear pin has failed. The LED indication will:

(a) use terminal blocks that include LED indication integral to their design; and

(b) be arranged and clearly labelled such that a Worker viewing the LEDs from a distance of 1 m can easily distinguish the status of each specific shear pin when the door of the Turbine Pit Terminal Panel is open.

A cable, provided and terminated by Others in the Turbine Pit Terminal Panel, will be used to connect each braking element to an external shear pin monitoring system provided by Others.

4.29.9 Servomotor Stroke Indication

A stainless steel or bronze scale will be attached to one Servomotor cylinder graduated in millimetres and in percentage of the Servomotor stroke and marked CLOSED at one end and OPEN at the other. A pointer will be attached to the Servomotor piston rod to indicate the stroke of the Servomotor. These marks will be clearly visible from where Workers may safely stand when the Unit is in operation.

4.29.10 Servomotor Differential Pressure Measurement

Each servomotor will have pressure gauges installed in a conveniently accessible location to measure the pressure on each side of the servomotor piston. Mechanical protection will be provided to prevent Workers from accidently damaging the pressure gauges when working in the Turbine Pit.

4.29.11 Shaft Seal Pressure Taps

The shaft seal housing will have pressure taps on the pressure side of the seal and for each seal chamber. These pressure tap piping will be routed to the manifold referred to in SPT 4.29.7.

4.29.12 Shaft Seal RTDs

The shaft seal will have multiple RTDs and a separate well for installation of each RTD, and will be designed for convenient removal.

4.29.13 Upper Runner Seal RTDs

Four RTDs will be installed in the headcover at the upper runner crown seals. The RTDs will be located in separate wells spaced 90° apart and will be designed for convenient removal.

All RTDs will be wired to Turbine Pit Terminal Panel.

4.29.14 Lower Runner Seal RTDs

Four RTDs will be installed in the bottom ring at the lower runner seals. The RTDs will be located in separate wells spaced 90° apart and will be designed for convenient removal.

All RTDs will be connected to the termination points to be determined by Hydro's Representative.

4.29.15 Lower Runner Seal Displacement Measurements

A provision will be made for installing four equally spaced displacement probes or vibration detectors to measure the lower runner seal horizontal displacement while the Unit is operating. The locations will be accessible from the lower wicket gate bushing access gallery. The vertical location will be selected to avoid being influenced by steps in the runner seal labyrinth if they are present. No permanent instrumentation or electrical conduit is required. The holes will be plugged with a sealed stainless steel plug or bolted on stainless steel cover.

4.29.16 Synchronous Condenser Water Level Measurements

Water level in the draft tube will be measured with a level transducer located adjacent to the draft tube access door. The water level signal will be transmitted to the Governor PLC via the Turbine Pit Terminal Panel.

4.30 Turbine Pit Terminal Panel

The Work includes a terminal panel (the "**Turbine Pit Terminal Panel**") in the Turbine Pit. The Turbine Pit Terminal Panel will:

(a) meet the requirements for Enclosures;

(b) except as otherwise expressly specified in Appendix 6-3 [Turbine Specifications (SPT)] or in Schedule 6 [Specifications and Drawings], be the final marshalling and termination point for all wiring and cabling located within the Turbine Pit;

(c) be recessed into the Turbine pit liner so that it does not need to be removed or altered to enable removal of the headcover, and so that it will not be damaged during headcover removal;

(d) have 30% extra space for future expansion;

(e) be supplied with hinged door(s), latches and handle; and

(f) have provision for cables, supplied and installed by Others, to enter it from either the side, back, or bottom.

Wiring and cabling within the Turbine Pit that will not be terminated in the Turbine Pit Terminal Panel includes:

(g) lighting and receptacle wiring for lights and receptacles affixed to the Turbine pit liner; and

(h) all cabling and wiring for lighting, receptacles, and equipment above 120 Vac or 125 Vdc.

4.31 Equipment Identification

4.31.1 Turbine Nameplate Placard

The information on the nameplate will include:

(a) type of runner;

(b) manufacturer's name;

(c) manufacturer's serial number;

(d) date of installation;

(e) rated and maximum Turbine power output at their respective net head;

(f) rated discharge;

(g) revolutions per minute;

(h) direction of rotation;

(i) the Unit number;

(j) BC Hydro purchase order number; and

(k) BC Hydro contract number.

4.32 Tooling and Lifting Devices

4.32.1 Tooling

The Work includes all tooling required to inspect or maintain any Turbine component. As a minimum the tooling will include:

(a) two sets of wicket gate servomotor stroke limiting devices sufficient for blocking of two Units as described in SPT 4.25.7(d);

(b) two draft tube platforms, total, for the entire facility as described in SPT 4.16;

(c) three guide bearing dismantling devices;

(d) three sets of: tools, fixtures, and lifting equipment necessary to remove and install a lower wicket gate bushing. The lifting equipment will be designed to allow lowering or raising of the wicket gate bushing housing by one person using an electric drive system or equivalent that synchronously raises or lowers the wicket gate bushing housing; and

(e) one device to bolt on to the bottom of the shaft, for mechanical protection, to facilitate rotating the shaft from horizontal to vertical and back.

4.32.2 Lifting Devices and Lifting Points

(a) General: The Work includes all Lifting Devices and Lifting Points required to lift any Turbine component.

(b) Miscellaneous Lifting Points: As a minimum, the following Turbine components will have designated Lifting Points:

- (i) seal rings (if applicable);
- (ii) bottom ring (if applicable);
- (iii) wicket gates;
- (iv) Turbine bearing pot components;
- (v) Turbine bearing pads (complete with brass plugs and jack screws as necessary);
- (vi) Turbine bearing support (complete with brass plugs and jack screws as necessary);
- (vii) Servomotors;
- (viii) operating ring; and
- (ix) wicket gate components (as applicable).

(c) Headcover Lifting Points: An adequate number of Lifting Points will be included to handle the headcover with the Powerhouse bridge crane and ensure clearance between the slings to the crane hook and the Turbine shaft flange when moving the headcover into place.

(d) Turbine Shaft and Runner Lifting Device: The Work will include one Turbine shaft and runner Lifting Device that:

(i) requires the use of only one Powerhouse crane main hoist;

(ii) is designed to lift the Turbine shaft with the Turbine runner still connected to the bottom of the shaft;

(iii) minimizes as much as possible the distance between the connection to the hoist and the connection to the Turbine shaft to thereby helping to limit the overall height of the Powerhouse superstructure;

(iv) is designed to connect to the Powerhouse crane main hoist using either a pin connection to a device bolted to the Turbine shaft flange or the Lifting Device may be designed to support the shaft from the underside of the flange; and

(v) if the Turbine shaft and runner Lifting Device cannot also be used to lift only the Turbine runner, then a second Lifting Device designed to lift the Turbine runner will be provided.

4.33 Draft Tube Temporary Closure

4.33.1 General

(a) The Work includes the Design, supply, install, and removal of four draft tube temporary closure devices to allow Turbine erection to be completed after water up of the tailrace. BC Hydro will make available to the Contractor the two sets of permanent draft tube gates which will allow for dewatering of two Units. The Contractor will provide the required temporary bulkheads for unwatering of the remaining four Units.

(b) The Work includes additional anchors, reinforcement, lifting equipment or any other temporary or permanent equipment required for the installation and removal of the temporary closure devices.

(c) Any anchors required in first stage concrete for the temporary closure will be provided. These anchors will be installed by Others under supervision of the Contractor.

(d) Not used.

(e) Upon removal of the draft tube temporary closure devices the Contractor will restore any damaged or modified permanent Work to as-new condition including providing provisions for grouting if voids behind the draft tube liner were created during the removal, weld removal and repairs, non-destructive testing of areas affected by temporary welds, protective coating, etc.

(f) Not used.

(g) The draft tube temporary closure devices will be designed for a tailwater level of 413.3 m.

(h) The allowable stresses for the permanent Work will also apply to the draft tube temporary closure devices.

(i) Any required draft tube temporary closure devices must be installed prior to the removal of the tailrace coffer dam.

(j) The draft tube temporary closure devices will be coated with a suitable primer prior to shipping. Other protective coatings are not required.

(k) All draft tube temporary closure devices are to be removed and disposed by the Contractor after completion of the Work.

4.33.2 Draft Tube Bulkhead

If a draft tube bulkhead is provided as a draft tube temporary closure device, it will be designed as follows:

(a) the draft tube liner will be designed to transfer all vertical loads from the bulkhead and draft tube liner into the concrete at the bottom of the liner. The load may be transferred directly to first stage concrete via vertical anchors attached to the bottom of the liner or transferred into second stage concrete via a thrust ring arrangement at the bottom of the liner;

(b) the draft tube liner and all associated embedded components will be designed to accommodate deflections of the liner resulting from the loads applied by the bulkhead on the liner, particularly the impact of vertical deflections on any vertical anchors, horizontal reinforcing ribs, lateral anchors, piping, etc., assuming all the surrounding concrete has been placed prior to the application of the load and does not deflect;

(c) the Work will take into consideration the effect of vertical or horizontal deflections, due to the bulkhead loading, on any non-embedded and removable parts connected to the draft tube liner during the assembly sequence, and the consequences when this temporary load is removed. In particular the draft tube liner, discharge ring, and bottom ring will be in proper alignment after the load has been removed; and

(d) if the Contractor requires a drain in the bottom of the bulkhead the drain may be connected to the specified gate leakage drain pipe in the draft tube liner. The drainage scheme will be submitted. If the Contractor does not provide a drain, the Contractor will be responsible for removing any water that collects in the bulkhead.

4.33.3 Not Used

SPT5 MANUFACTURING, INSPECTION AND TEST REQUIREMENTS

5.1 Stress Relief Heat Treatments

Shop stress relief heat treatments will be executed on components exposed to the upstream pressure and on large machined weldments. These include:

(a) stay ring;

(b) wicket gates;

(c) head cover;

(d) bottom ring;

(e) discharge ring;

(f) shaft;

(g) runner;

(h) operating ring; and

(i) all water passage doors.

Heat treatments will be executed in accordance with appropriate codes of ASME or ASTM.

5.2 Turbine Castings

5.2.1 General

The Contractor will submit Drawings showing the areas proposed to inspect on major castings. The proposed Procedure will be stated in terms of ASTM A609.

5.2.2 Inspection of Castings

All surfaces of the water passage component castings indicated below will be examined in accordance with CCH 70-3. The minimum acceptance criteria are as follows:

	Runner Crown and Band	Runner Blades	Other Water Passage Components
Ultrasonic Examination (UT)	UT 70-3 Class 2	UT 70-3 Class 1	UT 70-3 Class 2
Liquid Penetrant Examination (PT)	PT 70-3 Class 2	PT 70-3 Class 2	PT 70-3 Class 2
Magnetic Particle Examination (MT)[1]	MT 70-3 Class 2	MT 70-3 Class 1	MT 70-3 Class 2[2]

Notes:

(1) Magnetic particle examination will be conducted with a dc magnetizing current and a prod spacing of 150 mm.
(2) For critical locations, such as the fillet between the wicket gate stem and wicket gate body, MT 70-3 Class 1 will be used as the minimum acceptance criteria.

5.2.3 Inspection of Structural Welding of Runner Castings

All structural welding of the runner castings will be examined in accordance with CCH 70-3. The minimum acceptance criteria are as follows:

	Runner Welding
Ultrasonic Examination (UT)	UT 70-3 Class 1
Liquid Penetrant Examination (PT)	PT 70-3 Class 2
Magnetic Particle Examination (MT)[1]	MT 70-3 Class 1

Notes:

(1) Magnetic particle examination will be conducted with a dc magnetizing current and a prod spacing of 150 mm.

5.2.4 Defects

(a) Classification of “Major” excavations will be in accordance with GE5.1.2 of CCH 70-3.

(b) A casting with three or more Major excavations is not acceptable.

(c) A concentration of minor defects may be not acceptable, and will be submitted.

5.3 Shop Inspection and Tests

5.3.1 Prototype Turbine Homology

Appropriate shop measurements will be made to verify the homology and uniformity of critical Turbine water hydraulic surfaces and water passages by means of geometrical measurements for the runner(by component and assembled), wicket gates, and stay ring. The Contractor's ITP will clearly indicate the measurements to be made at the various stages of the Turbine manufacturing/assembly and also the main steps required to ensure compliance with the specified homology and uniformity requirements. The ITP will include reference Drawings showing the location, type and number of Turbine geometrical measurements and also forms for recording results of the measurements will be included with the Procedure.

5.3.2 Prototype Turbine Homology Schedule of Measurements

As a minimum, the following measurements for the prototype Turbine will be taken in the shop:

Stay vanes and shrouds	Complete profile of all vanes and both shrouds after machining of profile (if fabricated) and at completion of manufacturing.
Wicket gates	Complete profile of all gates after completion of all machining.
Runner blades, crown and band	Complete profile of all blades, crown and band after final machining using direct measurement methods (ref. SPT 4.6.3(a)).
Runner	Partial profile of blades using direct measurement methods (ref. SPT 4.6.3(a)) after setting up of at least four blades in crown and band. Measurements will be sufficient to verify correct position and location of blades.
	After complete assembly and post-weld heat treatment sufficient measurements to verify position and location of all blades. Measurements will include but not be limited to all measurements shown for the runner in Table 4.6.5, except for complete blade profile measurements.

5.3.3 Runner Modal Tests

The purpose of the runner modal tests is to experimentally identify and record the mode shapes and natural frequencies of the runner vibration for evaluating the runner design, for interpreting future vibration data taken during normal operation, and for demonstration that resonant conditions will not occur within required range of the Turbine Operating Conditions.

A modal test of the first manufactured runner will be performed in the shop with the runner in air and the results compared to the analysis performed in SPT 1.3.1(d) for the same situation. Any differences between the test and the analysis will be explained.

If, in the opinion of Hydro's Representative, a modal test of the runner in water also needs to be performed, then this test maybe conducted in the shop on the first manufactured runner, or at Site after the first Unit is fully assembled (likely during the runner strain gauge testing in SPT 7.4.2). Price adjustments runner modal tests in water in the shop or at site will be as shown in the Payment Schedule.

The results of modal testing of the runner, including frequencies and mode shapes, will be summarized and submitted in a test Report. This Report will include as a minimum the following information:

(a) description of instrumentation and techniques used for testing;

(b) discussion of differences between mounting conditions for the runner modal tests and for actual Turbine installation, and evaluation of possible effects of these differences on the runner natural frequencies and mode shapes;

(c) comparison of measured modal frequencies and mode shapes with frequencies and mode shapes predicted by the Contractor's numerical modal analysis as specified in SPT 1.3.1(d);

(d) evaluation of natural frequency shifts due to the added mass effect from submerged operation along with the correlation between the dry and wet tests;

(e) discussion of predominant excitation frequencies to be expected during operation of the Unit, and correlation of runner modal test results with these excitation frequencies; and

(f) results from the Contractor's previous experience in correlating experimental and analytic runner modal analyses in air and water with post-installation vibration behaviour of the Unit.

5.3.4 Servomotors

(a) Servomotors will be shop tested under a hydrostatic pressure equal to 150% of the maximum design pressure of the Governor system.

(b) The Servomotor piston bypass test will be performed in the shop at 100% design pressure for 2 hours on each side of the Servomotor piston while the opposite side is vented to atmosphere.

5.3.5 Wicket Gate Shear Pins

To establish the breaking strength of the shear pin and to demonstrate that the shear pin design will not allow distortion without fracturing, a shop break test will be carried out on at least six pins from each batch of raw material. A test Report with the complete results will be submitted.

5.3.6 Wicket Gate Friction Device

To establish the torque capacity of the friction devices and to demonstrate that the friction devices will operate as designed, a shop test will be carried out on at least six wicket gate friction devices. A test Report with the complete results will be submitted.

5.4 Shop Assemblies Before Shipment

5.4.1 Spiral Case and Stay Ring

For the first Unit, the spiral case plates will be formed and assembled with the stay ring, or with a simulated stay ring with the identical interface geometry including transition plates, in the shop so that the joint gaps between the adjacent plates before welding will not exceed 6 mm. Simultaneous assembly of all segments is not required.

All joints to be welded will be prepared, match-marked and fitted with braces and spiders required for Site assembly.

5.4.2 Tower Assembly

The Contractor will perform a tower assembly for the first Turbine. This assembly will have to include the main Turbine parts (bottom ring, headcover, wicket gates, wicket gate operating mechanism, main shaft seal components, and other related components) in an appropriate shop facility. The following minimum checks will be performed for the main parts assembly:

(a) concentricity of the headcover with bottom ring;

(b) contact of the wicket gates with gates in closed position but not forced closed;

(c) wicket gate clearances with the headcover face and bottom ring face;

(d) roundness of the wicket gate circle;

(e) wicket gate openings at 25%, 50%, 75% and 100% position;

(f) wicket gate seals;

(g) angular adjustment of the wicket gate eccentric pins when the gates are in closed position;

(h) headcover access; and

(i) maintainability of components within the headcover.

5.4.3 Draft Tube Liner, Turbine Pit Liner, and Pier Nose Cap

For the first Unit, the liner plates for the draft tube, Turbine Pit, and pier nose cap will be formed, fitted, and assembled in the Contractor's shop so that the joint gaps between adjacent plates before welding will not be more than 6 mm.

All joints to be Site welded will be prepared, match marked and fitted with braces and spiders required for Site assembly.

SPT6 SITE WORK

6.1 Site Measurements

6.1.1 Clearances, Dimensions, Runout and Shaft Verticality Measurements

The measurements to be taken and recorded by the Contractor for the Equipment during installation will include but not be limited to the following:

Item	No. of Readings
Clearance - turbine bearing journal to bearing support	8
Clearance - turbine bearing journal to every pad, top and bottom	All pads
Clearance - upper runner seal	8
Clearance - lower runner seal	8
Clearance - headcover inner seals if applicable	4
Runout check (number of points at each location) includes measurements at all bearings, seals, airhead if applicable	4

Item	No. of Readings
Shaft verticality check - 4 wires, 2 elevations (Single wire may be acceptable. An electronic level maybe used to supplement plumb wires.)	At least 2 rotations
Clearances - wicket gate top and bottom ends as well as vertical contact lines	All wicket gates
Vertical distance - bottom ring wear plate to headcover wear plate	All wicket gates
Vertical distance - bottom ring flange to headcover flange in stay ring. Measurements to start at U/S centre line and to be taken every 15°	24
Elevations: Distributor centreline, runner, spiral case inlet, shaft coupling	As required to get a representative measurement
Diameters: Flexible coupling, closure section, penstock spool piece, all spiral case sections, discharge ring, draft tube at each transition	8
Levels: Stay ring/Headcover Flanges, bottom ring	All wicket gates
Levels: Servomotors	Each
Levels: Guide bearing support	8

6.2 Flexible Coupling Pressure Testing

The flexible coupling will be pressure tested by the Contractor at the Site. In such a test the coupling seals will be tested at a pressure of at least 130% of the Spiral Case Design Pressure. The test pressure will be maintained for a minimum of 1 hour after all leaks in the coupling have been eliminated. For testing purposes, the flexible coupling may be installed in its entirety over one of the pipe sections. Internal braces will be used as necessary to maintain shape of pipe sections.

6.3 Spiral Case Hydrostatic Tests and Concrete Embedment

After complete assembly at the Site of the spiral case and stay ring, and with the test bulkheads at the case inlet and in the stay ring in place, but before being embedded in concrete, the Unit assembly will be subjected to a hydrostatic test at a pressure of at least 130% of the Spiral Case Design Pressure. The test pressure will be maintained for a minimum of 1 hour after all leaks in the spiral case and stay ring have been eliminated. During the test, micrometer-measurements will be taken to indicate the movement of the machined flanges of the stay ring.

The tests will be carried out by Others under the direction of Hydro’s Representative and under the supervision of the Contractor’s Supervisor. All test equipment will be supplied by Others.

During embedment of the spiral case in concrete, the internal water pressure will be not less than 50% or more than 70% of the Spiral Case Design Pressure and water will be circulated by Others at this pressure to control the temperature rise.

Upon completion of the concrete embedment curing the water will be drained by Others including the removal of any sediment that may have been introduced. Final cleaning prior to sand blasting and painting will be the Contractor’s responsibility.

Although the sections of the spiral case can be painted in the shop, there is a high likelihood that the paint will be damaged during the Installation Work. Depending on the degree of paint damage, as determined by Hydro’s Representative, spot repairs or another coat of paint may be required. If another coat of paint is required, then the entire area to be recoated will have to be cleaned in accordance with SSPC SP1, any exposed substrate abrasive blasted in accordance with SSPC SP10 and the remaining intact paint abrasive sweep blasted if the shop applied paint has passed its over-coating window. The Contractor will allow for the application of two coats of paint, one in the shop and one at the Site.

6.4 Wicket Gate Locking Device Test

After the wicket gate operating mechanism has been completely assembled, all wicket gate locks, both manual and automatic, for both fully open and fully closed wicket gate positions, will also be installed and tested with the Servomotors pressurized to 150% of the design pressure. The wicket gate locking device test can coincide with the Governor piping pressure test.

SPT7 SITE TESTING

7.1 Turbine Tests by BC Hydro

7.1.1 Turbine Efficiency Test

Turbine site tests will be carried out by BC Hydro on one or more Turbines after a Unit has been placed into Commercial Operation to determine the prototype Turbine efficiency.

7.2 Other Turbine Tests by BC Hydro

The tests as specified herein may be performed by BC Hydro. All test instruments and data acquisition equipment would be supplied by BC Hydro. The Contractor will make provision in the test schedule for these tests to be performed at no additional cost to BC Hydro:

(a) Wicket Gate Leakage Test: Wicket gate leakage will be calculated by measuring the change in water level in the intake gate shaft, with the intake gate closed and the wicket gates closed with 100% nominal oil pressure. Leakage past the intake gate will be neglected for the calculation.

The gross head to be used for the calculation will be the average value for the measurement period. If the wicket gate leakage measurement is carried out at a gross head that deviates from the reference gross head indicated in Table 3.3.3 then the measured leakage will be adjusted by the following formula:

$$L = LM \times \sqrt{Href / H}$$

Where:

L = the corrected leakage amount, calculated for Href;

LM = the measured leakage;

Href = 51.2 metres; and

H = the average gross head during the leakage measurement.

The wicket gate leakage will not exceed the value stated in the Turbine TDIF.

7.3 Turbine Inspection and Testing After Commercial Operation

Upon completion of the Work BC Hydro may, at its own expense, perform any or all of the following inspections or any other deemed relevant by BC Hydro. The purpose of these tests and inspections is for a thorough evaluation of all Work. During the warranty period the Contractor may participate, at its own expense, in the inspections and witness the testing. If the Contractor requires the following additional inspections these will be at the Contractor's expense:

(a) an inspection to determine if there is signs of cracking or cavitation on the runner, stay vanes, wicket gates, spiral case, draft cone tube liner, draft tube or pier nose caps;

(b) an inspection of the wicket gate linkages, Servomotors, and operating ring for signs of misalignment, excessive wear, binding, etc.; and

(c) an inspection of the cooling water and oil piping for signs of leaks.

7.4 Strain Gauge Testing

7.4.1 General

A strain gauge testing is required in order to validate the runner design and demonstrate its robustness and reliability.

BC Hydro may request the test to be repeated at the Contractor's cost if the quality of the testing is unsatisfactory.

7.4.2 Runner Strain Gauge Tests

Strain gauge tests on the runner of one Turbine will be made to confirm that runner stresses, both static and dynamic stress components, are within the allowable limits. The Contractor will carry out the runner strain gauge tests on a Unit to be determined by BC Hydro, as detailed below to determine the runner stresses and confirm that allowable stresses specified in Appendix 6-2 [General Technical Specifications (SPGT)] are not exceeded. These tests will be carried out at a time established by Hydro's Representative, after the Unit has been placed into commercial operation.

The runner strain gauge test Procedure will be submitted and will cover the location of the runner strain measurements, range of operating conditions to be tested, the number and type of strain gauges used for measurements, and instrumentation to be used during the tests. The operating conditions to be tested will include both steady state and transient conditions (Unit start up, load rejection from different gate positions, etc.).

A Report summarizing results of the runner strain gauge tests will be submitted and will include:

(a) real time signals of measured strain and calculation of stress levels for all measurement locations and operating conditions;

(b) spectral analysis of the strain signals;

(c) discussion of the strain/stress predominant frequencies and correlation with the external excitation frequencies;

(d) if due to any physical limitations, the measurements could not be obtained at the most critical locations with the highest level of static or dynamic stresses or the highest stress concentration, calculation of the stress transposition factors for the above critical locations will be included;

(e) evaluation of the maximum static stresses and the maximum peak to peak amplitudes of dynamic stresses;

(f) correlation with theoretically predicted static and dynamic stresses. If the results are, in the opinion of Hydro's Representative, significantly different from the original design calculations, the Contractor will produce, and submit a Report containing, as a minimum, a rationale for the differences, a clear statement as to which result in the Contractor's opinion is a more accurate representation, and a proposal to repeat either/or both the calculations and the testing to correct for the discrepancy. The costs for any additional work will be the Contractor's sole responsibility; and

(g) in the case of an insignificant discrepancy between the calculations and the results of the testing, the more conservative result will be considered for the evaluation of the design, and the runner design calculation Report will be updated and submitted if applicable.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-4

GOVERNOR SYSTEM SPECIFICATIONS (SPGOV)

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-4

GOVERNOR SYSTEM SPECIFICATIONS (SPGOV)

SPGOV1 GENERAL

1.1 Definitions

In this Appendix 6-4 [Governor System Specifications (SPGOV)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Auto-Mode**" has the meaning set out in SPGOV 3.2(a)(i);

"**Deadtime**" has the meaning set out in SPGOV 2.4;

"**Droop**" has the meaning set out in SPGOV 2.2(c)(ii);

"**Gate Limit Setpoint**" has the meaning set out in SPGOV 3.3(a);

"**Gate Position Error**" has the meaning set out in SPGOV 2.2(b)(i);

"**Gate Position Setpoint**" or "**Gate Setpoint**" has the meaning set out in SPGOV 2.1(b);

"**Gate Position Switch**" has the meaning set out in SPGOV 4.6;

"**Generate Mode**" has the meaning set out in SPGOV 3.2(d)(i);

"**Generator VT Speed Sensing System**" has the meaning set out in SPGOV 4.2.1;

"**Governor Configuration Software**" has the meaning set out in SPGOV 3.13.2;

"**Governor Control Cabinet**" or "**GCC**" has the meaning set out in SPGOV 5.2;

"**Governor Design Pressure**" has the meaning set out in SPGOV 6.1.2;

"**Governor Hardwired Controls**" has the meaning set out in SPGOV 5.2.4;

"**Governor HPU**" has the meaning set out in SPGOV 6.1.1;

"**Governor PLC**" has the meaning set out in SPGOV 5.2.2;

"**Governor Setpoint**" has the meaning set out in SPGOV 3.4;

"**Governor Shutdown Solenoid**" has the meaning set out in SPGOV 6.10;

"**Governor Software**" has the meaning set out in SPGOV 3.13.1;

"**Governor Speed Switch**" has the meaning set out in SPGOV 4.5;

"**Governor System**" or "**Governor**" has the meaning set out in SPGOV 1.2;

"**Governor System Data Table**" has the meaning set out in SPGOV 3.13.4;

“**Isolated Load Mode**” has the meaning set out in SPGOV 3.2(c)(iii);

“**Isolated Load Settings**” has the meaning set out in SPGOV 3.2(c)(iii)(B);

“**Isolation Detector**” has the meaning set out in SPGOV 4.8;

“**Manual Mode**” has the meaning set out in SPGOV 3.2(a)(ii);

“**Maximum Offline Wicket Gate Limit**” has the meaning set out in SPGOV 3.3(d)(iv);

“**Maximum Online Wicket Gate Limit**” has the meaning set out in SPGOV 3.3(d)(v);

“**Measured Gate Position**” has the meaning set out in SPGOV 4.4;

“**Measured Running Bus Frequency**” has the meaning set out in SPGOV 4.2.3;

“**Measured Unit Power**” has the meaning set out in SPGOV 4.7;

“**Measured Unit Speed**” has the meaning set out in SPGOV 4.2.4;

“**Offline Mode**” has the meaning set out in SPGOV 3.2(c)(i);

“**Offline Settings**” has the meaning set out in SPGOV 3.2(c)(i)(B);

“**Online Mode**” has the meaning set out in SPGOV 3.2(c)(ii);

“**Online Settings**” has the meaning set out in SPGOV 3.2(c)(ii)(B);

“**PD Transfer Function**” has the meaning set out in SPGOV 2.2(b);

“**Permanent Speed Droop**” has the meaning set out in SPGOV 2.2(c);

“**PID Transfer Function**” has the meaning set out in SPGOV 2.2(a);

“**Power Droop**” or “**Speed Regulation**” has the meaning set out in SPGOV 3.2(b)(i);

“**Power Error**” has the meaning set out in SPGOV 2.2(c)(i);

“**Power Setpoint**” has the meaning set out in SPGOV 2.1(c);

“**Running Bus VT Speed Sensing System**” has the meaning set out in SPGOV 4.2.3;

“**Setpoint Feedforward**” has the meaning set out in SPGOV 2.2(d);

“**Soft Start Stages**” has the meaning set out in SPGOV 3.6.2(b);

“**Speed Deadband**” has the meaning set out in SPGOV 2.4;

“**Speed Error**” has the meaning set out in SPGOV 2.2(a)(i);

“**Speed Setpoint**” or “**Speed Reference**” has the meaning set out in SPGOV 2.1(a);

“**Synchronous Condense Mode**” has the meaning set out in SPGOV 3.2(d)(ii);

“**Wicket Gate Droop**” has the meaning set out in SPGOV 3.2(b)(ii); and

"**ZVPU Probe**" has the meaning set out in SPGOV 4.2.2(a).

In addition to the above, words and phrases used in this Appendix 6-4 [Governor System Specifications (SPGOV)] which are not defined elsewhere in this Agreement but which are defined in Section 3 (Definitions) of IEEE125 will have the meanings assigned to them such Section 3 (Definitions).

1.2 Scope of Work

The Contractor will provide a Turbine governor system (the "**Governor System**" or "**Governor**") with each Unit, designed to achieve control of Turbine speed and power via hydraulic actuation of wicket gate servomotors. The Governor System will be of the electro-hydraulic type, and include:

(a) a Governor Control Cabinet;

(b) instrumentation systems, including:

  (i) Turbine speed sensing systems;

  (ii) Turbine wicket gate and distributing valve position sensing systems; and

  (iii) pressure, level, and temperature sensing systems;

(c) a hydraulic power unit and accumulator;

(d) Governor compressed air system;

(e) all necessary interconnections between the components listed above and to other Equipment; and

(f) all other parts and materials necessary to achieve functionality outlined in the requirements of Schedule 6 [Specifications and Drawings].

1.3 Submittals

In addition to the requirements of Appendix 6-1 [General Specifications (SPGS)] the following will be submitted:

(a) Calculation Reports to include sizing of all mechanical components of the HPU;

(b) Calculation Reports to include all requirements of SPGOV 2.6;

(c) Calculation Reports to include Governor models and data in PTI PSS/e format as required for system studies by Others;

(d) Calculation Reports to include results of computer model simulation studies conducted by the Contractor pursuant to section 6.1.3 and 6.1.4 of IEEE 125;

(e) Governor Software Design Plan;

(f) Governor Software at 30%, 70% and 90% Design intervals in native file format and as a [.pdf];

(g) final Governor Software in native file format and as a [.pdf]; and

(h) Block Diagrams of the Governor System that include:

(i) illustration of all AC and DC circuits, protection devices/modules, control devices/modules, isolation points, data communications links, and interconnections; and,

(ii) a representation of the dynamic relationship between Turbine speed and wicket gate servo positions, in Laplace transform notation, and including details of all significant non-linearities in the electrical and hydraulic equipment.

SPGOV2 GOVERNOR SYSTEM PERFORMANCE REQUIREMENTS

2.1 Control Algorithm

The Governor System will include a programmable closed-loop control algorithm intended to achieve accurate and stable control of the Turbine, as appropriate for the specific operating mode that the Governor System may be in, and according to the following control setpoints:

(a) the Unit speed setpoint (the "**Speed Setpoint**" or "**Speed Reference**") is the desired speed of the Unit;

(b) the Unit wicket gate position setpoint (the "**Gate Position Setpoint**" or "**Gate Setpoint**") is the desired position of the Turbine wicket gates; and

(c) the Unit power setpoint (the "**Power Setpoint**") is the desired real power output of the Unit.

2.2 Control Algorithm Elements

The Governor System programmable closed-loop control algorithm will be based on the following elements:

(a) a three-element PID (proportional, integral, derivative) transfer function (the "**PID Transfer Function**"), that includes:

(i) a summing junction that determines the difference (the "**Speed Error**") between its two inputs, Speed Setpoint and Measured Unit Speed;

(ii) proportional and integral functions that each utilize Speed Error as an input;

(iii) a derivative function that allows either Speed Error or Measured Speed to be selected as the input; and

(iv) a summing junction that adds output signals from the proportional, integral, and derivative elements to produce a Gate Position Setpoint signal as its output;

(b) a two-element PD (proportional, derivative) transfer function (the "**PD Transfer Function**"), connected in series with the PID Transfer Function, that includes:

(i) a summing junction that determines the difference (the "**Gate Position Error**") between its two inputs, Gate Position Setpoint and Measured Gate Position;

(ii) a proportional function that utilizes Gate Position Error as its input;

(iii) a derivative function that allows either Gate Position Error or Measured Gate Position to be selected as the input; and

(iv) a summing junction that adds output signals from the proportional and derivative functions to produce a wicket gate control command signal as its output;

(c) permanent speed droop functionality ("**Permanent Speed Droop**"), that allows the Unit to share power system load changes in proportion to its rated output, and that:

(i) includes a summing junction that determines the difference (the "**Power Error**") between its two inputs, Power Setpoint and Measured Unit Power;

(ii) includes a droop gain (the "**Droop**") that allows either Power Error or Gate Position Error to be selected as the input (the droop feedback parameter), and has its output connected to modify (i.e., sum with) the Speed Setpoint; and

(iii) causes the Unit to perform linearly, such that the change in Unit speed will be the same for equal changes of the feedback parameter (Power Error or Gate Position Error).

(d) a method of compensation ("**Setpoint Feedforward**"), intended to achieve a faster Governor System response to a change in Power Setpoint. Setpoint Feedforward functionality will include application of compensation for the nonlinear wicket gate versus power characteristic of the Turbine at rated NSHE. For information and reference and without limiting this requirement, one possible method of providing Setpoint Feedforward functionality is described here for reference:

(i) the Power Setpoint is converted to the estimated Gate Position Setpoint using a programmable quadratic equation. When the Governor is operating in Wicket Gate Droop mode the quadratic equation will be replaced with a unity gain;

(ii) the estimated wicket gate setpoint is fed forward through a first-order lag function that:

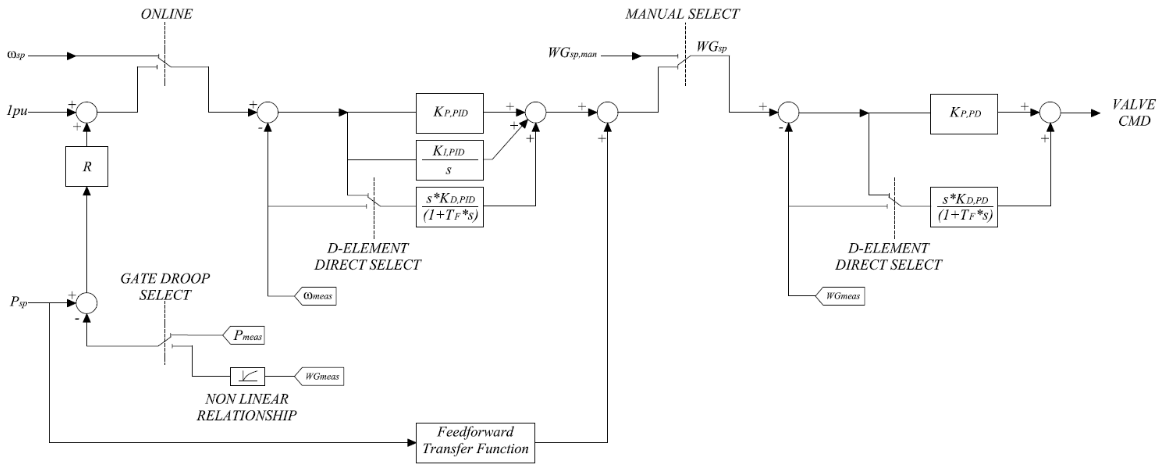
(A) includes a rate limit, expressed as a percentage of the maximum range of the input, that is on-line tunable from 0.1% per second to 100% per second, in steps of 0.1% or less;

(B) includes a first-order lag time constant (i.e., the time required for the output to reach 63% of its final steady state value in response to a step input), that is on-line tunable from 0 to 50 seconds in steps of 0.1 seconds or less; and

(C) includes a validation check of settings assigned to the rate limit and first-order lag time constant, to flag when the combination of selected settings may inhibit functionality; and

(iii) the output of the first-order lag function is used to modify (i.e., sum with) the Gate Position Setpoint.

The illustration below provides an overview of an implementation of the control algorithm described above:



2.3 <u>Stability</u>

The Governor System will be capable of controlling and regulating the Turbine speed, wicket gate position, and power, with an adequate margin of stability (as outlined below), under each of the following conditions, or any combination of these conditions:

(a) during isolated operation (connected to a load, with few or no other generating units operating in parallel with it);

(b) during offline operation, including Unit startup and synchronization;

(c) during Unit shutdown (including normal and protection-initiated shutdown sequences);

(d) any Unit power output over the full range of Unit power outputs from zero to Maximum Unit Output; and

(e) during transient conditions including generation ramping, load shedding, load rejection, or power system disturbances.

The Governor System will meet the following minimum stability requirements:

(f) <u>Sustained Conditions</u>:

(i) *Steady-State Governing Speed Band (speed stability index)*: The magnitude of the envelope of the steady state speed oscillation caused by the Governor System will not exceed 0.1% of rated speed when:

(A) when the Unit is offline (speed-no-load condition);

(B) when the Unit is online, at rated speed, connected to a constant isolated load with Droop set at 5%.

(ii) *Steady-State Governing Load Band (power stability index)*: The magnitude of the envelope of the steady-state Unit output power oscillation caused by the Governor System will not exceed 0.2% of the Maximum Unit Output when:

(A) the Unit is operating online, with a constant power setpoint, in parallel with many other units in an integrated multi-plant power system, with the Droop set at 5%, and excluding operation in any designated Turbine rough load zones;

(B) the Unit is operating online, with a constant wicket gate setpoint, in parallel with many other units in an integrated multi-plant power system, with the Droop set at 5%, and excluding operation in any designated Turbine rough load zones.

(g) <u>Load Rejection</u>: Subsequent to rejection of any Unit load (up to and including the Maximum Unit Output), the Governor System will act to restore the Unit speed to the nominal speed reference, as may be modified by the Speed Regulation setting, without exceeding:

(i) the Spiral Case Design Pressure specified in Appendix 6-3 [Turbine Specifications (SPT)];

(ii) one Unit underspeed deviation (of 5% or less of rated speed); and

(iii) one Unit overspeed deviation (of 2% or less of rated speed) subsequent to the initial Unit overspeed and underspeed deviation.

(h) <u>Speed control during fluctuating isolated load operation</u>: With the Unit operating connected to an isolated resistive load of 90% of the Maximum Unit Output, and with hydraulic head anywhere between +/-10% of rated head, the Governor System will be capable of providing damped control of Turbine speed that:

(i) when the Unit is subjected to a sudden load change of +5% of Maximum Unit Output, achieves attenuation of the peak amplitude of the second Turbine underspeed deviation to at least 25% that of the first; and

(ii) when the Unit is subjected to a sudden load change of -5% of Maximum Unit Output, achieves attenuation of the peak amplitude of the second Turbine overspeed deviation to at least 25% that of the first.

The Contractor will perform stability studies in accordance with Sections 6.1.3 and 6.1.4 of IEEE 125.

2.4 <u>Speed Deadband and Deadtime</u>

The Governor speed deadband (the "**Speed Deadband**") is the maximum change in steady-state Unit speed, expressed as a percentage of rated speed, and with Droop set to zero, required to reverse the direction of travel of the wicket gate servomotors. The Speed Deadband at rated speed will not exceed 0.02% of rated speed at any wicket gate position. One half of the Speed Deadband is the Governor speed insensitivity.

The Governor deadtime (or "**Deadtime**") is the elapsed time between a change in Unit speed and the onset of wicket gate servomotor movement as a result of corrective action by the Governor System. The Governor System will function such that the Deadtime does not exceed 0.2 s for a Speed Setpoint change of 0.1 Hz or larger.

2.5 Select Before Operate Control

Except where otherwise explicitly stated in this Appendix 6-4 [Governor System Specifications (SPGOV)], control commands issued to the Governor System by a Worker using the Governor HMI will be issued via a two-step select-before-operate (SBO) process (intended to cause deliberate operator action and reduce the possibility of operator error), whereby:

(a) Step 1: the Worker issues a command to select the control point to be acted upon, this selection is latched in by the Governor System, and indication of the latched-in selection is sent back to the Governor HMI as a permissive for the control command; and then

(b) Step 2: the Worker either:

(i) issues a “close/on/raise” command to send an assertion or increase command associated with the selected control point, or an “open/off/lower” command to send a de-assertion or decrease command associated with the selected control point; or

(ii) issues a one-step reset command, which un-latches and de-selects the currently selected control point.

The Governor System will not accept control commands from the Governor HMI if no control point is selected.

Commands that will not follow the SBO procedure include:

(c) commands from protective devices (either within or external to the Governor System) to shut down the Governor System;

(d) commands from emergency stop pushbuttons (either within or external to the Governor System) to shut down the Governor System; and

(e) the local/remote transfer switch included as part of the Governor Hardwired Controls.

2.6 Seismic Withstand

The completely assembled and installed Governor System will meet the high-performance level as defined in the IEEE 693. The Contractor will:

(a) employ a qualified seismic specialist to perform the work described in SPGOV 2.6;

(b) demonstrate the seismic withstand capability of the completely assembled and installed Governor System, through analysis and/or test in accordance with IEEE 693;

(c) utilize Annex A of IEEE 693 as general requirements for seismic qualification procedures for the Governor System (taking particular note of the equipment anchorage requirements);

(d) utilize Annex M of IEEE 693 as specific requirements for seismic qualification procedures for the Governor Control Cabinet;

(e) utilize Annex B of IEEE 693 as specific requirements for seismic qualification procedures for Governor System components other than the Governor Control Cabinet;

(f) prepare a seismic outline Drawing of the Governor System, including details of seismic bracing and anchoring, as well as a table showing all of the forces to be transferred at each anchor location; and

(g) prepare a seismic analysis qualification Report and/or a seismic test qualification Report, including seismic Calculations performed, signed by the Contractor's seismic specialist, and demonstrating that the Governor System complies with the high-performance level as defined in IEEE 693.

SPGOV3 GOVERNOR SYSTEM FUNCTIONAL REQUIREMENTS

3.1 Governor System Local/Remote Control Transfer

The Governor System will include functionality to operate in and transfer between local and remote control modes. In remote control mode, the Governor System will only accept control commands from devices external to the Governor System. In local control mode, the Governor System will only accept control commands from the Governor HMI (except for emergency stop commands from external protective devices).

3.2 Governor System Control Modes

(a) Auto and Manual Modes: The Governor System will include automatic and manual control modes as follows, as well as capability to transfer between them depending on whether the Governor System is in local or remote control mode:

(i) *Automatic Mode*: "**Auto Mode**" will be provided as the default and normal operating mode for the Governor System (i.e., when Manual Mode is not selected) and provide automated control of the Turbine.

(ii) *Manual Mode*: "**Manual Mode**" will be provided to allow specialized testing of the Governor System and Unit. Transfer to Manual Mode will only be allowed when the Governor System is in local control mode. If the Governor is transferred from local control mode to remote control mode while in Manual Mode, it will immediately and automatically transfer to Auto Mode. Manual Mode will include the following functionality:

(A) Automated servomotor timing test functionality for testing the opening and closing times will be provided, and will:

(I) include permissive interlocks that only allow testing to be conducted when the Unit is offline and after a password has been entered by a Worker;

(II) include capability to control the wicket gates from the Governor HMI;

(III) override all other control modes;

(IV) include a Governor HMI menu option for testing opening times, which, when selected by a Worker, will cause the servomotors to open from 0% to 100% of stroke, at the maximum rate allowed by the main distributing valve, and then display, on the Governor HMI, the resulting servomotor times for full travel from 0 to 100% and for half travel from 25% to 75%, accurate to the nearest tenth of a second;

(V) include a Governor HMI menu option for testing closing times, which, when selected by a Worker, will cause the servomotors to close from 100% to 0% of stroke, at the maximum rate allowed by the main distributing valve, and then display, on the Governor HMI, the resulting servomotor times for full travel from 100% to 0% and for half travel from 75% to 25%, accurate to the nearest tenth of a second;

(VI) include an explanation of the test Procedure and proper safety precautions (which will be supplied by BC Hydro), displayed on the Governor HMI.

(B) Distributing valve configuration functionality will be provided, including the ability to tune the valve's response, and adjust the valve dither and bias.

(C) Other manual testing functions recommended by the Contractor.

(b) Power Droop and Wicket Gate Droop Modes: The Governor System will include Power Droop and Wicket Gate Droop control modes as follows, as well as capability to transfer between them independent of whether the Governor System is in local or remote control mode (note that IEEE Annex C illustrates a method for implementing logic to transfer between Power Droop and Wicket Gate Droop modes):

(i) *Power Droop Mode*: "**Power Droop**" or "**Speed Regulation**" mode will:

(A) refer to operating conditions where the Governor System is configured to use Power Error as the feedback parameter to the Permanent Speed Droop function, causing the Governor System to regulate Unit real power output to the Power Setpoint;

(B) be the normal/default operating mode;

(C) automatically detect when the Governor MW transducer output becomes unavailable or is determined to be faulty, and cause the Governor System to automatically change to Wicket Gate Droop mode; and

(D) cause the Governor System to continually adjust the Gate Position Setpoint such that it tracks the Power Setpoint in a manner that, upon a Governor System transfer to Wicket Gate Droop mode, would not introduce a signal disturbance into the summing junction that determines Speed Error.

(ii) *Wicket Gate Droop Mode*: "**Wicket Gate Droop**" mode will:

(A) refer to operating conditions where the Governor System is configured to use Gate Position Error as the feedback parameter to the Permanent Speed Droop function, causing the Governor System to regulate Unit wicket gate position to the Gate Position Setpoint; and

(B) cause the Governor System to continually adjust the Power Setpoint such that it tracks the Gate Position Setpoint in a manner that, upon a Governor System transfer to Power Droop mode, would not introduce a signal disturbance into the summing junction that determines Speed Error.

(c) Offline Mode, Online Mode, and Isolated Load Mode: The Governor System will include an Offline Mode, Online Mode, and an Isolated Load Mode, as well as capability to transfer between them, as follows:

(i) *Offline Mode*: "**Offline Mode**" will:

(A) refer to conditions where the Unit circuit breaker is open;

(B) include a dedicated set of PID Transfer Function and Droop settings (the "**Offline Settings**") that are made to be the settings used by the Governor System when in Offline Mode; and

(C) include logic to transfer to Online Mode when the Unit circuit breaker closes.

(ii) *Online Mode*: "**Online Mode**" will:

(A) refer to conditions where the Unit circuit breaker is closed and the Unit is not operating in Isolated Load Mode (as determined by the Isolation Detector):

(B) include a dedicated set of PID Transfer Function and Droop settings (the "**Online Settings**") that are made to be the settings used by the Governor System when in Online Mode;

(C) cause the Governor System to transfer to Offline Mode when the Unit circuit breaker opens; and

(D) cause the Governor System to transfer to Isolated Load Mode when the Isolation Detector operates.

(iii) *Isolated Load Mode*: "**Isolated Load Mode**" will:

(A) refer to conditions where the Unit circuit breaker is closed and the Isolation Detector has operated;

(B) include a dedicated set of PID Transfer Function and Droop settings (the "**Isolated Load Settings**") that are made to be the settings used by the Governor System when in Isolated Load Mode;

(C) disable Setpoint Feedforward functionality;

(D) cause the Governor System to transfer to Isolated Load Mode when the Isolation Detector operates; and

(E) cause the Governor System to transfer to Online Mode when the Isolation Detector resets.

(d) <u>Generate and Synchronous Condense Modes</u>: The Governor System will include Generate and Synchronous Condense control modes as follows, as well as capability to transfer between them, depending whether the Governor System is in local or remote control mode:

(i) *Generate Mode*: "**Generate Mode**" will:

(A) refer to operating conditions where the Governor System is in either local or remote control mode, has not accepted a command to transfer to Synchronous Condense Mode, and is controlling the Turbine in either Power Droop or Wicket Gate Droop mode in order to generate power;

(B) be the normal/default operating mode;

(C) only allow transfer to Synchronous Condense Mode when the Governor System is in remote control mode; and

(D) upon accepting a command (from a device external to the Governor System and provided by Others) to transfer the Unit to Synchronous Condense Mode, cause the Governor System to close the wicket gates, provide cooling water to the runner seals, and operate the Turbine air depression system to depress the water level in the draft tube.

(ii) *Synchronous Condense Mode*: "**Synchronous Condense Mode**" will:

(A) refer to operating conditions where the Governor System is in remote control mode, has accepted a command (from a device external to the Governor System and provided by Others) to transfer from Generate Mode to Synchronous Condense Mode, and is controlling the Turbine, including the runner seal cooling water valve, and Turbine air depression system, to allow the Generator to operate as a synchronous condenser with minimized motoring power;

(B) only be possible when the Governor System is in remote control mode;

(C) in the event that the Governor System is transferred from remote to local control mode, cause the Governor System to automatically transfer to Generate Mode;

(D) upon accepting a command (from an external device provided by Others) to transfer the Unit from Synchronous Condense Mode to Generate Mode, cause the Governor System to exhaust the air out of the draft tube, open the wicket gates, and close the runner seal cooling water valve; and

(E) upon receiving a stop command (normal shutdown or protection initiated), cause the Governor System to exhaust the air out of the draft tube via the exhaust valve, close the runner seal cooling water valve, and perform automatic stop control.

3.3 Wicket Gate Limit Functionality

The Governor System will include wicket gate limit functionality that:

(a) overrides all other functionality within the Governor System to limit the opening of the Turbine wicket gates to any Worker-Adjustable position (the "**Gate Limit Setpoint**") within the full range of wicket gate travel, in steps of 0.1% or less;

(b) allows a local Worker to manually adjust the Wicket Gate Limit via raise/lower buttons provided on the Governor HMI;

(c) allows a remote Worker to adjust the Wicket Gate Limit via raise/lower hardwired inputs (provided by Others) to the Governor System; and

(d) includes settings as follows:

(i) A shutdown setting, which the Governor PLC will automatically set the Wicket Gate Limit to when the Governor System has accepted a shutdown command.

(ii) A Software-Adjustable offline Gate Limit Setpoint target, to which the Governor System automatically ramps the Gate Limit Setpoint when the Unit transitions to running offline.

(iii) A Software-Adjustable online Gate Limit Setpoint target, to which the Governor System automatically ramps the Gate Limit Setpoint when the Unit transitions to running online.

(iv) A Software-Adjustable maximum offline setting (the "**Maximum Offline Wicket Gate Limit**"), intended to prevent a Worker from adjusting the Gate Limit Setpoint to a point that would cause the Unit to go significantly above 100% speed when the Unit circuit breaker is open. The Maximum Offline Wicket Gate Limit will be adjustable, in steps of 0.1% or less.

(v) A Worker-Adjustable maximum online setting (the "**Maximum Online Wicket Gate Limit**"), intended to allow a Worker to change the maximum Gate Limit Setpoint allowed when the Unit is operating online with operating restrictions in effect. The Maximum Online Wicket Gate Limit will be adjustable in steps of 0.1% or less.

(vi) A Gate Limit Setpoint ramp rate that is Software-Adjustable, in steps of no greater than 0.01%/s.

When the Wicket Gate Limit function is in control of the Turbine (i.e., is calling for a lower wicket gate position than the PID Transfer Function output), the Power Setpoint will track the Measured Unit Power, in order to ensure bumpless transfer in the event a Worker raises the Wicket Gate Limit to a setting that causes control of the Turbine to be passed back to the PID Transfer Function. Other suitable techniques will be employed to avoid undesirable integrator wind-up or wind-down conditions.

3.4 Governor Setpoints

The Governor System will include the following setpoints (each a "**Governor Setpoint**") within the Governor PLC:

(a) Speed Setpoint;

(b) Power Setpoint;

(c) Gate Position Setpoint, and

(d) Gate Limit Setpoint.

Governor Setpoints will be Worker-Adjustable and will be modified by the Governor System according to:

(e) raise/lower adjustment commands accepted by the Governor PLC (by raising or lowering the current Governor Setpoint value by Software-Adjustable raise/lower ramp rates); and

(f) automatic overwrite of a Governor Setpoint value, according to automatic control algorithms within the Governor Software (for example, automatically overwriting the Power Setpoint with a value of 0 MW subsequent to the Governor System accepting a shutdown command).

Two sets of raise/lower commands are required (via select-before-operate controls) within the Governor System, used to adjust the Governor Setpoints as follows:

(g) one set of raise/lower commands for the Gate Limit Setpoint; and

(h) one set of raise/lower commands for shared use to adjust Speed Setpoint, Power Setpoint, or Gate Position Setpoint, based on the Unit circuit breaker status (e.g., Worker-adjustment of the Speed Setpoint will not be possible when the Unit circuit breaker is closed) and the Governor control mode (e.g., Worker-adjustment of the Gate Position Setpoint will not be possible when in Power Droop mode).

The Speed Setpoint will be:

(i) Worker-Adjustable between 85% and 105%, in increments of 0.01% or less when the Unit circuit breaker is open, at a Software-Adjustable ramp rate;

(j) set to 100% when the Unit circuit breaker is closed (required to ensure a return to rated speed if the Unit circuit breaker opens); and

(k) set to 0% when the Governor System has accepted a normal or protection-initiated stop command.

The Power Setpoint will be:

(l) Worker-Adjustable between Software-Adjustable upper and lower limits, in increments of 1% or less, and at a Software-Adjustable ramp rate;

(m) set to 0% when the Unit circuit breaker is open, and also when the Governor System has accepted a normal or protection-initiated stop command;

(n) ramped at a Software-Adjustable rate from 0% to a Software-Adjustable target value immediately upon closure of the Unit circuit breaker (this is required to prevent Unit operation in reverse power and any Turbine rough load zones immediately after the Unit circuit breaker is closed); and

(o) ramped at a Software-Adjustable rate to a Software-Adjustable value immediately upon transfer from Synchronous Condense Mode to Generate Mode (this is required to prevent Unit operation in reverse power).

The Gate Position Setpoint will be:

(p) Worker-Adjustable between Software-Adjustable limits, in increments of 0.01% or less, at a Software-Adjustable ramp rate; and

(q) set to the Software-Adjustable lower limit when the Governor System has accepted a normal or protection-initiated stop command.

The Gate Limit Setpoint will be:

(r) Worker-Adjustable between Software-Adjustable limits, in increments of 0.01% or less, at a Software-Adjustable ramp rate; and

(s) set to the Software-Adjustable lower limit when the Governor System has accepted a normal or protection-initiated stop command.

3.5 Transfer Function Setting Adjustments

The gains and time constants of each element of the PID Transfer Function and PD Transfer Function will be independently Software-Adjustable over the following ranges:

(a) Proportional elements: The proportional element gain (i.e., the ratio of the element’s per unit output to its per unit input), will be adjustable in increments of 0.01 or less over its full range.

(b) Integral elements: The integral element gain (i.e., the reciprocal of the time required for the element’s per unit output to be equal in magnitude to its per unit input, where the input is a step function), will be adjustable in increments of no more than 0.001 per second, over its full range.

(c) Derivative elements: The derivative element gain (i.e., the ratio of the element's per unit output to the time derivative of its per unit input), will be adjustable in increments of 0.01 second or less over its full range.

3.6 Automatic Start Control

3.6.1 Normal Automatic Start Control

Upon the Governor System accepting an automatic start command, it will:

(a) set the Speed Setpoint to 100% (or less as required by soft start control);

(b) release the gate lock;

(c) raise the Wicket Gate Limit setting from the shutdown setting (0%) to a Software-Adjustable setting according to the selected start mode (Soft Start or Fast Start);

(d) open the wicket gates according to the selected start mode (Soft Start or Fast Start);

(e) set the Wicket Gate Limit to the Maximum Offline Wicket Gate Limit once the Unit reaches a Worker-Adjustable speed for the selected start mode (Soft Start or Fast Start);

(f) enable Governor System automatic control algorithms to achieve control of Unit speed for the offline condition, in accordance with the requirements of Schedule 6 [Specifications and Drawings]; and

(g) await a command to either shut down, or begin automatic Unit synchronization.

3.6.2 Soft Start Control

The Governor System will include a soft start function, implemented in software within the Governor PLC as the default/normal start control mode, that:

(a) provides slow wicket gate opening speed during Unit start-up, in order to minimize Turbine stresses;

(b) includes a Software-Adjustable number of stages (the "**Soft Start Stages**");

(c) provides a minimum of three Soft Start Stages, with each stage including an independently Software-Adjustable:

   (i) target Unit speed (adjustable in steps of 0.1% or less);

   (ii) maximum wicket gate position (adjustable in steps of 0.1% or less); and

   (iii) wicket gate position ramp rate (adjustable in steps of 0.1% per second or less).

3.6.3 Fast Start Control

The Governor System will include a Worker-selectable fast start control function, implemented in software within the Governor PLC, that:

(a) provides faster acceleration of the Unit from standstill to near rated speed during automatic start-up (when compared to soft start control), in order to minimize Unit start-up impacts to the Generator Thrust Bearing;

(b) includes a Software-Adjustable wicket gate “breakaway” opening setting, which indicates the position the Governor System will immediately open the wicket gates to when performing a fast start;

(c) includes a wicket gate breakaway setting that is Software-Adjustable in steps of 0.1% or less;

(d) temporarily sets the Wicket Gate Limit to the wicket gate breakaway setting, until the Unit reaches a Software-Adjustable breakaway speed, at which point the Wicket Gate Limit will be restored to its offline setting; and

(e) includes a breakaway speed that is Software-Adjustable in steps of 0.1% or less.

3.6.4 Speed Match Control (during automatic Unit synchronizing)

When the Unit is running offline, the Governor System is in remote control mode, and the Governor System receives a signal from synchronizing equipment (provided by Others) indicating that synchronizing of the Unit to the Running Bus is to begin, the Governor System will control Unit speed to follow the sum of the Measured Running Bus Frequency and a small Software-Adjustable frequency bias (default 0.07 Hz).

The above approach ensures that the incoming (Unit) and running (power system) voltage waveforms will be in-phase with each other, presenting a possible opportunity to close the Unit circuit breaker, approximately once every 14 seconds, and eliminates the need to use a synchronizing “kicker pulse” speed adjustment. In addition, the use of a positive bias will ensure the Unit will pick up positive load immediately after synchronization (avoiding the possibility of encroaching onto any reverse-power protection).

The Governor System will include functionality to block speed matching if the Measured Running Bus Frequency is outside of a range that is Software-Adjustable between 58 and 62 Hz, in steps no greater than 0.01 Hz.

3.7 Automatic Stop Control

3.7.1 Normal Automatic Stop

The Governor System will stop the Unit in the following sequence when it receives a stop command:

(a) the Governor Shutdown Solenoid will be de-energized, causing the wicket gates to start closing;

(b) the Speed Setpoint will be set to 0%, the Power Setpoint will be set to 0 MW, and the Gate Position Setpoint will be set to its Software-Adjustable lower limit; and

(c) once the wicket gates are fully closed, the wicket gate lock will be applied.

3.7.2 Wicket Gate Closing Law

If a multi-stage closing law is required for the shutdown closing sequence, the multi-stage control will be performed by mechanical means without the need for Governor input or feedback during the operation. The mechanical control device(s) will be installed on the Turbine Servomotor(s).

3.7.3 Non Lock-Out Partial Shutdown Sequence

A Unit partial shutdown function will be implemented by Others that, when initiated, will include a command to the cause an immediate Unit circuit breaker trip, but will allow the Unit to continue running offline to await a re-synchronize command.

If the Governor System receives indication that the Unit circuit breaker has opened, it will continue to regulate Turbine speed using Offline Settings.

3.8 Governor System Protection

Non-critical Governor System failures will cause a Governor Alarm.

Protective elements within the Governor PLC will include those described in section 5 and Appendix D of BC Hydro design practice DP 45-Z0031 R1.

Critical Governor System failures will cause the Governor System to initiate an immediate Unit shutdown (trip) that causes the wicket gates to go to the fully closed position. Critical failures will include:

(a) Governor PLC failure;

(b) loss of the Measured Gate Position signal;

(c) loss of the Measured Unit Speed signal;

(d) failure of any pilot valve (PV), PV wiring, or PV power failure;

(e) loss of accumulator oil level sensing;

(f) accumulator oil level at low level trip;

(g) accumulator oil level at high level trip; and

(h) accumulator pressure at low pressure trip.

Control circuits and Software for critical signals (including Wicket Gate position, Unit power output, Unit speed) within the Governor System will be designed and configured to cause Wicket Gate closure on signal loss, power supply loss, during normal shutdowns, and during emergency shutdowns. Inherent safety will be built in to the Governor System in this regard, considering the entire signal path and all devices in the signal path.

3.9 Air Admission

The Governor System will include all control logic and hardware necessary to operate the Turbine air admission system described in Appendix 6-3 [Turbine Specifications (SPT)]. The Governor System will operate the air admission system to meet the performance requirements of the Turbine and the operational requirements of the Turbine air depression system for synchronous condenser operation.

Capability will be provided to manually open the Turbine air admission valve via an “open/auto” control switch (two-position, pistol-grip, mechanically-latched style) located inside the GCC. An alarm will be raised any time the automatic air admission controls are overridden.

3.10 Turbine Air Depression for Synchronous Condenser Operation

The Governor System will include the following functionality:

(a) The Governor System will include all protection and control logic, and hardware, necessary to operate the Turbine air depression system including:

    (i) operating the main air depression valve;

(ii) operating the maintenance air depression valve for initial air depression and as required to maintain the draft tube water level;

(iii) operating the exhaust air valve;

(iv) operating the runner seal cooling water valve; and

(v) operating the Turbine air admission valve.

(b) Capability will be provided to manually operate the main air depression valve, maintenance air valve, and exhaust valve via momentary-contact, spring-return, manual operate buttons located inside the GCC; manual control of these valves will not be provided on the Governor HMI.

3.11 High-Pressure Oil System

(a) General: The two main electric motor driven high-pressure oil pumps, and the jockey pump, for the Governor high-pressure oil will:

(i) have smooth and positive loading and unloading action with no partially unloaded state;

(ii) each include a starter; and

(iii) include controls that include an adjustable pressure differential between the loaded and unloaded position of each unloader.

(b) Controls: The pump controls will:

(i) include automatic control to start and stop each pump motor when the oil pressure in the accumulator falls and rises, respectively, to pre-set values. The control equipment will be arranged to start and stop each pump motor with the pump unloaded - during normal operation, or after power is restored following a power failure when the pump may have been loaded;

(ii) include automatic control to run the pumps in the following order based on the accumulator oil pressure falling: jockey pump, lead pump, and lag pump;

(iii) include a lead/lag selector switch to permit either of the main pumps to be selected as the lead pump and have the Lead-Lag mode initiated by pressure transducers and the Governor PLC. The lead pump will start and load first before the lag pump, which will operate later if accumulator pressure continues to fall;

(iv) include automatic control of the jockey pump for kidney loop filtering and warming of the sump oil;

(v) include unloader controls on each pump that are functional in both Manual and Auto mode;

(vi) include one stand-alone, non-volatile run-time counter for each pump motor; and

(vii) include the following indication lights on the Governor HPU local control panel to show running of the pump motors:

(A) Pump #1 on red light; and

(B) Pump #1 off green light;

(C) Pump #2 on red light; and

(D) Pump #2 off green light.

3.12 Make-up Air

The make-up air control will include automatic control of the make-up air valve for restoring the air-to-oil ratio of the accumulator when the oil level is too high. Operation of the make-up air valve will be coordinated with the operation of the high-pressure oil pumps

3.13 Software

3.13.1 Application Configuration Files (Governor Software)

"**Governor Software**" includes Application Configuration Files for the Governor System, and will be provided.

3.13.2 Configuration Tool Software (Governor Configuration Software)

"**Governor Configuration Software**" includes Configuration Tool Software for the Governor System, and will be provided.

3.13.3 Governor System Events

The Governor PLC, together with its Application Configuration Files designed by the Contractor, will include an Event Buffer that monitors and records Events identified in the Event List, and that uses the Event Data Structure. Functionality will also be included to communicate buffered Events to a device external to the Governor PLC (using a custom communication protocol defined by BC Hydro and provided to the Contractor), and subsequently remove these Events from the buffer once successful communication has been confirmed.

The Governor System will include Alarms for conditions that include:

(a) power supply failures (including fuse failures);

(b) Governor PLC health, including low battery and input/output channel or card failures;

(c) abnormal control status (test mode, Isolated Control Mode, device not in auto, device not in remote);

(d) abnormal device status (e.g., filter dirty, servomotor limit reached, pressure low/high, temperature high, level low/high); and

(e) unexpected or abnormal device operation, device failure, or unknown device status (e.g., speed signal trouble, power signal trouble, level signal trouble, temperature signal trouble, gate lock failure to apply/release, pump failure to operate, lag pump running).

One Target will be provided for each protective function within the Governor System, to indicate when the protective function has operated.

3.13.4 Governor System Data Table

The Contractor's Governor Software for the Governor PLC will include functionality to make all discrete and analog Governor System data that is deemed operationally relevant by the Contractor or by BC Hydro (the "**Governor System Data Table**") available in definite-address 4x register memory for polling by external devices via the Ethernet based Modbus TCP protocol. The data will be grouped into as small a range as practical in order to be read or written in a small number of packets (of approximately 100 registers each). Within the data table, analog values will be formatted in ANSII standard 32-bit floating numbers, spanning two 4x registers each. The analog values will be scaled in engineering units such as kV and MW. Discrete data such as on/off controls, statuses and alarms will be available as individual bits packed into the 4x registers. For example, alarms 1 to 16 would be in bits 1 to 16 of register 400001, alarms 17 to 32 would be in bits 1 to 16 of register 400002, and so on. All alarms and statuses will be included in the data table, and will be non-latching.

The Governor System Data Table will be developed collaboratively between the Contractor and BC Hydro until the first Unit is placed in full commercial service.

The Governor System Data Table will include:

(a) Analog (floating-point) Governor System data, including:

- (i) Speed Setpoint, Measured Unit Speed;
- (ii) Gate Position Setpoint, Wicket Gate Limit, Measured Gate Position;
- (iii) Power Setpoint, Measured Unit Power;
- (iv) Accumulator pressure, accumulator level;
- (v) Sump oil temperature, sump oil level;
- (vi) Servomotor timing test information; and
- (vii) Draft tube level; and

(b) Discrete (integer or binary) Governor System data, including:

- (i) Governor PLC heartbeat;
- (ii) auto/manual status;
- (iii) local/remote status;
- (iv) control mode;
- (v) start/stop status;
- (vi) generate/condense status;
- (vii) Isolated Load Mode status;
- (viii) fast/slow/normal start mode;
- (ix) lead pump status (pump #1 or pump #2);
- (x) bits indicating the current status (i.e., on or off) of all of the items in the Event List for the Governor System;
- (xi) Governor System device health status;

(xii) Governor System device control status; and

(xiii) pump status bits.

SPGOV4 GOVERNOR SYSTEM TECHNICAL REQUIREMENTS – INSTRUMENTATION

4.1 General

Unless otherwise specified, instrumentation described in SPGOV4 will be connected to and monitored by the Governor PLC.

Where redundant transducers are provided and connected to the Governor PLC, the Governor PLC will include adjustable mismatch detection functionality (i.e., an Alarm will be raised if the Governor PLC detects that the difference in indications received from the redundant transducers differs by an adjustable amount).

4.2 Unit and Running Bus Speed Sensing

The Work includes a minimum of three speed sensing systems including:

4.2.1 Generator VT Speed Sensing System

A Generator voltage transformer (VT) speed sensing system (the "**Generator VT Speed Sensing System**") will be provided to provide a measurement of Unit speed that is within 0.005% of the true Unit speed while the Unit is operating between 95% and 105% of Rated Speed, and will utilize the following elements:

(a) a signal conditioner that:

  (i) has its input connected to a Generator VT output;

  (ii) accepts 125 Vdc as its power input (AC powered devices are not acceptable);

  (iii) operates correctly over a range of Generator speeds spanning at least from 20% of Rated Speed to 200% of Rated Speed;

  (iv) operates correctly over a range of Generator terminal Voltage amplitudes spanning at least from 125% of rated Generator terminal Voltage, down to 1% of rated Generator terminal Voltage;

  (v) includes immunity to electromagnetic interference expected to be experienced within an operating generating station;

  (vi) includes at least 5 kV of galvanic isolation between its input and output;

  (vii) ignores saturation effects of the Generator VT at lower frequencies; and

  (viii) provides at its output, a pulse train that provides indication of Unit speed; and

(b) a high-speed counter-type electronic PLC module (frequency transducers will not be used) that:

  (i) is part of the Governor PLC;

  (ii) has its input connected to the output of the signal conditioner discussed above; and

(iii) provides indication of Unit speed to the Governor PLC.

The Generator VTs will be provided by Others.

4.2.2 Toothed-Wheel Speed Sensing System

A Toothed-Wheel Speed-Sensing system will be provided to provide a measurement of Unit speed that is within 0.005% of the true Unit speed while the Unit is operating between 95% and 105% of Rated Speed, and will utilize the following elements:

(a) a minimum of three magnetic proximity probe sensing devices (each a "**ZVPU Probe**"), two of which are to be used by Others to provide speed sensing signals to a system external to the Equipment, and that meet the following specifications:

(i) are of the zero-velocity pickup type (i.e., probes that are capable of correctly sensing and indicating a tooth or space when the Toothed-Wheel is not rotating), and are of adequate response time to ensure an accurate speed signal is generated, considering the number of teeth on the Toothed-Wheel and that the Toothed Wheel is rotating at the runaway speed of the Unit;

(ii) are arranged around the Toothed-Wheel to allow:

(A) each to distinctly and consistently sense teeth and spaces as they pass by when the Toothed-Wheel rotates;

(B) the two probes to be used by Others to be used for creep detection, by arranging them such that one probe is facing a tooth edge while the other probe is facing a tooth face;

(C) each enough clearance to the teeth of the Toothed-Wheel to ensure that contact with the Toothed-Wheel will never occur during Unit operation; and

(D) each enough clearance to the teeth of the Toothed-Wheel to allow a Worker to conveniently pass a thin metal object between the ZVPU Probe and the Toothed-Wheel for maintenance testing purposes when the Unit is stopped;

(b) a minimum of three ZVPU Probe signal conditioners, identical to the signal conditioner utilized for the Generator VT Speed Sensing System, except that the input of each ZVPU Probe signal conditioner will be connected to the output of a ZVPU Probe;

(c) a high-speed counter type electronic PLC module as part of the Governor PLC, and identical to the one utilized for the Generator VT Speed Sensing System;

(d) a Toothed-Wheel in accordance with Appendix 6-5 [Generator Specifications (SPG)]; and

(e) a simple system of ZVPU probe brackets and fasteners in accordance with Appendix 6-5 [Generator Specifications (SPG)].

4.2.3 Running Bus VT Speed Sensing System

A running bus voltage transformer (VT) speed sensing system (the "**Running Bus VT Speed Sensing System**") will be provided to measure running bus frequency, and will utilize elements that are identical to the Generator VT Speed Sensing System, with the exception that the signal conditioner will be connected to the running bus VT instead of the Generator VT. The Running Bus VT Speed Sensing System will be utilized to provide a measurement of the running bus speed (the "**Measured Running Bus Frequency**") to the Governor System for use during speed matching.

The running bus VT will be provided by Others.

4.2.4 Speed Signal Selection

The Governor PLC will select the signal provided by either the Generator VT Speed Sensing System or the Toothed-Wheel Speed Sensing System as the indication of Unit speed (the "**Measured Unit Speed**") to be utilized by the Governor System. When both the Generator VT Speed Sensing System and the Toothed-Wheel Speed Sensing System are healthy, the Generator VT Speed Sensing System will be selected by the Governor PLC as the default Measured Unit Speed. If the Generator VT Speed Sensing System fails or is determined to be unavailable or unhealthy by the Governor PLC, the Governor PLC will immediately, automatically, and bumplessly transfer to utilize the signal provided by the Toothed-Wheel Speed Sensing System as the Measured Unit Speed; once the Generator VT Speed Sensing System is available or healthy again, the Governor PLC will immediately, automatically, and bumplessly transfer back to utilizing the signal provided by the Generator VT Speed Sensing System as the Measured Unit Speed. Alarms will be generated if either speed sensing system fails.

4.3 Pilot Valve Position Sensing

A position transducer will be provided with the Governor System, to provide as its output a measurement of pilot valve position, and will be:

(a) of the linear variable differential transformer type;

(b) built for 4-20 mA output operation; and

(c) either integrated with the pilot valve or if not integrated with the pilot valve, be mounted externally to the pilot valve to facilitate inspection, removal, replacement, and adjustment.

Contact wiper potentiometer type devices will not be provided.

4.4 Wicket Gate Position Sensing

A minimum of two wicket gate position transducers will be provided with the Governor System, each to provide as its output a measurement (the "**Measured Gate Position**") of actual Turbine wicket gate position, and will be:

(a) of the magnetostrictive linear displacement transducer type;

(b) built for 4-20 mA output operation;

(c) mounted externally to servomotors (each to a different servomotor) to facilitate inspection, removal, replacement, and adjustment; and

(d) installed in a manner that permits each to measure the full range of the servomotor stroke, plus a minimum margin of 2.5% past each end of the servomotor stroke.

Contact wiper potentiometer type devices will not be provided.

One gate position transducer will be used by the Governor System and the other will be used by Others to provide wicket gate position indication to systems external to the Equipment.

The calibration gain and offset of each transducer will be independent and separately configurable.

If more gate position transducers are provided by the Contractor, each will be mounted on a different wicket gate servomotor, in order to avoid common mode failures.

Wicket gate position transducers will be supplied with protective covers to prevent inadvertent damage to the transducers.

4.5 Speed Switches

The Governor System will include one set of speed switches (each a "**Governor Speed Switch**"), consisting of auxiliary relays that are operated by the Governor PLC, according to the Measured Unit Speed.

The pick-up and drop-out value of each Governor Speed Switch, including whether pick-up is above or below the setpoint value, will be Software-Adjustable from 0.5% to 200% speed, and will be accurate to within 0.5% of the true Unit speed over this entire range.

The Governor PLC will operate the Governor Speed Switches with a hysteresis that is Software-Adjustable on a per-switch basis, with pick-up and drop-out values independently programmable over a range of from 0.5% to 5% hysteresis, in steps of no more than 0.1%.

Each Governor Speed Switch will be equipped with output relays. Relay contacts will be as specified in Appendix 6-2 [General Technical Specifications (SPGT)].

A summary of the preliminary speed switch requirements is included below:

Governor Speed Switch Function	Value
Overspeed trip	TBD
Overspeed if isolated and in manual	108%
Excitation initiation	95%
Vibration monitor supervision	85%
Emergency brake application	50%
Normal brake application	25%
Spare	TBD
Spare	TBD
Spare	TBD

A second, fully redundant, speed sensing system that is completely independent of the Governor System and that also trips into the Unit protection systems (thus providing a fully redundant protection) will be provided by Others. This system will be in accordance with independent electronic systems described in IEEE 125 Section 5.2.14.1 and IEC 61632 Section 5.15.3.

4.6 Wicket Gate Position Switches

The Governor System will include one set of wicket gate position switches (each a "**Gate Position Switch**"), consisting of auxiliary relays that are operated by the Governor PLC, according to the Measured Gate Position.

The pick-up and drop-out value of each Gate Position Switch, including whether pick-up is above or below the setpoint value, will be Software-Adjustable, and will be accurate to within 0.5% of the true wicket gate position over this entire range.

The Governor PLC will operate the Gate Position Switches with a hysteresis that is Software-Adjustable on a per-switch basis, with pick-up and drop-out values independently programmable over a range of from 0.1% to 5% hysteresis, in steps of no more than 0.1%.

Each Gate Position Switch that is to be connected to equipment external to the Governor will be equipped with output relays. Relay contacts will be as specified in Appendix 6-2 [General Technical Specifications (SPGT)].

A summary of the preliminary Gate Position Switch requirements is included below:

Gate Position Switch	Value
Gate Position Switch #1	1%
Gate Position Switch #2	speed-no-load
Spare	TBD
Spare	TBD

4.7 Governor MW Transducer

A three-element, four-wire Governor megawatt transducer will be provided within the Governor System to provide measurement of Unit output power (the “**Measured Unit Power**”) to the Governor System. The output from the MW transducer to the Governor PLC will be 4-20 mA.

The range of power measurement will span at least from minus 20% of Generator Rated Output to 120% of Generator Rated Output.

The Governor MW transducer will have an accuracy of at least 0.5% throughout the entire range, a temperature coefficient of accuracy of no more than 0.005% per ºC, and the step response time will be no more than 0.1 second.

4.8 Isolation Detector

The Governor System will include a device (the “**Isolation Detector**”) that utilizes measured electrical quantities (such as frequency deviation or other means), to detect and operate when the Unit is operating in Isolated Load Mode where it is connected to many fewer other turbine-generators, as compared to normal grid-connected operation where it is connected to many other turbine-generators as part of the Western North American interconnected power grid (a condition that, when detected, will cause the Isolation Detector to reset).

Isolated Load Mode may arise suddenly due to power system device operations external to the Unit. The intent of this functionality is to ensure adequate damping is provided by the Governor System, if the operating condition of the Unit changes abruptly between grid-connected and isolated load conditions.

It will be possible to:

(a) enable and disable the Isolation Detector via a Governor PLC discrete input; and

(b) force the Governor System to and from Isolated Load Mode via the Governor HMI.

4.9 Accumulator Instrumentation and Controls

4.9.1 Accumulator Pressure Sensing

Accumulator pressure sensing functionality provided with the Governor System will include:

(a) two adjustable pressure switches to indicate extreme low pressures (low pressure trip) in the accumulator and be fully redundant; and

(b) a minimum of two pressure transducers, each installed to measure accumulator pressure and be fully redundant.

The accumulator will have two instrument pressure headers each equipped with an isolation valve, pressure gauge, a test port, one of the above pressure switches, one of the above pressure transducers, and two spare ports (suitably plugged) for future use. If the Contractor requires additional pressure sensing devices they will also be installed on a similar instrument pressure header.

4.9.2 Accumulator Oil Level Sensing

Accumulator oil level sensing functionality provided with the Governor System will include:

(a) one guided-wave radar level transducer, and one magnetic float transducer, each installed to measure accumulator level and be fully redundant with regard to the other; and

(b) mechanical indication of accumulator oil level using magnetic semaphore flag indicators arranged around the sensing column of the accumulator level magnetic float transducer, in a manner that utilizes that transducer's magnetic float to operate the semaphore flag indicators (a pressurized oil level sight glass is not acceptable).

4.10 Oil Sump Instrumentation and Controls

The Work will include provision of:

(a) a sump oil level transducer (that may be inserted directly into the sump without a stilling well);

(b) a sump oil level sight glass with mechanical protection (that may be attached directly to the sump without a stilling well); and

(c) a sump oil temperature transducer.

4.11 Servomotor Pressure Transducers

The Work will include provision of pressure transducers and pressure gauges in the piping to the servomotors located near or on the HPU, to indicate the pressure in the wicket gate opening and closing lines.

4.12 Draft Tube Level Transducer

The draft tube level transducer described in Appendix 6-3 [Turbine Specifications (SPT)] will be connected to the Governor PLC.

SPGOV5 GOVERNOR SYSTEM TECHNICAL REQUIREMENTS – ELECTRICAL

5.1 High-Pressure Oil Pump Motors

Motors and starters provided to drive the main and jockey-high pressure oil pumps will:

(a) be rated for continuous service, considering the pump each motor is connected to;

(b) meet the requirements of Appendix 6-2 [Generator Technical Specifications (SPGT)] for motors and starters;

(c) include full-voltage, non-reversing starters, with power supplies connected such that failure of the power supply to one motor starter does not affect operation of the other motor;

(d) include full enclosure of exposed rotating parts (such as motor-pump couplings) to prevent accidental contact with Workers and other equipment;

(e) include engineered lifting points, supplied with a rigging plan and all necessary lifting equipment; and

(f) each have its output shaft flange-mounted to the input shaft of its respective high-pressure oil pump.

5.2 Governor Control Cabinet

A Governor control cabinet (the "**Governor Control Cabinet**" or "**GCC**") Enclosure will be provided, to mount major Governor System electrical and electronic system hardware, and to act as the primary interface for Workers using the Governor System.

The GCC will have:

(a) the Governor HMI, local/remote control transfer switch, emergency stop pushbutton, CT entrance FT-1 block, VT entrance FT-1 block, Governor MW transducer combination FT-1 block, and compact iso/test block mounted to its door;

(b) the Governor PLC, Governor Speed Switches, and Gate Position Switches mounted to its interior; and

(c) other devices and components mounted to it, as required to meet the requirements of Schedule 6 [Specifications and Drawings].

5.2.2 Governor PLC

The Governor System will utilize a Modicon Quantum or M580 type digital microprocessor-based programmable logic controller (the "**Governor PLC**") and associated hardware, to implement algorithms that:

(a) sense instrumentation and other inputs from the Governor System;

(b) perform Governor System diagnostic functions;

(c) provide Governor System indication and annunciation signals;

(d) implement Governor System control algorithms and determine Governor System control signals, including damping signals (dashpot type mechanical damping systems and mechanical type restoring systems are not acceptable);

(e) implement a Governor System sequence of events buffer for communication to a device external to the Governor System; and

(f) handle data communications, using:

    (i) Modbus TCP, between Governor System devices, and between the Governor System and devices external to the Governor System; and

    (ii) Modbus between the Governor PLC and the Governor HMI.

Governor PLC hardware will include the following:

(g) 125 Vdc redundant power supply modules;

(h) Modbus TCP communications capability;

(i) Modbus communications capability;

(j) 125 Vdc discrete input modules, to be utilized for all Governor PLC discrete inputs, that provide an IRIG-B (1 ms accuracy) GPS time-synchronized time-stamp for each change of state of each discrete input;

(k) Other input and output modules as required to meet the requirements of Schedule 6 [Specifications and Drawings];

(l) Spare hardwired analog and discrete input and output ports equivalent to at least 30% of the utilized inputs and outputs of each type (except for inputs and outputs associated with high-speed counter electronic PLC modules for the Toothed-Wheel Speed-Sensing system and Generator VT Speed-Sensing system, for which no spares are necessary);

(m) IRIG-B GPS time synchronization input hardware (IRIG-B signal to be provided by Others) that will be used by the Governor PLC to ensure the PLC clock is always synchronized to the IRIG-B timing signal, and also to timestamp Governor PLC hardwired discrete inputs to IRIG-B accuracy;

(n) Hardwired Analog Inputs and Outputs: All Governor PLC hardwired analog inputs and outputs will:

    (i) include a pair of wires per input or output (i.e., channels will be isolated, with no commoning);

    (ii) be 4-20 mA and user programmable on a per-channel basis;

    (iii) be galvanically isolated from ground and other channels;

    (iv) include short circuit protection; and

    (v) have their associated current value (measured input values in the case of analog inputs and calculated output values in the case of analog outputs) made available in Governor PLC registers for polling by external devices.

The following hardwired analog inputs to the Governor PLC will be provided by the Contractor. (additional analog inputs and outputs may be required by BC Hydro and identified at a later time):

(vi) Measured Gate Position;

(vii) pilot valve position;

(viii) Measured Unit Power;

(ix) accumulator pressure (two inputs);

(x) accumulator oil level (two inputs);

(xi) sump oil level;

(xii) sump oil temperature; and

(xiii) a test input (to be used by Others during maintenance and testing activities).

The following hardwired analog outputs from the Governor PLC will be provided by the Contractor:

(xiv) pilot valve command;

(xv) test output indication #1 (to be used by Others during maintenance and testing activities); and

(xvi) test output indication #2 (to be used by Others during maintenance and testing activities).

The Contractor will propose any additional hardwired analog inputs or outputs that may be of value to BC Hydro.

(o) Hardwired Discrete Inputs and Outputs: No discrete hardware indicators such as indicating lamps will be used.

Governor PLC binary discrete inputs will be 125 Vdc, and will have their current associated states (measured input states in the case of discrete inputs and calculated output states in the case of discrete outputs) made available in Governor PLC registers for polling by external devices.

The following hardwired discrete inputs (statuses and commands) to the Governor PLC will be provided by the Contractor:

(i) power supply and fuse monitoring (one per power supply/fuse);

(ii) filter clean/dirty indication (one per filter);

(iii) acceptable hydraulic pressure available to the distributing valve;

(iv) Unit breaker status;

(v) Governor Shutdown Solenoid pickup/dropout status;

(vi) pump running status (one per pump);

(vii) gate lock applied status;

(viii) gate lock fully released status;

(ix) Unit protection cleared status;

(x) pump control in auto status (one per pump);

(xi) pump control in manual status (one per pump);

(xii) Governor System local/remote status;

(xiii) Governor System Isolated Load Mode status;

(xiv) air admission valve status;

(xv) main air depression valve status;

(xvi) maintenance air depression valve status;

(xvii) exhaust air valve status;

(xviii) runner seal valve status;

(xix) speed no load command (commands the Governor System to control the Unit to speed no load);

(xx) synchronize command (commands the Governor System to control the Unit speed for synchronization to the running bus);

(xxi) start command;

(xxii) stop command;

(xxiii) generation to synchronous condense transfer command;

(xxiv) synchronous condense to generation transfer command;

(xxv) grid load operation to Isolated Load Mode transfer command;

(xxvi) Isolated Load Mode to grid load operation transfer command;

(xxvii) gate limit raise command;

(xxviii) gate limit lower command;

(xxix) raise command (used for MW, speed, and gate position); and

(xxx) lower command (used for MW, speed, and gate position).

The following hardwired discrete outputs from the Governor PLC will be provided by the Contractor (additional discrete inputs and outputs may be required by BC Hydro and identified at a later time):

(xxxi) Governor PLC major fault;

(xxxii) Governor PLC minor fault;

(xxxiii) urgent alarm asserted;

(xxxiv) non-urgent alarm asserted;

(xxxv) lag pump running;

(xxxvi) Isolated Load Mode selected;

(xxxvii) Wicket Gate Droop selected;

(xxxviii) Governor not in remote;

(xxxix) Governor not in auto;

(xl) run-time meter 1 running;

(xli) run-time meter 2 running;

(xlii) run-time meter 3 running;

(xliii) run-time meter 4 running;

(xliv) fast start mode enabled;

(xlv) Servomotor limit reached;

(xlvi) Gate Position Switch #x asserted (one output per Gate Position Switch will be provided);

(xlvii) speed switch #x asserted (one output per speed switch will be provided);

(xlviii) Governor start command (energize shutdown solenoid);

(xlix) Governor stop command (de-energize shutdown solenoid);

(l) gate lock release command;

(li) jockey pump start command;

(lii) jockey pump load command;

(liii) high-pressure main oil pump 1 start command;

(liv) high-pressure main oil pump 1 load command;

(lv) high-pressure main oil pump 2 start command; and

(lvi) high-pressure main oil pump 2 load command.

The Contractor will propose any additional hardwired discrete inputs or outputs that may be of value to BC Hydro.

(p) Preventative Maintenance Triggers: Preventative maintenance trigger functionality will be provided with the Governor System, to alert operations personnel (via one or more Governor Alarms) to Governor System performance that, over time, has drifted outside of a Worker-Adjustable range and may require maintenance. Preventative maintenance trigger information and Worker-adjustment functionality will be displayed on the Governor HMI. Preventative maintenance triggers will include:

(i) Wicket gate tracking error (e.g., steady-state Measured Gate Position and Gate Position Setpoint mismatched by a Worker-Adjustable percentage);

(ii) Abnormal Governor System start sequence time (e.g., one or more devices or subsystems within the Governor System took excessive time to start up);

(iii) Abnormal Governor System stop sequence time (e.g., one or more devices or subsystems within the Governor System took excessive time to stop);

(iv) excessive pump cycling;

(v) excessive oil pump up time; and

(vi) excessive oil leakage.

(q) <u>Communications Links</u>:

(i) *Physical Layer*: The Governor PLC will include a minimum of two communication ports as follows:

(A) an RJ 45 port used for Ethernet communications (100 Base-TX Full Duplex), to be connected to the generating station plant LAN using Modbus TCP; and

(B) a DB9 serial communications port, used for RS232/485 communications via a direct connection to the Governor HMI.

(ii) *Communication Layer*: The Governor PLC will be able to communicate Modbus RTU in addition to any proprietary communications protocols that may be required. The Ethernet communications will be TCP/IP with a user adjustable IP address, subnet mask and gateway. TCP/IP will include the following:

(A) data stream reconstruction from packets received;

(B) receipt acknowledgements;

(C) socket services providing for at least four connections (six or more preferred) to ports on the remote host;

(D) packet verification and error control;

(E) packet sequencing and recording; and

(F) conformity to IEEE 802 standards.

(iii) *Software Layers*: The Governor Software used in the Governor PLC will be arranged as follows:

(A) Maintenance level: This is defined as the level where the manufacturer's software is used to view, modify, and extract or download the program and data records. The ability to modify the operating software in any way (including parameter changes) will be password protected. The viewing of the variables and other data parameters will not be password protected.

(B) Control/data level: This is defined as the level that is used to send control commands to the unit and read any status/metering quantity in real-time. There will be no password required. The control commands (raise, lower, start, stop, etc.) and operating variables will scan at a rate of less than 500 msec.

Any passwords used by the Contractor must be provided to BC Hydro, and locking out any code or sections of Governor Software is not acceptable.

5.2.3 Governor HMI

A colour touchscreen Governor human machine interface (HMI) will be provided by the Contractor, as the primary means to:

(a) communicate visual display of Governor System indication, annunciation, metering, and monitoring, including those listed in Annex D of IEEE 125, to Workers using the Governor System; and

(b) accept Worker input commands from Workers using the Governor System.

The Governor HMI will:

(c) be a colour LCD touchscreen device, with a minimum diagonal screen size of 300 mm;

(d) have no moving parts (i.e., no hard disk drives or fans);

(e) have graphics designed to maximize readability, and consider the relative importance of data when arranging screen graphics. Simplicity and readability are valued over graphically accurate depictions of equipment; and

(f) communicate with the Governor PLC via a DB9 serial communications port, used for RS232/485 communications, and connected directly to the Governor PLC.

5.2.4 Governor Hardwired Controls

The following hardwired controls (the "**Governor Hardwired Controls**") will be provided with the Governor System:

(a) An "emergency stop" pushbutton, used to issue a command to cause immediate emergency shutdown of the Unit (including intake gate closure). This will be a red, mechanically-latched/reset pushbutton with mushroom operator, and a shroud to minimize the possibility of inadvertent operation.

(b) A "local/remote" control transfer switch (two-position, pistol-grip, mechanically-latched style), used to select the Governor System local/remote control mode.

All other control inputs to the Governor PLC will be via the Governor HMI or via hardwired control commands from a remote device external to the Governor System.

5.2.5 Power Supplies

The Governor System will include two power supplies as follows:

(a) connected in a redundant configuration using diode circuits, to ensure the Governor System will continue to operate if one of the power supplies fails;

(b) input and output voltages of each power supply will be 125 Vdc and 24 Vdc, respectively;

(c) power supply input and output terminals will have galvanic isolation with respect to each other of at least 2000 Vdc;

(d) each power supply will be powered from an independent 125 Vdc source, provided by Others. DC sources provided by Others are ungrounded and will not be grounded by the Governor System equipment; and

(e) each power supply will be rated to supply the entire Governor System load to which they are connected, under all operating conditions.

Governor System Equipment connected to the redundant power supply will include the Governor PLC, the Governor Shutdown Solenoid, and the pilot valve (electro-hydraulic transducer).

The Contractor will ensure that a Governor Alarm occurs if either or both of the power supplies fails as a result of input or output faults. The Contractor will ensure that local indications are provided with each of the supplies for input failure and output failure.

The Governor System will initiate an immediate Unit shutdown/trip if both power supplies fail.

Provided that adequate accumulator tank oil pressure exists and that at least one 125 Vdc control power source is available to the Governor System, the Governor System will be capable of starting or stopping the Turbine with no AC power available.

5.2.6 Run-Time Counters

Four elapsed time (run-time) counters will be supplied with the Governor System, and will each:

(a) be a stand-alone device;

(b) be mounted on the GCC door;

(c) be non-volatile (i.e., will not lose their stored count upon loss of power or failure of the Governor PLC); and

(d) be operated by the Governor PLC such that any quantity/condition or combination of quantities/conditions available to the Governor PLC can be tracked with each counter (e.g., Turbine run-time, synchronous condense run-time, rough load zone run-time, cavitation zone run-time, etc.).

SPGOV6 GOVERNOR SYSTEM TECHNICAL REQUIREMENTS - MECHANICAL

6.1 Mechanical Design Criteria

6.1.1 Governor Oil Systems

The Work as part of the Governor oil system includes a hydraulic power unit (the “**Governor HPU**”). The Governor HPU will, as a minimum, include:

(a) an oil sump;

(b) main pumps with unloaders, and associated motors;

(c) a jockey pump with unloader, and associated motor, complete with kidney-loop filter system;

(d) an electro-hydraulic control valve manifold;

(e) a hydraulic distributing valve assembly;

(f) a make-up air receiver;

(g) wicket gate lock equipment;

(h) pressure accumulator tank(s);

(i) instrumentation for monitoring oil pressure, temperature, and level;

(j) hydraulic oil piping and valves, including interconnection piping between the oil sump, accumulator, and servomotors, and all required drain and fill piping; and

(k) compressed air piping and valves, including interconnection piping between the compressor, air receiver, and accumulator.

Test points using “quick coupling with ball check” will be incorporated strategically throughout the hydraulic circuit to aid in troubleshooting.

Components of the Governor HPU, including test points, will be permanently identified using the same notations as in the hydraulic schematic. A plaque of the schematic, including all relevant operating and design data, will be attached to a visible location on the Governor HPU. BC Hydro may specify names and device numbers for some components that are to be incorporated into the Contractor’s drawings.

Governor HPU components except for the sump and air-over-oil style accumulator tanks will be standard industrial hydraulic products that are readily available commercially in North America. In general the hydraulic systems will conform to the SAE J514 standard.

Drains for hydraulic components will be piped back to the HPU sump.

6.1.2 Design, Operating, and Test Pressures

The nominal operating pressure of the Governor HPU will be 6,900 kPa.

For all components the Governor design pressure (the “**Governor Design Pressure**”) will be 1.1 times the nominal operating pressure of the Governor HPU. The Contractor will be able to demonstrate successful experience at the selected nominal operating pressure with reference Turbine(s) of similar size to the proposed Turbine. The Governor nominal pressure will be the normal maximum allowable operating pressure of the Governor HPU and associated components.

The test pressure for all mechanical equipment, including tanks falling under the Boiler and Pressure Vessel code, will be 1.5 times the Governor Design Pressure.

6.2 High-Pressure Oil Pumps

6.2.1 General

(a) Exposed rotating parts, such as motor-pump couplings will be fully-enclosed to prevent accidental contact with Workers and other equipment.

(b) Pumps will be equipped with a means of lifting, supplied with a rigging plan and all necessary lifting equipment.

(c) All motor-pump units will be rated for continuous service, and be provided with a separate adjustable pressure relief valve of adequate capacity.

(d) Each pump will be flange-mounted to its respective electric motor.

(e) All oil pumps will be provided with unloader valves for starting the motors in an unloaded condition.

6.2.2 Main Pumps

Each Governor HPU system will have two identical main pumps of the three-screw fixed-displacement type.

The combined pumping capacity will not be less than 1/4 of the sum of the maximum oil flow rate in the servomotors during a closing or an opening operation, whichever results in a greater flow rate, in accordance with IEEE 125.

6.2.3 Jockey Pump

Each Governor HPU system will include a jockey pump for pressure maintenance during normal unit operation.

The jockey pump will include a fixed displacement pump, an unloader, and function as the pump for the kidney-loop filter system.

The jockey pump will be able to provide a minimum of two times the expected oil consumption during steady-state operating conditions taking into account normal deterioration of components, or be capable of recirculating and filtering the nominal volume of oil in the Governor HPU sump once per hour, whichever is greater.

6.3 Oil Sump

6.3.1 Construction

The Governor oil sump tank will:

(a) have a capacity equal to at least 110% of the total oil volume in the Governor hydraulic system;

(b) be of welded steel construction;

(c) have base supports for floor mounting;

(d) have Lifting Points;

(e) have a filler pipe with cover;

(f) have a desiccant breather with replaceable 3-micron filter;

(g) have a clean-out cover, located on top of the sump, of a minimum size of 550 x 550 mm;

(h) have an additional smaller cover (approximately 250 x 250 mm) located distant from the clean-out cover for ventilation purposes;

(i) have a floor with a slight slope down to the low point of the sump;

(j) have the necessary valves and piping for filling and draining the sump, with the drain valve at the low point of the sump;

(k) have separate piping for filling and draining oil from the sump;

(l) have fill and drain piping that is at least 50 mm in nominal diameter, and will terminate with flanged connections the same size as used for the Turbine and Generator Bearing oil reservoirs at a location which the Contractor will submit for Review;

(m) have a sight glass for the full height of the sump;

(n) be equipped with oil sampling ports and connections for external filtering of the oil;

(o) have baffles separating the suction and return lines that are properly designed based on the hydraulic fluid used and ASTM Air Release Test Data, and including a removable strainer between the two sections;

(p) have on each pump suction line a strainer that is readily accessible;

(q) have all return lines terminate below the oil level with major lines fitted with diffusers to minimize aeration of the oil; and

(r) have, prior to application of any coatings, the sump tank tested for leaks with at a minimum air pressure of 30 kPa.

6.3.2 Oil Heating and Cooling

(a) Oil Cooling: If oil cooling is required, the Work includes a water-cooled heat exchanger with double wall tubes and all oil and water piping and valves for the exchanger.

(b) Oil Heating: To prevent condensation heating of the oil by a non-contact heater or other means (jockey pump fed kidney-loop) will be provided to maintain the oil temperature to at least 10ºC above the Powerhouse ambient temperature.

6.4 Accumulators

6.4.1 Design

In addition to all the requirements for air receivers each accumulator will be equipped with:

(a) an auxiliary inlet with an isolating and a check valve to allow each accumulator to be filled by an external air source;

(b) Lifting Points;

(c) a drain line, complete with dual-redundant isolation valves to allow the accumulator to be drained and serviced;

(d) a pressure-venting line, with dual-redundant isolation valves, complete with muffler;

(e) a float valve to prevent depressurization on low oil levels (the float valve will not inadvertently close at higher oil levels at maximum design oil flows);

(f) a small bypass line to pressure balance the system before opening the main isolating valve on the accumulator tank oil supply side;

(g) external bolted on stilling wells for the guided wave radar level transducers and for the magnetic float that operates the semaphore flag indicators including isolating and drain valves; and

(h) an inward hinged access hatch with an opening size of at least 600 mm x 400 mm that will be located approximately 1 m off the floor. A Worker will not be required to carry the weight of the hatch in order to open the access.

6.4.2 Volume

Sizing of the accumulators will be in accordance with IEEE 125 and IEEE 1207 and will meet the following minimum requirements:

(a) the accumulator will provide at least 1.5 servomotor volumes of oil between the Governor accumulator low level trip and the float valve closure; and

(b) the accumulator will hold an active tank volume (volume above the float valve) of at least 20 times the combined oil volume of the Turbine servomotors. With normal operating pressure in the accumulators, the oil will occupy 1/4 of total accumulator volume, the remaining 3/4 being occupied by air.

6.5 Governor Compressed Air System

A Governor compressed air system will be supplied for pre-charging the Governor accumulators and for maintaining pressure in the Governor accumulators.

The Governor compressed air system will be connected to the Governor accumulator tanks via a Governor air header pipe supplied and installed by Others that will terminate at an isolation valve adjacent to the Governor HPU for each Unit. The Work includes the connection from this isolation valve to the Governor HPU.

For each Unit, an electrically operated solenoid valve will control the pre-charging and make-up air to the accumulator tanks. The solenoid valve will have a handle for manual operation.

(a) General: The Governor air compressor system will be complete with:

  (i) a minimum of two air compressors;

  (ii) an intercooler for each compressor;

  (iii) an aftercooler for each compressor;

  (iv) twin tower desiccant air dryers for each compressor;

  (v) an air receiver for each compressor with a minimum combined volume equal to one Governor accumulator; and

  (vi) all necessary piping, valves, drains and controls for automatic admission of air to the Governor air header pipe.

(b) Air Compressors: Each air compressor for the Governor compressed air system will:

(i) be of reciprocating type capable of completely charging the accumulator for one unit, without using the air receivers, from ambient pressure to full operating pressure in eight hours (four hours with two compressors);

(ii) be driven by an electric motor;

(iii) have a motor, an MCC, and controls;

(iv) be air-cooled;

(v) have an operating pressure a minimum of 2000 kPa above the accumulator nominal pressure to charge the Governor makeup-air receivers;

(vi) have a design pressure not less than 1.1 times the nominal operating pressure;

(vii) have a valve system that permits the two air compressors to charge a Governor accumulator with one or both air receivers isolated;

(viii) include an after cooler and moisture separator such that all condensed liquid water is removed from the inlet air stream; and

(ix) operate in a lead-lag mode that is manually selectable.

(c) Desiccant Air Dryers: Each desiccant air dryer for the Governor air compressor system will:

(i) have particulate and coalescing pre-filters;

(ii) an particulate after filter;

(iii) use an actuated ball valve to switch between towers;

(iv) cycle the saturated inlet air alternately through each of two desiccant beds. One desiccant bed is on-line at full line pressure and flow, absorbing water vapor from the saturated inlet air while the second desiccant bed is being regenerated at atmospheric pressure by a depressurized portion of the dried outlet air; and

(v) have a bypass line around the desiccant air dryer system with bubble-tight isolation valve.

(d) Air Receivers: Each air receiver for the Governor air compressor system will be located in close proximity to the air compressors.

(e) Enclosures: If acoustic Enclosures are required for the Governor air compressors, then these Enclosures will be provided with suitable cooling systems.

(f) Make-up Air: Each Governor HPU will be supplied with a suitable make-up air receiver to prevent excessive cycling of the compressed air system and to minimise the impact when the Governor compressed air system is charging another accumulator. The size of the air receiver will be sufficient to provide 24 hours of make-up air during normal operation without the air compressors in service.

6.6 Valves

Lockable ball valves will be provided to isolate all major pieces of equipment including, as a minimum:

(a) servomotor piping with valves located adjacent to Governor HPU (Double Valve and Drain arrangement);

(b) wicket gate lock;

(c) accumulator;

(d) oil pumps (Double Valve and Drain arrangement);

(e) air compressors (Double Block and Bleed arrangement);

(f) pressure supply line to the hydraulic distributing valve (Double Valve and Drain arrangement);

(g) pressure instrumentation;

(h) filters;

(i) drains (redundant where specified);

(j) compressed air supply to Accumulator (Double Block and Bleed arrangement); and

(k) compressed air exhausts/vents (redundant valves).

6.7 Oil Filtration

The jockey pump filter will be equipped with a duplex filter assembly on the discharge side of the pump that operates at nominal system pressure when pressurizing the Governor HPU system, and as a kidney loop filter system, after normal system pressure has been established, with the discharge being directed to the sump for the purposes of filtration and heating.

All pilot oil will be separately filtered with its own duplex filter assembly and it will be filtered to a higher standard than the jockey pump kidney loop filter system.

All filter assemblies will use disposable elements that have a minimum pressure loss, be mounted in a convenient and accessible location, and be capable of being replaced safely while the Governor HPU and Unit are in normal operation.

Filter replacement will not be required more frequently than once every six months.

Each filter will have a visual indication, and pressure switch to indicate a plugged element and an internal bypass at a higher differential pressure.

6.8 Distributing Valve Assembly

The Governor HPU will be equipped with a wicket gate distributing valve assembly for controlling oil flow to the wicket gate servomotors. It will consist of a single four-way directional valve controlled by an electrically operated proportional pilot valve (electro-hydraulic transducer). The valves will be capable of operating with continuous dither to prevent sticking or sluggish operation.

The pilot valve will operate with a 4-20 mA signal and be capable of interfacing with the Governor PLC. Upon loss of electrical signal to the pilot valve, the distributing valve assembly will move the servomotors in the closing direction at a controlled rate that is Site adjustable. During a shutdown of the Unit, the Governor System will interrupt the electrical signal to the pilot valve.

The distributing valve will also be biased to close upon loss of pilot valve pressure.

The pilot and four-way valves will be designed with minimum internal oil leakage in the neutral position.

6.9 Servomotor Timing Devices

The Governor HPU will be equipped with a means of adjusting the oil flow rate to control the opening and closing times of the servomotors controlling the wicket gates. Travel time in each direction of the servomotors will be independently adjustable. However, once adjusted, it will not be possible for the servomotor to move at a rate faster than the set rates. Secure and positive means of locking the timing adjustments will be provided. Such devices will take the form of continuously adjustable position stops in the distributing valve that directs oil to the servomotors, or an external continuously adjustable flow control valve. Fixed orifices are not permitted.

The effective opening time and closing time will be defined, respectively, as twice the time required for the servomotor(s) to open from 25% to 75%, or to close from 75% to 25% of full travel.

6.10 Governor Shutdown Solenoid Valve

The Governor HPU will be equipped with one electrically operated solenoid valve (the "**Governor Shutdown Solenoid**") to permit start/stop operation from a remote location. The shutdown solenoid will be energized to permit starting and running of the Turbine. When de-energized, the solenoid valve will initiate complete closure of the servomotors at the maximum rate set by the timing devices, assuming an adequate supply of pressure oil is available. The solenoid valve will cause the servomotors to close regardless of any control action from the digital Governor System.

The solenoid coil will be rated for continuous service at 24 Vdc.

The shutdown solenoid circuit will be designed so that when it is de-energized, the pilot valve (electro-hydraulic transducer) power will also be removed.

6.10.1 Manual Shutdown Valve

The Governor HPU will be equipped with one manually operated valve, with a lockable handle if applicable, to permit a Worker to manually cause the Governor System to shut down the Turbine, and issue a signal to equipment external to the Governor System to initiate immediate emergency shutdown of the Unit. The function of this manual valve is identical to the shutdown solenoid valve described above. The manual valve will be accessible by a Worker standing beside the HPU.

6.11 Wicket Gate Lock Solenoid Valve

The Work includes a Governor HPU-mounted electrically-operated wicket gate lock solenoid valve and connection of it to the pressure oil supply within the Governor HPU. The wicket gate lock mechanism (hydraulic cylinder, locking device, and associated limit switches) external to the Governor HPU will be supplied and installed as described in Appendix 6-3 [Turbine Specifications (SPT)].

6.12 Oil Containment Pit

The Governor HPU sump and accumulator tanks will be contained in a separate concrete oil containment pit. The volume of the pit will be sized to contain the total volume of oil in the Governor System. The oil containment pit will have a small drainage sump with outlet valve and drain to the Powerhouse oil water separator. The outlet valve will be normally closed to retain any leaked oil within the oil containment pit.

The Work includes suitable gratings and guardrails as required to safely cover open areas of the oil containment pit and still maintain clear access to equipment for maintenance and isolation. The design of the gratings will be as specified in Appendix 6-2 [General Technical Specifications (SPGT)].

The top of the Governor HPU sump will be low enough to the gratings such that handrails and ladders are not required to access to top of the Governor HPU sump. Steps will be provided if the level of the sump is higher than 300 mm above the concrete floor.

If it is necessary to access the top of the sump for routine isolation of equipment, there will be a clear unobstructed path to that equipment.

6.13 Specialized Testing Equipment

The Work includes provision of means to test the Toothed-Wheel Speed Sensing System by passing teeth or other suitable metal object past the ZVPU Probes, in order to simulate motion of the Toothed Wheel. Means provided to accomplish this will not require disturbance of the ZVPU Probes (i.e., testing will be possible with the ZVPU Probes mounted in their in-service position).

The method of providing this testing capability will be submitted.

6.14 Equipment Identification

6.14.1 Governor System Nameplate Placard

The Governor System will be provided with a nameplate placard in a prominent location on the outside of the Governor Enclosure. The information on the nameplate will:

(a) be in accordance with IEEE 125; and

(b) include:

- (i) manufacturer’s name and address;
- (ii) type of equipment;
- (iii) serial number of the Governor System;
- (iv) model number and type number of the Governor System;
- (v) date of manufacture;
- (vi) hydraulic oil type;
- (vii) hydraulic oil volume (total) (L);
- (viii) ambient temperature rating (°C);
- (ix) BC Hydro contract number; and
- (x) BC Hydro purchase order number.

SPGOV7 TEST AND ISOLATION FACILITIES

7.1 Test Points

There will be 4-20 mA discrete-to-analog (D/A) outputs from the Governor PLC, wired to terminal blocks within the GCC. Each D/A output will be updated on each computational cycle of the Governor PLC. The selection of the digital values to be converted for each analog output, as well as the associated scaling, filtering, will be adjustable via settings from the connected laptop computer. The following signals will be provided as a minimum:

(a) wicket gate position;

(b) spool positions of both the pilot and distributing valves;

(c) Turbine speed;

(d) running frequency;

(e) MW;

(f) incoming frequency;

(g) frequency reference;

(h) frequency error;

(i) power reference;

(j) MW error;

(k) four spare, configurable independent D/A outputs; and

(l) eight other signals internal to the Governor System computer to be specified by BC Hydro after Contract award.

In addition to the above there will be live signal injection capability. The scaling will be 4 mA to 20 mA, or 0-10 Vdc, for 0 to 100% of the signal scaling. The scaling factor will be available through the laptop computer. Signal isolation will be provided in the Governor System. The signal will be converted and injected in the computation loop on each cycle. The isolation circuit and conversion will have a flat frequency response to at least 100 Hz. Two inputs selectable from the laptop computer will be provided. The following signals will be available as a minimum:

(m) Wicket gate position amplifier summing junction;

(n) frequency (speed) amplifier summing junction; and

(o) MW amplifier summing junctions.

7.2 Isolation Facilities

7.2.1 CT Entrance FT-1 Block

An entrance CT isolation and test block (ABB type FT-1) will be provided and connected in accordance with BC Hydro ES 45-X0010 for the Generator CT input to the Governor System.

7.2.2 VT Entrance FT-1 Blocks

An entrance VT isolation and test block (ABB type FT-1) will be provided and connected in accordance with BC Hydro ES 45-X0010 for each of:

(a) the Generator VT input to the Governor System; and

(b) the running bus VT input into the Governor System.

7.2.3 Compact Iso/Test Subpanel

A compact iso/test subpanel will be provided and connected in accordance with BC Hydro ES 45-X0011, and will be used to isolate:

(a) VT inputs between the VT entrance block and each downstream device;

(b) Governor PLC trip outputs between the Governor PLC and each downstream device; and

(c) other points agreed to between the Contractor and Hydro's Representative.

7.2.4 Combination FT-1 Block

A combined voltage and current isolation and test block, as outlined in section 4.6 of BC Hydro ES 45-X0010 (ABB type FT-1 670B197G18), will be provided and connected between the Governor MW transducer and CT/VT entrance blocks, to allow the Governor MW transducer to be isolated from Generator CT and VT circuits, and tested by Others via connection of test equipment.

SPGOV8 MANUFACTURING, INSPECTION AND TEST REQUIREMENTS

8.1 Shop Inspection and Tests

8.1.1 General

The Work includes performance testing of the Governor System to demonstrate the functionality for all operating conditions. The Equipment will be fully integrated to the maximum extent possible. Where it is not practical to integrate sub-systems of the equipment, or to test full functionality, the Equipment may be tested by simulating the operating conditions or interconnection required to demonstrate system performance. Simulation methods will be submitted for Consent.

Governor System shop inspection and tests will include the inspection and testing recommended in and be performed in accordance with IEEE 125, IEEE 1207, and IEC 60308 except as otherwise specified.

8.1.2 Governor Control Cabinet

The fully-integrated Governor Control Cabinet will be tested with the HPU. Simulated control of the HPU will not be accepted.

Testing of the controls for the air depression system for synchronous condenser operation, and the air admission system, may be deferred until the Equipment is on Site.

8.1.3 HPU

The HPU will be tested as a complete system including the accumulator.

Pumps will be operated a minimum of 4 hours continuously under load.

8.1.4 Compressed Air System

The compressed air system may be tested as a standalone system and is not required to be integrated with the rest of the Governor equipment.

SPGOV9 SITE ACCEPTANCE AND COMMISSIONING TESTS

9.1 General

Governor System site acceptance and commissioning tests will include the tests recommended in and be performed in accordance with IEEE 125, IEEE 1207, and IEC 60308 except as otherwise specified.

9.2 Governor System Tests by the Contractor

The Governor System will be thoroughly tested to confirm that its performance as an integrated part of the Unit is acceptable, considering all Unit and Governor System operating conditions outlined in the Specifications.

To the maximum extent possible, the Contractor will functional test and verify the performance of all aspects of the Governor system prior to watering up the Unit. As part of these tests, speed and power inputs will be simulated.

Governor System tests will include:

(a) Dry tests, including:

- (i) verifying performance of the HPU system and components including pumps, motors, instrumentation, valves;
- (ii) wicket gate position transducer calibration testing;
- (iii) wicket gate servo control loop response testing;
- (iv) gate lock testing;
- (v) wicket gate timing tests;
- (vi) limiter tests;
- (vii) control transfer (auto/manual and local/remote) testing (including loss of sensing tests);
- (viii) manual mode control, stability, and response testing (including “bump” disturbance testing);
- (ix) automatic mode control, stability, and response testing (including “bump” disturbance testing);
- (x) isolated mode control, stability, and response testing (including “bump” disturbance testing);
- (xi) turbine air depression system testing; and

(xii) synchronous condense mode control and transfer testing.

(b) Wet offline tests, including:

(i) start-up and speed-no-load control and response testing (including “bump” disturbance testing);

(ii) stop control and response testing;

(iii) limiter tests;

(iv) control transfer (auto/manual and local/remote) testing;

(v) synchronizing control testing (speed matching);

(vi) turbine air depression system testing; and

(vii) synchronous condense mode control and transfer testing.

(c) Wet online tests, including:

(i) manual mode control, stability, and response testing (including “bump” disturbance testing);

(ii) automatic mode control, stability, and response testing (including “bump” disturbance testing);

(iii) isolated mode control, stability, and response testing (including “bump” disturbance testing);

(iv) control transfer (auto/manual and local/remote) testing (including loss of sensing tests);

(v) limiter tests;

(vi) synchronous condense mode transfer and control testing; and

(vii) load rejection testing.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-5

GENERATOR SPECIFICATIONS (SPG)

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SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-5

GENERATOR SPECIFICATIONS (SPG)

SPG1 GENERAL

1.1 Definitions and Interpretation

In this Appendix 6-5 [Generator Specifications (SPG)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Connection End**" means the end of the Generator that has the circuit-ring bus and main Generator terminals;

"**Drive End**" means the end of the Generator that is driven by the Turbine;

"**Generator**" has the meaning set out in SPG 1.2.1(a);

"**Generator Enclosure**" has the meaning set out in SPG 2.10.1;

"**Generator Losses**" has the meaning set out in SPG 2.1.1;

"**Generator Pit**" means the area inside the Generator Enclosure that is within the circumference of the stator bore, below the rotor, and above the Turbine Pit;

"**Generator Pit Maintainable Components**" has the meaning set out in SPG 2.11.1;

"**Generator Rated Field Current**" has the meaning set out in SPG 2.2.3;

"**Generator Rated Operating Conditions**" has the meaning set out in SPG 2.2.4;

"**Generator Rated Output**" has the meaning set out in SPG 2.2.2;

"**Generator RTD Terminal Cabinet**" has the meaning set out in SPG 2.17.3;

"**Generator Terminal Cabinet**" has the meaning set out in SPG 2.17.2;

"**Regulated Cold Air Temperature**" has the meaning set out in SPG 2.4.6;

"**Toothed-Wheel**" or **"TW"** has the meaning set out in SPG 2.16.2(a)(i);

"**Toothed-Wheel Speed Sensing System**" or "**TW Speed Sensing System**" has the meaning set out in SPG 2.16.2; and

"**TW Housing**" has the meaning set out in SPG 2.15.

1.2 Scope of this Specification

1.2.1 Scope of Work for the Generators

Six identical Generators are required for the Project, together with related Work, as follows:

(a) each generator (a "**Generator**") includes the sole-plates, stator frame, stator core, stator winding, circuit-rings, main and neutral leads, rotor hub, rotor spider, rotor rim, rotor poles, thrust and guide bearings, brushgear housing, brushgear, field bus and cables, upper bracket, lower bracket (as applicable), brakes, jacking system, cooling systems, and instrumentation.

1.2.2 Scope of Related Work

The Work related to each Generator includes:

(a) a conceptual design of a stator Lifting Device and support pedestals for a Generator stator even if the Contractor does not require a stator Lifting Device or support pedestals for the Work;

(b) tooling and Lifting Devices;

(c) all specialized test instrumentation, current measurement, and voltage measurement required to complete the Generator acceptance and commissioning tests;

(d) the Generator short-circuit connection required for the Generator testing; and

(e) the Generator shorting breaker and shorting bus or cables required for the Generator sudden short circuit testing. BC Hydro can make available a shorting breaker on an as-is, where-is basis at no cost to the Contractor upon request. BC Hydro makes no representation or warranty as to the suitability of the BC Hydro-provided breaker for the required testing, and if the breaker does not work or is for any reason not suitable, the Contractor will provide a breaker for the required testing at no additional cost or expense to BC Hydro.

1.2.3 Work Not Included

Not Used.

1.3 Submittals

1.3.1 Generator Drawings

(a) Generator: The Generator Drawings will include:

(i) lower bracket / support cone, embedded parts and anchors, and supports;

(ii) upper bracket and top covers;

(iii) Generator shaft (if any), thrust block, connecting flanges, and shaft seal system;

(iv) thrust and guide bearing enclosures, thrust pads, and thrust collar;

(v) bearing lubrication system, jacking system, and oil cooling system;

(vi) bearing oil mist containment and removal system;

(vii) bearing insulation system;

(viii) brakes and jacking system, track and supports, and dust collection system;

(ix) cooling system including air coolers, bearing coolers, isolating valves, piping, and supports;

(x) fire protection system including detectors, sprinklers, and piping;

(xi) all instrumentation and wiring inside the Generator Enclosure; and

(xii) auxiliary systems equipment.

(b) Stator: The Generator stator Drawings will include:

(i) sole-plates and embedded parts and anchors, frame, and core;

(ii) core laminations, air ducts, key bars, core studs, clamping fingers, and details;

(iii) bar dimensions, materials, and cross-section;

(iv) stator winding bars assembled in the core, support rings, and bar end-turn support system;

(v) winding circuit-rings and main and neutral leads;

(vi) winding connections, including series clips, group jumpers, bar taps, circuit-ring taps, main and neutral leads taps, flexible links, and ferrules;

(vii) bar transposition drawing showing the development of strand cross-over, strand ends start and finish numbering system, method of insulating cross-over points, and strand interconnections;

(viii) bar design including sectional views of stator bars in the slot with all dimensions, showing stranding, strand and ground insulation, fillers, springs, wedges, and resistance temperature detectors;

(ix) winding design including overall dimensions and angles of the bars and defining whether the bars are left or right when viewed from inside the stator bore, slot skew (if any) end-turns, end-turn span and drop dimensions, support ring locations, bar-end supports, tying procedures, and insulation requirements for all components;

(x) copper cross-section area for the stator bars, circuit-rings, and main and neutral leads;

(xi) winding diagram, including:

(A) showing the parallel paths in each phase and showing the slot numbering system;

(B) showing the slot number in which each bar is located, and whether the bar is located in the front or back position;

(C) a tabulation listing the slot number and the corresponding phase in the slot and location from the line or neutral end of the parallel; and

(D) in all winding diagrams, showing in which slot, and the location in the slot, of the RTDs;

(xii) plan and sectional views of circuit-rings, blocking system, and connections between bars, between bars and circuit-rings, and between circuit-rings and the main and neutral leads;

(xiii) a step-by-step description of the insulation system (materials and application) including:

(A) description and thickness of the strand and groundwall insulation systems;

(B) net mica thickness and voltage stress in kV/mm of the ground insulation; and

(C) description of the insulation and partial discharge suppression system including a list of materials.

(xiv) frame, core, and winding RTDs plan and sectional views;

(xv) bar surface resistivity measurement device; and

(xvi) slot wedging details.

(c) Rotor: The Generator rotor Drawings will include:

(i) hub, spider, and rim, and rim keying system;

(ii) pole bodies, laminations, field coils, and pole keying system;

(iii) field bus and connections;

(iv) brushgear and carbon dust collection system; and

(v) field winding short-time thermal capability curve for setting the field thermal overload protection.

1.3.2 Generator Calculations

In general, Calculations will verify the ability of the Generator to withstand the operating conditions for the Equipment in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

(a) Generator: The Generator Calculations will include:

(i) rotor/stator airgap stability considering the stiffness of the mechanical and magnetic components. The Calculation will:

(A) demonstrate the adequacy of the mechanical components to maintain airgap stability and the specified minimum airgap under the operating conditions specified in Appendix 6-2 [General Technical Specifications (SPGT)]; and

(B) be compared with existing generators of similar capacity and physical size to demonstrate the geometrical stability and long-term reliability of the stator and rotor;

(ii) electro-magnetic design;

(iii) fault calculations and mechanical damping factors during faults;

(iv) Generator cooling and ventilation; and

(v) demonstration of the safety and stability of any equipment mounted in the airgap;

(b) Stator: The Generator stator Calculations will include:

(i) stator core compression and buckling;

(ii) stator core full-flux test electrical requirements;

(iii) stator winding components current density;

(iv) stator winding temperature rise;

(v) bar forces in the slots;

(vi) the maximum short-circuit force between conductors and the required spacing between ring bus supports;

(vii) stator slot ripple spring and wedges;

(viii) maximum allowable armature winding deflection during the sudden short circuit test; and

(ix) stator deflection during and after handling (if assembled on the Powerhouse service bay);

(c) Rotor: The Generator rotor Calculations will include:

(i) rim separation speed and required shrink interference value (if applicable);

(ii) current density for all field winding components;

(iii) field winding temperature rise;

(iv) field bus connections including the contact pressure and stress; and

(v) demonstration of the safety and stability of any equipment mounted on the rotating components.

1.3.3 Generator Procedures

(a) Generator: The Generator Procedures will include:

(i) lower bracket or thrust cone installation;

(ii) bearing(s) installation;

(iii) thrust block and shaft installation;

(iv) stator installation in the Generator Enclosure (if assembled in the Powerhouse service bay);

(v) rotor installation in the Generator Enclosure;

(vi) upper bracket and top cover installation;

(vii) brushgear and carbon dust collection system installation; and

(viii) brakes, jacking, and brake dust collection systems installation.

(b) Stator: The Generator stator Procedures will include:

(i) embedded parts, anchors, and sole-plate installation;

(ii) frame construction including the methods for levelling and maintaining the specified verticality, circularity, and concentricity;

(iii) method of checking and adjusting stator core compression and levelness including clamping pressure;

(iv) preparation of the core to receive the new winding;

(v) winding installation including connection and insulating methods;

(vi) determination of the amount of slot side packing required, the installation method, and the method used to confirm that there is sufficient contact between the stator bar and the side packing and between the side packing and the stator core;

(vii) wedging system installation including the method of measurement of bar tightness in the slot and of amount of spring-type filler compression;

(viii) installation of the circuit-rings and main and neutral leads including connection and insulating methods; and

(ix) winding testing during installation and when fully installed.

(c) Rotor: The Generator rotor Procedures will include:

(i) hub and spider construction;

(ii) rim construction including rim shrink and circularity, concentricity, and verticality measurements;

(iii) pole installation including key installation and elevation, circularity, concentricity, and verticality measurements;

(iv) field bus installation; and

(v) winding testing during installation and when fully installed.

SPG2 GENERATOR TECHNICAL DATA AND REQUIREMENTS

2.1 Generator Losses and Uncertainties

2.1.1 Losses

Generator losses (the "**Generator Losses**") means the total of the Generator fixed and variable losses as measured in accordance with SPG 5.2.20. Generator Losses will:

(a) be corrected to the Regulated Cold Air Temperature;

(b) include the bearing losses for the Generator guide bearing, Generator thrust bearing (including the contributions from both the weight of all rotating components and the Turbine hydraulic thrust at the corresponding Generator load) and the Turbine guide bearing;

(c) for synchronous condense operation, be the Generator Losses when the Generator is operating under-excited with a reactive power output in kVAr measured at the Generator terminals equal to 50% of the Generator Rated Output (kVA) excluding Turbine runner windage losses; and

(d) not exceed those stated in the tables in the Generator TDIF.

2.1.2 Uncertainties

The Generator Losses test uncertainties as stated in the tables in the Generator TDIF:

(a) will, for any operating point, not exceed the tolerances stated in IEC 60034-1 Table 20; and

(b) are considered final and will not be revised.

2.1.3 Updates to the Generator Losses Tables in the Generator TDIF

The Generator Losses tables in the Generator TDIF will be updated by BC Hydro with the Generator Losses measured during the site acceptance and commissioning tests using the following methodology:

(a) windage and fixed core losses will be assumed to be constant for all Turbine Weighting Regimes and equal to the values obtained in SPG 5.2.20;

(b) Turbine and Generator guide bearing losses and fixed Generator thrust bearing losses will be assumed to be constant for all Turbine Weighting Regimes and equal to the values obtained in SPG 5.2.20;

(c) Generator thrust bearing variable losses will be based on the values provided in the Generator TDIF and corrected for the actual hydraulic thrust measured in accordance with Appendix 6-2 [General Technical Specifications (SPGT)] versus the hydraulic thrust provided in the Turbine TDIF;

(d) armature I^2R and field I^2R losses will be calculated from the resistances measured in SPG 4.7.4 and SPG 4.9.4 using the square of the respective currents required for each Turbine Weighting Regime; and

(e) stray load losses will be interpolated from the values obtained in SPG 5.2.20 using the square of the armature current required for each Turbine Weighting Regime.

2.2 General Design Criteria

2.2.1 General

Except as otherwise expressly specified in this Appendix 6-5 [Generator Specifications (SPG)], the Generator will meet the requirements of IEEE C50.12.

Except as otherwise expressly specified in the Contract Documents, Generator power factor is for the over-excited operating condition.

2.2.2 Rated Output

The Generator rated output (the "**Generator Rated Output**") is the highest achievable continuous Generator output measured in megavolt amperes (MVA) at the Generator terminals while meeting all requirements of the Contract Documents and the following:

(a) Rated Power: The highest achievable continuous Generator power output measured in megawatts (MW) at the Generator terminals when the Generator is operated at rated power factor (pf).

(b) Reactive Power Capability: The Generator will be rated for continuous operation anywhere within its reactive power capability curve.

(c) Rated Power Factor (pf): The Generator will be rated for continuous operation at 0.95 pf over-excited.

(d) Rated Voltage (kV): The rated line-to-line rms voltage of the Generator will be in the range of 12 kV ≤ and ≤ 16 kV.

(e) Rated Frequency: The Generator rated frequency will be 60 Hz.

(f) Number of Phases: The Generator will have three phases.

The Contractor will determine the Generator Rated Output for the Generator operating at the Rated Operating Conditions.

The Generator will be rated so that the input power to the Generator is coincident with the Turbine Rated Output.

2.2.3 Rated Field Current

The Generator rated field current (the "**Generator Rated Field Current**") is the field current required in the Generator rotor field winding required to operate the Generator continuously at the Generator Rated Output.

2.2.4 Rated Operating Conditions

When the Generator is operating at the Generator Rated Output and with the cooling water at the Maximum Cooling Water Supply Temperature, the Generator rated operating conditions (the "**Generator Rated Operating Conditions**") will be as follows:

(a) Cold Air Temperature: The temperature of the air leaving the Generator air coolers as measured by RTDs will not exceed 40 °C.

(b) Stator Winding Temperature Rise: The temperature rise of the stator winding as measured by any embedded stator winding RTD over the slot length of the winding will not exceed 75°C[1].

(c) Stator Circuit-ring and End-winding Temperature Rise: The maximum temperature rise of the stator circuit-ring and end-windings as measured in accordance with SPG 5.2.17(f) will not exceed 80°C.

1 Temperature rise for V = 12 kV rated Generator only. Refer to IEEE C50.12 Clause 7.1.1 for V > 12 kV temperature rise limit reductions.

(d) Rotor Winding and Field Bus Temperature Rise: The temperature rise of the rotor winding and field bus as measured by the resistance method will not exceed 70°C.

The temperature rise limit calculations do not need to include the variation of rated frequency and rated voltage as specified in IEEE C50.12.

2.2.5 Out of Phase Synchronizing

The positive sequence equivalent Thevenin impedance looking into the network from the Generator terminals when one Generator is offline while the other five Generators are online is: 0.0021 + j0.102 pu. This value is based on 13.8 kV, 100 MVA base. The 500 kV bus Thevenin impedance is: 0.00132 + j0.01135 pu.

The Generator will be designed to withstand a non-synchronous closure (up to 180° out of phase) on to this external system when the Generator is operating at 110% of Rated Voltage and with the system at 110% of Rated Voltage. The duration of such closure will be assumed to be less than 160 ms.

2.2.6 Materials

All materials used in the Generator electrical or magnetic current carrying components, will:

(a) for winding insulation, have a thermal rating equal to or better than Class 155 (F);

(b) for core laminations, have a thermal rating equal to or better than Class 155 (F);

(c) for other components, have a thermal rating equal to or better than Class 130 (B);

(d) be mutually compatible;

(e) be fully-cured before completion of the Work;

(f) be capable of withstanding the stresses experienced during all operating conditions;

(g) have a voltage rating that is appropriate for the Generator stator and rotor rated voltages; and

(h) use blocking, filler, collar, wedging, etc., materials with properties equivalent to or better than NEMA G10.

Notwithstanding the above, the Generator, as a system, will be rated Class 155 (F).

2.3 Electrical Design Criteria

2.3.1 Reactances

(a) Synchronous Reactance: The direct-axis synchronous reactance (unsaturated) X_d will be 0.82 pu ± 10%.

(b) Direct-Axis Transient Reactance: The direct-axis transient reactance (unsaturated) X'_d will be 0.28 pu +0%, -10%.

(c) Direct-Axis Sub-transient Reactance: The direct-axis sub-transient reactance (unsaturated) X''_d will be 0.21 pu +10%, -0%.

(d) Reactance Ratio: The ratio of the quadrature-axis sub-transient reactance to the direct-axis sub-transient reactance (X''_q/X''_d) will be less than 1.35.

2.3.2 Short Circuit Ratio

The short circuit ratio (SCR) will be greater than 1.1.

2.3.3 Variation from Rated Voltage

The Generator will:

(a) operate satisfactorily at the Generator Rated Output within a voltage range of ±5%;

(b) be capable of occasional operation, such as increasing transmission circuit loading temporarily in the event of contingency outages of other transmission lines and transmission system equipment, when at Generator Rated Output within a voltage range of ±10%;

(c) be capable of withstanding for at least 30 minutes, and without operator intervention, a transmission system disturbance that results in the Generator terminal voltage of ±10% when the Generator is operating at any point within the capability curve; and

(d) be capable of operating for a period of at least 30 s at any Generator terminal voltage between 10% and 120% of the rated terminal voltage with Generator circuit breaker open to enable the Generator open-circuit saturation test to be conducted.

2.3.4 Variation from Rated Frequency

The Generator will operate satisfactorily at Generator Rated Output, but within a frequency range of ±2%.

2.3.5 Short Circuit and Negative Sequence Current Requirements

The Generator will be capable of withstanding without damage a 30 s, three-phase, short circuit at the terminals when operating at Generator Rated Output, with a 5% over-voltage and with fixed excitation in accordance with IEEE C50.12 Clause 4.2.1.

The I_2^2t characteristics and the continuous negative sequence current capability of the Generator will be in accordance with IEEE C50.12 Clause 4.2.1.

2.3.6 Phase Sequence

The phase sequence at the Generator terminals will be such that when facing the Generator phase terminals from outside the Generator, the terminals will be arranged in the horizontal order “A”, “B”, “C” reading from left to right and the voltages at the terminals will reach their maximum positive values (phase sequence) in the same order.

In addition to the terminal marking stated in IEEE C50.12, the Generator phase terminals will be marked with “A”, “B” and “C”.

2.4 Mechanical Design Criteria

2.4.1 Speed

(a) Rated Speed: The rated synchronous speed of the Generator will be determined by the Contractor and will match the Rated Speed of the Turbine.

(b) Runaway Speed: The runaway speed of the Generator will be determined by the Contractor and will match the runaway speed of the Turbine.

2.4.2 Inertia Constant

The Generator moment of inertia, J_G, and the Generator inertia constant, H_G, will be determined by the Contractor based on the requirement for the Unit inertia constant, H_{GT}, in Appendix 6-2 [General Technical Specifications (SPGT)] at Generator Rated Output.

2.4.3 External Thrust

The total external thrust, including the weight of the Turbine shaft and runner, between the no-load operating condition and the Generator Rated Output operating condition, will be determined by the Contractor. The total vertical deflection of the Generator thrust bearing support system caused by the maximum hydraulic down-thrust will be less than 5 mm.

2.4.4 Airgap

The Generator airgap is the minimum distance between the Generator rotor pole faces and the Generator stator core bore. The nominal design stationary airgap will be not less than 0.13% of the Generator rotor diameter.

At all times when the Unit is in operation, the airgap will have a total variation (minimum to maximum) that does not exceed 30% of the measured average stationary airgap excluding the contribution to the variation that is resultant from long-term movement of the Powerhouse substructure.

2.4.5 Dimensional Requirements

The Generator will be designed, manufactured, and erected in accordance with the Drawings and within the tolerances set out in the CEATI Report No. T052700-0329 Part II. The robustness of the Generator design will be such that these erection tolerances are not exceeded during the Design Life of the Generator except:

(a) in instances where an erection tolerance is exceeded due to movement of the Powerhouse substructure; and

(b) as noted in SPG 2.5.4(f) for the Generator Stator core.

With reference to the CEATI Report No. T052700-0329 Parts I and II:

(c) for all circularity measurements, the nominal design diameter of the measured component will be contained within the circularity tolerance zone;

(d) any measurements for circularity or concentricity of the Generator rotor will be based on the rotor pole faces or the rotor rim flats; and

(e) the level tolerance for the Generator stator core will be deemed to apply to any axial location of the stator rather than just the mid-height of the stator.

2.4.6 Generator Temperature Regulation

The air temperature within the Generator Enclosure (the cold air temperature) will be regulated to a constant temperature (the “**Regulated Cold Air Temperature**”). The set point for this Regulated Cold Air Temperature will be adjustable, but under no circumstances will the Regulated Cold Air Temperature, including any hysteresis around the set point, exceed the maximum allowable cold air temperature specified in the Generator Rated Operating Conditions.

2.5 Stator

2.5.1 General

The Generator stator will:

(a) be of sufficient strength and stiffness to ensure a stable shape and airgap uniformity under all operating conditions;

(b) be capable of withstanding all stresses under all conditions including a Generator short circuit (whether on the transmission system or Generator stator), synchronizing out of phase, seismic accelerations, during braking, or any other relevant condition;

(c) have uniform thermal expansion and contraction to ensure circularity and the radial and axial alignment of the stator bore under all operating conditions;

(d) have uniform temperature over the axial height of the stator bore and stator winding under all normal operating conditions; and

(e) have sufficient space around the stator winding Drive End to allow a Worker to inspect and clean the lower end of the Generator without the need to remove the Generator rotor.

2.5.2 Stator Weight Requirements

The total combined weight of the Generator stator and with the Generator stator Lifting Device attached will not exceed the combined lifting capacity of the Powerhouse bridge cranes.

2.5.3 Stator Frame

(a) General: Stress and deformations in the Generator stator frame will be kept to minimum practicable values consistent with operating conditions before, during, and after grouting.

(b) Adjustment: The Generator stator sole-plates and frame will have means for future adjustment of the stator frame both laterally and vertically after final grouting. As a minimum there will be 10 mm of adjustment in all directions.

(c) Vibration Amplitude: When the Generator is operating in a stabilized condition (constant power and temperature) at any output within the capability curve, the radial vibration amplitude of the Generator stator frame at 120 Hz will be less than 0.025 mm peak-to-peak (measured at the top of the stator frame).

(d) External Loads: The Generator stator frame will support the Generator upper bracket and any loads that the Generator upper bracket is designed to carry.

(e) Access Hatches: Access hatches or hinged doors in the Generator stator frame wrapper plate will be provided so that the back of the entire stator core can be inspected by Workers. There will be a minimum of one inspection hatch located between every pair of Generator air coolers. It will be possible for a Worker to inspect the back of the core at each frame shelf.

As an alternative to, or in combination with, the access hatches, the core can be inspected through the Generator air cooler openings provided that:

(i) convenient provisions are made to remove the coolers without hoisting the coolers;

(ii) disassembly of other equipment is not required;

(iii) no more than two Workers to remove the coolers; and

(iv) this alternative is accepted.

(f) Sole-Plates and Anchors: The Generator stator frame sole-plates and anchors will incorporate:

(i) design features that provide for free radial movement due to thermal expansion of the stator frame while simultaneously limiting any tangential or vertical movement;

(ii) design that incorporates radial stops to limit any inward movement of the stator frame;

(iii) design features on the sole-plates to restrain the radial component of loads;

(iv) provisions for grouting voids after backfilling the concrete blockout;

(v) design features that provide for self-centering the stator during cool down;

(vi) self-lubricating anti-friction materials on the bearing surfaces to facilitate the radial movement of the frame on the sole-plates;

(vii) the ability to remove the self-lubricating anti-friction materials and the radial keys without jacking the entire stator so that they can be routinely inspected or replaced;

(viii) match marks that mark the relative position of the stator frame to the stator sole plate after the Generator has been assembled and aligned; and

(ix) a mechanical indication device that enables a Worker to visually monitor or to measure the movement of the stator frame relative to the stator sole plates.

2.5.4 Stator Core

(a) Diameter: The Generator stator core inside diameter will be large enough to pass the Turbine headcover and runner through it.

(b) Interleaved Design: The Generator stator core laminations will be completely interleaved for the entire stator circumference. A segmented stator core design will not be accepted.

(c) Vibration Amplitude: When the Generator is operating in a stabilized condition (constant power and temperature) at any output within the capability curve, the radial vibration amplitude of the stator core at 120 Hz will be less than 0.038 mm peak-to-peak (measured at the top of the stator core).

(d) Magnetic Flux Density: The magnetic flux density in the Generator stator core will be less than 1.4 T in the yoke and less than 1.9 T in the teeth.

(e) Thermal Requirements: As measured by RTDs permanently mounted in the back of the Generator stator core and stator frame, the maximum temperature:

(i) variation around the circumference of the stator core will be less than 5°C;

(ii) variation between the top and bottom of the stator core will be less than 5°C; and

(iii) difference between the back of the stator core and the stator frame will be 5°C less than the maximum permissible temperature difference used in the stator core stability and stator core buckling calculations.

(f) Core Waves: The Generator stator core will meet the following requirements:

(i) there will be no core waves, buckling, or substantial loss of core pressure during installation or operation. After commencement of Commercial Operation, in any location of the stator core, the core will pass the knife test specified in SPG 4.5.1;

(ii) at any axial elevation, variation of the core level will not exceed 5 mm during the Design Life of the Unit; and

(iii) any variation of the core level will be stable and not change over time.

(g) Laminations: The Generator stator core laminations will:

(i) be of low-loss, high-grade, non-orientated electrical silicon steel;

(ii) use materials and have workmanship and a finish in accordance with ASTM A677/A677M, DIN EN 10106, or better;

(iii) be free from burrs before the insulating coating is applied;

(iv) be coated on both sides with an insulating, inorganic insulating material to minimize eddy current losses;

(v) use a coating that is not affected by: normal operating temperature, atmospheric humidity, or solvents that may be used to clean the stator core or stator winding; and

(vi) be adequately keyed or dovetailed to the stator frame.

(h) Air Ducts: The Generator stator core air ducts between stator core packets will be arranged to make the air flow smooth and quiet, minimize air friction loss, and uniformly cool the core and winding.

(i) Key-bars: The Generator stator core key-bars will:

(i) have uniform spacing around the inner periphery of the frame;

(ii) be installed in such a way that the errors in the location of the key bars are not cumulative; and

(iii) be independent from the stator core studs.

(j) Core Studs: The Generator stator core studs will:

(i) avoid resonant-frequency vibration during all Unit operating conditions including excitation and de-excitation of the Generator rotor field winding;

(ii) be independent from the Generator stator core key bar system; and

(iii) be arranged such that it is possible to verify core compression without any disassembly. Locking of the core stud nuts by welding will not be permitted.

If the stator core studs pass through the stator core laminations, the stator core studs will be coated with an insulating material so that no current can pass between the stator core and the stator core studs. The insulating material will be epoxy powder coating with a cured thickness of at least 0.25 mm.

(k) Stacking: When stacking the stator core the Generator stator core laminations will be pressed uniformly and at specific intervals. Intermediate pressings of the stator core will be performed:

(i) when the stator core is less than 500 mm in height as measured from the bottom stator core pressure fingers;

(ii) at an interval of less than 500 mm of stator stack height since the previous stator core pressing; and

(iii) at 100 mm before reaching the top of the stator core.

At each press:

(iv) the circularity, verticality, straightness, and horizontality will be measured in accordance with the same requirements that will be used for the final verification. Those tolerances will be met at each intermediate press. Corrections will be made as the stacking progresses to meet the tolerance required for the final verification;

(v) the inside and outside height of the stator core will be measured at the same locations and corrections will be made as the stacking progresses to meet the tolerance required for the final verification. The horizontality tolerance applies for this radial verification; and

(vi) the stator core will be tested using a Richard’s L-3 knife at the bore and core back for loss of stator core pressure. In any location of the stator core it will be impossible to insert the knife more than 13 mm by hand without prying against a fixed object.

(l) Clamping: The Generator stator core clamping system will:

(i) ensure that the design clamping pressure is maintained throughout the Design Life of the Generator;

(ii) provide uniform clamping pressure throughout the axial and radial dimension of the stator core;

(iii) be adjustable to accommodate core settlement;

(iv) have adjustable clamping plates by means of screw threads or other acceptable device; and

(v) provide sufficient elasticity to accommodate minor dimensional changes in the core and to accommodate for core settlement.

(m) Core Slot Walls: The assembled Generator stator core slot walls will be:

(i) smooth with no protruding laminations, burrs, sharp points, or edges inside the slots; and

(ii) coated with semi conducting slot paint prior to winding installation.

(n) Penetrating Resin: The Generator stator core will have:

(i) penetrating resin applied to the stator core bore face. The resin will be applied in such a manner to not interfere with the installation or removal of the stator winding wedges; and

(ii) no penetrating resin applied to the back of the stator core.

2.5.5 Stator Winding

(a) General: The Generator stator winding includes the stator winding bars, stator circuit-rings, the main and neutral leads, and all connections between and support of the various components.

(b) Connections: The Generator stator winding will:

(i) be designed for wye connection;

(ii) have the parallel path circuits of each phase arranged and connected so that they can be easily disconnected for winding resistance and insulation resistance measurements;

(iii) have the main and neutral leads that:

(A) are arranged to allow for application of portable safety ground connections;

(B) have flexible and removable links. The links will:

(I) be designed to allow for thermal expansion of the stator;

(II) be designed and positioned to enable Workers to easily remove them to facilitate Generator maintenance (isolation and testing);

(III) when removed, provide an open gap clearance of at least 225 mm; and

(IV) when removed, separate the parallel stator winding circuits so that each circuit can be isolated and tested;

(iv) have neutral leads that:

(A) are insulated from ground for full line-to-line voltage;

(B) are wye-connected internally within the Generator Enclosure; and

(C) are terminated in a manner suitable for connection to the metal-enclosed Generator neutral cubicle (by Others) located outside the Generator Enclosure. The neutral cubicle will ground the Generator stator winding through a high resistance ground;

(v) be arranged to accept protection and monitoring systems as outlined in SPG 2.16;

(vi) have all clamps supporting the stator winding chamfered to ensure that the winding insulation is not damaged during thermal expansion and contraction; and

(vii) have any taped or encapsulated joint free from air pockets and voids.

(c) Stator Bar Construction: Each Generator stator winding bar will:

(i) be of Roebel design with a minimum 360° Roebel transposition in the slot portion of the bar;

(ii) consist of two stacks of multiple copper conductor strands with an insulated separator between the stacks;

(iii) use a glass-fibre material to insulate each conductor strand. The crimping process which forms the Roebel crossovers will not damage the strand insulation; and

(iv) use additional specific insulation at each Roebel transposition location.

(d) Finish: All parts of the Generator stator winding will:

(i) be smoothly and uniformly taped such that folded tapes in the groundwall insulation do not occur;

(ii) have no sharp points, edges, crevices, or abrupt change in shape and dimension;

(iii) once bars are installed in the core, the end-winding configuration will produce a consistent space between adjacent end-turns. This space will be such that partial discharge does not occur;

(iv) have ties and lashings with smooth finishes to eliminate sharp points or edges;

(v) be consistent in shape and dimension: front stator bars will be identical and back stator bars will be identical; and

(vi) ensure all that leads:

(A) are pre-formed in the factory, cleaned and readied for immediate connection at the Site. There will not be any residue of resin or remnants of other surface contaminants from the manufacturing process;

(B) have the ends aligned in all planes to facilitate brazing at the Site; and

(C) have sufficient length of exposed copper to make the required connections. The exposed copper will include sufficient space for heat-sinks required for brazing.

(e) Ground Insulation System: The Generator stator winding ground insulation system will:

(i) use a mica-tape, polyester- or epoxy-based groundwall insulation for the insulation between the conductor strands and the stator core;

(ii) use service-proven technology of more than 10 years in a similar application;

(iii) have the same insulation thickness throughout the length of the slot portion of the stator bar;

(iv) based on the rated line-to-ground voltage, have a design and measured voltage stress based on production samples that does not exceed 2.75 kV/mm. For the calculation of voltage stress, the insulation thickness is to be measured excluding the semi-conductive tape at the center of the broad (radial) side of the stator bar in accordance with IEEE 1043 Section 7.4, Figure 4; and

(v) in the slot and the end-turn portion of a stator bar, have the same number of tape layers and overlap area.

(f) Partial Discharge (corona) Suppression System: The Generator stator winding will:

(i) have an internal partial discharge suppression system applied at the stator bar Roebel crossovers and gaps on the surfaces of the transposed bar prior to application of ground insulation. The partial discharge suppression material will be conductive tapes and mastic;

(ii) have an external (slot) partial discharge suppression system for the slot portion of the winding groundwall. The partial discharge suppression system will be pre-impregnated, conductive polyester or epoxy tapes;

(iii) have a voltage grading system to prevent partial discharge at the end-turn portion of the winding. The voltage grading system will use semi-conductive tapes; and

(iv) ensure proper contact for the bond to the insulation surface and the overlap between the slot and end-turn partial discharge suppression tapes at the slot exit to prevent partial discharge.

Paint-based system partial discharge suppression systems are not allowed.

(g) <u>Slot Support System, including Wedges</u>: The Generator stator winding slot support system (including wedges) will:

(i) use slot packing materials that are semi-conductive throughout their volume if they are in contact with the stator bars;

(ii) exert sufficient force to prevent stator bar vibration caused by the electromagnetic forces;

(iii) use a service-proven, resilient side packing system to maintain continuous contact between the stator winding and the stator core in the circumferential direction and that will compensate for insulating material shrinkage;

(iv) use a service proven ripple spring follow up system to maintain continuous pressure on the winding in the radial direction and that will compensate for insulating material shrinkage; and

(v) use slot wedges that have a two-piece design such as a counter, piggy back or taper wedge design.

(h) <u>Support</u>: The Generator stator winding support system will:

(i) include sufficient blocking and other restraining measures to prevent movement and damage under sudden three-phase short circuit at the Generator terminals when the Generator is operated at Generator Rated Output and Generator Rated Operating Conditions and when operated according to the test parameters specified in SPG 5.2.21;

(ii) not have blocking or lashing placed over any of the partial discharge suppression systems;

(iii) have sufficient clearance to prevent tracking and discharge between conductors of different voltages;

(iv) have end-turn T-spacing designed to be at least (1 mm/kV * E)*1.05 where E is the rated line-to-line rms voltage of the Generator; and

(v) have measures to allow for thermal expansion.

2.5.6 Stator Lift Requirements

To enable end-of-life replacement, the Generator stator will:

(a) be designed to be removed from the Generator Enclosure to the Powerhouse service bay in one complete piece; and

(b) have all necessary stiffeners, pre-threaded bolt holes, adaptor plates, etc., necessary to facilitate the attachment of a stator Lifting Device to the Generator stator frame and to facilitate the lift itself.

In addition to the above, if the Generator stator is assembled in the Powerhouse service bay, the Generator stator will:

(c) be designed to be moved from the Powerhouse service bay to the Generator Enclosure in one complete piece; and

(d) be designed to minimize Generator stator core deflection during lifting and to ensure that the stator core bore dimensions remain within the allowable tolerances after lifting.

2.6 Rotor

2.6.1 General

The Generator rotor will:

(a) be designed to accommodate equipment required for air admission and/or synchronous condenser operation. Such equipment may include, an air head, air piping, and water piping; and

(b) have provisions for the installation of a TW Speed Sensing System.

2.6.2 Rotor Weight Requirements

The total combined weight of the Generator rotor, with all poles assembled, and with the Generator rotor Lifting Device attached will not exceed the combined lifting capacity of Powerhouse bridge cranes.

2.6.3 Rotor Rim

(a) Circularity: The Generator rotor circularity and concentricity will remain within the tolerances set out in the CEATI Report No. T052700-0329 Part II under all operating conditions, including runaway.

(b) Shrink: The Generator rotor rim will be shrunk fit to the rotor spider such that it remains in contact with the rotor spider up to a minimum separation speed of 110% of the Rated Speed.

(c) Structure: The Generator rotor rim will present a smooth continuous surface for the placement of the rotor pole bodies, keys, and field winding insulating collars.

(d) Stacking: The Generator rim stacking pattern will be designed to minimize the risk of rim kinking. Vent spacers will be welded.

(e) Keys: The Generator rim keys in the rim guiding system will be adjusted in the rotor spider keyways thus avoiding any undue clearance that could weaken the quality of the rim guidance. The torque between the rim and spider will be completely transmitted by shear stress in the keys. The keys will be designed for stability in their keyways thus preventing the possibility that the keys could twist due to the driving torque. The rim shrinking radial effort will be transmitted between the rim and each rotor spider arm through a key over the full length of the rim.

2.6.4 Rotor Poles

(a) Arrangement: The Generator and the Generator rotor poles will be arranged so that:

(i) it is possible to remove individual rotor poles to give access for repairs to the Generator stator core bore and stator winding; and

(ii) the rotor poles can be removed from the rotor without removing the Generator upper bracket or the complete Generator rotor.

(b) Keys: Where the tapered-key method of Generator rotor pole and rim assembly is used, the keys will project sufficiently above the rotor rim surface to allow use of a rotor pole key extraction system.

(c) Amortisseur Winding: The Generator rotor will be equipped with an amortisseur winding. The amortisseur winding will:

(i) be designed for maximum stability and minimum voltage distortion under fault conditions and will meet the reactance ratio requirements of SPG 2.3.1(d);

(ii) be designed so that the amortisseur damper bars remain tight in the pole body. There will be sufficient provision for thermal expansion of the damper bar. If an open slot system is used, positive grounding of the bar will be provided by swaging the slot opening in at least five locations equally spaced along the slot;

(iii) have means in the amortisseur winding for the flow of currents between poles, such as direct inter-polar connections or an embedded copper plate at each end of the rotor pole. Direct inter-polar damper connections will not use ferromagnetic materials;

(iv) ensure individual damper bar connections are silver-brazed. No brazing will be performed near any critically loaded section of the amortisseur winding; and

(v) be designed to withstand negative phase sequence currents of I_2^2t less than 40.

(d) Pole Bodies: The Generator rotor pole bodies, including pole end-plates, will:

(i) be fabricated from punched thin sheets stacked and pressed between pole end-plates;

(ii) not exceed the allowable temperature rise of the Generator when operating at the Generator Rated Output at the Generator Rated Operating Conditions;

(iii) present a smooth continuous surface for the placement of the rotor pole keys and the rotor pole field winding insulating collars;

(iv) have pole stop blocks that allow easy adjustment of the pole elevation for alignment to the rotor magnetic centre; and

(v) be designed such that the lifting device(s) bolts to the pole body and does not clamp to, or sling around, the pole body. In addition the lifting device(s) will facilitate placing the pole on the ground and rotating it vertical to horizontal to vertical without the use of any temporary blocking.

(e) Pole Numbering: The Generator rotor poles will:

(i) have the numbers permanent and visible from the top, bottom, and exterior (stator view) of the rotor;

(ii) be punched and at least 18 mm tall;

(iii) be orientated so that they can be read from the rotor rim for the numbers on the pole-ends;

(iv) be orientated so that they can be read from standing outside the rotor for the numbers on the pole-face side;

(v) be numbered as Pole 1 for the first pole connected to the field bus in the direction of rotation;

(vi) be numbered in an increasing order for subsequent poles in the direction of rotation;

(vii) be the highest pole-number for the last pole that is connected to the field bus;

(viii) be based on the direction of rotation as seen from the stator Connection End; and

(ix) be based on the direction of rotation from a rotor-centric view.

2.6.5 Rotor Interpolar Baffles

The Generator rotor inter-polar baffles (or V-blocks), if required, will:

(a) be constructed from non-conductive materials;

(b) be easily removable with the complete Generator rotor installed; and

(c) withstand the forces incurred during Unit runaway speed.

2.6.6 Rotor Pole (Field-coil) Winding

(a) Field Winding: The Generator rotor pole field-coil winding will:

(i) be made of copper;

(ii) consist of one series-connected circuit;

(iii) have winding turns that are evenly compressed and bonded together;

(iv) be pressed on identical fixtures or jigs instead of the pole bodies;

(v) be designed to minimize mechanical stresses in the corner areas of the winding turns;

(vi) have the thermal expansion and contraction restricted to one sliding face; and

(vii) be protected with a chemical- and moisture-resistant coating.

(b) Turn Insulation: The Generator rotor pole field coil winding turn insulation will:

(i) be designed to prevent electrical creepage and shorts between turns;

(ii) maintain the rotor pole windings in the designed shape without distortion or separation of the winding turns; and

(iii) use a minimum of two layers of insulation. The joints in one layer will be overlapped by the other layer.

(c) Ground Insulation: The Generator rotor pole field-coil winding ground insulation system including collars will:

(i) be designed to prevent electrical creepage due to the collection of contaminants;

(ii) be composed of rigid materials;

(iii) be such that there is no displacement of the insulation system components;

(iv) be sealed by Permatex Ultrablue RTV to prevent the ingress of moisture or contaminants; and

(v) be easy to dismantle from the rotor pole body for repair.

2.6.7 Rotor Pole Inter-connections

The Generator rotor pole field winding pole-to-pole inter-connections will:

(a) have a conducting and contacting cross-section at least equal to the nominal winding cross-section;

(b) be rigid copper bars or flexible-braid copper conductors;

(c) not be insulated;

(d) have connections that are tin or silver-plated;

(e) enable individual poles to be disconnected for testing or for removal while the Generator rotor is installed. Soft-solder or brazed connections will not be used; and

(f) be capable of withstanding mechanical stresses of normal in-service vibration and thermal cycling, and also the stresses incurred at runaway speed.

2.6.8 Field-Bus

The Generator field-bus connects the Generator rotor poles to the Generator rotor brushgear and also connects the Generator rotor brushgear to the Excitation System at the interface connection located at the transition point from the Generator upper bracket to the Generator Enclosure wall. The Generator field-bus will:

(a) be configured such that the bus connects to the first and last Generator rotor poles;

(b) be constructed of rigid copper bus bars firmly supported at regular intervals;

(c) be protected with a chemical- and moisture-resistant coating;

(d) have flexible links in the bus to compensate for mechanical and thermal expansion at, as a minimum the rotor spider-to-rim interface and the Generator with respect to the Generator Enclosure;

(e) have NEMA-type bolted connections at the Generator rotor brushgear such that the field-bus can be disconnected to allow the Generator rotor brushgear to be removed;

(f) have NEMA-type bolted connections at the transition point from the Generator field-bus on the Generator upper bracket to the Excitation System dc bus such that they can be disconnected to allow the Generator upper bracket to be removed;

(g) have connections that are tin or silver-plated and covered with an insulating boot;

(h) be configured such that the field-bus polarity can be changed at the Generator rotor collector brushgear connection-end; and

(i) for Worker safety protection have means to ground the field-bus on top of the rotor. Both leads (polarities) of the two field buses will have permanently-installed ground ball-studs that are accessible after minimal disassembly of the Generator.

Use of cables to connect the Generator rotor brushgear to the Excitation System instead of rigid copper bus bars is acceptable provided the cables meet the requirements described in this SPG 2.6.8 with the exception of SPG 2.6.8(b) and meet the requirements for the Excitation System field cables in accordance with Appendix 6-6 [Excitation System Specifications (SPEXC)].

2.6.9 Rotor Brushgear

The Generator rotor brushgear includes: the collector brushgear assembly (comprised of the stationary brushgear components including collector brush holder support rings, insulators, stand-off bolts, collector brush holders, and collector brushes), collector slip ring assembly (comprised of the rotating brushgear components including collector slip rings (a positive slip ring and a negative slip ring), insulators, and clamping bolts), and instrument brush holders and brushes. The Generator rotor brushgear will meet the requirements of SPG 2.14 and:

(a) have means to ensure the temperatures of the collector slip rings and collector brushes do not exceed the brush manufacturer’s recommended maximum temperature limits under all operating conditions;

(b) ensure the temperature of the collector slip ring surfaces and each collector brush remains between 50°C and 85°C under all operating conditions;

(c) ensure the absolute temperature variance among all collector brushes is not greater than 20°C under all operating conditions;

(d) ensure that the brushes are installed in a staggered manner;

(e) ensure the collector slip rings and brushes are mounted so that inspection of the brushes while the Generator is running is both practical and safe for Workers;

(f) ensure that both the collector slip rings and brush holder support rings are each separated by an insulating barrier;

(g) use a solid (non-grooved) collector slip ring;

(h) ensure the collector slip rings are round with a total indicated run-out of less than 0.05 mm;

(i) ensure the run-out during operation of the collector slip rings is between 0.25 mm to 0.40 mm;

(j) ensure the surface finish of the collector slip rings is between 0.75 micrometres to 1.25 micrometres;

(k) ensure the degree of collector brush run-out, vibration and chatter, as measured by the motion at the back of the brushes, tracks the motion of the collector slip rings to within 5% of the measured displacement of the rings;

(l) have insulated brush holders to ensure that all of the current goes through the shunts/brush leads;

(m) use constant-pressure-type holders for all brushes including the collector brushes and instrument brushes;

(n) ensure the spring tension of the brush holders is within 10% of the recommended spring tension for the grade of brush used;

(o) ensure the collector brushes do not bounce, chatter, or excessively arc to ensure that the brush face surface is not detrimentally affected;

(p) ensure the collector brushes do not have highly polished or visibly worn areas on the sides of the brushes;

(q) have brushes of sufficient length and grade that they can remain in continuous operation for a minimum period of two years without having to be maintained;

(r) have clamps for holding the pig tails of the carbon brushes to the collector brushgear assembly. Threaded components will not be used for connecting the brush pig tails to the collector brushgear assembly; and

(s) ensure the audible noise emitted by the brushgear system does not exceed the values specified by the relevant standard and will not include any high-frequency components.

2.6.10 Rotor Ground and Field Ground Detection

The Generator will have an insulated rotor (or shaft) grounding brush to be used for field ground detection. The rotor ground brush will:

(a) be installed in an easily accessible location;

(b) be wired to the Powerhouse ground grid using insulated #2/0 AWG copper conductor; and

(c) meet the requirements of SPG 2.6.9 except for ventilation and temperature.

The Generator field ground detection system is included in the scope of Work for the Exciter.

2.6.11 Rotor Lift Requirements

(a) General: The Generator rotor will:

    (i) be designed such that once any turbine air admission and brushgear components are removed, the rotor can be removed from the Generator Enclosure to the Powerhouse service bay in one complete piece;

(ii) have all necessary stiffeners, pre-threaded bolt holes, adaptor plates, etc., necessary to facilitate the attachment of a rotor Lifting Device to the rotor hub and to facilitate the lift itself; and

(iii) be designed to minimize rotor deflection during lifting.

(b) Removal and Installation: The number of person-hours required to perform all necessary activities to remove or install the Generator rotor will be less than or equal to 400 person-hours, considering:

(i) removal is deemed to commence after a Unit has been isolated and dewatered, but before any disassembly of the Unit has commenced;

(ii) removal is deemed to be complete when the rotor has been set down in the service bay and the Powerhouse bridge cranes have been disconnected from the rotor Lifting Device;

(iii) installation is deemed to commence when the powerhouse bridge cranes have been made available to connect to the rotor Lifting Device for use in the rotor lift;

(iv) installation is deemed to be complete when the Unit is ready to be de-isolated and returned to commercial operation;

(v) removal or installation includes all activities required to prepare the rotor Lifting Device for use prior to the lift and to prepare the rotor Lifting Device for storage after the lift;

(vi) the personnel available to perform Generator rotor removal or installation include:

(A) one General Trades personnel;

(B) four Mechanical Trades personnel;

(C) four Electrical Trades personnel; and

(D) one powerhouse bridge Crane Operator;

with additional personnel required during actual rotor lift and transport to the Powerhouse service bay floor (assume two hours):

(E) two General Trades personnel;

(F) two Mechanical Trades personnel; and

(G) two Electrical Trades personnel.

The Work includes any special tools, lifting equipment, rotor pedestal required for the removal and placement of the rotor on the Powerhouse service bay.

2.7 Coupling

2.7.1 General

The coupling of the Generator rotor to the Generator thrust block and of the Generator thrust block to the Turbine shaft will:

(a) enable the Generator rotor to be removed without blocking or shimming the Turbine shaft and runner on the discharge ring;

(b) enable the Generator rotor to be removed with minimal disturbance to the alignment of the Unit; and

(c) be designed such that the Generator rotor hub can be separated from the Generator thrust block without removing the Turbine shaft-to-thrust block coupling bolts.

2.7.2 Drilling Template

A drilling template and pin gauge for the coupling of the Generator thrust block to the Turbine shaft will be provided. The Contractor will drill the coupling holes undersize in the Turbine coupling to suit the Generator thrust block coupling flange.

2.7.3 Shaft Runout

The indicated shaft run-out is the maximum vibratory peak-to-peak displacement of the shaft in accordance with the ISO 7919 5.

For all steady-state operating regimes at Rated Speed, excited or unexcited, the total indicated shaft run-out referenced to the Generator guide bearing support or bearing housing and combining the synchronous and asynchronous run-outs, will not exceed the following limits:

(a) 0.15 mm in Operating Zone 1;

(b) 0.20 mm in Operating Zone 2; and

(c) 0.13 mm in Operating Zone 3.

The Generator guide bearing clearance selected by the Contractor will allow for a minimum 0.1 mm instantaneous oil film thickness between the rotating shaft and guide bearing pads at the operating conditions with the highest run-out and/or eccentricity of the shaft within the bearing.

The synchronous shaft run-out at the Generator guide bearing for all steady state operating regimes will not exceed the limits specified in the CEATI International Report No. T052700-0329 Hydroelectric Turbine Generator Units Guide for Erection Tolerances and Shaft System Alignment – Part II – Table 10.

In addition to the above requirements the non-rotating parts will meet the requirements of ISO 10816-5 evaluated for Zone A based on displacement measurements.

2.8 Generator Bearings

2.8.1 General

The Generator bearings will:

(a) be a combined Generator thrust and guide bearing installed below the Generator rotor;

(b) be mounted on bearing brackets which include sole-plates, foundation anchor bolts, nuts, washers and sleeves; and

(c) have a thrust block arrangement that allows for removal of the Generator rotor without disruption to the thrust block / Turbine shaft connection and alignment.

The Work includes all the handling and servicing equipment required for Generator bearing maintenance, including a removable platform if required.

2.8.2 Lower Bracket

The Work includes a Generator lower bracket. The lower bracket will:

(a) be used to support the Generator thrust bearing;

(b) be supported by the Powerhouse concrete (i.e., it will not be supported by any Generator or Turbine components);

(c) be designed to be adjustable to facilitate future leveling and centering of the Generator rotor within the Generator stator bore both laterally and vertically after final grouting of the sole-plates without cutting or welding. As a minimum there will be 10 mm of adjustment in all directions; and

(d) have sole-plates and anchors that incorporate the following:

    (i) design features that provide for free radial movement due to thermal expansion of the lower bracket if the design requires the lower bracket to slide on the sole plate;

    (ii) if so required by the design, incorporate radial stops to limit movement;

    (iii) be provided with lateral anchors to restrain the radial component of loads that are directed towards the centre of the Unit;

    (iv) have provisions for grouting voids after backfilling the concrete blockout;

    (v) design features that provide for self-centering if the lower bracket is required to slide on the sole-plate; and

    (vi) self-lubricating anti-friction materials to facilitate the radial movement of the lower bracket if it is required to slide on the sole-plates.

2.8.3 Thrust Bearing

The Generator thrust bearing will:

(a) be of the segmented, babbitted type, that automatically load-equalizes while in operation, and is designed to provide uniform distribution of the load among the bearing pads;

(b) have a continuous thrust runner surface (i.e., not split);

(c) have a removable/replaceable thrust runner surface;

(d) be self-lubricating without requiring the use of auxiliary pumps for normal operation;

(e) be designed to carry the weight of all rotating parts of the Generator and Turbine and all external thrusts under all operating conditions, including starting, running, overspeed, Generator faults, and stopping; and

(f) when the lift pump is not available, be capable of handling Unit starting and stopping without damage to the bearing babbitt surfaces. For the case where the Unit is being started, it will be possible to do so at any time within 24 hours after the Unit last stopped.

Removal of the Generator thrust bearing thrust runner will require no, or very limited, disassembly of Turbine components.

2.8.4 Guide Bearing

The Generator guide bearing will be designed and constructed in accordance with Appendix 6-2 [General Technical Specifications (SPGT)].

2.8.5 High-Pressure Oil Injection System (Lift Pump)

The Generator thrust bearing will be equipped with a high-pressure oil injection system (lift pump). The lift pump will:

(a) include the oil pump, a 600 V, 3-phase high-efficiency pump motor, instrumentation, valves and piping necessary to deliver high-pressure oil to all Generator thrust bearing pads;

(b) have sufficient capacity to lift all rotating components, including the Generator rotor, Turbine shaft, and Turbine runner when starting and stopping the Unit;

(c) have a motor starter (MCC) that is either integral with the lift pump assembly or mounted on the wall near the assembly;

(d) have any necessary piping, valves, and pressure gauges to enable a Worker to verify that the check valves are working correctly;

(e) be located outside of the Generator Enclosure and Turbine Pit; and

(f) have a common standard Swagelok manifold complete with isolation valves for the pressure gauge(s), pressure transducer, pressure switches, etc., to permit isolation of the pumping circuit for testing and calibration of the devices.

The Work includes the wiring for all control, auxiliary, instrumentation, and pressure switch contacts to the Generator Terminal Cabinet. The power cables to the lift pump motor starter will be supplied by Others.

2.8.6 Protection Against Moisture Ingress

The Generator bearing will be designed to prevent moisture ingress to the Generator bearing lubrication system, including in scenarios where there may be a significant amount of moisture in the air within Generator Enclosure such as during operation of the Generator fire protection system.

Scenarios of significant moisture in the air within the Generator Enclosure will not:

(a) affect the normal and proper operation of the bearing lubrication system; and

(b) have any adverse effect on the Generator bearing operation.

2.8.7 Protection Against Generator Enclosure Pressurization

The Generator thrust bearing will be designed to ensure that the air pressure in all air-containing spaces within the Generator thrust bearing lubricating oil reservoir remain equal, including in extreme scenarios such as when the Generator Enclosure pressure relief device fails to operate during a Generator stator winding phase-to-phase fault event.

2.8.8 Maintainability and Access

Arrangement and design of the Generator bearings will:

(a) have four removable access hatches in the Generator guide bearing top cover(s) located at 90 degrees around the circumference of the Generator guide bearing to enable the installation of temporary shim and/or to enable temporary adjustment of four Generator guide bearing pads by a Worker to enable “spiking” or centering of the rotor to facilitate maintenance on the Unit. There will not be any instrumentation installed in or over these access hatches;

(b) have the ability to remove any thrust pad, for inspection or replacement, without significant disassembly such as rotor removal, oil cooler removal, disassembly of the oil reservoir, guide bearing disassembly; and

(c) ensure that the inspection or maintenance hatches located in the side of the Generator bearing oil pot(s) have a hatch design that will prevent a rapid, uncontrolled release of the oil from the bearing pot will one or more hatch fasteners become loose or fail. The rate of leakage will be such that there is sufficient time to shut down a Unit without damage occurring to the bearing after detection of a low bearing oil level.

2.9 Generator Brakes and Jacks

2.9.1 General

The Generator will be equipped with a combined rotor brake and jacking system. The rotor brake and jacking system will:

(a) have brakes that are pneumatically operated and capable of repeatedly bringing the Unit rotating components to a complete stop within the time specified in Appendix 6-2 [General Technical Specifications (SPGT)], with the field excitation removed, and with the Turbine wicket gates closed, but with normal leakage through the Turbine wicket gates;

(b) have a Generator rotor jacking system that is hydraulically-operated and capable of lifting all rotating components, including the Generator rotor, Turbine shaft, and Turbine runner to a distance sufficiently high enough to permit removal of all maintainable Generator thrust bearing components;

(c) be easily accessible by a Worker for operating the Generator rotor jacking system blocking device(s) or to replace the brake shoes without the need for a ladder or scaffolding; and

(d) include sole-plates if concrete pedestals are required.

A type of Generator brake in which oil is present in the brake cylinder during a Generator rotor braking operation will not be permitted.

The Work includes all control, instrumentation, limit switches, and pressure switch contacts needed for the operation of the Generator brakes and Generator rotor jacking system and includes wiring this equipment to the Generator Terminal Cabinet. The control PLC and control logic for automatic and manual admission to, and release of, air from the operating cylinders of the Generator brakes will be supplied by Others.

2.9.2 Brake Cylinder Assemblies

The pistons in the Generator brake cylinder assemblies will:

(a) be fitted with suitable synthetic composite piston rings shaped to make close contact and apply uniform pressure on the cylinder walls;

(b) have suitable rider bands of similar material to ensure no contact between the piston and cylinder wall; and

(c) have mechanical stops incorporated in each Generator brake cylinder assembly that physically limits the maximum stroke of the cylinder to a distance not greater than the maximum allowable jacking distance under a jacking operation.

2.9.3 Brake Shoes

The Generator brake shoes will:

(a) bear against the brake track wearing surfaces on the lower side of the rotor;

(b) be easily removable by a Worker to facilitate replacement;

(c) be keyed or otherwise securely fastened; and

(d) contain no hazardous substances.

2.9.4 Brake Track

The Generator brake track will:

(a) have segmented brake track wearing surfaces;

(b) have provisions to accommodate thermal expansion;

(c) be installed on a machined surface or on machined spacers to minimize the need for shimming;

(d) have means to adjust the track such that:

  (i) the flatness of the entire brake track can be set to within 2.5 mm; and

  (ii) the vertical gap between segments can be set to be between 0 mm to 0.35 mm and such that the step appears to be a step down to the brake pad as the brake pad rides against the brake track; and

(e) be secured using bolts that are mechanically locked by a means that can be verified visually.

2.9.5 Brake Compressed Air

The Generator brake compressed air system for each Unit will:

(a) have a dedicated Generator brake air receiver designed for three full stops of the Unit without additional air from the Powerhouse brake air system and will be sized sufficiently so that the third full stop of the Unit takes no more than 20% longer than the first full stop;

(b) have a check valve located downstream of the Powerhouse brake air supply Double Block and Bleed isolation valves, but before the Generator brake air receiver;

(c) have an electrically operated solenoid valve for actuation of the brakes, that operates on 125 Vdc input power, and also includes a manual operation handle or lever with a mechanical lock to keep the brakes applied;

(d) have a pressure gauge on the supply side and the brake side of the solenoid valve; and

(e) have a silencer on the exhaust of the solenoid valve described above.

2.9.6 Brake Dust Collection System

The Generator brake dust collection system will:

(a) be fully self-contained, fireproof brake dust vacuum removal and collection system used to prevent brake dust contamination of the Generator pit and windings;

(b) be activated only on Unit shutdown;

(c) start approximately 15 s (adjustable) prior to brake application;

(d) stop approximately 120 s (adjustable) after the Unit has come to a complete stop;

(e) be interlocked with the fire protection system to prevent operation in the event of a suspected fire;

(f) have a dust collection system designed in accordance with the American Conference of Government Industrial Hygienists publication “Industrial Ventilation, a Manual of Recommended Practice for Design”, latest edition;

(g) have a dust collection hood for each Generator brake assembly. The dust collection hood will be:

    (i) designed with replaceable seals that are pressed against the brake track during the braking sequence to ensure containment of brake dust; and

    (ii) designed and installed to facilitate brake pad replacement;

(h) have ductwork that:

    (i) is designed in accordance with SMACNA standards;

    (ii) has a minimum transport velocity of 20 m/s in the main duct and 23 m/s in branch ducts;

    (iii) minimizes interference with Worker mobility;

    (iv) is sufficiently robust that a Worker can stand on the ductwork without causing damage to the ductwork;

(v) minimizes the use of flexible ductwork;

(vi) has a layout that minimizes the number of bends;

(vii) has branch entries and transitions that are fabricated in metal;

(viii) has branches that enter the main duct at the top or the sides and at an angle of 30 degrees or less;

(ix) has cleanouts to inspect and clean the ductwork; and

(x) is well sealed at all joints;

(i) have ON, OFF, and REMOTE control capability. The contact for REMOTE control will be a form C contact; and

(j) be located outside of the Generator Pit and Turbine Pit.

2.9.7 Braking Sequences

The Equipment and the Generator brakes will be designed for two braking sequences:

(a) Normal Shutdown: For a normal Unit shutdown operation the Generator brakes will be:

(i) capable of being applied between 30% and 5% of Rated Speed;

(ii) capable of stopping the Generator a minimum of four times in each hour; and

(iii) continuously applied during the braking sequence and when the Generator is at rest.

(b) Emergency Shutdown: For an emergency Unit shutdown operation such as when there is a problem with the Generator thrust bearing or a Turbine wicket gate, the Generator brakes will be:

(i) applied at approximately 50% of Rated Speed;

(ii) designed to bring the rotating parts to a stop in less than 10 minutes with a leakage torque applied to the Turbine sufficient to maintain the Generator at 25% of Rated Speed; and

(iii) continuously applied during the braking sequence and when the Generator is at rest.

For both cases the field excitation is removed, and the generator disconnected from the system.

2.9.8 Rotor Jacking System

The Generator rotor jacking system will:

(a) use a portable Generator rotor jacking pump assembly to supply the hydraulic pressure required for the jacking operation;

(b) have means for easily and quickly blocking the rotor in the fully raised position at the completion of a jacking operation. The blocking devices will be such that it will not be necessary to maintain hydraulic pressure on the jacks while the rotor is in the raised position;

(c) have limit switches to prevent Turbine or Generator components from contacting other components during a jacking operation such as the runner contacting the headcover or the runner seals contacting the stationary seals;

(d) be lockable such that when the rotor is in the fully-raised position and with the blocking devices in place, a Worker cannot pressurize the jacking system; and

(e) have all required piping and control wiring routed to a location outside the Generator Enclosure or Turbine Pit that can be easily accessed by a Worker with the Generator rotor jacking pump.

2.9.9 Brake and Jack System Piping

The piping for the Generator brakes and Generator rotor jacking system will:

(a) include all piping, valves, pressure regulators, pressure relief valves, exhaust silencer, etc., necessary to deliver air and oil to the system and necessary to drain oil from the system;

(b) have the oil used in the jacking operation drain to the jacking oil pump sump after a jacking operation;

(c) collect oil that leaks past the brake pistons and return the oil to the jacking oil pump sump;

(d) allow all oil to be scavenged from the brake cylinders after a jacking operation;

(e) have an oil trap to collect oil that has remained in the Generator rotor jacking system after a jacking operation and capture oil mist during braking. This trap will be easily accessible by a Worker to permit draining of the oil from the trap;

(f) not permit oil used during or after a jacking operation to contaminate the Generator brake and process air system; and

(g) have a common standard Swagelok manifold complete with isolation valves for all pressure gauge(s), pressure transducer, pressure switches, etc., to permit isolation of the pumping and air delivery circuits for testing and calibration of the devices.

2.10 Generator Enclosure

2.10.1 General

The Generator enclosure system (the “**Generator Enclosure**”) consists of formed concrete walls surrounding the Generator, the Generator upper bracket, the Generator top covers and a Worker access platform or concrete floor above the Turbine Pit. The Work includes:

(a) all necessary steel parts, anchor bolts, and other Equipment components required for embedment in the Generator Enclosure concrete by Others; and

(b) supply and installation of all supplementary steel work and supports as may be necessary for Equipment after the Generator Enclosure walls and floor have been installed.

The Generator Enclosure will:

(c) be sealed to minimize air leakage into or out of the Generator Enclosure;

(d) have means for controlled relief of excess air pressure within the Generator Enclosure as a result of a severe Generator stator winding fault. The pressure relief device(s) will be sized to relieve the pressure quickly enough to prevent distortion or lifting of other Generator Enclosure components such as the Generator top covers;

(e) have permanent light fixtures. The number and arrangement of light fixtures required will be such that the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] are met in all areas of the Generator Enclosure; and

(f) have 600 V and 120 V power receptacles located so that no point on the Generator Enclosure walls is more than 8 m away from each type of receptacle.

2.10.2 Noise Insulation

The Generator Enclosure will have measures to minimize noise emission from within the Generator Enclosure, such that the maximum noise level outside the Generator Enclosure meets the requirements of Appendix 6-2 [General Technical Specifications (SPGT)]. Additional measures to reduce the noise level outside the Generator Enclosure will include:

(a) Generator Enclosure doors that are acoustically treated and provided with airtight seals resulting in sound transmission class ratings of 50 or greater;

(b) sealing all openings, etc., linking the Generator Enclosure to the Powerhouse to an equivalent sound transmission class rating of not less than 50; and

(c) acoustic treatment of the Generator top covers which will result in an overall sound transmission class rating of 50 or greater.

2.10.3 Enclosure Heaters

If required for the Contractor's design, the Work includes electric space heaters installed within the Generator Enclosure. The space heaters will:

(a) have sufficient capacity to prevent moisture condensation from forming on the Generator stator and rotor windings when the Generator is not in service;

(b) be capable of keeping the winding temperatures at least 5°C above the coolest expected ambient in the Powerhouse when all of the Generator Enclosure doors are closed and when the Generator top covers are in place;

(c) be designed to operate at 600 V and not more than 12 kW per heater circuit;

(d) have a HAND-OFF-REMOTE control switches that allows operation of the heaters manually or remotely;

(e) have fused disconnect switch and contactor assemblies for each heater circuit;

(f) have an integral thermostatic control switch for the heaters that turns the heaters on when the temperature within the Generator Enclosure drops to below 15°C; and

(g) be wired to the Powerhouse 600 V station service breaker panel for each Unit.

2.10.4 Access into the Generator Enclosure

Generator Enclosure access doors from the Powerhouse to the area behind the stator frame, each a part of an Access Route, will be provided. If the design of the Generators, together with the Generator Enclosures, allows Standing Workers to walk around the complete outside circumference of the

Generator stator, then a minimum of two Generator Enclosure doors will be provided for each Generator Enclosure. If it is not possible for Standing Workers to walk around the complete outside circumference of the stator, four Generator Enclosure doors will be provided (one per Generator quadrant).

The Generator Enclosure doors will:

(a) be arranged such that no tripping hazard is posed to Workers travelling through the door (floor surfaces located immediately inside and immediately outside the doors will be level, and the door sill will be flush with the adjacent floor surface);

(b) each have an access opening cross-section that is rectangular or rounded/chamfered-rectangular in shape, is unobstructed, and is of minimum clear dimensions 2000 mm high and 915 mm wide;

(c) when fully open, be hinged to swing wide enough open to allow the door to be flush against the outside wall of the Generator Enclosure;

(d) be equipped with a system that causes closing tendency, as well as a damper system to prevent slamming of the door (considering air pressure inside the Generator Enclosure);

(e) be equipped with a mechanism to enable it to be latched in the fully-open position during prolonged maintenance periods;

(f) have means to allow quick egress from the Generator Enclosure in the event of an emergency;

(g) be of adequate strength to withstand and be designed to remain completely closed if the Generator Enclosure is rapidly pressurized during a severe Generator stator winding fault or other similar event; and

(h) have a latching system that permits Workers inside and outside the Generator Enclosure to open the door, even after a sudden pressurization event.

2.10.5 Access within Generator Enclosure

The Generator Enclosure will be of sufficient size to enclose and provide Access Routes to the stator, Generator air coolers, piping and electrical connections and other parts of the Generator.

The design of the Generator, together with the Generator Enclosure and Generator Enclosure doors will provide Access Routes that allow:

(a) a Worker to inspect the back, bottom, and top of the Generator stator around its entire circumference;

(b) a Worker to inspect all Generator air coolers;

(c) two Workers to conduct a Rescue Operation involving a Patient in any location within the Generator Enclosure without requiring the use of overhead lifting equipment; and

(d) a Worker at any location inside the Generator Enclosure to have a minimum of two Access Routes available. The Access Routes and equipment within the Generator Enclosure will be arranged such that during normal operation and maintenance activities at least one Access Route will always be available if the alternate Access Route becomes unavailable.

Each Access Route will either:

(e) allow a Worker to be at all times at least 3.0 m from a normally energized component of a Unit or any other electrical Hazards; or

(f) if a distance of 3.0 m is not practicable, provide barriers to protect a Worker from normally energized components of a Unit or any other electrical Hazards.

2.11 Generator Pit

2.11.1 Generator Pit Maintainable Components

Each maintainable component within the Generator Pit (the "**Generator Pit Maintainable Components**") will be designed and will have a Procedure for moving it between its respective in-service position and a location outside of the Generator Pit, without removal of the Generator rotor. The Procedure will include consideration of the necessary tools, equipment, Worker complement, and lifting equipment. The key objective will be to eliminate all manual transfers and manipulation of any Generator Pit Maintainable Component by a Worker from the location where the component was removed to where it is set down on a Cart or other device.

The Generator Pit Maintainable Components include any Unit components installed in the Generator Pit that may require maintenance activities performed on them at any point during their Design Life, as required by the Contractor's Equipment design and Equipment maintenance schedule. Generator Pit Maintainable Components include:

(a) Generator bearing components:

   (i) all pads and shoes;

   (ii) coolers;

   (iii) covers; and

   (iv) instrumentation;

(b) Generator brakes (all components);

(c) permanently-installed rotor-turning device; and

(d) piping, valves, couplings, and instrumentation.

2.11.2 Lighting and Receptacles

The Generator Pit will:

(a) have permanent light fixtures. The number and arrangement of light fixtures required will be such that the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] are met in all areas of the Generator Pit; and

(b) have a minimum of one 120 V receptacle installed on each Generator brake pedestal.

2.11.3 Access to Generator Pit

A minimum of two Access Routes to the Generator Pit will be provided; neither of which can include a ladder. Access Routes to the Generator Pit from within the Generator Enclosure, Turbine Pit, or directly from the Powerhouse are acceptable. Access Routes sized to accommodate a Standing Worker are preferred to those sized to accommodate a Crouching Worker (sizing to accommodate Crouching Worker clearances will be considered a minimum requirement).

Access Routes will not expose a Crouching Worker to mechanical Hazards, including to Hazards associated with rotating equipment.

If staircase access to the Generator Pit is not provided, at least one Access Route will allow a Crouching Worker to conduct a Rescue Operation or to remove Generator Pit Maintainable Components by pushing a Cart, loaded with a Patient or Generator Pit Maintainable Components, from immediately beside the Generator bearings to either the Generator Enclosure or one of the Powerhouse floors.

Doors to the Generator Pit will be provided that meet the same criteria as for the Generator Enclosure access doors.

2.11.4 Access Within Generator Pit

The Worker access platform spanning from the Generator Pit concrete floor to the Generator bearings will be permanent (i.e., it can be left installed during Unit operation) and will have a surface that allows a Cart to move on it without its wheels getting caught in spaces or joints that may be present as part of the floor.

There will be adequate clearance between the Generator Pit floor or Worker access platform and the bottom of the rotor in the locations where Crouching Workers would be positioned to push the rotor to rotate it to a different position during maintenance activities. This push path will also be as free of tripping hazards as possible. The design will permit a Crouching Worker to manoeuver or push the rotor through a complete revolution in a continuous manner without the Crouching Workers needing to reposition themselves or otherwise interrupting pushing.

2.11.5 Access to Generator Bearings (Thrust and Guide Bearings)

The minimum clearance between the floor or permanent platform surface inside the Generator Pit and the bottom of the rotor, and around the periphery of the Generator bearing(s), will be sized and arranged to allow Standing Workers to perform inspection and maintenance work on the Generator bearing(s), using necessary tools and equipment.

The clearance between the top of the Generator thrust (and guide) bearing and the underside of the rotor will be sufficient to allow Workers to disassemble, inspect, maintain, and assemble the bearing(s) in accordance with the bearing maintenance Procedures.

2.11.6 Access to the Lower Bracket Sole-Plates

If the Generator design includes a lower bracket and if that lower bracket design is such that the Worker access platform spanning from the Generator Pit concrete floor to the Generator bearings is flush with the top of the lower bracket cross arms, access hatches will be provided to facilitate Worker access to the locations where the lower bracket cross arms rest on the lower bracket sole-plates. The hatches will be secured with latches that are operable from both inside the Generator Pit and the Turbine Pit.

2.12 Generator Ventilation and Cooling

2.12.1 Generator Ventilation System

(a) General: The Generator ventilation system will:

(i) meet the requirements of the Cooling Water System in Appendix 6-2 [General Technical Specifications (SPGT)];

(ii) be self-ventilating by means of the rotor acting as the fan;

(iii) be a closed circuit system in which the cooling air will be forced outward through the rotor, ventilating the rotor poles, the stator winding and the stator core, then passed through the Generator air coolers mounted on the outside of the stator frame and then re-circulated back into the rotor;

(iv) have sufficient capacity to ensure that the Generator is able to operate at Generator Rated Output at the Generator Rated Operating Conditions with one Generator air cooler out of service and with no heat being removed from the Generator by the heat recovery system; and

(v) have means to prevent vibration of components used in the ventilation system including, metal duct, acoustic silencers, steel plate, and shrouds.

(b) Stator and Rotor Shrouds: If the Generator ventilation system includes the use of shrouds over the stator end-windings, stator circuit-rings or over the rotor field poles and/or rim, the shrouds will:

(i) provide sufficient clearance to the stator end-windings, stator circuit-rings, the rotor field poles, or the rotor rim to prevent inadvertent contact with these components;

(ii) avoid the use of fasteners, anchors, hangers, or other components that might work loose and drop into the Generator;

(iii) be designed such that a Worker can remove the stator shrouds while the Generator rotor is in place; and

(iv) be made of light-weight material for easy removal by a Worker, but still retain sufficient mechanical strength to not distort or vibrate in service.

(c) Generator Air Coolers: The Generator air coolers will be water-cooled heat exchangers. The Generator air coolers will:

(i) be heavy duty, rugged construction, fin and tube heat exchangers;

(ii) have heat exchanger tubes made of 90/10 copper/nickel, seamless, soft annealed, ASTM B111 UNS C70600 Temper O61;

(iii) be designed so that individual tubes can be plugged with wooden dowels and still allow the Generator air cooler to function;

(iv) be designed to keep the rate of cooling water flow high enough at all times to prevent fouling the heat exchanger tubes. 10% extra surface area will be provided as a fouling margin;

(v) include isolation valves on the inlet and outlet cooling water piping to the Generator air cooler to enable a failed Generator air cooler to be quickly isolated;

(vi) include a manual balancing valve on the discharge side of each Generator air cooler;

(vii) have a condensation capture system or traps that drain to the sump. The drains from the capture system will drain through pipe(s) to the nearest floor drain;

(viii) be complete with a 25 mm drain connection. The drainage outlet will be connected to a gravity drain header terminating at a location to be determined by Hydro's Representative;

(ix) be complete with air vents at the top of each Generator air cooler to facilitate the purging of air when the Generator air coolers are being filled with water and to prevent a vacuum from forming in the Generator air coolers when cooling water is drained from the Generator air coolers; and

(x) be designed to automatically vent air if air becomes trapped in the cooling coils.

(d) Heat Recovery System Heat Exchangers: The heat exchangers used for the Generator heat recovery system specified in SPG 2.12.2 will meet the same requirements as the Generator air coolers.

Heat recovery system heat exchangers could be comprised of either:

(i) additional air coolers located between the stator frame and the conventional Generator air coolers; or

(ii) a number of Generator air coolers or portions of air coolers (split cooler configuration) capable of operating in a closed loop with the Powerhouse heating system (heat recovery mode) or as normal coolers (bypass mode) by actuation of three way valves.

The Generator heat recovery system heat exchangers will be connected to separate piping to the rest of the Generator air coolers. Refer to SPG 2.12.2 for additional details.

2.12.2 Generator Heat Recovery System

A Generator heat recovery system (HRS) will use heat from the Generator to supplement Powerhouse heating on demand from the Powerhouse heating system. The Generator heat recovery system will:

(a) have a total cooling capacity per Generator of 500 kW under the following conditions:

(i) Generator is operating at the Generator Rated Output;

(ii) water temperature entering the HRS heat exchangers is 25°C;

(b) operate in a closed loop between the Generator and the Powerhouse heating system to optimize the heat recovery temperature from the Generator; and

(c) not impede the ability of the Generator to operate at Generator Rated Output when at Generator Rated Operating Conditions.

The Work includes:

(d) the interconnecting wiring to the Generator Terminal Cabinet;

(e) the control valves, supply and return piping, and control and monitoring equipment/systems up to terminal point outside the Generator Enclosure; and

(f) collaboration with the Powerhouse heating system contractor on the design and interface with the Powerhouse heating system.

The Generator heat recovery system will have provision for thermal expansion of the water when operating as a closed loop. This will be located outside of the Generator Enclosure and be provided by Others.

2.12.3 Cooling Water and Piping Requirements

Generator cooling water piping system will be provided to deliver cooling water to the Generator air coolers, Generator bearings, and other Generator components as required.

Separate piping is required to circulate water to and from the Generator heat recovery system heat exchangers and the Powerhouse heating system.

The Generator cooling water and heat recovery system piping Work includes all piping up to the terminal points outside of Generator Enclosure or Turbine Pit. Final terminal points are to be accepted.

All the valves, meters, and monitoring devices that are part of the Generator cooling water piping, except for the:

(a) the individual Generator air coolers isolation and balancing valves;

(b) individual Generator bearing isolation valves;

(c) individual Generator air coolers drain valves; and

(d) any required air bleed and vacuum break assemblies,

will be installed outside the Generator Enclosure to facilitate ease of access for Workers to inspect and maintain this equipment.

2.12.4 Generator Cooling Water Flow Regulating Valve

A Generator cooling water flow regulating valve and temperature control equipment will be used to automatically regulate the cooling water discharged from the Generator air coolers to maintain a constant average air temperature leaving the Generator air coolers.

The Generator cooling water flow regulating valve will:

(a) be a globe valve rated for 1 MPa (150 pound ANSI), sized to pass the required maximum rate of flow of cooling water, and operate without cavitation throughout the range of flow based on the Cooling Water System design pressure;

(b) be either an air-operated actuator controlled by an electro-pneumatic valve positioner, or an electric actuator, and include an adjustable stop to block the valve from closing completely;

(c) use an electronic valve controller that, as a minimum, has an auto-manual control switch with the capability of manually setting the valve position, electronic valve position indication;

(d) fully open upon loss of the control signal or control pressure, or otherwise fail to the open position;

(e) be located outside the Generator Enclosure at a location accessible by a Standing Worker at floor level, to enable servicing and maintenance of the valve, actuator, and other components; and

(f) have a bypass piping arrangement to enable removal of the valve for maintenance. Two manual isolation valves and a manual balancing valve will be provided for the bypass, to enable operation of the Generator when the Generator cooling water flow regulating valve is out of service.

The Work for the Generator cooling water flow regulating valve includes:

(g) the Generator cooling water flow regulating valve;

(h) all interconnecting wiring from the valve to the Generator Terminal Cabinet;

(i) all wiring for the required instrumentation and indication devices to the Generator Terminal Cabinet; and

(j) the process air piping from the terminal point outside the Generator Enclosure to the valve positioner including the:

  (i) pressure regulator;

  (ii) pressure gauge; and

  (iii) any filter or dryer that may be required.

Powerhouse process air will be supplied by Others to a terminal point outside the Generator Enclosure.

2.12.5 Temperature Control System

The control logic and PLC for the Generator temperature control system will be provided by Others. The control logic will, as a minimum:

(a) use a Generator cooling control PLC located in the Unit Control Board;

(b) provide the 4-20 mA control signal to the Generator cooling water flow regulating valve;

(c) use the temperature signals from all of the Generator air cooler outlet air RTDs;

(d) have logic that filters out invalid RTD signals prior to averaging the RTDs signals together;

(e) average the RTD;

(f) use the 4-20 mA output signals for the valve position and the running and set temperature indication;

(g) provide control of the three-way valves for the Generator heat recovery system; and

(h) have provisions that allow for manual control from the Unit Control Board.

The Generator temperature control system will cause the Generator heat recovery system to go into bypass mode upon occurrence of:

(i) a Generator stop;

(j) a Generator trip;

(k) Generator equipment exceeding the Rated temperatures;

(l) when the cooling water exceeds a temperature at which the remaining coolers not used for heat recovery (with one cooler out of service) would be unable to adequately cool the Generator at Generator Rated Output;

(m) the Powerhouse heating not being required; or

(n) an initiation of the Powerhouse or Generator fire suppression system.

The Work includes provision of the control and instrumentation devices and wiring necessary to achieve the above Generator temperature control system features.

2.12.6 Maintainability and Access

(a) Inspection: The Generator, Generator Enclosure, Generator brake pedestals and Generator ventilation system will be designed with clearances that will permit Workers to comfortably complete a visual inspection of the core clamping system and the front and back of the complete stator end-winding system.

(b) Rotor Shrouds: To permit Workers to conduct inspections, if the Generator ventilation system includes shrouds over the rotor field poles and/or rim:

(i) it will be possible for two Workers to remove the shrouds without the aid of any lifting equipment. The effort and time required to remove the shrouds will be minimized; and

(ii) lifting handles will be provided on the shrouds to facilitate removal.

(c) Stator Shrouds: If the Generator ventilation system includes shrouds over any of the stator end-windings or stator circuit-ring:

(i) means, such as hinged inspection hatches in each shroud, will be incorporated to perform a cursory inspection of the stator winding and stator circuit-ring without the need to remove the shrouds;

(ii) it will be possible for two Workers to remove the shrouds without the aid of any lifting equipment. The effort and time required to remove the shrouds will be minimized; and

(iii) lifting handles will be provided on the shrouds to facilitate removal.

(d) Generator Air Cooler Removal: The arrangement of the Generator upper bracket will be such that it does not obstruct removal of the Generator air coolers. Each Generator air cooler will have permanently attached Lifting Points for removal using the Powerhouse bridge cranes.

(e) Generator Air Cooler Cleaning: Cooler waterboxes will be removable to permit access to the heat exchanger tubes for inspection and cleaning, and to enable the insertion of wooden dowel plugs in damaged or failed tubes.

2.13 Upper Bracket and Top Covers

A Generator upper bracket system that supports the Generator top covers, brushgear housing, TW Housing, Workers and small tools and equipment will be provided.

(a) General: The Generator upper bracket and Generator top covers will:

(i) completely cover the top of the Generator Enclosure to prevent contamination from entering or exiting the Generator Enclosure;

(ii) serve as a platform for Workers and equipment on the main floor of the Powerhouse;

(iii) be designed to accommodate a minimum uniform live load of 5 kPa;

(iv) have vibration isolators and gaskets;

(v) allow for appropriate circulation and temperature control of the air within the Generator Enclosure;

(vi) avoid the use of fasteners, anchors, hangers, or other components that might work loose and drop into the Generator; and

(vii) be designed to prevent the Generator upper bracket and the Generator top covers from lifting off of the Generator Enclosure if the Generator Enclosure is rapidly pressurized during a severe Generator stator winding fault or other similar event. Pressure relief device(s) can be used as one method to help limit the air pressure rise within the Generator Enclosure during such events. The system employed will minimally impact the effort required to remove the Generator top covers during Generator inspection and maintenance.

(b) <u>Lighting and Receptacles</u>: The Generator upper bracket will:

(i) have permanent light fixtures. The number and arrangement of light fixtures required will be such that the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] are met in all areas above the Generator rotor; and

(ii) have a minimum of eight 120 V receptacles equally spaced apart.

(c) <u>Drainage</u>: The Generator upper bracket and Generator top covers will:

(i) have Generator top cover panels that are designed to prevent liquids from leaking through the joints between each panel and between the panels and the Generator Enclosure walls;

(ii) have Generator top cover panels that are designed to prevent liquids from leaking through any openings on the Generator top cover surface; and

(iii) have a perimeter gutter and drainage system embedded in Generator Enclosure around the periphery of the Generator upper bracket and Generator top covers to collect liquids that have spilled onto the Generator top covers.

(d) <u>Removal and Installation</u>: The Generator top covers and Generator upper bracket will:

(i) for the Generator top covers, have means such as removable or built-in (preferred) Lifting Points to enable the use of one Powerhouse bridge crane to lift the Generator top covers off of the Generator upper bracket;

(ii) for the Generator upper bracket, have means such as removable or built-in (preferred) Lifting Points or provision for a Lifting Device to enable the use of one Powerhouse bridge crane to lift the Generator upper bracket off of the Generator with minimal disassembly of the Generator upper bracket (the Generator top covers can be removed in advance); and

(iii) have means to protect any noise insulation, isolators, gaskets, etc., installed on the Generator top covers and Generator upper bracket from mechanical damage during removal, storage, and reinstallation of the Generator top covers.

(e) Guardrails: The Generator upper bracket and Generator top covers will have a lightweight aluminum guardrail system that can be installed and removed by hand by one Worker. The guardrail system will:

(i) prevent Worker fall hazards;

(ii) be designed so that it is possible for a Worker to install the guardrails prior to removal of one or more Generator top covers;

(iii) be designed so that it is possible to configure the guardrails as necessary to completely enclose the open area created by the removal of one or more Generator top covers;

(iv) have sufficient quantity of guardrails to be able to completely enclose two Generator Enclosures in the event that all of the Generator top covers have been removed from two Units;

(v) have guardrail post hole pockets located around the periphery of each Generator Enclosure such that it is possible to place any guardrail in any location with minimal effort;

(vi) have, in addition to the above, guardrails for two Units that can be installed on the Generator top covers to create a safe pathway for Workers and Carts to access to the brushgear housing or to the Generator rotor access stairs from the Powerhouse main floor. A design where these pathway guardrails are identical to the Generator Enclosure guardrails is preferred;

(vii) have liquid tight Generator top cover post hole pockets; and

(viii) have at least twelve guardrail sections with a built in self-closing gate to enable Workers and Carts to get onto and off of the Generator top covers and onto and off of the Generator rotor access stairs when the guardrails are in place.

(f) Generator Rotor Inspection Hatch: A Generator rotor inspection hatch will be incorporated into the Generator top covers to enable Workers to access the Generator rotor spider from the top covers without the need to remove the top covers. The Generator rotor inspection hatch will:

(i) be hinged and include a latching mechanism that can be unlatched from the top cover side and rotor side of the hatch;

(ii) include a permanently fixed ladder that a Worker can use to climb down to the Generator rotor spider;

(iii) if necessary, include a removal extension for the ladder that provides something for Workers to hold onto when first starting to climb down from the top covers; and

(iv) be provided with removable handrails and a safety gate to prevent fall hazard when the hatch is in use.

2.14 Brushgear Housing

An enclosure, the brushgear housing, will be provided to house the Generator rotor brushgear.

2.14.1 Access and General Arrangement

The Generator brushgear housing will be configured such that:

(a) Workers can access the brushgear housing while the Generator is in operation;

(b) Workers can access the brushgear housing and brushgear assembly in the Standing position;

(c) there is sufficient height and width for a Standing Worker to walk around the entire circumference of the collector slip rings while the Unit is in service;

(d) there are no tripping hazards within the brushgear housing;

(e) the use of ladder(s) is not required for the primary means of access to the brushgear housing. Staircase access is acceptable;

(f) two Workers can conduct a Rescue Operation;

(g) there is a secondary means of egress for use during an emergency. This emergency egress will be located approximately 180 degrees opposite the primary means of access. Use of a ladder for the secondary means of egress is acceptable. This egress will have a minimize size sufficient to evacuate a Supine Worker;

(h) there is clear Lexan® viewing window to allow Workers to visually verify that it is safe to enter the brushgear housing when the unit is in service; and

(i) a Powerhouse bridge crane auxiliary hook can be used to remove the brushgear housing with minimal disassembly of the brushgear housing and, if the TW Speed Sensing System is located above the rotor, the TW Housing.

2.14.2 Ventilation and Cooling

The Generator brushgear housing will:

(a) if the brushgear equipment requires cooling, have a ventilation system that requires minimal maintenance (e.g., only filter changes) or electrical power;

(b) have means of adjusting (increasing or decreasing) the amount of ventilation in order to vary collector slip ring and brush operating temperatures; and

(c) have means to keep all brush (carbon) dust completely contained within the housing.

During the winter months, atmospheric humidity can drop below what is considered acceptable for the optimum function of the carbon brushes. A passive means will be provided, such as a place to secure a plastic ~20 L bucket full of water that can be safety removed from the brushgear housing by a Worker while the Unit is in service, to introduce additional moisture into the air within the brushgear housing.

2.14.3 Lighting and Receptacles

The Generator brushgear housing will:

(a) have permanent light fixtures. The number and arrangement of light fixtures required will such that the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] are met in all areas of the Generator brushgear housing; and

(b) have a minimum of one 120 V receptacle on the brushgear housing wall every 180 degrees.

2.14.4 Maintainability and Access

To facilitate inspection and maintenance of the Generator rotor brushgear, the brushgear housing will be configured such that there are:

(a) barriers as required to prevent Workers from being exposed to hazards when completing brushgear inspections while the Unit is in service;

(b) sufficient openings to permit Workers to visually inspect the brushgear assembly including the collector brushgear assembly and the collector slip ring assembly while the Unit is in service;

(c) sufficient openings to permit Workers to use an infrared temperature probe to measure the temperature of the brushgear assembly including all brush holders, all carbon brushes, the brush support ring, and the collector slip ring surfaces while the Unit is in service;

(d) sufficient openings or removable covers sized large enough to permit Workers to use a 203 mm x 152 mm collector slip ring stone on the collector slip rings in situ with minimal disassembly of the brushgear housing;

(e) sufficient openings or removable covers sized large enough to permit Workers to maintain the brushgear assembly including all brush holders, all carbon brushes, the brush support ring, and the collector slip ring surfaces with minimal disassembly of the brushgear housing; and

(f) sufficient passive ventilation to enable Workers to complete brushgear inspection and maintenance without the need for supplemental ventilation.

2.15 Toothed-Wheel Speed Sensing System Housing

If the Contractor's design utilizes a Toothed-Wheel that is installed above the Generator rotor, then the Contractor will provide a Toothed-Wheel housing (the "**TW Housing**") to house the Toothed-Wheel, ZVPU Probes and their mounting bracket system, and other parts of the Toothed-Wheel Speed Sensing System as required, and that:

(a) is located above the Generator brushgear housing;

(b) prevents Worker contact with moving parts of the TW Speed Sensing System while the Unit is in service;

(c) is sized large enough to permit Workers to access and maintain the TW Speed Sensing System in its in-service location and position, considering Workers using tools and equipment necessary for maintenance;

(d) includes clear Lexan® viewing windows to allow Workers to visually inspect the TW Speed Sensing System equipment while it is in operation, without disassembling or opening any part of the TW Housing;

(e) includes permanent light fixtures if required in order to meet the illumination requirements of Appendix 6-2 [General Technical Specifications (SPGT)] in all areas of the TW Housing;

(f) includes a 120 V receptacle; and

(g) includes stairs, and guardrails, if necessary, to provide access the TW Speed Sensing System for inspection and maintenance.

2.16 Instrumentation

2.16.1 General

(a) Except as otherwise expressly specified in the Contract Documents, all Generator instrumentation will be wired to and terminated in the Generator Terminal Cabinet.

(b) For clarity some instrumentation descriptions/requirements are located in other sections of Specifications.

2.16.2 Toothed-Wheel Speed-Sensing System

The Work includes a toothed-wheel speed-sensing system (the "**Toothed-Wheel Speed-Sensing System**" or "**TW Speed Sensing System**"), designed and arranged to measure Unit speed, and that:

(a) utilizes the following elements:

(i) a "**Toothed-Wheel**" or **"TW"** that:

(A) is made of steel;

(B) consists of alternating protruding sections (teeth) and recessed sections (spaces), that allow distinct sensing of its teeth and spaces by ZVPU Probes arranged around it;

(C) is firmly attached to the Turbine shaft or Generator shaft in a manner that ensures the rotational speed always matches the rotational speed of the Unit, and that includes any features necessary to accommodate movement of the Generator rotor (horizontally within the Generator guide bearing and vertically due to hydraulic thrust from the Turbine or rotor jacking operations) in a manner that ensures the ZVPU Probes will be able to sense Unit speed continuously during such movements;

(D) includes sufficient teeth to ensure accurate speed-sensing up to at least 105% of Unit runaway speed, and creep detection resolution of at least 3 degrees; and

(E) includes few enough teeth to allow a ZVPU Probe to distinctly and consistently distinguish between adjacent teeth or spaces;

(ii) ZVPU Probes in accordance with Appendix 6-4 [Governor System Specifications (SPGOV)];

(iii) a simple system of ZVPU probe brackets and fasteners, and that:

(A) ensures each ZVPU Probe will not move during Unit operation (considering vibration, windage, thermal cycling, and any other mechanical disturbances that may be experienced during Unit operation);

(B) ensures vertical alignment of the centre points of the ZVPU Probes' sensing faces with the plane that passes through the centreline of all of the teeth on the Toothed-Wheel; and

(C) allows for adequate radial, axial, and circumferential (relative to the Toothed-Wheel) adjustment of each ZVPU Probe, considering factors such as vertical movement due to lift pump operation, shaft runout and vibration, and Unit shimming and realignment that may be performed in the future;

(iv) signal conditioners in accordance with Appendix 6-4 [Governor System Specifications (SPGOV)]; and

(v) a high-speed counter-type electronic PLC module in accordance with Appendix 6-4 [Governor System Specifications (SPGOV)];

(b) includes all equipment and wiring necessary to generate the speed signals necessary for the correct operation of the Governor;

(c) includes sufficient allowance for movement to accommodate a rotor jacking operation; and

(d) if installed above the Generator rotor:

(i) be installed in the TW Housing; and

(ii) does not impede the ability to install an instrument slip ring assembly in the TW Housing to enable instrument signals to pass from the Generator rotor to the instrument slip ring assembly.

2.16.3 Stator Frame RTDs

The Generator stator frame will have a minimum of six RTDs. The stator frame RTDs will:

(a) be installed at the top, middle, and bottom of the frame in a minimum of two locations: at upstream and orthogonal to upstream in the opposite direction of rotation;

(b) be radially and vertically aligned in each location;

(c) be installed in the radial centre of the frame so that the frame temperature, and not the air temperature, is measured; and

(d) be replaceable without the need to disassemble the Generator.

One of the RTDs installation locations will be in the circumferential centre of an air cooler and one will be between two air coolers.

2.16.4 Stator Core RTDs

The Generator stator core will have a minimum of twelve RTDs. The stator core RTDs will:

(a) be embedded in and installed on the stator core at the top, middle, and bottom of the core in a minimum of two locations: at upstream and orthogonal to upstream in the opposite direction of rotation;

(b) be radially and vertically aligned in each location;

(c) measure the temperature in the stator core yoke approximately half the distance between the back of the slot and the back of the core. It is acceptable to glue these RTDs in the air-duct;

(d) measure the temperature of the back of the stator core. It is acceptable to glue these RTDs to the stator core back;

(e) be installed so that the core temperature, and not the air temperature, is measured; and

(f) be replaceable without the need to disassemble the Generator.

One of the RTDs installation locations will be in the circumferential middle of an air cooler and one will be between two air coolers.

2.16.5 Stator Winding RTDs

The Generator stator winding slots portion will have:

(a) at least two RTDs per circuit;

(b) at least one RTD per 15 stator slots; and

(c) a number of RTDs divisible by three.

The Generator stator winding slot RTDs will:

(d) be equally distributed around the circumference of the stator bore with one third located on the axial-top of the stator stack, one third in the axial-middle of the stack, and one third at the axial-bottom of the stack;

(e) be installed in the stator bar slots between the front and the back bars with the lead wire coming out of the top of the slot;

(f) be installed close to the neutral end of the winding;

(g) be of the dual-element type; and

(h) be integrated into filler strips that have the same dimensions and material properties as the stator winding slot centre fillers.

The Generator stator winding circuit-rings will have at least one RTD installed on each circuit-ring.

2.16.6 Field Winding RTDs

RTDs embedded in the rotor field windings are not required.

2.16.7 Generator Air Cooler RTDs

The Generator air coolers will each have two temperature averaging RTDs. Each RTD will:

(a) be installed in a zigzag pattern across the surface area of each Generator air cooler in order to measure the approximate average air temperature. One RTD will be on the hot side of the Generator air cooler for air leaving the Generator, and the other will be on the cool side for air leaving the Generator air cooler; and

(b) be terminated in such a manner that the RTDs can be easily disconnected to facilitate the removal of each Generator air cooler.

2.16.8 High-pressure Oil Injection System (Lift Pump)

The Generator lift pump will have the following instrumentation and controls:

(a) an oil pressure gauge for visual indication of the oil pressure;

(b) a temperature compensated pressure transducer; and

(c) pressure switch contacts with:

(i) one normally open contact that closes when adequate oil pressure has been established following a pump start when the Unit is at standstill; and

(ii) one normally closed contact that opens when oil pressure has been established following a pump start and remains open when adequate oil pressure is present during acceleration or deceleration of the Unit.

2.16.9 Brake Limit Switches

Each Generator brake assembly will be fitted with a limit switch that:

(a) indicates when the Generator brake cylinder is in the fully retracted position;

(b) is wired out to the Generator Terminal Cabinet such that it is possible to determine which Generator brake cylinder is not in the fully retracted position by measurement of the circuit resistance at the Generator Terminal Cabinet (i.e., the brake limit switches will not be wired in series); and

(c) is capable of adjustment for initial calibration purposes, and, where applicable, adjustment to accommodate brake shoe wear.

A red indicating LED for each brake limit switch will be provided in Generator Terminal Cabinet, and will be connected such that it will extinguish to indicate whenever the brake has released. The LED indication will:

(d) use terminal blocks that include LED indication integral to their design; and

(e) be arranged and clearly labelled such that a Worker viewing the LEDs from a distance of 1 m can easily distinguish the status of each specific brake when the door of the Generator Terminal Cabinet is open.

A cable, provided and terminated by Others in the Generator Terminal Cabinet, will be used to connect each brake limit switch to an external brake position monitoring system provided by Others.

2.16.10 Brake Air Pressure Switches

The Generator brake valve will:

(a) have a pressure switch installed upstream of it, used to indicate when the air supply pressure to the Generator brake valve is low, that is adjustable between 170 kPa and 1000 kPa; and

(b) have a pressure switch installed downstream of it, used to indicate that the valve has operated, that is adjustable between 170 kPa and 1000 kPa.

2.16.11 Rotor Jacking System Limit Switches

The Generator rotor jacking system will be fitted with limit switches that:

(a) are interlocked with the Generator rotor jacking system hydraulic control system such that hydraulic pump is automatically shut off when the maximum allowable jack travel has been reached; and

(b) are capable of adjustment for calibration purposes.

2.16.12 Current Transformers

(a) Protection and Metering Current Transformers: The Work includes two protection-class current transformers (CTs) per phase that will be installed inside the Generator Enclosure at the neutral end of the Generator stator winding. These current transformers will be used for primary and standby Generator protection.

The CTs will be supplied in accordance with ES 44-Z0510, IEEE C37.110 and IEC 60044-1 unless specifically noted otherwise. The CTs will be indoor, window-type with the ratings specified in Table 2.16.12(a). The CTs will not saturate under transient fault conditions.

Table 2.16.12(a) – CT Ratings

CT rated primary current	To be determined
CT rated secondary current	5 A
Type	TPS
Continuous current rating factor for secondary winding	1.5
Voltage class/BIL	To be determined
Accuracy limiting secondary exciting voltage (V_{al})	To be determined by BC Hydro
Accuracy limiting secondary exciting current (I_{al})	To be determined by BC Hydro
Mechanical short-time rating (crest)	To be determined
Thermal short-time rating (rms symmetrical)	To be determined
Maximum secondary resistance at 75°C	1.8 Ω
Frequency	60 Hz

In addition to the above, a third current transformer in each phase at the neutral end will be a metering class CT with a metering accuracy of 0.15B1.8. This transformer will be used for Unit efficiency testing and will be specially calibrated by the manufacturer with burdens of 0.1, 0.2, 0.5, 1.0 and 1.8 ohms and at 0.5, 1.25, 2.5, 3.75, 5.0 and 6.25 secondary amps.

(b) Neutral Balance CT: Neutral balance CT(s) will be installed at the neutral phase connection point(s).

(c) Neutral CT Compensating Windings: Previous BC Hydro experience with neutral current transformers, where the neutral connection of the Generator has been made in a limited space within the Generator Enclosure, has resulted in unacceptable current transformer performance. Compensating windings were required to correct the problem. The design of the neutral connection and the placement of the current transformers will be such that adequate spacing is used, which precludes the use of compensating or flux balancing windings.

(d) Split-Phase Current Transformers: Split-phase current transformers are not required.

(e) Current Transformer Construction and Wiring: Every current transformer will:

(i) have the secondary wiring of each current transformer fully distributed over the whole length of the core;

(ii) be made immune to proximity effects; and

(iii) be directly wired out to terminal blocks in an external junction box. Connections and terminations will be made as detailed in Appendix 6-2 [General Technical Specifications (SPGT)].

(f) Current Transformer Testing:

(i) If acceptable Type Test certificates and Reports (on identical CTs) are not available for submission, then type tests will be performed in accordance with IEC 60044-1.

(ii) Routine tests will be performed on each current transformer in accordance with IEC 60044-1.

(iii) The test Reports submitted for each current transformer will:

(A) include the manufacturer's serial number; and

(B) include record of calibration sheets that are included in the Report and submitted separately as Drawings.

(g) Protection-class CT: Protection-class CT(s) will have their accuracy class stated and stamped on the CT label according to CSA C60044-1:07 Table 1B.

2.16.13 Airgap Monitoring System

The Work includes a GE – Bently Nevada continuous online airgap monitoring system (AGMS). The AGMS will:

(a) be designed and installed in accordance with BC Hydro ES 44 Z0330;

(b) have four rotor- and four stator-mounted probes in accordance with the "slow", "tall" generator, "full" system design of BC Hydro ES 44 Z0330 (four rotor probes and four stator probes);

(c) be compatible with the Bently Nevada 3500 vibration monitoring rack;

(d) be compatible with the Bently Nevada 3500/46M hydro monitor modules;

(e) utilize Series 4000 50 mm BC Hydro-customized sensor probes, BC Hydro-customized extension cables, and signal conditioners;

(f) include the rotor- and stator-mounted AGMS Enclosures;

(g) be wired out to and terminated in rotor- or stator-mounted AGMS Enclosures; and

(h) be wired from the rotor- and stator-mounted AGMS Enclosures to the Generator Terminal Cabinet.

Others will supply and install the Bently Nevada 3500 vibration monitoring rack and the 3500/46M hydro monitor modules.

2.16.14 Partial Discharge Monitoring System

The Work includes an Iris Power Engineering Inc. continuous online partial discharge monitoring system. The partial discharge monitoring system will:

(a) be installed in accordance with the Iris PDA Coupler Installation Guide in a PDA differential mode;

(b) be compatible with the Iris Power Engineering, PDA-IV test instrument;

(c) have for each stator winding circuit, one epoxy-mica coupling capacitor installed;

(d) have, for each co-axial cable circuit, a surge arrester such the Network Technologies, Tii-355M, installed in an Enclosure near the epoxy-mica capacitor; and

(e) be wired out to and terminated in the continuous online partial discharge monitoring system monitoring cabinet mounted on the outside of the Generator Enclosure.

2.16.15 Field Temperature Monitoring System

A Field Temperature Monitoring System is not required.

2.16.16 Instrument Brushgear

The Generator rotor brushgear will include one set of permanently installed, insulated instrumentation brush holders and brushes for measurement of the Generator field voltage at the collector slip rings. The instrumentation brushes will be installed only during specialized Generator testing and otherwise removed from their holders when not in use. The grade of brush chosen will be such that the instrument brushes meet the requirements of IEEE 115.

2.17 Electrical Equipment and Devices

2.17.1 General

Except as otherwise expressly specified in the Contract Documents, Generator wiring and cabling will:

(a) for devices installed on the Generator upper bracket, be marshalled to a Generator upper bracket Enclosure mounted on the Generator upper bracket. Cabling from this Enclosure will be run in a common run of EMT or rigid conduit out of the Enclosure;

(b) for the stator winding RTDs, be marshalled to the Generator RTD Terminal Box;

(c) for devices installed on the Generator stator, except for the stator winding RTDs, be marshalled to the outside of the Generator stator frame in Enclosure(s); and

(d) for devices installed within the Generator Pit, be marshalled to a Generator bearing Enclosure(s) mounted on the side of or near the Generator bearing(s). Cabling from this Enclosure will be run in a common run of rigid conduit out of the Generator Pit.

The intent of marshalling wiring and cabling to a Generator upper bracket Enclosure and to a Generator bearing Enclosure is to minimize the amount of effort required to disconnect the instrumentation at these locations prior to removal of the Generator upper bracket or Generator bearing.

With the exception of the stator winding RTD cabling, cabling from the above Enclosures will be run to the Generator Terminal Cabinet.

Where feasible, tray systems may be substituted for conduit and the Contractor will submit the proposed tray systems for Consent.

2.17.2 Generator Terminal Cabinet

The wall-mounted Generator terminal cabinet (the "**Generator Terminal Cabinet**") will be located on the outside of the Generator Enclosure and will be supplied by Others. The Work includes cable entry and termination in the Generator Terminal Cabinet. The Generator Terminal Cabinet will:

(a) meet the requirements for Enclosures;

(b) except as otherwise expressly specified in this Appendix 6-5 [Generator Specifications (SPG)] or in Schedule 6 [Specifications and Drawings], be the final marshalling and termination point for all wiring and cabling located within the Generator Enclosure;

(c) have 30% extra space for future expansion;

(d) be supplied with hinged door(s), latches and handle; and

(e) have provision for cables, supplied and installed by Others, to enter the cabinet from either the top or bottom.

Wiring and cabling within the Generator Enclosure that will not be terminated in the Generator Terminal Cabinet include:

(f) stator winding RTD cabling;

(g) main and neutral CT cabling;

(h) partial discharge monitoring system coax cabling;

(i) lighting and outlet wiring within the Generator Enclosure; and

(j) the power cable for the lift pump.

Blockouts in the concrete wall will be installed by Others for transition of cables/conduits between the Generator Terminal Cabinet and devices/equipment inside the Generator Enclosure.

2.17.3 Generator RTD Terminal Cabinet

Special provision will be made for the termination of the Generator stator winding RTDs. A separate cabinet is required to remove exposure of the potentially high-voltage circuits from the other control and indication circuits.

The Work includes a wall-mounted Generator RTD terminal cabinet (the “**Generator RTD Terminal Cabinet**”) to be located on the outside of the Generator Enclosure and adjacent to the Generator Terminal Cabinet. The Generator RTD Terminal Cabinet will:

(a) meet the requirements for Enclosures;

(b) have 20% extra space for future expansion;

(c) be the marshalling and termination point for the Generator stator winding RTDs;

(d) be supplied with hinged door(s), latches and handle;

(e) provide surge protection devices on each lead from each RTD. The surge protectors will be commercially available devices, such as the Network Technologies, Tii-355M;

(f) have provision for cables, supplied and installed by Others, to enter the cabinet from either the top or bottom; and

(g) be arranged in accordance with the drawings 1006-H04-01031-001 and 1006-H04-01031-002.

2.18 Grounding

2.18.1 Connection to Station Ground

The Generator stator frame, Generator lower bracket or other Turbine support structure, the Generator upper bracket, and Generator brushgear housing will have provision made for, and be connected, each in four locations, to exposed ground plates and ground busses embedded or installed by Others inside and outside the Generator Enclosure. The Generator top covers will be bonded to the Generator upper bracket.

2.18.2 Personal Protection Grounds

The design of the Generator rotor and stator windings and connections will be accepted and will allow for installation of approved personal protection grounding hardware as listed in ASTM F855 and IEEE 1246. The personal protection grounds will be applied using a hotstick.

2.19 Fire Protection

The Work includes a complete fire protection and automatic water-spray deluge system including all the piping, connections, interconnections, and supply from the various plant systems such as plant air, cooling water return, fire protection water supply, protection, control, and station alarms in accordance with this Appendix 6-5 [Generator Specification (SPG)] and BC Hydro Generation Technical Specification 01.20.SPEC.01.

2.20 Equipment Identification

2.20.1 Generator Nameplate Placard

The Generator will be provided with a nameplate placard on the outside, downstream wall of the brushgear housing. The information on the nameplate will:

(a) be in accordance with IEEE C50.12; and

(b) include:

  (i) direction of rotation;

  (ii) insulation class;

  (iii) type of connection;

  (iv) the Unit number;

  (v) ambient temperature rating (degree C);

  (vi) date of installation;

  (vii) BC Hydro purchase order number; and

  (viii) BC Hydro contract number.

2.21 Tooling and Lifting Devices

2.21.1 Miscellaneous Tooling

The Work includes all tooling required to inspect or maintain any Generator component. As a minimum the tooling will include:

(a) two bar-pushers (if required for stator winding installation);

(b) three guide and thrust bearings dismantling devices;

(c) three dismantling devices for the removal of the Generator brakes;

(d) one spool piece that can be installed in place of the Generator temperature flow regulating valve when the valve is removed for maintenance;

(e) two removable Generator rotor access staircases that can be installed to provide Worker access from the Generator top covers to the Generator rotor or alternatively from the Powerhouse main floor to the Generator rotor. A Worker will be able to install a removable staircase while standing on the Powerhouse floor side of the Generator top cover guardrails; and

(f) two Generator upper bracket storage devices. The storage devices will be designed to enable storage of a Generator upper bracket assembly overtop of another Unit that is in service.

2.21.2 Rotor Jacking System Oil Pump

The Work includes one portable, motor-operated Generator rotor jacking oil pump and oil sump tank mounted on a base with wheels. The Generator rotor jacking pump will:

(a) have sufficient capacity to lift the rotating Generator and Turbine components; and

(b) be 600 V, 3-phase.

All electrical and piping equipment necessary to attach the Generator rotor jacking pump to the Generator rotor jacking system will be supplied including:

(c) Swagelok QF series Quick Connect nipple, complete with metal dust cap;

(d) flexible hose with Swagelok QF series Quick Connect valved coupler, complete with metal dust plug;

(e) Hubbell Twist-Lock - 2 wire inlet, Cat. No. 8815A, with No. 7420 lift cover and adapter Plate No. 7452 (for jacking limit switches);

(f) Hubbell No. 7101C connector with No. 6024 cover (for jacking limit switches); and

(g) Crouse Hinds Plug No. APJ-3385 (for main power supply).

The sump tank for the Generator rotor jacking pump will be provided with fill, drain, vent, oil inlet, oil outlet, gauge glass connections, and hand-hole cover.

The Work also includes all necessary controls and equipment for operation of the Generator rotor jacking pump including:

(h) flexible oil-resistant power cable for the pump motor;

(i) two-conductor, flexible, oil-resistant cable to connect to the jacking limit switches;

(j) momentary-type contact, heavy-duty, oil resistant START-STOP pushbutton;

(k) red running indication light;

(l) combination magnetic starter with 600-115 V single phase control transformer, three overload devices and fused disconnect switches; and

(m) oil pressure switch and oil pressure gauge.

2.21.3 Rotor-turning Device

The Work includes one permanently installed Generator rotor turning device for each Unit. Each rotor-turning device will:

(a) be capable of safely rotating the Unit for maintenance and inspection purposes, with the lift pump operating and the runner submerged;

(b) be capable of turning the Unit at a continuously-variable range of speeds in the forward direction of between 0.1 RPM and 1 RPM for up to 15 minutes and in the reverse direction at a minimum speed;

(c) be operable without disassembly of any Generator components; and

(d) be located such that it does not interfere with the maintenance and inspection of the Equipment.

It is expected that the rotor-turning device will consist of a hydraulically retracted friction drive wheel that would operate against the brake track. A hydraulically powered rotor-turning device will consist of the following:

(e) permanently installed hydraulically operated drive system for each Unit;

(f) two portable hydraulic power units to power the drive system that are capable of being easily moved to each Unit;

(g) permanent piping from the drive system to a convenient point outside the Generator Enclosure where the hydraulic power unit would be connected; and

(h) a control system that can be operated from either the hydraulic power unit or adjacent to the drive system.

2.21.4 <u>Rotor Pedestal</u>

The Work includes two rotor pedestals for the Generator rotors. The rotor pedestals will be designed to:

(a) support the Generator rotor in a high enough position that a Crouching Worker can access the underside of the Generator rotor while the rotor is sitting on the rotor pedestal;

(b) allow a Worker to access the inside of the Generator rotor hub from the underside of the rotor by including Worker access ports or other means; and

(c) enable a Worker to inspect and conduct NDT tests on the rotor hub to Turbine shaft flange by inclusion of access ports or other means.

2.21.5 <u>Lifting Devices and Lifting Points</u>

(a) <u>General</u>: The Work includes all Lifting Points and Lifting Devices required to lift any Generator component.

(b) <u>Lifting Points</u>: As a minimum, each of these Generator Components will have designated Lifting Points:

(i) TW Housing;

(ii) TW Speed Sensing System;

(iii) Generator brushgear housing;

(iv) Generator rotor brushgear collector slip rings;

(v) Generator guide bearing pads;

(vi) Generator upper bracket;

(vii) Generator air coolers;

(viii) Generator rotor (as a complete assembly);

(ix) Generator rotor poles;

(x) Generator rotor pole coils;

(xi) Generator thrust block;

(xii) Generator lower bracket; and

(xiii) Generator stator.

(c) Miscellaneous Lifting Devices: As a minimum, the following Lifting Devices are required for the first Generator:

(i) two brushgear housing Lifting Devices;

(ii) two top cover Lifting Devices;

(iii) two Generator rotor access staircase Lifting Devices;

(iv) three rotor pole coil Lifting Devices;

(v) two Generator upper bracket Lifting Devices (if other than standard rigging is required); and

(vi) two Generator lower bracket Lifting Devices (if the Generator is equipped with a lower bracket and other than standard rigging is required).

(d) Rotor Lifting Device: The Work includes one Lifting Device for the Generator rotor. The Generator rotor Lifting Device will be designed:

(i) to utilize the Powerhouse bridge cranes with a lifting beam to lift the fully-assembled Generator rotor including the Generator rotor poles;

(ii) so that a Generator rotor can be lifted over a Generator rotor sitting on a rotor pedestal on the Powerhouse floor in the Powerhouse service bay;

(iii) so that a Generator rotor can be lifted over a Generator stator sitting on the Powerhouse floor in the Powerhouse service bay; and

(iv) to allow the Generator rotor to traverse to the Powerhouse service bay without disassembly of the other Units.

(e) Stator Lifting Device: If a Generator stator Lifting Device is required by the Contractor for the Work, the Work includes one stator Lifting Device that will be designed:

(i) to utilize the Powerhouse bridge cranes;

(ii) to limit deformation and distortion of the Generator stator during lifting, travelling, and installation of the stator into the Generator Pit or Generator Enclosure;

(iii) so that the Generator stator can be lifted over a Generator rotor sitting on a rotor pedestal on the Powerhouse floor in the Powerhouse service bay;

(iv) so that the Generator stator can be lifted over a Generator stator sitting on the Powerhouse floor in the Powerhouse service bay; and

(v) to allow the Generator stator to traverse to the Powerhouse service bay without disassembly of the other Units.

(f) Rotor Pole Key Extraction System: The Work includes three rotor pole key extraction systems that will be designed to:

(i) extract the rotor pole keys without the use of the Powerhouse bridge crane;

(ii) allow one Worker to perform efficiently the key extraction process; and

(iii) ensure any components that are exposed to wear are readily commercially available.

(g) Rotor Pole Lifting Device: The Work includes three rotor pole Lifting Devices that will be designed to:

(i) be installed by two Workers, one working at each of the top and bottom of the pole (excluding the Powerhouse crane operator); and

(ii) enable the pole to be rotated from vertical to horizontal and back without the need for additional equipment or protection.

SPG3 MANUFACTURING, INSPECTION AND TEST REQUIREMENTS

3.1 Stator Bar Pre-Production Run Type Tests

As soon as possible after the Effective Date, but prior to the production of the Generator stator winding, pre-Production Run Type Tests will be performed on prototype stator bars.

3.1.1 Standards

The pre-Production Run Type Tests will generally be performed in accordance with the following standards:

(a) IEEE 1043: Recommended Practise for Voltage-Endurance Testing of Form-Wound Bars and Coils;

(b) IEEE 1310: Recommended Practice for Thermal Cycle Testing of Form-Wound Stator Bars and Coils for Large Generators; and

(c) IEEE 1553: Standard for Voltage-Endurance Testing of Form-Wound Coils and Bars for Hydrogenerators.

3.1.2 Testing

The Generator stator bar pre-Production Run Type Test parameters will be as follows:

(a) the prototype bars will be identical to the production bars in all respects;

(b) it is preferred that the tests be performed prior to manufacture of the production bars. However, if the tests are conducted concurrently with manufacture of the production bars, the Contractor will accept all risks associated with bars failing the tests including rejection of all bars produced;

(c) tests will be performed on each prototype bar in accordance with Table 3.1.5A;

(d) Type Tests 3 through 10 in Table 3.1.5B will be conducted by Powertech Labs Inc.;

(e) all costs associated with performing the tests will be borne by the Contractor;

(f) bars failing any test will not be repaired, but will be rejected and not supplied as part of the Work;

(g) all test results will be submitted by the test lab simultaneously to both Hydro's Representative and to the Contractor; and

(h) Hydro's Representative may select additional samples for dissection at BC Hydro's expense.

3.1.3 Test Results

The Generator stator bar pre-Production Run Type Test results will:

(a) include the test results of each and every prototype bar tested including rejects and test failures;

(b) be submitted electronically in the form of a Microsoft Excel workbook. The file will have a row for each bar and a column for each type of test data; and

(c) in addition to the Excel workbook, written Reports for each of the voltage endurance and thermal cycling test programs will be submitted.

3.1.4 Test Failures

If the Generator stator bar(s) fail the pre-Production Run Type Test program specified in SPG 3.1 then:

(a) the bar Production Run may be rejected;

(b) all bars that fail the test program will be dissected to identify the failure root cause;

(c) the Contractor will supply additional new bars for testing in which the failure cause has been corrected; and

(d) the additional supplied bars and testing of those bars will be at the Contractor's expense.

3.1.5 Testing Additional Generator Bars

Hydro's Representative may select additional Generator stator bars for testing from the Production Run(s). Testing of additional bars:

(a) will be at BC Hydro's expense; and

(b) may be subjected to any or all of the pre-Production Run Type Tests.

Table 3.1.5A – pre-Production Run Type Tests – Bar Quantity

Quantity	Voltage Endurance Test Program	Thermal Cycling Test Program	Finish-check Test and Corona-Imaging Tests
Bars to be Supplied	6 minimum (3 front, 3 back)	7 minimum (3 front, 3 back, one of either)	
Bars to be Tested	4: (2 front, 2 back) 5th and 6th bars: allocated as test failure replacement	6: (3 front, 3 back) 7th bar: control sample	The number of both back and front bars equal to at least the winding pitch plus one

Table 3.1.5B – pre-Production Run Type Tests – Test Sequence

Sequence	Test Type	SPG Section	Voltage Endurance Test Program	Thermal Cycling Test Program
1	Finish-check Test	3.1.6	Not applicable	Not applicable
2	Stator Core Model Winding Corona-imaging Test	3.1.7	Not applicable	Not applicable
3	Evaluative Tests	3.1.8	Yes	Yes
4	High-potential Test	3.1.13	Yes	Yes
5a	Voltage Endurance Test	3.1.14	Yes	Not applicable
5b	Thermal Cycling Test	3.1.15	Not applicable	Yes
6	High-potential Test	3.1.13	No	Yes
7	Evaluative Tests	3.1.8	Yes	Yes
8	Dissection Test	3.1.16	Yes, a minimum of 1 bar	Yes, a minimum of 1 bar
9	Voltage Endurance Test	3.1.14	Not applicable	Yes on 4 bars (2 front, 2 back)
10	Evaluative Tests	3.1.8	Not applicable	Yes at 200 hour and at test end for information only

3.1.6 Finish-Check Test

A finish-check test will be performed to confirm the Generator stator bar surface finish and physical shape. An acceptable stator model resembling a full-length section of the Generator stator core, and with a minimum number of full-size slots equal to one complete winding pitch plus one, will be used to check for bar-shape conformity. The:

(a) test will be performed on the number of both back and front bars equal to at least the throw plus one;

(b) bar surface will be smooth and consistent in cross-section, without bumps, depressions, or other defects;

(c) bar shape will allow bar installation to be in accordance with SPG 4.6.4;

(d) bar span (circumferential direction) dimension, when measured at the bar connection end, will vary from the design by less than 4 mm;

(e) bar drop (radial direction) dimension, when measured at the bar connection end, will vary from the design by less than 6 mm; and

(f) bar-ends will be well-aligned in all planes.

3.1.7 Stator Core Model Winding Corona-Imaging Test

To validate the clearance between adjacent Generator stator bars, a stator core model winding corona-imaging test will be performed:

(a) in accordance with IEEE 1799;

(b) in the phase-to-phase clearance test configuration;

(c) at the IEEE 1799 maximum recommended test voltage for factory testing;

(d) with the number of back bars and the number of front bars equal to one complete winding pitch;

(e) with the top bars installed on top of the back bars; and

(f) using an acceptable corona-imaging camera.

3.1.8 Evaluative Tests

Where the phrase “evaluative tests” occurs in Table 3.1.5B, it means the following Generator stator bar tests that are to be performed in the order listed:

(a) physical measurements test in accordance with SPG 3.1.9;

(b) surface resistivity test in accordance with SPG 3.1.10;

(c) partial discharge test in accordance with SPG 3.1.11; and

(d) dissipation factor and tip-up test in accordance with SPG 3.1.12.

3.1.9 Physical Measurements Test

Physical measurements of the Generator stator bar size will be taken. Upon VE test or TC test completion the bars will not suffer any damage.

Measurements will be taken at a minimum of the following Generator stator bar locations, but no further apart than 450 mm:

(a) at the Connection End, in the slot section 50 mm from the interface point of the slot tape and gradient paint;

(b) in the of the slot section, at the mid-point;

(c) at the Drive End, in the slot section 50 mm from the interface point of the slot tape and gradient paint;

(d) at the connection-end, in the corner-bend transition from the slot section to the end-turn straight section; and

(e) at the connection-end, in the straight section of the end-turn.

The following will be determined at each Generator stator bar location:

(f) the circumferential dimension (width) of the bar;

(g) the radial dimension (depth) of the bar; and

(h) the voltage stress in kV/m (using only the mica tape, thickness, not the semi-conductive tape thickness).

3.1.10 Surface Resistivity Test

Surface resistivity tests will be performed on the conductive material used on the slot section of the Generator stator bar prior to the application of any elastomeric materials applied to the slot surface of the bar.

The Generator stator bar surface resistivity will be measured using two methods:

(a) Ohms per Square Measurement Method: The resistivity of the conductive material will be measured in at least three locations along the length of the bar, but no further apart than 450 mm. The measured value will be between 200 ohms per square and 15 kohms per square:

  (i) the test will be performed by either using electrodes 25 mm long spaced 25 mm apart, or by using temporary conductive bands wound tightly around the perimeter of the bar at a distance equal to the perimeter length of the bar;

  (ii) for the electrode method, measurements will be performed on the wider sides of the bar; and

  (iii) using an ohmmeter, the resistance between the two electrodes or bands will be measured.

(b) Ohms Measurement Method: The resistivity of the conductive material will be measured along the bar slot section length. The measured value will be between 3000 ohms and 200 kohms:

  (i) the test will be performed by using temporary conductive bands tightly wound around the perimeter of the bar, near the ends of the slot portion of the bar; and

  (ii) using an ohmmeter, the resistance between the two bands will be measured.

3.1.11 Partial Discharge Tests

Partial discharge (PD) tests will be performed on the Generator stator bars in accordance with ASTM D1868. The test parameters will be as follows:

(a) the $|Q_m|_{max}$ values will be measured at a pulse rate of 10 pulses per second;

(b) the applied test voltage will be equal the rated Generator line-to-neutral voltage, and will be applied when the bars are at ambient temperature (20ºC approximately);

(c) a 1000 pF coupler capacitor will be used;

(d) the test unit will have a sensitivity of at least 2 mV. The preferred instrument for PD measurements is the IRIS Power Engineering, PDA-IV;

(e) PD pulses will be recorded over a one-minute period beginning two minutes after the application of the test voltage; and

(f) the number of pulses per second and phase angle will be categorized according to amplitude and polarity, and the results presented graphically in the form of 2D, 3D plots, and phase–resolved plots.

These Generator tests are for information only.

3.1.12 Dissipation Factor and Tip-up Test

Absolute dissipation factor and tip-up tests will be performed on the Generator stator bars according to IEEE 286.

The Generator stator bar tests will be performed at the voltages listed in Table 3.1.12A. The test results will be in accordance with Table 3.1.12B.

Table 3.1.12A – Dissipation Factor Test Voltages

Terminal Voltage [kV]	Dissipation Factor Test Voltages									Tip-Up Calc
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	
13.8	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	Col. 6-Col. 1
>14.3	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	Col. 7-Col. 1

Guard electrodes will be placed over the grading material where it overlaps the Generator stator bar semi-conductive slot material. The location of the guard electrodes will be in accordance with IEEE 286, paragraph 8.1.1 and Figure 4.

The Generator stator bar tests will be carried out at an ambient temperature between 15°C and 25°C.

Table 3.1.12B – Dissipation Factor and Tip-up Test

Criteria (for any one bar)	2 kV Dissipation Factor Value	Tip-up Value
Before either the VE Test or the TC Test	<= 1.2%	<= 0.6%
After either the VE Test or the TC Test	<= 1.5%	<= 0.9%
After the post-TC Test VE Test	for information only	for information only

3.1.13 High-potential Test

A 1 minute, 60 Hz high-potential test will be performed to ground on the Generator stator bars:

(a) prior to commencement of the VE or TC test program, at 1.40 times the total of twice the rated terminal voltage plus 1000 Vac (i.e., 1.40(2E+1);

(b) upon completion of the VE Test program, a high-potential test is not required; and

(c) upon completion of the TC Test program, in accordance with IEEE 1310.

During the Generator stator bar high-potential test, the slot portion of the bar will be in a grounded “dummy slot”.

3.1.14 Voltage Endurance Test

A voltage endurance (VE) test will be performed on the Generator stator bars in accordance with IEEE 1043 and 1553. The test voltage and duration will be according to the values shown in Table 1, Schedule A of IEEE 1553. The test temperature will be 110°C. There will be:

(a) no test failures prior to 200 hours of testing;

(b) not more than one failure after 200 hours of testing; and

(c) no damage to the corona suppression system such as de-bonding, carbonization, or coating deterioration.

For clarity, after 200 hours of testing, a maximum of one test failure will be permitted. In the case of any one failure after 200 hours, the failed bar will be replaced with two new bars. No additional failures will be accepted.

For information only, Hydro's Representative may decide to run some of the bars to failure at BC Hydro's expense.

3.1.15 Thermal Cycling Test

A thermal cycling (TC) test will be performed on the Generator stator bars in accordance with IEEE 1310. The bars will be tested for 500 cycles. The copper temperature will vary from 40°C to the thermal/temperature classification limit for Class 130 (B) systems. There will be:

(a) no de-bonding between the conductors and the groundwall insulation; and

(b) no delamination within the groundwall insulation.

At 50, 100, and 250 cycles, a tap test will be performed to determine if there are any obvious locations where the Generator stator bar insulation has delaminated.

At the completion of the thermal cycling test, Hydro's Representative will select a minimum of one bar for dissection.

3.1.16 Dissection Test

The Generator stator bar dissection will be performed:

(a) in accordance with the Contractor's Procedure;

(b) by the Contractor or the lab, at the preference of the Contractor; and

(c) while witnessed by both the Contractor and Hydro's Representative.

The Contractor's stator bar dissection Procedure will be submitted for Consent.

As a minimum, Generator stator bar dissections will be performed at the locations specified for physical measurements in SPG 3.1.9.

A tap test will be used to determine if there are any obvious locations where the Generator stator bar insulation has delaminated. If the tap test identifies one or more locations where the bar has delaminated, Hydro's Representative will select additional locations for dissection.

Each dissection will be visually inspected without the aid of a microscope. In the Generator stator bar slot section, there will be no delamination observed within the groundwall insulation or from the conductor. In the end-turn sections, unless significant delamination is observed, as determined by Hydro's Representative, acting reasonably, the dissections will be for information only. Delamination observed between the outer-two-most layers of ground insulation tape or in the outer-most 10% of the groundwall insulation thickness will be ignored.

For information only, Hydro's Representative may decide to dissect additional bars at BC Hydro's expense.

3.2 Stator Winding Factory Tests

3.2.1 General

(a) For each Generator stator bar shipment to the Site, test Reports for the factory tests specified in SPG 3.2, will be included in each crate.

(b) The following Production Tests will be performed on each Generator stator bar:

(i) strand-to-strand test in accordance with SPG 3.2.2;

(ii) bar surface resistivity test in accordance with SPG 3.2.3;

(iii) insulation resistance and high-potential test in accordance with SPG 3.2.4; and

(iv) dissipation factor and tip-up Test in accordance with SPG 3.2.5.

(c) The following Type Tests will be performed on Generator stator bars for each Production Run:

(i) finish-check test in accordance with SPG 3.2.6; and

(ii) stator core model winding corona-imaging test in accordance with SPG 3.2.7.

Type Tests will be performed on a number of front and back stator bars equal to the full winding pitch at the beginning of the manufacturing process when the first stator bars are produced.

(d) The Generator stator winding factory tests specified in SPG 3.2 are to be performed in accordance with the same tests specified in SPG 3.1 unless expressly stated otherwise.

(e) Generator stator bars not passing the tests specified in SPG 3.2 will not be reworked or refinished, but will be rejected and not supplied as part of the Work.

(f) Failure to pass any of the tests listed in SPG 3.2 may result in rejection of the bar Production Run.

3.2.2 Strand-to-Strand Test

The strand insulation of each combination of Generator stator bar strands will be tested for at least 1 second at 200 V, 60 Hz.

3.2.3 Bar Surface Resistivity Test

Surface resistivity tests will be performed on the Generator stator bars using both the ohms per square measurement method and the ohms measurement method:

(a) for the ohms per square measurement method, the results will be in the range of 200 ohm per square to 15,000 kohm per square; and

(b) for the ohms measurement method, the results will be in the range of 3000 ohm to 200 kohm.

3.2.4 High-potential Test

After completion of Generator stator bar manufacture and prior to shipment, a high-potential test of at least 1.5 times the total of twice the rated terminal voltage plus 1 kV (i.e., 1.5(2E+1)) at 60 Hz to ground for 1-minute will be performed on the Generator stator bars. During the test, the slot portion of the bar will be in a grounded “dummy slot”.

3.2.5 Dissipation Factor and Tip-up Test

Absolute dissipation factor and tip-up tests will be performed on the Generator stator bars. The test results will be in accordance with Table 3.2.5.

Table 3.2.5 – Dissipation Factor and Tip-up Test

Criteria (for any one bar)	2 kV Dissipation Factor Value for any one bar	Tip-up Value
Each bar Production Run	<= 1.2% maximum <= 1.0% average	<= 0.6% for 70% of the bars <= 0.8% for 30% of the bars

3.2.6 Finish-Check Test

A finish-check test will be performed on the Generator stator bars.

3.2.7 Stator Core Model Winding Corona-Imaging Test

A stator core model winding corona-imaging test will be performed on the Generator stator bars.

3.3 Stator Core Lamination Factory Tests

3.3.1 General

To ensure the integrity of the Generator stator core lamination steel and insulating material, Type Tests will be performed on the lamination punchings during each Production Run. Failure to pass any of the Type Tests listed in SPG 3.3 may result in rejection of the Production Run.

(a) The following Type Tests will be performed on the Generator stator core laminations:

(i) Epstein test in accordance with SPG 3.3.2;

(ii) Franklin test in accordance with SPG 3.3.3;

(iii) ductility test in accordance with SPG 3.3.4; and

(iv) enamel thickness test in accordance with SPG 3.3.5.

Generator stator laminations failing any Type Tests will not be reworked or refinished, but will be rejected and not supplied as part of the Work.

(b) Type Tests will be performed on punching samples during the Generator stator core lamination manufacturing. At each of the periods, a sufficient number of laminations will be selected to adequately perform the tests.

The Generator stator core Type Test periods are:

(i) at the beginning of the manufacturing process during the first few laminations produced;

(ii) approximately in the middle of the manufacturing process; and

(iii) near the end of the manufacturing of the process during the last few laminations produced.

3.3.2 Epstein Test

An Epstein test will be performed on the Generator stator core laminations in accordance with ASTM A 343 / A 343M. No annealing is required. The Epstein loss values at 1.0 T and 1.5 T before and after a thermal stabilization test will be within 5% of each other.

In addition to the Generator stator core lamination test results listed in ASTM A 343 / A 343M, the B-H permeability curves will be provided.

3.3.3 Franklin Test

A Franklin test will be performed on the Generator stator core laminations in accordance with ASTM A 717 / A 717M. The test will be performed with the lamination at room temperature.

The average current readings will be from readings taken on the Generator stator core lamination tooth sections and on the lamination core sections. The maximum value will not exceed 0.6 A and the average reading will not exceed 0.4 A.

3.3.4 Ductility Test

A ductility test will be performed on the Generator stator core laminations in accordance with ASTM A 720 / A 720M.

3.3.5 Enamel Thickness Test

An enamel thickness test will be performed on the Generator stator core laminations using a permascope electronic thickness gauge.

3.4 Rotor Pole Factory Tests

3.4.1 General

Prior to shipping from the manufacturer’s shop, each Generator rotor pole will:

(a) pass the following Production Tests:

(i) brazed connections test in accordance with SPG 3.4.2;

(ii) insulation resistance test in accordance with SPG 3.4.3;

(iii) high-potential test in accordance with SPG 3.4.4;

(iv) turn insulation test in accordance with SPG 3.4.5; and

(v) winding resistance test in accordance with SPG 3.4.6;

(b) be weighed and have a unique number assigned in accordance with SPG 3.4.7; and

(c) be completely assembled prior to testing.

3.4.2 Brazed Connections

All brazed connections in the Generator rotor pole coil construction and amortisseur winding will be checked using an approved process for brazing quality.

3.4.3 Insulation Resistance

A 1 minute, 2500 Vdc insulation resistance ($IR_{1\ min}$) test and a polarization index test will be performed on each Generator rotor pole in accordance with IEEE 43 and the result will be temperature corrected to 40°C. The temperature-corrected $IR_{1\ min}$ value will be greater than 10 Gohms.

3.4.4 High-potential

A 1 minute, 60 Hz high-potential test will be performed on the Generator rotor pole winding at a test voltage of a minimum of ten times the rated excitation voltage, but in no case less than 5000 Vac.

During the Generator rotor pole winding test, no type of temporary insulation will be used.

3.4.5 Turn Insulation

Tests will be performed on each Generator rotor pole to verify the turn insulation integrity including:

(a) a surge test using an impulse tester at a voltage equal to 120 V crest per turn and a rise time of 0.2 µs or shorter; and

(b) a high-frequency impedance test in accordance with BC Hydro MS 01.20.Test.05. A test at 415 Hz and a minimum of 30 A is preferred. The measured impedance value for each pole winding will not deviate from the average value by more than 5%.

3.4.6 Winding Resistance

A winding resistance test will be performed on each Generator rotor pole. The result will be recorded to five significant figures and then temperature corrected to the “reference temperature for use in determining I^2R losses” specified in IEEE C50.12. The temperature-corrected winding resistance value will not deviate from the calculated value by more than 2%.

If the temperature-corrected winding resistance value of the Generator rotor pole does not meet the above criteria, then the reason will be investigated and a written explanation submitted.

3.4.7 Weight and Number Assignment

Each Generator rotor pole will be weighed and the weight recorded. The pole weights will vary by less than 2%.

Based on the Generator rotor pole weights, the poles will be distributed around the rotor to minimize any out-of-balance condition. The rotor poles will be numbered in accordance with SPG 2.6.4(e).

3.5 Shop Testing and Assemblies Before Shipment

3.5.1 Generator Air Coolers

The Generator air coolers will be hydrostatically tested for two hours at a continuous water pressure of 1.5 times the Cooling Water System design pressure.

Leaks found during this test will be repaired and the air cooler retested.

3.5.2 Generator Brake Assemblies

Each Generator brake assembly will be pressure tested to 1.5 times the maximum Rotor Jacking Pressure system pressure to verify that:

(a) the mechanical stops have sufficient strength to limit the stroke of the brake cylinder without deformation of the stops; and

(b) there is no oil leakage past the brake cylinder seals after 1 hour under pressure.

The oil used for the Generator brake assembly test will be the same oil type used for the Generator rotor jacking system.

Leaks found during the Generator brake assembly test will be repaired and the Generator brake assembly will be retested to verify the repairs have been successful.

3.5.3 Lower Bracket

The Generator lower bracket boss, arms, and ring will be assembled together and the bearing oil coolers mounted.

3.5.4 Stator

The Generator stator frame will be assembled and the inside diameter checked. At least two layers of the stator core punchings will be stacked to check fit-up.

3.5.5 Rotor

At least 150 mm of the Generator rotor rim plates will be stacked to check fit-up. The rotor hub and arms will be bolted together.

3.6 Stress Relief Heat Treatments

Stress relief heat treatments will be executed on Generator large machined and weldment components. These include:

(a) the rotor hub;

(b) all rotating bearing components (if provided);

(c) the stub shaft (if provided); and

(d) the thrust bearing housing.

3.7 Brazing

3.7.1 General

Except as otherwise expressly specified in SPG 3.7, all brazed electrical connections will meet the specifications for welding as specified in Appendix 6-2 [General Technical Specifications (SPGT)].

For clarity, the words: brazing, braze, or brazer can generally be substituted for the words: welding, weld, or welder where used in the welding specifications in Appendix 6-2 [General Technical Specifications (SPGT)].

3.7.2 Standards

Brazing will be in accordance with AWS B2.2.

3.7.3 Qualifications

All personnel who perform brazing and all personnel who inspect brazed connections will be qualified to AWS B2.2 for every type of joint they work on or inspect.

3.7.4 Materials

The filler materials for brazing will be in accordance with AWS A5.8, Specification for Filler Metals for Brazing and Braze Welding.

3.7.5 Inspections

All brazed electrical connections, both those made in the factory and those made at the Site, will be 100% visually inspected.

SPG4 SITE WORK

4.1 Contractor's Work Force for Site Work

4.1.1 Winders

As a minimum, one-half but not less than two members of each shift of each Generator stator winding and Generator rotor winding installation crew will hold a valid British Columbia Certificate of Qualification in the trade of "Winder Electrician". All Winder Electricians will have a minimum experience of six installation projects similar to that specified in the Contract. The Contractor may make a request in writing to Hydro's Representative for an exception to the Winder Electrician requirement provided the Contractor can demonstrate to Hydro's Representative's satisfaction that the qualifications or experience of the substitute worker is equivalent to that of a Winder Electrician.

Prior to commencement of installation, and each time the Contractor makes any change to installation crew personnel, resumes and any other documentation that Hydro's Representative may request will be provided promptly.

4.2 Site Measurements

4.2.1 Clearances, Dimensions, Runout and Shaft Verticality Measurements

The measurements to be taken and recorded by the Contractor for the Equipment during installation will include but not be limited to the following:

Item	No. of Readings
Rotor and stator shapes by rotating rotor through 360° and measuring Airgaps from:	
Top of pole No. 1 to stator	18
Bottom of pole No. 1 to stator	18
Upstream point on stator to top of each pole	All poles
Upstream point on stator to bottom of each pole	All poles
Clearance - upper and lower brackets to shaft	4

Item	No. of Readings
Clearance - Generator bearing journals to bearing support	8
Clearance - Generator guide bearing pads to journal	Every pad
Clearance - creep detector to shaft	As required
Runout check (number of points at each location) Includes measurements at all bearings, seals, Generator collector slip rings.	4
Shaft verticality check - 4 wires, 2 elevations (Single wire may be acceptable. An electronic level maybe used to supplement plumb wires.)	At least 2 rotations
Elevations: Rotor/stator centreline, bearing reference	As required to get a representative measurement

4.3 Electrical Power

For the Generator stator core full-flux, short-circuit saturation, open-loop excitation, and sudden-short-circuit test performed as part of Generator assembly, testing, acceptance and commissioning test:

(a) electric power at 600 V, 3-phase, 1600 A will be made available at the Powerhouse station service panel; and

(b) electric power at Generator Rated Voltage, 3-phase, 70 A will be made available at the Powerhouse station service panel.

The Work includes all cabling, distribution panel(s), cable connectors, bracing and any protection devices required to use these power sources.

4.4 Instrumentation Grounding during High-voltage Tests

During any high-voltage tests on either the Generator stator or rotor winding, all permanently installed instrumentation will be grounded. This instrumentation includes RTDs, AGMS probes, CT secondaries, and PT secondaries,

4.5 Stator Core Tests

The Generator stator core tests specified in this SPG 4.5 will be performed prior to installation of the Generator stator winding.

4.5.1 Stator Core Knife Test

The completed Generator stator core will be tested for loss of core pressure using a Richard's L3 knife. Prior to this test there will be no resin applied to the core. In any location of the stator core, it will be impossible to insert the knife more than 13 mm by hand without prying against a fixed object.

4.5.2 Full-Flux Test

The completed Generator stator core will be electromagnetically compacted and tested for lamination and assembly quality by performing a full-flux test. The test will be witnessed by Hydro's Representative.

(a) Flux density and duration: The stator core will be uniformly excited to at least 85% of the normal rated flux for a minimum of 1 hour.

(b) Search coil: Prior to connection to the voltmeter the search coil used to determine the magnetic flux density will have suitable fuses installed in both sides of the circuit.

(c) Temperature measurement: An infrared camera will be used for general scanning of hot spots and a contact-type temperature probe will be used to confirm hot-spot temperatures.

(d) Core-to-frame temperature differential: The temperature differential between the stator core and the stator frame will be:

  (i) sufficiently small such that core waves or buckling does not occur; and

  (ii) less than 10°C.

(e) Core temperature: The stator core temperature will not exceed the normal operating temperature. Any core lamination packet exhibiting a temperature deviation of:

  (i) 5°C above the average core temperature will be considered defective; and

  (ii) 10°C above the average core temperature will cause the test to be terminated and any defects corrected.

(f) Post-test cooling: After the test and prior to core retightening, the stator core will be left to cool until the average stator core temperature is cooler than 30°C.

(g) Retightening: After the core has sufficiently cooled, and prior to winding installation, the core will be retightened.

(h) Core losses: During each full-flux test the stator core input power (both kW and kVAr) will be measured for information only.

(i) Defect Repair: The Contractor will submit for Consent the proposed correction method for correcting defects. After defect repair, the full-flux test will be repeated to demonstrate that the defects have been repaired.

(j) El-Cid test: The use of an “El Cid” test may supplement the full-flux test for comparison purposes.

4.5.3 Stator Core Stud Insulation Resistance Test (if applicable)

For a Generator stator core designed with core studs passing through laminations, after the application of the slot semi-conductive paint, a 1-minute, 500 Vdc insulation resistance test of each core stud to ground will be performed. The $IR_{1\ min}$ value will be greater than 100 Mohms.

4.6 Generator Stator Winding Installation

4.6.1 Painting

The Generator stator winding will not be painted.

4.6.2 Bar Numbering

The Generator stator core slot number will be clearly and permanently marked:

(a) at every tenth stator slot;

(b) directly on the stator bar at a location near the core on the straight, oblique section of the bar;

(c) at both the connection-end and opposite-connection-end;

(d) on both the bore-side and core-back side of the winding; and

(e) so that the numbers are visible with the rotor in place.

Bar numbering marking by hand with legible printing using a paint pen is acceptable.

4.6.3 Clearances and Connections

Sufficient clearance will maintained to prevent any electrical discharge between the various current Generator stator winding carrying components and also ground including:

(a) front and back bars;

(b) bars and ground;

(c) winding series connections;

(d) bars and circuit-rings; and

(e) circuit-rings and ground.

4.6.4 Bar Installation

Generator stator bars will be installed:

(a) at the designed elevation in the stator core;

(b) uniformly maintaining consistent and designed spacing; and

(c) such that the T-spacing is consistent and meets the requirements of SPG 2.5.5(h)(iv) multiplied by 0.85.

4.6.5 Slot Clearance

Confirmation that each of the Generator stator front and back bars are completely inserted in each slot will obtained. The proposed Procedure used to obtain conformance will be submitted in advance.

Before installation of a Generator stator front bar on top of a back bar or before wedging, the tangential tightness of each bar in each slot will be checked using feeler gauges. The mean side clearance of any bar will not exceed 0.05 mm in any 100 mm section of the slot.

If the mean side clearance does not meet the above criteria, then adequate semi-conducting side packing materials will be added to provide continuous and positive contact between the bar and the core.

4.6.6 Brazing

All Generator winding connections, excluding the main and neutral terminals, will be brazed using copper clips, ferrules, or other acceptable method.

The brazing process will include thermal protection, preferably with the application of water jackets or chill blocks between the factory applied insulation system and the joints to be brazed. The insulation system will not be damaged.

If the insulation system is damaged, then the affected components will be replaced.

4.6.7 Connections

(a) End-Cap Connections: The series connections of Generator stator bars that use end-caps will:

(i) have the connection encapsulated with electrical grade insulating compound and use epoxy-glass end-caps;

(ii) utilize an end-cap installation Procedure that will ensure that there are no voids in the insulating compound;

(iii) have the end-cap overlap the bar groundwall insulation by a minimum of 25 mm; and

(iv) ensure that adjacent end caps have sufficient clearance to prevent any electrical discharge and ensure proper cooling.

(b) Other Connections: Generator connections other than those using end-caps will be covered with an insulation system that will:

(i) prevent any electrical discharge; and

(ii) be cured fully before completion of the Work.

4.6.8 Bar Surface Contact Resistance

(a) After installation of each Generator stator bar, the surface contact resistance to ground will be measured using an accepted device near the top, centre, and bottom of the bar. Use of a device with a 150 mm long by 12 mm wide woven copper strap is preferred.

(b) For the Generator stator back bars, this test will be performed prior to inserting the front bars, and for front bars this will be performed before wedging.

(c) For each Generator stator bar the surface contact resistance value will be between 200 ohms and 5000 ohms.

(d) If the surface contact resistance value does not meet the above criteria, then the reason will be investigated and a written explanation submitted prior to correction of the deficiency.

4.6.9 Slot Wedge Tightness Test

Generator stator core slot ripple spring compression will be measured for at least 10% of the slots. The measured slots will be evenly distributed around the stator bore. For the slots that are measured, the measurements will be performed at various elevations, but no fewer than four locations for each slot. The Contractor's wedge installation Procedure and wedge tightness acceptance criteria will be submitted for Consent.

The Procedure will be suitable for use during maintenance when access is provided via a minimum of two removed poles. One such Procedure is by using holes drilled in the wedges for insertion of a depth gauge.

4.7 Stator Winding Tests

Unless otherwise specified, the Generator stator winding tests specified in this SPG 4.7 will be performed in accordance with the following standards:

(a) IEEE 115; and

(b) IEEE C50.12.

4.7.1 Insulation Resistance, Polarization Index, and High-potential Tests

After receipt at the Site, and during and after installation, insulation resistance, polarization index, and/or high-potential tests will be performed on the Generator stator bars and winding in accordance with Table 4.7.1.

Where listed in Table 4.7.1, the 1-minute, 5.0 kVdc insulation resistance to ground (IR1 min) and the 10-minute polarization index will be:

(a) measured;

(b) temperature corrected to 40°C; and

(c) accepted prior to performing a high-potential test.

For each Generator stator winding parallel, phase, or complete winding, the temperature-corrected $IR_{1\ min}$ will be greater than 100 Mohms.

Where listed in Table 4.7.1, 1 minute, 60 Hz high-potential tests will be performed to ground on the Generator stator winding at a voltage of at least "k_{hp}" times the total of twice the rated terminal voltage plus 1000 Vac (i.e., k_{hp} (2E+1)). For the various tests, the value of k_{kp} is listed in the table.

For all of the insulation resistance, polarization index, and high-potential Generator stator winding tests, all bars, circuits, or phases not under test will be grounded.

Table 4.7.1 Stator Winding High-Potential Tests

Item	When these tests will be performed…	IR and PI Test	High-potential Test (k_{hp})	Notes
1	…upon receipt at Site, on a random sample of bars consisting of not less than 4 bars in each Production Run.	IR, PI	1.40	The slot portion of the bar will be in a grounded "dummy slot" or simulated slot. It will be permissible to test multiple bars simultaneously.
2	…during winding installation, on each back (bottom) bar prior to installation of the front (top) bar.	IR	1.30	This test will be performed on a periodic basis on groups of bars at a time (for example at the end of each shift).
3	…during winding installation, on each front (top) bar prior to permanent wedge installation.	IR	1.30	This test will be performed on a periodic basis on groups of bars at a time (for example at the end of each shift).

Item	When these tests will be performed…	IR and PI Test	High-potential Test (k_{hp})	Notes
4	…during winding installation, on each front (top) and back (bottom) bar after a slot is wedged, but before the leads have been brazed.	No	1.20	This test will be performed on a periodic basis on groups of bars at a time (for example at the end of each shift).
5	…after circuit-ring installation, on all circuit-rings before connection to the bars.	IR	1.20	
6	…after the winding is completely installed	IR, PI	1.10	Each parallel of the winding will be tested separately.
7	…if applicable, after the stator has been lifted and placed in the Generator pit/enclosure, but before the rotor is installed.	No	1.05	Each phase of the winding will be tested separately.
8	…in accordance with SPG 5.2.6.	IR	1.00	Each phase of the winding will be tested separately. This test is the acceptance test.

4.7.2 Stator Winding Corona-Imaging Test

A Generator stator winding corona-imaging test will be performed:

(a) after the winding is completely installed;

(b) in accordance with IEEE 1799;

(c) in phase-to-ground clearance configuration and again in the phase-to-phase clearance test configuration;

(d) at the IEEE 1799 maximum recommended test voltage for fully assembled stator windings;

(e) on each Generator; and

(f) using an acceptable corona-imaging camera.

All corona discharge will be recorded with respect to location, intensity, and electrical position in the winding.

This test is for information only.

4.7.3 Winding Capacitance

After the Generator stator winding is completely installed, but prior to the neutral wye-point being connected, the capacitance to ground of each Generator stator winding phase and of the 3-phases connected together will be measured.

4.7.4 Winding Resistance

After the Generator stator winding has been completely installed, and prior to connection of the main-leads, a winding dc resistance test will be performed on each Generator stator winding phase. The results will be recorded to five significant figures and then temperature corrected to the “reference temperature for use in determining I^2R losses” specified in IEEE C50.12. The temperature-corrected resistance values will not deviate from the calculated value by more than 5%, and the temperature-corrected resistance difference between the highest and lowest phase values will not be greater than 0.5%.

If the temperature-corrected Generator stator winding resistance value does not meet the above criteria, then the reason will be investigated and a written explanation submitted.

4.7.5 RTD Tests

For each of the following RTDs, each Generator RTD element will pass a 1 minute, 1000 V, 60 Hz test to ground:

(a) stator core air-duct RTDs: after five laminations installed above each RTD; and

(b) stator winding RTDs: after each slot containing an RTD has been fully wedged and the bars in the slot have been lashed, but before any series connections have been made.

The $IR_{1\ min}$ value will be greater than 100 Mohms.

4.8 Partial Discharge Monitoring System Cables

Before the Generator stator winding partial discharge monitoring system cables are terminated permanently in the partial discharge monitoring system terminal box, Hydro’s Representative will witness and approve the calibration of the cables.

4.9 Rotor Winding Tests

Unless otherwise specified, the Generator rotor field winding tests specified in this SPG 4.9 will be performed:

(a) from the Generator rotor brushgear collector slip rings; and

(b) in accordance with the following standards:

(i) IEEE 115; and

(ii) IEEE C50.12.

4.9.1 Insulation Resistance

(a) Prior to Pole-coil Interconnection: Prior to interconnection of the Generator rotor pole-coil windings, a 1 minute, 1000 Vdc insulation resistance ($IR_{1\ min}$) test will be performed on each pole-coil winding in accordance with IEEE 43. The $IR_{1\ min}$ will be temperature corrected to 40°C. The temperature-corrected $IR_{1\ min}$ value will be greater than 10 Gohms. Any significant discrepancies between the test results obtained from the $IR_{1\ min}$ tests conducted in the factory and the $IR_{1\ min}$ results conducted at Site will be investigated and the findings submitted for Consent.

(b) After Rotor Assembly: After the Generator rotor field winding has been completely assembled up to and including the brushgear collector slip rings, a 1 minute, 1000 Vdc insulation resistance (IR_1

$_{min}$) test and a polarization index test will be performed on the Generator rotor field winding in accordance with IEEE 43. The $IR_{1\ min}$ will be temperature corrected to 40°C. The temperature-corrected $IR_{1\ min}$ value will be greater than 100 Mohms. The polarization index value will be for information only.

4.9.2 High-Potential

After the Generator rotor field winding has been completely assembled and the insulation resistance test specified in SPG 4.9.1(b) has been successfully completed, a 1 minute, 60 Hz high-potential test will be performed on the Generator rotor field winding at a test voltage of a minimum of ten times the rated excitation voltage, but in no case less than 5000 Vac.

During the Generator rotor field winding high-potential test, no temporary insulation may be used.

4.9.3 Turn Insulation

After the Generator rotor field winding has been completely installed, a high-frequency impedance test will be performed on the Generator rotor field winding in accordance with BC Hydro MS 01.20.Test.05. A test at 420 Hz and a minimum of 10 A is preferred. The impedance value for each pole winding will not deviate from the average value by more than 5%.

4.9.4 Winding Resistance

After the Generator rotor field winding has been completely installed, a winding resistance test will be performed on the Generator rotor field winding. The result will be recorded to five significant figures and then temperature corrected to the “reference temperature for use in determining I^2R losses” specified in IEEE C50.12. The temperature-corrected winding resistance value will not deviate from the calculated value by more than 1%.

If the temperature-corrected winding resistance value does not meet the above criteria, then the reason will be investigated and a written explanation submitted.

4.10 Generator Brake Dust Collection System

The Generator brake dust collection system will be tested in order to verify proper operation of the system and to verify the initial settings of blast gates to balance the system. Testing and balancing will be performed by an agency that specializes in this type of work. Balancing Procedures will be in accordance with National Environmental Balancing Bureau - Procedural Standards for Testing, Adjusting and Balancing Environmental Systems, SMACNA, and ASHRAE standards.

As a minimum, following successful start-up and balancing of the Generator brake dust collection system, the following tests and documented measurements are required:

(a) fan performance;

(b) volumetric flow rate at each hood pick up point and the total volumetric flow rate through the dust collection system;

(c) pressure drop across dust collector;

(d) total pressure and static pressure at fan inlet and fan outlet;

(e) static pressure measurements in each branch and in each main duct; static pressure at each hood opening; and

(f) air sampling analysis to determine the effectiveness of the dust collection system.

The Generator brake dust collection system will be designed such that it does not propagate fire.

SPG5 SITE ACCEPTANCE AND COMMISSIONING TESTS

5.1 General

Generator site acceptance and commissioning tests will be performed in accordance with IEEE C50.12 and IEEE 115, except as otherwise specified.

5.2 Generator Tests by the Contractor

5.2.1 Rotor Jacking System

The performance of the Generator rotor jacking system will be tested.

5.2.2 Current Transformer

After the Generator current transformers are installed, the following tests will be performed on all current transformers:

(a) insulation resistance;

(b) ratio; and

(c) polarity.

5.2.3 Generator Brakes

During the first set of mechanical runs, the performance of the Generator brakes will be tested for proper operation.

5.2.4 Rotor Unbalance (caused by Mechanical Imbalance)

The Generator rotor will be assessed for mechanical imbalance during the mechanical runs. If the rotor is unbalanced, then it will be balanced in accordance with a submitted Generator rotor balancing Procedure.

5.2.5 Generator Rotor Brushgear

The performance of the Generator rotor brushgear will be monitored during the acceptance testing.

An infrared temperature detector will be used to measure the temperature of the Generator rotor brushgear collector slip rings and brushes and confirm the temperature variances. The emissivity of the detector will be set appropriately.

5.2.6 Stator Winding Insulation Tests

After completion of all overspeed tests, the following tests will be performed on the Generator stator winding:

(a) insulation resistance;

(b) polarization index; and

(c) high-potential,

all in accordance with SPG 4.7.1.

Any discrepancies between the Generator stator winding insulation test results performed in SPG 4.7.1 and this SPG 5.2.6 will be submitted.

5.2.7 Rotor Winding Tests

After completion of all overspeed tests, the following tests will be performed on the Generator rotor winding:

(a) insulation resistance and polarization index tests in accordance with SPG 4.9.1(b);

(b) a high-potential tests in accordance with SPG 4.9.2;

(c) turn insulation tests in accordance with SPG 4.9.3; and

(d) a winding resistance test in accordance with SPG 4.9.4.

Any discrepancies between the Generator rotor winding test results performed in SPG 4.9 and this SPG 5.2.7 will be submitted.

5.2.8 Short-circuit Saturation Curve

A test will be performed to determine the Generator short-circuit saturation curve.

The Exciter will be operated in “open-loop” mode and supplied from the station service. The Work includes the supply cable and connections.

The Exciter open-loop voltage and current supply requirements will be accepted.

During this test, to verify the protection circuits, tests will be performed by Others.

5.2.9 Open-circuit Saturation Curve

A test will be performed to determine the Generator open-circuit saturation curve.

The Exciter will be operated in “open-loop” mode and supplied from the station service. The Work includes the supply cable and connections.

The Exciter open-loop voltage and current supply requirements will be accepted.

During this test, to verify the protection circuits, tests will be performed by Others.

5.2.10 Phase Sequence

The phase-sequence of the Generator stator will be tested.

5.2.11 Generator Parameters

Tests will be performed on each Generator to determine the following Generator parameters:

(a) direct axis synchronous reactance, X_d; and

(b) short circuit ratio, SCR.

Tests will be performed on one Generator to determine the following Generator parameters:

(c) direct axis, saturated transient reactance, $X'_{d, sat}$;

(d) direct axis, saturated sub-transient reactance, $X''_{d, sat}$; and

(e) zero sequence reactance, X_0.

5.2.12 Deviation Factor

The deviation factor of one Generator will be tested.

5.2.13 Telephone Influence Factor

The telephone influence factor of one Generator will be tested.

5.2.14 Bearing Insulation and Shaft Current Test

Tests will be performed to ensure the Generator bearing insulation effectiveness and to ensure shaft currents are not present.

5.2.15 Line Charging Capacity

The line charging capacity of one Generator will be determined. This test is for information only.

5.2.16 Zero Power Factor Saturation Curve

The zero power factor saturation curve of one Generator will be determined. The measurements will be taken:

(a) with the Generator connected to the system;

(b) at a minimum of three terminal voltage points; and

(c) with one of the measurement points at Rated Voltage.

5.2.17 Temperature Tests

Temperature tests will be performed on each Generator.

(a) Test Conditions: At a minimum the test will be performed at four test conditions. Recommended test conditions are: 0.50 pu, 0.71 pu, 0.87 pu, and 1.00 pu of the Generator Rated Output. The test will not be performed in the rough load zone. Test conditions will be submitted.

(b) Test Uncertainties: The absolute temperatures, reference coolant temperatures, and temperature rises will be calculated taking into account the test uncertainties stated in the Generator TDIF.

(c) Calculation or Extrapolation Method: If a specific calculation or extrapolation method is required for the test data, the method will be submitted.

(d) Cooling Water Flow and Temperature: For the purposes of confirming the Generator Rated Output, the cooling water flow through the air coolers at the Generator Rated Output will be at the Maximum Cooling Water Supply Temperature and will be calculated based on the measured cooling water flow and temperature at the maximum Generator output attainable at the time of the test.

For the Generator Rated Output, the calculated cooling water flow through the air coolers at the Maximum Cooling Water Supply Temperature must be less than or equal to the cooling water flow stated in the Generator TDIF.

(e) Stator and Rotor Winding Temperature Rise: For the purposes of confirming the Generator Rated Output, the stator and rotor winding absolute temperature and temperature rise will be calculated for the Generator Rated Output current by extrapolating the best-fit straight line through the respective test points plotted on a graph of temperature rise vs. per unit current squared.

At the Generator Rated Output current, the calculated:

(i) stator winding temperature rise must be less than or equal to that stated in SPG 2.2.4(b); and

(ii) rotor winding temperature rise must be less than or equal to that stated in SPG 2.2.4(d).

(f) Stator End Winding and Circuit-ring Temperature Measurement: At the Generator Rated Output current, the Generator stator end-windings and circuit-rings temperatures will be measured using thermal imaging or contact-type fibre optic sensors. If these measurement techniques are not feasible due to space or other physical limitations, the Contractor will propose an alternative measurement method for Consent. The alternative method will be capable of determining the hot-spot surface temperatures of the stator end-windings and circuit-rings.

The end-winding and circuit ring maximum copper temperature will each be no more than the temperature rise defined in SPG 2.2.4(c).

(g) Stator Core and Frame Temperature Measurement: At the Generator Rated Output, the Generator stator core and stator frame temperatures will be measured. The temperatures will meet the thermal limits defined in SPG 2.5.4(e).

5.2.18 Rotor Rim to Spider Separation

The degree of the Generator rotor rim shrink achieved will be tested after the majority of the Unit acceptance and commissioning tests have been completed including, the Unit overspeed test, the Unit runaway speed test, and the Generator temperature tests.

At least eight proximity probes will be provided to verify the Generator rotor rim separation and return with respect to the rotor spider. The probes will be spaced equally around the circumference of the rotor spider and distributed evenly between the top and bottom of the spider.

5.2.19 Rotor Unbalance (caused by Electrical Imbalance)

The Generator rotor will be assessed for electrical unbalance when the Generator is at Generator Rated Output and at Generator Rated Operating Conditions. If the rotor is unbalanced, then it will be balanced in accordance with a submitted Generator rotor balancing Procedure.

5.2.20 Generator Losses

(a) Losses: The Generator segregated-losses will be:

(i) measured on one Generator; and

(ii) measured by the heat transfer method.

(b) Compliance: For the purposes of determining compliance to the requirements of SPG 2.1.1 the test results obtained from testing one Generator will be assumed to be the same with respect to the other Generators unless tests of an additional Generator are requested.

Where tests conducted on a Generator indicate non-compliance of the requirements of SPG 2.1.1, the Contractor will have the right to request, in writing, a single re-performance of the tests on that Generator at the Contractor's expense. If the second test results differ from the first test results, the reasons for the difference(s) will be submitted. Hydro's Representative will determine which test is to be used to determine compliance to the requirements of SPG 2.1.1.

(c) Additional Generator Tests: An additional Generator may be loss tested if specifically requested by either party in writing. All costs of performing tests on an additional Generator will be borne by the party requesting such tests. Hydro's Representative will determine which test results are to be used to determine compliance to the requirements of SPG 2.1.1.

(d) Rated Operating Conditions: The Generator Rated Output operating conditions determined during the temperature tests described in SPG 5.2.17 will be used as a basis for the loss measurements described in this SPG 5.2.20. As a minimum, the Generator Losses will be measured at 0.50 pu, 0.71 pu, 0.87 pu and 1.00 pu of Generator Rated Output.

If, as a result of the temperature tests described in SPG 5.2.17, the Contractor is non-compliant with the Generator Rated Output requirements, Hydro's Representative will determine the maximum attainable operating conditions to be used for the loss measurements.

(e) Test Uncertainties: For the purposes of SPG 5.2.20, the actual losses will be the calculated value of losses determined from the tests minus the test uncertainties stated in the tables in the Generator TDIF for the same component of loss and operating condition.

(f) Calculation or Extrapolation Method: If a specific calculation or extrapolation method is required for the test data, the method will be submitted for Consent.

(g) Windage Losses: All windage losses determined will be considered to be Generator Losses. The best fit straight line drawn through the test points plotted on a graph of the cold air temperature vs. windage losses will be used to obtain the windage loss at the Regulated Cold Air Temperature.

(h) Bearing Losses: Generator bearing friction losses will be measured separately during the test. All bearing losses will be considered Generator Losses.

(i) I^2R Losses: The measured I^2R loss values of armature and field winding resistance will be temperature corrected using the reference temperature value stated in IEEE C50.12, Table 8, Class B.

The calculated Generator Rated Output armature and field I^2R losses will be respectively extrapolated from armature and field current measurements made at a voltage and power factor as close as possible to the Generator Rated Output, and at least three outputs between zero and the maximum output attainable at the time of the measurement.

(j) Air Temperature: Except for I^2R losses, all test results will be corrected to the Regulated Cold Air Temperature.

5.2.21 Sudden Short Circuit Tests

Sudden short circuit tests will be performed on one Generator.

Measurements will be made at a minimum of five voltage steps. If directed, sudden short circuit tests will be performed up to 110% of Rated Voltage.

(a) Instrumentation will be provided to measure:

  (i) armature current;

  (ii) terminal voltage using calibrated voltage transformers (VT) if the Generator VTs cannot be used;

  (iii) stator frame displacement in three axis;

  (iv) stator frame acceleration in three axis;

  (v) stator winding end-turn strain; and

  (vi) stator winding-end displacement.

  All of the above-listed instrumentation will be first accepted.

(b) Make-switch for applying the sudden short circuit:

  (i) the BC Hydro sudden short circuit test make-switch is rated 18 kV, 400 kA with 100 ms closing time and 50 ms opening time. The control voltage is 125 Vdc;

  (ii) if the BC Hydro owned make-switch is not available or is considered by the Contractor to be insufficient for this test, then the Contractor will supply a make-switch;

  (iii) the make-switch will be installed including the shorting bus work to the Generator main terminals; and

  (iv) the timing of the make-switch will be verified (regardless of the make-switch being provided by BC Hydro or not).

(c) Exciter Settings: The Exciter settings will be temporarily modified to ensure that the exciter can provide the required field current and voltage, and so that the Exciter is otherwise fit to perform the test.

(d) Related Tests and Inspection: Before and after the sudden-short circuit test:

  (i) an inspection will be performed. The Generator will be judged “fit for service” and, for both the stator winding and the rotor, no more than “minor repairs” as specified in IEEE C50.12 will be required;

  (ii) an insulation resistance test will be performed on the field winding in accordance with SPG 4.9.1(b). This test will be performed prior to performance of the high-frequency impedance test;

(iii) a high-frequency impedance test will be performed on the field winding in accordance with SPG 4.9.3;

(iv) an insulation resistance and polarization index test will be performed on the stator winding in accordance with SPG 4.7.1. This test will be performed prior to performance of the HDV step tests or high-potential test;

(v) a three single-phase HDV step tests will be performed on the stator winding in accordance with SPG 5.3.3. The “before” and “after” test results will be within 10% of each other; and

(vi) three single-phase high-potential tests will be performed on the stator winding in accordance with SPG 4.7.1. The test voltage will be 0.95(2E+1).

5.2.22 Cooling Water Flow

The Contractor will measure the cooling water flow rate for the Generator air coolers with the Generator operating at Generator Rated Output at Generator Rated Operating Conditions and at an inlet water temperature of 6°C.

The cooling water flow rate for the Generator air coolers of one Unit operating at the Generator Rated Output at Generator Rated Operating Conditions with a penstock water temperature of 6°C and the Generator heat recovery system inactive (all Generator air coolers fully functioning but with no heat being removed from the Generator by the Generator heat recovery system) will not exceed the value for cooling water flow rate stated in the Generator TDIF.

In the event that the measurements cannot be performed at an inlet water temperature of 6°C, interpolation between measured data for lower and higher water temperatures will be considered provided that the measurements are taken when the water temperatures are in the range of 2°C to 10°C. The Contractor will propose a methodology for the interpolation and submit for Consent.

5.3 Generator Tests by BC Hydro

5.3.1 General

The tests as specified in SPG 5.3 may be performed by BC Hydro. All test instruments and data acquisition equipment will be supplied by BC Hydro. The Contractor will make provision in the integrated test schedule for these tests to be performed at no additional cost to BC Hydro.

5.3.2 Stator and Rotor Winding Insulation Resistance Tests

Generator stator (single-phase and 3-phase) and rotor winding insulation resistance (IR) and polarization index tests may be performed in accordance with BC Hydro MS 01.20.TEST.01. In accordance with the maintenance standard, the test results will result in an “Equipment Health Rating” of “good”.

5.3.3 Stator Winding HDV Step Tests

Generator stator winding (single-phase and 3-phase) HDV step tests may be performed in accordance with BC Hydro MS 01.20.TEST.02. In accordance with the maintenance standard, the test results will result in an “Equipment Health Rating” of “good”.

5.3.4 Stator Winding Partial Discharge Tests

Generator stator winding partial discharge (PD) tests may be performed in accordance with BC Hydro MS 01.20.TEST.03. These tests are for information only.

5.3.5 Corona Probe Test

A Generator stator winding corona probe tested may be performed in accordance with BC Hydro MS 01.20.TEST.04. In accordance with the maintenance standard, the test results will result in an “Equipment Health Rating” of “good”.

The voltage supply to excite the stator winding to Rated Voltage will be supplied.

5.3.6 Stator Winding RTD Resistance and Insulation Resistance Tests

Generator stator winding RTD tests may be performed in accordance with BC Hydro MS 01.20.TEST.06. In accordance with the maintenance standard, the test results will result in an “Equipment Health Rating” of “good”.

5.3.7 Airgap Monitoring Tests

Generator dynamic airgap monitoring tests may be performed.

5.3.8 Split-Phase Current Tests

Generator split-phase current tests (using temporarily installed flexible current probes) may be performed.

5.4 Generator Inspection and Testing After Commercial Operation

5.4.1 General

Upon completion of the Work, BC Hydro may inspect and test the Equipment at its own expense. During the Warranty Period the Contractor may participate in the inspections and testing at its own expense.

Any Equipment component that does not meet the acceptance criteria defined in relevant sections of SPG3, SPG4, and SPG5 is considered to have failed the requirements of Section 5.4.

5.4.2 Inspections

The Generator inspections may include verification that the Generator components meet the requirements of Schedule 6 [Specifications and Drawings] including that:

(a) winding and insulating materials are tight;

(b) blockings and lashings are tight;

(c) there is no evidence of partial discharge activity;

(d) stator laminations, core clamping studs, and fingers are tight;

(e) there is no overheating, hotspots, or discolourations;

(f) there is no presence of dust or powder which may be related to stator winding or core deterioration;

(g) there is no evidence of unusual movement, cracking, or distortion; and

(h) the cooling water, air, and oil piping systems are not leaking or becoming fouled.

5.4.3 Testing

The Generator testing may include:

(a) performance of any of the testing specified in SPG3, SPG4 and SPG5 except the following tests:

(i) thermal cycling test in accordance with SPG 3.1.15;

(ii) full-flux test in accordance with SPG 4.5.2; and

(iii) sudden short circuit test in accordance with SPG 5.2.21;

(b) removal of one or more Generator stator bars to perform:

(i) a visual inspection of the bar(s) and slot(s); and

(ii) dissection tests in accordance with SPG 3.1.16.

SUPPLY AND INSTALLATION OF TURBINES AND GENERATORS CONTRACT

APPENDIX 6-6

EXCITATION SYSTEM SPECIFICATIONS (SPEXC)

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APPENDIX 6-6

EXCITATION SYSTEM SPECIFICATIONS (SPEXC)

SPEXC1 GENERAL

1.1 Definitions and Interpretation

In this Appendix 6-6 [Excitation System Specification (SPEXC)], in addition to the definitions set out in Schedule 1 [Definitions and Interpretation]:

"**Automatic Voltage Regulator**" or "**AVR**" has the meaning set out in SPEXC 2.12.6;

"**Ceiling Voltage**" has the meaning set out in SPEXC 2.1.6(b);

"**Excitation System**" or "**Exciter**" has the meaning set out in SPEXC 1.2.1(a);

"**Excitation System 30 Second Rating**" has the meaning set out in SPEXC 2.1.8(a);

"**Excitation System Data Table**" has the meaning set out in SPEXC 2.16.4;

"**Excitation System Rated Current**" has the meaning set out in SPEXC 2.1.2(b);

"**Excitation System Rated Output**" has the meaning set out in SPEXC 2.1.2;

"**Exciter Hardwired Controls**" has the meaning set out in SPEXC 2.14.2(d);

"**Exciter Human Machine Interface**" or "**Exciter HMI**" has the meaning set out in SPEXC 2.14.2(a);

"**Exciter Software**" has the meaning set out in SPEXC 2.16.1;

"**Exciter Transformer**" has the meaning set out in SPEXC 2.7.1;

"**ExcPCE**" has the meaning set out in SPEXC 2.12.1;

"**ExcRCE**" has the meaning set out in SPEXC 2.12.1;

"**Field Breaker**" has the meaning set out in SPEXC 2.4;

"**Field Discharge Resistor**" or "**FDR**" has the meaning set out in SPEXC 2.5.3;

"**Power Rectifier**" has the meaning set out in SPEXC 2.3.1;

"**Silicon Controlled Rectifier**" or "**SCR**" has the meaning set out in SPEXC 2.3.1; and

"**VT**" has the meaning set out in SPEXC 1.2.3(a).

1.2 Scope of this Specification

1.2.1 Scope of Work for the Excitation Systems

Six identical excitation systems are required for the Project, together with related Work, as follows:

(a) each static exciter (an “**Excitation System**” or “**Exciter**”) includes the redundant control system, redundant power supplies for the control system, fusing, air cooling system, temperature monitoring system, solid state controlled rectifier power converter SCR assembly in redundant or N+1 configuration, field isolation and reversing links, DC shunt, field discharge equipment, excitation transformer, instrumentation, field breaker (AC or DC), buswork, cabling, connection to the Generator isolated phase bus, connection to the Generator field-bus, protection systems, monitoring systems, metering systems, Human Machine Interface (HMI) systems and software.

1.2.2 Scope of Related Work

The Work related to each Excitation System includes:

(a) the cabling required to connect the Excitation System to the Powerhouse station service for the open-loop excitation mode during the Generator acceptance and commissioning tests.

1.2.3 Work Not Included

The following work will be provided by Others:

(a) the Generator and bus voltage transformers (“**VT**”) for voltage sensing; and

(b) the isolated phase bus from the Generator to the high-voltage side of the Excitation transformer.

1.3 Submittals

1.3.1 Excitation System Drawings

As a minimum, the Work includes submission of the following Excitation System Drawings:

(a) layout diagrams that detail all Equipment provided with the Excitation System, as well as its interconnections, including:

  (i) Enclosures and Equipment contained within them;

  (ii) the explosion-directed Exciter Transformer Enclosure;

  (iii) the connection between the excitation transformer and the Power Rectifier;

  (iv) Power Rectifier AC and DC buswork and its fastening system;

  (v) the Exciter Transformer iso-phase bus connection point;

  (vi) the Exciter Transformer manufacturer name, factory location, transformer type, insulation class, insulation type (e.g., VPI), winding construction (e.g., foil or other);

  (vii) cable entrances, including field lead cables;

  (viii) isolating facilities;

(ix) high-voltage phase barriers;

(x) ground connection points;

(xi) Enclosure anchor points; and

(xii) open-loop connection point details;

(b) Electrical Schematics and Electrical Wiring Diagrams of all Equipment provided with the Excitation System, as well as its interconnections, including:

(i) the Power Rectifier;

(ii) SCR bridge assembly;

(iii) field discharge equipment;

(iv) field breaker;

(v) the Exciter Transformer;

(vi) the single line and three line diagrams that will show all of the Excitation System equipment including the Exciter Transformer, SCRs, field breaker, field discharge resistor, CTs, VT, capacitor, etc., connections; and

(vii) protection, control, power, and instrumentation;

(c) a Nameplate or rating plate Drawing that shows all the Excitation System continuous and temporary ratings;

(d) a Nameplate or rating plate Drawing that will show all the excitation transformer continuous and temporary ratings;

(e) a Letter of Compliance, signed by a signing officer of the equipment manufacturer, for all major components of the Excitation System confirming that the Excitation System meets or exceeds the seismic requirements in these Specifications;

(f) a seismic outline drawing, as described in SPEXC 2.1.1(f); and

(g) Block Diagrams of the Excitation System that include illustration of all AC and DC circuits, protection devices/modules, control devices/modules, isolation points, data communications links, and interconnections.

1.3.2 Excitation System Procedures and Reports

As a minimum, the Work includes submission of the following Procedures and Reports:

(a) a Report with mechanical and civil Calculations demonstrating that the supporting steel structure to be supplied has adequate mechanical and structural safety factors for the most severe application mode including faults will be submitted within 90 Days after the Effective Date, to allow BC Hydro’s design to proceed;

(b) design documents covering as a minimum general product description, equipment option and ratings, the Static Excitation Systems ratings and related Calculations, type test information, and recommendations for grounding, erection and transportation;

(c) Procedure for rack-in/rack-out testing of Field Breaker rack-in/rack-out electrical connections;

(d) the power supply (voltage (Vac) and current (A)) requirements for operation of the Excitation System in an open-loop configuration;

(e) Procedure(s) for the configuration of and operation of the Excitation System in an open-loop configuration to complete the following Generator tests:

  (i) short circuit saturation test;

  (ii) open circuit saturation test;

  (iii) efficiency and segregated loss test by heat transfer or retardation method with the Turbine uncoupled; and

  (iv) three-phase sudden short circuit test;

(f) Procedure for the Excitation System heat run Production Test;

(g) Exciter Transformer factory heat run (resistive load) test Procedure; and

(h) the complete technical specifications provided by the Contractor to the manufacturer of the Exciter Transformer.

1.3.3 <u>Excitation System Calculations</u>

As a minimum, the Work includes submission of the following Calculations:

(a) seismic analysis qualification Report and/or seismic test qualification Report, in accordance with SPEXC 2.1.1;

(b) de-excitation SCR over-voltage trigger level Calculation;

(c) crowbar SCR over-voltage trigger level Calculation;

(d) FDR resistance and energy rating Calculation;

(e) field discharge time Calculation;

(f) all protective device settings and setting Calculations;

(g) harmonic content of load including FHL-we (Winding eddy current harmonic loss factor) and FHL-osl (Other stray loss harmonic loss factor);

(h) the amount of heat generated by the Excitation System for use by Others to calculate the HVAC requirements;

(i) the maximum allowable ambient temperature for the Excitation System for use by Others to calculate the HVAC requirements; and

(j) for the Exciter Transformer the:

  (i) hot-spot Calculation (predicted location of hottest spot on LV center winding and LV outer winding); and

(ii) predicted temperature differential between hottest spot and average and estimated additional temperature rise due to harmonic losses.

SPEXC2 EXCITER TECHNICAL DATA AND REQUIREMENTS

2.1 General Design Criteria

2.1.1 Seismic Withstand

The completely assembled and installed Excitation System will meet the high-performance level as defined in the IEEE 693. The Contractor will:

(a) employ a qualified seismic specialist to perform the work described in SPEXC 2.1.1;

(b) demonstrate the seismic withstand capability of the completely assembled and installed Excitation System, through analysis and/or test in accordance with IEEE 693;

(c) utilize Annex A of IEEE 693 as general requirements for seismic qualification Procedures for the Excitation System (taking particular note of the equipment anchorage requirements);

(d) utilize Annex G of IEEE 693 as specific requirements for seismic qualification Procedures for the Exciter Transformer;

(e) utilize Annex M of IEEE 693 as specific requirements for seismic qualification Procedures for all parts of the Excitation System except for the Exciter Transformer;

(f) prepare a seismic outline Drawing of the Excitation System, including details of seismic bracing and anchoring, as well as a table showing all of the forces to be transferred at each anchor location; and

(g) prepare a seismic analysis qualification Report and/or a seismic test qualification Report, including seismic Calculations performed, signed by the Contractor’s seismic specialist, and demonstrating that the Excitation System complies with the high-performance level as defined in IEEE 693.

2.1.2 Rated Output

The Excitation System rated output (the “**Excitation System Rated Output**”), as a minimum, will:

(a) enable the Generator to operate at the Generator Rated Output under Generator Rated Operating Conditions;

(b) have a rated output current (the “**Excitation System Rated Current**”) of no less than the Generator field current required for continuous operation of the Generator at Generator Rated Output under Generator Rated Operating Conditions when the Generator average airgap is 105% of the design average airgap; and

(c) enable the Generator to meet all other operational requirements of Schedule 6 [Specifications and Drawings].

The Excitation System will be capable of continuous operation at the Excitation System Rated Current while meeting all requirements of the Contract Documents.

2.1.3 Ambient Temperature

The Excitation System will be capable of continuous operation at the Excitation System Rated Output with a cooling air intake temperature of 40°C.

2.1.4 Voltage Operating Range

The Excitation System will be designed to operate:

(a) continuously over a range of 80% to 120% of Generator rated voltage;

(b) temporarily down to 2% of rated Generator rated voltage; and

(c) temporarily with over-voltages as defined in SPEXC 2.1.5 and SPEXC 2.1.6.

2.1.5 Transient and Dynamic Over-Voltages

The Excitation System will:

(a) have surge suppression devices, such as capacitors and/or MOVs, on the Excitation System AC bus;

(b) be capable of withstanding phase-to-ground fault conditions;

(c) be capable of withstanding switching surge voltages on the Generator output terminals of 2.75 times 1.414 of 1.10 times Generator rated voltage; and

(d) be capable of withstanding dynamic over-voltages of 1.30 times Generator rated voltage.

Switching surges are defined as having a rise time of several hundred microseconds and a decay time of several milliseconds, for instance 250/2500 µs.

The dynamic over-voltage waveform will be considered to be a 60 Hz waveform with decaying magnitude. The decay time of the dynamic over-voltage is defined as 1.0 s.

2.1.6 Response and Ceiling Voltage

The Excitation System will:

(a) be a high initial response type exciter as defined in IEEE 421.1;

(b) have maximum attainable Excitation System output voltage (the "**Ceiling Voltage**") of no less than 4.65 pu (where 1 pu is equal to the Generator field voltage at Generator Rated Output and Generator Rated Operating Conditions), while the Generator is operating at Generator Rated Output and Generator Rated Operating Conditions;

(c) when supplying the Generator (operating at Generator Rated Output and Generator Rated Operating Conditions), be capable of reaching, in 0.1 s or less, an output voltage that is greater than the Generator rated field voltage by 95% of the difference between the available Ceiling voltage and Generator rated field voltage; and

(d) have negative field forcing capability to no greater than minus 4.05 pu (where 1 pu is equal to the Generator field voltage at Generator Rated Output and Generator Rated Operating Conditions), while the Generator is operating at Generator Rated Output and Generator Rated Operating Conditions.

A Generator terminal voltage error of -2% will cause the excitation to be driven to Ceiling Voltage in no greater than 50 ms.

2.1.7 Voltage Regulation

The Excitation System will be equipped with an automatic voltage regulator (AVR). The AVR will be capable of automatically maintaining a steady-state Generator terminal voltage, without hunting, to:

(a) within ±0.5% of the set-point over the entire operating range of the Generator; and

(b) within ±0.5% of any set point within a range between plus 20% and minus 30% of the Generator rated voltage.

The Excitation System off-line small-signal step response (i.e., the 10% to 90% response in Generator terminal voltage to a 2% step) will not have an overshoot of more than 20%. The response time will not exceed 0.3 s.

2.1.8 Field Forcing Duty and Current Regulation

The Excitation System will be capable of periodic field forcing at:

(a) 1.6 times the Excitation System Rated Current (the "**Excitation System 30 Second Rating**") for 30 s, immediately preceded by continuous operation at Excitation System Rated Current, and immediately followed by continuous operation at Excitation System Rated Current to allow cooling of the SCR bridges; and

(b) an output current that permits operation of the Generator during an open-circuit saturation test, including continuous operation at rated voltage, followed by 30 seconds of operation at each of 105%, 110%, 115%, and 120% of Generator rated voltage.

The Excitation System will be capable of supplying and controlling its output current:

(c) from a minimum value of 1.5% of Excitation System Rated Current up to the Excitation System Rated Current on a continuous basis; and

(d) when operating on a temporary basis above the Excitation System Rated Current, up to the field forcing duty output currents described above.

Negative field current capability is not required.

2.1.9 Fault Capability and Duty Cycle

The Excitation System will be capable of withstanding the following, without causing the SCRs to exceed their allowable device junction temperature:

(a) Bus fault duty: any fault on the Generator bus for up to 60 s, followed by protection tripping of the Generator breaker and field circuit breaker.

(b) Reclose duty: any fault on the high-voltage side of the Generator step-up transformer, followed by protection clearing of the fault, a period of field forcing, reclosing onto the fault, clearing of the fault then closing into fault, then clearing the fault.

2.1.10 Frequency Operating Range

The Excitation System will be designed to operate correctly:

(a) in the event of Unit overspeed due to a load rejection, the frequency will be considered to be up to normal overspeed trip peak frequency. The duration of the over-frequency period will be considered to be up to 10 s rising and up to 35 s falling, during which time the Excitation System will operate correctly; and

(b) down to 90% of rated Generator speed, or to such lower speed as may later be decided with the Contractor as the desired Excitation System gating cut-off point during normal stopping of the Unit.

2.1.11 Generator Tests

The Excitation System will be capable of being used in the performance of the following Generator tests:

(a) three-phase sudden short circuit test up to 100% rated voltage[1];

(b) open-circuit saturation test from 2% of rated Generator terminal voltage to 120% of rated Generator terminal voltage[1];

(c) short-circuit saturation test (up to 110% of rated Generator current)[1];

(d) efficiency and segregated loss test by calorimetric method[1];

(e) overspeed test at runaway speed for up to 7 min;

(f) rated load saturation test at zero power factor;

(g) heat run temperature rise test;

(h) line charging capacity test;

(i) transient, sub-transient and negative sequence reactance measurement tests; and

(j) load rejection test.

2.2 Configuration

2.2.1 General

The Excitation System will:

(a) be entirely self-contained, independent of other generating Units and of external AC station service supplies;

(b) be capable of start-up with only the supply of Powerhouse 125 Vdc station service for control purposes. 120 Vac station service will be used only for such auxiliary services as will not restrict, or which are non-essential for start-up of the equipment; and

[1] The Excitation System and/or the Exciter Transformer will be fed from the powerhouse station service.

(c) be normally self-excited by taking SCR bridge power sourced from the Generator via the Exciter Transformer, except during initial Generator start-up where an external power source for the field flashing equipment is required.

Each major component of the Excitation System will be housed in a suite of Enclosures that include the:

(d) Exciter Transformer Enclosure;

(e) Power Rectifier Enclosure(s), which will include the Field Breaker Enclosure; and

(f) Excitation System control system Enclosure.

Other subcomponents will be housed inside these cubicles. An AC bus will interconnect the Exciter Transformer and the Power Rectifier, and a DC bus will connect between the Power Rectifier and the Generator field-bus.

2.2.2 Component Standardization and Modularity

The Excitation System components will be of standardized, modular construction so that any card or module may be easily removed from the Excitation System without breaking or making soldered connections.

2.2.3 Excitation System Cooling System

Excitation System components will be cooled by fans (i.e. forced air). The forced air cooling system for each SCR bridge will:

(a) include cooling fans that are dedicated to its associated SCR bridge;

(b) have sufficient capacity to cool its associated SCR bridge while all parallel bridges are in service and the Excitation System is supplying the Generator operating continuously at Generator Rated Output and Generator Rated Operating Conditions;

(c) have sufficient capacity to cool its associated SCR bridge while one parallel bridge is out of service and the Excitation System is supplying the Generator operating continuously at Generator Rated Output and Generator Rated Operating Conditions;

(d) be activated either based on SCR bridge temperatures or upon failure of one SCR bridge;

(e) generate an Alarm upon the failure of a cooling fan;

(f) include means for a Worker to test the operation of all fans while the Excitation System is in operation without restricting the operation of the Excitation System in any way; and

(g) include an Alarm generated if a fan fails to operate correctly.

In addition to the above requirements, if during detailed design of the Powerhouse it is found that the localized heating load from the Excitation System is greater than the capacity for the Powerhouse HVAC system to regulate the air temperature in that localized area, then BC Hydro has the option to require as part of the Work that the air exiting the Excitation System be cooled using water-cooled heat exchanger(s) with similar design requirements to the Generator air coolers specified in Appendix 6-5 [Generator Specifications (SPG)]. The optional work associated with complying with such additional requirements will only be included in the Work if Hydro's Representative so directs in writing delivered to the Contractor's Representative, and in such event:

(h) Hydro's Representative will issue a Change Order for that optional work;

(i) the Contractor will perform that optional work as part of the Work; and

(j) the price for that optional work will be as set out in Appendix 11-1 [Payment Schedule].

2.3 Power Rectifier

2.3.1 Solid State Silicon Controlled Rectifier (SCR)

The Excitation System power rectifier (the "**Power Rectifier**") will utilize three-phase, full-wave, solid-state silicon-controlled rectifier ("**Silicon Controlled Rectifier**" or "**SCR**") bridge assemblies to rectify the Excitation System AC power input to produce the DC output to be used to excite the Generator field. The Power Rectifier will consist of multiple SCR bridges connected in parallel.

2.3.2 Bridge Configuration

A minimum of two parallel SCR bridges will be provided. The bridges will be sized to permit continuous operation at Excitation System Rated Current with one bridge out of service (N+1 redundancy).

If operating with one bridge out of service, the Excitation System will detect this condition and generate an Alarm. Operating with one bridge out of service will not de-rate the Excitation System.

2.3.3 SCR Assembly

Each Excitation System SCR bridge will consist of an integrated, six SCR assembly.

The chassis of each SCR assembly will be solidly grounded with a grounding strap that is sized to handle the SCR fuse let-through current. The ground strap will be easily removable. Grounding of the SCR chassis will be shown on the Drawings.

It will be possible to replace an entire SCR assembly in one piece (i.e., without removing individual SCRs) in approximately 30 minutes or less.

2.3.4 SCR Fusing

Each SCR bridge will be supplied with fuses that will be coordinated with the SCRs, both with respect to the inverse-time characteristics and the current-squared time capability of the SCRs (I^2t). The SCRs will be properly sized and coordinated so that a fault on the DC bus of the Excitation System will cause the fuses to blow and prevent the SCRs from being damaged.

Parallel fuses will not be used unless the Contractor can demonstrate that this is safe under worst-case conditions.

Each SCR and SCR fuse will be supervised by means of conduction-monitoring, or by another method submitted for Consent and accepted by Hydro's Representative and appropriately annunciated.

SCR bridge designs with SCRs in series will not be provided.

2.3.5 DC Shunt

A DC shunt will be installed in the Power Rectifier output circuit for purposes of measuring field current. A means for connecting external test equipment to the DC shunt will be provided (such as threaded studs).

Wiring from the DC shunt to the sensing device will be 5 kV class or higher, and will be routed in raceway separate from all other wiring.

The sensing device connected to the shunt will meet the electrical clearances specified for Enclosures.

2.3.6 Component Inter-Changeability

If an ABB Excitation System is supplied, then the Excitation System will comply with this Specification and have electronic AVR control components that are identical to, and therefore interchangeable with, all Type A, B, and C Excitation Systems supplied under BC Hydro Contract Q7-7711.

In addition BC Hydro would prefer that all other Excitation System components be identical to, and therefore interchangeable with, all Type A, B, and C Excitation Systems supplied under BC Hydro Contract Q7-7711 as much as reasonably practicable to enable BC Hydro to realize synergises such as fleet wide common Excitation System component spare parts.

2.4 Field Breaker

The Excitation System field breaker (the "**Field Breaker**") will be a power circuit breaker rated and arranged to disconnect the current path that runs from the Exciter Transformer low-voltage winding through the Power Rectifier to the Generator field-bus.

BC Hydro prefers a DC Field Breaker. The Field Breaker will be designed and constructed in accordance with IEEE C37.18 for a DC Field Breaker and IEEE C37.13 for an AC Field Breaker.

If an AC Field Breaker is used, the Excitation System will include capability to interrupt SCR bridge firing pulses fast enough to ensure that when an instantaneous trip command is issued to or by the Excitation System, the AC Field Breaker is commanded to open without delay, while:

(a) the de-excitation SCR is operated and Generator field current is forced to discharge through the FDR; and,

(b) Generator field current does not discharge through the Power Rectifier SCR bridges.

The Field Breaker will:

(c) for an AC breaker, be a three-pole spring-operated circuit breaker with motor-operated spring charging suitable for the purpose, with two trip coils for redundancy, and no built-in protection trips (such as overcurrent and undervoltage etc.), and must be charged before it closes;

(d) for a DC breaker, be a one or two-pole circuit breaker with two trip coils/releases for redundancy, and no built-in protection trips (such as overcurrent and undervoltage etc.), and must be charged before it closes;

(e) have each trip coil/release rated for 125 Vdc operation;

(f) have a minimum continuous current rating to withstand 110% of normal duty and 110% of fault duty of the Excitation System;

(g) have a maximum operating time of 133 ms (eight cycles or fewer), where the operating time is defined as the time from trip signal initiation (from external circuitry) to arc extinction;

(h) be rated for operation from the 125 Vdc station service supply as the auxiliary power supply (including motor charging);

(i) be electrically trip-free (anti pumping);

(j) include an operations counter, that will be independent of the Excitation System controller electronics such that failure of same does not cause the counter to reset to zero;

(k) have means to lock the circuit breaker in the “open” position for Worker safety isolation purposes;

(l) have means for a Worker to measure the resistance across the main electrical contacts;

(m) have means for a Worker to measure the breaker pole close and open times (i.e., breaker timing tests);

(n) have means for a Worker to inspect the arc chutes;

(o) include all necessary pushbuttons, switches, and LED lights necessary for local and remote control, indication, and interlocks with the Unit protection and control systems;

(p) be provided with a minimum of six unused form A and six unused form B breaker auxiliary contacts to be used by Others, with all contacts electrically independent and rated for 125 Vdc, 5 A;

(q) have a mechanical position indicator for the current position of the circuit breaker (i.e., open or closed), which is visible from outside the closed Enclosure front, and utilizes a red indicator for the close position and a green indicator for the open position;

(r) operate even in the event of a simultaneous failure of the ExcPCE and ExcRCE; and

(s) have necessary auxiliary contacts to trigger required internal Excitation System functions such as de-excitation, crowbar, etc.

2.5 Field Discharge Equipment

2.5.1 General

The field discharge equipment will be designed to discharge the electrical energy in the Generator field winding under the worst possible circumstances, including the following conditions:

(a) tripping of the Field Breaker upon an normal or emergency shutdown of the Generator;

(b) Generator pole slip; and

(c) short circuit at the Generator terminals.

The field discharge equipment will be mounted in the Power Rectifier Enclosure.

2.5.2 Method of Field Discharge

A method of rapidly discharging the Generator field will be provided, and will include: tripping the Excitation System, opening the Field Breaker, and triggering the de-excitation SCR switch to discharge the Generator field current through the FDR.

The Contractor will produce a Calculation to estimate the field discharge time under the following conditions:

(a) Unit trip and subsequent de-excitation while the Generator is operating at Generator Rated Output and Generator Rated Operating Conditions (with no fault on the Generator terminals);

(b) Unit trip and subsequent de-excitation due to a phase-to-phase fault on the Generator terminals while the Generator is operating at Generator Rated Output and Generator Rated Operating Conditions; and

(c) Unit trip and subsequent de-excitation due to a three-phase fault on the Generator terminals while the Generator is operating at Generator Rated Output and Generator Rated Operating Conditions.

2.5.3 Field Discharge Resistor (FDR)

The field discharge resistor (the "**Field Discharge Resistor**" or "**FDR**") will be a non-linear resistor such as a ceramic varistor. The FDR will:

(a) have a resistance value that is chosen considering the Generator field winding resistance and time constant, and is sized to be as large as possible in order to achieve as short a Generator field current discharge time as possible;

(b) be designed to limit the voltage rise at the Generator field winding and/or Exciter DC Field Breaker to within allowable over-voltage ratings of these components;

(c) be connected in series with the discharge-triggering SCR switches or other means described in SPEXC 2.5.4 and 2.5.5 and across the Generator field winding circuit; and

(d) be capable of absorbing the energy associated with worst-case Generator field discharge scenarios, without damage or need for replacement, including:

    (i) field suppression 100 ms subsequent to a three-phase short circuit that occurs at the Generator stator terminals when the Generator is operating at Rated Output and Generator Rated Operating Conditions; and

    (ii) field suppression subsequent to a Unit trip while the Generator is operating offline at 140% of rated terminal voltage (and the Excitation System is supplying Generator field current to cause this terminal voltage).

The Contractor will complete a Calculation to determine the resistance and the energy rating of the FDR.

2.5.4 De-excitation SCR Switch

If required for the Contractor's design, a de-excitation SCR switch will be provided for the purpose of conducting Generator field current through the FDR in the event that the Field Breaker is opened. The discharge control for the de-excitation SCR switch will operate even for failure of the ExcPCE and ExcRCE.

The de-excitation SCR switch will also have the capability to be triggered from an external protective or lockout relay contact. The controls will be designed so as to prevent field current from passing through the SCR bridges and instead force the current through the FDR.

The Contractor will complete a Calculation to determine the over-voltage trigger level.

2.5.5 Field Shorting SCR Switch (Crowbar)

A field shorting SCR switch or crowbar will be provided for the purpose of conducting the negative field current induced during pole slip and Generator terminal fault conditions through the FDR. The discharge control for the crowbar will operate even for failure of the ExcPCE and ExcRCE. The crowbar will also have the capability to be triggered from an external protective or lockout relay contact.

The Contractor will complete a Calculation to determine the over-voltage trigger level.

2.6 Field Flashing Equipment

2.6.1 General

The Work includes the power, protection, and control equipment required for the automatic field flashing sequence including the rectifier transformer, fused rectifier bridge, blocking and free-wheeling diodes, limiting resistors, field flashing contactor, and connections to the ExcPCE/ExcRCE. Field flashing control will be directed and controlled from the ExcPCE/ExcRCE. A field flashing current limiting circuit will be provided to limit the current from the external sources.

Field flashing will consist of a primary AC source and a backup DC source. The AC source will be a three-phase 600 V source as specified in Appendix 6-2 [General Technical Specifications (SPGT)].

Backup DC field flashing will be provided as an option with manual or auto source change over. The backup source will be 125 Vdc Powerhouse station service. The Contractor will provide a 3-position manual transfer switch to select the supply (off, AC or DC, or if the transfer is automatic, the switch will default to AC field flashing whenever the AC potential is available).

2.6.2 Automatic Field Flashing

The field flashing equipment will provide the initial excitation field current for Generator startup until the Generator output rises sufficiently for the SCR bridges to supply the regular excitation current. Field flashing will be terminated when the controller establishes automatic control of the excitation.

Alarm for loss of AC source will be provided.

2.6.3 Field Flash Cut-Off

Field flashing will be cut off at the moment the ExcPCE (or ExcRCE) determines successful field flashing has been accomplished or upon the timeout of a user-adjustable timer. Acceptable methods of determining a successful field flash include:

(a) the Generator terminal voltage has exceeded a user adjustable threshold; and/or

(b) the Exciter Transformer current/field current has exceeded a user adjustable threshold.

If a DC field circuit breaker is provided, interruption of the field flash current following an incomplete field flash will be designed in such a way to open the DC field circuit breaker while leaving the field flash contactor closed and de-excitation takes place. If an AC field circuit breaker is provided, the de-excitation module is to be triggered to provide a current path prior to opening of the field flash contactor. Alternatively, if the contactor is opened during these conditions, it will be rated for this interrupting duty.

The design of the field flashing system will be such that successful field flashing is guaranteed with either hot or cold field winding with 90% AC source nominal voltage.

2.6.4 Field Flash Current Limiting

The field flashing current limiting circuit will limit the current drain on the field flash source. The design parameters of the current limiting circuit will be accepted with due consideration given to:

(a) field-bus fault conditions;

(b) supply cable resistance;

(c) current capacity of source equipment; and

(d) breaker and/or fuses ratings of source equipment.

2.6.5 Field Flash Equipment Ratings:

The field flash contactor and other field flash components (diodes, transformer, etc.) will have the capability to make and carry the following currents:

(a) field-bus fault current until interrupted by fuse or breaker; and

(b) field flashing current until a timer operates indicating incomplete field flash.

The field flashing equipment will be designed to supply, as a minimum, the Generator field current required to achieve 25% of the Generator's rated voltage when the Generator is offline and at rated speed.

2.6.6 Other Field Flash Component Location

The isolation disconnect switch and all equipment required for field flashing will be located within the Excitation System Enclosures.

2.7 Exciter Transformer

2.7.1 Rating

A transformer (the "**Exciter Transformer**") will be provided to transform Generator terminal voltage down to a level required by the Power Rectifier, and will be an indoor, arc resistant, epoxy resin vacuum pressure impregnated and encapsulated, dry-type, three-phase, two-winding transformer rated for rectifier duty, and manufactured in accordance with CSA C9-M. The Exciter Transformer rating will be as follows:

(a) Capacity: as required to achieve the Excitation System Rated Output;

(b) Primary Voltage: be equal to or greater than the line-to-line rms voltage of the Generator at Generator Rated Output;

(c) Secondary Voltage: as required to meet the rated and ceiling voltage requirements of SPEXC 2.1.6;

(d) Type: ANN;

(e) Insulation Class: 220;

(f) Temperature rise: 80°C;

(g) Ambient temperature: 40°C;

(h) Primary BIL: 110 kV;

(i) Secondary BIL: 20 kV; and

(j) Frequency: 60 Hz.

2.7.2 Design

The Exciter Transformer will:

(a) be either one three-phase transformer or three single-phase transformers connected wye-delta (HV-LV);

(b) have a capability established according to IEEE C57.110, IEEE C57.96, and CSA C9-02;

(c) in addition to the requirements in IEEE C57.12.01 Section 4.1.6, be capable of operating at 150% rated voltage for 3 s without exceeding the limiting temperature rise;

(d) in order to match the Generator capabilities, be designed to withstand on:

    (i) a continuous basis, a 10% increase or decrease in the high-voltage terminal voltage when at the Excitation System Rated Output, and;

    (ii) an intermittent basis, a variation in frequency from 90% to 160% of rated frequency that would be expected to occur during a dynamic disturbance event such as a Generator load rejection, transmission system disturbance, or equipment failure;

(e) have the insulation system designed with consideration of the additional electrical stress due to the existence of constant SCR switching transients produced by static excitation systems;

(f) use thermal Class 220 insulation for the complete core and winding insulation system, designed for the specified temperature rise over the specified ambient temperature with the maximum hot-spot operating temperature of 150°C as in accordance with IEEE C57.96;

(g) be designed and fabricated to take into consideration the harmonics generated by DC rectifier operation mode. Stray losses in each winding and the additional stray losses caused by the harmonics present due to rectification will be kept to a minimum;

(h) be designed to withstand the full harmonic content of the unfiltered highly inductive full load at Excitation System Rated Output;

(i) have a harmonic loss factor F_{HL} suitable to meet the Excitation System Rated Output and that meets the more stringent of the following two methods of determination:

    (i) in accordance with IEEE C57.116; or

    (ii) a K-factor of 13 in accordance with UL 1561;

(j) have a noise level that is consistent with the values shown in CSA C9-M Table 8 measured at 1 m;

(k) in deviation from CSA C9-M requirements, be capable of withstanding without damage:

  (i) a short circuit on one of the secondary terminals as described in IEEE C57.116 for a period determined by the Generator direct-axis transient open-circuit time constant specified in Appendix 6-5 [Generator Specifications (SPG)]; and

  (ii) induced field current resulting from a Generator short circuit;

(l) be capable of operating with a frequency variation from 90% to 160% of the rated value. During a load rejection the time to rise is 10 s and the time to fall is 35 s. Because of regulation features of the static exciter, the Generator terminal voltage will not increase more than 1% during the over-speed period;

(m) conform to CSA C9-M1981; ANN for convection cooling, A - Air cooling, N - Natural convection, N - Natural circulation in contact with the windings; and

(n) satisfy the requirements outlined with IEEE C57.18.

2.7.3 Enclosure

The Exciter Transformer Enclosure will:

(a) be a “knock-down” type construction for ease of dismantling for shipping and re-assembly on Site;

(b) be made of 12-gauge steel metal plates (or thicker);

(c) be designed to facilitate removal and installation of the transformer without dismantling the Generator iso-phase bus-to-Enclosure connections;

(d) be provided with adequate electrical clearances for voltage and current to avoid magnetic heating of the steel enclosure panels and to avoid reducing the voltage withstand capability;

(e) be provided with either a 600 V or 120 V anti-condensation strip heaters with an adjustable temperature controller, suitable to keep the transformer dry when the Generator is out of service for an extended period. The temperature controller will be accessible from the outside of the transformer Enclosure;

(f) be of an explosion-directed design that:

  (i) acts to vent products of an arcing fault or explosion inside the transformer Enclosure upwards;

  (ii) includes explosion-venting Enclosure top sheet sections that are secured with light-duty shear bolts, and include hinges on one edge;

  (iii) includes labels affixed to the transformer Enclosure beside each light-duty shear bolt, listing the type and size of each bolt, and warning that replacement with the same light duty bolt is mandatory.

  (iv) includes means to protect low-voltage instrument or control compartments from arcing faults and explosions within the Exciter Transformer;

(v) includes means to ensure the Enclosure can withstand the maximum calculated internal pressure build-up caused by an internal three-phase fault (e.g., vertical side-sheets that are reinforced with heavy-duty bracing such as angle or channel steel); and

(vi) includes means to connect duct to the explosion vents, such that explosion products can be vented directly outside or elsewhere; and

(g) for single-phase Enclosures, only have openings for cooling vents, and there will be no connections between Enclosures that may allow plasma or hot gas to pass between phases.

2.7.4 Core and Frame

The Exciter Transformer core will:

(a) have a rust-preventative coating applied to prevent rust formation during operation and storage over extended periods of time;

(b) be insulated from the frame; and

(c) be grounded through a copper ground strap. The ground strap will be easily accessible and easily disconnected from ground to allow testing of the core to ground insulation resistance.

The Exciter Transformer frame will:

(d) have a rust preventative coating applied to prevent rust formation during operation and storage over extended periods of time;

(e) be connected to the facility ground bus through a copper ground strap;

(f) be equipped with four lifting eyes that, in combination, will carry the full weight of the completely assembled Exciter Transformer; and

(g) be provided with jacking steps and with base channels along both axis of the Exciter Transformer, or other means where by rollers can be placed under the transformer to facilitate installation and removal of the transformer.

All other handling features will be as described in CSA C9.

2.7.5 Windings and Angular Displacement

The Exciter Transformer will:

(a) have windings made from copper. Aluminum as a winding conductor material will not be accepted;

(b) have a high-voltage winding that is designed for an ungrounded wye connection. The neutral point of the transformer will be insulated to withstand a permanent ground fault on one of the three phases of the Generator terminals;

(c) for the single three-phase option, have high-voltage windings that are separated by insulating phase barriers (NEMA GP-03, NEMA GP-10, or better) or better between each phase coil assembly. These barriers will be large enough to fully segregate the high-voltage winding and connections. The intent is to virtually eliminate the possibility of a phase-to-phase fault on the high-voltage side of the transformer;

(d) have a low-voltage winding will that is delta connected. The angular displacement between primary and secondary will be 30°; and

(e) have all windings supported to withstand the short circuit described in SPEXC 2.7.2(k).

2.7.6 Taps

Taps on the Exciter Transformer are not required.

2.7.7 Fire Retardant Capability

The Exciter Transformer will comprise materials that result in minimal toxicity upon burning and do not support combustion.

2.7.8 Current and Voltage Transformers

(a) Current Transformers (CTs): Two sets of current transformers (primary and standby) will be provided on the high-voltage (HV) bushing assembly for Excitation System protection. Each set of current transformers will:

(i) be Type TPS;

(ii) include up to four taps (required quantity and ratios of taps will be provided by BC Hydro at the time of equipment order);

(iii) have a CSA standard CAN3-C13-M83 accuracy class that is acceptable and with accuracy limiting voltage (VAL) of 800 and limiting current (IAL) of 10%;

(iv) have mechanical and thermal short-time ratings such that they are able to withstand a three-phase short circuit on the high-voltage side of the Exciter Transformer while operating at any excitation level up to the rated overload field current;

(v) be supplied with a continuous secondary thermal current rating factor of 1.5 and a maximum secondary resistance of 1 ohm at 75°C;

(vi) have a secondary winding that is fully distributed at all nominal taps. The actual exciting current will not vary more than 20% in current from the exciting current characteristic up to the knee point. The current transformer core will be demagnetized after shop tests.

The Work includes wiring the leads from all CT taps to a suitably located CT junction box Enclosure. The CTs will be wired directly to the junction box Enclosure. Two independent connections to each wire in accordance with BC Hydro ES 45–V0371 will be provided.

(b) Voltage Transformers (VTs): Generator terminal voltage transformers will be provided by Others.

2.7.9 High-Voltage and Low-Voltage Buswork

The Exciter Transformer Enclosure will be provided with high-voltage (HV) and low-voltage (LV) buswork. The buswork will meet the following requirements:

(a) Isolation Links: The HV and LV buses and terminals will include removable links for isolation of the transformer during maintenance as in accordance with SPEXC 2.8.4. The links will be clearly labelled as to identify their correct location.

(b) HV Bus Phase Barriers: The HV bus will be equipped with phase barriers made of rigid NEMA GP-03, NEMA GP-10, or better insulating material.

(c) HV Bus Insulation: The HV bus will be insulated up to the connection points to a minimum of 15 kV for 13.8 kV Generators and to a minimum of 25 kV for Generators with a rated voltage greater than 13.8 kV but less than or equal to 16 kV.

(d) LV Bus Insulation: The LV bus will be insulated up to the connection points to a minimum of 5 kV.

(e) HV Termination: The Exciter Transformer Enclosure will include provisions for termination of isolated phase bus (supplied, installed, and terminated by Others), and will be provided with matching flanges, bushings, and flexible copper braid connectors, and designed to fit the Generator/iso-phase bus. Flexible copper braid connectors will be entirely located within the Exciter Transformer Enclosure, located and arranged to allow convenient inspection, connection, and disconnection by Workers. The Work includes provision of all transformer connection details and dimensions for interfacing with the IPB.

(f) LV Termination: If the Exciter Transformer Enclosure and Power Rectifier Enclosure are installed side-by-side, complete LV buswork, suitable for the direct bus connection between the transformer LV terminal and the Excitation System will be provided.

If the Exciter Transformer Enclosure is installed separate from the Power Rectifier Enclosure, both Enclosures will provide connection between the Exciter Transformer and Power Rectifier low-voltage buses. The LV terminations will be setup to accept two-hole cable lugs.

2.8 Excitation System Buswork and Terminations

2.8.1 Materials

(a) All buses will be of copper bus bar; and

(b) All buswork support structures and barriers will be:

(i) made of NEMA GP-03, NEMA GP-10, or better rated material; and

(ii) fastened using non-conductive bolts; or if bolts are conductive, they will be insulated.

2.8.2 Connections

All buswork connections and links will:

(a) include at least two fasteners at each end for terminating and/or connection purposes. Single-hole connections and links will not be provided;

(b) include removable insulating boots for all connection points;

(c) be silver- or tin-plated at all contact surfaces; and

(d) be staggered between phases to minimize the chance of a phase-to-phase fault.

2.8.3 Excitation System Field Lead Terminations

The positive and negative Excitation System buses will each include provision for up to eight cable connectors per pole.

There will be adequate space between the Excitation System DC poles to allow for Excitation System field lead connections.

2.8.4 Field Reversing Links

The Excitation System DC buswork will include removable field reversing links, designed to allow the polarity of the Generator field equipment to be reversed, when the Unit is shut down, by reversing the connections of the links, The reversing links will:

(a) be solid copper bus bars of nut and bolt configuration, with a minimum of four bolted connection points per termination (in NEMA two-by-two configuration);

(b) be completely removable, and be sized and arranged to provide sufficient physical isolation to allow high-voltage testing of the Excitation System to be conducted when they are removed;

(c) be designed and arranged for convenient removal by Workers;

(d) provide visible isolation, and be designed and arranged such that they are easily viewable by Workers;

(e) be provided with blocking and bracing to support the weight of the field leads when the links are removed; and

(f) be clearly labelled so as to identify their correct location.

Reversing switches will not be provided.

2.8.5 Minimum Strength

Bus bars, interconnections, clamps and supports will be of sufficient capacity to withstand the maximum short-circuit stresses.

2.8.6 Support

All buses and terminals will be adequately supported to ensure mechanical integrity during operation, transient, short-circuit, and seismic events.

2.8.7 Temperature Rise

The temperature rise will not exceed the limits stated in CSA C22 No. 31.

2.8.8 Insulation

All DC and low-voltage AC buswork will be insulated to a minimum 5 kV rating. The entire buswork will be insulated up to (but excluding) the connection points.

All energized components will be insulated to withstand a high-potential test of two times rated voltage plus 1000 Vac for 2 min.

Devices that have uninsulated leads will be provided with insulating sleeves.

Bus bar insulation material will be Class 180 rated for 120˚C temperature rise.

2.9 Excitation System AC and DC Cables

2.9.1 General

The Excitation System will include the following power connections and cables that will be installed in bus ducts:

(a) AC cables between the Exciter Transformer and Power Rectifier Enclosure, if the two Enclosures are separate; and

(b) DC Exciter field cables between the Exciter Power Rectifier Enclosure and Generator Enclosure for connection to the Generator field-bus at the interface connection located at the transition point from the Generator upper bracket to the Generator Enclosure wall.

2.9.2 Exciter Field Cables

The Exciter field cables connect the Excitation System to the Generator field bus. The Exciter field cables will:

(a) be continuous;

(b) be CSA RW90 type, 5000 V, stranded single copper conductors with cross linked polyethylene insulation, fire-retardant FT-4 rated PVC-jacketed, unshielded, and rated at 90°C;

(c) be sized for the Rated Field Current with an allowance for transient conditions experienced during unusual operating conditions such as faults on the transmission system or Generator acceptance and commissioning tests;

(d) be provided as multiple cables per pole, in order to ease installation and assembly/disassembly of the Unit by providing more flexible cables with a smaller minimum cable bend radius;

(e) be terminated with tin-plated copper NEMA lugs that are designed for two compression crimps per cable termination, and two bolted connections per cable termination;

(f) be supported and secured in a Raceway;

(g) enter the Generator Enclosure at a point nearest the Power Rectifier Enclosure; and

(h) not pass through the Generator Terminal Cabinet.

2.10 Open-Loop Configuration and Operation Requirements

To permit configuration of the Excitation System for open-loop operation (where the Excitation System is powered by a separate AC source other than the Generator terminals), means will be provided for conveniently, safely, and securely connecting one of two alternative open-loop source cables to the Excitation System to provide an external three-phase power supply to either the Exciter Transformer or the Power Rectifier as follows (both alternatives are required):

(a) Three-phase source connection (with voltage equal to rated Generator terminal voltage) to the high-voltage winding of the Exciter Transformer, including:

  (i) means for open-loop source cable entry to the Exciter Transformer Enclosure (while preserving the performance of the explosion-directed design of the Exciter Transformer Enclosure);

(ii) means to securely harness the open-loop source cable near its entry point in the Exciter Transformer Enclosure;

(iii) means to securely terminate the open-loop source cable conductors to the Exciter Transformer termination point normally used for terminating the flexible copper braid connectors (these connectors will be removed to permit connection of the open-loop source cable);

(iv) an arrangement that provides adequate clearances between the Exciter Transformer high-voltage winding, the iso-phase bus terminals, and the open-loop source cable; and

(v) an arrangement that permits all panels and doors on the Exciter Transformer Enclosure to be closed and secured in their normal manner when the Excitation System is configured for open-loop operation.

(b) 600 V three-phase source connection to the Power Rectifier, including:

(i) means for open-loop source cable entry to the Power Rectifier;

(ii) means for securely harnessing the open-loop source cable near its entry point in the Power Rectifier;

(iii) means to disconnect the Exciter Transformer secondary bus from the Power Rectifier bus, in order to allow connection of the open-loop source cable;

(iv) means to securely terminate the open-loop source cable conductors to the Power Rectifier bus that is normally connected to the secondary terminals of the Exciter Transformer;

(v) an arrangement that provides adequate clearances between the Power Rectifier bus, the Exciter Transformer secondary bus, and the open-loop source cable; and

(vi) an arrangement that permits all panels and doors on the Power Rectifier Enclosure to be closed and secured in their normal manner when the Excitation System is configured for open-loop operation.

The Excitation System will be capable of operating continuously in open-loop operation without the need to modify or alter the Excitation System in any way other than to connect the open-loop source cable and change software set-points.

2.11 Communications Requirements and Protocol

Both the ExcPCE and the ExcRCE will have communications capability. Each controller will be capable of supporting a minimum of four concurrent communication connections. Any connection will be capable of access to the three levels of communications:

(a) Maintenance Level: The maintenance level will be used for uploading and downloading configuration files and/or firmware from/to a laptop computer. The maintenance level will have individual password protection and a hardware “setting change enable” switch.

(b) Control Level: The control level will be used for communicating real-time operating variables to other systems including all Alarms, statuses, metering/analog quantities and control commands (voltage raise/lower, Excitation System start/stop, etc.) as defined in SPEXC 2.14.3. The entire list of operating variables will be updated over the control level on a continuous basis every 500 ms or faster. The control level will conform to Modbus TCP protocol. The control level will have individual password protection. The password protection will have the ability to be disabled for the control level.

(c) Data Level: The data level will be used for uploading of Event records, oscillography records and internal Alarm logs to other systems. Password protection is not required for the data level.

All levels will be accessible via Ethernet.

A minimum of four RJ-45 Ethernet connection ports will be provided. Each port will have the ability to provide all three levels of communication concurrently.

Ethernet ports will be either 10BaseT or 100BaseT.

2.12 Control Requirements

2.12.1 Primary and Redundant Digital Computational Elements (ExcPCE and ExcRCE)

The Excitation System will utilize a primary computational element (an "**ExcPCE**") and an Excitation System redundant computational element (an "**ExcRCE**"), each of which will be a Software-Driven Device. The ExcPCE and ExcRCE will be completely redundant and completely independent of each other, and each will have its own full set of input/output hardware. The ExcPCE and ExcRCE will:

(a) have Excitation System start/stop sequence control, automatic regulator closed-loop control, field flash control, manual control, reactance drop compensation, gate pulse generation, logging, and display of Excitation System events and Generator data;

(b) direct communication of Excitation System information via the communication channels;

(c) include the necessary logic to respond to external commands provided by Others;

(d) have the ability to compute limiting variables and apply the associated control actions;

(e) have a logic sequencer that is available to BC Hydro for modification (such as PLC logic);

(f) have the ability to simulate the input commands and status values via a connected Laptop or Exciter HMI;

(g) have the ability to drive multiple Exciter HMIs and/or individual digital meters;

(h) have the ability to detect internal and external failures and apply the appropriate control actions;

(i) have the power system stabilizer function;

(j) include functionality to automatically and bump-lessly transfer control of the Excitation System to the ExcRCE, if a failure to operate at any limit is detected, or upon ExcPCE detected failure; and

(k) accept an IRIG-B timing signal (provided by Others), and use it to synchronize the ExcPCE and ExcRCE clocks and also to timestamp Events that occur within the Excitation System.

Programming of the ExcPCE and ExcRCE will be Software-Adjustable.

Transfer of control of the Excitation System from the ExcRCE to the ExcPCE will only be Worker-Adjustable (i.e., this transfer will not occur automatically, and capability for a device remote from the Excitation System to execute this transfer will not be provided).

The Work includes provision of the complete programming libraries including support software so that the complete system may be rebuilt from a system without code or settings. The object is to be able to maintain the software furnished over a period of many years and to not be required to be reliant on the manufacturer to perform this function.

2.12.2 Start Sequence Control

Excitation System start-up will be initiated by an external dry contact supplied by Others. The external start contact will remain closed until the unit start sequence has been completed or a stop command has been issued. Excitation System start-up will be blocked if external permissive conditions are not met, including:

(a) the external Excitation System start command is de-asserted;

(b) the external Excitation System stop command is asserted;

(c) the external Excitation System emergency stop command is asserted; or

(d) the external 95% speed indication is de-asserted.

If the field breaker is open prior to the start command, the start command will close the field breaker.

2.12.3 Synchronizing

The Work includes provisions for a discrete input and a “running” voltage transformer analog input (115 Vac nominal) for voltage matching purposes. After a successful field flash, a signal will be sent by Others to this discrete input whereupon the Excitation System will adjust the excitation level until the Generator terminal voltage equals the “running” potential (i.e. voltages are matched and ready for synchronizing). The voltage matching will be blocked if the running potential is out of range. The range will be adjustable from a lower setting of 70% to 90% to an upper range of 100% to 120% of nominal voltage. Enabling the voltage match will block external voltage control as described in SPEXC 2.12.8.

2.12.4 Stop Sequence Control

The Excitation System will be de-excited rapidly (by going to negative ceiling voltage) when an external dry contact supplied by Others initiates the Excitation System de-excitation. The operation of the de-excitation contact will override the operation of the Excitation System start contact. The field breaker will not be tripped during this sequence. The de-excite signal will remain until the Generator terminal voltage reaches 20%.

2.12.5 Emergency Stop Sequence

There will be a 125 Vdc input fed by two or more parallel dry contacts supplied by Others to initiate an emergency Excitation System stop. The initiation of this input will cause rapid de-excitation as described in SPEXC 2.12.4 and instantaneous trip of the DC field breaker, or rapid de-excitation followed by a delayed trip of an AC field breaker. The delay time will be adjustable and set to an initial value of 3 s.

2.12.6 Automatic Voltage Regulator (AVR)

The Excitation System will include automatic voltage regulation (“**Automatic Voltage Regulator**” or “**AVR**”) functionality, in order to derive the desired generator terminal voltage, a Generator terminal voltage error signal from the Generator terminal voltage feedback signal and the Generator terminal voltage set-point signal will to cause the Excitation System to automatically adjust its output to correct for the error.

The Generator terminal voltage feedback signal will be derived from sensing circuitry that utilizes phase-to-phase voltages. Phase-to-ground sensing will not be used. The sensing circuitry will compute the average of the three-phase voltages and detect the failure of one or more phases.

The AVR will:

(a) incorporate a software-based digital-type voltage regulator and will respond to changes in Generator terminal voltage. A rectified voltage proportional to the average three-phase Generator terminal voltage will be continuously compared against an accurately controlled reference set-point, supplemented by appropriate stabilizing and limiting signals to be derived within the controller;

(b) be provided with switching facilities that permit disconnection of the stabilizing signal, and substitution by an alternative stabilizing signal to be provided by Others; and

(c) be provided with a method to connect an external analog test signal to a high-resolution, high-speed analog input, and sum this signal to the Generator terminal voltage error signal.

2.12.7 Voltage Regulator - Manual Control Reference Setting Requirements

For manual control of Generator excitation, a manual set-point will be provided in the regulating system to set and maintain Excitation System current or voltage, over a range sufficient to control the Generator terminal voltage from 30% to 120% of rated voltage at no-load. This set-point will:

(a) not be operative to control the Excitation System output current at any time during AVR control;

(b) be Worker-Adjustable at a Software-Adjustable rate; and

(c) be adjustable via hardwired Excitation System inputs from devices external to the Excitation System;

2.12.8 Voltage Regulator - Automatic Control Reference Setting Requirements

The operating range of the AVR will cover the complete operating range of the Generator (as modified by any Excitation System limiter functions that are active).

Setting of the desired Generator terminal voltage during automatic control will be provided for within the regulating system by a voltage set-point capable of setting the Excitation System output voltage over a range sufficient to control the Generator terminal voltage from 80% to 110% of Generator rated voltage.

The voltage set-point will:

(a) be Worker-Adjustable at a Software-Adjustable ramp rate;

(b) be adjustable via hardwired Excitation System inputs from devices external to the Excitation System;

2.12.9 Auto/Manual Regulators - Dual Follower

If the Generator voltage transformer (VT) inputs to the Excitation System will fail while the AVR is in control, the Excitation System will automatically transfer to manual regulation. To facilitate this transfer, voltage transformer potential supervision will be provided. To prevent inadvertent operation, during field flashing and system fault conditions, the VT voltage will be compared with the Exciter Transformer secondary voltage. The manual set-point will automatically go to a pre set value if the Excitation System is in manual and the unit breaker opens.

(a) Auto Manual Control Transfer: Transfer from AVR to manual regulation, as well as transfer from manual regulation to AVR will be Worker-Adjustable.

(b) Dual Follower: The Work includes follower functionality in the excitation control system which will, after successful field flash, balance the manual regulator set-point and the AVR set-point to ensure essentially bump-less transfer from the AVR to the manual regulator and vice versa.

2.12.10 Power System Stabilizer

The Work includes power system stabilizing (PSS) functionality integral to the ExcPCE and ExcRCE, in order to cause the Excitation System to aid in the damping of Generator and power system oscillations.

The PSS will consist of two elements. The first element will be an input section whose function is to derive necessary PSS input signals and other stabilizing signals from Generator voltage transformer and current transformer signals. The second section will consist of a configurable Laplace transfer function. External transducers will not be used to derive PSS input signals.

The first element will be of the dual input type (Delta P/Delta Omega design) IEEE 421.5 PSS Type 2A compliant. It will derive accelerating power by subtracting electrical power from derived mechanical power. The mechanical power and electrical power terms will be derived from the Generator voltage transformer and current transformer inputs alone.

The Laplace section will have a minimum of two poles, two zeros and a washout term. The lead and lag terms of the poles and zeroes will be user adjustable over a range of 15 ms to 6 s in 5 ms steps. The limiter maximum term will be user adjustable over a range of 0 to 0.3 pu in 0.01 pu steps. The limiter minimum term will be user adjustable over a range of -0.3 to 0 pu in 0.01 pu steps. The gain term will be user adjustable over a range of -50 to +50 Vref/pu speed in steps of 0.1.

It will be possible to isolate the PSS input and output from the remainder of the Excitation System and the PSS input and output will be switchable to external test points.

The A/D and D/A converter sampling rates will be 1 ms or faster.

2.12.11 External PSS Provisions

The PSS output will have the ability to be summed into the summing junction where the Vref and voltage feedback signals are summed or at a point beyond the limiter control (the PSS will remain in service even if a limiter is limiting). In addition, this summing junction will have capability to add an additional signal from an external PSS in the future. One spare external analog input channel for this purpose will be provided. The A/D converter sampling rate will be 1 ms or faster.

2.12.12 PSS On/Off Control

The PSS will be disabled when the Unit circuit breaker is open or when the PSS is switched off for test purposes, or when the Generator loading is below a Software-Adjustable lower limit set-point. For this purpose, two external discrete input channels - one for circuit breaker status, and a second for PSS on/off test purposes will be provided. The PSS on/off test input will be normally jumpered to the “on” position (no switch required).

2.12.13 Synchronous Condenser Mode

The PSS will have two sets of gains available. One set of gains will be for generate mode, and the other will be for synchronous condense mode. It will be possible to set either gain to a positive or a negative value. Transfer from generate mode to synch condense mode will be controlled by an external discrete input. The rate of change of the gain will be adjustable.

2.12.14 Over Excitation Limiter

The over-excitation limiter will be provided to prevent continuous operation of the Excitation System beyond the Excitation System and Generator field winding thermal limits by reducing field current. It will have a user adjustable field current setting with an inverse time characteristic so that it can be coordinated with the Generator rotor field heating characteristic. It will also have a user adjustable reset time. The Contractor will provide, with the Excitation System equipment, the necessary field current sensing for this function.

The over-excitation limiter will not inhibit field forcing requirements as required by the duty cycle nor will it limit the transient action of the power system stabilizer. When the limiter operates, there will be a visual indication at the Excitation System and a contact output will be provided for connection to the external BC Hydro Alarm system. The Alarm will be blocked when the Excitation System is shut off.

2.12.15 Under (minimum) Excitation Limiter

An under-excitation limiter will be provided to prevent the Generator from entering under-excited loading conditions which could result in loss of synchronization. Programmable multiple-point operating curve (P, Q type) is preferred with compensation to the square of the terminal voltage. Simple straight line type under-excitation limiter will not be used.

The under-excitation limiter will not inhibit field forcing requirements as required by the duty cycle nor will it limit the transient action of the power system stabilizer. When the limiter operates, there will be a visual indication at the Excitation System and a contact output will be provided for connection to the external BC Hydro Alarm system. The Alarm will be blocked when the Excitation System is shut off.

2.12.16 Volts/Hertz Limiter

A volts/hertz limiter will be provided to prevent over-excitation as Generator speed declines or during Generator over-voltage conditions. The volts/hertz limit will be continuously adjustable over the range of 0.75 to 1.25 pu volts/pu frequency. When the limiter operates, there will be a visual indication at the Excitation System and a contact output will be provided for connection to the external BC Hydro Alarm system. The limiter will be accurate over a frequency range `of 15 Hz to 180 Hz. The Alarm will be blocked when the Excitation System is shut off.

2.12.17 Regulator Control and Gain

The Excitation System regulators will include the following characteristics:

(a) a proportional gain element that can be set high enough to obtain fast response with small initial error after settling, and low enough to enable stable operation; and

(b) an integral element that can be set to allow for a slower response to remove any difference between the actual and desired output.

2.12.18 Transformer/Line Drop Compensator

Transformer and line drop compensation will be provided to permit regulation of voltage on the high-voltage side of the Generator transformer (or to compensate for a portion of the transformer impedance), or to provide a droop characteristic in the event multiple Generators are directly connected to the same bus. The compensation level and polarity will be user adjustable.

2.12.19 Pre-set Runback

Automatic positioning of the automatic and manual voltage set-point to a pre-determined setting will be provided to allow start-up to a nominal Generator voltage level of 1.00 pu. This runback action will occur upon initiation of the Excitation System start signal as described in SPEXC 2.12.2. Voltage set-point raise/lower control as specified in SPEXC 2.12.8 will be enabled after a successful field flash.

2.13 Protection and Monitoring Requirements

2.13.1 General

All devices and functionality considered necessary to protect the Excitation System equipment against damage resulting from unusual conditions during operation and from service interruptions will be provided. The protection will include the devices and functionality listed in the following Sections, and implementation of the protective functions described in section 6 and Appendix E of BC Hydro DP 45-Z0031.

2.13.2 Field Flashing Protection

Field flashing protection will be provided to remove field flashing in the event that field flashing has not succeeded within a Software-Adjustable pre-set time from the moment of field flash initiation. Operation will cause an Alarm and a protection output contact will be closed to initiate a Generator shutdown via circuitry provided by Others.

2.13.3 Loss of Generator Terminal Voltage Sensing Protection

Loss of Generator terminal voltage sensing protection will be provided and be as described in SPEXC 2.12.9. An Alarm output will be provided. The Excitation System output over-voltage protection will be independent of the field control system and capable of coordinating with the normal duty cycle.

2.13.4 AC Overcurrent Protection

Overcurrent protection will be provided and will:

(a) be implemented using two SEL 351 digital protective relays, in three-phase, fully redundant (primary/standby) configuration, completely independent of the ExcPCE and ExcRCE, with each connected to the associated primary/standby Exciter Transformer high-voltage current transformers;

(b) be adequate for detection of high-voltage winding as well as low-voltage winding Exciter Transformer faults;

(c) be adequate for detection of AC faults on the connection between the Exciter Transformer and the Power Rectifier;

(d) be adequate for detection of AC bus faults within the Power Rectifier; and

(e) be secure, that is, not operate during normal operating conditions which are specified as part of the Excitation System duty cycle.

2.13.5 Field Over-Voltage Protection

Field over-voltage protection functionality will be provided. This protection is intended to protect the field winding against excessive voltage in the event of failure in the voltage control system and it will:

(a) be independent of the field control system;

(b) be capable of coordinating with the normal duty cycle;

(c) be capable of protecting against both positive and negative over-voltage;

(d) initiate an Alarm and close a protection output contact to initiate Generator shutdown via circuitry provided by Others; and

(e) be provided in the Excitation System Enclosures.

2.13.6 Field Overcurrent Protection

Field overcurrent protection functionality will be provided. This protection is intended to protect the field winding against excessive current in the event of failure of the current control system and it will:

(a) be independent of the over excitation limiter control system;

(b) have similar user-adjustable inverse-time overcurrent characteristics as the control system;

(c) be capable of being set to coordinate with the Generator rotor field heating characteristic;

(d) be implemented in each of the two SEL-351 protective relays provided with the Excitation System;

(e) initiate an Alarm and close a protection output contact to initiate Generator shutdown via circuitry provided by Others; and

(f) be provided in the Excitation System Enclosure.

2.13.7 Pole Slip (Crowbar) Protection

The Excitation System will include a suitable means of protecting the excitation system and field windings from damage caused by the voltages and currents during pole slip. Crowbar protection operation will:

(a) be designed to have this protection initiated from an external contact; and

(b) initiate an Alarm and close a protection output contact to initiate Generator shutdown via circuitry provided by Others.

2.13.8 100% Field Ground Protection

One hundred percent (100%) field ground protection functionality will be provided. This protection will detect grounds over the entire field winding, the DC and AC bus and the Exciter Transformer secondary winding and it will:

(a) be designed such that inadvertent operation of the protection does not occur during field flashing sequence (at which time the field may be grounded via the station service supply);

(b) include a field ground detector with separate Alarm and trip outputs;

(c) include a filter network, if required, to isolate the field ground detector from the harmonics and field forcing voltage generated by the Excitation System;

(d) include the Alarm and trip pickup points (to be set in kiloOhms) be separately adjustable such that the Alarm output can be triggered at a more sensitive level than the trip output;

(e) include the Alarm and trip be time-delayed (with separate adjustable pickup delays from one to 200 s) to override possible transient operation of the detector during field flashing sequences;

(f) include one Alarm point to indicate correct test operation of the detector; and

(g) include a display of the field-to-ground resistance.

2.13.9 Field Current Low (Third Harmonic Suppression) Output

Two field current low outputs will be provided. The outputs will be form C or A/B configurable contacts provided for use in Unit protective equipment provided by Others. These outputs are intended to be used for disabling the third harmonic under-voltage protection function. The field current set points will be Software-Adjustable.

2.13.10 Conduction Monitoring Protection

Conduction failure monitoring functionality will be provided. The provided method will employ multiple current sensing elements on each bridge. The Excitation System will be able to determine precisely which SCR has failed and provide Worker indication of the failed SCR. An Alarm will be raised for single bridge failures and protection shutdown for multiple bridge failures as required.

2.13.11 Shaft Voltage Suppression

The Excitation System will include equipment to help suppress voltages that may be induced on the Unit shaft.

2.13.12 AC Line Filtering

The Excitation System will have equipment on the low-voltage AC bus to filter out high-frequency switching transients.

2.13.13 Computer or Power Supply Failure Protection

Computer or power supply failure protection functionality will be provided. The protection will operate for any of the following conditions:

(a) failure of both the ExcPCE and ExcRCE;

(b) failure of critical I/O cards (any cards used for control purposes); and

(c) failure of both of redundant power supplies with the field breaker closed.

Protection operation will initiate an Alarm and a protection output contact close to initiate Generator shutdown via circuitry provided by Others.

If the power supplies for the gate pulse amplifiers (GPA) are separate from those used for the ExcPCE and ExcRCE, a power supply failure detection circuit for the GPA supplies is not required because this failure contingency will be covered by the conduction monitoring protection (detailed in SPEXC 2.13.10).

An Alarm only will be generated in the event that only one of the two redundant power supplies fail.

2.13.14 Excitation System Temperature Monitoring

Temperature sensing of the rectifiers will be provided. For this purpose, RTDs insulated to a minimum of 5 kV will be installed in the rectifier Enclosure in such location(s) as to measure:

(a) the inlet air temperature; and

(b) the temperature of each SCR heat sink located as close as practical to the SCR.

2.13.15 Exciter Transformer Winding Over-Temperature Protection

The Exciter Transformer will be equipped with RTDs installed in the locations where the manufacturer expects the hottest operating temperatures to occur. The Work includes a Calculation to determine the Exciter Transformer hot-spots, where Exciter Transformer RTDs specified in this SPEXC will be installed. As a minimum, RTDs will be installed in the following locations:

(a) two RTDs located in each low-voltage winding coil in the hottest location (6 RTDs total). The RTDs will be located in wells that extend down approximately 1/3 the height of each low-voltage coil and as close to the inner lead as practical to most closely indicate the hot spot temperature of each winding; and

(b) two RTDs will be located on each transformer core leg in the hottest location (6 RTDs total).

RTDs will not be located in the cooling air ducts.

The RTDs will:

(c) meet the requirements of Appendix 6-2 [General Technical Specifications (SPGT)];

(d) be wired to a junction box located in the Exciter Transformer Enclosure; and

(e) have a minimum 5 kV class insulation to insulate the RTD from the low-voltage winding.

Half of the RTD pairs will be connected to the ExcPCE and the other half of the RTD pairs will be connected to the ExcRCE. Both the ExcPCE and ExcRCE will provide trip output contacts and a high-temperature Alarm.

The RTD junction box will:

(f) be flush mounted with the Exciter Transformer Enclosure; and

(g) be accessible from outside the Exciter Transformer Enclosure.

2.13.16 Rotor V-I Temperature Monitoring

A field temperature Calculation function will be provided. This field temperature Calculation will:

(a) provide an Alarm upon exceeding a user adjustable pre-set limit;

(b) be performed using field voltage and field current as input variables;

(c) include an user-adjustable setting to compensate for the voltage drop across the brushes; and

(d) be appropriately low-pass filtered to avoid false Calculations during field voltage transient conditions (including start-up transients.

2.13.17 Fault Recording

The capability to record user-specified analog quantities/variables both prior to and following Excitation System initiated protection shutdowns will be provided. The recorded variables will:

(a) have a field adjustable sampling rate which will be submitted for Review;

(b) be stored in each of the ExcPCE's and ExcRCE's memory;

(c) store a minimum of 15 s of pre-trigger and 60 s of post-trigger information; and

(d) be user-assignable without restriction (i.e., any of the ExcPCE's and ExcRCE's internal variables will be assignable).

It will be possible to record a minimum of eight variables in each of the ExcPCE's and ExcRCE's memory.

Display of the fault recorder's memory will be via a Windows 7 compatible laptop PC using software supplied by the Contractor. The display software will:

(e) display the recorded variables in graphical form along with the initiating protection operation and the associated date and time;

(f) have the option to save the data in an ASCII, comma-separated-variable (CSV) and raw text file;

(g) have provision for storing the recorded data to a laptop

(h) have provision for graphical data printout; and

(i) allow for the events to be downloaded via the Ethernet communication system.

2.13.18 Unit Protection Interface

There will be two relays designated 94EG and 94EN for interface with external circuits in accordance with BC Hydro drawing G417 H14 B9.

2.14 Interface Requirements - Control, Status, Alarm, and Protection

2.14.1 Select Before Operate Control

Except where otherwise explicitly stated in this Appendix 6-6 [Excitation System Specifications (SPEXC)], control commands issued to the Excitation System, either by a Worker using the Exciter HMI, or by an external device (provided by Others) via hardwired input, will be issued via a two-step select-before-operate (SBO) process (intended to cause deliberate operator action and reduce the possibility of operator error), whereby:

(a) Step 1: the Worker or external device issues a command to select the control point to be acted upon, this selection is latched in by the Excitation System, and indication of the latched-in selection is sent back to the external device (via hardwired output) and Exciter HMI as a permissive for the control command; and then

(b) Step 2: the Worker or external device either:

(i) issues a “close/on/raise” command to send an assertion or increase command associated with the selected control point, or an “open/off/lower” command to send a de-assertion or decrease command associated with the selected control point; or

(ii) issues a one-step reset command, which un-latches and de-selects the currently selected control point.

The Excitation System will not accept control commands if no control point is selected.

Commands that will not follow the SBO Procedure include:

(c) commands from protective devices (either within or external to the Excitation System) to shut down the Excitation System;

(d) commands from emergency stop pushbuttons (either within or external to the Excitation System) to shut down the Excitation System; and

(e) the local/remote transfer switch included as part of the Exciter Hardwired Controls.

2.14.2 Local Operator Interface

(a) General: A digital colour touchscreen Exciter human machine interface (or “**Exciter Human Machine Interface**” or “**Exciter HMI**”) will be provided by the Contractor, as the primary means to:

(i) communicate visual display of Excitation System indication, annunciation, metering, and monitoring to Workers using the Excitation System; and

(ii) accept operator input commands from Workers using the Excitation System.

(b) Display: The Exciter HMI will:

(i) be a colour LCD touchscreen device, with a minimum diagonal screen size of 300 mm;

(ii) not include moving parts (i.e., no hard disk drives or fans);

(iii) include screen graphics that are designed to maximize readability, and consider the relative importance of data when arranging screen graphics. Simplicity and readability are valued over graphically accurate depictions of equipment;

(iv) communicate with the Exciter PLC via a DB9 serial communications port, used for RS232/485 communications, and connected directly to the Exciter PLC; and

(v) be mounted on the Excitation System control system Enclosure for use as local operator interface panel.

(c) HMI Control: It will be possible to control the Excitation System from the Exciter HMI, which will include the following functionality:

(i) Alarm acknowledge and reset;

(ii) Generator/field voltage raise (common for both auto and manual controls), in accordance with SPEXC 2.12.7;

(iii) Generator/field voltage lower (common for both auto and manual controls), in accordance with SPEXC 2.12.7;

(iv) auto/manual transfer (in accordance with SPEXC 2.12.9);

(v) ExcPCE/ExcRCE transfer (in accordance with SPEXC 2.12.1);

(vi) Excitation System start (in accordance with SPEXC 2.12.2);

(vii) Excitation System stop (de-excite – in accordance with SPEXC 2.12.4); and

(viii) Excitation System field breaker open control (in accordance with SPEXC 2.4).

(d) Exciter Hardwired Controls: The following hardwired controls (the "**Exciter Hardwired Controls**") will be provided with the Excitation System:

(i) An "emergency stop" pushbutton, used to issue a command to cause immediate emergency shutdown of the Unit. This will be a red, mechanically-latched/reset pushbutton with mushroom operator, and a shroud to minimize the possibility of inadvertent operation.

(ii) A "local/remote control transfer" pushbutton (two-position, pistol-grip, mechanically-latched style), used to select the Excitation System local/remote control mode.

All other control inputs to the Excitation System will be via the Exciter HMI, or via hardwired control commands from a remote device external to the Excitation System.

When in remote mode, all local Exciter HMI control and Exciter Hardwired Controls will be blocked. When in local mode, all remote control interface signals (SPEXC 2.14.3(a)) will be blocked. The local/remote will be a maintained-style rotary switch. The local/remote switch will not block external trips and Equipment indicators.

(e) Status: Status indications will be displayed on the Exciter HMI, including:

(i) field breaker open/closed (in accordance with SPEXC 2.4);

(ii) field current low;

(iii) manual/auto control status (in accordance with SPEXC 2.12.9(a));

(iv) ExcPCE/ExcRCE control status (in accordance with SPEXC 2.12.1(j));

(v) local/remote control status (in accordance with SPEXC 2.14.2(d)); and

(f) Alarms and Targets: Alarm and Target indications will be displayed on the Exciter HMI, including:

(i) Excitation System at minimum or maximum limit (all limiters as described in SPEXC 2.12.14, 2.12.15, 2.12.16, and 2.12.18);

(ii) field flash failure;

(iii) field flash in off position;

(iv) conduction failure;

(v) SCR fuse failure;

(vi) operation on redundant ExcRCE;

(vii) power supply failure;

(viii) inlet air high temperature;

(ix) SCR high temperature;

(x) Exciter Transformer winding temperature high;

(xi) open input and output detection for all 4-20 mA and RTD signals; and

(xii) individual latching targets for all applicable protections in SPEXC 2.13.

2.14.3 Remote Operator Interface Signals

The following remote operator interface signals are required for interconnection with equipment provided by Others that is external to the Excitation System. All circuits with the exception of the communication link will be capable of meeting surge requirements as detailed in Appendix 6-2 [General Technical Specifications (SPGT)].

(a) Control: Separate, hardwired, remote control inputs are required for each of the following:

(i) Generator/field voltage raise (common for both auto and manual controls), in accordance with SPEXC 2.12.7;

(ii) Generator/field voltage lower (common for both auto and manual controls), in accordance with SPEXC 2.12.7;

(iii) auto/manual transfer (in accordance with SPEXC 2.12.9(a));

(iv) Excitation System start control (in accordance with SPEXC 2.12.2);

(v) Excitation System stop (de-excite – in accordance with SPEXC 2.12.4);

(vi) Excitation System field breaker open control (in accordance with SPEXC 2.4).

(vii) synchronize (voltage match - in accordance with SPEXC 2.12.3);

(viii) emergency stop - primary protection (in accordance with SPEXC 2.12.5);

(ix) synchronous condense on/off; and

(x) four inputs for future use.

(b) Status Indications: Individual relay contacts are required for each of the statuses listed below, and are required for connection to UCB equipment (by Others) including discrete LEDs and in some cases PLC control circuits and protective relays. All statuses will also be available over the communications link in accordance with SPEXC 2.11 for communications with a UCB PLC supplied by Others. The status indications include:

(i) all status indications listed in SPEC 2.14.2(e);

(ii) two field current low (in accordance with SPEXC 2.13.9); and

(iii) four outputs for future use.

(c) Alarms and Protections: Individual relay contacts are required for each Alarm listed in SPEXC 2.14.2(f). This is required for connection to an Alarm and Event recording system supplied by Others.

Protection contacts will be as detailed in accordance with BC Hydro drawing G417-H14-B9.

(d) Control Input Electrical Requirements: The control inputs detailed in SPEXC 2.14.3(a) will be either relay coils or opto-couplers to facilitate galvanic isolation. Isolation will be a minimum of 2000 Vdc. The wetting voltages will be 125 Vdc nominal (range of 95 to 140 Vdc).

2.15 Interface Requirements - Metering and Analog

2.15.1 General

All metering and analog circuits will, with the exception of the serial communication link be capable of meeting surge requirements as detailed in Appendix 6-2 [General Technical Specifications (SPGT)].

2.15.2 Local Operator Interface

Local operator interface quantities will be displayed on the Exciter HMI. The following are required:

(a) Generator: terminal voltage (three-phase, line-to-line average, in kV), current (three-phase average, in A), active power (three-phase, in MW), reactive power (three-phase, in MVAr), apparent power (three-phase, in MVA), and power factor;

(b) field voltage (in V);

(c) field current (in A);

(d) individual SCR current (each bridge, in A);

(e) field winding temperature (in °C);

(f) field ground detector output (in ohms);

(g) PSS output (in pu);

(h) Exciter Transformer winding temperature (in °C);

(i) individual bridge input air temperature (each bridge, in °C); and

(j) individual SCR heat sink temperature (each SCR, in °C).

2.15.3 Remote Interface Signals

(a) General: The following analog interface signals will be provided for interconnection with equipment provided by Others that is external to the Excitation System. It is intended that some signals will be used for indication purposes while others will be used for interconnection with protection devices.

(b) Analog Inputs: Separate analog inputs will be provided for each of the following:

(i) external PSS signal;

(ii) external test input signal; and

(iii) four spare inputs for future use.

All analog inputs will be terminated in the Excitation System Enclosure.

(c) Analog Outputs: Separate analog outputs will be provided for remote metering purposes for each of the following:

(i) all local operator interface quantities listed in SPEXC 2.15.2 except for:

(A) the Generator interface quantities listed in SPEXC 2.15.2(a);

(B) SCR currents listed in SPEXC 2.15.2(d);

(C) bridge input air temperatures listed in SPEXC 2.15.2(i); and

(D) SCR heat-sink temperatures listed in SPEXC 2.15.2(j).

(ii) PSS output; and

(iii) four spare outputs for future use.

All analog outputs will be terminated in the Excitation System Enclosure.

In addition to the above, it will be possible to monitor all of the above quantities over the communications link in accordance with SPEXC 2.11 and SPEXC 2.16.4.

(d) Analog Input/Output Electrical Requirements: All hardwired analog inputs and outputs will:

(i) Include a pair of wires per input or output (i.e., channels will be isolated, with no commoning);

(ii) be 4-20 mA or ±10 Vdc, user programmable or per-channel basis, any mix allowed;

(iii) be galvanically isolated from ground and other channels; and

(iv) include short-circuit protection.

(e) Communications Requirements and Protocol: All metering and analog interface quantities will be in accordance with SPEXC 2.11 and SPEXC 2.16.4.

2.16 Software

2.16.1 Application Configuration Files (Exciter Software)

Application Configuration Files for the Excitation System (the “**Exciter Software**”) will be provided.

2.16.2 Configuration Tool Software (Exciter Configuration Software)

Configuration Tool Software for the Excitation System will be provided.

2.16.3 Excitation System Events

The ExcPCE and ExcRCE, together with their Application Configuration Files designed by the Contractor, will include an Event Buffer that monitors and records Events identified in the Event List, and that uses the Event Data Structure. Functionality will also be included to communicate buffered Events to a device external to the Excitation System (using a custom communication protocol defined by BC Hydro and provided to the Contractor), and subsequently remove these Events from the buffer once successful communication has been confirmed.

Excitation System Alarms will monitor conditions that include:

(a) power supply failures (including fuse failures);

(b) Excitation System health, including ExcPCE/ExcRCE health, low battery and input/output channel or card failures;

(c) abnormal control status (e.g., device not in auto, device not in remote);

(d) abnormal device status (e.g., temperature high); and

(e) unexpected or abnormal device operation, device failure, or unknown device status.

One Excitation System Target will be provided for each protective function within the Excitation System, to indicate when the protective function has operated.

2.16.4 Excitation System Data Table

The Contractor's Exciter Software for the ExcPCE and ExcRCE will include functionality to make all discrete and analog Excitation System data that is deemed operationally relevant by the Contractor or by BC Hydro (the "**Excitation System Data Table**") available in definite-address 4x register memory for polling by external devices via the Ethernet based Modbus TCP protocol. The data will be grouped into as small a range as practical in order to be read or written in a small number of packets (of approximately 100 registers each). Within the data table, analog values will be formatted in ANSII standard 32-bit floating numbers, spanning two 4x registers each. The analog values will be scaled in engineering units such as kV and MW. Discrete data such as on/off controls, statuses and Alarms will be available as individual bits packed into 4x registers. For example, Alarms 1 to 16 would be in bits 1 to 16 of register 400001, Alarms 17 to 32 would be in bits 1 to 16 of register 400002, and so on. All Alarms and statuses will be output in the data table, and will be non-latching.

The Excitation System Data Table will be developed collaboratively between the Contractor and BC Hydro until the first Unit is placed in full commercial service.

The Excitation System Data Table will include:

(a) Analog (floating-point) Excitation System data, including:

(i) terminal voltage set-point;

(ii) Generator kV, kA, MW, MVAR, frequency;

(iii) SCR heat-sink temperatures;

(iv) channel (main and redundant) balance; and

(v) limiter and PSS outputs;

(b) Integer Excitation System data, including:

  (i) ExcPCE and ExcRCE heartbeats;

(c) Binary Excitation System data, all of which will be packed into word data types by the Contractor's Exciter Software before writing to definite address registers, including:

  (i) bits indicating the current status (i.e., on or off) of all of the items in the Event List for the Excitation System;

  (ii) auto/manual status;

  (iii) local/remote status;

  (iv) control mode;

  (v) start/stop status;

  (vi) Excitation System device health status;

  (vii) Excitation System device control status;

  (viii) limiter status;

  (ix) PSS status; and

  (x) field breaker status.

2.16.5 Disturbance Analysis Software

Software for uploading and viewing of Event records and oscillography records will be provided.

2.16.6 Test Software

The Excitation System will have the ability to create computer generated test signals internal to the ExcPCE and ExcRCE. Test signal set-up and execution will be via a laptop IBM compatible computer. The software required to perform set-up and execution will be provided.

2.17 Control System Power Supplies

2.17.1 General

The Work includes two power supplies connected in a redundant configuration for supplying the Excitation System control system. The power supplies will:

(a) have outputs that are connected in parallel through diodes so that a failure of one power supply does not block or inhibit the ability of the other power supply to supply the load;

(b) each be rated to supply the entire load under all operating conditions including starting;

(c) each have an Alarm to indicate failure of the power supply; and

(d) have galvanic isolation of 2000 Vdc for the inputs and outputs of each power supply.

2.17.2 Power Supply Source

There will be two separate sources for the two Excitation System power supplies:

(a) One power source will be from the Powerhouse 125 Vdc station service system provided by Others. The nominal input voltage will be 125 Vdc with variations over a range from 95 Vdc to 140 Vdc.

(b) The other power source will be an AC supply operated from the Excitation System excitation transformer. The AC supply will operate over an input voltage range from 70% to 120% of the nominal transformer secondary voltage.

The output from each power supply will be monitored and Alarmed. Monitoring of each power supply voltage will be performed on the output (load) side of each the power supply.

2.18 Electrical Equipment and Devices

2.18.1 Enclosures

(a) General: All equipment in the Excitation System and other supplied equipment will:

(i) be factory installed into metal Enclosures, wired and tested; and

(ii) meet the requirements of Appendix 6-2 [General Technical Specifications (SPGT)] for electrical equipment and devices, except that the Excitation System is explicitly exempt from meeting the requirement to limit arc flash hazards to Category 2 or less.

(b) Arrangement: The Excitation System Enclosures will be mounted adjacent to one another to permit close-coupling of the Exciter Transformer low-voltage bus bars and the Power Rectifier bus bars and inter-panel wiring. If the Exciter Transformer enclosure and other Excitation System Enclosures are mounted separately, the Work includes the non-segregated phase cable bus between the two Enclosures.

(c) Provisions for External Cabling: Except for the high-current AC input and DC output cables, external cables, will be terminated on terminal blocks.

(d) Cable Entry: Excitation System AC and DC high-current cables will enter the Enclosure from the top. Cable clamps inside the Excitation System Enclosure for the cables will be provided.

(e) Operator Interface: Local operator interface facilities as defined in SPEXC 2.14.1 and SPEXC 2.15.2 will be located on the front of the Excitation System Enclosure.

(f) Access for Inspection and Maintenance: The Excitation System Enclosures will be designed and arranged to enable Workers to visually inspect, access, and maintain the Excitation System components including the control electronics, the SCR bridge assemblies, the Excitation transformer, electrical buses, electrical cables, electrical connections, and instrumentation with minimal disassembly of the Enclosures.

2.19 Safety Ground Provisions

All Excitation System buswork will include safety grounding ball studs to facilitating grounding of both high-voltage and low-voltage buswork in accordance with Appendix 6-2 [General Technical Specifications (SPGT)]. Safety grounding ball studs (used for connection of portable safety grounds) will be mounted on the:

(a) Excitation System AC bus;

(b) DC field leads (located on field side of reversing links);

(c) high-voltage connection for the Exciter Transformer; and

(d) Low-voltage connection for the Exciter Transformer.

The mounting locations will be at easily accessible locations inside the Excitation System Enclosures. It will not be possible to close an Enclosure door when portable safety grounds are installed.

2.20 Equipment Identification

2.20.1 Excitation System Nameplate Placard

The Excitation System will be provided with a nameplate placard in a prominent location on the outside of the Exciter Enclosure. The information on the nameplate will include:

(a) manufacturer's name and address;

(b) type of equipment;

(c) serial number of the Excitation System;

(d) model number and type number of the Excitation System;

(e) date of manufacture;

(f) the Excitation System Rated Output, including rated continuous output current (Adc) when operating at an output voltage equal to the Generator rated field voltage, and with at least N SCR Bridges in service (i.e., the Excitation System Rated Current);

(g) number of SCR Bridges;

(h) number of SCR Bridges required to achieve continuous operation at Excitation System Rated Output;

(i) field breaker configuration (AC or DC);

(j) the Excitation System 30 Second Rating (Adc);

(k) Ceiling Voltage (Vdc);

(l) ambient temperature rating (degrees Celsius);

(m) BC Hydro contract number; and

(n) BC Hydro purchase order number.

2.20.2 Exciter Transformer Nameplate Placard

The Exciter Transformer will be provided with a nameplate placard in a prominent location on the outside of the Exciter Transformer Enclosure. The information on the nameplate will include:

(a) manufacturer's name and address;

(b) type of equipment;

(c) serial number;

(d) model/type number;

(e) winding connection diagram;

(f) rating (kVA);

(g) rated primary voltage (kV);

(h) rated secondary voltage (V);

(i) number of phases;

(j) rated primary current (A);

(k) rated secondary current (A);

(l) rated power factor;

(m) rated frequency (Hz);

(n) insulation class;

(o) winding temperature rise (ºC);

(p) ambient temperature rating (ºC);

(q) BIL of primary insulation;

(r) K-factor;

(s) noise level at 1 m (dBA);

(t) positive and zero sequence impedance (%);

(u) indoor or outdoor application;

(v) dynamic earthquake withstand: IEEE 693;

(w) BC Hydro contract number; and

(x) BC Hydro purchase order number.

SPEXC3 TEST POINTS AND ISOLATION FACILITIES

3.1 Test Points

Two analog ±10 V inputs with a minimum sampling rate of one sample/ms (1 kHz) will be software configurable to facilitate test signal injection to the transfer function blocks of ExcPCE and ExcRCE.

Four analog ±10 V outputs with a minimum sampling rate of one sample/ms (1 kHz) will be software configurable to allow access to all values within the ExcPCE and ExcRCE.

The test points will be made available on rail-mounted terminal blocks.

3.2 Isolation Facilities

3.2.1 CT Entrance

An entrance CT isolation and test block (ABB type FT-1) will be provided and connected in accordance with BC Hydro ES 45-X0010 for each of the following inputs:

(a) Generator CT input to the Excitation System;

(b) primary Exciter Transformer CT input to the Excitation System; and

(c) standby Exciter Transformer CT input to the Excitation System.

3.2.2 VT Entrance

An entrance VT isolation and test block (ABB type FT-1) will be provided and connected in accordance with BC Hydro ES 45-X0010 for each of the following inputs:

(a) Generator VT input to the Excitation System; and

(b) running bus VT input into the Excitation System.

3.2.3 Compact Iso/Test Subpanels

Compact iso/test subpanels will be provided and connected in accordance with BC Hydro ES 45-X0011, with one associated with each of: the primary SEL 351 relay, the standby SEL 351 relay, and the exciter in general (i.e., all other isolation points that are not associated with the SEL 351 relays). These compact iso/test subpanels will be used to isolate:

(a) VT inputs between the VT entrance block and each downstream device;

(b) SEL 351 relay trip outputs between each SEL 351 relay and each downstream device;

(c) ExcPCE, ExcRCE, and other discrete device trip outputs between the initiating device and each downstream device; and

(d) other points agreed to between the Contractor and Hydro’s Representative.

3.2.4 Combination FT-1 Blocks

A combined voltage and current isolation and test block, as outlined in section 4.6 of BC Hydro ES 45-X0010 (ABB type FT-1 670B197G18), will be provided and connected for each of the following devices:

(a) the ExcPCE;

(b) the ExcRCE;

(c) the primary SEL 351 protective relay; and

(d) the standby SEL 351 protective relay.

3.2.5 Field Flash Source Transfer Switch

Lockable isolation disconnect switches, separate from the field flash source transfer switch, will be provided for the purpose of isolating the field flash sources for Worker safety. The source isolation switch status will be visible without opening the cover (window type).

3.2.6 Field Ground Detection System Isolation Switch

One fused, lockable disconnecting switch with visual break such that it can be used for BC Hydro isolation and lockout purposes, as well as protection of the field ground circuitry, will be provided.

SPEXC4 MANUFACTURING, INSPECTIONS AND TEST REQUIREMENTS

4.1 General

Excitation System shop inspection and tests will include the inspection and testing recommended in and be performed in accordance with IEEE 421.2, IEEE 421.3 and IEEE 421.4 except as otherwise specified.

4.2 Heat Run and Burn-in Tests

4.2.1 Heat Run Test

The Excitation System Power Rectifier assembly will be subjected to an eight-hour heat run Production Test. The test will be conducted using a DC load of sufficient size and rating to allow Excitation System Rated Current to be passed through the load bank. The temperatures of every Excitation System heat sink will be recorded every 15 min. If the temperature of any heat sink deviates by more than plus or minus 1°C from the average, the test will be deemed a failure. In the event of a test failure, repairs will be made and the test repeated as many times as necessary to achieve a successful result.

The Work includes a Procedure for the Excitation System Power Rectifier heat run Production Test.

4.2.2 Burn-in Test

All Excitation System electronic components will be subjected to a 96 hour burn-in Production Test. During the test the components will be operated at rated voltage and at an elevated temperature (to be monitored during the test), and the components will be monitored during the test to confirm they are functioning normally.

If the components' operation will not be monitored continuously during the burn-in test, then:

(a) the interval between monitoring periods will be short enough that the probability of a component mis-operation during non-monitored periods is insignificant; and

(b) the burn-in test Procedure will illustrate how the interval between monitoring periods is selected, and how the probability of component mis-operation during non-monitored periods is insignificant.

If abnormal operation is observed during the burn-in test, then the test will be considered a failure, and the failed device will not be used in the Excitation System.

The Work includes a Procedure for burn-in testing of Excitation System electronic components.

4.3 Field Breaker Rack-In/Rack-Out Tests

If the Field Breaker is of draw-out type, to confirm mechanical and electrical reliability, the Field Breaker will be subjected to Production Testing whereby it is racked in and out ten times and all draw-out electrical connections tested for continuity after each rack-in/rack-out cycle. If continuity is not confirmed after any rack-in/rack-out cycle, then the test will be considered a failure, and the failed rack-in/rack-out electrical connectors will not be used in the Excitation System.

The Work includes a Procedure for rack-in/rack-out testing of Field Breaker rack-in/rack-out electrical connections.

4.4 Exciter Transformer Tests

4.4.1 Exciter Transformer Production Tests

Exciter Transformer tests specified under CSA C9-M including load loss and impedance voltage will be performed as Production Tests. In deviation from CSA C9-M, resistance measurements will be performed as a Production Test on all Exciter Transformers.

4.4.2 Exciter Transformer Type Tests

(a) Tests specified in CSA C9-M, including tests to verify ratio, polarity, angular displacement, no-load losses, load losses, dielectric strength, and resistance will be performed as Type Tests.

(b) An induced voltage Type Test at 400 Hz using 200% of the rated supply voltage will be performed to verify insulation.

(c) A partial discharge Type Test, with a maximum allowable corona pulse intensity of 50 pC, will be performed in the following manner:

- (i) increase the supply voltage to 200% of the rated line to ground voltage of the transformer (V_r) at 400 Hz. Measure and record the discharge inception voltage (R_1) and the discharge level;

- (ii) maintain 200% V_r for 7200 cycles;

- (iii) decrease the supply voltage, measure and record the discharge level at 120% V_r, (R_2). The maximum permissible discharge level at 120% V_r, is 50 pC;

- (iv) measure and record the discharge extinction voltage (R_3) and discharge level immediately prior to extinction. The discharge extinction voltage level must be greater than 110% V_r; and

(v) the maximum permissible ambient discharge level, with the measuring circuit connected and the transformer de-energized is 5 pC.

(d) A sound level Type Test will be performed to verify the specifications of SPEXC 2.7.2(j).

(e) Electromagnetic frequency emissions Type Tests will be performed.

(f) Impulse testing on the primary side of the transformer will be performed as a Type Test to verify the specifications of SPEXC 2.7.1.

(g) Heat run Type Testing on the Exciter Transformer as a complete unit will be performed, and will:

(i) be performed at the rated AC input current for the Exciter Power Rectifier or rated Exciter Transformer output current; whichever is greater;

(ii) be performed using a resistive load;

(iii) be performed using temperature probes as follows:

(A) installed at locations specified in SPEXC 2.13.15.

(B) two temperature probes installed at the top of the inner-most turn of the LV winding;

(iv) include temperature measurements sampled at a minimum of 15 minute intervals;

(v) demonstrate a final temperature rise consistent with the ratings specified in SPEXC 2.7.1; and

(vi) include infrared Photos.

(h) Type Tests to verify ratio, polarity, angular displacement, dielectric strength, resistance and saturation will be performed on each of the transformer primary CTs.

(i) Destructive Type Testing to verify robustness and performance of the explosion-directed Enclosure design will be performed in accordance with IEEE C37.20.7 by subjecting the Exciter Transformer to fault current, and will:

(i) include room simulation testing and determination of resulting application guidelines for indoor installation of the Exciter Transformer; and

(ii) verify that the Exciter Transformer meets the following performance criteria:

(A) Doors, covers, etc., secured in their closed position will not open. Bowing or other distortion will be permitted, provided no part bows or distorts as far as the position of the indicator mounting racks or walls (whichever is closest) on any surface. Exhausting gases will not be directed outward from the Enclosure sides where Workers may be standing.

(B) No fragmentation of the Enclosure will occur. Ejection of small parts, up to an individual mass of 60 g, from any external Enclosure surface above a height of 2 m, is acceptable. There is no restriction on the number of parts allowed to be ejected.

(C) No external surfaces will experience burn-through as a result of arcing. No internal surfaces intended to isolate low-voltage instrument or control compartments will experience burn-through as a result of arcing. It will be assumed that any opening in the Enclosure caused by direct contact with an arc will also ignite an indicator mounted outside of the Enclosure at that same point. Since it is not possible to cover the entire Enclosure with indicators, any opening in the Enclosure resulting from direct contact with an arc will be considered a failure. Openings above the indicator mounting rack height of 2 m that do not cause ignition of the horizontally-mounted indicators will be ignored.

(D) No indicators will ignite as a result of escaping gases. Indicators ignited as a result of the burning of paint or labels, glowing particles, etc., will be ignored. High-speed video may be utilized to evaluate the cause of indicator ignition. Holes in horizontally-mounted indicators caused by particles that do not ignite the indicator will be ignored. Surface discoloration or charring that does not result in glowing or flaming of the indicator cloth will be considered acceptable. Any indicator cloth with surface discoloration or charring will be replaced with new cloth prior to further testing.

(E) All grounding connections will remain effective.

SPEXC5 SITE ACCEPTANCE AND COMMISSIONING TESTS

5.1 General

Excitation System site acceptance and commissioning tests will include the testing recommended in and be performed in accordance with IEEE 421.2, IEEE 421.3 and IEEE 421.4 except as otherwise specified.

5.2 Excitation System Tests by the Contractor

The Work includes thoroughly testing the Excitation System to confirm that performance as an integrated part of the Unit is acceptable, considering all Unit and Excitation System operating conditions outlined in the Specifications. Excitation System tests will include:

(a) SCR bridge firing and control tests;

(b) SCR bridge current balance tests;

(c) automatic voltage regulator control, stability, and response tests (including “bump” disturbance tests);

(d) manual regulator control, stability, and response tests (including “bump” disturbance tests);

(e) channel and regulator transfer tests (including loss of sensing tests);

(f) limiter tests (offline and online);

(g) heat run tests;

(h) power system stabilizer control, stability, and response tests (including “bump” disturbance tests);

(i) synchronizing tests (voltage matching);

(j) field flashing response tests (including field flash failure);

(k) field discharge tests (including full load testing of crowbar and de-excitation performance and response);

(l) load rejection tests; and

(m) Exciter Transformer tests, including:

  (i) winding insulation resistance and polarization index tests for the HV to LV + GND and LV to HV + GND. The HV winding will be tested at 5000 Vdc and the LV winding at 1000 Vdc;

  (ii) core insulation resistance test at 500 Vdc;

  (iii) winding resistance tests for the HV winding and the LV winding;

  (iv) winding turns ratio test;

  (v) high-voltage dissipation factor measurement on the HV winding and the LV windings; and

  (vi) if possible, using the dissipation factor bridge, an excitation current test.

During the Generator heat run test, the Contractor will conduct temperature rise measurements at a minimum of 15 min intervals on the Exciter Transformer. The final temperature rise will be consistent with the ratings specified in SPEXC 2.7.1 and consistent with the temperature rise results determined during the heat run tests conducted as part of the design tests described in SPEXC 4.4.2(g). The temperature probes used for this test will be installed in the same locations as described in SPEXC 4.4.2(g).