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A Report Submitted to Bruce Power

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Acronyms and Abbreviations

AHJ	Authority Having Jurisdiction
AIM	Abnormal Incidents Manual
BDBE	Beyond Design Basis Earthquake
BP	Bruce Power
BPMS	Bruce Power Management System
CANDU	Canada Deuterium Uranium
CFAM	Corporate Functional Area Manager
CLE	Checking Level Earthquake
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
DBA	Design Basis Accident
DBE	Design Basis Earthquake
ECC	Engineering Change Control
EM	Environmental Monitoring
EQ	Environmental Qualification
EQA	EQ Assessment
EQD	EQ Dossiers
EQE	EQ Evaluations
EQIS	EQ Information System
EQL	Environmental Qualification List
EQR	Environmental Qualification Requirements
EQSRCL	EQ Safety Related Components List
ERGM	Engineering Representation of Ground Motion
FASA	Focused Area Self Assessment
HECL	Harsh Environmental Components List
IAEA	International Atomic Energy Agency
ISR	Integrated Safety Review
LCH	Licence Conditions Handbook

LCMP	Life Cycle Management Plans
LTEP	Long Term Energy Plan
MCR	Major Component Replacement
NPP	Nuclear Power Plant
NSCA	Nuclear Safety and Control Act
OFI	Opportunities for Improvements
OPG	Ontario Power Generation
PEVS	Powerhouse Emergency Venting System
PROL	Power Reactor Operating Licence
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
QA	Quality Assurance
RCM	Room Condition Manual
RLE	Review Level Earthquake
SBR	Safety Basis Report
SCA	Safety and Control Area
SCR	Station Condition Record
SDE	Site Design Earthquake
SFR	Safety Factor Report
SIS	Systems Important to Safety
SMA	Seismic Margin Assessment
SSCs	Structures, Systems, and Components
SSCT	Structures, Systems, Components, and Significant Tools
UTC	Uniquely Tracked Commodity

1. Objective and Description

Bruce Power (BP), as an essential part of its operating strategy, is planning to continue operation of Bruce B as part of its contribution to the Long Term Energy Plan (LTEP) (http://www.energy.gov.on.ca/en/ltep/). Bruce Power has developed integrated plant life management plans in support of operation to 247,000 Equivalent Full Power Hours in accordance with the Bruce Power Reactor Operating Licence (PROL) [1] and Licence Conditions Handbook (LCH) [2]. A more intensive Asset Management program is under development, which includes a Major Component Replacement (MCR) approach to replacing pressure tubes, feeders and steam generators, so that the units are maintained in a fit for service state over their lifetime. However, due to the unusually long outage and de-fuelled state during pressure tube replacement, there is an opportunity to conduct other work, and some component replacements that could not be done reasonably in a regular maintenance outage will be scheduled concurrently with MCR. In accordance with Licence Condition 15.2 of the PROL [1], Bruce Power is required to inform the Canadian Nuclear Safety Commission (CNSC) of any plan to refurbish a reactor or replace a major component at the nuclear facilities, and Bruce Power shall:

(i) Prepare and conduct a periodic safety review;

(ii) Implement and maintain a return-to-service plan; and

(iii) Provide periodic updates on progress and proposed changes.

The fifteen reports prepared as part of the Periodic Safety Review (PSR), including this Safety Factor Report (SFR), are intended to satisfy Licence Condition 15.2 (i) as a comprehensive evaluation of the design, condition and operation of the nuclear power plant (NPP). In accordance with Regulatory Document REGDOC-2.3.3 [3], a PSR is an effective way to obtain an overall view of actual plant safety and the quality of safety documentation and determine reasonable and practicable improvements to ensure safety until the next PSR.

Bruce Power has well-established PSR requirements and processes for the conduct of a PSR for the purpose of life-cycle management, which are documented in the procedure Periodic Safety Reviews [4]. This procedure, in combination with the Bruce B Periodic Safety Review Basis Document [5], governs the conduct of the PSR and facilitates its regulatory review to ensure that Bruce Power and the CNSC have the same expectations for scope, methodology and outcome of the PSR.

This PSR supersedes the Bruce B portion of the interim PSR that was conducted in support of the ongoing operation of the Bruce A and Bruce B units until 2019 [6]. Per REGDOC-2.3.3 [3], subsequent PSRs will focus on changes in requirements, facility conditions, operating experience and new information rather than repeating activities of previous reviews.

1.1. Objective

The overall objectives of the Bruce B PSR are to conduct a review of Bruce B against modern codes and standards and international safety expectations, and to provide input to a practicable set of improvements to be conducted during the MCR in Units 5 to 8, and during asset management activities to support ongoing operation of all four units, as well as U0B, that will enhance safety to support long term operation. It will cover a 10-year period, since there is an expectation that a PSR will be performed on approximately a 10-year cycle, given that all units are expected to be operated well into the future.

The specific objective of the review of this Safety Factor is to determine whether equipment important to safety is qualified (including for environmental conditions) and whether this qualification is being maintained through an adequate program of maintenance, inspection and testing that provides confidence in the delivery of safety functions.

1.2. Description

The review is conducted in accordance with the Bruce B PSR Basis Document [5], which states that the review tasks are as follows:

1. The review of equipment qualification will include an assessment of the effectiveness of the plant's equipment qualification program. This program should ensure that plant equipment (including cables) is capable of fulfilling its safety functions for the period until at least the next PSR. The review will also cover the requirements for performing safety functions while subject to the environmental conditions that could exist during both normal and predicted accident conditions. These include seismic conditions, vibration, temperature, pressure, jet impingement, electromagnetic interference, irradiation, corrosive atmosphere and humidity, fire (for example, a hydrogen fire) and combinations thereof and other anticipated events. The review will also consider the effects of ageing degradation of equipment during service and of possible changes in environmental conditions during normal operation and predicted accident conditions since the program was devised;
2. Although many parties (such as designers, equipment manufacturers and consultants) are involved in the equipment qualification process, the operating organization has the ultimate responsibility for the development and implementation of an adequate plant specific equipment qualification program. The following aspects of implementation of the program will be covered:
    a. Assess if qualification of plant equipment important to safety has been formalized using a process that includes generating, documenting and retaining evidence that equipment can perform its safety functions during its installed service life;
    b. Confirm if this is an ongoing process, from its design through to the end of its service life; and
    c. Assess if the process takes into account plant and equipment ageing and modifications, equipment repairs and refurbishment, equipment failures and replacements, any abnormal operating conditions and changes to the safety analysis.

3. The review of equipment qualification will consider:
    a. Whether installed equipment meets the qualification requirements;
    b. The adequacy of the records of equipment qualification;
    c. Procedures for updating and maintaining qualification throughout the service life of the equipment;
    d. Procedures for ensuring that modifications and additions to Structures, Systems and Components (SSCs) important to safety do not compromise their qualification;
    e. Surveillance programs and feedback procedures used to ensure that ageing degradation of qualified equipment remains insignificant;
    f. Monitoring of actual environmental conditions and identification of 'hot spots' of high activity or temperature; and
    g. Protection of qualified equipment from adverse environmental conditions.

As required by the PSR Basis Document, preparation of this Safety Factor Report included an assessment of the review tasks to determine if modifications were appropriate. Any changes to the review tasks described in this section are documented and justified in Section 5.

2. Methodology of Review

As discussed in the Bruce B PSR Basis Document [5], the methodology for a PSR should include making use of safety reviews that have already been performed for other reasons. Accordingly, the Bruce B PSR makes use of previous reviews that were conducted for the following purposes:

- Return to service of Bruce Units 3 and 4 (circa 2001) [7];
- Life extension of Bruce Units 1 and 2 (circa 2006) [8] [9] [10];
- Proposed refurbishments of Bruce Units 3 and 4 (circa 2008) [11] [12] [13] [14] [15];
- Safety Basis Report (SBR) and PSR for Bruce Units 1 to 8 (2013) [6]; and
- Bruce A Integrated Safety Review (ISR) to enhance safety and support long term operation (2015) [16] [17].

These reviews covered many, if not all, of the same Safety Factors that are reviewed in the current PSR. A full chronology of Bruce Power safety reviews up to 2013 is provided in Appendix F of [18].

The Bruce B PSR Safety Factor review process comprises the following steps:

1. **Interpret and confirm review tasks:** As a first step in the Safety Factor review, the Safety Factor Report author(s) confirm the review tasks identified in the PSR Basis Document [5] and repeated in Section 1.2 to ensure a common understanding of the intent and scope of each task. In some cases, this may lead to elaboration of the review tasks to ensure that the focus is precise and specific. Any changes to the review tasks are identified in Section 5 of the Safety Factor Report (SFR) and a rationale provided.

2. **Confirm the codes and standards to be considered for assessment:** The Safety Factor Report author(s) validates the list of codes and standards presented in the PSR Basis Document against the defined review tasks to ensure that the assessment of each standard will yield sufficient information to complete the review tasks. Additional codes and standards are added if deemed necessary. If no standard can be found that covers the review task, the assessor may have to identify criteria on which the assessment of the review task will be based. The final list of codes and standards considered for this Safety Factor is provided in Section 3.

3. **Determine the type and scope of assessment to be performed:** This step involves the assessor confirming that the assessment type identified in Appendix C of the Bruce B PSR Basis Document [5] for each of the codes, standards and guidance documents selected for this factor is appropriate based on the guidance provided. The PSR Basis Document provides an initial assignment for the assessment type, selecting one of the following review types:

    - Programmatic Clause-by-Clause Assessments;
    - Plant Clause-by-Clause Assessments;
    - High-Level Programmatic Assessments;
    - High-Level Plant Assessments;
    - Code-to-Code Assessments; or
    - Confirm Validity of Previous Assessment.

    The final assessment types are identified in Section 3, along with the rationale for any changes relative to the assignment types listed in the PSR Basis Document.

4. **Perform gap assessment against codes and standards:** This step comprises the actual assessment of the Bruce Power programs and the Bruce B plant against the identified codes and standards. In general, this involves determining from available design or programmatic documentation whether the plant or program meet the provisions of the specific clause of the standard or of some other criterion, such as a summary of related clauses. Each individual deviation from the provisions of codes and standards is referred to as a Safety Factor “micro-gap”. The assessments, performed in Appendix A and Appendix B, include the assessor’s arguments conveying reasons why the clause is considered to be met or not met, while citing appropriate references that support this contention.

5. **Assess alignment with the provisions of the review tasks:** The results of the assessment against codes and standards are interpreted in the context of the review tasks of the Safety Factor. To this end, each assessment, whether clause-by-clause, high-level or code-to-code, is assigned to one or more of the review tasks (Section 5). Assessment against the provision of the review task involves formulating a summary assessment of the degree to which the plant or program meets the objective and provisions of the particular review task. This assessment may involve consolidation and interpretation of the various compliance assessments to arrive at a single compliance indicator for the objective of the review task as a whole. The results of this step are documented in Section 5 of each SFR.
6. **Perform program assessments:** The most pertinent self-assessments, audits and regulatory evaluations are assessed, and performance indicators relevant to the Safety Factor identified. The former illustrates that Bruce Power has a comprehensive process of reviewing compliance with Bruce Power processes, identifying gaps, committing to corrective actions, and following up to confirm completion and effectiveness of these actions. The latter demonstrates that there is a metric by which Bruce Power assesses the effectiveness of the programs relevant to the Safety Factor in Section 7. Taken as a whole, these demonstrate that the processes associated with this Safety Factor are implemented effectively (individual findings notwithstanding). Thus, program effectiveness, if not demonstrated explicitly in the review task assessments in Step 5, can be inferred if Step 5 shows that Bruce Power processes meet the Safety Factor requirements and if this step shows there are ongoing processes to ensure compliance with Bruce Power processes.
7. **Identification of findings:** This step involves the consolidation of the findings of the assessment against codes and standards and the results of executing the review tasks into a number of definitive statements regarding positive and negative findings of the assessment of the Safety Factor. Positive findings or strengths are only identified if there is clear evidence that the Bruce B plant or programs exceed compliance with the provision of codes and standards or review task objectives. Each individual negative finding or deviation is designated as a Safety Factor micro-gap for tracking purposes. Identical or similar micro-gaps are consolidated into comprehensive statements that describe the deviation known as Safety Factor macro-gaps, which are listed in Section 8 of the Safety Factor Reports, as applicable.

3. Applicable Codes and Standards

This section lists the applicable regulatory requirements, codes and standards considered in the review of this Safety Factor. Table C-1 of the Bruce B PSR Basis Document [5], identifies the codes, standards and guides that are relevant to this PSR. Modern revisions of some codes and standards listed in Table C-1 of the PSR Basis Document [5] have been identified in the licence renewal application and supplementary submissions for the current PROL [19] [20] [21]. Codes, standards and guides issued after the freeze date of December 31, 2015 were not considered in the review [5].

3.1. Acts and Regulations

The *Nuclear Safety and Control Act* (NSCA) [22] establishes the Canadian Nuclear Safety Commission and its authority to regulate nuclear activities in Canada. Bruce Power has a process to ensure compliance with the NSCA [22] and its Regulations. Therefore, the NSCA and Regulations were not considered further in this review.

3.2. Power Reactor Operating Licence

The list of codes and standards related to equipment qualification that are referenced in the PROL [1] and LCH [2], and noted in Table C-1 of the Bruce B PSR Basis Document [5], are identified in Table 1. The edition dates referenced in the third column of the table are the modern versions used for comparison.

The LCH contains one condition related to Environmental Qualification. Licence condition 5.3 states that “The licensee shall implement and maintain an environmental qualification program”, and under “Compliance Verification Criteria” the Canadian Standards Association (CSA) standard N290.13: Environmental Qualification of Equipment for CANDU Nuclear Power Plants (NPPs) is listed as requiring version control.

Table 1: Codes, Standards, and Regulatory Documents Referenced in Bruce A and B PROL and LCH

Document Number	Document Title	Modern Version Used for PSR Comparison	Type of Review
CNSC REGDOC-2.3.3	Periodic Safety Reviews	[3]	NA
RD/GD-210 (2012)	Maintenance Programs for Nuclear Power Plants	[23]	NA
CSA-N286-05 [24]	Management System Requirements for Nuclear Facilities	CSA-N286-12 [25]	NA
CSA N290.13-05	Environmental Qualification of Equipment for CANDU Nuclear Power Plants	CSA N290.13-05 (R2015) [26]	NA
Assessment type: **NA**: Not Assessed; **CBC**: Clause-by-Clause; **PCBC**: Partial Clause-by-Clause; **CTC**: Code-to-Code; **HL**: High Level; **2SF**: Assessment performed in another SFR; **CV**: Confirm Validity of Previous Assessments			

CNSC REGDOC-2.3.3: This PSR is being conducted in accordance with CNSC REGDOC-2.3.3 per Licence Condition 15.2 (i) [1], and associated compliance verification criteria [2]. Therefore, REGDOC-2.3.3 is not reviewed further in this document.

CNSC RD/GD-210: CNSC RD/GD-210 [23] is included in the plant licence and is not reviewed further in this document.

CSA N286-12: CSA N286-05 is noted in the PROL (Licence Condition 1.1 [1]). Per the LCH [2], an implementation strategy for the 2012 version is in progress to be submitted to the CNSC by the end of January 2016. CNSC staff have stated that in their view the CSA N286-12 version of CSA N286 "does not represent a fundamental change to the current Bruce Power Management System" and have acknowledged that "the new requirements in CSA N286-12 are already addressed in Bruce Power's program and procedure documentation"[27].

Bruce Power had agreed to perform a gap analysis and to prepare a detailed transition plan, and to subsequently implement the necessary changes in moving from the CSA N286-05 version of the code to the CSA N286-12 version, during the current licensing period [27]. This timeframe will facilitate the implementation of N286 changes to the management system, and enable the gap analysis results from the large number of new or revised Regulatory Documents or Standards committed in the 2015 operating licence renewal. Bruce Power has also proposed that in the interim, CSA N286-05 be retained in the PROL to enable it to plan the transition to CSA N286-12, and committed to develop the transition plan and communicate the plan to the CNSC by January 30, 2016 [28]. Bruce Power further stated CSA N286-12 does not establish any significant or immediate new safety requirements that would merit a more accelerated implementation. The gap analysis and the resulting transition plan were submitted to the CNSC [29]. Per [29], the major milestones of the transition plan to N286-12 are as follows:

- 22 January 2016: Discuss all the regulatory actions and the transition plan at the Corporate Functional Area Manager (CFAM) meeting
- 31 December 2016: Revision of CFAM Program Document(s) [with LCH notification requirements to the CNSC] to comply with CSA N286-12 requirements completed.
- 31 March 2017: Revision of CFAM Program Document(s) [that do not have LCH notification requirements to the CNSC] to comply with CSA N286-12 requirements completed
- 31 December 2017: Confirmation that that all impacted documents in the program suite comply with the requirements of CSA N286-12
- 15 September 2018: Verification via a Focused Area Self Assessment (FASA) that previously identified transition Gaps to meeting the requirements of CSA N286-12 have been addressed and effectively implemented
- 14 December 2018: issue notification to the CNSC regarding state of CSA N286-12 readiness, and, implementation date

This Safety Factor therefore has not performed a code-to-code assessment between CSA N286-05 and CSA N286-12 and will not be performing a clause-by-clause assessment of CSA N286-05, since it is in the current licence and there is a transition plan in effect.

CSA N290.13-05: This standard is included in the PROL (Licence Condition 5.3), and is not reviewed further in this document, since it is included in the Bruce Power governance documents and compliance will be monitored on an ongoing basis. The LCH [2] further states that "In addition to the criteria set out in N290.13, Bruce Power's Environmental Qualification (EQ) program shall include a monitoring program consisting of condition monitoring and environmental monitoring, to measure degradation and failures of qualified equipment, including cables."

3.3. Regulatory Documents

There were no additional Regulatory Documents identified in Table C-1 of the PSR Basis Document [5] considered for application to the review tasks of this Safety Factor beyond those identified in the Bruce Power PROL [1] and the LCH [2].

3.4. CSA Standards

In addition to those identified in the Bruce Power PROL [1] and LCH [2], the CSA standards identified in Table C-1 of the PSR Basis Document [5] considered for application to review tasks of this Safety Factor are included in Table 2.

The requirements for seismic qualification are included in the LCH under the heading "5.1 Design Program" and the N289 series of standards is listed under "Recommendations and Guidance" (page 46). In this section, the LCH also states "Seismically credited safety-related SSCs in a nuclear facility should be designed, installed and maintained to perform their safety function against earthquakes. The licensee should take relevant clauses of CSA N289.1 General Requirements for Seismic, Design and Qualifications of CANDU Nuclear Power Plants (sic) into consideration for this purpose. CNSC staff also recommends that Bruce Power provide a gap analysis and a transition plan to address any gaps that may have been identified for plant SSCs". [2]

Table 2: CSA Standards

Document Number	Document Title	Reference	Type of Review
CSA N289.1-08	General requirements for seismic design and qualification of CANDU nuclear power plants	[30]	HL
CSA N289.2-10	Ground Motion Determination for Seismic Qualification of Nuclear Power Plants	[31]	HL

Document Number	Document Title	Reference	Type of Review
CSA N289.3-10	Design procedures for seismic qualification of CANDU nuclear power plants	[32]	HL
CSA N289.4-12	Testing Procedures for Seismic Qualification of CANDU Nuclear Power Plants	[33]	HL
CSA N289.5-12	Seismic Instrumentation Requirements for CANDU Nuclear Power Plants	[34]	HL
Assessment type: **NA**: Not Assessed; **CBC**: Clause-by-Clause; **PCBC**: Partial Clause-by-Clause; **CTC**: Code-to-Code; **HL**: High Level; **2SF**: Assessment performed in another SFR; **CV**: Confirm Validity of Previous Assessments			

CSA N289.1-08: CSA N289.1-08 [30] defines a seismic success path as the "minimum set of SSCs that can perform the required nuclear safety functions following an earthquake"(page 7). The adequacy of the plant design to accommodate seismic events is also addressed by the seismic Probabilistic Safety Assessment (PSA) in the Safety Factor 6 report, Probabilistic Safety Analysis. An update in September 2014 added new requirements to N289.1-08, such as the periodic evaluation of a beyond design basis earthquake (DBE) (clause 5.3.11) and consideration of the effects of aging (clause 5.4.3), clarified a number of other requirements regarding the application of the seismic margin assessment methodology, and updated the reference publications (including the N289 series). A high level review of the current version of this standard is provided in Appendix A (A.2.1) of this report.

CSA N289.2-10: CSA N289.2-10 [31] describes the investigations required to obtain the seismological and geological information necessary to determine the seismic ground motion that will be used in seismic qualification of safety-related plant structures and systems, and the potential for seismically induced phenomena that can have a direct or indirect effect on plant safety or operation. A high level review of this standard is provided in Appendix A (A.2.2) of this report.

CSA N289.3-10: CSA N289.3-10 [32] applies to SSCs in nuclear power plants that require seismic qualification by analytical methods and specifies the design requirements, criteria, and methods of analysis for determining the engineering representation of ground motion, ground response spectra, and floor response spectra for use in the design and seismic qualification of SSCs and for performing seismic qualification of specified SSCs by analytical methods. A high level review of the current version of this standard is provided in Appendix A (A.2.3) of this report.

CSA N289.4-12: CSA N289.4-12 [33] provides design requirements and methods for seismic qualification of specific components and systems by testing methods. A high level review of the current version of this standard is provided in Appendix A (A.2.4) of this report.

CSA N289.5-12: CSA N289.5-12 [34] describes the requirements for seismic instrumentation systems for NPPs and nuclear facilities to monitor site-specific seismic responses. A high level review of the current version of this standard is provided in Appendix A (A.2.5) of this report.

3.5. International Standards

The international standard listed in Table 3 is relevant to this Safety Factor and was considered for this review.

Table 3: International Standards

Document Number	Document Title	Reference	Type of Review
IAEA SSG-25	Periodic Safety Review For Nuclear Power Plants	[35]	NA
Assessment type: **NA**: Not Assessed; **CBC**: Clause-by-Clause; **PCBC**: Partial Clause-by-Clause; **CTC**: Code-to-Code; **HL**: High Level; **2SF**: Assessment performed in another SFR; **CV**: Confirm Validity of Previous Assessments			

IAEA SSG-25: IAEA SSG-25 [35] addresses the periodic safety review of nuclear power plants. Per the PSR Basis Document [5] this PSR is being conducted in accordance with REGDOC-2.3.3. As stated in REGDOC-2.3.3 [3], this regulatory document is consistent with IAEA SSG-25. The combination of IAEA SSG-25 and REGDOC-2.3.3, define the review tasks that should be considered for the Safety Factor Reports. However, no assessment is performed specifically on IAEA SSG-25.

3.6. Other Applicable Codes and Standards

There was no additional international guidance identified for application to review tasks of this Safety Factor identified in Table C-1 of the PSR Basis Document [1]. In an earlier assessment (see below) the Darlington Design guides were reviewed, so the safety guide for EQ is listed in this table.

Table 4: Related Documents

Document Number	Document Title	Reference	Type of Review
Darlington DG-38-03650-8	Environmental Qualification of Safety Related Equipment	[36]	NA
Assessment type: **NA**: Not Assessed; **CBC**: Clause-by-Clause; **PCBC**: Partial Clause-by-Clause; **CTC**: Code-to-Code; **HL**: High Level; **2SF**: Assessment performed in another SFR; **CV**: Confirm Validity of Previous Assessments			

Darlington Design Guides: Clause-by-clause reviews were conducted against the Darlington Design Guides as part of the Bruce 1 and 2 ISR (NK21-CORR-00531-04059 [9]), which included NK21-REP-03600-00006 (a summary of environmental and seismic qualification) and NK21-REP-03600-00004 (a detailed review against all of the Darlington Design Guides). These reports concluded that, although the Bruce A qualification did not strictly meet all of the requirements of the Darlington Design Guides, it is a practicable approach for existing stations and has been previously accepted by the CNSC. The Bruce B Design Guide was prepared during a similar time period (1978 to 2002 for Bruce B, 1978 to 1992 for Darlington) and to a similar methodology to the Darlington Design Guide, resulting in an equivalent level of detail and requirements, so a detailed comparison would not provide useful results. Therefore, a review against the Darlington Design Guides was not repeated for this Safety Factor.

4. Overview of Applicable Bruce B Station Programs and Processes

The term “Equipment Qualification” is discussed in Section 5.37 of IAEA SSG-25 [35] as “plant equipment important to safety (that is, SSCs) should be properly qualified to ensure its capability to perform its safety functions under all relevant operational states and accident conditions, including those arising from internal and external events and accidents (such as loss of coolant accidents, high energy line breaks and seismic events or other vibration conditions).” Therefore, equipment qualification includes not only qualification for the environmental and seismic conditions that occur during the design basis events, but also the capability to perform their safety functions during the conditions that occur in the normal operation of the plant.

Bruce Power documents define “Equipment Qualification” as “verification of equipment design by demonstrating functional capability under anticipated operational stresses and service conditions resulting from normal operation, anticipated operational transients and Design Basis Accidents” (Section 3.1.8 of BP-PROC-00261 [37]).

The anticipated operational stresses and service conditions resulting from normal operation and anticipated operational transients (i.e., normal temperature and atmospheric conditions, electromagnetic interference, vibration) were addressed by qualification reports, tests, and analyses in the original design, as required by equipment specifications and standards at that time. That qualification is monitored and maintained by the Level 0, and Level 1 programs and procedures shown in Table 5. The Level 3 procedures include some of those listed in Table 5, as well as others that are discussed in more detail in Safety Factor Reports SF1 “Plant Design” and SF4 “Ageing”. These reports are listed in Section 6 of this report as interfacing reports.

The harsh environmental conditions resulting from Design Basis Accidents and from earthquake events are the main focus of this report, and are addressed under separate headings in Table 5. Environmental Qualification (EQ) includes the effects of ageing during normal plant operation in the environmental qualification process (i.e., EQ Assessments), so the procedures used to monitor normal plant conditions are identified below, as these are important to ensure that the equipment qualification is maintained for the life of the plant.

The main documents that manage the equipment qualification process are listed in Table 5, and are discussed below.

4.1. Design Basis Management

The Management System Manual, BP-MSM-1 [38], is the top level management system document that includes policy statements and governs the programs and processes for the Bruce Nuclear Generating Station. It establishes the hierarchy of documents and processes and provides the staff expectations and the management roles and responsibilities for the operation of the nuclear station. It provides the authority for the next lower level of documents, which includes various programs that implement the management system, including those which implement the equipment qualification process.

The Management System Manual provides the authority for the Plant Design Basis Management program, BP-PROG-10.01 [39], which in turn is implemented by the procedure BP-PROC-00335, Design Management [40], amongst others. The Design Management procedure provides the authority for the primary implementing procedures for Environmental and Seismic Qualification as outlined in Sections 4.2 and 4.3 below.

Other programs that supplement the Plant Design Basis Management Program to sustain the equipment qualification process throughout the life of the plant are:

- BP-PROG-10.02 Engineering Change Control [41]
- BP-PROG-11.01 Equipment Reliability [42] and
- BP-PROG-11.04 Plant Maintenance [43].

4.2. Environmental Qualification

The primary procedure identified in BP-PROC-00335, Design Management [40] (clause 4.9.2), that implements the environmental qualification process is BP-PROC-00261, Environmental Qualification [37]. This procedure provides a comprehensive description of the environmental qualification process, outlining the role of each of the procedures listed in Table 5 (amongst others), as well as the role of the following basis documents:

- NK29-DG-03650-003, Environmental Qualification of Safety Related Equipment [44]

This design guide was used for the environmental qualification of the original Bruce B design, and is a historical document that has not been updated to current requirements (see procedures listed below for current requirements). However, as stated in clause 4.1.3 of BP-PROC-00261 [37], it continues to be used as the basis to define a qualified line of defence for Design Basis Accident (DBA) events (along with current information). This design guide identifies the DBAs that result in global harsh environments, the safety related systems and structures that maintain the basic nuclear safety functions when exposed to harsh environments, and the system functional requirements necessary to maintain the basic nuclear safety functions when exposed to harsh environments.

- B-STQ-03651-10001 R001, Bruce B EQ Room Conditions Manual [45]

  This manual provides a single source of the normal service and post-accident environmental conditions for use in establishing and maintaining EQ of essential safety related equipment.

The procedures applicable to EQ are listed in Table 5 and summarized below in terms of their role in the overall EQ Program:

- SEC-EQD-00007 [46] provides guidelines for the revision of Environmental Qualification Assessments (Bruce B) and Environmental Qualification Dossiers (Bruce A).
- SEC-EQD-00012 [47] provides guidelines to define the start of the "qualified life" of equipment for use in EQ documents, including consideration of installations before and after initial criticality and long periods of shutdown.
- SEC-EQD-00013 [48] defines the process for the EQ Environment Monitoring (EM) Program, which monitors the actual conditions for selected environmentally qualified equipment to confirm they are within the range used to establish the equipment's qualified life. The main objectives of the EM program are to validate the normal temperature and radiation data in the EQ Room Conditions Manual for selected locations, to identify local hot spots, and to provide justification for extending or limiting the qualified life of equipment based on the collected data. Changes to EQ documentation are addressed in an EQ Evaluation (see SEC-EQD-00032 below).
- SEC-EQD-00015 [49] provides technical guidance for the qualified material, components, and maintenance procedures that may be used for an EQ installation.
- SEC-EQD-00017 [50] provides guidance for the use and control of lubricants for environmentally qualified equipment.
- SEC-EQD-00021 [51] defines the process for developing, revising, and cancelling Environmental Qualification Assessments (EQA) and Environmental Qualification Maintenance Requirements (EQR).
- SEC-EQD-00022 [52] describes the process used to develop and maintain the Environmental Qualification List (EQL), including the EQ Safety Related Components List (EQSRCL), and the Harsh Environmental Components List (HECL). This information is maintained for Bruce B in the EQ Information System (EQIS). As noted in Section 4.5 of this procedure, the document NK29-SRM-03651.04-00001, Environmental

Qualification Matrix [53], links the system functional requirements with the equipment functional requirements which are maintained in the EQIS EQ-12 reports. Components on the EQL are flagged in PassPort and in Online Wiring so their status is identified for maintenance or monitoring activities. In Appendix C of this procedure, the relationship between EQIS, PassPort, and Online Wiring and the administration of these databases is provided; briefly, it states that EQIS is the repository of what equipment needs to be qualified (including the rationale), and PassPort and Online Wiring are the repositories of what is qualified and includes tracking capability to ensure it remains qualified during installation and maintenance.

- SEC-EQD-00030 [54] describes the process used to identify condition monitoring credited in the assessment of the qualified life for environmentally qualified components, which are then monitored by the Performance Monitoring Plans outlined in DPT-PE-00008 [55].
- SEC-EQD-00032 [56] describes the process to provide an auditable and documented format for issues arising about the qualification of EQ equipment, in the form of EQ Evaluations (EQE).
- SEC-EQD-00033 [57] describes the process used to verify that EQ equipment and components are installed and configured in accordance with the applicable EQ Dossier (EQD) or EQA, using document reviews or walkdowns. This process is also used to verify assumptions in an EQE.
- SEC-EQD-00034 [58] describes the process used to track the sustainability of EQL components using the EQ Status Index, which considers the EQ equipment qualification status, documentation status, installation history, predefined maintenance activity, and changes in classification.
- SEC-EQD-00035 [59] describes the monitoring process used to ensure that maintenance performed on equipment on the EQL is well documented and does not compromise the qualification.
- SEC-EQD-00040 [60] describes the basic steps used to demonstrate and document the EQ of cables at the Bruce Power site.
- SEC-EQD-00049 [61] provides the process and expectation for the EQ Program Health Report, which is produced semi-annually, based on parameters like regulatory reportable events, document production, sustainability, etc.
- SEC-RSA-00001 [62] describes the requirements for the preparation of the EQ Room Conditions Manual, which define the normal and post-accident conditions for rooms which contain special safety and safety related equipment that is required to function in harsh environmental conditions.
- DPT-PDE-00019 [63] identifies the physical barriers that are required to mitigate harsh conditions or maintain mild conditions consistent with EQ assessments and provides requirements for the identification, maintenance, modification and inspection of these barriers.

4.3. Seismic Qualification

The primary procedure identified in BP-PROC-00335 Design Management [40] (clause 4.9.1) that implements the seismic qualification process is DPT-PDE-00017, Bruce Power Seismic Qualification Standard [64]. This procedure describes the engineering and administrative processes for preserving the seismic qualification of the systems, structures and components. It outlines the basis of qualification of Bruce B, noting in Section 4.1.2 that "The original seismic qualification of the Bruce B followed the criteria of Seismic Qualification of Safety-related Systems, NK29-DG-03650-002 which invokes CSA Standards CAN3-N289.3 and N289.4. The general scope of seismic qualification is described in the Bruce B Safety Report. Bruce Power is committed to preserving seismic qualification for Bruce B in accordance with NK29-DG-03650-002."

DPT-PDE-00017 also calls up equipment specification B-SPEC-01370-00001 [66] and B-SPEC-01370-00002 [67] for seismic qualification of equipment. A more recent specification, B-SPEC-01370-00003 [68], has also been produced that includes qualification for different mounting conditions (where this is known) and is referenced in the first two specification documents in this series.

The other main procedure is BP-PROC-00500, Control of Unsecured Equipment in Seismically Qualified Areas [69], which is used during plant operations and maintenance to ensure that any equipment used is properly secured so it would not damage nearby qualified equipment should an earthquake occur.

4.4. Supporting Procedures for Equipment Qualification

A number of supporting procedures are noted in the programs and procedures applicable to equipment qualification for normal plant conditions and anticipated operational conditions, as well as for environmental qualification and seismic qualification, as listed in Table 5[1]. These procedures address the procurement (BP-PROC-00244 [70]), life cycle management (BP-PROC-00400 [71]), maintenance of qualified equipment (BP-PROC-00695 [72]) and monitoring of qualified equipment (BP-PROC-00781 [73], BP-PROC-00684 [74], DPT-PE-00008 to 00011 [55][75][76][77]) as required by the equipment qualification procedures and programs, and the monitoring and inspection of qualified equipment required by the plant operations program and procedures (BP-PROG-12.01 [78], BP-OPP-00001 [79], GRP-OPS-00047 [80]).

[1] Table 5 lists the key governance documents used to support the assessments of the review tasks for this Safety Factor Report. A full set of current sub-tier documents is provided within each current PROG document. In the list of references, the revision number for the governance documents is the key, unambiguous identifier; the date shown is an indicator of when the document was last updated, and is taken either from PassPort, the header field, or the "Master Created" date in the footer.

Table 5: Key Implementing Documents

Level 0	Level 1	Level 2	Level 3
Environmental Qualification			
BP-MSM-1: Management System Manual [38]	BP-PROG-10.01: Plant Design Basis Management [39]	BP-PROC-00335: Design Management [40]	BP-PROC-00261: Environmental Qualification [37] SEC-EQD-00007: Environmental Qualification Assessment and Dossier Revisions [46]
			SEC-EQD-00012: Start of Qualified Life [47]
			SEC-EQD-00013: Environment Monitoring for EQ [48]
			SEC-EQD-00015: Environmental Qualification Installation Standards [49]
			SEC-EQD-00017: EQ and Lubricants [50]
			SEC-EQD-00021: Environmental Qualification Assessments [51]
			SEC-EQD-00022: Development of Environmental Qualification Lists [52]
			SEC-EQD-00030: EQ Equipment Condition Monitoring Procedure [54]

Level 0	Level 1	Level 2	Level 3
			SEC-EQD-00032: Environmental Qualification Evaluations (EQE) [56]
			SEC-EQD-00033: EQ Walkdown and Verification Process [57]
			SEC-EQD-00034: Environmental Qualification Status Index [58]
			SEC-EQD-00035: Environmental Qualification Sustainability Monitoring [59]
			SEC-EQD-00040: Cable Qualification Strategy [60]
			SEC-EQD-00049: Environmental Qualification Health Reporting [61]
			SEC-RSA-00001: Preparation of the EQ Room Conditions Manual [62]
			DPT-PDE-00019: Steam Protection Barriers [63]
Seismic Qualification			
BP-MSM-1: Management System Manual [38]	BP-PROG-10.01: Plant Design Basis Management [39]	BP-PROC-00335: Design Management [40]	DPT-PDE-00017: Bruce Power Seismic Qualification Standard [64]
			BP-PROC-00500: Control of Unsecured Equipment in Seismically Qualified Areas [69]

Level 0	Level 1	Level 2	Level 3
Equipment Qualification Supporting Procedures			
BP-MSM-1: Management System Manual [38]	BP-PROG-10.01: Plant Design Basis Management [39]	BP-PROC-00335: Design Management [40]	BP-PROC-00244: Procurement Engineering [70]
			BP-PROC-01008: Item Equivalency Evaluation [81]
	BP-PROG-10.02 Engineering Change Control [41]	BP-PROC-00539 Design Change Package [82]	
	BP-PROG-11.01: Equipment Reliability [42]	BP-PROC-00400: Life Cycle Management of Critical SSCs [71] BP-PROC-00781: Performance Monitoring [73]	DPT-PE-00008: System and Component Performance Monitoring Plans [55]
			DPT-PE-00009: System and Component Performance Monitoring Walkdowns [74]
			DPT-PE-00010: System Health Reporting [76]
			DPT-PE-00011: Component Program Health Reporting [77]
	BP-PROG-11.04: Plant Maintenance [43]	BP-PROC-00695: Maintenance Program and Activities [72]	
		BP-PROC-00684 Conduct of Maintenance [74]	

Level 0	Level 1	Level 2	Level 3
	BP-PROG-12.01 Conduct of Plant Operations [78]	BP-OPP-00001 Operating Policies and Principles [79]	GRP-OPS-00047 Operator Routines and Inspections [80]

5. Results of the Review Tasks

The results of the review of this Safety Factor are documented below under headings that correspond to the review tasks listed in Section 1.2 of this document. The review tasks assessed in this section have not changed from those listed in Section 1.2.

5.1. Effectiveness of the Equipment Qualification Program

The review of equipment qualification includes an assessment of the effectiveness of the plant's equipment qualification program to ensure that plant equipment (including cables) is capable of fulfilling its safety functions for the period until at least the next PSR.

The review also covered the requirements for performing safety functions while subject to the environmental conditions that could exist during both normal and predicted accident conditions. These include seismic conditions, vibration, temperature, pressure, jet impingement, electromagnetic interference, irradiation, corrosive atmosphere and humidity, fire (for example, a hydrogen fire) and combinations thereof and other anticipated events.

The review considered the effects of ageing degradation of equipment during service and of possible changes in environmental conditions during normal operation and predicted accident conditions since the program was devised.

Review Task Assessment

The equipment qualification process includes several different programs and procedures that interface with each other. When the plant was originally designed, equipment was specified, and in some cases analyzed or tested, to perform its functions while subjected to defined or assumed ambient conditions of vibration, temperature, humidity, radiation, electromagnetic interference, internal conditions, etc., which collectively constitute equipment qualification. During the subsequent plant operation, equipment important to safety was identified and is monitored, maintained, and modified or repaired to maintain its safety functions in the actual ambient conditions that exist at the plant, which may include additional or more severe conditions than assumed in the original design.

The main programs and procedures that maintain or enhance the original equipment qualification during normal plant operation, and therefore ensure that the equipment can fulfill its safety functions until the next PSR, are:

- Equipment Reliability, BP-PROG-11.01 [42]

This program employs several procedures to identify critical components, specify preventive maintenance, improve reliability, handling life cycle management, etc. Two of the more important procedures for maintaining equipment qualification are BP-PROC-00400, Life Cycle Management for Critical SSCs [71] and BP-PROC-00781, Performance Monitoring [73].

BP-PROC-00400 [71] describes the process for the development of Life Cycle Management Plans (LCMP) to document the long term mitigation options for SSCs that are deemed to be of critical importance (using BP-PROC-00666, Component Categorization [83]) and are susceptible to life limiting failure mechanisms and are of a value greater than $10M. This procedure identifies the service life prediction of environmentally qualified components as being one of the considerations for the identified components (clause 4.3.3).

BP-PROC-00781 [73] implements the process for system and component monitoring, and provides the framework for documenting and trending the results of the monitoring in the form of System and Component Health Reports. The monitoring and reporting of the health of systems and components is implemented by procedures DPT-PE-00008 [55], DPT-PE-00009 [74], DPT-PE-00010 [76], and DPT-PE-00011 [77]. These procedures are also called up in the EQ Equipment Condition Monitoring procedure SEC-EQD-00030 [54], which implements the condition monitoring process outlined in Section 4.4 of BP-PROC-00261 [37], and would also apply to seismically qualified equipment, although not specifically listed in DPT-PDE-00017 [64]. See Table 5 for a listing of the key procedures for life cycle management and system and component health reporting. This process is addressed in more detail in the Safety Factor Reports SF4, Ageing, and in SF2, Actual Condition of SSCs.

- Plant Maintenance, BP-PROG-11.04 [43]

  This program evaluates the function and performance of plant equipment against a set of criteria to ensure it continues to operate as per design, and ensures that preventive and corrective maintenance processes are in place to support nuclear safety. The main procedure that implements this program is BP-PROC-00695, Maintenance Program and Activities [72], which is also listed in Table 5.

- Engineering Change Control, BP-PROG-10.02 [41]

  This program ensures that design changes and modifications are controlled and documented so that SSCs continue to satisfy the design basis and operate safely. The program is implemented for equipment qualification through the interfacing program BP-PROG-10.01 described below.

- Plant Design Basis Management BP-PROG-10.01 [39].

  This program maintains the design basis to ensure that the plant can operate safely for its design life. The main procedure for implementing this program is BP-PROC-00335 Design Management [40]. As outlined in this procedure (section 4.10), the equipment qualification process for Environmental and Seismic Qualification (i.e., for Design Basis Accidents and external events) is addressed by two primary procedures, BP-PROC-

00261 for Environmental Qualification [37] and DPT-PDE-00017 for Seismic Qualification [64].

The above program documents and their implementing procedures describe a formalized process which requires that qualified SSCs are identified, that the qualification documentation is produced and maintained for the life of the station, that the qualification is maintained for the life of the plant where ageing is a factor, and that the qualification is sustained through control of maintenance and replacement and through monitoring during their life cycle.

The environmental conditions for SSCs are established during the original design and procurement processes for the plant, and the above programs and procedures ensure that the equipment qualifications continue to be maintained. For a more comprehensive assessment of the current capability of equipment to withstand the plant conditions and to withstand the conditions that are anticipated to occur in the future during normal station operation, refer to the reports for Safety Factor 1 “Plant Design”, Safety Factor 2 “Actual Condition of SSCs”, and Safety Factor 4, “Ageing”.

Although the plant performance monitoring and reporting assessment in the Safety Factor 4 report does not specifically address the Environmental Qualification aspect, the linkage between the EQ process and the plant performance monitoring process is provided through the procedures SEC-EQD-00030 [54], which calls up DPT-PE-00008 [55] and DPT-PE-00009 [74] in section 4.2, and DPT-PE-00008 [55] likewise calls up SEC-EQD-00030 [54] in section 4.1.1.3. The linkage between equipment qualification and performance monitoring, maintenance or modification activities is also provided by the display of the PassPort database (by an information box or “flag”), which is consulted and updated during these activities.

Environmental Qualification

Based on the procedures listed in Table 5, environmentally qualified SSCs are identified, based on their credited safety functions, using procedures SEC-EQD-00021 [51] and SEC-EQD-00022 [52]; the qualification documentation is produced using SEC-EQD-00021 [51], SEC-EQD-00040 (for cables) [60], and SEC-EQD-00017 (for lubricants) [50]; the qualified life is established using SEC-EQD-00012 [47]; maintenance and replacement activities are controlled through SEC-EQD-00015 [49]; and qualified components are monitored in accordance with SEC-EQD-00013 [48]. These procedures also identify the relevant technical background and information contained in design guides and reports.

Of the above procedures, SEC-EQD-00040, Cable Qualification Strategy [60] is of particular interest, as it describes the steps taken to identify and qualify the cables, which traverse many different rooms and areas of the plant, and are subject to various environmental conditions. The steps and methods used to identify and qualify the cables are included in this procedure, and the appendices provide the technical information that supports the qualification.

As described in Section 4.4.16 of the Environmental Qualification procedure BP-PROC-00261 [37], the effectiveness of the EQ program is monitored through the preparation of a semi-annual EQ Program Health Report (also see SEC- EQD-00049 [61]) and is periodically assessed by audits, self-assessments, or independent reviews and/or management oversight. See Section 7 for a summary of recent audits and self-assessments.

Any changes that may occur in the predicted environmental conditions for accidents are identified in the processes described in the Safety Factor 5 Deterministic Safety Analysis report and would be incorporated into the EQ process through SEC-EQD-00032 [56].

Seismic Qualification

Seismically qualified SSCs are identified using procedure DPT-PDE-00017 [64], which calls up a number of technical documents, including:

- NK29-DG-03650-002 Bruce B Seismic Qualification of Safety Related Systems [65]
- B-SPEC-01370-00001 Seismic Qualification of Mechanical Equipment [66]
- B-SPEC-01370-00002 Seismic Qualification of Instrumentation and Control Equipment [67]
- B-SPEC-01370-00003 Seismic Qualification of Equipment and Components [68]

These documents provide a comprehensive presentation of the methodology used to identify and qualify the systems and equipment that are seismically qualified

During the high level assessment of the seismic qualification procedures presented in Appendix A, some inconsistencies were noted in the identification of the CSA seismic qualification standards. BP-PROC-00335 [40] indicates in Sections 1.0 and 5.1 that only CSA N289.1 and CSA N289.3 are applied to the design management, whereas DPT-PDE-00017 [64] indicates in Section 5.1 (Relevant Statutory, Regulatory and Licensing Requirements) that CSA standards N289.1 to N289.4 are applied, and in Section 4.1 that N289.1 to N289.5 are used as a basis for qualification. The implementing document NK29-DG-03650-002 [65] references only CSA N289.1, but states in the text (clause 6.1) that the rest of the N289 series also applies. The assessment shows that CSA N289.5 has not been applied to Bruce B, and parts of the other standards in the series (in particular the 2014 update to N289.1) have also not been applied, as indicated by the identification of gaps SF3-1 to SF3-4. The governing and implementing documents should be updated to consistently indicate the extent to which the CSA N289 series applies to the design of Bruce B, and their actual status as indicated in the LCH. This is identified as gap SF3-5.

As discussed in the high level assessment in Appendix A, the DBE level used in the original design was 0.05 g above 33 Hz, as presented in NK29-DG-03650-002 [65]. A Probabilistic Seismic Hazard Assessment [84] was done in 2011, which indicated a peak ground acceleration of 0.016 g at 100 Hz for hard rock with soil amplification of 1.5 to 2.7 at the ground surface, which results in a peak ground acceleration of about 0.043 g for a probability of exceedance of 10^{-4} which is required by the current N289.1 standard. This appears to confirm that the design basis of the original design complies with the current standard, although the effect of differences in the lower frequency ranges are not evaluated here.

The programs and procedures that were in place during the plant design for the qualification of equipment important to safety ensured that it was capable of fulfilling its safety functions as installed. Based on the above assessment, it is concluded that processes are in place that will effectively maintain that qualification for the life of the plant, both for conditions that occur during normal operation and those that occur for Design Basis Accidents, and for less frequent internal and external events, such as seismic events.

5.2. Implementation of Equipment Qualification Program

Although many parties (such as designers, equipment manufacturers and consultants) are involved in the equipment qualification process, Bruce Power has the ultimate responsibility for the development and implementation of an adequate plant specific equipment qualification program. The following aspects of implementation of the program were assessed:

1. *If qualification of plant equipment important to safety has been formalized using a process that includes generating, documenting and retaining evidence that equipment can perform its safety functions during its installed service life;*

   Review Task Assessment:

   A formalized process is in place for equipment requiring environmental and seismic qualification, as described in the procedures BP-PROC-00261, Environmental Qualification [37], and DPT-PDE-00017, Bruce Power Seismic Qualification Standard [64], which are given authority through BP-PROC-00335 [40] and BP-PROG-10.01 [39]. For other aspects of equipment qualification, a robust process is in place through BP-PROG-11.01, Equipment Reliability [42] to identify and categorize that equipment, and to monitor and maintain it appropriately for the life of the plant. This process is described in more detail in Sections 4 and 5.1 of this report.

   It is concluded that this requirement is satisfied.

2. *Confirm if this is an ongoing process, from its design through to the end of its service life;*

   Review Task Assessment:

   This is an ongoing process, as clearly stated in the programs and procedures that manage equipment qualification as described in Section 4 of this report:

   - BP-PROG-10.01, Plant Design Basis Management [39], states that its purpose is "to ensure that the plant can operate safely for the full duration of its design life" (page 5) and calls up BP-PROC-00335, Design Management [40] as an implementing procedure (Section 4.1), which in turn calls up BP-PROC-00261 (Section 4.9.2) and DPT-PDE-00017 (Section 4.9.1). It also calls up the standard CSA N290.13-05 as one of the Relevant Statutory Regulatory and Licensing Requirements (Section 1.0).
   - BP-PROG-10.02, Engineering Change Control [41], states (in Section 1.0) that its purpose is "to ensure that design changes and modifications are controlled such that System, Structure, and Component and Significant Tools (SSCTs) continue to meet the design basis and operate safely for the full duration of design life" and calls up various procedures to implement this purpose. This ensures that the equipment qualification requirements are maintained from the original design and installation to the end of the service life of the equipment.
   - BP-PROG-11.01, Equipment Reliability [42], states (in Section 4.0) that its overall objective is "to ensure that all Systems Important to Safety (SIS) shall meet their defined design and performance criteria at defined levels of reliability throughout the life of the NPP" and calls up several implementing procedures (such as BP-PROC-00781, Performance Monitoring [73] and BP-PROC-00400, Life Cycle Management for Critical

SSCs [71]). This ensures that the equipment qualification requirements are maintained from the original design and installation to the end of the service life of the equipment.

- BP-PROG-11.04, Plant Maintenance [43], states (in Section 4.0) that "the Bruce Power Plant Maintenance program is intended to support the safe and effective achievement of production goals and requirements, both long term and short term, through an effective maintenance strategy" and calls up implementing procedures and interfacing programs that support this objective. This ensures that the equipment qualification requirements are maintained from the original design and installation to the end of the service life of the equipment.

The above programs and procedures clearly indicate that equipment qualification is an ongoing process that will be sustained throughout the life of the plant. It is concluded that this requirement is satisfied.

3. *Assess if the process takes into account plant and equipment ageing and modifications, equipment repairs and refurbishment, equipment failures and replacements, any abnormal operating conditions and changes to the safety analysis.*

Review Task Assessment:

The process takes this into account, as stated in the procedures described in Section 4 and assessed in Section 5.1 of this report, and through the ageing management process discussed in Section 4.1.1 of the Safety Factor 4 report. Equipment repairs and refurbishment are controlled through the maintenance procedure (BP-PROC-00695 [72]). The Safety Factor 5 report addresses the processes that are followed for changes to the safety analysis.

It is concluded that this requirement is satisfied.

5.3. Review of Equipment Qualification

The review of equipment qualification considered:

1. *Whether installed equipment meets the qualification requirements*;

***Review Task Assessment**:*

Procedures are in place to ensure that installations are done correctly, and these activities are performed under an overall quality assurance (QA) program. These include the procedures associated with BP-PROG-10.02, Engineering Change Control [41] and BP-PROG-11.04, Plant Maintenance [43].

For EQ, BP-PROC-00261 [37] includes a requirement in Section 4.3 to verify that installed equipment meets the EQ design and configuration requirements established in the EQ Assessment reports, SEC-EQD-00015 [49] provides technical guidance to ensure that installations meet EQ requirements, and SEC-EQD-00033 [57] provides requirements for walkdowns and document reviews to ensure that EQ equipment is installed correctly and verified.

For seismically qualified components, this is addressed through the normal work processes after being identified as being qualified in the Safe Shutdown Equipment List, in Passport, and in Online Wiring.

It is concluded that this requirement is satisfied.

2. *The adequacy of the records of equipment qualification*;

   Review Task Assessment:

   Equipment qualification records are comprehensive and prepared according to requirements included in the applicable procedures and are maintained for the life of the plant (e.g. SEC-EQD-00021, Environmental Qualification Assessments [51], SEC-EQD-00032, Environmental Qualification Evaluations (EQE) [56], DPT-PDE-00017, Bruce Power Seismic Qualification Standard [64]). The overall management of records is addressed by BP-PROC-00098, Records Management [85], which is referenced in BP-PROC-00335 [40]. For maintenance activities, BP-PROG-11.04 states in Section 4.1 that "records are kept to track equipment inspections, monitoring, repairs, failure information, including specific component, cause of failure and actions taken to correct, and equipment condition post repair". [43]

   The audit reports and self assessments summarized in Section 7 of this report have confirmed the adequacy of these procedures, and a considerable number of improvements have been made in response to the earlier audits. It is noted that many of the procedures have been prepared or revised recently, and have incorporated the recommended changes arising from the audits and self assessments.

   It is concluded that this requirement is satisfied.

3. *Procedures for updating and maintaining qualification throughout the service life of the equipment*;

   Review Task Assessment:

   Procedures are in place to update and maintain the qualification of SSCs for the service life of the equipment, and most have been recently revised, including SEC-EQD-00007, Environmental Assessment and Dossier Revisions [46], SEC-EQD-00032, Environmental Qualification Evaluations (EQE) [56] and DPT-PDE-00017, Bruce Power Seismic Qualification Standard [64]. For other equipment important to safety, this is managed through the normal programs and procedures (e.g. BP-PROG-10.01 [39], BP-PROG-11.04 [43]).

   It is concluded that this requirement is satisfied.

4. *Procedures for ensuring that modifications and additions to SSCs important to safety do not compromise their qualification*;

   Review Task Assessment:

   The programs and procedures that ensure that modifications and additions to SSCs do not compromise their qualification include:

- BP-PROG-11.04, Plant Maintenance [43], describes the maintenance process and objectives, and states in Section 4.1 that “Function and performance of plant equipment is evaluated against a baseline set of criteria to ensure it continues to operate as per design. Condition monitoring, testing, and surveillance are performed based on the safety importance of the system…”.
- BP-PROG-10.02, Engineering Change Control [41], states in Section 4.0 that “The program objective is to ensure that design changes and modifications are sufficiently controlled such that requirements are met and the Safe Operating envelope is maintained for the full duration of the plant design life.”
- SEC-EQD-00032, Environmental Qualification Evaluations (EQE) [56], describes the process and documentation required if an issue is found that affects environmentally qualified SSCs, including questions arising from EQ documentation, field observations, condition monitoring, maintenance activities, or proposed changes and modifications.
- SEC-EQD-00015, Environmental Qualification Installation Standards [49], provides technical guidance to those involved in design, material selection, installation, and maintenance to ensure that EQ requirements are satisfied.
- DPT-PDE-00017, Bruce Power Seismic Qualification Standard [64], describes in Sections 4.3, 4.4, and 4.5 the procedures, training, and administrative controls required for modifications to seismically qualified SSCs.

It is concluded that this requirement is satisfied.

5. *Surveillance programs and feedback procedures used to ensure that ageing degradation of qualified equipment remains insignificant*;

Review Task Assessment:

Comprehensive surveillance programs and feedback procedures are in place to ensure that ageing degradation of qualified equipment is understood and does not adversely impact performance, which are:

- SEC-EQD-00013, Environment Monitoring for EQ [48]: This procedure implements the Environmental Qualification environment monitoring program, with the objective of validating the temperature and radiation exposure data included in the Room Condition Manual (RCM), determining local hot spots, and justifying the extension or limitation of qualified life based on this data.
- SEC-EQD-00030, EQ Equipment Condition Monitoring [54]: This procedure describes the EQ condition monitoring requirements, including the identification of equipment to be monitored, the review of the implementation of monitoring, and the assessment of the results of monitoring.
- SEC-EQD-00035, Environmental Qualification Sustainability Monitoring [59]: This procedure ensures that maintenance performed on equipment does not adversely affect its qualification, by ensuring that only EQ approved equipment is used and that the work is properly documented.

- SEC-EQD-00049, Environmental Qualification Health Reporting [61]: This procedure provides the requirements for the EQ Program Health Report, which is produced on a semi-annual basis and includes a performance rating system, identifies performance indicators, and identifies future performance objectives.
- BP-PROC-00400, Life Cycle Management of Critical SSCs [71]: This procedure provides the process for the preparation of Life Cycle Management Plans, which includes identification of the age related degradation mechanism, the current condition, and options for repair or replacement in the future, where the costs exceed $10M.
- BP-PROC-00695, Maintenance Program and Activities [72]: This procedure is related to plant maintenance (i.e., BP-PROG-11.04 [43]), and sets the baselines for the measurement and monitoring of the function of structures, systems, and components.
- BP-PROC-00781, Performance Monitoring [73]: This procedure implements the monitoring requirements supporting the Equipment Reliability Program (BP-PROG-11.01 [42]) for important structures, systems, critical components, and programs. It is in turn implemented by the following four procedures, amongst others:
    - DPT-PE-00008, System and Component Performance Monitoring Plans [55]
    - DPT-PE-00009, System and Component Performance Monitoring Walkdowns [74]
    - DPT-PE-00010, System Health Reporting [76]
    - DPT-PE-00011, Component Program Health Reporting [77]

It is concluded that the requirement for comprehensive surveillance and feedback procedures is satisfied.

6. *Monitoring of actual environmental conditions and identification of 'hot spots' of high activity or temperature*.

Review Task Assessment:

Actual environmental conditions and identification of "hot spots" of high activity or temperature is done on a selective basis through procedure SEC-EQD-00030, EQ Equipment Condition Monitoring Procedure [54]. This procedure states that where an EQ Dossier "indicates that some specific monitoring activities are necessary, i.e., they are EQ critical and they are credited in the assessment of qualified life", they must be part of the Performance and Condition Monitoring Activities. The EQ specialist helps to identify the EQ requirements that need to be included in the Performance Monitoring Plans.

It is concluded that this requirement is satisfied.

7. *Protection of qualified equipment from adverse environmental conditions*.

Review Task Assessment:

Qualified equipment is protected from adverse environmental conditions where possible and practical. For example, a substantial amount of equipment is located outside of containment to protect it from radiation during normal plant operation and from adverse environment during accident conditions. In other cases, shielding is provided to reduce the radiation environment for qualified equipment. For the relevant design basis accidents (e.g., steam line breaks) certain identified walls have a function to protect equipment from the harsh steam environment, as required by the procedure DPT-PDE-00019, Steam Protection Barriers [63]. These barriers are subject to certain operating and monitoring requirements, as outlined in the procedure.

It is concluded that this requirement is satisfied.

6. Interfaces with Other Safety Factors

There is some degree of interrelationship among most of the 15 Safety Factors that comprise the Bruce B PSR. The following identifies specific aspects of this Safety Factor that are addressed in, or where more detail is provided in, another Safety Factor Report.

- "Safety Factor 1: Plant Design" in Appendix B.2, addresses several issues related to equipment qualification including maintenance of equipment qualification through the Plant Design Basis and Plant Design Basis Management programs and procedures. Per Appendix B.1 of "Safety Factor 1" plant design processes can impact equipment qualification for conditions that occur during normal plant operation (e.g., vibration, electromagnetic interference, etc) or the qualification of environmentally qualified or seismically qualified equipment.
- "Safety Factor 2: Actual Condition of SSCs" in Section 5.7, reviews the documented results of tests which demonstrate functional capability of SSCs to withstand environmental conditions during normal plant operation. This is important for the aspect of sustaining equipment qualification for the life of the plant.
- "Safety Factor 4: Ageing" in Section 5.8 addresses the review of the ageing management methodology. As well, in Section 5.4, the evaluation and documentation of potential ageing degradation that may affect safety functions of SSCs important to safety is important for sustaining the equipment qualification for the life of the plant.
- "Safety Factor 5: Deterministic Safety Analysis" in Section 5.2, addresses changes to the safety analysis, for various postulated initiating events leading to predicted accident conditions and associated environmental conditions.
- "Safety Factor 6: Probabilistic Safety Analysis" in Section 5.0 addresses the adequacy of the existing probabilistic risk assessment (PRA) including At Power Seismic PRA. In particular, Section 5 of that report assesses the compliance with safety criteria to ensure that sufficient equipment important to safety is identified for various events.
- "Safety Factor 7: Hazard Analysis" in Sections 5.1 and Section 5.2, respectively, assesses the external and internal hazards that may affect the plant which leads to predicted accident conditions and associated environmental conditions.

7. Program Assessments and Adequacy of Implementation

Section 7 supplements the assessments of the review tasks in Section 5, by providing information on four broad methods used to identify the effectiveness with which programs are implemented, as follows:

- Self-Assessments;
- Internal and External Audits and Reviews;
- Regulatory Evaluations; and
- Performance Indicators.

For the first three methods, the most pertinent self-assessments, audits and regulatory evaluations are assessed. Bruce Power has a comprehensive process of reviewing compliance with Bruce Power processes, identifying gaps, committing to corrective actions, and following up to confirm completion and effectiveness of these actions. While there have been instances of non-compliance with Bruce Power processes, Bruce Power's commitment to continuous improvement is intended to correct any deficiencies.

For the fourth method, the performance indicators relevant to this Safety Factor are provided. These are intended to demonstrate that there is a metric by which Bruce Power assesses the effectiveness of the programs relevant to this Safety Factor.

Taken as a whole, these methods demonstrate that the processes associated with this Safety Factor are implemented effectively (individual findings notwithstanding). Thus, program effectiveness can be inferred if Bruce Power processes meet the Safety Factor requirements and if there are ongoing processes to ensure compliance with Bruce Power processes. This is the intent of Section 7.

7.1. Self-Assessments

Generally, self-assessments are used by functional areas to assess the adequacy and effective implementation of their programs. The results of each assessment are compared with business needs, the Bruce Power management system, industry standards of excellence and regulatory/statutory or other legal requirements. Where gaps are identified, corrective actions are identified and implemented.

The self-assessments:

- Identify internal strengths and best practices;
- Identify performance and/or programmatic gap(s) as compared to targets, governance standards and "best in class";
- Identify gaps in knowledge/skills of staff;

- Identify the extent of adherence to established processes and whether the desired level quality is being achieved;
- Identify adverse conditions and Opportunities for Improvements (OFI); and
- Identify the specific improvement corrective actions to close the performance/programmatic gap.

7.1.1. SA-COM-2014-07, EQ Program Health [86]

This Focused Area Self-Assessment (FASA) reviewed maintenance procedures for compliance with EQ requirements found in EQ documents and for opportunities for enhancement of field verifiable attributes, in response to operating experience reports from Ontario Power Generation (OPG) and Canada Deuterium Uranium (CANDU) Owners Group (COG) that indicated an opportunity to improve awareness of EQ sustainability requirements within the plant. The plan was to enhance the maintenance procedures so EQ critical steps are reviewed by maintenance personnel during post maintenance activities, to satisfy the objective of periodic validation of installed components. The procedures reviewed for compliance with the requirements of BP-PROC-00261, Environmental Qualification [37] included BP-PROC-00781, Performance Monitoring [73], DPT-PE-00008, System and Component Performance Monitoring Plans [55], DPT-PE-00009, System and Component Performance Monitoring Walkdown [74], and SEC-EQD-00030, EQ Equipment Condition Monitoring Procedure [54].

The FASA identified one gap where a lubricant was missing EQ symbols and instruction, although it was confirmed that the correct lubricant was used and the lube list was correct. The FASA identified opportunities to update maintenance procedures for specific equipment to identify and document additional field verification “As Left” checks.

The Station Condition Records (SCRs) raised to implement the recommendations of this FASA were: 28473065, 28473069. These SCRs implemented the capability to add an EQ identification flag during the PassPort update, noted that procedure SEC-EQD-00034 [58] had been revised to address the issue of maintenance procedures not being aligned with EQ requirements, and addressed the specific equipment documentation issues related to EQ found during this assessment.

7.1.2. SA-COM-2013-07, EQ Program: Procedure Compliance and Effectiveness [87]

This Focused Area Self-Assessment (FASA) evaluated the compliance with the requirement in BP-PROC-00261 [37] and BP-PROC-00781 [73] to sustain EQ. It found good procedural guidance in Plant Engineering procedures, and the inclusion of EQ requirements in DPT-PE-00008, System and Component Performance Monitoring Plan [55]. Four adverse conditions were identified, for which three SCRs were raised:

- System walkdown procedures do not include EQ field verifiable attributes.

- There were no systematic walkdown or monitoring of EQ components for the Bruce B Active Drainage System, even though it includes safety related components that have post-accident functional requirements.
- Staff EQ training had expired.
- Station performance monitoring plans had passed their revision due dates.

An opportunity for improvement was identified, to assist in the development of the COG EQ Field Book, for which an Action Request was raised.

The SCRs raised to implement the recommendations of this self-assessment were: 28403801, 28403832 and 28403839, which addressed the specific equipment and training issues found, and the revision of Appendix H of DPT-PE-00008 [55] to include EQ field verifiable attributes. SCR 28403845 was raised to implement the opportunity for improvement identified to produce an EQ field guide book.

7.1.3. SA-COM-2012-02, EQ Program – Procedure Compliance and Effectiveness [88]

This FASA determined the level of compliance with the requirements of SEC-EQD-00032, Environmental Qualification Evaluations (EQE) [56]. Eleven EQE reports were reviewed for administrative compliance with the procedure (i.e., not for technical content). This FASA concluded that there was general compliance with the procedure, although minor document preparation issues were identified. Two of the more important issues were:

- Interactions between the EQEs and Engineering Change Control (ECC) were not clearly defined (i.e., EQ components of “equivalent design” type do not clearly require EQ related attributes in PassPort).
- The EQE production checklist is not a controlled document.

Among six identified opportunities for improvement, two were notable for the purposes of this assessment document:

- SEC-EQD-00032 requires several clarifications or corrections.
- Provide a mechanism for oversight of qualified life extensions that reduce the EQ safety margin (i.e., proactively track EQEs where qualified life is extended by reducing one or more of the EQ Safety Factors).

The SCRs raised to implement the recommendations of this self-assessment were: 28319644, 28319648, and 28319661. As a result of these SCRs, procedure SEC-EQD-00032 [56] was revised to include a clear definition of the EQE and ECC interface (Appendix B), and the EQE checklist was initiated as a controlled document.

7.1.4. SA-COM-2010-02, EQ Program Sustainability [89]

This FASA assessed the updating of the installation history in PassPort of Uniquely Tracked Commodities (UTC) by maintenance staff after completion of a work order as a key element of EQ Program sustainability.

In N290.13-05, maintenance performed on qualified equipment and parts used in the maintenance process is required to be documented and traceable, so a properly completed installation history is required to demonstrate that the station remains EQ qualified after maintenance. Despite several SCRs on the subject since 2005, several non-compliances have been observed in UTC installation history updates in PassPort. This FASA summarized several corrective actions currently in progress, including monitoring of the situation by EQ engineering staff and their immediate availability to maintenance staff to enter the required information into PassPort.

The following corrective actions were identified for which one SCR was raised:

- Perform a training needs analysis to ensure maintenance personnel are familiar with the UTC installation process
- Modify maintenance organization metrics to include percentage Work Orders closed with proper UTC fitted into the installation history.

The SCR raised to implement the recommendations of this FASA was 28223262. In response to this SCR, a contact was identified from maintenance to work with EQ engineering as needed, and a request was entered on the training website regarding a course on this topic for shop floor workers.

7.1.5. SA-PDE-2009-03, EQ Barrier Project – Baseline Complete and Sustained [90]

This FASA assessed the EQ requirements for the Steam Barrier Program to confirm that they are clearly defined and adequately documented, that closeouts for required modifications are complete, and that steam protection requirements are being sustained and satisfied. The assessment found that all field modifications for steam protection barriers were complete, that the main supporting documentation (e.g., procedure DPT-PDE-00019 [63] and supporting analysis models) was complete, and that steam protected room leak tests were complete.

A number of tasks were not yet completed, and the SCRs raised for these issues were 28184246, 2814247, and 28184276.

7.2. Internal and External Audits and Reviews

The objective of the audit process as stated in BP-PROG-15.01 [91] is threefold:

- To assess the Management System and to determine if it is adequately established, implemented, and controlled;

- To confirm the effectiveness of the Management System in achieving the expected results and that risks are identified and managed; and
- To identify substandard conditions and enhancement opportunities.

The objective is achieved by providing a prescribed method for evaluating established requirements against plant documentation, field conditions and work practices. The process describes the activities associated with audit planning, conducting, reporting, and closing-out. The results of the independent assessments are documented and reported to the level of management having sufficient breadth of responsibility for resolving any identified problems (as stated in Section 5.14.2 of [24]).

7.2.1. Internal Audits and Reviews

One comprehensive audit applicable to Bruce B was performed by the Bruce Power Audit Department in recent years, which assessed the sustainability of the EQ Program and its effectiveness within the management system as described below. Earlier audits were performed in 2008 and 2009 during the restart phase of Bruce A Units 1 and 2, to address issues during the early stages of the EQ project and to confirm that components were properly qualified. These are not relevant to the current plant governance for Bruce B.

7.2.1.1. AU-2011-00016, EQ Process Audit [92]

This audit was done to assess the completeness, implementation, and compliance to BP-PROC-00261, Environmental Qualification [37] and its effectiveness, and to verify EQ process integration within the Bruce Power Management System (BPMS). The scope included a review of a selection of systems and equipment in Bruce A and Bruce B, a review of preventive maintenance and outage scope deferrals with respect to EQ, a walkdown of selected systems, and a review of EQ Process interfaces and overall integration within the management system.

During the review of the procedures used for EQ, the audit identified a number of problems, such as inadequate identification of interfacing procedures, inadequate referencing of EQ requirements in other procedures (e.g., BP-PROC-00400 [71]), ineffective management of environmental monitoring and updating of the Room Conditions Manual, etc. The audit concluded that the EQ Process is supported by quality work being done by knowledgeable staff, but that EQ sustainability is heavily dependent upon the knowledge and capabilities of the staff. It noted that “effective establishment of documented processes and strict adherence to procedures and other instructions by all interfacing organizations is critical to the overall success of EQ sustainability” (Page 2).

An identified strength was “the rigorous monitoring performed on all EQ related Work Orders and the Focus Area Self Assessments” (Page 2).

This audit did not identify the SCRs raised to track the implementation of the recommendations, a process that was adopted in later audits. However, an examination of the current procedures indicates that interfacing procedures are well documented and that the processes to sustain the qualifications are well documented.

7.2.1.2. BB-2015-PDS-011, Independent Oversight Assessment – Seismic Qualification [93]

This assessment stated that seismically qualified areas were not being maintained to the standards documented in BP-PROC-00500, Control of Unsecured Equipment in Seismically Qualified Areas [69], in that during a walkdown, several unsecured items were found in listed seismically qualified areas. Six recommendations were made to improve the communication of the requirements to plant staff and to include the expectations and responsibilities for plant staff in the procedure.

7.2.2. External Audits and Reviews

In 2015, Bruce Power participated in an Operational Safety Performance Review (OSART Mission) led by a group of IAEA nuclear experts. The review focused on operations at Bruce B. The review Team identified 10 good practices and five recommendations. The findings of the OSART Mission relevant to equipment qualification are included in Section 12, Long Term Operation, which states the following: “The environmental qualification (EQ) programme documentation is complete and traceable. EQ files were properly established for all EQ equipment, monitoring of operational environment conditions and hot-spots were performed. All EQ equipment was assessed generically to EQ bounding conditions, and supplemented by location-specific calculations to demonstrate EQ compliance. Preventive maintenance activities are set up in the work management system (PASSPORT), to replace degradable parts prior to their end of qualified life, and whole components at the end of 40 years. Maintenance work orders have been monitored for EQ compliance, and performance has steadily improved over the years. Maintenance staff is well-trained to perform regular walk downs to monitor EQ equipment status. EQ equipment is identified in the field by a dedicated “EQ” label. The plant is currently sustaining the initial qualification, and has also begun to work on life time extension efforts, since the plant is approaching 40 years of operation, which was the original station life expectancy. The team recognized this as a good performance” [94]

7.3. Regulatory Evaluations and Reviews

After a licence is issued, the CNSC stringently evaluates compliance by the licensee on a regular basis. In addition to having a team of onsite inspectors, CNSC staff with specific technical expertise regularly visit plants to verify that operators are meeting the regulatory requirements and licence conditions. Compliance activities include inspections and other oversight functions that verify a licensee’s activities are properly conducted, including planned Type I inspections (detailed audits), Type II inspections (routine inspections), assessments of information submitted by the licensee to demonstrate compliance, and other unplanned inspections in response to special circumstances or events.

Type I inspections are systematic, planned and documented processes to determine whether a licensee program, process or practice complies with regulatory requirements. Type II inspections are planned and documented activities to verify the results of licensee processes and not the processes themselves. They are typically routine inspections of specified equipment, facility material systems or of discrete records, products or outputs from licensee processes.

The CNSC carefully reviews any items of non-compliance and follows up to ensure all items are quickly corrected.

7.3.1. CNSC Staff Integrated Safety Assessment of Canadian Nuclear Power Plants

The CNSC produces an annual report on the safety performance of Canada's NPPs. The report summarizes the ratings for Canada's NPPs in each of the 14 CNSC Safety and Control Areas (SCAs), including physical design which encompasses equipment qualification. The physical design rating is based on the performance of a number of design aspects, including design governance, environmental qualification, seismic qualification, component design, fitness for service, and aging management, all of which address equipment qualification to some extent.

The CNSC Staff Integrated Safety Assessment of Canadian Nuclear Power Plants for 2013 [95] states the following (page 49):

"Based on the information assessed, CNSC staff concluded that the physical design SCA at Bruce A and B met performance objectives and all applicable regulatory requirements… The environmental qualification (EQ) program is fully implemented at all Bruce A and B operating units. Bruce Power demonstrated EQ compliance with the related governing document by maintaining adequate EQ program sustainability."

CNSC staff rated Bruce B as "satisfactory" in this area.

The Regulatory oversight report for Canadian Nuclear Power Plants 2014 [96] states the following for environmental qualification:

"The licensees' EQ programs implemented at all NPPs are compliant with N290.13-05, *Environmental qualification of equipment for CANDU nuclear power plant* (sic). Although all licensees have mature EQ programs, maintaining a high standard in this area is becoming a greater challenge due to increased reactor aging" (page 26) and "CNSC staff found that Bruce Power's environmental qualification (EQ) program is in compliance with N290.13-05…there were no significant compliance verification observations for Bruce A and B's EQ program in 2014" (page 70).

For seismic qualification, the report states:

"All NPP licensees have established seismic qualifications for their sites. All licensees have performed site-specific seismic hazard analyses" (page 28).

The rating for Bruce B for "Physical Design", which includes the equipment qualification aspect, was "satisfactory".

7.3.2. CNSC Field Inspection Reports

A number of CNSC Field Surveillance Reports were reviewed that address inspection of the environmental qualification or seismic qualification aspects. The four listed below are typical of these reports:

- NK29-CORR-00531-08745, Bruce B Sustaining Environmental Qualification CNSC Compliance Inspection Report BRPD-2010-B-002 [97].

  This inspection was carried out in December 2009 and found that the documentation system for EQ should be improved so it is up-to-date for staff doing work on equipment, and that there were issues with communication of information and potential issues with training of staff. Four action notices were raised to confirm whether the Powerhouse Emergency Venting System (PEVS) required environmental qualification, to update the EQ documents to indicate the EQ status of PEVS, to provide a basis for the change from the System Health Report to the Program Health Report, and to do a training needs analysis for maintenance staff to determine if on-the-job training should be developed for EQ work. This inspection also recommended that Bruce Power confirm that the condition monitoring program adequately covers environmentally qualified equipment.

- NK29-CORR-00531-11932, Bruce A and B Quarterly Field Inspection Report for Q1 of 2014-15 BRPD-AB-2014-008 [98]

  This inspection was carried out in April to June 2014 and found that the requirements for seismic qualification and EQ are met, but in other areas improvement is needed in reducing the backlog of maintenance work requests, housekeeping, combustible material management and scaffold inspection.

- NK29-CORR-00531-12565, CNSC Type II Compliance Inspection Report BRPD-AB-2015-003, Bruce A and B Quarterly Field Inspection Report for Q4 2014-15 [99]

  This inspection report found that Bruce Power is meeting the requirements for seismic and EQ.

- NK29-CORR-00531-12910, CNSC Type II Compliance Inspection Report BRPD-AB-2015-011, Bruce A and B Quarterly Field Inspection Report for Q2 2015-16 [100]

  This inspection report found that Bruce Power is meeting the requirements for seismic and EQ.

- NK29-CORR-00531-13148 CNSC Type II Inspection Report: BRPD-B-2016-002 Environmental Qualification Program [101]

  This was a comprehensive inspection of the Bruce B station to verify compliance with the licence and other regulatory documents, compliance with licensee documentation, and staff awareness of the conditions in the station.

  Four action notices were issued to develop and implement corrective action plans in the following areas:

    - the roles and responsibilities in EQ process documentation are clearly defined and communicated to staff

- ensure all RSEs have and adequate knowledge of EQ component inspections for their respective systems
- improvement of steam protection barrier sustainability, including record retention for inspections and performance of leak testing of steam protected rooms.
- Ensure sufficient EQ aspects are incorporated into the system performance monitoring plans a walkdown checklists.

A number of recommendations for improvement were also made, including that the Room Conditions Manual should be updated to ensure that the normal conditions documented in it are current and accurate, that performance indicators be identified for the steam barrier program, and that a specific EQ Field Guide be produced to enhance the knowledge of EQ field verifiable components.

The inspection report concluded that the licensee met the regulatory requirements, but some non-compliances with licensee procedures were observed, and action notice 2016-07-7682 was raised to address the action notices outlined above.

7.4. Performance Indicators

Performance indicators are defined as data that are sensitive to and/or that signal changes in the performance of systems, components, or programs.

Performance indicators reported in the semi-annual EQ Program Health Report, which is produced in accordance with SEC-EQD-00049 [61], include:

EQ Program Compliance

- Regulatory Reportable Events
- Significant Technical Issues

EQ Program Documentation

- EQE Index
- EQ Document Production Index
- EQ Program Effectiveness Benchmarks/Self-Assessments
- Bruce A EQ Sustainability Index
- Bruce B EQ Sustainability Index
- Open Action Tracking Items

EQ Program Staffing and Resources

- Primary and Backup EQ Engineer
- Resources

- Training

The most recent EQ Program Health Report for the period July-December 2015 [102] was reviewed, which included a detailed review of the above performance indicators, which were all acceptable. It also included a summary of the self assessments (FASA) that have been performed since 2009, a detailed listing of the significant accomplishments in the reporting period, the focus areas for the next 12 months, and a 3 year improvement plan.

8. Summary and Conclusions

The overall objectives of the Bruce B PSR are to conduct a review of Bruce B against modern codes and standards and international safety expectations, and to provide input to a practicable set of improvements to be conducted during the MCR in Units 5 to 8, as well as U0B, and during asset management activities to support ongoing operation of all four units, that will enhance safety to support long term operation. The specific objective of the review of this Safety Factor is to determine whether equipment important to safety is qualified (including for environmental conditions) and whether this qualification is being maintained through an adequate program of maintenance, inspection and testing that provides confidence in the delivery of safety functions. The conclusions reached during the assessment of each review task show that that this specific objective has been satisfied.

This Safety Factor Assessment included a high level review of the most recent standards applicable to equipment qualification, including the CSA N289 series, and a programmatic review of the main programs and procedures that implement and sustain the equipment qualification requirements for the remaining life of the plant (i.e., BP-PROG-10.01 [39], BP-PROG-10.02 [41], BP-PROG-11.01 [42], BP-PROG-11.04 [43], BP-PROC-00335 [40], BP-PROC-00261 [37], and DPT-PDE-00017 [64]).

In Section 7, the IAEA OSART review of Bruce B completed in 2015 reviewed all aspects of the environmental qualification program and recognized its overall implementation as "good performance". Therefore, the management of the EQ program is considered to be a strength in this report. This section also examined Audit Reports and self-assessment reports from Bruce Power that showed a robust process in place to identify problem areas and to identify actions to resolve them. The review of the CNSC reports in Section 7 shows that the current equipment qualification process is effective, although some issues to be addressed were identified in the most recent 2016 comprehensive inspection report for the EQ program. Furthermore, the annual CNSC regulatory reports for the past two years and selected field inspections were reviewed to determine whether there are any ongoing regulatory issues for equipment qualification. These reports indicate that the equipment qualification programs are satisfactory and there are no significant issues in this area.

Table 6 summarizes the key issues arising from the Periodic Safety Review of Safety Factor 3.

Table 6: Key Issues

Issue Number	Gap Description	Source(s)
SF3-1	A periodic evaluation to demonstrate readiness to cope with the potential consequences of a beyond design basis seismic event once every 10 years, as a minimum, has not been done.	Section 5.1 Micro-gaps against requirement clauses: CSA N289.1-08 – Clause 5.3.11
SF3-2	Earthquake monitoring instrumentation that would provide accurate earthquake records to confirm that the plant is fit for continued operation following an earthquake is not installed in the plant.	Section 5.1 Micro-gaps against requirement clauses: CSA N289.1-08 – Clauses 6.5.6.3 and 6.5.6.4
SF3-3	An investigation of the potential for a seismic seiche and consequent surges along the shore that could affect the safety of the nuclear power plant has not been done.	Section 5.1 Micro-gaps against requirement clauses: CSA N289.2-10 – Clause 4.4.2.2
SF3-4	A free field accelerometer has not been installed on the site to confirm that a seismic event has occurred.	Section 5.1 Micro-gaps against requirement clauses: CSA N289.5-12 – Clause 4.1.1.3
SF3-5	The governing and implementing documents for seismic qualification do not consistently indicate the application and licensing status of the CSA N289 series of standards. The reporting and recording requirements for earthquake events and the more recent site investigations documented in the Probabilistic Seismic Hazard Assessment are not reflected in the seismic implementing procedures.	Section 5.1 CSA N289.1-08 – Clause 5

This review addressed the main aspects of the equipment qualification process, and it is recognized that there are many other related procedures, both implementing and interfacing, which play a role in equipment qualification. This assessment shows that the quality of the programmatic documents (i.e., programs and procedures) for the equipment qualification process was very good, with interfaces with other station procedures well identified, recent revisions and updating for most procedures, and incorporation of issues identified in audits and self-assessments.

Based on this review, it is concluded that Bruce B complies with the requirements of the most recent codes and standards for environmental qualification and seismic qualification, except for the gaps identified above due to recent changes to the N289 series of standards, and that the current equipment qualification process can be sustained for the life of the plant.

9. References

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[2] NK21-CORR-00531-12135/NK29-CORR-00531-12545/E-DOC 4659316, Licence Conditions Handbook, LCH-BNGS-R000, Bruce Nuclear Generating Station A and Bruce Nuclear Generating Station B Nuclear Reactor Operating Licence, PROL 18.00/2020 (Effective: June 1, 2015), Canadian Nuclear Safety Commission, May 27, 2015.

[3] CNSC REGDOC-2.3.3, Operating Performance: Periodic Safety Reviews, CNSC, April 2015.

[4] BP-PROC-01024-R000, Periodic Safety Reviews, November 7, 2015

[5] NK29-CORR-00531-12932, Bruce B Periodic Safety Review Basis Document, Bruce Power Letter, F. Saunders to K. Lafrenière, January 25, 2016.

[6] NK21-CORR-00531-11005/NK29-CORR-00531-11397, Submission of Safety Basis Report, Bruce Power Letter, F. Saunders to R. Lojk, December 30, 2013.

[7] NK21-CORR-00531-00514, Bruce A: CNSC Approval to Restart Units 3 and 4 and Application to Amend PROL 15.01/2003, Bruce Power Letter, F. Saunders to J.H.M. Douglas, November 16, 2001.

[8] NK21-CORR-00531-04636, Bruce A Units 1 and 2 Return to Service: Systematic Review of Safety – Basis, Bruce Power Letter, F. Saunders to D.A. Desjardins, December 22, 2006.

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[13] NK21-CORR-00531-06596, Bruce A Units 3 and 4 Refurbishment for Life Extension and Continued Operation: ISR Safety Factor Reports 1, 2, 3 and 4, Bruce Power Letter, F. Saunders to K. Lafrenière, December 18, 2008.

[14] NK21-CORR-00531-06076, Bruce A Units 3 and 4 Refurbishment for Life Extension and Continued Operation: ISR Safety Factor Reports 5, 6, and 7, Bruce Power Letter, F. Saunders to P. Elder, July 22, 2008.

[15] NK21-REP-03600-00025-R001, Bruce NGS A Units 3 and 4 Global Assessment Report and Integrated Implementation Plan, May 29, 2009.

[16] NK21-CORR-00531-11617, Integrated Safety Review for Bruce A, Bruce Power Letter, F. Saunders to K. Lafrenière, including enclosure K-421231-00010-R00, Candesco Report, October 27, 2014.

[17] NK21-CORR-00531-12269, Bruce A Integrated Safety Review – Safety Factor Reports, Bruce Power Letter, F. Saunders to K. Lafrenière, August 27, 2015.

[18] NK21-CORR-00531-10576/NK29-CORR-00531-10975, Application Requirements for Renewal of Power Reactor Operating Licences for Bruce Nuclear Generating Stations A and B, Bruce Power Letter, F. Saunders to R. Lojk, July 17, 2013.

[19] NK29-CORR-00531-11252, Application for the Renewal of the Power Reactor Operating Licence for Bruce Nuclear Generating Station B, Bruce Power Letter, F. Saunders to M. Leblanc, October 31, 2013.

[20] NK21-CORR-00531-11711/NK29-CORR-00531-12101, Bruce A and Bruce B Licence Renewal – Supplemental Update, Bruce Power Letter, F. Saunders to M. Leblanc, November 27, 2014.

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[22] Nuclear Safety and Control Act, 1997, c. 9, N-28.3, Assented to March 20, 1997.

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[24] CAN/CSA N286-05, Management System Requirements for Nuclear Power Plants, CSA, February 2005, (Update No.2, 2010), R2010.

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[26] CAN/CSA N290.13-05, Environmental Qualification of Equipment for CANDU Nuclear Power Plants, CSA, October 2009 (Update No. 1, 2009), R2015.

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[28] NK21-CORR-00531-11563/NK29-CORR-00531-11946, Action Item 1307-4697: CSA N286-12 - Management System Requirements for Nuclear Facilities, Bruce Power Letter, F. Saunders to K. Lafrenière, September 9, 2014.

[29] NK21-CORR-00531-12570/NK29-CORR-00531-12996, Action Item 1307-4697: CSA N286-12 - Management Systems Requirements for Nuclear Facilities, Bruce Power Letter, F. Saunders to K. Lafrenière, January 29, 2016.

[30] CAN/CSA N289.1-08, General Requirements for Seismic Design and Qualification of CANDU Nuclear Power Plants, CSA, September 2008 (reaffirmed 2013, updated September 2014).

[31] CAN/CSA N289.2-10, Ground Motion Determination for Seismic Qualification of Nuclear Power Plants, CSA, May 2010 (R2015).

[32] CAN/CSA N289.3-10, Design Procedures for Seismic Qualification of CANDU Nuclear Power Plants, CSA, May 2010 (updated August 2012, R2015).

[33] CAN/CSA N289.4-12, Testing Procedures for Seismic Qualification of Nuclear Power Plant Structures, Systems, and Components, CSA, August 2012.

[34] CAN/CSA N289.5-12, Seismic Instrumentation Requirements for Nuclear Power Plants and Nuclear Facilities, CSA, August 2012.

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Appendix A – High-Level Assessments Against Relevant Codes and Standards

A.1. Overall Review of Programs and Procedures Against Applicable Standards

A.1.1. Introduction

As summarized in Section 4 of this report, the Bruce B Equipment Qualification process is included in the Plant Design Basis Management program BP-PROG-10.01 clause 5 [39] and is implemented in the Design Management procedure BP-PROC-00335 clause 4.9 [40]. The Plant Design Basis Management program "ensures that the plant design meets safety reliability and regulatory requirements…" (section 4.0) [39] and lists CSA N290.13-05, CSA N289.1 and CSA N289.3 in section 5.1 "Relevant Statutory Regulatory and Licensing Requirements".

The Plant Design Basis Program interfaces with other programs which have a role in Equipment Qualification, including BP-PROG-10.02, Change Control [41] and BP-PROG-11.01, Equipment Reliability [42]. These programs address the procurement of replacement or new qualified equipment and the monitoring of qualified equipment to preserve the qualification for the life of the station.

The Bruce plant Licence Conditions Handbook [2] lists CSA N290.13-05, in clause 5.3 as requiring version control, and lists the CSA N289 series (CSA N289.1 to CSA N289.5) in clause 5.1 under the "Recommendations and Guidance" section.

The Design Management procedure BP-PROC-00335 [40] contains the following clauses to implement the Seismic and Environmental Qualification processes through the use of primary implementing procedures:

> "4.9.1 Seismic Qualification
>
> The implementing procedures necessary to sustain the plant's Seismic Qualification status shall be governed within the Design Management program. This shall establish proof of performance during and after an earthquake and maintain that proof current with the licensing basis, design basis, and operating condition. It shall provide assurance that applicable systems, structures and components are designed, purchased, installed and maintained in a manner that preserves their qualified status. Primary implementing procedure is DPT-PDE-00017, Bruce Power Seismic Qualification Standard.
>
> 4.9.2 Environmental Qualification
>
> The implementing procedures necessary to sustain the plants Environmental Qualification status shall be governed within the Design Management program. This shall establish proof of performance under design basis accident conditions, and maintain that proof current with the plant licensing basis, design basis, service conditions and operating configuration. In addition, it shall provide assurance that applicable items

> are purchased, stored, installed, configured, maintained and replaced in a manner that preserves their qualified status. Primary implementing procedure is BP-PROC-00261, Environmental Qualification."

As described in Section 4 of this report, the above procedures do not address equipment qualification for other environmental conditions that occur during normal operation, which are addressed by the plant programs and procedures listed in Section 4 (and other implementing and interfacing procedures included in them). In addition, the assessment discussion in Section 5.1 of this report provides additional detail on this aspect of equipment qualification. The Design Management procedure (BP-PROC-00335 [40]) also includes a number of other processes which interface with the Equipment Qualification process, such as BP-PROC-00244 Procurement Engineering [70], which are identified in each procedure.

The Environmental Qualification and Seismic Qualification processes are implemented by a number of lower level procedures that are listed in Table 5, with their purpose summarized in Section 4.

A.1.2. Assessment

The Equipment Qualification process is well defined in a number of procedures and supporting documentation. In each procedure, there are interface links to other supporting station programs and procedures that have an important bearing on preserving the equipment qualification, such as procurement, engineering change control and condition monitoring. There is a robust self-assessment and audit process to examine the various activities involved in maintaining the equipment qualification for the life of the plant, which have identified meaningful recommendations to improve the procedures and processes. Most of the procedures have been recently revised to implement these recommendations, and it is noted that substantial effort has been spent recently to keep the procedures current and clearly written.

A.2. CSA N289 Series, Seismic Qualification Standards

A.2.1. CSA N289.1-08 (R2013), General Requirements for Seismic Qualification of CANDU Nuclear Power Plants [30]

The first edition of this standard was issued in 1980 and contained very basic definitions (e.g., Design Basis Earthquake (DBE), Site Design Earthquake SDE) and requirements for seismic qualification. The 2008 edition of the CSA N289.1-08 [30] standard (referred to as the current edition) was substantially expanded to add a greater level of detail and to add the seismic margin assessment (SMA) methodology (which is used in Bruce A). It was updated in September 2014 and now includes twenty pages of requirements, compared with three pages of requirements in the first edition. A high-level review of the differences between these editions of the standard has been performed and the following changes are noted in the most recent updated edition:

- **Section 1 Scope**, clause 1.3 was added in the current 2008 edition, noting that this standard is applicable to plants in regions of low to moderate seismic hazard, and that additional provisions may be required for high seismic hazard sites.

  Assessment: The Bruce plant is located in a region of low seismic hazard. This is stated in the Bruce B Safety Report, clause 2.6.2.1 [103] and was reviewed and confirmed in 2001 for the Bruce site as part of the development of the Review Level Earthquake for Bruce A. [104]

- **Section 2 Reference publications** was added in the current edition and includes the relevant Electric Power Research Institute publications to support the SMA qualification methodology, as well as the most recent CSA and international standards relevant to seismic design. The 2014 revision updated the edition of the referenced standards, and included additional publications related to seismic fragility evaluations, probabilistic assessments, and reports on the Fukushima event.

  Assessment: This section does not include any requirements. Any requirements arising from these publications are applied through the requirements in Section 5. It should be noted that in the 2014 update, clause 5.4.1.2.3 was added to indicate that existing structures, systems, and components (SSCs) designed to earlier editions of the reference publications are not required to be requalified to comply with the most recent editions.

- **Section 3 Definitions and abbreviations** added many definitions currently used in seismic design (e.g., design basis earthquake), including the definition of the seismic margin assessment qualification methodology, and a number of other definitions associated with it (e.g., checking/review level earthquake, site operating earthquake, etc.). Among these definitions, the DBE was defined in the 1980 edition as having “a sufficiently low probability of being exceeded during the lifetime of the plant”, whereas in the 2008 edition it is defined as having “a selected probability of exceedance of $1x10^{-4}$ per year” (note: in this document, this is assumed to be a frequency or rate of occurrence, not a probability, due to the units used).

Assessment: This section does not include requirements, and the definitions are generally consistent with current Bruce Power governing documents. However, the definition of the DBE for Bruce B is stated to "correspond to an occurrence rate of less than 10^{-3} per year" (DPT-PDE-00017, clause 3.1.1 [64]). A Probabilistic Seismic Hazard Assessment was completed for the Bruce site in 2011 (NK29-03500.8 [84]) which indicated that the expected mean peak ground acceleration for an "annual probability of exceedance" of 10^{-4} at 100 Hz would be 0.016 g (Executive Summary, Page 4). A site response analysis was also performed, which indicated "amplifications at the ground surface of about 1.5 to 2.7 at 100 Hz". This indicates that the peak ground response used in the design of Bruce B of 0.05 g, stated as having a "small probability of exceedance during the life of the plant" (clause 4.1 of NK29-DG-03650-002 [65]) satisfies the definition of a DBE in the current standard. See the further discussion about this point in A.2.3 below.

- **Section 4 Application of the CSA N289 series of standards** is changed in the current edition to provide more detail and clarity regarding the SSCs to which the standard is to be applied, in terms of the safety functions performed or that could be affected by the failure of the SSC.

  Assessment: Although this section is extensively reworded for clarity and emphasis, it does not impose any new requirements and is consistent with current Bruce Power documents [65][64].

- **Section 5 General Seismic Requirements:** clause 5.2 (seismic classification) was revised in the 2008 edition to provide more detail for the seismic category, safety functions of SSCs and the earthquake level to be used in the qualification process, and introduced the SMA and probabilistic assessment methodologies (clause 5.2.4). However, the overall intent of this clause is the same as in the 1980 edition (clause 4.2). The 2014 update introduced a new clause (5.2.4.2) that requires the Checking Level Earthquake (CLE) to be used for the seismic margin evaluation of a beyond design basis earthquake, but is stated to be for new plants only (so does not apply to Bruce B).

  Clauses 5.2.6 through 5.4 are new clauses added to the 2008 edition that introduce the other standards in the series (i.e., N289.2, N289.3, N289.4) to address requirements for the development of earthquake ground motion, load combinations, seismic qualification, seismic evaluation of existing plants, and design modifications of qualified SSCs. These clauses include requirements for the application of the SMA methodology, for operator response to seismic events, for maintaining seismic qualification, for the seismic evaluation of existing plants and for the design modification of qualified SSCs. The 2014 update includes a new clause (5.3.11) that adds a requirement that states "Each facility shall have a periodic evaluation to demonstrate readiness to cope with the potential consequences of a beyond design basis seismic event", and a note that states "As a minimum, the evaluation will be carried out once every 10 years" [30].

  Assessment: Generally, these requirements are more detailed and update the standard to reflect current practices. These requirements are addressed in the current Bruce Power documents DPT-PDE-00017 [64], NK29-DG-03650-002 [65] and BP-PROC-00500 [69], except for the most recent update. The new requirement added in the 2014 update, clause 5.3.11, for a periodic evaluation every 10 years "to cope with the potential consequences of a beyond design basis seismic event", is identified as a gap (SF3-1). This also introduces the application of a related requirement from clause 5.2.6.2 stating: "The evaluation of nuclear power plants for effects beyond the DBE shall be addressed by seismic margin assessment…or seismic probabilistic safety assessment…" It is noted that clause 5.2.4.2 of this standard and clause 8.2 of CSA N289.3 refer to the use of the CLE/RLE to evaluate beyond design basis events as being applicable to new plants, not existing plants. As noted in the assessment for Section 3 above, a Probabilistic Seismic Hazard Assessment was done for the Bruce site in 2011 [84] which does provide information about earthquakes beyond the DBE level.

Clause 5.4.1.2.1, which states that "seismic evaluation of existing nuclear power plants SSCs can be required when…(d) performing a periodic safety review…or (e) performing a life extension" is considered to be a statement of possibility conditional on other changes (e.g., licence conditions, seismic hazard, major modifications of the SSCs), and does not by itself impose any new requirements. The Probabilistic Seismic Hazard Assessment [84] done in 2011 may be considered to be a re-evaluation of the DBE level used in the original design (0.05 g above 33 Hz) as presented in NK29-DG-03650-002 [65], indicating a peak ground acceleration of 0.016 g at 100 Hz for hard rock with soil amplification of 1.5 to 2.7 at the ground surface. This results in a peak ground acceleration of about 0.043 g for a probability of exceedance of 10^{-4}. This appears to confirm that the design basis of the original design remains valid for the future, although the effect of differences in the lower frequency ranges are not evaluated here.

The governing procedure (DPT-PDE-00017 [64]) and its implementing documents (NK29-DG-03650-002 [65]) have not been updated to reflect the latest requirements of CSA N289.1 (i.e., the 10^{-4} requirement for the definition of the DBE), including the 2014 update, nor the results of the Probabilistic Seismic Hazard Assessment done in 2011. This is identified as a gap (SF3-5) in Table 6.

- **Section 6 (Responsibilities and duties)** includes responsibilities and duties for the owner/licensee, manufacturer, architect/engineer, installer, and staff of the operating plant, including proposing and getting acceptance of the site ground motion (engineering representation of ground motion (ERGM)), defining the SSCs needing seismic classification and their seismic categories, ensuring that all SSCs on the safe shutdown equipment list are seismically qualified, implementing controls for design, procurement, operations installation and maintenance to ensure that qualification is maintained for the life of the facility, operator response to seismic events, and post-seismic recovery activities.

  Clause 6.5 states that a post-seismic operations manual shall be prepared and shall include the operator actions of assessment of seismic shaking level, immediate response, notification of the regulatory agency and local emergency response agencies, post seismic recovery, etc. Clause 6.5.4 states: "Regulatory authorities and local and regional emergency response agencies shall be advised of the plant status and earthquake effects on the plant within the specified notification periods. Plant operators shall provide plant status updates, as necessary, within the specified notification period if an earthquake is felt at the plant".

The section on post-seismic recovery (clause 6.5.6) requires that "…a detailed engineering report shall be prepared to document assessments of damage to SSCs…The report shall include all data records from in-plant seismic monitoring systems…to determine whether the seismic design basis of the plant has been exceeded.". Clause 6.5.6.3 states: "Operator response shall be based on accurate earthquake records. All significant earthquake data, including intensity and duration, shall be recorded to (a) account for loss of service life (fatigue usage factor) due to seismically induced stress cycles; and (b) aid in determination of the need to shut down or continue operation of the plant".

Assessment: The requirements in Section 6 are generally satisfied, based on DPT-PDE-00017 [64], NK29-DG-03650-002 [65], BP-PROC-00500 [69], and the overall design management process specified in BP-PROC-00335 [40] and related procedures.

However, the requirement to report earthquakes that are "felt" to the regulatory agency (clause 6.5.4) is not addressed in the above documents. DPT-PDE-00017 [64] section 4.6 states that the Abnormal Incidents Manual (AIM) specifies "regulator and emergency management notifications" (first paragraph), and that earthquake damage must be reported to the provincial emergency response organization within 10 minutes (second last paragraph), but makes no mention of the need to report an earthquake to regulatory authorities when one is "felt". The AIM (NK29-AIM-03600.1-25 [105]) was reviewed, and contained the information required by clause 6.5 to be included in a post-seismic response manual, but the action to notify the regulatory agency could not be found in that document. The reporting requirements for earthquake events outlined in CNSC REGDOC 3.1.1 (clause 5 and Table A.1-4(a)) [106] are addressed in BP-PROC-00059, Event Response and Reporting, clause 4.3.1 and Appendix B, Table 4 [107]. The response of the operating staff in notifying the regulatory agency is further outlined in BP-ERP-00001 [108], Shift Emergency Controller, and BP-ERP-00002 [109], Emergency Shift Assistant, which become effective when the AIM is initiated. Notifications are based on evaluation of the event by operating staff, and not solely on whether an earthquake is "felt", which is considered to be an acceptable deviation. The post-seismic reporting and recording requirements are not included in DPT-PDE-00017 [64] nor in NK29-AIM-03600.1-25 [105], although the reporting requirements are listed in BP-PROC-00059 [107]. This is identified as a gap and included in SF3-5 in Table 6.

The current governing documents do not address the need for recording equipment to be installed in the plant to satisfy the intent of clause 6.5.6 and the specific requirement stated in clause 6.5.6.3 to record all significant earthquake data. It would not be possible to satisfy the overall intent of these clauses (i.e., impact on fatigue usage factor and loss of service life) without earthquake recording equipment in the plant, so this is also identified as a gap (SF3-2 in Table 6). Clause 6.5.6.4 requires data collected from monitoring instruments installed at different levels in the plant to be compared with the design floor response spectra to assess if the design stress levels have been exceeded. This type of monitoring instrumentation would quickly confirm that the plant is fit for continued operation should an earthquake that can be "felt" were to occur.

- **Section 7 Quality Assurance** is a new section added in the 2014 update that specifies that “all activities within the scope of this Standard shall be performed in accordance with CSA N286”.

  Assessment: This is addressed in BP-PROG-10.01, Plant Design Basis Management [39], which states that the program is designed to satisfy CSA N286. As outlined in Section 3.2 of this document, the procedures and practices are currently being upgraded to comply with the latest edition CSA N286-12.

A.2.2. CSA N289.2-10, Ground Motion Determination for Seismic Qualification of Nuclear Power Plants [31]

The methodology and practices in the first edition of CSA N289.2 were used to develop the DBE and SDE used for seismic qualification in the original design, although the standard was issued late in the design process and is not referenced in NK29-DG-03650-002. The response spectra for the DBE and SDE are included in Section 4 of NK29-DG-03650-002 [65].

The current version of the standard has been updated to be consistent with CSA N289.1, and to include the latest information for the development of the seismic ground motion for a new or existing site. The ground motion for the Bruce site was reviewed in 2001 during the development of the Review Level Earthquake for Bruce A, as described in NK21-CALC-20091-00001 [104].

- **Section 1 Scope** states that the standard describes the investigations required to obtain the seismological and geological information necessary to determine the ground motion for a proposed or existing nuclear power plant site.

  Assessment: Although the detailed requirements later in the standard are more rigorous than the first edition, the overall scope is similar.

- **Section 2 Reference Publications:** A number of publications have been added to reflect the development of information and practices to determine earthquake ground motion. This section does not include requirements.
- **Section 3 Definitions**: A number of new definitions are included in this edition as they are used in the current methodologies. This section does not include requirements.
- **Section 4 Site, site vicinity, and geological investigations**: This section requires the earthquake history of the region to be investigated, justification of earthquake parameters when published information is re-evaluated (clause 4.2.1.2), presentation of the earthquake history in the form of maps and tables with the information compiled in a specific way, Local site related investigations are required by clause 4.3.3.2, which states “…detailed investigations shall be conducted to obtain the information specified in clause 4.3.3.1.” and clause 4.3.3.1 states “the main purposes of the site geological investigations are (a) to determine the structural, geological, and tectonic setting of the site in relation to the regional information in order to establish the potential for earthquakes in the site vicinity…”.

In Section 4.4 investigations of seismically induced phenomena are required, and clause 4.4.2.2 applies to the Bruce site, which states: "for sites on the shore of a confined body of water, an investigation shall be made of the potential for seismic seiches and consequent surges along the shore that could affect the safety and operation of the nuclear power plant."

Assessment: The original site investigations carried out to establish the seismic parameters for the Bruce site were not reviewed for this assessment, but are outlined in the Bruce B Safety Report (Section 2.6.2) [66]. The Bruce B Safety Report and the design guide used for the original design of Bruce B Earthquake Design Requirements for CANDU Nuclear Power Plants [110] indicates that regional information from Energy, Mines, and Resources was used to develop the ground response spectra for the DBE for Bruce B. The seismic evaluation done in 2001 to establish the Review Level Earthquake (RLE) for Bruce A [104] stated "there is no available site-specific assessment of the seismic hazard at the Bruce site" (Section 4.0, page 14). The evaluation for the Bruce A RLE used information from the Darlington site, which was considered to be conservative for the Bruce site, and which resulted in a peak ground acceleration of 0.099 g at 100 Hz (probability of exceedance of 10^{-4}). Since that time, a Probabilistic Seismic Hazard Assessment [84] has been done for the Bruce B site, which does address the specific seismic characteristics of the site, including the probability of exceedance of 10^{-4}.

The available documentation does not indicate that an investigation of the potential for a seismic seiche and consequent surges along the shore that could affect the safety of the plant were done, so this is also identified as a gap (SF3-3 in Table 6).

- **Section 5 Development of seismic hazard models** requires the local site investigations to be integrated into local and regional seismotectonic models, considering seismic source zones, earthquake recurrence, the maximum potential earthquake for each source, and ground motion prediction equations.

  Assessment: The local site characteristics were evaluated in the Probabilistic Seismic Hazard Assessment for the Bruce B site in 2011 [84].

- **Section 6 Evaluation of seismic hazard** requires the seismic hazard for the site to be based on the model described in Section 5, and the hazard assessment to be based on probabilistic methods and expressed as response spectra or time histories and other parameters as required (i.e., duration). Clauses 6.2 and 6.3 outline the requirements for probabilistic methods, including evaluation of the maximum potential earthquake for each seismic source, the recurrence model, the uncertainty associated with the evaluation, and taking into account the seismogenic potential of each source. Clause 6.4 requires that the results of seismic hazards investigations be provided, including probabilistic computations of the horizontal and vertical ground motion (including the uniform hazard spectrum for a wide range of frequencies), peak ground acceleration and velocities for probabilities of $1x10^{-2}$ to $1x10^{-5}$ (including uncertainty evaluations), and estimation of the parameters that produce the predominant contributions to the hazard.

  Assessment: According to DPT-PDE-00017 [64], the Bruce B DBE and SDE were defined in the early 1980s based on the methods and information available for the site at that time, and the ground response spectra are presented in NK29-DG-03650-002 [65].

During the development of the RLE for Bruce A, NK21-CALC-20091-00001 [104] reviewed the seismic information used in the development of the Bruce B response spectra (which was based on information published in 1980 by the Earth Physics Branch of the Department of Energy, Mines, and Resources), as well as several more recent studies done for other nuclear power plant sites in Ontario. More recently, in 2011 as discussed for Section 5 above, the local site characteristics were evaluated in the Probabilistic Seismic Hazard Assessment [84] for the Bruce site, which satisfies the intent of this section although uncertainty evaluations were not addressed.

- **Section 7 Documentation and records** requires that the owner be responsible for retaining records for the life of the plant, that the basic data and all reports are available, that key decisions and the data on which they are based are clearly identified, and that computation codes and inputs for the seismic hazard model are identified.

  Assessment: Section 7 of DPT-PDE-00017 assigns the responsibility to comply with the standard, but there are no requirements in the seismic procedure DPT-PDE-00017 [64] for the preparation or retention of documents and records. The preparation and retention of records is addressed under the governing document for design management BP-PROC-00335, clause 4.8 [40].

A.2.3. CSA N289.3-10, Design Procedures for Seismic Qualification of Nuclear Power Plants [32]

The first edition of this standard was issued in 1981, and the second edition was issued in 2010 (with a minor technical update issued in 2012) to be consistent with the content and terminology used in the most recent edition of CSA N289.1 (e.g., the SMA methodology), and to include more detail for the seismic design of SSCs and for seismic analyses.

A high level review of the standard was carried out, and the results are summarized below:

- **Section 1 Scope:** This section outlines the scope of the standard, which includes the requirements, criteria, and methods for ground motion time-histories and design response spectra, for design criteria for SSCs that require seismic qualification, and for performing seismic analyses.
- **Sections 2 Reference Publications** includes references and related standards and contains no requirements.
- **Section 3 Definitions and abbreviations** includes definitions, and abbreviations and contains no requirements.
- **Section 4 Application of seismic ground motion to engineering design:** This section addresses the application of the seismic ground motion to the design, including the requirements for the standard shape design ground response spectra, based on the peak ground motion parameters specified by CSA N289.2 and the amplification factors in Table 1 of N289.3. (Note: A large part of this section dealing with the development of the response spectra and time histories seems to be repetitive with CSA N289.2-10, so the assessment of those clauses will not be repeated for this standard.)

In clause 4.1.4 it is stated that "The free-field design ground response spectrum shall be specified at an annual frequency of 1 x 10^{-4} or lower, at the statistical mean confidence level as a minimum".

Clause 4.2 specifies that "The minimum design horizontal response spectra used in the design of new nuclear power plant SSCs shall be: (a) the standard-shape ground response spectrum anchored to a peak ground acceleration of 0.1 g on rock…and (b) modified to take into account the site specific geological conditions."

Assessment: The DBE ground response spectrum was based on an estimated probability of exceedance of less than 1 x 10^{-3}, according to clause 3.1.1 of DPT-PDE-00017 [64], and the Probabilistic Seismic Hazard Assessment [84] establishes the peak ground acceleration for 10^{-4} at 0.016 g for hard rock, and indicates that the ground surface acceleration would be about 0.043 g. The current peak ground acceleration specified for Bruce B SSCs is 0.05 g.[65], which does not appear to satisfy the requirement in clause 4.2 of 0.1 g, but clause 4.2 applies only to new plants (rather than to new SSCs in existing plants). A request for interpretation was submitted to the CSA N289.3 Technical Committee [111], asking "Is it the intent of clause 4.2 to be applicable only to the design of SSCs of new nuclear plants", to which the reply was "Yes". This would have been evaluated as a gap, were it not for this interpretation that it is only for new plants.

- **Section 5 Seismic analysis of foundations** requires the evaluation of the seismic performance and stability of the soil and rock supporting the nuclear power plant, including determination of the site-specific soil material properties, soil-structure interaction, identification of potential soil liquefaction, differential settlement of structures, slope stability, and structure stability (i.e., overturning or sliding). Buried structures (including piping systems) are addressed, as well as potential soil liquefaction and ground failure.

  Assessment: These topics were addressed in the original design of the plant [103], but the specific design analysis for Bruce B was not reviewed as part of this assessment.

- **Section 6 Seismic qualification by analytical methods** This section specifies acceptable methods of dynamic analysis and requirements for analytical methods used for the qualification of SSCs, including requirements for mathematical models, decoupling criteria for interactions between the supporting structure and components, values of damping (Table 4 of N289.3), and other effects (i.e., hydrodynamic effects, torsional effects, fatigue, aging degradation).

  Assessment: Similar dynamic analysis methods were used for the seismic qualification of SSCs for Bruce B, but these were not reviewed for compliance with the current detailed requirements listed in the standard, as it is noted in CSA N289.1 (clause 5.4.1.2.3) [30] that SSCs designed to the provisions of earlier editions of the reference publications (which include N289.3) are not required to be requalified to meet the provisions of the current standard. For new SSCs, the current requirements in N289.3 would be applied, as outlined in clause 4.2 of DPT-PDE-00017 [64].

- **Section 7 Seismic design criteria** provides criteria for the load combinations, transient load consideration, seismic fatigue, component supports and acceptance criteria used in the seismic design of SSCs.

  Assessment: Similar requirements were used for the seismic qualification of SSCs for Bruce B, but these were not reviewed for compliance with the current requirements listed in the standard. For new SSCs, the current requirements in N289.3 would be applied, as outlined in clause 4.2 of DPT-PDE-00017 [64].

- **Section 8 Seismic evaluation beyond design basis to demonstrate seismic ruggedness** notes that nuclear power plants can require re-evaluation as new seismic information becomes available, and provides a discussion of the approaches that can be used for seismic risk analysis (seismic probabilistic risk analysis and seismic margin assessment). For new plants, clause 8.2 requires a checking level earthquake to be considered to demonstrate seismic capacity at probabilities of exceedance lower than the DBE.

  Assessment: This section contains no requirements for an existing plant unless new seismic information becomes available.

- **Section 9 Other seismically induced phenomena** requires that seismically induced phenomena, including tsunami, seiche, volcanism, and dam failure, be mitigated by siting, layout and design, and that the potential for seismically induced flooding be evaluated.

  Assessment: Of the events listed, the applicable event for the Bruce site is the seiche, which is also evaluated as part of CSA N289.2 above, for which a gap is identified (SF3-3 in Table 6). It is noted that the seiche is addressed in NK29-CORR-00531-11136 [112], but it appears to be only due to weather (i.e., wind forces on the water) and atmospheric conditions (differences in air pressure) and not from a seismic event.

The methods and practices included in this standard are similar to those used for the seismic qualification of SSCs in the original design of Bruce B, in that they address the dynamic characteristics of the SSCs being seismically qualified. NK29-DG-03650-002 [65] specifies the requirements of the current standard for replacements or modifications of seismically qualified SSCs, so Bruce B is considered to comply with the requirements of this standard, except for the gap noted above (SF3-3 in Table 6).

A.2.4. CSA N289.4-12, Testing Procedures for Seismic Qualification of Nuclear Power Plants [33]

The first edition of this standard was issued in 1981, and was updated in 2012 to be consistent with the content and terminology used in the most recent edition of CSA N289.1 (e.g., the SMA methodology), and to include more detail for the seismic qualification of SSCs by testing.

- **Section 1 Scope:** This section outlines the scope of the standard, which includes the requirements and acceptable methods for seismic qualification by testing.

- **Section 2 Reference Publications** includes references and related standards and contains no requirements.
- **Section 3 Definitions and abbreviations** includes definitions and abbreviations for terms used in the standard, and contains no requirements.
- **Section 4 General requirements** states that testing shall achieve the objective of either demonstrating the ability of an SSC to perform its intended function under seismic conditions, or to test the SSC to the limit of its functional capability, or to determine the dynamic properties of the SSC. This section includes general requirements for different methods of seismic testing.
- **Section 5 Test requirements** includes requirements for the test motion, monitoring, and documentation.
- **Section 6 Test method selection** requires consideration of the nature of the floor motion transmitted to the equipment (i.e., single frequency or multi-frequency).
- **Section 7 Shake table methods** includes detailed requirements about the use of test specimens, exploratory testing methods, single and multi-frequency testing, and testing of line-mounted equipment.
- **Section 8 Other test methods** includes requirements when other test methods are used, such as side load testing, use of an experience based or industry database, scale model tests, etc.

Assessment: The original equipment test reports were not reviewed for compliance with the requirements in this standard, as it is noted in CSA N289.1 (clause 5.4.1.2.3) [30] that SSCs designed to the provisions of earlier editions of the reference publications (which include N289.4) are not required to be requalified to meet the provisions of the current standard. The methods and practices included in CSA N289.4 are similar to those used for the seismic qualification of SSCs in the original design of Bruce B, in that they evaluated the dynamic response of the equipment to the input response spectra, so the intent of these requirements were met. NK29-DG-03650-002 (clause 6.1) [65] and DPT-PDE-00017 (clauses 4.1 and 4.2) [64] specify the requirements of the current N289.4 standard for replacements or modifications, and new equipment being qualified would satisfy these requirements. Bruce B is considered to comply with the intent of the requirements of this standard.

A.2.5. CSA N289.5-12, Seismic Instrumentation Requirements for CANDU Nuclear Power Plants

The first edition of this standard was issued in 1991, and was updated in 2012. The standard was extensively changed, with the main changes being that the locations requiring seismic instrumentation (i.e., four locations in the reactor building and one outside) and the technical requirements for the instrumentation are more clearly specified and the standard is presented in terms of existing plants (section 4) and new plants (section 5).

- **Section 1 Scope** indicates that the standard is applicable to existing nuclear power plants (clause 1.1.1 (a), but in clause 1.2 (Purpose) uses the words "Where required to be installed…".
- **Section 2 Reference Publications** includes references and related standards and contains no requirements.
- **Section 3 Definitions and abbreviations** includes definitions and abbreviations for terms used in the standard, and contains no requirements.
- **Section 4 Existing nuclear power plants and on-site nuclear facilities** requires the seismic instrumentation to operate for the life of the plant, including outages, and recommends that a review of its capability be done every 10 years. It requires at least one free-field triaxial accelerometer, with annunciation to indicate the occurrence of any seismic event, loss of power to the system, and malfunction of the system. Instruments are required to be verified to be suitable for use at their selected location. A number of recommendations (i.e., should statements) are made about the location and number of instruments in single or multi-unit plants.
- **Section 5 New nuclear power plants and on-site nuclear facilities** contains similar requirements to those in Section 4, but most of the recommendations are changed to requirements for new plants.
- **Section 6 New small reactors and on-site facilities** includes similar requirements and recommendations to those in Section 5, with wording suitable for small reactors.
- **Section 7 New enriched fuel fabrication facilities and new high and intermediate-level radioactive waste storage facilities** includes similar requirements and recommendations to those in Sections 5 and 6, with wording suitable for these facilities.
- **Section 8 Design and installation** requires the instrumentation system to be designed and installed to maintain their structural integrity during a DBE, to be accessible for servicing and recalibration, to be rigidly attached to prevent response amplification, and to be protected from adverse conditions.
- **Section 9 Maintenance and testing** requires maintenance and testing procedures to be defined and documented prior to startup and updated as necessary, and a number of requirements to maintain maximum availability of the instrumentation.
- **Section 10 Seismic instrumentation system data records** requires data records for the instrumentation to be identifiable and traceable, and includes requirements for the collection of recorded data and the retention of records.

Assessment: The words "Where required to be installed…" in clause 1.2, and other words in Note 1 of Table 1 (i.e., "Plants undergoing a life extension follow the requirements established together with the AHJ") make it clear that this standard applies only if there is a stated requirement from the licensee or the authority having jurisdiction (AHJ), which is the CNSC.

The procedure DPT-PDE-0017, Bruce Power Seismic Qualification Standard [64] includes CSA N289.5 as a basis for seismic qualification (clause 4.1, second paragraph), but notes in Section 4.6 (Post Seismic Response) that notification of an earthquake of magnitude 5 or greater within 500 km of the site will be received from the Southern Ontario Seismograph Network, which has one monitoring station within 20 km of the Bruce site. This is also included in the operating procedures and has been accepted by the CNSC through the acceptance of the procedure noted above, which documents this monitoring approach.

Since the post-seismic event notification to the operating staff is considered to be adequate and has been accepted by the CNSC, it has been considered that the free field motion accelerometer (clause 4.2.2) is not required. However, since this standard is listed in the recently issued Licensing Condition Handbook in terms of additional recommendations and guidance (section 5.1, Design Program, page 46), and the time period considered is relatively long (until 2025), consideration could be given to placing a free-field accelerometer on the site, as required by clause 4.1.1.3, and placing accelerometers on structures and equipment as recommended in clause 4.2.3 (note: clauses 4.2.3.1.1 through 4.2.3.1.3 regarding the placement of accelerometers on equipment and structures use the term “should”, so are not mandatory requirements in this standard, but are recommendations). Damage to critical safety related structures and equipment could be more quickly assessed, probably enabling a return to service much sooner, rather than relying solely on post-seismic walkdowns to assess damage in response to notification of an earthquake, as currently outlined in DPT-PDE-00017 (clause 4.6). The requirement for a free field accelerometer is identified as a gap (SF3-4 in Table 6) for the purposes of this report.

Appendix B – Clause-By-Clause Assessments Against Relevant Codes and Standards

No codes or standards relevant to Safety Factor 3 were subjected to a clause-by-clause assessment. This Appendix is retained only for consistency with the Appendix numbering scheme in all other Safety Factor Reports.