AECL EACL

Safety Design Guide

SEISMIC REQUIREMENTS

ACR

108-03650-SDG-002

Revision 3

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				1. Secondary Control Building (SCB) replaced by Secondary Control Area (SCA) 2. Section 3.5 b) par.3 revised and Section 3.5 c) par.5 removed, to clarify the seismic requirements for the MSSVs, MSIVs and portions of the steam piping 3. Sections 4.2.2, 4.2.3, 4.2.4 , 5. and Table 1 contain minor editorial changes 4. Table 1 revised to reflect fact that the Spent Fuel Transfer and Storage system includes some Category "B" components such as the SF port valves 5. The RB heating system does not require seismic qualification and has been removed from Table 1 6. Table 1 revised to indicate that only a portion of the PAM equipment requires seismic qualification 7. Acronym table made more specific to ACR			

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1. PURPOSE

This Safety Design Guide describes the seismic design philosophy, defines the applicable earthquake level, and identifies the structures and systems requiring seismic qualification to ensure that the essential safety functions can be adequately provided during and following an earthquake.

Table 1 identifies the conceptual requirements for structures, systems and components that must be seismically qualified.

Structures and systems not qualified to design basis earthquakes (DBE) or site design earthquakes (SDE) shall be designed, as a minimum, to satisfy the seismic requirements of the local building code of the site on which the plant is located.

2. COMPLIANCE

Compliance with the Safety Design Guides is mandatory. A listing of Safety Design Guides is included in Appendix A. Deviations from the requirements identified in the guides may be allowed, after an appropriate internal safety review. All deviations shall be approved by completion of a Safety Design Guide Supplement, AECL form 0729-00.

3. SEISMIC DESIGN PHILOSOPHY

This section of the Safety Design Guide describes the safety concept and safety design philosophy used to develop safety requirements. It is to be considered as information for the interpretation and application of the safety requirements in Section 4.

3.1 General

Earthquakes are natural external common cause events which are required to be considered in the design of the plant. The structures, systems and components required to perform or support the performance of safety functions after an earthquake are seismically qualified. Equipment not seismically qualified is not credited in the safety analyses for post seismic functions unless continued operation of the equipment adversely affects the consequences of the event. Random failures of seismically qualified structures, systems and components coincident with an earthquake are not considered.

A loss of coolant accident is not considered to occur coincident with an earthquake since the heat transport system is qualified to withstand earthquakes, and a simultaneous occurrence of a random LOCA and earthquake is not credible. Following a loss of coolant accident, an earthquake may occur. For design purposes an earthquake of the SDE level is postulated to occur 24 hours after the event.

3.2 Seismic Levels

Two levels of earthquake are defined as design envelopes for achieving the safety objectives. These levels are defined in accordance with the CAN3-N289.1 “General Requirements for Seismic Qualification of CANDU Nuclear Power Plants” as follows:

a) Design Basis Earthquake (DBE)

   The “Design Basis Earthquake” (sometimes referred to as a “Safe Shutdown Earthquake”) is also designated as “SL-2” in the IAEA Guide 50-SG-S1. The Design Basis Earthquake means an engineering representation of the potentially severe effects of earthquakes applicable to the site that have sufficiently low probability of being exceeded, during the lifetime of the plant.

   The DBE effects on the site, will be described by the DBE Ground Response Spectra (GRS). Its effects within structures at the site are described by Floor Response Spectra (FRS). The FRS are developed for selected elevations in each structure.

b) Site Design Earthquake (SDE)

   For certain conditions, including some event combinations, post-accident inspection, national licensing requirements and economic considerations, a second level earthquake, known as Site Design Earthquake (SDE), may be considered in design. The SDE is an intermediate level earthquake, similar to IAEA Guide 50-SG-S1 seismic ground motion level “SL-1”. This level corresponds to a less severe, more likely earthquake load condition with different safety implications from DBE (SL-2).

   The “Site Design Earthquake” means an engineering representation of the effects at the site of a set of possible earthquakes with an occurrence rate, based on historical records, not greater than 0.01 per year.

The DBE and SDE values used for the design of a standard product are given in the document 108-10170-DG-001, "Design Earthquakes".

3.3 Seismic Categories

Two categories, "A" and "B", are defined to identify the extent to which components must remain operational during and/or after an earthquake.

a) Category "A" Components

   Those which must retain their pressure boundary integrity or structural integrity or passive function (i.e., components which do not have an active mechanical function but may have an electrical or load bearing function) during and/or following an earthquake.

b) Category "B" Components

   Those which must retain their pressure boundary integrity and in addition must remain operable during and/or following an earthquake. This category also includes components that are not part of the pressure boundary, but must operate during and/or following an earthquake.

The system designer has the responsibility to interpret the extent of qualification necessary for each component, and to consider the intended safety function of the system when specifying the qualification requirements for individual components. These requirements may involve a combination of, or departures from, the general definition of "A" and "B" categories. Where the extent of qualification is different from the definition of Category A or B, the extent should be described in the design documentation.

3.4 Objectives

The safety objective of the seismic design for the plant is to have sufficient capability to perform the following essential safety functions:

a) shut the reactor down and maintain it in the shutdown state,
b) maintain the heat transport system integrity for fuel cooling (i.e., no loss of coolant accident (LOCA) as a result of an earthquake),
c) cool the fuel in the reactor by heat transport to the steam generators by thermosyphoning, followed by manual initiation of the long term cooling system, to the extent that the dose limit is satisfied,
d) cool the fuel in the fuel handling system to the extent that releases outside containment remain within the dose limits for the event,
e) maintain the containment boundary and any necessary associated systems (i.e. to control hydrogen, and maintain suitable pressure and temperature),
f) maintain the structural integrity or operating function of systems, structures and components, as required to mitigate the earthquake consequences,
g) maintain sufficient qualified instrumentation for the operator to control and monitor the plant from a seismically qualified area. That is, control and monitoring shall be maintained from the main control room (MCR) or from the secondary control area (SCA) should the MCR become unavailable. A qualified route is provided for safe access to the SCA,

h) maintain the integrity of structures and systems outside containment that could cause radioactivity releases beyond allowable accident limits (e.g., Spent Fuel Bay), or directly or indirectly lead to another common cause event that could cause damage to systems required to perform a safety function,

i) maintain conditions inside containment within the limits used for environmental qualification of equipment required for long term post-seismic operation, and

j) maintain the above safety functions, as required during and/or following an earthquake occurring 24 hours or more, after a loss of coolant accident (LOCA).

3.5 Safety Functions

The systems and equipment which must be qualified to perform the safety functions, to maintain the release of radioactivity within the regulatory dose limits, are discussed below. Systems and equipment will be qualified to the DBE level only, for practicality (i.e., the SDE level should not be used for qualification, unless qualification to the SDE level is specifically required and justified). For brevity, the safety functions are presented in terms of shutdown, fuel cooling, containment, and control and monitoring.

a) Shutdown:

According to CNSC Regulatory Document R-8, both shutdown system no. 1 (SDS1) and shutdown system no. 2 (SDS2) must be qualified to shut the reactor down automatically, and to be manually actuated from a seismically qualified area. They are not required to be qualified to be re-poised.

The shutdown systems (SDS1 and SDS2) must be able to shut the reactor down despite seismically induced failures of the reactor regulating system that may cause an increase in positive reactivity, or any seismically induced distortion or deflection of the reactor structure.

b) Fuel Cooling:

The heat transport system pressure boundary, including the fuel channels, headers, pumps, pressurizer, steam generators, and connected subsystems and supporting structures must be seismically qualified to the DBE level. This ensures that a loss of coolant accident does not occur as a result of the earthquake. The heat transport pumps may not remain operable, in which case the fuel is cooled by natural convection (referred to as “thermosyphoning”), until the long term cooling system becomes available. The pumps are required to remain free-wheeling immediately after being tripped to enable pump rundown to assist the transition to thermosyphoning. The emergency coolant injection system must be qualified for coolant make-up, to cater for small leaks existing prior to a DBE or created through the depressurization of the system.

If the normal unqualified feedwater system fails, the reserve water system is a qualified source of feedwater, with an inventory suitable until an alternative heat sink can be established.

The MSIVs and the main steam piping up to the piping anchors downstream of the MSIVs must be qualified to DBE Category “A”. The MSSVs must be qualified to DBE Category “B” to ensure that they can be opened to discharge residual and decay heat to the atmosphere. The portion of the steam piping beyond the piping anchors downstream of the MSIVs must

either be qualified or the piping anchors downstream of the MSIVs must be designed to withstand the loading imposed by the failed steam lines.

The long-term cooling system is seismically qualified to provide cooling in the long term (recovery stage) of a LOCA and to remove decay heat indefinitely in the long term with the HTS pressure boundary intact, and is supplied with seismically qualified electrical power and service water.

Cooling water to seismically qualified components, including the long-term cooling heat exchangers, is supplied by seismically qualified service water systems.

A seismically qualified source of fuel cooling is provided to the irradiated fuel handling equipment.

c) Containment

The containment envelope is qualified to ensure that the dose limits for an earthquake postulated initiating event are satisfied. Class 3 dose limits, as defined in CNSC C-006, Rev. 1, will be applied as earthquake dose limits.

Structures or components outside the containment envelope, whose failure could result in the dose limits being exceeded, must also be seismically qualified. This includes the equipment in the spent fuel storage bay.

The reactor building containment system is qualified to remain available after an earthquake of DBE intensity, and its liner integrity must be maintained. Releases of radioactive materials within containment may be caused by minor leaks in the heat transport system (possibly existing prior to the earthquake).

The containment system must also remain functional for the occurrence of a loss of coolant accident followed by an earthquake of the SDE level at least 24 hours later. This means that the hydrogen control system must be qualified. If needed to maintain containment pressure and temperature within their design values, a sufficient number of air coolers may be qualified and supplied with qualified power and cooling water supplies.

Containment does not need to be qualified to withstand peak building pressure coincident with an earthquake. However, in accordance with the statement in Section 3.1, “An earthquake may occur 24 hours after a loss of coolant accident event”, and CAN/CSA N287.3, the containment structure must be qualified to withstand the loads due to an earthquake, combined with:

1) the internal pressure (if any) existing after a LOCA, and
2) a “reduced accident pressure”, due to the failure of piping or components that are not qualified and that may contain high energy fluids or compressed gases. This pressure is to be based on an appropriate review and analysis of piping and components (e.g. instrument air) that are not seismically qualified.

d) Control and Monitoring

The control and monitoring systems associated with the essential seismically qualified safety functions are qualified for operation from the main control room following an earthquake.

Electrical power is supplied from a qualified electrical power system, which consists of redundant divisions of on-site power supplies (standby generators and batteries). Non-qualified loads will be designed to disconnect from the qualified electrical buses

automatically by fuses/breakers should short circuits occur after an earthquake. Plant batteries will supply power to the Class I and Class II buses for a minimum of one hour. After this time, sufficient capacity is left in the batteries to support the Post-Accident Management (PAM) system for an additional seven hours.

A qualified source of instrument air is supplied, in the form of qualified local air tanks, where required for essential control functions. Structures and components that may pose a hazard to seismically qualified systems are also qualified.

Seismic monitoring instrumentation, designed to satisfy the requirements of CAN3-N289.5, is provided.

Should the main control room become unavailable, sufficient seismically qualified monitoring and control equipment is provided in the secondary control area to maintain the plant in a safe state.

3.6 Qualification of Structures

Structures that require seismic qualification are those that contain and support seismically qualified systems or components, and those whose failure could cause the subsequent failure of these structures. These include the reactor building, the reactor structure, the reactor auxiliary building, the structures that contain the MSSVs and MSIVs, the containment airlocks, the Spent Fuel Storage Bay, the Control Building, the Diesel Generator Building, the Secondary Control Area and the RSW Pumphouse. The turbine building must be qualified to the extent that it does not impair the function of the other qualified structures and systems. Structures are qualified in accordance with the requirements of CAN3-N289.3 or N 289.4 or a combination of both, as applicable.

4. SEISMIC DESIGN REQUIREMENTS

4.1 General

a) The objectives for seismic design listed in Section 3 shall be met for all modes of operation, including normal operation, maintenance, and testing, except for those that occur infrequently, such as the reactor building pressure test.

b) For practical reasons seismic qualification shall be to the DBE level, unless qualification to the SDE level is acceptable and justified through an SDG supplement. It may not always be necessary to qualify the entire system. Only the equipment whose response is necessary to ensure the system safety function is adequately performed, needs to be qualified. The system designer shall:

   1) identify and list this equipment in the design documentation,
   2) determine its safety function, seismic levels and category (see Sections 3.2 and 3.3), consistent with the requirements of the system, and
   3) ensure that the seismic qualification process is completed and documented.

c) Structures and components whose failure may pose a hazard to seismically qualified systems shall also be qualified sufficiently that the safety function of the seismically qualified systems is not affected, or the seismically qualified systems shall be suitably protected.

d) Equipment that is not seismically qualified, and is in the areas of seismically qualified systems, shall be suitably anchored so its failure does not cause the failure of the seismically qualified equipment. Where equipment is located in a seismically qualified area, and seismic qualification of the equipment is not done to the DBE level, it shall be demonstrated by additional calculations or otherwise, that the anchorage design is adequate to prevent failure of the DBE qualified equipment.

e) In certain instances, equipment whose response is not necessary to perform the system safety function, or which belongs to another system, may require seismic qualification if its failure could affect the proper operation of the equipment and systems which perform safety functions. System designers shall ensure that the necessary equipment in the seismically qualified systems is protected from the effect of failure of structures and equipment designed to a lower seismic level.

f) If equipment is needed to maintain suitable conditions for the continued operation of qualified systems (e.g., ventilation equipment), it shall be seismically qualified. Alternatively, the seismically qualified systems could be environmentally qualified to withstand the resulting environmental conditions, in accordance with 108-03650-SDG-003.

g) For qualified systems and components, Level C service limits shall be applied for pressure retaining components built to meet the requirements of ASME Boiler and Pressure Vessel Code, Section III.

h) The design of other buildings and structures not addressed in this Safety Design Guide, as a minimum, shall meet the seismic requirements of the applicable local building code for the plant location.

i) The design and physical arrangement of the qualified systems and components, <u>including any protection provisions such as barriers,</u> shall be such as to facilitate in-service surveillance, inspection and maintenance.

j) Equipment that needs to be manually operated after a seismic event shall be located in readily accessible area. Human factors shall be considered in locating such equipment.

4.2 Systems Required to Satisfy the Safety Objective

The structures, systems and components listed in Table 1 shall be seismically qualified to the extent indicated in the notes applicable to each system. It should be noted that Table 1 does not list every system and component in a comprehensive manner, and that the notes and other requirements in this section may require qualification of parts of additional systems. For example, all systems forming the heat transport pressure boundary are not listed, but are required to be qualified, in part, by the note for the heat transport system. Also, all systems forming the containment boundary are not listed, but are required to be qualified, in part, by the note for the containment system. The requirement for seismic qualification for these additional portions of systems must be identified in the relevant design documentation.

The requirements in the following subsections, based on the safety functions to be maintained, shall also be satisfied. The final qualification of structures, systems, and components shall be documented in an overview assessment, down to the subsystem and component level.

4.2.1 Reactor Shutdown

Both shutdown systems, SDS1 and SDS2, shall be seismically qualified to the DBE. The qualification shall include the entire trip chain from the sensing element to the final element. Provisions shall be made to enable manual initiation of the shutdown systems from the main control room and the secondary control area following an earthquake.

4.2.2 Residual Heat Removal

a) The heat transport system, including the fuel channels, headers, feeders, end-fittings, pumps, pressurizer, steam generators, and connected subsystems shall be qualified. The purpose is to ensure that a loss of coolant accident will not occur as a result of the earthquake and continued fuel cooling can be maintained. The main heat transport pumps are permitted to cease to operate, in which case the fuel shall be adequately cooled by natural circulation or another system.b) A defined seismically qualified HTS pressure boundary shall be established following a DBE to ensure retention of the inventory necessary for natural circulation. The designer shall identify the seismically qualified pressure boundary and shall ensure that open valves on the boundary will be closed automatically or can be closed manually from the MCR before fuel cooling is affected.

c) The heat transport pumps shall be designed to free wheel after a pump trip, as necessary to permit thermosyphoning.

d) Makeup capability, at a pressure sufficient to inject water into a “depressurized” heat transport system after cooldown to enable heat removal via the steam generators and long-term cooling system, shall be provided to compensate for any small leaks that will continue following an earthquake.

e) To maintain the heat transport system cooldown capability:

1) The reserve water system shall be seismically qualified to provide feedwater to the steam generators. The feedwater inventory shall be sufficient until initiation of the long-term cooling system (LTC).
2) Main Steam Safety Valves (MSSV) shall be seismically qualified and shall be provided with qualified means to open them and keep them open.
3) Main Steam Isolation Valves (MSIV) shall be seismically qualified (see Section 3.5 b).
4) The emergency coolant injection system shall be seismically qualified to cater for pre-existing small leaks and any shrinkage created through the depressurization of the heat transport system.
5) The long-term cooling system shall be seismically qualified and supplied with support services from qualified systems.
6) The Service Water Systems shall be seismically qualified and powered from the qualified electrical power system.
7) The Moderator System and Calandria Shield Tank shall be qualified to DBE Category A to support the HTS safety functions.

f) The ECC system and containment heat reduction systems shall be seismically qualified to DBE to cater for the possibility of an SDE following a LOCA.
g) The spent fuel in the spent fuel transfer system and spent fuel bay shall be kept cool enough to prevent failures after DBE.

4.2.3 Barriers to Radioactive Release

a) The containment envelope shall be qualified to ensure that Class 3 dose limits (per CNSC C-006 Rev. 1) will be met for the seismic event.
b) To contain radioactive releases, the plant design shall provide a number of seismically qualified barriers, namely, the fuel, the heat transport system boundary, the containment boundary, the fuelling machine pressure boundary and the spent fuel transfer system.
c) The containment system, including containment isolation and hydrogen control, shall be seismically qualified.
d) Suitable pressure and temperature conditions shall be maintained within the reactor building to maintain the containment boundary, and operation of seismically qualified systems.
e) Structures, systems and components, both inside and outside the reactor building, whose failure could result in the release limits being exceeded shall be seismically qualified, or analysis shall be performed to show that regulatory limits are not exceeded. This includes the spent fuel storage bay, the moderator system, and other systems that may contain radionuclides.

4.2.4 Control and Monitoring

a) A sufficient number of qualified control and monitoring functions, as required by CSA Standard N290.6, shall be provided in the main control room and in the secondary control area after a DBE, to shut down the reactor and maintain it in a safe shutdown condition. Human factors shall be considered in the selection and type of instrumentation to be

qualified. Qualified design measures, such as ventilation, isolation and radiation shielding, shall be provided as appropriate.

b) Qualified safety related control and monitoring capability shall be provided as follows:
   1) all control operations which must occur within 15 minutes after an earthquake shall be automatic,
   2) the number of separate manual operator actions required after an earthquake shall be kept to a minimum, and
   3) all monitoring or manual control functions required shall be exercisable from the main control room or the secondary control area.

c) Operator actions necessary to maintain the plant in a safe condition after an earthquake shall be identified in design documentation, along with the instrumentation needed to decide that the actions are necessary (where applicable), and to perform those actions.

d) The main control room and the associated equipment shall be designed to protect the operator during and following a seismic event.

e) A qualified route shall be provided to any seismically qualified equipment to which access is required to carry out operator actions after an earthquake, considering the following:
   1) passageways and stairs shall be qualified to DBE Category A,
   2) Failures of walls and ceilings etc. shall not cause obstacle and debris that may hinder access or cause personal injury,
   3) access and fire doors shall function, and shall not be wedged closed by surrounding wall damage,
   4) door seals which prevent steam or smoke ingress shall maintain their function,
   5) suitable environmental requirements (air quality, radiation, etc.) shall be maintained along the route, and
   6) suitable lighting shall be provided.

f) Systems and components whose failure may pose a hazard to the operating staff or to the operation of seismically qualified instrumentation shall be qualified to DBE Category A (e.g., water flooding, steam line break, hydrogen leaks, etc.).

g) Electrical power shall be supplied from the qualified power supply systems.

h) A qualified source of instrument air shall be supplied for the required mission time, where required for essential control functions.

i) The design of earthquake monitoring instrumentation shall comply with CSA Standard N289.5.

j) The seismically qualified monitoring and control functions required after a seismic event in the MCR and SCA shall be identified in design documentation. As a minimum the following shall be included as a part of the seismically qualified control capability available to the operator in the main control room:
   i) Ability to initiate SDS1 and SDS2,
   ii) Ability to initiate controlled cooldown using the steam generators and the reserve water system, followed by manual initiation of the long-term cooling system,
   iii) Ability to initiate standby generator(s) to power ECI, LTC, RSW and RCW,

iv) Ability to maintain the operation of ECI and LTC,

v) Ability to initiate containment isolation, and

vi) Ability to isolate certain systems not qualified to DBE, if their failure would jeopardize the function of qualified systems.

4.3 Applicable Codes, Standards and Guides

The design and qualification of systems and components shall comply with the following standards and guides:

a) CAN3-N287.3 "Design Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants".

b) CAN3-N289.1 "General Requirements for Seismic Qualification of CANDU Nuclear Power Plants".

c) CAN3-N289.2 "Ground Motion Determination for Seismic Qualification of CANDU Nuclear Power Plants".

d) CAN3-N289.3 "Design Procedures for Seismic Qualification of CANDU Nuclear Power Plants".

e) CAN3-N289.4 "Testing Procedures for Seismic Qualification of CANDU Nuclear Power Plants".

f) CAN3-N289.5 "Seismic Instrumentation Requirements for CANDU Nuclear Power Plants''.

g) CAN3-N290.6 "Requirements for Monitoring and Display of CANDU Nuclear Power Plant Status in the Event of an Accident".

h) CNSC Regulatory Document R-7, "'Requirements for Containment Systems for CANDU Nuclear Power Plants"'.

i) CNSC Regulatory Document R-8, "Requirements for Shutdown Systems for CANDU Nuclear Power Plants".

j) CNSC Regulatory Document R-9, "Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants".

4.4 Qualification Requirements

a) Qualification shall be in accordance with the National Standard of Canada (Canadian Standards Association) CAN3-N289.3, "Design Procedures for Seismic Qualification of CANDU Nuclear Power Plants," and CAN/CSA-N289.4, "Testing Procedures for Seismic Qualification of CANDU Nuclear Power Plants". Qualification may be done by seismic testing, analysis, or a combination of both. Design features that ensure compliance with IAEA 50-SG-D15, "Seismic Design and Qualification for Nuclear Power Plants" shall be considered for implementation, consistent with the CANDU plant overall safety design philosophy and economic considerations.

b) The effects of ageing during normal plant operation shall be considered for components to be qualified to DBE. The designer shall identify critical components affected by radiation/temperature and assess the ageing effect on its safety function. Many components requiring seismic testing will also require environmental testing. The requirements on

environmental qualification can be found in 108-03650-SDG-003. If the seismic qualification of a component is affected by harsh environmental conditions, the sequence of ageing, environmental test and seismic test can be used. Otherwise, testing shall follow the sequence of ageing, seismic test and environmental test. The designer shall decide and justify the sequence of testing.

c) The dynamic characteristics of all structures, systems and components to be qualified shall be considered in the qualification either by analysis or by test. This includes the effects of attached conduits and cables, taking into consideration their flexibility and support characteristics, and any resulting loading imposed on the qualified component (note that the requirements of 108-03650-SDG-004 shall be satisfied in terms of the routing and separation of cables).

5. DOCUMENTATION

a) The design documentation for each system requiring seismic qualification shall identify the following:
   1) structures and components that are seismically qualified, including clear definitions of boundaries on system flowsheets,
   2) the seismic level (DBE),
   3) the safety functions to be performed by the system or portions of the system during and/or after the earthquake (the use of categories ‘A’ or ‘B’ alone to describe a function should be avoided),
   4) the interface with other components and systems for supply and services, and
   5) assurance that seismically qualified components are protected from the effects of failure of components qualified to a lower level of earthquake.

b) A final assessment shall be prepared to review and document the seismic qualification of each system, down to the subsystem and component level.

c) The seismic qualification documentation for structures and components that are qualified by analysis shall be according to requirements in CAN2-N289.3 and for those qualified by testing shall be according to requirements in CAN3-N289.4.

6. REFERENCES

[1] IAEA 50-SG-S1, “Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting: A Safety Guide”

[2] IAEA 50-SG-D15, “Seismic Design and Qualification for Nuclear Power Plants”

Table 1
Structures and Systems Requiring Seismic Qualification

ASI	System	Category	Notes
20000	BUILDINGS AND STRUCTURES		
21000	Reactor Building	A	All components that make up the containment boundary shall maintain their structural integrity during and following a DBE so as not to compromise safety related systems. The design shall comply with CAN3-N287.3, "Design Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants". All internal structures, major equipment supports and shielding structures shall be qualified to retain structural integrity and/or load bearing capability. The containment boundary includes all those sections of piping systems, ducts and cable seals within the reactor building which penetrate the containment structure. Refer to CNSC document R-7 "Requirements for Containment Systems for CANDU Nuclear Power Plants".

ASI	System	Category	Notes
21600	Special Equipment (Airlocks, Shielding Doors, etc.)	B	The airlock and equipment hatch shall maintain their containment integrity during and following a DBE. Provision shall also be made for their manual operation after a seismic event.
22000 23000 23005 24000 25000 28003 24xxx	Turbine Building* Cooling Water Structures RSW Pumphouse Reactor Auxiliary Building Control Building (see also 66000) Main Control Room (see also 66100) Secondary Control Area (see also 66600) Standby Generator Area Structure MSSV/MSIV Room (* Turbine Building shall be qualified to the extent required to protect Reactor Auxiliary Building and MSSVs/MSIVs)	A	The structural integrity of the reactor auxiliary building, the MSSV/MSIV areas, and the raw service water pumphouse shall be maintained. Access for operation and maintenance of seismically qualified systems located in these buildings shall also be maintained. The areas and associated equipment necessary for ensuring safe post-seismic event plant operation shall be qualified to the DBE. The structural integrity of the equipment racks shall be maintained. All cables entering the MCR and SCA shall be suitably anchored to prevent the cables from pulling on equipment inside the MCR or SCA. Equipment within the secondary control area shall be qualified to function during and following a DBE. The main control room shall remain habitable and seismically qualified and equipment within the MCR shall remain operable during and following an earthquake. All non-qualified equipment shall be secured to prevent injury to the operating staff in the MCR.
24250	Spent Fuel Bay	A	Design of spent fuel bay shall accommodate loss of cooling (also see ASI 34410).
30000	REACTOR, REACTOR SYSTEMS AND AUXILIARIES		
31000	Reactor		
31100	Fuel Channel Assemblies	A	The fuel channel internals shall be designed so as not to cause flow blockage following a DBE, and shall not cause increase of reactivity, a LOCA, or impede function of reactivity control devices that are required for shutdown.

ASI	System	Category	Notes
31200	Calandria Shield Tank Assembly	A	Shield cooling system pipe failures shall not lead to draining of the end shields or the shield tank following an earthquake, unless the distortion of the structure can be shown to have no adverse effect on the Heat Transport pressure boundary.
31700	Reactivity Control Units	B	Those units required for proper operation of the safety systems shall remain operable (see ASI 68200 and 68300) following an earthquake.
31710	Reactivity Mechanisms Deck	A	Components above the reactivity mechanisms deck shall be qualified so they will not damage the mechanisms on the deck or the reactor structure.
32000	Moderator Systems and Auxiliaries		
32100	Moderator Systems	A	The moderator system and its auxiliaries shall be seismically qualified to prevent moderator draining, to the extent required to maintain acceptable stress levels in the calandria and fuel channels, to the extent that the Heat Transport System can perform its safety function. The loss of moderator cooling shall not cause dose limits to be exceeded nor damage the heat transport system.
32200	(Moderator) Purification System	B	To be qualified to the extent that after the reactor has been shutdown, the purification process can be terminated to ensure that the reactor remains in a shutdown state.

ASI	System	Category	Notes
33000	Heat Transport Systems and Auxiliaries		
33100	Heat Transport Circuit	A, B	The heat transport circulating pumps shall remain free wheeling and the heat transport system shall retain its natural circulation capabilities during and following a DBE. The steam generator shall be qualified so it will remain a heat sink following a DBE. The steam generator secondary side water shall not drain. The feedwater piping and check valves inside the reactor building shall be qualified. All the subsystems directly connected to the main circuit shall be qualified to DBE to ensure pressure boundary integrity of the HT system or be isolatable. All equipment necessary to support thermosyphoning shall be supplied with qualified power if necessary to maintain adequate inventory in the core, to be confirmed during design. HT system instrumentation associated with Post Accident Management (PAM) shall be seismically qualified. Seismic stresses shall consider any plant transient resulting from the failure of non-seismically qualified equipment.
33310	Heat Transport Pressure and Inventory Control System	A, B	All the subsystems directly connected to the main heat transport circuit shall be qualified to ensure pressure boundary integrity of the heat transport system, or be isolable. All equipment necessary to support thermosyphoning must be qualified (and their support systems). Appropriate instrumentation associated with Post Accident Management (PAM) shall be seismically qualified. The bleed and relief circuit shall be qualified such that overpressure protection remains available.
33340	HTS Pump Seal Circuit		See ASI 33100 (Heat Transport Circuit)
33350	Heat Transport Purification System		See ASI 33100 (Heat Transport Circuit)

ASI	System	Category	Notes
33540	Hydrogen Addition Circuit	A	The circuit shall be qualified to prevent release of combustible gas due to the circuit failure.
34000	Auxiliary Systems		
34320	Emergency Coolant Injection (ECI) System	B	The emergency coolant injection system shall be seismically qualified to be available for injection after a DBE.
34340	Reserve Water System	A, B	The reserve water system shall be seismically qualified, including any necessary controls, to provide a water supply to the heat transport system, steam generators, moderator system, LTC system and shield cooling system following the earthquake.
34350	Long Term Cooling System	B	The long term cooling system shall be seismically qualified to remove decay heat following a reactor shutdown or loss of coolant accident, with cooling water supplied from the qualified service water systems.
34410	(Spent Fuel Bay Systems) Cooling and Purification System	A, B	The system shall be designed to be such that water in the spent fuel bay does not drain after a seismic event. In addition, adequate cooling of the bay shall be provided after a seismic event; cooling may be provided by demonstrating that bay water provides sufficient cooling by vaporization for a short term without make-up, and identifying the qualified makeup water source for long term cooling.
34710	Liquid Injection Shutdown System (LISS) (Also see ASI 68300 SDS2)	B	Shutdown systems are required to operate during or following a DBE. Performance of the shutdown systems must be within specifications while under the impact of a DBE.

ASI	System	Category	Notes
35000	Fuel Handling and Storage		
35100	New Fuel Transfer and Storage	A	All components that make up the containment boundary shall maintain their structural integrity during and following a DBE so as not to compromise safety related systems. The design shall comply with CAN3-N287.3, "Design Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants".
35200	Fuel Changing	A	If an earthquake occurs during refuelling, the fuelling machine shall remain on-reactor with the fuelling machine support structure intact and not cause a leak after the seismic event. When the fuelling machine is uncoupled from the reactor, the fuelling machine support structure integrity shall be maintained to prevent damage to reactor fuel channels, feeders and the containment boundary at the fuel handling service ports. The fuelling machine support structure integrity shall also be maintained when the fuelling machine is coupled to the containment boundary service ports, to ensure no break in the containment boundary results. To meet these requirements, the F/M head and the reactor area bridge and carriage shall be qualified. It shall be shown that release limits are not exceeded if a qualified cooling water source is not available to cool the F/M head if it is off reactor following an earthquake, or a seismically qualified source of fuel cooling shall be provided. The failure of non-qualified fuel handling equipment shall not cause the safety functions for the seismic event to be impaired.

ASI	System	Category	Notes
35300	Spent Fuel Transfer and Storage	A, B	All components that make up the containment boundary shall maintain their structural integrity during and following a DBE so as not to compromise safety related systems. Included as part of this system are the peripherals between the bay itself and the containment boundary in which spent fuel can be present when it is outside of the containment. Storage bay equipment shall be designed to protect fuel from damage and enable fuel cooling to be maintained so regulatory release limits are not exceeded. A qualified method of cooling the fuel shall be provided for loss of the electrical power supply to prevent fuel failure in the fuel transfer system. The system shall be designed so the water in the spent fuel bay will not drain following an earthquake.
35730	(Fuelling Machine) Cable and Hose Management System (Catenary System)		See ASI 35200 Fuel Changing
36000	Steam Generator Systems		
36110 36140	Main Steam and Water System Main Steam Pressure Control and Relief System (MSSV's)	A B	The main steam lines shall be seismically qualified to ensure the integrity of the steam piping inside containment and of the containment envelope. Steam piping outside containment shall be qualified to the extent necessary to ensure the availability of the MSSVs and MSIVs. Any relief valves required to maintain stresses to within Level C service limits of ASME Section III shall be qualified.
36310	Steam Generator Blowdown System	A	The pressure boundary must be qualified to maintain containment boundary, refer to ASI 68400 Containment System.
37000	Fuel	A	The fuel shall be qualified to permit continued cooling.

ASI	System	Category	Notes
43000	Feedwater and Auxiliary systems		
43230	Feedwater System	A	The feedwater piping shall be qualified sufficiently to maintain the steam generator as a heat sink following a DBE. The steam generator secondary side water shall not drain following a DBE. The feedwater piping and check valves inside the reactor building shall be qualified. Note: The piping and the pumps located outside the reactor building are not seismically qualified.
50000	ELECTRIC POWER SYSTEMS		
50000	Electric Power System	B	The electric power systems shall be sized to supply the loads of all systems required following a DBE. The standby diesel generators shall be capable of being started during and following a DBE. If the standby diesel generators are running during a DBE, they shall continue to run during and after the DBE, or, if they trip, they shall be capable of being restarted immediately. The electrical distribution systems shall be qualified to the extent that electrical power can be provided to seismically qualified systems from the qualified power supplies. Relay chatter shall be considered in seismic qualification.
53000	Distribution System	B	See ASI 50000 Electric Power System.
56000	Lighting and Building Service Systems	B	Lighting provided by qualified supplies is required in areas in which manual control operations are required, including the main control room, the secondary control area, and the access to the secondary control area following an earthquake.
57000 57600	Cabling System Containment Penetrations (Electrical)	B A	Cables, cable trays, conduit, and their supports, supplying power to any system qualified for operation, shall also be qualified. A margin shall be applied to the tray capacity of qualified trays, to avoid potential overloading of trays.

ASI	System	Category	Notes
58000	Grounding and Cathodic Protection	A	The grounding system shall be designed to maintain function of seismically qualified components.

ASI	System	Category	Notes
60000	INSTRUMENTATION AND CONTROL		
62161	(Reactor Building) Airlocks	B	The airlock and equipment hatch shall maintain their containment integrity during and following a DBE. Provisions shall also be made for their manual operation after a seismic event.
63000	Reactor, Reactor Systems and Auxiliaries		
63100 63210 63220 63300 63331	Reactor Instrumentation Moderator Systems Purification System Heat Transport Systems Heat Transport Pressure and Inventory Control System	A, B	The instrumentation and control required following an earthquake shall be qualified to the same extent as the system, or to DBE Category B where the failure of the control function could impair the capability to perform a seismically qualified safety function. Instrumentation directly connected to the main circuit shall be qualified to ensure pressure boundary integrity of the heat transport system or be isolable. Appropriate instrumentation associated with the Post Accident Management (PAM) system shall be seismically qualified.
63500	Fuel Handling Control		See ASI 35200 Fuel Changing
63700	Plant Control (includes Reactor Regulating System)		See ASI 68200/68300 Shutdown Systems
66000 66100 66200	Control Centre Main Control Room (MCR) Control Equipment Room	B	The main control room shall remain habitable and seismically qualified equipment shall remain operable during a seismic event. All non-qualified equipment shall be secured to prevent injury to the operating staff in the MCR. In the control equipment room, seismically qualified equipment shall be located in an area separate from the non-qualified equipment, to the maximum extent practical.

ASI	System	Category	Notes
66600	Secondary Control Area	B	The secondary control area (SCA) and associated equipment necessary for ensuring safe post-DBE plant operation shall be qualified to function during and following the DBE. The structural integrity of the equipment racks shall be maintained. All cables entering the SCA shall be suitably anchored to prevent the cables from pulling on equipment inside the SCA.
67000	Common Process and Services		
67314	Containment Isolation	B	All components that make up the containment boundary shall maintain their pressure boundary integrity during and following a DBE. The containment boundary includes any instrument tubing and cable seals which penetrate the containment structure. Refer to CNSC document R-7 "Requirements for Containment Systems for CANDU Nuclear Power Plants".

ASI	System	Category	Notes
68000	Safety Systems		
68200 68300	Shutdown System No. 1 (SDS1) Shutdown System No. 2 (SDS2)	B B	Shutdown systems shall operate during or following a DBE. Performance of the shutdown systems must be within specifications while under the impact of a DBE. Control and monitoring functions for the two shutdown systems shall be provided in the main control room and the secondary control area for the purpose of post-accident monitoring of the reactor. Manual initiation of the shutdown systems and sufficient equipment for monitoring of the reactor shall be provided in the main control room and the secondary control area. The shutdown system equipment shall be located and designed to ensure that the system will shut down the reactor and maintain it in a shutdown condition, without reliance on non-qualified equipment. The failure of non-qualified equipment shall not adversely affect the capability of the system to satisfy the requirements of CNSC Regulatory Policy Statement R-8 "Requirements for Shutdown Systems for CANDU Nuclear Power Plants". The shutdown systems shall be designed to have adequate reactivity depth to handle all possible sources of reactivity, including the worst possible failure of the non-seismically qualified reactor regulating system.
68400 68480	Containment System (See 67314 for Containment Isolation System) Hydrogen Control System	B B	All components that make up the containment boundary shall maintain their pressure boundary integrity during and following a DBE. The containment boundary includes any instrument tubing and cable seals which penetrate the containment structure. Refer to CNSC document R-7 "Requirements for Containment Systems for CANDU Nuclear Power Plants".

ASI	System	Category	Notes
68570	Second Crash Cooldown System	B	The system shall be qualified to support, • the heat removal from the fuel by opening the main steam safety valves; • the introduction of an alternate water source into the steam generators after loss of normal feedwater systems.
68631	Containment Ventilation Isolation System	B	See ASI 67314 Containment Isolation System and 68400 Containment System
68900	Post Accident Management	B	Instrumentation and displays required for control and monitoring of seismically qualified systems and components following an earthquake, in accordance with CSA N290.6, shall be seismically qualified.
70000	COMMON PROCESSES AND SERVICES		
71300	Service Water Systems		
71310	Raw Service Water System	B	The raw service water system shall be seismically qualified to provide cooling to the recirculated cooling water system.
71340	Recirculated Cooling Water System	B	The system shall be seismically qualified to provide cooling to the long-term cooling system and to the containment cooling system after a DBE.
71400	Fire Protection System	B	Sufficient seismically qualified fire protection equipment shall be provided for each accessible area containing seismically qualified equipment. Fire protection systems shall not cause the unavailability of seismically qualified systems through collapse or spurious operation, refer to 108-03650-SDG-005. The plant shall have sufficient capability to successfully fight seismically induced fires.
72200	Fuel Oil Systems	B	See ASI 50000 Electric Power System

ASI	System	Category	Notes
73000	Heating, Cooling and Ventilation Systems		
73110 73120	(Reactor Building) Cooling System (Reactor Building) Ventilation System	B	These systems shall maintain suitable conditions for seismically qualified equipment following a DBE.
73140	Reactor Building Containment Isolation	B	See ASI 68400 Containment System and 67314 Containment Isolation.
73450	Main Control Room (heating and cooling)	B	The system shall maintain suitable conditions for operators and seismically qualified equipment following a DBE.
73460	Secondary Control Area (heating and cooling)	B	The system shall maintain suitable conditions for operators and seismically qualified equipment following a DBE.
73900	Miscellaneous Structures (Heating and Cooling)	A, B	The system shall be qualified to be functional, during and after a seismic event, to ensure safety related systems' proper operation.
75000	Compressed Gases		
75120	Instrument Air	B	Air supplies required by all qualified systems to perform essential safety functions shall also be qualified. This may be done by qualified local air tanks. Designers shall note that the normal air system may become unavailable soon after a DBE due to normal leakage.
76000	Material Handling (Cranes and Hoists)	A	Cranes and hoists shall either be located so their failure during an earthquake does not cause damage to seismically qualified components or they shall be qualified to withstand the earthquake without structural failure.
79000	Radioactive Waste Management	A	The spent resin tanks and liquid effluent holding tanks shall be qualified for DBE Category A, unless it can be shown that failure of these tanks would not cause the release limits or exposure limits for operating staff to be exceeded following a DBE.

Appendix A

List of Safety Design Guides

IDENTIFICATION	TITLE
108-03650-SDG-001	Safety Related Systems
108-03650-SDG-002	Seismic Requirements
108-03650-SDG-003	Environmental Qualification
108-03650-SDG-004	Separation of Systems and Components
108-03650-SDG-005	Fire Protection
108-03650-SDG-006	Containment
108-03650-SDG-007	Radiation Protection

Appendix B

Acronyms

AC	Alternating Current
ACR™*	Advanced CANDU Reactor™
AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonably Achievable
ASDV	Atmospheric Steam Discharge Valves
BOP	Balance Of Plant
CA	Control Absorber
CANDU®	Canadian Deuterium Uranium®
CCP	Critical Channel Power
CCW	Condenser Cooling Water
CHF	Critical Heat Flux
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CSA	Canadian Standards Association
D_2O	Heavy Water
DBE	Design Basis Earthquake
DC	Direct Current
DCS	Distributed Control System
DEL	Derived Emission Limit
DG	Diesel Generator
EAB	Exclusion Area Boundary
ECC	Emergency Core Cooling
ECI	Emergency Coolant Injection
EDS	Electrical power Distribution System
FRS	Floor Response Spectra
GRS	Ground Response Spectra
HTS	Heat Transport System
HV	High Voltage
IAEA	International Atomic Energy Agency
ICRP	International Commission for Radiation Protection
ISO	International Organization for Standardization

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LCDA	Limited Core Damage Accident
LOCA	Loss Of Coolant Accident
LTC	Long Term Cooling
LV	Low Voltage
LWR	Light Water Reactor
MCR	Main Control Room
MOT	Main Output Transformer
MSIV	Main Steam Isolation Valves
MSSV	Main Steam Safety Valves
NEW	Nuclear Energy Worker
NSP	Nuclear Steam Plant
NSSS	Nuclear Steam Supply System
OM&A	Operation, Maintenance and Administration
PAM	Post Accident Monitoring
PSA	Probabilistic Safety Assessment
PTR	Pressure Tube Reactor
PWR	Pressurized Water Reactor
RAB	Reactor Auxiliary Building
RB	Reactor Building
RCU	Reactivity Control Unit
RCW	Recirculated Cooling Water
RSW	Raw Service Water
RWS	Reserve Water System
SCA	Secondary Control Area
SDE	Site Design Earthquake
SDS 1	ShutDown System 1
SDS 2	ShutDown System 2
SEU	Slightly Enriched Uranium
SFC	Single Failure Criterion
SGTR	Steam Generator Tube Rupture
SST	System Service Transformer
SU	Shutoff Unit
ULC	Underwriter's Laboratories Canada
UPS	Uninterruptible Power Supply
UST	Unit Service Transformer
ZCU	Zone Control Unit