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Regulatory Document



Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants

A Regulatory Policy Statement

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Canada

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This document is part of a set of regulatory documents
relating to the safety requirements for CANDU nuclear power plants:

R-7, Requirements for Containment Systems for CANDU Nuclear Power Plants

R-8, Requirements for Shutdown Systems for CANDU Nuclear Power Plants

R-9, Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants

These documents apply to reactors licensed for construction after January 1, 1981.

REQUIREMENTS FOR EMERGENCY CORE COOLING SYSTEMS FOR CANDU NUCLEAR POWER PLANTS

1. DEFINITIONS*

In this document,

"minimum allowable performance standards" means the set of operating limits or the range of conditions established for components or subsystems which define the minimum acceptable states for those components or subsystems as credited in the safety analyses; (*normes de rendement minimal admissible*)

"primary heat transport system" means that system of components which permit the transfer of heat from the fuel in the reactor to the steam generators or other heat exchangers employing secondary cooling. For purposes of this document, it does not necessarily include auxiliary purification and pressure control subsystems; (*circuit caloporteur primaire*)

"special safety system" means one of the following systems: shutdown systems, containment system, emergency core cooling system. (*système spécial de sûreté*)

2. BASIC REQUIREMENTS

2.1 All CANDU nuclear power reactors shall be equipped with an alternate means of cooling the reactor fuel in the event that the inventory of fuel coolant is depleted to an extent that fuel cooling is not assured. In this document, such a system shall be referred to as the emergency core cooling system** (ECCS).

2.2 (a) Except as noted in paragraphs (b) and (c), all equipment required for correct operation of the ECCS shall be considered to be part of the ECCS and shall meet all requirements of this document.

(b) Equipment required to supply compressed air, electrical power or cooling water to equipment for operation of the ECCS shall be considered as safety support equipment. Such equipment shall meet all relevant requirements of this document with the exception of sections 3.5 and 3.10.

(c) Equipment which is part of normal plant process systems and which is not specifically designed to mitigate the consequences of accidents, but which contributes to the cooling of the fuel following an accident, shall be considered as process equipment contributing to fuel cooling. Such equipment shall meet all relevant requirements of this document with the exception of subsections 3.4.1 to 3.4.9 and sections 3.5, 3.6 and 3.10.

2.3 The design requirements of the ECCS shall be based on the assumption that the least effective of the shutdown systems has operated successfully.

2.4 The ECCS shall be considered to be a special safety system.

2.5 Procedures to ensure compliance with the requirements of this regulatory policy statement shall be prepared by the licensee and shall require the approval of the Atomic Energy Control Board (AECB) prior to the issuance of a construction approval (procedures relating to part 3) or an operating licence (procedures relating to parts 4 and 5).

* These definitions do not constitute a complete list of terms used in this document, but are included to clarify the meaning of some terms for the assistance of the reader. A more comprehensive list of definitions of terms relating to CANDU nuclear power plants is available from the Canadian Standards Association (CSA), *Manual of Definitions for CSA Nuclear Standards Use by CSA Technical Committees*, CSA-N9409A-1989.

** Current CANDU reactor designs incorporate various systems for emergency coolant injection supply, recovery, circulation and heat removal. In this regulatory document, all necessary subsystems and components performing these functions shall be collectively referred to as the emergency core cooling system (ECCS).

3. DESIGN REQUIREMENTS

3.1 Minimum Allowable Performance Standards

Minimum allowable performance standards shall be defined for the ECCS and shall be listed or referenced in the Safety Report and in the Operating Policies and Principles for the plant. The minimum allowable performance standards shall also be specified for all major equipment and subsystems necessary for correct operation of the ECCS.

3.2 Cooling Requirements

For all events specified in Tables 1 and 2, the ECCS shall be capable of maintaining or re-establishing sufficient cooling of the fuel and fuel channels so as to limit the release of radioactive material from the fuel in the reactor and to maintain fuel channel integrity. For such events, the ECCS shall meet all of the following requirements:

- (a) the release of radioactive material from the fuel in the reactor shall be limited such that the reference dose limits are not exceeded;*
- (b) for events listed in Table 1, there shall be no failure of fuel in the reactor due to lack of adequate cooling;**
- (c) all fuel in the reactor and all fuel channels shall be kept in a configuration such that continued removal by the ECCS of the decay heat produced by the fuel can be maintained,** and
- (d) after adequate cooling of the fuel is re-established by the ECCS, the system shall be capable of continuing to supply sufficient cooling flow for as long as it is required to prevent further damage to the fuel.**

3.3 Environmental Requirements

3.3.1 All parts of the ECCS which may be required to operate, or to continue operating in response to any event specified in Tables 1 and 2 shall be designed to meet all necessary performance requirements while subjected to the most severe environmental conditions which could be present when or before such operation is required. These conditions may include, but are not necessarily limited to, the effects of debris, steam, water, high temperature and radiation.

Qualification is required for all ECCS equipment which may be required to operate, or to continue operating, following exposure to any of the above conditions. Qualification shall consist of tests to demonstrate to the extent practicable that the type of equipment can operate under conditions similar to those which would exist during or following the events specified in Tables 1 and 2. Where such tests are impracticable, analysis is required to demonstrate that this requirement is met.

3.3.2 The ECCS shall be designed such that, for all events specified in Tables 1 and 2, dynamic effects or jet forces caused by the events cannot result in impairment of the ECCS to an extent that relevant requirements in section 3.2 would not be met.

3.4 Availability Requirements

3.4.1 The ECCS shall be designed such that the fraction of time for which it is not available can be demonstrated to be less than 10^{-3} years per year. The system shall be considered available only if it can be demonstrated to meet all the minimum allowable performance standards as defined in accordance with section 3.1.

The availability of safety support equipment necessary for correct operation of the ECCS shall be commensurate with the availability requirements of the ECCS.

Availability calculations to demonstrate that this requirement can be met shall be included or referenced in the Safety Report. Such calculations shall be based on direct experience or reasonable extrapolations therefrom.

* This regulatory document does not define comprehensive requirements for safety analysis and reference dose limits. The reference dose limits referred to in paragraph (a) are those contained in the reference or in any subsequent AECB regulatory document, or as otherwise agreed in writing between the licensee and the AECB.

** The cooling requirements specified in paragraphs (b), (c) and (d) apply only to fuel in the reactor. For events where the initiating failure is in a single fuel channel or its appurtenances, these requirements do not apply to that channel or the fuel associated with it.

3.4.2 The design of the ECCS and safety support equipment shall take into account the long-term reliability requirements of those components which must continue to function following an accident. Standards for the long-term reliability of such components shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval.

3.4.3 The design shall have sufficient redundancy such that no failure of any single component of the ECCS can result in impairment of the ECCS to an extent that the system will not meet its minimum allowable performance standards under accident conditions.

This requirement does not apply to components which are not required to change state and which do not depend on safety support equipment in order to perform their design functions, provided that they are designed, manufactured, inspected and maintained to standards acceptable to the AECB.

3.4.4 Correct operation of ECCS equipment following an accident shall not be dependent on power supplies from the electrical grid or from the turbine generators associated with any reactor unit sharing the same containment system as the reactor involved in the accident, unless it is shown to the satisfaction of the AECB that the availability of such power supplies could not be impaired by the consequences of any accident for which the ECCS is required to operate.

3.4.5 As far as practicable, all ECCS equipment shall be designed such that its most probable failure modes will not result in a reduction in safety.

3.4.6 As far as practicable, the design shall be such that all maintenance and availability testing which may be performed when the ECCS is required to be available, can be carried out without a reduction in the effectiveness of the system below its minimum allowable performance standards.

3.4.7 As far as practicable, the design shall be such that a failed component can be put into a safe state, or such that the failure can be converted to a safe failure in some other manner.

3.4.8 The design shall be such that all necessary actions of ECCS equipment which are initiated by automatic control logic in response to an accident can also be initiated manually from the appropriate control room.

3.4.9 The design shall be such that, in the event of an accident, it is not readily possible for an operator to prevent injection of emergency coolant from taking place when such injection is required.

3.4.10 Reliability standards for process equipment contributing to fuel cooling, as defined in paragraph 2.2(c), shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval.

3.5 Separation and Independence Requirements

3.5.1 As far as practicable, the ECCS shall be physically and operationally independent from other special safety systems. No equipment which is part of the ECCS shall be used as part of another special safety system.

3.5.2 As far as practicable, the ECCS shall be independent from all process systems.

3.5.3 Design principles for the separation of redundant instrument channels and the services to them, associated with the ECCS, shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval.

3.5.4 If subsystems of the ECCS are considered to be independent for the purpose of the safety analyses, principles for separation and independence of such subsystems shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval.

3.6 Leakage Control Requirements

ECCS components located exterior to the reactor containment structure, and which may contain radioactive material following a loss of coolant accident (LOCA), shall be located such that any leakage (liquid, vapour or gas) which may occur is confined to the immediate vicinity of the components or is directed in a controlled fashion to appropriate leakage collection facilities. This requirement does not apply to fully welded piping and components.

3.7 Inadvertent Operation

The ECCS shall be designed as far as practicable such that inadvertent operation of all or part of the system shall not have a detrimental effect on plant safety.

3.8 Shielding Requirements

There shall be provision for adequate shielding of any ECCS equipment which could contain radioactive material following an accident, to permit personnel access to plant equipment for which such access might be required.

3.9 Status Monitoring Requirements

3.9.1 The design of the ECCS shall be such that the status of all important equipment required for operation of the ECCS can be monitored or inferred from the control room.

3.9.2 As far as practicable, all failures of ECCS components which may interfere with proper functioning of the ECCS shall be annunciated in the control room.

3.10 Codes and Standards

3.10.1 The application for a construction approval shall identify any aspects of the design which fail to comply with the applicable requirements of CAN3-N285.0-M81, *General Requirements for Pressure-Retaining Systems and Components in CANDU Nuclear Power Plants*. All exceptions to the requirements of this standard shall require approval by the AECB prior to their implementation.

3.10.2 The minimum acceptable standards for pressure-retaining components of the ECCS shall be CAN3-N285.0 Class 3.

3.10.3 The rules of the CAN3-N285.0 Class 2 shall be applied, as a minimum, to those portions of the ECCS which may be outside containment and which could contain appreciable quantities of radioactive materials as a result of an accident.

3.10.4 A list of any additional codes and standards to be applied to the ECCS, and the extent of their application, shall be prepared and shall require approval by the AECB prior to the issuance of a construction approval.

3.11 Seismic Requirements

All equipment required for continued fuel cooling after such cooling has been re-established shall be designed to remain functional following the site design earthquake for the plant site.

4. OPERATING REQUIREMENTS

4.1 Requirements for Normal Operation

4.1.1 The ECCS shall not be intentionally made unavailable at any time when its operation could potentially be required except in accordance with procedures which shall be prepared and which shall require approval by the AECB prior to the issuance of an operating licence. The ECCS shall be considered to be available only when it meets all the minimum allowable performance standards as defined in accordance with section 3.1.

4.1.2 Procedures for taking corrective action, in the event that the ECCS is found to be impaired during periods when availability is required, shall be prepared and shall require approval by the AECB prior to the issuance of an operating licence.

4.1.3* If any component of the ECCS is found to be inoperable, or impaired below its minimum allowable performance standards, the component and its associated equipment shall, as far as practicable, immediately be put in a safe condition, except as approved in accordance with subsection 4.1.2.

4.1.4* As far as practicable, maintenance on an ECCS component shall be carried out only when that component and its associated equipment have been put in a state which does not reduce the availability of the ECCS.

4.1.5* If redundant components require maintenance, each component shall be thoroughly tested following its maintenance, prior to the start of work on a subsequent component.

* Requirements 4.1.3, 4.1.4 and 4.1.5 do not apply during periods when the ECCS has been made unavailable in accordance with procedures approved pursuant to subsection 4.1.1.

4.1.6 When maintenance on a component is completed, it shall be tested to the extent practicable to demonstrate that it and its associated equipment function in accordance with design requirements.

4.1.7 The standard of maintenance shall be such that the reliability and effectiveness of all equipment, as claimed in the Safety Report and other documentation in support of an operating licence, are assured.

4.2 Requirements for Accident Conditions

If operator action is required for actuation of any ECCS equipment, all of the following requirements must be met:

- (a) there shall be instrumentation to give the operator clear and unambiguous indication of the necessity for operator action;
- (b) the reliability of such instrumentation shall be commensurate with the requirements for availability of emergency core cooling, as specified in section 3.4. If indication of only a single parameter is required, the instrumentation shall be part of the emergency core cooling system;
- (c) there shall be 15 minutes available following such clear and unambiguous indication before the operator action is required, and
- (d) there shall be clear, well-defined and readily available operating procedures to identify the necessary actions.

5. TESTING REQUIREMENTS

5.1 Commissioning Tests

5.1.1 Performance Tests

Prior to first criticality of any reactor, tests of the ECCS equipment shall be performed to verify that all design requirements have been achieved. Exceptions to this requirement will be allowed only if it is shown to the satisfaction of the AECB that some operational characteristics are impracticable to demonstrate under non-accident conditions, or that such tests would have a detrimental effect on safety.

5.1.2 Wiring Tests

Prior to first criticality of the reactor, tests shall be carried out on all electrical wiring associated with the ECCS to demonstrate that all connections are in accordance with the design.

5.2 Availability Tests

5.2.1 All ECCS equipment shall be monitored or tested at a frequency which is adequate to demonstrate compliance with the availability requirements specified in subsection 3.4.1.

5.2.2 A report on the availability of the ECCS shall be included in each annual report on the operation of the station. This report shall include:

- (a) a statement of the total fraction of time in the year during which the ECCS was not demonstrated to be available, as defined in subsection 3.4.1. Only periods during which the ECCS is intentionally made unavailable, in accordance with the conditions of section 4.1 shall be excluded from such calculations;
- (b) a comparison of the failure modes and failure frequencies observed in the operation of the station with the failure modes and failure frequencies used in the availability calculations prepared in accordance with subsection 3.4.1, and
- (c) availability calculations sufficient to demonstrate that the availability requirement of subsection 3.4.1 can continue to be satisfied, based on observed failure modes and failure frequencies.

REFERENCE

D.G. Hurst and F.C. Boyd, "Reactor Licensing and Safety Requirements", AECB-1059, June 1972.

TABLES *

TABLE 1

1. Failure of any feeder pipe in the primary heat transport system
2. Failure of an end fitting
3. Failure of a pressure tube and its associated calandria tube
4. Fuel channel flow blockage
5. Failure of a fuelling machine to replace a closure plug
6. Inadvertent opening of pressure relief or control valves on the primary heat transport system
7. Failure of steam generator tubes
8. Failure of feedwater/steam system
9. Any of events 1 to 8 above accompanied by an impairment of the containment system.

TABLE 2

1. Failure of any pipe or header in the primary heat transport system
2. Event 1 accompanied by an impairment of the containment system.

* In these tables, "failure" means both total failure and partial failure.