Comparison between CNSC Regulatory Documents and CSA Standards of Overpressure Protection Requirements for Primary Heat Transport System in CANDU Reactors

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1. Introduction

The CANDU (CANadian Deuterium Uranium) reactor system is equipped with various safety systems and processes to maintain reactor safety. The requirements for this are defined by regulatory documents from the Canadian Nuclear Safety Commission (CNSC) and standards from the Canadian Standards Association (CSA). In Canada, the regulatory documents R-7/R-8/R-9/R-10/R-77 have been superseded by CSA standards N290.1/N290.2/ N290.3/N285.0 (containment, shutdown, emergency core cooling system, and overpressure protection).

This paper aims to provide valuable insights to experts in the field by comparing the requirements between CNSC regulatory documents (R-77) and CSA standards (N285.0) pertaining to the overpressure protection system, which plays a crucial role in ensuring the safety of the reactor's primary heat transport system.

2. Relevant Standards

Nuclear power plants in Canada are subject to a variety of regulatory standards, which encompass CNSC regulatory documents, CSA standards, and other regulations like the National Fire and Building Codes. CNSC Regulatory Documents, issued by the Canadian Nuclear Safety Commission (CNSC), delineate regulations and guidelines for nuclear facilities and activities, reflecting the CNSC's regulatory role and responsibilities. CSA Standards, established by the Canadian Standards Association (CSA), define and standardize requirements across various industrial sectors in Canada.

3. Overpressure Protection Requirements

3.1 Overpressure Protection System

The CANDU reactor system possesses unique design characteristics, which entail specific requirements. The CANDU system is equipped with its safety systems and processes to maintain its safety. The overpressure protection system is one of the key safety systems within the reactor system, designed to ensure safe operation in the event of overpressure conditions. An appropriate response to overpressure conditions is essential for maintaining system integrity, and for this purpose, the CANDU system requires highly reliable overpressure protection systems.

3.2 Requirements for Overpressure Protection of the Heat Transport System

R-77 & CSA N285.0 require that certain ASME Service Limits be met depending on event frequency and either the 1st or 2nd SDS is assumed to act. The service limit for moderate frequency events would be level B (upset) for 1st SDS and level C (emergency) for 2nd SDS. For a level B transient, the limit is 110% of design pressure. For level C conditions, a target of 120% of design pressure is used in the analysis for peak pressure. For level D (faulted), the same analysis target as for level C is conservative to ensure HTS integrity.

4. Comparison of CNSC Regulatory Documents and CSA Standards for Overpressure limits

The requirements for overpressure limits in R-77 and CSA N285.0 were compared in Table 1.

Table 1. Comparison between CNSC R-77 and CSA N285.0 for Overpressure Protection Requirements

<table>
<tr><th colspan="2">Section No.</th><th rowspan="2">CNSC R-77 [1]</th><th rowspan="2">CSA N285.0 (Section 7.6) [2]</th></tr>
<tr><th>CNSC R-77</th><th>CSA N285.0</th></tr>
<tr><td>3.1</td><td>7.6.2.2 Table 2</td><td>Agreement is to be reached between the licensee and the CNSC as to the correct placement of individual events in these categories on a case-by-case basis. To assist in this process the following numerical ranges of probability of occurrence are suggested:
(a) moderate frequency > 10^{-2}/RY
(b) low frequency, 10^{-2}/RY~10^{-4}/RY
(c) extremely low frequency < 10^{-4}/RY</td><td>The service limits to be applied shall be determined in terms of frequency of an event and the operation of one shutdown system (see Table 2), and the applicable regulatory documents.

Table 2
Guidelines for service limits vs. frequency of events
<table>
<tr><th rowspan="2">Frequency of events per year</th><th colspan="2">Service limits</th></tr>
<tr><th>First SDS trip</th><th>Other SDS trip</th></tr>
<tr><td>Moderate (>10^{-2})</td><td>B</td><td>C</td></tr>
<tr><td>Low (10^{-2} ~ 10^{-4})</td><td>C</td><td>D</td></tr>
<tr><td>Extremely low (<10^{-4})</td><td>D</td><td>D</td></tr>
</table></td></tr>
</table>

<table>
<tr>
<td>3.2</td>
<td>Table 2</td>
<td>Table 1 states the allowable service limit for each the event categories assuming that either:

(d) the first shutdown system trips as intended;
or
(e) the first shutdown system fails to act, but the second shutdown system trips

The "first shutdown system" is the one which is intended to trip first for the particular event under consideration. It may be either of the two shutdown systems (i.e., either SDS1 or SDS2).</td>
<td>Table 2
Guidelines for service limits vs. frequency of events
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<tr><td rowspan="2">Frequency of events per year</td><td colspan="2">Service limits</td></tr>
<tr><td>First SDS trip</td><td>Other SDS trip</td></tr>
<tr><td>Moderate ($>10^{-2}$)</td><td>B</td><td>C</td></tr>
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<tr><td>Extremely low ($<10^{-4}$)</td><td>D</td><td>D</td></tr>
</table>
Notes:
1) B, C, and D service limits are defined in Clause 7.3.1 c) and the ASME BPVC, Section III, NCA-2140.
2) SDS = shutdown system.
3) First SDS trip refers to first shutdown system to trip and can be either SDS 1 or SDS 2.
4) If the first shutdown system fails to act, the other shutdown system trips.
5) The placement of individual events in the category of moderate, low, or extremely low shall be accepted by the regulatory authority on a case-by-case basis.</td>
</tr>
<tr>
<td>3.3</td>
<td>7.6.2.3 (a)
7.6.2.3 (b)</td>
<td>In analyses to demonstrate that the requirements of Table 1 are met:

(a) process system protective action (including regulating system action) must not be credited;
and
(b) only second trip parameters in each of the shutdown system may be credited (except for the special cases outlined in Section 3.4 to 3.6 below).</td>
<td>(a) For some events, control system action, including the reactor regulating system by itself, is capable of protecting the heat transport system from overpressure. However, credit for these actions shall not be counted in the overpressure assessment.
(b) The first trip parameter shall be credited if it is heat transport system high-pressure; otherwise, the second trip parameter of each shutdown system shall be credited.</td>
</tr>
<tr>
<td>3.4</td>
<td>7.6.2.3 (b)</td>
<td>The first trip parameter may be credited in the case where this trip parameter is high pressure in the system under consideration. (This recognizes the unique relevance of a high-pressure trip to overpressure protection.)</td>
<td>(b) The first trip parameter shall be credited if it is heat transport system high-pressure; otherwise, the second trip parameter of each shutdown system shall be credited.</td>
</tr>
<tr>
<td>3.5</td>
<td>7.6.2.3 (c)</td>
<td>In a case where only one trip parameter is installed in the first shutdown system and where this parameter is not high pressure in the system under consideration, the service limits given for the first shutdown system in Table 1 must be met by the first parameter of the second shutdown system.</td>
<td>(c) When only one trip parameter is available on the first shutdown system to trip and it is not high pressure, only the first trip parameter of the other shutdown system shall be credited (i.e., the service limits given for the first shutdown system in Table 2 shall be met by the first parameter of the other shutdown system).</td>
</tr>
<tr>
<td>3.6</td>
<td>7.6.2.3 (c)</td>
<td>In a case where only one trip parameter is installed in the second shutdown system, this trip parameter may be credited.</td>
<td>(c) In a case where only one trip parameter is installed in the other shutdown system, this trip parameter may be credited, subjected to the regulatory authority's review and acceptance.</td>
</tr>
<tr>
<td>4.1</td>
<td>7.6.2.3 (d)</td>
<td>In reactor plants where power-actuated relief valves are installed and are connected to the instrumentation associated with one of the shutdown systems, these relief valves should be considered as part of the shutdown system in question. Consequently, such relief valves should only be credited in analyses in which it is assumed that the shutdown system in question trips.</td>
<td>(d) When power-actuated pressure-relief valves are installed and are connected to instrumentation associated with one of the shutdown systems, these pressure-relief valves shall only be credited to overpressure protection for the heat transport system when it is assumed that the shutdown system in question trips.</td>
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<tr>
<td>4.2</td>
<td>7.6.2.3 (e)</td>
<td>Where power-actuated relief valves are installed but are not connected to the instrumentation associated with either shutdown system, these relief valves may be credited in all overpressure protection analyses, providing that:

(a) each relief valve is equipped with its own instrumentation (and power supplies, etc.) so that no single failure would result in the disablement of more than one relief valve;
and
(b) this instrumentation is designed to the same standards as equivalent instrumentation in the shutdown system</td>
<td>(e) When pressure-relief devices are installed but are not connected to either shutdown system, the pressure-relief devices may be credited for overpressure protection purposes where either shutdown system operates, provided that each pressure-relief device is independent of any other (e.g., equipped with its own instrumentation and power supplies, etc.) so that no single failure would result in the disablement of more than one relief valve and its instrumentation is designed to the same safety standards used for shutdown system instrumentation.</td>
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<tr>
<td>Table 1</td>
<td>Table 2</td>
<td>Table 1
Overpressure protection requirements for primary heat transport systems in CANDU power reactors fitted with two shutdown systems
<table>
<tr><td rowspan="2">Frequency of event or failure</td><td colspan="2">Service limits</td></tr>
<tr><td>First SDS trip</td><td>Other SDS trip</td></tr>
<tr><td>Moderate</td><td>B</td><td>C</td></tr>
<tr><td>Low</td><td>C</td><td>D</td></tr>
<tr><td>Extremely low</td><td>D</td><td>D</td></tr>
</table>
Notes:
1) Process system protective action (including regulating system action) may not be credited.
2) Second trip parameters only may be credited, except as outlined in note 3 below.
3) The first trip parameter may be credited if it is high pressure in</td>
<td>Table 2
Guidelines for service limits vs. frequency of events
<table>
<tr><td rowspan="2">Frequency of events per year</td><td colspan="2">Service limits</td></tr>
<tr><td>First SDS trip</td><td>Other SDS trip</td></tr>
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Notes:
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2) SDS = shutdown system.
3) First SDS trip refers to first shutdown system to trip and can be either SDS 1 or SDS 2.
4) If the first shutdown system fails to act, the other shutdown system trips.</td>
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		the system under consideration. 4) The "first shutdown system" is first to trip (it may be either SDS1 or SDS2).	5) The placement of individual events in the category of moderate, low, or extremely low shall be accepted by the regulatory authority on a case-by-case basis.

It was confirmed that the two documents address identical technical requirements.

5. Conclusions

This paper compared the requirements between CNSC regulatory documents and CSA standards related to the overpressure protection system, which plays a crucial role in ensuring the safety of the reactor. We analyzed the technical details covered by each document and identified points of agreement between their requirements. This information could offer significant insights for future regulatory frameworks concerning the safety analysis of domestic reactors.

REFERENCES

[1] CNSC, R-77, Overpressure Protection Requirements for Primary Heat Transport Systems in CANDU Power Reactors Fitted with Two Shutdown Systems, 1987.
[2] CSA, N285.0, General requirements for pressure-retaining systems and components in CANDU nuclear power plants, 2017.