CANDU Fuel Safety Criteria: A CNSC Perspective

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ABSTRACT (Extended)

1. The fuel safety criteria concept and its role in ensuring nuclear safety

The ultimate goal of nuclear power plant safety is prevention of radiation-related harm to the workers at the plant, the public and the environment. The applicationof defence-in-depth (DID), throughout the design process and operation of the plant, is a cornerstone of the Canadian regulatory philosophy.

DID is implemented first by means of successive physical barriers to the release of radioactive material. The nuclear fuel matrix and the nuclear fuel sheath constitute the first two physical barriers. The other two physical barriers in a reactor are the primary heat transport system pressure boundary and the containment. The integrity of these physical barriers is protected by applying the concept of DID to them. This is achieved by ensuring effective performance of the fundamental safety functions, namely, control reactivity excursions, cool the nuclear fuel and contain the radioactive material.Deployment of several independent and overlapping layers (levels of DID) of provisions such as design features, operational measures and the introduction, for the whole spectrum of plant states, of various safety limits assist in ensuring effective performance of safety functions and maintenance of adequate safety margins.

In this presentation, the term “fuel safety criteria” refers to safety limits established to prevent or mitigate, for any specific plant state, damage to the nuclear fuel, and damage that the fuel may cause to its interfacing systems and structures.

Fuel safety criteria must be met in order to achieve an adequate level of DID. They are, among other things, required input to:

- demonstrate fuel fitness-for-service for normal operation and anticipated operational occurrences;
- determine effectiveness of special safety systems, through application of deterministic safety analysis, to protect the physical barriers that prevent the release of radioactive material for all design basis events;
- determine the plant Safe Operating Envelope and adequacy of safety margins through application of deterministic safety analysis.

For normal operation and anticipated operational occurrences, a number of CANDU fuel safety criteria have been defined to ensure that the fuel remains fit for service. Examples include limits on fuel element internal gas pressure, fuel sheath oxidation thickness, spacer pad and bearing pad wear, and axial loads on the fuel bundle.

The limit on total fuel enthalpy (the energy deposited in the fuel during normal operation plus the energy deposed due to the power pulse) in a large loss of coolant accident scenario, and the avoidance of fuel sheath dryout in a slow loss of regulation accident, are examples of CANDU fuel safety criteria for design basis accidents.

2. Fuel safety criteria related activities in Canada over the last fifteen years

In the last fifteen years or so there has been, within the Canadian nuclear industry, a significant amount of fuel safety criteria related activities. Key drivers forthese activities were:

- The need for improved understanding of safety margins related to the large loss of coolant accident;
- The decrease in safety margin for some relatively high frequency postulated design basis accidents due to the effect of HTS component ageing on fuel bundle dryout power;
- Crud deposition on fuel bundles in Pickering B units;
- Introduction of rod-based guaranteed shutdown state as a new means to ensure reactor subcriticality during an outage in order to enhance operational flexibility;
- Fuel bundle endplate cracking issues at Bruce B units;
- Fukushima event : fuel pool safety for beyond design basis accidents;
- Proposed new CANDU reactor designs, such as ACR-700/1000 and EC-6;
- Development of the Low-Void-Reactivity fuel bundle.

Although in Canada the prime responsibility for the safety of nuclear installations rests with the licensees, the regulator nevertheless plays an important role in ensuring that all nuclear activities are conducted in a safe manner and in accordance with the best international practices. The Canadian industry’s fuel safety criteria related activities are no exception.

3. Objectives of the presentation

The primary objective of this presentation is to provide a regulatory perspective regarding the fuel safety criteria related work performed in Canada over the past 15 years. A brief overview of the CNSC's regulatory oversight activities willbe provided; it will include a brief description and discussion of:

1) The regulatory requirements, expectations and guidance pertinent to the topic of fuel safety criteria;
2) Some of the fuel safety criteria related issues mentioned in section 2;
3) The licensing and compliance activities conducted by CNSC staff;
4) Some of the on-going fuel safety criteria related R&D activities in Canada;
5) Some of the challenges faced in performing those regulatory oversight activities and lessons learned.

Given that I am currently the Chair of an IAEA Working Group, whose mandate is to write a technical document (TECDOC) on fuel safety criteria used in countries where pressurized heavy water reactors are operated, I will conclude the presentation with a brief description of this project, covering the following topics:

1) Working group members and the participating countries;
2) Purpose and applicability of the IAEA TECDOC;
3) Project activity steps and timeline for completion.

[2]Note: My presentation *"CANDU Fuel Safety Criteria: A CNSC Perspective"* is available on the CNSC website (2016 Presentations):

https://www.cnsc-ccsn.gc.ca/eng/resources/presentations/2016.cfm

If you have difficulties having access to the presentation on the CNSC website, you can contact me at my email address: michel.couture@canada.ca