Regulatory Activities in the Area of Fuel Safety and Performance

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Abstract

Generic Action Item 94G02 "Impact of Fuel Bundle Condition on Reactor Safety" in many ways determined the present priorities in regulatory activities related to fuel performance. As one of the closure criteria it required that all licensees establish "an effective formal and systematic process for integrating fuel design, fuel and channel inspection, ... laboratory examination, research, operating limits and safety analysis". To date, such a process has been, to a large extent, put in place by all licensees. To assure that such processes remain operational and effective after the GAI closure, CNSC required, through S-99 [1], to report annually on fuel performance and major activities in the fuel safety area. The scope of reported information has been defined to allow CNSC staff evaluation of key events and trends in fuel performance. To compliment reporting by the industry, CNSC staff has conducted targeted inspections of fuel compliance programs at all sites. Combined together, these activities provide the regulator with the confidence that CANDU fuel is robust and operates with safety margins.

The scrutiny, to which fuel performance has been subjected lately, has allowed identification of certain programmatic weaknesses and gaps in the knowledge concerning the fuel behaviour under various conditions. It has become apparent that top-level strategies for assessment of fuel performance may have been inadequate and far from systematic; fuel inspection practices and capabilities have varied significantly from site to site; certain issues were identified but remained unaddressed for significant time; priorities in experimental or design support activities were not assigned consistently. The presentation gives examples of areas where, in the opinion of the CNSC staff, further work is required to support fuel design and safety envelopes.

The implementation of new CANFLEX fuel designs is currently being considered by the industry and CNSC staff has been engaged in the review process. These new designs are aimed, among other things, at restoring safety margins by reducing void reactivity and compensating for ageing effects. The CNSC fuel design review process is briefly described as well as its key review objectives and review areas.

Finally, the presentation touches upon the plans for the development of regulatory documents. These documents will formally state CNSC expectations in the area thus leading to more consistent and systematic processes, and promoting safe and reliable fuel operation.

Introduction

I would like to thank the conference organizers for the opportunity to address this audience and present the CNSC views on some aspects of CANDU fuel performance and safety.

As you may know, the CNSC mandate is to protect the health, safety and security of the Canadian public, to protect the environment and to ensure that Canada's commitments with regard to peaceful use of nuclear energy are respected. Of course, this mandate spans over all activities that involve nuclear energy and substances, but today my talk will only deal with nuclear fuel, and more specifically, use of fuel in power reactors.

Before I get into specifics it may be useful to spend a minute identifying some of the key factors that have bearing on activities in the fuel area.

- First of all, there is a whiff of nuclear revival up in the air, driven by increased demand for electricity, high prices of fossil fuel, and environmental pressures for emission-free energy sources. This leads to economic incentives to use the existing nuclear capacity to its fullest, refurbish plants nearing the end of design life, and look into new builds.
- Pressures brought up by opening, even if only partial, of electricity markets, lead to a more careful scrutiny of the economic bottom line, with ensuing need to better justify and prioritize all safety related work.
- Most of CANDU reactors are of respectable age, which is not always a good thing. Aging of reactors places new challenges to reliable performance of various systems.
- The number of experimental facilities, in particular, research reactors allowing in-core experiments, has shrunk dramatically world-wide. Many remaining R&D installations are often quite old and may not fully satisfy the current expectation.
- Similarly, a challenge exists in maintaining adequate level of expertise at the time of a retirement wave of highly qualified specialists who started their careers in the blooming years of CANDU technology.
- The regulatory regime is changing. There is an increased demand for accountability, transparency and effectiveness from the Government, public and industry likewise. The CNSC has embarked on a Power Reactor Regulation Improvement Program with the objectives of introducing a formal risk management approach and enhancing consistency of regulatory processes.

These factors are of general nature and influence the overall course the nuclear industry is taking; they also have impact on activities in the fuel area.

Regulatory perspective

The existing 28 and 37 element bundle designs are mature and appear to be well established. Indeed, the defect rate is generally quite low; any other fuel-related failures are few and far apart; there have been a very limited number of incidents during on-power fuelling or fuel transfer to the irradiated fuel bays. Everything points out that fuel performance in Canadian nuclear power reactors has been reliable and safe. The consistently high fuel performance can be attributed to a robust design, high quality manufacturing, build-in safety margins, and prudent operation assuring compliance with the set limits. Nevertheless, there are still areas where improved understanding of fuel condition and its impact on safety analysis results is required or desirable, including:

- characterization of material properties, e.g. for defective or doped fuel
- assessment of the reactor aging impact on fuel performance;
- assessment of fuel defect impacts on operation and safety analysis assumptions;
- confirmation of certain design or operational limits;
- validation of fuel codes and model to reduce the associated uncertainties, etc.

While the overall fuel performance has been good, there have been instances when defect rates increased for a variety of reasons. Safety analysis results periodically necessitated operational restrictions to assure acceptable consequences of design accidents. Corrective actions, taken in response to such “discoveries”, included changes in design, manufacturing processes and tightening of operational limits.

In this situation, how does the CNSC staff perceive the objective of regulatory activities in the fuel area? To state it briefly, we strive to establish and maintain adequate confidence that fuel is designed and operated to the highest safety standards. The overall confidence in safe fuel design and operation builds on confidence in associated processes, tools, expertise, and ability to respond to “discoveries”.

GAI 94G02 “Impact of Fuel Bundle Condition on Reactor Safety”

Generic Action Item 94G02 “Impact of Fuel Bundle Condition on Reactor Safety” in many ways determined the present priorities in regulatory activities related to fuel performance.

The underlying reason for initiation of this action item was the observation that the condition of certain fuel bundles irradiated in CANDU reactors differed from that predicted and accounted for in design, operation, and safety analysis documentation. The fuel bundles in question showed signs of more-than-expected degradation such as end plate cracking, spacer pad wear, element bowing, sheath wear, bearing pad wear, sheath strain, disappearance of CANLUB layer, oxidation of defective fuel, and fission product release.

Even though it was initiated largely in response to the Darlington acoustic vibration issue, the GAI scope included all aspects of fuel bundle in-core degradation and its impact on reactor safety.

It was noted that fuel bundle degradation depends on the reactor design, fuel channel, fuel design, fuel manufacturer, and operating conditions. Since theoretical models were unable to correlate adequately the fuel condition to these factors, fuel and pressure tube inspections were deemed necessary. In the view of CNSC staff, owing to the number of factors upon which the degradation depends, the inspection program must be extended beyond inspection of defective fuel to observe these changes. It was judged at that time that licensees did not have a formal process to ensure that the fuel and fuel channel conditions were identified and accounted for.
To address this situation, all CANDU licensees were requested to establish a formal process to ensure that the condition of the fuel and fuel channels are identified and accounted for, to determine the extent of fuel degradation and, in general, to determine whether fuel remains within the analyzed condition. The process was to have the following features:

a. annual review (by the licensee) to demonstrate effective implementation and adequate corrective actions taken for deficiencies identified in the review;
b. sufficient resources for each participating group (design, inspection, examination, research, safety analysis, and operation) to ensure that the fuel condition is known and accounted for adequately;
c. clearly defined maximum allowable limits, under normal operation, on fuel condition in terms of sheath strain, element bowing, wear (spacer pad, bearing pad, end plate), pressure tube scratching and wear, burnup and residence time; design documentation and pressure tube fitness-for-service guidelines should be updated accordingly;
d. a determination, for the full range of the operating envelope, the power boost sheath failure threshold for CANLUB fuel and the chemistry effects of CANLUB on centerline temperature and fission product release;
e. assurance that the safety analysis accounts for the allowable fuel condition when combined with aging effects such as pressure tube creep, the effect of CANLUB in the fuel, and any chemistry effects on temperature and fission product release, including a calculation of the number of sheath failures resulting from a bounded loss of power control;
f. a surveillance program that demonstrates compliance with identified limits, e.g., detection of significant changes in fuel condition caused by changes in fuel fabrication and factors affecting acoustic resonance; and
g. allowance for CNSC audits.

Fuel (and Fuel Channel) Programs

To achieve the closure of GAI 94G02, processes for integrated assessment of fuel performance and safety have been put in place by all licensees. While there are substantial differences in the approaches and scope of processes, the intent remains the same: to be able to verify, with high confidence, compliance of fuel to a set of established limits so that fuel remains within the design and operating envelope for which it has been qualified. It is acknowledged, both by the industry and the regulator, that the Fuel and Fuel Channel Programs (or similar processes) have brought a number of benefits, including an integrated assessment of information by experts in various subject matters; improved identification of trends in performance; consistent documentation of concerns and their closure; sharing of information and help in development of expertise. There also remain and will always be certain difficulties in maintaining the once setup processes: difficulties in securing the initial and continuous buy-in from management and staff; effort required to maintain processes up-to date and up-to the standard; lax approach to documentation; and overlaps with other existing processes.

It must be recognized that the value of programs increases with consistency of implementation; this does not mean that different licensees cannot tailor their activities to their specific needs and other existing programs. In fact, as we have seen, the approaches taken by CANDU licensees in establishing an integrated process to close GAI 94G02 are quite different. Moreover, as the experience accumulates, the processes develop and change. This is accepted by CNSC staff as long as the process in place continues to meet the following key objectives:

- identification of all relevant information that may indicate abnormal fuel performance in normal operation or accidents;
- integrated assessment of such information by subject matter experts;
- assessments of trends in fuel performance;
- linking of compliance activities with potential issues in fuel performance;
- linking the R&D effort with potential issues in fuel performance;
- consistent approach to documentation of issues and their resolution;
- maintaining up-to-date design documentation;
- implementation of self-assessment.

Annual fuel performance reporting

Following the closure of GAI 94G02 for some of licensees, CNSC staff felt that a systematic reporting mechanism needed to be set up to allow tracking of fuel performance in a "non-invasive" manner. Some licensees had already been providing fuel-related information to the CNSC on a regular basis and it was judged to be a practice deserving a wider application. Consequently, all licensees were requested to provide annual reports on fuel performance starting from 2002. The regulatory standard S-99 "Reporting Requirements for Operating Nuclear Power Plants" issued in 2003 [1], formally included a requirement to "file … a report describing licensee's fuel monitoring and inspection program over the previous calendar-year". To further increase the utility and consistency of annual reports CNSC staff met with the industry representatives to discuss the scope of reporting, such that only the essential activities and results, indicative of fuel performance and trends, would need to be reported. The following essential elements for reporting were identified:

- operating conditions
- changes in manufacturing processes and design

- results of in-bay inspections
- results of post-irradiation examinations
- occurrence of in-core fuel defects
- related activities, such as operational experience, special irradiations, R&D and safety analysis findings.

The experience to date – and we have had 4 annual reports submitted from each plant – has proved a great value of these reports to CNSC staff as a single source of essential information related to fuel performance. The information reported confirms, based on results of compliance activities that fuel continues to perform safely. It also allows a high level trending assessment when comparing the last-year results with the five-year average performance. We note, however, that some of the reports lack in detail or do not follow closely the reporting scope. CNSC staff believes that the consistency of reported information could be and should be improved. Perhaps, the industry could get together and work out a common, agreed-upon structure of reports, without waiting for an action from CNSC staff. Alternatively, CNSC staff would raise station specific actions to ensure that the reported information fully meets expectations.

Fuel compliance activities

Another type of activities that CNSC staff undertook as part of closure of GAI 94G02 is of a more intrusive nature. We have conducted fuel performance inspections now at all sites. While the primary focus of inspections carried out so far was related to issues raised under the GAI 94G02, we intend to periodically conduct similar inspections in the future, regardless of the status of this GAI. The purpose and scope of inspections may change, as we gain experience and depending on site specific situation, but the general objectives of CNSC staff inspections of fuel performance activities are as follows:

- to verify that station practices ensure that, during normal operation, fuel remains within well defined and justified envelopes of limits
- to confirm that there is an effective process that integrates assessments of activities related to fuel use, inspections, design, research and safety analysis.

What are the highlights of CNSC inspections so far? Our findings indicate that stations practices have strengths and potential weaknesses that generally do not repeat from site to site. Having said that, here are a few conclusions that are to some extent common to all stations:

- roles and responsibilities of groups involved in fuel-related activities generally needed to be defined better to provide an integrated approach to the assessment of fuel performance
- fuel design documentation required updating
- there were examples of lacking justification for some of fuel limits
- fuel inspection capabilities often limit the scope of compliance activities.

From the annual reports and on-site inspections we found out that there are large differences in the scope of confirmatory compliance activities, such as in-bay inspections of the irradiated bundles. While some stations inspect hundreds of bundles, others do next to none. CNSC staff is of the opinion that the station is in a better position to define a sufficient scope of in-bay inspections. However, we cannot agree with the situation when no inspections have been conducted in several years. As stated in the position statement for GAI 94G02, fuel inspections are deemed necessary because models are unable to correlate adequately the fuel condition to all the factors to which fuel could be subjected. The inspection program must be extended beyond inspection of only defective fuel to provide assurance that fuel condition remains as assumed in safety analysis and free of excessive degradation. In this context, the advance with development and installation of FEMER holds significant promise in improvement of the quantity and quality of fuel inspection data. While we would have preferred the industry to develop a common approach to post irradiation inspections and examinations, we are prepared to take an action and make sure that activities are in place to provide continued assurance of a good bundle health and compliance with limits.

Safety analysis issues

Unlike fuel performance in normal operating conditions, there is less confidence in fuel performance in accidents, at least in certain events. There are two reasons for that:

- some of CANDU design basis events results in quite severe conditions
- there is a relatively limited amount of experimental data for the limiting values of accident parameters

A number of accident scenarios, such as loss of coolant, flow blockage, end fitting ejection, fuelling accidents, etc result in degraded fuel cooling conditions and thus may lead to release of radioactive fission products from fuel into the coolant and containment, and eventually into the environment. Fuel behavior in such accidents must be analyzed using models which are able to consider a large number of phenomena that come into play. Our confidence in analysis results depends to a large degree on the adequacy of validation of computer codes. Because of complexity of phenomena involved, the mathematical models cannot be derived from first principles and depend on empirical correlations and coefficients. Uncertainty of code predictions results from lack of knowledge and build-in approximations, and must be evaluated through an appropriate validation process.

Realizing the role of codes as analytical tools in assuring confidence in analysis results, CNSC engaged independent consultants to review validation of the current fuel codes, such as ELESTRES-IST, ELOCA-IST and FACTAR. The objectives of such reviews were identified as:

- evaluation of the overall Canadian approach to code validation
- identification of gaps in experimental data
- assessment of the stated range of codes' applicability
- recommendations for modeling improvements
- assessment of validation documentation.

To give you a flavor of findings coming out of these independent reviews, here is a sample of observations:

- no fission product release model in ELOCA, which may have an impact on predictions of the gap pressure, gap heat transfer, and fuel volumetric changes
- deficiencies in the interface of ELOCA with ELESTRES, potentially leading to non-physical results and mismatches
- bundle geometrical deformation, with the exception of sheath strain, is not modeled, which could affect predictions of heat transfer to the coolant under high temperature conditions
- the maximum transient element linear power for which codes are formally validated may not be sufficient for some transients, such as LBLOCA power pulse
- gaps in experimental data used for code validation, in particular for power pulse and high temperature conditions predicted in the critical LBLOCA
- lack of ability to model non-uniform sheath strain (bulging)
- lack of ability to model fuel-to-end cap heat transfer
- lack of ability to model defected fuel
- lack of justification for pellet-cladding interaction model
- inability to correctly predict run-away oxidation as observed in some experiments

The conclusions that CNSC staff draws from our own reviews and the input provided by consultants can be summarized as follows:

- the current fuel codes incorporate models for most relevant phenomena
- when applied in deliberately conservative analyses, codes are likely to generate acceptable, bounding results
- when used in a best estimate type of analysis, the uncertainty in final results is quite large
- for the extreme ranges of parameters, for example in LBLOCA, stagnation breaks, and flow blockage events, the fuel codes may not have models for all key phenomena and may not be sufficiently validated.

In particular, the recent experience with prototype applications of the Best Estimate and Uncertainty (BEAU) methodology to the Large Break LOCA analysis has shown that accuracy of fuel codes, as could be determined from the current validation, is not sufficient for the purpose. Additional validation effort is likely to be required to narrow uncertainties in fuel code predictions for use in best estimate analyses.

CNSC staff is aware that the industry is in the process of addressing many of the identified weaknesses, mostly in a coordinated fashion through COG. We also note, however, that in some instances the progress has been rather slow.

Review of new fuel designs

Recently, CNSC staff has been involved in reviews of two new fuel designs: CANFLEX-LVRF[1] and the ACR[2] fuel. These new designs are aimed, among other things, at improving safety margins by reducing void reactivity and increasing critical channel power. They are viewed as a means of addressing current Large LOCA power pulse issues, and avoiding potential reactor de-ratings due to aging effects such as pressure tube diametral creep which tends to reduce the reactor overpower (ROP) trip margins.

These new designs differ from the 28 and 37-element CANDU© fuel being currently used in Canadian power reactors in essentially three ways:

- They are based on AECL 43-element CANFLEX bundle concept
- They will be using slightly enriched uranium fuel pellets
- They have a central burnable poison element.

CNSC review of the CANFLEX-LVRF design

The CNSC staff's review of the CANFLEX-LVRF design is being done on a request by Bruce Power. According to a power reactor operating license condition, the licensee must obtain the Commission approval for the design of fuel prior to its loading into a reactor. In order to grant such an approval for a fuel design, CNSC staff conducts a multi-disciplinary assessment to gain assurance that new fuel would perform safely under in- and out- reactor conditions. According to the current implementation process, the full core loading is preceded by a demonstration irradiation (DI) of several bundles.

CNSC approval of the DI will be based in part on a review of the CANFLEX-LVRF design verification activities. The objective of this review is to verify that the CANFLEX-LVRF design has been qualified to operate within a well defined and justified design and operating envelope and that envelope covers, at the very least, the DI operating envelope. The methods of demonstration that the CANFLEX-LVRF design meets its design requirements will therefore be examined. Those methods include in-reactor and out-reactor tests, operational experience, analyses and assessments. Particular attention will be given to the basis of certain operational and design limits, given their close relationship to acceptance criteria used in fuel compliance activities, and to fuel initial conditions assumed in safety analyses. Examples of such limits are the fuel design overpower envelope, power ramp limits, bundle integrity limits, allowable range

[1] LVRF stands for low void reactivity fuel
[2] Advanced CANDU Reactor

of heat transport system pressure and flows, pressure tube dimension envelope limits, element bowing, spacer and bearing pad wear.

CNSC review of the CANFLEX-LVRF design verification activities are organized into six topical assessments: physics, fuel thermalhydraulics, systems thermalhydraulics, thermal-mechanical aspects of fuel behavior, fuel/pressure tube interface and safety analysis. Although traditionally the term "design verification" refers to activities aimed at addressing issues related to normal operations, CNSC staff conclusions regarding the adequacy of the fuel qualification will also be based on the review of the safety analysis supporting the application. In the review of safety analysis, particular attention will be given to the experimental basis of the fuel integrity acceptance criteria which are used in the analysis of certain design basis accidents.

Regarding the documentation that must be submitted for CNSC review, the list includes the Fuel Design Description and Fuel Design Requirement documents, the fuel design drawings, the Fuel Design Verification Plan, the Fuel Design Manual, the Design and Operational Envelope document, various in-reactor and out-reactor tests specifications and test reports, as well as assessments/ analysis reports pertinent to the design verification activities, the safety analysis, and the validation reports of fuel design and safety analysis computer codes.

CNSC review of the ACR fuel design

The ACR fuel design review is in its very early stages, and is being performed in support of a CNSC licensability statement regarding the ACR reactor design. Accordingly, the scope of this review will differ from that of the CANFLEX-LVRF. Although many of the details of the review process have yet to be finalized, it is safe to say that the review of the ACR fuel design will be aimed at providing assurance to CNSC staff that the scope of R&D, which the designer has performed or is planning to perform in support of the ACR fuel design, is adequate. The review will cover the following three aspects of fuel related R&D:

- Fuel design verification/qualification
    - Normal operation
    - Anticipated operational occurrences
- Fuel design code validation
- Fuel related R&D in support of ACR safety analyses, including fuel safety analysis codes.

Priority activities for the future

What are the near term priority activities in the fuel area from the regulatory perspective?

Effort must be maintained to assure reliable and safe fuel performance. Any trends in fuel performance must be identified and evaluated in a timely fashion. Integrated programs, as have been established by licensees, should continue tracking fuel performance and provide assessment of emerging issues. These programs should also help prioritize activities aimed at providing better support of the fuel design envelope. The following issues can be mentioned where the currently available information is not fully adequate:

- time limits for cross flow exposure of new and irradiated bundles. Until now, the cross flow limits have been inconsistent among the licensees and partially lacking in experimental support
- maximum flow limits, including flows in cold or defuelled conditions and accounting for aging effects
- limits for axial loads on fuel bundles, in particular, asymmetrical loads in sagged channels
- characterization of material properties and behavior of defected fuel.

Compliance activities must be sufficient to verify, with confidence, that fuel condition in the core is known and within the qualified envelope of parameters. For this, certain scope of inspection and examination activities should be carried out annually. CNSC staff noted that inspection scopes, procedures and capabilities differ significantly from site to site. We intend to work with the industry towards a common understanding of the scope and objectives of such compliance activities, first of all, in-bay inspections of discharged fuel. We would also like the industry to develop a longer term vision regarding the need for post irradiation examination of fuel in hot cells so that adequate PIE capability is maintained.

Increased frequency of fuel defects experienced in the last 3 years at Bruce B units is a reminder that subtle changes in fuel conditions may lead to quite significant effects. It also proves that it is important to maintain sufficient knowledge and testing capabilities so that root causes of such experiences may be identified, consequences assessed and corrective actions implemented. CNSC staff is monitoring the situation and expects the licensee to take a critical look at as to why this happened and whether the processes and capabilities in place were sufficient to respond in an effective fashion.

CNSC staff has been raising an issue of defected fuel behavior in reactor accidents for quite some time. We note that recently, perhaps spurred by operational experience, the industry has initiated quite a large number of projects related to defected fuel. Activities in this area include generation of data on fuel oxidation, thermal conductivity, and degradation rates; implementation of improved detection capabilities; and development of modeling tools. It is expected that all these efforts will bring about better understanding of fuel defect behavior and minimize their impact on plant safety.

Effort should be put into addressing gaps in experimental data and modeling capabilities. CNSC staff finds that lack of capabilities to model bundle behavior under certain accident conditions affects the credibility of analysis results. Consequently, we have requested all licensees to conduct a targeted, systematic evaluation of the adequacy of bundle modeling under power pulse and high temperature conditions. A Parameter Identification and Ranking Table (PIRT) process provides a formalized approach, which have been used successfully for a variety of applications. The essential, from the CNSC staff viewpoint, features of this process are:

- defined up-front Figures of Merit or criteria
- completeness of the considered list of phenomena
- assessment of knowledge base
- documented rationale for ranking of phenomena
- relative independence from code developers or analysts
- identification, as the outcome, of any gaps or deficiencies in the knowledge base.

We expect that this activity will result in a state of the art report on fuel bundle behavior and form a basis for further code development and validation effort, and experimental work, if required.

CANDU fuel operational performance has been so good that there were little incentives to change anything in its design. In fact, there have been very little changes in fuel design since early 80-s. The situation has changed recently. CNSC staff is currently facing assessment of two new fuel designs – CANFLEX-LVRF and the ACR fuel. The departure from the existing designs is quite fundamental – the new bundles use enriched uranium and Dy-doped fuel. When the current fuel design was developed, there was no formal regulatory process for fuel design review and approval. Now, however, the operating license requires that no fuel can be loaded unless its design approved by CNSC. Hence, the task for CNSC staff is dual – to formulate a process for review and approval of new fuel designs; and to apply such a process to specific new designs.

Documentation of regulatory requirements

The CNSC is actively engaged in developing a comprehensive set of regulatory documents such as policies, standards and guides with the objective of improving regulatory transparency, certainty and consistency. The fuel area is no exception. As you may be aware, a regulatory standard S-327 “Requirements for Nuclear Criticality Safety” has been approved by CNSC management for development, recognizing the necessity for addressing criticality issues, including those associated with introduction of enriched fuel. The need for additional regulatory documents, in particular, to provide regulatory guidance on safe fuel use and fuel design, is currently being assessed by CNSC staff. A guide on safe fuel use, if approved for development, would set the regulatory expectations for fuel related activities conducted by a nuclear reactor licensee at the site, such as procurement, storage and handling, fuel management, surveillance, and assessments of design and operation issues. A guide on fuel design would specify the process and requirements to be met when introducing new fuel designs.

We plan to consult the industry as required by the CNSC process in the development of these new documents.

Conclusions

CANDU fuel is demonstrating a stable, safe and reliable performance. Its design is well established and its behavior under normal conditions is generally well understood. Nevertheless, the modern safety requirements necessitate a closer than in the past scrutiny of the design, operation and safety evaluation of the fuel. There is still work to be done even for the existing fuel to provide better support for some of the limits and to account for effects of aging. Certain gaps still exist in our knowledge about fuel performance under bounding accident conditions. Introduction of new CANDU fuel designs requires substantial effort from both the designer and regulator to assure the desired level of confidence in safe fuel performance.

It must be recognized that safe fuel performance can only be assured by quality work from several working groups, including manufacturers, designers, procurement, fuel handling, reactor operators, inspection, and safety assessment.

Reference

1. Reporting Requirements for Operating Nuclear Power Plants. Regulatory Standard S-99. March 2003.