A Standard Approach to Special Fuel Irradiations at Point Lepreau Generating Station

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Abstract

Point Lepreau Generating Station (PLGS) has gained a significant amount of experience in the area of special fuel irradiations. This experience has included irradiation of coupon-carrier bundles, T-pad bundles, "documented" and "non-CANLUB documented" bundles and the current demonstration irradiation of CANFLEX fuel. In the course of this, PLGS has developed a standard approach to evaluating these irradiations and evaluating the technical basis for them. In this paper, this standard approach is described.

The decision of whether to perform a special irradiation comes down to cost vs. benefit. However, "cost" and "benefit" must be defined broadly. Some of the benefits can include:

- *provision of information which can help address key safety or operational issues*
- *provision of technical benefits to station staff*

In addition, costs can include:

- *any impact on the safe and efficient operation of the reactor*
- *any potential of risk to the reactor*
- *the financial costs of a special irradiation, including the time of station staff*

In order to assess these costs and benefits comprehensively, PLGS has developed a systematic approach. This approach systematically considers the following elements:

- *the rationale for the special irradiation,*
- *the design basis of the fuel to be used,*
- *the impact of the special irradiation on the safety analysis that demonstrates the safety of the reactor and*
- *the operational considerations associated with the special irradiation.*
- *competition with other station priorities*

In discussing the various aspects considered for special irradiations, this paper will draw upon explicit examples from the special irradiations that PLGS has decided to perform over the years.

1. Introduction

PLGS has a great deal of experience in the area of special fuel irradiations (see Table 1). Over the years, a standard approach has been developed for evaluating the desirability of performing special irradiations and for preparing for them. The basic elements of this approach have been applied in each special irradiation, with increasing degrees of elaboration and detail as experience has been gained and the importance of comprehensive configuration management has become more and more apparent.

In this paper, each of the major components of this standard approach are outlined, with examples being given from various of the special irradiations which PLGS has performed in the past to illustrate the concepts being presented. These major components are:

- Defining the rationale for the special irradiation
- Assessing the design basis for the fuel to be used
- Assessing the impact on reactor safety
- Defining operational considerations
- Determining other costs

All of these components are inter-related; and it is by considering the impact of each of these considerations that a decision as to the desirability of a special irradiation can be made. In addition, the PLGS Reactor Operating Licence requires that only fuel of approved design may be irradiated. In the event of a special irradiation of fuel which is of a different design than our normal 37-element fuel, regulatory approval must be obtained. The results of the assessments which are discussed in this paper are a significant component of any submissions made in order to obtain this approval.

2. Defining the Rationale for the Special Irradiation

In considering a special irradiation, the rationale must first be set out. The reasons for the irradiation must be thoroughly understood so that the potential benefits can be balanced against the risks and costs.

For example, the first special irradiation undertaken by PLGS was the special irradiation of coupon-carrier bundles (Reference 1). This special irradiation was undertaken as NB Power's contribution to a COG-CANDEV project to study the behaviour (including corrosion and deuterium pickup) of pressure tube material in the presence of boiling. Participation in this program was important for NB Power since it addressed a phenomenon which was of interest for had the potential to have a great impact on PLGS production costs. Since the overall project was a joint endeavour within COG-CANDEV, both costs and risks to NB Power were reduced.

Another type of rationale was the basis for the special irradiation of T-Pad fuel bundles (Reference 2). In this case, the special irradiation was intended to evaluate a new fuel design which differed from the existing 37-element fuel in only one respect: the shape of the bearing pads. These bearing pads were designed to eliminate crevice corrosion of the pressure tube in the area of bearing pad / pressure tube contact. This irradiation was done in conjunction with Ontario Hydro, which was irradiating similar bundles at the Bruce A station. The purpose of this irradiation was a step in a potential path to address an operational concern with a minor design modification. The rationale for participation was similar to that for the coupon-carrier fuel: since it was a joint effort, costs to NB Power were reduced and the risk of the special irradiation was shared with the Bruce A units.

In defining the rationale for a special irradiation, there are often secondary benefits which should be considered. These include the spin-off technical benefits to station staff involved in such projects, including enhanced contact with other utilities, manufacturers and research organizations. The resulting technical exchanges can be of great benefit.

3. Assessing the Design Basis for the Fuel to be Used in the Special Irradiation

Another aspect that must be considered as part of the evaluation of a special irradiation is the design of the fuel to be irradiated. The detail involved in the evaluation of the design varies from case to case. It depends on the extent of the difference between the fuel to be used in the special irradiation and the already-approved 37-element natural Uranium fuel design.

An example of a special irradiation which did not require a very extensive design review is the irradiation of two "documented" fuel bundles (Reference3). These are fuel bundles which were manufactured within the existing specifications for 37-element fuel in all respects. However, the UO_2 densities and clearances of certain elements were controlled to specific ranges which were much smaller than the normal design range; that is to say the fuel elements' dimensions and densities were more tightly controlled than usual. This special irradiation was intended to provide quantitative observations of the effect of Uranium mass on fuel sheath strains, to address concerns that high Uranium mass could be associated with higher-than-expected fuel sheath strains. In the case of this special irradiation, no special addition design assessment was required, since the fuel *was* the already-approved 37-element natural Uranium design.

An example of the opposite extreme is the CANFLEX demonstration irradiation which is currently ongoing at PLGS (Reference 4). This special irradiation involves 24 CANFLEX fuel bundles, which are being irradiated in 2 fuel channels. The irradiation is designed to give PLGS staff operating experience with this new fuel design, and to provide operational feedback which will be used as input to the decision as to whether to change the fuel design in use from the current 37-element design to CANFLEX.

Since the CANFLEX demonstration irradiation involves a new fuel design which is different in several important ways from the current 37-element design, an extensive segment of the work in considering the CANFLEX demonstration irradiation was concerned with the design basis.

The PLGS assessment of the design basis included participation in the industry-wide CANFLEX design review. Another important element of judging the acceptability of the design basis of CANFLEX was a judgement as to the acceptability of the overall design review process. Some of the contributing factors to this judgement were:

- that the design review was independent (*i.e.* none of the reviewers had been directly involved in the design process),
- that it included industry participation from organizations other than AECL (*e.g.* fuel manufacturers and utilities were involved), and
- that the conclusion of the design review was that CANFLEX fuel met the design requirements (Reference 5)

In addition, PLGS performed an additional, internal design review in which every aspect of the design documentation and the design testing was considered. This review included participation from PLGS experts involved with reactor physics, fuel handling, safety analysis, fuel design, quality assurance, spent fuel storage and safeguards reporting. All concerns raised were addressed to the satisfaction of the person raising them before the design basis was judged to be adequate.

One measure of the difference in extent between these two cases can be seen in the amount of documentation involved. For the "documented" bundles, design issues were fully addressed within a single document, Reference 3. For the CANFLEX demonstration irradiation, a much larger number of documents was involved: the CANFLEX fuel design manual (Reference 6), the draft CANFLEX physics design manual (Reference 7), the qualification plan (Reference 8) and the test specifications and test reports for all of the qualification testing were required to assess the adequacy of the design basis.

4. Understanding the Impact of the Special Irradiation on Reactor Safety

In evaluating a special irradiation, it is of paramount importance that the safe operating envelope of the reactor, as defined by the existing safety analysis, not be compromised due to the planned activity. To that end, the impact of the presence of the special fuel in the reactor must be assessed. Just as with the design review, the depth and extent of the safety assessment depends strongly on the extent of the difference between the special fuel and the fuel which PLGS irradiates normally. In addition, the magnitude of any difference in operating state, planned or unplanned, which may occur during the special irradiation, must be considered in determining the scope of the safety assessment which is required.

In the case of the CANFLEX demonstration irradiation, the safety assessment consisted of an appraisal of the impact of the presence of up to 24 CANFLEX bundles in the core on each accident scenario considered in the safety report. This was done by performing a section-by-section review of the safety report (Reference 9) and evaluating the impact of CANFLEX fuel during the demonstration irradiation. In some cases a qualitative assessment, based on a physical understanding of the differences in the fuel designs and in the overall accident behaviour, was sufficient to come to a conclusion regarding the relative impact of the presence of a small number of CANFLEX bundles. For some other accident scenarios, detailed quantitative assessments of accident response were performed, in which CANFLEX behaviour was contrasted with 37-element fuel behaviour in similar accident conditions. Detailed quantitative assessments were performed for the following cases:

- Large Break Loss of Coolant Accidents (LOCA)
- LOCA with Coincident Loss of Emergency Core Cooling
- Small Break LOCA
- Pressure Tube Rupture
- Channel Flow Blockage
- Stagnation and Off-Stagnation Feeder Breaks
- Generic Post-Dryout Behaviour (relevant for Loss of Forced Flow, Loss of Regulation, Loss of Pressure and Inventory Control, etc.)
- Fuelling Machine Loss of Coolant

The general conclusion for all of the accident scenarios considered was that the presence of CANFLEX fuel resulted in either an improved or an unchanged margin of safety. In a few cases, the results of the consequence analysis for CANFLEX were nominally worse than for 37-element fuel. However, in each of these cases, the magnitude of the difference was insignificant when compared to the margin of safety which is demonstrated in the Safety Report.

The safety assessment for the CANFLEX demonstration irradiation was extensive. The detailed qualitative assessments were provided in a 9-volume report (Reference 10), which was combined with the section-by-section review of the safety report in Reference 4 to complete the work involved in the assessment.

5. Operational Considerations

The final aspect of the PLGS approach to special irradiations is an assessment of the operational impact of the planned activity. Any changes from normal operating practice and their ramifications must be thoroughly understood. Station staff involved in all significant aspects of the special irradiation are consulted so that nothing is overlooked. Central to the assessment is whether any station documentation (*i.e.* Operating or Design Manuals) needs to be revised. Information from this assessment is used when planning for the special irradiation to ensure that necessary resources are available and that the staff involved are appropriately informed as to any special activities which are required.

To assist in this assessment, PLGS has developed a "standard list" of operational considerations; this list has evolved over time through our various special irradiations in the past. This list includes the following operational considerations:

1. Core-tracking of the special fuel
2. Effect of the fuel on bundle power and channel power uncertainty allowances
3. Effect of the fuel on bulk power limits
4. Critical channel power of channels containing the special fuel

5. Effect on calibration factors for ROP trip set points due to ripple, error allowances, etc.
6. Effect on reactivity calculations and coefficients
7. Defect threshold of the special fuel
8. Effect on iodine control procedures
9. Decay power levels of the special fuel
10. Plutonium content of the special fuel
11. Response to various operational contingencies
12. Effect on spatial control
13. Effects on fuel burnup

An example of how an operational consideration is raised and addressed can be found for the case of the special irradiation of 2 "non-CANLUB documented" fuel bundles (Reference 11). One of the obvious operational considerations of irradiating fuel which is not CANLUB-coated is the impact on defect probabilities during power ramps. It was estimated that the probability of fuel sheath failure could be as much as six times greater than PLGS' normal operational limit of 1%. The operational assessment considered the small number of fuel bundles involved, along with the presence of the Delayed Neutron (DN) Monitoring System and the Gaseous Fission Product Monitoring system, as well as the impact on the iodine burden in the PHTS in the unlikely event that all of the "non-CANLUB documented" fuel elements were to fail. It was concluded that even in this latter case, PLGS would remain within licensed limits.

In order to minimize the possibility of the "non-CANLUB documented" fuel bundles being exposed to power ramps which could result in fuel sheath failures, channel selection and fuel bundle position criteria were developed. Among other things, the channel was required to have an operational DN signal prior to fuelling, the channel was to be located remote from liquid zone controllers and from adjuster rods in bank #1. Once the fuel was in core, additional restrictions were placed on the bundle shifting and on reactor power manoeuvring involving the movement of any reactivity devices while bulk power limits were increased to guard against large power ramps.

6. Determining Other Costs

Special irradiations often involve other costs associated with activities such as visual in-bay inspections, flasking bundles and shipping them off-site. These costs do not simply consist of the person-hours required to perform the tasks, but additional effort in work plan preparation, review and approval.

The real cost consideration here is not necessarily the expense of the staff salaries, but the value of the displaced work. If some of the station staff involved with work plan preparation, review and approval, or with performing these additional activities, is heavily committed to other station projects which have a higher priority and are more directly connected with the safe and economical operation of the reactor, then there is a significant cost associated with diversion of this staff member to supporting the special irradiation. However, these "costs" also bring benefits in that other, less urgent but still important tasks which are associated with supporting activities like flasking and shipping (such as work plan review and revision) can be completed and provide a "spin-off" benefit from the demonstration irradiation.

7. Conclusion

In this paper, the various elements of the standard approach which PLGS has evolved for assessing proposed special irradiations have been presented. The results of the assessment discussed in this paper are integrated into a review of the proposed activity as part of the means by which the cost/benefit of the special irradiation can be established and station approval obtained. In addition, these results form the basis of any regulatory submissions which may be required under the terms of PLGS' reactor operating licence.

Once this review has identified all of the potential risks, costs and benefits of a planned special irradiation, the decision as to whether or not to proceed can be made with confidence. The result is enhanced assurance that the special irradiations by PLGS address station priorities and provide important contributions to CANDU fuel development.

7. References

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Table 1 – Summary of Special Irradiations that PLGS has Performed

Special Irradiation	Timing	Purpose
Coupon-Carrier Bundles	1988-1989	Study Effect of Boiling on Corrosion & D Pickup
T-Pad Bundles	1993-1994	Evaluate Potential Design Modification
"Documented" Bundles	1994-1995	Study Impact of Manufacturing Variations
"Non-CANLUB Documented" Bundles	1996	Study CANLUB and Update Defect Correlations
CANFLEX Bundles	1998-2000	Evaluate Candidate Fuel Replacement