Mr. Robert H. Bryan, Chairman
Westinghouse Owners Group
Tennessee Valley Authority
Mail Code LP4J-C
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: ACCEPTANCE FOR REFERENCING OF TOPICAL REPORT WCAP-15604-NP, REV. 1, "LIMITED SCOPE HIGH BURN-UP LEAD TEST ASSEMBLIES" (TAC NO. MB0591)

Dear Mr. Bryan:

By letter dated November 29, 2001, the Westinghouse Owners Group (WOG) requested review and approval of Topical Report (TR) WCAP-15604-NP, Revision 1, “Limited Scope High Burn-up Lead Test Assemblies.” Additional information was provided by letter dated February 1, 2002.

The NRC staff has completed its review of the subject TR. The report is acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the report and in the associated NRC safety evaluation (SE), which is enclosed. The enclosed SE defines the basis for acceptance of the TR.

Licensees proposing to use this topical report must evaluate its impact on their current license and licensing basis. If the analytical methods that are currently used to determine and evaluate core operating limits that are referenced in the plant technical specifications are approved for use up to a specified burnup limit, use of this topical report will require a license amendment. Otherwise, implementation of this topical report will require evaluation using the 10 CFR 50.59 process.

Any reference in the report that the use of lead test assemblies does not require technical specification changes shall also be modified accordingly.

We do not intend to repeat our review of the matters described in the subject report, and found acceptable, when the report appears as a reference in license amendment applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the report.

In accordance with procedures established in the NRC’s website, the NRC requests that the WOG publish an accepted version within 3 months of receipt of this letter. The accepted version shall incorporate (1) this letter and the enclosed SE between the title page and the abstract, (2) all requests for additional information from the staff and all associated responses, and (3) a "-A" indicating an NRC approved report, after the identifier of the report.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, the WOG and/or the applicants referencing the TR will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

/RA/

William H. Ruland, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure: Safety Evaluation

cc w/encl:
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT WCAP-15604-NP, REV. 1

"LIMITED SCOPE HIGH BURN-UP LEAD TEST ASSEMBLIES"

WESTINGHOUSE OWNERS GROUP

PROJECT NO. 694

1.0 BACKGROUND

Over the last few years, the NRC staff has been developing guidelines for the use of lead test assemblies (LTAs). In doing so, the staff has engaged in several public meetings and exchanged written correspondence with representatives of the industry. The objective was to develop a set of guidelines that would provide a structured process for regulating lead test assemblies while maintaining safety. Following such guidelines will help ensure uniformity in data collection, make evaluation of new properties or limits more predictable, and ensure a structured process for data feedback to the NRC staff. The guidelines will be consistent with the NRC performance goals of maintaining safety, increasing public confidence, improving regulatory efficiency and effectiveness and reducing unnecessary regulatory burden.

By letter dated November 29, 2001 (Reference 1), the Westinghouse Owners Group (WOG) submitted Topical Report (TR) WCAP-15604-NP, Rev. 1, "Limited Scope High Burn-up Lead Test Assemblies" for NRC review and approval. The submittal was the result of the industry and NRC staff discussions about the need for lead test assembly guidelines. The document is intended to provide the basis for the operation of a limited number of fuel assemblies to rod burnups greater than the current lead rod average burnup limit of 62 GWD/MTU. In this context, "burnup limits" refer to the maximum burnup for which a particular fuel design methodology has been validated. The maximum burnup would be 75 GWD/MTU. The rationale is to provide a means to incrementally generate data to populate the range between the current lead rod average burnup limit and the proposed future burnup limit with fuel that has been irradiated under both nominal and limiting conditions (i.e., fuel that has experienced normal or possibly limiting fuel duty). While the WOG submitted the TR, it was developed by representatives of the entire U.S. commercial reactor power industry and is intended to apply to all pressurized water reactors (PWR) and boiling water reactors (BWR) facilities. By letter dated November 21, 2000 (Reference 2), the Nuclear Energy Institute (NEI), requested that the TR be reviewed generically for the entire industry. The NRC staff has reviewed this report accordingly and all conclusions apply to the entire commercial nuclear power industry.

The main areas to be addressed in the LTA guidelines are:

1. definition of a lead test assembly;
2. characterization of the fuel assembly, both pre- and post-irradiation;
3. identification of necessary pool side examinations;
4. identification of necessary hot cell examinations and when these examinations are necessary;
5. the number of LTAs allowed in any given core;
6. the location or placement of LTAs within the core;
7. scope of the safety analysis; and
8. reporting requirements.

In the last few years, operating experience has identified a series of fuel issues that raise important licensing questions. Among these issues are cladding oxidation levels higher than predicted, excessive internal gas pressure in burnable poison rods, incomplete control rod insertion (IRI) events, large axial offsets or axial offset anomalies (AOA), fuel failures due to high fuel duty, adverse effects of water chemistry, high crud buildup, and accelerated growth of rods and assemblies. All of these issues are associated with high burnup. The NRC plan for addressing high burnup fuel issues is described in the publicly available document, "Agency Program Plan for High Burn-up Fuel," (Reference 3) dated July 6, 1998. The NRC staff discussed the basic elements of this plan with representatives of NEI at a public meeting in November 1997 and again at several public meetings with the Advisory Committee on Reactor Safeguards (ACRS) and NEI.

The NRC staff has established some basic burnup extension guidelines which include:

1. a prototypical LTA program up to the proposed limit;
2. addressing all points in current licensing bases (standard review plan, fuel design criteria and General Design Criteria);
3. a risk-informed approach;
4. addressing reactivity insertion accidents, loss-of-coolant accidents and anticipated transients without scram; and
5. a fuel performance monitoring program (including oxidation and geometry changes).

The prototypical lead test assembly program is a very important aspect of a burnup extension request. Both the NRC staff and the industry have contributed to the development of a set of LTA guidelines. The intention of this effort was to develop a set of guidelines that provides a structured process for irradiating LTAs while maintaining safety. These guidelines are consistent with the NRC performance goals.

In the past, the NRC staff restricted the utilization of LTAs to non-limiting locations. This has resulted in burnup histories that were not aggressive and in many cases not typical. Fuel performance in recent years has led the NRC staff to conclude that LTAs should be prototypical in order to be of the maximum value. Many factors contribute to fuel performance, such as type of cladding, power history, flow conditions, and water chemistry. Each of these factors has contributed to the fuel performance issues that have been recently observed and each must be controlled for the LTA data to be useful for future burnup extensions. Recent events have

demonstrated that minor changes to these variables can lead to unexpected fuel behavior. Furthermore, the synergistic effects of these variables can complicate the extrapolation of one plant's performance history to more generic conclusions. These events have led the NRC staff to conclude that it is important to burn the LTAs in as prototypical a fashion as possible. Because so many variables affect fuel behavior, it will be necessary to have a sufficient number of LTAs to cover the range of operation expected by operating plants.

LTA guidelines providing for prototypical burnup of LTAs would ensure uniformity in data collection, make the evaluation of new fuel properties or limits more predictable, and ensure a structured process for data feedback to the NRC, benefitting the NRC, fuel vendors, licensees, and the public.

2.0 EVALUATION

2.1 Definition of an LTA

A limited scope LTA is a fuel assembly that is based on a currently available design and is capable of reaching higher burnups than currently used. The fuel cladding material is an NRC-approved cladding material. The assembly will receive pre-characterization prior to undergoing exposure in the "test" cycle that would permit the assembly to exceed current burnup limits. The fuel assembly shall be analyzed using either current fuel performance design models and methods or modified developmental versions of these models and must demonstrate that current design limits are met for the extended burnup analyzed.

The NRC staff considers this definition acceptable because it defines which fuel assemblies are eligible for the limited scope LTA program and generally describes attributes of the assembly that are further defined in other areas of the program.

2.2 Pre-and Post-Irradiation Characterization of the Fuel Assembly and Necessary Pool Side Examinations

Pre-characterization is the measurement of particular fuel performance parameters before the start of the cycle in which the burnup limits will be exceeded for the LTAs. The purposes of the pre-characterization are to (1) obtain data that is useful in understanding the fuel performance based on the known fuel duty, and (2) to ensure that fuel design criteria will not be exceeded in the projected cycle. Since the fuel performance models are being extrapolated to burnups that have not been approved by the NRC, the pre-characterization provides a measure of how much margin exists for a given design criterion to its limit, based on model predictions compared to the pre-characterization measurement. Thus, pre-characterization is necessary and provides valuable information. The TR stated: "Typically the parameters which would be subject to pre-characterization are fuel rod cladding oxide thickness, fuel assembly and/or fuel rod growth, and guide thimble and/or assembly/channel bow measurements." The NRC staff determined that a prescribed minimum set of tests should be performed for an assembly to be considered part of the limited scope LTA program. After discussion, the applicant agreed to the following minimum set of examinations: clad oxidation, rod/assembly growth, and visual examinations for PWRs and clad oxidation, rod/assembly growth, channel bow, and visual examinations for BWRs.

The NRC staff finds this minimum set of examinations acceptable because the parameters most likely to be limiting with higher burnup will be characterized prior to the cycle in which the LTA burnups would exceed current burnup limits. The fuel rod design criteria that are limiting at end-of-life and could be potentially challenged for these high burnup fuel assemblies are cladding oxidation, rod internal pressures, fatigue, and growth. Fatigue analyses typically show 30–50 percent margin to the cumulative fatigue usage factor of 1.0. Therefore, fatigue is not the limiting criterion at these high-burnup levels. As will be explained below, rod internal pressure can be related to cladding oxidation. This leaves cladding oxidation and growth, which will be measured and compared with the predicted values for the irradiation exposure that the lead test assembly rods have experienced before the "test" cycle.

Oxidation can lead to significantly increased fuel rod internal pressures on the outer surface of the cladding. Above certain oxidation levels, the impacts on rod internal pressure and the significant impacts on the cladding pressure limit characteristics could result in the rod internal pressure criterion being exceeded. Therefore, if oxidation is kept to a minimum, the fuel rod internal pressure criterion is less limiting than simply the oxidation criterion by itself. Also, at higher levels of oxidation, spalling of the oxide layer can lead to the formation of hot spots forming on the bare cladding surface. Accelerated oxidation at the hot spots can produce through-wall holes. In addition to oxidation causing increases in rod internal pressures, crud deposition has a similar effect since crud is a poor conductor of heat. Keeping crud deposition to a minimum also reduces the impact on rod internal pressures.

The visual examination will provide an additional check to assure that the fuel is operating as expected. It will verify that no pre-spallation or blistering is present and that the crud deposition is as expected for the burnup level.

Post-irradiation examinations (PIEs) are the key inspections/examinations that provide data to substantiate fuel performance behavior. These inspections/examinations are typically performed off the critical path of an outage, allowing extensive measurements to be taken. Most PIEs are pool-side inspections. Hot cell examinations will occasionally be done when deemed appropriate by the vendor or utility. PIEs will provide the majority of data points for the fuel characteristics that must be demonstrated to ultimately achieve higher burnup licensing limits. As with the pre-characterization examinations, the NRC staff determined that a minimum set of tests should be performed for an assembly to be considered part of the limited scope LTA program. After discussion, the applicant agreed to the same minimum set of tests as for pre-characterization. However, since PIEs need to be carefully planned and scheduled with the respective plants, and since the plant supplies personnel in an auxiliary role, it is desirable to obtain all the necessary data in one PIE rather then several separate PIEs. Therefore, even though a minimum set of PIEs is defined and agreed on, numerous other inspections and measurements will most likely be done during one PIE, since repeated PIEs are costly, inefficient and may not keep dose as-low-as-reasonably achievable (ALARA).

The NRC staff finds the proposed set of tests acceptable because these tests will provide data on the parameters most likely to be affected by higher burnup. Comparisons of the pre-and post-characterization data will provide a measure of the effect of the incremental burnup from below the current burnup level of 62 to the burnup of the particular fuel rod. In particular, the cladding oxidation provides a check of the corrosion model used in the fuel performance codes and provides a check of the metal-wastage and wall thinning effects.

2.3 Need for Hot-Cell Examinations

For the limited scope LTA program hot-cell examinations would not normally be planned in advance. Most hot cell examinations are planned after the pool-side PIEs are completed and a determination is made that an anomalous condition exists that warrants further investigation. As stated in the TR, if the pool-side examinations yield anomalous results, the licensee would inform the NRC and hot cell examinations would be considered.

The NRC staff finds this acceptable because the staff would be informed of the examination results and be aware of the investigation of any anomalous results including any hot-cell examinations. Some hot-cell data on fuel pellet behavior will be necessary for approval of use of certain methodologies at higher burnup limits, but routine hot-cell examinations of the limited scope LTAs are not required. For burnup extension, definitive hot-cell data will be needed to address phenomena such as rim effect, gas bubbles trapped in the grains, hydrogen content in cladding, cladding creep and reduced gap conductance. Hot-cell exams are important to resolve these high burnup fuel issues for burnup extension but will be limited in number.

2.4 Maximum Number of LTAs Allowed Per Reload

The maximum number of assemblies that would be considered for a limited scope LTA program will vary based on fuel management studies. However, for the overall limited scope LTA program, the maximum number of LTAs per cycle per core will be limited to nine assemblies for PWRs and thirty-two assemblies for BWRs. The rationale for setting the maximum number of assemblies is based on obtaining a sufficient amount of data while maintaining a high degree of confidence that no safety concerns exist.

The NRC staff considers this acceptable because setting the number of limited scope high burnup LTAs at the above levels is beneficial and justifiable for the following reasons:

- It allows for a variety of loading patterns and power histories in order to observe effects that might not be observable with fewer LTAs,
- It allows for protypical fuel patterns,
- It allows for symmetric locations in the core to be driven to higher burnups and allows for a center assembly to be accommodated,
- It restricts the total number of assemblies exceeding the current lead rod average burnup limit to a value < 10 percent of the core, which is consistent with many core damage frequency scenarios (e.g., for PWR cores with 121, 157, 177, 193, 204, 217, and 241 fuel assemblies, 9 assemblies would be 7.4 percent, 5.7 percent, 5.1 percent, 4.7 percent, 4.4 percent; 4.1 percent and 3.7 percent respectively; for BWR cores with 560, 724, and 764 fuel assemblies, 32 assemblies would be 5.7 percent, 4.4 percent and 4.2 percent respectively), and
- It makes the core design efficient enough to offset the increased analysis and surveillance effort.

2.5 Location or Placement of LTAs Within the Core

Previously, LTAs were restricted from being placed in limiting core locations. As a result the data from these LTAs was not comprehensive. The data did not necessarily represent behavior of all of the fuel under normal operations. The most challenging situations were not examined. To determine if an LTA meets the need for which it was designed, it must experience the same limiting conditions as other fuel in the reactor and should not be restricted in power or core location except as needed to meet design criteria. The unique aspect of these LTAs is that they are normal production fuel assemblies that will fall into two general categories. The LTAs will either be fuel assemblies that are reinserted for additional exposure after achieving a burnup instead of being discharged or fuel assemblies that have normal incore residence times, but are positioned in-core so that the power level results in the highest current burnup limit being exceeded. The maximum lead rod average burnup that these limited scope LTAs would experience is 75 GWD/MTU.

The NRC staff finds this acceptable because the LTAs will more closely represent the conditions that future fuel will experience and thus more accurately represent the behavior of the fuel. Having recognized that some of the unexpected fuel behavior that has been recently experienced was not foreseen due to the limited aspects of the LTAs, the NRC staff finds the current approach not only acceptable but necessary to obtain information required to support burnup extension.

2.6 Scope of the Safety Analysis

Licensees proposing to use this TR must evaluate its impact on their current license and licensing basis. If the analytical methods that are currently used to determine and evaluate core operating limits that are referenced in the plant technical specifications are approved for use up to a specified burnup limit, use of this TR will require a license amendment. Otherwise, implementation of this TR will require evaluation using the 10 CFR 50.59 process.

In addition, for all fuel rods in the LTAs, the predicted oxidation must be less than 100 microns on a best-estimate basis with prediction of no blistering or spallation based on current data. The validity of the evaluations will be based on the use of current fuel design acceptance criteria and appropriate analytical models.

It is anticipated that future work will confirm the validity of most of the current criteria for burnups beyond those being achieved. The deposited enthalpy criterion for design basis reactivity insertion accidents may be an exception. Current available data indicates that this criterion may need to be revised. The small number of assemblies involved in these LTA programs, the conservative methods used in the industry to evaluate deposited enthalpy for hypothetical reactivity insertion accidents, and the low deposited enthalpy for high burnup assemblies is sufficient to justify the use of the current deposited enthalpy criteria for the LTAs.

The second step of the safety analysis is the assessment of the models reviewed and approved by the NRC for the purpose of evaluating the performance of the LTAs beyond current burnup limits. The analytical models used to evaluate the performance of the LTAs beyond current burnup limits may need to be modified versions of the models reviewed and approved by the NRC. In some cases, conservatism may be added, as appropriate. If the available data

indicates that the approved models are appropriate, then no modifications to the approved models will be necessary. The revised models would be used only for the limited scope high burnup LTAs and not for any other assemblies in the core. The justification of the model revisions will be documented and available for NRC review in accordance with the 10 CFR 50.59 criteria.

The staff believes that the fuel will not fail in an unexpected way and licensees will continue to be able to demonstrate acceptable fission product release behavior because the LTAs that will be tested will use existing designs and existing approved analyses methods, which will be incrementally extrapolated to include the operating conditions of the LTAs. The staff expects that the use of these LTAs will not change the consequences of the 10 CFR Part 100 offsite dose calculations for individual plants. Those calculations generally assume the failure of large quantities of fuel at the start of limiting accident sequences, and the use of the LTAs will not alter this assumption.

The NRC staff finds this approach acceptable since it is already allowed under 10 CFR 50.59 and the number of LTAs in any given core is limited.

2.7 Reporting Requirements

The TR provides that licensees using the limited scope high burnup LTA program shall submit two reports to the NRC for information.

The first report is a notification of intent to irradiate LTAs above the current burnup limit. It would contain the utility and plant names, the cycle for which and the date when the LTAs will be inserted, the number and locations of the LTAs, the anticipated pre- and post-cycle burnups for each LTA, the purpose of the LTAs, the estimated dates of the characterizations and the estimated date of the second report. In addition, the initial report would contain a statement that the LTA will not be irradiated if current design limits are not met, if the predicted oxidation is not below 100 microns, or if the pre-characterization shows any anomalous result. The second report would give the results of the pre- and post-irradiation examinations.

The NRC staff finds this acceptable because these reports will provide the information the staff needs to evaluate the number and kinds of LTAs being irradiated, allow the staff to know when data will be available and be informed of the data when it is available. It will keep the staff informed and put the staff in a better position to review industry applications for burnup extension.

3.0 CONCLUSIONS

On the basis of the evaluation discussed above, the staff concludes that it is acceptable for and individual power reactor licensee to irradiate limited scope LTAs to a maximum burnup of 75 GWD/MTU subject to the following conditions (Reference 4). Since review and approval of the TR was based on the entire program, all conditions must be met in order for any particular licensee to participate in the limited scope LTA program.

4.0 CONDITIONS

1. The number of fuel assemblies with fuel rods exceeding the current lead rod average burnup shall be limited to a total of nine in PWRs and thirty-two in BWRs. No fuel rods shall exceed peak rod burnups greater than 75 GWD/MTU.

2. The fuel shall be typical production fuel and be pre-characterized before operation above the current lead rod average burnup limit. The fuel may also be an LTA that was characterized during fabrication and was designed to test aspects of the fuel assembly but was not initially identified as a high burnup LTA. The latter fuel shall be pre-characterized before operation above the current lead rod average burnup limit.

3. The pre-characterization of the fuel shall consist of at least the following examinations: clad oxidation, rod/assembly growth, and visual examinations for PWRs, and clad oxidation, rod/assembly growth, channel bow, and visual examinations for BWRs.

4. The post-irradiation examinations of the fuel shall consist of at least the following examinations: clad oxidation, rod/assembly growth, and visual examinations for PWRs, and clad oxidation, rod/assembly growth, channel bow, and visual examinations for BWR's burn-up limits. Current or modified fuel performance methods and codes shall be used.

5. The fuel shall be evaluated against and must meet all current design criteria even though the current analytical methodologies may not be approved for use at the higher burnups.

6. For all fuel rods in the LTAs, the predicted oxidation shall be less than 100 microns on a best-estimate basis with prediction of no blistering or spallation based on current data.

7. A licensee using the limited scope high burnup LTA program shall submit two reports to the NRC for information.

   The first report shall be a notification of intent to irradiate LTAs above the current maximum burnup limit. It shall contain at least the following information:

   - Licensee name
   - Plant name
   - Cycle and date when the LTA shall be inserted
   - Number of LTAs
   - Location of the LTAs
   - Anticipated pre-and post-cycle burnups for each LTA
   - Purpose of LTAs
   - Estimated dates for pre-and post-irradiation characterizations or the results of the pre-characterization and an estimation of the date for the post-irradiation characterization
   - Estimated date of second report
   - Statement that the LTAs will not be irradiated if Conditions 5 and 6 are not met or if the pre-characterization examinations show anomalous results

The second report shall give the results of the pre-and post-irradiation examinations. It shall consist of at least the following information:

- Licensee name
- Plant name
- Assembly identification number
- Specific measurements - actual data and predictions
- Comment section

5.0 REFERENCES

1. Letter from Robert H. Bryan, Chairman, Westinghouse Owners Group, to NRC Document Control Desk, dated November 29, 2001.

2. Letter from David J. Modeen, Nuclear Energy Institute, to Gary M. Holahan, Director, Division of Systems Safety and Analysis, NRC, dated November 21, 2000.

3. Memorandum to Commissioners from L. Joseph Callan, "Agency Program Plan for High-Burnup Fuel," dated July 6, 1998.

4. Letter from Robert H. Bryan, Chairman, Westinghouse Owners Group, to NRC Document Control Desk, dated February 1, 2002.

Principal Contributors: Margaret S. Chatterton
Girija Shukla

Date: January 8, 2003