Licensing Guidance for Lead Test Assemblies

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Topical Report

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

List of Figures

List of Nomenclature

Acronym	Definition
AOO	Anticipated operational occurrence
BWR	Boiling water reactor
CFR	Code of Federal Regulations
COLR	Core Operating Limits Report
DBA	Design basis accident
GDC	General Design Criteria
GESTAR	General Electric Standard Application for Reactor Fuel
HBLUA	High burnup lead use assembly
HBLUC	High burnup lead use channel
LAR	License amendment request
TR	Topical report
LOCA	Loss-of-coolant accident
LRA	Lead research assembly
LRC	Lead research channel
LTA	Lead test assembly
LTR	Lead test rod
LUA	Lead use assembly
LUC	Lead use channel
PCT	Peak cladding temperature
PWR	Pressurized water reactor
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
RG	Regulatory Guide
SSC	System, structure, or component
TS	Technical Specification
UFSAR	Updated Final Safety Analysis Report

ABSTRACT

Lead test assemblies (LTAs) provide vital information to characterize irradiated properties and performance that is necessary for the development and licensing of new technologies. Due to the lack of regulatory guidance and industry standards, the licensing approach for many past LTA programs has diverged significantly. There are differing interpretations and opinions amongst NRC and industry staff regarding the Technical Specification (TS) LTA provision, constraints within 10 CFR 50.59, *Tests, changes, and experiments*, and the correct licensing approach for LTA programs. Given this regulatory uncertainty, many licensees have opted to submit a License Amendment Request (LAR) in accordance with 10 CFR 50.90, *Application for amendment of license, construction permit, or early site permit*. These past LARs have reinforced certain long-held positions amongst both NRC and industry staff that the TS LTA provision provides little opportunity and flexibility and § 50.59 constraints direct licensees to submit LARs.

Building upon more recent NRC staff interpretations, positions, and informal guidance, this topical report provides licensees the regulatory guidance needed to interpret and implement the TS LTA provision, and a clear licensing framework for different types of LTA programs.

1.0 INTRODUCTION

The purpose of this topical report is to provide guidance on the interpretation and implementation of the TS LTA provision within the construct of the plant's existing licensing bases. The TS LTA provision includes restrictions on the quantity and placement of LTAs. If the LTA irradiation program satisfies these restrictions, then the LTAs may be loaded and irradiated without prior NRC approval. This topical report provides guidance to assist licensees in making the decision as to whether a future LTA irradiation program satisfies these requirements.

Regulatory positions related to LTA licensing are scattered throughout NRC letters and proprietary vendor topical reports dating back decades. Within this topical report, Framatome has collected regulatory positions from the past 20 years, identified common positions, added clarification, and expanded applicability to the entire fleet. The licensing guidance in this topical report provides a non-proprietary, widely applicable, sole source of information which is intended to provide comprehensive regulatory guidance for the licensing of LTAs.

2.0 LICENSING FRAMEWORK

The licensing framework for LTAs may consist of multiple approaches including the following:

1. For plants with the TS LTA provision which have shown compliance with the restrictions on quantity and placement, the LTAs may be loaded and irradiated without prior NRC approval. In this instance, the LTAs are compliant with the plant's licensing bases as defined in the TS.
2. For plants with the TS LTA provision which do not show compliance with the restrictions on quantity and placement, the LTAs may not be loaded and irradiated without prior NRC approval. In this instance, the LTAs are outside of compliance with the plant's licensing bases as defined in the TS. A LAR in accordance with § 50.90 would be necessary.

For plants without the TS LTA provision, loading and irradiating LTAs under the provisions of § 50.59 may be allowed but is not the subject of this topical report.

As discussed in this report, LTAs may be comprised of many different mechanical, thermal-hydraulic, or nuclear design features, new or different combinations of materials, and/or application of existing, approved designs or materials beyond their experience base (i.e., higher burnup or fluence). Due to these differences, the acceptance criteria used to judge compliance with the TS LTA provision restrictions may be different.

While Framatome will support their customers with technical information and justification, licensing decisions are solely the responsibility of the licensee and will be made in accordance with their internal procedures. It is expected that this guidance will be incorporated into these internal procedures to assist the licensee with these decisions.

2.1 *Technical Specification LTA Provision*

Technical Specifications play a vital role in NRC's authorization and license to operate a commercial nuclear power plant. As an appendix to the plant's operating license, Technical Specifications are a key component of the plant's licensing bases. For most nuclear power plants, a provision exists within their Technical Specifications allowing for the restricted use of LTAs. TS 4.2.1, *Fuel Assemblies*, contains the following language associated with LTAs. While this text was extracted from the Standard Technical Specifications, General Electric BWR/4 Plants (Reference 1), it is common to most nuclear power plants.

> *A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.*

Hence, LTAs are inherently part of the plant's licensing bases and an allowance for their restricted use already exists.

TS Bases provide background material, links to applicable safety analyses, and details regarding associated surveillance requirements and action items. However, TS Bases only cover TS Section 2, *Safety Limits*, and TS Section 3, *Limiting Condition for Operation*. No bases section exists for TS 4.2.1 which could provide useful background and guidance for implementing the TS LTA provision. Furthermore, there are no Regulatory Guides (RGs) defining an acceptable means of irradiating LTAs within the bounds of the TS LTA provision.

Approved[1] fuel assembly designs are comprised of design features and materials which are fully characterized, analyzed using approved codes and methods, and have been shown by tests or analyses to comply with all safety design bases. These fuel assembly designs may be batch loaded with no restrictions; provided they comply with all safety design bases. LTAs have not completed representative testing and therefore restrictions must be applied to their quantities (i.e., limited number) and placement within the core (i.e., nonlimiting core regions).

The term “representative testing” relates to the characterization of irradiated properties and performance of the fuel assembly design features and materials. LTAs play a vital role in the characterization and demonstration of in-reactor performance.

The term “limited number” is purposely ambiguous as what constitutes a limited number depends on many factors such as the relative impact of the LTA’s new feature on applicable regulatory requirements and design criteria, the available margin to those criteria, and any uncertainty incurred by the lack of in-reactor experience or characterization of irradiated properties. For example, an acceptable limited number for LTAs containing a different fuel pellet material (e.g., U3Si2) may be restricted to just a few fuel rods (e.g., less than 0.1% of core) to limit the potential impact of any unpredictable performance resulting from a finite irradiated database. Whereas an acceptable limited number for LTAs comprised of a proven fuel assembly design with ample in-reactor experience may be several assemblies (e.g., 4.0% of core).

[1] For the purpose of this guidance, new or modified fuel designs licensed and deployed in accordance with an NRC-approved design change process and/or 10 CFR 50.59 are considered approved.

In general, the restriction on LTA placement in “nonlimiting core regions” has been interpreted as an operational restriction on thermal power where peak fuel rod power levels remain below the leading co-resident fuel. Given fuel management flexibility, there are no inherent, in-board core locations which are nonlimiting with respect to thermal power. LTA thermal power restrictions are controlled via enrichment and poison loadings and fuel loading patterns. Note that due to excess neutron leakage, core peripheral locations are generally operating at lower power levels. This restriction was never intended to force the placement of LTAs solely at core peripheral locations.

Based on the type of lead feature, there may be physical core locations which are more limiting with respect to a certain performance aspect. For example, PWR grid-to-rod fretting may be more prevalent at peripheral core locations due to water jetting from gaps between baffle plates or higher core bypass flow. Avoiding these core locations for LTAs designed to test a new feature aimed at improving grid-to-rod fretting protection defeats the intended purpose of the LTA program. For the purpose of gathering data or demonstrating performance relative to a specific performance requirement or degradation mechanism, it is acceptable to place LTAs at these “limiting” core locations.

TS restrictions on “limited number” and “nonlimiting core region” work in concert to provide reasonable assurance of adequate protection of public health and safety. Combinations of limited numbers and thermal margin setbacks should be commensurate with the amount of in-reactor experience, degree of characterization of irradiated properties, and relative impact of the LTA’s new feature on applicable regulatory requirements and design criteria, as well as available margin to those criteria. As experience and characterization increases, larger quantities and/or lower thermal margin setbacks are justifiable.

Combinations of limited numbers and thermal margin setbacks may be influenced by the LTA's core location. For example, placement at a core location under a regulating bank control element assembly may impact the quantity of lead test rods whose irradiated properties and performance (e.g., irradiated pellet thermal expansion) under a rapid power excursion (driven by the uncontrolled withdrawal or ejection of a control element assembly) have not been fully characterized. Avoiding these more challenging core locations may allow larger quantities.

Combinations of limited number and thermal margin setbacks may be influenced by the degree to which irradiated material characterization is relied upon in the design and licensing process. There are fuel assembly design and performance aspects which do not rely on the characterization of irradiated properties and performance (e.g., spacer grid crush strength). In these instances, either unirradiated or pseudo-irradiated material characterization has been judged to be conservative or appropriate. Hence, for these instances, lack of irradiated data would not be a consideration in determining the need for an LTA program or in justification of limited number or nonlimiting location in an LTA program.

An important distinction is that these two restrictions apply only to the LTA's unapproved features and not the balance of fuel assembly components which are operating within their range of approval. As such, there are certain types of LTAs for which application of thermal margin setbacks (i.e., nonlimiting location) is unnecessary to provide reasonable assurance of adequate protection. In general, LTAs which contain limited departures in non-fuel component design features (i.e., maintain approved fuel rod design) fall into this category. For these instances, compliance to this restriction is achieved with no thermal margin setback. Compliance with limited number restriction would still need to be demonstrated.

2.2 *10 CFR 50.59*

2.2.1 Background

Under § 50.59, licensees are allowed to make changes in the facility and procedures as described in the Updated Final Safety Analysis Report (UFSAR) and conduct tests or experiments not described in the UFSAR, without obtaining a license amendment pursuant to § 50.90, provided specific criteria are met. The first criterion, as specified in § 50.59(c)(1)(i), is that a change to the technical specifications incorporated in the license is not required. This criterion has been in the rule since its inception in 1962.

> *….unless the proposed change, test or experiment involves a change in the technical specifications incorporated in the license or an unreviewed safety question,…*

Originally, there was only one additional criterion that the change did not involve an unreviewed safety question. The rule stated that a proposed change, test, or experiment shall be deemed to involve an unreviewed safety question if:

1. The probability of occurrence of an accident previously analyzed in the hazards summary report may be increased; or,
2. If consequences of an accident previously analyzed in the hazards summary report may be increased; or,
3. If a possibility for a nuclear accident of a different type than any analyzed in the hazards summary report may be created.

The rule was refined in 1968, but it was not until 1999 when unreviewed safety question was completely replaced by the eight criteria in today's rule. Regulatory guidance, RG 1.187, *Guidance for Implementation of 10 CFR 50.59, "Changes, Tests, and Experiments"* (Reference 2), is silent on LTAs. NRC-endorsed industry guidance, NEI 96-07, *Guidelines for 10 CFR 50.59 Evaluations* (Reference 3), also does not provide adequate guidance with respect to LTAs. Within the NEI document, reference to LTAs appears only once. The guidance states that *operation with fuel demonstration assemblies* would "screen in" for an evaluation.

It does not appear that any thought was given to LTA licensing when the eight evaluation criteria were codified. As a result, potential conflicts exist between earlier LTA licensing and the following § 50.59(c)(2) evaluation criteria:

> *(iii) Result in more than a minimal increase in the consequences of an accident previously evaluated in the final safety analysis report (as updated);*
>
> *(vii) Result in a design basis limit for a fission product barrier as described in the FSAR (as updated) being exceeded or altered; or*
>
> *(viii) Result in a departure from a method of evaluation described in the FSAR (as updated) used in establishing the design bases or in the safety analyses.*

For example, the licensee may need to rely upon new or modified analytical model to demonstrate compliance to the TS LTA provision restrictions on quantity and placement. Based upon a literal read of § 50.59(c)(2)(viii), the licensee would fail (i.e., positive response) the § 50.59 evaluation and would be required to submit a license amendment request. However, recent staff positions would allow a negative response to this evaluation criterion (See Section 5.0 for further information).

As described in Section 5.1 of this topical report, the NRC has approved several lead fuel assembly programs and issued a clarification letter regarding LTAs. In many of these actions, the NRC staff has established a link between § 50.59 evaluation criteria and compliance to the TS LTA provision. While conflicts may exist with § 50.59(c)(2)(iii) minimal increase in consequences, § 50.59(c)(2)(vii) design basis limit, and § 50.59(c)(2)(viii) departure of a method of evaluation, the NRC position was that compliance with the TS LTA provision superseded these potential conflicts. Effectively establishing a regulatory position that compliance to the TS LTA provision equated to a negative § 50.59 evaluation (i.e., no license amendment request needed to irradiate LTAs).

Buried within letters and proprietary topical reports, this regulatory position has not been broadly incorporated in licensees § 50.59 procedures and remains a source of confusion and potential conflict with the regulation. Guidance on § 50.59 is provided below to capture this significant regulatory position in a more universal, public available, and widely applicable source.

2.2.2 Screening and Evaluation

After completing the LTA safety evaluation documenting the technical rationale for satisfying the TS LTA restrictions, the licensee would follow their internal procedures to determine the appropriate licensing strategy including whether a § 50.59 evaluation and/or license amendment request would be necessary. Figure 2-1 provides a logic diagram which illustrates this process.

The TS LTA provision allows the introduction and irradiation of LTAs, provided restrictions are satisfied. Hence, an allowance for LTAs already exists in the plant's licensing bases. As a result, some licensees may conclude that LTAs which comply with the TS LTA provision do not meet the definition of a change to the facility or its procedures, nor a test or experiment. Therefore, LTAs which conform to the TS LTA program should screen out of the § 50.59 process.

NEI 96-07 Figure 1 provides a logic diagram for performing § 50.59 screenings and evaluations which asks the question: Is the activity controlled by another regulation or change process? A negative response to this question kicks the activity out of the § 50.59 process. Section 1.2.1 of NEI 96-07 provides further clarification and is shown below.

- Where changes to the facility or procedures are controlled by more specific regulations (e.g., quality assurance, security and emergency preparedness program changes controlled under 10 CFR 50.54(a), (p) and (q), respectively; Off-site Dose Calculation Manual changes controlled by technical specifications), 10 CFR 50.59 states that the more specific regulation applies.

LTAs are effectively controlled by the plant's technical specifications which are mandated by 10 CFR 50.36, *Technical specifications*. Therefore, some licensees may conclude that LTAs which conform to the TS LTA program should screen out of the § 50.59 process.

If the licensee's § 50.59 screening procedures direct the licensee to perform an evaluation, there are several past NRC staff positions which help with potential conflicts. With respect to § 50.59(c)(2)(iii) minimal increase in consequences, the staff previously rejected an application which employed the "no more than a minimal increase" criterion for demonstrating compliance to the TS LTA provision. The following text is from the staff's safety evaluation for GESTAR II (Reference 10).

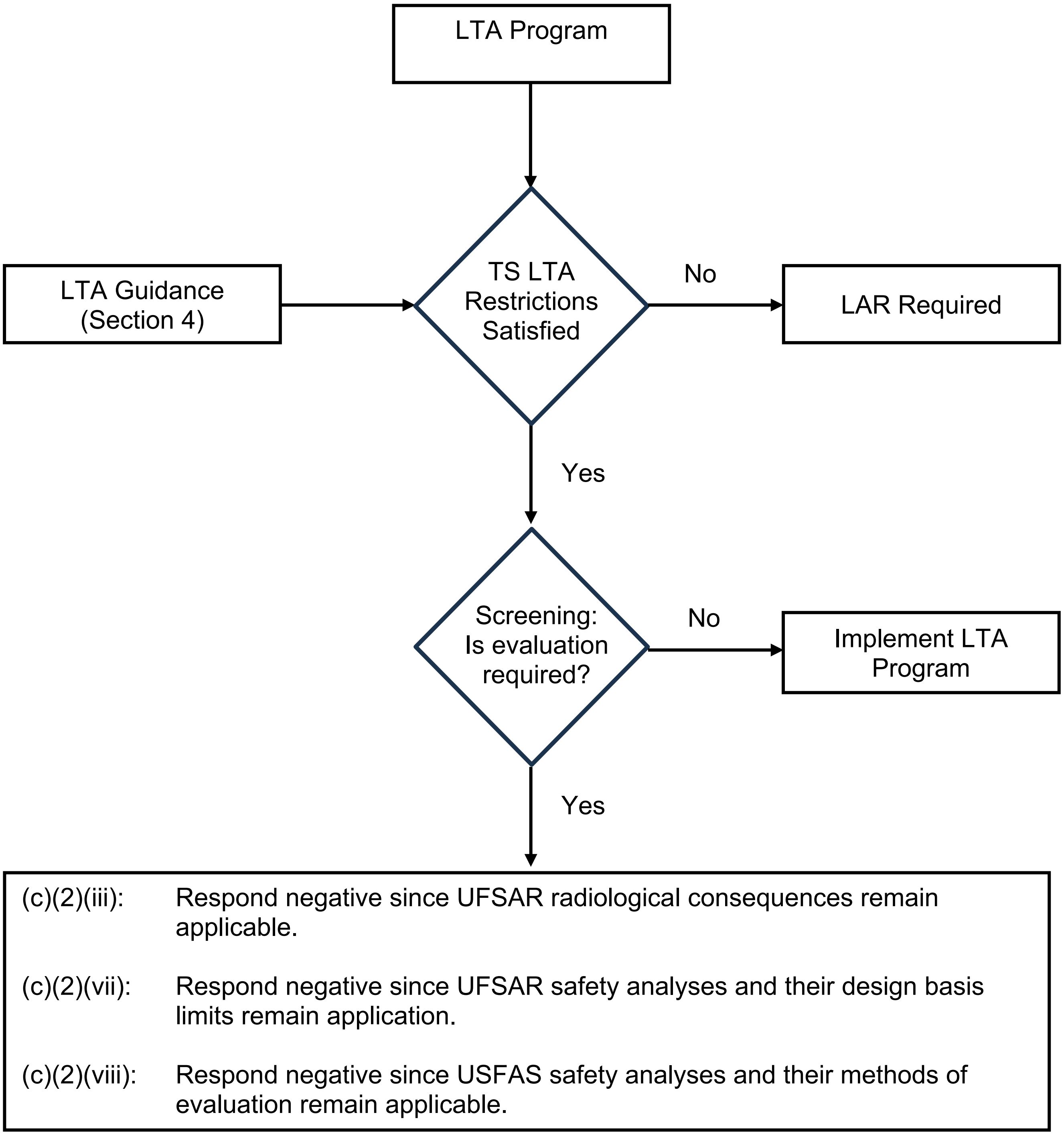
> *Under 10 CFR 50.59(c)(2)(iii), a licensee may make proposed changes or conduct tests or experiments if the proposed change, test, or experiment would not "[r]esult in more than a minimal increase in the consequences of an accident previously evaluated in the [UFSAR]." While the above-discussed demonstration is consistent with this requirement, altering or slightly increasing said radiological consequences is not consistent with the non-limiting restriction of the STS 4.2.1 LTA provision. To satisfy the more restrictive STS 4.2.1 LTA provision, the lead assembly technical evaluation report must demonstrate that all radiological consequences docketed within the licensee's UFSAR remain applicable and bounding.*

The staff's position was that no increase, even a minimal increase, in radiological consequences was acceptable while demonstrating compliance to the TS LTA provision. Hence, there is a potential conflict between the criteria used to satisfy the TS LTA provision and the allowance under § 50.59. However, if the LTA program satisfies the more limiting TS restrictions, then the licensee would be able to respond negative to § 50.59(c)(2)(iii).

With respect to § 50.59(c)(2)(vii) design basis limit, a potential conflict exists for LTA design features with different design basis limits. The staff's position was that LTA programs which satisfy the TS LTA restrictions demonstrate that UFSAR safety analyses, and the design basis limits used to judge compliance with applicable regulations, remain applicable. Therefore, there is no change and the licensee may respond negative to § 50.59(c)(2)(vii).

With respect to § 50.59(c)(2)(viii) method of evaluation, a potential conflict exists for LTA design features which are analyzed using different or modified methods relative to those documented in the UFSAR. The staff's position was that LTA programs which satisfy the TS LTA restrictions demonstrate that UFSAR safety analyses, and the evaluation methods used to demonstrate compliance with applicable regulations, remain applicable. Therefore, there is no change and the licensee may respond negative to § 50.59(c)(2)(viii).

Figure 2-1
10 CFR 50.59 Screening and Evaluation



3.0 CLASSIFICATIONS OF LEAD TEST ASSEMBLIES

LTAs may be comprised of many different mechanical, thermal-hydraulic, or nuclear design features, new or different combinations of materials, and/or application of existing, approved designs or materials beyond their experience base (i.e., higher burnup or fluence). To allow for more explicit guidance, LTAs are segregated into three distinct groups, each with their own limitations and restrictions with respect to the TS LTA provision:

1. Lead Research Assemblies (LRA)
2. Lead Use Assemblies (LUA)
3. High Burnup Lead Use Assemblies (HBLUA)

Descriptions for each classification are provided below.

3.1 *Lead Research Assemblies*

LRAs are BWR or PWR fuel assemblies containing one or more unapproved design feature and/or material. The purpose of LRA programs is to collect data and/or material to characterize the irradiated properties and performance for the design and licensing of a new technology. This may include direct pool-side measurements or shipping irradiated material for hot-cell examination, separate-effects testing, and integral fuel rod testing.

In general, LRAs contain unapproved materials and/or significant changes in design that cannot be justified under an NRC approved change process. LRAs may include, but are not limited to, the following examples:

- An approved BWR fuel assembly design (e.g., ATRIUM 10XM) containing several lead test rods (LTRs) comprised of standard UO_2 fuel pellets within an unapproved cladding material (e.g., advanced zirconium alloy, FeCrAl alloy, Chrome coated zirconium, stainless steel alloy, ceramic material).

- An approved PWR fuel assembly design (e.g., CE16HTP) containing several lead test rods (LTRs) comprised on non-standard UO_2 fuel pellets (e.g., doped UO_2, UN, U_3Si_2) within an unapproved cladding material (e.g., advanced zirconium alloy, Chrome coated zirconium, stainless steel alloy, ceramic material).
- A new PWR fuel assembly design containing a developmental, unapproved guide tube material (e.g., advanced zirconium alloy, nickel alloy, SiC/SiC ceramic material).

Due to their unique characteristics and performance functions, BWR lead research channels (LRCs) are being defined as a subset of LRAs. Similar to LRAs, LRCs generally contain unapproved materials and/or significant changes in design that cannot be justified under an NRC approved change process.

3.2 *Lead Use Assemblies*

Framatome's design control procedures manage the deployment of new or modified fuel assembly designs. As part of this process, new fuel design features or new commercial fuel products which are designed and analyzed in accordance with Framatome's approved BWR fuel design criteria (ANF-89-98(P)(A), Reference 4) or approved PWR fuel design criteria (EMF-92-116(P)(A), Reference 5) are approved and do not need to be submitted to the NRC for explicit review. New design features for reload batch application may also be evaluated under the provisions of § 50.59 to determine whether the change may be implemented without a license amendment request. In certain cases, LUAs (referred to a Lead Fuel Assemblies within cited topical reports) are used to confirm in-reactor performance of new design features. Hence, LUAs may be a new or modified fuel design being introduced under the above design control procedures.

In general, LUAs contain approved materials with only evolutionary changes in design. Hence, the irradiated properties and performance of the fuel assembly component materials are understood and well characterized. This is the bases for not requiring LUAs for all new design features licensed under the above design change processes.

LUA programs may also consist of an approved BWR or PWR fuel assembly design being introduced in limited quantities by a potential new customer. This type of demonstration of in-reactor performance is often used by licensees to inform future commercial decisions involving an upgrade to improved fuel designs or change in fuel vendor.

Due to their unique characteristics and performance functions, BWR lead use channels (LUCs) are being defined as a subset of LUAs. Similar to LUAs, LUCs generally contain approved materials with only evolutionary changes in design.

3.3 *High Burnup Lead Use Assemblies*

HBLUAs are approved BWR or PWR fuel assembly designs which will be irradiated beyond current licensed burnup limits. The purpose of HBLUAs is to increase operating experience and collect data needed to extend the burnup limit.

HBLUAs contain no unapproved materials or design features. HBLUAs may include, but are not limited to, the following examples:

- A PWR fuel assembly design (e.g., GAIA W17x17) being irradiated beyond the approved burnup limit.
- A BWR fuel assembly design (e.g., ATRIUM 11) containing several fuel rods which have been re-inserted into this fresh bundle from prior irradiation. These high burnup LTRs will exceed their approved burnup limit.

Since LRAs may contain unapproved materials and design features which may be analyzed with unapproved methods and acceptance criteria, no official, approved burnup limit exists. Hence, LRAs operated to extended burnup would not fall into the HBLUA category. LRAs must be assessed for their projected end-of-life.

Due to their unique characteristics and performance functions, BWR high burnup lead use channels (HBLUCs) are being defined as a subset of HBLUAs. Similar to HBLUAs, HBLUCs are being irradiated beyond their approved burnup (or fluence) limits. For example, retrofitting an unirradiated BWR fuel assembly design (e.g., ATRIUM 10XM) with a previously irradiated Z4B channel box would be a HBLUC.

4.0 GUIDANCE

Building on the NRC staff's previous interpretations, positions, and guidance, the following guidance was developed to assist licensees in their pursuit of LTA programs. Justification for this guidance is provided in Section 5.

Using this guidance, licensees can complete an LTA safety evaluation documenting the technical rationale for satisfying the LTA restrictions on quantity and placement, compliance with the TS LTA provision, and reasonable assurance of adequate protection for public health and safety.

4.1 *Common Guidance*

The following guidance is common to all types of LTA programs.

4.1.1. TS restrictions on "limited number" and "nonlimiting core region" work in concert to provide reasonable assurance of adequate protection of public health and safety. In some instances, application of a restriction on core placement, which has been historically defined in terms of a thermal margin setback, is unnecessary to provide reasonable assurance of adequate protection. For these instances, compliance to this restriction is achieved with no thermal margin setback.

4.1.2. Combinations of limited numbers and thermal margin setbacks should take into account the relative impact of the LTA's new feature on applicable regulatory requirements and design criteria, the available margin to those criteria, and any uncertainty incurred by the lack of in-reactor experience or characterization of irradiated properties. As experience and characterization increases, larger quantities of LTAs and/or lower thermal margin setbacks are justifiable.

4.1.3. To satisfy the TS restrictions, the LTA evaluation must confirm that potentially limiting UFSAR safety analyses, including docketed radiological consequences, remain applicable.

4.1.4. The LTA’s presence in the reactor core and/or anticipated performance must not necessitate changes to plant Technical Specification or Core Operating Limits Report (COLR) limits.

4.1.5. With respect to demonstrating compliance to “nonlimiting core region”, the nuclear aspects of the LTA shall be designed such that reload batch fuel assemblies are limiting during steady state operation (e.g., with respect to radial peaking factors, MCPR). Any necessary thermal margin setbacks should be defined and verified for each operating reload cycle with LTAs. Traditional methods such as core reload depletion power profiles or core monitoring computer systems (e.g., POWERPLEX) may be used to verify the LTA thermal margin setbacks. LTA thermal margin setbacks should not be included in the COLR.

4.1.6. LTAs shall be designed and analyzed to provide reasonable assurance that regulatory requirements associated with fuel performance under AOOs and DBAs are satisfied with sufficient margin to account for limited in-reactor experience or gaps in the degree of characterization of irradiated properties and performance. This may require larger thermal margin setbacks and/or reduced quantities of LTAs.

4.2 *LRA Specific Guidance*

4.2.1. An acceptable limiting number of LRAs, taken in concert with any necessary thermal margin setback, depends on the nature of the new design feature, amount of in-reactor experience, and characterization of irradiated properties and performance.

4.2.2. The number of lead test rods comprised of new materials which represent a significant departure from historical practice (i.e., non-UO_2 fuel pellet, non-zirconium cladding material) with minimal or no prior in-reactor experience and characterization of irradiated properties and performance needs to be restricted to limited quantities (e.g., less than 0.1% of core) such that unanticipated, unacceptable performance would not interfere with the ability of safety-related systems, structures, and components (SSCs) to perform their intended functions.

4.2.3. The LRA evaluation requires some engineering judgment because of the potentially incomplete availability of representative data before irradiation of the LRAs, and evaluation may necessitate using modified or different codes and methods in the form of: (1) modifications to approved codes and methods, (2) use of approved codes and methods outside the bounds for which they were explicitly approved, or (3) use of a code or method, based on well-established engineering practices, that the NRC has not previously approved.

4.2.4. An acceptable limiting number for lead research channels, taken in concert with any necessary thermal margin setback, depends on the nature of the new design feature and/or material, amount of in-reactor experience, and characterization of irradiated properties and performance.

4.2.5. Lead research channels do not require restrictions on core placement. An augmented surveillance plan may be used to provide additional assurance against unanticipated channel distortion. For example, specifying requirements on the number of lead research channels included in scram-time testing or settle time testing within each nominal TS surveillance interval.

4.3 *LUA Specific Guidance*

4.3.1. The number of LUAs shall be limited to 8 for PWRs, 16 for BWRs with greater than or equal to 560 assemblies, and 8 for BWRs with fewer than 560 assemblies.

4.3.2. The LUA evaluation is performed using approved analytical methods and design criteria. Since the guidance restricts LUAs from dictating or forming the bases of COLR operating limits, these approved methods and design criteria do not need to be present in (or added to) the plant’s TS/COLR list of methods.

4.3.3. The number of lead use channels shall be limited to 32 for BWRs with greater than or equal to 560 assemblies, and 16 for BWRs with fewer than 560 assemblies.

4.3.4. Lead use channels do not require restrictions on core placement or thermal margin setbacks.

4.3.5. LUAs and LUCs shall not be operated beyond the approved fuel burnup (or fluence) limit defined in their license basis (e.g., fuel design change process, fuel rod thermal-mechanical model).

4.4 *HBLUA Specific Guidance*

4.4.1. An acceptable limiting number of HBLUAs depends on the amount of in-reactor experience and characterization of irradiated properties and performance at the target burnup (beyond licensed burnup limit). If large data gaps exist in the irradiated properties database or trends with increasing burnup are unknown, then the number of HBLUAs (or high burnup lead use rods) need to be restricted to limited quantities (e.g., less than 1.0% of core) such that unanticipated, unacceptable performance would not interfere with the ability of safety-related systems, structures, and components (SSCs) to perform their intended functions.

4.4.2. Nominal ^{235}U depletion eliminates the need for explicit thermal margin setbacks (i.e., HBU fuel will operate at lower power than low burnup fuel rods).

4.4.3. The HBLUA evaluation requires some engineering judgment because of the potentially incomplete availability of representative data beyond the licensed burnup limit, and evaluation may necessitate using modified or different codes and methods in the form of: (1) modifications to approved codes and methods, (2) use of approved codes and methods outside the bounds for which they were explicitly approved, or (3) use of a code or method, based on well-established engineering practices, that the NRC has not previously approved.

4.4.4. An acceptable limiting number of high burnup lead use channels depends on the amount of in-reactor experience and characterization of irradiated properties and performance at the target fluence/burnup (beyond licensed burnup limit).

4.4.5. High burnup lead use channels do not require restrictions on core placement or thermal margin setbacks.

4.5 *Coincident Lead Assembly Programs*

The following guidance applies to situations where multiple, concurrent LTA programs are being irradiated in the same reactor. Given the potential variety and possible interactions between combinations of multiple, concurrent programs, numerical values for acceptable limited numbers are not being proposed.

4.5.1. Each LTA program must independently satisfy the applicable requirements put forth in this guidance.

4.5.2. Potential combined effects of the multiple, concurrent LTA programs must be accounted for in the LTA safety evaluation.

4.6 *Allowable Analytical Approaches for Radiological Consequence Assessment*

The LTA evaluation must demonstrate that the docketed radiological consequences for the UFSAR safety analyses remain applicable. Potential additional contributions to radiological source terms from LTA fuel rods must be accounted for in the demonstration that all radiological consequences docketed within the licensee's UFSAR remain applicable. Changes to inputs and assumptions may be used in the LTA technical evaluation to demonstrate no increase in consequence compared to existing UFSAR radiological consequences. For this purpose, these changes do not constitute a departure from an approved methodology as defined by § 50.59 and the requirement of NRC approval to use under 10 CFR 50.67.

Examples of allowable analytical approaches include:

4.6.1. Recognition of LTA fuel rod design relative to design in docketed dose calculations when calculating both radionuclide release fractions (Release/Birth for short-lived radionuclides) and cumulative quantities of radionuclides in the fuel rod plenum.

4.6.2. Recognition of reduced fuel rod power histories (e.g., thermal margin setback or nominal ^{235}U depletion) relative to power levels assumed in docketed dose calculations when calculating both radionuclide release fractions (Release/Birth for short-lived radionuclides) and cumulative quantities of radionuclides in the fuel rod plenum.

4.6.3. Recognition of time-in-life release fractions (Release/Birth for short-lived radionuclides) and cumulative quantities of radionuclides in the fuel rod plenum (as opposed to a composite worst time-in-life where maximum values for each radionuclide are combined regardless of time-in-life).

4.6.4. Recognition of radionuclide decay enroute to and while residing in the fuel rod plenum. With low production rates (power), low release rates (temperature), and natural decay over time, the quantity of active, short-lived radionuclides within the fuel rod plenum region will likely be lower in lower power and high burnup fuel rods (relative to earlier-in-life fuel rods operating at higher powers).

4.7 *10 CFR 50.46 Range of Applicability – Exemption Requirements*

10 CFR Part 50, Appendix A, *General Design Criteria for Nuclear Power Plants* (GDC), Criterion 35, *Emergency core cooling*, mandates a safety system whose function shall be to transfer heat from the reactor core following any loss of reactor coolant at a rate such that (1) fuel and clad damage that could interfere with continued effective core cooling is prevented and (2) clad metal-water reaction is limited to negligible amounts. § 50.46 acceptance criteria provide a means to satisfy GDC-35. However, § 50.46 acceptance criteria are limited in applicability to *uranium oxide pellets within cylindrical zircaloy or ZIRLO cladding*. The empirically-based, prescriptive analytical limits (i.e., 2200°F, 17% ECR) are directly tied to the embrittlement of these zirconium alloys.

All recent LARs for **batch** application of advanced zirconium alloys outside the definition of zircaloy or ZIRLO (e.g., M5) have included (1) research findings which demonstrate that the embrittlement mechanisms and § 50.46 acceptance criteria are applicable and (2) an exemption request to expand the applicability of § 50.46 to these newer cladding materials. Following this precedence, many licensees have submitted similar exemption requests, with or without an accompanying LAR, to irradiate LTAs containing developmental zirconium alloys.

The purpose of the following guidance is to reduce regulatory uncertainty and provide direction with respect to the need for a § 50.46 exemption request. This guidance is applicable to all LTA programs, although it is expected that LUAs and HBLUAs will be comprised of materials which have already been included within a § 50.46 ECCS performance compliance demonstration (either with or without accompanying exemption requests).

4.7.1. If the LTA program satisfies the TS LTA provision, then the licensee's existing § 50.46 ECCS performance compliance demonstration, which itself is based upon approved methods, remains applicable. No exemption from § 50.46 (and Appendix K, if applicable) or alternate means of compliance with GDC-35 is necessary.

4.7.2. If an LAR is required or preferred, and the licensee demonstrates that the existing § 50.46 ECCS performance compliance demonstration, which itself is based upon approved methods, remains applicable, then no exemption from § 50.46 (and Appendix K, if applicable) or alternate means of compliance with GDC-35 is necessary.

4.8 *NRC Oversight and Communications*

Regulatory oversight of technical specification compliance and planned changes and modifications to the plant conducted in accordance with 10 CFR 50.59 is provided via inspection by NRC resident inspectors (augmented by regional and headquarter staff as deemed necessary). LTA programs which comply with the TS LTA provision fall under the same regulatory oversight. Framatome routinely conducts fuel performance update meetings with NRC staff to communicate operating experience, new design features, improved analytical methods, and future licensing actions. With permission of our customers, Framatome intends to share information regarding ongoing LTA programs.

5.0 JUSTIFICATION FOR GUIDANCE

The guidance documented in Section 4.0 builds upon the NRC staff's previous interpretations, positions, and guidance with respect to licensing LTAs. This experience, summarized in Section 5.1, is cited to support the justification provided in Section 5.2.

5.1 *Recently Approved LTA Programs and Guidance*

Limited Scope High Burnup Lead Test Assemblies

In 2003, the NRC staff approved Westinghouse Topical Report (TR) WCAP-15604-NP, Revision 2-A, *Limited Scope High Burnup Lead Test Assemblies* (Reference 6). The purpose of TR WCAP-15604-NP was to provide guidance and a basis for the operation of a limited number of HBU fuel assemblies beyond current fuel design limits. Within this TR, the staff accepted the following attributes of a HBU LTA program:

- Limited number defined as up to 9 pressurized water reactor (PWR) HBU LTAs and 32 boiling water reactor (BWR) HBU LTAs,
- Irradiation to a rod-average burnup up to 75 GWd/MTU is permitted,
- 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.

GNF Expanded NSF Lead Use Channel Program

In 2013 the NRC staff approved GNF's request for an expanded LUC program for their developmental NSF channel material (Reference 7). The LUCs were to be irradiated in accordance with the TS LTA provision. Within this TR, the staff accepted the following attributes of the Expanded NSF LUC program:

- Limited number defined as up to 8% of core inventory
- Unrestricted placement (i.e., no non-limiting restriction)

AREVA Expanded Z4B Lead Use Channel Program

In 2017, the NRC staff approved Framatome's (formerly AREVA) request for an expanded LUC program for their developmental Z4B channel material (Reference 8). The LUCs were to be irradiated in accordance with the TS LTA provision. Within this TR, the staff accepted the following attributes of the Expanded Z4B LUC program:

- Limited number defined as up to 8% of core inventory
- Unrestricted placement (i.e., no non-limiting restriction)

NRC LTA Guidance Letter to NEI

In 2019, NRC issued a letter to NEI (Reference 9) providing clarification of the staff's interpretation of the TS LTA provision and providing a regulatory path for irradiating LTAs. Key positions are captured below.

- The evaluation of LTA campaigns requires some engineering judgment because of the incomplete availability of representative data before irradiation of the LTAs, and evaluation may necessitate using modified or different codes and methods in the form of: (1) modifications to approved codes and methods, (2) use of approved codes and methods outside the bounds for which they were explicitly approved, or (3) use of a code or method, based on well-established engineering practices, that the NRC has not previously approved.
- Use of these modified or different codes and methods, solely for the evaluation of "a limited number" of LTAs, may be acceptable without additional NRC approval for confirming that the LTAs are placed in nonlimiting regions and that the core operating limits and UFSAR safety analyses, which themselves are calculated using approved codes and methods, remain applicable.

- With respect to 10 CFR 50.59(c)(2)(viii), the letter states that lead assembly programs which satisfy the TS LTA provisions do not result in a "departure from a method of evaluation" because the presence of these lead assembly programs does not affect the performance of safety-related SSCs, and therefore, the method of evaluation used in establishing the design bases will remain the same.

GESTAR II Lead Assembly Program

In 2020, the NRC approved Global Nuclear Fuel's Amendment 51 to NEDE-24011-P-A-29, General Electric Standard Application for Reactor Fuel (GESTAR II) (Reference 10). Amendment 51 introduces an overarching lead assembly program that defines an acceptable regulatory path under the TS LTA provision, including specific limitations and restrictions, for each of three different types of lead assemblies: LTAs, LUAs, and HBLUAs. Within this TR, the staff accepted the following attributes of the GESTAR II lead assembly program:

- Limited number defined for each of the three different types of lead assemblies.
    - For LTAs, no specific numerical value provided. A numerical limit depends on the nature of the design and the degree of prior characterization of the LTAs' performance.
    - For LUAs, limited number defined as up to 16 for plants with greater than or equal to 560 assemblies and up to 8 for plants with less than 560 assemblies.
    - For HBLUAs, limited number defined as up to 16 for plants with greater than or equal to 560 assemblies and up to 8 for plants with less than 560 assemblies.

- The definition of non-limiting location was established.
  - Lead assemblies shall be designed and their associated core locations chosen such that reload fuel assemblies are limiting during steady state operation as determined by the Reference Loading Pattern and associated Technical Specification thermal limits monitoring for LHGR, MAPLHGR and MCPR. Only regulatory requirements potentially impacted by the new design features in lead assemblies are considered.
  - Similar to licensed fuel designs, for Design Basis Accidents (e.g., LOCA), lead assemblies shall be designed and analyzed to assure regulatory requirements for DBAs are maintained with sufficient margin to account for uncertainties.
  - For HBLUAs, nominal ^{235}U depletion eliminates the need for thermal margin setbacks (i.e., HBU fuel will operate at lower power than low burnup fuel rods) and this reduced power may be credited to account for uncertainties in performance under DBA conditions.
- The lead assembly technical evaluation report shall demonstrate that all radiological consequences docketed within the licensee's UFSAR remain applicable and bounding even with some bundles or rods exceeding current exposure limits. Changes to inputs and assumptions may be used in the technical evaluation to demonstrate that lead assemblies have no increase in consequence compared to existing UFSAR radiological consequences and these changes do not constitute a departure from an approved methodology as defined by 50.59 and the requirement of NRC approval to use under 10 CFR 50.67.
  - Several examples of acceptable analytical approaches are provided.

5.2 *Justification*

Common guidance provided in Sections 4.1.1 through 4.1.6 are consistent with the approved guidance in GESTAR II. Consistent with GESTAR II, the LTA thermal setbacks may be governed by (1) nominal operations or (2) anticipated performance under AOOs and DBAs with respect to satisfying regulatory requirements.

The anticipated performance of the LTA under AOOs and DBAs does not have to be bounded by the co-resident fuel, it only must satisfy the underlying regulatory requirements. This is an important distinction, especially for plants which have large margins to safety limits. For further clarity, two examples are provided below.

- Predicted peak cladding temperature (PCT) during a postulated large break loss-of-coolant accident (LOCA) is 1700°F for co-resident fuel and 1740°F for the LTA fuel rods. This situation is acceptable provided the margin to 2200°F (2200°F - 1740°F = 460°F) is sufficient to cover any additional uncertainties associated with LTA performance under LOCA conditions. This example assumes that the 2200 °F PCT criterion is applicable to or conservative with respect to preserving coolable geometry for the LTA fuel rod cladding.
- Predicted transient cladding strain and fuel centerline temperature during an Inadvertent Bank CEA Withdrawal event are 0.2% and 4200°F for co-resident fuel and 0.3% and 4400°F for the LTA fuel rods. This situation is acceptable, provided the margins to the LTAs respective cladding strain limit and centerline melt temperature are sufficient to cover any additional uncertainties associate with LTA performance under these AOO conditions. This example assumes that these performance metrics are applicable to or conservative with respect to preserving cladding integrity for the LTA fuel rod design.

LRA specific guidance provided in Sections 4.2.1 through 4.2.3 are consistent with the approved guidance in GESTAR II. Section 4.2.4 guidance for LRC is consistent with LRAs. In Section 4.2.5, the unrestricted placement for LRC is consistent with the NRC's approval for NSF and Z4B lead channels.

LUA specific guidance for allowable BWR quantities provided in Section 4.3.1 is consistent with GESTAR II. In their safety evaluation, the NRC staff stated:

> *Given that LUAs are pre-production prototype fuel designs, analyzed with NRC-approved codes and methods, and satisfy all GESTAR II thermal-mechanical design criteria, the NRC staff finds the numerical limits acceptable.*

LUAs, as defined in this topical report, are also pre-production prototype fuel designs, analyzed with NRC approved codes and methods, and satisfy approved thermal-mechanical design criteria. As such, it is reasonable to apply the same BWR limitation on quantity. For PWRs, an alike small quantity was defined, recognizing the need for traditional octant symmetry in core loading patterns.

Section 4.3.2 guidance on use of approved methods and design criteria are consistent with GESTAR II.

Section 4.3.3 allowable quantities of LUCs were defined similar to, but smaller than, the approved NSF and Z4B LUC programs. And consistent with these approved LUC programs, no restrictions on core placement or thermal margin setbacks were levied in Section 4.3.4.

Section 4.3.5 restriction on operation within approved range of applicability is consistent with GESTAR II.

HBLUA specific guidance is provided in Sections 4.4.1 through 4.4.3. Whereas GESTAR II defined an acceptable quantity (i.e., numerical value) of HBLUAs with an associated limit on allowable fuel rod burnup based upon documented experience, this guidance maintains the undefined TS LTA restriction on limited quantity which must be justified based on operating experience and characterization of irradiated properties and performance. With the recent approval of fuel rod thermal mechanical models (e.g., GALILEO) up to extended fuel rod burnup, a future, even higher target burnup for which future HBLUA programs would help justify and license has not yet been defined. As such, specifying an acceptable quantity with justification up to a defined target burnup limit is premature.

Consistent with GESTAR II, it is recognized that HBLUAs will operate at reduced local power levels relative to lower burnup co-resident fuel due to ^{235}U depletion during nominal operation up to the licensed burnup limit. This nominal ^{235}U depletion eliminates the need for explicit thermal margin setbacks during nominal operation and may be credited to account for potentially higher uncertainties in fuel performance during AOOs and postulated DBAs.

In Section 4.4.4, the approach to high burnup lead use channels with respect to limited numbers is consistent with HBLUAs. Consistent with NSF and Z4B LUC programs, no restrictions on core placement or thermal margin setbacks were levied in Section 4.4.5.

Section 4.5 provides guidance specific for addressing multiple, concurrent LTA programs. With respect to multiple, concurrent LTA programs, the NRC approved specific limitations on combined quantities in GESTAR II. The staff's approval is summarized below.

> *Given that the individual and combined effects of the multiple lead assembly programs will need to satisfy the general program requirements listed above pertaining to demonstrating compliance with lead assembly quantities and location restrictions, the NRC staff finds this limitation acceptable.*

Given the potential variety and possible interactions between combinations of multiple, concurrent programs, numerical values for acceptable limited numbers are not being proposed in this topical report. However, the guidance maintains the requirement that both the individual and combined effects be specifically accounted for in the LTA safety evaluation.

Section 4.6 provides guidance related to LTA radiological consequence assessments. Consistent with GESTAR II, several analytical approaches are provided for assessing the potential impact of LTAs on the radiological source term and downstream dose calculations.

Section 4.7 provides guidance with respect to the need for a § 50.46 exemption request. This guidance is consistent with that found in GESTAR II and the NRC clarification letter to NEI.

Section 4.8 defines the regulatory oversight process for LTA programs which comply with the TS LTA provision. Regulatory oversight is consistent with historical practice for plant operations conducted in accordance with plant's license bases and Technical Specifications.

Unlike some of the precedents cited earlier, no new commitments for information letters to the NRC are included in this guidance. These earlier topical reports were approved LTA/LUC programs, not generic guidance. The NRC's letter to NEI which provided LTA clarification and guidance did not impose new requirements for information letters. Similarly, no new commitments are made for licensee's applying this guidance.

6.0 REVISION TO TS LTA PROVISION

Changes to the language in the TS LTA provision are provided below which capture the guidance in this topical report. This expanded definition may help reduce regulatory uncertainty for future LTA programs. Licensees may consider bundling this TS change into a future LAR.

Recommended Change:

> ~~A limited number of fuel assemblies that have not completed representative testing may be placed in nonlimiting core regions.~~
>
> [paragraph break]
>
> A limited number of lead assemblies may be placed in the reactor core. The presence of these lead assemblies shall not necessitate changes to Technical Specification or COLR limits, negatively influence the performance of co-resident fuel assemblies, or interfere with the ability of safety-related systems, structures, and components to perform their intended functions. Thermal margin setbacks, in combination with limited quantities, should be applied, as necessary, to account for additional uncertainties associated with the anticipated performance of the lead assemblies. These restrictions should take into account the relative impact of the LTA's new feature on applicable regulatory requirements and design criteria, the available margin to those criteria, and any uncertainty incurred by the lack of in-reactor experience or characterization of irradiated properties.

7.0 CONCLUSIONS

The purpose of this topical report is to provide guidance on the interpretation and implementation of the TS LTA provision within the construct of the plant's existing licensing bases. The TS LTA provision includes restrictions on the quantity and placement of LTAs. If the LTA irradiation program satisfies these restrictions, then the LTAs may be loaded and irradiated without prior NRC approval. This topical report provides guidance to assist licensees in making the decision as to whether a future LTA irradiation program satisfies these requirements. Since the guidance restricts LTAs from dictating or forming the bases of COLR operating limits, this topical report does not need to be added to the COLR list of approved methods (e.g., TS 5.6.5).

8.0 REFERENCES

1. NUREG-1433, Standard Technical Specifications, General Electric BWR/4 Plants, Revision 5, Volume 1, September 2021.
2. Regulatory Guide 1.187, Guidance for Implementation of 10 CFR 50.59, “Changes, Tests and Experiments”, Revision 3, June 2021.
3. NEI 96-07, Guidance for 10 CFR 50.59 Implementation, Revision 1, November 2000.
4. ANF-89-98(NP)(A), Generic Mechanical Design Criteria for BWR Fuel Designs, Revision 1, Supplement 1, May 1985.
5. EMF-92-116(NP)(A), Generic Mechanical Design Criteria for PWR Fuel Designs, Revision 0, February 1999.
6. Westinghouse Topical Report, Limited Scope High Burnup Lead Test Assemblies, WCAP-15604-NP, Revision 2-A, September 2003.
7. NRC Letter to GNF, Final Safety Evaluation for Global Nuclear Fuel – Americas Topical Report (TR) Enhanced Lead Use Channel Program for NSF Fuel Bundle Channels, March 29, 2013.
8. ANP-10336NP-A, Z4B™ Fuel Channel Irradiation Program, Revision 0, July 2017.
9. NRC Letter to NEI, Clarification of Regulatory Path for Lead Test Assemblies, June 24, 2019.
10. NRC Letter to GNF, Final Safety Evaluation for Global Nuclear Fuel Proposed Amendment 51 to Topical Report, NEDE-24011-P-A-29, General Electric Standard Application for Reactor Fuel, November 12, 2020.