5 MATERIALS

The lead test assembly (LTA) materials were selected so that the properties satisfy the functional requirements and compatibility requirements of the other reactor components, reactor coolant, emergency core cooling fluids, fuel pool components, and fuel pool cooling systems. Chapter 5 of the Department of Energy (DOE) report addresses materials specifications (Section 5.1), materials properties (Section 5.2), materials performance (Section 5.3), and nondestructive examination (Section 5.4).

5.1 Materials Specifications

In Section 5.1 of its report, DOE states that the LTA is constructed of materials that have been chosen for their ability to perform successfully considering results from in-reactor and ex-reactor test programs, and for their compatibility with the other internal reactor components, fuel assemblies, the reactor coolant system, fuel pool components, and fuel pool cooling systems. The LTA hold-down assembly is a Westinghouse component used in burnable poison rod assemblies (BPRAs) and is, therefore, not unique to the LTA. The materials of the tritium producing burnable absorber rod (TPBAR) have been selected to reflect design characteristics suitable for the production and retention of tritium. Earlier tritium target rod designs were irradiated in the Advanced Test Reactor. On the basis of experience with those designs, material requirements for the tritium-producing rods have continued to evolve. DOE states that numerous improved design features and materials have been incorporated into the TPBAR to ensure that the functional requirements will be met.

DOE states that quality standards for material selection, fabrication, handling, storage, and inspection are specified to ensure that important functions are maintained. To verify that materials are in compliance with specifications, materials and components are subjected to quality inspections by the vendor and by Pacific Northwest National Laboratory (PNNL). The venders prepare certified material test reports (CMTRs) for all TPBAR components.

DOE presents information based on results from in-reactor and ex-reactor test programs, and for the materials' compatibility with the other reactor internal components, fuel assemblies, the reactor coolant system, fuel pool components, and the fuel pool cooling system. This information offers reasonable assurance that the materials chosen for this program will perform successfully in the TPBAR. The staff notes that some changes may be required in the quality standards, as mentioned in the discussions on Section 2 of this safety evaluation. DOE must evaluate the effects of thermal cycling, particularly on the cladding and cladding coating as noted by the Advisory Committee on Reactor Safeguards (ACRS) (discussed later in this section). Finally, consideration needs to be given to metal-metal and intermetallic interactions during design-basis accidents, also as suggested by the ACRS.

5.2 Materials Properties

The properties of TPBAR materials are given in the Materials Property Handbook (MPH). The properties indexed in the MPH are listed in Table 5-2 of the DOE report. The MPH was used for the design and analysis of the TPBAR cladding, and component dimensions were specified to prevent interactions caused by thermal expansion, irradiation growth, and swelling. The cladding and components were designed to prevent excessive changes in dimensions that could lead to degradation. The design is described in Chapter 2 of DOE's report.

As discussed in Section 2 of this safety evaluation, DOE has presented sufficient information to give reasonable assurance that there will be no adverse interactions caused by thermal expansion, irradiation growth, and swelling. Further evidence of no adverse interactions comes from operating experience with austenitic stainless steel fuel cladding at Northeast Utilities' Haddam Neck plant, Southern California Edison's San Onofre Unit 1, Consumers Power Company's Big Rock Point plant, and Dairyland Power Cooperative's La Crosse plant.

5.3 Materials Performance

In Section 5.3 of its report, DOE addresses the materials performance aspects of TPBAR design. The key materials that enable a TPBAR to generate and store tritium are: (1) permeation-resistant Type 316 stainless steel (316 SS) barrier-coated cladding and end plugs, (2) oxidation-resistant nickel-plated Zircaloy-4 getters, (3) lithium aluminate absorber pellets, and (4) Zircaloy-4 liner. Other materials are the American Society for Testing and Materials (ASTM) 302 stainless steel (302 SS) spring and helium gas. The opportunity for material degradation of the TPBAR is limited by the in-core residence period of one fuel cycle.

5.3.1 Cladding and End Plug Material

The TPBAR design has evolved from years of operating experience at a number of reactors. 316 SS has been the material historically used for tritium target cladding. Processes for permeation barrier application were developed using 316 SS cladding. Sufficient experimental and performance data for barrier-coated tubing using other materials are not available. 316 SS with 20-percent cold-worked (CW) was specified to establish adequate strength while staying within the experience base established for 300-series SS.

A 20-percent CW 316 SS was specified for all TPBAR components that form the pressure boundary (cladding and end plugs) with the reactor coolant. Tubing used for fabrication of the TPBAR is seamless (non-welded). When compared with 304 SS, which has been extensively used in pressurized-water reactors (PWRs) for BPRA cladding and fuel cladding, 316 SS exhibits better general corrosion resistance and better resistance to pitting corrosion, higher resistance to transgranular stress corrosion cracking (TGSCC) and to intergranular stress corrosion cracking

(IGSCC) in aggressive environments, and greater strength and resistance to creep. Figure 5-1 of the DOE report shows that the allowable stress for the ASTM A 771 316 SS between 100 (38 °C) and 850 °F (454 °C) is much higher than the allowable stress for 304 SS.

The most commonly used austenitic stainless steel in the nuclear industry is 304 SS. This material has a nominal composition of 19-percent chromium, 9-percent nickel, 1-percent manganese, and up to 0.08-percent carbon. This material is used for cladding in dummy fuel pins that shield reactor vessel walls from radiation damage, for active fuel pins, for reactor vessel cladding, for primary coolant system piping and valves, and as fuel cladding in four domestic PWRs. A significant increase in corrosion resistance is achieved by using 316 SS instead of 304 SS. Type 316 SS has a nominal composition of 17-percent chromium, 12-percent nickel, 2.5-percent molybdenum, 1-percent manganese, and up to 0.08-percent carbon. The molybdenum addition gives the 316 SS improved corrosion resistance and also provides higher creep, stress-to-rupture, and tensile strength at elevated temperatures. Type 316 SS has been used in nuclear piping, pumps, valves, and previous tritium target cladding.

Coolant/316 SS Compatibility

Section 5.3.1.1 of the DOE report states that 316 SS is compatible with the reactor system primary coolant. Experience in operating PWR and boiling-water reactor (BWR) plants with stainless steel cladding of fuel rods, control rods, and structural components (e.g., end-plate castings and support grids) confirms that uniform corrosion of stainless steel is negligible; less than 0.0001 in. per year (2.5 μm per year). DOE states that the cladding wastage in a commercial light-water reactor (CLWR) caused by uniform corrosion of the TPBAR external surface during 550 effective full power days (EFPDs) is less than 0.0003 in. (7.6 μm).

DOE has presented sufficient calculational results, test results, and operating experience to adequately assure that the corrosion rate of the TPBAR components will be negligible and that the TPBAR components are compatible with the primary coolant. Furthermore, there is considerable operational experience in commercial reactor coolant systems with austenitic stainless steel to give assurance that these steels are compatible with the primary coolant.

As discussed in Sections 2.2.1 and 2.2.6 of this safety evaluation, the staff has asked DOE to provide additional information concerning the effect of thermal cycling on TPBAR components and metal-metal and intermetallic interactions during a design basis accident. This information must be included as part of the Tennessee Valley Authority's (TVA's) application for an amendment to the facility operating license for Watts Bar.

Stress Corrosion Cracking

Section 5.3.1.2 of the DOE report states that stress corrosion cracking (SCC) in 300-series stainless steel requires: (1) thermal sensitization or irradiation-induced susceptibility, (2) high stresses (near or above the yield stress), and (3) an aggressive environment (e.g., reactive species such as oxygen, chloride, and/or fluoride in an aqueous medium at concentrations much higher than typical levels in PWR coolant; typical levels are less than 5 ppb oxygen, less than 50 ppb chloride, and less than 50 ppb fluoride). Each of these factors is described below.

- Materials Susceptibility

  Thermal treatments in the temperature range of 800 °F (425 °C) to 1500 °F (815°C) have the potential to sensitize 304 or 316 SS. The process of applying an aluminide coating to the internal surface of TPBAR cladding requires temperatures within this range. Therefore, TPBAR cladding may be thermally sensitized, depending on the actual carbon content of the 316 SS and the time that the 316 SS is held in the sensitizing temperature range.

  Irradiation of 300-series SS to neutron fluences greater than 1 to 2 x 10^{22} n/cm^2 (E less than 1 MeV) may decrease chromium (Cr) concentrations at grain boundaries by promoting Cr diffusion away from the grain boundary region, thereby increasing the susceptibility to SCC. The peak neutron fluence expected for the TPBAR cladding is approximately 5 x 10^{21} n/cm^2 (E less than 1 MeV). Therefore, TPBAR cladding may be subject to some reduction in grain boundary Cr during irradiation, resulting in irradiation-induced susceptibility to SCC. However, the PWR environment would not cause SCC.

- Stress

  The TPBAR design inner pressure limit of 3000 psia (20.7 MPa) is approximately 750 psi (5.2 MPa) above the reactor system external pressure of 2250 psia (15.5 MPa). Therefore, the tensile hoop stresses from internal pressurization remain very low throughout the period of irradiation. Material considerations related to design-basis accidents are discussed in Section 2.2.1 of this safety evaluation. Irradiation-induced swelling of the pellets and irradiation growth of the getters are insufficient to stress the cladding. The absorber pellets remain intact during irradiation. Absorber pellets generally do not fracture, but if a pellet fractured, localized stresses in the cladding from interaction of the cladding with pellet fragments would be prevented by the intervention of the getter, which confines the absorber pellet material. The thin walls of the absorber pellets, nominally 0.040 in. (1 mm), will prevent mechanical damage from interaction between pellets and cladding, such as could result from fracturing of solid absorber pellets or fuel. The stress in the TPBAR is insufficient to cause or propagate SCC.

- Environment

  DOE states that the external operating environment for the TPBAR during irradiation will be standard PWR coolant maintained within Technical Specification chemistry limits for oxygen and reactive compounds. Austenitic stainless steel is not considered susceptible to attack in this environment. Severely sensitized stainless steels do not undergo any intergranular attack in Westinghouse PWR coolant environments. Issues such as boiling, crevices, highly borated solutions, and stagnant flow, which can result in more severe environmental conditions, are not present in the TPBAR operating environment.

DOE states that, during reactor shutdown and cooldown, the TPBAR cladding is not susceptible to SCC because the temperature is below 200 °F (93 °C) and the stresses are low. Experience with SS-clad spent nuclear fuel at temperatures below 200 °F (93 °C) has shown that for storage periods up to 25 years, there is no measurable degradation of stainless steel cladding in pool water typical of PWR spent fuel pools.
Although the TPBAR material may become sensitized or susceptible, SCC is not anticipated because a TPBAR has very low tension stress and the reactor coolant chemistry control program ensures a non-aggressive environment.

The staff concludes that DOE has presented analyses and operating experience to give adequate assurance that the stainless steel components will be resistant to SCC in PWR environments, particularly since they are only required to survive one operating cycle. It is unlikely that the stainless steel components would fail in one operating cycle even if they were highly susceptible and in a higher oxygen environment. Operating experience in commercial nuclear reactors lends support to this conclusion.

The ACRS raised several issues at the March 7, 1997, presentation by DOE. The issues are that DOE's report does not address the effects of thermal cycling during postulated design-basis accidents (DBAs) on the materials, particularly on the cladding and the aluminide barrier. Also, DOE has not discussed whether any metal-metal or intermetallic interactions that could result in the development of brittle microstructures will occur during postulated DBAs. Discussion is also needed on temperature limits for metal-metal and intermetallic interactions and the failure mechanism as a result of these interactions. The staff concludes that information on these issues will have to be evaluated before it can reach a conclusion on the acceptability of irradiating LTAs containing TPBARs in any facility licensed by the Nuclear Regulatory Commission. DOE has agreed to investigate these issues and to give the findings of their investigation to ACRS and the staff.

Effect of Barrier Coating on Cladding Performance

Section 5.3.1.3 of the DOE report states that the strength of the barrier- coated cladding is adequate to prevent buckling of the cladding at the beginning of life (BOL) before a TPBAR has generated sufficient internal pressure to support the external coolant pressure.

The staff concludes that, as discussed previously in Section 2 of this safety evaluation, DOE has presented analyses and test data to give reasonable assurance that the cladding will not buckle before internal pressure develops.

Furthermore, the experience with stainless steel cladding at Palisades in dummy fuel pins and at Haddam Neck, Big Rock Point, San Onofre Unit 1, and La Crosse indicates that the cladding will not buckle.

Results of Cladding Burst Tests

Section 5.3.1.4 of the DOE report states that cladding burst tests were conducted to support evaluation of cladding performance under DBAs. The test results shown in Figure 5-2 of the DOE report indicate that the burst stresses and temperatures for uncoated 20-percent cold-worked (CW) tubing and for coated cladding are indistinguishable. Therefore, burst tests conducted on 20-percent CW tubing (or on heat-treated cladding that simulates the coating process) are applicable to barrier-coated cladding used in TPBARs.
DOE states that, for the operating design pressure of 3000 psia (20.7 MPa), the hoop stress at 1500 °F (815 °C) is 43,800 psi (302 MPa). These pressure-temperature conditions approach the cladding breach curve presented in Figure 5-2 of the DOE report. These results indicate that 1500 °F is a threshold temperature for burst of TPBAR cladding. In all of these burst tests, the cladding strain exceeded 6 percent, considerably in excess of the 1-percent minimum strain design criterion to ensure adequate cladding ductility.

DOE's experimental burst test data indicate that the limiting temperature before the cladding will burst is in the vicinity of 1500 °F. These results indicate that the cladding would burst during a design-basis large-break loss-of-coolant accident (LBLOCA). The consequences of a burst of the cladding are discussed in Section 6.3.3 of this safety evaluation.

Weld Qualification

Section 5.3.1.5 of the DOE report states that the internal contents are contained by plugs that are welded to each end of the TPBAR cladding. DOE states that welding forms a sound metallurgical and structural joint between the end plug and the stainless steel cladding, and weld preparation of the cladding involves removing the aluminide barrier in the weld region to avoid alloying the weldment with aluminum. The welding procedure specifies the requirements for welding operator qualification and the welding process parameters to produce weldments that meet specifications. Weldment quality is tested in accordance with (1) American Society for Testing and Materials Standard E2 (ASTM E2) for metallographic examination, (2) American Society of Mechanical Engineers (ASME) requirements for helium leak testing, (3) internal PNNL specifications, and (4) radiographic examination.

DOE states that the TPBAR end plugs are attached to the cladding by means of an autogenic (no filler metal added) weld process; therefore, DOE finds that the conditions of Regulatory Guide 1.31 do not apply.

On the basis of the information in the DOE report, the staff concludes that the weld qualification procedure for TPBARs is deficient. Since the TPBAR is considered safety- related, the welder qualification and weld process specification must conform to the requirements of Section IX of the ASME Code, as well as to additional requirements of the construction code, owners specifications, and the additional requirements for special processes of NQA-1 and the Westinghouse quality assurance (QA) program. The DOE report does not address which construction code will be used for welder qualification and weld process specifications. ASTM E2 is no longer an approved standard; it was replaced in 1982 by ASTM E883. ASTM E883 describes how to conduct metallographic examinations, and its use for examining these welds needs to be described in more detail. Therefore, TVA must supplement the welding procedure described in Section 5.3.1.5 of the DOE report to address these concerns before the staff can conclude that TPBAR LTA irradiation in the Watts Bar reactor is acceptable.

Hydrogen Isotope Permeation

In Section 5.3.1.6 of its report, DOE states that the inner surface of the cladding is aluminized to limit the permeation of tritium through the cladding into the reactor coolant and the permeation of hydrogen from the coolant into the TPBAR. This is achieved by applying an aluminumized barrier on the inner surface of the cladding.

DOE's conclusion that the use of an aluminized barrier to limit the permeation of tritium through the cladding is based on its on prior experience with this coating in DOE reactors.

Materials Compatibility

Section 5.3.1.7 of the DOE report states that the TPBAR materials do not interact chemically below their melting temperatures indicated in the MPH. DOE further states that (1) the stainless steel cladding provides structural strength to withstand reactor irradiation, flow, pressure, and temperature conditions, and (2) in-reactor and ex-reactor test results indicate that the aluminide barrier will not peel or blister.

Should a TPBAR become water-logged from a cladding breach (an abnormal event), DOE states that aluminum, chlorine, suspended solids, tritium, and helium would be released when the aluminide barrier on the inner surface of the cladding dissolves. A very small quantity of nickel contained in the getter will dissolve when it is exposed to reactor coolant. DOE states that for simultaneous breach of 32 TPBARS, the maximum concentrations released to the reactor coolant are predicted to occur between 200 and 300 hours following the breach; and the maximum contributions are orders of magnitude below the reactor coolant system (RCS) chemistry limits. Therefore, cladding breach of 32 TPBARs would not affect the chemistry of the reactor coolant. The effects of tritium release to the reactor coolant are assessed in Chapter 6 of the DOE report.

The staff concludes that DOE has provided sufficient analyses and ex-reactor and in-reactor data to give reasonable assurance that the TPBAR materials are compatible with RCS coolant for one operating cycle.

5.3.2 Pencils

The TPBAR's main internal subassemblies, shown in Figure 2-2 of the DOE report, are a stack of subcomponents, referred to as "pencils." The cylindrical getters serve as the outer structure for

the pencils. The pencils are coined on the ends to confine the absorber pellets, but are not hermetically sealed.

5.3.3 Absorber Pellets

Within each pencil is a stack of right-cylindrical, high-density, annular, lithium aluminate ($LiAlO_2$) absorber pellets enriched with ^6Li. The concentration of ^6Li is 25 to 33 percent, but higher or lower concentrations of ^6Li can be accommodated. DOE states that the physical properties of absorber pellets are insensitive to the ^6Li content. The absorber pellets are ceramic and have a melting point of 3182 °F (1750 °C), a temperature that is not expected to be reached during normal operating or DBA conditions.

Absorber Pellet Mechanical Properties

In Section 5.3.3.1 of its report, DOE states that strength, density, irradiation, swelling, and gas release affect the mechanical performance of pellets. The absorber pellets are resistant to thermal shock. Thermal shocking of the pellets by rapid increase from ambient temperature to 1652 °F (900 °C) within 2 minutes did not have an observable effect on microstructure or strength. DOE states that the axial compressive fracture strength of absorber pellets is in the range of 80,000 psi (550 MPa) to 130,000 psi (900 MPa) at ambient temperature, as indicated in Figure 5-3 of the DOE report. The increased fracture strength shown in Figure 5-3 for several pellets tested at 1652 °F (900 °C) was caused by the onset of high- temperature plasticity.

DOE states that pellets are capable of withstanding loads of 150 pounds per linear inch (26.8 kg/cm) applied in the radial direction. The mechanical strength of the pellets supports the conclusion that they will withstand shipping and handling load requirements without sustaining damage.

DOE has presented test data to provide reasonable assurance that the absorber pellets have sufficient strength and thermal shock resistance to survive an operating cycle and to survive shipping and handling load requirements without damage. DOE also submitted calculations that indicate that the melting temperature of the pellets will not be exceeded during normal operating and DBA conditions.

Absorber Pellet Irradiation Performance

In Section 5.3.3.2 of its report, DOE states that, as shown in Table 5-1 of the DOE report, the absorber pellets evaluated by post-irradiation examinations (PIEs) were intact after irradiation to 154 to 239 gas volume ratio (GVR). Only minor microcracking, negligible grain growth, and small (less than 1 μm) as-fabricated porosity was observed. Therefore, pellet disintegration, major cracking, or redistribution is not expected below the TPBAR peak design goal of 215 GVR. In Chapter 2 of its report, DOE discusses the GVR expected during in-core residence.

DOE states that gas retention in absorber pellets depends on production rate and temperature. The absorber pellets release approximately 97 percent of the generated helium. During irradiation, the pellets retain some tritium, to the extent of 30 to 40 Ci per cc.

DOE states that absorber pellets are insoluble and do not disintegrate in water. Therefore, in the event of a cladding breach, absorber pellets remain intact and lithium is not redistributed.

DOE submitted test data based on the observations of the pellets after irradiation. These data provide reasonable assurance that the absorber pellets will perform as intended.

5.3.4 Getter

DOE states that the pencils are enclosed by a getter tube of Zircaloy-4 plated with nickel. The getter maintains a low tritium partial pressure by absorbing tritium as it is released from the absorber pellets. The nickel protects the Zircaloy-4 from oxidation, thereby enhancing the absorption of tritium.

5.3.5 Liner

DOE states that absorber pellets generally do not fragment, but, if fragments were generated, the Zircaloy-4 liner provides additional assurance that the fragments will be confined. The liner functions to control oxygen and moisture by reacting with T_2O and H_20. Zircaloy-4 liners are insoluble in water and have no effect on the reactor coolant in the event of a cladding breach.

5.3.6 Plenum Subassembly and Getter Disk

As illustrated in Figure 2-2 of the DOE report, the plenum subassembly contains a 302 SS spring enclosed by a getter tube, with an upper getter disk attached to the lower end of the getter tube. The plenum subassembly is supported by the top pencil and prevents axial movement of the pencils during TPBAR shipping and handling. The spring is similar to springs in PWR fuel rods and BPRAs. Because the weld areas and the top and bottom end plugs are not coated, the upper getter tube and getter disk and the lower getter disk maintain low tritium pressure at the extremities of the TPBAR. DOE states that these materials will not dissolve in water.

5.3.7 LTA Hold-Down Assembly

The hold-down assembly (shown in Figure 2-1 of the DOE report) is supplied by Westinghouse and meets Westinghouse material specifications.

DOE submitted sufficient test data to offer reasonable assurance that the getters, liners, plenum subassembly and getter disk, and LTA hold-down assemblies will not be damaged by the primary coolant for one operating cycle, and that any fragmentation of the absorber pellets will be confined by the Zircaloy-4 liners.

5.4 Nondestructive Examination

DOE states that nondestructive examination (NDE) of tubular products and fittings must be sufficient to ensure that the critical characteristics of the material meet specified acceptance criteria. DOE inspects TPBAR materials and components for compliance with specifications. Potential inspection methods range from standard visual inspections to discrete and unique methodologies specific to particular characteristics of a component.
DOE states that, although the internal components of each rod serve distinct functions for the production of tritium, the rod's cladding and end plugs form the pressure boundary between the TPBAR components and the reactor coolant system. The principal methods employed to examine the TPBAR cladding and end plugs are ultrasonic, eddy current, radiography, and helium leak testing. DOE states that the cladding and end plugs are tested in conformance with applicable codes and standards. After the barrier coating is applied, NDEs are performed to verify the acceptability of the barrier coating in terms of such key parameters as the thickness, integrity, and consistency. Table 5-5 of the DOE report notes the NDE techniques and applicable standards used during TPBAR fabrication. DOE also states that contamination of the TPBARs is minimized during assembly, and that testing performed before shipment confirms that the specified cleanliness requirements are met.

The staff concludes that, since the TPBAR is being classified as safety- related and is being produced to the criteria of Section III of the ASME Code, the NDE techniques and applicable standards should conform to the requirements of Section III, or an alternative to the requirements must be submitted to the NRC for approval under Title 10 of the Code of Federal Regulations, Section 50.55a (10 CFR 50.55a). Since DOE states that the TPBARs are being designed to the 1995 edition of the code, the staff concludes that the NDE techniques performed by PNNL and by subvendors should be qualified to the requirements of Section XI, Appendix VIII or to an acceptable alternative proposed under 10 CFR 50.55a.

5.5 Conclusions

The staff has reviewed the materials used in the TPBAR and agrees that they are adequate for the LTA. On the basis of experimental results and operating experience in domestic nuclear power plants, the staff finds that the materials in the TPBAR will not be affected by the environment and will not be adversely affected during Conditions I to IV[2], with the possible exception of thermal cycling. Austenitic stainless steel has been used for more than 100 operating years as a fuel cladding with no adverse reaction with the primary coolant.

The staff agrees that the cladding will fail during an LBLOCA and that there may be metal-metal or intermetallic interactions during DBAs. The consequences of cladding failure would be inconsequential, as discussed in Section 6 of this safety evaluation.

The staff identified potential deficiencies in the weld qualification program in terms of adherence to the requirements of Section IX of the ASME Code. Furthermore, the proposed nondestructive examination methods do not conform to the requirements of Section III of the ASME Code. Before these methods can be used at Watts Bar, TVA must submit a relief request to the NRC in accordance with the provisions of 10 CFR 50.55a.

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[2]Condition I = normal operation and operational transients, Condition II = faults of moderate frequency; Condition III = infrequent faults; Condition IV = limiting faults

6 OPERATIONAL IMPACTS OF LTAs

Chapter 6 of the Department of Energy (DOE) report addresses the operational impacts of tritium-producing burnable absorber rod (TPBAR) lead test assemblies (LTAs) with respect to normal operations, refueling operations, off-normal events, and accidents. The main impact on normal and abnormal operation is the leakage of tritium from the TPBARs. Even in normal operation with full integrity of the cladding and a permeation-resistant barrier, tritium cannot be completely contained because tritium diffuses through the TPBAR cladding material. The staff notes that the analyses presented are narrative in nature and no calculations are presented. The licensee, Tennessee Valley Authority (TVA), will have to determine whether the installation of the TPBAR LTAs into the Watts Bar reactor will affect normal and refueling operations or the accident analyses described in Chapter 15 of the Watts Bar Final Safety Analysis Report (FSAR). The staff will review the potential impacts as part of its review of TVA's application for an amendment to the facility operating license for Watts Bar.

6.1 Normal Operations

In Section 6.1 of its report, DOE calculates the increase in tritium inventory in the primary coolant and the incremental increase in radiological release from the plant due to the design goal release rate from all 32 TPBARs. The design goal of less than 6.7 Ci (248 GBq) per year for a single TPBAR correlates to an annual tritium release to the reactor coolant system (RCS) of 214 Ci (7.96 TBq) for all 32 rods. The staff notes that the design goal is a parameter established to meet specific DOE, environmental safety and health, and occupational safety requirements. DOE expects that actual tritium leakage from the TPBARs will be below this value. On the basis of the maximum tritium inventory in the RCS for Watts Bar during Cycle 1, 0.712 μCi per g (26.3 Bq per kg), the impact of design goal tritium leakage from the TPBARs on the tritium inventory in the RCS would be a 25-percent increase. However, the staff notes that any tritium that is released from the TPBARs during normal operations would be distributed throughout the RCS, chemical and volume control system, liquid radwaste system, and gaseous radwaste system, and processed along with the rest of the coolant. Any release to the environment from normal operations must be within the limits specified in 10 CFR Part 50, Appendix I.

6.2 Refueling Operations

6.2.1 TPBAR Assembly Storage in Fuel Pool or New Fuel Storage

In Section 6.2.1 of its report, DOE briefly discusses the placement of the TPBAR LTAs into Watts Bar's new fuel storage area or spent fuel pool preceding irradiation and in the spent fuel pool after irradiation. The revised DOE report states that the LTAs with the TPBARs weigh less than a fuel assembly containing 24 burnable poison rod assemblies (BPRAs). Therefore, DOE states that the current seismic analysis for the fuel storage racks bounds the analysis for racks containing the TPBAR LTAs.

The DOE report states that 150 hours after reactor shutdown, the heat load of each LTA is less than 0.024 kW (3 W per pin). The total heat load to the spent fuel pool from all four LTAs after irradiation should not increase significantly from normal assemblies with BPRAs and should be within the capability of the Watts Bar spent fuel pool cooling system. The staff notes that theTPBARs will not remain in the spent fuel pool for very long. The TPBARs will be removed from the fuel assemblies and shipped off-site once the refueling outage is complete. However, the staff believes that the increase in heat load to the spent fuel pool will be neglible even if the irradiated TPBARs remain in the spent fuel pool indefinitely. The staff will confirm this capability during its review of TVA's amendment to the facility operating license for Watts Bar.

6.2.2 Onsite TPBAR Assembly Movement and Handling

In Section 6.2.2 of its report, DOE states that the loading and shipping of the TPBAR LTAs will be completed in accordance with the administrative policies and procedures at Watts Bar. The staff notes that no special tools are needed for loading or removing TPBAR LTAs, since the dimensions and the handling features of the TPBAR are identical to those of conventional BPRAs. Current procedures for handling BPRAs are applicable to TPBARs. Therefore, there are no special mechanical concerns with the proposed TPBAR movement and handling. The radiological consequences of breaching the cladding of the TPBAR during movement and handling are discussed in Section 6.3.3 of this safety evaluation.

6.2.3 Occupational Exposure During Refueling

The TPBARs are designed to have minimal effect on plant operations, including refueling operations. Preceding irradiation, it may be necessary to assemble the LTAs; however, as the unirradiated TPBARs are essentially "not radioactive," they will produce no increase in exposure, occupational or non-occupational.

After irradiation, the TPBARs are expected to contain some 370,000 Ci (13.7 PBq) of tritium (^{3}H). This is far more tritium, but far less radioactivity, than that produced by the reactor core. The tritium does not pose a particular threat because (1) tritium emits only a low-energy (E_{max}= 0.0186 MeV) beta and (2) the tritium is bound in the TPBARs. Some of the tritium beta energy is converted into x rays (bremsstrahlung) but 370,000 Ci of tritium produces less photon energy than is produced by 1 Ci (37 GBq) of ^{137}Cs and the ^{137}Cs radiation is much more penetrating. The spent fuel removed for refueling contains about a million curies of ^{137}Cs and many other nuclides. Thus, the effect of tritium as a source of external radiation in the reactor environment is negligible.

Tritium in this quantity could be a potential problem if it were released from the TPBPRs; however, the DOE report states that the release can be expected to be limited to 6.7 Ci (248 GBq) per rod annually, which constitutes a total release rate of less than 215 Ci (7.96 TBq) per year for all the TPBPRs. This quantity is consistent with the nominal amounts of tritium expected in pressurized water reactor (PWR) coolant systems. The NRC licensing calculation, the GALE code, predicts about 250 Ci (9.25 TBq) of tritium in the reactor coolant and tritium releases to the environment from large PWRs are averaging over 600 Ci (22.2 TBq) per year per reactor and ranging as high as 4,000 Ci (148 TBq) per year without exceeding regulatory limits. Thus, the TPBARs might produce an observable but not dramatic increase in the tritium concentration in the spent fuel pool. Increasing the tritium in the spent fuel pool could increase occupational exposure but, since tritium exposure is not an important contributor to occupational exposure (according to NRC data summarized in NUREG-0713), the increase would be expected to be negligible. This is consistent with the results reported in the DOE report.

The staff concludes that the TPBARs could cause some increase in occupational radiation exposure. However, this increase would be negligible and would not constitute a safety, or an "as low as is reasonably achievable" (ALARA), concern.

6.3 Offnormal Events

In Section 6.3 of its report, DOE addresses a number of offnormal events, including the effects of TPBAR absorber relocation, cladding defects, radiological consequenses of a TPBAR cladding breach, inadvertent loading and operation with an LTA in an improper position in the core, and anticipated transient without scram (ATWS) events.

6.3.1 Impacts of TPBAR Absorber Relocation

Section 6.3.1 of DOE's report pertains to the physical form of the absorber pellets during the irradiation cycle. As discussed in Chapter 2 of DOE's report, the absorber pellets are not expected to undergo densification or significant phase changes over the range of temperatures during Condition I, II, III, and IV[3] events. Therefore, relocation of the absorber pellets does not appear to be a concern.

6.3.2 TPBAR Cladding Defects

DOE states that the TPBAR cladding is made from Type 316 stainless steel material (316 SS), which is stronger and more corrosion resistant than 304 SS. During manufacture, the TPBARs will be subjected to tests and inspections to ensure that cladding defects do not occur.

DOE states that if a cladding defect does exist, the amount of contaminants released to the reactor coolant system (RCS) will remain below normal chemistry limits and will not degrade other components. The absorber pellets would lose a microscopic layer of lithium to the coolant

[3]Condition I = normal operation and operational transients, Condition II = faults of moderate frequency, Condition III = infrequent faults; Condition IV = limiting faults

due to leaching. There is no loss of the absorber materials comparable to the B_4C leaching from a wet annular burnable absorber (WABA) pellet.

The staff concludes that DOE has presented procedures to give adequate assurance that any cladding defects in the 316 SS cladding will be identified during the testing and inspections. In the event that a cladding defect is not identified, DOE has demonstrated that the amount of contaminants released will remain below normal chemistry limits and will not result in degradation of other components.

6.3.3 Radiological Consequences of a TPBAR Cladding Breach

In the event of a cladding breach, tritium would be released to the reactor coolant water. Because tritium is hydrogen, it tends to be retained in the water. A cladding breach in the spent fuel pool is possible, but less likely, and the consequences would be less severe because the lower temperature would result in less tritium being released (see Section 6.4.1 of this safety evaluation, below). Experience (NUREG-2859) shows that tritium releases to the environment occur predominantly in liquid effluents; e.g. from normal operations at the Sequoyah nuclear plant in 1993, more than 90 percent of the tritium release was in liquid effluents. In evaluating this event, DOE postulates the complete release of the tritium from 1 TPBAR, about 12,000 Ci (444 TBq), with 20,000 gpm (= 4×10^{10} L) dilution, resulting in an average concentration of 3×10^{-7} Ci per liter (= 3×10^{-4} μCi per milliliter). This <u>average</u> concentration is well below the <u>instantaneous</u> concentration limit established for most nuclear power plants, including Watts Bar. Because most liquid releases are batch releases, it would be necessary for the licensee to implement a control program to ensure that the instantaneous concentration limit is not exceeded. As this is true for all releases, the TPBAR cladding failure would not impose new requirements on the licensee.

The average concentration of 3×10^{-4} μCi per milliliter is far too high to be acceptable under the dose constraints related to §50.36(a) and Appendix I to Part 50. For Watts Bar, this does not constitute a problem because, for the dose calculations, the effective concentration is further reduced by "near field dilution" of 1000 cfs (= 7×10^{11} L per year), resulting in an average concentration of 1.7×10^{-5} μCi per milliliter. Furthermore, the only exposure modes available at Watts Bar are the fish, drinking water, and shoreline pathways. Tritium produces no dose by the shoreline pathway. The "maximum individual" (H) dose by the fish pathway is:

$$H = 1.7x10^{-5}\left(\frac{\mu Ci}{mL}\right)0.9\left(\frac{mL}{gm}\right)21{,}000\left(\frac{gm}{yr}\right)0.105\left(\frac{mrem}{\mu Ci}\right)1\ (yr) = 0.034\quad (mrem)$$

For Watts Bar, there may be another factor of 10 dilution for the drinking water pathway (because the nearest drinking water intake is far downstream), but at this concentration, the above dose is increased by a factor (F) of

$$F = 730/(21 \times 0.9) = 39$$

The resulting total dose would be 1.35 mrem (13.5 μSv), which is less than half the dose criterion. (Since tritium is distributed throughout the body, the dose calculated is the committed dose equivalent and it is compared to the most limiting annual dose criterion from Appendix I to 10 CFR Part 50, which is 3 mrem (30 μSv) to the whole body.)

If it is assumed that 10 percent of the tritium released from the TPBAR is released to the atmosphere, the methodology of the Watts Bar offsite dose calculation manual (ODCM) for the breathing, milk, meat, and vegetable pathways gives estimates of the dose as about 0.5 mrem (5 μSv). This is a small fraction of the relevant Appendix I dose criterion of 5 mrem (50 μSv) in a year.

The staff concludes that Watts Bar could continue to operate and comply with the offsite dose criteria after a TPBAR cladding breach.

6.3.4 Inadvertent Loading and Operation of an LTA in an Improper Position

In Section 6.3.4 of its report, DOE states that LTA loading errors are precluded by the Watts Bar administrative procedures that are in place to prevent fuel assembly and burnable poison misloading. These procedures confirm the final core configuration via video tape. The DOE report states that in the unlikely event that an LTA is loaded in the wrong location, the resulting power distribution will be detectable by the in-core movable detector system or the core power distribution perturbation will be within the specified fuel design limits. However, it is not clear to the staff whether this misloading was assumed to be a limiting location. The purpose of this analysis is to verify that misloading the TPBAR LTA to a limiting location is within the limits of the safety analysis report. Also Chapter 3 of the DOE report discusses how the TPBARs are designed to mimic the reactivity characteristics of the BPRAs. Therefore, it is not clear how the in-core detectors would be able to distinguish the TPBARs from the BPRAs.

In addition, the DOE report states that the thermal-hydraulic analysis in Chapter 4 demonstrates that the LTA would not exceed the TPBAR design limits even if it were loaded in the limiting fuel assembly in the core. The staff is unable to concur with these conclusions on the basis of the information presented in the DOE report. DOE's analysis in Chapter 4 is preliminary and states that the thermal-hydraulic criteria are met with the TPBAR located in an assembly with a total power peaking of up to 1.42 and with the TPBAR adjacent to a fuel rod with an $F_{\Delta h}$ (enthalpy hot-channel factor) of 1.65 or less. As noted in Table 4-4 of the DOE report, TPBARs have a slightly higher power than the BPRAs. Therefore, placement of the TPBAR LTAs in a location other than described, and thus more limiting, must be analyzed. The staff is concerned that the thermal-hydraulic behavior of the TPBAR LTAs located in limiting positions in the core could increase the probability of occurrence or the consequences of an accident previously evaluated in the safety analysis report, or could reduce a margin of safety. Therefore, on the basis of the information presented by DOE, the staff cannot determine whether the inadvertent loading and operation of an LTA in an improper position in the core presents an unreviewed safety question. TVA must submit information evaluating the consequences of loading the LTA in the limiting assembly in the core before the staff can determine whether TPBAR irradiation is acceptable at Watts Bar.

6.3.5 Anticipated Transient Without Scram (ATWS)

In Section 6.3.5 of its report, DOE discusses the TPBAR LTA impact on ATWS events. The DOE report states that the TPBARs could affect the reactivity assumptions of the ATWS analysis, although this effect would be minimal due to the ^{6}Li cross-section. As stated in Chapter 3, the TPBARs are designed to mimic the neutronic behavior of conventional BPRAs and, therefore, the TPBARs are not expected to affect the existing ATWS neutronics analysis. The staff is unable to conclude that the TPBARs will have minimal impact on the ATWS neutronics analysis, based on the information presented by DOE. The staff will verify that the installation of the TPBAR LTAs in the Watts Bar core will not result in an unanalyzed condition with regard to ATWS during its review of TVA's application for an amendment to the facility operating license for Watts Bar.

6.4 Accidents

In its report, DOE has addressed the effects of a TPBAR on postulated accidents, including a TPBAR assembly dropped during refueling, radiological consequences of release of reactor coolant (steam generator tube rupture or steamline break), and TPBAR damage and radiological consequences during a design-basis loss-of-coolant accident.

6.4.1 Impacts of a Dropped LTA

In Section 6.4.1 of its report, DOE has addressed the effects of a TPBAR assembly dropped during refueling operations. There is no significant radioactivity in an unirradiated TPBAR. If an irradiated LTA were dropped, it would be under several feet of water because of the administrative controls in current procedures at pressurized-water reactors (PWRs). DOE states that the TPBAR LTA weighs less than a fuel assembly with 24 BPRAs; therefore, the effect of dropping a TPBAR on fuel, racks, or other equipment in the reactor pool or fuel handling pool is bounded by the existing analysis. The DOE report implies that the consequences of such an accident would likely be limited to damage to the LTA, resulting in a possible breach of the cladding. If the impact damaged an irradiated LTA, it would initiate or exacerbate tritium leakage.

DOE estimates that, because of the distribution of the tritium in the LTA, a small release (tens of curies) could occur quickly, but that the bulk of the tritium would not be released for some time, giving the licensee ample time for placing the damaged LTA in a container (preventing further release to the environment). The tritium released immediately would largely be retained in the spent fuel pool water. The addition of a few tens of curies of tritium to the spent fuel pool water would not have a significant effect on doses, either occupational or offsite.

To provide an estimate of the consequences, the staff has analyzed the prompt release of 100 Ci (3.7 TBq) of tritium to the atmosphere. For Watts Bar, atmospheric dispersion is taken as 1.8 x 10^{-4} sec m^{-3}. The resulting maximum individual dose (H) would be:

$$H = 1.8 \times 10^{-4}\left(\frac{\text{sec}}{m^3}\right)\ 100\ (Ci)\ 3.47 \times 10^{-4}\left(\frac{m^3}{\text{sec}}\right)\ 64\left(\frac{rem}{Ci}\right) = 4 \times 10^{-4}\quad (rem)$$

A worker in the fuel handling building might be more highly exposed, but, on the basis of the staff's analysis, the dose is not expected to exceed 5 mrem (50 μSv).

On the basis of its analysis, the staff concludes that the radiological impact of a dropped LTA would not be significant.

6.4.2 Impacts of Design Tritium Leakage on Radiological Consequences of a Steam Generator Tube Rupture or Steamline Break

In Section 6.4.2 of its report, DOE addresses these events and their impact on the TPBARs. DOE states that the RCS pressure and temperature caused by a locked rotor event are much more severe than the conditions from a steam generator tube rupture or main-steamline break events. Thus, neither of these events is expected to damage a TPBAR. However, normal leakage from TPBARs is expected to add tritium to the primary coolant. By the end of core life, the TPBARs could have added some 300 Ci (11 TBq) of tritium. If all this tritium were released to the atmosphere at Watts Bar, the maximum offsite dose would be about 1.2 mrem (12 μSv). The addition of 1.2 mrem to the doses projected to occur in the event of such an accident from other radionuclides would not likely cause the total dose to exceed the dose criterion in Section 6.4 of NUREG-0800 (the Standard Review Plan) for these accidents, which is 2500 mrem (25 mSv) to the whole body.

On the basis of its analysis, the staff concludes that the presence of the TPBARs would not contribute significantly to the radiological consequences of these accidents.

6.4.3 Impacts of LTAs in the Event of a LOCA

In Section 6.4.3 of its report, DOE discusses the potential failure of the TPBARs during design basis loss-of-coolant accident (DBLOCA) events. DOE states that the TPBAR stresses do not exceed the stresses from temperature and pressure that occur during the small-break loss-of-coolant accident (SBLOCA) at Watts Bar. Therefore, the TPBAR is not assumed to fail during the SBLOCA at Watts Bar.

DOE states that, for the large-break loss-of-coolant accident (LBLOCA), the maximum core temperature does exceed the TPBAR stresses and could damage the TPBARs. DOE considers the LBLOCA to be the most limiting accident with regard to potential TPBAR failure. The staff has calculated an upper bound estimate of the radiological consequence of the resulting tritium release by assuming the release of the entire inventory of 370,000 Ci (13.7 PBq) to containment. Using the Watts Bar parameters, containment leakage is at the rate of 0.25 percent per day for 2 hours, which would result in the release to the atmosphere of about 77 Ci (2.8 TBq) of tritium. The resulting dose at the exclusion area boundary would be about 0.3 mrem (3 μSv). Although not zero, this dose is negligible in comparison to either the 10 CFR Part 100 dose criterion of 25,000 mrem (250 mSv), or the dose calculated for the LBLOCA without the TPBARs, and thus would not cause the dose criteria to be exceeded. However, because an increase in offsite dose is anticipated, this increase in offsite dose represents an increase in the consequences of an accident previously evaluated in the safety analysis report and, therefore, this potential increase requires prior NRC approval.

For the LBLOCA, 10 CFR 50.46 requires that the emergency core cooling system maintain the following: (1) peak cladding temperature to less than 2200 °F (1204 °C), (2) total oxidation of the cladding to less than 17 percent of the total cladding thickness before oxidation, (3) maximum hydrogen generation to less than 1 percent, (4) coolable geometry, and (5) long-term cooling. Since the maximum design temperature for TPBARs is 1500°F (816 °C), localized TPBAR cladding failure or rupture is assumed for the LBLOCA. However, the staff believes that the requirements of 10 CFR 50.46 are maintained because of the limited number of TPBAR LTAs in the core. The DOE report states that the effect of TPBARs and the additional tritium on the combustible gas inventory following a LOCA is negligible. In addition, the maximum stored inventory of tritium in TPBAR LTAs is a very small fraction of the hydrogen that would be released from a zirconium-water reaction. Consequently, TPBARs would have no significant contribution to combustible gas in a LOCA. The tritium released to the coolant would not be released as a gas and, therefore, would not produce an increase in hydrogen concentration. On this basis, the staff has confidence that the requirements of 10 CFR 50.46 will continue to be met following an LBLOCA.

6.5 Summary

During its review of Chapter 6 of DOE's report, the staff has determined that because there is an increase, although negligible, in offsite radiological impact of LTAs in the event of a LOCA, a licensee must seek prior NRC approval for this change. This issue is discussed in Section 6.4.3, above.

In addition, the staff concludes that additional analyses must be provided concerning inadvertent loading and operation of an LTA in an improper position, as discussed in Section 6.3.4, above. TVA must submit information evaluating the consequences of loading the LTA in the limiting assembly in the core before the staff can determine whether TPBAR irradiation is acceptable at Watts Bar.

7 QUALITY ASSURANCE

The staff is continuing its review of Chapter 7 of the Department of Energy's (DOE's) report to determine whether DOE's quality assurance (QA) program controls are adequate to establish conformance with the requirements of 10 CFR Part 50, Appendix B. Fundamental issues concerning the safety classification of specific components in the tritium-producing burnable absorber rod (TPBAR) lead test assemblies (LTAs), commercial-grade dedication, design information controls, and the adequacy of Pacific Northwest National Laboratory's (PNNL's) QA program related to the design and manufacture of TPBARs remain unresolved.
Although DOE has not requested that NRC review and approve PNNL's QA plan, the fact that PNNL is identified as maintaining primary responsibility for the design and fabrication of the TPBARs establishes that an evaluation of PNNL's QA program will constitute an integral component of the staff's review of the TPBAR LTA program as applied to commercial light-water reactors. Therefore, the staff will conduct onsite inspections at PNNL in order to verify the adequate implementation of 10 CFR Part 50, Appendix B requirements related to the design and fabrication of the TPBARs.

Because the Tennessee Valley Authority's Watts Bar plant has been selected as the location for the confirmatory TPBAR LTA irradiation, TVA will need to provide TPBAR suppliers (PNNL and the Westinghouse fuels fabrication facility in Columbia, South Carolina) with the programmatic controls and processes that will demonstrate compliance with the requirements of 10 CFR Part 50, Appendix B, before installing these assemblies into the Watts Bar reactor core.

8 SECURITY OF CLASSIFIED MATTER

In Chapter 8 of its report, the Department of Energy (DOE) addresses transportation and physical security aspects of tritium-producing burnable absorber rod (TPBAR) lead test assemblies (LTAs). DOE states that the TPBARs and some related documentation necessary for utility nuclear safety committee review will be classified "confidential restricted data." As classified matter, they require measures to prevent diversion of, unauthorized access to, and disclosure of classified information.

8.1 Transportation of Classified Hardware

DOE states that the TPBARs will be brought to the site by a DOE-approved carrier that meets Department of Transportation requirements for shipment of nuclear fuel. Once inside the protected area, movement of TPBARs will be monitored by personnel who have DOE clearances. While the TPBAR LTAs are stored in the new fuel storage racks or in the fuel pool, a suitable level of protection will be provided.

8.2 Control of Classified Documents and Hardware

Because the TPBAR hardware and certain of the documentation are classified, licensees undertaking irradiation of TPBAR LTAs will have to meet the requirements for access to confidential restricted data specified in 10 CFR Parts 25 and 95, and Section 50.37. By letter dated October 4, 1996, DOE advised the staff that a limited number of licensee employees at Westinghouse Nuclear Fuels and at the Tennessee Valley Authority (TVA) needed access authorization in order for them to perform their responsibilities in support of the DOE Commercial Light-Water Reactor (CLWR) Project. DOE proposed that it perform the necessary personnel security clearance function and process a limited number of "L" and "Q" access authorizations for these licensee employees. By letter dated November 1, 1996, the staff agreed with DOE's proposal and stated that no additional NRC clearance is required to satisfy the requirements of 10 CFR 50.37 and 54.17(g). This is consistent with the memorandum of understanding between the NRC and DOE, dated September 19, 1996, concerning provisions of the National Industrial Security Program.

DOE has stated that no classified documents related to the TPBARs will be maintained on site at Watts Bar or at TVA headquarters. A reading room is being maintained at Oak Ridge National Laboratory so that individuals with a "need to know" will have access to the classified documents associated with the CLWR Program.

With regard to the facility (security) clearance (FCL), following discussions between DOE Office of Safeguards and Security and the NRC Division of Facilities and Security, the staff and

DOE have agreed to allow DOE to perform the "cognizant security agency" responsibilities applicable to the protection of classified matter at NRC-licensed facilities involved with the TPBAR LTA irradiation. These facilities include the Westinghouse fuels facility at Columbia, Industrial Security Program," dated September 19, 1996.) In its letter dated April 18, 1997, the staff summarized the agreement and stated that DOE would have authority over the FCL at the Westinghouse, Columbia and Watts Bar facilities during the LTA irradiation phase of DOE's program for the production of tritium in CLWRs. As agreed, DOE will provide the NRC with South Carolina, and TVA's Watts Bar plant. (The functions of the "cognizant security agency" are delineated in the "Memorandum of Understanding Between the Department of Energy and the United States Nuclear Regulatory Commission Under the Provisions of the National copies of the DOE-approved security plans for these facilities, invite NRC to participate in facility security reviews, and keep the NRC Division of Facilities and Security fully and currently apprised of security and classification matters at these facilities. The letter also informed DOE that the agreement and the decision regarding future overall security responsibility for this program will be re-evaluated following completion of the LTA irradiation phase.

9 REGULATORY ANALYSIS

The provisions of 10 CFR 50.59 allow operating license holders to make changes to their facility as described in the facility safety analysis report (SAR), to implement changes to facility procedures described in the SAR, and to conduct tests or experiments not described in the SAR without prior NRC approval if the change, test, or experiment does not involve a change to the Technical Specifications (TS) and does not involve an unreviewed safety question. A proposed change, test, or experiment involves an unreviewed safety question (1) if it increases the probability of occurrence or the consequences of an accident previously evaluated in the SAR, (2) if it creates the possibility for an accident of a different type from any evaluated previously, or (3) if it reduces a margin of safety, as defined in the basis for any technical specification.

Because the Department of Energy (DOE) has announced the selection of the Tennessee Valley Authority's (TVA's) Watts Bar plant as the facility at which the one-time confirmatory test of components that could be used in the production of tritium will be conducted, the staff shifted the focus of its review to evaluate the proposed tritium-producing burnable absorber rod (TPBAR) lead test assembly (LTA) irradiation at Watts Bar.

9.1 Effect on Plant Technical Specifications

In Section 9.1 of its revised report, DOE states that no provisions of the Watts Bar TS were viewed as prohibiting the irradiation of a limited number of LTAs containing TPBARs. DOE states that the Watts Bar TS titled "Design Features - Reactor Core" allows a limited number of LTAs to be placed in nonlimiting regions of the core. DOE also states that operation of the Watts Bar reload core with TPBAR LTAs will be within the core design limits of the TS titled "Power Distribution Limits" for Watts Bar.

The staff has reviewed the Watts Bar TS and concludes that nothing in the TS specifically prohibits operation of the facility with TPBAR LTAs in the core. Therefore, no changes to the Watts Bar TS are required. However, as noted in Section 9.3, below, an amendment to the facility operating license will be required because irradiation of LTAs containing TPBARs requires NRC review and approval.

9.2 Effect on Plant Final Safety Analysis Report

The confirmatory test of irradiating a limited number of TPBAR LTAs in the Watts Bar reactor will require revisions to the Watts Bar SAR. Also, TVA and Westinghouse, as part of the reload safety analysis for Watts Bar, must verify that operation within existing core design limits can be accomplished with the TPBAR LTAs installed in the core.

Some changes to the SAR sections dealing with radiological consequences will be necessary. Although the radiological impacts of TPBAR irradiation are small, the changes in the dose due to the TPBARs are not zero and must be described.

In addition, the staff has identified a number of issues for which TVA will have to provide additional information in its SAR for Watts Bar in order to support a request for an amendment to the facility operating license that would allow the staff to determine that TPBAR LTA irradiation is acceptable at that facility. These issues are summarized in Section 10.2 of this safety evaluation.

9.3 Licensing Impact

The staff has identified issues requiring prior NRC review and approval. Therefore, the provisions of 10 CFR 50.59, allowing certain actions by licensees without prior NRC approval, do not apply. The staff concludes that TVA must submit a request for an amendment to the facility operating license for Watts Bar and receive NRC approval before inserting TPBAR LTAs into the Watts Bar reactor core.

10 SUMMARY AND CONCLUSIONS

The staff has reviewed the Department of Energy's (DOE's) report and supporting information concerning the tritium-producing burnable absorber rod (TPBAR) lead test assembly (LTA). Many technical issues have been satisfactorily addressed in the DOE report, as documented in this safety evaluation.

During its review, the staff identified an issue that requires further NRC review. Therefore, the staff does not concur with DOE's position that a limited number of LTAs containing TPBARs can be irradiated in a commercial light-water reactor (CLWR) under the provisions of 10 CFR Part 50.59, without prior NRC approval. The staff also needs additional information on several issues before it can determine whether additional unreviewed safety questions are involved.

On February 7, 1997, DOE announced the selection of the Tennessee Valley Authority's (TVA's) Watts Bar plant as the facility that will conduct the one-time confirmatory test of components that could be used in the production of tritium. Accordingly, the staff shifted the focus of its review to evaluate the proposed TPBAR LTA irradiation at Watts Bar.

The staff concludes that should TVA wish to irradiate LTAs containing TPBARs at the Watts Bar facility, it must first submit an application for an amendment to the facility operating license for Watts Bar to permit such irradiation.

10.1 Issues Requiring Further NRC Review

During its review, the staff has identified an issue involving the offsite radiological impact of LTAs in the event of a design basis loss-of-coolant accident (LOCA) that requires further NRC review. This issue is discussed in Section 6.4.3 of this safety evaluation.

Because the staff has identified an issue requiring further NRC review during its review of DOE's proposal to conduct the confirmatory test of irradiating TPBAR LTAs in a CLWR, TVA must submit an application for an amendment to its facility operating license for Watts Bar before inserting TPBAR LTAs into the reactor core.

10.2 Issues Requiring Additional Analysis

The staff has identified a number of areas in which TVA will have to supplement the information in the DOE report before the staff can determine whether the proposed irradiation is acceptable at Watts Bar. These are listed below, along with the section(s) of this safety evaluation in which each is discussed.

(1) use of the 1995 edition of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (2.2.1)

(2) use of American Society for Testing and Materials (ASTM) Standard A 771 for the purchase of the cladding (2.2.1)

(3) effects of thermal cycling on TPBAR components and quality standards to address them (2.2.1, 5.1)

(4) metal-metal interactions occurring during a LOCA, including temperature limits and failure mechanisms that result from them (2.2.1, 5.1)

(5) demonstration that the MATHCAD model is conservative (2.2.5)

(6) comparison of reactivity characteristics of the TPBAR to burnable poison rod assemblies (3.1)

(7) Cycle-2 reload analysis (3)

(8) analysis of the 400-mil pellet gap (3.2)

(9) maximum negative worth of TPBAR LTA (3.3)

(10) benchmarking of PHOENIX-L code (3.4)

(11) thermal-hydraulic analysis for Cycle-2 (4.1, 4.2)

(12) weld qualification procedure (5.3.1)

(13) nondestructive testing techniques and applicable standards (5.4)

(14) inadvertent loading and operation of an LTA in an improper position (6.3.4)

(15) quality-assurance program (7)

TVA must present additional information and analyses in these areas in its safety analysis accompanying the application for amendment to the facility operating license for Watts Bar.

APPENDIX A

CHRONOLOGY OF CORRESPONDENCE

This appendix contains a chronological listing of correspondence between the NRC and DOE and other correspondence related to DOE's program for the production of tritium in commercial light-water reactors. All documents, with the exception of certain enclosures to correspondence marked with an asterisk (*) (denoting "confidential restricted data") have been placed in the Commission's Public Document Room, the Gelman Building, 2120 L Street, NW., Washington, D.C., under Project No. 697.

March 15, 1996	SECY-96-058, "Memorandum of Understanding Between the Department of Energy and the Nuclear Regulatory Commission."
April 19, 1996	Staff requirements memorandum related to SECY-96-058, "Memorandum of Understanding Between the Department of Energy and the Nuclear Regulatory Commission."
May 22, 1996	"Memorandum of Understanding Between the Nuclear Regulatory Commission and the Department of Energy."
July 16, 1996	Letter from D. B. Matthews, NRC, to S. M. Sohinki, DOE, requesting use of Project No. 697 on all correspondence related to DOE's program for the CLWR production of tritium.
August 26, 1996	Letter from G. C. Sorensen, PNNL, to J. H. Wilson, NRC, transmitting white paper on stress corrosion cracking in 316 stainless steel cladding for PWR tritium-producing burnable absorber rods.
September 30, 1996	Reimbursible agreement between NRC and DOE for NRC review related to DOE's tritium program.
October 3, 1996	SECY-96-212, "Review of Department of Energy's Proposal for Tritium Production in Commercial Light-Water Reactors."
October 4, 1996	Letter from S. M. Sohinki, DOE, to T. M. Martin, NRC, regarding DOE clearances for NRC licensees supporting Tritium Program, Project No. 697.

November 1, 1996	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, concerning DOE clearances for NRC licensees supporting tritium program.
November 21, 1996*	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting draft classified report on tritium-producing burnable absorber rod lead test assembly.
December 4, 1996*	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting classified version of tritium-producing burnable absorber rod lead test assembly topical report (supersedes draft report submitted on November 21, 1996).
December 4, 1996	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting unclassified version of tritium-producing burnable absorber rod lead test assembly topical report.
December 10, 1996	Staff requirements memorandum related to SECY-96-212, "Review of Department of Energy's Proposal for Tritium Production in Commercial Light-Water Reactors."
December 10, 1996	Letter from S. M. Sohinki, DOE, to Document Control Desk, providing correction to tritium-producing burnable absorber rod lead test assembly topical report (unclassiified version).
December 16, 1996	Letter from R. J. Guenther, PNNL, to S. M. Matthews, NRC, prioritizing the importance of components in tritium-producing burnable absorber rods.
December 23, 1996	*Federal Register* Notice 61 FR 67584, "Notice of Receipt of DOE Topical Report on Tritium Producing Burnable Poison Rod Lead Test Assemblies".
January 3, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting the staff's request for additional information regarding DOE's report on the tritium-producing burnable absorber rod lead test assembly.
January 13, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting the staff's supplemental request for additional information regarding DOE's report on the tritium-producing burnable absorber rod lead test assembly.

January 21, 1997	Notice of public meeting on January 22, 1997, with DOE to discuss response to staff's requests for additional information concerning DOE's report on tritium-producing burnable absorber rod lead test assemblies.
January 24, 1997	Summary of public meeting held on January 22, 1997, to discuss response to staff's requests for additional information regarding DOE's report on tritium-producing burnable absorber rod lead test assemblies.
January 25, 1997	Letter from C. G. Frazier, DOE, to T. M. Martin, NRC, regarding draft request for proposal DE-RP02-97DP00414 for the commercial light-water reactor production of tritium.
January 27, 1997	*Federal Register* Notice 62 FR 3925, "Notice of Public Meeting on DOE's Proposal to Produce Tritium in Commercial Light-Water Reactors."
February 4, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting guidance on benchmarking the VIPRE code to validate the implementation and user application of changes to accommodate the use of lithium burnable poison rods for the production of tritium.
February 5, 1997	Notice of public meeting with DOE on February 25, 1997, to provide the opportunity for public comment on DOE's program for the CLWR production of tritium.
February 7, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting additional information regarding the tritium-producing burnable absorber rod lead test assembly report.
February 13, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting NRC staff's position on quality assurance requirements for tritium-producing burnable absorber rods.
February 14, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, transmitting supplemental information regarding the tritium-producing burnable absorber rod lead test assembly report.
February 24, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting supplemental guidance on benchmarking the VIPRE

	code to validate the implementation and user application of changes to accommodate the use of lithium burnable poison rods for the production of tritium.
February 28, 1997	Summary of February 25, 1997, public meeting on DOE's Program to Produce Tritium in Commercial Light-Water Reactors (including meeting transcript).
March 3, 1997*	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting Revision 1 to the classified and proprietary version of the Lead Test Assembly Evaluation Report.
March 5, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, concerning facilities security clearance at NRC-licensed facilities participating in DOE's program for tritium production.
March 7, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, transmitting revised responses to NRC requests for additional information and informational copy of PNNL project QA plan.
March 12, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, transmitting requested information on failure modes and effects analysis and modifications made to the PHOENIX-P computer software.
March 17, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, regarding response to NRC staff request for additional information on commercial light-water reactor lead test assembly report.
March 17, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, submitting commercial light-water reactor lead test assembly unclassified technical report, Revision 1.
March 18, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, regarding lead test assembly safeguards and security information.
April 3, 1997	Letter from S. M. Sohinki, DOE, to Document Control Desk, requesting NRC inspection of commercial light-water reactor program lead test assembly activities.
April 9, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting ACRS scoping assessment of potential unreviewed safety questions associated with materials interactions for TPBAR LTAs.

April 17, 1997	Letter from D. B. Matthews, NRC, to S. M. Sohinki, DOE, announcing inspection of procurement and fabrication activities at Pacific Northwest National Laboratory for the fabrication of TPBAR LTAs.
April 21, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, transmitting a discussion of DOE's quality assurance program for tritium-producing burnable absorber rod lead test assemblies.
April 21, 1997	Letter from T. M. Martin, NRC, to S. M. Sohinki, DOE, concerning facilities security clearance at NRC-licensed facilities participating in LTA phase of DOE's program for tritium production.

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11. ABSTRACT (200 words or less)

The NRC staff has reviewed a report, submitted by DOE to determine whether the use of a commercial light-water reactor (CLWR) to irradiate a limited number of tritium-producing burnable absorber rods (TPBARs) in lead test assemblies (LTAs) raises generic issues involving an unreviewed safety question. The staff has prepared this safety evaluation to address the acceptability of these LTAs in accordance with the provision of 10 CFR 50.59 without NRC licensing action.

As summarized in Section 10 of this safety evaluation, the staff has identified issues that require NRC review. The staff has also identified a number of areas in which an individual licensee undertaking irradiation of TPBAR LTAs will have to supplement the information in the DOE report before the staff can determine whether the proposed irradiation is acceptable at a particular facility.

The staff concludes that a licensee undertaking irradiation of TPBAR LTAs in a CLWR will have to submit an application for amendment to its facility operating license before inserting the LTAs into the reactor.

12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.)

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commercial light-water reactor (CLWR)
Department of Energy
irradiation
lead test assembly (LTA)
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