TRITIUM TARGET QUALIFICATION PROJECT

DESCRIPTION OF THE TRITIUM-PRODUCING BURNABLE ABSORBER ROD FOR THE COMMERCIAL LIGHT WATER REACTOR

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REVISION 5

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Revision 5

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1.0 ABSTRACT

Tritium-producing burnable absorber rods (TPBARs) used in the U.S. Department of Energy's Commercial Light Water Reactor (CLWR) Project are designed to produce tritium when placed in a 17x17 fuel assembly and irradiated in a typical Westinghouse pressurized water reactor (PWR). This document provides an unclassified description of the design baseline for the TPBAR employed in the CLWR. However, this design baseline is currently valid only for the Watts Bar reactor production core. This design baseline has not yet been confirmed as applicable for use in the Sequoyah production cores.

2.0 DESIGN BASIS DOCUMENTS

The TPBAR design basis for the Watts Bar reactor production core consists of this unclassified design basis description plus the collection of design basis documents. The design basis documents include the design drawings, the design specifications, and the component acceptance test requirements. These documents are listed in Appendices A, B, and C respectively.

3.0 GENERAL FUNCTIONS AND REQUIREMENTS

TPBARs are similar in size and nuclear characteristics to standard, commercial PWR, stainless-steel-clad burnable absorber rods. The exterior of the TPBAR is a stainless-steel tube, approximately 152 inches from tip to tip at room temperature. The nominal outer diameter of the stainless-steel cladding is 0.381 inches. The internal components have been designed and selected to produce and retain tritium.

Figure 1 illustrates the concentric, cylindrical, internal components of a TPBAR. Within the stainless-steel cladding is a metal "getter" tube that encircles a stack of annular, ceramic "pellets" of lithium aluminate. The pellets are enriched with the ^{6}Li isotope. When irradiated in a PWR, the ^{6}Li pellets absorb neutrons, simulating the nuclear characteristics of a burnable absorber rod, and produce tritium, a hydrogen isotope. The tritium chemically reacts with the metal getter, which captures the tritium as a metal hydride.

To meet design limitations on rod internal pressure and burn-up of the lithium pellets, the amount of tritium production per TPBAR is limited to a maximum of 1.2 grams over the full design life of the rod (less than 495 equivalent full-power days). The potential release rate of tritium into the reactor coolant is subject to a design limit of less than 1000 Ci/1000 TPBARs per year. This is achieved by the combined effects of the metal getter tube surrounding the lithium aluminate pellets and an aluminide barrier coating on the inner surface of the cladding.

4.0 TPBAR COMPONENTS

The TPBAR cladding is double-vacuum-melted, Type 316 stainless steel. To prevent hydrogen from diffusing inward from the coolant to the TPBAR getter and to prevent tritium from diffusing outward from the TPBAR to the reactor coolant, an aluminide coating is on the inner surface of the cladding. This coating barrier must remain effective during fabrication, handling, and in-reactor operations.

The ceramic pellets are composed of sintered, high-density, annular lithium aluminate ($LiAlO_2$).

The metal getter tube located between the cladding and the lithium aluminate pellets is composed of nickel-plated Zircaloy-4. The getter absorbs the molecular tritium (T_2) generated during irradiation. Nickel plating is used on both sides of the getter to prevent oxidation of the Zircaloy-4 surfaces, which would reduce the tritium absorption rate. Consequently, this plating must remain effective during fabrication, handling, and in-reactor operations.

An unplated Zircaloy-4 tube lines the inside of the annular pellets. This component is called the "liner." Because some of the tritium produced in the pellets may be released as oxidized molecules (T_2O), the liner reduces these species to molecular tritium by reacting with the oxygen. The liner also provides mechanical support to prevent axial movement of pellet material in case any pellets crack during TPBAR handling or operation.

5.0 AXIAL ARRANGEMENT OF THE COMPONENTS

The getter tube is cut and rolled over (coined) to capture the liner and pellets within an assembly called a "pencil." There are a total of 11 pencil assemblies stacked within the cladding tube of each TPBAR. The majority of the pencils are of standard length (approximately 12 inches). One or more of the pencils are of variable length.

To minimize the impact of power peaking in adjacent fuel rods resulting from the axial gaps between the stacked pencils, there is more than one type of TPBAR. The types are differentiated by where the variable-length pencil or pencils are loaded within the stack. The loading sequence of the pencils is tracked, and each TPBAR is identified by type so that the location of each TPBAR type within a TPBAR assembly can be specified.

As shown in Figure 2, a gas plenum space is located above the top pencil and below an end plug at the top of the TPBAR. A spring clip in this plenum space holds the pencils in place during pre-irradiation handling and shipping. For hermetic closure of the TPBARs, end plugs similar to those used in commercial PWR burnable absorber rods are welded to each end of the cladding tube. A top plenum getter tube is placed in the plenum space to further absorb tritium.

The length of the column of enriched lithium aluminate must be variable to provide optimal flexibility in reactor core design. Consequently, the column of enriched lithium aluminate is approximately centered axially about the core mid-plane elevation, but ranges in total length from about 127 to 142 inches. A thick-walled, nickel-plated, Zircaloy-4 spacer tube is placed between the bottom of the pencil column and the bottom end plug both to support the pencil column and to absorb tritium.

A TPBAR assembly is shown in Figure 3. It should be noted, however, that a typical design used in a 17x17 fuel assembly would be 24 TPBARs, rather than the 8 illustrated in Figure 3. Multiple fuel assembly designs can be accommodated by changes to the TPBAR lengths and end plugs.

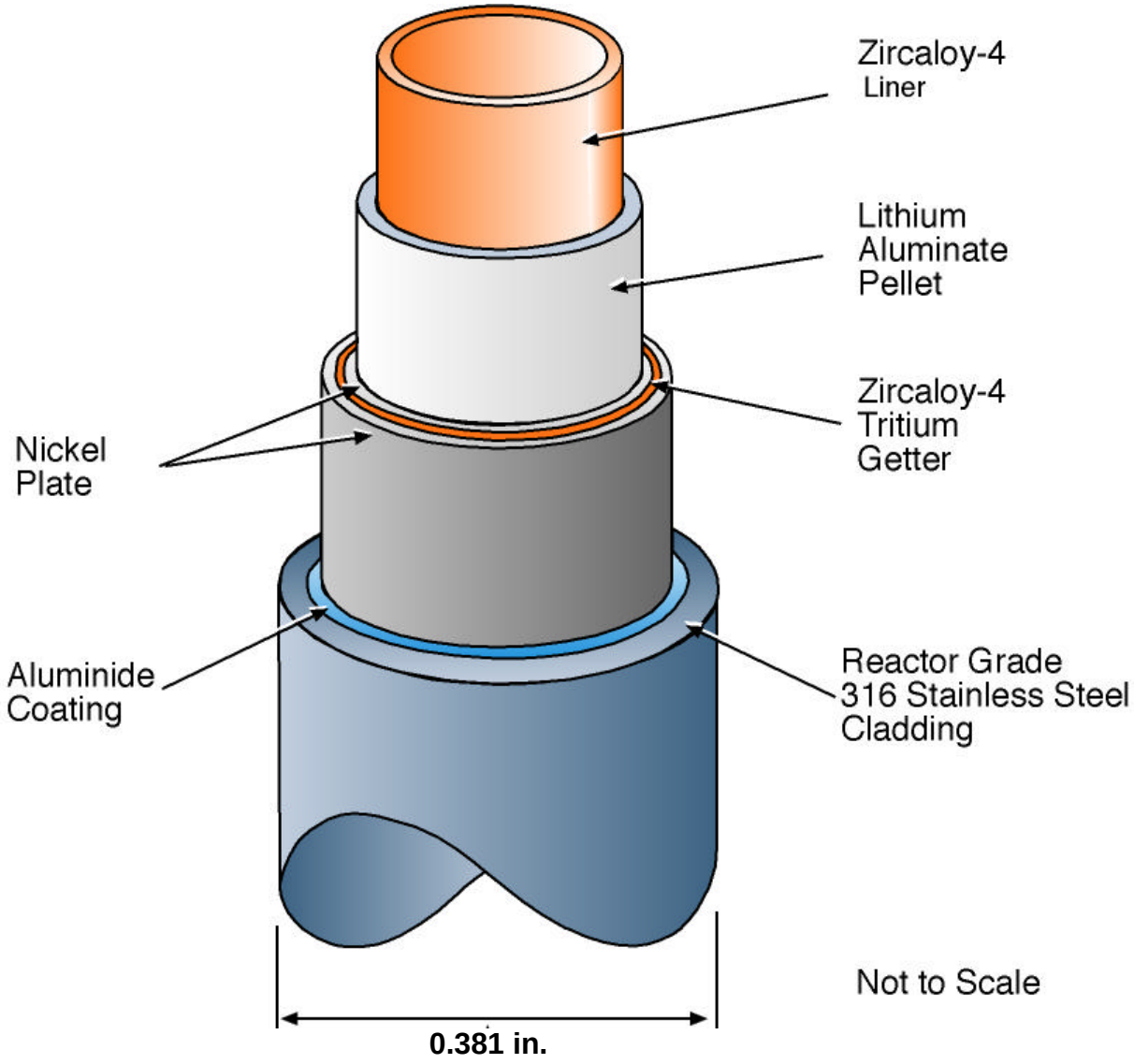

Figure 1. Isometric Section of a Tritium-Producing Burnable Absorber Rod

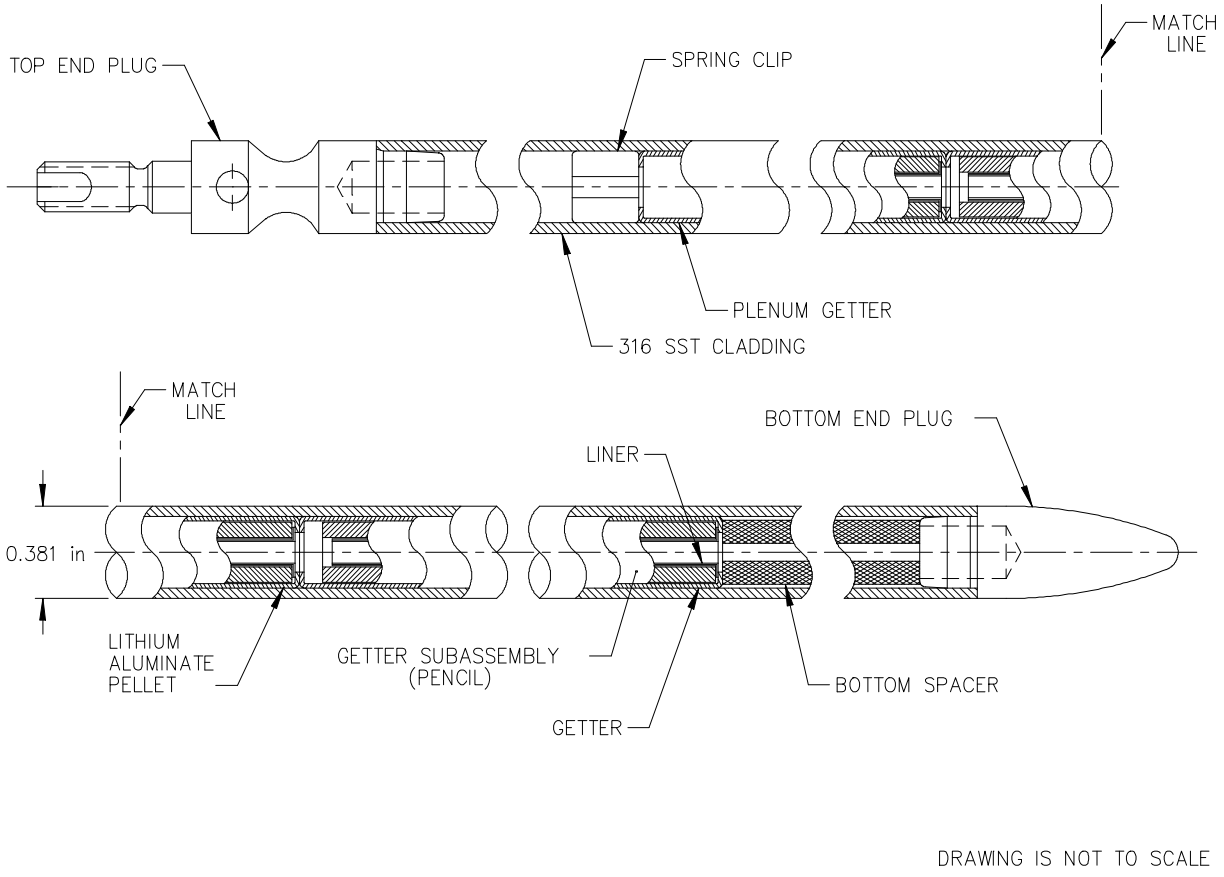

Figure 2. Axial Layout of TPBAR Internal Components

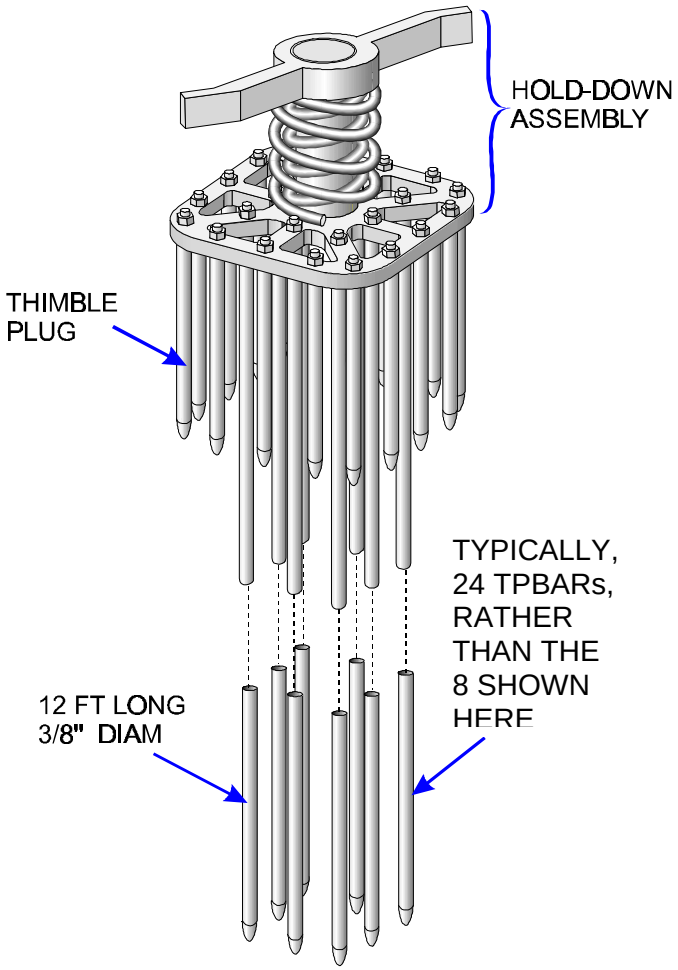

Figure 3. TPBAR Assembly

APPENDIX A
LIST OF DESIGN DRAWINGS

Drawings are compiled in PNNL-TTQP-1-720, *Design Drawings for Watts Bar Production TPBAR*.

Drawing	Revision	Title (Note: "U" designates an unclassified title.)	Classification
H-3-307843 Sheet 1, Sheet 2	2	Production Tritium Producing Burnable Absorber Rod (TPBAR) (U)	Classified
H-3-307844	~~2~~3	Production Design Drawing List	Unclassified
H-3-307845 Sheet 1, Sheet 2	3, 2	Production TPBAR Interface Dimensions	Unclassified
H-3-307846	2	Production Cladding Tube	Unclassified
H-3-307847	~~2~~3	Production Coated Cladding Tube (U)	Classified
H-3-307848	2	Production Trimmed Coated Cladding Tube with End Prep (U)	Classified
H-3-307849	2	Production Standard Pencil Assembly (U)	Classified
H-3-307850	2	Production Variable Length Pencil Assembly (U)	Classified
H-3-307851 Sheet 1, Sheet 2	2	Production Bottom Spacer (U)	Classified
H-3-307852	2	Production Top Plenum Spacer (U)	Classified
H-3-307853	~~2~~3	Production Standard Pellet Stack	Unclassified
H-3-307854	~~2~~3	Production Variable Length Pellet Stack	Unclassified
H-3-307855	2	Production Getter Tube Stock	Unclassified
H-3-307856	1	Production Plated Getter Tube (U)	Classified
H-3-307857	2	Production Standard Inner Liner Tube	Unclassified
H-3-307858	~~2~~3	Production Variable Length Inner Liner Tube	Unclassified
H-3-307859	~~2~~4	Production Bottom Spacer Stock	Unclassified
H-3-307860	2	Production Top End Plug	Unclassified
H-3-307861	2	Production Bottom End Plug	Unclassified
H-3-307862	2	Production Spring Clip	Unclassified

APPENDIX B
LIST OF DESIGN SPECIFICATIONS

Document Number (Note: "PNNL" prefix denotes a classified document.)	**Revision**	**Title (Note: "U" designates an unclassified title.)**
TTQP-1-072	1	*Production Specification for 316 Stainless Steel Seamless Cladding Tubes*
TTQP-1-073	2	*Manufacturing Specification for LWR Tritium Target Rod Getter Tube Stock*
TTQP-1-075	1	*Production Specification for LWR Tritium Target Rod Stainless Steel Bar Stock for Cladding*
TTQP-1-076	0	*Production Specification for Enriched Annular $LiAlO_2$ Pellets*
TTQP-1-077	1	*Production Specification for LWR Tritium Target Rod Inner Liner Tube*
TTQP-1-079	0	*Production Specification for LWR Tritium Target Rod Top and Bottom End Plugs*
TTQP-1-080	0	*Production Specification for LWR Tritium Target Rod Top and Bottom End Plug Welding*
TTQP-1-083	1	*Production Specification for LWR Tritium Target Rod Stainless Steel Bar Stock for End Plugs*
TTQP-1-089	0	*Production Specification for LWR Tritium Target Rod Spring Clip*
PNNL-TTQP-1-688	2	*Production Specification for LWR Tritium Target Rod Pencil and Spacer Assembly (U)*
PNNL-TTQP-1-690	2	*Production Specification for LWR Tritium Target Rod Final Assembly (U)*
PNNL-TTQP-1-691	1	*Manufacturing Specification for Production LWR Tritium Target Rod Getter Plating and Activation (U)*
PNNL-TTQP-1-692	2	*Manufacturing Specification for LWR Tritium Target Rod Inside Diameter Aluminide Barrier (U)*
PNNL-TTQP-1-826	1	*Final Product Specification for Production LWR Activated, Plated Getter Material (U)*

APPENDIX C
COMPONENT ACCEPTANCE TEST REQUIREMENTS

Document Number (Note: "PNNL" prefix designates a classified document.)	**Revision**	**Title (Note: "U" designates an unclassified title.)**
TTQP-1-081	3	*TPBAR Component Characteristics and Related Importance Factors for the Watts Bar Production Design (plus all referenced appendices)*
TTQP-1-085	0	*Design Requirements for TTQP Weld Joint Burst Testing Matrix / Test Plan*
PNNL-TTQP-1-829	0	*Standard Getter Rate Test Requirements (U)*
PNNL-TTQP-1-830	0	*Requirements for a Standard Cladding D2 Permeation Test (U)*
PNNL-TTQP-1-867	0	*Test Plan for Target Rod Spring Clip (U)*