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Description of the Tritium- Producing Burnable Absorber Rod for the Commercial Light Water Reactor

TTQP-1-015, Revision 19

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February 2012



Pacific Northwest
NATIONAL LABORATORY

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TRITIUM TECHNOLOGY PROGRAM PROCEDURE

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

TTQP-1-015

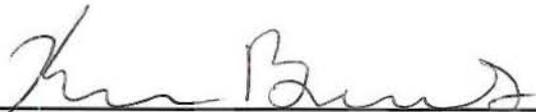
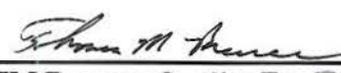
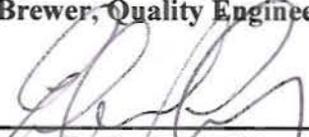
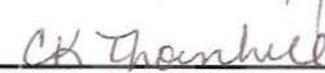
Revision 19

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TRITIUM TECHNOLOGY PROGRAM PROCEDURE

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

Revision 19

Prepared By:	<u></u> KA Burns, Engineer	<u>1/18/2012</u> Date
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Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 1 of 9

1.0 ABSTRACT

Tritium-producing burnable absorber rods (TPBARs) used in the U.S. Department of Energy's Tritium Readiness Program are designed to produce tritium when placed in a Westinghouse or Framatome 17x17 fuel assembly and irradiated in a pressurized water reactor (PWR). This document provides an unclassified description of the current design baseline for the TPBARs. This design baseline is currently valid only for Watts Bar reactor production cores. A description of the Lead Use TPBARs will not be covered in the text of the document, but the applicable drawings, specifications and test plan will be included in the appropriate appendices.

2.0 DESIGN BASIS DOCUMENTS

The TPBAR design basis for the Watts Bar reactor production cores consists of this unclassified design basis description plus a collection of design basis documents. The design basis documents include the design drawings, and the design specifications and component acceptance test requirements. These documents are listed in Appendices A and B, 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. 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 ${}^6\text{Li}$ isotope. When irradiated in a PWR, the ${}^6\text{Li}$ 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 (approximately 600 equivalent full-power days).

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 2 of 9

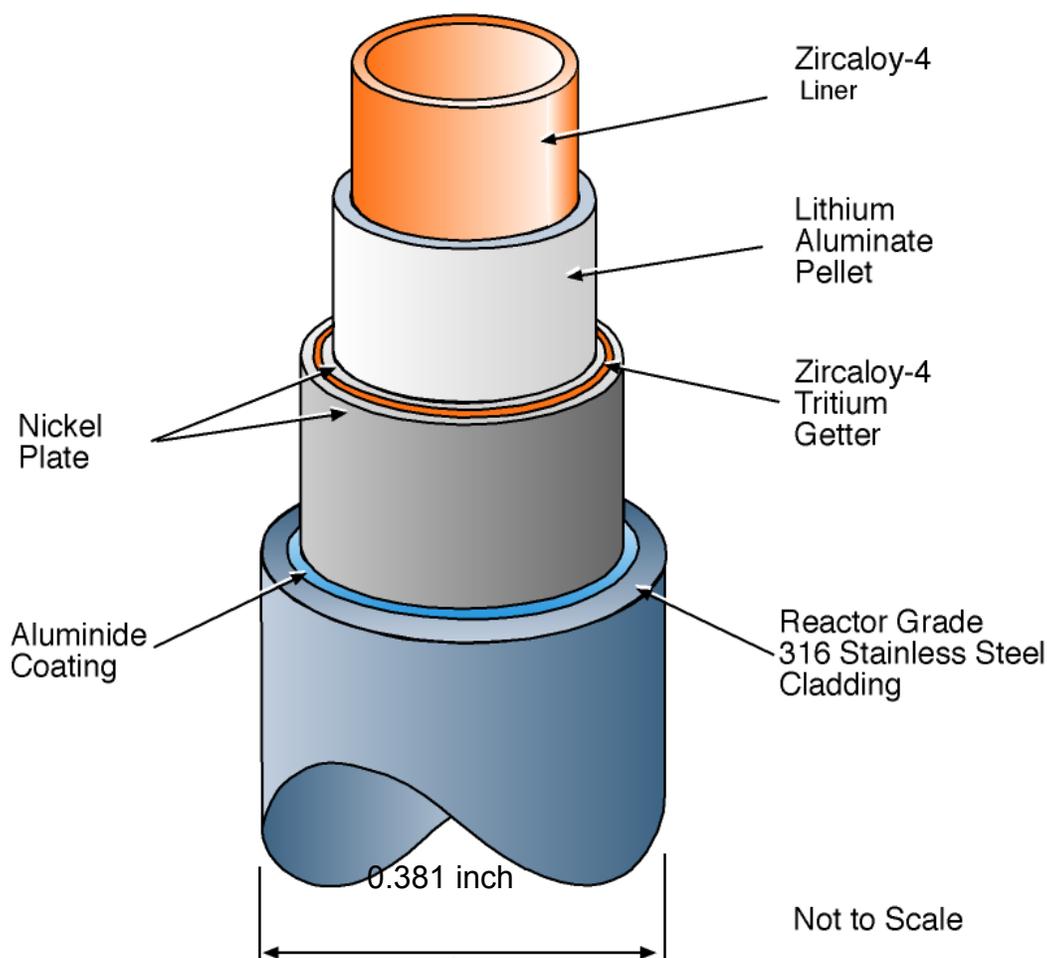


Figure 1. Isometric Section of a Tritium-Producing Burnable Absorber Rod

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 annular ceramic pellets are composed of sintered, high-density, 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

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 3 of 9

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.

A liner comprised of Zircaloy-4 tube(s) resides inside of the annular pellets. Because the tritium produced in the pellets may be released as oxidized molecules (T_2O), a reactive metal liner is needed to reduce 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 THE MARK 9.2 AND MARK 10 DESIGNS

Figure 2 illustrates the axial layout of the components for the Mark 9.2 and Mark 10 designs.

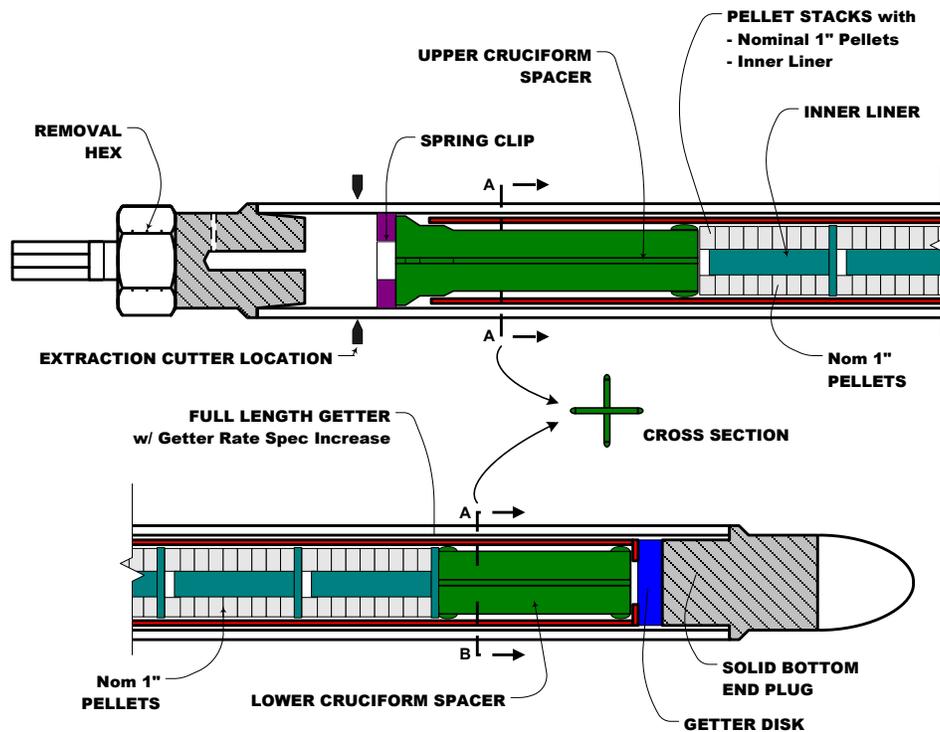


Figure 2. Axial Layout of Internal Components – Mark 9.2 and Mark 10 Designs. (Note: Getter disk on top of bottom end plug insert.)

The Mark 9.2 and Mark 10 designs incorporate a long getter tube, or full length getter (FLG), that runs almost the full length of the rod, from the bottom end plug to near the top of the upper plenum. Pellets are stacked on liner(s) within this long getter tube. Pellet length is nominally 1.0 inch; the pellet column length is approximately 132 inches.

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 4 of 9

The upper and lower plenums in the FLG design each contain a Zircaloy cruciform-shaped spacer. At the bottom end, this spacer provides the support for the pellet column. At the top end, the cruciform spacer flares outward at the top to contact with the spring clip. In the Mark 9.2 design both spacers are bare Zircaloy, but in the Mark 10 design the lower cruciform spacer has been surface-modified to include a surface layer of Ni-Zr intermetallics, which improves the oxidation performance.

In both the Mark 9.2 and Mark 10 designs, the top end plug includes a hex-shaped shank on the upper body, and the top end plug contains a bored out region while the bottom end plug does not. A getter disk resides on the bottom end plug.

6.0 TPBAR ASSEMBLIES

A TPBAR assembly is shown in Figure 3. It should be noted, however, that a typical design used in a 17x17 fuel assembly would contain between four and twenty-four TPBARs, rather than the eight illustrated in Figure 3.

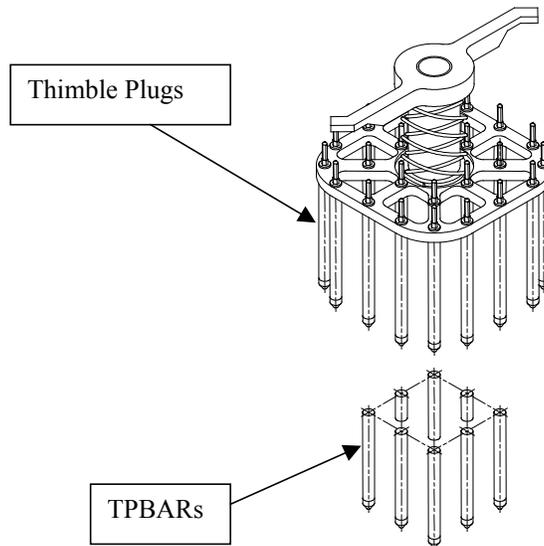


Figure 3. Typical TPBAR Assembly

**Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor**

TTQP-1-015

Revision 19

Page 5 of 9

APPENDIX 1

LIST OF DESIGN DRAWINGS

Drawings are compiled in the current revision of PNNL-TTQP-1-976, *TPBAR Design Drawings*.

Table A.1. Design Drawings for Mark 9.2 and Mark 10 TPBAR Designs

Drawing	Title (Note: "U" designates an unclassified title.)	Classification
H-3-310732 Sheet 1	TPBAR Drawing List	Unclassified
H-3-310733 Sheet 1	TPBAR General Notes (U)	Classified
H-3-310733 Sheet 2	TPBAR Mark 9.2 Materials List	Unclassified
H-3-310733 Sheet 3	TPBAR Mark 10 Material List	Unclassified
H-3-310733 Sheet 4	TPBAR Mark 11 Material List	Unclassified
H-3-310733 Sheet 5	TPBAR Mark 9.2 with FLL Material List	Unclassified
H-3-310733 Sheet 6	TPBAR (U)	Classified
H-3-310733 Sheet 7	TBPAR (U) ON HOLD	Classified
H-3-310733 Sheet 8	TBPAR (U) ON HOLD	Classified
H-3-310733 Sheet 9	TPBAR Details (U)	Classified
H-3-310733 Sheet 10	TPBAR Details (U)	Classified
H-3-310733 Sheet 11	TPBAR Internals and General Assembly (U)	Classified
H-3-310733 Sheet 12	TPBAR Internals and General Assembly (U)	Classified
H-3-310733 Sheet 13	TPBAR Internals and General Assembly (U)	Classified
H-3-310734 Sheet 1	TPBAR Reactor Interface	Unclassified
H-3-310734 Sheet 2	TPBAR Extraction Interface (U)	Classified
H-3-310734 Sheet 3	TPBAR Extraction Interface (U) ON HOLD	Classified
H-3-307322 Sheet 1	Full-Length Getter Tube Stock	Unclassified
H-3-307323 Sheet 1	Full-Length Getter Plated Getter Tube (U)	Classified
H-3-310735 Sheet 1	Finished Full Length Getter Tube (U)	Classified
H-3-310739 Sheet 1	Pellet Stack Groups	Unclassified
H-3-310750 Sheet 1	Variable Pellet Stack	Unclassified
H-3-310751 Sheet 1	Standard Pellet Stack	Unclassified
H-3-310751 Sheet 2	Standard Pellet Stack	Unclassified
H-3-310753 Sheet 1	Variable Inner Liner Tube	Unclassified
H-3-310745 Sheet 1	Upper Cruciform Spacer	Unclassified
H-3-310745 Sheet 2	Upper Cruciform Spacer	Unclassified
H-3-310745 Sheet 3	Upper Cruciform Spacer	Unclassified
H-3-310746 Sheet 1	Lower Cruciform Spacer	Unclassified

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 6 of 9

Table A.1. (contd)

Drawing	Title (Note: "U" designates an unclassified title.)	Classification
H-3-310825 Sheet 1	Lower Cruciform Machined	Unclassified
H-3-310828 Sheet 1	Upper Cruciform Machined	Unclassified
H-3-310761 Sheet 1	Lower Cruciform Surface Modified	Unclassified
H-3-310761 Sheet 2	Lower Cruciform Heat Treatment Profile	Unclassified
H-3-310571 Sheet 1	Top End Plug	Unclassified
H-3-310571 Sheet 2	Top End Plug	Unclassified
H-3-310754 Sheet 1	Top End Plug Chrome Plating	Unclassified
H-3-310755 Sheet 1	Top End Plug Stock	Unclassified
H-3-310755 Sheet 2	Top End Plug Stock (WesDyne Proprietary Information)	Unclassified
H-3-310572 Sheet 1	Trimmed Coated Cladding Tube with End Prep (U)	Classified
H-3-310572 Sheet 2	Trimmed Coated Cladding Tube with End Prep (U)	Classified
H-3-310573 Sheet 1	Coated Cladding Bottom End Plug Assembly (U)	Classified
H-3-310574 Sheet 1	Coated Cladding Bottom End Plug Assembly with End Prep (U)	Classified
H-3-310584 Sheet 1	Getter Disk (U)	Classified
H-3-310585 Sheet 1	Getter Disk Stock	Unclassified
H-3-310586 Sheet 1	Bottom End Plug	Unclassified
H-3-310586 Sheet 2	Bottom End Plug (WesDyne Proprietary Information)	Unclassified
H-3-307846 Sheet 1	Production Cladding Tube	Unclassified
H-3-307847 Sheet 1	Production Coated Cladding Tube (U)	Classified
H-3-307862 Sheet 1	Production Spring Clip	Unclassified
H-3-307853 Sheet 1	Production Standard Length Pellet Stack	Unclassified
H-3-307854 Sheet 1	Production Variable Length Pellet Stack	Unclassified
H-3-307857 Sheet 1	Production Standard Inner Liner Tube	Unclassified
H-3-307858 Sheet 1	Production Variable Length Inner Liner Tube	Unclassified
H-3-314868 Sheet 1	Pellet Stack Groups	Unclassified
H-3-314869 Sheet 1	Variable Pellet Stack	Unclassified
H-3-314870 Sheet 1	Standard Pellet Stack	Unclassified
H-3-307320 Sheet 1	Full Length Getter Pellet Stacks	Unclassified

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 7 of 9

Table A.2. Design Drawings for Cycle 12 Lead Use TPBAR Designs

Drawing	Title (Note: "U" designates an unclassified title.)	Classification
H-3-311447 Sheet 1	Full Length Getter Tube/Disk Assembly (U)	Classified
H-3-311448 Sheet 1	Full Length Getter Tube/Disk Assembly Final Trim (U)	Classified
H-3-311449 Sheet 1	Machined Getter Disk (U)	Classified
H-3-314864 Sheet 1	Full Length Liner	Unclassified
H-3-314864 Sheet 2	Full Length Liner	Unclassified
H-3-314865 Sheet 1	Full Length Liner Tube Stock	Unclassified
H-3-314865 Sheet 2	Full Length Liner Tube Stock	Unclassified
H-3-314866 Sheet 1	Full Length Liner Flange	Unclassified
H-3-314873 Sheet 1	LU Rod Pellet Stack Groups	Unclassified
H-3-314874 Sheet 1	LU Rod Variable Pellet Stack	Unclassified
H-3-314875 Sheet 1	LU Rod Standard Pellet Stack	Unclassified
H-3-314881 Sheet 1	Full Length Liner Spacer	Unclassified
H-3-314893 Sheet 1	Cleaned Full Length Getter Plated Getter Tube (U)	Classified
H-3-314894 Sheet 1	Lead Use (LU) Rod 1 TPBAR (U)	Classified
H-3-314894 Sheet 2	Lead Use (LU) Rod 1 Materials List	Unclassified
H-3-314894 Sheet 3	Lead Use (LU) Rod 1 TPBAR (U)	Classified
H-3-314894 Sheet 4	Lead Use (LU) Rod 1 TPBAR Details (U)	Classified
H-3-314894 Sheet 5	Lead Use (LU) Rod 1 TPBAR Internals & General Assembly (U)	Classified
H-3-314895 Sheet 1	Lead Use (LU) Rod 2 TPBAR (U)	Classified
H-3-314895 Sheet 2	Lead Use (LU) Rod 2 Materials List	Unclassified
H-3-314895 Sheet 3	Lead Use (LU) Rod 2 TPBAR (U)	Classified
H-3-314895 Sheet 4	Lead Use (LU) Rod 2 TPBAR Details (U)	Classified
H-3-314895 Sheet 5	Lead Use (LU) Rod 2 TPBAR Internals & General Assembly (U)	Classified
H-3-314896 Sheet 1	Lead Use (LU) Rod 3 TPBAR (U)	Classified
H-3-314896 Sheet 2	Lead Use (LU) Rod 3 Materials List	Unclassified
H-3-314896 Sheet 3	Lead Use (LU) Rod 3 TPBAR (U)	Classified
H-3-314896 Sheet 4	Lead Use (LU) Rod 3 TPBAR Details (U)	Classified
H-3-314896 Sheet 5	Lead Use (LU) Rod 3 TPBAR Internals & General Assembly (U)	Classified
H-3-314899 Sheet 1	Cleaned Full Length Getter Tube/Disk Assembly (U)	Classified
H-3-314900 Sheet 1	Cleaned Full Length Getter Tube/Disk Assembly Final Trim (U)	Classified
H-3-314901 Sheet 1	FLL Lead Use (LU) Modified Upper Cruciform	Unclassified

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 8 of 9

APPENDIX 2

LIST OF DESIGN SPECIFICATIONS AND COMPONENT ACCEPTANCE TEST REQUIREMENTS (All at Latest Revision)

Table B.1. Design Specifications for Mark 9.2 and Mark 10 Designs

Document Number	Title
TTQP-1-072	<i>Production Specification for 316 Stainless Steel Seamless Cladding Tubes</i>
TTQP-1-075	<i>Production Specification for LWR Tritium Target Rod Stainless Steel Bar Stock for Cladding</i>
TTQP-1-076	<i>Production Specification for Enriched Annular LiAlO₂ Pellets</i>
TTQP-1-077	<i>Production Specification for LWR Tritium Target Rod Bare Zircaloy Tube</i>
TTQP-1-079	<i>Production Specification for LWR Tritium Target Rod Top and Bottom End Plugs</i>
TTQP-1-080	<i>Production Specification for LWR Tritium Target Rod Top and Bottom End Plug Welding</i>
TTQP-1-081	<i>TPBAR Component Characteristics and Related Importance Factors</i>
TTQP-1-083	<i>Production Specification for LWR Tritium Target Rod Stainless Steel Bar Stock for End Plugs</i>
TTQP-1-085	<i>Design Requirements for TTQP Weld Joint Burst Testing Matrix/Test Plan</i>
TTQP-1-089	<i>Production Specification for LWR Tritium Target Rod Spring Clip</i>
TTQP-1-096	<i>Appendix H of TTQP-1-081: Inner Liner Tube</i>
TTQP-1-097	<i>Appendix J of TTQP-1-081: Activated Nickel Plated Getter Material, Manufacturing Specification</i>
TTQP-1-098	<i>Appendix K of TTQP-1-081: Activated Nickel Plated Getter Tubes</i>
TTQP-1-110	<i>Appendix M of TTQP-1-081: Top and Bottom End Plug Welding</i>
TTQP-1-132	<i>Appendix Q of TTQP-1-081: Full-Length Getter Tubes</i>
TTQP-1-134	<i>Production Specification for Assembling TPBARs onto a Holddown Base Plate</i>
TTP-1-140	<i>Test Plan for Full Length TPBAR Burst Testing</i>
TTP-1-151	<i>Appendix S of TTQP-1-081: Getter Disk</i>
TTP-1-170	<i>Specification for LWR TPBAR Zircaloy Strip</i>
TTP-1-171	<i>Specification for LWR TPBAR Cruciform Spacers</i>
TTP-1-173	<i>Appendix T of TTQP-1-081: Cruciform</i>
TTP-1-184	<i>Specification for LWR TPBAR Zircaloy Bar Stock</i>
TTP-1-185	<i>Specification for LWR TPBAR Machined Cruciform Spacers</i>
TTP-1-189	<i>Specification for LWR TPBAR Surface Modified Cruciforms</i>

Tritium Technology Program
Description of the Tritium-Producing Burnable Absorber Rod
for the Commercial Light Water Reactor

TTQP-1-015

Revision 19

Page 9 of 9

Table B.1. (contd)

Document Number	Title
PNNL-TTQP-1-692	<i>Specification for LWR Tritium Target Rod Inside Diameter Aluminide Barrier (U)</i>
PNNL-TTQP-1-829	<i>Standard Getter Rate Test Requirements (U)</i>
PNNL-TTQP-1-867	<i>Test Plan for Target Rod Spring Clip (U)</i>
PNNL-TTQP-1-920	<i>Specification for Production LWR Full-Length Getter Tubes (U)</i>
PNNL-TTP-1-1073	<i>Specification for LWR TPBAR Getter Disks (U)</i>
PNNL-TTP-1-1078	<i>TPBAR Final Assembly Specification (U)</i>

Table B.2. Design Specifications for Cycle 12 Lead Use TPBAR Designs

Document Number	Title
TTP-1-191-00	<i>Full Length Getter to Getter Disk Weld Specification</i>
TTP-1-191-01	<i>Full Length Getter to Getter Disk Weld Specification</i>
PNNL-TTP-1-1227	<i>Test Plan for WBN1 Cycle 12 Lead Use TPBARs (U)</i>