SRS H1616 Hydride Transport Vessel Qualification Report

by

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SRS H1616 HYDRIDE TRANSPORT VESSEL QUALIFICATION REPORT (U)

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SRS H1616 HYDRIDE TRANSPORT VESSEL QUALIFICATION REPORT

APPROVALS

Signature ____________________ Date 12/14/98
E. K. Opperman (Manager, Packaging and Transportation Group)

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M. A. Ebra (L3 Manager, Engineering Development Section)

Signature Dennis L. Hayes Date 12/15/98
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REVISION LOG

Revision/	Date	Affected Sections	Description of Changes
0	10/21/92	All	Original Issue
1	4/30/93	1.0	Clarified para. 3 H1616 transport qualification; added para. 4 operating temperature discussion; deleted para. 5 LP-50 reference and "design requirements" from para. 7 appendices description.
1	4/30/93	2.0	Clarified dual facility/transportation qualification.
1	4/30/93	2.1	Stated NRC source documents.
1	4/30/93	2.1.2	Stated ASME Code Section III, Subsection NB.
1	4/30/93	2.1.3	Added permeation leakage contribution and control.
1	4/30/93	2.2	Added tritium capacity discussion.
1	4/30/93	2.2.1	Added para. 2 operating versus design temperature discussion.
1	4/30/93	2.2.2, 3.2.1, 4.2.3.3	Changed valve from SS-4HS-TW to SS-4H-TW.
1	4/30/93	3.0	Added vessel data table.
1	4/30/93	3.1	Added geometric restriction discussion, Figure 3 migration in H1616, and Figure 2, components layout; clarified Figure 1 callouts.
1	4/30/93	3.1.1	Stated formula in °K; clarified definition of design condition in second major para.; deleted last para.; added service life, major para. 3.
1	4/30/93	3.1.2.1, 3.1.2.2	Added containment boundary Figures 4 and 5.
1	4/30/93	3.2.1	Deleted service history reference, stellite stem specification and comparison with B-series valve.
1	4/30/93	3.2.2	Added hydrogen, helium discussion, para. 2.
1	4/30/93	3.2.3	Changed "porous cup" to "porous filter".
1	4/30/93	3.2.6, 3.2.7	Added prototype discussion.
1	4/30/93	3.2.8	Replaced oxide layer removal with reference to 5.1.3.
1	4/30/93	4.1.1	Added Table note for 0.1 psia external pressure.
1	4/30/93	4.1.1.3	Changed allowed weight from 12.7 to 16.1 pounds.
1	4/30/93	4.1.1.5	Added para. 4 drop target material, dimension, hardness, support, and damage, and para. 5 drop orientation discussion; deleted para. 3 valve discussion; changed "nominal 200 psig" to "201 psig."
1	4/30/93	4.1.1.6	Noted analyses assume uniform 71°C.
1	4/30/93	4.1.1.8	Deleted para. 4, valve discussion; changed "nominal 200 psig" to "213 psig."
1	4/30/93	4.1.1.11	Added permeation discussion, para. 2, 4, 5, Table 9.
1	4/30/93	4.1.3	Added para. 2 permeation discussion; changed para. 2 "945 ± 5 psi" to "965 ± 20 psi."
1	4/30/93	4.1.4.5	Added para. 2 prototype weld deviation discussion.
1	4/30/93	4.1.4.7	Changed "Tables I-1.0 of the Appendices, ASME Code, Section III" to "Table UHA-23, ASME Code Section VIII."
1	4/30/93	4.2.2	Added service life discussion, para. 3.

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
1	4/30/93	4.2.2.1	Added in para. 1 that above 500°C is abnormal use; noted undefined Table values.
1	4/30/93	4.2.2.11	Added para. 4 discussion of tritium, helium degradation.
1	4/30/93	5.0	Added that activities shall satisfy 7.0.
1	4/30/93	5.1	Added para. 3 operating temperature, service life discussion.
1	4/30/93	5.1.1.4	Added, surface contamination mitigation.
1	4/30/93	5.1.2.1	Clarified para. 1 leak test frequency.
1	4/30/93	5.1.3	Added para. 1 oxide layer penetration discussion; changed para. 2 "nominally" to "approximately" and prohibited tritium as activating gas.
1	4/30/93	5.1.5	Changed step 4 "approximately 450°C" to "at most 450°C" and restricted tritium pressure to 0.1 psia or less.
1	4/30/93	5.1.7	Added para. 3 surface contamination discussion.
1	4/30/93	5.1.8.2	Deleted allowance for fitting repair.
1	4/30/93	5.1.8.4	Added, "Service Life Conditions Exceeded."
1	4/30/93	6.0	Added 5.0 citation and that activities shall satisfy 7.0.
1	4/30/93	6.1.1	Clarified proof test discussion, para. 2, 3; changed para. 2 and 3 "1140 ± 5 psig" to "1160 ± 20 psig."
1	4/30/93	6.1.2	Changed para. 1 "the design pressure of 945 ± 5 psig" to "965 ± 20 psig."
1	4/30/93	6.2.2	Changed "or has been transported less than 3 times" to "and has been transported for the third time."
1	4/30/93	6.2.4, 6.2.5	Deleted repair allowances, invoked 7.15 and 7.16.
1	4/30/93	6.2.4.3	Added entirely, "Cleaning."
1	4/30/93	6.2.5.1	Deleted entirely; added general non-routine maintenance requirement to 6.2.5.
1	4/30/93	7.1	Added procurement, acceptance testing, maintenance and repair to para. 1; added procurement to Tritium Department para. 3 activities.
1	4/30/93	7.2	Added procuring to para. 5 activities for which Tritium Department implements 1Q.
1	4/30/93	7.3	Changed para. 3 "Any design change requests" to "All design change requests;" changed Step 3 so that design agency proposes changes to design authority; clarified Step 5 design agency role, cited 7.6; deleted last paragraph.
1	4/30/93	7.4	Cited 7.7 in para. 2; added para. 4 design agency approval; changed para. 5 to state HTV procurements and independent uranium procurements are level 1; changed para. 6 "Purchase requisition requirement" to "Procurement document."
1	4/30/93	7.6	Added "approved" revision to para. 3; replaced later half para. 5 with "released by SRS for implementation;" added para. 6 steps 1 through 5 document revision control.
1	4/30/93	7.7	Added procurement control steps 1 through 7.

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
1	4/30/93	7.9	Added para. 4 citation to 7.7.
1	4/30/93	7.13	Added para. 2 protection external features, fittings .
1	4/30/93	7.15	Included para. 2 and 3 "HTV assemblies in use;" deleted para. 2 maintenance allowances; qualified para. 3 dispositions to need approval prior to implementation.
1	4/30/93	7.16	Noted owner or designee as responsible, para. 2.
1	4/30/93	7.17	Noted owner or designee as responsible for hardware records, para. 4.
1	4/30/93	8.0	Deleted 7.
1	4/30/93	Appendix 1	Changed drawings from Rev. 0 to Rev. 1.
1	4/30/93	Appendix 3	Added Appdx. 3.1 service life report, 3.5 surface hardness report, 3.9 permeation analysis, Appdx. 3.6 vibration and shock test report.
1	5/25/93	1.0	Cited SNL kit, para 3; added service life discussion, para 4.
1	5/25/93	3.0	Changed service life, added SNL kit, Table 1.
1	5/25/93	3.1.1	Referred service life to 5.1, para 3.
1	5/25/93	3.2.2	Noted embrittlement "is expected to be insignificant," referred material discussion to 4.2.2.11, para 2.
1	5/25/93	3.2.6	Compared 304L in test to 304/316 specified, para 2.
1	5/25/93	4.1.1.11	Changed % tritium from 2.2×10^{-4} to 6.6×10^{-2} and basis to 500 microns from loading, para. 2.
1	5/25/93	4.2.2	Referred service life to 5.1, para 3.
1	5/25/93	4.2.2.11	Added helium and hydrogen effect data, para 4; referred service life to 5.1, para 5.
1	5/25/93	5.1	New section, "Operating Limits and Estimated Service Life," displaced previous 5.1 to 5.2.
1	5/25/93	5.2	Cited 5.1 limits at mandatory, para 3.
1	5/25/93	5.2.3	Modified furnace controls, para 2; removed "ambient temperature," step 6; added Figure 6, furnace orientation.
1	5/25/93	5.2.4	Added service life verification, para 2.
1	5/25/93	5.2.5	Modified limits and cited 5.1, step 4; removed "less than 200°C" and made cooling prior to back filling, step 5.
1	5/25/93	5.2.6	Modified limits and cited 5.1, removed "ambient temperature," steps 4, 5; added flow through loading to steps; changed pressure from 0.2 psia to 500 microns (1×10^{-2} psia), step 6.
1	5/25/93	5.2.8.4	Changed entire paragraph, reflecting new service life controls.
1	5/25/93	7.3	Added design agency task leader to report approval.
1	5/25/93	7.8	Changed "commercially available" to "commercial grade," para 5.
1	5/25/93	7.9	Added service life related requirements, para 5.
1	5/25/93	7.14	Added service life related requirements, para 3.
1	5/25/93	7.17	Added "Service Life Substantiation," table 21.
1	5/25/93	Appendix 1	Changed R-R1-H-0035 from Rev. 1 to Rev. 2.

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
1	5/25/93	Appendix 2	Changed Appdx 2.1 from Draft Issue A to Issue C.
2	10/4/95	2.2.2, Table 1, 3.2.1, 4.2.3.3	Changed valve from SS-4H-TW to SS-4HS-TW.
2	10/4/95	3.2.1, 4.1.1.5, 4.1.1.8	Added descriptions of SS-4H-TW and SS-4HS-TW valves.
2	10/4/95	3.2.3, 5.2.1.1	Noted braze material incompatibility with mercury.
2	10/4/95	4.1.1.2, 4.1.1.11, 4.1.3, 6.1.2, Appendix 3.4	Incorporated Interim Revision of Revision 1 leak rate changes.
2	10/4/95	Table 9	Added leakage rate units to headings.
2	10/16/95	3.2.1	Revised SS-4H-TW and SS-4HS-TW equivalency defense.
2	10/16/95	4.1.1.5, 4.1.1.8	Added reference to 3.2.1 valve equivalency defense.
2	10/16/95	4.1.1.2, 4.1.1.11	Changed STP to 25°C and 14.7 psi differential.
3	3/20/98	Approvals	Changed approvals to be design agency L4 and L3 and Customer.
3	4/2/98	2.0, 7.1, 7.2, 7.3	Changed Tritium "Department" to "Division".
3	4/2/98	2.1.2	Added "applicable" to discussion of ASME Code design criteria.
3	4/2/98	2.2.3.3	Changed H1616 height limit to 10 and a half inches.
3	4/2/98	Table 1	Added reference to 5.2.2.1 for valve torque requirements.
3	4/2/98	3.2.1	Deleted comparison to SS-4H valves in para 2, to other applications in para 3; referred reader to 5.2.2.1 for new torque of 20±1 in para 3.
3	3/20/98	3.2.8	Changed uranium length to not greater than .5 in.
3	4/2/98	4.1.1.5	Deleted comparison to SS-4H valve in para 3 and steel shot mass in para 4; changed impact pad description in para 4.
3	3/20/98	Table 6	Revised leakrates, damages and footnotes
3	3/20/98	4.1.1.8	Changed leakrate to 2.5×10^{-9} in para 1, fill pressure to 202 in para 4, deleted para 5 SS-4H valve comparison.
3	4/2/98	4.1.1.7	Added reference to 4.1.2.3 in para 1.
3	4/2/98	4.1.1.11	Added valve cycle degradation and reference to Appendix 3.7 for containment temperature range in para 3.
3	4/2/98	Table 10	Added Cold loading condition.
3	4/2/98	4.1.2	Made requirements distinction between vessel and valve; added para 4 for Cold load condition, added valve stem assessment reference, 4.1.2.3.
3	4/2/98	4.1.2.3	Added this section on valve stem structural assessment.
3	3/20/98	4.2.4	Added reference to 5.2.2.1 torque requirements.
3	3/20/98	5.1	Added para 3 valve cycle life discussion.
3	3/20/98	5.1.1	Added para 2 defining ambient temperature requirement and discussion.
3	3/20/98	5.2.2.1	Accentuated torque requirement and added referenced to 5.1.1.
3	4/2/98	5.2.3	Added reference to 5.2.2.1 for torque requirement to Step 7.

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
3	4/2/98	5.2.4	Added reference to 5.2.2.1 for torque requirement to para 1.
3	4/2/98	5.2.5	Added reference to 5.2.2.1 for torque requirement to Step 6.
3	3/20/98	5.2.6	Added reference to 5.2.2.1 for torque requirement in Step 6.
3	4/2/98	6.1.1	Added reference to 5.2.2.1 for torque requirement in para 2.
3	4/2/98	6.1.2	Added reference to 5.2.2.1 for torque requirement in para 1.
3	3/20/98	6.2.3	Made periodic valve lubrication required; added top-of-valve-stem lubrication and visual examination for stem bending.
3	3/20/98	7.1	Deleted reference to P&T's departmental organization in para 4.
3	4/2/98	7.1 et al.	Changed Tritium Department to Tritium Division.
3	3/20/98	Figure 7	Updated organization names.
3	3/20/98	7.3	Changed drawing CHKD and Customer Other approvals to cognizant engineers; changed report approvals to design agency manager, section manager and customer program leader.
3	3/20/98	7.6	Deleted "preliminary" release revision control procedure.
3	4/2/98	Appendices	Added listing of Appendices and included documents.
3	3/20/98	Appendix 1	Incremented all drawing revisions by one.
3	3/20/98	Appendix 3.1	Added SRT-IES-98-0061 and SRT-MTS-984042, Rev. 1.
3	3/20/98	Appendix 3.5	Replaced report with SRT-IES-980004.
3	4/2/98	Appendix 3.6	Replaced report with H1616/HTV-TR-2.
3	4/2/98	Appendix 3.7	Added M-CLC-H-01587 and M-CLC-H-01616.
4	7/23/98	1.0, 8.0, Appendix 2.1, 3.6	Changed Sandia National "Laboratory" to "Laboratories".
4	7/23/98	1.0	Limited transport authorization to H1616-1.
4	7/23/98	2.1.3, 4.1.1.11, 4.1.3	Changed "gross leakage" to "bulk leakage".
4	7/23/98	Table 1	Updated to SS393217, Issue D criteria of < 1.26×10^{-7} cc/s tritium, added "nominal" to weight citations.
4	7/23/98	3.2.2	Added "Type 347H has high-temperature strength required for the HTV application. Type 347 carbon content is limited to...while that of Type 347H is limited to... It is judged that this ..will not appreciably effect hydrogen behavior." in para. 2.
4	7/23/98	3.2.6	Added, after "...would result in...", "no greater peak...duration. Because Type 304...any of the materials. What will differ is...to yield. Hence, the...duration will. Since...yield strength. Types 304L...were used. Given the...significant effect." and deleted "...greater energy dissipation...by plastic deformation. Initial impact...of elasticity."
4	7/23/98	4.1.1 and subtier	Revised SS393217 section references to match Issue D.
4	7/23/98	Table 2	Changed "outgassing" to "offgassing" and temperature from 191°C to 232°C.
4	7/23/98	4.1.1.2, 4.1.1.11, 4.1.3.	Updated to SS393217, Issue D criteria of < 1.26×10^{-7} cc/s tritium.

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
4	7/23/98	4.1.1.2	Deleted "Accounting for tritium permeation...differential." and replaced "is more stringent than" with "satisfies" in para. 2.
4	7/23/98	4.1.1.3	Added "(12 verified HTV weights ranged from 9.01 pounds to 9.55 pounds)".
4	7/28/98	Table 3	Deleted "energy content" and added "gas quantity" data and 19 grams for H1616 content limit.
4	7/23/98	4.1.1.4, Table 4	Revised to address pressure increase at 232°C per SS393217 Issue D, changed "outgassing" to "offgassing", added para. 3 and 4 and changed Table 4 "Outgassing to "Release Pressure".
4	7/23/98	4.1.1.5–4.1.1.10	Changed "remain leaktight" to "contain tritium".
4	7/23/98	4.1.1.6	Revised condition statement and deleted solar plus 38°C ambient condition in para. 1, deleted para. 2 (71°C limit analysis).
4	7/23/98	Table 5	Corrected subtitle symbols back to "≤" and "Δ".
4	7/23/98	4.1.1.8	Changed test pressure from 202 psig to 203 psig in para. 4.
4	7/23/98	4.1.1.11	Changed title from "leak rate" to "acceptance criteria", added "Bulk leakage...controlled by testing.", "...established as <u>leak tight (</u>less than...", and "Permeation leakage...controlled by operating limits. The leak tight criteria...compared to the SS393217 criteria. Allowance...less than 1.26×10^{-7} std. cm^3/sec tritium." and deleted "accounts for tritium permeation...of SS393217" in para. 2, added "With an estimated 20 cycles...represents 20 years. Operational experience indicates...HTV life." in para. 3 and added "...and results of permeation leak rate measurements." and "Measurements on a typical advanced-life HTV...confirmed that the analyses were conservative." and changed second sentence in para. 4.
4	7/23/98	4.1.2	Changed "...are assessed." to "...were originally assessed." in first sentence and added "A stress..not occur with 3b." in para. 3.
4	7/23/98	Table 12	Separated into 12a "Internal Pressure Condition 7b" and 12b "External Pressure Condition 3b" and added and entirety of 12b.
4	7/23/98	4.1.2.3	Added sentence "The basis for HTV valve qualification..." in para. 3.
4	7/23/98	4.1.3.2	Added "Accident testing is not required for the HTV and was not performed."
4	7/23/98	4.2.2.11	Added "...which demonstrated hydrogen compatibility similar to Type 304L.", changed "assumed" to "judged", added "with <u>hydrogen and thus</u> tritium.", and added "Type 347 carbon content is limited to...while that of Type 347H is limited to... It is judged that this...will not appreciably effect tritium compatibility." in para. 2.
4	7/23/98	6.1	Added "Acceptance testing during fabrication...detailed in the Appendix 1 design drawings."

REVISION LOG (CONTINUED)

Revision/	Date	Affected Sections	Description of Changes
4	7/23/98	7.3	Changed "containment boundary" to "qualification (approved shipping configuration)" in Step 5.
4	7/23/98	7.7	Deleted record retention requirement, second bullet.
4	7/23/98	7.11	Added "design performance tests" to applicable tests in para. 2.
4	7/23/98	7.15	Added para. "Notification to the DOE Albuquerque certification authorities is required... Notification is to identify...unit(s)."
4	7/23/98	8.0	Updated references 6 and 14.
4	7/23/98	Appendix 1	Replaced drawings with next revisions (R-R1-H-0035 Rev. 5, R-R3-H-0016 Rev. 4, R-R4-H-0056, Rev. 4).
4	7/23/98	Appendix 2.1	Replaced SS393217 Issue C with derivation of Issue D.
4	7/23/98	Appendix 3.4	Replaced with Rev. 1 having clarified transport correlation.
4	7/23/98	Appendix 3.6	Replaced with final report, SAND98-1230.
4	7/23/98	Appendix 3.7	Added external pressure calculation T-CLC-G-00105, Rev. 0.
4	7/23/98	Appendix 3.9	Added offgas evaluation, memorandum DPD-TED-98-0088.
5	12/9/98	4.1.1.3	Revised wording to reflect changes in SS393217 Issue E.
5	12/9/98	Table 3	Deleted 8.3 pound single item weight limit.
5	12/9/98	4.1.1.4	Clarified wording that pressure increase is 19.8 psi.
5	12/9/98	Table 4	Changed pressure increase to 19.8 psi.
5	12/9/98	4.1.1.4	Last paragraph: clarified that FelPro off gassing was minimal.
5	12/9/98	4.1.1.8	Replaced "leak tight" with "leak rate.....remain acceptable".
5	12/9/98	4.1.1.11	Implemented numerical criterion for leak tightness.
5	12/9/98	5.2.2.1	Changed "leak tight capability" to "leak rate acceptability".
5	12/9/98	3.1	Fourth paragraph: replace 9.995 with 10.0.
5	12/9/98	4.2.6	Replaced 9.995 with 10.0.
5	12/9/98	6.1.3	Replaced 9.995 with 10.0.
5	12/9/98	7.7	Updated responsible organizations in Step 4.
5	12/9/98	Appendices	List of Appendices, Appendix 2.1: revised to reference Issue E.
5	12/9/98	Appendix 2.1	Revised to reference Issue E.
5	12/9/98	Appendix 2.1	Page 1: inserted "Issue E based on an unclassified version of".
5	12/9/98	Appendix 2.1	Page 2: inserted "Issue E based on an unclassified version of".
5	12/9/98	Appendix 2.1	Page 4, Sec. 3.2.1: Inserted "*"and associated comment.

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CONTENTS

CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

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1.0 INTRODUCTION

This report serves as the design qualification basis for both transport and facility use. Headings identify report sections as containing qualification information for transport use, facility use, or both transport and facility use.

This report demonstrates that the Savannah River Site (SRS) hydride transport vessel (HTV) both satisfies the requirements for shipment in the H1616 packaging and satisfies the facility requirements set forth for Savannah River Site use. This report, together with the HTV design drawings in Appendix 1, establishes the design control, fabrication, use, and quality assurance requirements for the HTV.

For H1616-1 transport, the HTV meets Sandia National Laboratories (SNL) specification SS393217, "Reservoir Qualification AL-SX (H1616)," included in report Appendix 2. Packaging the HTV in the H1616-1 is defined in SNL drawing 413232, *Special Purpose Kit, H1616-1*. Of the two H1616 variations, qualification is sought for transport in the H1616-1. In this report, "H1616" signifies the H1616-1.

For facility qualification, the HTV is designed for 945 psig at a 600°C base temperature to the requirements of American Society of Mechanical Engineers (ASME) [21] Boiler and Pressure Vessel Code, Section VIII, Division 1, 1991 Addenda with lethal service requirements per Code paragraph UW-2. The maximum normal unloading temperature is 450°C. Heating to temperatures above 500°C is considered abnormal; the 600°C design condition provides overheat and over pressure safety margins rather than an extended operating range. Further mandatory operating limits are defined in Chapter 5.0. Service life estimates are supported by comparison to existing reservoir life storage program data.

The HTV is a reusable tritium containment vessel with an 18 gram tritium capacity. The Savannah River Site developed the HTV as a means for the Savannah River Site to safely transport tritium.

The HTV is designed to retain tritium in the form of solid uranium tritide rather than gaseous tritium. Within the HTV the tritium gas chemically reacts exothermically with depleted uranium to form solid uranium tritide. The retention of tritium as solid uranium tritide affords improved safety over gaseous tritium containment. To reverse the reaction and generate appreciable gaseous tritium is an endothermic process requiring temperatures exceeding 350°C.

The report is organized in the following manner: Chapter 2 provides the HTV design requirements; Chapter 3 presents the HTV design description; Chapter 4 presents the assessment of the HTV to the design requirements; Chapters 5 and 6 provide the HTV operating, acceptance testing, and maintenance requirements; Chapter 7 provides the quality assurance requirements; and Appendices include the HTV design drawings, supporting tests, analyses, assessments, and supporting information.

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2.0 DESIGN REQUIREMENTS

The HTV design is governed by both transport and facility conditions and ensuing requirements. This report is therefore a dual purpose document, demonstrating both transportation and facility safety. The HTV is qualified for shipment in the H1616 packaging by meeting SNL specification SS393217 and general packaging fabrication and structural requirements and guidelines. Facility requirements were imposed by the design authority, Tritium Division, Westinghouse Savannah River Company. While imposed by Savannah River, these facility requirements are typical of what would be required of the HTV by other qualified users. The HTV has been structurally assessed to both ASME Boiler and Pressure Vessel Code, Section III, Division 1 requirements for transportation and to Section VIII, Division 1 requirements for facility use.

Listed below are the transport and facility requirements required to qualify the HTV design for shipment in the H1616 and for facility use.

2.1 HTV Transport Requirements

Transport requirements are cited below. In addition to the mandatory SNL specification SS393217, US Nuclear Regulatory Commission (NRC) Regulatory Guide 7.6, which entails structural analysis per ASME Section III, Division 1, and NUREGs CR-3854 and CR-3019, which implement fabrication criteria of ASME Section III, Division 1, have been invoked.

2.1.1 H1616 Content Requirement

SNL specification SS393217, "Reservoir Qualification AL-SX (H1616)", included in Appendix 2, serves as the primary transport requirement that must be satisfied for transport qualification in the H1616 packaging.

2.1.2 Structural Requirement

US NRC Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Revision 1, included in Appendix 2, was chosen as the transport structural requirement. It is used to demonstrate that the stresses within the HTV satisfy applicable ASME Code structural design criteria when subject to the H1616 content load conditions.

2.1.3 Leakage Rate Verification Requirement

ANSI N14.5-87, "Leakage Tests on Packages for Shipment" [1], serves as the bulk leakage rate verification requirement. In conjunction with facility operating limits to control permeation leakage, it is used to establish conditions for demonstrating that the H1616 content leakage rate requirement is satisfied.

2.1.4 Fabrication Requirement

NUREG/CR-3019, "Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials" [2], and NUREG/CR-3854, "Fabrication Criteria for Shipping Containers" [3] were chosen for HTV fabrication requirements. They are US NRC-sponsored documents providing guidance in applying ASME Boiler and Pressure Vessel Code, Section III, Division 1, fabrication and welding requirements to radioactive materials packagings. The Code applications are summarized in NUREG/CR-3019 Table 2 and NUREG/CR-3854 Table 4.1. These tables are included in Appendix 2.

2.2 HTV Facility Requirements

The HTV facility requirements are cited below. Geometric interfacing requirements are cited in addition to the requirements imposed to ensure facility safety. A maximum tritium capacity was required within the content limit of SS393217. The 18 gram tritium capacity satisfied SS393217 and facility requirements.

2.2.1 Structural and Fabrication Requirements

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1991 Addenda is the primary facility requirement for structural design and fabrication. The HTV is to be unstamped but designed and constructed per the Code. Lethal service requirements of paragraph UW-2 also apply. The design temperature is established as 600°C at the HTV base (thermocouple wells) to 500°C at the vessel body top.

The design temperature is established as an overpressure protection margin above the 450°C normal operating limit. Heating above 500°C is abnormal usage.

2.2.2 Piping Requirements

Westinghouse Savannah River Company, Engineering Standard 15060-01-R, Pipe Code P265, Revision 2, included in Appendix 2, was chosen as the facility piping requirement. It applies to the tubes, valves, and fittings extending from the HTV. Exceptions to P265 allowed for the HTV are the use of Nupro® SS-4HS-TW valves and 3/8 inch × 0.065 inch tubing.

2.2.3 External Feature Requirements

2.2.3.1 Closure Requirement The HTV valve handles are required to accept a torque limiting closure device such as a torque wrench.

2.2.3.2 Lifting Requirement The HTV is required to have a handle for lifting purposes.

2.2.3.3 Geometric Requirement The HTV is required to fit in an existing 4.81 inch diameter × 12 inch deep calorimeter well. Additionally, the H1616 further limits the HTV height to approximately 10 and a half inches.

2.2.3.4 Thermal Monitoring Requirement Two thermocouple wells are required on the base of the HTV. These are to be temperature control attachment locations.

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3.0 HYDRIDE TRANSPORT VESSEL DESIGN

The HTV design and functional parameters are described below. Design drawings are in Appendix 1. General data required by SNL Specification SS393217 §4.3 is in Table 1.

Table 1. Hydride Transport Vessel Data

Part number(s) when filled and empty: Part number: R-R1-H-0035.	*Fill pressure*: 14.7 psia at 25°C (4.98×10^{-7} psia tritium, balance argon or helium-4).	*Weight*: 9.3 pounds nominal.
Valve designation: Nupro® SS-4HS-TW.†	*End of life pressure+6 months*: Not directly applicable. 200.51 psig at maximum fill, 1 year storage, and 71°C.	*Total shipping weight*: 9.4 pounds nominal (9.3 pound vessel, 0.1 pound bagging).
Valve design temperature: 315°C.	*Proof and burst test pressure*: Proof: 1160 ± 20 psig. Burst: Undetermined.	*Structural or service life*:‡ Life = $(388 / P_{max})^{1/2}$ (years) $P_{max} < 2.9$ psia tritium unloading pressure
Shipping configuration: SNL drawing 413232, *Special Purpose Kit, H1616-1*.	*Maximum PV energy*: 8425 inch-pounds.	*Maximum number of reclamations*: Unlimited within service life.
Thermal output: 5.83 watts maximum.	*Vessel body and tube material and material yield strength*: Body: 347H, $S_{y,71°C} = 28.5$ kpsi Tubing: 316L, $S_{y,71°C} = 22.7$ kpsi	*Stockpile life*: 1 year from closure.
Tritium fill volume: 42.03 in^3 (493 grams uranium)	*Maximum specified tritium leak rate in std cc/s*: $<1.26 \times 10^{-7}$ std cc/s.	*Sketches*: See Figures 1 and 2.

†See Section 5.2.2.1 for valve torque specification. ‡See further discussion in 5.1.

3.1 HTV Design

The HTV design , Figures 1 and 2, is comprised of a ellipsoidal-headed vessel body, two valved fill ports, a handle providing for HTV lifting and protection, and a base skirt. The body is made of two 4 inch schedule 40 pipe caps with a machined nozzle extending axially from the center of the upper cap. Curved tubes extend from the nozzle to the two valves, with additional curved tubing from the valves to the fittings. The handle is welded to the upper pipe cap. The base skirt is welded to the bottom cap. Two thermocouple wells are provided on the bottom pipe cap exterior. The HTV surface has no sharp protrusions. Removable items are the valve handles, the tube fitting caps, and fitting gaskets.

Within the HTV are two filter-tipped tubes extending from the nozzle. The filters are porous metal cups. A long tube allows access directly to the hydride (uranium tritide) powder, while a short tube allows access to the free volume above the hydride powder. The hydriding material is 493 grams of depleted uranium.

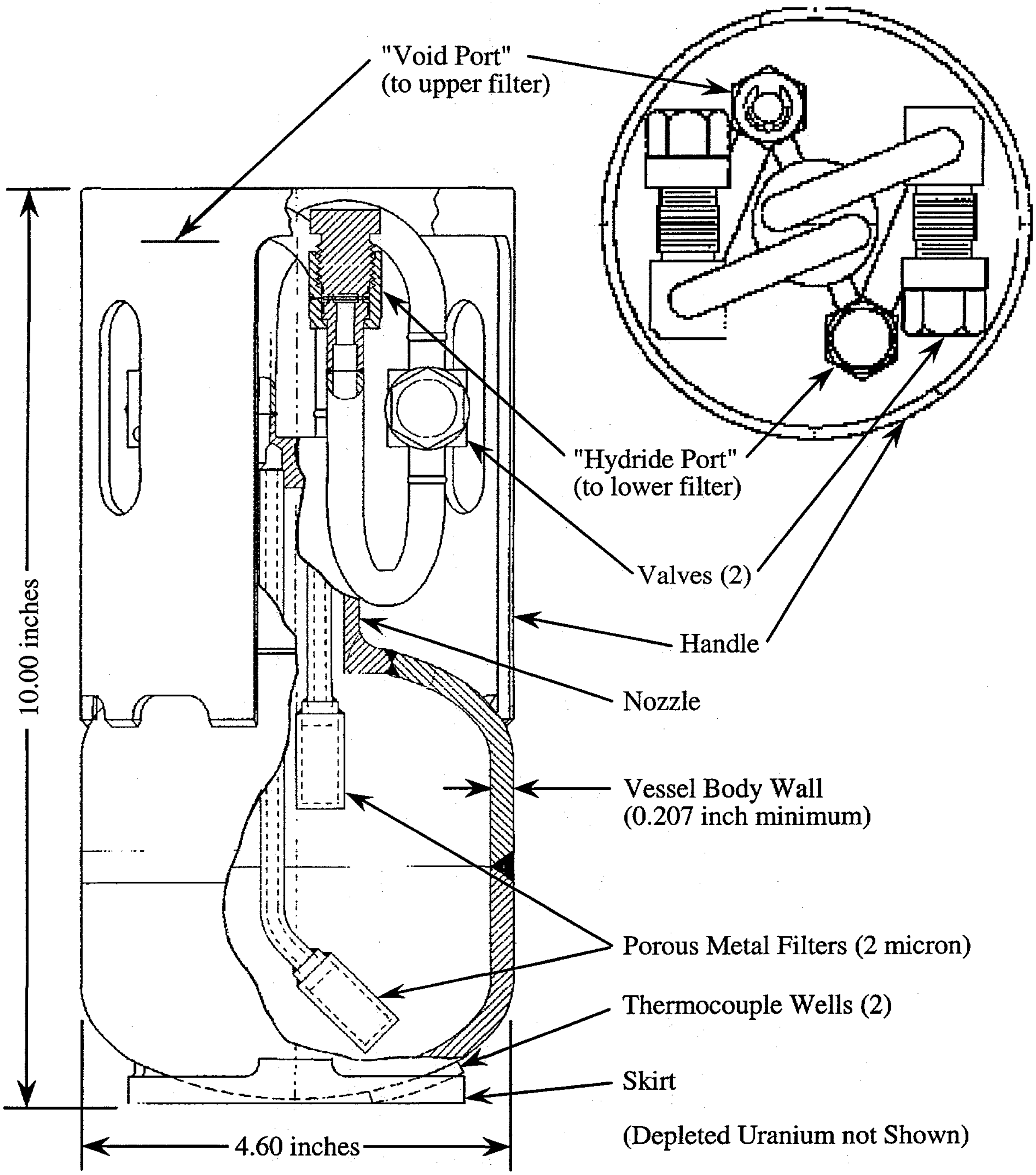


Figure 1. Hydride Transport Vessel Schematic

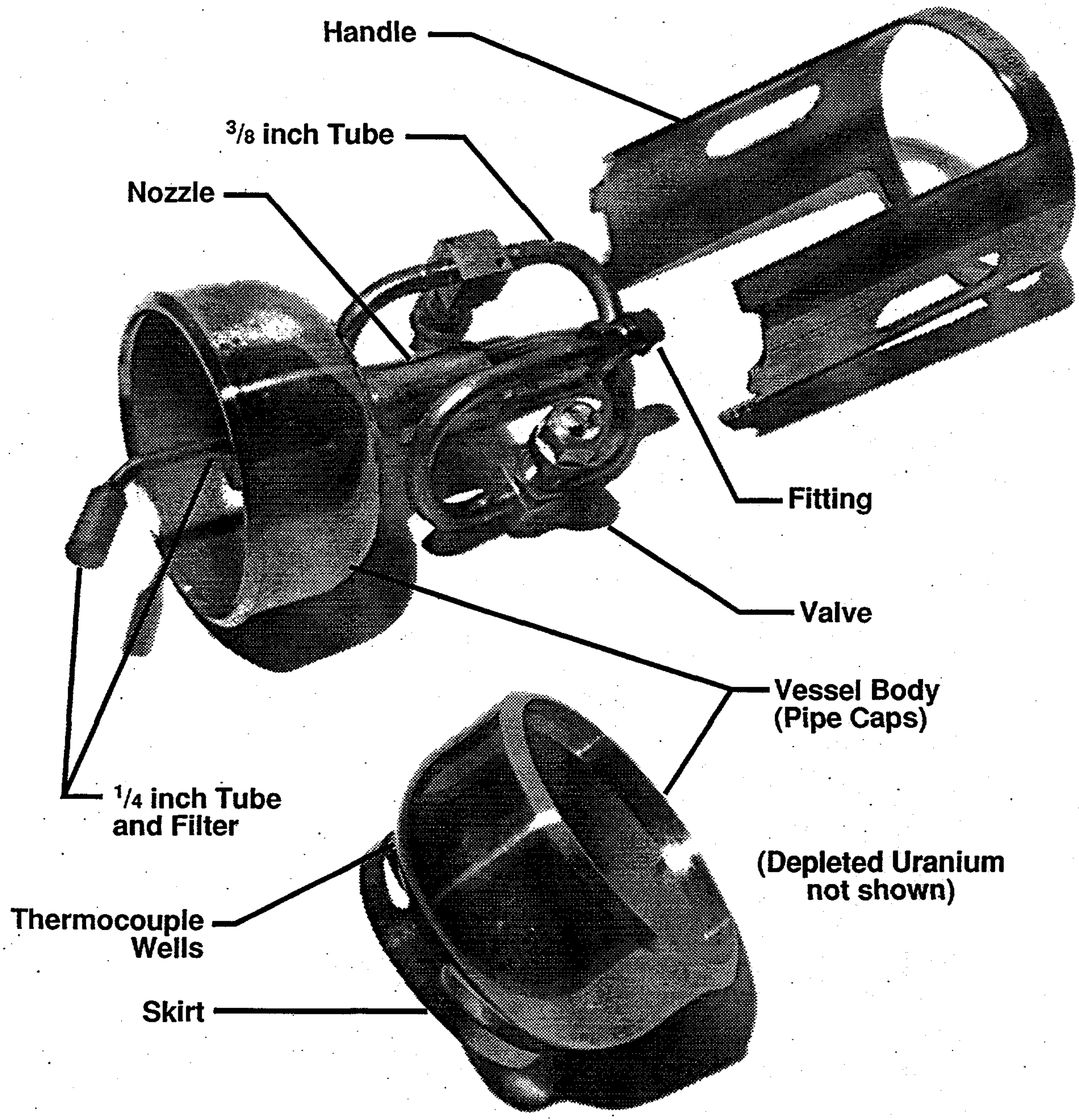


Figure 2. Hydride Transport Vessel Components

The two fittings allow for gas flow through if required during loading and provide redundant unloading paths if a valve malfunctions. The fittings are not symmetric - one is male and one is female - to differentiate between the "void" port exiting in the volume above the hydride and the "hydride" port exiting in the hydride.

The HTV weighs 9.3 pounds, fits within a 4.600 inch diameter cylinder, and has a 10.0 inch height. The 4.600 inch diameter and 10.0 inch height restrictions are facility compatibility requirements. During transport, the HTV can randomly migrate within the H1616, as shown in Figure 3.

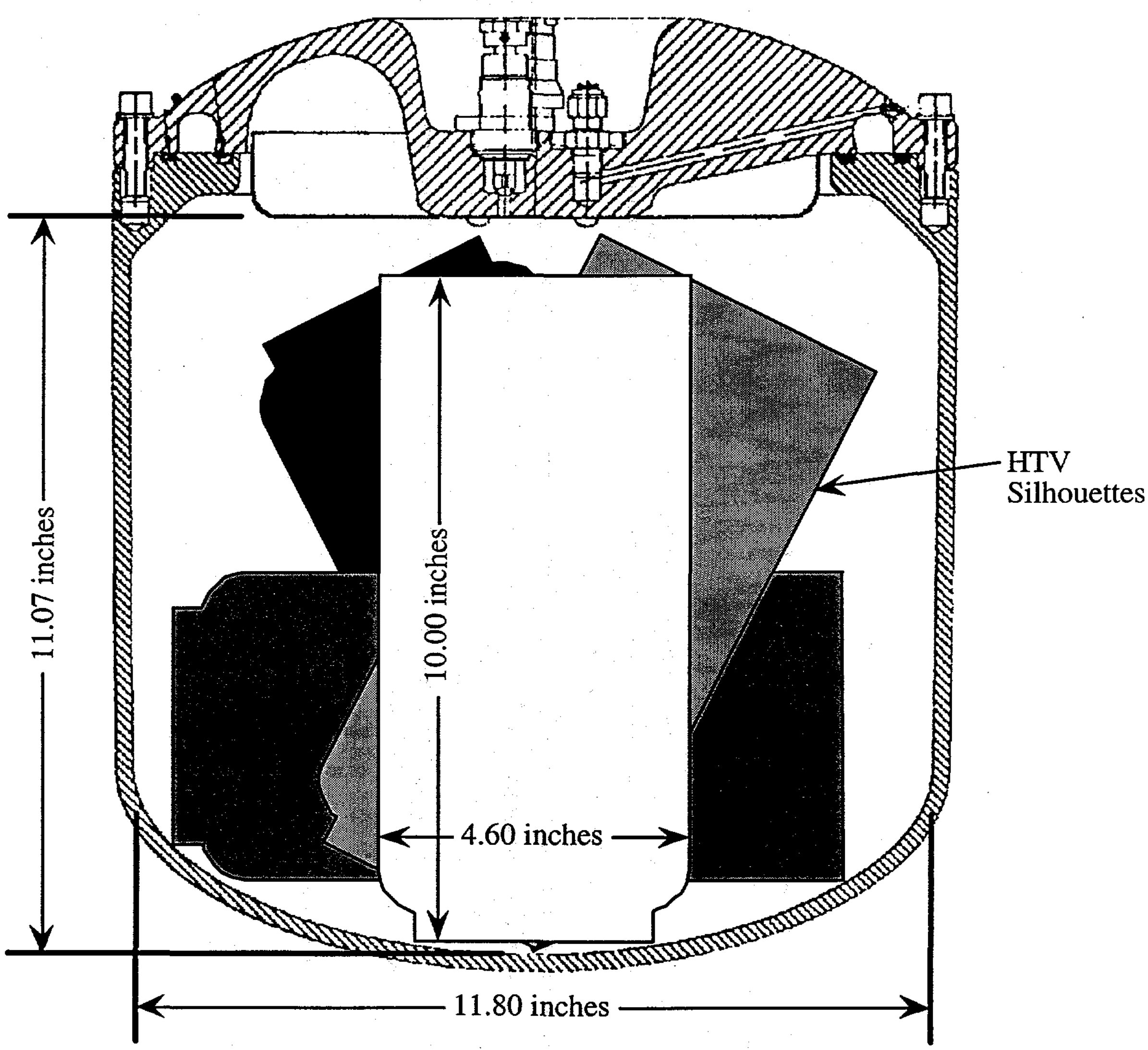


Figure 3. HTV Movement in H1616
(H1616-2 Shown)

3.1.1 HTV Functional Parameters

The HTV is a reusable tritium container for transporting up to 18 grams of tritium. The tritium is stored as uranium tritide when reacted with the contained 493 grams of depleted uranium. Although the theoretical uranium:tritium stoichiometry is 1:3, the practical limit is 1:2.9. Uranium tritide is formed by an exothermic reaction and requires temperatures in excess of 350°C for substantial reversal and subsequent tritium release. The tritium vapor pressure in the uranium-tritium system as a function of temperature for U:T = 1:2.9 is:

$$\log P_{atm} = -4038.2/T + 6.074; \quad \text{or} \quad \log P_{psia} = -4038.2/T + 7.2413 \quad (T \text{ degrees K}) \qquad [4]$$

The tritium vapor pressure is lower at lower stoichiometries.

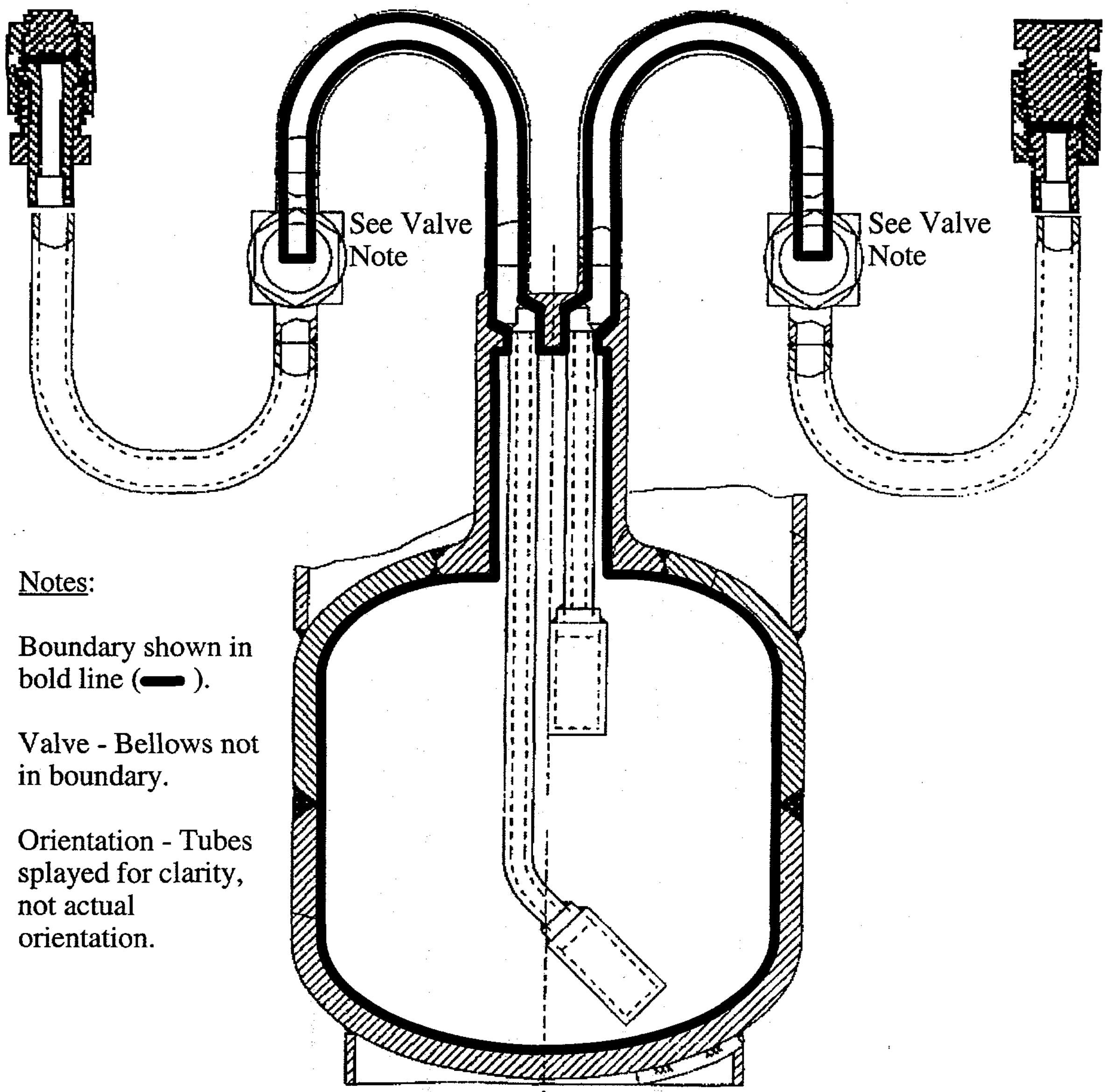
Facility conditions govern the static structural HTV design. The HTV is designed for 945 psig at a 600°C vessel bottom cap temperature measured at the thermocouple wells, cooling to 500°C at the nozzle juncture. This pressure and temperature accounts for an accident condition equivalent to heating the HTV in excess of normal operating limits to 600°C with the HTV valves closed. The HTV was dynamically assessed at the transport maximum normal operating condition of 201 psig at 71°C. Derivations of the transport maximum normal operating conditions are reported in 4.1.1.6 and Appendix 3. Design pressures included one year of helium generation, 14.7 psia initial fill, and tritium vapor pressure. While in facility use, the HTV is processed independent of the H1616.

HTV service life is governed in use by the facility operating temperature and associated tritium pressure. These in turn dictate the tritium and helium present in the HTV body materials and subsequent material degradation. The HTV service life is defined in 5.1.

3.1.2 Containment Boundary

<u>3.1.2.1 Transport Containment Boundary</u> In transport, the HTV containment boundary is comprised of the two pipe caps and joining weld, the nozzle and joining weld, the two tubes connecting the valves to the nozzle, the associated 4 tube welds, and the valves up to the valve seats. The valve bellows are not part of the transport containment boundary. All containment welds are full penetration welds with associated NDE. Figure 4 shows the transport containment boundary.

<u>3.1.2.2 Facility Containment Boundary</u> The facility boundary includes, for each port accessed, the transport boundary, less the valve seat, plus the bellows, the tube connecting the valve to the fitting, the two associated tube welds, and the fitting. All containment welds are full penetration welds with associated NDE. Figure 5 shows the facility containment boundary.



Notes:

Boundary shown in bold line (▬).

Valve - Bellows not in boundary.

Orientation - Tubes splayed for clarity, not actual orientation.

Figure 4. HTV Transport Containment Boundary

3.2 HTV Components

3.2.1 Valves

Nupro® SS-4HS-TW HS-series all welded bellows valves are used [5]. They were chosen because they have the most favorable pressure at temperature rating of any comparably sized valve, including the Nupro® BW-series valve. The HS-series is rated at 315°C and 1000 psig. The valve body edges contain extra material not required for valve performance. A chamfer added on one edge of each valve to provide fabrication clearance does not affect the valve rating.

The SS-4HS-TW valve has a Stellite™ spherical stem tip, which is a hard, cobalt-alloy ball-bearing welded to the valve stem. The Nupro® BG-series valve, which is used on the H1616 containment vessel, also has a Stellite™ tip. The Stellite™ tip is recommended by the manufacturer for improved shut-off cycle life in severe service applications and is much harder than the 316 stainless steel valve body seat.

A closure torque for closing the HS-series valves and for satisfying structural requirements is specified in Section 5.2.2.1.

Stock HS-series handles are machined to accept a standard 3/4 inch hex socket for opening and closing the valve.

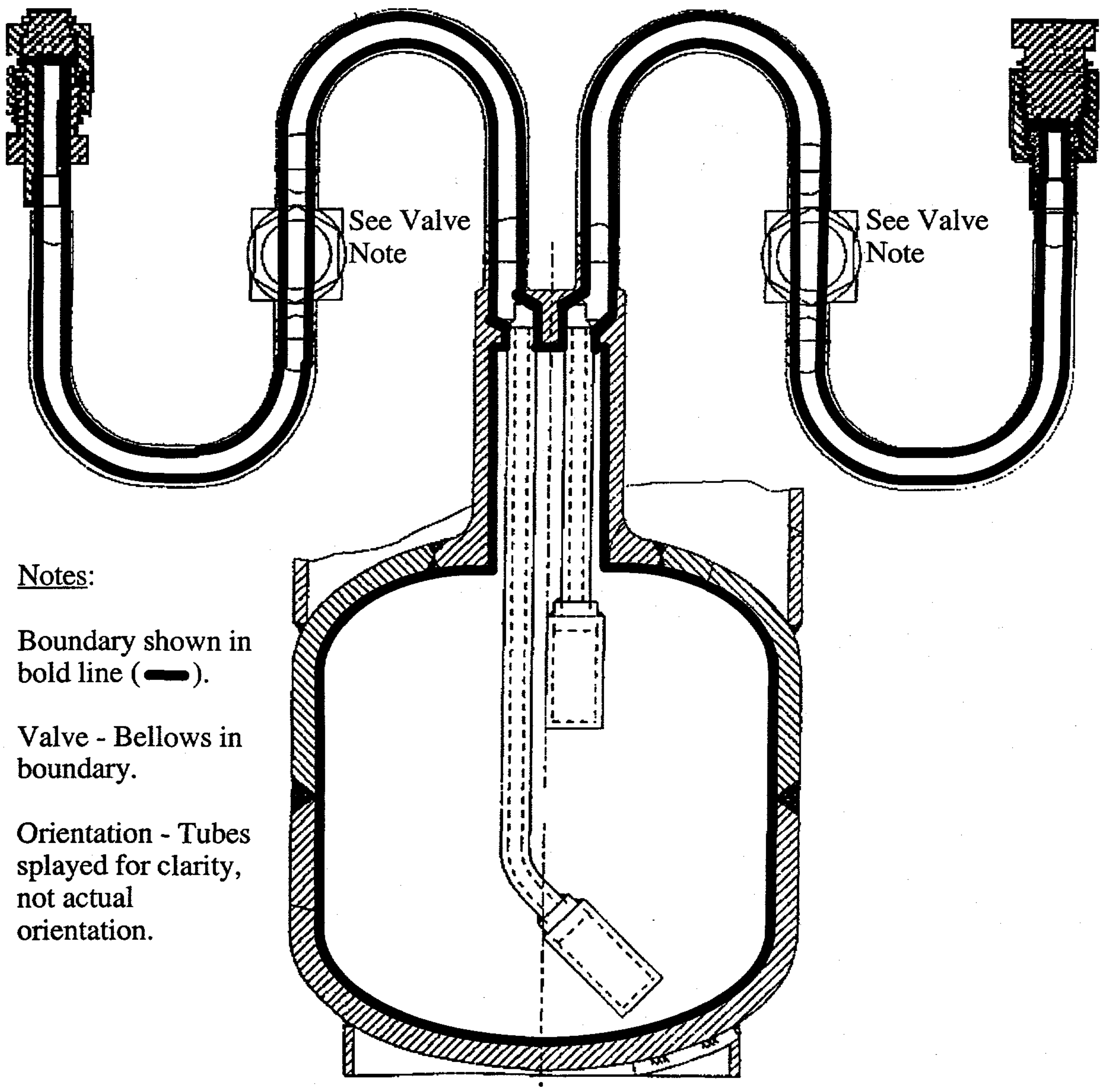


Figure 5. HTV Facility Containment Boundary

3.2.2 Vessel Body Shell

Three components comprise the HTV body shell - the two ellipsoidal pipe caps and the nozzle. These components are part of the HTV containment boundary. They are designed for exposure to temperatures of 500°C to 600°C. Type 347H austenitic stainless steel is specified for each component. Type 347H is the high temperature grade of Type 347, both of which are niobium-stabilized. The stabilization ensures corrosion resistance is retained, therefore eliminating the need for post weld heat treatment. The suitability of Type 347H stainless steel is addressed in Appendix 3. Pipe caps per ASME/ANSI B16.9 [22] meet the ellipsoidal head shape requirement of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1991 Addenda, and have the wall thickness necessary for structural integrity. ER347 weld material is specified as appropriate for gas tungsten arc welding (GTAW) of the Type 347H base material. All welds are specified as full penetration butt welds.

As noted in paragraph 4.2.2.11, Appendix 3 includes an assessment of Type 347 and 347H stainless steel materials in gaseous hydrogen environments. Extensive data exists supporting the use of Type 347 material in gaseous hydrogen. Type 347H is determined to be acceptable by showing it is similar to Type 347. Type 347H has high-temperature strength required for the HTV application. Type 347 carbon content is limited to no more than .08 percent, while that of Type 347H is limited to between .04 and .10 percent. It is judged that this slightly higher carbon allowance will not appreciably effect hydrogen behavior. By establishing the HTV normal operating limit at 450°C and that above 500°C is abnormal use, helium embrittlement of the HTV material is expected to be insignificant. Hydrogen, tritium, and helium effects are further discussed in 4.2.2.11.

3.2.3 Vessel Interior

The two internal tubes do not provide containment, however, they must maintain integrity to ensure uranium does not escape during facility use. The tubes are not load bearing, therefore Type 316L austenitic stainless steel was chosen as a suitable material. The porous metal filters are also specified to be Type 316L. Type 316L is not significantly sensitized from welding and has proven successful in tritium service. The porous filters are attached by GTAW to the tube. High-temperature AWS BAu-4 braze material, further described in 4.1.4.6, is specified for brazing the tube assemblies to the nozzle interior sockets. The BAu-4 braze material is predominantly gold, which is incompatible with mercury; therefore, mercury must not be allowed in the vessel. Socket tolerances are specified for adequate braze joining. The tube assembly geometries are important for fabrication and function. The lower tube is given a curved end to place the filter at an angle to the pipe cap, thereby reducing any tendency of the uranium hydride to compact between the adjoining surfaces. The tube lengths are specified so that the lower tube will not contact the pipe cap and the upper tube would not project into the radiography region of the pipe cap weld.

3.2.4 External Tubes

The external tubes are part of the containment boundary. Type 316L austenitic stainless steel was chosen for the external tubes. Type 316L attaches directly to the nozzle since the nozzle top temperature is less than the 454°C upper limit on Type 316L use imposed by the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1991 Addenda and is within the 315°C limit of Pipe Code P265. The tubes are connected by GTAW to the Type 316 valve bodies and fittings and the Type 347H nozzle. All tube welds are full penetration. ER316L welding material is specified for these welds. Liquid penetrant testing of the bent tubes is specified to ensure that bending does not introduce surface cracks.

3.2.5 Fittings

The fittings are part of the facility containment boundary. Cajon® VCR® metal-gasketed fittings are specified based on facility experience. The fittings are Type 316 austenitic stainless steel. Female threads on the fitting nuts have standard silver-plating to reduce galling. The Type 316 components do not require post-weld heat treatment due to their low operating temperatures.

3.2.6 Handle

The HTV handle serves as a lifting point and as a protective feature around the valves, tubes, and fittings. The handle is designed to provide planar impact protection. Notches in the handle base limit heat transfer from the vessel body while the HTV is being heated in the facility. The 3-point attachment of each handle leg ensures that adequate strength is retained for side impact protection. Notches near the valve bodies allow for fabrication variances and for the handle to be bent if dropped without impacting the valve body. Types 304 and 316 austenitic stainless steel are specified for the handle because they are readily available and have higher minimum yield strengths than Types 304L and 316L.

As noted in 4.1.1.5, material identified as Type 304L stainless steel was used for the prototype handle material and performed adequately during testing. While most 304 and 316 stainless steels are dually certified as L-grade, the final HTV design specifies use of Type 304 or Type 316 to ensure the higher yield strength materials are used. Assuming that the tested Type 304L was not dually certified and thus had a lower yield strength, a comparable drop with the higher yield strength material would result in no greater peak load but a slightly longer peak duration. Because Type 304, 316, 304L or 316L stainless steel have the same elastic modulus, initial loading through handle impact will be the same for any of the materials. What will differ is the duration of the peak loading prior to the handle material being strained to yield. Hence, the peak impact load will not differ, but its duration will. Since the yield strengths are similar, the duration of the peak loading will be roughly proportional to the yield strength. Types 304L and 316L have a nominal yield strength approximately 17% less than that of Types 304 and 316 (25 ksi compared to 30 ksi at room temperature); therefore, the tested peak load duration could have been approximately 17% less than if design-basis Types 304 and 316 material were used. Given the variations in the tests themselves and the robustness of the HTV, this possible variation in peak load duration is not expected to have a significant effect.

3.2.7 Skirt and Thermocouple Wells

The vessel skirt provides a flat base for keeping the HTV upright. Cut-outs are provided to improve radiative and convective heat transfer while the HTV is being heated for facility use. Two thermocouple wells are provided to allow consistent temperature monitoring during facility use. The wells are designed for .063 inch diameter thermocouples and provide suitable contact length-to-diameter for accurate measurement. The skirt and thermocouple wells provide no structural role and therefore can be made of Types 304, 304L, 316, or 316L materials.

During testing, Type 304L was used for the skirt. While Type 304L has a lower allowed strength than do Types 304 and 316, the skirt was compressed axially and therefore would have responded similarly for any of the allowed materials of construction.

3.2.8 Depleted Uranium

No industry standard exists for depleted uranium for hydride applications. The depleted uranium chemical composition is that given in the Savannah River Site specification and is similar to other specifications, as reported in Appendix 2. The depleted uranium stock is specified as 0.5 inch to 1.0 inch diameter bar in lengths not greater than 0.5 inch and providing the 493 ± 0.5 grams material. Turnings are not suitable because their poor packing efficiency results in uranium in the immediate girth weld region during welding. Depleted uranium is a heavy metal poison hazard, similar to lead. Depleted uranium is also a **radiation poisoning hazard** since adsorbed uranium is radioactive, and is a **pyrophoric hazard**. These hazards are fully realized when the uranium is finely divided. Fabricators must have adequate hazard controls when working with depleted uranium.

After the HTV is assembled, the uranium bar stock is decomposed to powder by hydride activation. Uranium activation is addressed in 5.2.3.

Uranium readily reacts with oxygen to form stable uranium oxide. Air ingestion and other oxygen sources will degrade the HTV tritium capacity as oxide forms. Therefore, **the HTV feed gas and internal atmosphere should be oxygen free**.

An assessment of the radiological emissions from the depleted uranium and tritium was performed and is included in Appendix 3. Shielding provided by the HTV stainless steel containment boundary was shown to mitigate emissions to within transport and SRS facility limits.

4.0 ASSESSMENT TO DESIGN REQUIREMENTS

This chapter demonstrates that the HTV design satisfies the transport and facility requirements.

4.1 Assessment to Transport Requirements

4.1.1 Assessment to H1616 Content Requirements

This section demonstrates that the HTV satisfies the qualification requirements set forth in Section 3. of SNL specification SS393217. Table 2 summarizes the significant transport load conditions derived from SS393217 and the assigned load values to which the HTV is evaluated. Derivation of HTV pressures are included in Appendix 3.

Table 2. Transport Load Conditions

Condition		Loading			
No.	Type	Vessel Temperature (°C)	Internal Pressure (psia)	External Pressure† (psia)	Other Loadings
1.	Offgassing	232	Inapplicable	Inapplicable	
2a.	Free Drop	–40	145.8	14.7	4 foot impact
2b.	Free Drop	71	215.2	14.7	4 foot impact
3a.	Heat	71	215.2	16.7	
3b.	Heat	71	0.0	22.7	
4a.	Cold	–40	145.8	16.7	
4b.	Cold	–40	0.0	22.7	
5a.	Vibration	–40	145.8	16.7	Vibration‡
5b.	Vibration	71	215.2	16.7	Vibration‡
6a.	Shock	–40	145.8	16.7	Shock‡
6b.	Shock	71	215.2	16.7	Shock‡
7a.	Reduced External Pressure	–40	145.8	0.1*	
7b.	Reduced External Pressure	71	215.2	0.1*	
8a.	Increased External Pressure	–40	0.0	22.7	
8b.	Increased External Pressure	71	0.0	22.7	

†H1616 back fill pressure is 19.7 ± 3 psia [6].

‡Defined in SAND91-2204 [8].

*Occurs during H1616 assembly, not during transport.

4.1.1.1 SS393217 §3.1, Quality Assurance The transport quality assurance requirements are addressed in Chapter 7.0.

4.1.1.2 SS393217 §3.2.1, Containment Boundary Seal To facilitate processing and reuse, the HTV uses two valve closures rather than the welded closures. The performance criterion invoked for the valved closures is that for welded closures; namely, that the valve closures maintain a leak rate of less than 1.26×10^{-7} cm^3/sec tritium in transport as demonstrated through the conditions of SS393217 sections 3.3 through 3.9.

The HTV containment acceptance criteria is defined as a helium leak rate, which can be more readily verified than a tritium leak rate. The acceptance criteria is set at less than 1×10^{-7} cm^3/sec helium-4 at 25°C and 14.7 psi differential, which is the facility criteria and satisfies the SS393217 requirement for welded closures. The leak rate correlation is provided in Appendix 3.

4.1.1.3 SS393217 §3.2.2, Comparison to H1616 Limits The HTV weighs approximately 9.3 pounds (12 verified HTV weights ranged from 9.01 pounds to 9.55 pounds). This is within the H1616 reservoir weight limit of 16.1 pounds. Although 18 grams of tritium is the maximum design limit based on the practical limiting U:T = 1:2.9 stoichiometry, 18.66 grams tritium is theoretically possible given 493.5 grams of uranium and the theoretical U:T = 1:3 stoichiometry. Table 3 compares the HTV with H1616 content limits.

Table 3. Comparison to H1616 Limits

Limited Item	Hydride Transport Vessel	H1616 Limit
Weight	9.3 pounds	16.1 pounds
Gas Quantity	19.8 psig at 232°C	177 psig at 232°C
Tritium Content	18.64 grams‡	19 grams

‡Maximum theoretical, while 18 grams is the practical design limit

4.1.1.4 SS393217 §3.2.3, Pressure Increase at 232°C This condition requires that the combined pressure due to an HTV release and offgassing be less than 2/3 the maximum allowable pressure in the containment vessel, which is 177 psig. The only offgassing contributors are the Fel-Pro® N-5000 valve lubricant and the standard Velostat® H1616 content bagging. Fel-Pro® N-5000 is a low-chloride, nickel and graphite flake lubricant in a petroleum carrier.

As shown in Table 4, the pressure increase at 232°C is nominally 19.8 psi. The corresponding pressure inside the containment vessel is 19.8 psig, which is well within the 177 psig allowed.

Table 4. Comparison to Release Pressure Limit

Source	Pressure Increase in H1616 at 232°C (psi)
Velostat® H1616 content bagging	0.0†
Fel-Pro N-5000 valve lubricant	0.002‡
HTV release	19.8
Total	19.802

†"Essentially no pressure" as reported in Sandia Report SAND91-2780 [9].
‡Fel-Pro manufacturer data at 191°C, see Appendix 4.

HTV release pressure was determined given the 8425 in-lb maximum PV energy at 71°C reported in Table 1, gross H1616 vessel volume of approximately .65 ft^3 (1123 in^3) [14] and HTV shape volume of 166.2 in^3 based on its 4.6 in. diameter and 10.0 in. height. With a net expansion volume of (1123 - 166.2) = 956.8 in^3, the released pressure becomes 8.81 psig (23.51 psia) at 71°C. At 232°C, this pressure is 34.5 psia.

Fel-Pro N-5000 offgassing is reported at 191°C but due to the small amount of material used is not expected to increase when at 232°C such that the nominal 19.8 psi total pressure increase, reported in Table 4, will result in a containment vessel pressure that approaches the 177 psig allowable.

4.1.1.5 SS393217 §3.3, Free Drop This condition requires that the HTV contain tritium during and after a 4 foot drop onto an essentially unyielding horizontal surface in the orientation likely to cause greatest damage. The HTV was shown to satisfy the free drop condition by testing without the H1616 packaging. These tests were more severe than a 4 foot drop of the HTV within the H1616 packaging and better approximate the conditions anticipated in a possible facility drop. The tests demonstrated that the HTV leak rate remained less than 1×10^{-7} cc/s helium following each drop, and that the valves, fittings, and tubing remained operable.

From Table 2, the free drop load conditions 2a and 2b are the maximum positive differential pressure conditions at -40°C and 71°C, with atmospheric external pressure. Actual free drop tests were performed at ambient temperature with no internal pressurization. Ambient temperature was chosen because the yield and ultimate strengths and elastic moduli of the HTV materials vary little over the -40°C to 71°C temperature range, as shown in Table 5. Facility drops would likely occur at room temperatures (25°C). Given that the 201 psig maximum transport pressure causes only 9.4 pounds axial force in the HTV external tubing and that the HTV body is designed for a 945 psig facility pressure, testing with internal pressurization was determined to be unnecessary.

Type 304L stainless steel, used for the prototype handle material, performed adequately during testing. To further increase handle strength, the final HTV design specifies use of Type 304 or Type 316, which are higher strength materials.

Table 5. Material Properties over Normal Temperature Range

Material[†]	Yield Strength at 71°C and ≤38°C, Δ%	Ultimate Strength at 71°C and ≤38°C, Δ%	Elastic Modulus at 71°C and -40°C, Δ%
347H SS	28.5 / 30.0 kpsi 5%	73.1 / 75.0 kpsi 3%	27.8 / 28.8 Mpsi 3%
316L SS	22.7 / 25.0 kpsi 9%	68.7 / 70.0 kpsi 2%	27.8 / 28.8 Mpsi 3%
316 SS	27.5 / 30.0 kpsi 8%	75.0 / 75.0 kpsi 0%	27.8 / 28.8 Mpsi 3%
304L SS	22.8 / 25.0 kpsi 9%	67.7 / 70.0 kpsi 3%	27.8 / 28.8 Mpsi 3%
304 SS	25.6 / 30.0 kpsi 15%	72.6 / 75.0 kpsi 3%	27.8 / 28.8 Mpsi 3%

[†]Data taken from ASME B&PVC Section III, Division 1, Appendices, 1991 Addenda

Table 6. Drop Testing Summary

Orientation	Justification	Leak Rate After Drop	Damage
(Pre-test verification[†])	Initial base line value	$< 1.2 \times 10^{-9}$ cm^3/sec	Initial condition
Center of Gravity over corner, impacting handle	Test valve and fitting protection	$< 9.2 \times 10^{-10}$ cm^3/sec	Handle deformation, exposed valve body corner
Side, impacting body and exposed valve	Test valve jarring	$< 9.0 \times 10^{-10}$ cm^3/sec	Skirt deformation
Inverted axial	Test handle buckling, impart high general shock	$< 7.9 \times 10^{-10}$ cm^3/sec	Additional handle deformation
Upright axial	Test expected facility drop orientation, impart high general shock	$< 8.0 \times 10^{-10}$ cm^3/sec	Slight skirt deformation
(Post-test verification[†])	Final base line value	$< 8.3 \times 10^{-10}$ cm^3/sec	Final condition

[†]Tested at 195 psig helium, all others at 0 psig helium.

The drop test report is included in Appendix 3. One HTV prototype was subjected to four drops with cumulative damages. Steel shot was used instead of uranium. The drops were done in the order of anticipated severity starting with the most severe. The test vessel was back-filled with an atmosphere of helium. The target was a 6.25 inch thick by approximately 5 foot square steel armor plate anchored in a 30 inch thick reinforced concrete slab and weighing approximately 15,600 pounds. This impact surface has been used for a number of years for drop testing of nuclear packages. "The target satisfied International Atomic Energy Agency recommendations [10]. Test results are summarized in Table 6.

Tested drop orientations included a center of gravity over edge orientation impacting on the handle side. This test verified that the handle side would bend like a hinged plate and expose the valve body corner. An alternate, untested center of gravity over edge orientation was that impacting the .5 inch wide lifting portion of the handle. This alternate orientation was judged less critical than the tested orientation because the expected behavior was that .5 inch strip would be bent inward toward the adjacent fitting and downward toward the vessel body, likely exposing the fitting but not the adjacent valve handle or body. Fittings are not part of the transport containment boundary.

4.1.1.6 SS393217 §3.4, Heat This condition requires that the HTV contain tritium at a maximum temperature of 71°C. The analysis below demonstrates that the HTV satisfies the heat condition.

Table 7 shows that a 71°C uniform temperature imparts little differential thermal expansion. A 71°C temperature will have no other detrimental effects on the 300-series austenitic stainless steel HTV construction. The manufacturer rates the valve for 315°C.

Table 7. Differential Thermal Expansion at 71°C

Material†	Mean‡ Coefficient of Thermal Expansion (in/in/°F)	Maximum Differential Thermal Expansion (%, comparison basis)
347H SS	8.78×10^{-6}	1.4 (316/316L)
316 & 316L SS	8.66×10^{-6}	1.4 (347H)
304 & 304L SS	8.69×10^{-6}	1.0 (347H)

†Data taken from ASME B&PVC Section III, Division 1, Appendices, 1991 Addenda
‡Mean coefficient of thermal expansion going from 21°C (70°F) to 71°C (160°F)

Heat condition 3a (Table 2) results in a maximum positive differential pressure of 198.5 psi, which occurs with a fully loaded HTV and the H1616 at minimum internal pressure. A positive differential pressure occurs when the internal pressure of the HTV is greater than the external pressure. Heat condition 3a is less severe than the reduced external pressure condition 7b (Table 2) because condition 7b results in a greater maximum positive differential pressure of 215.1 psia at the same temperature of 71°C. Heat condition 3b results in a maximum negative differential pressure of -22.7 psi, which occurs with an evacuated HTV and the H1616 at maximum internal pressure. A negative differential pressure occurs when the internal pressure of the HTV is less than the external pressure. Heat condition 3b is a limiting load condition because it is at the maximum negative differential pressure and at the maximum temperature, at which the austenitic stainless steel HTV construction has lower strength. The HTV structural assessment at this condition is reported in 4.1.2.

4.1.1.7 SS393217 §3.5, Cold This condition requires that the HTV contain tritium at temperatures down to -40°C. The analysis below demonstrates that the HTV satisfies the cold conditions. Evaluation of valve stem stresses is discussed in 4.1.2.3.

The 300-series austenitic stainless steel HTV construction retains structural integrity, including ductility, at -40°C. Assuming linear proportionality, the 1.4 % maximum difference in the mean coefficient of thermal expansion when going from 21°C to 71°C, Table 7, corresponds to a 1.7 % maximum difference in the mean coefficient of thermal expansion when going from 21°C to -40°C. The manufacturer rates the valve for -62°C.

Cold condition 4a (Table 2) results in a maximum positive differential pressure of 129.1 psi, which occurs with a fully loaded HTV and minimum H1616 pressure. Heat from the 5.83 watts power is neglected. Cold condition 4a is less severe than the reduced external pressure condition 7a. Cold condition 4b results in a maximum negative differential pressure of -22.7 psi, which occurs with an evacuated HTV and maximum H1616 pressure. Cold condition 4b, while at the same maximum negative differential pressure as heat condition 3b, is less severe because the austenitic stainless steel strengths are greater at lower temperatures.

4.1.1.8 SS393217 §3.6, Vibration, and §3.7, Shock This condition requires that the HTV contain tritium when subjected to the appropriate vibration and shock environments described in SAND91-2204 [8]. The HTV is shown to satisfy these conditions by testing. The HTV had no detectable leak before and after the shock and vibration testing, as measured to a sensitivity of 2.5×10^{-9} std cm^3/sec helium.

Typically the HTV will experience a one-way transport sequence as it moves between facilities. The scenario in Table 8a represents the maximum number of activities and durations expected for HTV transport.

Testing incorporated the limiting transport scenario as shown in Table 8b. Testing is described in the vibration and shock test report, included as Appendix 3. By using the H1616 as a containment vessel during shock and vibration testing, the HTV leak rate was shown to remain acceptable during these conditions.

The temperature and pressures for vibration condition 5a and shock condition 6a are equivalent to the temperature and pressures for cold condition 4a. Material effects at -40°C are addressed in 4.1.1.7. The temperature and pressures for vibration condition 5b and shock condition 6b are equivalent to the temperature and pressures for heat condition 3a. Material effects due to 71°C heat are addressed in 4.1.1.6. Testing was done at room temperature. As discussed for the drop test, ambient temperature was chosen because the yield and ultimate strengths and elastic moduli of the HTV materials vary little over the -40°C to 71°C temperature range. Testing was done with a 203 psig fill, and with 511.0 grams steel shot instead of uranium. Pressurization was included because it could impart a significant load to the valves given the repetitive, extended duration of the testing.

Table 8. Transport Scenario

Table 8a. Limiting Actual Transport Scenario

Activity	Transport Environment	Duration
Transfer	From facility to truck	not applicable
Movement	Truck transport	8 hours
Transfer	From truck to truck	not applicable
Movement	Truck transport	1 hour
Transfer	From truck to aircraft	not applicable
Movement	Aircraft flight	3 hours
Movement	Aircraft flight	3 hours
Movement	Aircraft flight	3 hours
Movement	Aircraft flight	8 hours
Transfer	From aircraft to ground, depalletize	not applicable
Transfer	From ground to aircraft	not applicable
Movement	Aircraft flight	3 hours
Transfer	From aircraft to truck	not applicable
Movement	Truck transport	45 minutes
Transfer	From truck to facility	not applicable

Transport scenario totals:

Transfers	7
Take off/landings	5
Truck movement	9 hours 45 minutes
Air movement	20 hours

Table 8b. Tested Transport Scenario

Transport Environment	Test Duration
Forklift Handling Shock	16 shocks
Road Transport	9.75 hours
Aircraft Cruise	20.0 hours
Aircraft Takeoff/Landing	5 sequences at 5 minutes each

4.1.1.9 SS393217 §3.8, Reduced External Pressure This condition requires that the HTV contain tritium when subjected to a 0.1 psia external pressure. This condition assumes that the H1616 is stationary in a facility while the H1616 is being evacuated prior to back filling. The HTV is qualified for the reduced external pressure condition by analysis as addressed below.

Reduced external pressure condition 7a results in a maximum positive differential pressure of 145.7 psi at -40°C (Table 2). This assumes a full tritium content with heat from the 5.83 watts power neglected. Reduced external pressure condition 7b results in a maximum positive differential pressure of 215.1 psi at 71°C (Table 2), which occurs with the HTV fully loaded. Reduced external pressure condition 7a is less severe than reduced external pressure condition 7b because the 300-series austenitic stainless steel is stronger at the -40°C than at 71°C. The pressure differential is also greater at 71°C. Reduced external pressure condition 7b is a limiting load condition because it results in the largest positive differential pressure at the maximum temperature of 71°C for the HTV. The HTV structural assessment for this condition is reported in 4.1.2.

4.1.1.10 SS393217 §3.9, Increased External Pressure This condition requires that the HTV contain tritium when subjected to an 22.7 psia external pressure. This condition assumes that an evacuated HTV is in transport within the H1616, which in turn has the maximum allowed back fill pressure. The HTV experiences the same pressure differential of -22.7 psi in both increased external pressure conditions. The HTV is qualified for the increased external pressure condition by analysis as addressed below.

Increased external pressure condition 8a is equivalent to cold condition 4a and is not a design limiting condition. Increased external pressure condition 8b has the same maximum negative differential pressure as condition 8a but is at the maximum temperature of 71°C and, therefore is more severe because the austenitic stainless steel construction is weaker at the higher temperature.

Increased external pressure condition 8b is equivalent to heat condition 3b (see Table 2) and is likewise a design limiting condition. The HTV structural assessment for this condition is reported in 4.1.2.

4.1.1.11 SS393217 §3.10, Acceptance Criteria This requirement establishes that the HTV shall contain tritium to a leakage rate of less than 1.26×10^{-7} std. cm^3/sec tritium during and following exposure to the preceding requirements of SS393217 sections 3.3 through 3.9. Actual HTV leakage will be less than 1.26×10^{-7} std. cm^3/sec tritium.

Leakage from the HTV may be bulk leakage or permeation. Bulk leakage, which results from leak paths in the containment boundary, is determined by leak testing. To provide a readily verifiable HTV leakage criteria, the HTV acceptance criteria is established as less than 1×10^{-7} cm^3/sec helium-4 at 25°C and 14.7 psi differential. Permeation leakage, which results from tritium diffusion through the containment boundary and subsequent offgassing from the surface, is controlled by operating limits. The acceptance criterion correlates to a maximum HTV bulk leakage of 2.299×10^{-13} std. cm^3/sec tritium, which is insignificant compared to the SS393217 criteria. Allowance for permeation leakage is then essentially the SS393217 criteria of less than 1.26×10^{-7} std. cm^3/sec tritium. Full derivation is included in Appendix 3.

The analyses and tests assessed in 4.1.1.5 through 4.1.1.10 demonstrate that the HTV leak rate remains acceptable during and following exposure to the required conditions. Drop, shock, and vibration are conditions most detrimental to HTV containment. HTV qualification to these conditions was assessed by testing. Resulting leak rates satisfied the criteria. Valve degradation due to use cycles may also cause leakage. Testing reported in Appendix 3 indicate that the valves will satisfy the leakage criteria for at least 400 cycles. With an estimated 20 cycles per year bounding case, 400 cycles represents 20 years. Operational experience indicates that 20 years bounds anticipated HTV life. Temperatures ranging from -40°C to 71°C do not alter the HTV geometry or material integrity significantly and do not impair containment as documented in Appendix 3.7. Likewise, a range of differential pressures from -22.7 psi to 215.1 psi does not impair containment. The HTV is designed for facility conditions of 945 psig and -14.7 psig at 600°C.

Appendix 3 includes the permeation leakage analysis and results of permeation leak rate measurements. The analysis demonstrated that tritium permeation leakage is less than 1.26×10^{-7} cm^3/sec tritium for even HTV facility accident conditions. Each analysis started with a fully loaded HTV saturated with tritium at a defined elevated temperature. Corresponding tritium partial pressure was that of a closed vessel except for 2 cases typical of loading under reduced pressures. The HTV was then reduced to 71°C or 25°C and the permeation leakage determined. Results are summarized in Table 9. Measurements on a typical advanced-life HTV used within operating limits indicated a maximum permeation leak rate of 2.83×10^{-11} cm^3/sec tritium, which confirmed that the analyses were conservative.

Table 9. Permeation Leakage Rates

Initial Saturation Condition		Resulting Permeation Leakage	
Temperature (°C)	Pressure (psia)†	71°C (cm^3/sec tritium)	25°C (cm^3/sec tritium)
600	413.1	4.68×10^{-8}	2.69×10^{-8}
500	104.4	2.06×10^{-8}	1.18×10^{-9}
400	17.6	7.09×10^{-9}	4.08×10^{-10}
400	0.39‡	1.05×10^{-9}	6.05×10^{-11}
400	0.19‡	7.47×10^{-10}	4.29×10^{-11}

†Tritium partial pressure.

‡Partial vacuum typical of operational use, all others at equilibrium for fully loaded vessel.

Since permeation resulting from use above 500°C may cause the total leakage rate to exceed the allowable, users must verify by test or other defendable means that for an HTV used at temperatures above 500°C, the total tritium release is less than 1.26×10^{-7} cm^3/sec prior to shipment. Note that use above 500°C exceeds the normal 450°C unloading temperature and is considered abnormal, as addressed in 5.0.

4.1.2 Assessment to Transport Structural Requirement

This section demonstrates that the HTV satisfies the normal condition design requirements set forth in US NRC Regulatory Guide 7.6 (RG 7.6) by addressing the limiting transport load conditions from 4.1.1, shown in Table 10. The normal condition design requirements for the vessel are set forth in RG 7.6 Regulatory Positions C.1 through C.4, and the structural evaluation is presented in 4.1.2.1 and 4.1.2.2. The valve stem structural assessment is in 4.1.2.3.

Table 10. Limiting Transport Load Conditions

Condition	Loading		
	Vessel Temperature	Internal Pressure	External Pressure
Heat (condition 3b)	71°C	0.0 psia	22.7 psia
Reduced external pressure (condition 7b)	71°C	215.2 psia	0.1 psia
Cold (condition 4a)	-40°C	145.8 psia	16.7 psia

Heat condition 3b, which is equivalent to increased external pressure condition 8b, results in the maximum negative differential pressure. The 71°C maximum normal temperature is chosen because the 300-series austenitic stainless steel strength reduces with increasing temperature. Reduced external pressure condition 7b results in the maximum differential pressure, again at 71°C. Pressure derivations are included in Appendix 3.

Because the maximum differential pressure of 7b results in higher stresses than does the maximum negative differential pressure of 3b, only the stresses of condition 7b were originally assessed. A stress analysis of 3b was later performed and is included in Appendix 3. Results of this 3b analysis were reported only for maximum stresses, which for the HTV body occurred along the mid-span of the shell wall. Vibration loading does not occur with 3b. The structural assessment demonstrating that the HTV satisfies the Regulatory Guide 7.6 normal transport requirements given the maximum differential pressure is included in Appendix 3 and summarized in the following report sections.

Cold conditions 4a and 4b result in the maximum thermal change for an HTV initially at typical operating conditions. The temperature change and corresponding differential material contractions and resultant stresses are of interest in this condition, rather than the pressure load.

4.1.2.1 Regulatory Guide 7.6, Regulatory Position C.1 This regulatory position requires that material property values, design stress intensities (S_m), and design fatigue curves be taken from the applicable subsection of ASME Boiler and Pressure Vessel Code, Section III. ASME Code changes since publication of the Regulatory Guide now have the applicable data in the Code, Section III Appendices. The material properties in Table 11 were used in the analyses.

Table 11. Material Properties for Transport Structural Assessment

Material[†]	Design Stress Intensity, S_m(T•93°C)	Design Fatigue Stress Intensity
ASME SA-403 Type WPS347H	20.0 kpsi	28.2 kpsi (10^6 cycles)
ASME SA-479 Type 347H	20.0 kpsi	28.2 kpsi (10^6 cycles)
ASME SA-213 Type TP316L	16.7 kpsi	16.5 kpsi (10^{11} cycles)

[†]Data taken from ASME B&PVC Section III, Division 1, Appendices, 1991 Addenda

Table 12. Summary of Transport Condition Stress Assessment

Table 12a. Internal Pressure Condition 7b

Worst Location[†]	P_m / S_m, Safety Margin	P_m+P_b/ 1.5S_m, Safety Margin	S_{alt} / Allowable, Safety Margin	S_n/ 3S_m, Safety Margin
Vessel Body	2.2 / 20.0 kpsi 8.09	4.8 / 30.0 kpsi 4.25	2.7 / 28.2 kpsi 9.44	5.3 / 60.0 kpsi 10.3
External Tube	1.50 / 16.7 kpsi 10.1	1.50 / 25.0 kpsi 16.7	1.04 / 16.0 kpsi 14.4	2.08 / 50.0 kpsi 23.0
Long Inner Tube[‡]	4.64 / 16.7 kpsi 2.60	4.64 / 25.0 kpsi 4.39	4.64 / 16.0 kpsi 2.45	9.28 / 50.0 kpsi 4.39
Short Inner Tube[‡]	1.17 / 16.7 kpsi 13.3	1.17 / 25.0 kpsi 20.4	1.17 16.0 kpsi 12.7	2.35 / 50.0 kpsi 20.3

[†]For more detailed information, see the assessment report in Appendix 3.
[‡]Although not containment, these are required to confine uranium hydride in facility use.

Table 12b. External Pressure Condition 3b

Worst Location[†]	P_m / S_m, Safety Margin	P_m+P_b/ 1.5S_m, Safety Margin
Vessel Mid-span	0.284 / 20.0 kpsi 69.4	0.580 / 30.0 kpsi 50.7
External Tube	0.173 / 16.7 kpsi 95.5	0.173 / 25.0 kpsi 143.5

[†]For more detailed information, see the assessment report in Appendix 3.

4.1.2.2 Regulatory Guide 7.6, Regulatory Positions C.2, C.3, and C.4 Each of these regulatory positions apply to normal conditions. Regulatory position C.2 requires that the primary membrane stress intensities, P_m, be less than the design stress intensities, S_m, and that the primary membrane plus primary bending stress intensities, P_m+P_b, be less than 1.5 S_m. Regulatory position C.3 requires that the alternating stress intensities, S_{alt}, be less than the design fatigue stress intensities. Regulatory position C.4 requires that the stress intensities associated with the range of primary plus secondary stresses, S_n, be less than 3S_m. HTV stress intensities and allowables resulting from the assessment are summarized in Table 12. In addition to the containment boundary, stresses for the inner tubes were assessed since, although not providing containment, their integrity is necessary to provide uranium retention in facility use.

All normal condition stresses are within the RG 7.6 allowables.

4.1.2.3 . Valve Structural Assessment The only part of the valve that sustains any significant stresses is the valve stem. These include a primary membrane stress from internal pressure and secondary stresses from 1), valve closure torque (torque load can not produce unrestrained yielding in the valve stem) and 2), differential thermal expansion within the H1616 under NCT. The chief function of the valve closure torque is to maintain sufficient load on the valve seat to satisfy the package containment requirement. Therefore, a conservative value of 2/3 yield stress was selected as the allowable design stress intensity (S_m) for this load condition. The allowable value of stress intensity for thermal stresses is $3S_m$. Stress from internal pressure is extremely small and neglected.

Valve stem material is ASTM A-479 Type 316 stainless steel specially procured by the valve manufacturer to have a minimum yield of 82,000 psi and a minimum tensile strength of 100,800 psi. Valve stem mechanical properties are reported in Appendix 3.7.

Analysis of the valve stem presented in Appendix 3.7 identified 22 in-lb. as the valve closure torque corresponding to the maximum allowable stress in the valve stem. Therefore, valve closure torque is limited to 20 ±1 in-lb. The effects of changes in valve temperature that could occur within the H1616 under NCT after torquing at ambient temperature (see Section 5.1.1) were also evaluated in Appendix 3.7. Thermal stress analysis showed a maximum effective valve torque reduction of 3 in-lb. for a minimum effective torque of 16 in-lb. The basis for HTV valve qualification given the SS393217 temperature requirements (-40°to 71°C) is that the requirements are well within the operating temperatures of the valve (-62°C to 315°C). Stem stresses produced by differential thermal expansion are secondary and an order of magnitude below the allowed $3S_m$. Valve stem stresses under NCT are all within the allowable limits judged applicable to the stem design.

4.1.3 Assessment to Leakage Rate Verification Requirement

This section explains the implementation of ANSI N14.5-87 section 6, "Containment system test requirements", for the HTV transport containment boundary. N14.5 provides requirements for seal verification prior to shipments and for periodic maintenance. Inherent with the N14.5 periodic verification requirement is a 1 year limit on the time an HTV could be loaded and subsequently transported. This is the basis for the 1 year maximum helium generation assumed in the pressure derivations of Appendix 3.

To establish a readily verified leakage criteria that satisfied the H1616 qualification requirement of less than 1.26×10^{-7} cm^3/sec tritium, the HTV leakage criteria is established at less than 1×10^{-7} cm^3/sec helium-4 at 25°C and a 14.7 psi pressure differential. The correlation equation is in Appendix 3. It also satisfies the N14.5 "leak tight" criteria for bulk leakage, which is the most stringent N14.5 leak rate criteria. Total leakage in transportation due to bulk leakage and permeation is assured to be less than 1.26×10^{-7} cm^3/sec tritium given prior facility use up to 500°C, as discussed in 4.1.1.11. Facility operating requirements limiting permeation are addressed in 5.0.

4.1.3.1 ANSI N14.5-87 Section 6.1, General This N14.5 section requires implementing ensuing ANSI N14.5-87 sections 6.2 through 6.5 and procedures complying with ANSI N14.5-87 section 7. ANSI N14.5-87 sections 6.2 through 6.5 are addressed below. Procedures complying with ANSI N14.5-87 section 7 are ensured by requiring that HTV leak test personnel be qualified per ASME Boiler and Pressure Vessel Code, Section III, Subsection NB.

4.1.3.2 ANSI N14.5-87 Section 6.2, Containment System Design Verification This N14.5 section requires that the containment claimed for the HTV design be verified as part of design development. This was done by performing the prototype testing in 4.1.1. The prototype leakage was less than 1×10^{-7} cm^3/sec helium following each test. Accident testing is not required for the HTV and was not performed.

4.1.3.3 ANSI N14.5-87 Section 6.3, Containment System Fabrication Verification This N14.5 section requires that containment be demonstrated for each HTV prior to first use and following modifications or repairs to the containment boundary. This is satisfied by requiring on the design drawing and 6.1.2 that a post-fabrication acceptance leak test be done to ensure each HTV accepted for service has leakage less than 1×10^{-7} cm^3/sec helium. No repairs or modifications of the HTV transport containment boundary are authorized; therefore, related containment verification is not applicable. Exchanging damaged fittings, discussed in 6.2.5, while not effecting the transport containment boundary, does require reverification of the facility containment boundary.

4.1.3.4 ANSI N14.5-87 Section 6.4, Containment System Periodic Verification This N14.5 section requires that for each new HTV, the containment be re-verified to less than 1×10^{-7} cm^3/sec helium after the first 3 uses or the first year service, whichever occurs first. Thereafter, prior to shipment, the containment of an HTV must have been verified within the prior year. This is satisfied by specifying this requirement in the operating requirements of 5.2.7 and maintenance requirement of 6.2.2.

4.1.3.5 ANSI N14.5-87 Section 6.4, Containment System Assembly Verification This N14.5 section requires that the assembly of an HTV for shipment be in accordance with written procedures and that the HTV containment be verified for proper assembly and function prior to shipment. The verification need only demonstrate that the HTV was properly assembled per the written procedures. Therefore, a test sensitivity of 1×10^{-3} cm^3/sec air is acceptable. This is ensured by specifying this requirement in the operating requirements of 5.2.7. Assembly verification tests will use the inert HTV back fill rather than air. Although the test is intended to verify that the valve is closed, the valve bellows is also tested.

4.1.4 Assessment to Transport Fabrication Requirements

This section demonstrates how the fabrication requirements of NUREG/CR-3019 and NUREG/CR-3854 were applied to the HTV. NUREG Category 1 containment-related criteria were justified because of the high curie-content payload possible with the HTV (174.6 kCi). The requirements provided in NUREG/CR-3019 Table 2 and NUREG/CR-3854 Table 4.1, included in Appendix 2, are summarized below in Table 13. ASME Boiler and Pressure Vessel Code, Section III, 1991 Addenda, is used.

Table 13. Summary of Transport Fabrication Requirements

Fabrication Feature	HTV Component Safety Function	
	Containment†	Other Safety
	Requirements	
Base Materials	NB-2000 NB-4100	Section VIII Division 1
Welding and Brazing Material	NB-2400	
Forming, Fitting and Aligning	NB-4200	
Qualification of Procedures and Personnel	NB-4300	
Welding	NB-4400	
Brazing	NB-4500	
Heat Treatment	NB-4600	
Examination	NB-5000	
Acceptance Testing	NB-6000	
Quality Assurance	Title 10, Code of Federal Regulations, Subpart H, Part 71	

†Citations from ASME Boiler and Pressure Vessel Code, Section III.

4.1.4.1 Base Materials, NB-2000 and NB-4100 All the containment boundary base material specifications are taken from Tables I-1.0 of the Appendices, ASME Code, Section III. Base materials are those listed in Table 11 and are identified, with qualification requirements, on the design drawings.

4.1.4.2 Welding and Brazing Materials, NB-2400 AWS (American Welding Society) welding and brazing materials as cited in ASME Code, Section II are specified to satisfy the ASME Code, Sections II and IX requirements referenced by NB-2400. These are identified on the design drawings. ER347 welding material is specified for the GTAW joining of Type 347H parts, while ER316L welding material is specified for the remaining welds. AWS BAu-4 high temperature braze material is specified for the inner tube-to-nozzle brazes.

4.1.4.3 Joint preparation and Forming, Fitting, and Aligning, NB-4200 NB-4200 requirements are largely superseded by the ASME Code, Section VIII, Division 1, lethal service requirements that all containment welds be full penetration. All containment welds are therefore designed for full penetration butt welds with associated joint preparation. This is shown on the design drawings.

ASME/ANSI B16.9 pipe cap tolerances [22] are specified rather than the less restrictive NB-4200 requirements. SRS Engineering Standard 15060-01-R Pipe Code P265 governs external tubing bends. Rather than citing NB-4233 for alignment, the HTV alignment is specified as such so that the finished HTV can slip-fit into a 4.600 inch diameter cylinder.

4.1.4.4 Qualification of Procedures and Personnel, NB-4300 The need for procedures and personnel to be qualified per ASME Code, Section IX is specified on design drawing notes.

4.1.4.5 Welding, NB-4400 All containment welds are designed as full penetration butt welds, as shown on the design drawings. Welding procedures and qualifications are specified on the design drawings to satisfy ASME Code, Section IX.

The girth weld defect found in the drop test prototype reported in Appendix 3.5 is not possible for the actual HTV. The actual HTV weld design is a full penetration weld rather than the makeshift partial penetration lap weld design in the prototype. Also, the actual HTV weld is subject to full radiographic examination unlike the prototype weld, which was not volumetrically examined.

4.1.4.6 Brazing, NB-4500 The inner tube-to-nozzle brazed joints are not containment-related. The AWS BAu-4 braze material has a solidus of 949°C, which satisfies the NB-4512(a) thermal requirements for service at the maximum HTV design temperature of 600°C. Brazing procedures and qualifications are specified on the design drawings to satisfy ASME Code, Section IX.

4.1.4.7 Heat treatment, NB-4600 Post weld heat treatment is not necessary for the Types 347H and ER347 materials which experience the high temperature service. Niobium-stabilization of these materials precludes corrosion due to carbide precipitation. The base materials do require solution annealing per Table UHA-23, ASME Code Section VIII. This is specified on the design drawings.

4.1.4.8 Examination, NB-5000 Volumetric and topical non-destructive examinations (NDE) are specified for all containment welds. All welds are specified to satisfy visual inspection, with specific citation for the fillet welds and braze. The handle welds are specified to be topically examined as well due to the need for structural integrity. NDE call outs and notes are included on the engineering drawings. Qualifications of NDE personnel are specified on the design drawings to satisfy NB-5500.

4.1.4.9 Acceptance testing, NB-6000 A pneumatic proof test and leak test, satisfying the intent of NB-6300, is specified on the design drawings. Qualification requirements for personnel performing acceptance proof and leak testing is the same as for other non-destructive examinations.

4.1.4.10 Quality Assurance HTV quality assurance requirements are addressed in 7.0.

4.2 Assessment to Facility Requirements

This section demonstrates that the HTV satisfies facility requirements. The primary facility requirement is that the HTV be an unstamped vessel designed and constructed per ASME Boiler and Pressure Code, Section VIII, Division 1, including the UW-2 lethal service requirements.

4.2.1 Facility Load Conditions

Table 14 shows the significant facility load conditions and assigned load values for which the HTV was evaluated. The assigned values are primarily imposed by the Savannah River Site user, but are such that they would be satisfactory for other users.

The HTV facility design temperature is 600°C at the HTV base. By allowing for the thermal cooling gradient existing when the HTV is heated, the design temperature at the nozzle base is established as 500°C. These conditions were verified by thermal tests reported in 4.2.2.1.

Table 14. Facility Load Conditions

Condition	Loading		
	Vessel Temperature (°C)	Internal Pressure (psia)	External Pressure (psia)
Desorb Closed HTV	600	959.7	14.7
Evacuated HTV	600	0.0	14.7

The desorbed closed HTV condition accounts for heating a vessel to the design temperature with the valves closed. This would result in the highest pressure condition. The evacuated HTV condition represents the normal evacuation gas removal process but at the design temperature.

4.2.2 Assessment to Facility Structural and Fabrication Requirements

This section demonstrates that the HTV satisfies structural and fabrication requirements set forth in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, 1991 Addenda, that have not already been addressed as transport requirements in 4.1. Although small size precludes the HTV from the stated Code scope, the Code is applicable for design and fabrication requirements. This assessment does not demonstrate that the HTV satisfies all "U" Code stamp requirements.

Service constraints preclude providing a pressure relief device as otherwise required by ASME Code, paragraph UG-125. To ensure over pressure safety, the HTV design provides Code structural protection when heated to 600°C while closed. Normal facility usage would have at least one valve open and a 450°C operating temperature limit.

Facility operations, particularly unloading, cause tritium permeation into the HTV body walls. Subsequent tritium decay results in helium-3 formation in the body wall material. The tritium and helium degradation to the material does limit the HTV service life. Service life is defined in 5.1.

4.2.2.1 UG-20, Design Temperature The vessel maximum design temperature is 600°C. This temperature was chosen because it provides a generous safety margin from the 450°C normal operating limit and is significantly below the 700°C iron-uranium eutectic. Operating temperatures above 500°C are considered abnormal.

The design condition assumes that both valves are left shut when the vessel base is heated to 600°C. Accounting for the anticipated cooling gradient, the facility design condition allows for vessel designs such that the nozzle base is limited to 500°C. This allowance is incorporated into materials selections. This ensured that the 315°C valve rating was not exceeded and the Type 316L tube operates below the 454°C ASME material application limit and the 315°C limit imposed by Pipe Code P265.

Tests were performed to verify that the allowed thermal gradient is conservative. Two conditions were tested. The first demonstrated the thermal profile with the base at 600°C, while the second demonstrated the thermal profile with the nozzle base at 500°C. Table 15 presents the results. In each test, an HTV was heated in an open top, 5 inch diameter furnace, with the vessel body top surface covered by 0.25 inch insulation. Test results, summarized in Table 15, show that the 500°C nozzle base condition requires a base temperature far exceeding 600°C. Alternate heating sources may alter the profile, but the 500°C nozzle base limit would not be exceeded. The results show that under these conditions the valve rating and material limits are not exceeded. The thermal test report is included in Appendix 3.

4.2.2.2 UG-21, Design Pressure The maximum design pressure is 945 psig. This pressure is governed by the 600°C design temperature, the limited volume, the maximum tritium load, and the 1 year maximum use period after sealing. The 1000 psig valve rating is not exceeded. The minimum design pressure is full vacuum. The vessel is evacuated while at temperature to pull off generated gas. The pressure derivations are included in Appendix 3.

4.2.2.3 UG-23, Maximum Allowable Stress Values The nozzle construction is not addressed by general Code construction formulas. Therefore, an analysis of the HTV body was performed to verify that the nozzle satisfies the UG-23(c) primary membrane and primary membrane plus primary bending stress requirements. The analysis was done for the 945 psig internal pressure condition with the entire vessel assumed to be at 600°C. The analysis was done at 600°C rather than allowing a cooling gradient because any thermal differential stresses would be secondary stresses and not pertinent to Code, Section VIII Division 1 analyses, and because the material properties are most diminished at 600°C. Because vacuum conditions produce lesser stresses than the 945 psig condition, the analysis did not consider vacuum conditions. Also analyzed were the HTV body locations already addressed by general design rules. Vessel design thicknesses were used for the assessment. Results are summarized in Table 16, with the complete structural assessment in Appendix 3.

All stresses were below the maximum allowable stress.

Table 15. Thermal Profile Verification

HTV Location	Allowable Temperature (as applicable) (°C)	Heating Condition: Temperature Base at 600°C (°C)	Heating Condition: Temperature Nozzle at 500°C† (°C)
Vessel base	600	601	734
Vessel girth weld	‡	564	696
Nozzle base	500	395	502
Handle base	‡	447	565
Handle top	‡	81	104
Valve body	315	105	130
Tube at nozzle	315	216	268
Inlet tube at valve	315	104	126
Outlet tube at valve	315	122	154

†Excessive temperatures result from test condition.

‡Not defined.

Table 16. Summary of Facility Structural Analysis

Vessel Location†	Primary Membrane Stress (Assessed, Safety Margin)		Primary Membrane + Bending (Assessed, Safety Margin)	
Nozzle, at 1" Section	4.4 kpsi	1.9	8.4 kpsi	1.3
Nozzle, at Head	9.2 kpsi	.38	12.3 kpsi	.54
Head Knuckle	4.1 kpsi	2.1	16.6 kpsi	.14
Vessel Wall	10.6 kpsi	.20	10.6 kpsi	.79
Bottom Head Center	9.2 kpsi	.38	13.9 kpsi	.37
Allowable Stress‡	12.7 kpsi		19.0 kpsi	

†For more detailed information, see analysis.

‡Allowable stress at 600°C for ASME SA-403 Type WPS347H, SA-479 Type 347H.

4.2.2.4 UG-27, Thickness of Shells Under Internal Pressure This condition was assessed for the 600°C, 945 psig desorb closed condition. Vessel materials were assumed to be uniformly at 600°C. Table 17 compares the Code required thicknesses with vessel thicknesses. Calculations are included in Appendix 3.

Table 17. Wall Thickness for Internal Pressure

HTV Section	Minimum Thickness Required (inch)	Minimum Thickness Provided (inch)	Safety Margin
Vessel body	0.164	0.207†	.26‡
Nozzle	0.047	0.158	2.4
Tube	0.014	0.065	3.6

†Minimum per ASME/ANSI B16.9-86.

‡Based on the stresses presented in 4.2.2.3, safety margin is .20.

4.2.2.5 UG-28, Thickness of Shells and Tubes under External Pressure This condition was assessed for the 600°C, evacuated condition. Vessel materials were assumed to be uniformly at 600°C. Assessment was limited to the vessel body, which was shown to be the stress limiting feature when internally pressurized. Table 18 presents the Code required thicknesses given the HTV pressure and the allowed external pressure given the HTV thickness. Calculations are included in Appendix 3.

Table 18. Wall Thickness for External Pressure

Limiting Parameter	Limiting Value	Minimum Provided	Safety Margin
Minimum wall thickness	0.005 inch	0.207 inch†	40.
Maximum external pressure	587 psig	14.7 psig	39.

†Minimum per ASME/ANSI B16.9-86.

4.2.2.6 UG-32, Formed Heads and Sections, Pressure on Concave Side This condition was assessed for the 600°C, 945 psig desorb closed condition. Vessel materials were assumed to be uniformly at 600°C. The ASME/ANSI B16.9 pipe cap head satisfies the Code ellipsoidal geometry. Table 19 compares the Code required thickness with vessel thickness. Calculations are included in Appendix 3.

4.2.2.7 UG-33, Formed Heads, Pressure on Convex Side This condition was assessed for the 600°C, evacuated condition. Vessel materials were assumed to be uniformly at 600°C. The ASME/ANSI B16.9 pipe cap head satisfies the Code ellipsoidal geometry. Table 20 presents the Code required thicknesses given the HTV pressure and the allowed external pressure given the HTV thickness. Calculations are included in Appendix 3.

Table 19. Head Thickness for Internal Pressure

HTV Section	Limiting Value	Minimum Provided	Safety Margin
Vessel head	0.158 inch	0.207 inch†	.31

†Minimum per ASME/ANSI B16.9-86.

Table 20. Head Thickness for External Pressure

Limiting Parameter	Limiting Value	Minimum Provided	Safety Margin
Minimum wall thickness	0.0064 inch	0.207 inch†	31.
Maximum external pressure	475 psig	14.7 psig	31.

†Minimum per ASME/ANSI B16.9-86.

4.2.2.8 UW-2, Service Requirements In accord with the UW-2 lethal service requirements, all pressure-retaining welds are specified as full penetration welds through the entire wall thickness. Pressure retaining, or facility containment, welds are those joining the pipe cap body halves, the nozzle to the top pipe cap, the tubes to the nozzle, valves and fittings.

Liquid penetrant topical examination and 100% radiographic volumetric examination are specified for all containment welds and bent tubing.

4.2.2.9 UW-12, Joint Efficiencies All pressure-retaining welds are designed for 100% efficiency. This is valid because all pressure-retaining welds are specified as full penetration with non-destructive examination specified to be topical and 100% volumetric.

4.2.2.10 UW-16, Minimum Requirements for Attachment Welds at Openings The nozzle is designed per Figure UW-16.1 Sketch (f-4). The strength of the attachment was determined to be adequate based on the analysis results provided in 4.2.2.3.

4.2.2.11 UHA-6, Conditions of Service This Code section requires that the materials be suitable for the intended service considering both corrosion resistance and mechanical properties over the service life.

All high-temperature pressure-retaining materials are specified to be Type 347H austenitic stainless steel. High-temperature strength required the "H" grade. Niobium stabilization ensures Type 347H materials retain corrosion resistance without need for post-weld heat treatment. Tritium compatibility of Type 347 is acceptable, based on the material report provided in Appendix 3 which demonstrates hydrogen compatibility similar to Type 304L. Type 347H is judged to have a similar compatibility with hydrogen and thus tritium. Type 347 carbon content is limited to no more than .08 percent, while that of Type 347H is limited to between .04 and .10

percent. It is judged that this slightly higher carbon allowance will not appreciably effect tritium compatibility.

The balance of the HTV pressure-retaining materials are specified as Type 316L or Type 316 austenitic stainless steels. Type 316L materials are used at locations operating well within the 454°C Code operating limit and the 315°C P265 Pipe Code limit. Type 316 materials are used for the valves and fittings and operate at temperatures below those requiring post-weld heat treatment. Both Types 316L and 316 are well-proven tritium service materials.

In general, tritium will permeate boundary materials as a function of material properties, temperature, and tritium pressure. Tritium present in materials decays to helium-3. Tritium diffuses monoatomically into austenitic stainless steels. The helium-3 decay product is not soluble in the steel and, if mobilized by elevated temperatures, will congregate together. A series of tensile tests of high-energy-rate-formed 316L stainless steel provided comparison data for the effects of internal hydrogen and of internal tritium with subsequent helium decay product [23]. Results showed that hydrogen only slightly effected mechanical properties - ultimate tensile strength was slightly reduced at room temperature and yield strength was slightly increased. Results showed that helium embrittlement, or reduction in ductility, becomes severe above 500°C, but that material retains ductility when cooled to room temperature. Strengths remained similar to normal and hydrogen-charged material, while yield strength was slightly increased at 600°C.

Facility operations, particularly unloading, cause significant tritium permeation into the HTV body walls. Based on existing data, the tritium and helium degradation to the material does limit the HTV service life. Service life is defined in 5.1.

<u>4.2.2.12 UHA-21, Welded Joints</u> By having all pressure-retaining welds specified as full-penetration, the HTV satisfies this Code requirement for welded joints.

<u>4.2.2.13 UHA-23, Maximum Allowable Stress Values</u> The appropriate maximum allowable stress values from the ASME Code, Table UHA-23 were used for the facility condition assessments.

<u>4.2.2.14 UHA-32, Requirements for Postweld Heat Treatment</u> Type 347H austenitic stainless steel is a niobium (columbium) stabilized high temperature material. It maintains corrosion and strength properties without post-weld solution heat treatment. Per note 17 of ASME Code Table UHA-23, heat treatment is specified for the Type 347H base materials prior to fabrication.

<u>4.2.2.15 UHA-51, Impact Tests</u> Because the HTV design satisfies the structural condition of UHA-51 paragraph (b), impact tests are not required for the HTV containment materials. UHA-51(b) requires that the design satisfy Code structural requirements at the most severe pressure and temperature condition above -29°C and, with pressure multiplied by 2.5, below -29°C.

The most severe elevated temperature condition, 945 psig at 600°C, is shown in 4.2.2.3 through 4.2.2.7 to satisfy structural requirements. The low temperature condition of 134 psig at -40°C is due to transport conditions. Because austenitic stainless steels increase in strength at lower temperatures and 945 psig is satisfactory at 600°C, 2.5 × 134 psig, or 335 psig, would be satisfactory at -40°C.

4.2.3 Assessment to Facility Piping Requirements

This section demonstrates that attachments to the HTV body satisfies the SRS Engineering Standard 15060-01-R Pipe Code P265 and associated exceptions. P265 requirements are summarized and addressed in the following sections.

4.2.3.1 Temperature Limit The HTV satisfies the P265 temperature limit. P265 imposes a 315°C temperature limit on HTV external tubing, valves, and fittings. The maximum temperature experienced by any of these items is 268°C, as shown in Table 15. This temperature occurs at the tubing-to-nozzle connection when the vessel top is at the 500°C design limit.

4.2.3.2 Tube Material The HTV tube materials are ASME specification SA213 Type 316L, 3/8 inch outside diameter by 0.065 inch wall tube. The geometry is as allowed by the exceptions to P265. The ASME specification is used rather than the ASTM A269 specification, which is not listed in the Code. The minimum specified tube cold bend radius is the minimum limit of 15/16 inch.

4.2.3.3 Valves Two Nupro® SS-4HS-TW valves are specified, as is allowed by the P265 exceptions. The valve-to-tube weld connections have the same 0.375 inch outside diameters and differ by 0.005 inch on the inside diameter.

4.2.3.4 Fittings The HTV uses Cajon® VCR® fittings. Butt-welded socket weld glands are specified since they are more suitable than automatic tube weld glands for the HTV application. The resulting diametral weld mismatch to the tube is 0.025 inch outside and 0.005 inch inside using the butt-welded socket weld glands, compared to no outer mismatch and a 0.055 inch inside mismatch using automatic tube weld glands. Socket weld glands conserve space by allowing use of 4-VCR nuts rather than the 8-VCR nuts needed with automatic tube weld glands. The thicker minimum wall of the socket weld glands, 0.050 inch compared with 0.038 inch for the automatic tube weld glands, is desirable for strength.

4.2.3.5 Welding All tube welds are specified to be per the gas tungsten arc (GTAW) process using welders and procedures qualified to ASME Boiler and Pressure Vessel Code, Section IX requirements. Non-destructive examination of all tube welds is specified to be liquid penetrant surface examination and radiographic volumetric examination.

4.2.3.6 Specifications Invoked by P265 P265 invoked additional Savannah River Site specifications to minimize stress corrosion cracking and to ensure suitable fabrication, cleaning, and acceptance testing. The corrosion requirements are satisfied by requiring that during fabrication and maintenance, materials directly contacting the HTV have a chloride content of less than 250 parts per million (ppm). Fabrication requirements are essentially satisfied by prohibiting steel stamping and other mechanical marring of the containment boundary parts and by having full radiography of containment welds. Cleaning requirements are addressed by citing pertinent paragraphs of ASTM A380 [11]. Proof and leakage acceptance tests satisfying the acceptance test requirements are specified. The design drawings note the above requirements.

4.2.4 Assessment of Closure Device

The aluminum valve handles are machined to accept standard 3/4 inch hex sockets. Torque wrenches with socket drives can readily be used to close the valve handles. Section 5.2.2.1 specifies mandatory torque requirements.

4.2.5 Assessment of Lifting Device

A handle is provided for lifting and protection of the valves and fittings. The handle provides adequate clearance for gloved hand access for both lifting the HTV and functioning the fittings and valves.

4.2.6 Assessment to Geometric Constraints

HTV dimensional limits are that the HTV slip fit into a 4.600 inch diameter cylinder and be at most 10.0 inches high. The HTV therefore meets the geometric constraints of the 4.81 inch diameter calorimeter well and the approximately 10.5 inch H1616 cavity depth.

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5.0 TRANSPORT AND FACILITY OPERATING REQUIREMENTS

This section specifies the operating requirements and provides guidance to be incorporated by users' written procedures. Operating and maintenance requirements incorporate information provided by the cognizant SRS hydride application technical function and included in report Appendix 4. Operating activities shall satisfy requirements of 7.0.

5.1 Operating Limits and Estimated Service Life

Operating parameters and limits are required to ensure helium concentration in the body wall remain within safe limits. Concentration of helium-3, a tritium decay product, is dependent on the concentration of tritium present in the wall material. Tritium concentration is dependent on the combination of heating temperature and tritium pressure.

HTV service life is governed by helium build up in the body wall. To initiate helium formation, tritium must be charged into the wall. This occurs during the high-temperature unloading. Tritium saturation is reached after one or two unloadings; therefore helium build up is assumed to begin after the first unloading. The tritium concentration and subsequent helium concentration in the wall are functions of the unloading temperature and pressure. Studies summarized in Appendix 3 showed that the time in which helium builds up to a safe limit was little effected by subsequent cycling at lesser or equal temperatures and pressures. Also important are temperature-dependent helium embrittlement effects. A study showed that helium-charged austenitic stainless steels become significantly embrittled above 500°C [23].

Tests documented in Appendix 3 demonstrated that the valves should maintain adequate sealing through at least 400 cycles. This does not establish a service life condition but indicates the expected service. Sustained performance is governed by periodic leak tests.

5.1.1 Temperature Limits

The maximum normal HTV operating temperature is 450°C. The maximum temperature which the HTV can be subjected to without impacting the estimated service life is 500°C. Thus, heating to at most 450°C allows a 50°C margin until 500°C is reached. Routine use above 450°C is not authorized. An excursion into the buffer margin does not impact the estimated service life, but does require corrective action on part of the user. An excursion above 500°C may result in tritium and subsequent helium concentrations exceeding a safe limit and requires that the HTV be removed from service.

HTV valves shall be at ambient temperature before closing and torquing. The range of temperatures evaluated in Appendix 3.7 as ambient extend from 10°C to 50°C.

5.1.2 Pressure Limits

Tritium pressure during unloading limits service life. 2.9 psia tritium is the limit above which tritium and subsequent helium concentrations exceed a safe limit. Unlike for temperature, no margin above 2.9 psia is provided. Therefore, the user must ensure that 2.9 psia is not exceeded. The pressure limit applies only at elevated temperature. Tritium pressurization above 2.9 psia at room temperature causes little tritium permeation into the wall and is permissible.

5.1.3 Estimated Service Life

The estimated service life in years is given by the below equation from Appendix 3:

$$L = (388 / P_{max})^{1/2}$$

P_{max} is the maximum tritium pressure to which the HTV has been exposed and as noted in 5.1.2 shall be less than 2.9 psia. The shortest estimated life, 11.5 years, corresponds to use starting with an initial tritium pressurization at first unloading of 2.9 psia. Given operation within the temperature limits of 5.1.1, estimated service life is not a function of temperature.

The service life begins at the time an HTV is heated with tritium present. This typically will occur at the first unloading. Prior to the first heating with tritium present, the HTV may be used for tritium storage for an unlimited time if the conditions of 5.2.2.3 are satisfied.

The HTV owner or designee has considerable leeway in choosing a desired HTV service life. The owner or designee shall control the temperature and pressure limits corresponding to the estimated service life. If the limits are exceeded, the owner or designee shall invoke actions of 5.2.8.4.

If the pressure limit is exceeded but not beyond 2.9 psia, the owner or designee shall correct the service life by estimating service life at the new maximum pressure multiplied by the fraction of service life remaining. For example, say the owner desires a 20 year HTV service life. From the above equation, the owner shall control the tritium pressure to ensure it does not exceed 0.97 psia. Assume that at 7 years of operation within this limit the HTV is exposed to 1.8 psia tritium while heated. The owner invokes 5.2.8.4 and, from the above equation, estimates the service life at 1.8 psia to be 14.7 years. The owner then estimates the remaining service life to be 14.7 years multiplied by (1- 7/20), or 9.56 years.

The number of loading and unloading cycles to which the HTV can be subjected is not restricted as long as each cycle remains within the temperature and pressure limits of the estimated service life.

5.2 Operating Requirements

In brief, the HTV stores tritium by chemically reacting the tritium gas with contained depleted uranium through an exothermic reaction to form solid uranium tritide. The vapor pressure is a function of temperature as defined in 3.1.1. Initial uranium activation is addressed in 5.2.3. The HTV releases the tritium upon heating of the vessel to drive the reverse reaction.

Personnel using the HTV must be trained radiation workers. Training is to comply with the applicable requirements of the governmental agencies that regulate the user. Personnel are to follow written procedures when using the HTV. Facilities in which the HTV is used must have radiation and contamination monitoring coupled with written exposure mitigation procedures.

The HTV normal operating range is 450°C and below. Heating above 500°C is considered abnormal. The HTV design temperature of 600°C provides for over pressure safety and not an extended normal operating range. Elevated temperatures and the associated likelihood of elevated pressures shorten the HTV life time and increase permeation leakage through the HTV walls. **Adherence to the operating limits established from 5.1 is mandatory. The HTV owner shall control the unloading temperatures and pressures and maintain an accurate record of the remaining HTV service life.**

5.2.1 Precautions

5.2.1.1 Reactive Feed Gas Impurities Gases other than hydrogen isotopes also react with uranium. Uranium readily reacts with oxygen to form stable uranium oxide. To a lesser extent uranium reacts with nitrogen. Uranium preferentially reacts with oxygen over tritium. Therefore, **oxygen must be kept from within the HTV** to both ensure safety and to maintain capacity. The HTV feed gas and internal atmosphere should be oxygen free. If both HTV valves are open, unforced ingress of oxygen contaminated gas is greatly limited by the HTV port design and the use of argon (preferred option) or helium blanketing gas.

Mercury must also be kept from entering the vessel. Mercury unfavorably alloys with the AWS BAu-4 braze material attaching the inner tubes. This could lead to failure of the attachment and subsequent release to the facility of pyrophoric uranium or uranium tritide.

Written user procedures must emphasize the need to prohibit oxygen and mercury ingress.

5.2.1.2 System Uranium Contamination The 2 micron port filters are designed to contain all uranium powder within the HTV. To further reduce the chance of any uranium fines from escaping the HTV and entering a facility system, 2 micron filter gaskets should be used when making the fitting connections.

5.2.1.3 Thermal Precautions While being heated or while cooling after being heated, the HTV handle will be at temperatures that could cause personal injury unless thermal barrier gloves are used. Table 13 lists handle temperatures from testing. **Thermal gloves should then be used when handling heated HTVs.**

5.2.1.4 Surface Contamination Mitigation The HTV surface will become contaminated during normal use as a result of tritium permeation at elevated temperatures. ALARA (as low as reasonably achievable) is the requirement for packaging in the H1616, which has no quantitative content surface contamination limits. Users must be aware of and comply with facility operational and health protection requirements for surface contaminated objects when using an HTV.

Surface decontamination methods must ensure that the vessel surface is not damaged and that materials with chloride content above 250 parts per million are not used. An acceptable decontamination method is use of ethyl or denatured alcohol and cotton swabs.

Surface contamination is greatly reduced if HTV elevated temperature operations are performed with very low internal tritium pressures. Therefore, user procedures should minimize such pressures.

5.2.2 General Requirements

5.2.2.1 Valves and Fittings The valves are to be closed at all times except when necessary for use. Closing shall be to a 20 ±1 inch-pound closure torque and per the thermal limitations of 5.1.1. **Do Not exceed this torque since doing so may damage the valve structure and seat and reduce its sealing capability. A lesser torque may not adequately seal the valve for transportation environments.** Leak rate acceptability is verified for every use and tested annually. The fittings are to be sealed following the manufacturer's requirements [12]. At all times other than at time of connection, the fittings are to be sealed with the specified gasket in place. A gasket with retainers may be used, but gaskets are not to be reused.

5.2.2.2 Blanketing Gas At all times when not being loaded or unloaded, the HTV volume is to be filled with an inert blanketing gas. Either argon (preferred option) or helium may be used as the blanketing gas. Nitrogen is not to be used as blanketing gas. Nitrogen can react unfavorably with both uranium and tritium.

5.2.2.3 Operating and Storage Environments The HTV should be used and stored in a clean environment removed from routine personnel occupancy. Storage temperatures should be those suitable for personnel occupancy. Materials contacting the HTV pressure retaining materials are to have less than 250 ppm total chloride content.

Uninterrupted long term storage is limited by the 1-year helium generation design basis. Generated helium must therefore be vented from a loaded HTV at least yearly. This ensures that a vessel will at no time exceed the design conditions.

5.2.3 Uranium Activation Prior to First Use

Prior to first use, the depleted uranium in a new HTV must be activated. During activation, hydrogen isotopes react with the uranium bar stock to decompose the bar stock into powder. Heating during activation accelerates penetration of any uranium oxide layer by the hydrogen isotopes.

The facility system should connect the HTV to a manifold providing a vacuum pump, blanketing gas, pressure gauge, and hydrogen isotope supply. The facility system should minimize internal piping volume. The system shall have a furnace suitable for maintaining the HTV at an unloading temperature less than or equal to 450°C with controls that shall ensure the 450°C normal operating limit is not exceeded. Thermal protection shall ensure the 600°C design limit is not exceeded. Flame heating is not to be used. Temperatures are to be monitored at the thermocouple attachments provided on the HTV base. The HTV top pipe cap surface should be insulated with approximately 0.25 inch insulation to improve heating efficiency and to minimize heat exposure to the valves. The insulation elevation must not extend past the lower tubes. Doing so may cause valve and tubing temperature limits to be exceeded. Figure 6 shows proper HTV placement in a furnace. **Tritium shall not to be used for activation**; doing so will result in excessive tritium permeation into the body materials and invalidate the established service life.

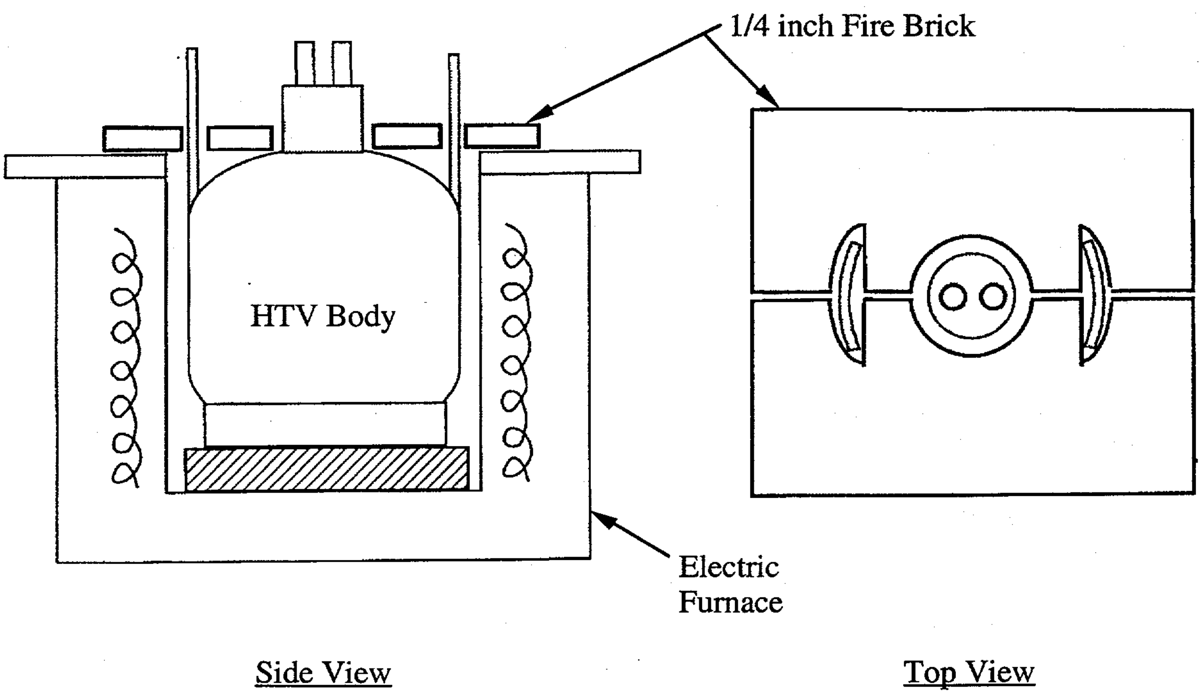

Figure 6. HTV Orientation in Furnace

Activation can be accomplished as follows:

Step 1. Remove the fitting from either the HTV "Hydride" or "Void" port and connect the port into the facility system. (Note: Use of the Void port is preferred)

Step 2. Evacuate the system and verify the system is closed by a pressure rate-of-rise test.

Step 3. Open the connected HTV port valve and verify it is open by a system pressure rise.

Step 4. Heat the HTV to 450°C and evacuate until off-gassing is complete. This should take about 4 hours. Allow the vessel to cool to 200°C.

Step 5. While maintaining the vessel at 200°C, admit protium or deuterium (preferred option) at pressure of 40 psig for about 3 hours, or until the uranium has absorbed enough gas to give an atomic hydrogen to uranium stoichiometry of at least 2.5.

Step 6. Desorb the hydrogen from the uranium by heating the HTV to between 400°C and 450°C and evacuate until pressure is less than 0.02 psia. Allow the HTV to cool to less than 200°C.

Step 7. Starting at a 0.02 psia vacuum or better, back fill the HTV with blanketing gas to ambient (14.7 psia) pressure. Close the HTV valve and *torque as specified in Section 5.2.2.1.* Verify the valve is closed by a pressure rate-of- rise test per the assembly verification method of 4.1.3.5. Then disconnect the HTV from the system. Reinstall the fitting.

5.2.4 Pre-Use Inspection

Prior to use, the HTV should be inspected to ensure that the valves and fittings are closed. If a valve is suspected to be unclosed, the user should close the valve and *torque as specified in Section 5.2.2.1.* Anticipating some release will occur, remove the fitting and either reseal the fitting or continue with facility processing.

The user shall determine if the remaining HTV service life is adequate for completing the intended use and shall notify the recipient of the remaining service life.

5.2.5 Gas Unloading

The following outline provides guidance for unloading tritium gas from the HTV.

The facility system should be set up the same as for activating except a tritium receptacle replaces the hydrogen isotope supply.

Step 1. Remove the fitting from the HTV "Void" port and connect the port into the facility system.

Step 2. Evacuate the system and verify the system is closed by a pressure rate-of-rise test.

Step 3. Open the "Void" port valve and verify it is open by a system pressure rise.

Step 4. Heat the HTV and remove the evolved tritium gas. **The temperature shall not exceed 450°C and the tritium pressure shall not exceed the limit set from 5.1 for the desired service life. The remedies in 5.2.8.4 shall be invoked if these parameters are exceeded.** While maintaining temperature, remove tritium until off-gassing is completed. The time required to recover a full load is about 5 hours at temperatures near 450°C.

Step 5. Allow the HTV to cool to ambient temperature and evacuate the HTV to less than 0.02 psia, then back fill with blanketing gas to ambient pressure (14.7 psia).

Step 6. Close the HTV valve and *torque as specified in Section 5.2.2.1.* Verify the valve is closed by a pressure rate-of-rise test per the assembly verification method of 4.1.3.5. Then disconnect the HTV from the system. Reinstall the fitting.

5.2.6 Gas Loading

The following outline provides guidance for loading tritium gas into the HTV. The uranium within the HTV readily reacts by exothermic reaction with hydrogen isotopes. The facility system should be set up the same as for gas unloading except a tritium supply replaces the tritium receptacle.

If the tritium gas contains significant levels of inerts such as helium, the inerts accumulate in the vessel and must be purged intermittently during loading. Alternatively, the loading may be accomplished by circulating the gas through the vessel using both ports. The outflow should be connected to the HTV "Void" port.

Step 1. Remove the fitting from either the HTV "Hydride" or "Void" port and connect the port into the facility system. If using flow through, connect both ports with outflow through the "Void" port.
Step 2. Evacuate the system and verify the system is closed by a pressure rate-of-rise test.
Step 3. Open the connected HTV valve(s) and verify it is open by a system pressure rise.
Step 4. Heat the HTV and evacuate until off-gassing is complete. **The temperature shall not exceed 450°C. Residual tritium pressure shall not exceed the limit set from 5.1 for the desired service life. The remedies in 5.2.8.4 shall be invoked if these parameters are exceeded.** Allow the HTV to cool to less than 200°C.
Step 5. Admit tritium to the HTV. If using flow through, add tritium through the "Hydride" port. When possible, use a minimum 1 psia tritium feed pressure. The higher the pressure, the shorter the loading time. Valve off the tritium supply when the desired amount is accumulated. Allow the HTV to return to ambient temperature.
Step 6. Evacuate the HTV to less than 500 microns (1×10^{-2} psia) to remove any residual tritium gas and back fill with blanketing gas to ambient pressure (14.7 psia). Cool the HTV to ambient, close the HTV valve(s) and *torque as specified in Section 5.2.2.1.* Verify the valve(s) is closed by a pressure rate-of-rise test per the assembly verification method of 4.1.3.5. Then disconnect the HTV from the system. Reinstall the fitting(s).

5.2.7 H1616 Loading and Unloading

Prior to transport, the HTV containment system assembly and periodic verification requirements provided in 4.1.3.5 and 6.2.2 must be satisfied. If helium blanketing gas is used, both requirements can be satisfied by performing a leakage test to the periodic verification criteria.

Existing H1616 loading and unloading requirements are to be used with the HTV. When packaged in the H1616, the HTV is put in the standard H1616 content bagging. The bagging serves to keep the HTV clean while in the H1616 packing material.

As noted in 5.2.1.4, ALARA (as low as reasonably achievable) is the contamination requirement for packaging in the H1616, which has no quantitative content surface contamination limits.

5.2.8 Off-Normal Conditions

5.2.8.1 Stuck Valve or Bent Valve Stem If a valve sticks in the closed position, ensure that the full closure torque is applied, then disconnect the HTV from the facility system. Retire the vessel unless it is loaded. If it is loaded, unload it through the other port, then retire the vessel. If a valve is found to have a bent stem, the HTV shall be retired from service.

5.2.8.2 Failed Containment If an HTV can not provide the containment specified in 4.1.3.4, the vessel is to be retired.

5.2.8.3 HTV Retirement and Disposal A dysfunctional HTV is to be retired from service and disposed of. Retirement may only be performed by the vessel owner or the owner's designee. Prior to disposal, tritium in the vessel should be reduced to a minimum by evacuation at 400°C to 500°C. If necessary to further reduce residual tritium, the evacuation should be followed by isotope exchange with deuterium (preferred option) or protium. Disposal is to follow the owner's facility requirements or those of the owner's designee.

5.2.8.4 Service Life Conditions Exceeded If the operating limits establishing the estimated service life are exceeded, the owner or designee shall invoke action per 6.2.5, "Non-routine maintenance." If the HTV temperature has exceeded 500°C or the tritium pressure has exceeded 2.9 psia while heated, the HTV is to be retired per 5.2.8.3. If 450°C is exceeded, the owner or designee shall take corrective action to limit recurrence. If the tritium pressure while heated exceeds the operating limit but not 2.9 psia, the estimated service life is to be corrected per 5.1.3.

6.0 TRANSPORT AND FACILITY ACCEPTANCE TESTING AND MAINTENANCE

This section addresses post fabrication acceptance testing and maintenance. Operational precautions and general requirements of 5.0 are applicable to inspection testing and maintenance activities. Proof and leak test procedures are to satisfy ANSI N14.5-87 §7 with personnel qualified per ASME Boiler and Pressure Vessel Code, Section III Subsection NB, 1991 Addenda. Acceptance testing and maintenance activities shall satisfy requirements of 7.0.

6.1 Acceptance Testing

The following acceptance tests are required and successful completion of each is a condition of acceptance for each newly fabricated HTV. Acceptance testing during fabrication, including acceptance of HTV weldments and parts, is a procurement action with acceptance criteria detailed in the Appendix 1 design drawings.

6.1.1 Acceptance Proof Test

Each HTV is to be pneumatically proof tested using argon or helium. Proof testing is not performed periodically. Proof testing should be performed on the vessel prior to uranium activation to reduce potential uranium dispersion if a failure occurs.

The testing, specified on the design drawings, cites ASME Code NB-6300 requirements. The leakage test of 6.1.2 supersedes the leakage test required by NB-6300. Both the pressure boundary to the valve seats and to the fittings are to be proof tested. This may be accomplished by pressurizing the vessel, then closing both valves in accordance with the torque specification given in Section 5.2.2.1, then, with fittings sealed, open both valves. The minimum proof pressure of 1.20 times the design pressure per NB-6321(c), or 1160 ± 20 psig, is specified so that the valve rating is not overly exceeded. Time at pressure is to be 1 hour, as required by Specification 7093, Revision 4, which is referenced in WSRC Engineering Standard 15060-01-R, Pipe Code P265, Revision 2. Acceptable proof gases are argon or helium.

US Code of Federal Regulations 10 CFR 71.85(b) requires that a transport containment boundary be proof tested at 1.5 times the maximum normal operating pressure (MNOP). Since 1.5 times the transport MNOP of 201 psig, or 301.5 psig, is less than the facility proof requirement of 1160 ± 20 psig, the facility proof test meets and exceeds the transport proof test requirement.

Acceptance is that no observable deformation occurs and that the post-proof leakage tests are acceptable.

6.1.2 Acceptance Leak Tests

Containment of each HTV is to be verified by helium-4 leak testing. Leak testing, as specified on the design drawings, is per ANSI N14.5-87 or later, using the helium mass spectrometer evacuated envelope (bell jar) method with the HTV at a 14.7 psi differential and 25°C. Both the pressure boundary to the valve seats and to the fittings are to be leak tested. This may be accomplished by pressurizing the vessel, then closing both valves to the torque specified in Section 5.2.2.1 with fittings removed, then test with fittings sealed and both valves opened.

Acceptance is that leakage of each boundary be less than 1×10^{-7} cm^3/sec helium-4.

6.1.3 Geometric Fit Acceptance Tests

The ability of each HTV to fit in the specified cylinder and height are to be verified. This ensures sufficient clearance within the H1616, calorimeter wells, and other facility equipment.

Acceptance is, as specified on the design drawings, that each HTV slip fit into a 4.600 inch diameter cylinder. Also, the height of each HTV is to be 10.0.

6.1.4 Thermocouple Well Functional Acceptance Test

The ability of each thermocouple well on each HTV to accept an 0.063 inch diameter sheathed thermocouple is to be verified.

Acceptance is, as specified on the design drawings, that an 0.063 inch diameter sheathed thermocouple be able to slip fit into each thermocouple well.

6.1.5 Hydride Capacity Acceptance Test

As specified on the design drawings, the initial hydride capacity of each HTV is to be from 2.9 to 3.0 gram-moles of gas. This is to be verified by loading deuterium (preferred option) or protium per the procedure described in 5.2.6 after the uranium has been activated per the procedure described in 5.2.3.

6.2 Maintenance Requirements

6.2.1 Uranium Content Maintenance

There is no need for maintenance to the uranium in the vessel. Consumption of the uranium by reactive feed gas impurities may eventually cause a noticeable degradation of the vessel hydride absorption capacity. When the vessel capacity becomes less than what the owner requires, the vessel should be retired.

6.2.2 Periodic Containment System Verification

Containment of each HTV is to be periodically verified by helium leak testing. The test and acceptance are the same as the acceptance leak test of 6.1.2. An HTV must have had this verification performed no greater than 1 year prior to the HTV shipment date. If the HTV is in its first year of service and has been transported for the third time, the additional requirements of 4.1.3.4 apply.

6.2.3 Routine Valve Maintenance

Valve handle and bonnet threads and top of valve stem shall be periodically lubricated. If when turning the handles by hand there is noticeable rough resistance, the threads shall first be cleaned. Lubricate sparingly with Fel-Pro® N-5000. The valve stems shall be annually visually inspected for bending. Any indication of bending shall result in the suspect HTV being removed from service and action taken per 7.15 and 7.16.

6.2.4 Routine Maintenance Inspection

6.2.4.1 Vessel Handle and Skirt If the vessel handle or skirt is bent beyond what the design drawing allows, the HTV owner or his designee shall remove the HTV from service and shall file action per 7.15 and 7.16.

6.2.4.2 Fittings and Tubing Observable tube damage, as may occur if a fitting were over torqued, or if the fitting sealing surface is damaged to the extent that the fitting no longer provides containment, the HTV owner or his designee shall remove the HTV from service and shall file action per 7.15 and 7.16.

6.2.4.3 Cleaning If the HTV surface has noticeable dirt or surface film, the HTV shall be cleaned following design drawing specifications. HTV body material discoloration due to elevated temperature service is normal and does not necessitate cleaning.

6.2.5 Non-Routine Maintenance

If a condition exists requiring non-routine maintenance, the HTV owner or his designee shall remove the HTV from service and shall file action per 7.15 and 7.16.

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7.0 TRANSPORT AND FACILITY QUALITY ASSURANCE

This section provides the quality assurance (QA) requirements necessary for control of the HTV design, procurement, fabrication, acceptance testing, maintenance, repair, and use. The section follows the 18-point criteria of 10 CFR 71 Subpart H [13].

Quality assurance requirements are addressed based on the following premises:

- SRS is the organization responsible for originating the HTV design and maintains control of the HTV design.
- SRS is the organization primarily responsible for HTV fabrication and may utilize Site and contractor resources. Other organizations, in arrangement with SRS, may be allowed to fabricate HTVs.
- SRS and other organizations are responsible for HTV use.
- Organizations using the H1616 packaging, in which the HTV is transported, are responsible for meeting all applicable H1616 requirements. These are specified in the H1616 documentation [14].

The provided synopses of 10 CFR 71 Subpart H requirements do not replace the full requirements as stated in 10 CFR 71 Subpart H. Implementing organizations must refer to, and implement the requirements of, 10 CFR 71 Subpart H.

This report and the design drawings establish the quality assurance and control activities applicable to the HTV.

7.1 Organization

Organizations responsible for the HTV design, procurement, fabrication, acceptance testing, maintenance, repair, and use must have a defined structure to ensure responsible personnel achieve specified quality requirements and that personnel not directly responsible for the work verify the achievement of requirements.

Westinghouse Savannah River Company (WSRC) is the SRS Management Contractor acting for the DOE and is responsible for the HTV design and fabrication. WSRC conducts business according to the requirements of the DOE-approved QA plan [15] cited in the WSRC Quality Assurance Manual, 1Q [16]. WSRC has a documented organizational structure that identifies organizational elements and responsibilities [17]. Figure 7 presents the WSRC organizational chart specific to the HTV.

WSRC Tritium Division is the HTV design authority. Tritium Division established facility HTV requirements and are in the HTV design review and approval process. They have established procedures and a quality control system which assures the HTV packaging and it's procurement, operation, maintenance, and use are in accordance with this qualification report. The WSRC Tritium Quality Group provides management and independent measurement of the Tritium Division quality program adequacy and effectiveness.

WSRC Packaging and Transportation Group (P&T) is the SRS design agency for certified radioactive materials packagings, including the HTV. P&T is responsible for the HTV development and qualification. P&T has implemented a Task Quality Assurance Plan [18] covering the HTV design development and qualification. The WSRC Savannah River Technology Center Quality Section is the cognizant quality function (CQF) designated to provide assistance and oversight for P&T programs. The Quality Section management structure is independent of that of P&T, as shown in Figure 7.

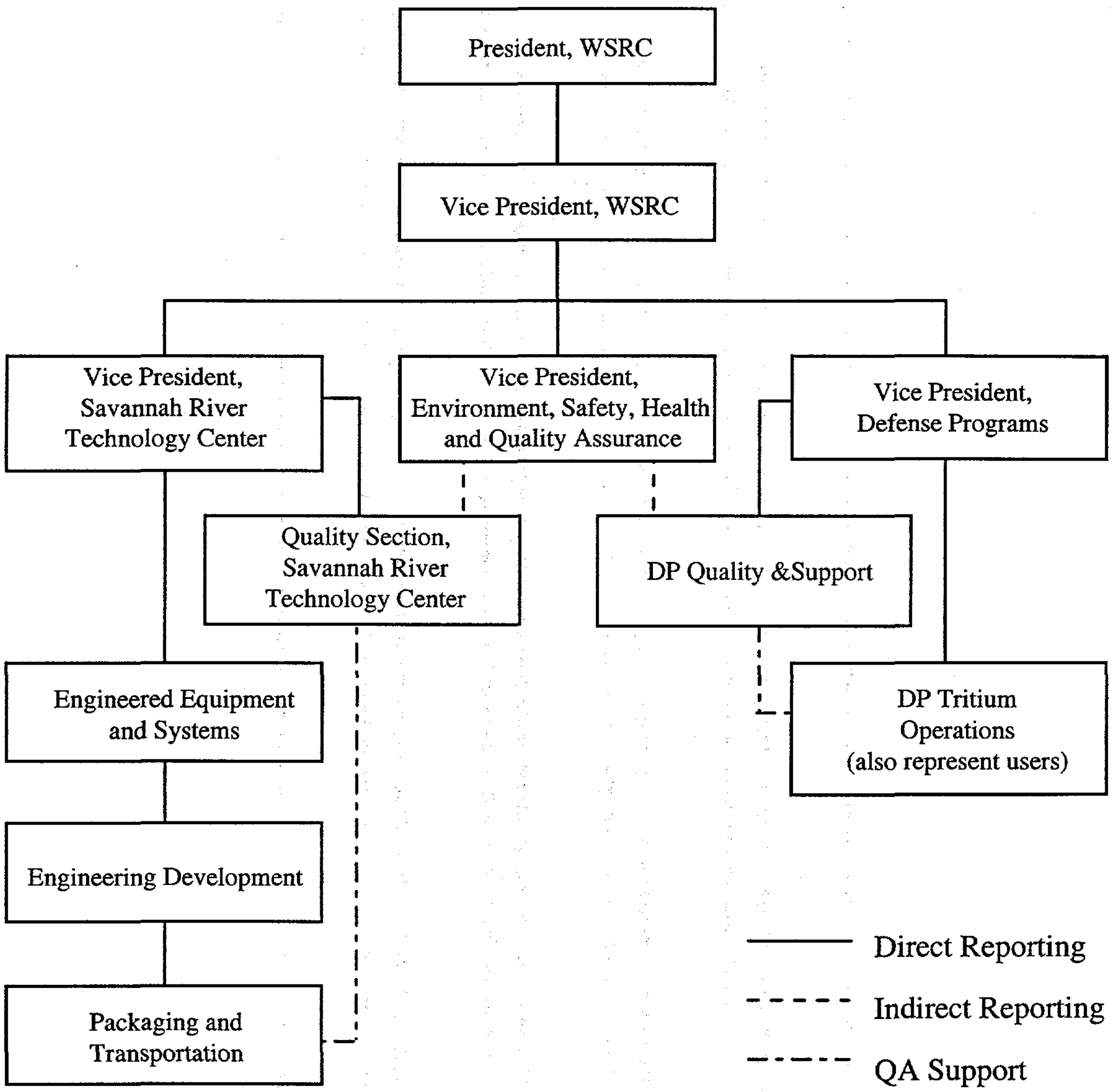

Figure 7. WSRC Quality Assurance Organization for HTV

Each organization other than WSRC responsible for HTV fabrication or use shall establish similar procedural controls according to the responsible organization's approved QA organization.

7.2 Quality Assurance Program

Following is a synopsis of the 10 CFR 71 Subpart H quality assurance program requirements:

- An established QA program complying with requirements of 10 CFR 71 Subpart H. The program shall be documented by written procedures or instructions, identifying the items to be covered by the program, and identifying the organizations participating in the program, and their organizational function.
- Control of activities affecting the quality of the items covered by the program in a graded manner based on the importance to safety afforded by the individual items.
- Indoctrination and training of personnel performing activities affecting quality to ensure suitable proficiency.
- Review of the program's status and adequacy at established intervals.

The WSRC QA program is defined in the 1Q manual. The program is implemented by the quality assurance procedures (QAPs) within the 1Q manual. QAP 1-1 of the 1Q Manual requires all WSRC organizational elements to implement QA programs complying with appropriate sections of ASME/ANSI NQA-1 [19]. The program includes an overall quality assurance indoctrination and training program, training programs for personnel performing specific tasks, quality assurance implementation and acceptance procedure requirements and independent inspection personnel requirements.

WSRC employees are responsible for effective implementation of the 1Q manual within their job responsibility limits. WSRC management assesses at least annually the adequacy and effectiveness of the QA program to ensure proper implementation.

The WSRC design agency implemented the WSRC QA program for the HTV design development and qualification through a Task Plan [18] and Quality Assessment Report [20].

In procuring and using the HTV, the WSRC Tritium Division implements the WSRC 1Q manual in conjunction with procedures specifically applicable to shipping activities. WSRC operators are trained for HTV use as specified in QAP 2-2. Training documents are placed in training files. Training is accomplished primarily by supervisory management with QA group assistance as appropriate. The Tritium Quality group provides independent monitoring and review of activities. WSRC Site Quality Assurance provides independent auditing of activities.

Each organizations other than WSRC responsible for HTV fabrication or use shall establish a similar program implementing the organization's QA plan.

7.3 Design Control

Following is a synopsis of the 10 CFR 71 Subpart H design control requirements:

- Establish measures to ensure regulatory and design requirements are translated into specifications, drawings, procedures, and instructions. This includes specification of quality requirements in design documents and control of deviations, and review of items essential to safety.
- Identify and control design interfaces with organizations performing review, testing, and analysis.

- Provide for verification of the design adequacy.
- Apply design control measures to items important to safety and ensure that any subsequent design changes are controlled commensurate with the design control applied to the original design. Changes in the packaging design require approval by the transport certification authority.

WSRC Tritium Division is the HTV design authority. Tritium Division established facility HTV requirements and is in the HTV design review and approval process. The design authority is responsible for providing facility design requirements and for ensuring that the requirements are satisfied. The design authority is also responsible for presenting the design agency with design change requests.

WSRC Packaging and Transportation Group (P&T) is the HTV design agency. The design agency retains design control of the HTV until cessation of HTV program or until official transfer of control to another design agency. All design change requests require disposition by the design agency. Design agency control of the design drawings is noted on the drawings. The design agency, with design authority approval and with the concurrence and coordination of the DOE Savannah River Field Office, ensures that the HTV design and subsequent changes are submitted to and approved by the DOE Albuquerque certification authorities prior to implementation. The WSRC CQF provides the design agency with QA assistance and oversight.

The following procedure is to be followed for HTV design changes:

Step 1. The originator of the design change request, if other than the design authority, submits a written petition to the design authority. The request is to clearly define the requested changes or issues, justify the need for action, and note a priority level.

Step 2. The design authority transmits valid requests to the design agency and identifies the priority level, need date, and associated requirements.

Step 3. The design agency proposes a disposition consistent with transport and facility design requirements to the design authority and, if appropriate, the originator. The design agency gains disposition concurrence of the originator and design authority. This may require iteration.

Step 4. If the disposition requires revising this report or the design drawings, the design agency oversees the revisions and obtains WSRC approvals equivalent to those on the original.

Step 5. The design agency is responsible for determining if changes effect the HTV qualification (approved shipping configuration). If such is the case, the design agency is to ensure changes are acceptable to, and reviewed and approved by, the DOE Albuquerque certification authorities prior to implementation per 7.6.

WSRC design document approvals are as follows.

Design drawing (referring to drawing notation):

"PRPD" - Draftsman
"CHKD" - Design agency cognizant engineer
"DEM" - Design agency manager
"Customer Appr" - Design authority HTV program leader
"Customer Other" - Design authority cognizant engineer

Report:

Design agency manager
Design agency section manager

Design authority HTV program leader

7.4 Procurement Document Control

Following is a synopsis of the 10 CFR 71 Subpart H document control requirements:

- Establish measures to assure quality in procurement documents of the organization and its contractors.
- To the extent necessary, the organization's contractors are to have a quality assurance program consistent with 10 CFR 71 Subpart H.

WSRC is to implement QAP 4-1 to control procurement documents. Control of procurement activities is further addressed in 7.7

This report and the design drawings specify quality requirements for purchased items. Design agency CQF approval of this report includes approval of the specified quality requirements. Procurement documents are to be controlled to ensure that these requirements are identified.

Procurement documents for HTV assemblies, components, and materials shall be reviewed and approved by the design agency to ensure that all specified quality requirements are identified, including as applicable the design bases, standards, specifications, codes, documentation, inspections, tests, packaging, shipping, and handling requirements, and other pertinent quality assurance considerations. The initiator of a purchase requisition or order request is responsible for including the specified quality requirements, requesting design agency review, and obtaining proper approval signatures.

Under the WSRC graded procurement system, procurement of HTV assemblies and independent procurement of uranium is to utilize Level 1 procurement controls, including vendor pre qualification.

Where this report or the design drawings allow use of equivalent items, the design agency shall be requested to review and approve items selected as equivalent to specified items prior to the use of the items. Procurement document changes must have design agency approval and the approval of the individual, organization, or designated representative who approved the original documents.

Copies of all procurement documents are to be filed by the WSRC Procurement Department as permanent records.

7.5 Instructions, Procedures, and Drawings

Following is a synopsis of the 10 CFR 71 Subpart H requirements for instructions, procedures, and drawings:

- Activities affecting quality shall be prescribed by documented instructions, procedures and drawings as appropriate for the activities. Adherence to the instructions, procedures and drawings must be assured.

- The instructions, procedures and drawings must include appropriate acceptance criteria for determining satisfactory accomplishment of activities.

This report and the design drawings specify quality requirements, including acceptance criteria as appropriate, for HTV fabricating and use.

Organizations responsible for HTV activities including, but not limited to, fabrication, acceptance, loading and unloading, maintenance, repair, or retirement, shall perform the activities in accordance with documented, written instructions and procedures incorporating the requirements of this report and the design drawings. The instructions and procedures are to include, as applicable, operating limits, acceptance criteria, and references.

7.6 Document Control

Following is a synopsis of the 10 CFR 71 Subpart H document control requirements:

- Organizations must control the issuance of documents prescribing quality activities. This includes ensuring original and revised documents are adequate, approved by authorized personnel, and distributed and used at the location of the prescribed activities.

HTV documents to be controlled include, but are not limited to, the following:

- Procurement documents
- Fabrication documents
- Operating procedures
- Maintenance procedures
- Inspection and Test procedures
- Loading and Unloading procedures
- Repair procedures
- Specifications
- Design drawings
- This report

Document revisions are to be handled in the same manner as original issues. Only the latest approved revision is to be available for implementation.

HTV fabrication documents are to be filed by HTV serial number and be traceable to all affected HTV hardware.

As needed, organizations are responsible for receiving a controlled distribution of this report or design drawings. Organizations are to base implementing documents on the latest revision of this report and design drawings released by SRS for implementation.

The design agency controls revisions to, and distribution of, this report and the design drawings using the WSRC Document Control organization. Once the revised report has received all required approvals, P&T shall release it to SRS Document Control for controlled distribution. Note that if the approval cycle results in further revisions, a gap will occur in the revision numbers being sent to controlled distribution.

7.7 Control of Purchased Material, Equipment, and Services

Following is a synopsis of the 10 CFR 71 Subpart H requirements for control of purchased material, equipment, and services:

- Established measures ensuring that purchased material, equipment, and services conform to the procurement document requirements. This applies to contracted activities as well. As appropriate, measures are to include source evaluation and selection, objective evidence of quality by contractors, contractor source inspection, and delivery inspection.
- Document evidence that purchased material, equipment, and services conform to specific procurement specification requirements.
- The implementing organization is to established assessments of contractor quality control effectiveness at intervals consistent with the activity.

WSRC is to implement QAPs 7-1 through 7-3 and QAP 4-1 to control HTV equipment, material, and service purchases . Implementation of QAP 4-1 is further discussed in 7.4.

This report and the design drawings specify requirements pertaining to HTV materials, equipment, and services. These requirements are to be stipulated in procurement documents.

Procurement controls shall implement the following steps.

Step 1. SRS shall prepare a procurement specification incorporating all applicable supplier and inspection requirements. The specification shall clearly state both the supplier inspection requirements and the inspection requirements of a supplier surveillance organization independent of the supplier. The specification shall be approved by the preparing procurement organization manager, the responsible Tritium Engineering manager, the P&T design agency manager, and the Tritium Quality manager.

Step 2. The SRS procurement organization shall select a qualified supplier and supplier surveillance organization.

Step 3. The supplier shall prepare, and submit to SRS for review and approval, the Fabrication and Inspection Plan (F&IP) which clearly states how the supplier intends to meet the specification, and all supplier procedures and personnel qualification records supporting the F&IP.

Step 4. SRS shall review and, upon the supplier's acceptable disposition of all comments, approve the supplier submittals as follows:

Supplier Submittal	Required SRS Review and Approval
F&IP	Tritium Quality, Tritium Engineering, P&T
All procedures	Tritium Quality, Tritium Engineering, P&T
Welding and Brazing procedures	Materials Technology Section
Welding and Brazing Personnel qualifications	Quality Services Deptartment-Quality Control
Examination procedures and personnel qualifications	Quality Services Deptartment-Quality Control
Inspection personnel qualifications	Quality Services Deptartment-Quality Control

Step 5. The supplier surveillance organization shall prepare, and submit to SRS for review and approval, the inspection plan which clearly states how the supplier surveillance organization intends to meet the specification.

Step 6. SRS Tritium Quality and P&T shall review and, upon the supplier surveillance organization's acceptable disposition of all comments, approve the inspection plan.

Step 7. Fabrication, inspection, and SRS acceptance shall be conducted as agreed to in the specification, F&IP, and inspection plan.

7.8 Identification and Control of Materials, Parts, and Components

Following is a synopsis of the 10 CFR 71 Subpart H requirements for identification and control of materials, parts, and components:

- Establish measures for identifying and controlling materials, parts, and components through out fabrication and use of the item. These controls prevent the use of incorrect or defective materials, parts, and components.

The design drawings specify identification and control requirements for HTV materials, parts, and components by invoking ASME Boiler & Pressure Vessel Code, Section III, 1991 Addenda, requirements.

Individual serial numbers uniquely identify each HTV. Material, part, and component documents are to be filed by HTV serial number.

HTV owners are to file, by HTV serial number, the materials, parts, and components identification and control documents. The filing and documents must allow for identification of all materials, parts, and components of each HTV. All modified or changed materials, parts, or components introduced during HTV life are to be identified, controlled, and documented in the same manner.

Procurement documents are to specify identification requirements for commercial grade parts in a manner consistent with the invoked ASME Code requirements and the need to maintain traceability by HTV serial number.

7.9 Control of Special Processes

Following is a synopsis of the 10 CFR 71 Subpart H requirements for control of special processes:

- Establish measures to ensure special processes are controlled and accomplished by qualified personnel using qualified procedures.
- Qualifications are to conform with established practice and any special requirements.

WSRC is to implement QAP 9-1 to control HTV special processes.

Special processes are to be conducted following written procedures, instructions, or other appropriate documents.

This report and the design drawings specify the degree of control to be placed on special processes. They likewise specify the qualification requirements for associated personnel and procedures. Special processes include, but are not limited to, welding, brazing, cleaning, non-destructive examinations, uranium use, and HTV loading and unloading. Reviews of special processes prior to implementation is addressed in 7.7.

The HTV owner or designee shall maintain records substantiating that the temperature and pressure limits for the estimated service life have not been exceeded. Any service life corrections are likewise to be recorded.

7.10 Internal Inspection

Following is a synopsis of the 10 CFR 71 Subpart H requirements for internal inspection:

- Establish program for inspection to verify conformance with instructions, procedures and drawings.
- Inspections must be performed by individuals other than those performing the activity.
- Hold points, if required, must be witnessed or inspected by representative of requesting organization before work continues.

HTV inspection activities primarily apply during procurement and fabrication.

Inspections are to be performed to ensure that items and activities satisfy the specified requirements of this report and the design drawings. Fabrication organizations are to include these inspections in the fabrication plan and place inspection documentation in the HTV fabrication files by HTV serial number.

Inspection personnel must be qualified as attested by qualification records. Inspection reports are filed as QA records.

7.11 Test Control

Following is a synopsis of the 10 CFR 71 Subpart H requirements for test control:

- Establish test program to identify the testing required to assure packaging components are satisfactory prior to use.
- Perform test activities in accordance with written, documented test procedures incorporating established test requirements and acceptance criteria, ensuring applicable prerequisites are met, implementing proper instrumentation, and ensuring a suitable test environment.
- Document and evaluate test results to assure test requirements have been satisfied.

This report and the design drawings specify HTV test requirements and acceptance criteria, including test personnel and test procedure requirements. Tests include the design performance tests, acceptance proof and leak tests and hydride capacity verification, the periodic leak test, and pressure rise test verifying valve closure prior to shipment.

7.12 Control of Measuring and Test Equipment

Following is a synopsis of the 10 CFR 71 Subpart H requirements for control of measuring and test equipment:

- Establish measurements to ensure measuring and testing devices used in activities affecting quality are controlled, and calibrated and adjusted at specified times, to maintain accuracy within necessary limits.

Measuring and test equipment used in establishing HTV quality records, including those associated with fabrication inspections, acceptance tests and periodic tests, are to be controlled. Measuring and testing device calibrations are to be traceable to the National Institute of Standards Technology (NIST).

7.13 Handling, Storage, and Shipping

Following is a synopsis of the 10 CFR 71 Subpart H requirements for handling, storage, and shipping:

- Establish measures to control handling, storage, shipping, cleaning, and preservation of items as specified.

This report and the design drawings specify handling, storage, and shipping as applicable. The requirements primarily ensure that the hydride capacity is not destroyed by uranium reactions with oxygen and nitrogen, and that the 300-series austenitic stainless steels are not exposed to chloride levels above 250 parts per million. Additionally, valves and other external features, and the sealing surfaces on the fittings are to be protected from damage.

Written procedures are to be used to ensure the specified requirements are satisfied.

7.14 Inspection, Test, and Operating Status

Following is a synopsis of the 10 CFR 71 Subpart H requirements for inspection, test, and operating status:

- Establish measures to indicate the status of materials and components during fabrication so that only accepted materials and components are used.
- Establish measures to identify the operating status of the item in service.

This report and the design drawings specify HTV inspection requirements and acceptance tests.

Inspection and test status of materials and components during fabrication and acceptance must be indicated. Operational status must be identified, including the remaining service life, the temperature and pressure limits for the estimate service life, the date of the most recent periodic leak test, the tritium content, and, if applicable, that an HTV is removed from service pending maintenance or retirement. Retired HTVs are to be clearly marked as not for service.

7.15 Control of Nonconforming Materials, Parts, or Components

Following is a synopsis of the 10 CFR 71 Subpart H requirements for control of nonconforming materials, parts, or components:

- Establish measures to control nonconforming items so they are not used.
- Establish measures to disposition nonconforming items by acceptance, rejection, repair, or rework in accordance with documented procedures.

This report and the design drawings specify the conformance requirements of HTV materials, parts, components, and HTV assemblies in use.

Nonconforming materials, parts, components, and HTV assemblies in use are to be identified and segregated for disposition. Once identified, nonconforming items or activities require documented investigation and disposition, typically using a nonconformance report. Disposition may be by rejection, acceptance (use as-is), repair, or rework. Technical justification is required as part of the disposition for repair or use as-is. Dispositions require approval of the design agency and the organization's cognizant quality function prior to implementation. For repair or use as-is dispositions, the design agency provides or reviews and approves the technical justification. For repair or use as-is dispositions, as-built or design records must be reviewed for necessary revisions to reflect the accepted deviation.

Conditions to be identified as nonconformance include but are not limited to items or activities not meeting specified requirements or whose performance is unacceptable, items or activities with indeterminate quality, or when an in-process activity is indeterminate or nonconforming.

Notification to the DOE Albuquerque certification authorities is required prior to final disposition if the approved shipping configuration has been violated. Notification is to identify intended subsequent use of the effected unit(s).

7.16 Corrective Action

Following is a synopsis of the 10 CFR 71 Subpart H requirements for corrective action:

- Establish measures to ensure conditions adverse to quality are promptly identified and corrected. Significantly adverse conditions require written, documented corrective actions.

The HTV owner or his designee shall promptly identify nonconforming items or activities, correct them, and identify the cause of nonconformance. Investigation is taken to a level ensuring the nonconformance will not be repeated. The cognizant quality function of the organization making the corrective action investigation is responsible for concluding and documenting the investigation.

Corrections requiring changes to this report or the design drawings are to be made following the procedure in 7.3.

7.17 Quality Assurance Records

Following is a synopsis of the 10 CFR 71 Subpart H requirements for quality assurance records:

- Maintain sufficient written records to describe activities affecting quality.
- A records retention program is required.
- Records are to be maintained for 3 years beyond the last activity for which the quality assurance program exists.

Documents attesting to the design and assessment activities are controlled using the WSRC document control system. The records retention system is used and records are maintained in WSRC retention vaults. The design agency is responsible for generating the design and assessment records.

Table 21 lists quality assurance records that will be generated during the HTV program. HTV QA records other than those tabulated are likely and should be controlled in a like manner.

The HTV owner or his designee shall ensure generation of, and retain, all records associated with fabrication, operating and maintenance, and general use so that the records are identified and are readily retrievable by HTV serial number.

7.18 Audits

Following is a synopsis of the 10 CFR 71 Subpart H requirements for audits:

- Carry out a comprehensive system of planned and periodic audits, verifying compliance with all aspects of the quality assurance program and determining its effectiveness.
- Audits must be performed by appropriately trained personnel following written procedures or checklists.
- Audit personnel are not to be directly responsible for the areas being audited.
- Audit results are to be documented and reviewed by the responsible area management. Follow-up actions are to be identified and taken.

Prior to first use of a new HTV, the owner should audit the fabrication records to verify completeness and that fabrication requirements have been satisfied. Organizations should perform periodic audits and surveillances of HTV procedures and activities.

The HTV design agency activities have been reviewed by an independent WSRC work review team. Further design agency activities and design authority and user activities are subject to audit within the WSRC program. DOE Quality and Materials Assurance Division conducts formal audits of SRS hazardous materials transportation activities at least annually. Organizations contracted by WSRC to perform HTV activities are subject to audit by the WSRC QA external audit program.

Audit findings and corrective action reports are to be documented.

Table 21. Quality Assurance Records[†]

Type of Record	Retention Period[‡]
Design	
SRS H1616 Qualification Report	Life
Design Review Reports	Life
Certificate of Compliance, including amendments	Life
Fabrication	
Procurement Specifications	Life
Fabrication and Inspection Plans	Life
Fabrication Records, including fabrication drawings, material certifications, NDE	Life
reports, NDE procedures, NDE personnel qualifications, inspection reports, inspector qualifications, welder qualifications, welding and brazing procedures, completed cleaning procedures, nonconformance reports	Life
Acceptance Leak and Proof Test Results	Life
Acceptance Dimensional Inspection Reports	Life
Acceptance Hydride Capacity Test Reports	Life
Acceptance Test Procedures	Life
Acceptance Test Personnel Qualifications	Life
Operating and Maintenance	
Completed Routine Maintenance Procedures	Life
Qualification Records for Routine Maintenance Personnel	Life
Completed Nonroutine Maintenance Procedures	Life
Qualification Records for Nonroutine Maintenance Personnel	Life
Completed Retirement Procedures	Life
Procedure Qualification Records	Life
Completed Loading Procedures	S + 2
Assembly Verification Leak Test Results	S + 2
Completed Unloading Procedures	S + 2
Service Life Substantiation	Life
General	
Procurement Specifications	Life
Audit Reports	Life
Training Records	Life
Corrective Action Reports	Life
Nonconformance Reports	Life

[†]Table is not intended to be all inclusive; other QA records are likely and require like control.
[‡]Lifetime is 3 years after termination of HTV use; S + 2 is Shipping date plus 2 years.

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APPENDICES

Appendix 1 Design Drawings

(included in envelope at end of document)

Drawing, *H1616 Hydride Transport Vessel - H1616 Hydride Transport Vessel Assembly*, R-R1-H-0035, Revision 5.

Drawing, *H1616 Hydride Transport Vessel - H1616 Hydride Transport Vessel Weldment*, R-R3-H-0016, Revision 4.

Drawing, *H1616 Hydride Transport Vessel - H1616 Hydride Transport Vessel Details*, R-R4-H-0056, Revision 4.

Appendix 2 Design Requirements

Appendix 2.1 Reservoir Design Requirement

Reservoir Qualification AL-SX (H1616) (U), Specification SS393217, Issue E, 9/98, Sandia National Laboratories, Albuquerque, NM.

Appendix 2.2 Structural Requirement, US NRC Regulatory Guide 7.6

Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, US NRC Regulatory Guide 7.6, Revision 1.

Appendix 2.3 Fabrication Requirements, NUREG CR-3019 Table 2 and CR-3854 Table 4.1

Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials, NUREG/CR-3019, Table 2.

Fabrication Criteria for Shipping Containers, NUREG/CR-3854, Table 4.1.

Appendix 2.4 Piping Requirement, WSRC P-001R Pipe Code P265

Engineering Standard 15060-01-R, Pipe Code P265, Rev. 2, Westinghouse Savannah River Company, Aiken, SC.

Appendix 2.5 Uranium Composition, Guidance Memorandum

Memorandum, L. K. Heung to Mark N. Van Alstine, *Uranium Information for Shipping Container*, SRT-HTS-92-0024, January 23, 1992.

Appendix 3 Tests, Analyses and Assessments

Appendix 3.1 Materials and Service Life Assessments

Memorandum, E. A. Clark to Mark N. Van Alstine, *Use of AISI Type 347 Stainless Steel in Hydride Transport Vessels (U)*, SRT-MTS-92-4041, August 19, 1992.

Memorandum, E. A. Clark and C. F. Jenkins to Mark N. Van Alstine, *Lifetime of Hydride Transport Vessel (U)*, SRT-MTS-93-4040, May 14, 1993.

Memorandum, D. J. Trapp to M. N. Van Alstine, *Cycle Test of Nupro SS-4HS Valve, Phase III (U)*, SRT-IES-98-0061, March 18, 1998.

Memorandum, W. L. Daugherty to M. N. Van Alstine, *Post-Test Examination of Nupro Valves (U)*, SRT-MTS-984042, Rev.1, March 30, 1998.

Appendix 3.2 Shielding Assessment

Memorandum, L. T. Burckhalter to Mark N. Van Alstine, *Verification of New Hydride Transport Vessel Shielding (U)*, ESH-HPT-92-0292, August 14, 1992.

Appendix 3.3 Pressure Derivations and Wall Stress Calculations

Memorandum, Mark N. Van Alstine to E. K. Opperman, *Reviewed and Approved Hydride Transport Vessel Calculation (U)*, SRT-PTG-92-0123, September 11, 1992.

Appendix 3.4 Leak Rate Correlation

Calculation, Mark N. Van Alstine, *"Determination of HTV Leak Rate Criterion (U)*, R-CLC-H-00001, Revision 1, July 23, 1998.

Appendix 3.5 Drop Test Report

Memorandum, M. D. Goodell to M. N. Van Alstine, *Hydride Transport Vessel (HTV) Drop Test Results (U)*, SRT-IES-980004, March 30, 1998.

Appendix 3.6 Vibration and Shock Test Report

D. G. Tipton, *Hydride Transport Vessel Vibration and Shock Test Report*, SAND98-1230, Sandia National Laboratories, Albuquerque, NM, June, 1998.

Appendix 3.7 Structural Assessment

G. E. Mertz, *Structural Assessment of a Proposed Hydride Transport Vessel (U)*, SRT-MTS-921162, Rev. 1, September 22, 1992.

Calculation, C. A. McKeel, *Analysis of Hydride Transport Vessel for External Pressure (U)*, T-CLC-G-00105, Rev. 0, July 23, 1998.

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Calculation, T. Wu, *Effect of Temperature Variation on HTV Valve Performance (U)*, M-CLC-H-01616, Rev. 0, April 1, 1998.

Appendix 3.8 Thermal Test Report

Memorandum, L. K. Heung to Mark N. Van Alstine, *Hydride Transport Vessel Thermal Test*, SRT-HTS-92-0153, September 23, 1992.

Appendix 3.9 Permeation Leakage Analysis

Memorandum, L. K. Heung to Mark N. Van Alstine, *Hydride Transport Vessel Permeation Analysis*, SRT-HTS-92-0226, December 8, 1992.

Memorandum, A. M. Herb to Mark N. Van Alstine, *HTV Permeation Offgas Evaluation (U)*, DPD-TED-98-0088, July 1, 1998.

Appendix 4 Supporting Information

Appendix 4.1 Lubricant Off-gassing

Memorandum, P. Montero to Mark N. Van Alstine, October 15, 1992.

Appendix 4.2 Hydride Operating and Maintenance Requirements

Memorandum, L. K. Heung to Mark N. Van Alstine, *Operating Requirements for HTV*, September 25, 1992.

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Appendix 1 Design Drawings

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Drawing, *H1616 Hydride Transport Vessel - H1616 Hydride Transport Vessel Weldment*, R-R3-H-0016, Revision 4.

Drawing, *H1616 Hydride Transport Vessel - H1616 Hydride Transport Vessel Details*, R-R4-H-0056, Revision 4.

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Appendix 2 Design Requirements

Appendix 2.1 Reservoir Design Requirement

Reservoir Qualification AL-SX (H1616) (U), Specification SS393217, Issue E, 9/98, Sandia National Laboratories, Albuquerque, NM.

Appendix 2.2 Structural Requirement, US NRC Regulatory Guide 7.6

Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels, US NRC Regulatory Guide 7.6, Revision 1.

Appendix 2.3 Fabrication Requirements, NUREG CR-3019 Table 2 and CR-3854 Table 4.1

Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials, NUREG/CR-3019, Table 2.

Fabrication Criteria for Shipping Containers, NUREG/CR-3854, Table 4.1.

Appendix 2.4 Piping Requirement, WSRC P-001R Pipe Code P265

Engineering Standard 15060-01-R, Pipe Code P265, Rev. 2, Westinghouse Savannah River Company, Aiken, SC.

Appendix 2.5 Uranium Composition, Guidance Memorandum

Memorandum, L. K. Heung to Mark N. Van Alstine, *Uranium Information for Shipping Container*, SRT-HTS-92-0024, January 23, 1992.

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1. GENERAL

1.1 Scope.

The AL-SX/2 (H1616-1) and AL-SX/3 (H1616-2) (without getter) shipping containers are certified for transport of a reservoir if this reservoir has been evaluated and successfully qualified to the requirements of this specification. "Qualified" is defined as to show by test, analysis, or comparison with similar reservoirs that a reservoir will contain tritium, as demonstrated to a sensitivity of 10^{-6} A_2 per hour, under normal transportation environments. This requirement implies a leak rate of less than or equal to 1.26×10^{-7} cc/sec of tritium. The effect on the ability to contain tritium under normal conditions must be assessed by the appropriate design laboratory using the requirements set forth within this specification, which are based on 10 CFR 71.51(a)(1).

10 CFR 71.51(a)(1) requires evaluation to tests specified in paragraph 71.71, Normal Conditions of Transport. The water spray, compression, and penetration requirements of 10 CFR 71.71 are not applicable because the containment vessel and packaging of the AL-SX (H1616) will shield the reservoir against these environments.

Successful qualification to this specification will fulfill the requirements of 10 CFR 71.71 for normal conditions of transport for reservoirs shipped in the AL-SX (H1616).

Since tritium reservoirs are the primary contents of the AL-SX (H1616), the term "reservoir" is used throughout this specification. However, other tritium filled components may be qualified for transport in the AL-SX (H1616). Those components must also meet the requirements of this specification.

For military purposes the AL-SX/2 (lighter version) and the AL-SX/3 (heavier version) are designated H1616-1 and H1616-2, respectively.

1.2 Quality Standards.

The design laboratory responsible for reservoir testing and evaluation shall meet 10 CFR 71, Subpart H, Quality Assurance. Equivalent requirements are those of NQA-1.

2. DOCUMENTS

The following documents form a part of this specification to the extent stated herein.

10 CFR 71	Code of Federal Regulations, Title 10, Part 71
SAND91-2204	Transportation Environments of the AL-SX (H1616)
SAND91-2205	Safety Analysis Report for the Type B(U) AL-SX (H1616) Reservoir Packages
SAND91-2780	Summary of Outgassing Tests Performed in Support of the AL-SX Program

EP401021	Engineering Procedure, Tritium Reservoir Kit Definitions
NQA-1	Quality Assurance Program Requirements for Nuclear Facilities, ANSI/ASME
QC-1	Quality Criteria, DOE/AL

3. REQUIREMENTS

3.1 Quality Assurance.

Give a general outline of the quality assurance plan(s) for reservoir design, manufacture, and use or cite references where this information may be obtained.

3.2 Reservoir Description.

3.2.1 The Reservoir shall be sealed with welded closures.*

3.2.2 The following maximum limits for reservoirs apply for the thick and thin walled containers.

(original table censored in SNL (U) version)

*The welded closure and single reservoir weight requirements do not apply to the Savannah River Site's Hydride Transport Vessel (HTV).

3.2.3 Organic materials (e.g. port plugs or foam or plastic overpacks) that are part of the reservoir shipping configuration shall not generate high pressure gaseous products when exposed to an accident scenario.* The Al-SX (H1616) containment vessel may reach temperatures up to 450°F in an accident (per SAND91-2205). The combined pressure increase due to a reservoir release and offgassing shall be less than 2/3 the maximum allowable pressure in the containment vessel at 450°F. *(Remaining original text censored in SNL (U) version.)*

3.3 Free Drop.

The reservoir shall be subjected to a free drop through a distance of four (4) feet onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected. Alternatively, the reservoir can be subjected to a 4-foot drop that meets the above conditions while packaged in an AL-SX (H1616).

3.4 Heat.

The reservoir shall be qualified for a maximum temperature of 160°F.

3.5 Cold.

The reservoir shall be qualified for a minimum temperature of –40°F.

3.6 Vibration.

The reservoir shall be qualified for the appropriate vibration environment as described in SAND91-2204.

3.7 Shock.

The reservoir shall be qualified for the appropriate shock environment as described in SAND91-2204.

3.8 Reduced External Pressure.

The reservoir shall be qualified for an external pressure of 0.1 psia. This pressure occurs in the containment vessel before backfilling with argon or dry nitrogen.

3.9 Increased External Pressure.

The reservoir shall be qualified for an external pressure of 8 psig. This pressure may occur in the containment vessel after backfilling with argon or dry nitrogen. The backfill specification is 5±3 psig.

* See SAND91-2780 for relevant data on outgassing of various substances.

3.10 Acceptance Criteria.

As a minimum, the reservoir shall contain tritium (tritium leak rate less than 1.26×10^{-7} cc/sec) during and following exposure to the requirements of Section 3.3 through 3.9. This criteria is based on $10^{-6} A_2$ per hour for tritium.

4. DOCUMENTATION

A formal report should be prepared entitled *(text censored in SNL (U) version)* H1616 Reservoir Qualification Report, to document the reservoir evaluation process. As a minimum, the following information should be included.

4.1 Introduction.

Identify in tabular form the reservoirs for which your report is claiming successful qualification to the requirements of this specification. State in which container the reservoir will be transported (thick or thin walled). Note if you limited testing by choosing worst case scenarios. State whether you followed 10 CFR 71.117 – 71.125 for testing. State where the test and /or analysis records are held and who by position is responsible for their safekeeping.

4.2 Evaluation.

Explain how each reservoir or group of similar reservoirs was evaluated for the requirements in Section 3. For each reservoir or group of reservoirs, include at least the following information:

A. Justify reservoir grouping (if applicable). State why the results for the tested/evaluated reservoir are representative for the entire group. Items of importance may be the following:

- weight
- location of center of gravity
- moment of inertia about CG
- materials of fabrication
- stem and stem protector length, diameter, and thickness (both fill and discharge stem if applicable)
- stem protector thread type and length

B. Evaluate the requirements in Section 3. The following items should be included in the discussion for each requirement:

1. State the evaluation method used (test and/or analysis) and why

2. If qualified by test, discuss the following:
   - test objective(s)
   - justification for reservoir orientation(s)
   - show (or reference) sketch of test setup
   - data collected from test
   - test results; show sketch or photo if necessary

3. If qualified by analysis, discuss the following:
   - analysis method used
   - software benchmarks (i.e., finite element codes should be documented)
   - assumptions made and their effect on your solution: include reservoir orientation(s)
   - show sketch of analysis model and important parameters
   - analysis results

4. Other types of qualification:
   - Give engineering arguments why test or analysis is not needed and how the reservoir in question is qualified to the required environment.

4.3 Reservoir Data.

Include in the qualification report the following reservoir information.

part number(s) when filled and empty	fill pressure	reservoir and valve* weight
valve designation*	end of life pressure +6 months	total shipping weight
valve design temperature*	proof and burst test pressure	structural or service life
shipping configuration	maximum PV energy	maximum number of reclamations
thermal output	reservoir and stem material and material yield strength	stockpile life
tritium fill volume	maximum specified tritium leak rate in std cc/s	sketches of each reservoir

4.4 Test Documentation.

Include in the qualification report a test plan or procedure and data collection sheet for each type of test performed.

4.5 Distribution.

Provide a full copy of the qualification report to DOE/AL/WPD, DOE/AL/WSD, and Sandia National Laboratories, WMD Container Systems department 2165 (see EP401029)

* If valve is integral to reservoir when shipped.

Appendix 3 Tests, Analyses and Assessments

Appendix 3.1 Materials and Service Life Assessments

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Memorandum, E. A. Clark and C. F. Jenkins to Mark N. Van Alstine, *Lifetime of Hydride Transport Vessel (U)*, SRT-MTS-93-4040, May 14, 1993.

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Memorandum, W. L. Daugherty to M. N. Van Alstine, *Post-Test Examination of Nupro Valves (U)*, SRT-MTS-984042, Rev.1, March 30, 1998.

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Appendix 3.4 Leak Rate Correlation

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Appendix 3.5 Drop Test Report

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Appendix 3.6 Vibration and Shock Test Report

D. G. Tipton, *Hydride Transport Vessel Vibration and Shock Test Report*, SAND98-1230, Sandia National Laboratories, Albuquerque, NM, June, 1998.

Appendix 3.7 Structural Assessment

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Calculation, T. Wu, *Maximum Allowable Closure Torque for HTV Valves (U)*, M-CLC-H-01587, Rev. 0, March 5, 1998.

Calculation, T. Wu, *Effect of Temperature Variation on HTV Valve Performance (U)*, M-CLC-H-01616, Rev. 0, April 1, 1998.

Appendix 3.8 Thermal Test Report

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Appendix 3.9 Permeation Leakage Analysis

Memorandum, L. K. Heung to Mark N. Van Alstine, *Hydride Transport Vessel Permeation Analysis*, SRT-HTS-92-0226, December 8, 1992.

Memorandum, A. M. Herb to Mark N. Van Alstine, *HTV Permeation Offgas Evaluation (U)*, DPD-TED-98-0088, July 1, 1998.

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