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Vital Safety Systems Requirements Verification Roadmap for the Remote-Handled Low-Level Waste Disposal Facility

Project File: 31055

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	03/2018	All	New document

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VITAL SAFETY SYSTEMS REQUIREMENTS VERIFICATION ROADMAP FOR THE RH LLW DISPOSAL FACILITY PROJECT

1. Overview and Background

This document summarizes the flow-down of requirements from TFR-483 and SAR-419 and provides a roadmap for a verification of the requirements.

The project vital safety systems include the vault shield plugs (VSP) and the cask-to-vault adapting structure (CVAS).

The vaults are constructed of reinforced, precast concrete cylinders stacked on end and placed in honeycomb-type arrays (see Figures 1 and 2). A 5-ft thick (minimum) removable concrete plug is placed on top of each vault. The plug serves as a radiation shield for emplaced waste.

One CVAS has been designed and constructed to support loading of HFEF-5 canisters and includes CVAS cavity plugs to serve as radiation shielding while loading vaults that include multiple partition voids (see Figure 3).

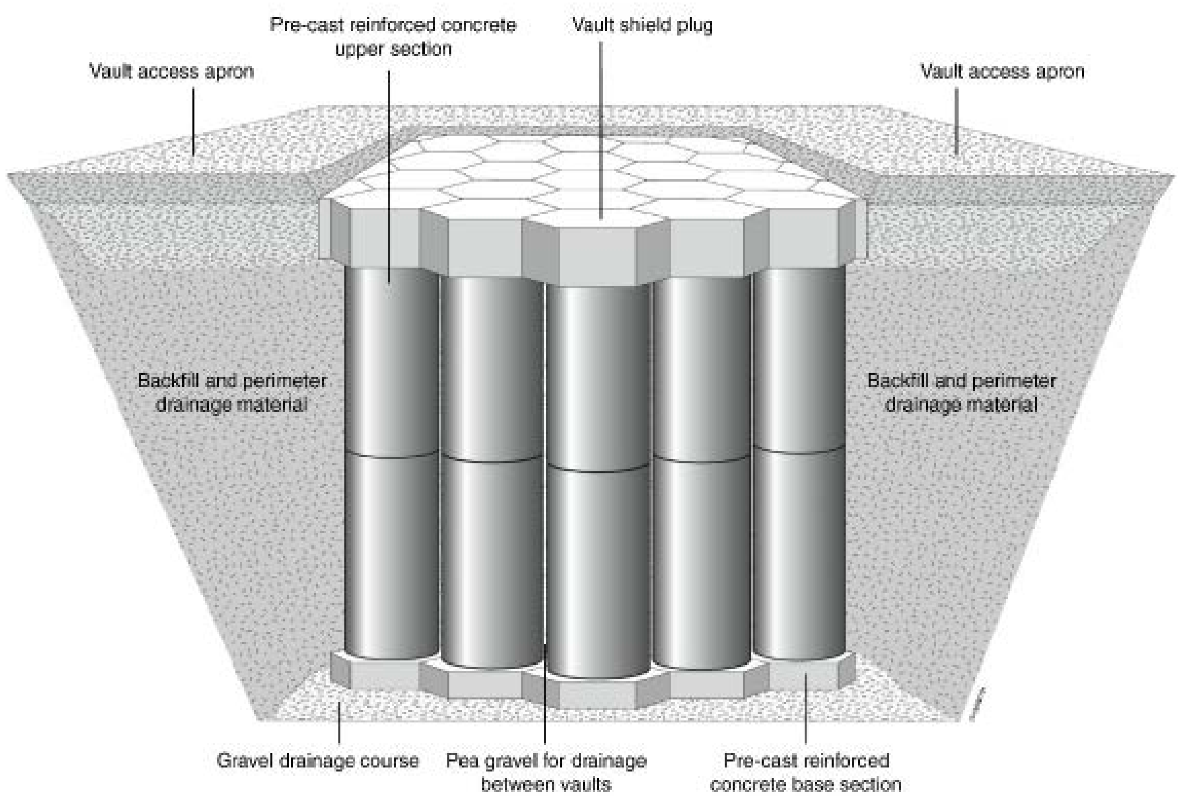

Figure 1. Vault array cross section.

Figure 2. Vault array installation prior to backfill.

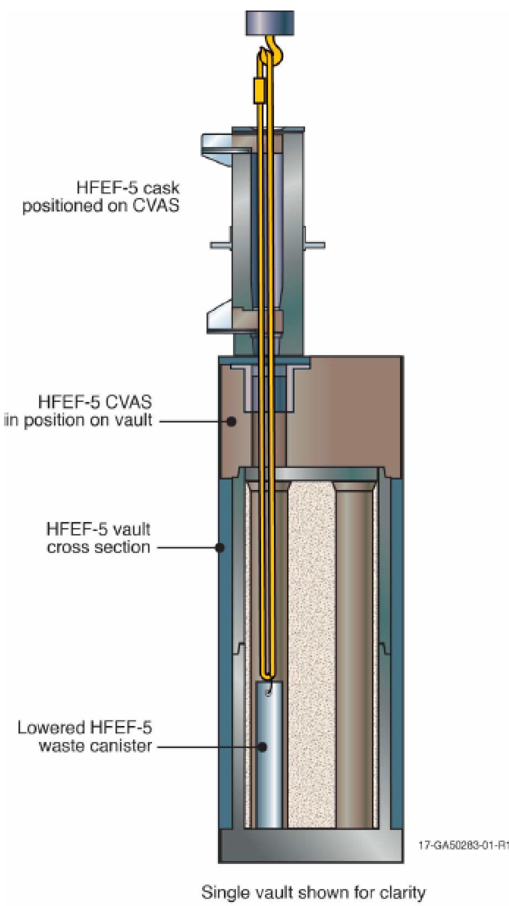

Figure 3. HFEF-5 CVAS.

2. Vault Shield Plugs (VSP)

2.1 VSP Requirements

Table 1 summarizes the requirements for the vaults (including the shield plugs) from SPC-1437, "Design-Build-Operate Performance Specification for the RH LLW Disposal Facility" and TFR-483, "Technical and Functional Requirements for the RH LLW DF" and identifies the design documents that implement the requirement. Requirements were verified through technical checking by Areva and an informal design review by BEA. The design review is documented in the individual deliverable eCRs (see EJ-1683 for eCR numbers for each deliverable).

Table 1. VSP requirements and implementing design documents.

Requirement Reference	Requirement	Resulting Design Documents
Addenda to SPC-1437 and TFR-483 2.0-1 SPC-1437: Section D2., Water, Waste Water, and Drainage Section 2.5.1	Concentrated storm water, industrial waste water, and sanitary waste water discharges shall be at least 400 feet from the vaults.	Drawing 788752, Site Plan
SPC-1437: Section G32., Sanitary Sewer Section 2.8.2.2	Subsurface sewage disposal systems shall be located at least 400 ft from the vaults.	Drawing 788761, Utility Layout Plan -1
TFR-483: Facility, Structure, System, and Component Functions Section 2.1	Provide a reinforced precast concrete vault disposal system that can accommodate waste canisters that are currently being used for disposal of RHLLW resins and activated metals generated at NRF and 60-in.-diameter waste canisters anticipated for future use (see Table 1). Provide a reinforced precast concrete vault disposal system that can accommodate waste canisters that are anticipated to be used for disposal of RHLLW activated metals generated at ATR, MFC, and from new missions, including processing of waste currently in storage at RSWF (see Table 1) Provide a reinforced precast concrete vault disposal system that can accommodate cask liners that are currently being used for disposal of RHLLW ATR resins (see Table 1). The RHLLW disposal facility shall provide reinforced precast concrete disposal vaults for disposing of the estimated quantities of RHLLW generated at INL from FY 2018 through at least FY 2037 (as shown in Table 1).	Drawing 788644, Site Layout Plan Drawing 788643-788658, Vault Drawings
TFR-483: Facility, Structure, System, and Component Functions	Design the facility to accommodate a future Contractor-provided mobile boom crane or a full	ECAR-2815, (RHLLW-CALC-00010) Civil Design Calculations

Requirement Reference	Requirement	Resulting Design Documents
2.1 TFR-483: Functional and Performance Requirements and Key Performance Parameters Section 3.1	span mobile gantry crane; where full span is defined as being able to span the transportation system and the vault array.	
TFR-483: Facility, Structure, System, and Component Functions Section 2.1	Provide a vault and plug assembly to provide shielding, minimize entry of water into the vaults, and allow drainage of any moisture/condensate that accumulates inside the vaults.	Drawings 788643-788658, Vault drawing package
TFR-483: Special Requirements Section 3.2	Vaults and Other Safety Significant Structures, Systems, and Components: The seismic design category for the RHLLW disposal facility vault system and other safety significant structures, systems, and components has been established as a Seismic Design Category-1 with a Limit State of C in accordance with American National Standards Institute 2.26 and DOE-STD-1189 (2008). Design for other natural phenomena shall be designed in accordance with DOE-STD-1020 and DOE-STD-1021 for a Performance Category-2 facility.	ECAR-2810 (RHLLW-CALC-00001), Vault System Structural Design
SPC-1437: Section G.2.8, Sitework	A snow removal area shall be provided. It shall be: 1) Located at least 20-ft from security fences and shall not block the visual line of site of the vaults from ATR-C or the facilities 2) Located further than 400 ft from the vaults. No salts shall be stored within 500 ft of the vaults or used within any area closer than 100 ft from the vaults. No salts shall be used within any area that may drain to the vaults.	Drawing 788644, Site Layout Plan PLN-3368, Maintenance Plan for Performance Assessment and Composite Analysis
SPC-1437: Section H.2.9, Vaults 2.9	Cement specifications shall consider the standards for resistance to degradation as specified by Annex 5 of American Society of Testing and Materials (ASTM) C1562-10"Standard Guide for	PLN-4953 (RHLLW-EIR-00001), Vault Concrete Mix Design Report

Requirement Reference	Requirement	Resulting Design Documents
	Evaluation of Materials Used in Extended Service of Interim Spent Nuclear Fuel Dry Storage." Cement shall meet standards for freeze-thaw protection (A5.4.2), leaching of calcium hydroxide (A5.4.3), aggressive chemicals (A5.4.4), reactions with aggregates (A5.4.5), corrosion of embedded steel (A5.4.6), elevated temperatures (A5.4.7), irradiation (A5.4.8), creep (A5.4.9), shrinkage (A5.4.10), and managing aging-related degradation effects (A5.4.11). a. Minimum cement design should correspond to the exposure categories (ACI 318-08 Table 4.2.1) as follows: · Freezing and Thawing Category freezing class F2 – defined as concrete exposed to freezing and thawing cycles and in continuous exposure to moisture. · Sulfate category S2 ((as determined by the American Geotechnics report, the total sulfate in soil is in the range 22- 87 mg/kg, corresponding water soluble sulfate (SO_4) is 200 ppm). · Low permeability class P1 – defined as concrete in contact with water where low permeability is required. · Corrosion protection of reinforcement Class C2 – defined as concrete exposed to moisture and to external sources of chlorides from deicing chemicals, salt, brackish water, seawater, or spray. b. Corresponding air content, cementitious material types, w/cm ratios, and maximum water-soluble chloride ion content in concrete, percent by weight should be determined as specified in Table 4.3.1 of ACI 318-08.	

Requirement Reference	Requirement	Resulting Design Documents
SPC-1437: Section H.2.9, Vaults	Aggregates including rock, pozzolans, fly ash, and slag shall be selected to minimize alkali-aggregate reaction (AAR) including alkali-carbonate reaction (ACR) and alkali-silica reaction (ASR) using the guidance provided in ACI 201.2R-08.	PLN-4953 (RHLLW-EIR-00001), Vault Concrete Mix Design Report
SPC-1437: Section H.2.9, Vaults	Vaults must maintain structural integrity during operations (years 2018 through 2067) and through the first 500 years of the post-closure period (years 2067 through 2667).	PLN-4953 (RHLLW-EIR-00001), Vault Concrete Mix Design Report PLN-4952 (RHLLW-EIR-00014), RHLLW Vault Durability Report
SPC-1437: Section H.2.9, Vaults	Vault riser sections shall be designed to limit water transport through joints between the riser sections. If multiple riser sections are used in a vault, the design shall not incorporate sealing materials would degrade during the first 500 years via the radiolytic dose rates provided in the facility performance assessment or that could increase water transport between vault sections.	788646 (RH LLW-DRAW-0004), 55-ton Cask Vaults 788649 (RH LLW-DRAW-0007), Nu-Pac 14 210L Cask Vaults 788652 (RH LLW-DRAW-0010), HFEF-5 Cask and LCC Vaults 788655 (RH LLW-DRAW-0013), Modified FTC Cask Vaults
SPC-1437: Section H.2.9, Vaults	Vault Bases: Vault bases shall be designed to fit and support the assembled vault array under all loading conditions bearing on the prepared sub-base.	ECAR-2810 (RHLLW-CALC-00001), Vault System Structural Design
SPC-1437: Section H.2.9, Vaults	Vault bases shall allow water to drain freely from both inside the vault and from between vaults.	788646 (RH LLW-DRAW-0004), 55-ton Cask Vaults 788649 (RH LLW-DRAW-0007), Nu-Pac 14 210L Cask Vaults 788652 (RH LLW-DRAW-0010), HFEF-5 Cask and LCC Vaults 788655 (RH LLW-DRAW-0013), Modified FTC Cask Vaults 788645 (RHLLW-DRAW-0003), 55-ton Cask Vault Array 788648 (RHLLW-DRAW-0006), NuPac 14 210L Cask Vault Array

Requirement Reference	Requirement	Resulting Design Documents
		788651 (RHLLW-DRAW-0009), HFEF-5 Cask and LCC Cask Vault Arrays 788655 (RHLLW-DRAW-0013) Modified FTC Cask Vaults
SPC-1437: Section H.2.9, Vaults	All materials used in the vault system including materials placed beneath and between individual vaults and between the steel liner and concrete vault to reduce the void space shall withstand the expected radiolitic dose ranges provided in the facility performance assessment without degrading during the first 500 years and shall not be degraded during the first 500 years via chemical or biological means. Degradation in this context refers to the creation of additional void space in the concrete that would increase the concrete porosity and permeability. Materials subject to radiolytic degradation include polymer, for example.	ECAR-2810 (RHLLW-CALC-00001), Vault System Structural Design ECAR-2747 (RHLLW-CALC-00006), Vault Plug Shielding Analysis PLN-4952 (RHLLW-EIR-00014), RHLLW Vault Durability Report PLN-4954 (RHLLW-EIR-00013), RHLLW Vault Concrete Safety-Related Design Report PLN-4955 (RHLLW-TEST-00001), RHLLW Vault Concrete Safety-Related Test Plan
SPC-1437: Section H.2.9, Vaults	Snow accumulation over the vaults and adjacent roadway shall be removed to reduce the amount of infiltrating water, and to mitigate the potential for freeze-thaw cracking of the vaults. Snow shall be stored no closer than 400 ft from the vaults.	Drawing 788644, Site Layout Plan PLN-3368, Maintenance Plan for Performance Assessment and Composite Analysis
TFR-483: Facility, Structure, System, and Component Functions Section 2.1	Provide a vault and plug assembly to provide shielding, minimize entry of water into the vaults, and allow drainage of any moisture/condensate that accumulates inside the vaults.	Drawings 788643-788658, Vault drawing package ECAR-2747 (RHLLW-CALC-00006), Radiation Shielding for RHLLW DF.
TFR-483: Facility, Structure, System, and Component Functions Section 2.1	Allow access to individual vaults without disturbing adjacent vaults.	Drawings 788643-788658, Vault drawing package
TFR-483: Special Requirements Section 3.2	Design the vault components to withstand loads based on the proposed vault loading and facility	ECAR-2810 (RHLLW-CALC-00001), Vault System Structural Design

Requirement Reference	Requirement	Resulting Design Documents
	operation and the limits of the equipment used, including the existing and proposed cranes, waste liners, casks, cask transfer equipment, cask transporters, and service vehicles.	
SPC-1437: Section H.2.9, Vaults	Vaults shall be designed to be top-loading, reinforced, precast concrete cylinders with structurally supportive bases and a removable plug for top access and shielding. Unless specifically required, component sizes and thicknesses shall be based on the strength required to meet static and dynamic loading criteria during the disposal operation (SPC-1437, Section H.1.K), dynamic and static loads imposed during operations on the interim soil cover (SPC-1437, Section H.1.L.2), and static load of the engineered cover after facility closure (SPC-1437, Section H.1.K.3).	ECAR-2810 (RHLLW-CALC-00001), Vault System Structural Design
SPC-1437: Section H.2.9, Vaults	Vaults shall be precast concrete with a minimum 28-day compressive strength of 5,000 psi. Reinforcement shall be uncoated carbon steel.	SPC-1857 (RHLLW-SPC-00005), Vault Fabrication Specification
SPC-1437: Section H.2.9, Vaults	Materials used in vault construction shall not adversely impact the corrosion of stainless steel, zircaloy, inconel, carbon steel, or aluminum and shall not decrease the sorption capacity of the resins beyond the range considered in the facility performance assessment. Conditions adversely impacting corrosion include low pH (acidic) environments, and those adversely impacting sorption capacity include high ionic strength solutions.	Drawings 788643-788658, Vault drawing package PLN-4953 (RHLLW-EIR-00001), Vault Concrete Mix Design Report
SPC-1437: Section H.2.9, Vaults	Materials used in the vault shall not generate explosive gases.	PLN-4953 (RHLLW-EIR-00001), Vault Concrete Mix Design Report

2.2 VSP Derived Safety Requirements

The PDSA (now SAR-419) was updated based on the final design and the Vault Shield Plugs were confirmed as safety significant systems, structures and components (SS-SSC)s. The PDSA included the following safety functions:

- The safety function of the Vault Shield Plug is to remain in place and mitigate direct radiation exposure to facility workers during postulated accident conditions.

Several postulated accident scenarios result in derivation of the VSPs as safety significant. These include:

- A scenario in which a design basis seismic event impacts the ability of the VSP (or CVAS) to perform its shielding function [the performance of the vault system during the design basis seismic event is analyzed in ECAR-2810 (RHLLW-CALC-00001).]
- A scenario in which an object is dropped on the VSP (or CVAS) challenging its ability to perform its shielding function. [the drop analysis is documented in ECAR-3273, “RHLLW Cask Drop Analysis”]

The safety functions defined above are reflected in the commercial grade dedication plans. To address shielding and seismic performance, the following design parameters (as defined in the approved final design) are verified as part of commercial grade dedication.

- Critical shielding characteristics (e.g., concrete thickness)
- Concrete density
- Demonstration that the concrete components have no cracks, gaps, or voids that would impact shielding efficacy
- Concrete compressive strength.

2.3 VSP Commercial Grade Dedication Plan

VDR-514691 (RH LLW-CGDP-00001-005), “RHLLW Commercial Grade Dedication Plan,” defines the dedication process by which the VSP is to be designated for use as safety significant and provide reasonable assurance that the item to be used as a safety significant item will perform its intended safety function. The basic safety function of the VSP is to remain in place and mitigate direct radiation exposure to facility workers during postulated accident conditions. See Figures 4 through 7 below for excerpts from VDR-514691 for the derived requirements that are important to the VSP safety function

Technical Evaluation of the CGI Safety Function:

The safety functions of the VSP are evaluated and defined in the approved facility safety basis (PDSA/SAR-419). The safety function of the VSP is to remain in place and mitigate direct radiation exposure to facility workers during postulated accident conditions (see CFP-114 [2.15]; copy provided in Attachment 1).

The ability of the CVAS to mitigate direct radiation exposure during these conditions is addressed in a separate CGD plan. The ability of the VSP to mitigate direct radiation exposure to facility workers during the limiting postulated accident scenarios involving seismic events and drop scenarios is evaluated in this plan as follows:

Shielding Function

RH LLW-CALC-00006, Rad Shielding for RH LLW Facility, [2.5] analyzes VSP parameters density and thickness to demonstrate VSP ability to ensure worker exposure is limited to one mrem/hour as specified in Section 3.1.5 of TFR-483 [2.1] based on an internal source term of 60,000 R/hour.

Seismic Phenomena

RH LLW-CALC-00001, Vault System Structural Design, analyzes VSP compressive strength to demonstrate vault structures including VSP to sustain operating loads (gravity, lateral sub-soil and 'worst case' crane outrigger pad) combined with seismic related loads in accordance with the criteria specified in SPC-1437 [2.3] and TFR 483 [2.1] Section 3.2.5.2 Natural Phenomena Design.

Drop Scenarios

The postulated accident scenario where an object is dropped on the VSP (or CVAS) challenging its ability to perform its shielding function was performed by INL.

Design Requirements

RH LLW-EIR-00013, Vault Concrete Safety-Related Design Parameters, [2.7] evaluates safety functions and other considerations to establish the design requirements for the VSP concrete including a compressive strength of 5000 PSI, optimum density, longevity, and relevant codes and standards. Reference 2.7 Attachment 1 shows actual compressive strength values at 28 days for VSP concrete, Design Mix 2 (at 6500 psi or higher). Reference 2.7 Attachment 2 shows a nominal density of 135 lb/cu-ft based on a unit weight computation of the raw material immersed in water.

RH LLW-EIR-00014, Vault Concrete Selection Report, [2.8] evaluates concrete mixtures to promote longevity, without lessening density and strength.

RH LLW-EIR-00001, Vault Concrete Mix Design Report, [2.9] specifies the raw material constituents for Mix 3 for Vault Base and Upper Riser and Mix 2 for the VSP. The constituents are defined by manufacturer product data and supplier source. During CGD inspection, the certificates of the raw material constituents must match those shown in the design mix report.

Figure 4. Excerpt from VDR-514691, "RHLLW Commercial Grade Dedication Plan"

Considerations for Failure Modes and Effects

References [2.14 and 2.15] both identify critical characteristics to provide reasonable assurance that the VSP will perform its safety function. A review of ***failure modes and effects*** of various aspects of the VSP provides added check for other critical characteristics that might apply.

	Postulated Failure Mode	Evaluation and Mitigating Actions
1	Density, less than 134 PCF [2.5]	If the density is less than required, the VSP cannot be assured to limit exposure below one mrem/hr. Density is assured by implementing the quality inspection plans RH LLW-EIR-00024 [2.11] and RH LLW-TEST-00010 [2.16].
2	Compressive Strength less than 5000 PSI at 28 days [2.7]	If the strength is less than required, VSP cannot be assured the structural integrity to withstand operating and seismic loads. Compressive strength is assured by implementing the quality inspection plans RH LLW-EIR-00024 [2.11] and RH LLW-TEST-00010 [2.16].
3	Failure of the VSP to provide the required thickness	The first set of concrete parts for each steel form type will be subject to constructability checks per fit-up test procedure, RH LLW-EIR-00023, Fit-Up Inspection Plan [2.10]. Correct dimensions are assured by implementing the quality inspection plans RH LLW-EIR-00024 [2.11] and RH LLW-TEST-00010 [2.16].
4	Unacceptable Workability - Casting of the concrete can lead to abnormalities that could, reduce shielding capacity of the VSP.	The self-consolidating concrete (SCC) is formulated and proven in industry use to flow readily to ensure workability and uniform placement. The SCC will be batch tested per RH LLW-EIR-00024 [2.11] or RH LLW-TEST-00010 [2.16] by 'J-Ring' test to meet ASTM Standard C1621-14 [3.8]. This CGD Plan thus designates workability to prevent voids in the concrete as a critical characteristic to be verified by the 'J-Ring' test.
5	Failure of Rebar function	Per RH LLW-CALC-00005, Vault System Min Reinforcement and Lifting Lug Design [2.12], applies steel reinforcement sufficient to meet ACI-318 [3.5] for crack prevention during curing. RH LLW-CALC-00001, Vault System Structural Design [2.6], analyzes loads for a VSP that does not contain structural reinforcement steel. Failure of the rebar does not impact the VSP ability to perform its safety function.
6	Failure Lifting Lug	Per RH LLW-CALC-00005, Vault System Min Reinforcement and Lifting Lug Design [2.12], lifting lugs are designed with sufficient strength for lifting and handling. In addition each shield plug will have been through five lifts prior to being placed into operation.
7	Undersized Width Dimension	The VSP width dimension is not high risk and was validated with the initial validation of the cast. The cast mold was not modified from the initial cast and is not variable ensuring that subsequent pours remained in specification. This was further validated through dimension verification performed with TEST-00010. Based on validation of the initial cast, and subsequent TEST-00010 dimensional verifications, the VSP width is not listed as a characteristic that needs to be validated (low risk) in dedicating the VSP.

Figure 5. Excerpt from VDR-514691, "RHLLW Commercial Grade Dedication Plan"

Critical Characteristics of the CGI to be Verified for Acceptance:

To ensure shielding and seismic performance, the following design parameters will be verified as part of CGD. Quantifiable objective evidence shall be provided for each VSP.

- Concrete thickness
- Concrete density
- Concrete workability
- Concrete compressive strength

Allowable cracks are as follows (identified in RH LLW-SPC-00005):

Cracks – General (All concrete components)

- ≤ 0.01-inch in width (unlimited length). Level 1 – No repair; however, for visible cracks > 0.005-inch in width and ≤ 0.01-inch in width mark ends of cracks and write date using a permanent marker.

  [Note: Visible cracks are cracks that are observed under normal lighting conditions without magnification and without adding solutions or other means to illuminate the crack.]

- > 0.01-inch in width (any length). Level 3 – Write CAR.

Cracks – Spider (All concrete components)

- Spider Cracks (three (3) or more visible cracks all within 2 inches of each other at some point) ≤ 0.005-inch width (any length). Level 1 – No repair; however, for visible spider cracks ≤ 0.005-inch in width mark the extent of the spider crack by circling the area and write date using a permanent marker.

  [Note: Visible cracks are cracks that are observed under normal lighting conditions without magnification and without adding solutions or other means to illuminate the crack.]

- Spider Cracks (three (3) or more visible cracks all within 2 inches of each other at some point) > 0.005-inch width (any length). Level 3 – Write CAR.

Based on the aforementioned Technical Evaluation of the CGI Safety Function, and Considerations for Failure Modes and Effects, this CGD Plan affirms the selection of above BEA provided Critical Characteristics. Verification of these critical characteristics, combined with an NQA-1 graded approach for inspection and testing of manufactured VSP concrete parts per RH LLW-EIR-00024, Vault Component and CVAS Fabrication Quality Inspection Plan [2.11] or RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.16], will provide reasonable assurance that the items will perform the safety function evaluated in Reference [2.14] and specified in BEA CFP-114 [2.15] (attached).

Figure 6. Excerpt from VDR-514691, "RHLLW Commercial Grade Dedication Plan"

Dedication Method(s) to be Used for Accepting the CGI:

The specified critical characteristics for acceptance should be verified using EPRI Method 1, Special Test and Inspection [3.1], as delineated with acceptance criteria, in Table 1, Critical Characteristics for Acceptance [3.1]. Special Inspections Method 1 will be performed by an AFS approved independent inspection agency.

Table 1: Critical Characteristics for Acceptance (CCFA)

	CCFA	Acceptance Criteria	Reference
1	VSP Thickness	minimum 60.0"	RH LLW-CALC-00006 [2.5]
2	Density	Minimum of 134 PCF by Unit Weight per C138-14 [3.3] Volume at 0-Day applies at 14-day and 28-day	RH LLW-EIR-00013 [2.7]
3	Workability	J-Ring test per ASTM C1621 [3.7]	RH LLW-TEST-00003 [2.13].
4	Compressive Strength	Minimum 5000 PSI during the 28 day test Break test per ASTM C39-14 [3.4]	RH LLW-EIR-00013 [2.7]

Special Tests, Inspections, and Analyses to be Performed:

RH LLW-EIR-00024, Vault Component and CVAS Fabrication Quality Inspection Plan [2.11] and RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.16] specify a comprehensive set of inspections and tests to be performed for all manufactured concrete parts including the critical characteristics identified in this CGD Plan for the VSP.

CGI Sampling Plan:

Each VSP concrete part will be 100% visually inspected and tested for thickness and plug integrity.

Each 50 cubic yards and at least one batch will be tested daily for density and compressive strength for Mix 2.

Each 25 cubic yards and at least one batch will be J-Ring flow tested daily for Mix 2.

Documents / Records Required for Acceptance of the CGI:

Documents/records as Quantifiable Objective Evidence (QOE) will result from the implementation of the inspections and tests in this CGD Plan.

The documents/records to be produced will be primarily the result of implementing RH LLW-EIR-0024, Vault Component and CVAS Fabrication Quality Inspection Plan [2.11] and RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.16] for a comprehensive set of parameter measurements for each concrete part including the VSP critical characteristics.

Any and all non-conformances will be address through the AFS non-conformance process with an NCR or SNR.

Figure 7. Excerpt from VDR-514691, "RHLLW Commercial Grade Dedication Plan"

2.4 VSP Verification of Requirements Important to Safety

VDR-629521, “Commercial Grade Dedication Report for HFEF Vault Shield Plugs (HFEF-P1 through HFEF-P15)” references the testing performed and the documents the critical characteristic test results for the VSPs. The references from VDR-629521 can be found in the vendor data system or in EDMS under the following:

- VDR-514691, RHLLW-CGDP-00001, “Vault Shield Plug Commercial Grade Dedication Plan”
- Vault Component Fabrication Data Packages: see Appendix A for a list of vendor data reference numbers
- VDR-575559, RH LLW-GP-022, ”General Submittal for MTI Inc. Materials & Testing Equipment”
- ECAR-2810, RH LLW-CALC-00001, “RH LLW Disposal Vault System Structural Design”
- ECAR-2747, RH LLW-CALC-00006, “Radiation Shielding for RHLLW Facility”
- PLN-4954, RH LLW-EIR-00013, “Vault Concrete Safety-Related Design Parameters”

2.5 VSP Construction Change Verification

Changes during construction followed the Areva change control process and included Engineering Change Notices (ECN) and Field Change Notices (FCN). Areva submitted drafts and final versions of ECN/FCN changes to BEA for review. The final ECN/FCN changes were officially approved via the BEA Construction Field Problem/Change (CFP) process. The CFP records include email approvals from the Design Authority and SMEs as appropriate. After a set number of ECN/FCNs, the Areva QPP required a revision to the engineering document. The document revisions incorporating the ECN/FCN changes also followed the same draft review and CFP approval process.

VSP-related changes included:

- CFP-028, Change to MFTC Canister Size
- CFP-067, Pea Gravel Between Vaults
- CFP-069, Vault Perimeter Gravel
- CFP-071, Stainless Steel Lifting Lugs on Vaults
- CFP-089, Revision to RHLLW-SPC-00014 and Drawing 788658
- CFP-114, SS-SSC Safety Functional as Defined in PDSA-419
- CFP-116, RHLLW-TEST-00003R003-E1 Potable Water and Slump Flow
- CFP-118, ECN RHLLW-EIR-00001R002-E1 Fly Ash Requirements
- CFP-123, SPC-1437 Porosity-Permeability-Chloride Ion Test Requirements
- CFP-130, ECN RHLLW-SPC-00005R002-E2 Defect/Damage Criteria
- CFP-131, ECN RHLLW-TEST-00003R003-E3 Defect/Damage Criteria
- CFP-140, ECN RHLLW-SPC-00005R002-E3 Concrete Repairs
- CFP-141, ECN RHLLW-SPC-00014R002-E1 Vault Subgrade
- CFP-145, ECN RHLLW-SPC-00005R002-E4 Concrete Inspection Criteria Modification

- CFP-168, ECN RHLLW-DRAW-0016R002-E2 Vault Installation Tolerances
- CFP-178, ECN RHLLW-SPC-00005R002-E5 Concrete Repairs
- CFP-225, ECN RHLLW-SPC-00014R002-E2, Changes to Installation Specification
- CFP-229, ECN RHLLW-SPC-00005R002-E7, Concrete Repairs
- CFP-270, ECN RHLLW-SPC-00005R003-E1 Concrete Repair, Temperature and Duration
- CFP-272, ECN RHLLW-DRAW-00015R001-E1, Vault Plug Gravel Clarification
- CFP-281, ECN RHLLW-SPC-00014R003-E2, Concrete Vault Component Field Damage
- CFP-282, ECN RHLLW-SPC-00005R003-E2, Concrete Repair Requirements
- CFP-290 ECN RHLLW-SPC-00005R003-E1 and E3, Field Damage Evaluation
- CFP-314 ECN RHLLW-DRAW-00003, 6 and 9R001-E3 Vault Yard Gravel

Non-conformances were evaluated using the UDQE process to evaluate whether the change had the potential to affect the vault performance assessment, safety basis, or vulnerability and physical protection assessment in accordance with MCP-4058.

2.6 Verification of VSP Operability

VDR-639733, “Vault Array Functional Test – Plug Removal”, documents the test results verifying that the vault shield plugs were removable after the installation of the entire vault array was complete.

2.7 TSR Implementation

The following TSR 419 Specific Administrative Controls (SAC) are implemented in RH-OI-4000, “HFEF-5 Cask Waste Disposal”:

- TSR SAC 5.419.1 Fissionable Material Inventory Limit
- SAC 5.419.2 Container Handling Limit
- SAC 5.419.3 Contractor-approved Cask/Container/Payload Control List

The TSRs are not related to the VSP.

2.8 VSP Configuration Management

See EJ-1683 for a list of the Essential Drawings, System Design Description, PMJs, work orders, and procedures associated with the configuration management of the vault shield plug systems. In addition, configuration management plan SCMP-209 is approved and identifies documentation applicable to the vault plugs. SDD-410 is the system design description for the vault shield plugs and CVAS.

3. CVAS

3.1 CVAS Requirements

Table 1 summarizes the requirements for the CVAS from SPC-1437, “Design-Build-Operate Performance Specification for the RH LLW DF” and TFR-483, “Technical and Functional Requirements for the RH LLW DF” and identifies the design documents that implement the requirement.

Table 2. CVAS Requirements.

Requirement Reference	**Requirement**	**Resulting Design Documents**
SPC-1437 Section H., Vaults 2.9 TFR-483 Functional and Performance Requirements and Key Performance Parameters 3.1	Operations shall accommodate the generator-provided HFEF-5 cask and provide a CVAS and other rigging equipment/platforms as necessary to unload the waste canisters from the cask to the vaults.	See EJ 1727 • Drawing 791351, "CVAS HFEF-5 Cask" • SPC-1857, RHLLW-SPC-00005, "Vault Construction Spec, Fabrication" • ECAR-2810, RHLLW-CALC-00001, "Vault System Structural Analysis" • ECAR-2747, RHLLW-CALC-00006, "Vault Plug Shielding Analysis" • PLN-4954, RHLLW-EIR-00013, "Vault Concrete Safety-Related Design Parameters" • PLN-4952, RHLLW-EIR-00014, "Vault Concrete Selection Report" • PLN-4953, RHLLW-EIR-00001, "Vault Concrete Mix Design Report" • PLN-5076, RHLLW-EIR-00023, "Fit-Up Inspection Plan" • ECAR-2744, RHLLW-CALC-00005, "Vault System Min Reinforcement and Lifting Lug Design" • PLN-4956, RHLLW-TEST-00003, "Vault Compliance Test Plan"

3.2 CVAS Derived Safety Requirements

The PDSA (now SAR-419) was updated based on the final design and the CVAS's were confirmed as safety significant systems, structures and components (SS-SSC)s. The PDSA included the following safety functions:

- The safety function of the CVAS is to mitigate direct radiation exposure to the workers during postulated accident scenarios.

Several postulated accident scenarios result in derivation of the CVAS as safety significant. These include:

- A scenario in which the canister becomes lodged during placement such that the radiological source is positioned at the interface of the cask and CVAS. [This scenario is analyzed in ECAR-2747 (RHLLW-CALC-00006).]
- A scenario in which a design basis seismic event impacts the ability of the VSP (or CVAS) to perform its shielding function [the performance of the vault system during the design basis seismic event is analyzed in ECAR-2810 (RHLLW-CALC-00001).]
- A scenario in which an object is dropped on the VSP (or CVAS) challenging its ability to perform its shielding function. [the drop analysis is documented in ECAR-3273, "RHLLW Cask Drop Analysis"]
- A scenario in which a direct radiation exposure occurs due to toppling of the shielded transfer cask/container while on the CVAS, resulting in shielding failure [This scenario is analyzed in

ECAR-2878 (RHLLW-CALC-00013), "Seismic Stability Evaluation of the RH LLW Casks"]

The safety functions defined above are reflected in the commercial grade dedication plans. To address shielding and seismic performance, the following design parameters (as defined in the approved final design) are verified as part of commercial grade dedication.

- Critical shielding characteristics (e.g., concrete thickness, HFEF-5 CVAS shield ring)
- Concrete density
- Demonstration that the concrete components have no cracks, gaps, or voids that would impact shielding efficacy
- Concrete compressive strength.

3.3 CVAS Commercial Grade Dedication Plan

VDR-633687, "RHLLW Cask to Vault Adapting Structure (CVAS) Commercial Grade Dedication Plan," defines the dedication process by which the CVAS is to be designated for use as safety significant and provide reasonable assurance that the item to be used as a safety significant item will perform its intended safety function. The basic safety function of the CVAS is to remain in place and mitigate direct radiation exposure to facility workers during postulated accident conditions. See Figures 4 through 7 below for excerpts from VDR-633687 for the derived requirements that are important to the CVAS safety function.

Technical Evaluation of the CGI Safety Function:

The safety function of the CVAS is evaluated in the applicable Component Classification Evaluation [2.13] and as specified by Battelle Energy Alliance (BEA) in CFP-114 [2.14] (copy provided in Attachment 1) as remaining in place and mitigating direct radiation exposure to facility workers during postulated accident conditions.

Shielding Function

RH LLW-CALC-00006, Rad Shielding for RH LLW Facility, [2.5] analyzes CVAS parameters density and thickness to demonstrate the CVAS ability to ensure worker exposure is limited to one mrem/hour as specified in Section 3.1.5 of TFR-483 [2.1] based on an internal source term of 60,000 R/hour.

Seismic Phenomena

RH LLW-CALC-00001, Vault System Structural Design, analyzes the CVAS compressive strength to demonstrate vault structures including the CVAS to sustain operating loads (gravity, lateral sub-soil and 'worst case' crane outrigger pad) combined with seismic related loads in accordance with the criteria specified in SPC-1437 [2.3] and TFR 483 [2.1] Section 3.2.5.2 Natural Phenomena Design.

Design Requirements

RH LLW-EIR-00013, Vault Concrete Safety-Related Design Parameters, [2.7] evaluates safety functions and other considerations to establish the design requirements for the VSP concrete including a compressive strength of 5000 PSI, optimum density, longevity, and relevant codes and standards. Because the safety function of the CVAS temporarily replaces that of the VSP during cask loading operations for the HFEF-5 and Modified FTC vaults, the density and compressive strength requirements of the CVAS are bounded by these VSP requirements. Reference 2.7 Attachment 1 shows actual compressive strength values at 28 days for VSP concrete, Design Mix 2 (at 6500 psi or higher). Reference 2.7 Attachment 2 shows a nominal density of 135 lb/ft^3 based on a unit weight computation of the raw material immersed in water.

RH LLW-EIR-00014, Vault Concrete Selection Report, [2.8] evaluates concrete mixtures to promote longevity, without lessening density and strength.

RH LLW-EIR-00001, Vault Concrete Mix Design Report, [2.9] specifies the raw material constituents for Mix 3 for Vault Base and Upper Riser and Mix 2 for the CVAS. The constituents are defined by manufacturer product data and supplier source. During CGD inspection, the certificates of the raw material constituents must match those shown in the design mix report.

Figure 8. Excerpt from VDR-633687, "RHLLW Cask to Vault Adapting Structure (CVAS) Commercial Grade Dedication Plan

Considerations for Failure Modes and Effects

References [2.13 and 2.14] both identify critical characteristics to provide reasonable assurance that the CVAS will perform its safety function. A review of ***failure modes and effects*** of various aspects of the CVAS provides added check for other critical characteristics that might apply.

	Postulated Failure Mode	Evaluation and Mitigating Actions
1	Density, less than 134 PCF [2.5]	If the density is less than required, the CVAS cannot be assured to limit exposure below one mrem/hr. Density is assured by implementing the quality inspection plans RH LLW-TEST-00010 [2.15].
2	Compressive Strength less than 5000 PSI at 28 days [2.7]	If the strength is less than required, the CVAS cannot be assured the structural integrity to withstand operating and seismic loads. Compressive strength is assured by implementing the quality inspection plans RH LLW-TEST-00010 [2.15].
3	Failure of the CVAS to provide the required thickness	Each CVAS will be subject to constructability checks per fit-up test procedure, RH LLW-EIR-00023, Fit-Up Inspection Plan [2.10]. Correct dimensions are assured by implementing the quality inspection plans RH LLW-TEST-00010 [2.15].
4	Unacceptable Workability - Casting of the concrete can lead to abnormalities that could, reduce shielding capacity of the CVAS.	The self-consolidating concrete (SCC) is formulated and proven in industry use to flow readily to ensure workability and uniform placement. The SCC will be batch tested RH LLW-TEST-00010 [2.15] by 'J-Ring' test to meet ASTM Standard C1621-14 [3.8]. This CGD Plan thus designates workability to minimize voids in the concrete as a critical characteristic to be verified by the 'J-Ring' test.
5	Failure of Rebar function	RH LLW-CALC-00001, Vault System Structural Design [2.6], analyzes loads for a CVAS that does not contain structural reinforcement steel. Failure of the rebar does not impact the CVAS ability to perform its safety function.
6	Failure Lifting Lug	Per RH LLW-CALC-00005, Vault System Min Reinforcement and Lifting Lug Design [2.11], lifting lugs are designed with sufficient strength for lifting and handling. In addition each shield plug will have been through five lifts prior to being placed into operation.

Figure 9. Excerpt from VDR-633687, "RHLLW Cask to Vault Adapting Structure (CVAS) Commercial Grade Dedication Plan

Critical Characteristics of the CGI to be Verified for Acceptance:

To ensure shielding and seismic performance, the following design parameters will be verified as part of CGD. Quantifiable objective evidence shall be provided for each CVAS.

- Concrete thickness
- Concrete density
- Concrete workability
- Concrete compressive strength

Based on the aforementioned Technical Evaluation of the CGI Safety Function, and Considerations for Failure Modes and Effects, this CGD Plan affirms the selection of above BEA provided Critical Characteristics. Verification of these critical characteristics, combined with an NQA-1 graded approach for inspection and testing of manufactured VSP concrete parts per RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.15], will provide reasonable assurance that the items will perform the safety function evaluated in Reference [2.13] and specified in BEA CFP-114 [2.14] (attached).

Figure 10. Excerpt from VDR-633687, "RHLLW Cask to Vault Adapting Structure (CVAS) Commercial Grade Dedication Plan

Dedication Method(s) to be Used for Accepting the CGI:

The specified critical characteristics for acceptance should be verified using EPRI Method 1, Special Test and Inspection [3.1], as delineated with acceptance criteria, in Table 1, Critical Characteristics for Acceptance [3.1]. Special Inspections Method 1 will be performed by an AFS approved independent inspection agency.

Table 1: Critical Characteristics for Acceptance (CCFA)

	CCFA	Acceptance Criteria	Reference
1	CVAS Thickness	Minimum 60.0"	RH LLW-CALC-00006 [2.5]
2	Density	Minimum of 134 PCF by Unit Weight per C138-14 [3.3] Volume at 0-Day applies at 14-day and 28-day	RH LLW-EIR-00013 [2.7]
3	Workability	J-Ring test per ASTM C1621 [3.7]	RH LLW-TEST-00003 [2.12].
4	Compressive Strength	Minimum 5000 PSI during the 28 day test Break test per ASTM C39-14 [3.4]	RH LLW-EIR-00013 [2.7]

Special Tests, Inspections, and Analyses to be Performed:

RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.15] specify a comprehensive set of inspections and tests to be performed for all manufactured concrete parts including the critical characteristics identified in this CGD Plan for the CVAS.

CGI Sampling Plan:

Each CVAS concrete part will be 100% visually inspected and tested for thickness.

Each 50 cubic yards and at least one batch will be tested daily for density and compressive strength for Mix 2.

Each 25 cubic yards and at least one batch will be J-Ring flow tested daily for Mix 2.

Documents / Records Required for Acceptance of the CGI:

Documents/records as Quantifiable Objective Evidence (QOE) will result from the implementation of the inspections and tests in this CGD Plan.

The documents/records to be produced will be primarily the result of implementing RH LLW-TEST-00010, Vault Component and Cask-To-Vault (CVAS) Fabrication Quality Inspection/Test Plan [2.15] for a comprehensive set of parameter measurements for each concrete part including the CVAS critical characteristics.

Figure 11. Excerpt from VDR-633687, "RHLLW Cask to Vault Adapting Structure (CVAS) Commercial Grade Dedication Plan

3.4 CVAS Verification of Requirements Important to Safety

VDR-633706, “Commercial Grade Dedication Report for the Modified FTC and HFEF CVAS Plugs,” references the testing performed and the documents the critical characteristic test results for the CVAS Plugs. The references from VDR-633706 can be found in the vendor data system or in EDMS under the following:

- VDR-628984, RH LLW-CP-HFEF-CVAS, “Vault Component Fabrication Data Pkg: Component Fabrication HFEF CVAS”
- VDR-575559, RH LLW-GP-022, ”General Submittal for MTI Inc. Materials & Testing Equipment”

- ECAR-2810 (RH LLW-CALC-00001), “RH LLW Disposal Vault System Structural Design”
- ECAR-2747 (RH LLW-CALC-00006), “Radiation Shielding for RHLLW Facility”
- PLN-4954 (RH LLW-EIR-00013), “Vault Concrete Safety-Related Design Parameters”

3.5 CVAS Construction Change Verification

Changes during construction followed the Areva change control process and included Engineering Change Notices (ECN) and Field Change Notices (FCN). Areva submitted drafts and final versions of ECN/FCN changes to BEA for review. The final ECN/FCN changes were officially approved via the BEA Construction Field Problem/Change (CFP) process. The CFP records include email approvals from the Design Authority and SMEs as appropriate. After a set number of ECN/FCNs, the Areva QPP required a revision to the engineering document. The document revisions incorporating the ECN/FCN changes also followed the same draft review and CFP approval process.

CVAS-related changes included:

- CFP-163, CVAS ECNs (Fabrication detail additions)
- CFP-226 CVAS Protective Iron Edges Fabrication
- CFP-260 Aluminum Tube & Ring for CVAS
- CFP-262 RHLLW-DRAW-0221R000-E1 Corten Steel
- CFP-286 CVAS Drawing ECNs (Aluminum material changes)
- CFP-305, CVAS Chamfer

Three non-conformances (SNR-139, 141, and 145) were evaluated using the UDQE process to evaluate whether the change had the potential to affect the vault performance assessment, safety basis, or vulnerability and physical protection assessment in accordance with MCP-4058.

3.6 Verification of CVAS Operability

VDR-631019, “HFEF CVAS Fit-Up Test Report”, documents the test results verifying that the HFEF CVAS component hole aligns with the HFEF vault and each partition void lines up without any protruding edges and that the dimension from the top of the test canister to the top of the HFEF CVAS Plug is greater than the minimum required for all void partitions in accordance with PLN-5463, RH LLW-TEST-00012, “Vault Fit-Up Inspection Plan.” Results can be found in VDR-631019, “HFEF CVAS Fit-Up Test Report.”

3.7 TSR Implementation

The following TSR 419 Specific Administrative Controls (SAC) are implemented in RH-OI-4000, “HFEF-5 Cask Waste Disposal”:

- TSR SAC 5.419.1 Fissionable Material Inventory Limit
- SAC 5.419.2 Container Handling Limit
- SAC 5.419.3 Contractor-approved Cask/Container/Payload Control List

The TSRs are not related to the CVAS.

3.8 CVAS Configuration Management

See EJ-1727 for a list of the Essential Drawings, System Design Description, PMJs, work orders, and procedures associated with the configuration management of the CVAS systems. In addition, configuration management plan SCMP-208 is approved and identifies documentation applicable to the CVAS. SDD-410 is the system design description for the vault shield plugs and CVAS.

Appendix A

RHLLW Disposal Facility Vault Shield Plug Fabrication Data Package Vendor Data Number References

Vault Data Package Vendor Data Numbers

Vault Component Fabrication Data Pkg: Component Package HFEF-P1	VDR-581911
Vault Component Fabrication Data Pkg: Component Package HFEF-P2	VDR-581917
Vault Component Fabrication Data Pkg: Component Package HFEF-P3	VDR-585235
Vault Component Fabrication Data Pkg: Component Package HFEF-P3	VDR-585235
Vault Component Fabrication Data Pkg: Component Package HFEF-P4	VDR-585240
Vault Component Fabrication Data Pkg: Component Package HFEF-P4	VDR-585240
Vault Component Fabrication Data Pkg: Component Package HFEF-P5	VDR-581922
Vault Component Fabrication Data Pkg: Component Package HFEF-P6	VDR-581928
Vault Component Fabrication Data Pkg: Component Package HFEF-P7	VDR-581933
Vault Component Fabrication Data Pkg: Component Package HFEF-P8	VDR-581938
Vault Component Fabrication Data Pkg: Component Package HFEF-P9	VDR-581943
Vault Component Fabrication Data Pkg: Component Package HFEF-P10	VDR-585245
Vault Component Fabrication Data Pkg: Component Package HFEF-P11	VDR-581948
Vault Component Fabrication Data Pkg: Component Package HFEF-P12	VDR-585250
Vault Component Fabrication Data Pkg: Component Package HFEF-P12	VDR-585250
Vault Component Fabrication Data Pkg: Component Package HFEF-P13	VDR-581958
Vault Component Fabrication Data Pkg: Component Package HFEF-P14	VDR-581963
Vault Component Fabrication Data Pkg: Component Package HFEF-P15	VDR-581968