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1	1	Design Authority L.H. Goldmann [signature] 11/29/99 L6-56			
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[signature] 11/29/99 L.H. Goldmann — Signature of EDT Originator, Date	Authorized Representative for Receiving Organization, Date	J. D. Cloud [signature] 11-29-99 — Design Authority/ Cognizant Manager, Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

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SPENT NUCLEAR FUEL MULTI-CANISTER OVERPACK DESIGN VERIFICATION SUMMARY

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Abstract: This document summarizes the design verification activities performed on the Multi-Canister Overpack design and documents verification plans for design changes during fabrication.

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SPENT NUCLEAR FUEL
MULTI-CANISTER OVERPACK
DESIGN VERIFICATION SUMMARY

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TABLE OF CONTENTS

SPENT NUCLEAR FUEL MULTI-CANISTER OVERPACK

DESIGN VERIFICATION SUMMARY

1.0 PURPOSE

The purpose of this document is to provide a summary of the design verification activities that have been performed on the Spent Nuclear Fuel (SNF) Multi-Canister Overpack (MCO) design and to identify the design verification methods that will be used for design changes during fabrication.

2.0 BACKGROUND

Design of the MCO was initiated in the fall of 1995 and was completed in the spring of 1999 after numerous revisions to the design criteria. Throughout this period, various design verification methods, including Independent Review, Alternate Calculations, and Qualification Testing were used to provide assurance that the design complied with technical requirements. The technical baseline requirements for the MCO are contained in HNF-S-0426, Performance Specification for the SNF Multi-Canister Overpack.

Appendix A to this summary is a matrix listing the technical baseline requirements from the MCO Performance Specification, corresponding verification methods employed, and documentation to support the verification activity.

3.0 VERIFICATION METHODS

The following three design verification methods were used:

3.1 Independent Review

Multiple independent design reviews were held as the MCO design progressed from the Phase I (Conceptual) design through Phase II (Final) design. Subsequent to Phase II design, the design was modified to accommodate changes to the pressure rating, and additional independent reviews were held.

The design reviews conducted included representatives from all interfacing SNF organizations (e.g., subproject Design Authorities, Nuclear Safety, Operations, Environmental, Radiological Protection, Quality assurance, welding engineers, NDE, etc.) and representatives from the US Department of Energy, Richland Operations (DOE-RL) together with their Technical Advisory Group. In addition to these reviewers, an Independent Review Team was established to provide expert review from qualified personnel outside of the SNF organization. These independent reviewers included personnel with ASME Code, materials, and structural engineering experience. At each design review, reviewers were instructed to review the design media for conformance with the requirements in the applicable revision of the MCO Performance Specification. Design features that addressed functional criteria not quantified in the Performance Specification were reviewed by the interfacing subproject design authorities and analysts to determine their acceptability.

Independent Design Reviews were performed on the MCO design in accordance with SNF procedure AP 6-027, which implements the verification requirements of HNF-PRO-1819. Independent design reviews were held at the following design stages:

Phase I – MCO 50% Design
Phase I – MCO 90% Design
Phase II – MCO 60% Design
Phase II – MCO 90% Design
Phase II – MCO 100% Design
450 psig Design Change
450/150 psig Design Change

Both the Phase I and Phase II design reviews included the fuel baskets which are stacked inside the MCO. The baskets were not modified with the pressure rating changes to the MCO.

Reviewers commented on various aspects of the design, and their comments where recorded on Review Comment Records (RCRs). The Design Agent dispositioned comments pertaining to the design documents while the MCO Project Team provided dispositions for comments pertaining to the design requirements. Dispositioned RCRs were then returned to the reviewers for concurrence and approval signatures.

A compilation of the design review documentation is contained in HNF-5222, MCO Design Review Completion Report.

3.2 Qualification Testing

As the MCO design evolved and prototypes were fabricated, numerous testing activities were performed to demonstrate the MCO design's compliance with performance requirements. Test plans were issued identifying test methods, procedures, and acceptance criteria, and test reports were issued to document test results. Most of the testing was completed at the 305/306 laboratories at the Hanford site. Tests performed under the direction of the MCO Project include:

- Prototype Fuel Basket Loading Tests
- Mechanical Closure Prototype Tests
- Shield Plug Threaded Components Torque/Gall Tests
- Shield Plug C-seal Tests
- Final Basket Stacking, Process Tube Insertion and Basket Removal Tests
- Final Shield Plug Seal Leakage Test

In addition to MCO testing peformed by the MCO Project, a full scale proof of performance (first article) test was conducted on the Cold Vacuum Drying (CVD) process equipment. A prototype MCO was used in the test to determine the MCO's performance during the CVD process. Various other informal tests have been conducted to verify the interface of the MCO with the transport cask, the MCO Handling Machine, lifting grapples and fixtures, tooling, and leak test fixtures.

3.3 Alternate Calculations

A significant number of analyses have been performed to demonstrate the performance and safety of the loaded MCO during various lifecycle steps from loading at K Basins through final sealed storage at the Canister Storage Building (CSB). These analyses involve thermal modeling, gas composition determination, drying performance evaluations, corrosion evaluations, pressure relief sizing, and shielding evaluations. As these analyses were based on materials and configurations of the MCO design, they serve as verification that the MCO will perform adequately at K Basins, during transport, at the CVD, and at the CSB.

4.0 VERIFICATION OF DESIGN CHANGES

While it is not anticipated that significant design changes will be made during MCO fabrication, there may be minor modifications to accommodate fabrication techniques or to incorporate improvements. The MCO Design Authority has responsibility for ensuring that all design changes are compliant with technical requirements and that design verification is performed in accordance with governing procedures. Independent reviews of the design changes will be performed and documented for modifications to the MCO Fabrication Specification and MCO design drawings. Evidence of the independent review will be documented on the Engineering Change Notice accompanying the changed document or drawing. Consistent with earlier practice, any modifications that have the potential to impact interfacing SNF subprojects will be presented to the subproject's Design Authority for review prior to implementation.

Should a design change present a question regarding functional performance, additional qualification testing will be performed as determined necessary by the MCO Design Authority and MCO Project Manager.

5.0 CONCLUSION

Design verification methods applied to the MCO design included Independent Review, Alternate Calculations, and Qualification Testing. Results of these verification activities are documented in test reports, analyses, calculations, assessments, and design review completion reports as listed in Appendix A. Any future design changes will be verified by performing Independent Reviews and Qualification Testing, as necessary.

APPENDIX A

DESIGN VERIFICATION MATRIX

SNF Multi-Canister Overpack - Design Verification Matrix

Design Requirements	Verification Method	Verification Document
Design Life: The MCO shall maintain fuel elements and fuel fragments in a *critically* safe array throughout its design life of 40 years both before and after being subjected to Design Basis Accidents (DBAs). The MCO shall not knowingly have design features that would prevent its design life from being extended to a total of 75 years. Design life of the rupture disk shall be one year.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
SNF Confinement: The MCO shall confine its contents during all normal operations and after being subjected to DBAs. The MCO shall be designed to facilitate confinement while process connections are being made and in conjunction with process piping during process operations. This confinement requirement does not apply to a pressure relief discharge path during actuation of any MCO or CVD pressure relief device.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
	Qualification Testing	WHC-SD-SNF-TRP-018, "MCO Mechanical Closure Prototype Testing," S.R. Crow, 12/5/96
SNF Containment: The MCO shall maintain its containment capabilities during and after being subjected to DBAs, except for the cask drops. *During Hanford* on-site transportation and process operations, the total gaseous leakage across the MCO pressure boundary, including process connection seals but excluding *controlled flow through any port, shall not exceed* 1×10^{-5} scc/sec. This gaseous leakage rate is based on a clean seal and a clean sealing surface at the final mechanical closure boundary and associated process boundaries. The MCO, when sealed by welding at the CSB sampling/weld station, shall be capable of not exceeding a maximum total leak rate of 1×10^{-7} scc/sec.	Alternate Calculation	HNF-2155, "MCO Combustible Gas Management Leak Test Acceptance Criteria," Rev. 1, D.L. Sherrell, 2/22/99
	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
	Qualification Testing	Cogema Test Report, 99-1506, "MCO Large Main Seal/Cover Port Seal Leak Rate Test Report," B.L. Hopkins, 10/7/99
	Qualification Testing	WHC-SD-SNF-TRP-018, "MCO Mechanical Closure Prototype Testing," S.R. Crow, 12/5/96
	Qualification Testing	HNF-2709 DRAFT, "MCO

SNF Multi-Canister Overpack - Design Verification Matrix

		Shield Plug Threaded Components Torque/Gall Testing and C-Seal Testing," E.S. Ruff, 8/3/98
Maintainability: The MCO shall be designed to minimize the need for preventative maintenance throughout its design life. The MCO shall be designed to allow removal/replacement of the rupture disk at the K Basins, *CVD*, and the CSB as needed.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Human Factors: The MCO components shall be designed to facilitate handling and assembly with the use of *appropriate handling equipment*. The MCO design shall also enable handling while wearing protective clothing used in radiation zones (e.g., coveralls, gloves, booties, mask, breathing apparatus, etc.).	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Interchangeability and Marking: To the maximum extent possible (design goal), MCO components with like functions shall be interchangeable (i.e., any set of like baskets *can be loaded into any MCO shell, any MCO shield plug and* locking ring can be used to close and seal any MCO shell, etc.). The MCO shell, *shield plug, lifting ring, cover cap,* and the baskets *shall* have unique identification numbers for tracking and accountability purposes.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Environmental Conditions – Hanford Site: The MCO shall be capable of performing its mission while subjected to the environmental conditions listed below: **Temperature (air):** Range: -33°C to 46°C (-27°F to 115°F) Rate of Increase: 14°C (26°F) in 20 minutes Rate of decrease: 13°C (24°F) in 1 hour **Relative Humidity:** Range: 5 to 100 percent Rate of Change: Negligible	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Environmental Conditions – K Basin Storage Pool: The MCO shall be capable of performing its mission while subjected to the environmental conditions listed below: **Temperature (Water):**	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99

SNF Multi-Canister Overpack - Design Verification Matrix

Current Range: 6°C to 38°C (43°F to 100°F) Maximum Allowable: 38°C (100°F) **pH:** Current Range: KE: 5.5 to 7.5; KW: 5.5 to 7.5 Allowable Range: KE and KW: 5.0 to 9.5 **Electrical Conductivity:** Range: KE: up to 5 μS/cm; KW: up to 2 μS/cm Note: μS/cm = micro Siemen per centimeter **Chloride Content:** less than 1 ppm **Nitrate Content:** less than 1 ppm **Sulfate Content:** less than 1 ppm **Phosphate Content**: less than 1 ppm **Fluoride Content:** 0.25 ppm **Sodium Content:** 1 ppm **Calcium Content:** 2 ppm **Iron Content:** 1 ppm	Alternate Calculation	SNF-4079, "Impact of Aluminum on Anticipated Corrosion in a Flooded Spent Nuclear Fuel MCO," P.C. Ohl, R.G. Ballinger, and D.R. Duncan
Environmental Conditions – Cold Vacuum Drying Facility: The MCO shall be capable of performing its mission while subjected to the environmental conditions listed below: **Temperature:** 10°C to 75°C (50°F to 167°F)	Independent Review Alternate Calculations Alternate Calculations	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-2324, "GOTH-SNF Simulation of the Hanford Spent Nuclear Fuel Cold Vacuum Drying Proof of Concept Tests," C.R.Miska, M.J.Thurgood, and B.C.Fryer, 3/2/98 SNF-4083, "Hanford Spent

	 Alternate Calculations	Nuclear Fuel Cold Vacuum Drying Process-Post Test GOTH-SNF Model Simulations of Proof of Performance or First Article Tests and Equipment Performance Evaluation," B. A. Brea and B.C. Fryer, 6/2/99 JMI-980305-6, "Evaluation of Pure Vacuum Pumping Versus Vacuum Pumping with Helium Purge," M.J.Thurgood, 1999
Environmental Conditions – Transportation: The MCO shall be capable of performing its mission while subjected to the environmental conditions listed below: **Temperature:** 0°C to 75°C (32°F to 167°F)	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Environmental Conditions – CSB (Storage and Monitoring): The MCO shall be capable of performing its mission while subjected to the environmental conditions listed below: **Temperature (Tube gas):** 10°C to 132°C (50°F to 270°F) **Temperature Cycling:** Refer to Chapter 4 of HNF-SD-SNF-RPT-004 **Relative Humidity:** Refer to Chapter 8 of HNF-SD-SNF-RPT-004	Independent Review Alternate Calculations Alternate Calculations	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-2256, "Simulation of Normal and Off-Normal Multi-Canister Overpack Behavior,," Rev. 2, D.R. Duncan and M.G. Plys, 10/21/98 HNF-SD-SNF-TI-040, "MCO Internal Gas Composition and Pressure During Interim Storage," Rev. 3, D.R. Duncan and M.G. Plys, 10/23/98

SNF Multi-Canister Overpack - Design Verification Matrix

	Alternate Calculations	HNF-5059, "Evaluation of Internal Gas Composition and Pressure During the Interim Storage of Sealed MCOs in the CSB," M.J. Packer, 9/21/99
Transportability: After fabrication, MCO components shall be transportable by highway from the fabricating facility to the location within the Hanford site where they will be warehoused until requested for the packaging and removal of SNF.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
MCO Design – Code Requirements: The MCO shall be designed in accordance with Divisions 1, 11, 13, and 15 of DOE Order 6430.1A, *General Design Criteria* (DOE 1989). *Safety Class (SC) and Safety Significant (SS)* components providing fuel containment, confinement, and criticality control, shall be constructed to the rules of ASME Boiler and Pressure Vessel Code, Section III, *Rules for Construction of Nuclear Power Plant Components*, Subsection NB (ASME 1998) under the component safety group as guided by the NUREG/CR 3854, UCRL-53544, *Fabrication Criteria for Shipping Containers*. ASME B&PV, Section III, Code Case N-595 shall be used for designing the MCO welded closure that is used after the fuel is loaded and processed. The U.S. Nuclear Regulatory Commission (NRC) positions in Regulatory Guides 1.84 *and* 1.85 *on ASME Section III code cases shall be* reviewed prior to using such code cases for safety class applications for the MCO. Use of additional applicable Section III code cases shall be approved by the Buyer.	Independent Review Alternate Assessment	SNF-5222, "MCO Design Review Completion Report," Rev. *0*, B.A. Christensen, 11/30/99 HNF-3570, "Compliance Assessment of SNF Project MCO with DOE Order 6430.1A," L.H. Goldmann, 10/98
MCO Design Criteria: *The MCO design shall implement the following criteria:* • ASME Section III Code stamp required • Design pressure for collar, shell, bottom plate, and cover cap: 450 psig • Design pressure for shield plug, mechanical closure assembly: 150 psig • Design temperature: 132°C • Processing operating pressure: full vacuum internal with 60 psig external pressure, at 75°C • Processing operating pressure: full vacuum internal with 0 psig external pressure, up to 132°C • Processing operating pressure: 75 psig internal with 0 psig external pressure up to 132°C • The MCO assembly must be designed to accommodate 0.65 inch nominal	Independent Review Alternate Calculations Alternate Calculations	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-2256, "Simulation of Normal and Off-Normal Multi-Canister Overpack Behavior,," Rev. 2, D.R. Duncan and M.G. Plys, 10/21/98 HNF-SD-SNF-TI-040, "MCO Internal Gas Composition and

SNF Multi-Canister Overpack - Design Verification Matrix

differential thermal expansion in the axial direction, between the basket stack and the MCO shell and maintain basket nesting and engagement of the top basket with the shield plug • Maximum allowed radial temperature gradient between the outside of the MCO shell and the center of the MCO shield plug of 100°C, and a design radial temperature difference within the MCO shell wall of 5°C. This requirement is not applicable when the cover cap is welded onto the fueled MCO's collar at the CSB	Qualification Testing	Pressure During Interim Storage," Rev. 3, D.R. Duncan and M.G. Plys, 10/23/98 HNF-2709 DRAFT, "MCO Shield Plug Threaded Components Torque/Gall Testing and C-Seal Testing," E.S. Ruff, 8/3/98
Maximum MCO Assembly Weight: The gross weight of an MCO (including baskets) containing 288 Mark IA fuel assemblies should not exceed 16,082 lbs. or 17,394 lbs. flooded. These weights are based on a 288 Mark IA SNF assembly fuel load with a SNF weight of 11,343 lbs. The gross weight of a MCO containing 270 Mark IV fuel assemblies shall not exceed 19,242 lbs. dry or 20,457 lbs. flooded. This is based on a 270 Mark IV SNF assembly fuel load with a SNF weight of 15,050 lbs. Quoted weights are design goals.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Height of the MCO: The maximum height of the MCO shall not exceed 160 inches (without final cover cap) at a temperature of 25°C. This includes any connections or devices integral to the MCO in facilitating connections to external process equipment and in providing pressure relief. When the final cover cap is welded in place, the maximum height shall not exceed 167.30 inches.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Diameter of the MCO: The nominal outside diameter of the MCO is 24 inches. In no case, including post-accident conditions, is the MCO inside circumference below the bottom of the shield plug allowed to exceed 73.04 inches (23.25 inches * π). The MCO shell is allowed to have a 25.31-inch maximum as-built OD above the 148-inch elevation measured from the MCO bottom. These dimensional limits are applicable during normal operations and post accident conditions.	Independent Review Alternate Calculation	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-3158, "Detailed Simulation of Cask and MCO Drop Onto the Transport Trailer Edge with Subsequent Horizontal Slapdown onto the Canister Storage Building Receiving Area Floor," D. M.

SNF Multi-Canister Overpack - Design Verification Matrix

		Chenault, 9/21/98
MCO Shell Design: The MCO shell is a cylindrical vessel that provides access to its cavity through its top end and receives a shield plug assembly at its top end for closing. The MCO shell has a bottom assembly that provides a permanent sealed closure on the shell bottom end. The MCO bottom assembly is nominally flat and must include an internal liquid collection sump at the MCO centerline. The MCO must be designed with a 1.00-inch minimum allowable distance between the inside of the MCO bottom assembly and the bottom of the lowest basket. The MCO must permit or allow loading and stacking of the fuel baskets within its cavity. The empty shell must be designed to load into and out of the transport cask.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
MCO Closure Design: The MCO shall be designed with a mechanical closure configuration. The closure shall rely on a mechanical elastic/crushable seal to maintain the containment and confinement requirement at the final closure interface. The closure system shall utilize the shield plug/shell interface as the closure boundary where the crushable seal shall be located. The shield plug shall be held in place via a locking ring threaded into the MCO shell. The locking ring shall contain screws that will be tightened to force the shield plug down against the elastic/crushable seal while pushing up on the locking ring. The MCO shall be designed to incorporate a final welded closure cap over the shield plug. The cap shall be welded to the MCO shell, and the weld geometry shall permit a 100 percent ultrasonic examination of the weld. The cap shall be capable/configured for lifting the MCO with the same equipment described in Section 4.13 of HNF-S-0426, *Performance Specification for the Spent Nuclear Fuel Project Multi-Canister Overpack.* The cap shall be capable of withstanding the design pressure rating of 450 psi at 132°C. The cap shall also be capable of withstanding a drop equivalent to a vertical acceleration of 35 g's. The closure cap shall be capable of being fitted with a recessed threaded plug to be used for helium leak testing after welding. This penetration in the cover cap shall be adequately sized and located to permit insertion of a tool to access the threaded plug contained in Port #2. The closure cap shall be designed to accommodate a recessed pressure sensor located in Port #1. The weld joining the closure cap to the MCO shell shall be helium leak tight to 1 x 10^{-7} scc/sec.	Independent Review Qualification Testing Qualification Testing	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 WHC-SD-SNF-TRP-018, "MCO Mechanical Closure Prototype Testing," S.R. Crow, 12/5/96 HNF-2709 DRAFT, "MCO Shield Plug Threaded Components Torque/Gall Testing and C-Seal Testing," E.S. Ruff, 8/3/98
Fuel Basket Designs -- Mark IA/Mark IV Baskets: The Mark IA fuel storage and scrap baskets shall meet the rules of Articles NG-2000, NG-3000, NG-4200, NG-4600, and NG-5000 as applicable; and the ASME Boiler and Pressure Vessel Code Section III Subsection NG (ASME 199) under the	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen,

SNF Multi-Canister Overpack - Design Verification Matrix

component safety group as guided by the NUREG/CR 3854, UCRL-53544, *Fabrication Criteria for Shipping Containers*, 1984. However, no ASME Section III Code stamp is required for the baskets. The design shall meet Service Level A requirements for normal operating loads and Service Level D for accident conditions under ASME Boiler and Pressure Vessel Code, Section III, Subsection NG. During accident conditions the baskets designed for Mark IA fuel and Mark IA fuel fragments/scrap shall maintain the criticality control features defined in HNF-S-0426, Section 4.19.3, *Performance Specification for the Spent Nuclear Fuel Project Multi-Canister Overpack*. The Mark IV fuel storage and scrap baskets do not have to be designed to meet the ASME Code.		11/30/99
Mark IA and Mark IV Baskets: For the handling of both loaded and unloaded Mark IA and Mark IV baskets, the design shall meet safety factors of 3 on material yield and 5 on material ultimate strength. (Design and qualification of the basket grapple interface will be performed by the Cask/Transportation subproject and will not be the responsibility of the MCO Design Agent). These safety factors apply from 5°C through 100°C as the basket handling occurs underwater at the K Basins. Materials of construction for the Mark IV and Mark IA storage and scrap baskets shall be 304L or a material having equal or greater corrosion resistance properties. Scrap baskets materials shall include copper for thermal conductivity. All baskets will be annular open-top containers with a maximum OD of 22.625 inches at 25°C, with the exception of the flexible reed portion of the scrap basket flow restrictor. All baskets will be able to support the fuel at 1.0 g while at 132°C. The basket grapple interface for all baskets shall be a 1/8 inch deep by 1 inch long internal radial groove beginning 1-7/8 inches from the top end of the basket center tube. Basket sizing shall accommodate an approximate 1/2-inch clearance between the top of the fuel elements and the bottom plate of the basket above.	Alternate Calculations Alternate Calculations Alternate Calculations Alternate Calculations	SNF-5526, "Comparison Cases Simulated with HANSF 1.3.2 to Supplement Thermal Analyses Documented in HND-SD-SNF-CN-023," M.G. Piepho, 10/8/99 HNF-SD-SNF-CN-023, "Thermal Analysis of Cold Vacuum Drying of Spent Nuclear Fuel," Rev. 1, M.G. Piepho and R.D. Crowe, 7/20/98 HNF-SD-SNF-ER-018, "Evaluation of Cast Carbon Steel and Aluminum for Rack Insert in MCO Mark IA Fuel Basket," C.E. Graves, 3/21/97 HNF-SD-SNF-ER-019, "Evaluation of Copper for Divider Subassembly in MCO Mark IA and Mark IV Scrap Fuel Baskets," C.E. Graves, 9/29/97

SNF Multi-Canister Overpack - Design Verification Matrix

	Independent Review Qualification Testing	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-4639 DRAFT, "Test Plan and Procedures for MCO Basket Stacking, Process Tube Insertion, and Basket Removal," E.S. Ruff, 11/99
Summary of MCO Fuel Basket Types: The MCO fuel baskets are categorized into two major configurations: 1) intact fuel element baskets and, 2) scrap fuel (fragment) baskets. Fuel baskets must also maintain criticality control for the higher enriched (Mark IA) fuel. These basic requirements lead to four different basket types as follows: • Type (1) must have the ability to hold 48 Mark IA (higher enriched) intact-fuel elements and must have a criticality control exclusion void built into the basket. • Type (2) must have the ability to hold 54 Mark IV intact-fuel elements and does not need the exclusion void. • Type (3) will hold Mark IA (higher enriched) scrap fuel (fragments) and must have a criticality control exclusion void built into the basket. • Type (4) will hold Mark IV scrap fuel (fragments) and does not need the exclusion void. *Note: SPR fuel will be loaded into Mark IA baskets that have been modified to* permit stacking and organization of the smaller diameter SPR fuel elements.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Summary of Fuel Basket Functions: All basket designs shall incorporate a center support tube for axial support during lifting and for protection for the long process tube. Each basket shall be capable of being loaded, in the upright position, by the fuel retrieval system equipment in the K Basins pool.	Alternate Calculations	HNF-2324, "GOTH-SNF Simulation of the Hanford Spent Nuclear Fuel Cold Vacuum Drying Proof of Concept Tests," C.R. Miska, M.J. Thurgood, and B.C.

SNF Multi-Canister Overpack - Design Verification Matrix

		Fryer, 3/2/98
The baskets must be stackable inside the MCO with the basket centerline coincident with the MCO centerline. While stacked inside the MCO, the baskets must provide for insertion of a long process tube down the MCO centerline for water draining, and gas transport, as needed. The loaded baskets shall be capable of being easily and safely handled in the basin water, reliably loaded and nested into the MCO/cask assembly in the K Basins load out pits, and engaged with the shield plug shield/guard plate and axial stabilizer. Basket design shall account for differential thermal expansion when subjected to processing temperatures inside the MCO.	Alternate Calculations	SNF-4083, "Hanford Spent Nuclear Fuel Cold Vacuum Drying Process-Post Test GOTH-SNF Model Simulations of Proof of Performance or First Article Tests and Equipment Performance Evaluation," B. A. Brea and B.C. Fryer, 6/2/99
The baskets shall drain free and not capture or retain excessive water to accomplish the bulk water removal step by the CVD System.	Alternate Calculations	JMI-980305-6, "Evaluation of Pure Vacuum Pumping Versus Vacuum Pumping with Helium Purge," M.J. Thurgood, 1999
The baskets shall support heat transfer into and out of the fuel while in gaseous and vacuum environments inside the MCO. The primary heat transfer mode is radiation and conduction during the static (storage/monitoring) state. Flow capability through the basket baseplates shall be provided to facilitate draining and drying operation. The baskets shall support gas flows needed to properly dry and condition intact fuel and scrap fuel during the vacuum drying process.	Alternate Calculations	JMI-980305-7, "Evaluation of New Intact Fuel Basket Bottom Plate Hole Design on Flow Distribution, Drying and Heating in the MCO (DRAFT)," M.J. Thurgood, 1/18/98
The baskets shall be compatible with the fuel and MCO containment materials during the expected temperatures, pressures, and atmospheres inside the MCO during handling, shipping, storage and processing. The baskets shall maintain their structural integrity during expected internal MCO environmental conditions, normal MCO handling situations, and after accidents (Mark IA storage and scrap baskets only). This structural integrity is required to maintain criticality safety of the MCO when loaded with Mark IA baskets.	Alternate Calculations	SNF-4079, "Impact of Aluminum on Anticipated Corrosion in a Flooded Spent Nuclear Fuel MCO," P.C. Ohl, R.G. Ballinger, and D.R. Duncan,"
The baskets shall be sufficiently strong to preserve the processing ability of the MCO for the bulk water removal and vacuum drying process during normal MCO handling, various internal MCO environments, and after MCO DBA loadings. The baskets shall not introduce any additional gas producing materials into the MCO which significantly increase the pressure of the MCO during storage.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99

SNF Multi-Canister Overpack - Design Verification Matrix

The baskets shall not introduce any materials that will appreciably accelerate corrosion of or significantly alter the properties of the MCO containment boundary. The baskets' bottom structural plate shall have a minimum weight of 50 lbs.	Qualification Testing Qualification Testing	HNF-4639 DRAFT, "Test Plan and Procedures for MCO Basket Stacking, Process Tube Insertion, and Basket Removal," E.S. Ruff, 11/99 HNF-4057, "CVD Proof of Performance (First Article Testing) Test Results," K.J. McCracken, 4/23/99
Mark IA and Mark IV Scrap Baskets: In order to facilitate the safety basis for the CVD process, the scrap baskets shall be designed to remove the heat of radiolytic decay and fuel corrosion/oxidation during the drying process. Thermal analyses have determined that this can be accomplished by providing the equivalent to a minimum 1/8-inch thick, full height copper shroud around the perimeter of the basket, with six equally spaced ¼-inch thick copper divider plates to segment the scrap into six equal area compartments. The six copper divider plates shall be thermally bonded to the outside copper shroud. Alternately, this copper subassembly may be constructed by forming a 1/8-inch thick copper plate into six pie-shaped segments and then thermally joining the segments together, both at the outside perimeter and along the top joints where two 1/8-inch thick plates meet to form a ¼-inch thick divider between segments. Should a material other than copper be considered for thermal conductivity, it must be at least comparable to 1/8-inch thick copper or better when considering the material's thermal conductivity and thickness. A partitioned area within the basket shall be designed for scrap fines loading. Scrap fines will vary in size from ¼-inch pieces to approximately 1-inch pieces. The total volume of the partitioned area shall not exceed 10 percent of the basket area. Material for the partition shall be the same as the other material selected for heat conductivity. The partitioned area for scrap fines must be thermally joined to the segmented plates and must be designed for water draining, gas flow through the container and thermal conductivity, consistent	Alternate Calculations Alternate Calculations Independent Review	SNF-5526, "Comparison Cases Simulated with HANSF 1.3.2 to Supplement Thermal Analyses Documented in HND-SD-SNF-CN-023," M.G. Piepho, 10/8/99 HNF-SD-SNF-CN-023, "Thermal Analysis of Cold Vacuum Drying of Spent Nuclear Fuel," Rev. 1, M.G. Piepho and R.D. Crowe, 7/20/98 SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99

with other areas of the scrap basket. In addition, the partitioned area divider shall have perforations to permit gas flow through the partition wall. The copper subassembly of the scrap basket shall be designed to withstand a distributed load in tension on the outside shroud of 10,350 pounds before yielding and 17,250 pounds before failure. This provides a safety factor of three to yield and five to failure during loading of the basket into the MCO.		
Mark IA Baskets Modified for SPR Fuel: The Mark IA fuel basket design shall be modified to permit loading of SPR fuel elements. SPR fuel elements to be loaded range in length from approximately 5 to 9 inches with an outside nominal diameter of 1.5 inches. A loading jig to be inserted in place of the Mark IA aluminum fuel rack shall be designed to permit stacking of SPR fuel elements either 2 or 3 high to allow loading of all SPR fuel elements in a maximum of 6 baskets. The inside diameter of each loading position shall be sized to allow for a minimum acceptable clearance on the diameter for the largest diameter element. The total equivalent weight load limit of the Mark IA fuel basket shall not be exceeded. Flow paths shall be included in the walls of the loading jig to permit airflow during drying operations. Materials for the jig shall be selected such that the potential for any galvanic action between it and the SPR fuel and cladding is minimized. Hold down criteria for the loading jig shall be the same as that specified for the copper subassembly.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
MCO Shield Plug Design: The MCO shield plug will be a cylindrical forging designed to mate with the open end of the MCO shell. The MCO shield plug also mates with the end effector on the top SNF fuel basket. The MCO assembly must be designed to have at least a one-inch nominal free space between the bottom of the guard plate and the top of the SNF elements or fragments at 72°F. The shield plug will only provide worker shielding on the top of the MCO. The shield plug shall feature an integrally machined axisymmetric lifting ring with a 12 ton lifting capacity when gripped with six equally spaced 1.97 inch tangential length by 0.66 inch radial contact length grippers. The ring will facilitate handling of the MCO package when unloading from the transport cask, CSB storage tubes, and CSB sampling/weld stations with the MHM. The MCO lifting ring design and cover cap lifting rim area must exhibit a safety factor of three on material yield and five on material ultimate strength. The MCO shielding design shall meet as low as reasonably achievable	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99

requirements in accordance with 10 CFR 835, *Occupational Radiation Protection* (CFR 1993), Subpart K, DOE Order 5480.11, *Radiation Protection for Occupational Workers* (DOE 1988), Paragraph 9a, HSRCM-1, *Hanford Site Radiological Control Manual* (RL 1994), Sections 111 and 311, WHC-IP-1043, *WHC Occupational ALARA Program* (WHC 1995d), Section 8.0, and NRC Regulatory Guide 8.8, *Information Relative to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations will be As Low As Reasonably Achievable*, Revision 3, Section C.2.b, "Radiation Shields and Geometry," and Section C.2.f, "Isolation and Decontamination."		
The MCO shield plug will shield workers against photons and neutrons emanating from the inside of the MCO. This shielding shall maintain an average dose across the top of the shield plug of 30 mrem/hr on contact (2 inches) for the average MCO fuel inventory. The 30 mrem/hr limit includes radiation streaming between the MCO shield plug and MCO shell and streaming around penetrations. Streaming emanating from between the MCO and cask is not included. Streaming shall be minimized.	Alternate Calculations	HNF-SD-SNF-CN-026,"MCO Shield Plug Dose Rate Analysis," K.E. Hillesland, 10/06/97
For the worst case MCO Radioactive Source Term, the average dose across the top of the shield plug on contact (2 inches) shall not exceed 100 mrem/hr.	Alternate Calculations	Parsons Infrastructure and Technology Group, Letter # NAN-99-587, "MCO Shield Plug – Supplemental Shielding Analysis, 10/15/99
The shield plug will provide access to the interior of the MCO. The penetrations will connect to four ports counterbored into the top of the shield plug. Flow from Ports 1, 2 and 4 begin at the screens in the guard plate. Flow from Port 3 begins at the screen at the long end of the process tube. A description of the ports, penetrations and associated equipment interface follows:		
Port #1 - Connects to a pressure monitoring penetration that leads to the internal high-efficiency particulate air (HEPA) filter bank. • Up to one-inch diameter drilled penetration, • Capable of accepting a seal and threaded plug, and • Contains a pressure monitoring capsule under the port cover plate,		
Port #2 - Connects to a penetration that leads to the internal HEPA filter bank. • 1-inch diameter drilled penetration, and • Port contains a process valve with a socket head.		
Port #3 - Connects to the long process tube that has a 2 mm screen at the end. • Approximately .59 inch inside diameter (ID) (1 inch schedule XXS pipe) minimum diameter drilled penetration,		

SNF Multi-Canister Overpack - Design Verification Matrix

• Port contains a process valve, and • Requires differentiation in connection for valve operator. **Port #4** - Connects to a rupture disk. • 1-inch diameter drilled penetration, • Port contains a safety class rupture disk that is incorporated into a process valve head, • Connects to guard plate chamber cavity that is filtered with approximately 2 mm screens, and • *Provides backup port to Port #2.* The connections leading to Ports #2 and #3 shall be designed to be easily differentiated by a worker looking at either the top or bottom of the shield plug. The design of the penetrations, ports, and valve mechanism shall implement the following criteria:		
• Process valves shall be capable of normal operation and achieve sealing criteria for five complete cycles. • Provisions for pressurizing the MCO interior with an inert gas. • Provisions for purging gas from the MCO interior. • Penetrations, connections, and seals shall be leakage rate testable in accordance with ANSI N14.5, *Leakage Tests on Packages for Shipment of Radioactive Materials* (ANSI 1987). • Provisions to make or break all connections while continuing to maintain SNF containment, with minimal spread of contamination. • All penetrations to be sealable to the containment leak rate criteria after the *process connection is terminated.* • Connections shall be such as to facilitate their decontamination.	Qualification Testing	HNF-2709 DRAFT, "MCO Shield Plug Threaded Components Torque/Gall Testing and C-Seal Testing," E.S. Ruff, 8/3/98
• Ports, penetrations and connections shall be accessible to the operator from the top face of the MCO. • Penetrations and connections shall not appreciably reduce or impair MCO shielding. • Provisions for removal or reinstallation of sealing mechanisms as required to cover shield plug appurtenances; these sealing mechanisms cannot extend above the top of the shield plug, including fasteners. • Provision to bleed down, in a controlled way into the process piping, internal MCO pressure after process connections are made. • Penetrations and connections shall be designed to facilitate remote operation via long handled tools, via a manipulator, and via manual means.	Qualification Testing	HNF-4057, "CVD Proof of Performance (First Article Testing) Test Results," K.J. McCracken, 4/23/99

SNF Multi-Canister Overpack - Design Verification Matrix

• Port for rupture disk shall contain a cover with minimum 1-inch orifice for protection of rupture disk from an overhead strike. • Process connections shall be designed with a 1 5/16-inch hex head on the process valves and plugs for the operator to engage. • The bottom side of the shield plug shall incorporate a feature (guardplate) that will keep the internal filter elements dry during insertion of the shield plug into the MCO at the K-Basin pool. The guardplate shall contain screened (approximately 2 mm) holes that will pass water during draining operations, gas during drying operations, and flow when the internal pressure is relieved. Approximately 6 square inches of screened opening is adequate. In order to protect the shield plug appurtenances from damage during overhead drops, a minimum of 3/8-inch clearance shall be provided between the top of the installed process valves and the bottom of the cover plates. A counter bore shall be provided in the shield plug that accepts a contact temperature indicator. The size of the counter bore shall be 2.50 inches in diameter and 1.00 inches deep. The location for this device shall be between Ports 3 and 4 on the shield plug's upper surface.		
Internal Process Filter: The MCO shall have internal process filters to support the vacuum drying outflows from the MCO. These filters shall meet the requirements of HNF-S-0556, MCO Internal HEPA Filter Specification, and be installed between the shield plug bottom and the guardplate. The internal process filters shall be protected by a guardplate capable of withstanding a drop equivalent to a horizontal acceleration of 100 g's and a vertical acceleration of 35 g's. The filter assembly installed with the shield plug shall be capable of withstanding the same equivalent drop and still maintain flow capability. (Note: MCO Design Agent is responsible only for the structural attachment of the filter assembly to the shield plug). The filter assembly weight shall not exceed 50 lbs.	Alternate Calculation Independent Review	SNF-4636, "Evaluation of Filter Loading and Pressure Drop During Spent Fuel Drying Processes," B.A. Crea and M.J. Thurgood, 7/2/99 SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Materials, Processes and Parts: The MCO shell shall be fabricated from type 304/304L stainless steel. All components welded to the MCO shell must be made of austenitic stainless steels compatible for welding to 304L stainless steel. A mechanically attached shield plug and any components thereof must be made from either 304L, 304N, B8S, or B8SA. All materials shall be ASME/ASTM certified materials. Provision shall be made to preclude metal-to-metal galling in threaded MCO components. The use of B8S or B8SA material	Independent Review Qualification Testing	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99 HNF-2709 DRAFT, "MCO

SNF Multi-Canister Overpack - Design Verification Matrix

is acceptable for the locking ring set screws, the cover plate bolts, the process valves, threaded plugs, and the rupture disk body. Thermal and chemical compatibility of materials must be shown suitable.		Shield Plug Threaded Components Torque/Gall Testing and C-Seal Testing," E.S. Ruff, 8/3/98
MCO Corrosion Control: Specifications generated for the MCO and MCO components shall require cleanliness during fabrication, handling, and storage - before and during use. ASTM A 380-94, *Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems*, (ASTM 1996a), and ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*, Subpart 2.1, Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components for Nuclear Power Plants (ASME 1994), shall be invoked for cleanliness control. Appendix A, "MCO Corrosion Conditions," describes the corrosion environment encountered by the MCO during various phases of its operation. The MCO shall be designed and constructed to provide full service life under these corrosion conditions. The mechanical seal required for final closure shall be of a material best suited for this application.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Welded Joints: All MCO fabricator pressure boundary welds shall be made in accordance with ASME Section III requirements. All welds shall be sufficiently smooth to enable easy decontamination. Butt welds to be ground flush to within .03 inches of base metal. Weld joint designs shall avoid potential contamination traps to the greatest extent practicable. All MCO pressure boundary welds and welds bearing the weight of the fully loaded MCO must be designed for and pass 100 percent volumetric examination (radiographic or ultrasonic) per ASME requirements. The field weld joining the cover cap to the MCO shell shall be designed to permit a 100 percent ultrasonic examination. As determined by the Buyer, flat surfaces behind the weld a minimum of 1.10 inches below and 1.325 inches above the weld centerline are required to facilitate this examination.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Decontamination Provisions: MCO exposed surfaces shall facilitate their decontamination. All exposed surfaces shall be smooth without cracks or crevices. Blind or hidden corners or joints in areas potentially exposed to contamination that cannot be readily accessed by hand held spray devices shall be minimized.	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Safety Requirements – Safety Classification: MCO components shall be classified by safety class in accordance with the requirements of HNF-PRO-704, *Hazard and Accident Analysis Process*, Section 9.0. MCO components	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen,

SNF Multi-Canister Overpack - Design Verification Matrix

providing fuel containment and criticality control shall be Safety Class items and comply with the requirements of HNF-PRO-704. All other MCO components shall be Safety Significant or General Service items. Safety Class items are: • MCO shell assembly (bottom plate assembly, shell wall and collar) • Mark IA storage and scrap baskets (structural components) • SPR storage baskets (structural components) • MCO Shield Plug Assembly, blind port cover plates, and Port #4 rupture disk (excluding all other port components) • Cover Cap		11/30/99
Design Basis Accidents: All Safety Class items shall maintain containment, confinement, and subcriticality during and after the DBAs listed in HNF-S-0426, *Performance Specification for the Spent Nuclear Fuel Project Multi-Canister Overpack*. All Safety Significant items, whose failure could result in the failure of the Safety Class items above, shall also be designed to withstand the DBAs.	Independent Review Alternate Calculation	SNF-5222, "MCO Design Review Completion Report," Rev. *0*, B.A. *Christensen*, 11/30/99 SNF-3951, "Hydrogen *Combustion in an* MCO During Interim Storage (Fauske and Associates Report 99-14)," M.G. Plys and D.R. Duncan, 2/16/99
Nuclear Criticality Safety: The MCO design shall achieve and maintain a critically safe array throughout the MCO design life. A criticality safety value of 0.95 for Keff shall be used for the MCO design, functions, and related activities. Per criticality analyses performed by the Buyer, this will be satisfied for MCOs containing Mark IA fuel by a nominal 6.625-inch diameter void space at the longitudinal centerline of the MCO. This void space is defined by the 6.625 inch outer by 1.75-inch inner diameter of the center bar of the Mark IA fuel baskets. As this void space is solid steel, by definition, it will preclude intrusion of fuel into this void space. The void space centerline shall not deviate more than two inches from the MCO centerline. The MCO shall maintain these conditions during and after being subjected to the DBAs. MCOs containing Mark IV fuel do *not require this void space. Additionally*, the MCO *(for all fuel types) shall* be capable of withstanding the effects of the DBAs with the maximum inside circumference not exceeding the limits allowed.	*Alternate Calculation* Independent Review	HNF-SD-SNF-CSER-*005*, "Criticality Safety Evaluation Report for Multi-Canister Overpack," S.F. Kessler, 10/11/99 SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Relieve Overpressure: The MCO shall relieve internal pressure in excess of 150 psig while it is flooded with water. The MCO shall provide a safety class rupture disk imbedded in the shield plug to facilitate overpressure protection.	*Alternate Calculation*	HNF-SD-CN-*016*, "Evaluation of MCO Pressure Relief Orifice Effectiveness," D.R.

SNF Multi-Canister Overpack - Design Verification Matrix

The rupture disk shall have a minimum 1-inch diameter flow area to accommodate pressure relief. The rupture disk shall be capable of being covered with a removable 1 inch minimum orifice plate to provide protection to the disk from potential overhead strikes (i.e., dropped tools, gauges, equipment, etc.). Once water is removed from the MCO and the cold vacuum drying process is complete, the plate covering the rupture disk will be replaced with a blind, sealed, cover plate and the disk will become inactive and remain inactive during cover cap welding and interim storage at the CSB.	Independent Review	Duncan and M.J. Thurgood, 12/17/97 SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99
Quality Assurance Requirements: Quality assurance requirements from the SNFP Quality Assurance Program Plan (SNF AP 11-014-01) shall be applied to fabrication, inspection, testing, handling, cleaning, shipping, and storage, including documentation requirements for processes, procedures, training, qualification, and other activities that may affect the ability of the MCO to perform its intended function. The SNFP Quality Assurance Program Plan requires that all SNF Project activities comply with Title 10, *Code of Federal Regulations*, Part 830, "Nuclear Safety Management," Section 830.120, "Quality Assurance Requirements" (10 CFR 830), in accordance with the Site implementation plan, HNF-SP-1228, *Quality Assurance Program and Implementation Plan for Nuclear Facilities* (HNF1998e). Before implementation, the U.S. Department of Energy, Richland Operations Office, will review and approve any changes to HNF-SP-1228 for the SNF Project that could be interpreted as decreasing the Quality Assurance Program's existing commitments for the SNF Project. (Note: Quality Assurance requirements from 10 CFR 72, relating to "important to safety" SSCs are considered encompassed by 10 CFR 830.120 and the Hanford site procedures per WHC-SD-SNF-DB-002, *Spent Nuclear Fuel Project Path Forward, Nuclear Safety Equivalency to Comparable NRC Licensed Facilities*.)	Independent Review	SNF-5222, "MCO Design Review Completion Report," Rev. 0, B.A. Christensen, 11/30/99

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