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FEB 12 1998

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 624278

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Nuclear Safety	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Spent Nuclear Fuel Project	6. Design Authority/ Design Agent/Cog. Engr.: S. D. Roblyer	7. Purchase Order No.: N/A
8. Originator Remarks: This document is being distributed for approval and release.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: CVDF
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-SD-SNF-CSER-006		0	Criticality Safety Evaluation Report for the Cold Vacuum Drying Facility's Process Water Handling System	S	1-2	1-2	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	1	Independent Reviewer V. E. Roetman	for	2/9/98	R3-26						
1	1	Independent Reviewer W. T. Watson			R3-26						
1	1	Cog.Eng. S. D. Roblyer	Steven P Roblyer		R3-26						
1	1	Cog. Mgr. L. J. Garvin		2/9/98	R3-15						
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1	1	Safety D. W. Bergmann		2/9/98	X3-79						
1	1	Safety M. A. Jenson	Mark Jenson	2/9/98	X3-79						

18. S. D. Roblyer Steven P Roblyer 2/9/98 Signature of EDT Originator Date	19. Authorized Representative Date for Receiving Organization	20. L. J. Garvin 2/11/98 Design Authority/ Cognizant Manager Date	21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

Criticality Safety Evaluation Report for the Cold Vacuum Drying Facility's Process Water Handling System

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U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 624278 UC: 510
Org Code: 2T640 2/11/98 Charge Code: LH062
B&R Code: ~~EW31354~~ 39EW70400 Total Pages: 45

Key Words: criticality, safety, cold vacuum drying facility, water, handling, system,

Abstract: This report addresses the criticality concerns associated with process water handling in the CVDF. The controls and limitations on equipment design and operations to control potential criticality occurrences are identified. The effectiveness of equipment design and operation controls in preventing criticality occurrences during normal and abnormal conditions is evaluated and documented in this report.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

Kara J Broz 2/12/98
Release Approval Date

DATE:
STA: 4
HANFORD RELEASE
ID:
FEB 12 1998
Release Stamp

Approved for Public Release

CRITICALITY SAFETY EVALUATION REPORT FOR THE COLD VACUUM DRYING FACILITY'S PROCESS WATER HANDLING SYSTEM

HNF-SD-SNF-CSER-006
Revision 0

December 1997

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ACRONYMS AND ABBREVIATIONS

CSER	Criticality Safety Evaluation Report
CVDF	Cold Vacuum Drying Facility
DOE	U.S. Department of Energy
MCO	multicanister overpack
SNF	spent nuclear fuel

1.0 INTRODUCTION AND SUMMARY OF LIMITS AND CONTROLS

Spent nuclear fuel (SNF) is removed from existing canisters in both the K East and K West Basins and loaded into a multicanister overpack (MCO) in the K Basin pool. The MCO is housed in a shipping cask surrounded by clean water in the annulus between the exterior of the MCO and the interior of the shipping cask. The fuel consists of spent N Reactor and some single pass reactor fuel. The MCO is transported to the Cold Vacuum Drying Facility (CVDF) near the K Basins to remove process water from the MCO interior and from the shipping cask annulus. After the bulk water is removed from the MCO, any remaining free liquid is removed by drawing a vacuum on the MCO's interior. After cold vacuum drying is completed, the MCO is filled with an inert cover gas, the lid is replaced on the shipping cask, and the MCO is transported to the Canister Storage Building.

The process water removed from the MCO contains fissionable materials from metallic uranium corrosion. The process water from the MCO is first collected in a geometrically safe process water conditioning receiver tank. The process water in the process water conditioning receiver tank is tested, then filtered, demineralized, and collected in the storage tank. The process water is finally removed from the storage tank and transported from the CVDF by truck.

1.1 PURPOSE AND SCOPE

The purpose and scope of this report are limited to addressing the criticality concerns associated with process water handling in the CVDF. The controls and limitations on equipment design and operations to control potential criticality occurrences are identified. The effectiveness of equipment design and operation controls in preventing criticality occurrences during normal and abnormal conditions is evaluated and documented in this report.

1.2 LIMITS, CONTROLS AND ENGINEERED FEATURES

The analyses carried out in this Criticality Safety Evaluation Report (CSER) show that for all normal operation, and for accident conditions that satisfy the double contingency criteria, the equipment in the CVDF handling the process water from the MCO will meet the acceptance criteria when the following limits and operational guidelines are met.

1.2.1 Limits

Limit 1 Maximum allowed enrichment in the MCO shall be 1.25 wt% ^{235}U.

Basis: This CSER evaluated the range of enrichments present in the K Basins up to 1.25 wt% ^{235}U, which is the highest enrichment present in the K Basins.

Limit 2 Fuel fragments loaded into the MCO shall be too large to pass through a 0.6-cm (1/4-in.) screen.

Basis: Criticality safety calculations were based on a homogenized mixture of uranium oxide. The fissionable materials in the process water were assumed to be fine particles of UO_2. The flakes of oxides caused by corrosion are highly porous and water filled so that the homogenized model is justified. Metallic fuel particles are screened before they are loaded into the MCO to prevent small metallic particles from migrating out of the scrap baskets or mixing into the process water.

Limit 3 The combined masses of uranium or fissionable materials allowed in unfavorable geometry containers, such as the storage tank or floor drain tank, shall not exceed 615 kg.

Basis: The combined mass of uranium or fissionable materials penetrating process water conditioning systems under normal operation, or by a credible contingency, shall not exceed the safe mass of homogenized UO_2 at 1.25 wt% ^{235}U enrichment. This safe mass is more limiting, from a reactivity standpoint, than all possible variations in enrichments at or below the limit of 1.25 wt% ^{235}U, or transuranic isotopes produced in exposed fuel in the MCOs.

Limit 4 The combined transfer of fissionable materials to contaminated unfavorable geometry containers, resulting from a single contingency, shall not exceed 200 kg.

Basis: The combined mass of uranium or fissionable materials, in unfavorable vessels such as the storage tank, resulting from a single credible contingency, such as an overflow of the process water conditioning receiver tank, shall not exceed one-third of the safe mass allowed in Limit 3. This limit, in combination with Limit 5 that allows for a controlled level of fissionable material contamination, allows for an inadvertent increase of fissionable materials over the control limits 4 or 5 by a factor of two.

Limit 5 The combined mass of uranium or fissionable materials dissolved or suspended in the water, and in the sediments of unfavorable geometry containers, resulting from chronic penetration of the filter and ion exchange system, shall not exceed 200 kg.

Basis: The combined mass of uranium or fissionable materials resulting from normal penetration of the process water conditioning system to unfavorable geometry containers, such as the storage tank, will not exceed one-third of the safe mass allowed in Limit 3. This limit, in combination with Limit 4, allows for an inadvertent increase of fissionable materials over the control limits 4 or 5 by a factor of two.

Limit 6 Vessels containing uncontrolled levels of fissionable materials that does not, or will not, inadvertently contain demineralizer resins, shall not exceed the controlled safe inner diameters for the following situations: A single vessel isolated from neutron interaction with other fissionable materials, an inner diameter of 59.8 cm (23.5 in.). Double parallel vessels with at least 15.2 cm (6 in) separation between outer vessel surfaces, an inner diameter of 59.8 cm (23.5 in.). Double parallel vessels with no separation control between outer vessel surfaces, an inner diameter of 52.5 cm (20.7 in.).

Basis: The safe inner diameter limit of vessels that contain an uncontrolled mixture of fissionable materials and water, such as the MCO process water conditioning receiving tank, floor drain tank, filters, and piping containing unfiltered fissionable materials, was determined for a homogenized mixture of 1.25 wt% ^{235}U enriched uranium oxide at optimum water moderation and total reflection. The reactivity of these vessels will be less than the criticality safety limit for all possible combinations of moderator materials, reflection, and enrichments with all credible buildup levels of transuranic isotopes at or below the limit of 1.25 wt% ^{235}U enrichment.

Limit 7 Single vessels that are isolated from neutron interaction with other fissionable materials, that contain uncontrolled levels of fissionable materials, and that contain, or may inadvertently contain demineralizer resins, shall not exceed the controlled safe inner diameter of 59.8 cm (23.5 in.).

Basis: The safe inner diameter limit of vessels such as the filters was determined for a homogenized mixture of 1.25 wt% ^{235}U enriched uranium oxide at optimum water moderation and total reflection. The reactivity of these vessels will be less than the criticality safety limit for all possible combinations of moderator material, reflection, and enrichments with all credible buildup levels of transuranic isotopes at or below the limit of 1.25 wt% ^{235}U enrichment.

Limit 8 Inadvertent spills of water or liquid with uncontrolled concentrations or masses of fissionable materials from an MCO or a favorable geometry tank, or concentrated water mixtures such as ion exchange materials, shall not exceed a depth of 26.6 cm (10.5 in.).

Basis: The safe slab thickness corresponds to 1.25 wt% ^{235}U enriched uranium oxide at optimum water moderation and total reflection. The depth of potential fissionable material spill volumes shall not exceed the safe depth because of curbs, sump pits, or other features, unless specific situations are analyzed. If water with low fissionable material concentrations mixes with such spills, the height of such a combination will comply with this limit.

Limit 9 The ion exchange module shall consist of six vessels fully encased in concrete. The vessels shall be placed in pairs forming three rows in square array. The dimensions of the ion exchange vessels shall have a maximum outer height of 107.32 cm (42.25 in.), a diameter that corresponds to 16 in. pipe, and a wall thickness at least that of schedule 30 pipe.

Basis: The ion exchange module has been analyzed for its specific geometry so that the criticality safety limit shall not be exceed for all combinations of fissionable material mass, and water and resin moderation for enrichments up to 1.25 wt% ^{235}U. If the concrete thickness covering the vessels is at least 30.5 cm (12 in.) thick, Limit 10 will be satisfied.

Limit 10 A minimum isolation distance of 0.9 m (3 ft) shall be maintained between fissionable materials, such as samples, being transferred outside of process piping and the surfaces of equipment with controlled parameters such as favorable geometry and fissionable material mass restrictions. The minimum isolation distance will be satisfied by at least 12 in. of concrete shield.

Basis: A minimum isolation distance between equipment with favorable geometry or other controlled parameters and other fissionable materials shall prevent significant interaction that may exceed the criticality safety limit basis of the equipment design. The minimum distance specified allows a reasonable 12 in. safety margin to allow for difficulty in controlling materials in transit. Less restrictive minimum isolation distance requirements may be allowed for situations that can be definitely controlled. A concrete shield provides positive isolation that cannot be credibly violated.

Limit 11 The combined transfer of fissionable materials to uncontaminated unfavorable geometry containers, resulting from a single contingency, shall not exceed 300 kg.

Basis: The combined mass of uranium or fissionable materials, in unfavorable vessels such as the floor drain tank that are not normally contaminated with fissionable materials, resulting from a single credible contingency such as a spill of water from an MCO, will not exceed one-half of the safe mass allowed in Limit 3. This limit allows for the estimated credible fissionable material level to be inadvertently increased of by a factor of two.

1.2.2 Administrative Controls

Administrative controls will be used to meet the requirements of Limits 1, and 10. The above limits that will be controlled either administratively, or by an engineered feature or a combination of both administrative controls and engineered features are 3, and 5. Administrative controls will have sufficient checks and reviews so that a violation of the limit requirements will not be credible. In general, engineered features are preferred in lieu of administrative controls when they can be implemented.

1.2.3 Engineered Features

Engineered features will be used to meet the requirements of Limits 2, 4, 6, 7, 8, 9, and 11. In addition, engineered features, or a combination of engineered features with administrative controls, will be used to meet those requirements identified in Section 1.2.2. In general, engineered features, especially those with passive or non active components, are preferred over engineered features that require an active response. The active engineered features require adequate redundancy to complete their required function so that a single failure does not result in a limit requirement violation.

1.3 DIMENSIONS AND CALIBRATIONS REQUIRING QUALITY CONTROL VERIFICATION

1.3.1 Process Water Conditioning Receiver Tank Diameter

The process water conditioning receiver tank's inner diameter shall not exceed 59.8 cm (23.5 in.) for a single tank or two tanks separated by at least 15.2 cm (6 in.). Two tanks with no separation control shall not exceed an inner diameter of 52.5 cm (20.7 in.).

1.3.2 Filter Differential Pressure

The flow differential pressure indicator on the filter downstream of the ion exchange module shall alarm at a level at or below the level determined in final design to meet the requirements of Limit 4 (200 kg fissionable material). This differential pressure corresponds to the limiting fissile material loading.

1.3.3 Demineralizer Vessel Dimensions

Each demineralizer vessel will have a maximum outer height of 107.32 cm (42.25 in.), a nominal diameter that corresponds to 16 in. pipe, and a minimum wall thickness of 0.635 cm (0.26 in.).

1.3.4 Floor Depressions and Curb Heights

Floor depressions and curb heights of unanalyzed situations shall not cause potential spill depths of fissionable materials to exceed the safe depth specified in Limit 8 (26.6 cm [10.5 in.]).

1.3.5 Filter Diameter

The filter inner diameter shall not exceed 59.8 cm (23.5 in.).

2.0 FACILITY AND OPERATION DESCRIPTION

2.1 GENERAL

The CVDF is used to remove free water from SNF contained in the MCO and to vacuum dry the SNF before it is transferred to the Canister Storage Building. A shipping cask–MCO is loaded with fuel underwater at the K Basins, the cask is drained, and the MCO, still full of water, is transported to the CVDF. The cask–MCO is transported on a trailer, and processing at the CVDF occurs with the cask–MCO remaining on the transport trailer. At the CVDF, the basin water, or process water, is drained from the MCO, and the MCO is heated by the tempered water system and vacuum dried to remove as much additional water as feasible. At the end of the vacuum drying process, the MCO vapor is tested for an acceptable level of water content. After sealing the MCO, it is transported to the Canister Storage Building.

The CVDF is housed in a separate new structure located in the Hanford Site's 100 K Area. The building comprises four areas: the processing bays, the process water conditioning room, the transfer corridor and auxiliary spaces, and the administrative area. The processing bays house the vacuum and purge system and the MCO–tempered water system used for MCO drying operations. The process water conditioning room houses the process water conditioning receiver tanks, ion exchange module, and filter that receive and process the contaminated water from the MCOs. The transfer corridor houses change rooms, which provide separate access to each processing bay; various operations support rooms; the pipe runs; and heating, ventilating, and air conditioning ducting to the process bays. See Figure 2-1 for a schematic view of the CVDF.

Each processing bay has two separate process equipment skids, one for the vacuum and purge system and the other for the MCO–tempered water system. The vacuum and purge system is connected to the MCO through hoses attached to the MCO's ports. Bulk water is pumped from the MCO to a process water conditioning receiver tank in the process water tank room. The MCO–tempered water system is connected to the cask annulus and includes a hot and chilled water system that establishes and controls the temperature of the MCO during the drying process. Water circulates through the cask annulus throughout processing.

During bulk water removal, water is drawn from the bottom of the MCO through a long axial tube down the center of the MCO, and purge gas is supplied through the top of the MCO. The bulk water in the MCO is drained to the process water conditioning receiver tank. Following bulk water removal, the MCO is purged with nitrogen to partially dry the fuel and to sweep loose particulate into the internal MCO metal filter. Residual water removed by the vacuum and purge system is collected in a condenser and is then drained to the small collection tank, which is pumped to the process water conditioning receiver tank. Liquid spills within each bay will be confined by the use of a liquid retention basin provided with the process equipment skids. All process connections drain to the skids and all processing equipment (e.g., piping, pumps, valves) are within the skid, so liquid spills and sprays will be retained within the skid basins. The liquid height from spills shall not exceed the control of Limit 8 (26.6 cm [10.5 in.]).

The process water collected in the process water conditioning receiver tank is pumped through a filter and ion exchange module in the process water conditioning system to remove fissionable materials and radionuclides. The processed water is then transferred into an 18.9-kL (5,000-gal) storage tank. A filter is located downstream of the ion exchange module. In this location, the filter will prevent an inadvertent flow of fissionable materials from an ion exchange vessel failure from flowing to the storage tank. The fissionable materials from such a release will thus be retained in the safe geometry of the filter. The level of fissionable material buildup on the filter are maintained below the Limit 4 level (200 kg fissionable material) by differential pressure measurement so that an inadvertent release of fissionable materials by a filter failure will not exceed the allowable limit of fissionable material in the storage tank. The radioactive liquid waste collected in the storage tank is periodically transferred by tanker truck from the CVDF to the Liquid Effluent Treatment Facility.

2.2 FISSIONABLE MATERIALS

The fissionable materials addressed in this CSER originate in the process water drained from the MCO. The fissionable materials are primarily low enriched uranium and plutonium in the oxide form with less than 1% plutonium in the fuel mass. The exposed metallic fuel either is in the form of intact fuel, damaged and degraded fuel, or pieces of fuel scrap that will not pass through a 0.6-cm (0.25-in.) screen. These metal forms of fuel are too large and too dense to flow upwards through the vertical tube during draining. However, part of the fuel oxide is expected to become suspended into the flow with the process water removed from the MCO. The oxides of the fissionable materials have been formed by corrosion. Therefore, the flakes or particles that may exist are highly permeable and water filled. Therefore, a homogeneous model of the oxide-water solution is appropriate.

An upper bounding estimate has been made (Pajunen and Cowan 1996) of the oxides remaining after fuel cleaning and oxidation of uranium fuel in the various processing steps. The oxide limits were reported as 142 kg after cleaning, 0.85 kg formed during MCO filling, and 0.005 kg formed during shipping to the CVDF. The maximum oxide quantity in the MCO is 143 kg at the time the process water is drained from the MCO.

The quantity of fissionable material in the process water has a number of uncertainties. These uncertainties include the quantity of fuel oxide that will be contained in the process water and the levels of uranium and plutonium isotopes that result from the variations in fuel exposures. The quantity of fuel oxides accompanying the process water will most likely be only a fraction of the combined quantity of fuel oxides formed during MCO filling and shipping (0.855 kg). The readily removed oxides that might also have accompanied the process water will have been removed from the fuel by the cleaning operations at the K Basins. The fraction of fuel oxide accompanying the process water is not expected to exceed 25% of the readily removable oxides. Therefore, 0.2 kg of oxide represents the normal design level of oxides in the 1.14-kL (300-gal) of process water drained from the MCO. A maximum design level of oxides in the process water drained from the MCO is represented by 143 kg of fuel oxides, the maximum oxide quantity in the MCO at the time the process water is drained (Pajunen and Cowan 1996).

The initial enrichments of the N Reactor fuels are 0.95 wt% ^{235}U in the Mark IV fuel, and 0.95 and 1.25 wt% ^{235}U in the Mark IA fuel. The fissionable isotopes of plutonium in N Reactor Mark IV and Mark IA fuels are formed in the exposed fuel during reactor operation. The plutonium isotopes build up at a rate that is less than the burnout of fissionable uranium isotopes for both of these uranium enrichments. Analyses on the effects of burn up and fission product decay show that the fresh N Reactor fuel is neutronically more reactive from criticality considerations (higher infinite medium reactivity) than spent fuel with the presence of plutonium products and lower ^{235}U levels due to burnup (Schwinkendorf 1996). As such, all the criticality analyses discussed in this chapter are conservatively performed for the fresh N Reactor fuel. Analysis of the effect on k_{eff} of decay of fission products over a long period of time (e.g., 100 years or more) is described in WHC-SD-SNF-CSER-005 (Schwinkendorf 1996) and provides justification for use of the fresh fuel characteristics in the analyses presented in the chapter. As a result, the isotopic contents of unexposed fuel are the most limiting from a criticality standpoint. The fissionable content of 1.25 wt% ^{235}U in UO_2 is the most limiting form to represent the fuel oxides.

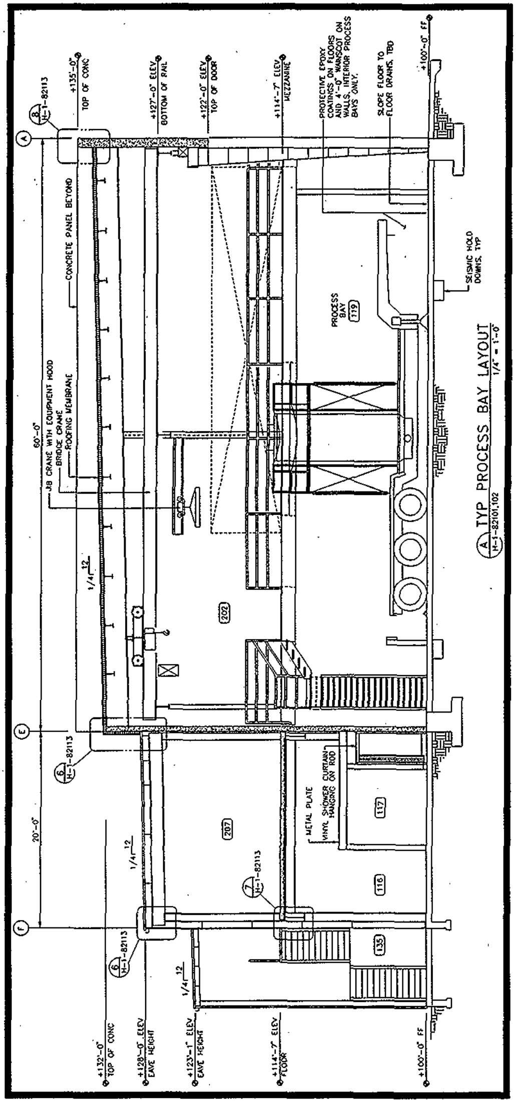
2.3 FISSIONABLE MATERIAL HANDLING AND TRANSFER

MCO water is first collected in a geometrically favorable tank or tanks. These tanks will contain the total free volume of water inside the MCO. All but trace quantities of fissionable materials are then removed from the MCO water by geometrically safe filter vessels and geometrically safe ion exchange columns. The filtered and ionized water is then collected in a large storage tank where it is loaded into trucks and removed from the facility.

The accumulation of fissionable materials in the form of sludge in unfavorable geometry vessels such as the storage tank is maintained within acceptable limits by sampling and monitoring the level of fissionable material, and by initiating corrective actions such as sludge removal.

Engineered safety features are designed to mitigate the consequences to acceptable levels of fissionable materials inadvertent flow or transfer from favorable geometry vessels to unfavorable geometry vessels. The engineered features will satisfy the double contingency principle defined in Section 3.3.

Figure 2-1. Cold Vacuum Drying Facility.



3.0 REQUIREMENTS AND EXEMPTIONS

3.1 DESIGN CODES, STANDARDS, REGULATIONS, AND U.S. DEPARTMENT OF ENERGY ORDERS

This section lists the design codes, standards, regulations, and U.S. Department of Energy (DOE) orders that are specific to criticality prevention in the CVDF.

3.1.1 U.S. Department of Energy Orders and Standards

The following DOE orders are applicable:

- DOE Order 5480.23, *Nuclear Safety Analysis Reports*
- DOE Order 5480.24, *Nuclear Criticality Safety*
- DOE Order 5480.20A, *Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities*
- DOE Order 6430.1A, *General Design Criteria.*

3.1.2 Industry Consensus Standards

The following industry standards are applicable:

- ANSI/ANS-8.3-1979, *Criticality Accident Alarm System*
- ANSI/ANS-8.1-1983, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.*

3.1.3 U.S. Nuclear Regulatory Commission Rules

The following rule is applicable:

- 10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," specifically Section 72.124, "Criteria for Nuclear Criticality Safety."

3.2 CRITICALITY SAFETY LIMIT

The principal criticality prevention criterion or parameter is that the effective neutron multiplication (or criticality) factor (k_{eff}) shall not exceed 0.95 ($k_{eff} = 0.95$). This criterion is based on recommendations for implementing the NRC equivalency requirements described in WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements* (Garvin 1996). A discussion of the computer model validation and bias factors used to achieve a 95% confidence level in the analytical results is given in Section 4.3.

3.3 DOUBLE CONTINGENCY PRINCIPLE

The double contingency principle, as defined in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, to meet the requirements of DOE Orders 5480.23 and 5480.24, states that the process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions to occur before a criticality accident is possible. DOE Order 5480.23, Attachment 1, paragraphs 4.f.3(d)8 b and c, requires application of the double contingency principle as defined in ANSI/ANS-8.1-1983 (ANSI/ANS 1983). These requirements are prescriptive without providing any quantitative limits on the value of k_{eff} under the double contingency conditions. ANSI/ANS-8.1-1983 (ANSI/ANS 1983) is similarly prescriptive. DOE Order 6430.1A, Chapter 13, Section 1320, delineates criteria for irradiated fissile material storage facilities. It provides no specific guidance on double contingency but references 10 CFR 72 for further guidance. The double contingency criterion delineated in paragraph 10 CFR 72.124 (a) is similar to the one quoted from DOE-STD-3009-94 without defining a quantitative limit on the value of k_{eff}.

As interpreted in this report, the criticality safety limit shall not be exceeded by single, unlikely, and independent contingencies. The abnormal and accident scenarios addressed in Section 6.0 are postulated based on events that, because of design controls, have a very low probability of occurrence. In addition, the factors affecting the reactivity of each single occurrence have been conservatively defined, within the constraints of the design or the realistic extent of a control loss, so that the reported consequences represent or exceed all credible situations that can be involved in the scenario considered. The following are examples of single, unlikely, and independent contingencies that can occur in the CVDF:

- MCO drain line break or process water conditioning receiver tank spill
- Filter failure
- Ion exchange column failure
- Process water conditioning receiver tank overflow
- Design basis earthquake.

The following are examples of exceeding single, unlikely, and independent contingencies:

- Concurrent failure of two filters or ion exchange columns
- Concurrent failure of two independent engineering controls
- Beyond a design basis earthquake.

3.4 EXEMPTIONS

There are no exemptions.

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4.0 METHOD OF ANALYSIS AND RESULTS

4.1 MODEL DESCRIPTION

The MCNP code (Breismeister 1993) was the analysis tool used in the preparation of this document. The MCNP code is a Monte Carlo model that is used for modeling of three-dimensional geometries in detail; it uses continuous energy nuclear data libraries. The Monte Carlo technique simulates individual particles, such as neutrons, and tallies the interactions and effects specified by the user. The Monte Carlo method can solve complicated geometries that are difficult to model by other methods. The accuracy and precision of the results, such as reactivity, depend on the number of particle histories used in the calculation. The MCNP code has been benchmarked with a large variety of experimental data and is used extensively for reactivity calculations.

4.2 ASSUMPTIONS

The following assumptions were made in the model.

- Highest uranium enrichment is 1.25 wt% ^{235}U.
- Fissionable materials are homogenized solutions of UO_2.
- Theoretical density of UO_2 is 10.96 g/cm^3
- Bounding density of UO_2 powder is 5 g/cm^3 (Pajunen 1996)
- Uranium enrichment of 1.25 wt% ^{235}U is the limiting case for all lesser enrichments and for fissionable materials formed by fuel exposure.
- Normal design concentration of UO_2 in process water is 0.00018 g/cm^3, which corresponds to 0.2 kg per 1.14 kL (300 gal) of process water from MCO draining.
- Maximum design concentration of UO_2 in process water is 0.13 g/cm^3, which corresponds to 143 kg per 1.14 kL (300 gal) of process water from MCO draining.
- Design concentration of UO_2 in sludge is 0.01 g/cm^3.
- Total process water volume in MCO and shipping cask is 1.14 kL (300 gal).
- Density of $C_{18}H_{18}$ ion exchange resin is 0.92 g/cm^3

4.3 COMPUTER MODEL VALIDATION

4.3.1 Critical Benchmark Experiments

The MCNP computer code (Breismeister 1993) is used all over the world and has been extensively tested with its ENDF/B-V-based cross sections. The code development group at Los Alamos National Laboratory, where MCNP was developed, has a set of 25 calculational benchmarks that extensively test various options within the code. Additionally, MCNP has been certified for use on Hanford Site computer platforms (Carter 1995). This section justifies the validity of the calculational methods and neutron cross sections used by reporting the results of critical benchmark experiment analyses.

4.3.2 Benchmark Experiments and Applicability

Benchmark analyses have been performed with MCNP and the associated cross sections, as documented in Appendix G of *MCNP--A General Monte Carlo Code N-Particle Transport Code, Version 4a* (Breismeister 1993). These analyses were performed for both fast and thermalized benchmark problems (Whalen 1991). Six problems dealt with various uranium critical systems. In addition to these experiments, experiments with N Reactor fuel and low-enriched uranium were performed that are particularly applicable to the MCO models. These experiments and results are discussed below.

An evaluation of K Basin criticality made by Wittekind (1992) included a validation of the MCNP code (Carter 1991). Comparisons were made to several criticality experiments and to other criticality codes, specifically the WIMS (versions D and E) code (WTC 1992). The comparisons provide good support for the use of MCNP in low-enriched uranium systems typical of N Reactor fuel in the K Basins.

The experimental support for the validation of this study was reexamined (Schmittroth and Ruben 1996) to determine a calculational bias to be used in further criticality evaluations. New validation calculations were not undertaken. Two experiments reported by Wittekind were considered: an early report on UO_3-H_2O solutions (Neeley and Handler 1961) and a lattice experiment using actual Mark IA N Reactor fuel elements (Brown et al. 1965). A third experiment performed by Douglas United Nuclear in the 105 N Fuel Storage Basin (Toffer 1975) reported k_{eff} values that were often well below the MCNP results. Finally, results from a benchmark experiment using 2.35 wt% enriched fuel (Briggs et al. 1992) are included. The experimental results, a statistical analysis, and analysis results and recommendations are discussed in detail in Schmittroth and Ruben (1996). A few details are provided below from that report.

4.3.2.1 UO_3-H_2O Solution Measurements. The homogeneous wet uranium UO_3-H_2O solution experiments consisted of 12 measured values for three different enrichments and a range of hydrogen-to-uranium ratios from 3.73 to 7.45 (Neeley and Handler 1961). Table 4-1 shows numerical values for both the experimental and MCNP results.

Table 4-1. Monte Carlo N-Particle (MCNP) Calculations and Experimental Results for Homogeneous UO_3-H_2O Systems.

Enrichment	H/U	MCNP	Experiment	Experimental uncertainty
1.0059	3.772	0.9898	0.9920	0.0060
	4.999	0.9945	0.9925	0.0050
	6.614	0.9830	0.9875	0.0058
	6.881	0.9761	0.9821	0.0054
	7.449	0.9680	0.9702	0.0070
1.0704	3.728	1.0125	1.0063	0.0070
	5.778	1.0103	1.0064	0.0080
	7.075	0.9964	0.9957	0.0061
1.1586	3.728	1.0358	1.0298	0.0060
	5.926	1.0412	1.0330	0.0051
	6.838	1.0311	1.0313	0.0032
	7.449	1.0240	1.0209	0.0051

H/U = Hydrogen to uranium (ratio).

4.3.2.2 Mark IA Lattice Experiment. A set of criticality measurements was made using a lattice of actual unexposed N Reactor Mark IA fuel elements (Brown et al. 1965). The experiment consisted of three distinct types of measurements (exponential pile, neutron multiplication, and pulsed-neutron) and two fuel lattice configurations (Mark IA outers and tube-in-tube assemblies). Several different lattice pitches (2.8 in., 3.1 in., and 3.4 in.) were also included.

The experiment was representative of actual N Reactor fuel configurations, using fuel elements of metallic uranium with density close to 18.64 g/cm^3. However, experimental uncertainties were not reported either in the initial report or by Wittekind (1992). Representative MCNP statistical uncertainties were determined to be 2 mk. An experimental uncertainty of ±5 tubes was determined, which corresponded to an uncertainty of ±0.005 in k_{eff}.

Experimental and calculated values were compared by fitting curves to the calculated points. Ratios of the MCNP-fitted curves to the experimental values were found to be 0.9979, 0.9968, and 1.0077 for the lattice pitches 2.8 in., 3.1 in., and 3.4 in., respectively.

4.3.2.3 Benchmark Experiment for 2.35 wt% Enriched Lattice. A set of measurements was performed at the Pacific Northwest National Laboratory critical mass laboratory and documented in LEU-COMP-THERM-001 (Briggs et al. 1992). Results are given for eight water-moderated

UO_2 (2.35 wt% enriched) lattices, mostly grouped in three clusters. The reported benchmark value for k_{eff} is 0.9998 ± 0.0031. (The value less than one accounts for a small correction from acrylic lattice plates omitted from the model.) The benchmark report also includes MCNP results with statistical errors for comparison (approximately 1.6 mk). Resulting values are shown in Table 4-2.

Table 4-2. Monte Carlo N-Particle Calculations from Benchmark Report LEU-COMP-THERM-001.*

Case number	Number of clusters	Cluster dimensions (No. of rods, X x Y)	Monte Carlo N-Particle
1	1	20 x 18.08	0.9987 ± 0.0016
2	3	20 x 17	0.9977 ± 0.0017
3	3	20 x 16	0.9956 ± 0.0016
4	3	20 x 16 (center) 22 x 16 (two outer)	0.9992 ± 0.0014
5	3	20 x 15	0.9970 ± 0.0016
6	3	20 x 15 (center) 24 x 15 (two outer)	0.9955 ± 0.0015
7	3	20 x 14	0.9968 ± 0.0017
8	3	19 x 16	0.9921 ± 0.0015

*Source: Briggs, J. B., et al., 1992, *International Handbook of Evaluated Criticality Safety Benchmark Experiments, Volume IV, Low Enriched Uranium Systems*, NEA/NSC/DOC(95)03/IV, Nuclear Energy Agency, Organization for Economic Cooperation and Development, Paris.

4.3.3 Statistical Analysis

The results of the above cases were used to determine a calculational bias, b, defined by

$$k_{calc} = k_{eff} + b$$

where k_{calc} represents the calculated estimate of k_{eff}.

A lower tolerance limit, b_L, was established such that one is 95% confident that 95% of the population is above the limit. The non-central t-distribution gives a prescription (Resnikoff and Lieberman 1956) for this limit:

$$b_L = b_{ave} - K_b s_b$$

where b_{ave} is the mean value and s_b is the corresponding sample variance. The multiplier K_b was found from statistical tables of the non-central t-distribution that depended on the number of degrees of freedom for the supporting measurements.

Table 4-3 shows the results: the average bias, b_{ave}, and the associated sample variance (expressed as a standard deviation, s_b) for each of the three individual data sets and for the pooled total set of data. The average assigned experimental uncertainty, $\sigma_{m\text{-}ave}$, is shown for comparison.

Table 4-3. Statistical Monte Carlo N-Particle Bias Results for Three Experiments and the Pooled Data.

Description	n	b_{ave}, mk	s_b, mk	$\sigma_{m\text{-}ave}$, mk	$sb/\sigma_{m\text{-}ave}$
UO_3-H_2O solution	12	1.2	4.4	5.8	0.76
Mark IA elements	3	0.8	6.0	5.0	1.20
Benchmark experiment	8	-3.2	2.2	3.5	0.64
Pooled data	23	-0.4	3.8	4.9	0.78

b_{ave} = average bias.
S_b = sample variance.
$\sigma_{m\text{-}ave}$ = average assigned experimental uncertainty.

Based on the results in Table 4-3, the pooled bias (b_{ave} = -0.4 mk), was chosen to use in computing the calculational bias. This choice includes the lower values of the benchmark data, giving a conservative result. A standard deviation (s_b) of 5.0 mk was chosen in favor of the somewhat lower value of 3.8 mk associated with a pooled sample variance. The latter value assumes that all the data points are independent, while the larger value is generally consistent with the results in Table 4-3.

Finally, a value of the multiplier K_b was determined. A precise value for K_b can only be determined for a known number of degrees of freedom. Nevertheless, for a 95/95 tolerance limit, standard non-central t-distribution tables show that K_b ranges from 2.4 to 1.9 as the degrees-of-freedom range from 20 to 100. Given that a somewhat conservative value was already chosen for s_b, a conventional and rounded value of $K_b = 2.0$ is a good practical choice.

The final result for the lower tolerance limit of the bias (calculated to two significant figures and rounded up to be conservative) is

$$b_L = -0.4 - (2)(5.0)$$

$$= -11 \text{ mk} .$$

Therefore, +11 mk should be added to MCNP-computed criticality results before checking for other prescribed limits.

To account for MCNP statistical uncertainties, an additional value 1.645 σ_c is added in quadratic form to the bias uncertainty. This means that the MCNP statistical uncertainties are not correlated to the uncertainty in the bias when compared to experiment. The value of 1.645 is the number of standard deviations in the standard normal distribution required to yield 95% confidence in the calculation. For example, a value of $\sigma_c = 2.0$ mk would yield a combined limit of

$$-0.4 - [10^2 + (1.645 \times 2)^2]^{1/2} = -10.9 \text{ mk} .$$

4.3.4 Results

The results are summarized by

$$k_{calc} + 0.0004 + \sqrt{0.010^2 + (1.645\sigma_{calc})^2} < k_{limit}$$

where k_{calc} and σ_{calc} represent the calculated value for k_{eff} and its standard deviation respectively. The limit, k_{limit}, is an established limiting value. The multiplier of 1.645 was obtained from tables of the normal distribution. This multiplier ensures that 95% of the MCNP population is bounded by the limit and assumes that there is no uncertainty in the standard deviation, σ_{calc}.

A value of 0.004 k for σ_{calc} is larger than that accepted by almost all criticality calculations done by specialists using MCNP. For this value, the bias limit would be

Equations below were modified to remove k

$$k_{calc} + 0.0004 + \sqrt{0.010^2 + (1.645 * 0.004)^2} < k_{limit}$$

$$k_{calc} < k_{limit} - 0.013$$

so

$$k_{calc} + 0.013 < k_{limit}.$$

All resulting values are rounded up to be conservative.

Using the above calculated bias value means that the k_{calc} computed from a new MCNP run would have to be below k_{limit} - 0.013 k in meeting the allowable limit on k_{eff}. For a k_{limit} of 0.95, k_{calc} would have to be less than 0.937 to be within acceptable limits. If this particular value is used for the acceptable limit, the σ_{calc} must be less than 0.004 for each calculation.

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5.0 NORMAL OPERATION EVALUATION

This section discusses the design acceptability of equipment containing fissionable materials in the CVDF. A summary of the normal operations and controls of these equipment items is listed in Table 5-1. The accident conditions included in Table 5-1 will be discussed in Section 6.0.

5.1 PROCESS WATER CONDITIONING RECEIVER TANK

The 1.14-kL (300-gal) process water conditioning receiver tank collects process water from the MCO. The process water will not be tested for fissionable material content prior to transfer to the process water conditioning receiver tank. Therefore, the diameter not greater than 23.5 in. single vessels or double vessels with at least 6 in. spacing was controlled by Limit 6 so that the criticality safety limit will be satisfied for all fissionable material concentrations of the incoming process water. The tank volume is adequate to hold the liquid contents of an MCO. The tank will be emptied before receiving process water from an MCO. Instrumentation will stop tank filling in the case of an overflow. These controls are not required for criticality safety.

5.2 PROCESS WATER CONDITIONING ION EXCHANGE COLUMNS MODULE

The process water conditioning ion exchange columns module removes almost all of the fissionable materials from the process water transferred from the process water conditioning receiver tank. The accumulation and the concentration of fissionable materials in the incoming process water are not controlled. Therefore, the geometry of the ion exchange module is controlled in accordance with Limit 9. Ion exchange module vessel maximum outer height (42.25 in.) diameter corresponds to 16 in. pipe and wall thickness of schedule 30 pipe with at least 12 in. thick concrete covering. No other controls are needed to satisfy criticality safety.

5.3 STORAGE TANK

The storage tank receives filtered and demineralized process water from the process water conditioning receiver tank. Only a very small fraction (less than 0.0001) of the uranium oxide and other fissionable materials is expected to penetrate the filter and ion exchange module because of the finite efficiency of the system components. Part of these fissionable materials that penetrate the filter and ion exchange module will remain soluble and be trace contaminants in the process water removed from the tank. The remainder of the fissionable materials will settle and form deposits in the tank. Final design of the tank will include a method of controlling the quantity of fissionable materials in the storage tank so that it remains below 200 kg (Limit 5).

Table 5-1. Normal and Accident Conditions of Cold Vacuum Drying Facility Equipment. (2 sheets)

Equipment item	Normal function	Criticality controls	Accident condition	Accident discussion reference
300-gal process water conditioning receiver tank	Collects water volume from MCO before other processing is initiated. This tank meets criticality safety criterion for all credible quantities of fissionable materials and water.	Inner diameter not greater than safe diameter (23.5 in.) specified in Limit 6	No credible accident will violate control	None
Ion exchange module with six vessels	Removes fissionable materials from MCO water. This module meets criticality safety criterion for all credible quantities of fissionable materials and water.	Diameter, wall thickness, and length of ion vessels do not exceed specifications of Limit 9.	No credible accident will violate control	None
Filter located upstream of ion exchange module	Removes particles of UO_2 from MCO water. The filter vessel meets criticality safety criterion for all credible quantities of fissionable materials and water.	Inner diameter not greater than safe diameter (23.5 in.) specified in Limit 6	No credible accident will violate control	None
Filter located downstream of ion exchange module	Removes particles of UO_2 from MCO water. The filter vessel meets criticality safety criterion for all credible quantities of fissionable materials and water.	Inner diameter not greater than safe diameter (23.5 in.) specified in Limit 7	No credible accident will violate control	None
Storage tank	Collects filtered and demineralized processed water from MCO	Mass of fissionable materials in tank sediments does not exceed 200 kg (Limit 5)	Tank monitoring and water quality program fail to limit fissionable material buildup in sediments.	Section 6.1
		Mass of fissionable materials from accidental release into storage tank does not exceed 200 kg (Limit 4)	Filter or ion exchange vessel failure releases fissionable materials	Section 6.2

Table 5-1. Normal and Accident Conditions of Cold Vacuum Drying Facility Equipment. (2 sheets)

Equipment item	Normal function	Criticality controls	Accident condition	Accident discussion reference
Floor area in region of potential spills of MCO water with no fissionable mass controls	Contains spill from process water conditioning receiver tank, and associated equipment and piping containing MCO water.	Spill depth of curbed regions, or floor depressions, will not exceed safe depth of 10.5 in. (Limit 8)	MCO water spills to floor. MCO water mixes with storage tank water due to common cause failure	Section 6.3
Floor drain tank or floor area in region of potential vessel failures with fissionable mass controls	The floor drain tank is not normally used to store liquids. It is a standby tank to contain water from inadvertent spills of water containing fissionable materials and water used for fire fighting.	Total inventory of fissionable materials does not exceed a level of 300 kg (Limit 11)	MCO water spills to floor and is contained in floor area or drains to floor drain tank depending on final design. In addition, fire fighting water is added to the volume of the liquid spill.	Section 6.4
Transported fissionable materials	Transport of samples or other fissionable materials by personnel	Isolate fissionable materials a minimum of 0.9 m (3 ft) from controlled fissile material vessels such as process water conditioning receiver tank, filter, or ion column module (Limit 10)	No credible accident will violate control because controlled fissionable materials are isolated by at least 12 in. of concrete shield.	None

5.4 FLOOR DRAIN TANK

The floor drain tank receives spill water from the processing bay floor drain system. The floor drain tank is covered and located outside the CVDF building. The volume of the floor drain tank is adequate to contain the volume of water containing fissionable material from potential spills and piping breaks. In addition, it will contain the volume of water used for fire fighting in the building. The floor drain tank is not geometrically favorable because it will not be contaminated by fissionable materials prior to its use, and the credible quantity of fissionable contained in the water flowing into it will not exceed 300 kg specified by Limit 11.

5.5 PROCESS WATER CONDITIONING FILTER

The process water conditioning filter is located downstream of the ion exchange column module so that it will prevent the release of fission products from a potential ion exchange column module failure from flowing to the storage tank. The potential release of fissionable materials from such a failure is uncontrolled. Therefore, the filter diameter is controlled to be less than 23.5 in. by Limit 7.

The filter also removes most of the fissionable material particulate that may flow from the process water conditioning ion exchange module. The buildup of these fissionable materials on the filter is controlled to ensure that the quantity of fissionable material that flows to the storage tank from a filter failure will not exceed 200 kg specified by Limit 4.

6.0 CONTINGENCY ANALYSIS

This section discusses the credible contingencies that may occur in the equipment at the CVDF. The controls and accident conditions are listed in Table 5-1.

6.1 *BUILDUP OF FISSIONABLE MATERIALS IN STORAGE TANK*

The maximum quantity of fissionable material allowed to build up in the sediments or to be dissolved or suspended in the water of the storage tank due to penetration through the process water conditioning system is limited to 200 kg (Limit 5). The design of the program or system to control to this limit will provide positive controls, preferably engineered features, that will assure that the 200 kg limit will not be exceeded by any single credible contingency.

A limiting scenario was evaluated that assumed the quantity of fissionable materials in the storage tank was at the allowed limit of 200 kg fissionable materials (Limit 5). At this time, an accident was assumed to occur that released an additional allowed limiting quantity of 200 kg fission products (Limit 4) into the storage tank from a single contingency. The combined total of these fissionable materials is 400 kg. This combined total has a safety margin of at least 200 kg of fissionable materials from the limit of 615 kg fissionable materials (Limit 3) in geometrically unfavorable vessels such as the storage tank. This safety margin allows for the inadvertent doubling of either the accidental release controls, or the tank buildup controls of fissionable material in the storage tank before the criticality safety limit is challenged. A second independent and concurrent contingency would have to occur in order to exceed the reactivity of this case. Therefore, the double contingency principle is met.

6.2 RELEASE OF FISSIONABLE MATERIALS INTO STORAGE TANK

The maximum quantity of fissionable material allowed in the storage tank from a filter failure, process water conditioning receiver tank overflow, or other credible accident is 200 kg (Limit 4). If required, the design of the system will provide positive controls, preferably engineered features, that will assure that the 200 kg limit will not be exceeded by any single credible contingency.

An accident scenario was evaluated that assumed the full limit of 200 kg fissionable material was released into the storage tank from a single contingency. In addition, the storage tank was assumed to have the allowed limit of 200 kg fissionable materials (Limit 5) in the sediments and dissolved in the tank liquid at the time of the contingency. The combined total of these fissionable materials is 400 kg. This combined total has a safety margin of at least 200 kg of fissionable materials from the limit of 615 kg fissionable materials (Limit 3) in geometrically unfavorable vessels such as the storage tank. This safety margin allows for the inadvertent doubling of either the accidental release controls, or the controls of fissionable material buildup in the storage tank before the criticality safety limit is challenged. A second independent and concurrent contingency would have to occur in order to exceed the reactivity of this case. Therefore, the double contingency principle is met.

6.3 MULTICANISTER OVERPACK OR PROCESS WATER CONDITIONING RECEIVER TANK SPILL

The process water containing fissionable materials from the MCO is first pumped to the process water conditioning receiver tank. The maximum combined quantity of process water is 1.14 kL (300 gal). The process water conditioning receiver tank is emptied by processing the contents through the process water conditioning filters and ion exchange column module before a new batch of process water is transferred from the MCO. Hence, the process water containing a significant quantity of fissionable material will not exceed the volume of an MCO in the accident evaluation. The accident assumes the total volume of 1.14 kL (300 gal) of this water containing fissionable materials is spilled to the operating room floor. The water in other vessels such as the 5,000-gal storage tank can also fail by common cause such as a design basis earthquake. The water from the storage tank by itself does not cause a criticality concern because its total allowed quantity of fissionable materials is not greater than a third of a 615 kg safe mass (Limit 5) and the height of its contained spill volume does not need to be controlled. However, if the spilled water from a source such as the storage tank is not isolated from the spilled water from the MCO or process water conditioning receiver tank, the volume of this water can raise the level of water spilled from the MCO or process water conditioning receiver tank and its combined volume must be provided for in the spill floor area in the accident evaluation.

The floor area not having grading or depressions that contains the spilled water must be at least large enough to contain the volume of the MCO and process water conditioning receiver tank and other potential spills and not exceed the 10.5 in. height limit of Limit 8. All curbs that can contain this spill in a smaller floor area must not exceed that safe slab height. The floor area must be increased to allow for depressions, such as sump pits or grading in the floor, that can increase the local spilled water height. These controls of the spill area will prevent the height of the spill from exceeding 10.5 in. specified by Limit 8 for all credible situations.

Limit 8 was established for an uncontrolled area of UO_2 solution at optimum moderation and reflection from the floor and ceiling (Roblyer 1997). The controlled thickness of the potential spill will maintain the reactivity below the criticality safety limit established in Section 3.2. Because the credible height of the spill is below 10.5 in. specified by Limit 8 in this contingency, the reactivity is below the criticality safety limit. A second independent and concurrent contingency would have to occur in order to exceed the reactivity of this case. Therefore, the double contingency principle is met.

6.4 RELEASE OF FISSIONABLE MATERIALS INTO FLOOR DRAIN TANK OR CONTAINED IN FLOOR SPILL AREA

The maximum quantity of fissionable material allowed in the geometrically unfavorable floor drain tank or floor spill area with no liquid height control from a vessel failure or other credible accident is 300 kg (Limit 11). All sources of fissionable material that can enter the floor drain tank or floor area will be evaluated when the design is finalized. The inadvertent release of fissionable materials into the floor drain tank or contained by the floor spill area has been identified as a single or multiple pipe breaks or spill of water drained from an MCO. The total credible content of fissionable materials in the water from an MCO that would be involved in this accident scenario is less than 200 kg (see Section 4.2). The design of the system will provide positive controls, preferably engineered features, that will prevent the fissionable materials in the ion exchange vessels and filters from the floor drain tank and ensure that the 300 kg limit of fissionable materials will not be exceeded by any single credible contingency.

An accident scenario was evaluated that assumed the full limit of 300 kg was released into the floor drain tank or contained by the floor spill area from a single contingency. The floor drain tank or floor spill area was assumed to not be contaminated by fissionable materials at the time of the contingency. The total quantity of fissionable materials in the floor drain tank or contained by the floor spill area from the single pipe break or spill accident is 300 kg. This total has a safety margin of at least 300 kg of fissionable materials from the limit of 615 kg fissionable materials (Limit 3) in geometrically unfavorable vessels. This safety margin allows for the inadvertent doubling of the 300 kg fissionable materials allowed by Limit 11 before the criticality safety limit is challenged. A second independent and concurrent contingency would have to occur in order to exceed the reactivity of this case. Therefore, the double contingency principle is met.

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7.0 REFERENCES

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APPENDIX A

CHECKLIST FOR INDEPENDENT REVIEW

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APPENDIX A

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed: HNF-SD-SNF-CSER-006, Rev. 0, *Criticality Safety Evaluation Report for the Cold Vacuum Drying Facility's Process Water Handling System*

Author: Steven P. Roblyer

Yes	No	N/A	
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[ ]	[ ]	[X]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[ ]	[ ]	[X]	Hand calculations checked for errors.
[ ]	[ ]	[X]	Code run streams correct and consistent with analysis documentation.
[ ]	[ ]	[X]	Code output consistent with input and with results reported in analysis documentation.
[X]	[ ]	[ ]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.
[X]	[ ]	[ ]	Have all reasonable accidents been considered?
[ ]	[ ]	[X]	Has low density water (steam) been evaluated as a moderator?
[ ]	[ ]	[X]	Is the fuel and other hardware composition correct?
[X]	[ ]	[ ]	Are the cases considered conservative? Too conservative?
[ ]	[ ]	[X]	Do the computer models adequately reflect the actual geometry? Have cross sectional cuts of the geometry been made and do they show the desired geometry?
[ ]	[X]	[ ]	Has the analysis been reviewed by Safety? This may not be required in a preliminary design.
[ ]	[X]	[ ]	Has the reviewer completed the Criticality Safety Course for Managers and Engineers?

Date completed ____________________

Reviewed by: Victor E. Roetman Victor Roetman Date 12/12/97

NOTE: Any hand calculations, notes, or summaries generated as part of this review should be signed, dated, and attached to this checklist. Materials should be labeled and recorded so that it is intelligible to a technically-qualified third party.

Reviewer Comments:

This CSER used data from HNF-SD-SNF-CSER-009 which contains all the criticality support calculations used here. CSER-009 has been through independent review, therefore this review involves only the application of those calculations.

Victor E. Roetman 12/12/97

Victor Roetman

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Project Title/Work Order Criticality Safety Evaluation Report for the Cold Vacuum Drying Facility's Process Water Handling System		EDT No. 624278 ECN No. N/A

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
G. D. Benecke	R3-15	X			
D. W. Bergmann	X3-79	X			
J. R. Brehm	R3-26	X			
R. D. Crowe	R3-26	X			
J. P. Estrellado	B4-44	X			
L. J. Garvin	R3-26	X			
J. J. Irwin	R3-85	X			
M. A. Jensen	X3-79	X			
C. R. Miska	R3-85	X			
C. Pili-Vincens	R3-26	X			
S. D. Roblyer	R3-26	X			
V. E. Roetman	R3-26	X			
W. T. Watson	R3-26	X			
SNF Project Files	R3-11	X			