

[DOE LETTERHEAD]

IDAHO OPERATIONS OFFICE

March 24, 1998

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W., Suite 700
Washington, D.C. 20005

SUBJECT: INEEL Initial Site Assessment Report on the Storage of U-233 (OPE 98-010)

Dear Mr. Chairman:

Enclosed is the Idaho National Engineering and Environmental Laboratory Initial Site Assessment Report which summarizes information developed from initial inspections and assessments of material containing uranium-233 at the Idaho National Engineering and Environmental Laboratory (INEEL). The report represents the deliverable for Commitment 6 of the Department's Implementation Plan for addressing the Defense Nuclear Facilities Safety Board's Recommendation 97-1 concerning the safe storage of uranium-233 material.

The report describes the type of uranium-233 material in inventory, the facilities where the material is located and the actions completed to date to determine any remediation efforts needed. We will continue to update this report as inspections and assessments progress, and plan to provide the final report to you in December 1998.

We have completed the actions identified under this milestone and propose closure of this commitment. If you have any questions, please contact me or have your staff contact Robert Stallman (208-526-1995) or William Jensen (208-526-7500) of my staff.

Sincerely,

J.M. Wilcynski
Manager

**INEEL INITIAL SITE ASSESSMENT REPORT
THE STORAGE OF U-233**

**Leroy C. Lewis
Dennis R. Wilkinson**

Published March 1998

**Idaho National Engineering and Environmental Laboratory
Lockheed Martin Idaho Technologies Co.
Idaho Falls, ID**

**Prepared for the
U. S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223**

INEEL INITIAL SITE ASSESSMENT REPORT ON THE STORAGE OF U-233

Table of Contents	Page
1.0 Description	1
1.1 Background	1
1.2 Physical Form	3
1.2.1 Physical Forms of Material at CPP-749	3
1.2.2 Physical Forms of Material at RWMC	5
1.3 Facility Description	7
1.3.1 CPP-749 Facility Description	7
1.3.2 RWMC Facility Description	10
2.0 Observations	15
2.1 Material Characterization and Data Quality	15
2.2 Analyses	15
2.2.1 Chemical Analysis of the Fuel at CPP-749	15
2.2.2 Chemical Analysis at RWMC	16
2.3 Nondestructive Analysis (NDA)	17
2.3.1 NDA Examination of Vaults in CPP-749	17
2.3.2 NDA of U-233 Drums at the RWMC	17
2.4 Packaging	19
2.4.1 Visual Inspection at CPP-749	19
2.4.2 Visual Inspection of LWBR Drums at the RWMC	27
2.4.3 NDA Inspection at the CPP-749 Vaults	28
2.4.4 NDA Inspection of the RWMC Material	28
2.5 Remediation	28
2.5.1 Remediation at CPP-749	28
2.5.2 Remediation at the RWMC	28
2.6 Facility Considerations	28
2.6.1 Safety Analyses	28
2.6.2 Criticality Safety at CPP-749	29
2.6.3 Criticality Safety at the RWMC	30
2.6.4 Criticality Considerations	31
2.7 Facility Measurements	31
2.7.1 Ventilation at ICPP	31
2.7.2 Ventilation at RWMC	31

Table of Contents (<i>continued</i>)		Page
2.8	Off-Gas Monitoring	31
2.9	Radiation Assessments	32
2.10	Condition Considerations	32
	2.10.1 CPP-749	32
	2.10.2 RWMC	32
3.0	Evaluation of the 97-1 Implementation Plan Near-Term Actions	34
4.0	Assessment Conclusions	35

Appendices

- A The Idaho National Engineering and Environmental Laboratory
- B LWBR Drums Containing Rod and Pellets in Storage at the RWMC
- C Criticality review for LWBR Material at the Radioactive Waste Management Complex
- D Inadvertent Criticality Safety Section from the RWMC Safety Analysis Report

Figures		Page
1	Storage Canisters for LWBR Fuel in CPP-749	4
2	DOT 6M Drum 6	6
3	CPP-749 Fuel Storage Area	8
4	Fuel Storage Vaults at CPP-749	9
5	Radioactive Waste Management Complex	11
6	Storage Drums in Shielded Overpack Boxes	12
7	Overpack Boxes in WMF-633	13
8	TSA Asphalt Storage Pad	14
9	Tomography Scan of 6M/2R Drum	18
10	Portable Gamma Ray Spectrometer	20
11	Mechanical Surface Damage to 6M Drum	21
12	Corrosion of External Surface of Drum Lid	22
13	Corrosion to Internal Surface of Drum Lid	23
14	Interior of Drum No. E-304	24
15	Interior of Drum No. E-448	25
16	Interior of Drum No. E-308	26
Appendix A-1 Map of the INEEL		A-2

Tables		Page
1	INEEL Inventory of Unirradiated U-233	2
2	Head Space Gas Analyses from LWBR Vaults	16
3	Status of the INEEL Near Term Actions	34

INEEL INITIAL SITE ASSESSMENT REPORT ON THE STORAGE OF U-233

1.0 DESCRIPTION

1.1 Background

The unirradiated U-233 stored at the Idaho National Engineering and Environmental Laboratory (INEEL) consists of fabricated fuel materials, scrap, and waste that was generated during the development of the Light Water Breeder Reactor (LWBR) during the 1970s. This material is currently stored in two locations at the INEEL as shown in Appendix A. The material is in the form of a single seed fuel assembly for the Shippingport Reactor, unassembled fuel rods, and sintered oxide fuel pellets that are stored in subterranean, carbon steel-lined vaults at the Idaho Chemical Processing Plant (ICPP). The balance of the material is stored in 6M and 17C drums (these are shipping drums that meet the specifications in 49 CFR 178) at the Radioactive Waste Management Complex (RWMC). The forms of the material at the RWMC range from fabricated LWBR single rods and loose pellets to waste generated during the fabrication of the fuel. This material was received from the Bettis Atomic Power Laboratory from the mid 1970s into the 1980s.

The LWBR fuel pellets are high-fired, ceramic material manufactured from a mixture of uranium dioxide (UO_2) and thorium oxide (ThO_2). The ceramic contains, on the average, slightly more than 2.1% U-233 as UO_2 to as high as 12 % U-233. The uranium is a mixture of 97% U-233 and 3% other uranium isotopes.

The ceramic was manufactured by the Bettis Atomic Power Laboratory under the direction of the Office of Naval Reactors. The fuel pellets were fabricated by compressing intimate mixtures of UO_2 and ThO_2 powders. The compressed pellets were then sintered at a temperature of 1790°C for 12-hour periods. The resultant high-fired pellets have densities greater than 97% of the theoretical density and have the characteristics of a glass in that the material is tightly bonded together in a nearly crystalline form and exhibits conchoidal fracture that is characteristic of a glass.

The LWBR fuel was made from U-233 oxide powder prepared at Oak Ridge that contained less than 10 ppm U-232. The low concentration of U-232 meant that the fuel could be handled in non-shielded facilities for a short time period immediately after separation of the U-233 from the U-232 daughter products. Also, because of the low concentration of U-232 (less than 1 ppm U-232) in the final fuel matrix, and the self-shielding effects due to the large amount of thorium oxide in the ceramic, the fuel pellet's radiation field is insufficient to cause significant radiation damage to surrounding materials or personnel.

The Idaho Chemical Processing Plant also stores a large inventory of irradiated spent nuclear fuel from various reactors that were fueled with a uranium-thorium mixture. By far, the largest part of the inventory is the irradiated U-233 fuel. There is approximately 500 kg of U-233 in the irradiated LWBR fuel stored in the CPP-749 vaults. Both cores of irradiated Peach Bottom fuel are also stored at the ICPP and contain a total of 46 kg of U-233. The third reactor fuel is the Fort St. Vrain fuel

stored in the Irradiated Spent Fuel Storage Facility containing 90 kg of U-233. In addition, the INEEL is responsible for the irradiated Fort St. Vrain fuel that is stored in Colorado on the site of the former Fort St. Vrain Reactor. That storage facility has 236 kg of U-233 in its inventory. Peach Bottom fuels and Fort St. Vrain fuels also contain U-235 as the fissile isotope. Both the Fort St. Vrain fuel and the Peach Bottom fuel are graphite matrix uranium carbide fuels that were manufactured by General Atomics for the High Temperature Gas Cooled Reactor development program. Because these fuels are irradiated, they are outside the scope of the DNFSB recommendation 97-1. All of these spent fuels are managed under the National Spent Nuclear Fuel Program.

The inventory of unirradiated U-233 at INEEL is shown in Table 1:

Table 1 INEEL Inventory of Unirradiated U-233

CPP-749						
No. of Storage Units	Type of Material	Total U(kg) ^{a,b}	Total U-233(kg)	Thorium(kg)		
40 Containers	Fuel and blanket rods	306.64	300.80	9807.		
1 Assembly	Complete assembled seed module	<u>16.84</u>	<u>16.56</u>	<u>535.</u>		
	Total	323.48 kg	317.36 kg	10342. kg		
RWMC						
No. Drums	Container Size	Storage Location	Storage Drum Contents	U-233(kg)	Thorium(kg)	
12	55 gal 6M	Overpack RCRA Storage	Rods and pellets	1.7	55	
53	110 gal 6M	Overpack RCRA Storage	Rods and pellets	14.8	478	
56	55 gal 6M	TSA-RE ^c	Rods and pellets)			
24	110 gal 6M	TSA-RE	Rods and pellets)	17.5	566	
27	110 or 55 gal 6M	TSA-RE	Rods and pellets)			
47	17C	Storage Bldg.	Fabrication scrap)	60	1940	
<u>1650</u>	17C	TSA-RE	Fabrication scrap)	<u>94 kg</u>	<u>3039 kg</u>	
1869		Total				

- a) U-233 content is greater than 97%
- b) U-232 content is less than 10 ppm
- c) TSA-RE is the Transuranic Storage Area - Retrieval Enclosure

1.2 Physical Form

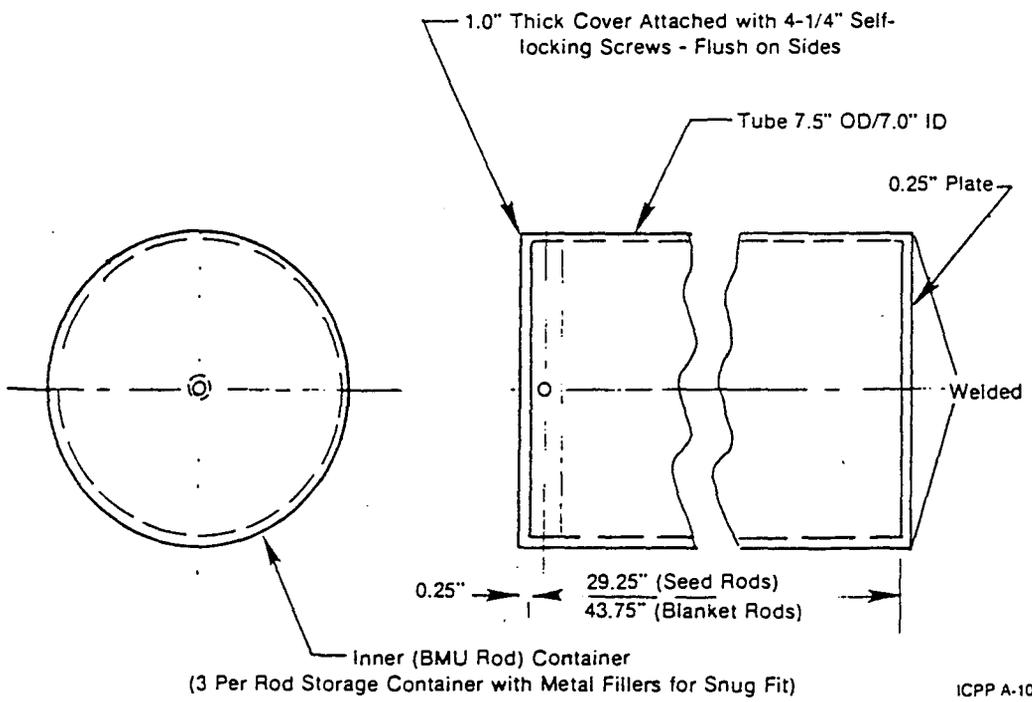
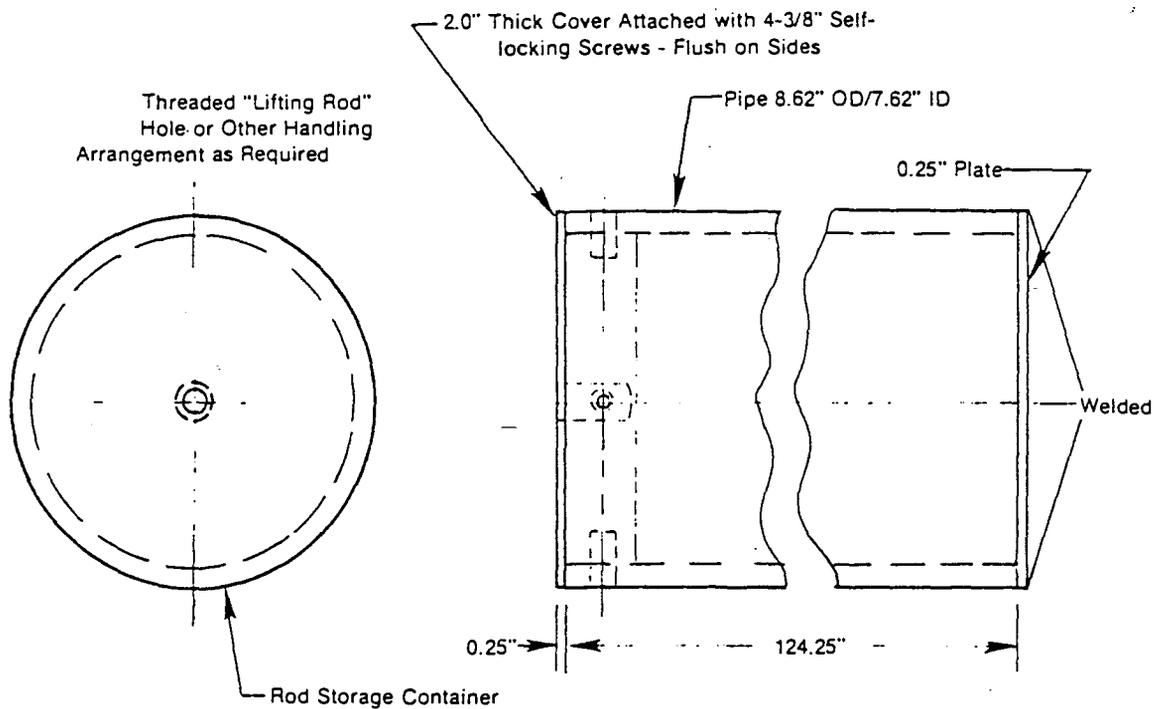
1.2.1 Physical Forms of Material at CPP-749

The LWBR material stored at CPP-749 is fabricated fuel assembly components that consist of one complete unirradiated seed assembly, 38 canisters of Zircaloy clad unassembled fuel rods and two canisters of stainless steel rods filled with fuel pellets. This material is stored in stainless steel canisters fabricated from 8 5/8-inch outside diameter stainless steel pipe with a 0.5-inch wall thickness. A .25-inch thick steel plate is welded to the bottom of the container with a 2-inch thick cover, attached with four screws, that forms the lid and seals the canister. The canisters for the LWBR fuel rods are approximately 125 inches long, with a group of smaller containers used for the storage of 98 kg of LWBR Breeder Mock-Up (BMU) fuel. This fuel has a U-233 concentration between 2% and 12%. These smaller containers are constructed from 7-inch O.D. stainless steel pipe with a 0.25-inch wall thickness. The cans storing the BMU seed rods or the BMU blanket rods are either 30 inches or 45 inches long respectively. These smaller containers are designed to be stored inside the larger 8-5/8-inch containers. Typical storage canisters are shown in Figure 1. This material is stored under SAR WIN-107-4.7A, Revision 1, March 1989.

There are four storage system barriers to the release of material. The pellet is a ceramic that seals the actinides and the daughter products into the ceramic matrix. The second barrier of containment is the Zircaloy cladding for the fuel assembly or fuel rods and the pellet packaging of stainless steel tubing or in plastic bags. The third barrier of containment is the Buna-N O-ring sealed stainless steel canisters in which the fuel rods and pellet packages are stored. The final containment barrier is the vault surrounding the storage canisters.

During fuel fabrication, the pellets are placed in Zircaloy IV tubing with the end seal-welded shut. The amount of U-233 in each rod is a function of its intended placement in the core configuration. There are seed rods, with the highest fuel loadings, standard blanket rods, and power flattening blanket rods. The loading of the rods into the storage canisters averages 7.5 kg of uranium per storage canister up to a maximum of 11.1 kgs per storage canister. Once the load limit is reached, the storage canisters are filled with aluminum rods to eliminate void space. This material was shipped dry in 1985 from Bettis Atomic Power Laboratory and is being stored dry.

In addition to the 38 canisters of rods, there are two standard storage canisters of pellets stacked in stainless steel tubes. One canister contains only pellet-filled rods; the second contains an additional 92 Zircaloy-clad rods. One storage canister contains 7.5 kg of fissile uranium; the second canister contains 3.5 kg. The stainless steel, pellet-filled rods have a Buna-N O-ring seal.



ICPP A-10.039
(10-83)

Figure 1 Storage canisters for the LWBR fuel in the vaults at CPP-749.

1.2.2 Physical Forms of Material at RWMC

Some of the material at RWMC is similar to the material stored at CPP-749. A number of drums contain rod and pellet material; others contain fabrication waste which includes anti-C clothing, grinding sludges, polyethylene material, rags, gloves, etc. None of the waste material is stored at CPP-749. There are also pieces of equipment used in the pellet preparation and fuel rod fabrication that had been irretrievably contaminated and became waste. All of the rod and pellet material is contained in DOT-2R containers inside 55-gallon DOT-6M shipping drums or in 110-gallon DOT-6M shipping drums (the actual volume is approximately 100 gallons). There are 172 drums that contain 34 kg of U-233 in the form of rod and pellet material. Sixty-five of these drums, containing 16.5 kgs, are in shielded overpacks, stored in a RCRA-approved storage building, and 107 drums, containing 17.5 kgs, are under earthen cover on the TSA-RE pad, which was covered by a steel storage building in 1996. Of the other 1,697 drums, 43 DOT-17C drums and 9 DOT-6M drums are in a waste storage building and 1,645 DOT-6M and DOT-17C drums are under earthen cover on the TSA-RE storage pad. The 1,697 drums, containing fabrication scrap and debris, amount to a total of 60 kg of U-233. A typical DOT 6M storage drum with a 2R inner container is shown in Figure 2. The 17C is a standard, top-opening carbon steel drum, identical to the 6M drum but without a 2R internal container or spacing material. Appendix B provides a drum-by-drum loading description of the 172 6M/2R drums containing the rod and pellet material. This material was shipped by the Bettis Atomic Power Laboratory from the mid-1970s until the mid 1980s.

The LWBR fuel material shipped from the Bettis Laboratory to the RWMC contained a maximum of 300 grams of U-233 in the 6M/2R. They averaged 283 grams per drum. The waste material contains an average of 35 grams per drum.

There are also pellets stored in polyvinyl chloride (PVC) plastic sacks, which were specifically obtained to resist the damage caused by radiation fields.

The RWMC storage systems provide several barriers to prevent release of material. The primary barrier is the ceramic fuel matrix that seals the actinides and their daughter products in the fuel pellet. The second barrier is the packaging inside the 2R can that contains the loose pellets and the rods. The next barrier is the 2R container. The next barrier is the 6M drum, and the final barrier is the shielded overpacks or the earthen-covered asphalt pad. The 1,697 drums of waste materials have two less barriers because the material may not have the ceramic matrix and there is not a 2R container inside the drum.

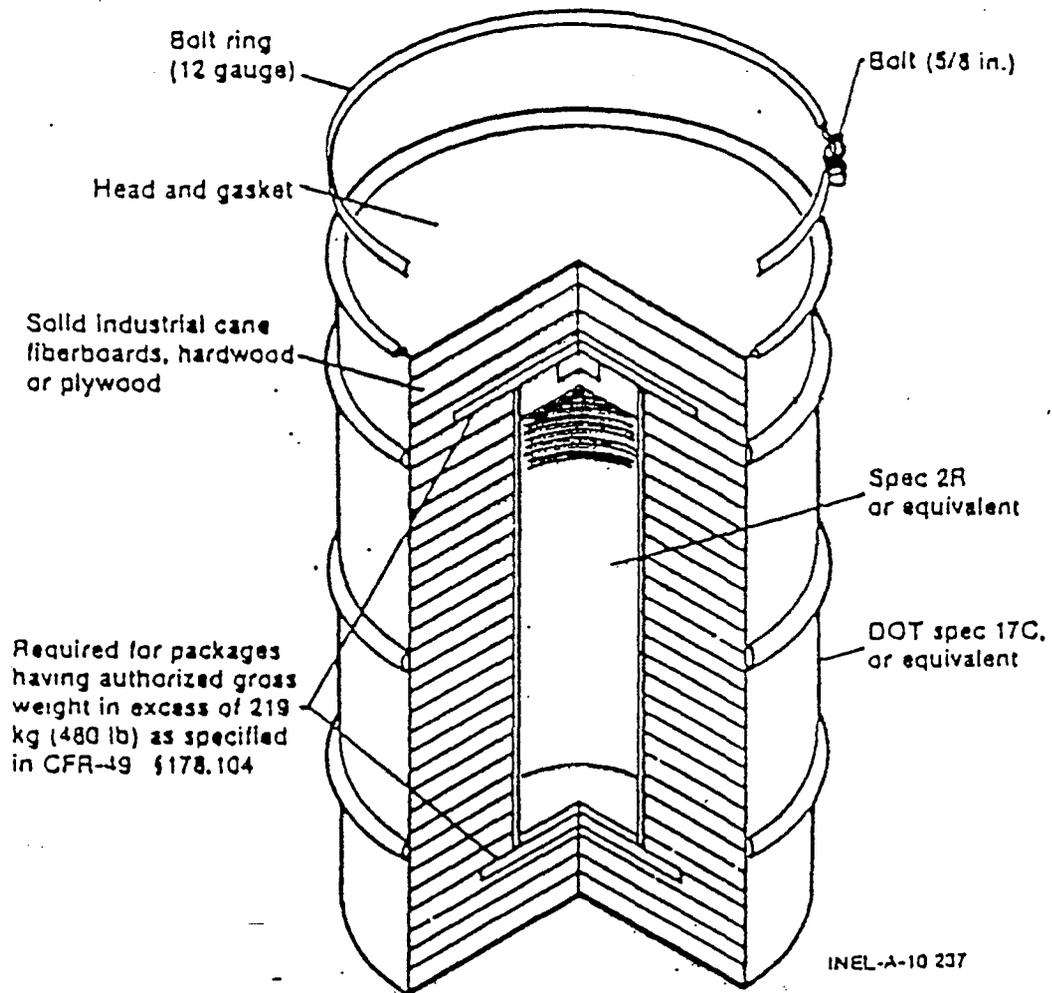


Figure 2 DOT 6M drum used for the storage of U-233 at the RWMC. For the material that is fuel pellets or fuel rods, a 2R container is used. For waste the outer drum is a 17C drum and does not have the spacers or the 2R container.

1.3 Facility Description

1.3.1 CPP-749 Facility Description

The CPP-749 is an unenclosed area in the southern part of the ICPP facility. The vaults are lined wells in which the top of the well is embedded in a concrete slab which extends above grade to prevent surface water from entering the vault. The storage vaults at CPP-749 (shown in Figure 3) for the unirradiated LWBR fuel materials were constructed in 1984 by drilling and casing with mild steel an 18-inch diameter hole 22 ft. 9 inches deep. The casing walls are 3/8 inch thick. Four inches of sand was poured into the bottom of the hole and then a dry vault was lowered into place and vertically aligned such that it is not more than one-quarter inch in 5 ft. off of vertical. The vault liner is fabricated from 12-inch, schedule 40 pipe and has a seal-welded bottom. The inside and outside surfaces of the vault are coated with epoxy paint to prevent rust. The vault is grouted in place. The bottom plate of the vault is sloped such that water will accumulate at a single point. A level support plate is installed above the sump plate that bears the canister weight. A stainless steel crush pad is placed on the level plate. The vaults in the CPP-749 area are shown in Figure 4.

A 12-inch thick concrete pad 8 ft. wide runs continuously down the row of dry wells and provides a working surface. There are 21 twelve-inch vaults on 10-foot centers. In addition, there is one 30-inch vault for the storage of the intact seed assembly at the south end of the linear array. Twenty of the vaults are in service with one in reserve as a spare.

Each vault is designed with a line into the top of the vault to take gas samples and a line that extends to the low point in the bottom of the vault to remove water from the vault sump should that become necessary. These lines also allow the vault to be pressurized to test for leaks, to purge the vault with a dry gas, and to take liquid samples.

The vaults are deep enough for two storage canisters to be stored vertically. In addition to the crush pad in the bottom of the well, a second steel crush pad is placed between the two storage canisters.

The storage vaults are under cathodic protection. This system was installed in 1984 for the irradiated fuel storage vaults and extended to the unirradiated vaults after they were constructed. The vault liner is bonded to both the cathodic protection system and the well casing.

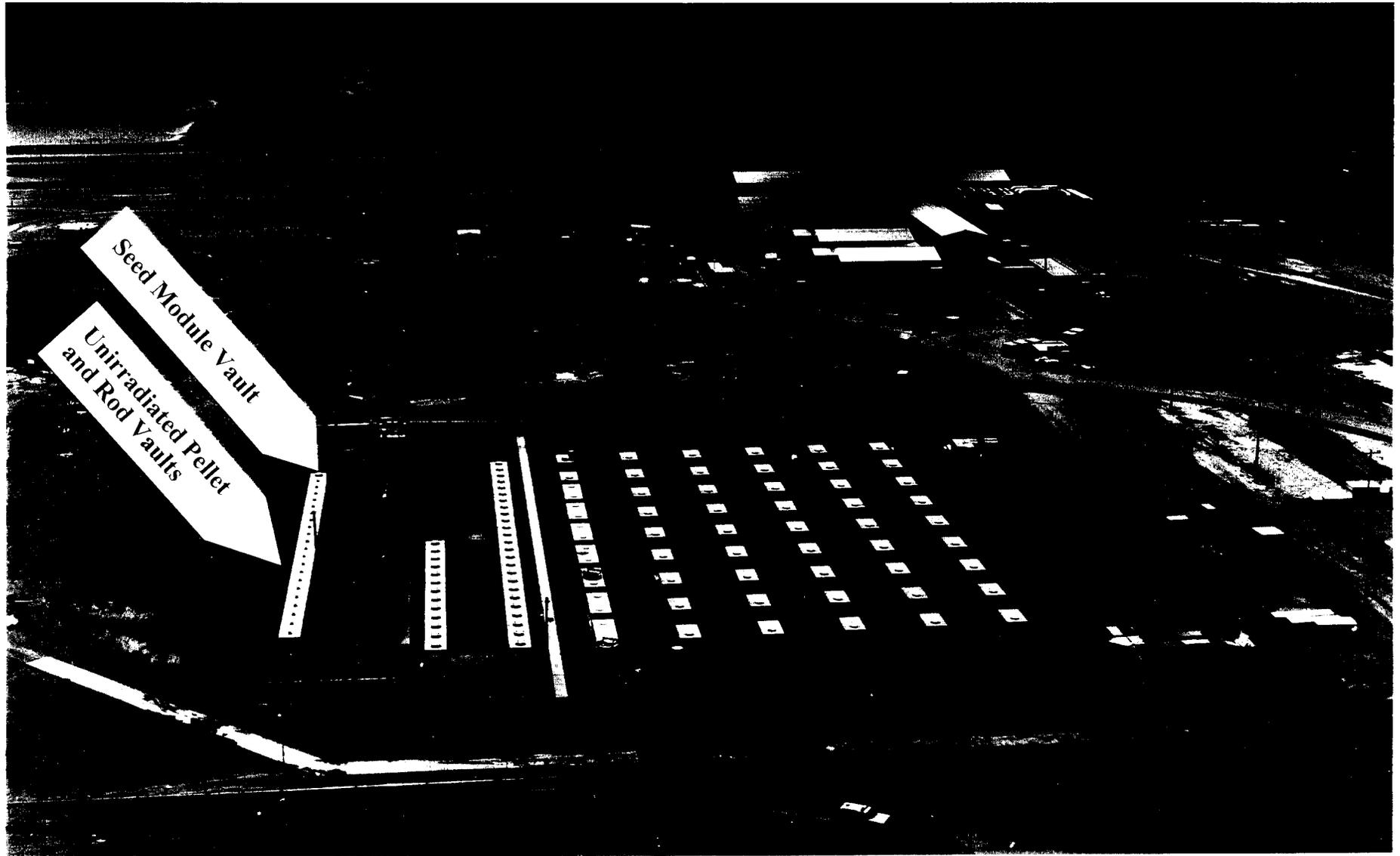


Figure 3 The 749 fuel storage area. Unirradiated LWBR fuel is stored in the vaults on the left and the irradiated LWBR fuel is stored in the two lines of vaults immediately to the right. Fermi blanket is stored in the next row of vaults to the right and the Peach Bottom Core I fuel is stored in the remaining 5 rows.

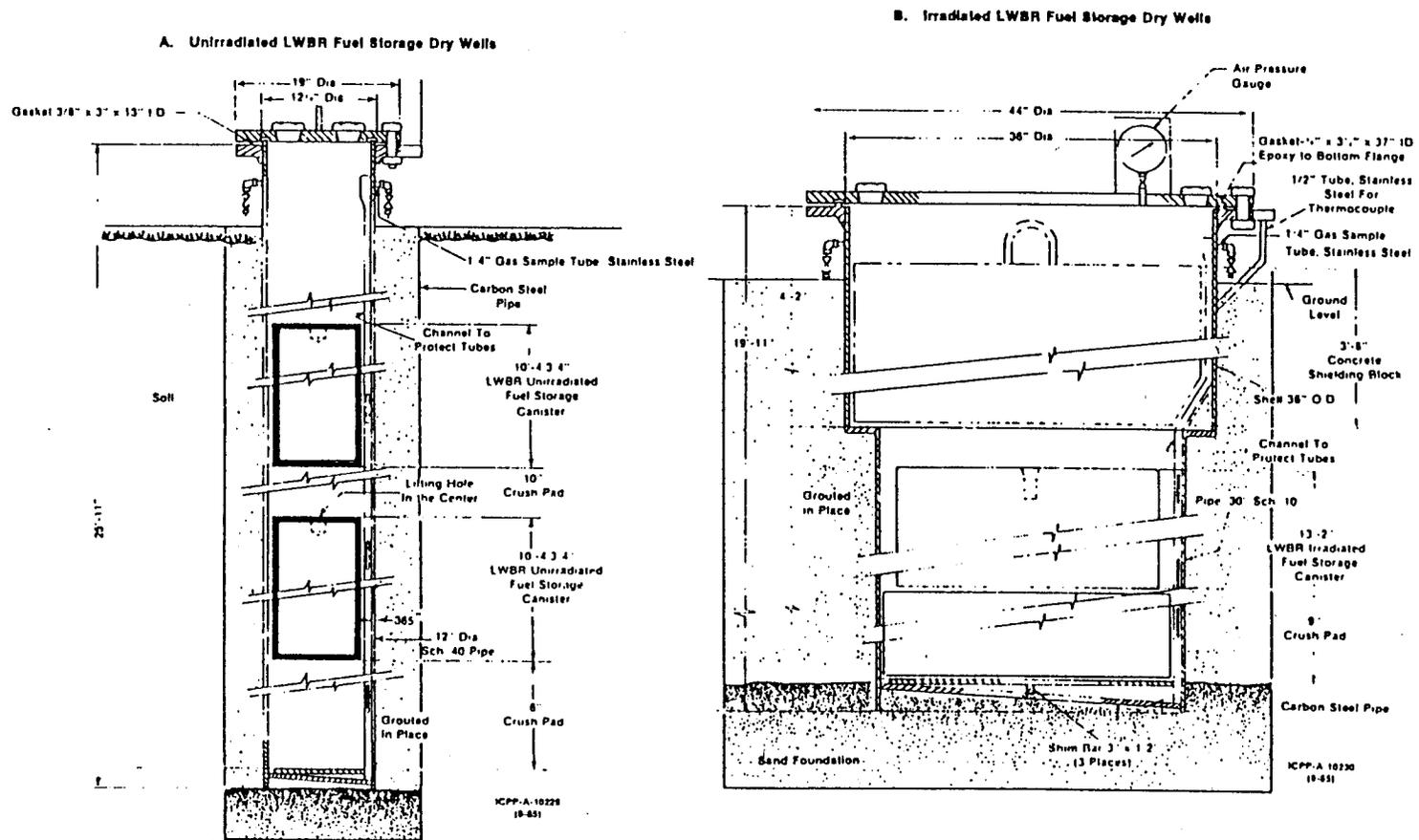


Figure 4 Section view of the unirradiated and irradiated LWBR fuel storage vaults. The unirradiated seed module is stored in a vault with the same design as the irradiated fuel storage vaults.

1.3.2 RWMC Facility Description

Most of the U-233 material stored at the RWMC is on asphalt pads under plastic sheeting, plywood and an earthen cover for a weather shield. The remainder is stored in a RCRA- permitted steel building constructed on concrete pads. Sixty-five 6M drums with 2R inner containers filled with rod and pellet material are stored in one of the waste storage buildings inside lead-shielded overpacks. The material is stored in the shipping drums that it was received in from the Bettis Laboratory. Figure 5 shows the storage building on the left where the shielded overpacks are located and the TSA pad in the large building on the right side of the photo. The U-233 stored above-ground in RCRA-approved storage is inspected on a weekly basis and is compliant to all Environmental Protection Agency and Idaho State Department of Environmental Quality regulations.

Figure 6 shows an array of six drums inside the shielded overpack and Figure 7 shows the overpacks in the RCRA-compliant building.

The TSA pad is an asphalt pad with a large array of drums standing vertically. A plywood decking is layered across the top of the drums and a plastic cover placed over the top. The ends and sides are made up of 4 x 4 x 8 ft. plywood rad-waste boxes. The plywood decking extends over the plywood boxes with the plastic cover extending down to cover the boxes. Finally, an earthen cover is mounded over the top and sides to provide a weather-resistant structure. Figure 8 shows drum storage on the TSA pad. The entire pad is now enclosed inside a steel building constructed in 1996 to the UCRL-15910 moderate use category. It is equivalent to a facility use category II facility. The earthen cover does not contact the steel containers during storage. Ventilation stacks have been installed through the earthen cover with mechanical wind-driven caps to remove moisture. During construction of the retrieval enclosure building in 1996, these ventilation stacks were cut off and plugged. Previous inspections in the earthen-covered storage have found the stored waste containers to be clean, dry, and free of degradation. The drums in the stack are protected from moisture by the plywood layer, the plastic sheeting, and the layer of earth.

The U-233 drums are intermingled with drums of waste from Rocky Flats, INEEL, and other DOE sites. They were deliberately dispersed among all of these drums. Because there are approximately 100,000 drums in this array, it would be very difficult and very expensive to find and retrieve these drums for inspection or repackaging. Retrieval of these drums would require stack dismantlement, including removal of the overburden earthen layer, removal of the plywood and plastic sheeting, removal of part of the rad-waste boxes and then removal of the drums one at a time from the stack. Because all of the drums on this pad are to be exhumed

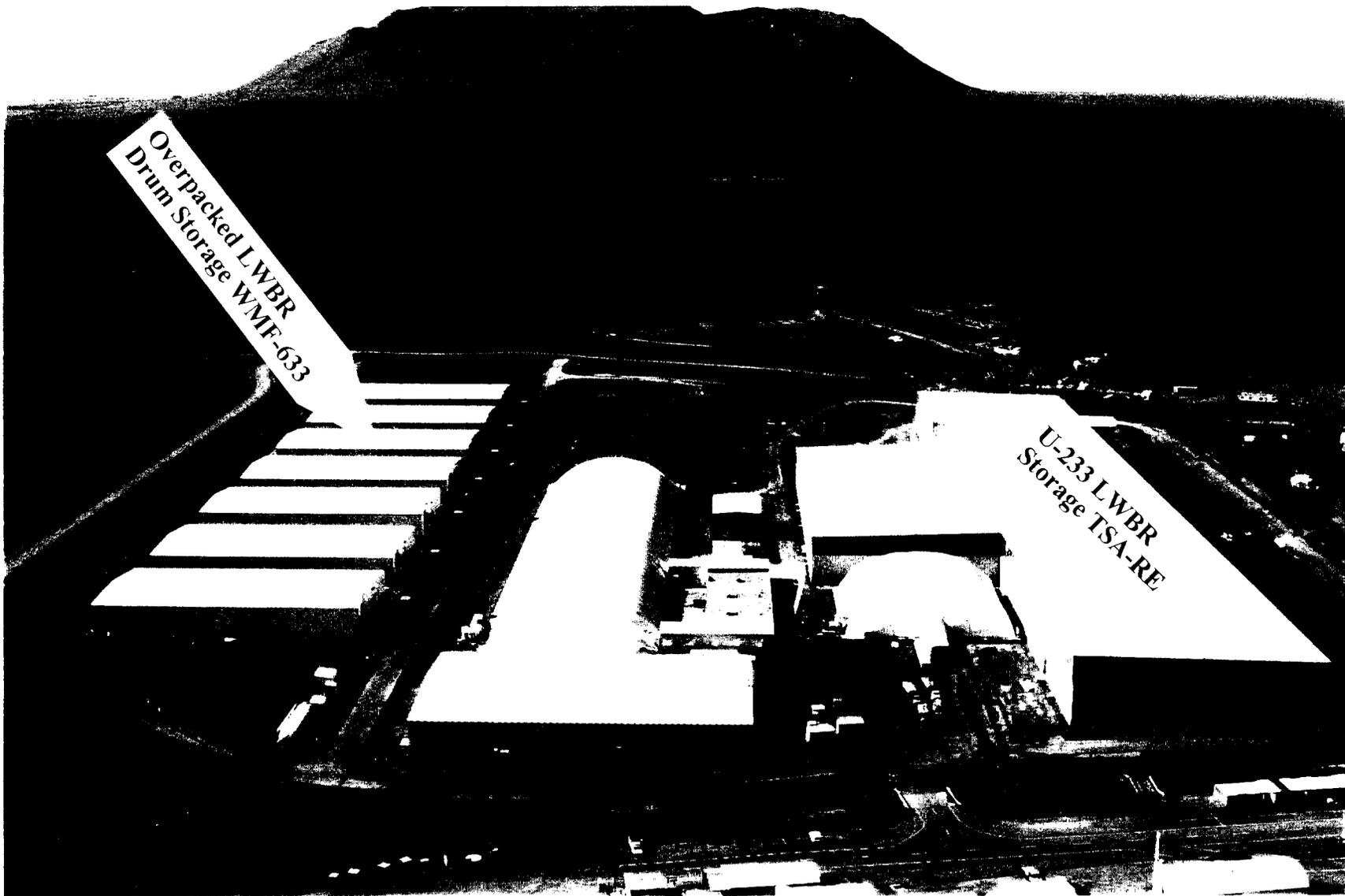


Figure 5 Radioactive Waste Management Complex. The 65 drums of U-233 material that has been overpacked is stored in the third from the top building in the row of seven RCRA compliance buildings on the left. The 1804 remaining drums of U-233 fuel materials and the drums of waste are stored in one of the drum storage buildings or in the Transuranic Storage Area inside the large retrieval enclosure building on the right.



nf972064

Figure 6 Six drums stored inside the lead-lined overpack.

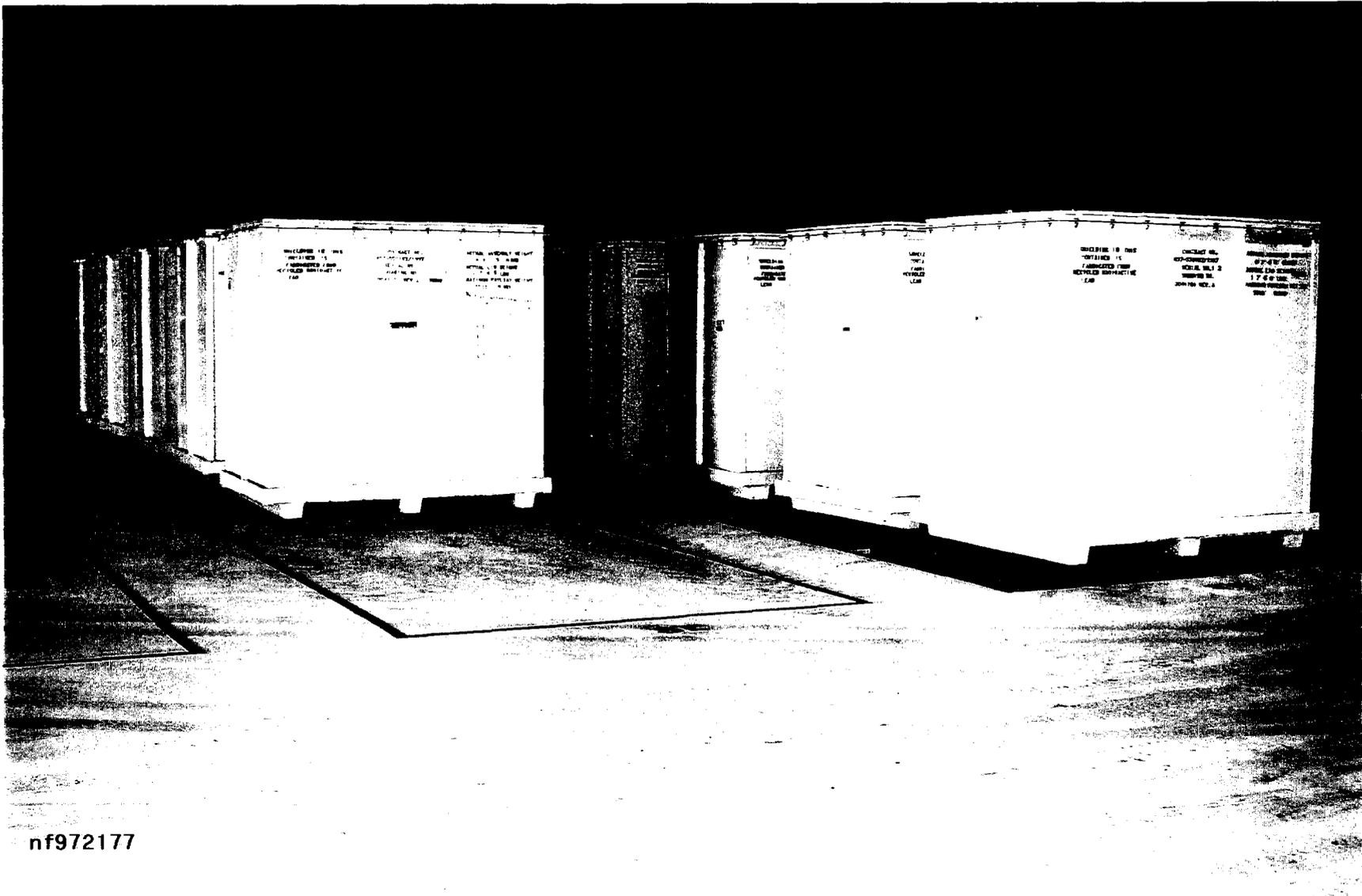


Figure 7 Shielded overpack containers stored inside the WMF-633 building.

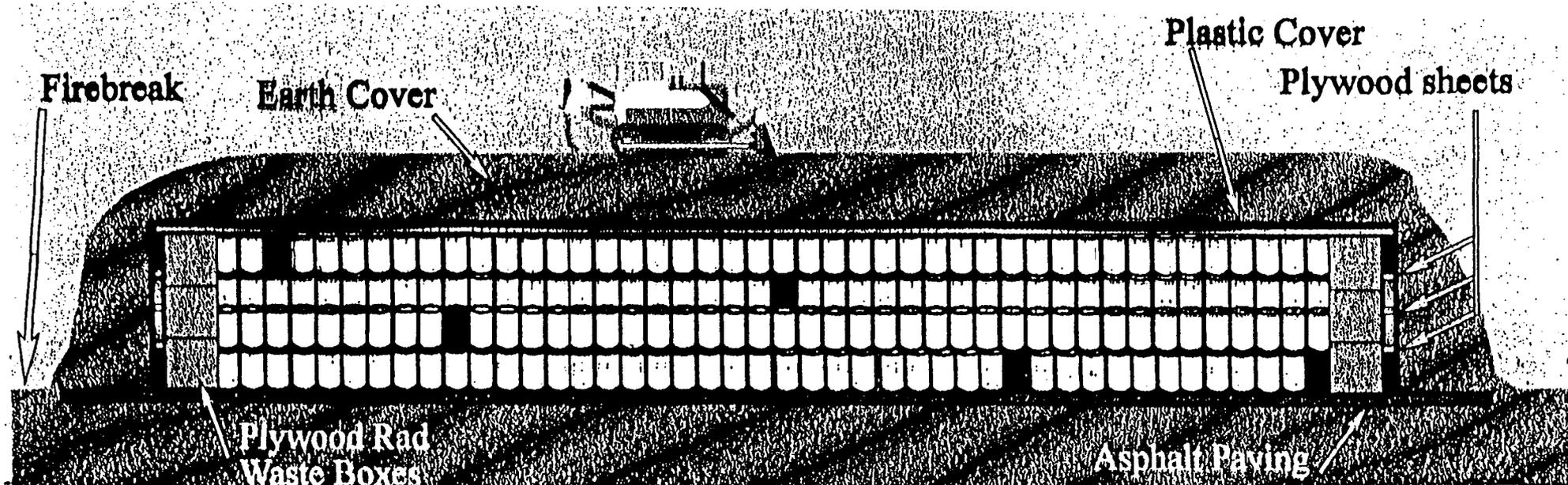


Figure 8 Cross-section of the TSA asphalt storage pad where most of the LWBR drums are stored. This pad is presently under a steel building which is designated as the retrieval enclosure in anticipation of treating this waste in the Advanced Mixed Waste Treatment Facility.

for processing through the Advanced Mixed Waste Treatment Facility beginning within the next five years, the U-233 drums can be segregated and retrieved during that operation.

2.0 OBSERVATIONS

2.1 Material Characterization and Data Quality

The LWBR fuel and reactor design were developed at the Bettis Atomic Power Laboratory operated by Westinghouse Electric Corporation under the direction of the Office of Naval Reactors (NR) to demonstrate the light water breeding technology managed by Bettis.

Because of the close ties to NR, the fuel component met the NR Program specifications with all of the requisite NR quality assurance requirements. Thus, the fuel assembly would have met the quality documentation requirements that would allow it to have been used in the core of the reactor. The pellets and rods have been fabricated and inspected to the QA standards applicable to fabrication into fuel rods and the rods subsequently into assemblies. The fuel pellets were manufactured by Bettis personnel. Accordingly, the appropriate quality assurance specifications have been applied to all manufacturing steps and to the assemblies produced in support of the Naval Reactor Program. Details on the quality assurance, testing, fabrication and performance specifications are in the Report WAPD-TM-1244(L). The documentation is held by The Bettis Atomic Power Laboratory and is available upon request.

2.2 Analyses

2.2.1 Chemical Analysis of the Fuel at CPP-749

No chemical analysis has been performed directly on the fuel, fuel components or the fabrication wastes since they have been received in Idaho.

Samples of the head space gases from the unirradiated fuel vaults at ICPP have been analyzed under the requirements of a technical specification (TS 4.7C2) which requires that 50% of the vaults are analyzed each year. Thus, a head space gas sample from each vault is analyzed at least once every two years.

The samples were taken through the existing sample line into the head space of the sealed vaults. Of particular interest is the oxygen content, hydrogen content, the concentration of neon that could result from the cover gas in the canisters, helium, and humidity indicating water leaks. The presence of oxygen indicates air leakage into the carbon steel vaults. No gases have been found that are indicating leaking fuel.

The goal of gaseous analysis is to verify canister integrity, any buildup of hazardous gases, or air or water leaks into the well. The humidity level is a direct measure of

unique isotopes present in the U-233 material would immediately indicate a problem with a U-233 drum. To date, there has been no indication of any contamination from a U-233 drum.

2.3 Nondestructive Analysis (NDA)

2.3.1 NDA Examination of Vaults in CPP-749

At the ICPP storage area, four of the dry vaults' interior walls and the exterior surfaces of the fuel storage canisters were examined in July 1997 by a small video camera. When removed from the vault, the camera was checked for surface contamination, which would indicate a leaking canister. No contamination was found.

The cathodic protection system is designed to minimize corrosion damage to the metallic components that are exposed to the soil. Such a system has been installed to protect the CPP-749 vaults. The system prevents corrosion by making the vaults cathodic to a set of aluminum anodes which are sacrificial to the steel in the vaults. The condition of the vaults can be ascertained by measuring the vault to soil potential which makes certain that the vault is cathodic with respect to the soil. This measurement is done annually. The output of the rectifiers are also read monthly. This provides an indication of the condition and depletion of the anodes. The cathodic protection system is providing adequate protection for the CPP-749 vaults.

2.3.2 NDA of U-233 Drums at the RWMC

Fuel packages can be examined by nondestructive analysis (NDA) techniques without opening them. These containers have significant radiation fields (30 to 60 mR/hr at contact with the drums). X-ray techniques, gamma scans, and tomography allow a limited examination of the contents of the storage containers. These systems have limitations because some types of material are not visible using these techniques. However, these techniques do permit verification of the contents and provide some data about the packaging and the distribution of fuel and pellets in the 2R container. An example of a tomographic examination of a U-233 fuel storage drum is shown in Figure 9.

A computerized x-ray tomography instrument was used to examine the contents of the twelve 55-gallon drums that had been stored in the Air Support Building. This instrument is designed to be used only with the 55-gallon drums. Nothing unusual or unexpected was found in these twelve drums. These drums were later examined as part of the internal inspection process. The internal inspection verified the internal condition of packaging and the absence of free liquid.

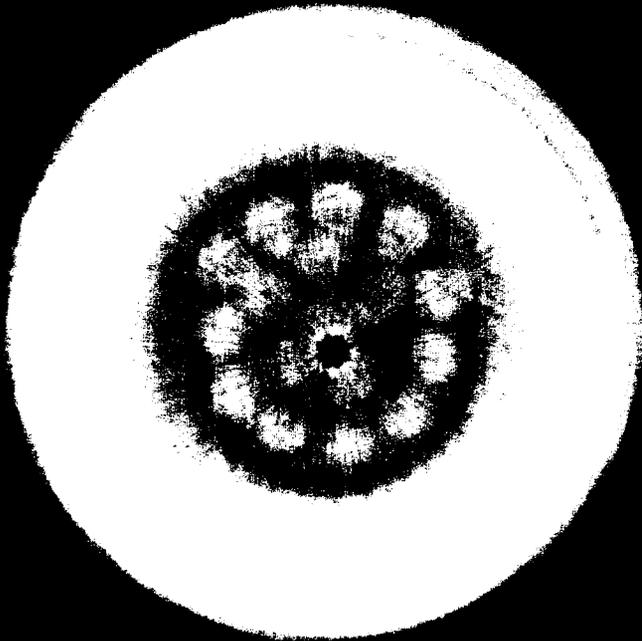
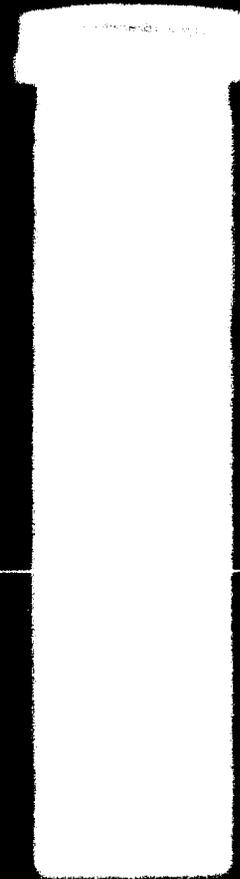


Figure 9 Tomography Scan of a DOT 6M 55 gallon drum containing U-233 fuel material. The scan on the left is a view looking down on the top of the drum. The view on the right is through the side of the drum looking at the 2R container.



The gamma-ray spectrometer shown in Figure 10 was set up to measure the gamma rays emitted from the LWBR material in the storage drums at the RWMC. The spectrometer was placed in a shield made of heavy concrete blocks to minimize stray radiation fields. The intrinsic germanium detector head was collimated to minimize the risk of overloading the detector. A drum was moved into the shielded enclosure and the detector head aimed at the drum. The composition of the LWBR fuel, which was 97% U-233 and 10 ppm U-232 in a thorium matrix that comprises 98% of the fuel matrix, was used to set the parameters for the spectrometer. The gamma scans have also confirmed that the radioisotope gamma ray distribution matches that of aged U-233/U-232 and also shows a strong thorium signature.

Pictorial documentation was used to assess the condition of 20 percent of the 65 storage containers at RWMC. Twelve 55-gallon 6M drums and one 100-gallon drum were opened and extensively photographed with a still camera. These photos show the pattern of corrosion and the extent of the corrosion as well as any physical damage. The photos, taken during the summer of 1997, become a part of the record and can be used to determine the progression of any damage or corrosion with time. The radiation field on the material inside the 2R containers has ranged from 60 to 250 mR/hr. The outside drum radiation field is approximately 30 mR/hr. The condition of drums presently stored in the shielded overpacks is exemplified in Figures 11, 12, 13, 14, 15 and 16. It is important to note that the photos were chosen to indicate the worst case condition in order to be able to point out that these drums are at least as good as those shown and typically in much better condition. In no case were any drums penetrated or detected with water inside. The results of internal inspections found the galvanized drum and 2R containers to be in "like new" condition with minimal staining on the drum interior lids and with no free liquid found on any of the samples.

2.4 Packaging

2.4.1 Visual Inspection at CPP-749

The exterior surfaces of the LWBR fuel material containers at ICPP have been inspected using a small video camera. The records of these inspections are maintained on a video tape. No significant damage to the vaults had been observed. The stainless canisters did not show any sign of degradation.

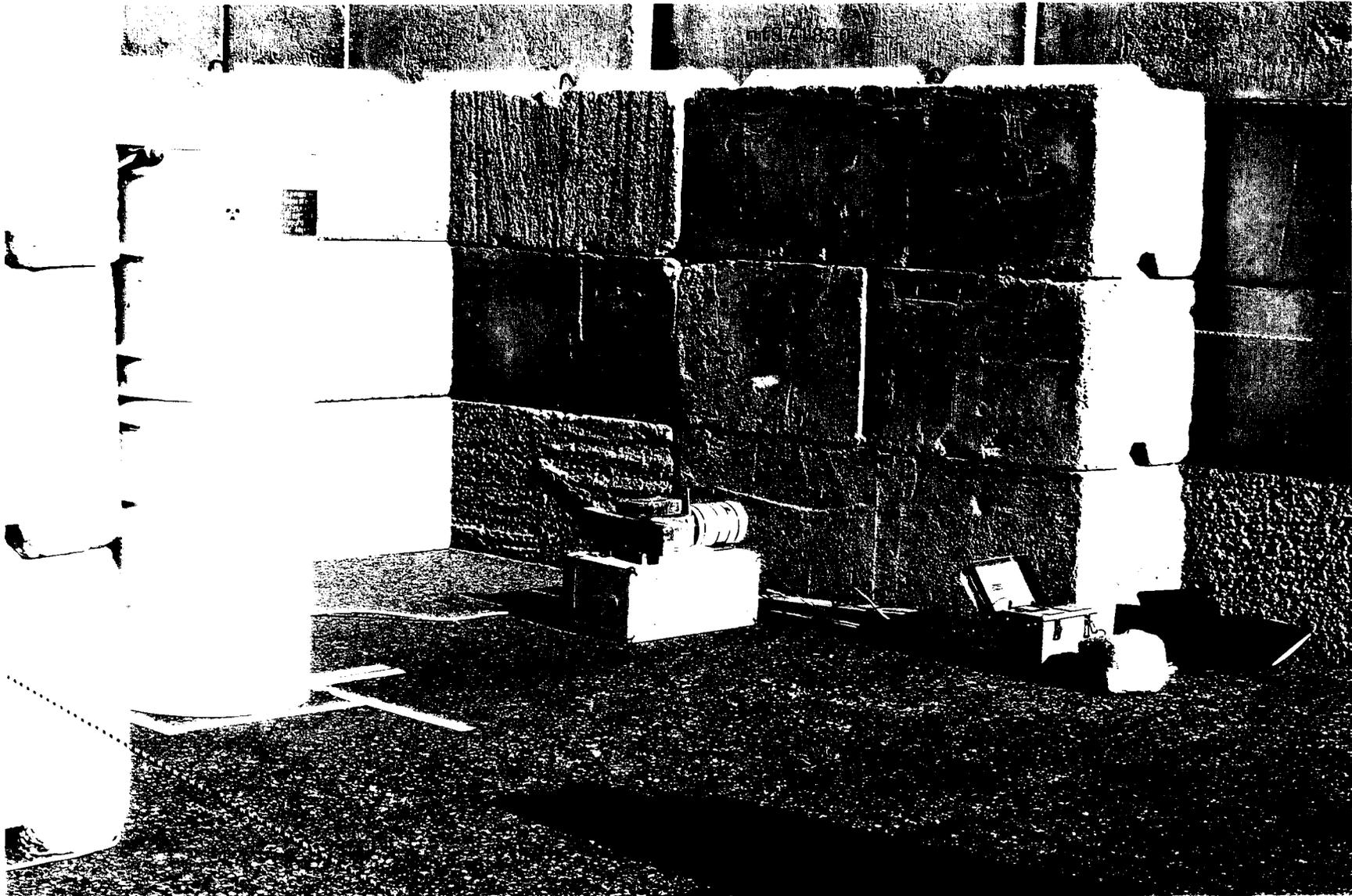


Figure 10 The gamma ray spectrometer used to measure the gamma rays from the 65 drums that were overpacked. The germanium detector is shown on top of the box collimated with lead bricks. The discriminator is in the blue box to right and the data recorder is the lap top computer.

nf971662



Figure 11 Drum number 443 surface showing mechanical damage to the surface coating as well as rust on the coating from the band used to band the drums together.

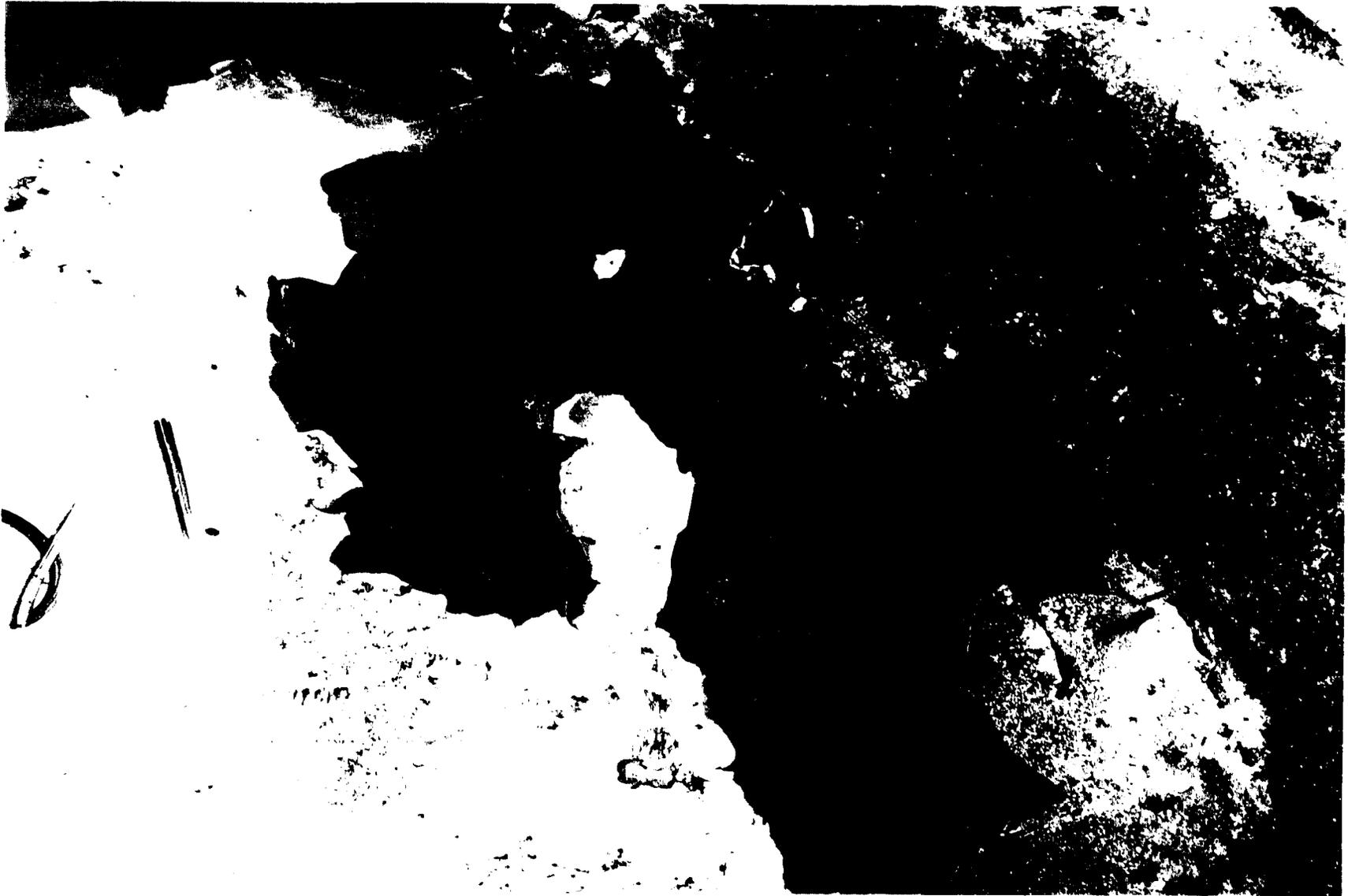


Figure 12 Rust on one of the storage drum lids. This appears to be rust from something that had been set on the lid. The liquid lifted the coating but there is only minor surface corrosion that took place on the metal. This is the worst damage noted on any of the lids. Typically, there was no disturbance of the painted surface on these lids.

nf971758



Figure 13 Surface corrosion on the inside surface of the drum number E-304 lid. This appears to have been the result of corrosion taking place when the drum was closed up with moisture inside. The drum had not been penetrated by the corrosion. This is the worst example of any internal corrosion noted. Typically, no corrosion was observed on the inside of the drum lids.

nf971761



Figure 14 Interior of drum number E-304 showing the condition of the fiberboard spacers, the galvanized interior of the drum and the 2R container. The 2R container has been coated to minimize corrosion.



Figure 15 Drum number E-448 showing the condition of the interior surfaces of the drum and the 2R containers.

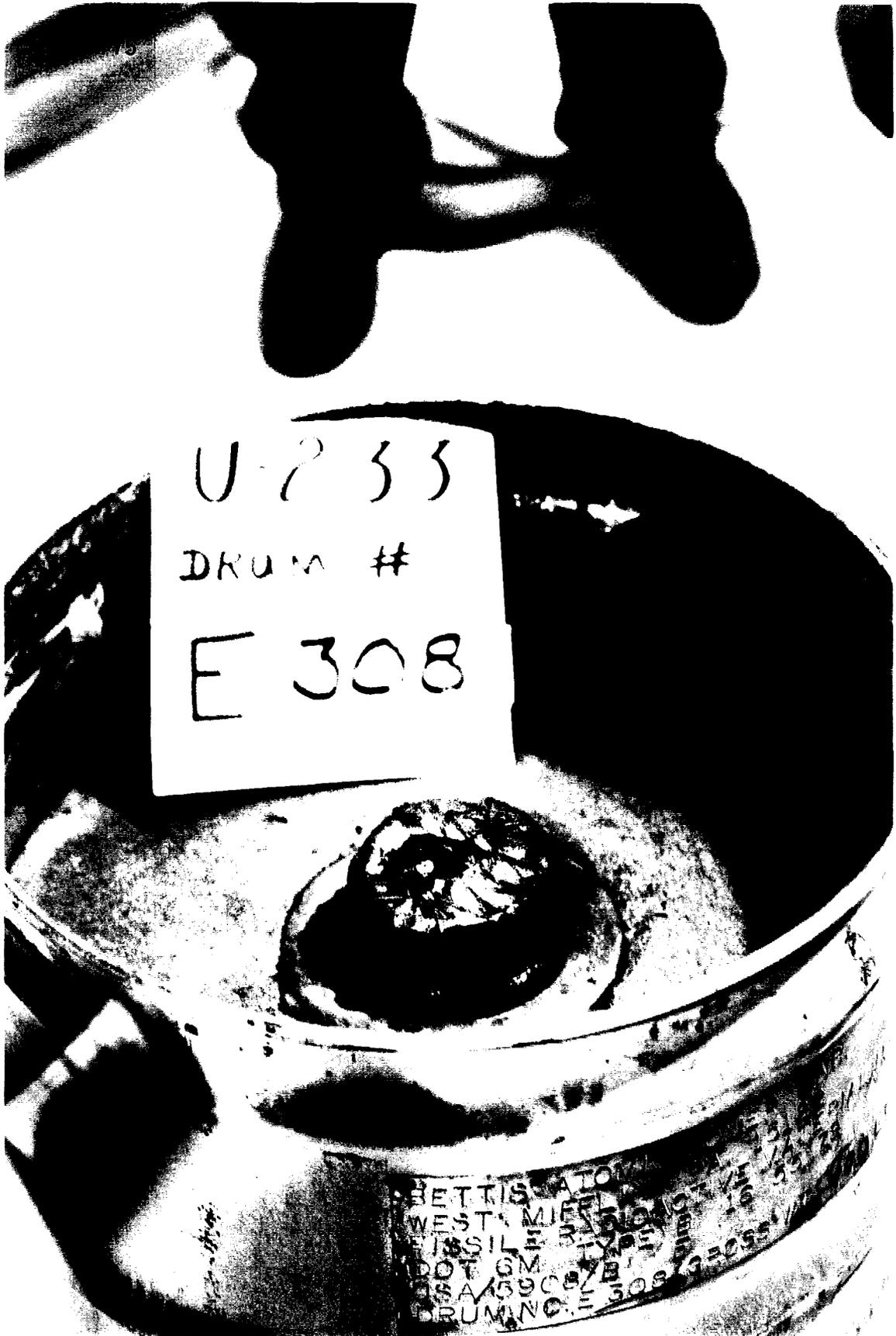


Figure 16 Drum number E-308 showing the plastic packaging from inside the 2R container.

2.4.2 Visual Inspection of LWBR Drums at the RWMC

The exterior surfaces of the 65 above-ground LWBR 55- and 110-gallon containers and internal packaging and 2R inner containers were visually inspected. Thirteen drums (20 percent) that included both container sizes were internally inspected. The interior surfaces were found to be moisture-free with minor staining on the drum lid under-surface. The interior drum wall above the fiberboard packing and the 2R inner containers were clean, dry, and free of rust or degradation. As part of the interior inspection process, the fiberboard packaging was removed to expose the 2R inner container closure cap. The closure cap was removed to further inspect the condition of the 2R contents. Smears for radiological contamination were also taken on all interior surfaces of the drum, 2R inner container, underside of the 2R closure cap, and from the top of the exposed PVC sack holding the fuel rods. No contamination was found on any of the interior surfaces inspected. The 2R container did not indicate that there had been any degradation of the container. The PVC sack was intact, pliable and had not changed color.

Sampled containers were closed in reverse order with pictorial inspections to document the opening inspection and sampling process. After closure of the 6M drums and re-installation of the closure ring bolt, a new tamper indicating device (TID) was installed to verify a secured package. The process used to document the secured package was multiple personnel verifying closure and application of the TID. An individual inspection record was generated for all above-ground stored containers (65) involved in the inspection and shielding process. The shipping containers at the RWMC, containing most of the U-233, were overpacked and moved into covered storage. Inspections of above-ground stored waste indicate a high degree of confidence for package integrity for the TSA stored U-233.

The U-233 drums stored in the TSA-RE facility have not been inspected since they were placed in that array. However, other drums stored under similar circumstances that have been retrieved from other locations at the RWMC have been inspected. The degradation has been found to be insignificant. These drums are galvanized both inside and out, with a corrosion-resistant coating on the outside, and have been stored in an environment protected from the weather. The recent construction of the retrieval enclosure building over the earthen-covered storage pad provides an additional layer of protection for the drums. This design provides high confidence that the drums have not degraded more than drums that have been inspected from the other opened RWMC pads.

The PVC sacks enclosing the material in the 2R containers were pliant and were transparent with the appearance and feel of a fabric. These sacks were closed with tape. One of the sacks was pulled out of the 2R container about 3 inches and the plastic was found to be in excellent condition.

2.4.3 NDA Inspection at the CPP-749 Vaults

No NDA techniques have been applied to the fuel materials at CPP-749 due to the vault configuration and physical limitations of the NDA instruments. Visual verification and limited access have provided sufficient protection.

2.4.4 NDA Inspection of the RWMC Material

The twelve 55-gallon drums stored in the Air Support Building at the RWMC were inspected using x-ray tomography. Gamma scans have also been performed on all of the drums, both 55- and 110-gallon, to verify that the gamma spectrum is consistent with aged U-233/U-232 and thorium. Neutron assay has also been used to examine packages of LWBR fuel materials.

2.5 Remediation

2.5.1 Remediation at CPP-749

There was no remediation required at the dry vault storage.

2.5.2 Remediation at the RWMC

The shipping containers at the RWMC, containing about half of the U-233 not considered waste, were overpacked and moved into covered storage.

2.6 Facility Considerations

2.6.1 Safety Analyses

Safety Analyses Reports (SARs) have been prepared, reviewed and approved. The SAR for the RWMC has been updated to comply with the requirements in DOE-STD-3009, which implements DOE-Order 5480.23. The SAR for the CPP-749 dry vault storage facility was last upgraded in 1991. The Implementation Plan for DOE Order 5480.23 specifies upgrading the SARs at the INEEL. CPP-749 is currently operating under a Basis for Interim Operation (BIO) that permits continued operation under the existing SAR. This SAR is scheduled for update beginning in FY-99.

The LWBR fuel materials are radiation hazards for personnel because of the alpha and beta/gamma radiation associated with the U-233, U-232, and Th-232. These isotopes and many of their daughters are alpha-emitters, which are radiotoxicity concerns. In addition, the presence of U-232 also results in a high-energy gamma-emitting daughter (Tl-208) that can result in significant gamma fields. In order to protect personnel, this material is stored in a manner to limit access and provide

shielding, and is monitored frequently to identify any releases of contamination from the packaging.

Criticality is the other major concern associated with the U-233 fuel materials. Criticality control is maintained by rigid spacing, loading limits, and designs that prevent the intrusion of water into the packaging. The safety analyses from both the CPP-749 area and the RWMC deal extensively with those concerns.

Because of the robust nature of the fuel materials and the robust storage conditions, these controls are believed to be adequate for storage of the LWBR fuel material until it is removed for dispositioning.

2.6.2 Criticality Safety at CPP-749

The criticality safety in the CPP-749 facility is based on the controlled geometry and the rigid spacing of the array of vaults. A set of criticality safety evaluations form the basis for the criticality controls and authorization basis for the CPP-749 facility. A new set of calculations based on updated cross section data are planned prior to the end of FY 1998.

The criticality calculations for the unirradiated LWBR fuel storage canisters stored in CPP-749 are based on storage canisters filled with seed rods in which the U-233 content is 5.6%. This is the upper level of U-233 concentration in the LWBR fuel. The calculation assumptions vary from fully loaded and flooded to a situation where various numbers of rods were removed and that void filled with water. The K_{eff} vary from 0.58 to 0.91 in these situations. A second set of calculations were run with BMU fuel rods with a maximum U-233 concentration of 12.0%. Again, the flooding varied from the minimum void space filled with water to 25% of the rods removed and that void space filled with water. The K_{eff} ranged from 0.71 to 0.93. The calculations were based on the assumption that there were four canisters loaded in a shipping cask.

For criticality to occur, the fuel geometry must be disturbed to increase the void fraction between fuel rods and then the storage canisters must be flooded. For this to happen, three independent events must take place. The canister has to be dropped into the dry vault. Second, there is no crush pad under the canister to cushion its fall and the canister is damaged during the fall. Finally, the vault is filled with water and the canister is flooded. The operational safety requirements for the CPP-749 area are designed to prevent damage to a canister if it is dropped by assuring that crush pads are in place during fuel moves. Also, there are operational safety requirements that will isolate the fuel storage canister from water during the storage lifetime.

2.6.3 Criticality Safety at the RWMC

The criticality safety of 6M drums stored at the RWMC is based on fissile material load limits, favorable geometry and spacing maintained by the 6M drums, and a low risk of drum degradation and flooding. New calculations for the material stored in the shielded overpacks have been completed and form the bases for the safety analysis for the shielded overpack storage.

A criticality safety analysis for the U-233 drums at the RWMC was recently completed by the LMITCO criticality safety group. The models were developed based on available data for the U-233 mass inventories. The shipping data indicates that each of 6M/2R drums contain 300g U-233 or less. Calculations assumed an infinite array of 6M 110-gallon drums containing a double batch of 600 grams of U-233 in water at the optimum slurry height. All of the 6M drums were assumed to be together in the array. In reality, the drums are dispersed throughout the stack. The infinite array was surrounded on the top and bottom by two feet of concrete that would act as an excellent reflector. Various center-to-center spacings were also assumed. In these calculations, the fiberboard spacer and the iron in the drum walls were assumed to be missing. At the spacing provided by the drum's diameter, the K_{eff} was 0.87, but was found to be very sensitive to separation distance.

A 15 x 15 planar array of drums was analyzed using the assumptions above in which drum walls and spacer materials were missing. The K_{eff} for this array was 0.67. A second three-dimensional model using an 11 x 11 x 2 array was tested to determine the effect from stacking for the same assumptions. The K_{eff} for this array was 0.78.

The U-233 drums are interspersed with transuranic waste from Rocky Flats. The quantity of Pu-239 present in those drums is less than 23 grams per drum. Dispersing the U-233 6M drums with either Pu or U-233 waste drums will reduce reactivity because the waste drums are much less reactive than the 2R container filled with the optimum U-233/water slurry.

Criticality safety for the fuel storage drums at RWMC is based on the double contingency principle and on compliance checks for strict adherence to the waste generator plan that must be approved before shipment. A neutron assay system coupled with real time radiography are used to perform a random check of the drum contents. A criticality safety program assures criticality safety during handling but also is designed to assure safety under all normal and credible abnormal conditions without regard to container integrity. Acceptance criteria that limits the fissile material concentrations in the waste drums preserves criticality safety. The criticality section from the Safety Analysis Report for the RWMC (Report No. INEL-94/0226 Rev. 1 effective 11/04/96) is attached as Appendix D and provides additional details on maintaining criticality safety.

2.6.4 Criticality Considerations

A recent Unreviewed Safety Question Determination (USQD) screening process identified an unreviewed safety question regarding a difference in the cross section data for U-233 in the presence of thorium and in the absence of thorium. This difference appears to result in a bias low for calculations that use the cross section data without the effect of thorium. Code validation and updated CSEs will be done this fiscal year.

It is believed that the cross sections that take into account thorium were used for the original shipping and packaging operations. As the result, no significant changes are anticipated in the safety analyses from the resolution of this question.

2.7 Facility Measurements

2.7.1 Ventilation at ICPP

The storage facility at CPP does not have a forced ventilation system for the vaults because the actinides are not in an easily dispersible physical form, the material is chemically stable, and the material is adequately controlled by several barriers. The combination of a non-dispersible form, minimal inspections and sampling, and multiple barriers precludes the need for a ventilation system. Accordingly, there are no measurements of the ventilation system at CPP.

There is periodic radiological monitoring of the surface of the concrete pad and the surrounding earth. Whenever a lid is removed from the storage vault, it is smeared for contamination. While this is not a direct measurement of the ventilation system, it is an indirect measure of airborne contamination.

2.7.2 Ventilation at RWMC

The RWMC RCRA-approved storage facility, WMF-633, containing all of the above-ground shielded overpack containers, is monitored for compliance to the RCRA Part B Permit. Periodic radiological sampling including beta/gamma samples, is done weekly, with alpha samples collected daily. All storage areas are monitored by continuous air monitoring instruments (CAMs).

2.8 Off-Gas Monitoring

Periodic gas monitoring is performed on the gases in the head space of the CPP-749 dry vaults. A Technical Specification for operation of this storage area requires that all of the dry vaults in use shall undergo surveillance at least once every two years. This shall consist

of sampling and analysis of the dry vault atmosphere for oxygen, nitrogen, humidity, hydrogen, helium, neon and volatile fission products. The data obtained is to be examined and evaluated within 30 days in terms of corrosion reactions, fuel canister integrity, hazardous gas mixtures, radioactive contamination of the dry vault, and leakage of air and water into the dry vault.

2.9 Radiation Assessments

There are no fission product isotopes associated with the stored unirradiated materials. However, the actinides and many of the decay products are radioactive. No radioactive contamination has been found during the examination of the LWBR materials that can be associated with any of the unirradiated LWBR fuel.

The drums in the cargo containers stored at the RWMC have been overpacked with shielded containers to reduce the radiation field and have been relocated to a Waste Storage Building. In the absence of contamination associated with the stored material, no further measurements are planned. Surface dose measurements were made on the containers during the overpacking operations. Weekly inspections will be performed to remain compliant to the RWMC Part B RCRA Permit. Radiological assessments will also be performed (both daily alpha and weekly beta/gamma) as long as the U-233 remains in storage in the WMF.

The weekly RCRA inspections and the frequent surveys for the presence of contamination are adequate to identify an event that could indicate that the storage package has been compromised. The purpose for the RCRA inspections is specifically to identify any degraded packaging. Continuous air monitoring is used to identify any airborne contamination or dispersed radioisotopes from a leaking or damaged package.

2.10 Condition Assessments

2.10.1 CPP-749

There have been no observable changes in the LWBR material stored in the CPP-749 dry vaults, and the seed module canister has not changed since it was put into that facility. The routine biennial off-gas monitoring and the video inspection will continue pending final disposition. Maintenance and calibration of the cathodic protection system on the CPP-749 dry vaults will continue through the life of the facility.

2.10.2 RWMC

The drums of LWBR material that had been stored above grade at the RWMC appear to be in good to excellent condition. There is external corrosion of some drum lids, resulting in discolored paint and a small amount of peeled paint. However, that appears to be due to the corrosion of an object sitting on top of the

drum rather than corrosion of the drum itself. The drums under the earthen cover have not been inspected since they were put in the drum storage area in the 1970s and 1980s. Other similar containers removed from similar TSA-type storage locations have not shown significant degradation of the packages. The U-233 drums on the TSA pad will be retrieved when the TRU waste is exhumed for treatment at the Advanced Mixed Waste Treatment Facility.

The only damage observed has been superficial corrosion on the drum lid coating. Because the drums are being transferred to weather-tight storage inside a shielded overpack, no remediation was done or considered necessary. The main drum body on the 55- and 110-gallon 6M drums is galvanized on both the internal and external surfaces. We would expect to see the same drum coatings on the earthen-covered storage containers with similar results, e.g., no internal or external corrosion to the primary drum bodies. The lids of these drums are not galvanized and are only coated on one side. Some surface corrosion of the inside lid surface had been seen but is probably due to moisture that was inside the drum when it was sealed.

The fuel materials inside the drums are stored in sealed 2R containers. Some of the material is in Zircaloy fuel rods or in stainless steel tubes. The 2R container construction is schedule 40 pipe with a red lead oxide (lead pigment) paint. The machine threads on the 2R container and the cap have a thin coating of oil or grease to inhibit corrosion and facilitate removal. During the internal inspection process, all surfaces of both the primary drum, 2R container, and 2R closure caps were inspected for corrosion or signs of degradation with none identified. Only mild staining was noted on the under-side of drum lids with no visible moisture found on any of the sample population.

In all instances related to the storage of this material, there appears to have been no degradation of the actinide material nor of the internal storage containers. The material under the earthen cover is not expected to have degraded based on the condition of drums that have been removed from similar earthen-covered storage from other locations at RWMC.

3.0 EVALUATION OF THE 97-1 IMPLEMENTATION PLAN NEAR-TERM ACTIONS

Several near-term action items were identified during preparation of the Recommendation 97-1 Implementation Plan. These items and their status is shown in Table 3.

Table 3 Status of the INEEL Near Term Actions

<u>Near-Term Actions</u>	<u>Status</u>	<u>Date Completed</u>
CPP-749		
1. Analyze gas samples from 50% of LWBR vaults at CPP-749.	Complete	June 1997
2. Inspect (video) LWBR dry storage vaults.	Complete	July 1997
RWMC		
1. Relocate 12 drums from the air support building to the ILTSF.	Complete	June 1997
2. X-ray tomography of 12 drums in ASB.	Complete	June 1997
3. Conduct a 20% internal inspection on 6M drums and 2R inner containers at the RWMC/WMF-602 Facility.	Complete	August 1997
4. Inspect and overpack 65 drums at ILTSF.	Complete	November 1997
5. Relocate 65 drums from ILTSF to enclosed storage in a waste storage building.	Complete	November 1997

All near-term actions have been completed.

4.0 ASSESSMENT CONCLUSIONS

The unirradiated U-233 inventory at the INEEL includes LWBR fuel material from various stages of the fuel manufacturing process and waste materials contaminated by U-233 during the manufacturing process. It is presently stored under conditions that will minimize package degradation and uncontrolled release of U-233 until a disposition path forward can be identified. Storage of this material is expected to continue until approximately 2025, when it will be moved to an acceptable repository for continued storage or disposal. Under the present material storage conditions, there should be no degradation that would preclude future handling or result in increased environmental, safety, or health risk.

A The Idaho National Engineering and Environmental Laboratory

Appendix A

The Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental laboratory (INEEL) shown in Figure A-1, is a 900 square mile reservation located in South Eastern Idaho. It was set aside for the testing of reactors in 1949. Through the years, there have been a total of 52 reactors constructed and operated at the INEEL. In addition to the reactors, there were two major support facilities; The Idaho Chemical Processing Plant (ICPP) and the Radioactive Waste Management Complex (RWMC).

The Idaho Chemical Processing Plant began operation in 1953 and processed a wide variety of fuels from reactors throughout the DOE complex and from all over the world. It received 40 containers of unirradiated LWBR fuel in 1985 for storage.

The Radioactive Waste management Complex received waste from the INEEL, Rocky Flats and other sites for disposal from 1951 on. At the request of the Bettis Laboratory, they received the scrap and the waste from the LWBR fuel fabrication process. Most of the drums containing this material were intermingled with other waste from other locations. There were 65 drums that were segregated and stored in readily accessible storage in the event that there should be a need for easy access to this material. That material is presently overpacked and is stored in a RCRA compliant storage building at RWMC.

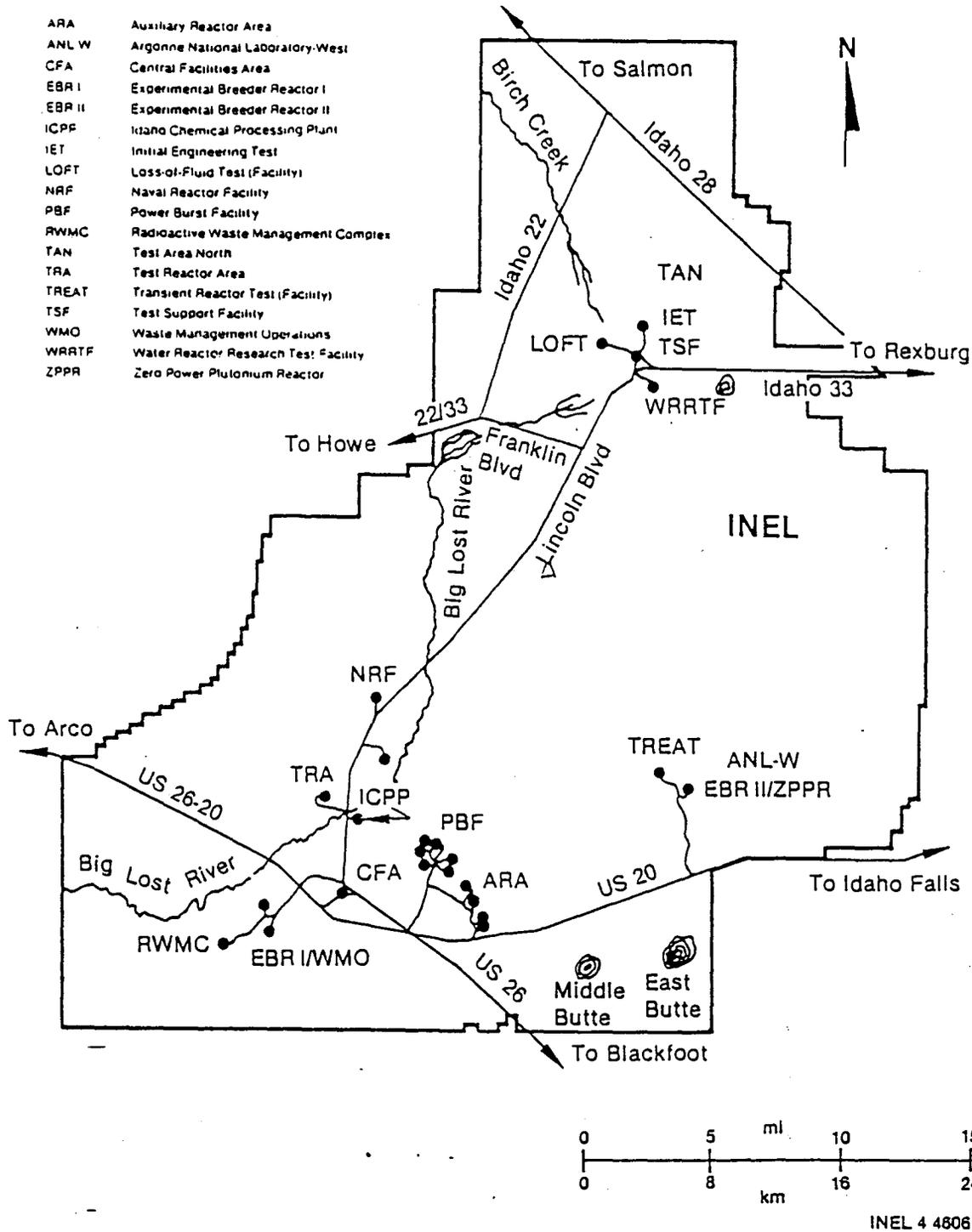


Figure A-1 Map of the Idaho National Engineering and Environmental Laboratory. The facilities of interest in this report are the Idaho Chemical Processing Plant (ICPP) and the Radioactive Waste Management Complex (RWMC), both of which are in the southern third of the site and are approximately ten miles apart.

5:

B LWBR Drums Containing Rod and Pellets in Storage at the RWMC

PART I

WASTE DESCRIPTION

The following tables provide the description information of the waste barrels that were evaluated during the vulnerability assessment, which includes the barrel identification number and isotope content per barrel.

1. RWMC Intermediate Level Transuranic Storage Facility (ILTSF) Connex Waste Barrels (see Attachment III RWMC map for location)

For purpose of clarification, the three connex's that contain the waste barrels that were analyzed can best be described as either a north, middle or south connex. The north connex contains 6 barrels, the middle connex contains 23 barrels and the south connex contains 24 barrels. A total of 53 barrels are contained within the three connex's.

ILTSF CONNEX WASTE TABLE

SHIPMENT DETAILS				
CONTAINER	AMOUNT	741	²³³ U GRAMS	²³² Th Kg
E401M	12 RODS	PZA-VSB-52	287	9.3
E404M	12 RODS	PZA-VSB-52	287	9.3
E415M	12 RODS	PZA-VSB-52	287	9.3
E420M	12 RODS	PZA-VSB-52	287	9.3
E426M	10 RODS	PZA-VSB-52	287	9.3
E427M	12 RODS	PZA-VSB-50	287	9.3
E429M	12 RODS	PZA-VSB-49	287	9.3
E430M	12 RODS	PZA-VSB-51	287	9.3
E431M	12 RODS	PZA-VSB-51	287	9.3
E432M	10 RODS	PZA-VSB-49	239	7.7
E433M	10 RODS	PZA-VSB-51	287	9.3
E434M	12 RODS	PZA-VSB-50	287	9.3
E435M	12 RODS	PZA-VSB-52	287	9.3

E436M	12 RODS	PZA-VSB-51	287	9.3
E437M	12 RODS	PZA-VSB-52	287	9.3
E438M	12 RODS	PZA-VSB-49	287	9.3
E439M	12 RODS	PZA-VSB-51	287	9.3
E440M	12 RODS	PZA-VSB-48	287	9.3
E441M	12 RODS	PZA-VSB-49	287	9.3
E442M	12 RODS	PZA-VSB-49	287	9.3
E443M	12 RODS	PZA-VSB-49	287	9.3
E444M	12 RODS	PZA-VSB-49	287	9.3
E445M	12 RODS	PZA-VSB-48	287	9.3
E446M	12 RODS	PZA-VSB-52	287	9.3
E447M	10 RODS	PZA-VSB-48	239	7.7
E448M	11 RODS	PZA-VSB-51	287	8.5
E449M	12 RODS	PZA-VSB-48	287	9.3
E450M	12 RODS	PZA-VSB-49	287	9.3
E451M	12 RODS	PZA-VSB-50	287	9.3
E452M	12 RODS	PZA-VSB-52	287	9.3
E453M	12 RODS	PZA-VSB-49	287	9.3
E454M	12 RODS	PZA-VSB-49	287	9.3
E455M	12 RODS	PZA-VSB-50	287	9.3
E456M	10 RODS	PZA-VSB-48	239	7.7
E458M	6 RODS	PZA-VSB-50	143	4.6
E459M	12 RODS	PZA-VSB-49	287	9.3
E460M	12 RODS	PZA-VSB-49	287	9.3
E461M	12 RODS	PZA-VSB-50	287	9.3
E462M	12 RODS	PZA-VSB-51	287	9.3
E463M	12 RODS	PZA-VSB-50	287	9.3
E465M	12 RODS	PZA-VSB-51	287	9.3
E466M	12 RODS	PZA-VSB-48	287	9.3
E467M	12 RODS	PZA-VSB-48	287	9.3
E468M	12 RODS	PZA-VSB-51	287	9.3

E469M	12 RODS	PZA-VSB-48	287	9.3
E470M	12 RODS	PZA-VSB-48	287	9.3
E471M	12 RODS	PZA-VSB-51	287	9.3
E472M	12 RODS	PZA-VSB-50	287	9.3
E473M	12 RODS	PZA-VSB-50	287	9.3
E474M	12 RODS	PZA-VSB-48	287	9.3
E475M	12 RODS	PZA-VSB-50	287	9.3
E477M	12 RODS	PZA-VSB-48	287	9.3
I362	METAL	----	188	9.3
TOTAL	607 RODS	----	14,818 GRAMS	482.6 KG

2. RWMC Air Support Building (ASB) II Waste Barrels (see Attachment III. RWMC map for location)

All barrels described within the below table were dispersed among 6,300 barrels within the ASB II.

ASB-II WASTE TABLE

SHIPMENT DETAILS			
CONTAINER	741	²³³ U GRAMS	²³² Th Kg
E301M	PZA-VSB-53	148	48.0
E302M	PZA-VSB-53	148	48.0
E303M	PZA-VSB-53	164	53.0
E304M	PZA-VSB-53	148	48.0
E305M	PZA-VSB-53	140	45.0
E306M	PZA-VSB-53	140	45.0
E307M	PZA-VSB-53	148	48.0
E308M	PZA-VSB-53	54	18.0
E309M	PZA-VSB-53	148	48.0
E310M	PZA-VSB-53	148	48.0
E311M	PZA-VSB-53	148	48.0
E312M	PZA-VSB-53	148	48.0
TOTAL	----	1,682 GRAMS	545 KG

C Criticality review for LWBR Material at the Radioactive Waste Management Complex

**Lockheed Martin Idaho Technologies Company****INTERDEPARTMENTAL COMMUNICATION**

Date: April 24, 1997

To: A. G. Ramos, MS 4201

From: K. B. Woods, 6-3743, MS 3458 ^{KBW}

Subject: STORAGE OF 6-M DRUMS CONTAINING U-233 IN THE WASTE STORAGE FACILITY BUILDINGS AT RWMC - KBW-01-97

References:

1. D. J. Bright and D. R. Wilkinson, "INEL Plan for the Storage of U-233 at RWMC Until a Repository or Treatment Facility is Identified," Document ID: PLN-130, Rev. 0, March 1997.
2. Drawing No. 422503, *SWEPP TX4 Overpack Container*, February 1987.

Summary

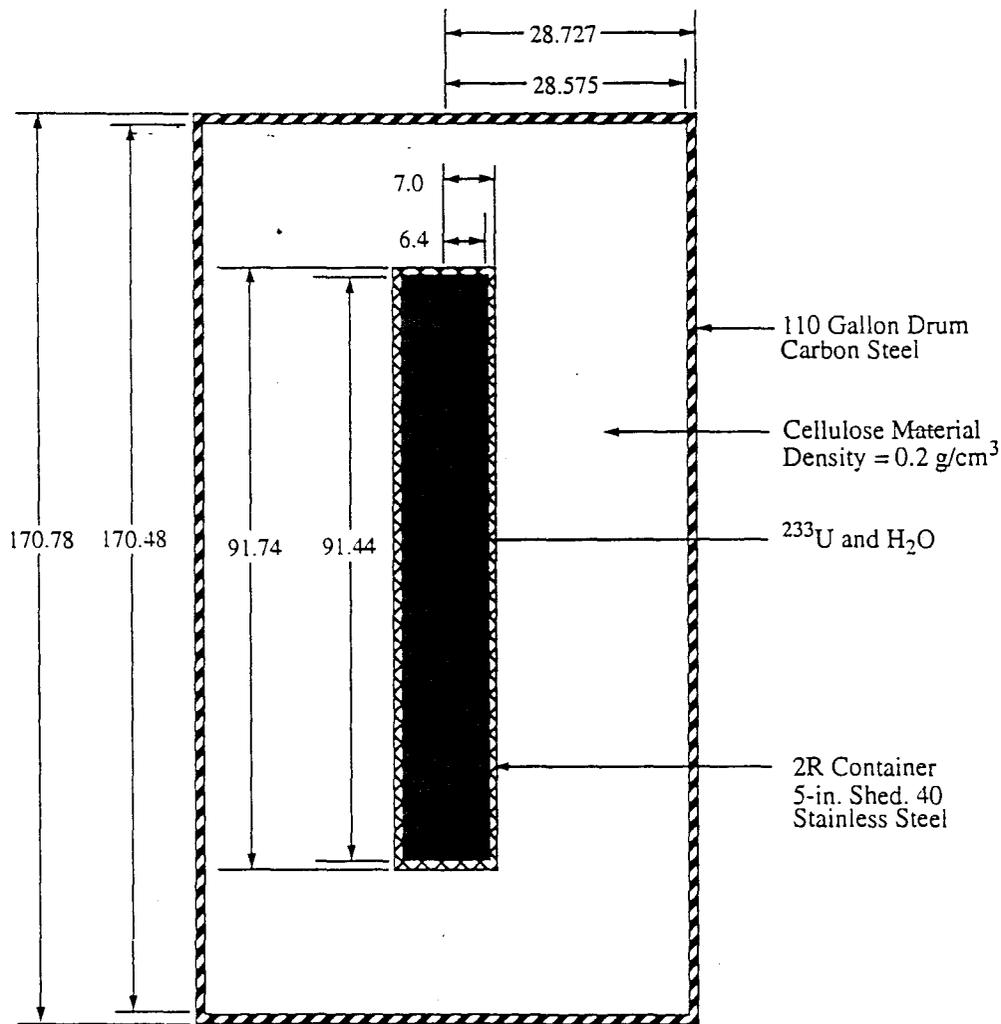
Due to the geometry and ^{233}U loading of the DOT 6M drums, it was not expected that the lead shielding of the TX-4 overpacks would increase reactivity. However, calculations were performed to verify that 6M drums could be safely stored in TX-4 overpacks in one of the existing Resource Conservation and Recovery Act (RCRA) Type II Waste Storage Facility (WSF) Buildings at Radioactive Waste Management Complex (RWMC).

There are currently twelve (12) 55 gallon and fifty-three (53) 110 gallon (sometimes stated as 100 gallons) 6M drums stored on the Intermediate Level Transuranic Storage Facility (ILTSF) pad in the international cargo containers shielded by a concrete radiation barrier. Each 6M drum is equipped with a 2R container centered in the 6M drum. The 2R container is held in place with a cellulose type structure. Six 6M drums will be stored in one TX-4 overpack. The maximum ^{233}U fissile material limit for each 6M drum is 500 grams. The highest loaded 6M drum at the ILTSF pad contains approximately 300 g ^{233}U . In order to reduce the radiation dose to personnel, the overpacks will be surrounded with a 3/4 in.-thick lead shield. Although lead reduces the radiation dose, it is also an excellent neutron reflector.

Calculations shown in this letter indicate that the addition of the 3/4 in.-thick lead shield does not significantly increase the reactivity when compared to a similar system without the lead shield. In addition, the calculated k_{eff} value of a planar infinite array of lead lined TX-4 overpacks remains well below the criticality safety limit ($k_{\text{eff}} \leq 0.95$). Therefore, 6M drums configured in the TX-4 overpacks will be critically safe for storage at the WSF.

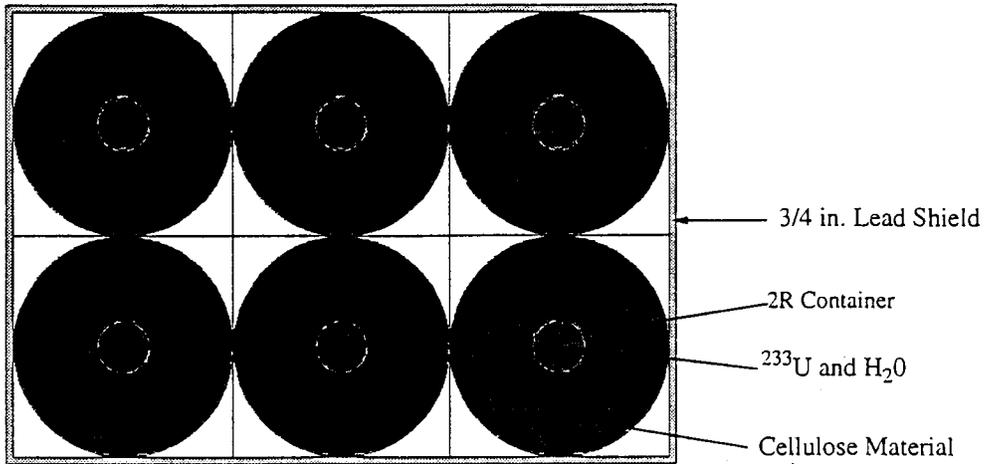
Discussion

Six 6M drums will be stored in one TX-4 overpack. The overpacks will be stacked in a planar array. The 6M drums contain Bettis ^{233}U rod and pellet material. The highest loaded 6M drum contains approximately 300 g ^{233}U . The calculations used 600 g ^{233}U per 6M drum to be conservative. Figure 1 shows a sketch of the 110 gallon 6M drum as used in calculation models. A 2 x 3 array of 110 gallon 6M drums was modeled to simulate the loading in one TX-4 overpack. The array was surrounded on the top and bottom with 2 feet of concrete. The array was infinitely reflected in the x-y planes to simulate an infinite planar array. The interior and exterior steel walls and structure of the overpack were neglected in the calculational models. This assumption is conservative since it allows individual 6M drums to be closer than actually possible. Figure 2 shows details of the calculational models.

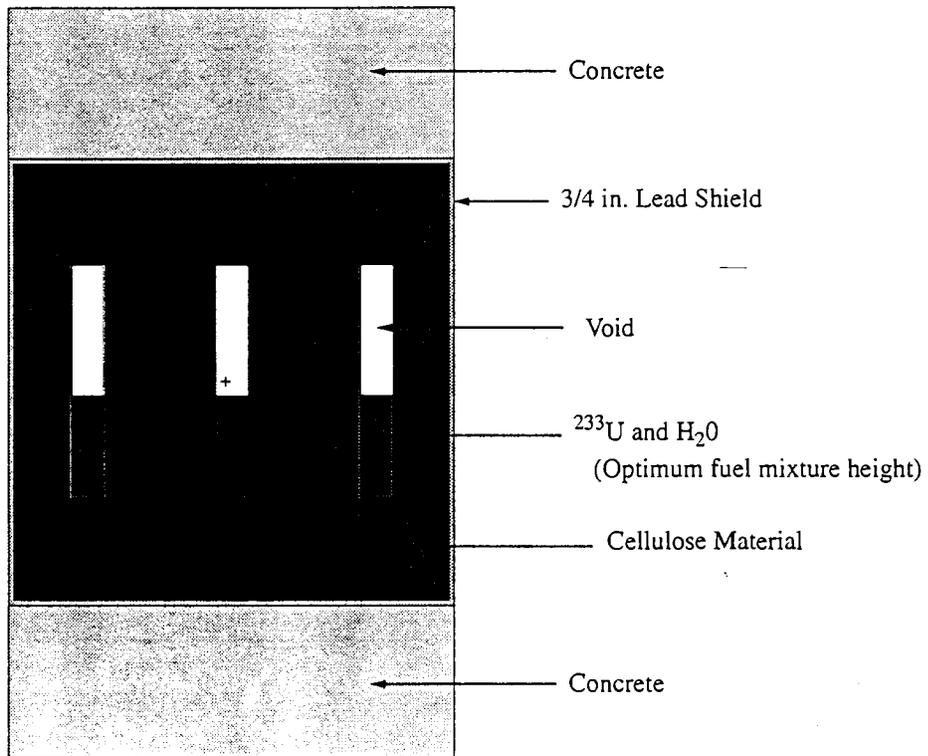


* All dimensions in cm.

Figure 1: Sketch of 110 Gallon 6M Drum.



X-Y View of 6M Drum Array
Infinitely reflected in the x-y planes



Y-Z View of 6M Drum Array

Figure 2: Details of Calculational Models.

Table 1 shows the results of calculations for the 2 x 3 arrays with and without the 3/4 in. lead shield. The results show that the addition of the 3/4 in.-thick lead shield to the overpacks has little effect on the calculated k_{eff} value.

These results were expected. Lead is an excellent neutron reflector but in order for it to enhance the reactivity of a system, it must be close to the fissile region and the fissile region must be either concentrated or large enough to benefit from the return of neutrons. The 6M drums are lightly loaded with fissile material and provide adequate separation to negate the lead reflection effect. Additionally, stacking TX-4 overpacks on top of each other would not appreciably raise the k_{eff} value since there is little axial interaction.

Table 1: Results of Calculations

Case #	Description	$k_{eff} \pm \sigma$	$k_{eff} + 2\sigma$
swepp1	Infinite Planar 2 x 3 Array of 6M Drums Without Lead Shield	0.7179 ± 0.0012	0.720
swepp2	Infinite Planar 2 x 3 Array of 6M Drums With Lead Shield	0.7178 ± 0.0014	0.721

In summary, these calculations show that the sixty-five 6M drums containing ^{233}U stored at the ILTSF pad can be safely stored in TX-4 overpacks at the WSF.

KBW

cc: Bill McBath, MS 4201
Dennis Wilkinson, MS 4201
J. Todd Taylor, MS 3458



Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: March 10, 1998
To: L. C. Lewis, MS 3114
From: K. B. Woods, 6-3743, MS 3458 ^{KBW}
Subject: STORAGE OF DRUMS CONTAINING U-233 AT RWMC - KBW-01-98

- References:**
1. K. B. Woods, "Criticality Safety Evaluation for RWMC," INEL-96/216, August 1996.
 2. D. J. Bright and D. R. Wilkinson, "INEL Plan for the Storage of U-233 at RWMC Until a Repository or Treatment Facility is Identified," Document ID: PLN-130, Rev. 0, March 1997.
 3. K. B. Woods, KBW-01-97 to A. G. Ramos, "Storage of 6-M Drums Containing U-233 In The Waste Storage Facility Buildings At RWMC," dated April 24, 1997.
 4. V. L. Putman, "Criticality Safety Evaluation: Simple Geometry, Single Unit ²³³U Systems," INEL/INT-97-00573, May, 1997.

Summary

Drums containing ²³³U are currently stored at the Radioactive Waste Management Complex (RWMC). Fifty-five gallon drums contain a majority of the ²³³U material, which are enveloped by an existing criticality safety evaluation (Reference 1). Approximately 300 other drums contain ²³³U material contained within 2R containers stored in DOT 6M shipping drums. Calculations using very conservative assumptions were performed and determined a very large margin of safety exists for the 6M drums containing ²³³U material stored under the earthen cover.

Discussion

A large fraction of drums (approximately 1600) stored at the RWMC contain fabrication waste in 55 gallon drums stored on the TSA pad. The drums are stored under earthen cover on an asphalt pad. Approximately 300 more drums contain ²³³U sludge, rods and pellets stored in DOT 6M drums. These 300 drums are stored in two locations at the RWMC: 155 buried on the TSA pad and 65 stored at the Resource Conservation and Recovery Act (RCRA) Type II Waste Storage Facility (WSF) Buildings (recently 53 drums were moved from the ILTSF pad and 12 moved from the ASB-II).² For analysis purposes, the ²³³U drums were divided into three categories: 55 gallon waste drums stored on the TSA pad, 6M drums now stored in the WSF, and 6M drums stored on the TSA pad (under earthen cover). The first group, the 55 gallon drums, contain ²³³U waste in matrices that are enveloped by results reported in Reference 1. The second group, the 6M drums that have never been under the earthen cover and are now at the WSF, are enveloped by results reported in Reference 3. The group of 6M drums stored on the TSA pad are evaluated in this letter.

Each 6M drum is equipped with a 2R inner container centered in the 6M drum. The 2R container is a critically safe Sch. 40 stainless steel pipe with an inner diameter of ~5 in. and is held in place with a cellulose type structure. Figure 1 shows a sketch of a typical 110 gallon 6M drum. This configuration results in a 43.5 cm edge-to-edge separation between 2R containers in a square pitched array. The 6M drums were apparently stored on the TSA pad in a random order and are dispersed throughout the drum stack. The maximum allowable ^{233}U limit for each 6M drum is 500 grams (Fissile Class 1 mass limit from 49 CFR §173.417), although RWMIS data indicate that each drum has 300 grams ^{233}U or less.

Calculations were performed with infinite arrays of 6M drums to simulate storage on the TSA pad. Each 6M container was modeled with a double batch of 600 g ^{233}U and water at the optimum slurry height. Various spacings between the 2R containers were analyzed to determine the sensitivity of reduced spacings resulting from drum degradation. The iron drum walls, cellulose material, and associated materials between drums (i.e. soil and/or water) were conservatively assumed to be missing. The material of the 2R container was included since it is thick stainless steel and is not expected to degrade at the same rate as iron in the drum.

Calculations presented have include several conservatisms. The calculations assumed water intrusion in all 2R containers that is homogeneously mixed with ^{233}U to the optimum slurry height. Additionally, the calculated models have 600 g ^{233}U per 2R container, even though shipping records indicate that each drum has approximately 300 grams ^{233}U or less. All 6M drums were modeled together in an array, which is not likely, since they were apparently dispersed in the stack in a random order. Void was conservatively modeled between the 2R containers in the array, which provides no neutron absorption between 2R containers. Plutonium or ^{233}U waste matrices that fill the entire void between 2Rs would increase reactivity for the reduced separation cases, but this condition is not deemed credible at this time.

An infinitely reflected 3 x 3 array of 6M drums was modeled to simulate drums containing ^{233}U located on the TSA pad. The array was surrounded on the top and bottom with 2 feet of concrete and was infinitely reflected in the x-y planes to simulate an infinite planar array. Concrete was conservatively assumed since it is an excellent reflector. Figure 2 shows details of the calculational models. Various center-to-center spacings between the 2R containers were calculated to see the effect on spacing between 2R containers. The results are shown in Table 1. With the given modeling assumptions, it can be seen that the system reactivity is very dependant on the separation between 2R containers.

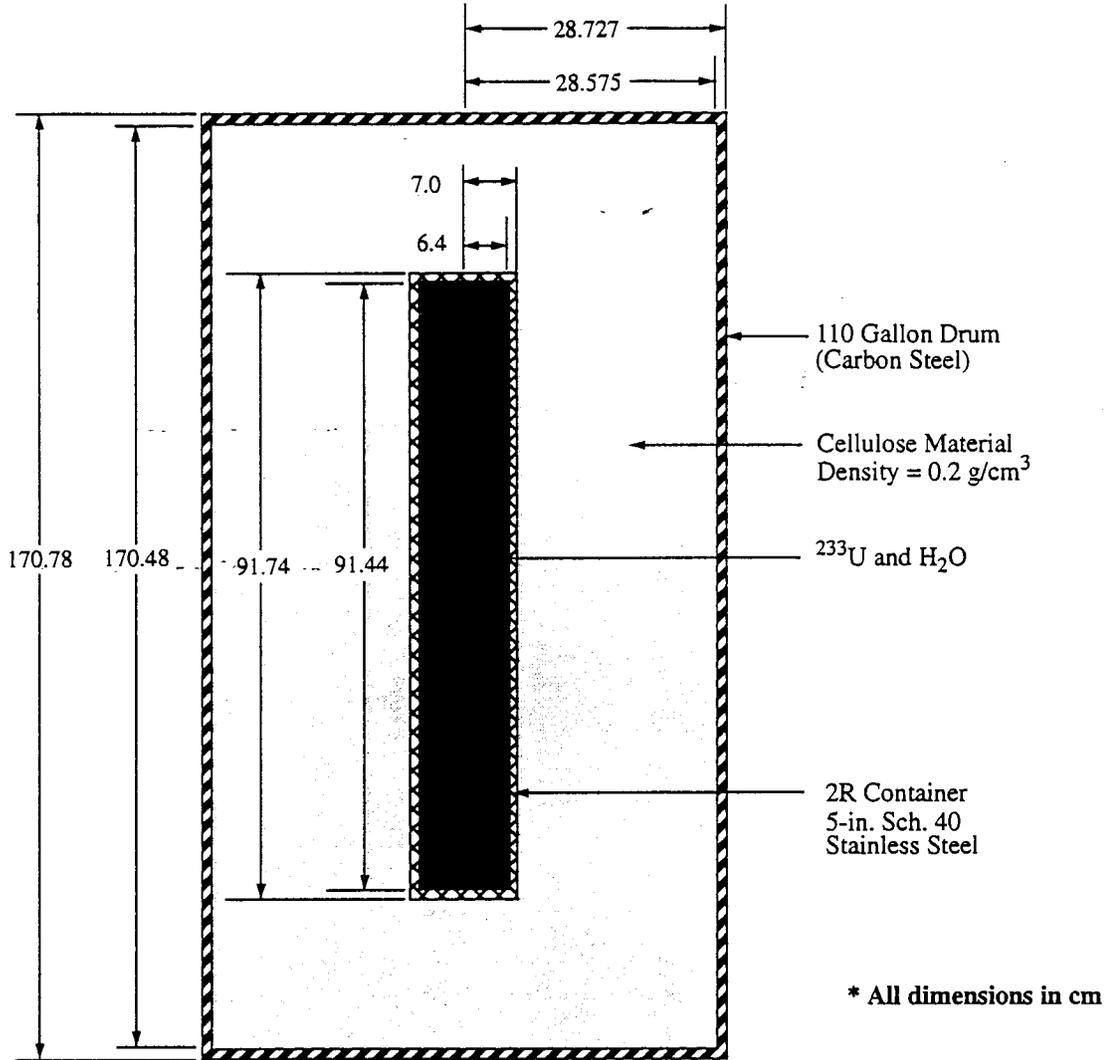


Figure 1: Details of 6M Drum.

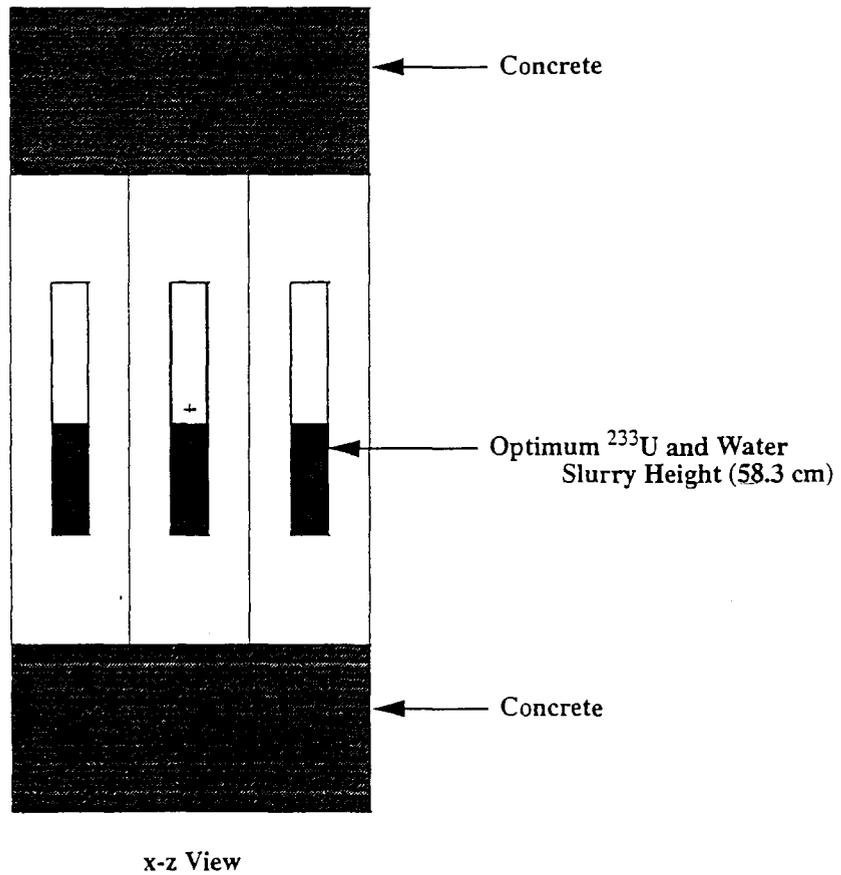
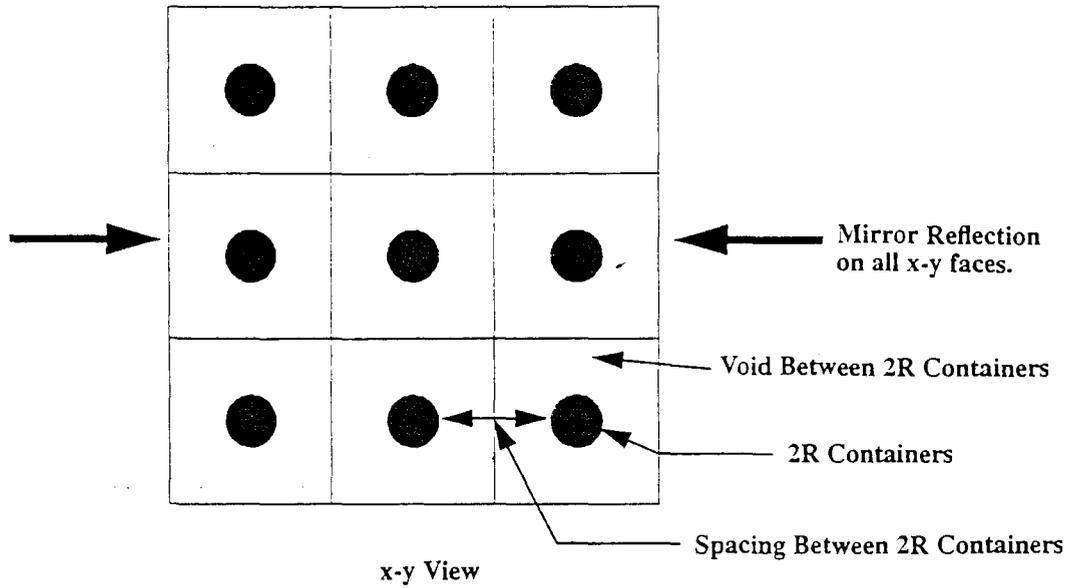


Figure 2: Details of Calculational Models for 3 x 3 Infinite Arrays.

Table 1: 2R Containers in Infinite Array at Various Spacings

Case #	Center-to-Center Spacing Between 2R Containers (cm)	$k_{eff} \pm \sigma$	$k_{eff} + 2\sigma$
sp20	20	1.1362 ± 0.0019	1.140
sp30	30	0.9978 ± 0.0018	1.001
sp43.5	43.5 ^a	0.8660 ± 0.0023	0.871

a. Nominal spacing of 2R containers in array of 6M drums.

A 15x15 array of 2R containers was also analyzed with a 2R container edge-to-edge spacing of 43.5 cm. An array of 225 containers provides an enveloping number of 6M drums stored on the TSA pad. As modeled previously, the iron drum walls, cellulose material, and associated materials between drums were assumed to be missing. All 6M drums were modeled together, which is not likely. Arrays were surrounded with the allowable RWMC WAC diluent limit for a ²³³U-MgO waste matrix, ²³⁹Pu-MgO waste matrix, and ²³⁹Pu-SiO₂ waste matrix to simulate storage conditions on the TSA pad. The waste matrices consisted of 0.15 g ²³³U/lb MgO matrix, 0.15 g ²³⁹Pu/lb MgO matrix, and 0.09 g ²³⁹Pu/lb SiO₂, which were found to be the threshold fissile material concentrations (Reference 2).

An 11x11x2 array was also analyzed to see the effect of multiple layers of 6M drums. An array of 242 containers again provides an enveloping number of 2R containers. The 2R containers had a horizontal spacing of 43.5 cm (the spacing provided by a drum). The vertical spacing between 2R containers was 79 cm.

Table 2 shows the calculations for these configurations. As seen, the arrays with a finite number of 2R containers listed in Table 2 indicate that the infinite arrays shown in Table 1 provide very conservative results.

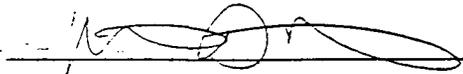
Table 2: Results of Calculations

Case #	Description	$k_{eff} \pm \sigma$	$k_{eff} + 2\sigma$
arr1	15x15 array of drums surrounded by ²³³ U-MgO matrix	0.6646 ± 0.0016	0.668
arr2	15x15 array of drums surrounded by ²³⁹ Pu-MgO matrix	0.6760 ± 0.0016	0.679
arr3	15x15 array of drums surrounded by ²³⁹ Pu-SiO ₂ matrix	0.6403 ± 0.0018	0.644
arr4	11x11x2 array (2 tiers) of drums surrounded by ²³³ U-MgO matrix	0.7772 ± 0.0012	0.780

In summary, the calculations along with associated modeling assumptions and conservatisms indicate the 6M waste drums containing ^{233}U , even if all stored together, will remain subcritical as long as the separation provided by the 6M drums is maintained.

In order for unsafe conditions to occur, multiple 2R containers must be flooded with water, no water can be between the 2Rs, and the spacing between 2Rs must be reduced. These conditions could occur over many, many years of storage under earthen cover, but are not conceivable in the short term.

These calculations are not meant to be all enveloping, but do provide information as to the large margin of safety for the 6M drums on the TSA pad. Although no specific validation data exist for these types of fuel arrangements, benchmark experiments with solutions containing ^{233}U have been analyzed and provide some validation information for the calculations performed.⁴

Calculations Checked by:  3/12/98

KBW

cc: Bill McBath, MS 4201
Dennis Wilkinson, MS 2414
J. Todd Taylor, MS 3458
Amadeo Ramos, MS 4201

D Inadvertent Criticality Safety Section from the RWMC Safety Analysis Report

6. INADVERTENT CRITICALITY PROTECTION

6.1 Introduction

This chapter describes the essential features of the criticality safety program in place at the Radioactive Waste Management Complex (RWMC). In doing so, the chapter adheres largely to the format and content guidance provided in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, issued in July 1994.

Waste to be stored or disposed of at the RWMC falls into two broad categories: transuranic (TRU) waste, containing more than 100 nanocuries (nCi) of transuranic nuclides (those with atomic numbers greater than 92) per gram of waste; and low-level radioactive waste (LLW), containing fewer than 100 nCi/g. At the RWMC, TRU waste is retrievably stored, and LLW is disposed of by burial in pits, trenches, and soil or concrete vaults. Two practices depart from this strict technical definition: U-233 is treated as a TRU isotope, notwithstanding its atomic number; and LLW with a TRU content between 10 and 100 nCi/g is retrievably stored in the same manner as TRU waste.

Most retrievably stored waste containers are stacked in arrays on concrete and asphalt pads at the Transuranic Storage Area (TSA). The Intermediate-Level Transuranic Storage Facility (ILTSF) is intended for retrievable storage of TRU waste containers having surface radiation fields above 200 mR/h.

6.2 Requirements

The criticality safety program at the RWMC complies with the intent of the requirements of DOE Order 5480.24, *Nuclear Criticality Safety*, and its associated Interpretive Guidance,⁶⁻¹ and with the American National Standards Institute/American Nuclear Society (ANSI/ANS) Standards called out in the order.

6.3 Criticality Concerns

Criticality safety at the RWMC is a concern because much of the waste stored or disposed there contains fissile materials. Because of the large quantities of waste [there are well over 100,000 waste containers retrievably stored at the TSA and many more have been disposed at the Subsurface Disposal Area (SDA)], total quantities of fissile plutonium and uranium are many times the minimum critical masses of these isotopes. They are, however, mostly dispersed in low concentrations throughout the waste materials. In most cases, the fissile material exists only as contamination of the waste material, although bulk items, such as pieces of reactor fuel and metallographic mounts, are occasionally included. A study⁶⁻² of the fissile nuclide distribution in retrievably stored TRU waste (the waste type most likely to include substantial quantities of fissile materials) indicates that the concentration of the most important fissile isotope, Pu-239, exceeds a value of 3.1 g/ft³ in only 0.5% of this waste type (see Table 9 of Reference 6-2). In other words, only five out of every 1,000 55-gal stored TRU waste drums contain more than 23 g of Pu-239.

6.4 Criticality Controls

It will be shown in this and the following sections that an accidental criticality in stored or disposed waste is not credible at the RWMC. The extremely low likelihood of such an event depends primarily on inherent properties of the waste, and only to a small degree on engineering or administrative controls at the storage or disposal site (although those inherent properties are ensured by acceptance criteria imposed on waste generators). The following sections contain a summary of the criticality safety evaluation (CSE)⁶⁻³ for waste containers loaded as reported by the waste generator, an argument for the safety of containers that may depart from the fissionable material loading reported by the waste generator, a section on ILTSF vault storage, and a section for special criticality safety concerns. An additional section discussing compliance with the Company's criticality safety program contains the discussion of the application of the double contingency principle.

The criticality safety argument in this section is based on two separate approaches for two separate considerations. The criticality analysis presented in Section 6.4.1 provides the basis for the safety of large arrays of normally loaded waste containers. Although prohibited by waste acceptance criteria, a few containers that have a significant overload of fissionable material might have been inadvertently received and placed on the TSA pads. The large-array analysis is inadequate to give any assurance of safety for containers with enough fissionable material that a criticality is possible in a single container or from interaction of a few such containers. Engineering judgement and a qualitative analysis is presented in Section 6.4.2 and provides additional criticality safety basis for those containers.

6.4.1 Criticality Considerations for Large Waste Arrays

The CSE for TRU waste stored on the TSA pads (Reference 6-3) uses an engineering judgement and process knowledge (known acceptance criteria for RWMC waste) approach. This approach is based on taking credit for the presence of the waste matrix in which the fissile material is dispersed, but no credit is taken for container shape or array configuration. Waste at the RWMC is identified by its major constituents and assigned an appropriate content code for those constituents. The approximately 150 content codes have been divided into nine waste matrix groups, and each group includes several content codes. The matrix material that defines a group is either the major constituent of the content codes in the group or a conservative substitution for the actual constituents (e.g., aluminum stands for all metals, polyethylene for plastics, cellulose for wood and paper, etc.).

All fissile materials are represented in the CSE by Pu-239. This substitution is conservative for all fissile nuclides included in the waste at the RWMC, except for U-233, which is treated separately and results in less conservative threshold concentrations for the metal and salt matrix groups.⁶⁻⁴ The plutonium in the stored TRU waste was produced for nuclear weapons and is composed of greater than 90 wt% Pu-239, and about 6 to 8 wt% Pu-240.⁶⁻⁵

Several different neutronics codes and cross section data sets were used for the calculations in Reference 6-3. The majority of calculations were performed with the SCAMP one-dimensional transport theory, using 16-group Hansen-Roach cross sections. Additional calculations were performed with the three-dimensional Monte Carlo code KENO-V.a, using both 16-group KENO cross section data

(primarily comprised of Hansen-Roach data) and 27-group cross section data based on ENDF/B-IV data. Calculations intended to verify the SCAMP results using Hansen-Roach cross sections were performed with the three-dimensional Monte Carlo code, MCNP, using continuous energy ENDF/B-V cross sections, and with SCAMP, using 16-group ENDF/B-V cross sections generated through the neutron spectrum and cross section generation program, COMBINE. Detailed references and discussions of the verification methods and computer modeling are given in Reference 6-3. In general, infinite systems have been modeled for the calculations reported in Reference 6-3, where the fissile material is uniformly dispersed in the matrix material. However, effects of heterogeneity, mixing of different waste matrices, addition of water to the matrix, and discrete modeling of drums are also considered. Through a series of calculations, the relationship between fissile material concentration (in grams of Pu-239 per pound of matrix material) and the system multiplication factor k (strictly k_{inf} rather than the usual k_{eff}) is obtained. Thus, the Pu-239 concentrations in each matrix that produce multiplication factors of 1.0 (critical) and 0.95 are found.

Threshold concentrations are established at 75% of those producing critical ($k=1.0$) infinite systems. Figures 1 and 2 in Reference 6-3 show that these threshold concentrations yield infinite system k -values well below 0.95. All new incoming waste will be accepted only if it is shown to be safe by the infinite system standard (e.g., it does not exceed threshold concentrations). Table 6-1 shows the waste matrix groups and calculated threshold concentration values. A typical example of this criteria would be a 55-gal drum containing concrete pieces weighing 500-lbs; criteria - $(0.38\text{g/lb}) \times (500\text{lb}) = 190\text{g Pu-239}$. Content codes are assigned to a waste matrix group during the approval process of INEL Form L-0669#, "Material and Waste Characterization." The content codes are used by waste generators to describe the wastes

Table 6-1. Waste matrix groups and threshold fissile material concentrations.

Matrix group	Threshold concentration ^a (Pu-239 g/lb matrix)	Threshold concentration ^a (U-233 g/lb matrix)
Polyethylene	3.10	4.98
Cellulose	1.30	2.16
Metal (Al)	0.82	0.38
Concrete	0.38	0.62
Brick	0.23	0.34
Glass/slag	0.09	0.15
Graphite	0.02	0.03
Salts	5.53	4.27

a. Threshold concentration is 75% of that concentration that produces a critical ($k_{inf}=1.0$) infinite system.

shipped to the RWMC for storage. Each content code has been assessed to determine the waste type (TRU or LLW), form, generation source of the waste, recovery methods, waste packaging and handling practices, waste container preparation, assay method, and a subjective evaluation of the wastes' compliance with the requirements of the Waste Isolation Pilot Plant (WIPP)-Waste Acceptance Criteria (WAC). The threshold values are compared in the CSE to a database of waste containers that includes approximately 73,000 metal drums, 10,000 wooden boxes, and 500 metal bins (all from the same originating site: Rocky Flats). This database is a representative sample of all stored TRU waste. Containers in the database are grouped by content codes, and then by the nine matrix material groups.

A review of the Rocky Flats database shows that a small fraction of all containers presently stored at the TSA has fissile material concentrations exceeding the threshold values. [Of 72,728 containers, 3,275 (4.5%) exceed the threshold concentrations.] Because the infinite system standard is too conservative for these containers, a different analytical approach is used in the CSE to show the safety of containers with higher fissile concentrations. In this approach, which is discussed in more detail below, containers are modeled in compact arrays surrounded by an infinite system containing the threshold concentration. Table 4 in Reference 6-3 shows that, overall, fewer than 5% of all drums in the database exceed the threshold concentrations. For added conservatism, all containers that have fissile material concentrations exceeding 37.5% (one-half of the threshold concentration) of the infinite system critical concentration are included in the separate analytical approach. As shown in Table 16 of Reference 6-3, this still only comprises about 6% of all drums.

The following discussion of graphite matrix drums illustrates the analytical approach used for all drums addressed under this separate approach. The graphite matrix group contains 2,365 drums, of which 1,904 exceed the threshold (75% of critical) concentration. The contents of this finite number of drums is modeled as a cubic array of pseudo drums surrounded on all six sides by a blanket of the second-most reactive matrix (glass or slag) containing the threshold concentration of Pu-239 found for the fully infinite system. All internal and external void space that is characteristic of an array of drums has been removed from the model. Therefore, the structural integrity of the drums is not required to maintain the criticality safety margins. The cubic array of pseudo drums is sized to envelope all graphite waste in the database (as if all containers in the graphite group were stacked in a cubic array). The array is modeled with a Pu-239 concentration corresponding to the highest found in a single container in the database.

The pseudo drums are cuboid with volumes corresponding to those of the contents of the heaviest drum and the drum with the greatest fissile concentration in the group. The total mass of steel in a 55-gal drum is placed tightly around the waste volume of each pseudo drum. This methodology allows taking credit for the neutron absorption properties of steel in a conservative manner. Mirror reflection is applied to all six sides of the blanketed cubic array to model an infinite system. The blanket material chosen was SiO (the next lowest threshold concentration material) at the threshold concentration.

The arrays of pseudo drums are surrounded by a layer of homogeneous matrix with Pu, the next most severe type after graphite, and finally by mirror reflection to make an infinite system. The thickness of the homogeneous layer is increased until k reaches a stable value. This is equivalent to stacking all the worst drums in the worst possible way in the center and surrounding them with the next worst set, and so forth. This is very conservative.

The thickness of the blanket material is determined from a series of parametric calculations to isolate the graphite arrays in the infinite system from one another (as the blanket thickness is increased, the multiplication factor reaches a constant value, indicating that neighboring graphite cubes no longer interact). The resulting multiplication factors in all cases are less than 0.95.

The modeling described above represents an assumption that all of the drums of a matrix group that exceed one half of the threshold concentration (or, in the graphite group, all the drums in the group) are stacked close together. The stack is shown to be subcritical under this very conservative assumption.

This analytical approach contains many conservatisms, including the assignment of content codes to the matrix group of the most reactive major constituent, analysis of infinite systems, and use of Pu-239 as the isotope representing all fissile materials. Stacking configuration, whether orientation of drums (vertical versus horizontal) or stacking height, is not a factor in the safety of any of the analyzed systems. The fissile isotope of concern in LLW is U-235, which is less reactive than Pu-239 on which the bounding analysis of the CSE is based. Consequently, the analysis is conservative when applied to LLW disposal.

Future waste receipts are limited to containers that have been shown to be safe in an infinite matrix. Typically, this will be done by showing that the container has an average fissile material concentration below the threshold value indicated in Table 6-1 for the waste matrix group to which the container belongs as determined by the major constituent in the waste container. Alternatively, a specific analysis for a container could be provided, showing criticality safety in an infinite system. Such analysis would have to comply with the CSE requirements of Company procedures.

The conclusion drawn from the waste acceptance criteria and above analyses is that the stored waste is highly subcritical in its current configuration and that no credible rearrangement of containers, whether performed by RWMC personnel or caused by natural forces such as wind or earthquake, can result in a criticality accident. The preceding discussion includes very large margins of safety (use of the 75%-of-critical level as the threshold, and 37.5%-of-critical as the cutoff for the separate analysis treatment) to accommodate postulated significant errors (more than a factor of two) in the database that could theoretically arise from, an extremely unlikely, consistent under-reporting of fissile content by the waste generator. The next section contains a qualitative analysis supporting the argument that a criticality is an incredible event (under severe overload conditions) in waste containers.

6.4.2 Criticality Considerations for Individual Overload Conditions

All containers are received at RWMC with documentation certifying their compliance with waste acceptance criteria, which include limits on fissile material content. It is possible, however, that overloads have escaped the waste generator accountability system. In fact, a limited assay sampling at the RWMC has found some containers that appear to contain such overloads. The following paragraphs provides a qualitative discussion concerning the safety of unidentified overloaded containers.

Two criticality accident scenarios are postulated for evaluation. The first involves a breakdown in controls at the generator facility and fissile material in excess of the minimum critical mass, in the form of contaminated waste (anti-contamination clothing, lab, or process equipment) or in the form of dilute concentrations in process residues (sludges or salts), is placed in a waste container. The second assumes is that fissile material in excess of the minimum critical mass but not intended for waste (e.g., Pu "buttons," or other product) is inadvertently disposed of with the waste. The resulting analyses for both accident scenarios show that the conditions for criticality are not credible.

The following discussion is based on concepts contained in Reference 6-6, and the contributions of the author of that reference are hereby gratefully acknowledged.

To achieve criticality in a single container, generally five factors must be present: there must be (a) sufficient fissile mass and (b) sufficient moderator and reflector material at the hydrogen most reactive density for the system; (c) the fissile material must be intimately mixed with the moderator at an appropriate concentration and the concentration must be nearly uniform throughout the critical volume of the mixture; (d) the mixture must be in a near spherical shape; and (e) there must be insufficient neutron-absorbing and diluent material in the mixture to prevent criticality. These factors must combine for a critical system to be formed. For example, consider a spherical system of plutonium and water that is just critical: as the plutonium mass is increased above the minimum required for criticality, the shape can depart from spherical and the system can still be critical. The likelihood of a mixture of water and plutonium being the right shape for criticality (exactly spherical at the minimum plutonium mass) is extremely small. However, as the plutonium mass is allowed to increase, this likelihood increases, whereas the overall frequency of having that much mass available decreases. A larger fissile mass is less likely to be distributed uniformly throughout the volume of concern because it likely consists of heterogeneous pieces rather than being uniformly divided. It is, of course, true that with a sufficient degree of overloading (e.g., much greater than 5 kg of Pu) a criticality is possible without moderation. For even more severe cases, the geometry does not have to be spherical anymore, and, with sufficient Pu available, there could be significant poisons and diluents and the system could still be critical. However, the likelihood of having this much Pu mass available is several orders of magnitude smaller than having 500 g available.

Because it is impossible to estimate the frequency (likelihood) for all combinations of the factors that contribute to form a critical system in a waste container, only one combination is analyzed: a minimum critical mass with near optimum conditions for the other parameters. This example combination envelops all other combinations. The parameters for this critical system are taken from Figure 6-1 (Figure 31 in Reference 6-7). This figure shows that criticality occurs for water moderated spherical systems with plutonium masses between 510 and 800 g at concentrations between 15 and 90 g/L, with the minimum critical plutonium mass being approximately 510 g at a concentration of approximately 30 g/L. Note that while the factors (a) through (e) must coincide as discussed above, the likelihood of any one of them occurring in a waste drum is independent from the others.

Conditions more reactive than the conservative models described in Section 6.4.1 (full density of the most reactive moderator/diluent for each waste type) are difficult to achieve. Intuitively, it appears that assembly of a critical system in waste material is not credible: a moderated sphere of plutonium where the plutonium is in the form of surface contamination or exists as trace concentration in process

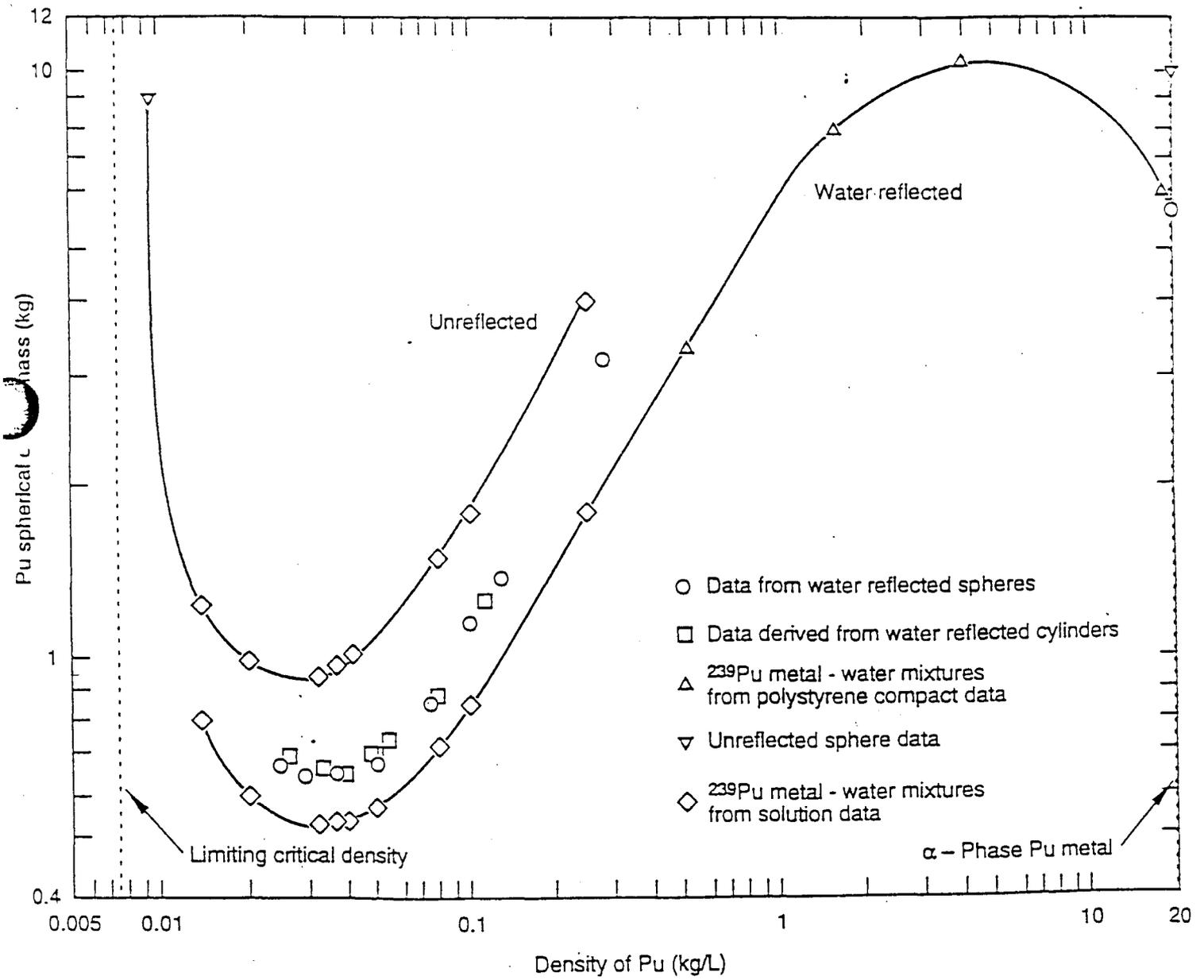


Figure 6-1. Critical masses of homogeneous water-moderated plutonium spheres.

residues is extremely rare. In fact, a critical condition in waste requires extreme assumptions. A qualitative analysis with estimates of likelihood for each of the necessary conditions for criticality is given in order to confirm this reasoning.

The likelihood of condition (a), sufficient fissile mass, occurring is taken as "unlikely" (frequency of $1.0E-04$ to $1.0E-02$). Assays have been performed at the RWMC for the purpose of certifying waste containers for shipment to WIPP. Of 17,000 waste drums assayed, 47 were initially set aside because the initial assay could not confirm with a sufficient degree of certainty that their fissile material content was less than 200 g, the mass limit that applied when these drums were received at the RWMC. Of these 47 drums, 11 have been found that may contain greater than 75% of a minimum critical mass of plutonium in a water-moderated system (i.e., taken to be 380 g Pu-239). It is assumed here, for conservatism, that 17 out of the original 17,000 drums assayed might contain a minimum critical mass of plutonium (although not expected to be distributed in such a manner, to present a safety concern).

The likelihood of the presence of sufficient moderator is also estimated as unlikely. While some waste includes moderator material such as plastic, clothing, rags, etc., these types of moderators are not present at sufficient density to be of concern. Also, cemented sludges and salts may contain moderators but they are not effective moderators for infinite systems and the plutonium would not be sufficiently concentrated so this would not be a credible criticality scenario. Process residues (such as sludges and salts), plant scrap, lab equipment, anti-contamination clothing, and waste from decontamination and environmental cleanup encompass nearly all of the waste streams. Water is not likely to exist in these waste streams. Nevertheless, the estimate of "unlikely" is based on the facts that (a) the WAC prohibit water (must be less than 1%) and (b) human error of omission or commission for proceduralized operations is generally accepted, from human factor studies, as $1.0E-3$. This value is considered very conservative by personnel who have performed real-time radiography on 17,000 drums but have never seen water in a drum other than in a small container within a drum. Video recordings of each real-time radiography are on file at the RWMC to document the personnel observations. Thus, $1.0E-3$ is an upper bound estimate for sufficient water to be put in a drum during waste processing.

Critical systems with minimum amounts of fissile material require that the moderator and fissile material be intimately mixed at the requisite concentration and that the fissile material be uniformly distributed throughout the mixture volume. Figure 6-1 shows that the concentration for 510 g of plutonium is approximately 30 g/L. As more plutonium is available, the concentration can lie within a broader range; e.g., for 800 g of plutonium the concentration can be between 15 and 90 g/L. The likelihood of the fissile concentration being "just right" and the fissile material being distributed uniformly in the mixture are each estimated as being unlikely. These estimates are considered to be conservative. The combined frequencies of these two conditions remain unlikely.

The data in Figure 6-1 are based on spherical systems. The importance of shape is difficult to establish. An indication of the importance of shape can be found in data presented in Tables 13 and 14 of Reference 6-7. The tables show the critical dimensions of cylinders of solutions of $\text{Pu}(\text{NO}_3)_4$ from experiments conducted in France. These indicate that plutonium mass must increase as the shape of the system departs from that of a sphere. It is unlikely that the system will have a reactivity enhancing shape (nearly spherical). No near-optimum geometrical distributions of fissionable material in waste have ever been found during real-time radiography, supporting this analysis as being very conservative.

The final factor to be considered is recognition of the fact that no system made of waste materials can be as "clean" as the laboratory-produced minimum critical mass systems of Figure 6-1. In waste, moderator material is generally mixed with other nuclides that at least are less efficient moderators than the hydrogen nuclei of a water-fissile material mixture and often act to reduce neutron levels through parasitic absorption. Typical waste matrixes consist of concrete (containing Ca and Cl), plastics (Cl and F), structural materials (wood, gypsum board, and various metals), glass, paper, and soil. The absence of significant amounts of diluents and neutron absorbers within the volume of the moderator-fissile material mixture is also unlikely. Experience with waste types received in different content categories and that gained through real-time radiography observations bear out the conservative nature of this estimate.

The new WAC provides additional assurance of criticality safety by requiring sufficient matrix material to prevent criticality in an infinite array. Thus, there is no limit on the number of containers that can be received.

It has been assumed to this point that the source of moderation is from within the waste. There are external events (fire or flood) that could introduce sufficient amounts of moderator material into breached containers. Reference A-21 of Appendix A shows that even a flood with a 10,000-year recurrence interval will not flood the waste containers stored on the TSA pads. Flooding by actuation of the fire suppression system has a probability no greater than $1.0E-3$ per year.^{6-3,6-9} Flooding from external sources is thus no more probable than presence of moderator in the waste.

A variation of the single container criticality scenario is that two overloaded but less than critical drums become critical when placed next to each other. The likelihood of a drum being close to criticality when placed next to another is greater than in the single drum scenario. However, it can be shown in a similar qualitative analysis as above, that criticality would still be incredible. In addition, the fissile material and water would have to be in a nearly hemispherical shape and have to be so located within each drum so as to complete the sphere, e.g., top/bottom of two adjacent drums.

This analysis of criticality in waste proceeded in a step-wise fashion with a search for common causes at each step; none were found for waste products at the RWMC. The conclusion is that the first scenario (criticality in waste material) is not credible. The qualitative analysis used is a useful tool in determining scenario credibility and can be used to substantiate sound engineering judgement. Although the individual and overall likelihood estimates discussed for the overloaded drums admittedly have uncertainties, the conclusion of the analysis is identical to that determined by engineering judgement.

The five factors discussed earlier have to coincide in a container to produce a critical system. If any waste container were found with at least a minimum critical mass of fissile material, it would most probably be an instance of inadvertent disposal of nonwaste. However, derivation of the above analysis of the mass condition in the discussion on waste materials does not account for the magnitude of an overbatch, but is based on observational data. Thus, no change is expected in the likelihood of condition (a). Condition (b), the presence of sufficient moderator, is also no more likely for nonwaste, and may, in fact, be less likely because process rules for inherently moderated fissile materials usually require subdivision into containers of volumes well below minimum critical. Condition (c), fissile

material is mixed with the moderator at the appropriate density, roughly uniformly throughout the required minimum volume, is almost certainly smaller for nonwaste material than for waste. This is so, because inadvertently disposed process material is most likely in the form of chunks and pieces, or, if inherently moderated material is involved, would not be available in the quantities required for criticality. The shape condition, or even homogeneous mixtures of fissile and moderator materials would tend to settle towards the bottom of a container, because they have a higher density than typical waste materials. The likelihood of absence or presence of diluent (neutron absorbing) materials is judged to be no different for nonwaste materials disposed of with waste than for real waste. Although the foregoing is not as quantitative as the discussion on criticality in waste materials, it is clear that, while fissile masses involved might be larger than for waste materials, the likelihood of a criticality resulting from inadvertently disposed nonwaste is no greater than for waste materials and is enveloped by that discussion.

6.4.3 ILTSF Vault Storage

While the primary reason for ILTSF vault storage is the high surface radiation of the containers stored there, the storage method used there also allows higher fissile loadings than that of containers stored on the TSA pads. This is because the ILTSF vaults are essentially single columns of waste containers isolated from each other by the steel walls of the vaults and a minimum of 1.8 m (5.9 ft) of soil between vaults. Thus, containers stored in these vaults have either higher allowed fissile mass loadings or higher fissile concentrations, as a result of lower waste matrix mass, than those stored on the pads or disposed of as LLW. The ILTSF vaults may also be used to store U-233 in 6M-type drums. CSEs and independent verification CSEs have been performed for four special container types or fissile loadings. The primary CSE is Reference 6-10 and the independent CSE is Reference 6-11.

6.4.3.1 6M Drums. 6M-type drums are 55-gal steel drums that have a 2R inner container (6M and 2R are U.S. Department of Transportation container specifications). The 2R inner container has a maximum inside diameter of 5.25 in. This geometric restriction allows greater fissile loadings per drum than for a regular 55-gal drum. CSEs have been performed for storage of the 6M drums on a pad in an infinite planar array with a finite stacking height. This is a very conservative model for storage in the ILTSF vaults, where one-dimensional, vertical stacks of drums are isolated by 1.8 m (5.9 ft) of soil from one another. The interior of each inner container is modeled as a cylinder of fissile material and water, which is also very conservative. The analysis in the CSEs show that the infinite planar array of drums will not exceed a k_{eff} value of 0.95 for loadings up to 800 g of U-233 per drum. The acceptance criteria limit of the 6M drums is 500 g of U-233, and the actual maximum recorded content from the RWMIS database for this container type is less than 300 g of U-233, providing another large safety margin. Accidental assembly of a critical system in a one-dimensional vertical stack of 6M drums would require a degree of overload so large as to make this scenario incredible.

6.4.3.2 HFEF-5 Containers and NWCF Filter Canisters. References 6-10 and 6-11 also contain CSEs for the Hot Fuel Examination Facility (HFEF)-5 containers and the New Waste Calcining Facility (NWCF) off-gas filter canisters. The analysis, performed with the KENO-V.a criticality computer code, models a cylinder of an optimized mixture of water and plutonium in each of the two HFEF-5 canisters that fit into a vault. The plutonium mass loading is determined, which gives a multiplication factor of 0.95 for an infinite array of vaults. This mass is approximately 470 g per canister. This is 135%

of the approved maximum fissile loading of 200 g. HFEF-5 containers are used for the disposition of hot cell waste. Their fissile material content consists of reactor fuel pieces, metallographic samples, and similar hot cell operations waste. This type of material is under more stringent mass controls (piece counts, etc.) than contamination waste. The analytical model is extremely conservative. The likelihood of accidentally achieving such a system in any one canister is approximately on the same order as discussed in Section 6.4.2. A criticality involving HFEF-5 canisters in the ILTSF vaults is, therefore, judged to be incredible.

The analysis for NWCF off-gas filter canisters in the CSEs involves computer calculations with the SCAMP and KENO-V.a codes. Only a single canister is modeled per vault, but the fissile bearing region, in spherical shape, is assumed to contain the total fissile material loading from the two canisters placed in each vault. This envelopes the condition where hemispherical regions in two filters (at the top of one and the bottom of the other) interact as a single system. The one-dimensional calculations for a single vault indicate that the k-value of such a system does not exceed 0.95 until the plutonium mass exceeds 400 g. KENO calculations show that the reflector conditions (fully flooded vault), which produce maximum single vault reactivity, also essentially prevent fissile materials in the vaults from interacting with each other, as is expected. Acceptance criteria for the filters in storage specify a maximum fissile mass limit of 100 g per filter. The analysis of Reference 6-10 shows that twice that amount will remain subcritical. Both values are extremely conservative because off-gas filters become plugged and require changeout long before such mass levels could be reached.

The CSE for the ILTSF vault storage assumes optimum conditions of moderation, fissile distribution, and absence of neutron absorber materials to produce the report K_{eff} -values. These very conservative assumptions have small probabilities of occurrence, somewhat analogous to the discussion in Section 6.4.2. It can, therefore, be concluded that the formation of a critical system in the ILTSF storage vaults is incredible.

6.4.4 Special Criticality Safety Concerns

Some temporary fissile material configurations that do not obviously fall under the envelopes established in the previous sections are discussed in this section. This configuration includes storage of known or suspected overloaded containers, storage of 110-gal. 6M drums, the criticality safety aspects of the container assay system, and fissile material used for assay system calibration.

6.4.4.1 Suspected Overloaded Containers. Some 17,000 metal drums have been subjected to waste characterization procedures in anticipation of the opening of WIPP in New Mexico. As part of the characterization process, an attempt was made to determine the TRU content of these drums. For some drums, with fissile material contents close to 200 g (the limit in effect for all drums shipped to RWMC prior to 1994), the initial assay could not conclusively show that they complied with that limit. These drums originally were set aside and placed on an unused portion of the ILTSF pads, with a requirement that they remain isolated from each other and other fissile waste by at least 12 ft. Forty-seven such drums were found.

Improvements to the assay systems have been made and some are still planned for the future. Re-assay of several of the suspect drums with a modified system has already shown them to contain less than

200 g of fissile material. An examination of the waste types listed in the waste generator documentation for the suspect drums indicates that they contain waste matrices that would require plutonium masses far greater than 510 g (the minimum critical mass for plutonium in an optimal water moderated system) for criticality. Of the 47 drums, 23 contain filter media and cement; 11 contain various types of salts; seven contain sand, slag, and crucible heels; three contain cemented sludge; two contain scrap metal; and one is coded "unknown." The content codes have been verified by real-time radiography. The contents closely resemble the waste described by the codes; discrepancies have been minor. The analysis summarized in Section 6.4.1 shows, using very conservative models, that drums completely filled with a mixture of the above-listed waste matrices and fissile material at concentrations similar to those found in the suspect drums (according to the initial assay that first identified these drums as suspect) would be safe when placed in a close packed array. The likelihood arguments presented in Section 6.4.2 indicate that, even if a few of the suspect drums were severely overloaded, the chance of an accidental criticality is negligible. To provide an extra margin of safety and ensure an additional level of control, any container found to contain greater than 380 g of fissile material will continue to be isolated from other waste containers in a special Isolation Fissile Material Control Area (FMCA) until further evaluation of the drum contents provides the basis for eventual disposition.

6.4.4.2 Criticality Safety of the Assay System. One of the operating modes of the assay system is active neutron interrogation, during which neutrons are injected into the waste drum. The neutrons do not by themselves change the multiplication characteristics of the waste matrix and do not enhance the reactivity of the waste. A drum placed inside the assay system is closely reflected by lead and polyethylene, which enhance the reactivity of its fissile contents. Although this effect has not been quantified with an analysis, it is judged to be small for typical waste systems. As discussed in Section 6.4.2, there is a negligible chance that a waste drum would be "pushed over the line" of criticality by this increased reflection. The assay system therefore, does not pose an accidental criticality hazard for waste containers being assayed.

6.4.4.3 Assay System Calibration. The assay system must be calibrated against known fissile material configurations in mockup waste drums. Fuel plates of known plutonium content are used for this purpose. The plates, brought in from Argonne National Laboratory-West for the duration of a calibration campaign, consist of a plutonium-aluminum or plutonium-depleted uranium alloy clad in steel. Various plate sizes contain between 10 and 50 g of fissile plutonium.

The total amount of plutonium that will be brought to RWMC at any one time in the form of these standards is limited to 380 g. While the standards are at the RWMC, the area surrounding the assay system (see Figure 2-5 in Section 2.4.2.3) will be posted as an FMCA. The calibration standards will be stored either in a locked cabinet or in their approved shipping container within this FMCA. For calibration, the standards will be placed in mockup waste drums, which will then be placed into the assay system. No other waste container (fissile material) is permitted in the FMCA when any of the standards are out of the locked storage cabinet.

The combination of mass limit (75% of minimum critical, per Figure 6-1, 84% of the subcritical limit from the National Standard, ANSI/ANS-6.1-1983) and plate configuration (which is not conducive to producing optimum conditions of geometry, moderation, and concentration) make formation of a critical system with the calibration standards incredible. The discussion in Section 6.4.2

indicates that an accidental criticality is incredible even when violations of the mass limit or of the requirement to exclude other waste containers from the FMCA are postulated.

The 380 g fissile material mass limit and the incredibility of a criticality exempts the FMCA from the requirements for criticality detection or alarm systems, per DOE Order 5480.24. Operations in the FMCA will be performed by trained fissile material handlers. Movements of the calibration standards into and out of the FMCA will be recorded in a log maintained at the assay area.

6.4.4.4 Uranium-233 Waste Storage. Beginning in the early 1970s through 1987, radioactive waste was received from the Light Water Breeder Reactor program. This waste has been designated as TRU waste, although its major isotope is U-233. According to the Radioactive Waste Management Information System (RWMIS) database, the total waste of this type contains approximately 94 kg of U-233 and is packaged in 1,869 metal drums. Of this, approximately 60 kg is in fuel fabrication scrap packaged in 1,724 standard 55-gal 17C drums, for an average of 35 g per drum. The remaining 34 kg of U-233 are in whole or partial fuel rods and canned fuel pellets packaged in 145 6M drums (68 drums of 55-gal. and 77 drums of 110-gal. outer drum volume). Most of the 1,869 drums have been placed in container stacks on the TSA pads. There are currently 53 of the 110-gal 6M drums with U-233 waste stored in cargo containers, surrounded by concrete shield blocks, on an otherwise unused portion of the ILTSF pad. These drums are not but could be stored in the ILTSF vaults from a criticality safety perspective but this is not likely since that would require additional handling and personnel exposure. Radioactive decay processes in that waste have increased the surface radiation levels of these containers since their receipt, changing them to the remote-handled category.

The U-233 waste has higher average fissile material loadings per drum than TSA waste overall, but RWMIS data show that the drums comply with the fissile material limits in place at the time of receipt of this waste (200 g/drum for 17C/H 55-gal drums, and 500 g/drum for 6M drums of any capacity). The higher average loading comes from the nature of the waste, i.e., uranium/thorium oxide in solidified sludge, scrap, and pellets, rather than surface contamination. However, average fissile concentrations per container are still mostly within the threshold values discussed in Section 6.4.1. Containers of scrap are generally below 0.5 g of U-233 per pound of waste, while those containing fuel pellets and rods (primarily in 6M drums) are below 1.3 g per pound, with most being below 1 g per pound. Conversations with personnel from Bettis, the generator of the U-233 waste, indicate that the part of the waste classified as "fabrication scrap" consists primarily of solidified sludge, which thus would best fit in the concrete matrix group. To ensure that U-233 systems are indeed covered by the Pu-239 calculations in Reference 6-3, calculations identical to those in the reference in every respect except for the fissile isotope have been performed.⁶⁴ The results show that for the matrix materials investigated: polyethylene, cellulose, metal, concrete, brick, glass, graphite, and salts; infinite system critical concentrations are lower than for the plutonium systems except for metal and salts. The 17C drums loaded with U-233 waste are, therefore, covered by this additional analysis. There was also some concern because in some instances lead is more reactive than aluminum. An investigation of the storage data base with subsequent criticality analysis runs indicated that the quantity and storage practices of lead at the RWMC did not warrant additional controls.

For the 6M drums, more relevant are the results of the 6M drum analyses reported in Reference 6-10. These show that a k-value of 0.95 is not exceeded, for an infinite planar array of 6M drums six containers high until the U-233 mass loading exceeds 800 g per drum. According to the RWMIS data, all 6M drums are loaded with less than 300 g of U-233. The calculations in References 6-10 were performed with the KENO-V, a criticality computer code. The computer model is extremely conservative, with only U-233 and water occupying the inner container of the drums. Auxiliary calculations reported in Reference 6-10 show that more realistic assumptions, such as less water in the inner container or fiberboard spacers of more realistic density, lower k-values drastically. The few 6M drums on the TSA pads could be stacked in a very compact array within the general container stacks (a $5 \times 6 \times 6$ array contains more drums than are on the pads) and their configuration would not be as reactive as the model (which is $\text{inf.} \times \text{inf.} \times 6$). The actual situation, where the 6M drums are dispersed or only in small groups, is much less reactive than the modeled one. Thus the 6M drums currently stored at the RWMC are covered by the array analysis and are subcritical in any stacking arrangement.

6.4.4.5 Fire Protection. The use of fire water at the RWMC will not adversely affect criticality safety at the facility. RWMC has three distinct types of storage that contain fissile material and could potentially be affected by fire water. These are (a) the waste material stored in buildings that have fire suppression systems, (b) the Assay FMCA for storing up to 380 g of fuel plates used for calibration purposes, and (c) the Isolation FMCA for storing containers that contain more than 380 g of Pu-239.

According to the CSE⁶⁻³, water ingress into the stored waste results in a decrease in reactivity. The flooding of the fuel plates stored in the Assay FMCA will have no effect on criticality because more fuel, homogeneous mixing, and a specific geometry are required. The flooding of the Isolation FMCA will also have no effect on criticality because homogeneous mixing and a specific geometry are required.

6.4.4.6 RWMC Criticality Control Listing. As was presented in Section 6.3 Criticality Concerns, RWMC does not have the type of waste that could easily be made critical. The CSE⁶⁻³ shows that drums containing less than 380 g of Pu-239 are safe in any configuration. The analysis shows that even though a few drums may exceed 380 g of Pu-239, they are safe in any configuration. However, as an extra margin of safety, any drums known or suspected to contain greater than 380 g of Pu-239 will be isolated in a FMCA until its disposition is determined by analysis that considers all parameters necessary for criticality safety. For this CSE⁶⁻³ to remain valid, the assumptions must be maintained. Therefore, we have the gram concentration limits for any incoming waste. There are some carryover limits from the previous SARs for wastes that are not expected to be received anymore. We will keep the limits to cover the existing waste and to provide for any future shipments even though none are anticipated. The following is a list of the criticality controls or requirements at the RWMC.

1. Container fissile gram concentration limits which are provided in Table 6-1
2. HFEF-5 Container - 200 g Pu-239 per container limit
3. NWCF Filter Canisters - 100 g Pu-239 per filter canister limit

4. Any container found to have > 380 g fissile material will be stored in the Isolation FMCA pending evaluation.
5. U-233 limit for 6M drums is 500 g
6. Maintain & post FMCAs; log activities as required
7. Generator requirements:
 - a) must submit written plan for approval prior to shipping any waste to RWMC
 - b) annual audit of plans required

6.5 Criticality Protection Program :

The RWMC's compliance with, and exemptions from, the Company's criticality safety program are discussed in this section. This section also departs from the format given in DOE-STD-3009-94.

The analyses in Section 6.4 show that an accidental criticality at the RWMC has an insignificantly small likelihood of occurring, which makes this event incredible during the lifetime of the facility. The factors involved in this conclusion are inherent in the waste stored or disposed of at the RWMC. Of primary importance is the small concentration of fissile material in waste matrices that are mostly not reactivity enhancing, combined with the absence of mechanisms for increasing that concentration, either by human error or by the effect of natural forces. The latter, in fact, tends to lead to greater dispersion, especially in the case of disposed wastes, where soil will tend to migrate into voids between waste containers and even inside containers as these deteriorate.

6.5.1 Performance and review of Criticality Analyses

The Company criticality safety program provides that all CSEs are performed and independently reviewed by competent analysts. In many cases this review includes the performance of check calculations (see Appendix F to Reference 6-3).

6.5.2 Designation of FMCAs

The areas with the greatest, albeit still not credible, risk of an accidental criticality have been designated as FMCAs. This designation provides management with increased control over operations (entry, placement into, and removal from the area of fissile and other materials) of those areas, through posting and designation and training of personnel approved as fissile material handlers. The risk of accidental criticality is so small as to make this event incredible. This is true even for those areas designated as FMCAs. For this reason, all areas of the RWMC are exempt from the requirements for a criticality alarm system, as provided in Section 7.b of DOE Order 5480.24. Except for the assay FMCA, all other RWMC areas are exempted from the requirement to maintain and post accumulative fissile material total. This is because no area at the RWMC areas are exempted from the requirement to maintain and post a cumulative fissile material total. This is because no area at the RWMC, other than the assay FMCA, review on total inventory as a criticality safety control. Fissile material loading and gross container weight are recorded in waste generator records and maintained in databases. From these, fissile material concentrations can be calculated. The RWMIS provides this information.

The Assay FMCA is a storage cabinet used to store fissile material available for calibration purposes and is limited to 380 g of fissile material. The Isolation FMCA is for waste containers with greater than 380 g fissile material and must provide required individual drum isolation as determined by analysis and be separated from other operations.

6.5.3 Double Contingency Principle

DOE Order 5480.24 requires adherence to the "double contingency principle" in all operations with fissile materials outside nuclear reactors. This principle states that "process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible." It has been shown in Section 6.4 that an accidental criticality is incredible in any waste storage or disposal system at the RWMC. This is due in most cases to the inherent nature of the waste. Where mass limits are imposed, multiple violations would have to coincide with other conditions that have a small likelihood of occurrence.

6.5.4 Compliance Checks

Mass and concentration of fissile material in the waste and other characteristics upon which criticality safety at the RWMC is based are not under the control of RWMC personnel; they are under the control of the waste-generating organizations. For this reason, each prospective waste generator must submit a written plan to RWMC for approval prior to sending waste to the RWMC. The plans are audited annually, with the DOE Idaho Operations Office reserving the right to audit plans and operations at non-INEL generator sites.

A limited capability for investigating container content does, however, exist at the RWMC. The capability exists to examine drums with real-time radiography, which displays the contents of the drum and allows a limited determination of the nature of the contents. A passive-active neutron assay system is also available to estimate transuranic content. These systems are described in greater detail in Sections 2.5.6.3 and 2.5.6.4 of Chapter 2. Only a few sample containers can be investigated, because of the time involved to obtain meaningful data from these systems. Currently, these capabilities are used primarily to determine a proper disposition of the "suspect" drums discussed earlier. In the future, they may be used to perform running checks on the criticality safety assumptions used in Section 6.4.

6.5.5 Criticality Safety Program

The goal of the RWMC's criticality safety program is not only criticality safety during operations but also assurance of criticality safety in final disposition of the waste. The primary criterion for criticality safety is that the waste must be safe under all normal and credible abnormal conditions without regard for container integrity. The analyses summarized in Section 6.4 demonstrate that this is the case for TRU waste containers stored at the RWMC. Acceptance criteria limiting the fissile material concentrations in waste received in the future will preserve this degree of safety. Thus, there are no limiting conditions applicable to criticality safety for the storage and handling operations for

waste at the RWMC. The criticality program consists of limiting conditions for containers at the ILTSF; acceptance criteria for future receipts, and mass/separation limits for those areas designated as FMCAs.

6.6 References

Note: References to DOE orders and standards, Company manuals, and citations from the Code of Federal Regulations are not treated as standard references. Full information on each of these types is presented in the text when the item is first mentioned. Subsequent referrals are to the shortened title or number (e.g., DOE Order 5480.23, Safety Manual, 10 CFR 20). They are therefore not listed in the references.

- 6-1. Neal Goldenberg letter to Distribution, *Interpretive Guidance for DOE Order 5480.24, "Nuclear Criticality Safety,"* U.S. Department of Energy memorandum, February 17, 1994.
- 6-2. C. L. Arwood and M. J. Schlafman, *Empirical Distributions of Radionuclides, From RWMIS Data,* EGG-RAAM-10741, April 1993.
- 6-3. Maria E. Shaw, et. al. *Criticality Safety Evaluation For The TRU Waste In Storage At The RWMC,* EGG-NRE-10754, November 1993.
- 6-4. Kenneth B. Woods, *Criticality Safety Evaluation for the RWMC,* INEL-96/216, August 1996.
- 6-5. *Health Physics Manual of Good Practices for Plutonium Facilities,* PNL- 6534, UN-41, May 1988.
- 6-6. S. C. Chay, "Probabilistic Risk Assessment of Drum and Culvert Containing Suspect FB-Line TRU Waste," *Proceedings of the 1992 Topical Meeting on Advances in Reactor Physics, Charleston, South Carolina, March 8-11, 1992.*
- 6-7. H.C. Paxton and N. L. Pruvost, *Critical Dimensions of Systems Containing ^{235}U , ^{239}Pu , and ^{233}U ,* 1986 Revision, Los Alamos National Laboratory, LA-10860-MS, July 1987, p. 65.
- 6-8. EDF-RWMC-872, *Historical Hazard and Accident Analysis Data at the RWMC,* May 1996.
- 6-9. EDF-RWMC-873, *Hazard Event Frequencies for WSF,* May 1996.
- 6-10. J. B. Briggs, *Criticality Safety Evaluation for the Storage of DOT 17C Drums, DOT 6M Containers, HFEF-5 Containers, and NWCF Off-Gas Filter Canisters at RWMC,* NRRT-N-88-012, February 1988.
- 6-11. R. R. Jones, *Independent Criticality Safety Evaluation for the Storage of DOT 17C Drums, DOT 6M Containers, HFEF-5 Containers, and NWCF Off-Gas Filter Canisters at RWMC,* NRRT-N-88-010, February 1988.