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REVISED APPLICATION FOR IMMOBILIZATION WITH PORTLAND CEMENT OF LIQUID ANALYTICAL RESIDUES FROM THE LIGHT WATER BREEDER REACTOR PROOF-OF-BREEDING (LWBR-POB) PROJECT

APRIL 1983

22244

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B. Personal Communication, "Determination of Radiation Shielding Effectiveness," R. H. Land to N. M. Levitz, April 8, 1983.

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LIGHT WATER BREEDER REACTOR PROOF-OF-BREEDING
(LWBR-POB) PROJECT

SUMMARY

Argonne National Laboratory (ANL) proposes to use Portland cement to immobilize radioactive liquid analytical residue from the dissolution of LWBR fuel element segments, using a steel can as a primary storage container. The primary can, a secondary steel can, lead shielding, and an approved 55-gal drum comprise the basic package. The basic package will be packed into a steel bin and then into either the Supertiger Overpack or Polypanther Overpack for transport to Rockwell-Hanford Operations (RHO) at Richland, Washington for interim storage.

DESCRIPTION OF WASTE MATERIALS

The dissolver solutions are generated in the course of dissolving segments of irradiated LWBR fuel rods. The approximate amounts of the major components in the residual analytical solutions produced during the total LWBR-POB analytical campaign are summarized as follows:

Total Volume	700 L
HNO_3	490 Kg
H_2O	350 Kg
Th	32.2 Kg
^{233}U	0.6 Kg
Zr	3.5 Kg
Al	3.5 Kg
^3H	25 Ci
Fission Products	~25,000 Ci
Heat Generation	50 watts

The concept of immobilizing the solution in cement grout has, in principle, been approved and has undergone extensive testing. The addition of extra lime works to neutralize the HNO_3, which, in turn, enhances the nature of the final cement product, e.g., fewer cracks formed.

PACKAGING CONSIDERATIONS

The solidified waste is contained in a primary steel can sealed with a specially-prepared slip-cover lid. Two of these cans are placed into a secondary steel can sealed with a friction lid. A protective radiation shield holds the waste cans and is approximately centered within a 55-gal drum. The protective shield is sturdily designed and possesses considerable structural strength. Sufficient lead is provided to reduce the radiation level at the drum exterior surface to a value complying with transportation and handling requirements.

The drums are now loaded into steel bins. The drums are held in place in the steel bins by foaming in place or by foam dunnage. This provides drum protection for normal transporting and would also reduce drum damage in the event the total package is subjected to an accident. The bins are loaded into a Polypanther or Supertiger overpack for shipment.

Attachment A presents results of calculations made to assess a measure of the shield's structural capability. Attachment B summarizes the radiation shielding analysis method. The package can withstand the normal conditions of transportation. It is felt there would be no reduction in the package effectiveness due to normal transportation conditions and the shield reduces radiation levels adequately.

The structural assessment shows it would take considerable force to cause shield damage or release of the shield lid. It is felt protection provided by the overpack, and the rigid restraining of the drums, makes significant shield damage not feasible in a transportation accident. Following an accident the radiation level at the external surface of the package should meet code of federal regulation requirements. This is supported by results of the shielding analysis which showed the radiation dose rates at the exterior of the drum (after 2-y cooling) were 105 mR/hr at the center of the drum top, 104 mR/hr at the midplane of the drum side and 164 mR/hr at the center of the drum bottom. These values are all below a level of 200 mR/hr at the drum surface which meets disposal criteria, and consequently, assures the overpack exterior radiation levels would meet requirements.

UTILIZATION OF SUPERTIGER AND POLYPANTHER SHIPPING CONTAINERS

SINGLE BATCH WASTE CHARACTERISTICS

Individual batches of waste will consist of 2.6 L of dissolver solution mixed with a cement-water slurry in a 1-1/2-gal steel can. The mix will cure for 72 hr and be dehydrated by heating at 125°C for ~ 200 hr. The end product is a 6000-g monolithic waste block within the 1-1/2-gal can. The can is closed with a slip cover lid. The compressive strength of the waste block is ~ 2000 psi. The final product has a cracked crust after drying which consists of <1.0% of the total mass of the block. The materials used for a 1-1/2-gal batch of cemented waste and selected batch properties are listed below:

Dissolver Solution	2600 mL
Portland Cement	2600 g
Slaked Lime	750 g
Water	2250 g
Final Total Weight (after dehydration)	6000 g
Heat Generation (based on an average value)	0.19 watts
^{233}U Content	3.8 g
Fission Product Content	~ 145 Ci

PACKAGING CONFIGURATION

Two ~ 1-1/2-gal cans of cemented waste will be placed in a secondary steel containment can which then will be sealed with a press fit friction lid. This secondary containment package will be placed inside a protective radiation shield, see Fig. 1 and 2.

The shield consist of a thick lead sleeve formed and encased within a thick steel support structure. The opening on the top of the structure is closed with a plug-type lid consisting of lead, cast within a steel form. This lid is securely bolted to the lower steel structure. The shield assembly is placed inside a DOT 17-C 55-gal galvanized steel drum. The steel structure serves to center the shield within the drum. An additional aluminum plate placed on top of the shield restrains the shield from moving within the drum. Fabrication materials are indicated in Table 1. The drums are sealed with a gasket made of styrene-butadiene rubber meeting ASTM Standard D1418. The lid closure ring bolt will be sealed with a type "E" tamper indicator seal. The shield will be of a thickness that reduces the radiation dose rate, at the surface of the drum, below the acceptable 200 mR/hr criteria. Two shipping methods are being considered:

1. Should the Polypanther Overpack method be selected, one of these drums will be packed into a M-3 steel bin, ANL Drwg. No. CS-2273, as shown in Fig. 3. The dunnage material will be polyurethane foam Instapack 200 or equivalent. The bin will be sealed and packed into the Polypanther shipping container. The maximum weight of the drum, dunnage, and the M-3 bin, will be 3000 lb. Six of the Polypanther packages will be transported with each shipment to RHO at Richland, Washington. The M-3 bins will be removed from the Polypanther, and the individual drums will be removed for interim storage. The M-3 bin will be reused.

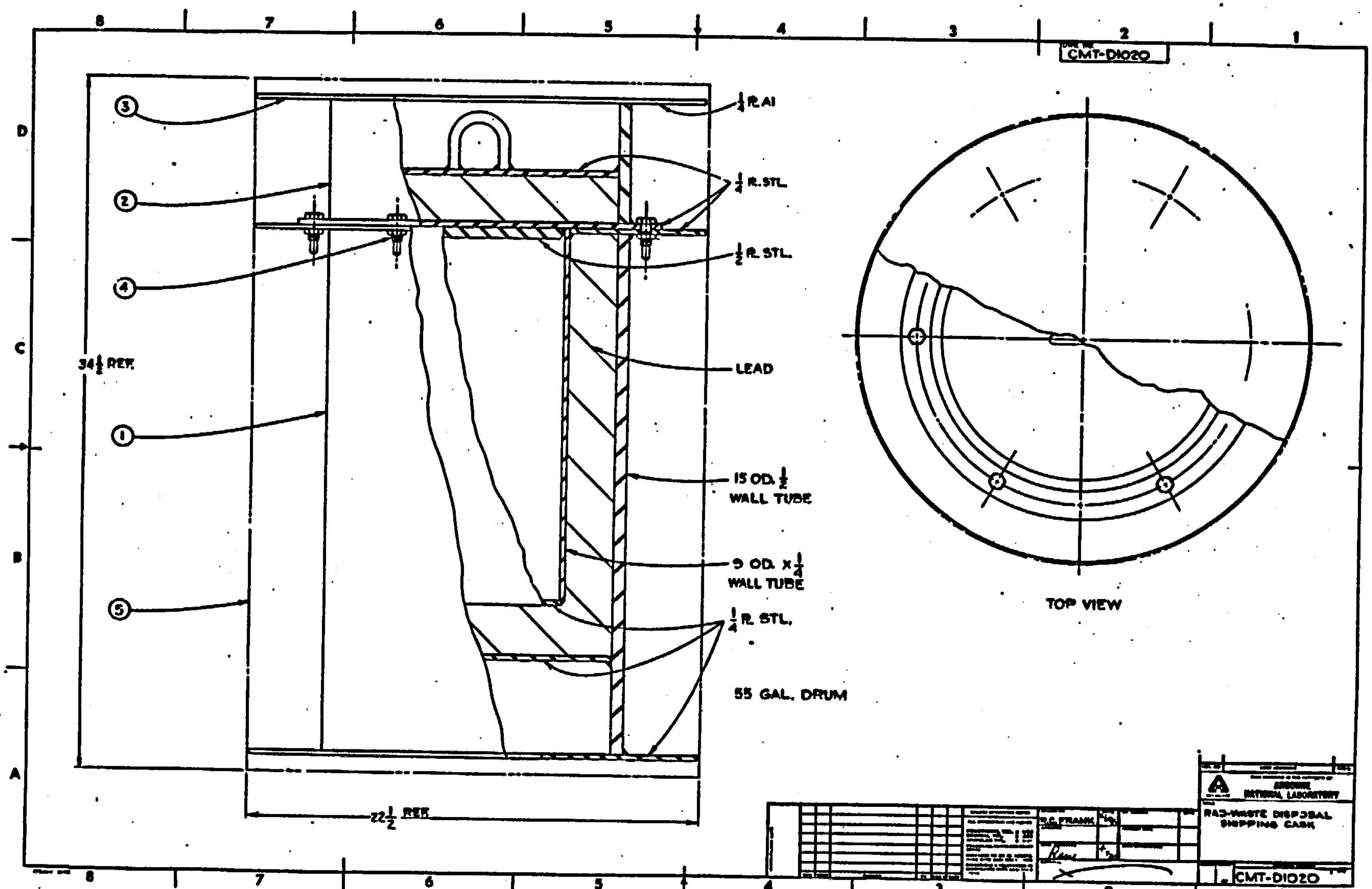


Fig. 1
1450# Waste Package

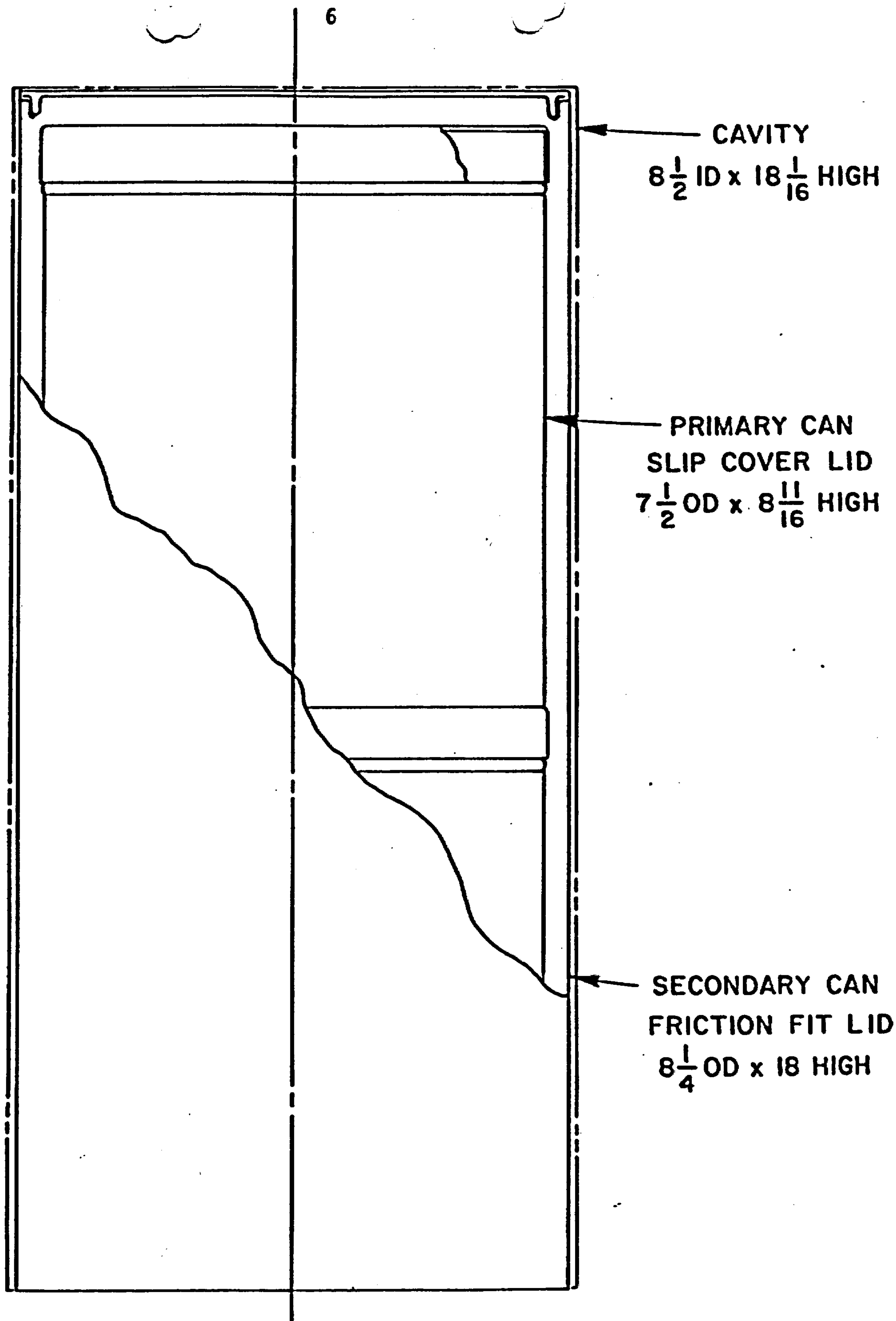


Fig. 2
Cask Cavity with Can Arrangement

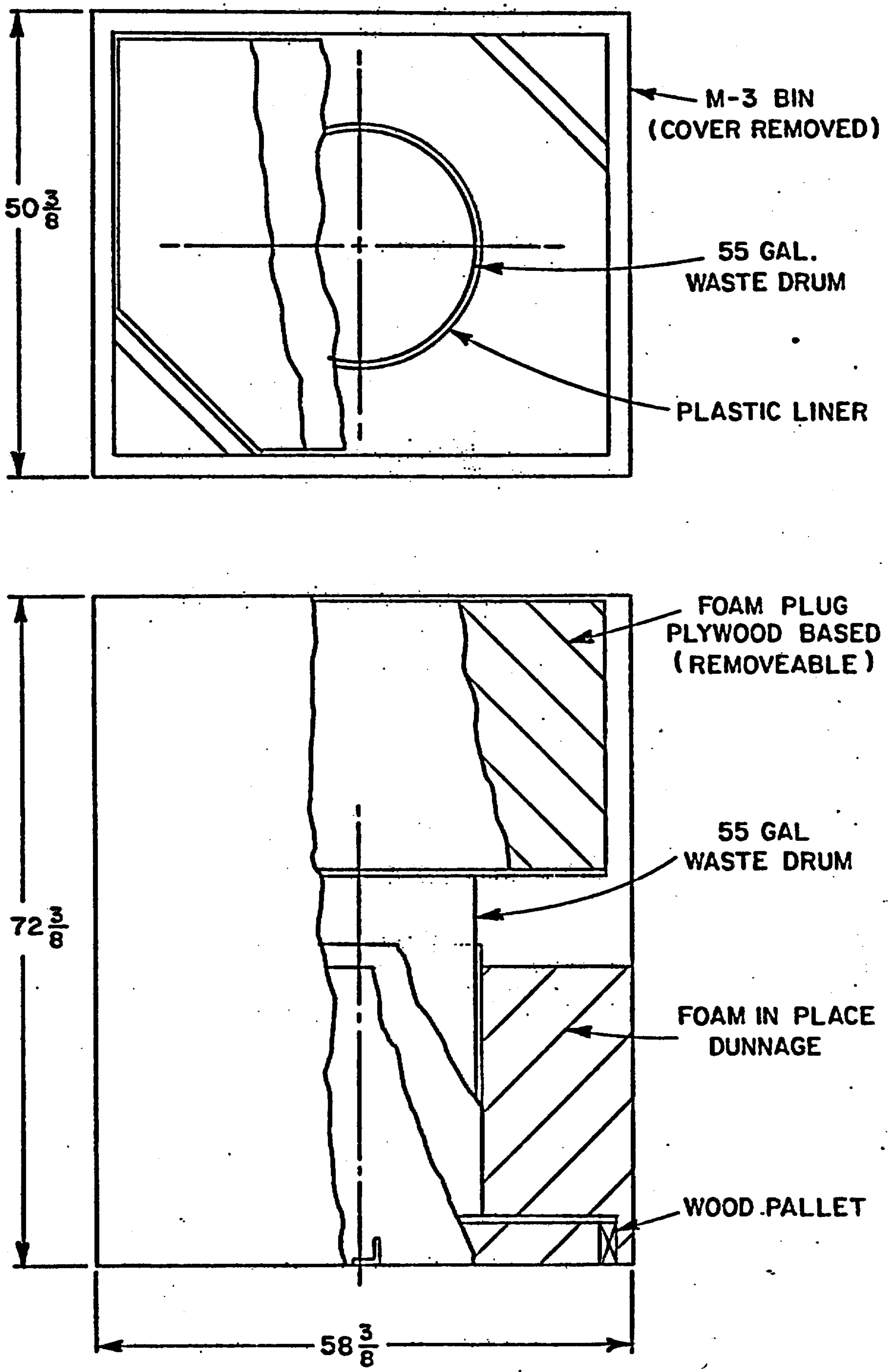


Fig. 3
M-3 Bin Packaging for 1450# Drums

Table 1. Shielding Materials

Piece	Material
Tube 15-in. OD x 1/2-in. wall	AISI 1026 Steel
Tube 9-in. OD x 1/4-in. wall	AISI 1018 Steel
Steel Plate 1/4-in. thick	ASTM A36 Steel
Aluminum Plate 1/4-in. thick	AISI 6061-T6 Al
Lead	99.5% Pure

2. Should the Supertiger Overpack method be selected, six of these drums will be packed into the steel corrugated box specified in the RHO Drwg. No. H-2-91888, Sheet 1, Rev. 0. The space between the drums and the box will be filled with foam to a minimum thickness of 1-in. Void spaces between drums will be filled with foam to a minimum thickness of 1/2-in. Polyurethane foam Instapack 200 or equivalent will be used. The box will be closed and sealed. Two of these boxes will be loaded into the Supertiger shipping container for transport to R-H waste storage facility. At R-H, the steel boxes will be removed from the Supertiger and buried intact.

APPLICABLE TEST RESULTS FOR THE CEMENT GROUT

Reference 1: General Electric Company Model 1600 Package; Application for Immobilization of Waste Materials Using Hydraulic Cement, December 1, 1981.

The solidified LWBR-POB waste in cement grout has been described above. Information on cement grout, contained in Ref. 1, is relevant to the POB waste, as tabulated in Table 2; appropriate sections of the GE report are referenced. The conclusion has been made that there is sufficient comparability in the cement compositions to reference specific GE test data. Namely, the break-up fraction of the cement, F_2, (see Ref. 1), the dispersal size fraction, F_3, and the drum thermal dispersal fraction, F_4, are considered suitable representations of the ANL waste. Although different shipping containers are to be used and it is felt a larger amount of the radioactive material released from the primary container will be retained within the interior packaging of the drum and the shipping container, a factor of 10% is still used for the container release factor, F_5.

Table 2. Characteristics of Cement Grout for LWBR-POB Waste

Compressive Strength	2000 psi
Resistance to Heat	See results of Ref. 1, p. 10
Grout Drop Test	See results of Ref. 1, pp. 15-16
Applicable Dispersal Fractions or Containment Factors	See Ref. 1, pp. 16-20
Breakup Fraction, F_2	0.0175
Dispersal Size Fraction, F_3	0.25
Drum Thermal Dispersal Fraction, F_4	0.02
Container Release Fraction, F_5	0.10

APPLICATIONS OF CONTAINMENT FACTORS

The total inventory of fissile material, ^{233}U, and fission products are 600 g ^{233}U and 25,000 curies, respectively. The total heat generation is 50 watts. These values are for the entire 700 L. Inventories per drum and per shipping container are tabulated in Table 3.

The inventory data in Table 3 is used to determine the quantity of radioactive material which might be released to the environment. The containment factors are applied to this data and an estimated release of radioactivity is determined as per Ref. 1, p. 20. It is estimated about 2.5 mCi of fission products would be released for the individual drums with the Supertiger option, and 2.5 mCi for the PolyPanther option.

Table 3. Data for Thermal and Radioactive Material Dispersal

A. Inventories

	Fission Products (Ci)	^{233}U (g)	Heat Source (Watts)
Total Inventory	25,000	600	50
Supertiger Option			
Drum	290	7.6	0.38
Steel Box	1740	45.6	2.28
Shipment	3480	91.2	4.56
PolyPanther Option			
Drum	290	7.6	0.38
M-3 Bin	290	7.6	0.38
Shipment	1740	45.6	2.28

B. Calculated Dispersal of Fission Product Radioactivity from Individual Drums
(F values from Ref. 1.)

	Supertiger	
C_f[a]	= 290 Ci	
$C_f \times F_2$	= 290 x 0.0175	= 5.075 Ci
$C_f \times F_2 \times F_3$	= 5.075 x 0.25	= 1.269 Ci
$C_f \times F_2 \times F_3 \times F_4$	= 1.269 x 0.02	= 0.025 Ci
$C_f \times F_2 \times F_3 \times F_4 \times F_5$	= 0.025 x 0.1	= 0.0025 Ci

	Polypanther	
C_f[a]	= 290 Ci	
$C_f \times F_2$	= 290 x 0.0175	= 5.075 Ci
$C_f \times F_2 \times F_3$	= 5.075 x 0.25	= 1.269 Ci
$C_f \times F_2 \times F_3 \times F_4$	= 1.269 x 0.02	= 0.025 Ci
$C_f \times F_2 \times F_3 \times F_4 \times F_5$	= 0.025 x 0.10	= 0.0025 Ci

[a] C_f = fission product level in a given 55-gal drum.

CONCLUSION

It is concluded that cement grout is a good medium for immobilizing the LWBR-POB waste for transport and interim storage. The composite packaging arrangement will provide suitable containment, and the proposed shipping containers, used in the manner discussed, will be in full compliance with all Federal regulations pertaining to the shipment of radioactive material.

PROPOSED CHANGE IN CERTIFICATE OF COMPLIANCE USA/6400/B( )F

5 (b) Contents

"addition of a sixth category."

(6) Liquid analytical residues from the dissolution of spent reactor fuel rods, solidified in cement. The cement is contained in 1.5-gal steel can closed with a slip cover lid. The two primary cans are packed in a secondary steel can sealed with a press fit lid. The secondary containment package and contents are placed within a radiation shield centered in a DOT Specification 17-C 55-gal steel drum. The drums are sealed with a styrene-butadiene rubber gasket contained with a standard drum closer. Total weight of the drum will be less than 1450 lb, and each drum will not exceed a fissile quantity of 60 g.

Sealed drums will be enclosed in a tight-fitting 3/16-in. thick corrugated steel box constructed in accordance with Rockwell-Hanford Operations' Drawing H-2-91888, Sheet 1, Rev. 0 (modified or unmodified). The space between the drums and the box, as well as void spaces between drums, must be filled with polyurethane foam Instapack 200 or equivalent.

PROPOSED CHANGE IN CERTIFICATE OF COMPLIANCE USA/6272/B()

5 (b) Contents

(I) General Waste

(i) Type and form of material. Dry, solid radioactive material within the waste storage bin.

(ii) Maximum quantity of material per package not to exceed Type B quantities of radioactivity. The maximum weight of the contents shall not exceed 3,000 lb.

"addition of category II."

(II) Solidified liquid waste.

(i) Type and form of material. Liquid analytical residues from the dissolution of spent reactor fuel rods, solidified in cement. The cement is contained in a 1-1/2-gal steel can closed with a slip cover type lid. Two primary cans are packed in a secondary steel can sealed with a press fit friction lid. The secondary containment package is placed within a radiation shield centered in a DOT Specification 17-C 55-gal steel drum. The drum is sealed with a styrene-butadiene rubber gasket contained with a standard drum closer. One drum will be secured within the M-3 storage bin.

(ii) Maximum quantity of material per package. The quantity of radioactivity will be < 435 curies of mixed fission products. Maximum weight of the contents and dunnage shall not exceed 3,000 lb.

ARGONNE NATIONAL LABORATORY

Attachment A

INTRA-LABORATORY MEMO

CT/SA1489
March 23, 1983

TO: N. M. Levitz, Project Manager, LWBR-POB
Analytical Support Project, CMT (Building 200)

FROM: M. G. Srinivasan and C. A. Kot, CT (Bldg. 335)

SUBJECT: Static Ultimate Strength Results for 55-gal Drum Shielding Packages

The attachment gives the results of our calculations for the failure strength of various components of the subject packages with no air gap at the bottom. Please note that the results give only the ultimate strengths of the components the failure of which would directly weaken the radiation shielding. The absence of information about the likely forces to be experienced by the drums in any postulated accident conditions, precludes the comparison of the failure strengths with the maximum forces likely to be experienced by the different components.

Please contact us if you have any questions.

CAK/MGS:eb
enclosure

cc: w/o enclosure
R. S. Zeno
G. S. Rosenberg

ANL-25 (11-68)

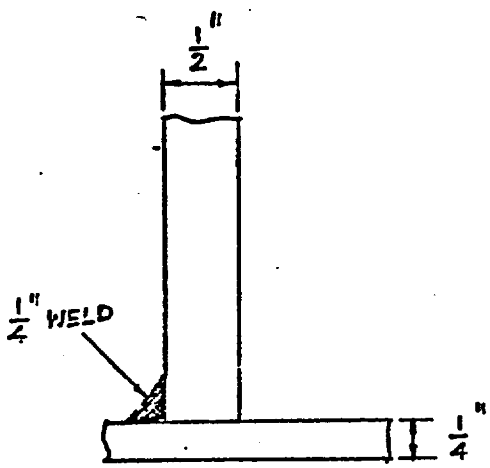
SUMMARY OF RESULTS

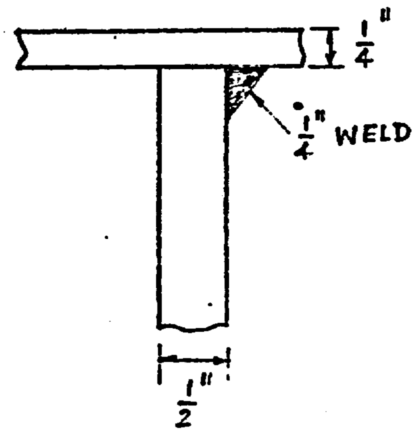
RADIATION SHIELDING INSIDE 55-GAL DRUMS

The following gives the ultimate strengths of the parts of the package inside the 55-gal drums. The ultimate strength is the static force that would cause a postulated failure condition.

Strength of weld connecting steel tubing to top or bottom plate	277,400 lb
Strength of weld connecting steel tubing to upper plate of closure plug	258,700 lb
Strength of bolted connection of closure plug to top plate	117,800 lb

1. <u>Failure of Welds Connecting Steel Tubing to Top or Bottom Plate:</u>





Weld length = π x 15 = 47.1 in

Weld size = 1/4 in

Throat area = 47.1 x .707 x .25 = 8.33 in^2

Assume nominal shearing strength of the weld is not less than 2/3 ultimate tensile strength of base metal.

Ultimate tensile strength of plate material = 50,000 psi

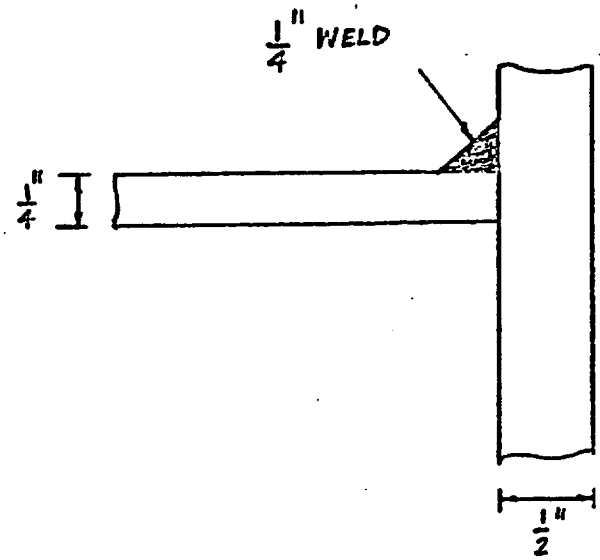
Strength of weld metal = 2/3 x 50,000 = 33,300 psi

Ultimate strength of weld = 8.33 x 33,500

= <u>277,400</u> lb

2. Failure of Welds in Closure Plug

The weaker of the two welds is that connecting the upper plate of plug to the steel tubing



Weld length = π x 14 = 43.98 in

Weld size = 1/4 in

Throat area = 43.98 x .707 x .25 = 7.77 in^2

Assume nominal shearing strength of the weld is not less than 2/3 ultimate tensile strength of base metal

Ultimate tensile strength of plate material	= 50,000 psi
Strength of weld metal	= 33,300 psi
Ultimate strength of weld	= 7.7 x 33,300
	= 258,700 lb

3. <u>Failure of Bolts Retaining Closure Plug</u>

Bolt	= 1/2 in. (13 UNC-2A) Grade 5
Number of bolts	= 6
Area of cross section of bolts	$= 6 \times \pi \times (.25)^2 = 1.178 \text{ in}^2$
Tensile strength of Grade 5 bolt material	= 100,000 psi
Total tensile strength of bolts	= 100,000 x 1.178
	= 117,800 lb

Attachment B

DOT-IV[1], a two-dimensional radiation transport code system, using the method of discrete ordinates, has been used to calculate gamma ray fluxes in and surrounding containers to be used in shipping radioactive waste from the LWBR-POB Project. The strength of the gamma sources were calculated from data supplied in private communications by BAPL.[2] The gamma ray spectrum from fission products for rods subjected to 30,000 effective full power hours averaged over the rod were used. Gamma rays emanating from the U^{232} decay chain at three years after shutdown were included. This is conservative, since the latter increases with time for several years after shutdown, and in any event is only about 11% of the total dose. A total of 14 energy groups are used covering the energy range from 0.05 mev. to 2.65 mev.

The gamma ray cross sections were generated by the use of SMUG[3] a computer code for generating multigroup photon cross sections.

Once the gamma ray flux is known, the dose rate is readily calculated from conversion factors.[4]

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1. Rhoades, W. A., et al., "The DOT-IV Two-Dimensional Discrete Ordinates Transport Code," Oak Ridge National Laboratory, ORNL/TM-6529 (August 15, 1978).

2. Bettis Atomic Power Laboratory, West Mifflin, PA.

3. Greene, N. M., et al., "AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B," Oak Ridge National Laboratory, ORNL/TM-3706 (March 1976).

4. Claiborne, H. C. and Trubey, D. K., "Dose Rates in a Slab Phantom from Monoenergetic Gamma Rays," Oak Ridge National Laboratory, ORNL/TM-2574 (April 28, 1969).

DOCKET NO. 71-6400 + 71-6272

CONTROL NO. 22244

DATE OF DOC. 04/15/83

DATE RCVD. 04/21/83

FCUF ____ PDR ✓

FCAF ____ LPDR ____

WM ____ I&E REF. ✓

WMUR ____ SAFEGUARDS ____

FCTC ✓ OTHER ____

DESCRIPTION:

Revisions to their Certificate of Compliance

05/10/83 INITIAL CEC