Enclosure 1

WAPD-LP(CE)-256

SAFETY ANALYSIS REPORT FOR PACKAGING SUPER TIGER SHIPPING CONTAINER AS ADAPTED FOR SMALL NUMBERS OF LWBR TYPE FUEL RODS

(LWBR Development Program)

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Contract No. DE-AC11-76PN00014

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CHAPTER 1 GENERAL INFORMATION

1.1 Introduction

This Safety Analysis Report supports the required revision to the Super Tiger shipping container Certificate of Compliance USA/6400/BLF (DOE-NR) to permit the transport of small amounts of U-233 (up to two kilograms) in the form of LWBR type unirradiated fuel rods or equivalent as a Fissile Class III shipment.

Nine BAPL 5910 Birdcage shipping containers, Certificate of Compliance USA/5910/BF (DOE-NR), are used as secondary packaging within the Super Tiger cavity for this application. Both the Super Tiger and the Birdcage were designed and tested to the requirements of Code of Federal Regulations (CFR) Title 10, Part 71 to assure nuclear safety during transport. Both containers have been certified and extensively used for a wide range of fissile material shipments, including those similar to this new application.

Recent evaluations have confirmed that the as-built Super Tiger may not meet all original design requirements and Reference 1 supports the proposed use of this container with secondary packaging to ship large quantities of U-233 (up to 50 kilograms). The analysis of Reference 1 is referenced extensively in this document to confirm that the as-built Super Tiger conservatively meets all defined safety requirements for this application.

1.2 Package Description

1.2.1 Packaging

The packaging (Figure 1) consists of the Super Tiger shipping container (Figure 2) with nine BAPL 5910 Birdcage shipping containers (Figure 3) as secondary packaging. Each Birdcage container may contain one LWBR rod transport box (Figure 4) or equivalent with up to 16 seed rods, eight blanket rods, or four reflector rods per container. The Super Tiger configuration is described in Reference 1 and the Birdcage configuration is described in Reference 2. The three by three array of 24 inch square by 12 foot long Birdcage containers will be shored snug within the 76 inch square by 14.3 foot long Super Tiger inner cavity. Six empty 17C Type 55 gallon steel drums (two foot diameter by three foot high) will be pre-inserted in front of the Birdcages and the sides and rear will be shored with plywood sheet stock.

1.2.2 Operational Features

Shipments in the Super Tiger shipping container are made dry with only natural modes of heat removal. The passive nature of the shipping container design requires no analysis of operational features since no operations are required.

1.2.3 Contents of Packaging

The package will be limited to no more than two Kg of fissile material per shipment in the form of LWBR-type fuel rods. Typical fuel rod characteristics are summarized in Table 1.1.

1.2.3.1 Quantity of Radionuclides

1. Fissile Material (Maximum) 2.0 Kg

2. Curie Content by Nuclide:

U-233 (and Daughters)	19.07
U-234	0.19
U-235	0.27×10^{-5}
Ra-228	0.22×10^{-2}
Ac-228	0.22×10^{-2}
Th-232	0.01
U-232	0.26
Th-228	0.12
Th-228 Daughters*	0.67
	21.00 ci

* Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Po-212, Ti-208

1.2.3.2 Chemical and Physical Forms

The fissile material will be in the form of solid high density high integrity UO_2 + Th O_2 pellets retained within Zircaloy fuel rod cladding with welded end closures.

1.2.3.3 Material Density

Refer to Table 6.4 of Reference 1.

1.2.3.4 Moderator Ratios

There are no significant quantities of moderators in the rod transport boxes under normal transport conditions.

1.2.3.5 Decay Heat

The Super Tiger is currently certified for 30 watts decay heat. The allowable load of two Kg of fissile material will generate approximately one watt and therefore comply with this limit.

1.2.3.6 Internal Pressure Buildup

The maximum pressure reached within the Super Tiger during shipment is 18.3 psia based on a maximum internal design temperature of 200°F as calculated in Chapter 3 of Reference 1.

TABLE 1.1
AVERAGE AS-BUILT LWBR CORE FUEL CHARACTERISTICS

	Pellet OD (in)	Pellet Length (in)	Percent of Theoretical Density	U-Fissile (w/o)*	U-Fissile (grams/in.)	Rod Length (in)	Rod O.D. (in)	Clad Thickness (in)
Seed								
Thoria	0.2556	0.530	98.01	None	None	118.37-	0.3063	0.02217
Low zoned	0.2520	0.444	97.71	4.337	0.3416	119.14		
High zoned	0.2520	0.615	97.55	5.202	0.4114			
Standard Blanket								
Thoria	0.5106	0.616	97.80	None	None	121.88-	0.5717	0.02808
Low zoned	0.5105	0.531	98.61	1.214	0.3920	122.12		
Medium zoned	0.5105	0.868	98.22	1.668	0.5421			
High zoned	0.5105	0.785	98.11	2.005	0.6498			
Power Flattening Blanket								
Thoria	0.4696	0.447	98.06	None	None	121.88-	0.5274	0.02642
Low zoned	0.4695	0.870	98.03	1.654	0.4537	122.12		
Medium zoned	0.4695	0.786	98.04	2.009	0.5509			
High zoned	0.4696	0.701	97.91	2.739	0.7492			

$$*\text{U-Fissile (w/o)} = \frac{\text{U-233} + \text{U-235}}{UO_2 + ThO_2} \times 100$$

U Isotopic Composition	
U-232	<0.001 w/o
U-233	98.23
U-234	1.29
U-235	0.09
U-236	0.02
U-238	0.37

CHAPTER 2 STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The structural members which contribute to the safe transport of LWBR fuel rods are the Super Tiger shipping container, the BAPL 5910 Birdcage shipping containers, the LWBR rod transport boxes, and the rod cladding. The Super Tiger and rod cladding structural characteristics are discussed in Paragraph 2.1.1 of Reference 1 and the Birdcage structural characteristics are described in Reference 2. Reference 1 analyzed the application of the Super Tiger to transport a 23,000 pound payload enclosed within a polyurethane foam inner liner within the Super Tiger inner compartment thus providing a conservative comparison to the current application with a 3,600 pound payload.

2.1.2 Design Criteria

Refer to paragraph 2.1.2 of Reference 1 for the Super Tiger design criteria. The carbon steel Birdcage components are comparable to the Super Tiger components such that the design criteria is applicable.

2.2 Weights and Center of Gravity

The allowable gross weight of the Super Tiger shipping container is 45,000 pounds. The maximum weight of the individual components for this application is as follows:

1.	Empty Super Tiger	19,000 lbs.
2.	Loaded Birdcages (Nine containers at 400 lbs. each)	3,600 lbs.
3.	Shoring Material (Empty 55 gallon drums and plywood)	1,400 lbs.
	Total (Maximum)	24,000 lbs.

All components are symmetrical and the center of gravity of the empty or loaded Super Tiger is at the approximate mid-point for all orientations.

2.3 Mechanical Properties of Materials

Refer to paragraph 2.3 of Reference 1.

2.4 General Standards for all Packages

Refer to Paragraph 2.4 of Reference 1.

2.5 Standards for Type B and Large Quantity Packaging

Refer to Paragraph 2.5 of Reference 1.

2.6 Normal Conditions of Transport

Refer to Paragraph 2.6 of Reference 1 for the Super Tiger analysis which is valid for this new application except for the additional assessment of the effects of a one foot drop with the nine contained Birdcages. A Birdcage container was subjected to a 30 foot drop as discussed in Reference 2 and the effects of a 30 foot drop on the multiple stack of Birdcage containers within the Super Tiger chassis are discussed in Paragraph 2.7 of this document. Based on this prior 30 foot drop testing and analysis, no detectable damage is expected to the Birdcage container or contents during a one foot drop within the polyurethane foam lined Super Tiger chassis.

2.7 Hypothetical Accident Conditions

Refer to Paragraph 2.7 of Reference 1 for the Super Tiger analysis. The analysis for the 30 foot free drop of the 45,000 pound loaded Super Tiger container is very conservative for the 24,000 pound loaded container of this application. The Birdcage structural members and the shoring material effectively distribute the Birdcage impact loads over the Super Tiger inner cavity wall surface such that minimal Super Tiger damage would be incurred.

As discussed in Reference 2, the impact loads during the 30 foot drop test of a prototype Birdcage container were absorbed primarily through bending of the Birdcage inner structural components. The contents of each Birdcage container will be limited to a maximum weight of 99 pounds (nine pounds per foot of inner container length) for compliance with the drop test criteria. The individual Birdcage containers will be submitted to considerably less impact loads during a hypothetical 30 foot drop within the Super Tiger cavity due to the impact absorbing features of the polyurethane lined Super Tiger chassis. The three by three Birdcage container array will be shored snug within the Super Tiger cavity such that the vertical Birdcage structural members in the direction of drop will be aligned. The positioning of the lateral braces in the Birdcage construction precludes (slender column) buckling of the lower Birdcage structural components due to the impact loads of the upper Birdcages. Birdcage damage would be expected to be limited to minimal lateral bending of the inner structural members similar to that incurred during the prototype 30 foot drop test. The Birdcage container structure also would preclude impact of the steel pins in the Super Tiger chassis walls, as discussed in Paragraph 2.7.2 of Reference 1, with the rod transport boxes within the Birdcages.

As discussed in paragrah 2.7.1.1 of Reference 1, a loaded 45,000 pound Super Tiger chassis would be subjected to a peak G (gravity) load of up to 50.6 during a hypothetical 30 foot (side) drop. The peak G load could be approximately doubled during this application due to the 50% lower container weight and resultant lower crush depth. Even considering any additional credible dynamic acceleration loads up to a factor of two, the possible 200 G load is within the allowable rod cladding load of 260 G, as discussed in Paragraph 2.7.1.5 of Reference 1, without considering the additional impact absorbing feature of the Birdcage structure.

In summary, shipping package damage under the defined sequential accident conditions would be limited to minor deformation of the Super Tiger chassis and the Birdcage inner structural components. The rod cladding would remain intact and the fuel material would be retained even if the Super Tiger chassis containment boundary was ruptured.

2.8 Special Form

This requirement is not applicable since special form is not claimed for the rod shipments.

2.9 Fuel Rods

The fuel rod cladding was analyzed in Paragraph 2.7.1.5 of Reference 1 and determined to retain structural integrity during a hypothetical 30 foot drop.

The rods were designed and tested to withstand operational pressures of 2000 psi at 500°F such that induced pressures due to shipping container boundary failure and compartment flooding are insignificant.

CHAPTER 3 THERMAL EVALUATION

3.1 Discussion

The Super Tiger shipping container was analyzed for the effects of an external radiation environment of 1475°F for 30 minutes as discussed in Chapter 3 of Reference 1.

The current rated thermal heat capacity of the Super Tiger shipping container as documented in the Certificate of Compliance is 30 watts and the maximum heat generation due to radioactive decay of 2 Kg of U-233 is approximately one watt as derived from chapter 3 of Reference 1. Even with no dissipation of internally generated heat due to the insulation features of the polyurethane foam in the Super Tiger liner, internal temperature rise is negligible.

The internal pressure would rise only 3.6 psi even if the enclosed air in the sealed container was heated from ambient 70°F (530°R) to the 200°F (660°R) maximum design temperature. The pressure rise would be proportional to the temperature rise as follows:

$$P_{max} = P_{amb} \cdot T_{max}/T_{amb} = 14.7 \text{ psi} \cdot 660^0/530^0 = 18.3 \text{ psia } (3.6 \text{ psig})$$

CHAPTER 4 CONTAINMENT

4.1 Discussion

The Super Tiger shipping container containment boundary, as designed, consisted of the 3/16 inch thick mild steel inner shell and the 1/4 inch thick aluminum closure plate with full length silicon rubber gasket. The closure plate is secured to the inner shell with 36-1/2 inch diameter steel bolts torqued to 35-45 foot pounds. A pressure fitting with cap on the closure plate provides a means for leak testing. The new rod transport application is compatible with the original container design criteria as discussed in Chapter 4 of Reference 1 and summarized below:

(1) The existing Super Tiger chassis will be used without modification and no new containment penetrations are incorporated.

(2) Shipments will continue to be made dry with only natural modes of heat removal.

(3) The center of gravity of the loaded Super Tiger will remain near the geometric center of the container.

(4) The impact loads of the new inner containment will be distributed over the applicable surface area of the Super Tiger cavity.

(5) Acceptable internal temperatures and pressures will be generated during transport.

Since this containment boundary may no longer be reliable due to as-built Super Tiger deviations as discussed in Paragraph 2.1.1.1 of Reference 1, total fuel material containment for this application will be provided by the container chassis in conjunction with the new inner components. The fuel rod cladding will retain the fuel materials during all defined normal transport and accumulative accident conditions as discussed in Chapter 2. The Birdcage containers will retain structural integrity under all accident conditions and absorb part of the drop test impact loads to prohibit massive Super Tiger chassis failure. The Super Tiger chassis therefore will insure containment of all rods. The container also will remain nuclearly safe under the worst case loading and multiple accident conditions as discussed in Chapter 6.

CHAPTER 5 SHIELDING EVALUATION

5.1 Discussion

Since the Super Tiger always will be shipped exclusive use for this application, the following total radiation dose rate limits of 49 CFR 173.441(b) will be used:

200 mrem/hr on contact with the container

10 mrem/hr at two meters from the container

2 mrem/hr in the cab of the transporting vehicle

1,000 mrem/hr at three feet from the container after hypothetical accident conditions (10 CFR 71 limit)

Actual radiation levels for each shipment will be maintained as low as possible and within allowable limits by limiting the quantity of shipped rods as required and by effectively spacing the rods and Birdcage containers within the composite one half inch of steel in the Super Tiger chassis. The combined beta-gamma and neutron radiation dose rates will be measured and recorded as the Super Tiger container is loaded and the loading will be terminated prior to exceeding these limits. In no case will a shipment be initiated with dose rates exceeding allowable levels. No significant fuel rearrangement will occur during the hypothetical accidents as discussed in Chapter 2; therefore, the allowable accident condition dose rate also will never be exceeded. For example, the dose rate at three feet from the container would not exceed the normal shipping limit (200 mrem/hr on contact) even if the fuel load were rearranged an equivalent three feet off center during an accident.

CHAPTER 6 CRITICALITY EVALUATION

6.0 General

The criticality evaluation for this shipping configuration is based on the LWBR Core Manufacturing Feasibility Report analysis, Reference 3. This analysis confirmed that the minimum number of high zone LWBR rods required to achieve criticality under flooded and optimum spacing condition is 174 seed rods or 194 blanket rods. A maximum of 58 high zone seed rods, 44 high zone blanket rods, or a proportionally lower number of special reflector-size rods could be shipped within the two Kg of U-233 limit for this application. Within these limits, no possible combination of rods could approach criticality (K effective of 1.0) even under multiple case accident conditions of a flooded shipping container and optimum rod spacing. It is noted the optimum rod spacing, as determined in Reference 3, is approximately 0.5 inches. The clusters of rods in each Birdcage container are restrained approximately 24 inches apart by the Birdcage structure. Total Birdcage failure and rearrangement of all rods to the 0.5 inch spacing would be required to achieve the optimum conditions as defined in Reference 3.

CHAPTER 7 OPERATING PROCEDURES

7.0 Introduction

All of the rods to be transported will be shipped in LWBR rod transport boxes or equivalent. The Super Tiger shipping container will be pre-installed on a flatbed trailer and the nine Birdcage containers will be pre-installed and shored snug in the Super Tiger prior to loading the rod transport boxes.

7.1 Procedures for Loading the Package

The complete loading sequence will be documented by formal procedure summarized as follows:

(1) Confirm that the shipping container/trailer maintenance program has been completed as defined in Paragraph 8.2.2 of Reference 1.

(2) Confirm that any loading devices have been load tested and serviced for operation.

(3) Prepare the Super Tiger for loading by removing the 10-one inch bolts and manually opening the door, performing a leak test as defined in Paragraph 8.2.2 of Reference 1, removing the 36-one half inch bolts and removing the inner seal plate, and removing the rear plywood shoring material and Birdcage end stops.

(4) Perform a radiation survey of the storage area and a contamination survey of the accessible portion of the Super Tiger inner compartment.

(5) Implement applicable radiation area controls.

(6) Lift the selected rod transport box and insert it into the selected Birdcage inner cage.

(7) Install the Birdcage end stop to restrain the rod box in position.

(8) Repeat steps (6) and (7) to complete the Super Tiger load. Periodically record all Super Tiger external radiation levels and terminate loading if any level approaches the allowable transport limit (200 mrem/hr on contact with any external surface, 10 mrem/hr at 2 meters from any external surface, and 2 mrem/hr in the truck cab).

(9) Prepare the Super Tiger for transport by reinstalling the rear shoring material, installing the inner seal plate with the 36-one inch bolts, performing a leak test as defined in paragraph 8.2.2 of Reference 1, and closing and securing the Super Tiger door with the 10-one inch bolts.

(10) Close and secure the storage area and retain the Super Tiger/trailer under appropriate safeguard requirements until the shipment is initiated.

7.2 Procedures for Unloading the Package

The complete unloading sequence will be formally documented with the significant shipping container provisions summarized as follows:

(1) Position the shipping container/trailer for unloading and prepare for unloading by removing the 10-one inch bolts and manually opening the door, removing the 36-one half inch bolts; removing the inner seal plate, and removing the rear shoring material.

(2) Perform a contamination survey of the accessible portions of the shipping container as the above operations are in progress.

(3) Remove the applicable Birdcage end stop and extract the rod transport box.

(4) Repeat step 3 for the remaining rod transport boxes.

7.3 Preparation of an Empty Package for Transport

The preparation for empty transport will be performed to a written checklist summarized as follows:

1. Perform a contamination survey of the accessible portion of the Super Tiger inner compartment.

2. Reinstall the Birdcage end stops and rear shoring material.

3. Install the inner seal plate with the 36-one half inch bolts.

4. Remove the leak test valve to assure that the Super Tiger cavity is vented for empty transport.

5. Close and secure the Super Tiger door with the 10-one inch bolts.

6. Confirm that the trailer has been currently serviced and inspected for Highway use.

7. Confirm that the Super Tiger tiedown bolts are secured.

7.4 Transport Limits

All Super Tiger loading procedures will include provisions for ensuring that the following limits are maintained:

1. No shipment to exceed 2 Kg of U_{233}.

2. Rods are packaged in LWBR rod transport boxes or equivalent at not more than 16 seed, eight blanket, or four reflector rods per box, using the nylon rod spacers or other rod shoring material as shown in Figure 4.

3. Each rod transport container gross weight is not over 99 pounds.

4. Gross shipping container and trailer weights are within allowable transport limits.

5. No recorded external beta-gamma and neutron radiation dose rates to exceed 200 mrem/hr on contact with any external surface, 10 mrem/hr at 2 meters from any external surface, and 2 mrem/hr in the truck cab.

CHAPTER 8 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.0 Discussion

The acceptance test and maintenance program for this application will be the same as described in Chapter 8 of Reference 1 with those portions of Reference 1 applicable to the "storage compartment" now applicable to the Birdcage containers.

APPENDIX

References

1. WAPD-LP(FE)-220, "Safety Analysis Report for Packaging, Super Tiger Shipping Container as Adapted for LWBR Type Fuel Rods" Revision 3, Feb. 1983.

2. WAPD-RS(CC)-1269, "Revision to the BAPL 5910 Birdcage Safety Analysis Report, April 1975.

3. WAPD-RS(CC)-100 "Minimum Critical Numbers of LWBR Rod and Pellets" Revision 1, April 1972 (Enclosure 3 to Section V of WAPD-RS(CC)-110 "LWBR Core Manufacturing Feasibility Report, Revision 1, March 1973) - Enclosed

Figures

1. Super Tiger Shipping Container with Birdcage containers as Secondary Packaging

2. Super Tiger Shipping Container

3. BAPL 5910 Birdcage Shipping Container

4. LWBR Rod Transport Container

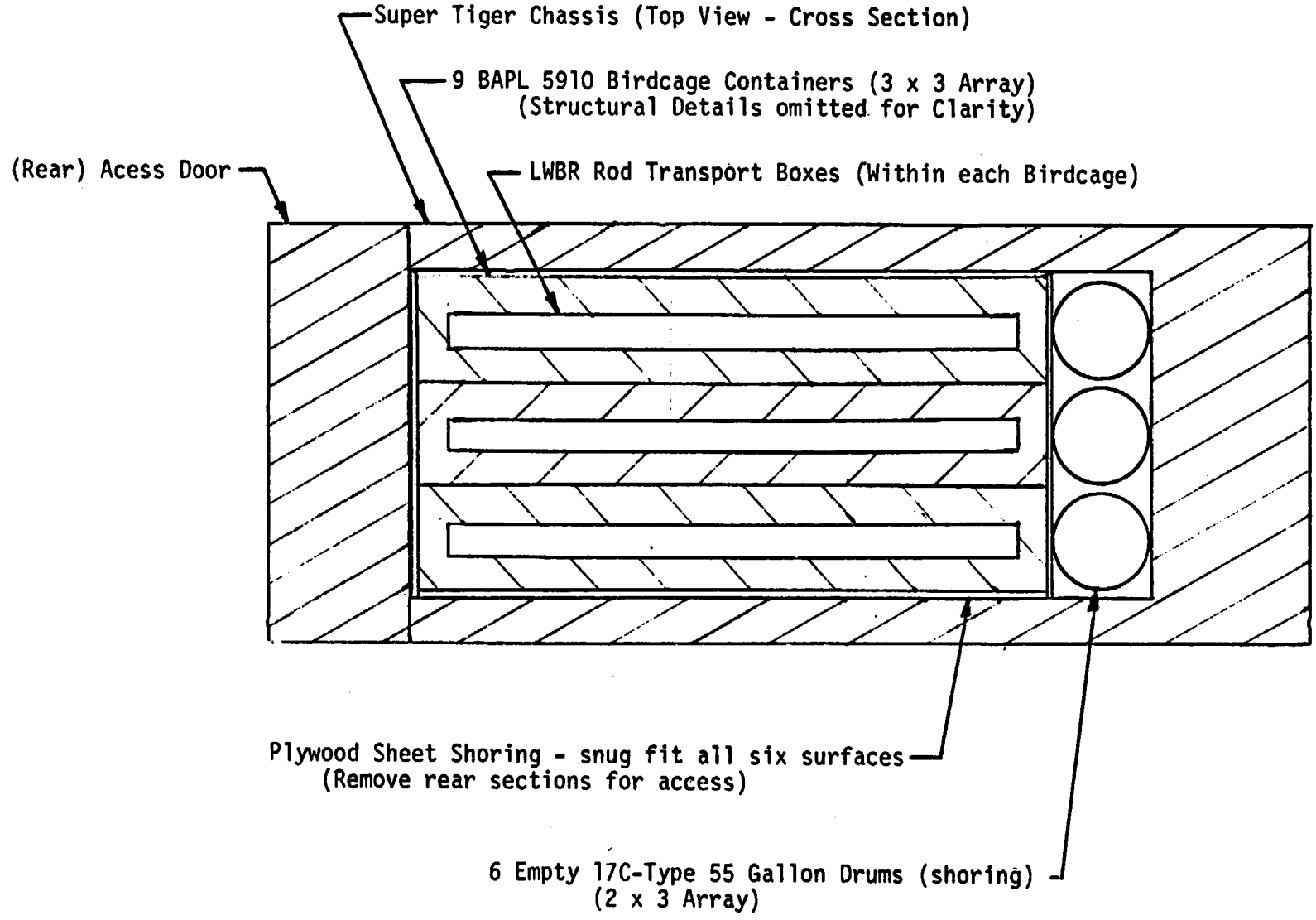


FIGURE 1. SUPER TIGER SHIPPING CONTAINER
WITH BIRDCAGE CONTAINERS AS SECONDARY PACKAGING

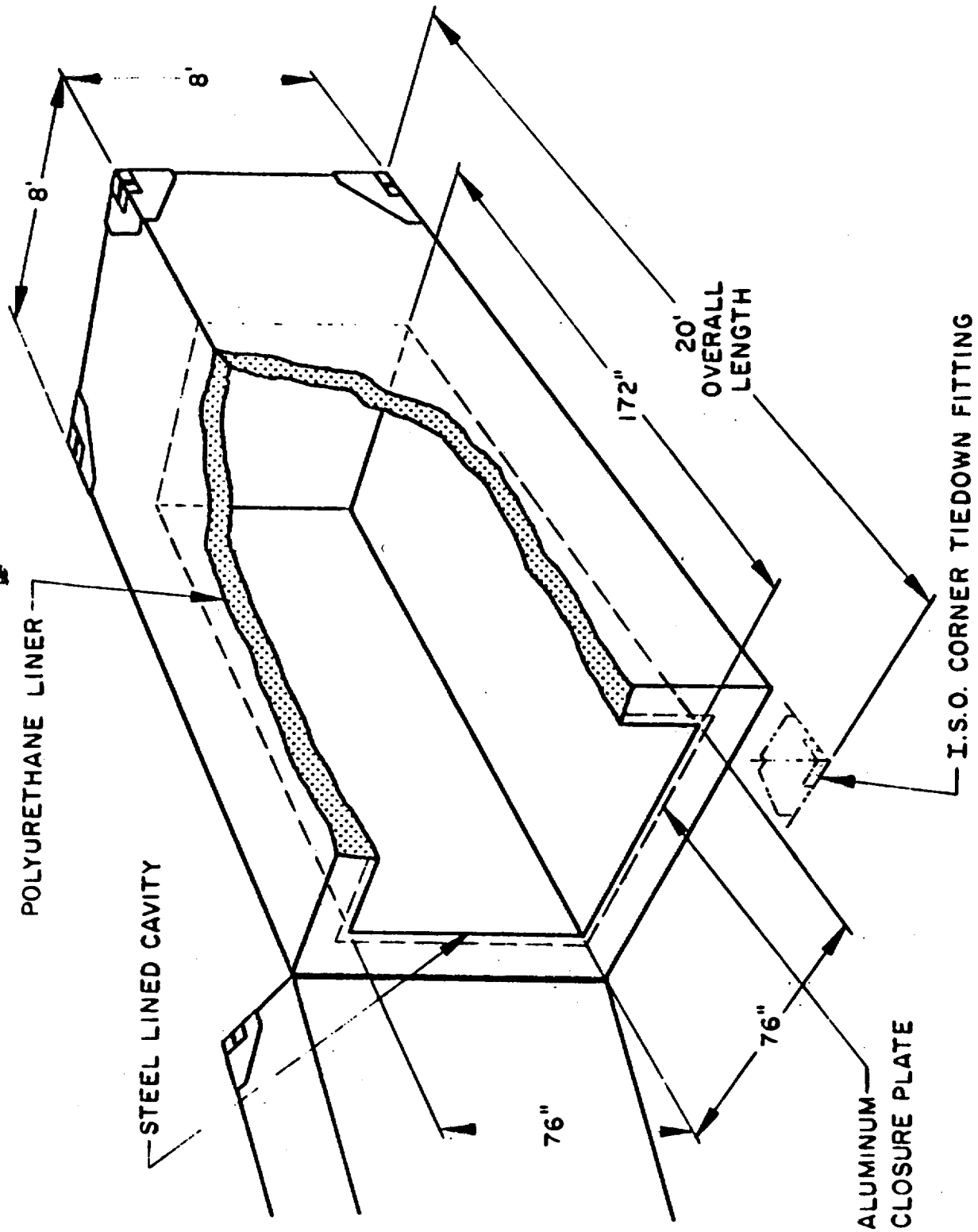


FIGURE 2. SUPER TIGER SHIPPING CONTAINER

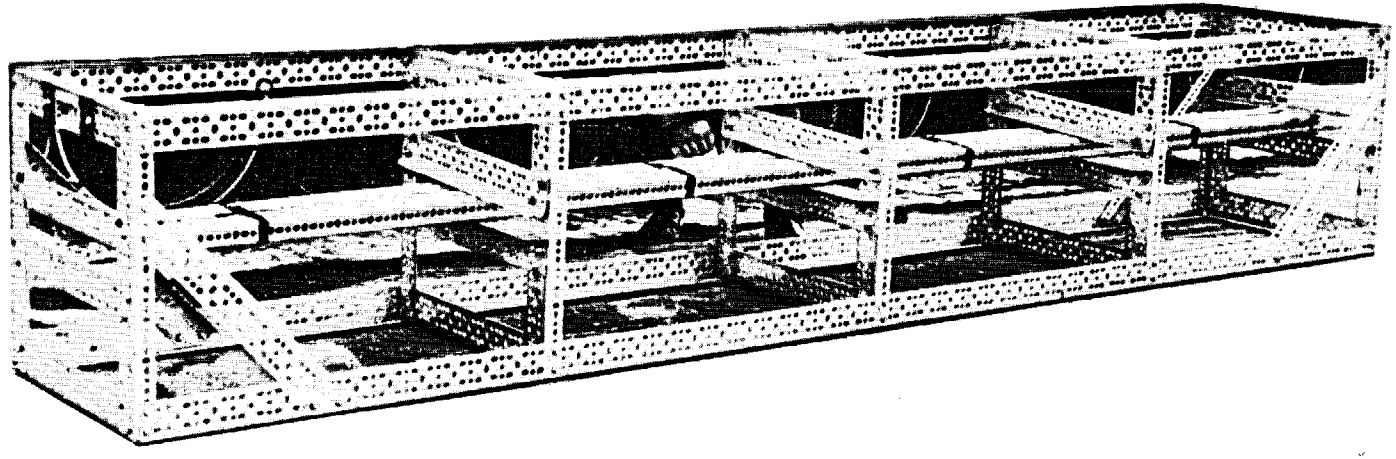
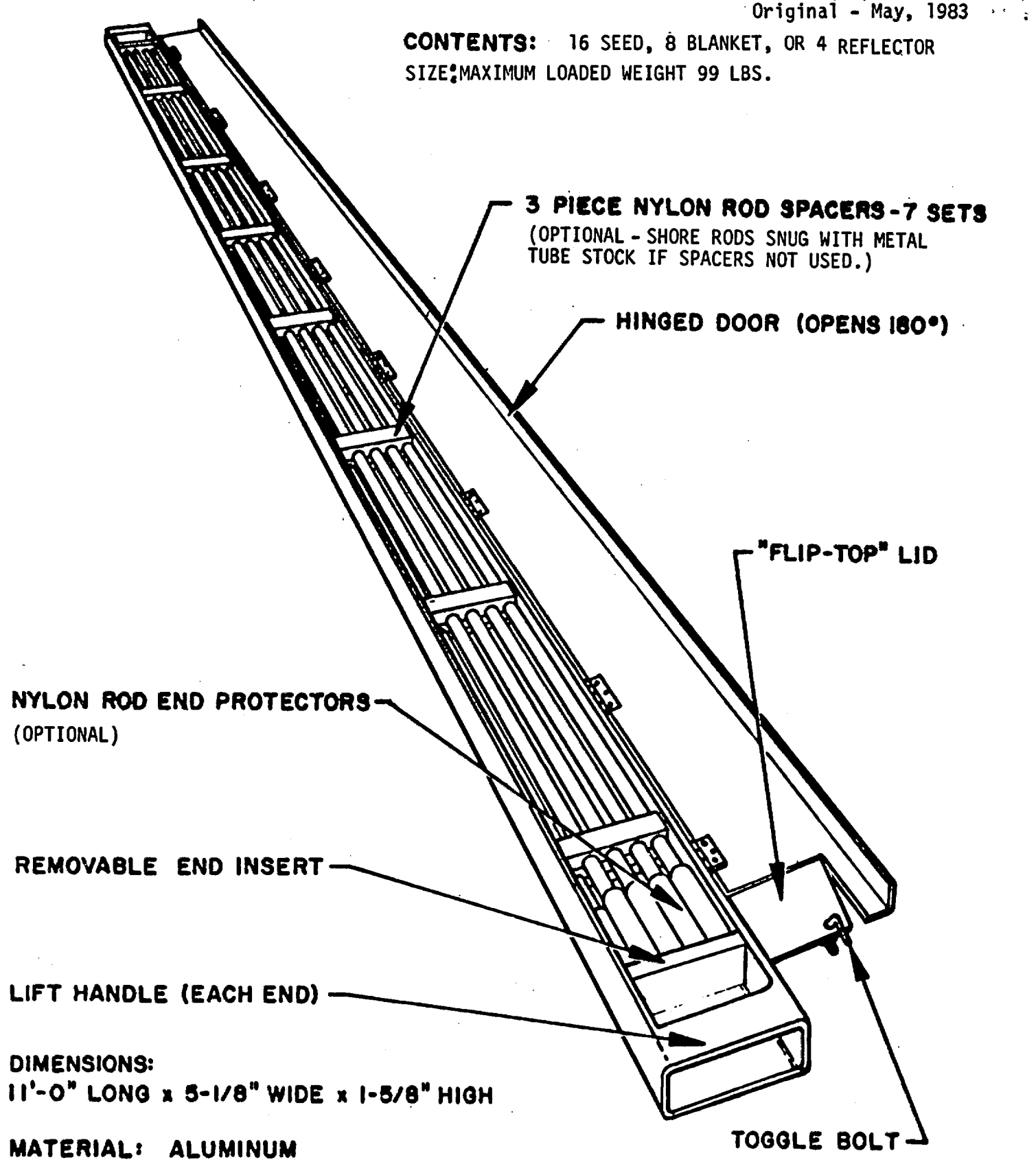


FIGURE 3.BAPL 5910 BIRDCAGE SHIPPING CONTAINER
(12 FOOT LONG) REF. WESTINGHOUSE DWG. 1528E73



*U.S. GOVERNMENT PRINTING OFFICE: 1983/605-027/579

FIGURE 4 LWBR ROD TRANSPORT BOX