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EVALUATION OF THE "MACHINED PARTS" CASK FOR OFF-SITE SHIPMENTS OF IRRADIATED LITHIUM

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EVALUATION OF THE "MACHINED PARTS" CASK FOR
OFF-SITE SHIPMENTS OF IRRADIATED LITHIUM

by

Glenn E. Peck

Plant Design Unit
Design Engineering Subsection
FACILITIES ENGINEERING SECTION

July 12, 1963

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EVALUATION OF THE "MACHINED PARTS" CASK FOR
OFF-SITE SHIPMENTS OF IRRADIATED LITHIUM

I. INTRODUCTION

With the issue of the Atomic Energy Commission Manual Chapter 0529 draft of proposed regulations in April, 1962, the Irradiation Processing Department began evaluating for compliance all casks used for off-site shipment of radioactive materials. The Savannah River Installation has shipped "machined parts" casks to Hanford for loading with irradiated lithium alloy slugs for a number of years. Although these casks are the property of the Savannah River Installation, it is thought prudent that an evaluation be made of the cask design in accordance with proposed regulations since General Electric as the contractor to the Richland Operations Office-AEC is responsible for the loading and tie-down of the casks. Although the shipment is the responsibility of the AEC and the carrier once loaded and moved off the site, the public view would probably place responsibility with General Electric.

II. PURPOSE

The purpose of this design evaluation study is to evaluate the integrity of the "machined parts" cask design in accordance with the criteria published in document HW-76476, which is based primarily upon proposed regulations of the Atomic Energy Commission and the Interstate Commerce Commission.

III. CONCLUSIONS

After evaluation of the cask against the criteria of proposed regulations, it is concluded:

- A. That the cask will not meet the requirements for the following reasons:
 - 1. The cask would not survive drop tests without rupture and/or losing its cover.
 - 2. The cask would not survive a two-hour fire of 2000 F without rupture of the shell and/or loss of shielding material and probable dispersion of tritium gas.
 - 3. The concentration of weight per square foot of bearing surface is excessive.
- B. That no great hazard would result from failure of a cask subjected to impact conditions alone.
- C. That present cask tie-down is adequate for ordinary shipping conditions, but that casks would be separated from the car in the event of a credible impact accident.
- D. That a program be initiated to bring the container assemblies for shipment of irradiated lithium including tie-down to railway car into compliance with the criteria established by document HW-76476.

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IV. SUMMARY

The "machined parts" casks are shipped to Hanford by the Savannah River Installation for loading with irradiated lithium alloy slugs and returned for processing.

This evaluation is based upon the shipment of irradiated lithium alloy in accordance with the design criteria (1). Tritium is a beta emitter of rather low activity as shipped. Since about 500,000 curies per cask shipped is above the limits placed by the ICC on ordinary shipments of radioactive materials, the shipment in "machined parts" casks is classified as a large radioactive source and therefore must meet the requirements of AEC Manual Chapter 0529 in addition to the requirements of the ICC and the Bureau of Explosives.

The casks have been in service for about ten years and have shielding material in excess of that required to attenuate radiation levels allowed for exterior surfaces of the cask by proposed regulations. Evaluation of structural properties reveals that rupture of the shell is probable for an edge or corner drop with considerable displacement of shielding material. The cask would fail under conditions of a two-hour fire of 2000 F with loss of shielding material and dispersal of the product is probable. Bolts securing the cover to the cask are satisfactory for ordinary shipping conditions, but are inadequate in the event of an accident and do not meet requirements of the criteria.

V. DISCUSSION

A. Introduction

The discussion of design evaluation for the "machined parts" casks shall be limited to compliance with the Criteria (1) as applied to shipment of irradiated lithium alloy from Hanford. The casks were designed by duPont and are based at the Savannah River Installation. The evaluation will analyze the cask from known physical properties of the materials and be analogous to destructive or experimental test results for similar casks. Impact and exposure to fire are areas where little specific data is available; however, casual comparison of cask physical details with the criteria indicate that the cask would fail under conditions of impact and/or fire.

B. Description of the Cask

The machined cask was designed by duPont for the Savannah River AEC Installation in 1952 and fabricated in 1953. The casks have been shipped to Hanford for loading over a period of some years in a gondola railway car as shown in Figures 1 and 2 on the pages following. The cask is rectangular in shape with an average of 4-inch lead shielding. (See Figure 4 for a sketch of physical dimensions.) The estimated weight of this cask is 10,446 pounds, which places 1387 pounds per square foot bearing pressure on the car or the floor.

NOTE
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MACHINED PARTS CASK

FIGURE 1. Machined Parts Cask as shipped in Gondola Car before structural steel was used for cask tie-down.

(a) Top view of cask showing recent cover hold-down fabrication which eliminated banding shown on Figure 1.

FIGURE 2

(b) Recent gondola car loading of casks with structural steel tie-down.

(a) Cask Interior with Bucket Removed

(c) Cask with Product Bucket in Place

(b) Top View of Cover in Place

(d) Cover Tie-Down to Trunnion with U-Bolt

FIGURE 3

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The most evident weakness of this cask design is the cover hold-down with two eye-bolts of small size (3/4-in.dia.) compared to the weight of parts which are joined. Steel-banding was used to secure the cover until a recent April 1963 shipment when a hold-down device was fabricated at Hanford and is shown in various views on Figures 2 and 3.

The product is placed in the cask in a square bucket which is of standard design for underwater loading of radioactive materials, although the loading is done dry at the present time.

C. Description of Radioactive Material

The cask is presently used for transportation of irradiated lithium-aluminum alloy with the end product being tritium which is the name for H_3 , an isotope of hydrogen which does not occur naturally. Li^6 , the less common isotope of lithium, is about 7.5 per cent of natural lithium metal but is enriched to approximately 38.5 per cent Li^6 and irradiated as an alloy of aluminum for increased production of tritium. Tritium decays to form Helium-3, with the emission of a negative beta-particle having a maximum energy of 0.018 Mev.

The target elements used at Hanford are of two types, clad with aluminum alloy X-8001-F. The first type of target is a 6-inch solid slug, while the second type is a 4-inch hollow center slug. Details of the specifications for the encapsulation or canning of these slugs are to be found in Document HW-47029. The approximate weight of these slugs are 0.7 pounds for the 6-inch and 0.45 pounds for the 4-inch with 350 and 550 slugs respectively, loaded in one cask. The average expected production per cask is 30 grams of tritium.

The radioactive emission level of tritium is very low as shipped. The primary source of emission which requires shielding material is from the irradiated impurities in the aluminum. A recent check of radiation levels reveals a maximum of 2 mr/hour at 2-inches from the outside surface of the cask. Each cask contains about 500,000 curies, which classifies this as a large radioactive source.

D. Resistance to Structural Failure

1. Impact

Evaluation of the cask shall be in accordance with the Criteria (1) and shall be by empirical means rather than theoretical. Calculations cannot be used reliably for accurate prediction of impact results. Although impact testing of shipping casks has been limited, the reported results of tests have aided or confirmed the analysis made in this evaluation.

Classification of the radioactive material to be evaluated is dependent to some extent on the cask in which it is shipped and therefore the evaluation for impact shall compare capabilities relative to both dispersible and non-dispersible sources. Impact forces shall therefore be considered for both the 15 and 30-foot drop heights.

The dynamic loading which the cask must withstand is dependent upon the deceleration which is in turn dependent upon the nature of the impact, the materials involved, and the velocity at impact. It is convenient to express dynamic loading in terms of gravity or G's. From Reference (2), the number of G's can be computed from various empirical shock-rise times. A plot of this computation for 15 and 30-foot drop heights may be found on Figure 5. A 1 millisecond shock-rise time will give 966 G's and 1368 G's for 15 and 30-foot falls respectively, and a 2 millisecond shock-rise time would be one-half of the above. Drop tests by ORNL (3) produced recorded shocks of 1100 to 1400 G's which compares favorably with the G's given above for a 30-foot fall.

For a bottom area of 1085 square inches and a total cask weight of 10,500 pounds and a 30-foot drop condition, dynamic stress of 13,239 psi would be developed if the stress were considered to be spread evenly over the entire area. Practical analysis of drop tests indicate that there is a concentration of stress near the outside edge of the cask. For one-fourth the area the stress would be in the danger zone for design strength although the dynamic strength of stainless steel is over 100,000 psi if inconsistencies in the material and weld joints are not considered. If the concentration of stresses is limited to one-inch around the perimeter, the stress would be in excess of 100,000 psi. There is no definite way of predicting accurately failure for a flat side drop such as this, but it is felt that the shell would survive a drop flat on one side without failure.

For a corner or edge impact there is practical reason to believe that the cask would fail for reason of the greatly reduced area available. Shappert (3) reports weld cracking for corner drops of 16-feet with considerable displacement of shielding material. Lead has free-flowing properties at about 12,000 psi (4) so that dynamic loading is transmitted to the cask shell by impact and deceleration forces are borne by the shell primarily. Therefore, it is expected that permanent displacement would be greater than 10 percent and be accompanied by weld cracking for either corner or edge drop of this cask.

From Appendix A.1, it can be seen that the two bolts designed to secure the cover are only about one-fifth adequate for the loading requirements of the criteria. A more stringent requirement is indicated by impact values discussed above.

2. Puncture

Criteria for puncture is a force equal to 30 times the weight of the loaded container over any circular area 6-inches in diameter with the duration of the applied force assumed to be no less than 16 milliseconds. Using these conditions, calculation of shear stress was found to be 36,605 psi by calculations of Appendix A.2 and just safe for 40,000 psi design stress if no size factors or factor of safety are applied.

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The puncture portion of the criteria arbitrarily penalizes larger casks where increased weight develops proportional increase in stress values. Applying the criteria conditions to the formula of Reference (2) we find that this would be equivalent to a fall of 44.4 inches. Since impact conditions would develop greater forces, a fall on the trunions for this cask would be equivalent to that developed in Reference (5) and indicate failure by puncture and is confirmed by reported experience of Reference (6) papers on test programs.

3. Fire

Tharim (7) indicates that at about 300 C (572 F) the alpha phase of the lithium-aluminum alloy begins to change to the beta phase and with additional heat (increasing temperature) gaseous tritium is driven off. Tritium easily dissolves in water or water vapor and thus is a health hazard since contaminated air and water are introduced to the human body easily. Considering a 2000 F temperature per the criteria and the analysis of heat transfer to a lead shielded cask with stainless steel inner and outer shells developed in Reference (5), it is evident that the cask being evaluated will not meet the criteria of a two-hour fire without losing shielding material and releasing radioactive material to the atmosphere in a manner presenting a contamination and health hazard.

4. Internal Pressure

The cask has three pressure relief devices on the cover, but since specifications are not available, no evaluation of pressure relief capability or for pressure containment of the cask was made. The criteria and proposed regulations clearly indicate that protection of the cask so that temperatures at which vapors can be generated will not be reached is preferable to pressure relief. Since the shipping period is not long it is thought that very little helium would be produced as a result of tritium decay and hence not a problem of internal pressure as with lithium alloy control rods. While the cask has a sealing gasket there is some doubt as to what design pressure should be applicable with only two bolts holding the cover down besides the weight of the cover itself.

E. Maintenance of Adequate Shielding

During loading of casks on the car for a recent shipment of tritium, radiation monitors recorded a maximum measurement of 2 mr at a distance of 2-inches which is a radiation level far below that allowed by the criteria. The lead shielding material averages 4-inches or more for these casks and is excessive for the shipment of tritium.

Offset design of cover is adequate to prevent beaming of radiation to the exterior of the cask and the shielding material is assumed to be generally free of voids.

The inner shell is supported so that it will not be displaced should the lead shielding be melted. The bar stock on the inner and outer shell should prevent ordinary displacement of shielding material due to vibration.

F. Provision for Heat Removal

Since the amount of energy released due to decay of tritium is small and the percentage of emitting material small also, there is no appreciable heat generation by irradiated lithium alloy and therefore no provision for heat removal is necessary.

G. General Container Design Standards

1. The box shape of the cask makes consideration as simple beam predictable and calculations in Appendix A.3 bear this out with a maximum fiber stress of 616 psi.
2. The casks have been shipped many times over a period of years and there are no known failures incident to shipment which could be attributed to vibration. The heavy walls of the cask when compared to the longest dimension are self-dampening for the range of vibration cycles normally experienced on railway shipment.
3. No means for applying a seal which would be destroyed by opening the cask is provided.
4. The cask is fabricated of stainless steel of thickness greater than the minimum specified by the Bureau of Explosives and is suitable to the service with no problems of decontamination.
5. No information is available concerning welds and brazing.
6. The exterior of the cask is generally suitable for decontamination.
7. The trunnions on this cask were not designed for tie-down and referral to Figures 1 and 2 will reveal that tie-downs have been a problem even for ordinary shipment. No evaluation of present tie-down with channel and angle iron in the car has been made, but it is doubtful that the casks would survive a credible accident without breaking loose. The general criteria of ICC regulations is that bearing pressure of a cask will be no more than 500 lbs. per square foot. This cask has a weight concentration of about 1387 lbs. per square foot.
8. Since previous evaluation disclosed that the cask would not meet the criteria, no evaluation was made of tie-down component strength.
9. Assuming a design stress of 40,000 psi, both the trunnions on the cover and on the cask would meet the safety factor requirement of 6 times the weight of the loaded cask. Note: the cover trunnions can be used only to lift the lid; since only two small bolts retain the cover to the cask.

10. As pointed out above, trunnions on the cover can be used only to lift the cover. These devices are not protected during shipment and would not meet the requirements of part 8 of the criteria.
11. The bucket spacers are screwed into the cover and do not end in a welded boss pad and loss of shielding material from the cover could result.
12. Equalizing pressure is not a problem as a normal cask unloading procedure.
13. Specifications for the pressure relief devices are not known, but are not equipped with filters. A filter would be of little benefit for the pressures generated would be pure gas, either helium or tritium, or both. No pressure would be generated except in case of fire and then only if severe enough to melt the can and product. There is no protection from shock.
14. Iodine is not a material under evaluation for this cask.
15. No primary coolant is involved, so this part of the criteria is not applicable.
16. Same evaluation as (15) above, as there are no valves.
17. Same evaluation as (15) above, as there is no coolant being used and no sampling or measurement equipment required.
18. Although damage to the relief valves could result, there would be no problem of radiation exposure in excess of the criteria requirements even if the valve were broken off.
19. There is a drain which meets the requirements and the pipe plug is thought to provide positive closure.
20. The piping installed in the shielding material is so designed that deformation of shielding material which might result during handling or shipment will not be damaging.

H. Possible Modification to MP Casks

Although several modifications to the machined parts casks could be made to protect it from impact and fire, it is not thought to be appropriate to consider modifications to casks belonging to another site; in this case, the machined parts casks are the property of the Savannah River Installation. The extra cover tie-down presently being provided by Hanford does provide extra protection in transit, but is of no value during cask transfer.

Glen E. Peck

Plant Design Unit
Design Engineering Subsection

GE Peck:dl

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REFERENCES

- (1) Peck, G.E., "Design Criteria for Evaluation of Off-Site Shipping Casks in Current Use by IPD," HW-76476, May 8, 1963.
- (2) Magner, R.T., "Design for Shock Resistance," Product Engineering, December 10, 1962.
- (3) Shappert, L.B., "Cask Test Program at ORNL," TID-7635, May, 1962.
- (4) Goldsmith, Werner, "Impact", Edward Arnold Ltd., Publishers, London, 1960.
- (5) Peck, G.E., "Evaluation of the B-Cask in Accordance with Proposed Regulations of the AEC and ICC for Off-Site Shipments of Irradiated Bismuth," HW-77338, July 12, 1963.
- (6) TID-7651, "Summary Report of AEC Symposium on Packaging and Regulatory Standards for Radioactive Materials," December 5, 1962.
- (7) Thorim, D.W., "Kinetics of Gas Extraction from Irradiated Li-Al Alloy," DP-743, December, 1962.
- (8) Maleev, V.L., "Machine Design," International Textbook Co., Rev. 1st Edition, 1946.

APPENDIX A
STRUCTURAL CALCULATIONS

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A.1 Impact

Approximate cover weight = 2,250 lbs. x 60 = 135,000 lbs.

Total cask weight = 10,500 lbs. x 15 = 157,500 lbs. Governing Cond.

Given: two 3/4" stainless steel bolts.

From Maleev (8), size factor $e_{ez} = 1 - 0.4 \left(1 - \frac{Se_3}{Se}\right)(h - 0.5)$

For $\frac{Se_3}{Se} = .85$, and $h = .75$

$$e_{ez} = 1 - 0.4 (1 - .85)(.75 - .5) = .985$$

Design stress, $Sd = \frac{Se \times .985}{n} = 25,600$ psi when $Se = 40,000$
 $n = 1.5$

Root area of bolt = .302 sq. in.

Safe loading of bolts = 25,600 x .302 x 2 = 15,462 lbs.

Requirement is 157,500 lbs. so bolts only one-fifth of necessary loading strength.

A.2 Puncture

30 x 10,500 = 345,000 lbs.

$As = 6 \pi \times .500 = 9.425$ sq. in.

$Ss = \frac{345,000}{9.425} = 36,605$ psi, only marginally safe

A.3 Cask as Simple Beam

$z = \frac{I}{c} = \frac{BH^3 - bh^3}{6H}$, when $B = 30.875$, $b = 29.875$, $H = 34.875$
and $h = 33.875$

$z = 708.43$

$M_{max} = \frac{W \times l}{8} (10) = \frac{10,500 \times 33.25 \times 10}{8} = 436,406.25$

$f = \text{max. fiber stress} = \frac{M}{z} = \frac{436,406.25}{708.43} = 616.02$ psi, safe stress

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