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Rover Shipping Cask

by

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ROVER SHIPPING CASK

by

Betty Lobb, Horace E. Noyes, and David R. Smith

ABSTRACT

A large well-shielded shipping container, commonly known as the Rover cask, has been designed to accommodate fuel elements from the Rover and TORY IIC reactors in compliance with existing regulatory requirements. Background material and approvals are given in the Appendixes.

INTRODUCTION

The shipping container is a steel-jacketed lead-filled cask weighing approximately 17.7 tonnes (39000 lb). Fuel from the Rover and TORY IIC reactors, currently stored at the Nevada Test Site of the Energy Research and Development Administration, will be shipped to the Idaho Chemical Processing Plant in the Rover cask within a cask insert designed by Group J-6 (LASL-NTS). The 1.37-m (54-in.)-long insert consists of a 5 by 5 square array of 76.2-mm (3-in.) o.d. by 0.508-mm (0.020-in.)-wall steel tubes in a welded aluminum box. The regions between the tubes are packed with boron carbide and are sealed at each end by a poured epoxy plug. The 25 steel tubes may be loaded with Rover fuel in cardboard tubes or TORY IIC fuel in welded aluminum tubes. These inner arrangements are for the convenience of the processing plant. The Rover fuel will go into an incinerator, whereas the TORY IIC fuel starts its reprocessing in a dissolver.

To demonstrate compliance with existing regulatory requirements, the background material and approvals are given in the Appendixes.

ROVER FUEL CASK DESIGN CRITERIA

The authorized packaging consists of a rectangular, lead-filled, steel-jacketed weldment, which conforms to DOT Specification 55, providing a 254 mm-

(10-in.) lead shielding thickness and a minimum of 9.52-mm (3/8-in.) steel-jacket thickness. The inner cavity dimensions are 406 by 406 mm by 1.57 m (16 by 16 by 62 in.) and the gross weight is approximately 17.7 tonnes (39000 lb).

The cask, identified as Model No. AL-L8, is described in Los Alamos Scientific Laboratory (LASL) Drawings ENG E-374 (Rev. F) R1, D2, and D3.

The allowable contents include Rover fuel elements and other fissile and radioactive materials in special form. When used for shipping more than 15 Rover fuel elements, all loaded elements will be in boron-poisoned cask inserts (Drawing 34Y43605 E2, LASL Drawing 530030, and insert Drawings 34Y-31474 D1-D7, or equivalent). Insert closures will use gaskets of silastic or other material of equivalent high-temperature capability. Fuel elements not in these cask inserts will be encapsulated to comply with special form criteria.

Fast reactor fuel pins may be packaged in an insert with a single length of 128-mm (5-in.)-diam. schedule 40 steel pipe with threaded or Silastic gasketed flanged closure. The total fissile material loading for this configuration will not exceed 75 g/cm of pipe length.

For shipping ^{233}U or plutonium bearing material, the atomic ratio of boron to ^{233}U or plutonium will be at least twice the ratio of boron to ^{235}U normally

provided for the loaded Rover fuel element cask inserts, which is a factor of 2 greater than calculated to provide a k_{∞} less than unity.

These considerations dictate a maximum of 60 kg of ^{235}U or 30 kg of ^{233}U or plutonium. Mixtures of fissile materials shall be so limited that the number of kilograms of ^{235}U divided by 60, plus the number of kilograms of plutonium and ^{233}U divided by 30, will not exceed unity.

The closure device includes holes for a security seal insertion in the lid channel and cask lid guide pins in each end. The security seals must be affixed before shipment.

To facilitate underwater loading, the cask is equipped with a drain line which is to be closed with a fusible plug.

STRUCTURAL ANALYSIS

The structural analysis of the shipping container is attached as Appendix A.

QUALITY ASSURANCE

Quality assurance specifications are attached as Appendix B.

RADIOLOGICAL SAFETY

Shielding calculations are attached as Appendix C.

THERMAL ANALYSIS

The thermal analysis is attached as Appendix D.

NUCLEAR CRITICALITY SAFETY ANALYSIS

The nuclear criticality safety analysis is attached as Appendix E.

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

The Certificate of Approval issued by the Operational Safety Division, Albuquerque Operations Office, ERDA, identified as USA/5645/BLF (ERDA-AL) is attached as Appendix F.

CONTAINER DRAWINGS

Isometric drawings of the cask and of several cask inserts are provided in Appendix G. These present needed information for prospective users of the cask. Structural and fabrication details may be obtained from the LASL Drawings ENG-E-374 (Rev. F), R1, D2, and D3 for the cask. LASL Drawings ENG-E-530030 R1, 31474 D1-D7 and 34Y-31474 E2 present fabrication information for cask inserts.

APPENDIX A

STRUCTURAL ANALYSIS OF THE ROVER SHIPPING CASK

Introduction

This appendix presents the structural analysis applicable to the Rover cask.

The analysis is to demonstrate compliance with Sec. II, Packaging Standards, of ERDAM 0529 Safety Standards for Packaging of Radioactive and Fissile Materials.

The analysis is numbered to correspond to Sec. II of 0529, and summarizes the mathematical analysis presented as an appendix.

STRUCTURAL ANALYSIS OF THE ROVER SHIPPING CASK

(Numbers refer to ERDAM 0529)

- II.A.1. The cask and cask insert materials have demonstrated compatibility through more than 10 yrs. of service. No significant chemical, galvanic, or other reactions have occurred or would be expected to occur.
- II.A.2. The cask lid is secured to the body in an extremely rugged fashion so that inadvertent opening is not possible. Also, double security seals provide positive indication that the cask has not been opened.
- II.A.3.a. The container which will be handled by forklift or by crane, weighs approximately 17.7 tonnes (39,000 lb).
- Design calculations indicate that the lifting devices can support three times the cask weight without exceeding the yield strength of the material (Sheets 12 and 13).
- II.A.3.b. Calculations on sheet 14 show that the lid lifting devices are adequate.
- II.A.3.c. Not applicable.
- II.A.3.d. Failure of the lifting device would in no way affect the containment or shielding properties of the package.
- II.A.4. This container has no built-in tie-down devices.
- II.B.1. Beam load resistance is more than adequate. (See calculations, Sheet 15)
- II.B.2. An external pressure of 175kPa is a trivial condition for this shipping cask.

- II.C. Criticality standards are discussed in Appendix E.
- II.D.1. See Appendix E.
- II.D.2. The package has been evaluated independent of the transport vehicle.
- II.D.3. No deviations from requirements are necessary.
- II.E. There will be no compromise of the integrity of the container or its contents as defined in Annex 1. Normal Conditions of Transport. Following is a summary of the findings of the calculations for the normal conditions of transport(Appendix, Annex 1):
1. HEAT: At 55° C, no part of the cask will in any way be affected.
 2. COLD: An ambient temperature of -40° C in still air and shade presents no problem to this container.
 3. PRESSURE: The seals used in this container are extreme pressure and temperature seals. Pressures of 1/2 atm. are completely insignificant in this application.
 4. VIBRATION: This shipping container is not susceptible to vibration damage.
 5. WATER SPRAY: The container seal will preclude entry of any moisture into the container.
 6. FREE DROP: A free drop of 1.22 m (4 ft) is much less than the accident condition requirements and will not compromise the integrity of the container.
 7. CORNER DROP: Not applicable.
 8. PENETRATION: This test is trivial for this package.
 9. COMPRESSION: Not applicable.

11.F. Calculations indicate the containment capabilities of this container would not be impaired when subjected to the accident conditions specified. There would be no release of radioactive material and no unacceptable changes in radiation dose rates external to the container.

Following is a summary of the hypothetical accident test condition calculations in lieu of actual test:

1. FREE DROP: The most damaging orientation of the cask for the 9.14 m (30-ft) drop test is assumed to be such that the cask impacts on a corner with the center of gravity directly above the point of impact.

The lid attachment has been modified as shown in the cask drawing Revision F so that the design has more than ample strength to retain the lid for any drop orientation. Calculations are shown on Sheets 17 through 29.

2. PUNCTURE: The analyses to simulate a test of dropping the cask on a 152.4 mm (6 in.) diam. rod from a height of 1.01 m (40 in.) indicates distortion but no failure of the steel jacket. The drop was assumed onto a flat side of the container (Sheets 6 through 11).
3. THERMAL: The thermal analysis, performed in 1968, is attached as Appendix D. This evaluation, coupled with configuration (3) of the Radiological Calculations (Appendix C), demonstrates that exposure to the standard fire will not compromise the shielding capability of the cask.
4. WATER IMMERSION: The radioactive contents would not be released as a result of water immersion; criticality safety evaluations have been based on assumed optimum moderation.

APPENDIX A
ANNEX 1

STRUCTURAL ANALYSIS

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Shipping Cask	DATE 11/1/67	SHEET No 1 of 20
DESCRIPTION DROP TEST	CALC BY / /	APPROVED BY

Shipping container:

Lead filled --See LASL Drawing ENG-E-374

Properties:

Lead:

$\tau_y = 4$ ksi (Static), yield stress
 $E = 2 \times 10^6$, modulus of elasticity

Steel:

$\sigma_y = 35$ ksi (Static)
Fult = 65 ksi (Static)
 $\xi = 30 \times 10^6$

Lead strength under impact loading subjected to high strain rate may be expressed as:

$$\dot{r} = \int_0^R \mu \frac{dr}{dt} + C \quad \text{where } C \text{ is a constant}$$

depending upon the static characteristics of lead and μ is the viscosity coefficient of a newtonian liquid. On previous tests using lead blocks as energy absorbers, GMX-3 has obtained dynamic resistances of lead up to 9 ksi. These cylindrical lead test specimens were free to deform laterally and subjected to drop heights comparable to the shipping container under consideration. These tests give evidence that one will have conservative results if the velocity term is dropped and with this possible error of 100% on the conservative side the calculations are made. The results are not to show the exact amount of deformation expected, rather they will show the maximum possible deformation due to the loading condition chosen.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Shipping Cask	DATE 12 - 1 - 73	SHEET No 2 of 20
DESCRIPTION DROP TEST	CALC BY J. L.	APPROVED BY J. L.

Test conditions:

1. 30 foot drop on unyielding surface striking:
 - A. Corner of Cask.
2. 40" drop on a 6" diameter spike.

1. A.

30 drop. - 360" cask wt. = 42,800# with lid.*

$$\text{Energy of Cask} = 360 \times 42,800\# = 15.4 \times 10^6 \text{ \#}$$

Neglecting the bulging effect will produce somewhat less contact area than one would actually get during a drop but with the steel jacket as confinement material the bulging is difficult to estimate.

*Calculations are based on a cask weight of 42,800#. This provides conservative results for the actual cask.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT
ENGINEERING CALCULATIONS

JOB	DATE	SHEET NO.
Rover Element Cask	2/1/67	3 of 20
DESCRIPTION	CALC BY	APPROVED BY

$\bar{e}_A$ = unit Vector in the direction of drop

$$\bar{e}_A = .381 i + .381 j + .842 k \text{ (See p. 5)}$$

$$\overrightarrow{OD} \cdot \bar{e}_A = 1, \quad OD = 2.62 i$$

$$\overrightarrow{OE} \cdot \bar{e}_A = 1, \quad OE = 1.18 k$$

$$\overrightarrow{OG} \cdot \bar{e}_A = 1, \quad OG = 2.62 j$$

$$\overrightarrow{GD} = \overrightarrow{OD} - \overrightarrow{OG} = 2.62 i - 2.62 j$$

$$\overrightarrow{GE} = \overrightarrow{OE} - \overrightarrow{OG} = 1.18 k - 2.62 j$$

$$\text{Area for unit } \bar{A} = \left| \overrightarrow{GD} \times \overrightarrow{GE} \right| / 2 =$$

$$A = 1/2 \begin{vmatrix} i & j & k \\ 2.62 & -2.62 & 0 \\ 0 & -2.62 & 1.18 \end{vmatrix} = 1/2 \sqrt{(9.56) + (9.56) + (47.12)} = 4.07$$

$$A(y) = 4.07 y^2 \text{ (Area is linear with } y^2 \text{ since } \overrightarrow{GD} \text{ \& } \overrightarrow{GE} \text{ are functions of } (y) \text{.)}$$

Then $|\overrightarrow{DE}| + |\overrightarrow{GE}| = 2$ lengths of side plate assumed to resist deformation of cask.

$$|\overrightarrow{DE}| = |\overrightarrow{GE}| = 2.87'' \text{ for unit } A.$$

$$L = 2(2.87)y = 5.74 y$$

$$\text{Energy absorbed by lead} = E_L = 4000 \int_0^{y_m} 4.07 y^2 dy = 5427 y_m^3$$

$$\text{Energy of side plates} = 60,000 (3/8) \int_0^{y_m} 5.74 y dy = 64,575 y_m^2$$

$$\text{Energy of angles} = 60,000 (5.72) \int_0^{y_m} 1.18 dy = 404,976 y_m$$

Area of $L_s = 5.72$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 7-1-73	SHEET No 4 of 20
DESCRIPTION DROP TEST	CALC. BY J. L. ...	APPROVED BY ...

$$E_{Total} = 404,976 y_m + 64.575 y_m^2 + 5427 y_m^3 = 360(42,800)$$

$$\text{then } y_m^3 + 11.90 y_m^2 + 74.62 y_m = 2839$$

solving for y_m one finds

$$y_m = 9.8" \quad , \quad d = \text{See Sheet 5} = 17.64"$$

One could expect some internal distortion of the inner liner due to this corner drop, this would be desirable for loss of shielding prevention but will cause high stresses in the inner jacket.

Due to the extremely large deformation of the outer jacket, cracks will probably develop at the weld joints. There is no calculation that will accurately predict this event and the crack development is purely an opinion of the author.

A drop on the top corner would cause the lid to become deformed and the container seal would probably be destroyed permitting water to enter the container.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE - 11/24/67	SHEET No 5 of 20
DESCRIPTION DROP TEST	CALC. BY E.C. RWT	APPROVED BY

$\vec{A}$ = Vector from 0, 0, 0
to 19, 19, 42

$$\vec{A} = 19 \mathbf{i} + 19 \mathbf{j} + 42 \mathbf{k}$$

$$A = 49.86"$$

$$\mathbf{e}_A = .381 \mathbf{i} + .381 \mathbf{j} + .842 \mathbf{k}$$

α from A to Z axis

$$\vec{e}_A \cdot \lambda = \cos \alpha = .842, \alpha = 32.5^\circ$$

$\vec{C}$ = Vector from pts. 1 to 2

0, 0, 0 to 11, 11, 11 (Assume 11" walls)

$$\vec{C} = 11 \mathbf{i} + 11 \mathbf{j} + 11 \mathbf{k}$$

d = projection of $\vec{C}$ upon $\vec{A}$ = distance along $\vec{A}$ from plane through 1
to plane through pt. 2

$$d = \vec{C} \cdot \mathbf{e}_A = \left\{ 11 \mathbf{i} + 11 \mathbf{j} + 11 \mathbf{k} \right\} \cdot \left\{ .381 \mathbf{i} + .381 \mathbf{j} + .842 \mathbf{k} \right\} = 17.54"$$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 10/12/67	SHEET No 6 of 20
DESCRIPTION DROP TEST	CALC. BY C. D. J. A.	APPROVED BY

Spike Drop @ 40"

Spike Properties

Dia. 6.0"
Area 28.3 in²
Circum. 18.8"

Shell Thickness = 3/8"

Potential Energy = 40 (42.8K) = 1712 in. K

Consider:

1. Radius of Curvature = ∞ , i.e., flat plate.
2. Steel plate acts as membrane (2 Dim)
3. Neglect Elastic Action

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ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 12/2/57	SHEET No 7 of 20
DESCRIPTION DROP TEST	CALC. BY D. J. ...	APPROVED BY

$$\sigma_y = 35 \text{ Ksi (Steel)}$$

$$\sigma_y = 2.5 \text{ Ksi (Lead)}$$

$$\Delta = R - R \cos \theta = R(1 - \cos \theta)$$

$$T = 35K(3/8) = 13.1$$

where

T = membrane force

From $\Sigma F_x = 0$

$$T \sin \theta = 2.5 R \sin \theta; \quad R = \frac{13.1}{2.5} = 5.24"$$

Since the material is not flexible the radius will increase slightly, use the conservative value of 5.24.

Energy absorption is a function of the lead, plate & Δ .

(1) Plate

$$E p l = f \{ (13.1 \sin \theta) \Delta \}, \quad \text{where } \theta = f(\Delta)$$

$$= \int_0^{\Delta} F(\Delta) d\Delta; \quad F(\Delta) = T \sin \theta, \quad \Delta = R(1 - \cos \theta)$$

$$\frac{\Delta}{R} - 1 = -\cos \theta, \quad \cos \theta = (1 - \frac{\Delta}{R})$$

$$= (1 - \frac{\Delta}{5.24})$$

$$\theta_f = \cos^{-1} (1 - \frac{\Delta}{5.24})$$

$$F(\Delta) = T \sin \left[\cos^{-1} \left(1 - \frac{\Delta}{5.24} \right) \right]$$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 12/15/67	SHEET No 8 of 20
DESCRIPTION DROP TEST	CALC. BY E. O. H. L.	APPROVED BY

$$\text{or } E_{pL} = \int_0^{\Delta} T \sin \theta d\Delta, \quad \Delta = R(1 - \cos \theta), \quad d\Delta = R \sin \theta d\theta$$

$$E_{pL} = \int_0^{\theta} T \sin \theta R \sin \theta d\theta = \int_0^{\theta} RT \sin^2 \theta d\theta$$

Where $T = 13.1 (18.8) = 246$, $R = 5.24$ & $RT = 1290$

$$\begin{aligned} E_{pL} &= 1290 \int_0^{\theta} \sin^2 \theta d\theta = 1290 \left(\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right) \\ &= 1290 \left[\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right]_0^{\theta} = 1290 \left(\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right) \end{aligned}$$

Then $\theta = \cos^{-1} \left(1 - \frac{\Delta}{R} \right), \cos^{-1} \left(1 - \frac{\Delta}{5.24} \right)$

(2) Lead

$E_{\text{Lead}} = 28.5(2.5) \Delta = 70.7 \Delta$

$$1712 = 70.7\Delta + 1290 \left[\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right] \quad \left(E_{\text{Potential}} = E_{\text{Lead}} + E_{\text{Plate}} \right)$$

Try $\Delta = 5.2$

$$\theta = \cos^{-1} \left(1 - \frac{5.2}{5.24} \right) = \cos^{-1} (.0076)$$

$$\theta = 89.55^\circ$$

$$\frac{\theta}{2} = \frac{1.668}{2} = .834$$

$$\frac{\sin 2\theta}{4} = \frac{\sin 179.1}{4} = .00393$$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 12/15/67	SHEET No 9 of 20
DESCRIPTION DROP TEST	CALC. BY C. C. R. W. A.	APPROVED BY

$$1712 = 376.6 + 1290 (.834 - .00393)$$

$$1712 \neq 1447.4$$

Since θ approaches 90° and the equation is not satisfied, it appears the spike will puncture the cask.

At this point elongation is:

$$R \sin \theta = 5.24 \sin 89.55^\circ = 5.23$$

$$R\theta = 5.24 \left(\frac{89.55}{57.3} \right) = 5.17$$

$$\% \text{ Elongation} = 100 \left(\frac{8.17 - 5.23}{5.23} \right) = 100 \left(\frac{2.94}{5.23} \right) = 56.28$$

The steel shell will yield before the 90° Δ is attained.

Find Δ @ allowable 30% elongation.

$$5.24(1.3) = 6.81"$$

$$\text{Circ.}/4 = 8.23"$$

$$\frac{6.81}{8.23}(30) = \theta = 74.4^\circ$$

$$\Delta = R(1 - \cos \theta) = 5.24(1 - .269)$$

$$= 5.24(.731)$$

$$\Delta = 3.83"$$

Assume the distance of yielding occurs for only 1 R from the spike. The steel plate fails at 3.83" of puncture and the lead must absorb the remaining energy.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 12/10/67	SHEET No 10 of 20
DESCRIPTION DROP TEST	CALC. BY G.O. K. J. M.	APPROVED BY

Since puncture occurs recalculate R and the corrected Δ for the ultimate strength of steel 60 ksi.

$$\therefore T = 60 K(3/8) = 22.5K$$

&

$$R = \frac{T}{2.5} = \frac{22.5}{2.5} = 9.00" \quad (\Sigma F_x = 0, \text{ See page 7})$$

Yield will occur @ $\theta = 74.4^\circ$

& again assume all yielding will occur within 1R of spike.

So find E pL absorbed for 74.4° if that is less than 1712 the steel plate fails and the rest of the energy is absorbed by the lead.

$$E pL = \int_0^{\theta} RT \sin^2 \theta d\theta \quad (\text{See page 8})$$

$$\text{where } T = 22.5 (18.8) = 423K$$

$$RT = 9(423) = 3807$$

$$\begin{aligned}
 E pL &= 3807 \left[\frac{\theta}{2} - \frac{\sin^2 \theta}{4} \right]_{\theta=74.4^\circ} \\
 &= 3807 \left(\frac{74.4}{57.3} - \frac{\sin^2 148.8}{4} \right) \\
 &= 3807 (.652 - .130)
 \end{aligned}$$

$$E pL = 3807 (.522) = 1987 \text{ in.K Steel plate will not fail at ultimate of 60 ksi}$$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 12/12/67	SHEET No 11 of 20
DESCRIPTION DROP TEST	CALC. BY <div style="text-align: center;"> </div>	APPROVED BY <div style="text-align: center;"> </div>

So now set $E_{pL} = 1712$ & solve for new θ & Δ .

$$1712 = 3807 \left[\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right]$$

where,

$$\theta = \cos^{-1} \left(1 - \frac{\Delta}{9} \right)$$

$$\& E_{Lead} = 28.3(4)\Delta = 113.2\Delta$$

$$\therefore 1712 = 113.2\Delta + 3807 \left[\frac{\theta}{2} - \frac{\sin 2\theta}{4} \right]$$

Try $\Delta = 4.5$ "

$$\theta = \cos^{-1} \left(1 - \frac{4.5}{9} \right) = \cos^{-1}(.5) = 60^\circ$$

$$\frac{\theta}{2} = \frac{60}{2} = \frac{57.3}{2} = \frac{1.047}{2} = .523$$

$$\frac{\sin 2\theta}{4} = \frac{\sin 120^\circ}{4} = \frac{.866}{4} = .217$$

$$1712 = 113.2(4.5) + 3807(.523 - .217)$$

$$= 510.7 + 1164.9$$

$$1712 \approx 1675.6$$

$$\therefore \theta = 60^\circ \& \Delta = 4.5"$$

$$R \sin \theta = 9.00(\sin 60^\circ) = 7.79$$

$$R\theta = 9.00 \left(\frac{60}{57.3} \right) = 9.42$$

$$\% \text{ Elongation} = 100 \left(\frac{9.42 - 7.79}{7.79} \right) = 100 \left(\frac{1.63}{7.79} \right)$$

$$= 20.9\%$$

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Shipping Cask	DATE 12-1-67	SHEET No 12 of 20
DESCRIPTION LIFTING DEVICES	CALC BY L. J. ...	APPROVED BY ...

. Art II Section 3 a. AEC Appendix 0529

Package lifting devices must withstand 3 x wt. without yielding.

Wt = 42000#

Test ult = TW = 126 kips

4 lugs are provided ~ assume vertical component of force = $126/4 = 31.5^k$
each lug. Loads perpendicular to this direction will depend upon the
sling or other device used.

Net Area @ Section A-A
 $A_{AA} = (4-2) 1.25 = 2.5 \text{ in}^2$

$$\sigma = \frac{31.5}{2.5} = 12.6 \text{ Ksi (tension) ok}$$

Net Section at eye

Next assume the $4 \times \frac{1}{2}$ PL carries all load:

$$\sigma = \frac{31.5}{2} = 15.75 \text{ Ksi ok}$$

Note that this is not likely to happen
~ however the lift device is still sound.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Cask	DATE 1-27-67	SHEET No 13 of 20
DESCRIPTION LIFTING DEVICE	CALC. BY E. J. J. R. L.	APPROVED BY

Assume a single lift point cable sling is used to lift the cask, whose individual lengths are 11.5 feet (This is a description at the actual system used) then loads produced on the lifting lugs are as follows:

$$Z' = \sqrt{(133)^2 - (19)^2 - (38)^2} = 131.2''$$

$$\cos \theta_x = .275$$

$$\cos \theta_y = .138$$

$$\cos \theta_z = .949$$

$$F_z = 31.5K$$

$$F_y = 4.58K$$

$$F_x = 9.13K$$

$$M_z = 0$$

$$M_x = 3 F_y = 13.74''K$$

$$M_y = 3 F_x = 27.39$$

Base properties

$$\text{Area} = 4.0(1.25) = 5.0 \text{ in.}^2$$

$$I_x = \frac{1}{12} (4)(1.25)^3 = .651 \text{ in.}^4$$

$$I_y = \frac{1}{12} (1.25)(4)^3 = 6.67 \text{ in.}^4$$

$$\sigma \text{ max normal} = \frac{31.5}{5} + \frac{27.39(2)}{6.67} + \frac{13.74(.625)}{.651} = 27.7 \text{ Ksi}$$

$$\text{Shear} = 1.5 \frac{P}{A} = 1.5(9.13)/5 = 2.74 \text{ Ksi and } 1.37 \text{ Ksi}$$

With the above sling arrangement stresses less than yield result with 3xWt applied.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB Rover Fuel Element Shipping Cask	DATE 12/12/67	SHEET No 14 of 20
DESCRIPTION LIFTING DEVICE FOR LID	CALC BY C. D. KLM	APPROVED BY

By standard rigging practice the lid lifting device could not be used to lift the entire cask, therefore, one may check stresses produced by the factored weight of the lid only.

Stresses developed when lifting the lid are as follows:

Weld attaching the 6I 12.5 beam to the lid

$$\sigma = \frac{6000(3)}{2L} = \frac{6000(3)}{2(67)} = 134 \text{ pounds/linear inch.}$$

A minimum size weld will carry this load.

No other stresses need be considered since the member is attached along its entire length; and by observation one may approve the bearing stresses developed on the surface at the lifting holes.

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB	DATE	SHEET No
Rover Fuel Element Shipping Cask	12/12/67	15 of 20
DESCRIPTION	CALC BY	APPROVED BY
BEAM ACTION TEST		

$$M_{max} = \frac{210(34)}{8} = 2205 \text{ k}$$

or

$$2205 \times 10^3$$

Consider only steel jacket - and neglect the lid as effective in resisting bending.

Sketch Showing Effective Bending

Element	Area (A)	Centroid z	Ay	Ay ²	I _o
1	40.4	0.38	15.4	5.8	Neglected
2	11.4	2.80	31.9	89.4	
3	20.2	19.1	386.	7370.	
4	11.4	35.4	404.	14300.	
5	1.12	38.0	42.5	1620.	
6	7.50	32.9	247.	8120.	
$\Sigma A = 92.2$			$\Sigma Ay = 1130$	$\Sigma Ay^2 = 31500$	

LOS ALAMOS SCIENTIFIC LABORATORY - ENGINEERING DEPT.
ENGINEERING CALCULATIONS

JOB	DATE	SHEET No
Rover Fuel Element Shipping Cask	12/12/67	16 of 20
DESCRIPTION	CALC. BY	APPROVED BY
BEAM ACTION TEST		

$$\bar{z} = \frac{\sum Ay}{\sum A} = \frac{1130}{92.2} = 12.2 \text{ (in.)}$$

$$I_{NA} = \sum Ay^2 - \sum A (\bar{z})^2 = 17800 \text{ (in.}^4\text{)}$$

Extreme Fiber Stress

$$\sigma_{\max} = \frac{Mc}{I} = \frac{2205 (38.25 - 12.2)}{17800} = 3220 \text{ (psi)}$$

Conclusion

The strength of the steel jacket alone is more than adequate. A $\sigma_{\max}$ of 3220 shows a M.S. (margin of safety) of ~10 based on a σ_y (yield stress) of 35,000 psi.

FREE DROP CONDITION

30 Ft. Drop to Unyielding Surface

ASSUMPTIONS

- Loss of lid is critical
- Maximum acceleration forcing lid to come off occurs when the longer edge strikes at 45° .
- All energy absorption is due to plastic deformation of the lead

NOTE: 24 bolts hold lid in place:
 4(A307) - $3/4"$ bolts each along the longer edges of the lid in the existing bolt pattern and 8(A307) - $1"$ bolts each along the longer edges of the cask.

VIEW AENERGY IN DEFORMED LEAD

$$E_L = \sigma_Y \cdot dV$$

$$\sigma_Y = 4000 \text{ lb/in}^2 \text{ (Yield Strength)}$$

V = Deformed Volume

$$V = (Y_m^2 + 8 Y_m)L \quad (L = \text{Length})$$

EQUATING DROP ENERGY TO ENERGY OF DEFORMED LEAD

$$(Y_m^2 + 8 Y_m) 84 \text{ in.} \cdot 4000 \text{ lb/in}^2 = 42800 \text{ lb.} \cdot 30 \text{ ft} \times 12 \text{ in/ft}$$

$$336 Y_m^2 + 2688 Y_m - 15408 = 0$$

$$Y_m^2 + 8 Y_m - 45.857 = 0$$

$$Y_m = \frac{-8 \pm \sqrt{64 + 183.428}}{2}$$

$$Y_m = \frac{-8 \pm 15.729}{2} = 3.864 \text{ in.}$$

$$A_{\max} = (15.729) (84) = 1321.2 \text{ in}^2$$

where, A = Area

$$a_{\max} = \frac{F}{M} = \frac{\sigma_y A_{\max}}{M} = \frac{400 \text{ lb/in}^2 \cdot 1321.2 \text{ in}^2}{\frac{42800 \text{ lb}}{32.2 \text{ f/s}^2}}$$

where,

a = acceleration

m = mass and F = force

$$a_{cg} = 3976 \text{ f/s}^2$$

$$R = M \cdot a$$

where,

R = Lid Component of Force

$$R = \frac{W_{\text{Lid}}}{32.2} (3976 \cos 45^\circ) = \frac{6000 (2811)}{32.2}$$

$$R = 524000 \text{ lb}$$

$$F/\text{Bolt} = \frac{524000}{16} = 32750 \text{ LB (Using 1 inch bolts only)}$$

ASSUME LID PIVOTS ABOUT ONE EDGE

$$\Sigma M_o = 0; 6000 \left(\frac{35}{2} \right) (.707) + (524000) \left(\frac{35}{2} \right) = F(35)$$

$$F = 264000$$

$$F/\text{Bolt} = 33000 \text{ LB}$$

Conclusion:

Because the minimum strength of a 1" A307 bolt is 33350 lbs and the maximum calculated bolt load resulting from the 30 foot drop condition is 32750 lbs, the 1" bolt pattern furnishes ample strength to keep the lid on.

QUALITY ASSURANCE PROGRAM PLAN

21-Ton Rover Fuel Cask

This Quality Assurance Program Plan has been prepared and complies with the applicable sections of LASL Quality Assurance Manual for Engineering and Construction, LA-5220-M, for a Type I consequence-of-failure, and is in compliance with the U. S. Code of Federal Regulations, Title 10, Part 71, Appendix E, "Quality Assurance."

The following program shall serve as a minimum requirement:

1. Design Control: A Project Engineer shall be designated for overall design control of the project. He shall prepare the design criteria for use by the designers. This design control shall include provisions for the following:
 - (a) Provisions for applicable codes and standards.
 - (b) Establishment of qualitative and quantitative acceptance criteria.
 - (c) Control of Engineering issued documents.
 - (d) Provisions for design verification by independent groups or individuals. (The Project Engineer can assign this function to the Design Review Board at his option.)
 - (e) To document this design control, a log of each applicable item shall be maintained by the Project Engineer. As a minimum, logs shall be used for the following items:
 - (1) Design Criteria (ENG-6)
 - (2) Design calculations (ENG-6)
 - (3) Construction or fabrication drawings (ENG-3)
 - (4) Special processes or work procedures (ENG-6)

As each revision is made, the corresponding log shall be updated. The log shall be transmitted along with each revision. The Project Engineer shall maintain a distribution list for each controlled item

and each transmittal shall require receipt acknowledgement of the item and the disposition of the superseded document from the recipient. All revisions or changes shall be handled in a manner commensurate with the original design control.

2. Document Control: Documents other than those controlled directly by the Project Engineer shall be controlled by a designated document controller (ENG-3), in a manner identical to those employed by the Project Engineer.

Document Control shall be applied to the following items:

- (a) Procurement documents
- (b) Work procedures prepared by groups other than the Project Engineer.

No document may be issued for use on the project until it has received the written approval of the Project Engineer.

3. Procurement: No procurement documents shall be released for purchasing without the written approval of the Project Engineer. Each document shall contain the following minimum information.

- (a) Industrial standards to be met
- (b) Special requirements, if needed, for handling, packaging, etc.
- (c) Shop drawings and other descriptive submittals
- (d) Catalogue information
- (e) Instructions for receiving inspection
- (f) Control of nonconforming items.

The procurement document shall state if the sub-tier contractors shall have their own Quality Assurance Program. Such programs shall be approved by the Project Engineer and the LASL Quality Assurance Head prior to any orders being placed.

4. Fabrication: Fabrication shall be accomplished utilizing written procedures approved by the Project Engineer as follows:

- (a) Welding procedure specifications

- (b) NNE procedures including acceptance criteria
- (c) NNE personnel qualifications (qualifications to become part of the job records)
- (d) Inspection, including dimensional verifications, visual weld inspectors and other items required by the specifications
- (e) Acceptance testing such as performance testing.

5. **Control of Nonconforming Items:** Controls shall be established to ensure that no nonconforming material, item or service, is incorporated into or used on the project. It is the responsibility of each individual on the project to notify the Inspector, Project Engineer, or Quality Assurance Engineer, of any nonconformance detected. The Quality Assurance Head is to be notified in writing of any significant nonconformance within 24 hours of its detection. Significant nonconformances shall receive a documented technical review. This review shall utilize a Quality Assurance Review Board.

Nonconforming items shall be placed in a marked segregated area or marked (tags, etc.) in such a fashion as to prevent inadvertent use pending disposition.

A log of written nonconformances (NCR's) shall be maintained, with their ultimate disposition recorded, in the Project Engineer's files. All reports are to receive sequential numbers for control purposes.

6. **Selection of Review Board Members:** The selection of the various review board members is the responsibility of the LASL Quality Assurance Head. For this project, this responsibility is delegated to the Project Engineer. A list of key personnel, and members for the various review boards is to be included as an attachment to the Quality Assurance Program.

7. **Records:** Sufficient documents shall be maintained to demonstrate that all quality activities have been performed in accordance with the plans and specifications and the project Quality Assurance Program. Records shall be stored in a moisture proof, fire protected environment.

The following documents are to be stored:

- (a) Design Criteria (ENG-7)
- (b) Design calculations (ENG-7)
- (c) Fabrication and construction drawing (one copy of each revision issued) (ENG-3)
- (d) Procurement documents (one copy of each revision issued) (ENG-6)
- (e) Document control logs (ENG-6)
- (f) Written procedures and instructions (ENG-6)
- (g) Personnel qualification records (SD-DO)
- (h) Nonconformance Reports (ENG-7)
- (i) As-built drawings (ENG-6)
- (j) Material Test Reports and Certificates of Compliance (SP-DO)
- (k) Records of any review board actions (ENG-7).

<p>Los Alamos Scientific Laboratory of the University of California</p>	LA-5220-M ENGINEERING & CONSTRUCTION QUALITY ASSURANCE PROGRAM	NO. 00002																														
		DATE 9-19-74																														
Quality Assurance Project Organization		SUPERSEDED																														
APPROVED <i>Richard W. Andrae</i> Project Engineer, Design																																
CMB-14 21-Ton Rover Fuel Cask (DOT SP 5645) L. J. 5216-0		PAGE <u>1</u> OF <u>1</u>																														
<p style="text-align: center;">Key Personnel</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Operating Manager:</td> <td style="width: 50%;">John W. Schulte, CMB-14</td> </tr> <tr> <td>Project Engineer, Design:</td> <td>Richard W. Andrae, ENG-7</td> </tr> <tr> <td>Project Engineer, Fabrication:</td> <td>John W. McMullen, ENG-6</td> </tr> </table> <p style="text-align: center;">Design Review Board</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 33%;">David R. Smith.</td> <td style="width: 33%;">P-5</td> <td style="width: 33%;">Criticality</td> </tr> <tr> <td>Carl Buckland,</td> <td>H-1</td> <td>Health Physics</td> </tr> <tr> <td>John W. Schulte</td> <td>CMB-14</td> <td>Radiation Shielding</td> </tr> <tr> <td>Betty Lobb</td> <td>SP-DO</td> <td>Shipping</td> </tr> <tr> <td>J. Bennie Montoya</td> <td>ENG-3</td> <td>Records Management</td> </tr> <tr> <td>John W. McMullen</td> <td>ENG-6</td> <td>Fabrication</td> </tr> <tr> <td>Richard W. Andrae</td> <td>ENG-7</td> <td>Structural</td> </tr> <tr> <td>William E. Stocum</td> <td>H-7</td> <td>Industrial Hygiene</td> </tr> </table>			Operating Manager:	John W. Schulte, CMB-14	Project Engineer, Design:	Richard W. Andrae, ENG-7	Project Engineer, Fabrication:	John W. McMullen, ENG-6	David R. Smith.	P-5	Criticality	Carl Buckland,	H-1	Health Physics	John W. Schulte	CMB-14	Radiation Shielding	Betty Lobb	SP-DO	Shipping	J. Bennie Montoya	ENG-3	Records Management	John W. McMullen	ENG-6	Fabrication	Richard W. Andrae	ENG-7	Structural	William E. Stocum	H-7	Industrial Hygiene
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Form ENG-01-07 (Rev. 8-74)

APPENDIX C

RADIOLOGICAL SAFETY

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO 87544
TELEPHONE:

OFFICE MEMORANDUM

TO : D. R. Smith, N-2

DATE: March 8, 1968

FROM : R. E. Malenfant, N-2

SUBJECT: Shielding Calculations for a 200-Element Shipping Cask

SYMBOL: N-2-8173

A series of calculations has been made to evaluate the shielding provided by a 200-element shipping cask. Of the criteria indicated, the value which limits the loading is the dose rate three feet from the lateral surface of the undamaged cask.

The geometry for the base calculation is indicated on Fig. 1. Table I gives the material densities associated with the various regions. Densities inside the cask insert are intended to be representative of 200 Phoebus-type fuel elements in a matrix of borated phenolic. All elements were considered to have the same activity with a distribution function along the length similar to the power density distribution during operation. The point-kernel program QAD (LA-3573) was used for the calculation.

Gamma-ray source strengths were taken from data to be published by Peterson, Graves, and Seale as LA-2902. The particular spectrum employed is characteristic of 1×10^6 sec (11.6 days) after shutdown from a 3600 sec (1 hr) reactor run. The results would not be significantly affected by the particular choice of exposure and decay time however.

Table I

Material Densities for Shipping Cask
(g/cm³)

Iden. #	Material				
	Hydrogen	Carbon	Iron	Uranium	Lead
1	.076	1.27	.077	.000	--
2	.10	.90	--	--	--
3	--	--	8.0	--	--
4	--	--	--	--	11.5

Fig. 1

Configuration of undamaged Cask

TO: N-2-8173

-3-

DATE: March 8, 1968

Three configurations of the cask were considered:

- 1) the intact cask as indicated on Fig. 1,
- 2) the cask with 1/2 inch of lead removed,
- 3) the cask deformed by a plane perpendicular to a line from the cask center to an exterior corner such that the minimum thickness of lead remaining was 7.3 inches.

For configuration 1, the cask loadings to give 200 mr/hr in contact with the lateral and end surfaces and 10 mr/hr three feet from the lateral and end surfaces were determined. Loadings to yield 1 r/hr three feet from the lateral and end surface were determined for the second configuration. For the third, the loading to give 1 r/hr three feet from the deformed surface was calculated. Results are given in Table II. The limiting value for the cask is seen to be 1.1×10^3 watts or 1.9×10^5 curies, a value which gives 10 mr/hr three feet from the lateral surface.

As a check on the technique, values derived solely from calculation (as above) were compared with measurements. On April 10, 1967, 189 elements from the Phoebus 1B run were shipped from NTS. According to Richard Davis, J-8, the monitor reported < 1 mr/hr at three feet and ~ 2 mr/hr in contact with the cask. Data from the decay calculations reference 1 indicate a source strength of 27.55 watts (~ 4684 curies). The calculated results were 0.3 mr/hr at three feet and 1.3 mr/hr in contact. Considering that the total attenuation of the cask is greater than 10^5 , the agreement is quite good.

The values given in Table II are specific to the cask and cask insert considered. As self-shielding was taken into account (and it must, to be correct) an un-self-shielded source of 1.9×10^5 curies of Co^{60} would probably give a dose rate higher, perhaps by a factor of 5-10, than 10 mr/hr three feet from the surface of the cask.

I would be happy to elaborate on additional details of the calculations if you consider it necessary.

REM:jf

- c: D. R. Smith, N-2 (3 copies)
J. D. Orloff, N-2
G. A. Graves, N-2
R. E. Malenfant file (6 copies)

TO: N-2-8173

-4-

DATE: March 8, 1968

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

Table II

Source Strengths in Watts and *Curies to Provide Dose Rates as Indicated

Config- uration	Contact with Lateral Surface		Three Feet from Lateral Surface		Contact with End Surface		Three Feet from End Surface		Three Feet from Deformed Surface	
	<u>y watts</u>	<u>curies</u>	<u>y watts</u>	<u>curies</u>	<u>y watts</u>	<u>curies</u>	<u>y watts</u>	<u>curies</u>	<u>y watts</u>	<u>curies</u>
1	8.2×10^3	1.59×10^6	1.1×10^3	1.9×10^5	3.3×10^4	5.7×10^6	7.5×10^3	1.3×10^6	--	--
2	--	--	5.5×10^3	9.4×10^5	--	--	3.8×10^4	6.5×10^6	--	--
3	--	--	--	--	--	--	--	--	1.1×10^6	1.2×10^8

*The conversion from watts of γ activity to curies was made on the basis of an average energy per disintegration of 1 MeV.

THERMAL ANALYSIS

LOS ALAMOS, NEW MEXICO 87544
TELEPHONE

OFFICE MEMORANDUM

TO J. C. Rowley, N-7

DATE: February 16, 1968

FROM W. L. Sibbitt, N-7

SUBJECT: PREDICTION OF PERFORMANCE OF CASKET IN "FIRE QUALIFICATION TEST"
(Analysis requested by Dave Smith, N-2)

SYMBOL: N-7

Conclusions:

If the molten lead is contained in place the melting will progress about 1/2 inch on the large plane sides and nearly 6 inches on the corner diagonals. If the molten lead leaks out to form a small gap between the steel plate and the main body of the lead, then less than 1/10 of this quantity will be melted. Of course this assumes that the 3/4 inch exterior steel plate remains between the heat source and lead.

Qualification Test

The casket is exposed to a flame (heat source) with an equivalent temperature of 1475°F and an effective emissivity of 0.9 for 1/2 hour.

Given:

1. The casket is as follows
 - a. Exterior - 83-1/2" x 38-1/4" x 38-1/4"
 - b. Interior cavity - 16" x 16" x 62"
(Exterior steel plate 3/4" thick, 10" of lead, cavity liner of 3/8" steel plate)
 - c. Emissivity of exterior surface is 0.8.
 - d. Cavity is empty
 - e. Initial uniform temperature of 120°F
2. Heat source
 - a. Effective temperature 1475°F
 - b. Effective emissivity $\epsilon = 0.9$
 - c. Completely surrounds the casket

To Prove

That the efficacy of the casket has not been seriously impaired at the end of the test. (Apparently this would mean that an appreciable portion of the lead must remain in place.)

Assumptions:

1. The "effective" heat source allows for all exterior heat losses from the casket. The view factor from the source to the sink is unity. Therefore the net heat radiated to the casket raises the temperature of the material or melts the lead, i.e., no heat is lost by convection or conduction to the surroundings.
2. The contact between the steel and the lead is perfect, i.e., it does not introduce an additional resistance to heat flow.
3. When the lead melts it remains within the casket and sets up convection currents such as to form a perfect heat conductor (actually the conductivity of liquid lead is about $1/2$ that of solid lead). All solid surfaces in contact with the melt remain clean. (This means that the maximum amount of lead will be melted.)

If the molten lead leaks out and leaves a small gap between the solid lead and the steel plate then the rate of heat flow will decrease to about 10% of the original value. However the $3/4$ " exterior steel plate will be at a much higher temperature level ~ about 1420°F.

Discussion of Heat Flow Phenomena

The heat flow can be considered as approximating three different cases:

Case 1 - One Dimensional Transient Heat Flow

This case is approximated at the center of the large plane sides. After 27 minutes from the start of the test the lead starts to melt. After 30 minutes the maximum amount of lead which could be melted is 1.28 inches the amount which actually would melt is about 0.5 inch. Thus a maximum of 12.8% of the lead could melt but probably only 5% would melt (the melt must remain in contact with the solid surfaces).

Case 2 - Two Dimensional Transient Heat Flow

This case is approximated by the edges (far removed from the corners). In this case the lead starts to melt in 23.9 minutes and after 30 minutes about 40% of the lead is molten. In terms of an analogous slab this amounts to about 2 inches of molten lead. Actually a little more lead would melt on the bottom edges than on the top edges.

Case 3 - Three Dimensional Transient Heat Flow

This case is approximated in the eight corners. In 18.3 minutes the lead will start to melt. In 30 minutes the melt will have progressed about 5.84 inches along the corner diagonal.

Case 4 - Lead Exposed Directly to the Heat Source

If the 3/4" exterior steel plate were removed such as to expose the lead directly to the heat source the times required to reach the melting point of the lead would be about the same as previously computed. Since the lead surface would probably be dirty with an emissivity of about 0.65 (this corresponds to a heavily oxidized surface).

As soon as the lead melts and the molten lead runs down the emissivity of the surface decreases to about 0.06 thus the heat flux would decrease to 9.24% of the initial value. If we assume no heat loss to the interior of the casket (maximum melting rate) then this corresponds to less than 2 inches per hour.

Summary:

This analysis was based on estimating the maximum amount of lead which could be melted. If some of the melt leaks out then the rate of heat flow to the massive solid lead will be drastically reduced.

The white paint on the casket has a reflectivity of about 5% for the long wave lengths corresponding to the 1475°F source. Aluminum paint has a reflectivity of 70% in this same wave length region. In addition aluminum paints with silicone base are touted for temperatures up to 1200°F.

W. L. Sibbitt

WLS:db

Distribution:

Case 1 Plane Wall

Case 2. Edge Section

NUCLEAR CRITICALITY SAFETY ANALYSIS

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO 87544

OFFICE MEMORANDUM

TO : H. E. Noyes, SP-DO

DATE: September 17, 1974

FROM : D. R. Smith, P-5

SUBJECT : Nuclear Safety - Shipping Configuration for Rover and
Tory IIC Irradiated Fuel

SYMBOL : P-5-447

Fuel from the Rover and Tory IIC reactors, currently stored at Jackass Flats, Nevada, is to be shipped to the Idaho Chemical Processing Plant in the LASL Rover casks which were granted DOT Special Permit 5645. The proposed shipping configurations have been evaluated using the DTF 71 transport code and the KENO Monte Carlo code. Results demonstrate that these configurations comply with Fissile Class I criteria.

Fuel is to be shipped in a Cask Insert Box which has been designed by Avery Bond, J-6 (NTF), and is shown on his drawings 31474D1 through D7. The 54" long insert consists of a 5x5 square array of 3" o.d. x 0.020" wall steel tubes in a welded aluminum box. The regions between the tubes are packed with boron carbide and sealed at each end by a poured epoxy plug. The twenty-five steel tubes may be loaded with Rover fuel in cardboard tubes or Tory IIC fuel in welded aluminum tubes. These inner arrangements are both for the convenience of the processing plant; the Rover fuel will go into an incinerator while the Tory IIC fuel starts its reprocessing in a dissolver.

The 2.5" o.d. cardboard tubes may contain up to seven Rover fuel elements. For purposes of this criticality safety evaluation it was assumed that the tubes were flooded with water, and the fuel and water were homogenized. All fuel was assumed to contain 800 kg/M³ of enriched uranium. The entire cask was defined in a KENO problem, with the boron carbide assumed to be at half theoretical density. Using 16 group Hansen-Roach cross sections, this problem was run for seventeen batches of 300 neutrons each. Neglecting the first three batches, the resulting value of k_{eff} was found to be 0.166 ± 0.002 .

A second configuration was investigated in a similar manner. Here the fuel was homogenized only with the water that would occupy the holes in the elements, and the remainder of the water within the tube served as an annular reflector region around the fuel zone. Sufficient batches were processed for this configuration to demonstrate that it was less reactive than the first.

TO: H. E. Noyes

2.

DATE: September 17, 1971

In the absence of water moderator some fifteen hundred Rover fuel elements would be needed to achieve criticality. Since the insert box has provision for only 175 elements, the unmoderated cask would be far subcritical even without the boron carbide.

The aluminum tubes for the Tory IIC are as yet undesignated, so Tory fuel was assumed to fill the 3" steel tubes of the insert box. Whatever size aluminum tube is chosen will result in a less reactive configuration than that which was calculated. The steel tube was surrounded with an appropriate volume of boron carbide, again at half density. The outer boundary of the boron carbide was specified as a reflecting surface, so that the DTF cell calculation would provide a value of the multiplication factor indicative of an infinite array. The 34 approximation was used, again with 16 group Hansen-Roach cross sections. While the Tory fuel has UO_2 loadings from about 1.25% to 8.12%, all fuel was assumed to have the higher loading. The maximum volume fraction occupied by fuel was assumed to be 0.5, and full and partial flooding were considered.

Results tabulated below indicate that an infinite array of these cells would be substantially subcritical at any achievable moderation.

Volume fraction

fuel	water	k_{∞}
0.5	0.0	0.225
0.5	0.2	0.283
0.5	0.5	0.513
0.3	0.7	0.490
0.2	0.8	0.430

The low value of k_{∞} obtained for the cask containing Rover fuel, coupled with the thickness of lead in the cask walls (11") provides confidence that an infinite array of these loaded casks would be subcritical, while the cell calculations show the same for the Tory fuel.

This cask, loaded with Rover or Tory fuel in the Cask Insert Box, will comply with Fissile Class I criteria.

DRS:af

C: H. E. Noyes, SP-DO
A. L. Bond, J-6 NTS
K. E. Elliott, ALO
C. Bromley, NVO
Neal Powell, ID

Wm. Morrison, ACC
P-DO
D. R. Smith, P-5
Mail & Records, 2

OFFICE MEMORANDUM

TO : Betty Lobb, Traffic

DATE: November 21, 1974

FROM : D. R. Smith, P-5 *DRS*

SUBJECT : Nuclear Safety - Neutron Absorbing Inserts for the Rover
Cask

SYMBOL : P-5-509

Several cask insert designs have been used with the Rover casks. Early inserts were fabricated from aluminum and had a capacity of 100 elements. Strips of boral were placed in the interstitial regions, with the quantity of boron more than twice that calculated to provide an infinite multiplication factor less than unity. Two of these inserts could be loaded into each cask. The so-called "miniserts" were of similar construction but held only 25 elements.

A less costly insert was developed later, and consisted of boron loaded Epon plastic (LASL specification J9L-68-159) poured into the desired shape. The nominal boron content of the plastic was in excess of fifteen atom percent, and again was calculated to provide subcriticality for an unlimited accumulation of loaded inserts.

During 1963 measurements were performed in Kiva 2 of the Los Alamos Critical Facility to provide confidence in the safety calculations used for the design of inserts. An array of 380 one-inch diameter lucite tubes was loaded into the Tank geometry. This was a 20" square box positioned in a large tank that could be filled with water. Control and safety rods were located on two of the outer surfaces of the inner tank. The plastic tubes were loaded with Rover fuel elements of the type used in the B-4 reactor. The average fuel element loading was approximately 320 mg uranium/cm³, or about 120 g uranium per element. Plastic rods were placed in the regions between the plastic tubes so that the inner tank contained 45.4 kg of uranium at a carbon-to-uranium atom ratio of 108 and a hydrogen-to-uranium atom ratio of 14.3. Some 35 boral strips were needed to keep this loading subcritical when fully reflected by water, or about 1/10 the number provided in the cask inserts. These measurements resulted in increased confidence in the transport calculations which were used to specify boron loadings for the cask inserts. The allowable fissile material loadings for both the plastic loaded insert and the insert containing boral strips was specified as 30 kg ²³⁵U per 100 element insert or 60 kg for the cask loaded with two inserts.

LOS ALAMOS SCIENTIFIC LABORATORY
UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO 87544

TO: Betty Lobb

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DATE: November 21, 1974

It is assumed that twice as much boron would be needed to compensate for plutonium or uranium 233 when these materials are present, so the maximum loading of these materials is specified as 30 kg. For mixed loadings the mass of uranium 235 divided by 60 kg plus the sum of the plutonium and uranium 233 masses divided by 30 kg should not exceed unity.

As boron loadings for all cask inserts have been specified on the basis of an infinite array of inserts being subcritical at the optimum achievable moderation, a loaded cask will comply with Fissile Class I transport criteria.

DRS:af

Distribution:

B. Lobb, SP-DO
John Schulte, CMB-14
A. L. Bond, J-6-NTS
P-DO
D. R. Smith, P-5
Mail & Records, 2

MATERIAL SPECIFICATION

BORON IMPREGNATED PLASTIC

J-9L-68-159

Prepared by: J. W. House

January 9, 1968

Telephone 505 299-2731

**TestFab
Materials and Engineering Co.**

9718 Trumbull Avenue, SE Albuquerque, New Mexico 87112

August 27, 1968

University of California
Los Alamos Scientific Laboratory
P.O. Box 980
Los Alamos, New Mexico 87544

Attention: Mr. Donald L. Grisham
Assistant Group Leader
Division J-2

Reference: LASL Purchase Order LPS-00000-1, CASK Insert -XII-.

Dear Sir:

This letter is in regards to your recent request for information as to the Plastic Batch Formulation and Cured Plastic Density relative to LASL purchase Order LPS-00000-1.

The Plastic Materials, Formulation, and Processing employed in this work were in compliance with LASL Specification J-9L-00-100. The following batch formulation was used throughout the project;

<u>Specification Requirements</u>		<u>Batch Size *</u>
Epon 828	60 lb	16 lbs.
Epon 871	40 "	10 "
Phenolic Microballoons	6 "	1.5 "
Curing Agent Z	20 "	5 "
Boron Carbide	10 "	2.5 "
		<u>34 Lbs. Total</u>

* Note: Two 34 Pound Batches were required for each CASK INSERT.

The Cured Plastic Density, resulting from the above formulation was determined using excess material from the production potting operation. This density was found to be between 60 and 63 Pounds per Cubic Foot.

We are also enclosing copies of the Aluminum Metal Certifications.

Sincerely,

I. D. McCord

TDL:gn
cc: Mr. Jack House, Div. J-6.

February 1, 1968

BORON IMPREGNATED PLASTIC

<u>MATERIAL</u>	<u>PARTS BY WEIGHT</u>
Epon 823	60
Epon 871	40
Phenolic Microballons	6
Epon Curing Agent Z	20
Boron Carbide	10
	<u>136</u>

Process as follows:

1. Combine Epon 823 and Epon 871 resins.
2. Preheat to 140°F.
3. Add preheated (140°F) boron carbide and phenolic microballons.
4. Evacuate at 5 mm mercury.
5. Reheat or cool as necessary to stabilize temperature of mixture at 120°F ± 5°F.
6. Add Curing Agent Z (room temperature).
7. Mix mechanically (2000 rpm with Gyroblade).
8. Evacuate.
9. Pour castings.
10. Cure 16 hours at 120°F, plus 2 hours at 160°F, plus 2 hours at 250°F.

A post cure with an additional 300°F cycle may be desirable.

Suggested sources of materials are as follows:

Epon 823	Shell Chemical Company Plastics and Resins Division New York, New York
Epon 871	Shell Chemical Company Plastics and Resins Division New York, New York
Epon Curing Agent Z	Shell Chemical Company Plastics and Resins Division New York, New York
Phenolic Microballons, 18.7 lbs/ft ³ Union No. BJ00950	Plastics Division Union Carbide Corp. Los Angeles, California
Boron Carbide (T.C.), Technical Grade, High - Non-impregnated, must contain -10.	Morton Abrasives Worcester, Mass.

APPENDIX F

CERTIFICATE OF COMPLIANCE

Form AEC-618
(12-73)
14 CFR 71
AECMS201

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1a. Certificate Number USA/5645/BLF (ERDA-AL)	1b. Revision No. Original	1c. Package Identification No. AL-L8	1d. Page No. 1	1e. Total No. Pages 2
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2. PREAMBLE

- 2a. This certificate is issued to satisfy Sections 173.333a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189 and 14 CFR 103) and Sections 146-19-10a and 146-19-100 of the Department of Transportation Dangerous Cargo Regulations (46 CFR 146-149), as amended.
- 2b. The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material Under Certain Conditions."
- 2c. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application—

(1) Prepared by (Name and address): Los Alamos Scientific Laboratory of the University of California Los Alamos, New Mexico 87544	(2) Title and Identification of report or application: LA-5834-MS Rover Shipping Cask by Betty Lobb, Horace E. Noyes, and David R. Smith	(3) Date: August 1975
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4. CONDITIONS

This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specified in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References:

The Rover cask is a rectangular, lead filled, steel jacketed weldment which provides a ten-inch thick lead shielding contained in a 3/8 inch steel jacket. Outer dimensions are approximately 85"x38"x38". The inner cavity dimensions are 62"x16"x16" and the gross weight is approximately 21 tons.

The cask insert is 54" long and consists of a 5x5 square array of 3" O.D. steel tubes in a welded aluminum box. The regions between the tubes are packed with boron carbide and sealed at each end by a poured epoxy plug.

Authorized Contents

Allowable contents include Rover and Tory IIC elements and other fissile and radioactive materials in special form. When used for shipment of more than fifteen Rover fuel elements all loaded elements will be in boron poisoned cask inserts. Fuel elements not in these inserts will be encapsulated to comply with special form criteria.

Fast reactor fuel pins may be packaged in an insert consisting of a single length of five-inch diameter schedule 40 steel pipe with threaded or silastic gasketed flanged closure. The total fissile material loading for this configuration will not exceed 75 grams per cm of pipe length

6a. Date of Issuance January 25, 1975 FOR THE U.S. ERDA	6b. Expiration Date: N/A
7a. Address of ERDA Issuing Office) Albuquerque Operations Office P.O. Box 5400 Albuquerque, New Mexico 87115	7b. Signature, Name, and Title of ERDA Approving Off. <i>Jack R. Roeder</i> Jack R. Roeder, Director Operational Safety Division

For the shipment of uranium 233 or plutonium-bearing material, the atomic ratio of boron to uranium 233 or plutonium will be at least twice the ratio of boron to uranium 235 normally provided for the loaded Rover fuel element cask inserts, which is a factor of two greater than calculated to provide a k_{∞} less than unity.

These considerations dictate a maximum of 60 kg of uranium 235 or 30 kg of uranium 233 or plutonium. Mixtures of fissile materials shall be so limited that the number of kilograms of ^{235}U divided by 60, plus the number of kilograms of plutonium and ^{233}U divided by 30 will not exceed unity.

Shipments made using above criteria will meet Fissile Class I requirements.

CONTAINER DRAWINGS

SHIPPING CASK (ROVER)
USA / 5645 / BLF (AEC-AL)
(For structural and fabrication details see LASL drawing ENG-E-374)

CASK INSERT BOX NRDS FUEL
(For Structural and Fabrication details see LASL drawing 31474)

Overall dimensions:

398 mm wide (15.66 in)

192 mm high (7.56 in)

7239 mm long (28.5 in)

CASK INSERT, SHIPPING

(For structural and fabrication details see LASL drawing 34Y43605 E2)

Overall dimensions :
398 mm wide (15.66 in)
192 mm high (7.56 in)
1494 mm long (58.8 in)

XL CASK INSERT

(For structural and fabrication details see LASL dwg 530030)