DOE Form EV-618
(11-77)
10 CFR 71

U.S. DEPARTMENT OF ENERGY

CERTIFICATE OF COMPLIANCE

For Radioactive Materials Packages

1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages.
6459	1	USA/6495/B( )F-SAN	1	3

2. PREAMBLE

2a. This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189).

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)*:

Energy Systems Group
Rockwell IXternational
8900 De Soto Avenue
Canoga Park, CA 91304

(2) Title and Identification of report or application:

(a) DPSPU 71-124-4
Safety Summary Report
Paducah Demonstration Cask, Revised Feb. 1982
(Packaging of Radioactive and Fissile Material)

(b) Ltr. V.J. Schaubert to C.J.Mauck (b) Dec. 2, 1982

(3) Date:

(a)March 5, 1982

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:

(A) Packaging

(1) Model No.: Paducah Demonstration Cask

(2) Description: The cask consists of two concentric stainless steel shells separated by 5.75-inches of laminated depleted uranium. The inner shell is 0.25-inches thick and has a cavity 50.75-inches long by 17-inches ID. The outer shell is 0.5-inches thick, 80-inches long, with a 30-inch OD, which is also the base for 3-inch by 3/16-inch heat transfer fins. Cask net weight is approximately 27,500 pounds.

(3) Drawings:

E-M-12170A, Rev. 3 (Union Carbide)	EC2-6860-11 (Du Pont)
E-M-12170B, Rev. 2 (Union Carbide)	EC2-6860-12 (Du Pont)
E-M-12170C, Rev. 1 (Union Carbide)	EC2-6860-13 (Du Pont)
E-M-12170D, Rev. 2 (Union Carbide)	W447019 (Du Pont)
	W447053 (Du Pont)

No Number (Energy Systems Group) Figure 1, Page 7, DPSPU 71-124-40, Supplement No. 2.

045000036 (Energy Systems Group), Basket

6a. Date of Issuance:	6b. Expiration Date: March 31, 1987

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address *(of DOE Issuing Office)*	7b. Signature, Name, and Title *(of DOE Approving Official)*
San Francisco Operations Office 1333 Broadway Oakland, CA. 94612	R A Du Val Richard A. Du Val Acting Manager, SAN

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

(B) Contents

(1) Type and Form of Material

(i) Irradiated Mixed-Oxide SEFOR Fuel Rods

Fuel rods consist of 0.98-inch OD by approximately 48-inch long stainless steel rods containing helium-bonded mixed oxide and depleted uranium oxide pellets. Each standard element weighs approximately 11 pounds and, before irradiation, contained 600 grams of plutonium and 2470 grams of depleted uranium. Several non-standard rods carry slightly different contents.

(ii) Irradiated Mixed-Oxide SEFOR Fuel - Repackaged

Fuel contents of mixed oxide pellets crushed to pieces and powder which has been packaged into aluminum transfer canisters. Transfer canisters are nominal 1.0-inch diameter by 0.035 wall thickness by approximately 40 inches long. Each canister contains approximately ½ the contents of an original standard SEFOR rod, or approximately 300 grams of plutonium and 1235 grams of depleted uranium. Several canisters with non-standard material will contain somewhat different loadings.

A miximum of six fuel transfer canisters are packaged into each shipping canister. Each shipping canister consists of a 3.5 inch diameter by 0.125 wall thickness by approximately 44-inch long aluminum tube with a plate welded at one end and a handling fixture at the other. Overall length is approximately 48 inches. Canister gross weights are approximately 15.8 kilograms.

(2) Maximum Quantity of Material Per Package

(i) Cask insert constructed to hold 21 SEFOR fuel and 3 SEFOR B_4C poison rods in each of four compartments or quadrants: Rods may be subpackaged, in varying numbers per package, prior to placing into the insert quadrants.

(ii) The cask SEFOR fuel return basket is designed to hold 13 shipping canisters in a fixed configuration. The three cneter holes will not be used for SEFOR return shipments and contain obstructions to prevent inadvertent usage. A maximum of 60 fuel transfer canisters can be shipped by utilizing the ten remaining basket openings. This equates to 30 original SEFOR pins or approximately 18 kilograms of Plutonium and 74 kilograms of depleted Uranium. Thirteen (13) hollow cylindrical basket supports are filled with B_4C to also act as poison rods. These are constructed of nominal 1-inch diameter by 44-inch hollow pipes, capped, and welded into place.

(iii) Content plus insert not to exceed 2500 pounds. Content not to exceed decay heat generation of 12 watts per fuel rod/transfer canister or 1343 watts total (= 4590 Btu/hr).

(C) Fissile Class

(i) Fissile Class III.

6. The cask shall be leak tested in accordance with Appendix A, Supplement 2, of DPSU 71-124-4B, "Operating Procedures, Paducah Demonstration Cask."

7. The lid metal O-ring must be replaced for each shipment.

8. The package authorized by this certificate is approved for use under the general provisions of 49 CFR 173.393a and the intent of 10 CFR 71.12(b).

18 JAN 1983

CONCURRENCES	
RTG. SYMBOL	DP
INITIALS/SIG.	Mauck
DATE	1/ /83
RTG. SYMBOL	DP
INITIALS/SIG.	RTAB
DATE	1/17/83
RTG. SYMBOL	
INITIALS/SIG.	
DATE	
RTG. SYMBOL	
INITIALS/SIG.	
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INITIALS/SIG.	
DATE	
RTG. SYMBOL	
INITIALS/SIG.	
DATE	

San Francisco Operations Office, DP

Paducah Cask
Certificate of Compliance USA/6495/B( )F - SAN

Joe La Grone, Manager, SAN

The DOE Certificate of Compliance USA/6495/B( )F-SAN has been amended to include the conditions for return of SEFOR declad and repackaged fuel to the Savannah River Plant in a new basket configuration. In providing this modification, comparisons were made with previous Paducah Cask analyses and tests conducted for a configuration with package contents weighing greatly in excess of the SEFOR shipment (2,500 lbs vs 600 lbs). Supplement 20.3 has been added to DPSPU 71-124-4B and includes the revised analyses in the following areas:

1. Structural Evaluation
2. Thermal Evaluation
3. Criticality

The proposed content weight of approximately 600 pounds for a declad fuel shipment is considerably less than the 2,500 pounds used in the Appendix A analysis of the Paducah Cask Safety Summary Report. The new basket should easily survive any projected impact loads.

The thermal calculations show a total decay power of 62.4 watts. This is considerably less than the 1,324 watts per cask loading as calculated for the original shipment of the fuel from the SEFOR site and the 12 watts per fuel rod (1,343 watts total) allowed in the original certificate.

Because of criticality considerations, only 10 holes are being utilized of the 13 available. By using only the 10 outer holes, the annular geometry of the original shipment is maintained, thus allowing use of the original criticality evaluation. The new evaluation shows that the fuel configuration in the new basket is less reactive than that stated in the original basket loading due to the method of fuel clustering and there being less fuel, greater flux depression, reduced thermal utilization, and an increase of the poison rod surface area.

As a result of the additional safety analyses, illustrating the use of the Paducah Cask for return shipments, the cask will meet the requirements of DOE Order 5480.1, Chapter 111. The amended certificate is recommended for approval.

Original signed by: RTAB

Charles J. Mauck

cc: C. J. Mauck

DOE FORM AD-9 (12-77)

OFFICIAL FILE COPY

FILE #
INITIAL

Energy Systems Group
D/780 Correspondence

LTR. NO. 82ESG-8671 — LTR/ENC

NDERSON, R.V. LA29
NDERSON, T. L. LB14
ASH LA24
SHWORTH LB22
BARTO 055, AA89
BEELEY, R. LB01
BELL, J. A. LA26
BINNS, D. R. LB09
BRADLEY, J. W. EMSC
CARTER, E. H. LB23
COCKERAM HAN
DETTERMAN LA17
DPOL, C. LA42 /
DORR, J. E. ROK
EMPEY, D. C. KB44 /
FARRAR, H. NA02
EILER LA30 /
FOWLER, P. E. KB04
YLFE LA39
ALLINAN, G. LB12
HARRIS-WASH
HARTZLER KB05
OLBROOK LA07
ACOBSON, J. LA20
OHNSON, R. A. (D 798) LA34
ONES, R. G. LA06
ULIAN, M. KB03
ITTINGER NB02
OLIN LA35
AKI, L. M. NB02
ASON, D. NB02 /
COURT LA02
DONALD, J. S. LB11
EYERS, G. W. LA10
OSS, T. NB02
AGAMATSU KB08
LDENKAMP LB17
ARKER, T. G. NB02
ARRY EMSC
EINECKER LA20
EMLEY NB08 /
OBERTS, W. J. LA21
ANDERS NB01
CHIRM, R. C. LA23
CHMITT LA17
SILVERMAN LB16
WANSON, G. K. LB09
INGER NA14
HEELER LA33
IESENECK T038
ILLIAMS, R. D. LA04

N.S.I. CLASSIFICATION — LTR/ENC
UNCLASSIFIED
CLASSIFIED
LTR. APPROVALS
ORIG. & TYPIST INITIALS
IN REPLY TO LTR. NO.
FORM N 77-H REV. 3-82

Energy Systems Group
8900 De Soto Avenue
Canoga Park, California 91304

Telephone: (213) 341-1000
TWX: 910-494-1237
Telex: 181017

Rockwell International

December 2, 1982 — In reply refer to 82ESG-8671

Mr. Charles Mauck
Defense Programs Division
Department of Energy
San Francisco Operations Office
1333 Broadway
Oakland, California 94612

Dear Mr. Mauck:

Subject: Paducah Cask
Certificate of Compliance USA/6495/B( )F-SAN

Enclosed is Revision 1 of Certificate of Compliance USA/6495/B( )F-SAN for the Paducah Cask. It has been amended to include the conditions for return of SEFOR declad and repackaged fuel to the Savannah River Plant in a new basket configuration. Also enclosed are our internal review documents supporting the Certification Change along with a drawing of the cask basket.

The thermal calculations show that a full loading using all 13 holes in the basket would yield a total decay power of 62.4 watts. This thermal load calculated value is considerably less than the 1324 watts per cask loading as calculated for the original shipment of the fuel from the SEFOR site to the Savannah River Plant and the 12 watts per fuel rod or 1343 watts total allowed in the Certificate of Compliance. In addition, only 10 holes are being used because of criticality considerations.

The proposed content weight of approximately 600 pounds for a declad fuel shipment is considerably less than the 2500 pounds used in the Appendix A analysis of the Paducah Cask Safety Summary Report. Our structural evaluation shows that the new basket should easily sustain any projected impact loads.

The criticality evaluation was conducted using only the 10 outer canister positions. By this means, the annular geometry of the original shipment configuration was maintained, thus also allowing the use of the original shipping criticality evaluation. Our evaluation

Rockwell
International

shows that the fuel configuration in the new basket for return shipments is less reactive than that stated for the original basket loading due to there being less fuel, greater flux depression, and reduced thermal utilization and because of the method of clustering of the fuel and an increase of the poison rod surface areas.

Approval of the Certificate of Compliance for the new basket insert is requested. Also enclosed for your files are the following copies of our internal review documents.

Internal letter dated October 20, 1982, E. M. Mouradian to D. C. Campbell, "Fuel Pins in SEFOR Shipping Canisters to be Transported in Paducah Shipping Cask" (Thermal Evaluation)

Internal letter dated October 12, 1982, W. L. Propes to R. S. Frazier, "Declad SEFOR Fuel Shipment in the Paducah Cask" (Structural Evaluation)

Supporting Document 045SRR000005, "Criticality Study for Return Shipments of SEFOR Fuel in the Paducah Demonstration Cask"

Drawing 045000036, "Paducah Cask Insert for Declad SEFOR Fuel Shipping Canisters."

Very truly yours,

V. J. Schaubert

V. J. Schaubert, Manager
Nuclear Materials Management
Energy Systems Group

6007A/slh

Enclosures as stated

DOE Form EV-618
(11-77)
10 CFR 71

U.S. DEPARTMENT OF ENERGY

CERTIFICATE OF COMPLIANCE

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1a. Certificate Number	1b. Revision No.	1c. Package Identification No.	1d. Page No.	1e. Total No. Pages
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2. PREAMBLE

2a. This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189).

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)*:

Energy Systems Group
Rockwell International
8900 De Soto Avenue
Canoga Park, Ca. 91304

(2) Title and Identification of report or application:

DPSPU 71-124-4
Safety Summary Report
Paducah Demonstration Cask, Revised Feb. 1982
(Packaging of Radioactive and Fissile Material)

(3) Date: Nov. 10, 1982

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:

(A) Packaging

(1) Model No.: Paducah Demonstration Cask

(2) Description: The cask consists of two concentric stainless steel shells separated by 5.75-inches of laminated depleted uranium. The inner shell is 0.25-inches thick and has a cavity 50.75-inches long by 17-inches ID. The outer shell is 0.5-inches thick, 80-inches long, with a 30-inch OD, which also is the base for 3-inch by 3/16-inch heat transfer fins. Cask net weight is approximately 27,500 pounds.

(3) Drawings:

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E-M-12170B, Rev. 2 (Union Carbide)
E-M-12170C, Rev. 1 (Union Carbide)
E-M-12170D, Rev. 2 (Union Carbide)

EC2-6860-11 (Du Pont)
EC2-6860-12 (Du Pont)
EC2-6860-13 (Du Pont)
W447019 (Du Pont)
W447053 (Du Pont)

No Number (Energy Systems Group) Figure 1, Page 7, DPSPU 71-124-40, Supplement No. 2.

045000036 (Energy Systems Group), Basket

6a. Date of Issuance: April 5, 1982	6b. Expiration Date: March 31, 1987

FOR THE U.S. DEPARTMENT OF ENERGY

7a. Address *(of DOE Issuing Office)*	7b. Signature, Name, and Title *(of DOE Approving Official)*
San Francisco Operations Office 1333 Broadway Oakland, Ca. 94612	

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

(B) Contents

(1) Type and Form of Material

(i) Irradiated Mixed-Oxide SEFOR Fuel Rods

Fuel rods consist of 0.98-inch OD by approximately 48-inch long stainless steel rods containing helium-bonded mixed oxide and depleted uranium oxide pellets. Each standard element weighs approximately 11 pounds and, before irradiation, contained 600 grams of plutonium and 2470 grams of depleted uranium. Several non-standard rods carry sligntly different contents.

(ii) Irradiated Mixed-Oxide SEFOR Fuel - Repackaged

Fuel contents of mixed oxide pellets crushed to pieces and powder which has been packaged into aluminum transfer canisters. Transfer canisters are nominal 1.0-inch diameter by 0.035 wall thickness by approximately 40 inches long. Each canister contains approximately 1/2 the contents of an original standard SEFOR rod, or approximately 300 grams of plutonium and 1235 grams of depleted uranium. Several canisters with non-standard material will contain somewhat different loadings.

A maximum of six fuel transfer canisters are packaged into each shipping canister. Each shipping canister consists of a 3.5 inch diameter by 0.125 wall thickness by approximately 44-inch long aluminum tube with a plate welded at one end and a handling fixture at the other. Overall length is approximately 48 inches. Canister gross weights are approximately 15.8 kilograms.

(2) Maximum Quantity of Material Per Package

(i) Cask insert constructed to hold 21 SEFOR fuel and 3 SEFOR B_4C poison rods in each of four compartments or quadrants: Rods may be subpackaged, in varying numbers per package, prior to placing into the insert quadrants.

(ii) The cask SEFOR fuel return basket is designed to hold 13 shipping canisters in a fixed configuration. The three center holes will not be used for SEFOR return shipments and contain obstructions to prevent inadvertent usage. A maximum of 60 fuel transfer canisters can be shipped by utilizing the ten remaining basket openings. This equates to 30 original SEFOR pins or approximately 18 kilograms of Plutonium and 74 kilograms of depleted Uranium. Thirteen (13) hollow cylindrical basket supports are filled with B_4C to also act as poison rods. These are constructed of nominal 1-inch diameter by 44-inch hollow pipes, capped, and welded into place.

(iii) Content plus insert not to exceed 2500 pounds. Content not to exceed decay heat generation of 12 watts per fuel rod/transfer canister or 1343 watts total (= 4590 Btu/hr).

(C) Fissile Class

(i) Fissile Class III.

6. The cask shall be leak tested in accordance with Appendix A, Supplement 2, of DPSU 71-124-4B, "Operating Procedures, Paducah Demonstration Cask."

7. The lid metal O-ring must be replaced for each shipment.

8. The package authorized by this certificate is approved for use under the general provisions of 49 CFR 173.393a and the intent of 10 CFR 71.12(b).

abg:1124

Internal Letter

Rockwell International

DATE: October 12, 1982

350-82-83

TO: R. S. Frazier
731, 071-T020

FROM: W. L. Propes
731, 071-LB30

3607

Subject: Declad SEFOR Fuel Shipment in the Paducah Cask

The attached information is supplied in support of the effort to obtain Regulatory Agency permission to proceed with the declad SEFOR fuel transhipment to the Savannah River site.

The Paducah Cask structural evaluation for the SEFOR fuel shipment is accomplished in the same manner as was done in DPSPU71-124-4A Supplement 1, that is, by comparison to prior Paducah Cask analyses and tests conducted for a configuration with a package contents weight greatly in excess of the SEFOR shipment (~ 2500 lb. vs. 600 lb.).

The cask insert (Ref. dwg. no. TBD) analysis is attached and appears as part of the new Supplement no. 3 of DPSPU 71-124-4B. The information follows the format used in previous supplements and is in accordance with 10CFR part 71.

W. L. Propes
Pressure & Structural Components
Stress Analysis

pho:WLP

cc: *H. M. Minami LB30
*D. Campbell LB14
W. Dennison NB02
*R. De Minico T020
*L. Rico LB30
*T. Shimazaki LB30
*E. Mouradian LB30

* No Attachment

Draft Copy of DPSPU 71-124-4B Supplement no. 3

ABSTRACT

This supplement to Safety Summary Report DPSPU 71-124-4A Supplement 1 evaluates the Paducah cask for shipping decladded SEFOR fuel from the Santa Susana Field Laboratory (SSFL) of the Energy Systems Group of Rockwell International to the Savannah River Plant, Aiken, South Carolina. All shipping is done in compliance with DOE Order 5480.1, Safety Requirements for the Packaging of Fissile and Other Radioactive Materials (formerly AEC Manual Chapter 0529). The Paducah demonstration cask, which has been equipped with a new insert for SEFOR fuel, will be used for these shipments.

DESCRIPTION OF SHIPMENT

Decled SEFOR fuel, packaged in transfer canisters, six of which are then loaded into a shipping canister, then thirteen shipping canisters are loaded into the Paducah Cask, will be shipped from the SSFL to the Savannah River Plant (SRP). An insert, (see fig. TBD) was specially built to maintain the thirteen shipping canisters in the array as shown.

(Note: continued description of shipment TBD)

COMPARISON WITH REGULATIONS

I. Definitions and Exemptions

No comment required

II. Package Standards

A. General Standards for all Packaging

1. No reaction between package and contents
2. Positive closure on packaging, Reference 1
3. Lifting devices, Appendix A of Reference 1
4. Tiedown devices, Appendix A of Reference 1

B. Structural Standards for Large Quanity Packaging

(Appendix A. of Reference 1)

C. Criticality Standards for Fissile Material Packages

1. A package with complete water moderation and reflection is subcritical (Appendix 1 of DPSPU 71-124-4A Supplement 1).
2. N/A
3. N/A

D. Evaluation of a Single Package

1. (a.) The package withstands conditions likely to occur in normal transport (Appendix 1 of DPSPU-71-124-4C.
   (b.) The package withstands conditions likely to occur in the hypothetical accident (Appendix 1 of DPSPU-71-124-4C.
2. Evaluation of Packge and vehicle together. N/A.
3. Approval of different accident conditions. N/A.

E. Standards for Normal Conditions of Transport for a Single Package

Discussed in para. II.-D.-1.(a). No activity release.

F. Standards for Hypothetical Accident Conditions for a Single Package.

Discussed in para. II.-D.-1.(b)

G. Evaluation of an Array of Packages of Fissile Material

N/A

H. Specific Standards for a Fissile Class I Package.

N/A

I. Specific Standards for a Fissile Class II Package.

N/A

J. Specific Standards for a Fissile Class III Package.

(Note: writeup TBD)

APPENDIX 1.

I Evaluation of a Single Package - Normal Conditions of Transport

A. Structural Analysis of Cask

1. The structural integrity of the Paducah Cask lifting and tie-down devices, load resistance, and external pressure are all assured by virtue of the previous analysis found in DPSPU 71-129-4 Appendix A; and, the fact that the contents weight of approximately 600 lb. for the SEFOR decked fuel shipment is considerably less than the 2,500 lb. used in the Appendix A analysis.

II Evaluation of a Single Package - Hypothetical Accident Conditions.

A. Structural Integrity Verification of Cask.

1. The drop and puncture tests conducted on the Paducah Cask and described in DPSPU 71-129-4 Appendix D verify the adequacy of the Paducah Cask, when loaded with SEFOR decked fuel, to withstand the 30 ft free drop and 40 in. puncture tests.

III Evaluation of a Single Package - Normal Conditions of Transport

A. Structural Analysis of Insert

1. Heat — The insert is an open container and vents into the cask cavity. The potential for pressure buildup in the cavity from heat generation is discussed in Appendix TBD.

2. Cold — The materials of which the insert and shipping canisters are constructed maintain reasonable ductility at -40°F.

3. Pressure — N/A for insert structure.

4. Vibration — The lowest frequency of the cask insert is associated with the shipping canisters contained within the insert. The calculated minimum frequency of ~250 Hz. is believed to be well above the prevalent forcing frequencies of the carrier; therefore, no damage is expected from vibration in transit.

5. Water Spray — Applicable to the cask rather than to the Insert

4. Free Drop. (2 ft.) — In the succeeding section which addresses the accident conditions for the insert for a 30 ft drop it is shown that containment is maintained. Therefore the 2 ft. drop problem is trivial.

7. Corner Drop — Not Applicable

8. Penetration — Applicable to the cask rather than to the insert. (Ref. no. 1)

9. Compression — Applicable to the cask rather than to the insert (Ref. no. 1)

IV Evaluation of a Single Package - Hypothetical Accident Condit.

A. Structural Analysis of Insert

1. Free Drop. (30 ft) The 30 ft. drop test results outlined in DPSPU 71-124-4 Appendix D indicated a deceleration of 200 g's was measured on the dummy fuel load. The same conservatism as used in DPSPU 71-124-4A Supplement 1 Appendix 3 will be used for the following calculations (deceleration force = 250 g's)

2. End-On Impact - Lower End

A lower end impact load will be carried by the solid central post and the seven pipe posts that provide stability for the birdcage-like structure of the cask insert.

Assume total impact load is carried by the solid central post (1" dia.):

Max column length = 23 in. $\therefore P_{CR} = \pi^2 EI/\ell^2$

$P_{CR} = \pi^2 (30 \times 10^6 \times .049)/23^2 \approx 27{,}000$ lb.

Estimated weight of cask insert structure only is approx. 112 lb.

This indicates the insert has the capability of sustaining $\sim \frac{27{,}000}{112} = 241$ g's prior to the onset of a column instability failure for the lower end impact case.

Considering the column load carrying capability of each of the seven peripheral support pipes, (~59,000 lb. each) the total capability of the structure should easily sustain a 250 g impact load.

b. End-On Impact - Upper End

An upper end impact will be sustained by the shipping canisters which provide a cushioning effect for the actual insert structure. The shipping canisters are addressed in subsequent sections. Should the upper end impact case subject the insert to the full 250 g loading then the same conclusions for lower end impact would be applicable.

c. Side Impact

1" sch 80 pipes ($I/c = .1606 in^3$), ($w = 2.172$ lb/ft.)

$$\sigma_b = \frac{wL^2}{8(I/c)} \cdot \frac{2.172(23)^2(250)}{12(8)(.1606)} = 18,630 \text{ psi}$$

For ASTM A106 Gr. A $F_{TY} = 30,000$ psi

∴ No yielding is indicated

1" Center rod ($I/c = .098$), ($w = 2.667$ lb/ft.)

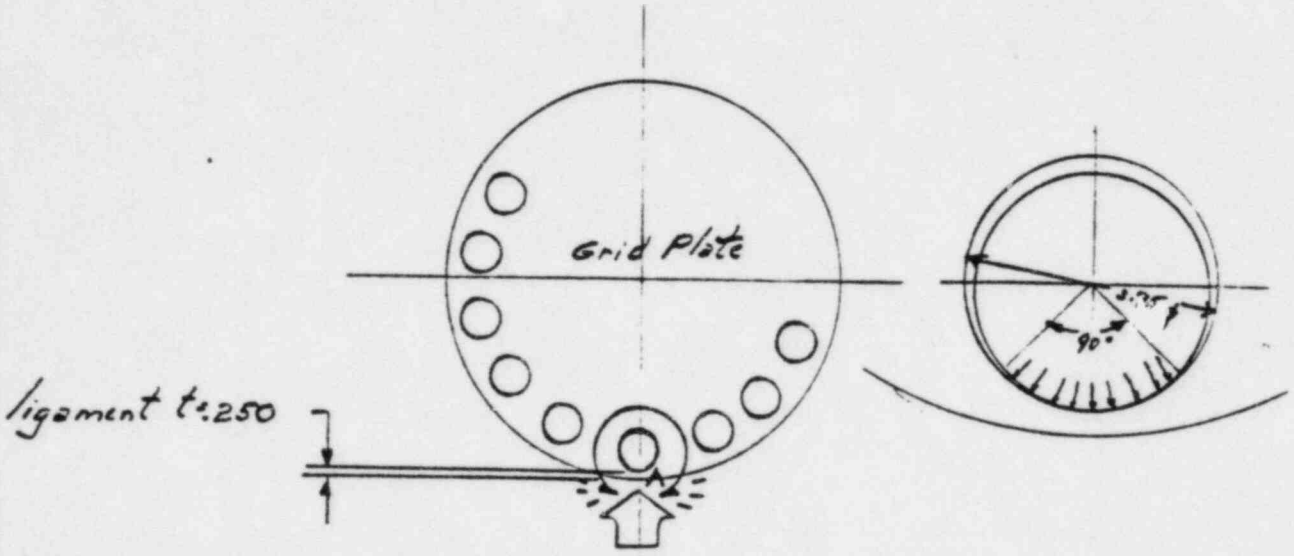
$$\sigma_b = \frac{2.667(23)^2(250)}{12(8)(.098)} = 37,490 \text{ psi}$$

∴ Slight yielding but no fracture is indicated and neither containment nor confinement is compromised.

3/8" thk. Grid Plate:

Assume a maximum of 50% of the load of any one shipping canister (loaded = 35.2 lb. (16 kg.) is exerted in bearing on the ligament as shown in the following sketch.

PREPARED BY: M. I. Soplet	Rockwell International Energy Systems Group	PAGE NO. 7 OF
CHECKED BY:		REPORT NO.
DATE: 10-12-82		MODEL NO.



Impact load = 35.2 (.5)(250) = 4400 lb.

" Area = $\frac{3.75\pi}{4}$ (.375) = 1.1 in^2

Bearing pressure = $\frac{4400}{1.1}$ = 4000 psi

ligament membrane stress = $\frac{4000(1.875)}{.25}$ = 30,000 psi

Slight yielding and permanent deformation is indicated however the configuration will remain intact and confinement is assured.

Note: The possible consequences of the damage to the insert that is indicated previously is that difficulty may be encountered in grappling out the shipping canisters during unloading.

PREPARED BY: I.S. Thompson	Rockwell International Energy Systems Group	PAGE NO. 8. OF
CHECKED BY:		REPORT NO.
DATE: 10-12-82		MODEL NO.

B. Structural Analysis of SEFOR Shipping Canister
(Hypothetical Accident Conditions - 30ft. Drop)

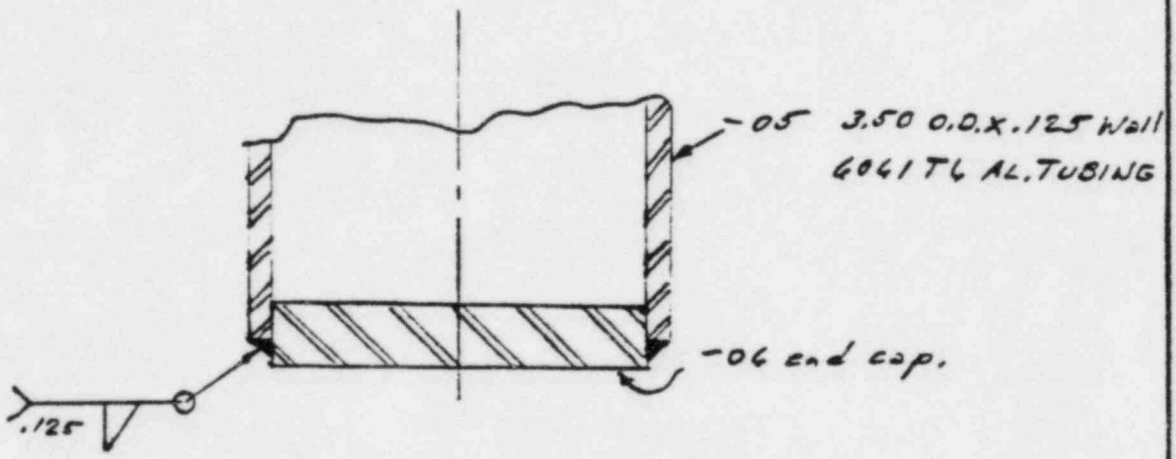
Ref. dwg. no. 045000003 Rev. B

Assume deceleration force = 250 g's

1. Lower End Impact:

Canister and contents wt. = 16 kg (35.2 lb.)

a.) -06 canister bottom to -05 canister tube weld.



$$T_{WELD} = \frac{35.2(250)}{3.25\pi(.125)(.7)} = 9850 \text{ psi}$$

$F_{SU_{weld}}$ = 11,500 psi for 4043 Aluminum filler alloy
Ref. Alcoa welding handbk. "Welding Alcoa Aluminum" table 1 48 p. 239.

No failure of the weld is indicated.

b. -05 Tube : Ck local instability

σ' (critical compressive stress) $= \frac{1}{\sqrt{3}} \frac{E}{\sqrt{1-\nu^2}} \left(\frac{t}{r}\right)$

where $t = .125$ in.
$E = 10 \times 10^6$ psi Ref. Roark 3rd Ed.
$r = 1.6875$ (r mean) Table XVI case 25.

$$\sigma' = \frac{1}{\sqrt{3}} \frac{10 \times 10^6}{\sqrt{1-.3^2}} \left(\frac{.125}{1.6875}\right) = 448 \text{ ksi}$$

No instability problems of the shipping canister are indicated. Note: $\frac{P}{A} = \frac{55.2(250)}{1.325} = 6640$ psi

2. Upper End Impact

Loading: 250 g's

Load per canister $= 250[(13)(55.2) + 112]/13 \cong 11{,}000$ lb.

Impact occurs with the -02 head striking the bottom face of the cask closure head

Note: Cask closure head lower plate is ½" thk. 304L S.S.

Assuming that, in the limit, impact stress and deformations are twice the static case and that both target (cask head) and projectile (shipping canister) have the same Modulus of Elasticity; a worst case for the cask head, the depth of penetration is:

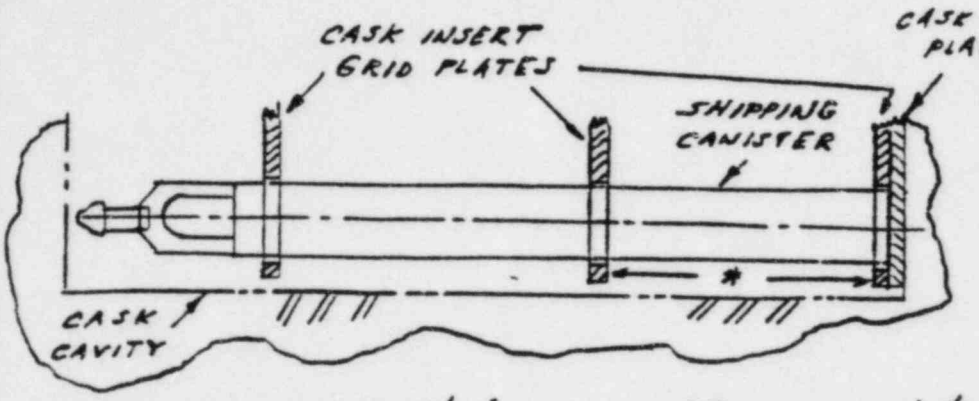
$$y = (2)(1.55)\sqrt[3]{\frac{P^2}{E^2 D}}$$

where $D = 2(.12) = .24$ in.
Ref. Dwg. no. 045000003
detail -02
Roark 3rd Ed Table XIV Case no. 1

$$y = (2)(1.55)\sqrt[3]{\frac{(11{,}000)^2}{(30 \times 10^6)^2 (.24}}$$

$y = .026$ in. Negligible penetration is indicated.

3. Side Impact (of shipping canister)



Assume: 250 g's impact deceleration load.

* max. unsupported span ~23 in. canister $(\frac{I}{c})$ = 1.08 in^3

$M_{max} = WL/8 = 16.2(23)/8 \approx 46.6$ in-lb.

$\sigma_b = 250(46.6)/1.08 \approx 10,800$ psi

6061-T6 Alum. $F_{ty} = 40,000$ psi $\therefore$ No yielding is indicated.

C. Miscellaneous Stress Checks of Shipping Canister and Cask Insert for Conditions of Normal Grappling

1. Shipping Canister:

a) Assuming grappling is accomplished by -02 head (ref. dwg. no. 04506 0003) and loading is sym. about ℄ of -05 tube:

-02 Head Mt'l.: 6061 T6 $S_y = 40,000$ psi

Criteria for "lifting devices" is:

$\sigma \leq S_y/3 = 13,300$ psi

Assume for welds: $\tau \leq F_{SU}/3$ where $F_{SU} = 11,500$ psi for 4043 Al. weld filler material (ref. pg. 8)

For the -02 head: $A_{min} = \frac{\pi}{4}(.750-.010)^2 = 0.43\,in^2$

$\sigma_T = 35.2/.43 = 82\,psi$ (negligible)

-02 head to -03 lifting bale weld:

$$\tau = \frac{35.2}{4(.25)(.5)(.7)} = 100\,psi \text{ (negligible)}$$

-03 bale to -04 lid weld:

$$\tau = \frac{35.2}{4(.72)(.12)(.7)} = 146\,psi \text{ (negligible)}$$

-04 lid to -05 tube weld:

$$\tau = \frac{35.2}{3.25\pi(.125)} = 28\,psi \text{ (negligible)}$$

2. Insert:

a.) Lifting Eye: Ref.: "The Crosby Group" Catalog #950 p. 37 Pad Eyes.

Size no. 4 (1" Ø of eye) No. S-264

Note: No safe working load is specified for pad eyes: however, for the same size eye bolt (p. 38) a safe working load of 2200 lb. is specified.

Note: Ultimate load is 5 times safe working load.

∴ The design margin of the pad eye is:

$\frac{2200}{600} - 1 = +2.66$ on S.W.L.

and

$5(\frac{2200}{600}) = +17.$ on Ultimate ∴ pad eye is adequate

b.) Pad Eye Weld:

Shoulder Dia. = 1 7/16 in. & Assume a minimum 1/8 in. fillet weld

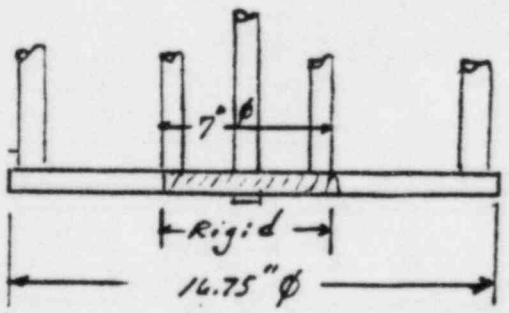
$$\tau = \frac{600}{1.44\pi(.125)(.7)} = 1520 \text{ psi}$$

$F_{S_{Allow}} = 13{,}600$ psi (E60 filler) $\quad$ D.M. $= \frac{13600}{1520} - 1 = +7.95$

Weld is adequate.

c.) Base Plate

For the purpose of a quick check, assume the plate dia. bounded by the 3 center pipes as rigid and conservatively neglect the support provided by the four outer pipes.



determine the load intensity (lb/in.) based on the total load (600 lb.) distributed uniformly over the annular area bounded by the 7"ϕ and 16.75"ϕ.

$$\therefore q\,(\text{lb/in.}) = \frac{600}{\pi/4\,(16.75^2 - 7^2)} \approx 4 \text{ lb/in.}$$

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$\sigma_{max.} = k\frac{qa^2}{h^2}$ Ref. Timoshenko "Plates & Shells" p. 61
Case 3

where $a = 8.375$ in. $b = 3.5$ in.
$h = 0.375$ in. $\therefore \frac{a}{b} \sim 2.4$
$k \sim 1.1$

$$\sigma_{max.} = \frac{1.1(4)(8.375)^2}{(.375)^2} \sim 3200 \text{ psi}$$

Mt'l. ASTM A 285 Gr. C $S_y = 30{,}000$ psi

$$\therefore \frac{S_y}{3} = 10{,}000 \text{ psi}$$

$$D.M. = \frac{10{,}000}{3{,}200} - 1.0 + 2.12 \quad \text{(Base Pl. is adequate)}$$

Rockwell International

Date: October 20, 1982

No.: 640-82-52

TO: Atomics International Area

D.C. Campbell
731, 071-T020

FROM: Atomics International Area

E.M Mouradian
731, 071-LB30
Ext. 3320

Subject: Fuel Pins in SEFOR Shipping Canisters to be transported in Paducah Shipping Cask

Ref: 1). Personal Communication, David Campbell, ETEC (Ext. 5387)

2). Safety Summary Report - Paducah Demonstration Cask DPSPU-71-124-4, Rockwell International, February 1982, (Supplement No. 1, DPSPU 71-124-4A, Pgs. 22-28)

3) I.L. - R.E. Rankel to J.R. Miller/W.F. Dennison, "Paducah Demonstration Cask: Hypothetical Accident (Fire)". I.L. #650-82-004, January 25, 1982.

The Paducah Fuel Shipping Cask is to be employed to transport declad fuel material in "SEFOR Fuel Shipping Canisters". Thirteen such canisters, containing fuel material with a total decay power of 62.4 watts (213 BTU/hr) are to comprise the full load for the shipping cask. See Fig. 1 & 2.

This thermal load is considerably less than the 1324 watts on which the calculation of Reference 2 (DPSPU 71-124-4 Supplement 1, Pg. 22-28) was based.

A simplified calculation has been made for the current 62.4 watts loading, and is shown on the attached sheets. The analysis indicates that the peak fuel pin material temperature would be approximately 120°F higher than that of the ambient environment.

Assuming an ambient 100°F, the indicated peak fuel pin temperature is approximately 220°F in the steady-state condition. No transient calculations have been made. However, as the bulk of the thermal capacitance is in the cask, transient behavior in response to a fire should be similar to previous analysis by Rankel. (See Reference 3).

Data on the acceptable temperature criteria was not made available to this analyst. However, it is apparent that the calculated temperatures are far below those in Reference 2, even if a generous margin were to be allowed.

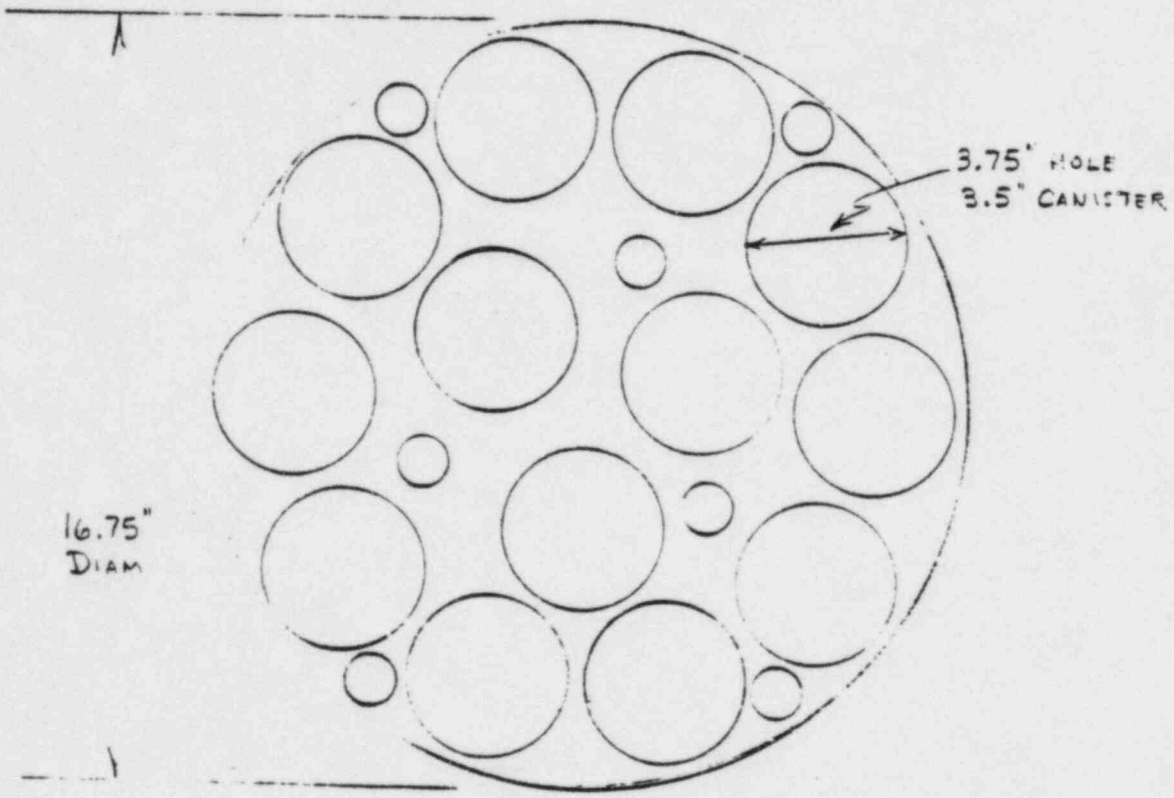
Edward M. Mouradian

E.M Mouradian
Thermal/Hydraulic Analysis

cc: W.F. Dennison NB02 *
R.J. Tuttle NB13 *
W.R. McCurnim T020 *
J.H. Walters LB07 *
W.L. Propes LB30 *
L.G. Rico LB30

* Without Attachment

Form 131-R Rev. 3-76



PADUCAH CASK INSERT
FOR DECLAD SEFOR
FUEL SHIPPING CANISTERS

FIGURE 1

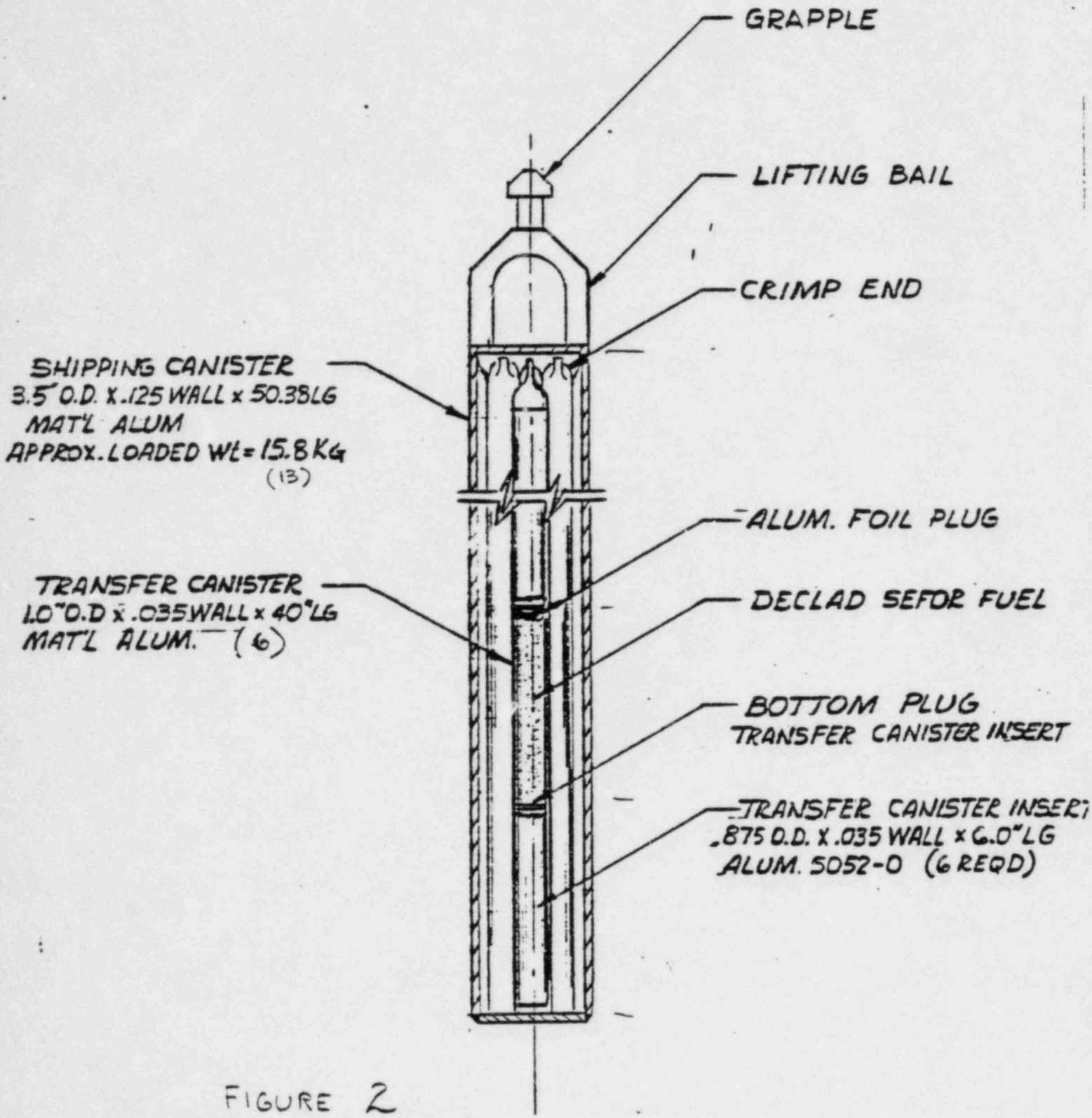


FIGURE 2

RJD

SEFOR SHIPPING CANISTER

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ONE (1) SHIPPING CASK:

CONTAINING:

THIRTEEN (13) SHIPPING CANISTERS; (O.D = 3.5")

EACH CONTAINING:

SIX (6) TRANSFER CANISTERS; (O.D. = 1.0")

EACH CONTAINING:

EQUIVALENT OF ONE-HALF ($\frac{1}{2}$) FUEL PIN @ 1.6 WATTS/FUEL PIN.

(Ref. 1 David Cambell)

See Figures 1 & 2: GEOMETRIC CONFIGURATION OF CANISTERS.

POWER:

1 TRANSFER CANISTER CONTAINS $\frac{1}{2}$ FUEL PIN @ 1.6 watts/Pin

$\therefore$ 0.8 watts /Transfer Canister

1 SHIPPING CANISTER CONTAINS 6 TRANSFER CANISTERS.

$\therefore$ 6 x 0.8 = 4.8 watts/Shipping Canister

SHIPPING CASK CONTAINS 13 SHIPPING CANISTERS.

$\therefore$ 13 x 4.8 = 62.4 watts /CASK

INNER 3 SHIPPING CANISTERS: 3 x 4.8 = 14.4 watts = 49 BTU/hr

OUTER 10 SHIPPING CANISTERS: 10 x 4.8 = 48.0 watts = 164 BTU/hr

TOTAL OF 13 SHIPPING CANISTERS: 13 x 4.8 = 62.4 watts = 213 BTU/hr

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It is assumed that the fuel material is concentrated in the center 1/3 of the transfer canisters. Since each transfer canister is 40 inches long, (see Fig. 2), it is assumed that the active fuel length is 12 inches. However, there is some axial transport of heat due to the gas circulation. As a simplifying assumption, the effective length (for heat transfer area) is taken to be 18 inches.

However, the cask wall is assumed to have good axial conduction, such that radial temperature differences are as calculated in DPSF-1 Supplement No. 1, Fig 22-28, - appropriated proportioned according to the power level.

See Figure 3 for the heat transfer schematic used in this calculation.

Natural Convection Coefficient Assumed:

$$h_{\substack{\text{NAT}\\\text{CONV}}} = 0.60 \frac{\text{BTU}}{\text{hr ft}^2\,^\circ\text{F}} \qquad (\text{Note: } .2(27)^{1/3} = 0.6)$$

Radiation Coefficient

$$h = 4\left(\frac{\epsilon}{2-\epsilon}\right)\sigma\left(\frac{T}{T_R}\right)^3$$

$$h = 4\left(\frac{.5}{1.5}\right)(1.713 \times 10^{-9})(460+175)^3$$

$$h_{RAD} = 0.6 \text{ BTU/hr ft}^2\,^\circ\text{F}$$

$$\therefore h_{EFF} \cong 1.2 \cdot \text{BTU/hr ft}^2\,^\circ\text{F}$$

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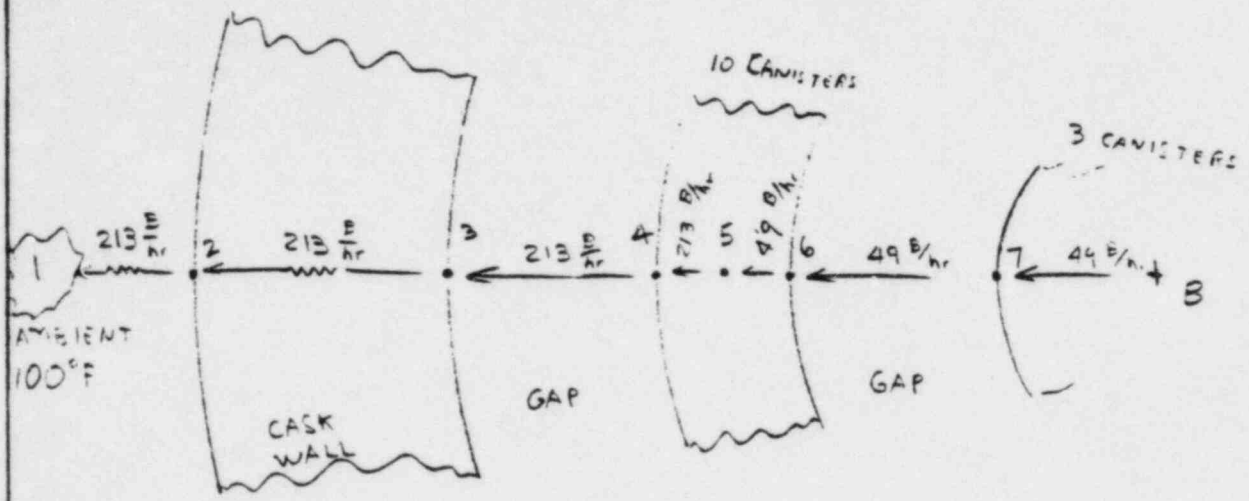

FIGURE 3

HEAT TRANSFER SCHEMATIC

POINT	
1	AMBIENT
2	CASK OUTER SURFACE
3	CASK INNER SURFACE
4	OUTER SURFACE, OUTER RING OF CANISTERS
5	FUEL IN OUTER RING OF CANISTERS
6	INNER SURFACE, OUTER RING OF CANISTERS
7	OUTER SURFACE OF INNER RING OF CANISTERS
8	FUEL IN INNER RING OF CANISTERS

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THERMAL PATH 2 → 1 CASK OUTER SURFACE → AMBIENT

From DPSPU-71-124-4A, Pg 25 (Ref 2)

For P = 1342 watts, $\Delta T_{(Surf \to Amb)} = 130°$

By Proportion,

For 62.4 watt (213 $\frac{BTU}{hr}$):

$$\Delta T' = \Delta T_o \left(\frac{P'}{P_o}\right) = 130\left(\frac{62.4}{1342}\right) = 6.0\ °F$$

To compensate for non-linearities, say $\Delta T = 10°F$

$\Delta T_{\text{cask outer surface} \to \text{ambient}} = 10°F$

$T_1 = 100°F$

$T_2 = 110°F$

THERMAL PATH 3 → 2 CASK INNER SURFACE → CASK OUTER SURFACE

From DPSPU-71-124-4A Pg 25 (Ref 2)

For P = 1342 watts, $\Delta T_{(\text{cask wall})} = 23°F$

By Proportion:

For 62.4 watts (213 $\frac{BTU}{hr}$):

$$\Delta T' = \Delta T_o \left(\frac{P'}{P_o}\right) = 23\left(\frac{62.4}{1342}\right) = 1.0°F$$

$\Delta T_{\text{Across Cask Wall}} = 1.0°F$

$\therefore T_3 = 111°F$

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APPROXIMATE TEMPERATURES; POINTS 1 THROUGH 7

THERMAL PATH	$Q\ \left(\frac{BTU}{hr}\right)$	HEAT TRANSFER SURFACE AREA (ft^2)	h_{eff} BTU/hr ft² °F	$\Delta T = \frac{Q}{hA}$ (°F)	TEMPERATURE (°F)
2 → 1	213			$\Delta T_{2\to1} = 10°$ SEE PREVIOUS PAGES	$T_1 = 100°$ $T_2 = 110°$
3 → 2	213			$\Delta T_{3\to2} = 1°$ SEE PREVIOUS PAGES	$T_3 = 111°$
4 → 3	213	$\pi DL = \pi\left(\frac{16.75}{12}\right)\left(\frac{18}{12}\right)$ 6.578	1.2	$\Delta T_{4\to3} = 27°$	$T_4 = 138°$
5 → 4	213	$NdL = 10\left(\frac{3.5}{12}\right)\left(\frac{18}{12}\right)$ 4.375	1.2	$\Delta T_{5\to4} = 41°$	$T_5 = 179°$
6 → 5	49	$N\left(\frac{\pi}{2}d\right)L = 3\left(\frac{\pi}{2}\right)\left(\frac{3.5}{12}\right)\left(\frac{18}{12}\right)$ 2.062	1.2	$\Delta T_{6\to5} = 20°$	$T_6 = 199°$
7 → 6	49	2.062	1.2	$\Delta T_{7\to6} = 20°$	$T_7 = 219°$

POINT 7
INNERMOST FUEL
$T_7 \cong 220°F$

[illegible] ~ 825°F [illegible]