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Page 1 of 1

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1	1	Safety: DW McNally		11-8-95	G2-02	SS Shiraga		11/8/95	G2-02	1	1
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Scientific Ecology Group, Inc., 3-82B Cask Safety Evaluation for Packaging

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Abstract: This safety evaluation for packaging (SEP) provides the analysis and authorization to transport high-activity waste from the 324 Facility to PUREX, using the SEG 3-82B Type B cask.

For the proposed campaign, the payload has larger quantities of radioactive material, is not fissile-exempt, and has higher decay heat loads than that specified by the 3-82B cask certificate of compliance. No changes will be made to the current design of the packaging.

Onsite transport of the package with the higher source term will be authorized by this SEP to demonstrate equivalent safety of the package, as specified in PNL-MA-81, *Hazardous Material Shipping Manual*.

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LIST OF TERMS

ALARA	as low as reasonably achievable
Btu/lb-°F	British thermal units per pound-degree Fahrenheit
Btu/h-in^3	British thermal units per hour-cubic inch
CFR	*Code of Federal Regulations*
CoC	Certificate of Compliance
DOT	U.S. Department of Transportation
gal	gallon
g/cm^3	grams per cubic centimeter
HAC	hypothetical accident condition
HIC	high-integrity container
ID	inside diameter
in.	inch
kg	kilogram
kCi	kilocurie
kPa	kilopascal
kW	kilowatt
ksi	1000-lb per square inch
lb/ft^3	pounds per cubic foot
LSA	low specific activity
m	meter
MCNP	Monte Carlo N-Particle (computer code)
mi/h	miles per hour
MPa	megapascal
mrem/h	millirems per hour
NCT	normal conditions of transport
NRC	U.S. Nuclear Regulatory Commission
NWVP	Nuclear Waste Vitrification Program
OD	outside diameter
PNL	Pacific Northwest Laboratory
PUREX	Plutonium-Uranium Extraction (Facility)
RLFCM	radioactive liquid-fed ceramic melter
SST	stainless steel
rem/h	rems per hour
SAR	safety analysis report
SEG	Scientific Ecology Group, Inc.
SEP	safety evaluation for packaging
WHC	Westinghouse Hanford Company

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SCIENTIFIC ECOLOGY GROUP, INC., 3-82B CASK SAFETY EVALUATION FOR PACKAGING

PART A: PACKAGE DESCRIPTION AND OPERATIONS

1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The Scientific Ecology Group, Inc. (SEG), 3-82B cask is a U.S. Nuclear Regulatory Commission (NRC)-certified cask for transport of Type B quantities of fissile-exempt radioactive waste. For the Pacific Northwest Laboratory (PNL) campaign to transport radioactive remote-handled waste from the 324 building to the Plutonium-Uranium Extraction (PUREX) Facility, it was determined that the 3-82B cask is the most economic and safest means for transport of the waste within the Hanford Site. PNL leases the 3-82B cask from SEG and routinely uses it for waste shipments in accordance with its NRC Certificate of Compliance (CoC) USA/6574/B( ).

For the proposed campaign, the payload has larger quantities of radioactive material, is not fissile-exempt, and has higher decay heat loads than those specified by the 3-82B cask CoC. No changes will be made to the current design of the packaging.

Onsite transport of the package with the higher source term will be authorized by this safety evaluation for packaging (SEP) to demonstrate equivalent safety of the package, as specified in PNL-MA-81, *Hazardous Material Shipping Manual*.

1.2 SYSTEM DESCRIPTION

1.2.1 Packaging

The 3-82B cask packaging consists of a steel-lead-steel annulus cask, fabricated in the form of a right circular cylinder, and two nested inner containers. The shielded cask, closed at one end with a lid closure at the other, is 168.28-cm (66.25-in.) outside diameter (OD) by 189.23-cm (74.5-in.) outside height. The cask wall consists of a 0.95-cm (0.375-in.) inner steel shell, 9.53 cm (3.75 in.) of lead, and a 2.54-cm (1-in.) outer steel shell. A steel flange connects the two shells. The outer shell is surrounded by a 2.54-cm (1-in.) layer of insulating material and canned in 11-gauge steel.

Two nested inner containers are placed in the cavity of the cask for the purposes of handling the payload. The outer container is a 3-82B liner; the inner container is a 3-82B grout container. The payload is placed directly in the 3-82B grout container in a rack, pails, drums, or grout.

The lid, sealed by a silicone gasket, is bolted to the cask body. A cylindrical shield plug is located in the center of the cask lid. Lifting and tiedown devices are attached to the cask body. Impact skirts, consisting of removable rings of shock-absorbing foam, are attached to the ends of the cask. Gross weight of the package is 22,680 kg (50,000 lb).

Further information regarding the configuration of the packaging is available in *Safety Analysis Report for the 3-82B Radwaste Shipping Cask* (SEG 1991), which provides the analytical basis for the package CoC. Reference drawings are available in Part A, Section 10.0, of this SEP.

1.2.2 Transport

The 3-82B cask will be transported by rail, using a similar tiedown system to that used by SEG for highway transport.

1.3 REVIEW AND UPDATE CYCLES

This SEP will expire upon completion of the shipping campaign for the payload defined herein or within one year of issuance, whichever is first.

2.0 PACKAGING SYSTEM

The following sections describe the 3-82B cask. No design changes are being made to the cask or tiedown system; thus, its current Type B performance documented by SEG (1991) is unaffected. Therefore, the following sections are cursory, to provide sufficient information to describe the cask for review of this SEP. Detailed information is available in SEG (1991) and on the reference drawings of the 3-82B cask and inner containers found in Part A, Section 10.0, of this SEP.

2.1 CONFIGURATION AND DIMENSIONS

The 3-82B cask configuration consists of a steel-lead-steel annulus right circular cylinder, welded closed at one end with a lid closure at the other end. The cask is 168.28-cm (66.25-in.) OD by 189.23-cm (74.5-in.) outside height.

The cask wall consists of a 0.95-cm (0.375-in.) inner steel shell, 9.53 cm (3.75 in.) of lead, and a 2.54-cm (1-in.) outer steel shell. A steel flange connects the two shells. The outer shell is surrounded by a 2.54-cm (1-in.) layer of insulating material and canned in 11-gauge steel. The annulus of the cask is 137.16 cm (54 in.) in diameter by 157.8 cm (62.125 in.) high. The 3-82B liner fits within the cask annulus, as described previously in Section 1.2.1.

The lid, sealed by a silicone gasket, is bolted to the cask body. A cylindrical shield plug is located in the center of the cask lid. Lifting and

tiedown devices are attached to the cask body. Impact skirts, consisting of removable rings of shock-absorbing foam, are attached to the ends of the cask. Overall dimensions of the 3-82B cask, with impact limiters, is 257.18 cm (101.25 in.) in diameter by 288.93 cm (113.75 in.) high.

2.2 MATERIALS OF CONSTRUCTION

Steel shells:	ASTM A516 Grade 55
Lead shielding:	ASTM B29
Impact limiter:	General Plastics Last-A-Foam FR-3718.25 with a density of approximately 292.3 kg/m^3 (18.25 lb/ft^3)
Bolts:	ASTM A320 and ASTM A354
Gaskets:	Silicone, with operating temperature limit of 204.4 °C (400 °F)

2.3 WEIGHTS AND CENTER OF GRAVITY

The total weight of the package is 22,680 kg (50,000 lb), and the unloaded weight is 18,962 kg (41,805 lb), giving an allowable weight of 3,717 kg (8,195 lb) for the contents. The center of gravity of the 3-82B package is located approximately at the geometric center of the package.

2.4 CONTAINMENT BOUNDARY

The majority of the 3-82B cask containment boundary is defined by its inner steel shell, connected to the outer shell by a welded flange at the top of the cask. The remainder of the containment boundary consists of the bolted joint between the cask body and the cask lid, and the bolted joint between the cask lid and the shield plug. These joints are sealed by circumferential silicone gasket seals loaded in compression by bolt tension.

2.5 SHIELDING

Shielding is provided by a total of 3.49-cm (1.375-in.) steel and 9.53-cm (3.75-in.) lead on the sides, 7.62-cm (3-in.) steel and 6.03-cm (2.375-in.) lead on the bottom, and 6.35-cm (2.5-in.) steel and 6.35-cm (2.5-in.) lead in the lid shield plug.

2.6 LIFTING DEVICES

Three equally spaced lifting lugs are welded to the upper steel flange and the outer steel shell of the cask body. A special cask lifting frame is utilized to engage the three cask lifting lugs. This frame ensures that only vertical loads are sustained by the cask lifting lugs when the lifting frame is lifted by a crane. The lifting system for the cask lid consists of three circumferential lifting lugs equally spaced and welded to three of the head stiffener bars. The lifting system for the shield plug consists of a single-clevis pin-type shackle assembly attached to a lifting eye that is welded to the center of the outer steel plate of the shield plug.

2.7 TIEDOWN DEVICES

The tiedown devices consist of four identical lengths of cable, which are secured to the transporter body and the four cask tiedown lugs. The lugs have a working strength of 113,398 kg (250,000 lb). Kickblocks hold the cask bottom relative to the flatcar bed.

3.0 PACKAGE CONTENTS

The following describes the contents authorized by this SEP.

3.1 GENERAL DESCRIPTION

For the purposes of this SEP, the payload for the SEG 3-82B cask is defined in Jarrett (1995). The payload consists of remote-handled transuranic waste, remote-handled mixed waste, special-case waste, and high-level waste, including vitrified waste canisters from the 324 Facility B-Cell. The waste will be divided among approximately 15, 3-82B liners.

3.2 RADIOACTIVE MATERIAL

The worst-case heat load will be 2.1 kW with an associated radioactive inventory totaling 751 kCi (Part B, Section 2.0, Table B-1).

The worst-case fissile load will be no greater than 30 g of fissile (Part B, Section 2.0, Table B-2).

All other liners will be within the envelope defined above. Liners with a heat load equal to or less than 60 W shall be shipped in accordance with the cask's NRC CoC USA/6574/B( ).

4.0 TRANSPORT SYSTEM

4.1 TRANSPORTER

Transport will be by railroad flatcar with a 90,718-kg (200,000-lb) load capacity.

4.2 TIEDOWN SYSTEM

The material strengths and angles of the cable tiedown system shall be the same as that used by SEG for highway transport. Description and analysis of the tiedown system is available in SEG (1991). Evaluation of the tiedown system is in Part B, Section 10.0.

The tiedown system that is currently used on the SEG trailer will be matched on the railcar. The only difference between the trailer and the railcar system is that the trailer uses a shear ring to secure the bottom of the cask, whereas the railcar uses a kickblock system (see drawings in Part A, Section 10.0).

4.3 SPECIAL TRANSFER REQUIREMENTS

4.3.1 General

Transport of the 3-82B cask shall be in accordance with PNL-MA-81, *Hazardous Material Shipping Manual.*

4.3.2 Routing and Access Control

Transport of the package will be by rail from the 300 Area to the PUREX Facility in the 200 East Area. The route may include turnaround of the train in the 1100 Area.

All railroad crossings will be barricaded to prevent public access to the train and to prevent possible collisions with other vehicles. Also, all access roads to the rail line south of the Wye Barricade shall be cleared and closed during the shipment to prevent public access.

4.3.3 Radiological Limitations

The radial dose rates from the package shall not exceed 1,000 mrem/h on the exterior surface of the package and 10 mrem/h at a distance of 2 m from the package. Worst-case analysis (Part B, Section 5.0) indicates that the axial dose rate (cask top and bottom) may exceed the limit of 10 mrem/h at 2 m, but should not be higher than 50 mrem/h at 2 m. Because the axial dose rates may be higher than the U.S. Department of Transportation (DOT) limits, loading and unloading procedures will be performed following as low as reasonably achievable (ALARA) precautions and HSRCM-1, *Hanford Site Radiological Control Manual.*

Dose rate to the locomotive occupants shall be maintained at less than 2 mrem/h. As necessary to meet this limit, distance from the loaded cask shall be maximized by appropriate orientation of the locomotive, railcar, and cask or by the use of spacer cars.

4.3.4 Contamination Limits

Contamination on all exterior surfaces of the 3-82B cask shall be held to the limits DOT 49 CFR 173.443.

4.3.5 Speed Limitations

The railcar speed shall not exceed 40 km/h (25 mi/h) on the route or 8 km/h (5 mi/h) on facility spurs. No humping is permitted when the 3-82B cask is loaded on the railcar.

4.3.6 High-Heat Payload Warning

For high-heat payloads (greater than 2 kW), transportation workers shall be made aware that the surface temperature of the cask may reach 148.9 °C (300 °F), in excess of the DOT limit of 82.2 °C (180 °F). Precautions shall be taken to prevent burns.

5.0 ACCEPTANCE OF PACKAGE FOR USE

The 3-82B cask is leased from SEG. The cask is in service, and no new casks are anticipated to be built. As specified in SEG (1991), no acceptance tests are applicable.

6.0 OPERATING REQUIREMENTS

6.1 GENERAL REQUIREMENTS

1. The approved SEP shall be the controlling document for the shipment of 324 Facility material, as defined in Part A, Section 3.0. The approved SEP shall be valid for one year from the date of release.

2. All applicable instructions and procedures for onsite shipment of radioactive material shall comply with PNL-MA-81.

3. All applicable procedures outlined in Chapter 7.0 of SEG (1991) for loading, unloading, and preparing an empty cask for shipment shall be followed. Transport shall be in accordance with Part A, Section 4.0, of this SEP.

4. The 3-82B cask system (including tiedown system) shall not be altered or revised without the concurrence of WHC Packaging Engineering and SEG.

6.2 SPECIFIC REQUIREMENTS

1. When loading the 3-82B grout container, the payload shall be placed in a rack, pails, drums, or grout. The payload shall be secured to minimize movement inside the 3-82B grout container. Additional shielding and dunnage may be added, if necessary, within the gross weight limit of 22,680 kg (50,000 lb) for the 3-82B cask. For

high-heat payloads (greater than 2 kW), materials used for dunnage shall be noncombustible. Ensure that the 3-82B liner lid polyethylene pipe plug is replaced with a carbon composite high-efficiency particulate air filter.

2. For high-heat payloads (greater than 2 kW), operators shall be made aware that the surface temperature of the cask may reach 148.9 °C (300 °F), in excess of the DOT limit of 82.2 °C (180 °F). Precautions shall be taken to prevent burns.

3. For high-heat payloads (greater than 2 kW), replace the 3-82B cask silicone gaskets after each shipment and leak test in accordance with SEG (1991).

7.0 QUALITY ASSURANCE PROGRAM

Quality assurance requirements related to using the 3-82B cask (e.g., operations and maintenance) will be based on PNL's hazardous material shipping program. PNL is responsible for complying with the operating and maintenance requirements of SEG (1991). PNL will package and ship in compliance with a PNL safe operating procedure based on SEG (1991) and PNL-MA-81, Section 3.0.

8.0 MAINTENANCE

Maintenance, including periodic testing, of the 3-82B cask shall be in accordance with Chapter 8.0 of SEG (1991).

9.0 REFERENCES

10 CFR 71, 1994, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

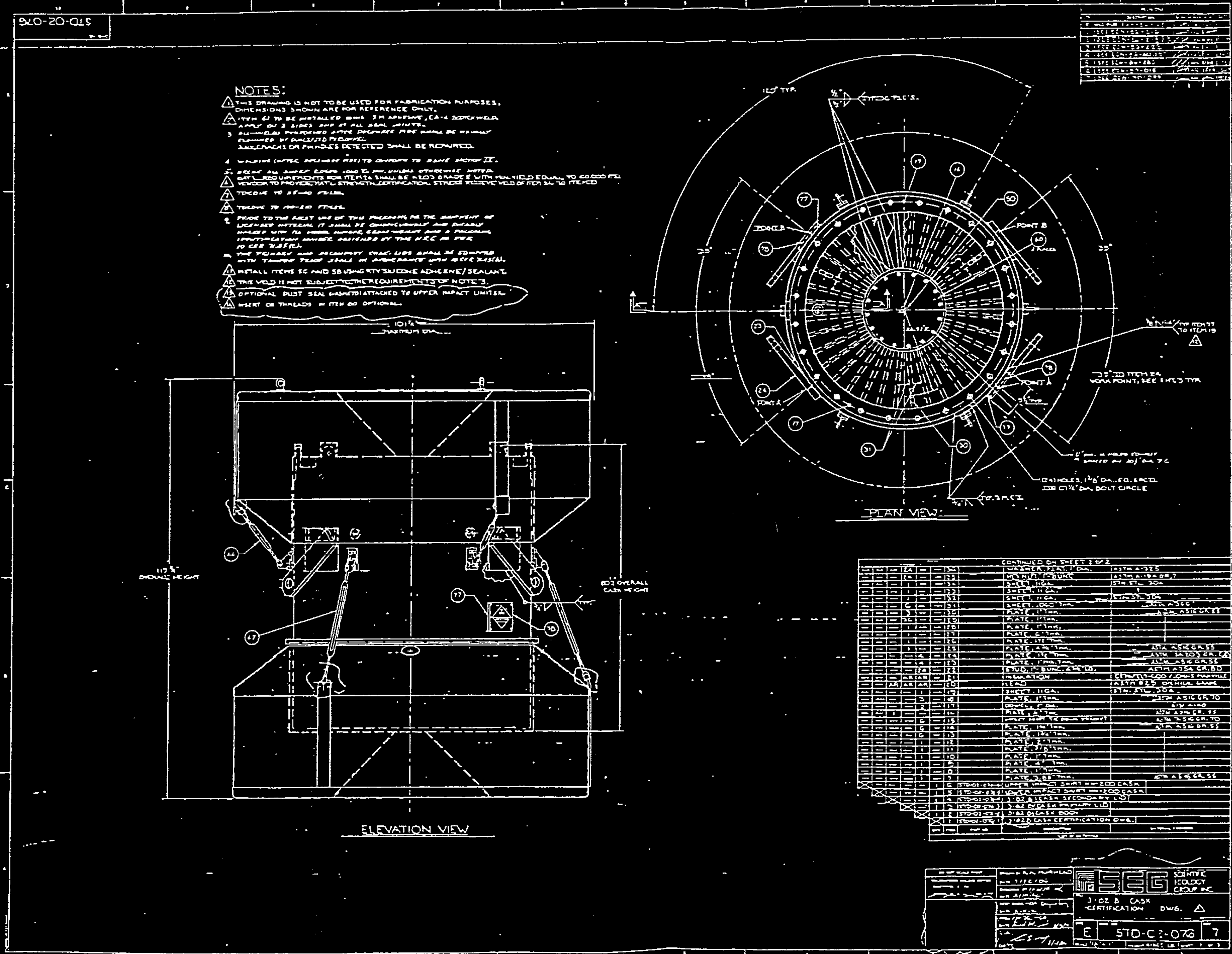
49 CFR 173, 1994, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Jarrett, J., 1995, *Technical Base for SEP and SARP* (memo to J. G. Field, Westinghouse Hanford Company, October 17), Pacific Northwest Laboratories, Richland, Washington.

PNL-MA-81, *Hazardous Material Shipping Manual*, Pacific Northwest Laboratory, Richland, Washington.

SEG, 1991, *Safety Analysis Report for the 3-82B Radwaste Shipping Cask*, STD-R-2-014, Scientific Ecology Group, Inc., Oak Ridge, Tennessee.

10.0 APPENDIX: DRAWINGS



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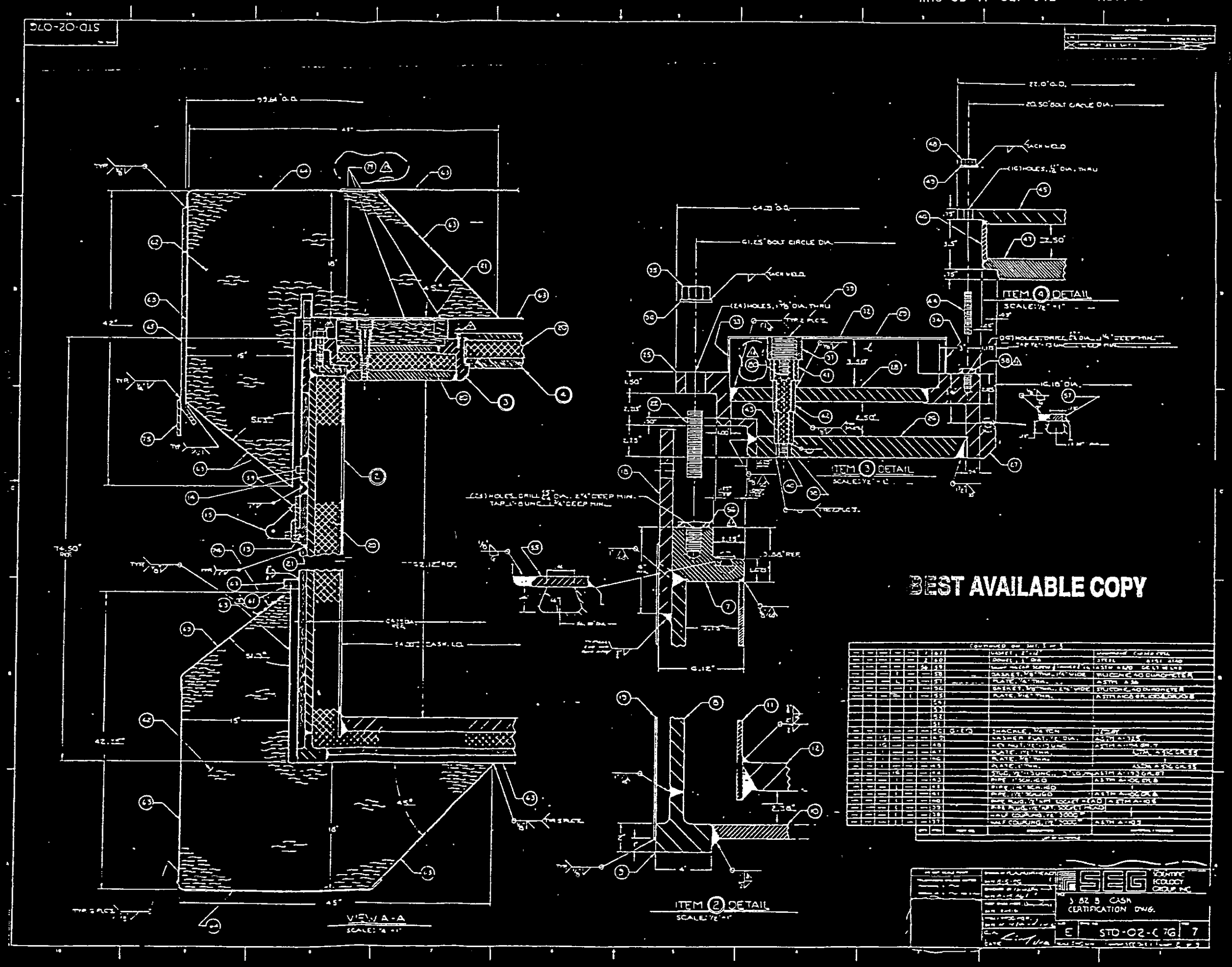
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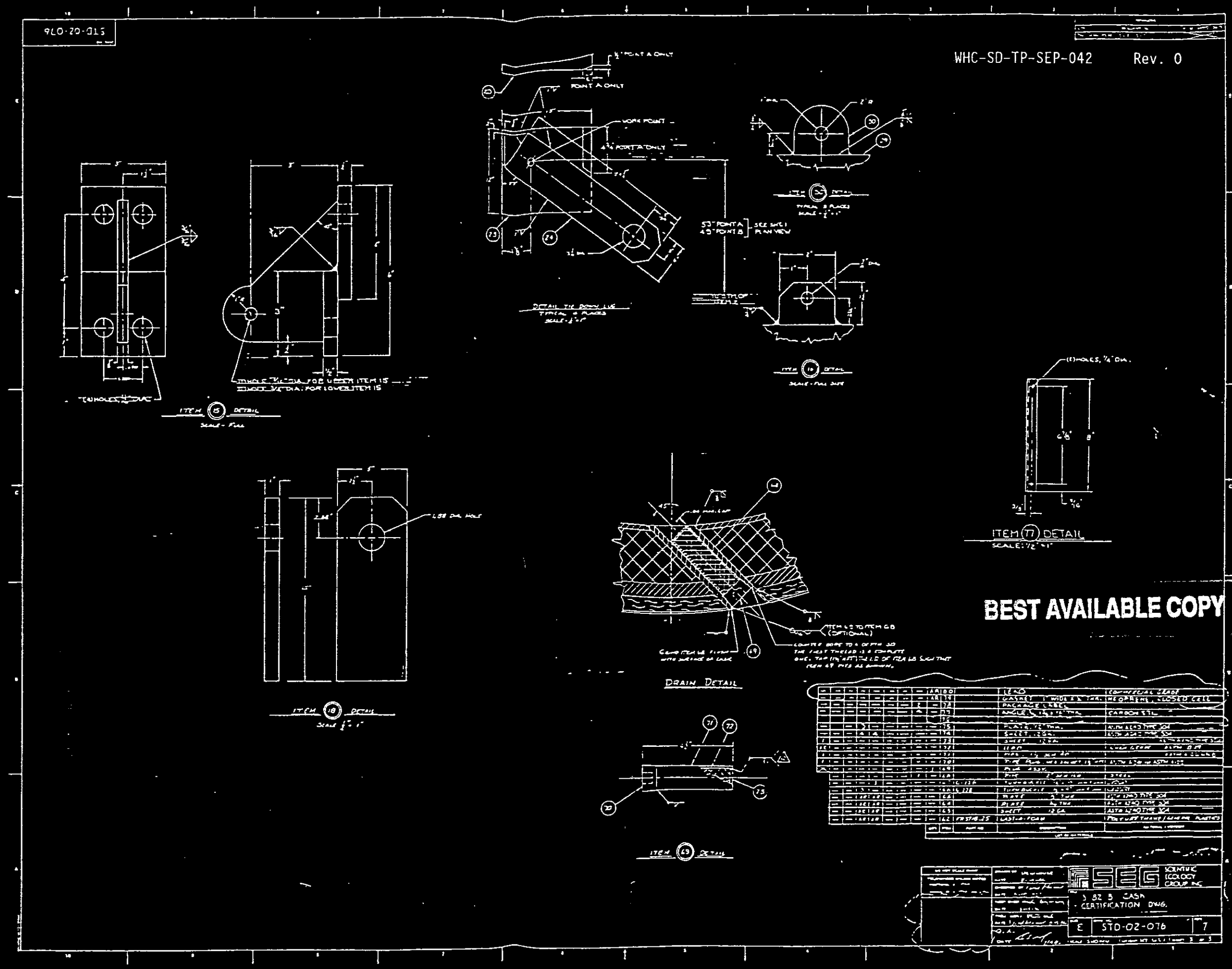
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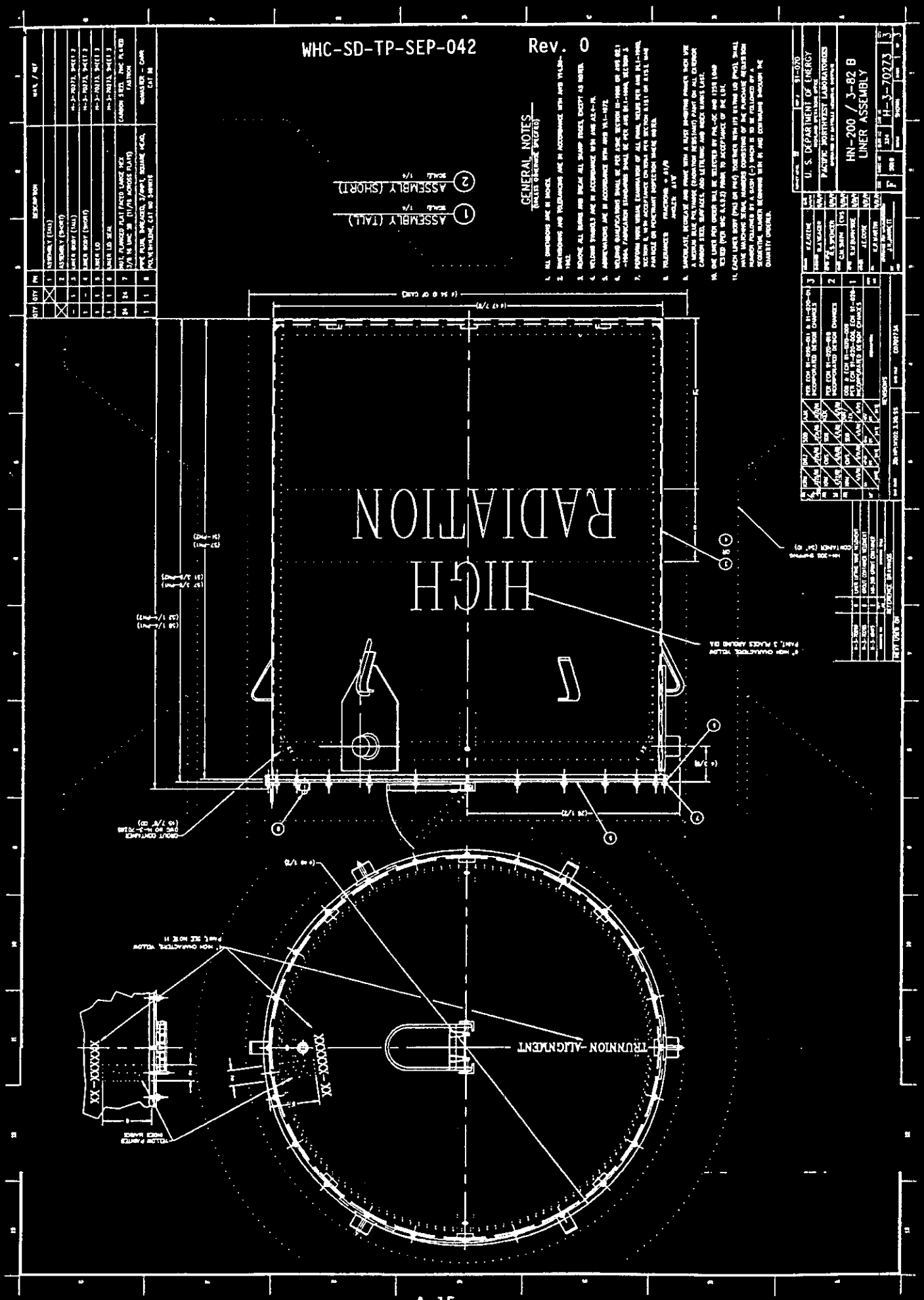
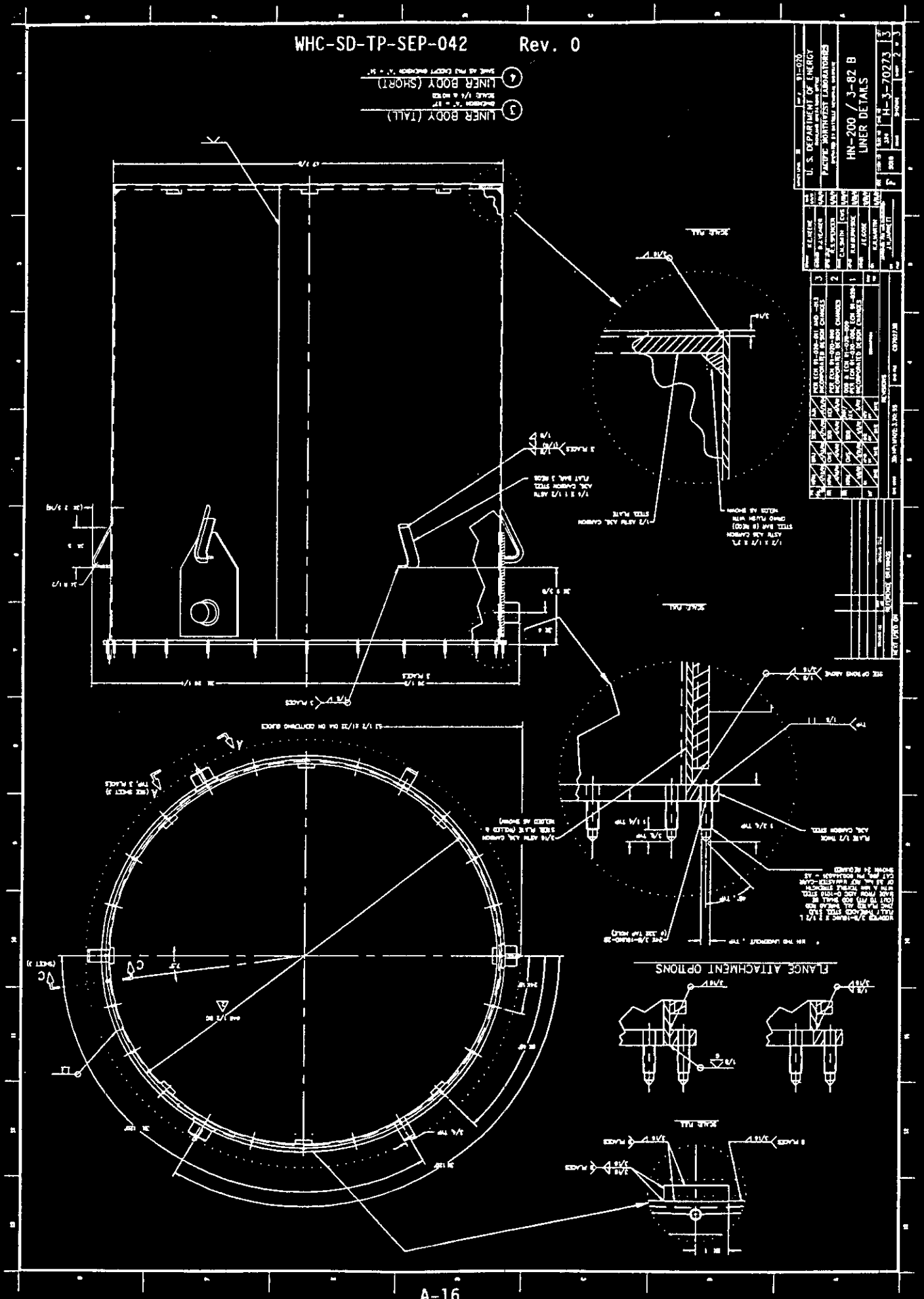
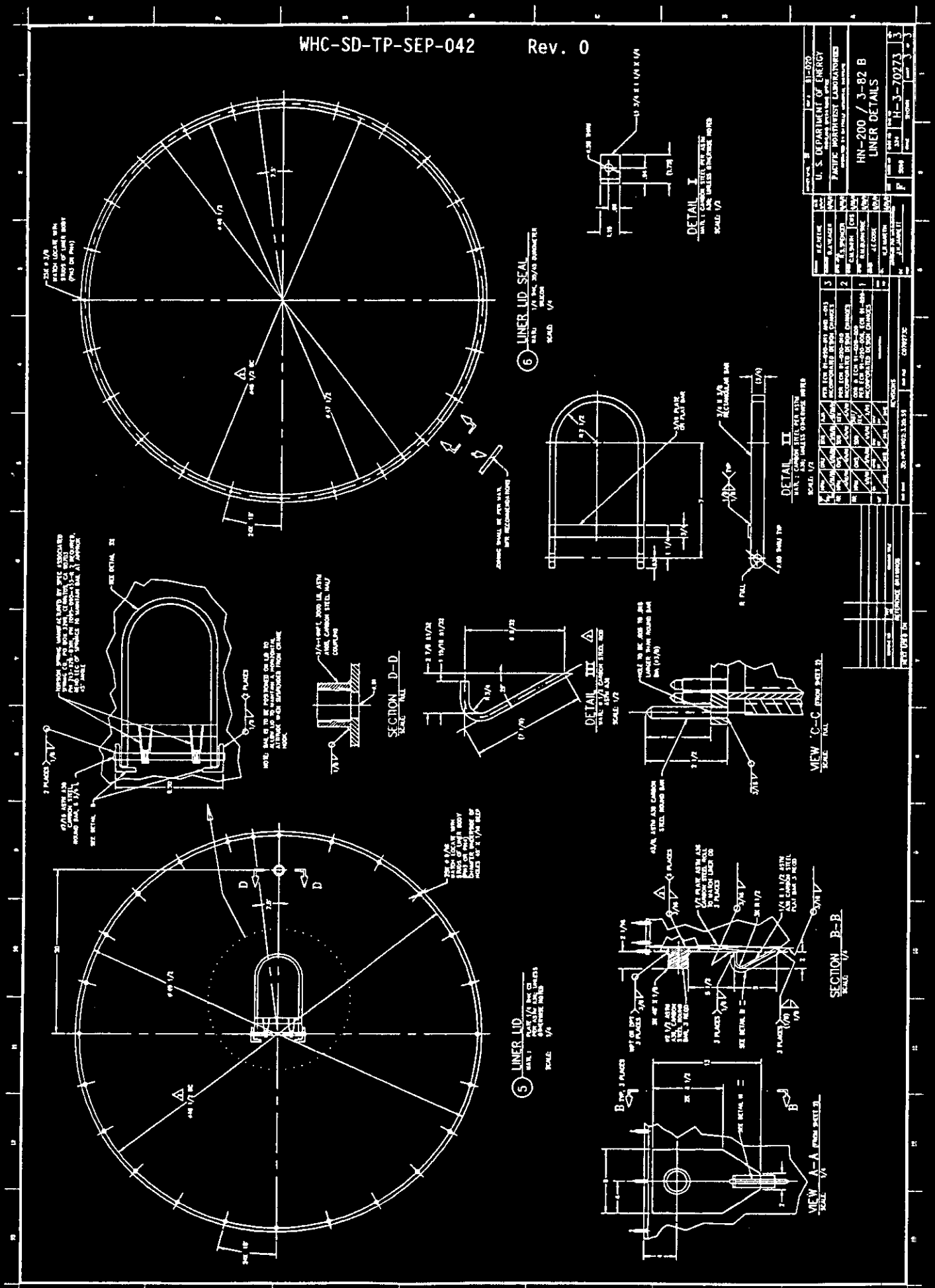
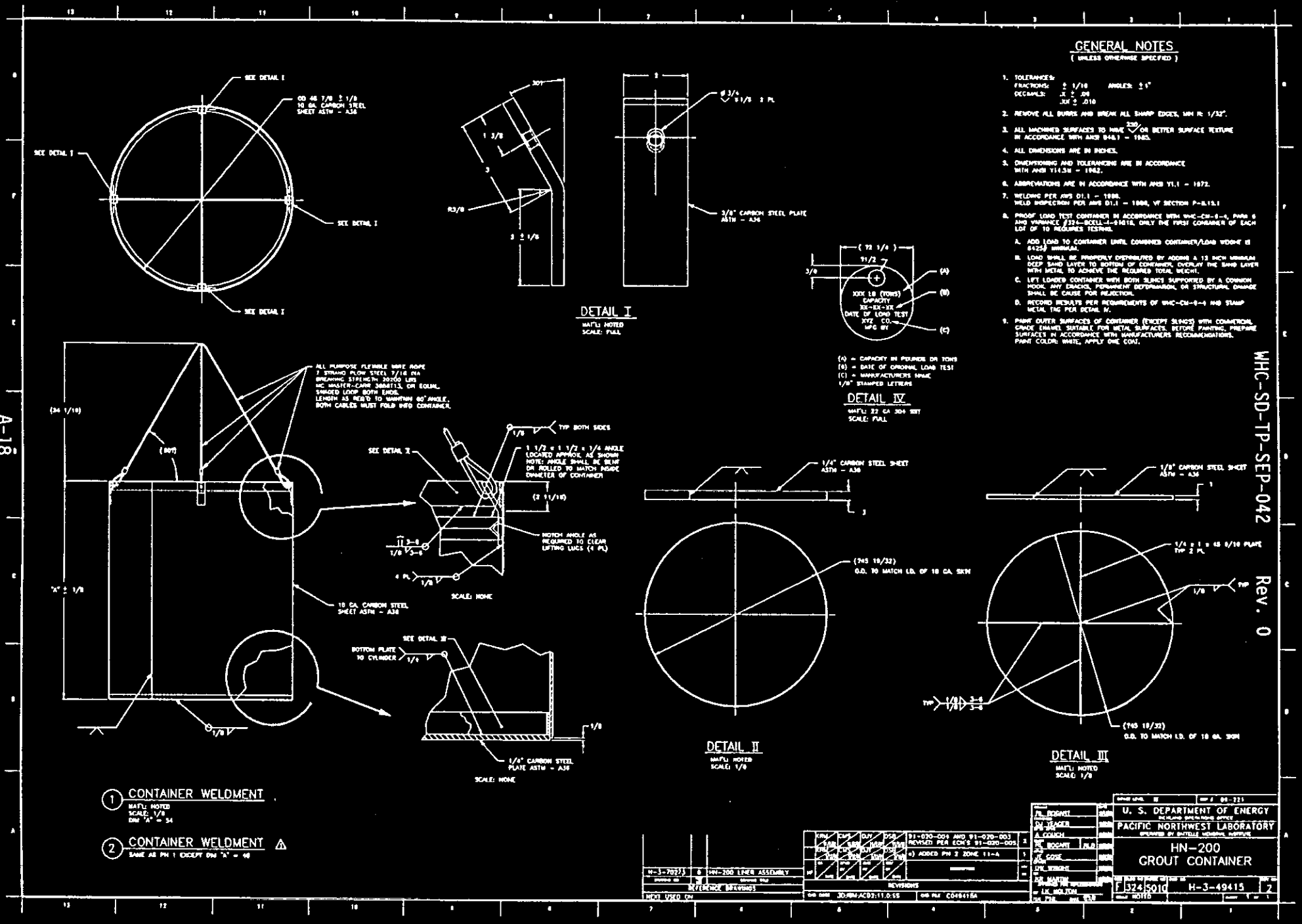
DRAIN DETAIL
ITEM 69 DETAIL
ITEM 77 DETAIL
SCALE: 1/2" = 1"
BEST AVAILABLE COPY
SCIENTIFIC ECOLOGY GROUP INC
CERTIFICATION DWG.
STD-02-076


HIGH RADIATION
TRUNNION ALIGNMENT
GENERAL NOTES
ASSEMBLY (TALL)
ASSEMBLY (SHORT)
U. S. DEPARTMENT OF ENERGY
PACIFIC NORTHWEST LABORATORIES
HN-200 / J-82 B
LINER ASSEMBLY
H-3-70273


U. S. DEPARTMENT OF ENERGY
PACIFIC NORTHWEST LABORATORIES
HN-200 / 3-82 B
LINER DETAILS
H-3-70273
LINER BODY (TALL)
LINER BODY (SHORT)
FLANGE ATTACHMENT OPTIONS


U. S. DEPARTMENT OF ENERGY
PACIFIC NORTHWEST LABORATORIES
HN-200 / 3-82 B
LINER DETAILS
H-3-70273
LINER LID SEAL
DETAIL I
DETAIL II
DETAIL III
SECTION D-D
LINER LID
SECTION B-B
VIEW C-C
VIEW A-A

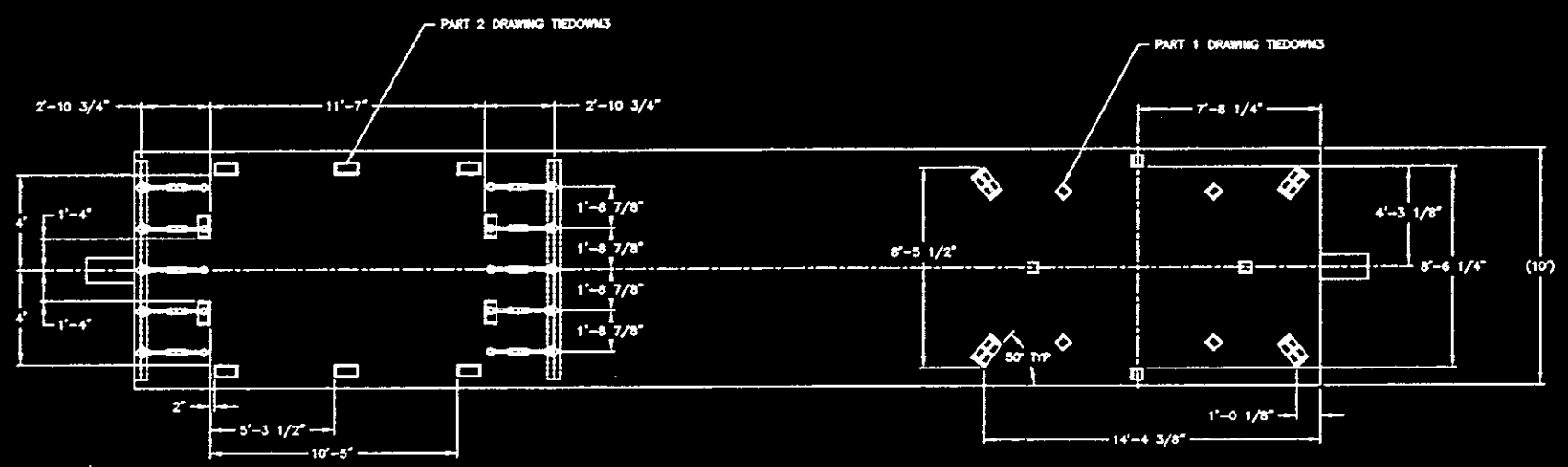

GENERAL NOTES
(UNLESS OTHERWISE SPECIFIED)
1. TOLERANCES:
FRACTIONS: ± 1/16 ANGLES: ± 1°
DECIMALS: .X ± .06
.XX ± .010
2. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES, MIN R: 1/32".
3. ALL MACHINED SURFACES TO HAVE 250 OR BETTER SURFACE TEXTURE IN ACCORDANCE WITH ANSI B46.1 - 1985.
4. ALL DIMENSIONS ARE IN INCHES.
5. DIMENSIONING AND TOLERANCING ARE IN ACCORDANCE WITH ANSI Y14.5M - 1982.
6. ABBREVIATIONS ARE IN ACCORDANCE WITH ANSI Y1.1 - 1972.
7. WELDING PER AWS D1.1 - 1988.
WELD INSPECTION PER AWS D1.1 - 1988, VT SECTION P-8.15.1
8. PROOF LOAD TEST CONTAINER IN ACCORDANCE WITH WHC-CM-8-4, PARA 8 AND VARIANCE #32-RCRA-2-91018, ONLY THE FIRST CONTAINER OF EACH LOT OF 10 REQUIRES TESTING.
A. ADD LOAD TO CONTAINER UNTIL COMBINED CONTAINER/LOAD WEIGHT IS 64250# MINIMUM.
B. LOAD SHALL BE PROPERLY DISTRIBUTED BY ADDING A 12 INCH MINIMUM DEEP SAND LAYER TO BOTTOM OF CONTAINER, OVERLAY THE SAND LAYER WITH METAL TO ACHIEVE THE REQUIRED TOTAL WEIGHT.
C. LIFT LOADED CONTAINER WITH BOTH SLINGS SUPPORTED BY A COMMON HOOK. ANY CRACKS, PERMANENT DEFORMATION, OR STRUCTURAL CHANGE SHALL BE CAUSE FOR REJECTION.
D. RECORD RESULTS PER REQUIREMENTS OF WHC-CM-8-4 AND STAMP METAL TAG PER DETAIL IV.
9. PAINT OUTER SURFACES OF CONTAINER (EXCEPT SLINGS) WITH COMMERCIAL GRADE ENAMEL SUITABLE FOR METAL SURFACES. BEFORE PAINTING, PREPARE SURFACES IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS. PAINT COLOR: WHITE, APPLY ONE COAT.
SEE DETAIL I
OD 46 7/8 ± 1/8
10 GA CARBON STEEL SHEET ASTM - A36
DETAIL I
MAT'L: NOTED
SCALE: FULL
3/8" CARBON STEEL PLATE ASTM - A36
(A) = CAPACITY IN POUNDS OR TONS
(B) = DATE OF ORIGINAL LOAD TEST
(C) = MANUFACTURERS NAME
1/8" STAMPED LETTERS
DETAIL IV
MAT'L: 22 GA 304 SST
SCALE: FULL
ALL PURPOSE FLEXIBLE WIRE ROPE
7 STRAND PLOW STEEL 7/16 DIA
BREAKING STRENGTH 30200 LBS
MC MASTER-CARR 3884T13, OR EQUAL
SWAGED LOOP BOTH ENDS
LENGTH AS REQ'D TO MAINTAIN 60° ANGLE
BOTH CABLES MUST FOLD INTO CONTAINER
SEE DETAIL II
1 1/2 x 1 1/2 x 1/4 ANGLE LOCATED APPROX. AS SHOWN NOTE: ANGLE SHALL BE BENT OR ROLLED TO MATCH INSIDE DIAMETER OF CONTAINER
NOTCH ANGLE AS REQUIRED TO CLEAR LIFTING LUGS (4 PL)
SCALE: NONE
10 GA CARBON STEEL SHEET ASTM - A36
SEE DETAIL III
BOTTOM PLATE TO CYLINDER
1/4" CARBON STEEL PLATE ASTM - A36
SCALE: NONE
1/4" CARBON STEEL SHEET ASTM - A36
(745 19/32)
O.D. TO MATCH I.D. OF 10 GA. SKIN
DETAIL II
MAT'L: NOTED
SCALE: 1/8
1/8" CARBON STEEL SHEET ASTM - A36
1/4 x 1 x 45 9/16 PLATE TYP 2 PL
(745 19/32)
O.D. TO MATCH I.D. OF 10 GA. SKIN
DETAIL III
MAT'L: NOTED
SCALE: 1/8
(34 1/16)
"X" ± 1/8
1/8
CONTAINER WELDMENT
MAT'L: NOTED
SCALE: 1/8
DWG "X" = 34
CONTAINER WELDMENT
SAME AS PN 1 EXCEPT DWG "X" = 46
H-3-70273 B HN-200 LINER ASSEMBLY
REFERENCE DRAWINGS
NEXT USED ON
REVISIONS
91-070-004 AND 91-070-003 REVISED PER ECN'S 91-070-005
A) ADDED PN 2 ZONE 11-A
U. S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
PACIFIC NORTHWEST LABORATORY
OPERATED BY BATTELLE MEMORIAL INSTITUTE
HN-200
GROUT CONTAINER
F 32450 10
H-3-49415
WHC-SD-TP-SEP-042
Rev. 0
A-18

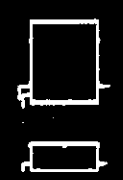
GENERAL NOTES
(UNLESS OTHERWISE SPECIFIED)

1. ALL MATERIAL SHALL BE AS SPECIFIED OR AN APPROVED EQUAL QUALITY.
2. ABBREVIATIONS ARE IN ACCORDANCE WITH ANSI Y1.1-1972.
3. DIMENSIONING AND TOLERANCING ARE PER ANSI Y14.5M-1982.
4. ALL DIMENSIONS ARE IN INCHES.

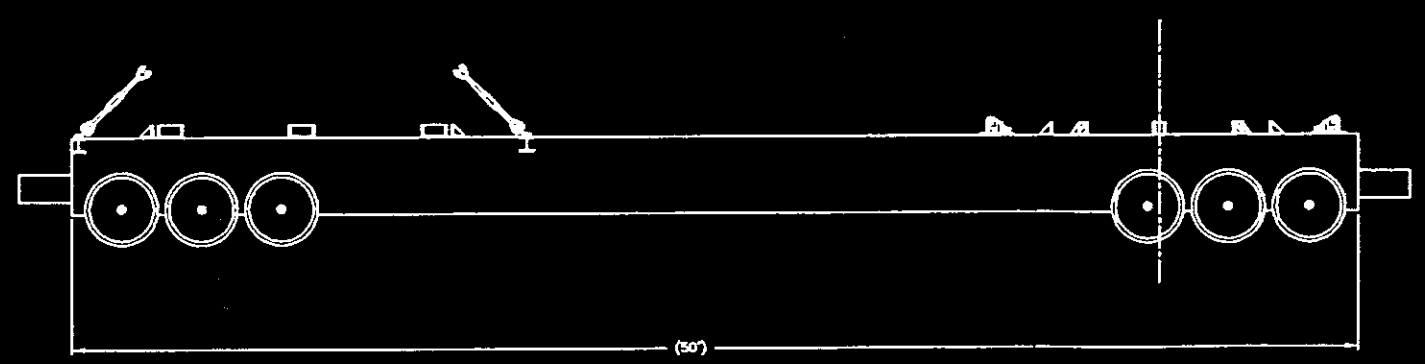
TOLERANCES:		
	DECIMAL X	+/- .06
	XX	+/- .03
	FRACTIONS X/X	+/- 1/16
	ANGLES	+/- 0° -30'

5. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS.
6. ALL MACHINED SURFACES SHALL BE 250√ OR BETTER IN ACCORDANCE WITH ANSI B46.1-1978.





THE CONTROL BOX WILL BE POSITIONED LATER



APPROVED FOR CONSTRUCTION

R.L. Bogart 10-12-95

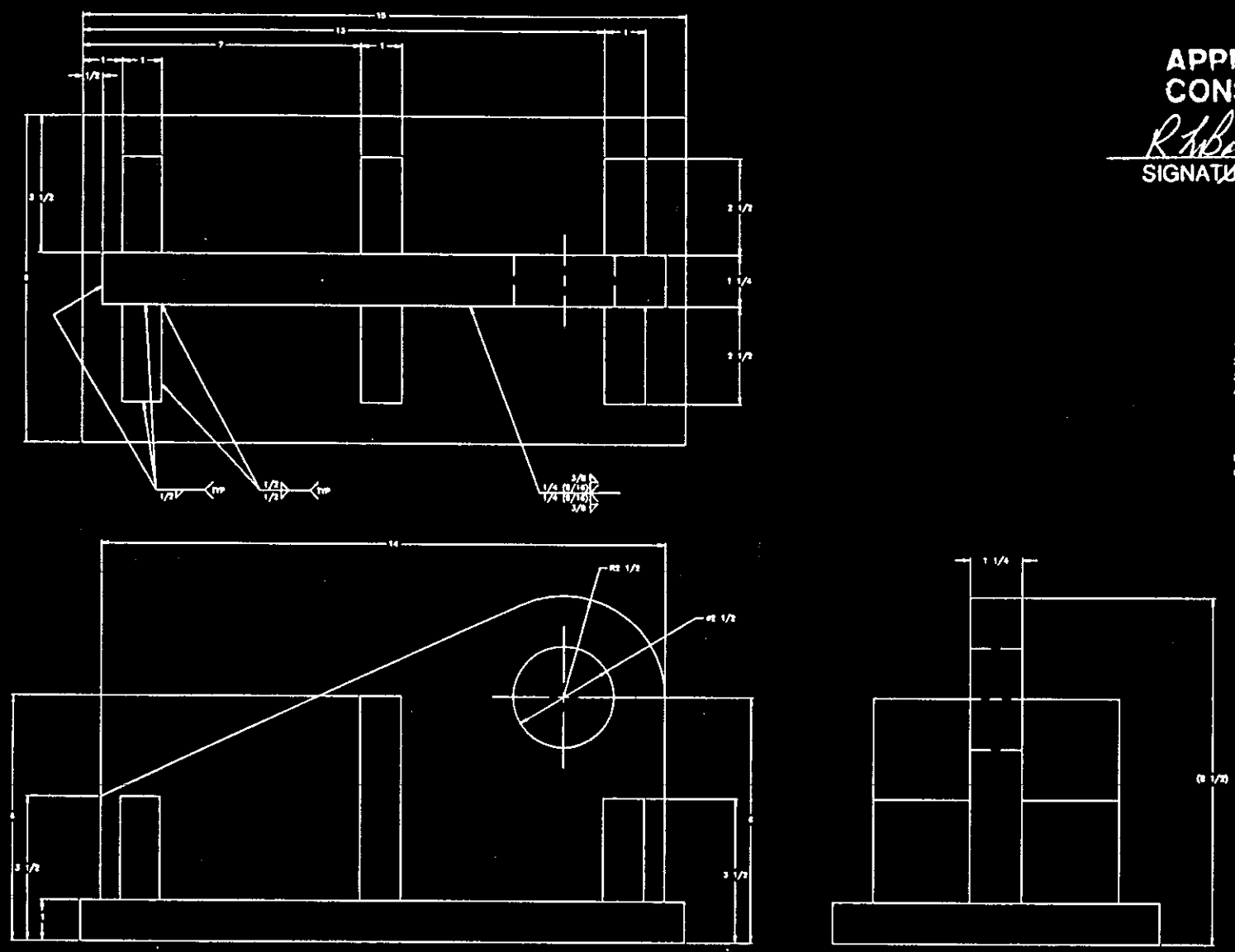
SIGNATURE DATE

DRAWN RL BOGART	U. S. DEPARTMENT OF ENERGY RICHLAND OPERATIONS OFFICE
	PACIFIC NORTHWEST LABORATORY OPERATED BY BATTELLE MEMORIAL INSTITUTE
	SEG CASK AND 22 TON SHIPPING BOX TIE-DOWN ARRANGEMENT
	B CELL CLEANOUT
SIZE F	PROJECT NO 5010 · SYSTEM NO 300G · TIEDOWN4 · REV NO 0
	SCALE 3/8"=1'-0" · SHEET 1 OF 1

REFERENCE DRAWINGS — NEXT USED ON

REVISIONS — CADFILE TIEDOWN4

A-19/20



1 TIEDOWN WELDMENT
SCALE: FULL
MAT'L: 304 OR 304L SST ASTM A240

APPROVED FOR CONSTRUCTION

R L Boyd 10-12-95
SIGNATURE DATE

GENERAL NOTES

(UNLESS OTHERWISE SPECIFIED)

1. ALL MATERIAL SHALL BE AS SPECIFIED OR AN APPROVED EQUAL QUALITY.
2. ABBREVIATIONS ARE IN ACCORDANCE WITH ANSI Y1.1-1972.
3. DIMENSIONING AND TOLERANCING ARE PER ANSI Y14.5M-1982.
4. ALL DIMENSIONS ARE IN INCHES.

TOLERANCES:	DECIMAL	.X	+/- .06
		.XX	+/- .03
	FRACTIONS	X/X	+/- 1/16
	ANGLES		+/- 0° -30'

5. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS.
6. ALL MACHINED SURFACES SHALL BE 250/ OR BETTER IN ACCORDANCE WITH ANSI B46.1-1978.

U. S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
PACIFIC NORTHWEST LABORATORY
OPERATED BY BATTELLE MEMORIAL INSTITUTE

SEG CASK
AND IMPACT LIMITER
TIEDOWN WELDMENT

B CELL CLEANOUT

F 5010 3000 TIEDOWN1 0

SCALE FULL SHEET 1 OF 1

REVISIONS

REFERENCE DRAWINGS

NEXT USED ON

DRAWING 3D:IBM:AC02:13.0:S3 CAPTURE TIEDOWN1

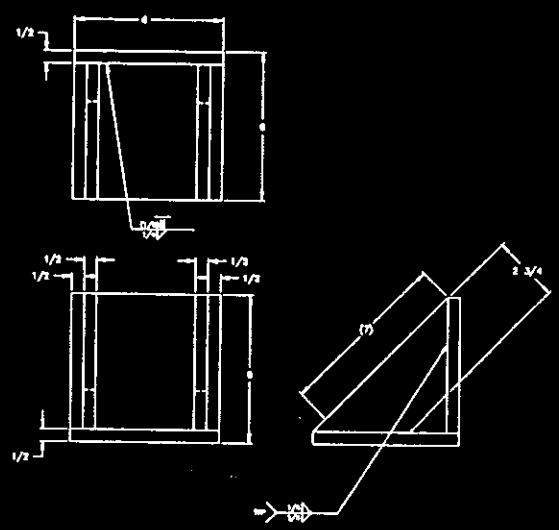
GENERAL NOTES

(UNLESS OTHERWISE SPECIFIED)

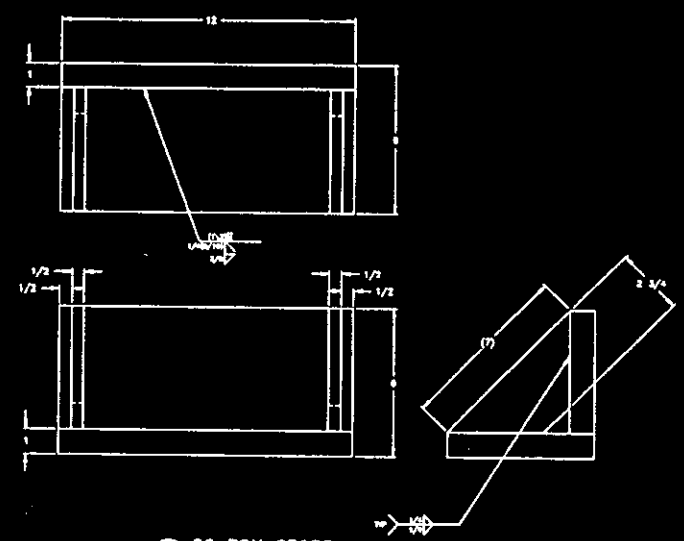
1. ALL MATERIAL SHALL BE AS SPECIFIED OR AN APPROVED EQUAL QUALITY.
2. ABBREVIATIONS ARE IN ACCORDANCE WITH ANSI Y1.1-1972.
3. DIMENSIONING AND TOLERANCING ARE PER ANSI Y14.5M-1982.
4. ALL DIMENSIONS ARE IN INCHES.

TOLERANCES:		
DECIMAL	.X	+/- .06
	.XX	+/- .03
FRACTIONS	X/X	+/- 1/16
ANGLES		+/- 0° -30'

5. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS.
6. ALL MACHINED SURFACES SHALL BE 250√ OR BETTER IN ACCORDANCE WITH ANSI B46.1-1978.



1 SEG STOPS
SCALE: 1/2
MAT'L: 304 OR 304L PLATE ASTM A240



2 22 TON STOPS
SCALE: 1/2
MAT'L: 304 OR 304L PLATE ASTM A240

APPROVED FOR CONSTRUCTION

SIGNATURE 10-12-95 DATE

U. S. DEPARTMENT OF ENERGY
PACIFIC NORTHWEST LABORATORY
SEG CASK AND 22 TON SHIPPING BOX STOPS FOR RAILCAR
TIEDOWN3 | 0
SCALE 1/2

WHC-SD-TP-SEP-042 Rev. 0

PART B: PACKAGE EVALUATION

1.0 INTRODUCTION

Part B of this safety evaluation for packaging (SEP) provides the evaluations that show the adequacy of the Scientific Ecology Group, Inc. (SEG), 3-82B cask in meeting the requirements of PNL-MA-81, *Hazardous Material Shipping Manual*, for a controlled onsite shipping campaign with a payload that exceeds the limits of the cask CoC. The following is a summary of these evaluations.

Section 2.0, "Contents Evaluation," provides the worst-case source term used in all other evaluations. Approval of this SEP authorizes shipment of this source term in the SEG 3-82B cask under the conditions imposed in Part A of this SEP.

Section 3.0, "Radiological Risk Evaluation," is not applicable, because the 3-82B cask meets 10 CFR 71 performance requirements for normal conditions of transport (NCT) and hypothetical accident condition (HAC).

Section 4.0, "Containment Evaluation," indicates possible high temperatures in the seal area for the 2.1-kW payload under NCT. The seal will be changed after this particular payload is shipped. Also, the HAC (fire) indicates that the seal temperature may exceed its operating limit of 204.4 °C (400 °F). This is not considered a concern, as the cask will be shipped under controlled conditions, and the payload is a solid vitrified material that is not likely to be released in a catastrophic incident. Only approximately 15 liners are anticipated to be shipped, and of those 15, just one liner will have a heat load in the 2.1-kW range. All other liners will impose temperatures well within the operating limits of the seal for NCT and HAC.

Section 5.0, "Shielding Evaluation," indicates that U.S. Department of Transportation (DOT) radiation limits will be met for NCT and HAC, for both the highest gamma and highest neutron source terms defined in Part B, Section 2.0. The exception is the worst-case NCT gamma dose rate in the axial (top and bottom) direction on the cask (44.4 mrem/h at 2 m). However, the public and onsite workers will only be exposed to the radial portion of the cask during shipment, and as low as reasonably achievable (ALARA) precautions shall be taken during loading and unloading.

Section 6.0, "Criticality Evaluation," shows that the highest fissile loading (30 g) imposes no criticality concerns.

Section 7.0, "Structural Evaluation," shows that the higher thermal loading of the cask imposes additional thermal stresses and reduces the strength of the cask materials. Structural analysis of thermal stresses indicates that fatigue limitations due to thermal cycling will not be exceeded for this limited campaign. Regarding reduction of material strength, the only area of concern is at the cask tiedown lugs. Shipment controls are imposed to reduce the loading at the cask tiedown lugs.

Section 8.0, "Thermal Evaluation," indicates that the DOT surface temperature limits may be exceeded under NCT for the worst-case heat load. Precautions shall be taken to prevent burns during operation.

With the worst-case heat load, there is a possibility that the seal operating temperature limit may be exceeded (particularly under HAC). The seal shall be changed out after the high heat load shipment. For HAC, seal concerns are mitigated by the controlled circumstances of the shipment, as discussed in Section 4.0, "Containment Evaluation."

The lead shielding temperature remains well under its melting point for both NCT and HAC.

Section 9.0, "Pressure and Gas Generation Evaluation," shows that the higher pressure imposed by the greater heat load is within the structural limits of the cask. Gas generation is not a concern for the vitrified payload.

Section 10.0, "Package Tiedown System Evaluation," shows that the tiedown system is adequate for this application.

2.0 CONTENTS EVALUATION

Payload for the SEG 3-82B cask is defined in Jarrett (1995). The payload consists of remote-handled waste from the 324 Facility B-Cell. The waste will be divided among approximately 15, 3-82B liners. The worst-case shipment for radioactive decay heat and radiation will be the cask liner that contains processed borosilicate glass pieces collected during the size reduction and removal of the radioactive liquid-fed ceramic melter (RLFCM) from the 324 Facility B-Cell. This material represents about a 5 ft^3 heel left in the melter at shutdown. This glass will be confined in a drum, which will be centered in the 3-82B grout container. The grout container will be placed into a metallic-gasketed stainless steel 3-82B liner, which will be loaded into the 3-82B cask.

The worst-case heat load will be 2.1 kW with an associated radioactive inventory totaling 751 kCi (Table B-1). The glass matrix at 100% theoretical density has a specific gravity of 2.7 and a specific heat in the range of 0.16 - 0.185 Btu/lb-°F. This source term is used to calculate the maximum gamma dose rate (Part B, Section 5.0) and to calculate the worst-case thermal condition (Part B, Section 8.0).

From Jarrett (1995) the greatest fissile content is estimated to be no more than 30 g. The calculated radionuclide distribution is shown in Table B-2. This source term is used to calculate the maximum neutron dose rate (Part B, Section 5.0) and to evaluate the cask criticality (Part B, Section 6.0).

Table B-1. Worst-Case Heat Load--
Radioactive Liquid-Fed Ceramic
Melter Glass Pieces.

Nuclide	Activity, Ci	kW	Fissile, g
^{90}Sr	1.10E+05	0.735	
^{90}Y	1.10E+05		
^{37}Cs	2.71E+05	1.362	
^{137m}Ba	2.60E+05		
^{238}Pu	8.76E-02		0
^{239}Pu	5.60E-02		0.9
^{240}Pu	1.90E-01		
^{241}Pu	5.08E-02		0
^{242}Pu	1.37E-05		
Total	7.51E+05	2.097	0.9

Table B-2. Nuclear Waste Vitrification Program Canisters
Worst-Case Fissile Loading. (2 sheets total)

	NWVP-1 can (solid glass in 8-in.-ID x 96-in.-long SST pipe)			NWVP-2 can (solid glass in 8-in.-ID x 96-in.-long SST pipe)		
Nuclide	Activity, Ci	kW	Fissile, g	Activity, Ci	kW	Fissile, g
^{3}H	3.54E+01			8.85E+01		
^{79}Se	1.67E-01			4.17E-01		
^{85}Ke	5.66E+02			1.41E+03		
^{90}Sr	1.46E+04	0.098		3.66E+04	0.246	
^{90}Y	1.46E+04			3.66E+04		
^{99}Tc	6.02E+00			1.51E+01		
^{106}Ru	6.87E+00	0.000		1.72E+01	0.000	
^{106}Rh	6.87E+00			1.72E+01		
^{113m}Cd	6.31E-01			1.58E+00		
^{125}Sb	8.34E-01			2.08E+00		
^{125m}Te	2.03E-01			5.08E-01		
^{129}I	1.55E-02			3.88E-02		
^{134}Cs	1.28E+00			3.19E+00		
^{137}Cs	2.10E+04	0.100		5.26E+04	0.252	
^{137m}Ba	2.01E+04			5.03E+04		
^{144}Ce	6.93E-01	0.000		1.73E+00	0.000	
^{144}Pr	6.44E-01			1.61E+00		

Table B-2. Nuclear Waste Vitrification Program Canisters Worst-Case Fissile Loading. (2 sheets total)

	NWVP-1 can (solid glass in 8-in.-ID x 96-in.-long SST pipe)			NWVP-2 can (solid glass in 8-in.-ID x 96-in.-long SST pipe)		
Nuclide	Activity, Ci	kW	Fissile, g	Activity, Ci	kW	Fissile, g
^{147}Pm	8.36E+00			2.09E+01		
^{151}Sm	4.23E+02			1.06E+03		
^{154}Eu	3.14E+02			7.86E+02		
^{155}Eu	6.58E-01			1.65E+00		
^{234}U	1.09E-04			2.74E-04		
^{235}U	6.92E-06		3.3	1.73E-05		8.2
^{236}U	9.03E-05			2.26E-04		
^{238}U	1.48E-02			3.69E-02		
^{237}Np	1.42E-01			3.56E-01		
^{239}Np	5.55E+00			1.39E+01		
^{238}Pu	1.48E+00		0.1	3.69E+00		0.2
^{239}Pu	2.38E-01		3.8	5.95E-01		9.6
^{240}Pu	4.62E-01			1.15E+00		
^{241}Pu	2.30E+01		0.2	5.74E+01		0.5
^{241}Am	8.94E+03			2.23E+04		
^{242m}Am	3.89E+00			9.72E+00		
^{242}Am	3.92E+00			9.80E+00		
^{243}Am	5.55E+00			1.39E+01		
^{242}Cm	3.24E+00	0.000		8.09E+00	0.000	
^{243}Cm	7.90E-01			1.97E+00		
^{244}Cm	1.36E+02	0.005		3.39E+02	0.012	
Total	8.08E+04	0.203	7.4	2.02E+05	0.509	18.6

ID = Inside diameter.
NWVP = Nuclear Waste Vitrification Program.
SST = Stainless steel.

Other payloads include remote-handled transuranic waste, remote-handled mixed waste, and special-case waste. Liners with these payloads shall be within the envelope defined previously or will be shipped in accordance with the cask's NRC CoC USA/6574/B( ), if the liner heat load is equal to or less than 60 W.

3.0 RADIOLOGICAL RISK EVALUATION

Radiological risk evaluations, including accident frequency and dose consequence analyses, are not required, because the 3-82B cask design meets 10 CFR 71 performance requirements for NCT and HAC. Major exceptions noted in this document include higher dose rates (Part B, Section 5.0) and higher thermal loading (Part B, Section 8.0). However, neither of these exceptions significantly affect the ability of the cask design to meet 10 CFR 71 performance requirements when operated in accordance with the procedures provided in Part A, Sections 4.0 and 6.0.

Accident frequency analysis is not required, because accident consequences are not significantly different from those imposed by 10 CFR 71 and the performance elements for accident frequency analysis (drop, puncture, fire, crush) are the same as those specified by 10 CFR 71.

Dose consequence analysis is not required, because there is no postulated radioactive release from the cask containment in excess of that which would normally be expected from the NCT and HAC. The higher direct dose imposed by the higher source term is handled procedurally in accordance with ALARA principles, rather than by analysis of dose consequence. Dose consequence analyses generally consider the respirable dose to the worker and public due to release fractions from the cask, rather than direct dose.

4.0 CONTAINMENT EVALUATION

The thermal evaluation indicates possible high temperatures in the seal area for the 2.1-kW payload under NCT. The seal will be changed after this particular payload is shipped. Also, the HAC (fire) indicates that the seal temperature may exceed its operating limit of 204.4 °C (400 °F). This is not considered a concern, as the cask will be shipped under controlled conditions, and the payload is a solid vitrified material that is not likely to be released in a catastrophic incident. Only approximately 15 liners are anticipated to be shipped, and of those 15, just one liner will have a heat load in the 2.1-kW range. All other liners will impose temperatures well within the operating limits of the seal for NCT and HAC.

Cask shipment controls shall include limiting the speed to 25 mi/h and barricading all crossings to prevent collisions and resulting fire. Of note, the Hanford Fire Department can respond to a fire anywhere on the Hanford Site within 15 minutes of a call.

5.0 SHIELDING EVALUATION

5.1 INTRODUCTION

This shielding evaluation supports the transport of remote-handled wastes from the 324 building in SEG 3-82B casks. Two packages were evaluated: a worst-case gamma-ray source package and a worst-case neutron source package. The gamma-ray source waste consists of 0.1416 m^3 (5 ft^3) of borosilicate glass pieces of various shapes and sizes. The neutron source waste consists of a Nuclear Waste Vitrification Program (NWVP)-1 canister and an NWVP-2 canister, each cut into two pieces and placed inside the cask.

The limits for this package are 1,000 mrem/h at any point on the exterior surface of a package and 10 mrem/h at a distance of 2 m from the package. After an HAC resulting in a loss of shielding, the limit, as given in 10 CFR 71.51, is 1 rem/h at 1 m.

For the gamma-ray source package, ISOSHLD (Rittman 1995) calculations were made to determine the gamma-ray source term, and the Monte Carlo N-Particle (MCNP [Carter 1995]) calculations were made to determine the dose rates at the cask surface and beyond in both the axial and radial directions. The MCNP code was also used to calculate the neutron dose rates.

5.2 DIRECT RADIATION SOURCE SPECIFICATION

The sources used for these evaluations represent worst-case, one-time-only shipments. Nominal shipments are bounded by this evaluation.

5.2.1 Gamma Source

The gamma source consists of ^{90}Sr, ^{90}Y, ^{137}Cs, and ^{137m}Ba contained in the borosilicate glass. The total activity and the activities of the constituents of the waste were provided by Jarrett (1995) and used in the input to the ISOSHLD calculations. Only the gamma rays with energies above 0.6 MeV were used for the MCNP shielding calculations, because all lower energy gamma rays will be absorbed by the lead and steel shields.

The principal radioisotopes are listed in Table B-3.

Table B-3. Principal Radioisotopes in Source.

Isotope	Curies
^{90}Sr	1.10E+05
^{90}Y	1.10E+05
^{137}Cs	2.71E+05
^{137m}Ba	2.60E+05

5.2.2 Beta Source

The beta source within a loaded container leads to a negligible dose rate outside because of the attenuation provided by the glass, 0.9525-cm- (0.375-in.-) thick inner steel shell, 9.525-cm (3.75-in.) lead shielding, and 2.54-cm- (1-in.-) thick outer steel shell.

Bremsstrahlung gamma rays are included in the ISOSHLD calculations of gamma-ray source term.

5.2.3 Neutron Source

The neutron source term is summarized in Table B-4. The neutron source consists of a full NWVP-1 canister and a full NWVP-2 canister combined into a single payload. The total neutron source is dominated by the spontaneous fission of ^{244}Cm, which contributes to 68% of the neutron source. The remainder of the neutron source is from (Alpha,n) reactions.

Table B-4. Neutron Source for SEG Cask.

Neutron source	NWVP-1 canister (neutrons/s)	NWVP-2 canister (neutrons/s)	Total (neutrons/s)
^{241}Am (Alpha,n)	8.58E+06	2.14E+07	3.00E+07
^{244}Cm (Alpha,n)	1.55E+05	3.87E+05	5.42E+05
Total (Alpha,n)	8.75E+06	2.18E+07	3.06E+07
^{242}Cm fission	2.11E+04	5.27E+04	7.38E+04
^{244}Cm fission	1.87E+07	4.66E+07	6.53E+07
Total fission	1.87E+07	4.67E+07	6.54E+07
Total	2.75E+07	6.85E+07	9.60E+07

NWVP = Nuclear Waste Vitrification Program.

5.3 SUMMARY OF SHIELDING PROPERTIES OF MATERIALS

The gamma-ray and neutron shielding attenuation properties for the bulk materials were obtained using the data library for the MCNP computer code. The problem-specific descriptions of the calculational models are given in Section 5.4.3.

5.4 NCT

5.4.1 Conditions to be Evaluated

The dose rate will be calculated at the surface and at various distances from the container.

5.4.2 Acceptance Criteria

The placement of the cask on the railcar during NCT could allow workers and the public to be exposed to radial doses, but not to axial doses. The dose rates from the package must meet the limits of 1,000 mrem/h on the exterior surface of the package and 10 mrem/h at a distance of 2 m from the package. Additionally, the dose rate in any normally occupied areas must be less than 2 mrem/h. Because the axial dose rates may be higher than the DOT limits, loading and unloading procedures will be performed following ALARA and HSRCM-1.

5.4.3 Gamma Shielding Model

The MCNP computer program was used for all gamma dose rate calculations in this study. The MCNP code performs a transport calculation from the source region to a dose point to compute the radiation dose rate.

The SEG cask was modeled as a 137.16-cm- (54-in.-) inside diameter (ID) cylinder with an inside height of 157.7975 cm (62.125 in.). The cask wall consists of a 0.9525-cm (0.375-in.) inner steel shell, a 9.525-cm (3.75-in.) lead shield, and a 2.54-cm (1-in.) outer steel shell. The bottom of the cask has a 5.08-cm (2-in.) inner steel shell with 6.0452-cm (2.38-in.) lead shielding and a 2.54-cm (1-in.) outer steel liner. The shield plug has a 3.81-cm (1.5-in.) inner steel shell, a 6.35-cm (2.5-in.) lead shield, and a 2.54-cm (1-in.) outer steel shell. The 0.1416 m^3 (5 ft^3) of glass pieces will be inside a 55-gal drum that will be placed in a steel liner with an ID of 120.396 cm (47.4 in.), an OD of 121.666 cm (47.9 in.), and an inner height of 143.764 cm (56.6 in.). For this analysis the 0.1416 m^3 (5 ft^3) of glass waste is smeared over the 55-gal drum volume. The drum has an inside height of 84.455 cm (33.25 in.) with an ID of 57.15 cm (22.5 in.). The waste is assumed to be located in the center bottom of the cask with an air gap between the waste and the inner surface of the cask.

The density of the glass is 2.7 g/cm^3. This was smeared over the drum volume to give a density of 1.76 g/cm^3. The source material is assumed to be water. The materials and densities used in the calculational model are given in Table B-5.

Table B-5. Materials and Densities Used.

Material	Density (g/cm^3)	Where used
Lead	11.35	Side, top, and bottom of container
Water	1.76	Source region
Carbon steel	7.82	Side, top, container bottom, and pipe
Air	0.00129	Inside container between grout and top, plus outside container

5.4.4 Neutron Shielding Model

The neutron shielding model is identical to the gamma-ray shielding model, except the 55-gal drum has been replaced with a glass cylinder (modeled as water) having a radius of 20.32 cm (8 in.) and a density of 2.7 g/cm^3. Additionally, the source region has an axial extent of 121.92 cm (48 in.).

5.4.5 Gamma-Ray Shielding Calculations

The calculated dose rates on the surface and up to 6 m from the cask are summarized in Table B-6. The dose rate is 729.0 mrem/h on the axial surface and 47.3 mrem/h on the radial surface. At 2 m from the axial surface, the dose rate is 44.4 mrem/h, and at 2 m from the side, it is 5.3 mrem/h. At 6 m from the cask end, the dose rate is 6.0 mrem/h, and at 6 m from the side, it is 0.87 mrem/h.

Table B-6. SEG Cask Gamma-Ray Dose Rates.

Distance from container	Dose rate (mrem/h)	
	Axially	Radially
On surface	729.0	47.3
2 m	44.4	5.3
6 m	6.0	0.87

5.4.6 Neutron Shielding Calculations

The calculated neutron dose rates outside the cask at the surface and at 1 m away from the surface are shown in Table B-7. All of the dose rates are substantially less than the gamma-ray dose rates reported in Table B-6. Thus, the gamma-ray source term represents the bounding source.

Table B-7. SEG Cask Neutron Dose Rates.

Distance from container	Dose rate (mrem/h)	
	Axially	Radially
On surface	41	16
1 m	2.6	2.3

5.5 HAC

5.5.1 Conditions to be Evaluated

The HAC assumes a loss of 0.353 cm (0.139 in.) of lead shielding. The loss of shielding is based on the maximum lead slump caused by the HAC, as

given in SEG (1991) on page 2-62. Because the gamma-ray source term bounds the neutron source, calculations were only made for the gamma-ray source term.

5.5.2 Acceptance Criteria

The dose rate at a distance of 1 m from the exterior of the cask following a loss of shielding accident will not exceed 1 rem/h at 1 m.

5.5.3 Shielding Model

The shielding model is the same as for NCT, except that the lead shielding has been reduced by 0.353 cm (0.139 in.).

5.5.4 Shielding Calculations

The dose rates are summarized in Table B-8. The dose rate is 1,052.0 mrem/h at the end surface of the cask and 80.5 mrem/h on the side. At 1 m from the end surface, the dose rate is 198.0 mrem/h, and at 1 m from the side, it is 19.7 mrem/h. At 2 m from the end surface, the dose rate is 66.5 mrem/h, and at 2 m from the side, it is 7.9 mrem/h.

Table B-8. Gamma-Ray Dose Rates for Hypothetical Accident Conditions.

Distance from container	Dose rate (mrem/h)	
	Axially	Radially
On surface	1,052.0	80.5
1 m	198.0	19.7
2 m	66.5	7.9

5.6 SHIELDING EVALUATION AND CONCLUSIONS

The shielding calculations have shown that for NCT, the radial dose rates from the gamma and neutron sources meet the DOT limits. The analysis assumed a conservative payload that results in a conservative calculation of the dose rate. Due to the high axial gamma-ray dose rates, precautions during loading and unloading will be taken to ensure ALARA to the workers. The accident shielding analysis showed that DOT criteria are met.

A number of uncertainties affect the accuracy of the results presented. Included are uncertainties in material compositions and densities, in data in the MCNP library, and in the ISOSHLD source term.

The major uncertainty is with the source term. The source term includes conservatisms that should result in conservative dose rate calculations.

5.7 APPENDICES

5.7.1 Example of ISOSHLD Input File

```
0         2  Shielding for SEG Cask
Cylindrical source model - dose rate at surface
 &Input  Next= 1,  Option= 1,  Igeom= 7,
   Slth= 84.455, Ntheta=35, Npsi=25, Delr=1.00,
   Y= 42.2275, X= 81.5975, Nshld= 5, Jbuf= 5,
   T(1)= 28.575, T(2)=39.37, T(3)=1.5875,
   T(4)= 9.525, T(5)= 2.54
   Weight(335)= 2.71e+5, Weight(336)= 2.60e+5
   Weight(82)=1.10e+5, Weight(84)=1.10e+5 &
  Water  1  1.7600
  C      6                    0.08000            0.0800
  Fe     9                    7.74000            7.7400
  Lead  14                              11.35
1 Air    3           0.00129
Detector is 1cm from surface
 &Input Next=4, X= 82.5975 &
 Detector is 1 m from surface
 &Input Next=4, X=181.5975 &
 Detector is 2 m from surface
 &Input Next=4, X=281.5975 &
 Detector is 6 m from surface
 &Input Next=4, X=681.5975 &
END OF RUN
 &Input Next= 6  &
```

5.7.2 MCNP Gamma-Ray Input File for NCT at 1, 2, and 6 M

```
SEG CASK PHOTON SOURCE - POINT DETECTOR TALLIES
    1   202      -7.82000 -2 -4 1 3
    7   202      -7.82000 -8 7 3 -2
    8   231     -0.001220 -2 3 8 -1
   12     0  (42 -15 -38 -53 )(14 :6 :-11 )
   13   231     -0.001220 -2 3 16 -7
   14   236      -1.76000 -17 -16 3
   15   231     -0.001220 17 -16 -2
   16     0  15
   17   202      -7.82000 9 -18 -4
   18   202      -7.82000 18 -19 -4
   19   202      -7.82000 19 -20 -4
   20   202      -7.82000 20 -21 -4
   21   202      -7.82000 21 -3 -4
   22   288      -11.35 10 -22 -5
   23   288      -11.35 22 -23 -5
   24   288      -11.35 23 -24 -5
   25   288      -11.35 24 -25 -5
   26   288      -11.35 25 -26 -5
   27   288      -11.35 26 -9 -5
   28   202      -7.82000 11 -27 -5
   29   202      -7.82000 27 -10 -5
   30   288      -11.35 4 -28 9 -12
   31   288      -11.35 28 -29 9 -12
   32   288      -11.35 29 -30 9 -12
   33   288      -11.35 30 -31 9 -12
   34   288      -11.35 31 -32 9 -12
   35   288      -11.35 32 -33 9 -12
   36   288      -11.35 33 -34 9 -12
   37   288      -11.35 34 -35 9 -12
   38   288      -11.35 35 -36 9 -12
   39   288      -11.35 36 -5 9 -12
   40   202      -7.82000 5 -37 11 -14
   41   202      -7.82000 37 -6 11 -14
   42     0  38 -39 -15
   43     0  -15 -41 39
   44     0  41 -40 -15
   45     0  40 -15
   46     0  -42 43 -38
   47     0  -43 -15 -38
```

48	202	-7.82000 2 -44 -4
49	202	-7.82000 44 -45 -4
50	202	-7.82000 45 -46 -4
51	202	-7.82000 46 -12 -4
52	288	-11.35 12 -47 -5
53	288	-11.35 47 -48 -5
54	288	-11.35 48 -49 -5
55	288	-11.35 49 -50 -5
56	288	-11.35 50 -51 -5
57	288	-11.35 51 -13 -5
58	202	-7.82000 13 -52 -5
59	202	-7.82000 52 -14 -5
60	0	-54 53 -38
61	0	-15 -38 54

1	cz	68.580000
2	pz	78.899000
3	pz	-78.899000
4	cz	69.532500
5	cz	79.057500
6	cz	81.597500
7	cz	60.198000
8	cz	60.833000
9	pz	-83.979000
10	pz	-90.024200
11	pz	-92.564200
12	pz	82.709000
13	pz	89.059000
14	pz	91.599000
15	so	1000.0000
16	cz	28.575000
17	pz	5.5560000
18	pz	-82.963000
19	pz	-81.947000
20	pz	-80.931000
21	pz	-79.915000
22	pz	-89.016667
23	pz	-88.009133
24	pz	-87.001600
25	pz	-85.994067
26	pz	-84.986533
27	pz	-91.294200
28	cz	70.485000
29	cz	71.437500
30	cz	72.390000
31	cz	73.342500
32	cz	74.295000
33	cz	75.247500
34	cz	76.200000
35	cz	77.152500
36	cz	78.105000
37	cz	80.327500
38	cz	181.59750
39	cz	281.59750
40	cz	681.59750
41	cz	431.59750
42	pz	-192.56420
43	pz	-292.56420
44	pz	79.851500
45	pz	80.804000
46	pz	81.756500
47	pz	83.767333
48	pz	84.825667
49	pz	85.884000
50	pz	86.942333
51	pz	88.000667
52	pz	90.329000
53	pz	191.59900
54	pz	291.59900
55	pz	-46.671500
56	pz	-26.671500
57	cz	10.000000

```
mode  p
m288  82000.50c -1.000000
m202  26000.55c -7.74 6000.50c -0.08
m231  7014.50c -0.765000 8016.50c -0.235000
m236  1001.50c 0.666700 8016.50c 0.333300
imp:p       2.00000      1.00000      2            1.00000     3r       $ 1, 15
            0.00000      64.0000      32.0000      16.0000      8.00000 $ 16, 20
            4.00000  131072  32768  8192      2048.000 $ 21, 25
            512.000      128.000  1048576  524288      2.00000 $ 26, 30
            12.0000      36.0000      108.0000      324.000      972.000 $ 31, 35
            2916.000  8748  26244  78732  236196 $ 36, 40
            354294      1.00000     5r            4.00000      8.00000 $ 41, 49
            16.0000      32.0000      64.0000      256.000      1024.000 $ 50, 54
            4096.000  16384  65536  131072  262144 $ 55, 59
            1.00000     1r       $ 60, 62
pd0       .2      .1      .2            .1     3r       $ 1, 15
            0.00000      .5      .4      .3      .2 $ 16, 20
            .1  1  1  .5      .5 $ 21, 25
            .5      .5  1  1      .3 $ 26, 30
            .4      .5      .6      .7      .8 $ 31, 35
            .9  1  1  1  1 $ 36, 40
        1      1.00000     5r            .1      .1 $ 41, 49
            .1      .1      .5      .5      .5 $ 50, 54
            .5  1  1  1  1 $ 55, 59
            1.00000     1r       $ 60, 62
phys:p   j j 1
sdef    cel = 14 erg  d1  pos = 0 0 0 ext = d2  rad = d3 axs = 0 0 1
        wgt = 8.663e+15
si2    -78.899 5.556
sp2   -21 0
si3    28.575
sp3   -21 1
sc1  photon source from ISOSHLD
#            si1     sp1         sb1
             l        d           d
              0.65     8.660E+15   8.660E+15
              0.825    1.324E+12   1.324E+13
              1.0      9.231E+11   9.231E+12
              1.225    4.915E+11   4.915E+13
              1.475    1.689E+11   1.689E+13
              1.7      1.783E+11   1.783E+14
              1.9      9.096E+09   9.096E+12
              2.1      6.484E+09   6.484E+12
              2.3      1.168E+07   1.168E+10
c      ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0    log  .01 .015 .02 .03 .04 .05
          .06 .08 .10 .15 .20 .30
          .40 .50 .60 .80 1.0 1.5
          2.0 3.0 4.0 5.0 6.0 8.0
         10. 12.
df0    log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
          1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
          7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
          2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
          8.892e-3 1.040e-2
c     fc5  dose rate at bottom surface
c     f5:p   0 0 -95 0
fc15  dose rate 1 meter from bottom surface
f15:p   0 0 -192.5 0
fc25  dose rate 2 meter from bottom surface
f25:p   0 0 -292.5 0
fc35  dose rate 6.0 meter from bottom surface
f35:p   0 0 -692.5 0
c     fc45  dose rate at side surface
c     f45:p   0 84 -36.672 0
fc55  dose rate 1 meter from side surface
f55:p   0 181.6 -36.672 0
fc65  dose rate 2 meter from side surface
f65:p   0 281.6 -36.672 0
fc75  dose rate 6 meter from side surface
f75:p   0 681.6 -36.672 0
ctme  700.0
```

5.7.3 MCNP Gamma-Ray Input File for HAC at 1, 2, and 6 M

```
SEG CASK PHOTON SOURCE - POINT DETECTOR TALLIES
   1   202      -7.82000 -2 -4 1 3
   7   202      -7.82000 -8 7 3 -2
   8   231     -0.001220 -2 3 8 -1
  12     0  (42 -15 -38 -53 )(14 :6 :-11 )
  13   231     -0.001220 -2 3 16 -7
  14   236      -1.76000 -17 -16 3
  15   231     -0.001220 17 -16 -2
  16     0  15
  17   202      -7.82000 9 -18 -4
  18   202      -7.82000 18 -19 -4
  19   202      -7.82000 19 -20 -4
  20   202      -7.82000 20 -21 -4
  21   202      -7.82000 21 -3 -4
  22   0      10 -22 -5
  23   288      -11.35 22 -23 -5
  24   288      -11.35 23 -24 -5
  25   288      -11.35 24 -25 -5
  26   288      -11.35 25 -26 -5
  27   288      -11.35 26 -9 -5
  28   202      -7.82000 11 -27 -5
  29   202      -7.82000 27 -10 -5
  30   288      -11.35 4 -28 9 -12
  31   288      -11.35 28 -29 9 -12
  32   288      -11.35 29 -30 9 -12
  33   288      -11.35 30 -31 9 -12
  34   288      -11.35 31 -32 9 -12
  35   288      -11.35 32 -33 9 -12
  36   288      -11.35 33 -34 9 -12
  37   288      -11.35 34 -35 9 -12
  38   288      -11.35 35 -36 9 -12
  39   0      36 -5 9 -12
  40   202      -7.82000 5 -37 11 -14
  41   202      -7.82000 37 -6 11 -14
  42     0  38 -39 -15
  43     0  -15 -41 39
  44     0  41 -40 -15
  45     0  40 -15
  46     0  -42 43 -38
  47     0  -43 -15 -38
  48   202      -7.82000 2 -44 -4
  49   202      -7.82000 44 -45 -4
  50   202      -7.82000 45 -46 -4
  51   202      -7.82000 46 -12 -4
  52   288      -11.35 12 -47 -5
  53   288      -11.35 47 -48 -5
  54   288      -11.35 48 -49 -5
  55   288      -11.35 49 -50 -5
  56   288      -11.35 50 -51 -5
  57   288      -11.35 51 -13 -5
  58   202      -7.82000 13 -52 -5
  59   202      -7.82000 52 -14 -5
  60     0  -54 53 -38
  61     0  -15 -38 54

   1        cz      68.580000
   2        pz      78.899000
   3        pz     -78.899000
   4        cz      69.532500
   5        cz      79.057500
   6        cz      81.597500
   7        cz      60.198000
   8        cz      60.833000
   9        pz     -83.979000
  10        pz     -90.024200
  11        pz     -92.564200
  12        pz      82.709000
  13        pz      89.059000
  14        pz      91.599000
  15        so      1000.0000
  16        cz      28.575000
  17        pz      5.5560000
  18        pz     -82.963000
```

```
   19        pz      -81.947000
   20        pz      -80.931000
   21        pz      -79.915000
   22        pz      -89.6712
   23        pz      -88.009133
   24        pz      -87.001600
   25        pz      -85.994067
   26        pz      -84.986533
   27        pz      -91.294200
   28        cz       70.485000
   29        cz       71.437500
   30        cz       72.390000
   31        cz       73.342500
   32        cz       74.295000
   33        cz       75.247500
   34        cz       76.200000
   35        cz       77.152500
   36        cz       78.7045
   37        cz       80.327500
   38        cz       181.59750
   39        cz       281.59750
   40        cz       681.59750
   41        cz       431.59750
   42        pz      -192.56420
   43        pz      -292.56420
   44        pz       79.851500
   45        pz       80.804000
   46        pz       81.756500
   47        pz       83.767333
   48        pz       84.825667
   49        pz       85.884000
   50        pz       86.942333
   51        pz       88.000667
   52        pz       90.329000
   53        pz       191.59900
   54        pz       291.59900
   55        pz      -46.671500
   56        pz      -26.671500
   57        cz       10.000000

mode  p
m288  82000.50c -1.000000
m202  26000.55c -7.74 6000.50c -0.08
m231  7014.50c -0.765000 8016.50c -0.235000
m236  1001.50c 0.666700 8016.50c 0.333300
imp:p       2.00000      1.00000     2            1.00000     3r       $ 1, 15
            0.00000      64.0000      32.0000      16.0000      8.00000 $ 16, 20
            4.00000  131072  32768  8192      2048.000 $ 21, 25
            512.000      128.000  1048576  524288      2.00000 $ 26, 30
            12.0000      36.0000      108.0000      324.000      972.000 $ 31, 35
            2916.000  8748  26244  78732  236196 $ 36, 40
            354294      1.00000     5r            4.00000      8.00000 $ 41, 49
            16.0000      32.0000      64.0000      256.000      1024.000 $ 50, 54
            4096.000  16384  65536  131072  262144 $ 55, 59
            1.00000     1r       $ 60, 62
pd0       .2      .1     .2            .1     3r       $ 1, 15
            0.00000      .5      .4      .3      .2 $ 16, 20
            .1  1  1  .5      .5 $ 21, 25
            .5      .5  1  1      .3 $ 26, 30
            .4      .5      .6      .7      .8 $ 31, 35
            .9  1  1  1  1 $ 36, 40
        1      1.00000     5r            .1      .1 $ 41, 49
            .1      .1      .5      .5      .5 $ 50, 54
            .5  1  1  1  1 $ 55, 59
            1.00000     1r       $ 60, 62
phys:p   j 1 1
sdef    cel = 14 erg  d1  pos = 0 0 0 ext = d2  rad = d3 axs = 0 0 1
        wgt = 8.663e+15
si2    -78.899 5.556
sp2   -21 0
si3    28.575
sp3   -21 1
```

```
sc1  photon source from ISOSHLD
#            si1     sp1          sb1
             l        d            d
              0.65     8.660E+15   8.660E+15
              0.825    1.324E+12   1.324E+13
              1.0      9.231E+11   9.231E+12
              1.225    4.915E+11   4.915E+13
              1.475    1.689E+11   1.689E+13
              1.7      1.783E+11   1.783E+14
              1.9      9.096E+09   9.096E+12
              2.1      6.484E+09   6.484E+12
              2.3      1.168E+07   1.168E+10
c      ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0    log  .01 .015 .02 .03 .04 .05
          .06 .08 .10 .15 .20 .30
          .40 .50 .60 .80 1.0 1.5
          2.0 3.0 4.0 5.0 6.0 8.0
         10. 12.
df0    log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
          1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
          7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
          2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
          8.892e-3 1.040e-2
c      fc5  dose rate at bottom surface
c      f5:p   0 0 -95 0
fc15  dose rate 1 meter from bottom surface
f15:p   0 0 -192.5 0
fc25  dose rate 2 meter from bottom surface
f25:p   0 0 -292.5 0
fc35  dose rate 6.0 meter from bottom surface
f35:p   0 0 -692.5 0
c      fc45  dose rate at side surface
c      f45:p   0 84 -36.672 0
fc55  dose rate 1 meter from side surface
f55:p   0 181.6 -36.672 0
fc65  dose rate 2 meter from side surface
f65:p   0 281.6 -36.672 0
fc75  dose rate 6 meter from side surface
f75:p   0 681.6 -36.672 0
ctme  700.0
```

5.7.4 MCNP Neutron Transport Input File

```
SEG CASK NEUTRON SOURCE
    1   202      -7.82000 -2 -4 1 3
    2   288      -11.3000 4 -5 -12 9
    3   202      -7.82000 -14 11 5 -6
    4   202      -7.82000 -3 9 -4
    5   288      -11.3000 -9 10 -5
    6   202      -7.82000 -10 11 -5
    7   202      -7.82000 -8 7 3 -2
    8   231     -0.001220 -2 3 8 -1
    9   202      -7.82000 -12 2 -4
   10   288      -11.3000 -13 12 -5
   11   202      -7.82000 13 -14 -5
   12     0  (-15 )(14 :6 :-11 )
   13   231     -0.001220 -2 3 16 -7
   14   236      -2.70000 -17 -16 3
   15   231     -0.001220 17 -16 -2
   16     0  15

    1        cz      68.580000
    2        pz      78.899000
    3        pz     -78.899000
    4        cz      69.532500
    5        cz      79.057500
    6        cz      81.597500
    7        cz      60.198000
    8        cz      60.833000
    9        pz     -83.979000
   10        pz     -90.024200
   11        pz     -92.564200
   12        pz      86.519000
```

```
    13        pz      92.869000
    14        pz      95.409000
    15        so      500.00000
    16        cz      20.320000
    17        pz      43.021000

mode   n
imp:n  4 8 16 4 8 16 1 1 4 8 16 1 1 1 1  0
sdef    cel = 14 erg  d1  pos = 0 0 0 ext = d2  rad = d3 axs = 0 0 1
        wgt = 9.595e+7
sc1    Neutron spectrum  (alpha,n), fission
si1    s 20 21
sp1    0.319  0.681
si2    -78.899 43.021
sp2   -21 0
si3    20.32
sp3   -21 1
sc20    (alpha,n) neutron source on OXYGEN from  Jacobs & Liskien
c       Energy of the alpha particles = 5.5 MeV
#            si20     sp20
              0.0      0.0
              0.1      0.68
              0.2      0.76
              0.3      0.74
              0.4      0.88
              0.5      1.20
              0.6      1.35
              0.7      1.48
              0.8      1.62
              0.9      1.55
              1.0      1.28
              1.1      1.34
              1.2      1.45
              1.3      1.63
              1.4      1.76
              1.5      1.80
              1.6      1.89
              1.7      2.05
              1.8      2.28
              1.9      2.37
              2.0      2.49
              2.1      2.50
              2.2      2.61
              2.3      2.65
              2.4      2.54
              2.5      2.43
              2.6      2.34
              2.7      2.23
              2.8      2.06
              2.9      2.00
              3.0      1.88
              3.1      1.66
              3.2      1.56
              3.3      1.34
              3.4      1.09
              3.5      0.92
              3.6      0.79
              3.7      0.64
              3.9      0.48
              4.0      0.39
              4.1      0.35
              4.2      0.23
              4.3      0.18
              4.4      0.11
              4.5      0.07
sc21    spontaneous fission source spectrum (Cm 244)
sp21    -3  0.906  3.848
m288  82000.50c -1.000000
m202  26000.55c 64.379997 24000.50c 19.080000 28000.50c 13.050000
      25055.50c 1.800000 42000.50c 1.470000 6000.50c 0.220000
m231  7014.50c -0.765000 8016.50c -0.235000
m236  1001.50c 0.666700 8016.50c 0.333300
c      ansi/ans-6.1.1-1977 fluence-to-dose,neutrons(mrem/hr/(n/cm**2/s)
de0    log   2.5e-08 1.0e-07 1.0e-06 1.0e-05 1.0e-04
             .001     .01     .1      .5      1.0
              2.5     5.0     7.0     10.0    14.0  20.0
```

```
df0    log   3.67e-3 3.67e-3 4.46e-3 4.54e-3  4.18e-3
             3.76e-3 3.56e-3 2.17e-2 9.26e-2  .132
              .125    .156    .147    .147    .208  .227
fc5  dose rate at top surface
f5:n   0 0 96 5
fc15  dose rate at bottom surface
f15:n   0 0 -93 5
fc25  dose rate at side surface
f25:n   0 82 -17.94 5
fc35  dose rate 1 meter from top surface
f35:n   0 0 196 5
fc45  dose rate 1 meter from bottom surface
f45:n   0 0 -193 5
fc55  dose rate 1 meter from side surface
f55:n   0 182 -17.94 5
ctme  960.0
```

5.7.5 ISOSHLD and MCNP Input and Output Files

These files are saved on a diskette that is kept with the original copy of this report.

File Name	Description
SEGCSK1J.IN	ISOSHLD Input file for generating source
SEGCSK1J.OUT	ISOSHLD Output file for SEGCSK1H.IN
SEGNEU.IN	MCNP input file for neutron source
SEGNEU.OUT	MCNP output file for neutron source
SEGNORM.IN	MCNP input file for normal conditions at 1, 2, 6 meters
SEGNORM.OUT	MCNP output file for normal conditions at 1, 2, 6 meters
SEGNSIDE.IN	MCNP input file for normal conditions at the side
SEGNSIDE.OUT	MCNP output file for normal conditions at the side
SEGNBOT.IN	MCNP input file for normal conditions at the bottom
SEGNBOT.OUT	MCNP output file for normal conditions at the bottom
SEGACC.IN	MCNP input file for accident conditions at 1, 2, 6 meters
SEGACC.OUT	MCNP output file for accident conditions at 1, 2, 6 meters
SEGASIDE.IN	MCNP input file for accident conditions at the side
SEGASIDE.OUT	MCNP output file for accident conditions at the side
SEGABOT.IN	MCNP input file for accident conditions at the bottom
SEGABOT.OUT	MCNP output file for accident conditions at the bottom

5.7.6 Peer Review Check Sheet

8M730-RAS-95-009
ATTACHMENT 2
Page 1 of 1

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: 8M730-RAS-95-009
TITLE: SHIELDING EVALUATION FOR THE SEG CASK

Reviewer(s): S. R. GEDEON

I. Method(s) of Review

(✓) Input data checked for accuracy
(✓) Independent calculation performed
( ) Hand calculation
(✓) Alternate computer code: Microshield
( ) Comparison to experiment or previous results
( ) Alternate method (define)

II. Checklist (either check or enter NA if not applied)

(✓) Task completely defined
(✓) Activity consistent with task specification
(✓) Necessary assumptions explicitly stated and supported
(✓) Resources properly identified and referenced
(✓) Resource documentation appropriate for this application
(✓) Input data explicitly stated
(✓) Input data verified to be consistent with original source
(✓) Geometric model adequate representation of actual geometry
(✓) Material properties appropriate and reasonable
(NA) Mathematical derivations checked including dimensional consistency
(NA) Hand calculations checked for errors
(✓) Assumptions explicitly stated and justified
(✓) Computer software appropriate for task and used within range of validity
(NA) Use of resource outside range of established validity is justified
(✓) Software runstreams correct and consistent with results
(✓) Software output consistent with input
(✓) Results consistent with applicable previous experimental or analytical findings
(✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
(✓) Conclusions consistent with analytical results and established limits
(✓) Uncertainty assessment appropriate and reasonable
( ) Other (define)

III. Comments:

IV. REVIEWER: [signature] DATE: 7 Nov 95

6.0 CRITICALITY EVALUATION

The SEG cask maximum fissile content is projected to be 30 g in liner No. 6 (Jarrett 1995). Taking the conservative assumption that all the fissile material is ^{239}Pu, a comparison with the minimum critical mass of plutonium in water of 531 g shows that 30 g is subcritical under any conditions of water moderation and reflection. The contents of 17 SEG casks with liner No. 6 would have to combine in an optimally moderated and fully reflected sphere to approach criticality. Concrete, plastic, and some other common materials can decrease the minimum critical mass of a plutonium system, but not to less than 300 g. Criticality is impossible in the SEG cask with less than 100 g of plutonium.

7.0 STRUCTURAL EVALUATION

7.1 SUMMARY

For the purposes of shipping vitrified waste from the 324 Facility, no design or operational changes to the SEG 3-82B cask are authorized. The payload weight, cask configuration, and operation of the cask will be identical to that stated in its CoC and related safety analysis (SEG 1991), with the exception of the higher heat load of the payload.

As a result of the higher heat load evaluated in Part B, Section 8.0, of this SEP, the following analyses are performed to verify cask performance:

- Evaluation of thermal stresses (Part B, Section 7.2)
- Evaluation of loss of material strength (Part B, Section 7.3)
- Pressure rise due to increased heat load (Part B, Section 9.0).

These structural evaluations confirm that the SEG 3-82B cask will continue to meet 10 CFR 71 performance criteria for the higher heat load, under the SEP controls mandated for this limited campaign.

7.2 EVALUATION OF THERMAL STRESSES

An axisymmetric finite element model of the SEG 3-82B cask was developed for the purpose of assessing the thermal stresses developed in the cask as a result of NCT. All elements of the cask were modeled using the ANSYS[1] (SAS 1989) STIF 51 Axisymmetric Conical Shell element. Table B-9 shows the geometry, material, and real-property data used to represent the cask components.

[1] ANSYS is a trademark of Swanson Analysis Systems, Inc.

Table B-9. Geometry, Material, and Real Property Data of Cask Components.

Component	Thickness (in.)	Young's modulus (psi)	Poisson's ratio	Thermal expansion coefficient (in/in/F)
Inner steel	0.375	26.19E+06 @ 530 °F	0.3	7.304E-06 @ 530 °F
Lead shield	3.75	2.0E+06	0.43	16.3E-06
Outer steel shell	1.0	26.19E+06 @ 530 °F	0.3	7.304E-06 @ 530 °F
11-gauge stainless steel sheet	0.125	27.148E+06 @ 292 °F	0.3	8.674E-06 @ 292 °F
Closure head	4.0	27.421E+06 @ 293 °F 26.19E+06 @ 530 °F 26.874E+06 @ 421 °F	0.3	6.856E-06 @ 293 °F 7.304E-06 @ 530 °F 7.104E-06 @ 421 °F

For simplicity and conservatism, the cask was treated as symmetrical about a horizontal midplane; i.e., the top and bottom closure heads were addressed identically. The thickness of the closure head was conservatively represented as 10.16 cm (4 in.), somewhat overstating its real stiffness and thereby contributing to upper-bound estimates of thermal stress in the other components of the cask. The thermal gradient between the carbon steel outer shell and the 11-gauge stainless steel plate predicted by the heat transfer analysis is considered to be quite conservative and results in an overstatement of the stress level in the stainless steel plate. For the normal thermal condition, two bounding conditions for assessing thermal stress in the inner and outer steel shells were addressed.

In the worst-case scenario, the 276.7 °C (530 °F) temperature predicted by the heat transfer analysis was imposed upon the inner steel, lead shield, and outer steel shell, while a temperature of 144.4 °C (292 °F) was imposed on the 11-gauge stainless steel sheet. For the closure head, the 276.7 °C (530 °F) temperature was imposed between the inner and outer steel plates; a 145 °C (293 °F) temperature was imposed from the center of the cask to the inner steel shell; and a temperature profile that linearly varies from 276.7 °C (530 °F) at the outer steel shell to 144.4 °C (292 °F) at the 11-gauge stainless steel sheet was also imposed. See Figure B-1.

In the best-case scenario, the 276.7 °C (530 °F) temperature predicted by the heat transfer analysis was imposed upon the inner steel, lead shield, and outer steel shell, while a temperature of 144.4 °C (292 °F) was imposed on the 11-gauge stainless steel sheet. For the closure head, the 276.7 °C (530 °F) temperature was imposed from the center of the cask to the outer steel shell, and a temperature profile that linearly varies from 276.7 °C (530 °F) at the outer shell to 144.4 °C (292 °F) at the 11-gauge stainless steel sheet was also imposed. See Figure B-2.

For the worst-case scenario, the maximum predicted stress intensity is 465.4 MPa (67.5 ksi) in the outer steel shell at its attachment to the head, with bending being the primary contributor. The maximum predicted stress intensity in the 11-gauge stainless steel sheet was 527.45 MPa (76.5 ksi), with membrane being the primary contributor. Referring to Appendix 4 of *1992 ASME Boiler & Pressure Vessel Code* (ASME 1992), Section VIII, Division 2,

Figure B-1. Worst-Case Thermal Loads for Normal Conditions.

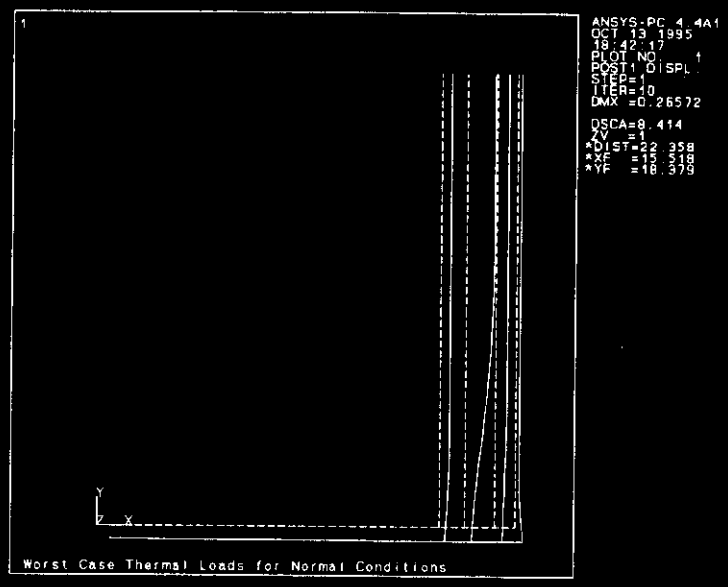
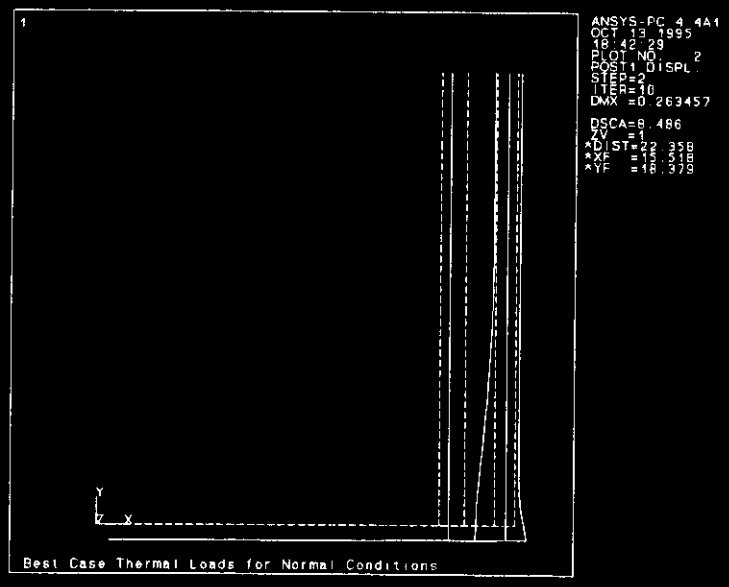


Figure B-2. Best-Case Thermal Loads for Normal Conditions.



the range of primary plus secondary stress intensity is usually limited to $3S_m$. However, for the case where the range of primary plus secondary membrane plus bending stress intensity, excluding thermal bending stresses, is less than $3S_m$, simplified elastic-plastic analysis may be performed. This situation prevails for all components of the cask. In accordance with Appendix 5 of ASME (1992), Section VIII, Division 2, the peak stress intensity range is determined by the conservative use of a fatigue strength reduction factor of 5. In applying the simplified elastic-plastic analysis, the value of S_a used for entering the design fatigue curve is multiplied by the factor K_e, where

$$K_e = 1.0 + \frac{(1-n)}{n(m-1)}\left[\frac{S_n}{3\ S_m} - 1\right]$$

and $m = 3.0$ for carbon steel, 1.7 for austenitic stainless steel.

$n = 0.2$ for carbon steel, 0.3 for austenitic stainless steel.

$K_e = 1.852$

Then $S_{alt} = 5.0 \times 1.852 \times 67.5/2 = 312.5$ ksi

Based upon the fatigue curve (Figure 5-110.1) of Appendix 5, the allowable number of cycles that can be sustained by carbon steel (with an ultimate tensile strength < 80 ksi) at $S_{alt} = 312.5$ ksi is 38 cycles.

For the "best-case" scenario, the maximum predicted stress intensity is 92.3 ksi in the 11-gauge stainless steel sheet, with bending being a primary contributor. Stress levels in the other components of the cask were all below their yield strength (30 ksi). Applying the simplified elastic-plastic analysis, the value of S_a used for entering the design fatigue curve is multiplied by the factor K_e computed as follows:

$$K_e = 1.0 + \frac{(1-n)}{n\ (m-1)}\left[\frac{S_n}{3\ S_m} - 1\right]$$

$K_e = 2.79$

Then $S_{alt} = 5.0 \times 2.79 \times 92.3/2 = 644.8$ ksi

Based upon the fatigue curve (Figure 5-110.2.1) of Appendix 5, the allowable number of cycles that can be sustained by the stainless steel at $S_{alt} = 644.8$ ksi is 13 cycles.

It should be noted that the 11-gauge stainless steel sheet is an insulation barrier, not a containment barrier, as are the inner and outer steel shells. For the inner and outer shells,

$S_{alt} = 5.0 \times 22.2/2 = 55.5$ ksi

Based upon the fatigue curve (Figure 5-110.1) of Appendix 5, the allowable number of cycles that can be sustained by the carbon steel containment barrier is in excess of 2,000.

The cask will be subjected to less than two of the full thermal cycles addressed in this calculation during its authorized use (Part A, Section 1.3).

7.3 EVALUATION OF LOSS OF MATERIAL STRENGTH

The most severe reduction in material strength (yield strength) for the cask lifting lugs is 11% in their minimum (room temperature) yield strength at 144.4 °C (292 °F). On page 2-19 of SEG (1991), a safety factor of 1.05 corresponding to pin bearing stress is identified. The safety factor, however, is based on a yield strength of 30 ksi, whereas the drawings identify the stressed component as being ASTM A516 Grade 70, which has a yield strength (at room temperature) of 38 ksi. If such is the case, the safety factor after loss of material strength due to the thermal condition would be 1.18 and thereby acceptable.

On pages 2-31 of SEG (1991), safety factors of 1.21 and 1.03 corresponding to longitudinal and circumferential stresses in the cask outer shell due to tiedown loads are identified. On pages 2-32 and 2-33 of SEG (1991), addressing the cask tiedown adapter, stress ratios of 1.11 for pin hole bearing stress, as well as for tearing stress, and 1.18 for weld strength are identified. The critical 1.03 safety factor on circumferential stress in the cask outer shell would degrade to a value of 0.82 for losses in material strength due to elevated temperatures. Consequently, special precautions need to be taken in resisting the "10-5-2-g" cask tiedown lug load condition. These precautions are identified as follows.

- The cask will only be shipped once with the high-heat (2.1 kW) payload that imposes this condition.
- The railcar will be shipped under controlled conditions and at controlled speeds (at or under 25 mi/h). Crossings shall be barricaded to prevent collisions, and no railcar humping is permitted when the cask is on the railcar.

Of note, the "10-5-2-g" cask lug condition is intended to prevent damage to the cask containment under excessive loading conditions. In an accident, the tiedown system itself is designed to break away at a lower load than the *g*-loading required for the lugs.

7.4 APPENDICES

7.4.1 ANSYS (SAS 1989) Analyses

```
FILENAME : segp1.out          DATE : 10-16-95          TIME : 12:04p                PAGE 1
TITLE   : Worst Case Thermal Loads for Normal Conditions


 STORE SIT  FOR ELEMENT TYPE STIF 51  FROM ITEM   26

 STORE SIB  FOR ELEMENT TYPE STIF 51  FROM ITEM   36

 STORE SET  FOR ELEMENT TYPE STIF 51  FROM ITEM   27

 STORE SEB  FOR ELEMENT TYPE STIF 51  FROM ITEM   37

 STORE SXT  FOR ELEMENT TYPE STIF 51  FROM ITEM   11

 STORE SXB  FOR ELEMENT TYPE STIF 51  FROM ITEM   19

 STORE SYT  FOR ELEMENT TYPE STIF 51  FROM ITEM   14

 STORE SYB  FOR ELEMENT TYPE STIF 51  FROM ITEM   22

 STORE SZT  FOR ELEMENT TYPE STIF 51  FROM ITEM   16

 STORE SZB  FOR ELEMENT TYPE STIF 51  FROM ITEM   20

 USE LOAD STEP   1  ITERATION   10  SECTION   1  FOR LOAD CASE   1


 GEOMETRY STORED FOR   156  NODES   155  ELEMENTS
  TITLE =  Worst Case Thermal Loads for Normal Conditions

 DISPLACEMENT STORED FOR  156 NODES

 STRESSES STORED FOR   10  SELECTED ITEMS

 ITERATION SUMMARY INFORMATION STORED

 NODAL FORCES STORED FOR  155 ELEMENTS

 ***WARNING ***                    CP =     8.900   TIME =  12.06825
 ACCUMULATED SOLUTION PHASE WARNING MESSAGES =     1.
    SEE FILE19 OR FILE06

 REACTIONS STORED FOR   8 REACTIONS

 FOR LOAD STEP =    1  ITERATION =   10  SECTION =   1
  TIME =  0.000000E+00   LOAD CASE =  1
  TITLE =  Worst Case Thermal Loads for Normal Conditions

 ESEL  FOR LABEL = REAL  FROM    1 TO    1 BY   1

    35  ELEMENTS (OF   155  DEFINED) SELECTED BY  ESEL  COMMAND.

 PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4     A  1   38280-PC/L1-4.4A MAY 1,1990
    ANSYS(R)  COPYRIGHT(C) 1971, '78, '82, '83, '85, '86, '87, '89, '90, '91   SWANSON ANALYSIS SYSTEMS, INC. AS UNPUBLISH
ED WORK.
    PROPRIETARY DATA - UNAUTHORIZED USE, DISTRIBUTION OR DUPLICATION IS PROHIBITED.  ALL RIGHTS RESERVED.
    FOR SUPPORT CALL                PHONE                TWX

 Worst Case Thermal Loads for Normal Conditions                    12.0683  OCT 16,1995 CP =     9.070

      ***** POST1 ELEMENT STRESS LISTING *****

 LOAD STEP    1  ITERATION =    10  SECTION =  1
 TIME =   0.00000E+00     LOAD CASE =  1
```

ELEM	SIT	SIB	SET	SEB
1	18473.921	14122.736	16227.097	12384.058
2	14795.783	11313.058	13130.426	10043.394
3	13716.538	10487.746	12700.360	9712.2478
4	13259.533	10138.215	12597.661	9632.7204
5	13024.325	9958.3148	12563.862	9606.4835
6	12887.562	9853.7089	12550.218	9595.8788
7	12801.089	9787.5683	12543.879	9590.9478
8	12742.964	9743.1092	12540.614	9588.4075
9	12702.024	9711.7955	12538.797	9586.9924
10	12672.107	9688.9128	12537.720	9586.1541
11	12649.584	9671.6852	12537.050	9585.6321
12	12632.204	9658.3921	12536.615	9585.2933
13	12618.514	9647.9204	12536.323	9585.0658
14	12607.538	9639.5249	12536.121	9584.9084
15	12598.603	9632.6908	12535.977	9584.7967
16	12591.233	9627.0536	12535.873	9584.7157
17	12585.082	9622.3494	12535.796	9584.6558
18	12579.897	9618.3830	12535.739	9584.6107
19	12575.484	9615.0079	12535.694	9584.5763
20	12571.698	9612.1121	12535.660	9584.5496
21	12568.426	9609.6089	12535.633	9584.5287
22	12565.578	9607.4306	12535.612	9584.5121
23	12563.084	9605.5231	12535.595	9584.4988
24	12560.888	9603.8435	12535.581	9584.4880
25	12558.944	9602.3567	12535.570	9584.4793
26	12557.215	9601.0344	12535.561	9584.4720
27	12555.671	9599.8532	12535.553	9584.4661
28	12554.286	9598.7937	12535.546	9584.4611
29	21868.644	21876.890	18990.226	19009.606
30	40705.071	43483.305	36964.217	39677.822
31	36501.441	41752.487	33958.469	37857.752
32	35563.440	47341.579	30931.837	41093.424
33	31452.670	36622.171	29205.513	33166.639
34	19435.094	21164.636	18020.954	19745.684
35	7021.5318	6051.8008	6477.2573	5649.8600

MINIMUMS

ELEMENT	35	35	35	35
VALUE	7021.5318	6051.8008	6477.2573	5649.8600

MAXIMUMS

ELEMENT	30	32	30	32
VALUE	40705.071	47341.579	36964.217	41093.424

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

ANSYS(R) COPYRIGHT(C) 1971, '78, '82, '83, '85, '86, '87, '89, '90, '91 SWANSON ANALYSIS SYSTEMS, INC. AS UNPUBLISHED WORK.

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0683 OCT 16,1995 CP= 9.180

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
1	6525.0683	5118.1405	0.00000000E+00	0.00000000E+00	16298.329	14122.736
2	10265.242	7865.7832	0.00000000E+00	0.00000000E+00	13054.421	11313.058
3	11351.775	8683.8076	0.00000000E+00	0.00000000E+00	12102.142	10487.746
4	11810.468	9031.6506	0.00000000E+00	0.00000000E+00	11698.874	10138.215
5	12046.225	9211.0009	0.00000000E+00	0.00000000E+00	11491.320	9958.3148
6	12183.209	9315.3857	0.00000000E+00	0.00000000E+00	11370.635	9853.7089
7	12269.785	9381.4238	0.00000000E+00	0.00000000E+00	11294.329	9787.5683
8	12327.963	9425.8301	0.00000000E+00	0.00000000E+00	11243.036	9743.1092
9	12368.932	9457.1145	0.00000000E+00	0.00000000E+00	11206.910	9711.7955
10	12398.866	9479.9798	0.00000000E+00	0.00000000E+00	11180.510	9688.9128
11	12421.400	9497.1965	0.00000000E+00	0.00000000E+00	11160.635	9671.6852
12	12438.787	9510.4827	0.00000000E+00	0.00000000E+00	11145.298	9658.3921

13	12452.482	9520.9496	0.00000000E+00	0.00000000E+00	11133.217	9647.9204
14	12463.462	9529.3419	0.00000000E+00	0.00000000E+00	11123.531	9639.5249
15	12472.399	9536.1737	0.00000000E+00	0.00000000E+00	11115.647	9632.6908
16	12479.771	9541.8092	0.00000000E+00	0.00000000E+00	11109.143	9627.0536
17	12485.922	9546.5122	0.00000000E+00	0.00000000E+00	11103.716	9622.3494
18	12491.109	9550.4776	0.00000000E+00	0.00000000E+00	11099.140	9618.3830
19	12495.522	9553.8521	0.00000000E+00	0.00000000E+00	11095.246	9615.0079
20	12499.309	9556.7473	0.00000000E+00	0.00000000E+00	11091.905	9612.1121
21	12502.582	9559.2500	0.00000000E+00	0.00000000E+00	11089.017	9609.6089
22	12505.430	9561.4280	0.00000000E+00	0.00000000E+00	11086.504	9607.4306
23	12507.924	9563.3352	0.00000000E+00	0.00000000E+00	11084.303	9605.5231
24	12510.120	9565.0146	0.00000000E+00	0.00000000E+00	11082.366	9603.8435
25	12512.064	9566.5012	0.00000000E+00	0.00000000E+00	11080.650	9602.3567
26	12513.793	9567.8233	0.00000000E+00	0.00000000E+00	11079.125	9601.0344
27	12515.338	9569.0044	0.00000000E+00	0.00000000E+00	11077.762	9599.8532
28	12516.723	9570.0639	0.00000000E+00	0.00000000E+00	11076.540	9598.7937
29	12330.922	9383.9700	0.00000000E+00	0.00000000E+00	-11015.321	-12492.920
30	9231.5542	9242.4051	0.00000000E+00	0.00000000E+00	-32857.208	-34240.900
31	5844.6234	9662.1120	0.00000000E+00	0.00000000E+00	-31373.596	-32090.375
32	-14916.431	20886.775	0.00000000E+00	0.00000000E+00	-31009.122	-26454.804
33	-5190.2469	8608.5944	0.00000000E+00	0.00000000E+00	-29733.124	-28013.577
34	-3278.4002	3238.2272	0.00000000E+00	0.00000000E+00	-18680.751	-17926.409
35	-1279.5261	915.75857	0.00000000E+00	0.00000000E+00	5896.9032	6051.8008

MINIMUMS

ELEMENT	32	35	1	1	30	30
VALUE	-14916.431	915.75857	0.00000000E+00	0.00000000E+00	-32857.208	-34240.900

MAXIMUMS

ELEMENT	28	32	1	1	1	1
VALUE	12516.723	20886.775	0.00000000E+00	0.00000000E+00	16298.329	14122.736

ESEL FOR LABEL = REAL FROM 2 TO 2 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0684 OCT 16,1995 CP = 9.450

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION = 10 SECTION = 1
TIME = 0.00000E+00 LOAD CASE = 1

ELEM	SIT	SIB	SET	SEB
36	67457.749	40240.937	59845.870	34898.399
37	37217.469	34336.876	32320.694	30166.963
38	19065.556	33229.330	17412.434	29769.961
39	10741.128	27311.304	9801.8001	26657.895
40	8553.5888	23204.180	7447.0265	22298.887
41	9331.2089	19549.051	9038.3392	18374.519
42	11674.892	16601.554	11358.487	15641.836
43	13512.682	14772.194	13060.111	14151.681
44	14393.767	13895.151	14013.326	13584.086
45	14657.063	13633.063	14411.799	13535.865
46	14609.455	13711.209	14487.075	13695.856
47	14457.256	13940.339	14417.817	13886.463
48	14316.906	14086.147	14313.001	14033.096
49	14243.809	14158.257	14224.512	14120.738
50	14187.218	14181.557	14167.619	14160.750
51	14153.204	14179.573	14139.127	14171.133
52	14137.578	14168.541	14129.655	14167.246
53	14133.449	14160.842	14130.151	14159.042
54	14134.884	14154.015	14134.297	14151.556
55	14139.251	14148.500	14138.637	14146.498
56	14142.694	14145.072	14141.800	14143.821

57	14144.348	14143.426	14143.605	14142.821
58	14144.845	14142.931	14144.373	14142.746
59	14144.758	14143.074	14144.525	14143.046
60	14144.474	14143.501	14144.399	14143.401
61	14144.208	14143.774	14144.202	14143.675
62	14144.068	14143.910	14144.033	14143.842
63	14143.956	14143.957	14143.921	14143.922
64	14143.887	14143.962	14143.859	14143.951
65	14143.855	14143.959	14143.834	14143.958

MINIMUMS

ELEMENT	40	45	40	45
VALUE	8553.5888	13633.063	7447.0265	13535.865

MAXIMUMS

ELEMENT	36	36	36	36
VALUE	67457.749	40240.937	59845.870	34898.399

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0684 OCT 16,1995 CP= 9.560

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
36	46714.147	-18276.971	0.00000000E+00	0.00000000E+00	-30492.269	-40240.937
37	16206.182	12091.049	0.00000000E+00	0.00000000E+00	-21628.557	-22245.827
38	4003.6467	24237.610	0.00000000E+00	0.00000000E+00	-12026.815	-8991.7201
39	2280.8370	25952.517	0.00000000E+00	0.00000000E+00	-4909.5389	-1358.7869
40	5041.8392	23204.180	0.00000000E+00	0.00000000E+00	-787.39847	1936.9526
41	8713.8117	19549.051	0.00000000E+00	0.00000000E+00	1007.8888	2633.1747
42	11674.892	16601.554	0.00000000E+00	0.00000000E+00	1400.7429	2139.7421
43	13512.682	14772.194	0.00000000E+00	0.00000000E+00	1146.8151	1335.7418
44	14393.767	13895.151	0.00000000E+00	0.00000000E+00	719.91102	645.11870
45	14657.063	13633.063	0.00000000E+00	0.00000000E+00	350.13579	196.53579
46	14609.455	13680.452	0.00000000E+00	0.00000000E+00	108.59365	-30.756800
47	14457.256	13831.953	0.00000000E+00	0.00000000E+00	-14.590518	-108.38604
48	14309.093	13979.437	0.00000000E+00	0.00000000E+00	-57.261306	-106.70967
49	14205.135	14082.917	0.00000000E+00	0.00000000E+00	-57.006766	-75.339485
50	14147.939	14139.852	0.00000000E+00	0.00000000E+00	-40.492002	-41.705084
51	14125.008	14162.678	0.00000000E+00	0.00000000E+00	-22.546299	-16.895809
52	14121.719	14165.951	0.00000000E+00	0.00000000E+00	-9.2244649	-2.5896440
53	14126.852	14160.842	0.00000000E+00	0.00000000E+00	-1.4987547	3.5997986
54	14133.710	14154.015	0.00000000E+00	0.00000000E+00	1.8725523	4.9181616
55	14139.251	14148.500	0.00000000E+00	0.00000000E+00	2.6160081	4.0033005
56	14142.694	14145.072	0.00000000E+00	0.00000000E+00	2.1454180	2.5021122
57	14144.348	14143.426	0.00000000E+00	0.00000000E+00	1.3484394	1.2101479
58	14144.845	14142.931	0.00000000E+00	0.00000000E+00	0.65692498	0.36995050
59	14144.758	14143.018	0.00000000E+00	0.00000000E+00	0.20496477	-0.56130863E-01
60	14144.474	14143.300	0.00000000E+00	0.00000000E+00	-0.25247077E-01	-0.20142782
61	14144.197	14143.577	0.00000000E+00	0.00000000E+00	-0.10424757	-0.19723344
62	14143.999	14143.773	0.00000000E+00	0.00000000E+00	-0.10256168	-0.13636250
63	14143.885	14143.887	0.00000000E+00	0.00000000E+00	-0.70920723E-01	-0.70695102E-01
64	14143.832	14143.940	0.00000000E+00	0.00000000E+00	-0.38787455E-01	-0.22561265E-01
65	14143.813	14143.959	0.00000000E+00	0.00000000E+00	-0.20183240E-01	0.17558307E-02

MINIMUMS

ELEMENT	39	36	36	36	36	36
VALUE	2280.8370	-18276.971	0.00000000E+00	0.00000000E+00	-30492.269	-40240.937

MAXIMUMS

ELEMENT	36	39	36	36	42	41
VALUE	46714.147	25952.517	0.00000000E+00	0.00000000E+00	1400.7429	2633.1747

ESEL FOR LABEL = REAL FROM 3 TO 3 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0685 OCT 16,1995 CP = 9.830

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION = 10 SECTION = 1
TIME = 0.00000E+00 LOAD CASE = 1

ELEM	SIT	SIB	SET	SEB
66	19370.300	27438.387	16993.953	24324.729
67	14610.894	21643.810	12689.004	19630.767
68	10221.097	16814.367	9631.0474	15725.658
69	9057.1189	12884.689	8034.9311	12504.819
70	8831.0291	9952.4992	7817.3119	9863.6865
71	8525.2256	7990.5078	8430.4670	7705.8744
72	10358.929	6230.4440	9304.9363	5952.3874
73	11634.184	4686.8729	10128.828	4553.2596
74	12445.510	3629.3280	10780.279	3503.5648
75	12880.620	3212.4233	11229.118	2855.8575
76	13018.858	3079.9696	11484.835	2674.7695
77	12930.355	3164.7693	11572.927	2906.9264
78	12675.750	3408.7221	11524.051	3383.5361
79	12306.332	4130.8622	11368.909	3959.6316
80	11864.509	4850.5138	11135.821	4554.7667
81	11384.488	5504.0888	10849.660	5129.1467
82	10893.099	6084.7959	10531.511	5663.1824
83	10410.690	6590.4636	10198.723	6147.4629
84	9952.0434	7022.4465	9865.1759	6578.1708
85	9555.9591	7384.6719	9541.6559	6954.8502
86	9327.0260	7682.8241	9236.2686	7279.1819
87	9100.4767	7923.6606	8954.8622	7554.2155
88	8885.0277	8114.4474	8701.4291	7783.8267
89	8687.2109	8262.5032	8478.4826	7972.3038
90	8511.7777	8374.8374	8287.3997	8124.0172
91	8362.0706	8457.8690	8128.7317	8243.1540
92	8240.3520	8517.2125	8002.4809	8333.5027
93	8148.0867	8557.5203	7908.3402	8398.2843
94	8086.1698	8582.3687	7845.8947	8440.0229
95	8055.1010	8594.1814	7814.7774	8460.4514

MINIMUMS

ELEMENT	95	76	95	76
VALUE	8055.1010	3079.9696	7814.7774	2674.7695

MAXIMUMS

ELEMENT	66	66	66	66
VALUE	19370.300	27438.387	16993.953	24324.729

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0685 OCT 16,1995 CP = 9.940

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION = 10 SECTION = 1
TIME = 0.00000E+00 LOAD CASE = 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
66	12403.246	-27438.387	0.00000000E+00	0.00000000E+00	-12943.299	-18919.544
67	6355.6307	-21643.810	0.00000000E+00	0.00000000E+00	-12455.179	-16655.095
68	1315.2943	-16814.367	0.00000000E+00	0.00000000E+00	-11625.252	-14344.701
69	-2785.9853	-12884.689	0.00000000E+00	0.00000000E+00	-10571.924	-12086.730
70	-6034.1741	-9772.4075	0.00000000E+00	0.00000000E+00	-9391.7642	-9952.4992
71	-8525.2256	-7385.5840	0.00000000E+00	0.00000000E+00	-8161.4541	-7990.5078
72	-10358.929	-5628.6045	0.00000000E+00	0.00000000E+00	-6939.9926	-6230.4440
73	-11634.184	-4406.7081	0.00000000E+00	0.00000000E+00	-5770.9942	-4686.8729
74	-12445.510	-3629.3280	0.00000000E+00	0.00000000E+00	-4684.9770	-3362.5497
75	-12880.620	-3212.4233	0.00000000E+00	0.00000000E+00	-3701.5570	-2251.3274
76	-13018.858	-3079.9696	0.00000000E+00	0.00000000E+00	-2831.4883	-1340.6550
77	-12930.355	-3164.7693	0.00000000E+00	0.00000000E+00	-2078.5134	-613.67551
78	-12675.750	-3408.7221	0.00000000E+00	0.00000000E+00	-1441.0016	-50.947429
79	-12306.332	-3762.6834	0.00000000E+00	0.00000000E+00	-913.36845	368.17876
80	-11864.509	-4186.0201	0.00000000E+00	0.00000000E+00	-487.27953	664.49375
81	-11384.488	-4645.9559	0.00000000E+00	0.00000000E+00	-152.64694	858.13290
82	-10893.099	-5116.7844	0.00000000E+00	0.00000000E+00	101.56423	968.01150
83	-10410.690	-5579.0098	0.00000000E+00	0.00000000E+00	286.70187	1011.4539
84	-9952.0434	-6018.4657	0.00000000E+00	0.00000000E+00	413.94413	1003.9808
85	-9527.2880	-6425.4490	0.00000000E+00	0.00000000E+00	493.94702	959.22286
86	-9142.7538	-6793.8939	0.00000000E+00	0.00000000E+00	536.60124	888.93021
87	-8801.7733	-7120.6074	0.00000000E+00	0.00000000E+00	550.87832	803.05319
88	-8505.4046	-7404.5757	0.00000000E+00	0.00000000E+00	544.74738	709.87172
89	-8253.0739	-7646.3487	0.00000000E+00	0.00000000E+00	525.14576	616.15454
90	-8043.1337	-7847.5047	0.00000000E+00	0.00000000E+00	497.98835	527.33270
91	-7873.3396	-8010.1945	0.00000000E+00	0.00000000E+00	468.20270	447.67447
92	-7741.2461	-8136.7611	0.00000000E+00	0.00000000E+00	439.77867	380.45143
93	-7644.5276	-8229.4328	0.00000000E+00	0.00000000E+00	415.82328	328.08751
94	-7581.2281	-8290.0837	0.00000000E+00	0.00000000E+00	398.61330	292.28496
95	-7549.9441	-8320.0588	0.00000000E+00	0.00000000E+00	389.63974	274.12253

MINIMUMS

ELEMENT	76	66	66	66	66	66
VALUE	-13018.858	-27438.387	0.00000000E+00	0.00000000E+00	-12943.299	-18919.544

MAXIMUMS

ELEMENT	66	76	66	66	87	83
VALUE	12403.246	-3079.9696	0.00000000E+00	0.00000000E+00	550.87832	1011.4539

ESEL FOR LABEL= REAL FROM 4 TO 4 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0686 OCT 16,1995 CP= 10.220

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT	SIB	SET	SEB
96	63042.319	34132.993	57218.465	29560.128
97	47638.749	26613.358	41822.357	26299.035
98	35072.180	30908.980	30390.947	26917.482
99	25582.088	31637.429	22209.575	27698.442
100	18954.946	30221.578	16535.424	27510.213
101	14739.925	27728.777	12813.951	26389.970
102	12400.651	24898.881	10746.900	24682.167
103	11412.684	23242.463	10110.301	22738.188
104	11318.458	21662.747	10502.871	20828.830
105	11751.385	20054.224	11420.046	19130.772
106	12513.480	18613.034	12476.590	17737.851
107	13705.655	17433.359	13458.082	16679.083
108	14608.787	16539.697	14270.302	15937.317

109	15241.634	15913.485	14888.096	15466.831
110	15645.955	15513.404	15322.713	15208.853
111	15872.014	15289.714	15602.455	15103.695
112	15969.242	15193.506	15761.318	15098.569
113	15980.927	15181.944	15832.494	15151.304
114	15941.851	15241.370	15844.950	15231.001
115	15877.894	15349.695	15821.993	15316.902
116	15806.822	15438.357	15781.062	15396.463
117	15739.665	15505.538	15734.250	15463.282
118	15696.077	15552.690	15689.188	15515.207
119	15663.181	15583.016	15650.053	15552.783
120	15633.757	15600.382	15618.548	15578.048
121	15609.514	15608.621	15594.763	15593.680
122	15590.905	15611.124	15577.875	15602.417
123	15577.681	15610.639	15566.684	15606.695
124	15569.308	15609.208	15560.002	15608.444
125	15565.273	15609.804	15556.910	15608.984

MINIMUMS

ELEMENT	104	113	103	112
VALUE	11318.458	15181.944	10110.301	15098.569

MAXIMUMS

ELEMENT	96	96	96	96
VALUE	63042.319	34132.993	57218.465	29560.128

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0687 OCT 16,1995 CP= 10.330

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
96	48644.308	-17138.964	0.00000000E+00	0.00000000E+00	-24265.502	-34132.993
97	30676.614	640.34047	0.00000000E+00	0.00000000E+00	-21467.577	-25973.018
98	18568.716	12621.288	0.00000000E+00	0.00000000E+00	-17395.578	-18287.693
99	11231.292	19881.779	0.00000000E+00	0.00000000E+00	-13053.223	-11755.650
100	7489.3242	23584.513	0.00000000E+00	0.00000000E+00	-9051.3439	-6637.0656
101	6252.6838	24808.187	0.00000000E+00	0.00000000E+00	-5703.9154	-2920.5899
102	6604.9753	24459.589	0.00000000E+00	0.00000000E+00	-3117.4841	-439.29197
103	7834.9981	23242.463	0.00000000E+00	0.00000000E+00	-1266.5662	1044.5535
104	9431.4533	21662.747	0.00000000E+00	0.00000000E+00	-52.310730	1782.3833
105	11057.020	20054.224	0.00000000E+00	0.00000000E+00	655.21616	2004.7967
106	12513.480	18613.034	0.00000000E+00	0.00000000E+00	989.04497	1903.9781
107	13705.655	17433.359	0.00000000E+00	0.00000000E+00	1068.7799	1627.9355
108	14608.787	16539.697	0.00000000E+00	0.00000000E+00	992.58829	1282.2249
109	15241.634	15913.485	0.00000000E+00	0.00000000E+00	835.02463	935.80221
110	15645.955	15513.404	0.00000000E+00	0.00000000E+00	648.47446	628.59173
111	15872.014	15289.714	0.00000000E+00	0.00000000E+00	466.52459	379.17959
112	15969.242	15193.506	0.00000000E+00	0.00000000E+00	308.06049	191.70007
113	15980.927	15181.944	0.00000000E+00	0.00000000E+00	181.31510	61.467634
114	15941.851	15220.610	0.00000000E+00	0.00000000E+00	87.425988	-20.760116
115	15877.894	15283.896	0.00000000E+00	0.00000000E+00	23.301049	-65.798598
116	15806.822	15354.224	0.00000000E+00	0.00000000E+00	-16.243796	-84.133489
117	15739.665	15420.676	0.00000000E+00	0.00000000E+00	-37.013016	-84.861307
118	15682.289	15477.450	0.00000000E+00	0.00000000E+00	-44.514114	-75.239911
119	15636.892	15522.372	0.00000000E+00	0.00000000E+00	-43.466546	-60.644630
120	15603.295	15555.616	0.00000000E+00	0.00000000E+00	-37.614062	-44.765846
121	15579.971	15578.696	0.00000000E+00	0.00000000E+00	-29.734293	-29.925552
122	15564.812	15593.696	0.00000000E+00	0.00000000E+00	-21.760794	-17.428157
123	15555.664	15602.748	0.00000000E+00	0.00000000E+00	-14.954175	-7.8915944
124	15550.680	15607.680	0.00000000E+00	0.00000000E+00	-10.077896	-1.5279866
125	15548.533	15609.804	0.00000000E+00	0.00000000E+00	-7.5495101	1.6412156

```
MINIMUMS
ELEMENT    101          96          96          96          96          96
VALUE    6252.6838    -17138.964    0.00000000E+00  0.00000000E+00  -24265.502    -34132.993

MAXIMUMS
ELEMENT     96         101          96          96         107         105
VALUE    48644.308     24808.187    0.00000000E+00  0.00000000E+00  1068.7799     2004.7967

ESEL  FOR LABEL= REAL  FROM    5 TO    5 BY   1

   30  ELEMENTS (OF   155  DEFINED) SELECTED BY  ESEL  COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4     A  1   38280-PC/L1-4.4A MAY 1,1990
    ANSYS(R)  COPYRIGHT(C) 1971, '78, '82, '83, '85, '86, '87, '89, '90, '91   SWANSON ANALYSIS SYSTEMS, INC. AS UNPUBLISH
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    FOR SUPPORT CALL                PHONE                TWX

 Worst Case Thermal Loads for Normal Conditions                    12.0687  OCT 16,1995 CP=     10.550

      ***** POST1 ELEMENT STRESS LISTING *****

 LOAD STEP    1  ITERATION=    10  SECTION=  1
 TIME=   0.00000E+00     LOAD CASE=  1

 ELEM      SIT          SIB          SET          SEB
  126    36431.718    76537.602    31574.510    66925.096
  127    62811.447    50190.971    57443.467    46296.027
  128    65206.711    47938.673    62819.879    47868.846
  129    61041.368    54066.731    60735.288    53044.201
  130    58374.918    56722.589    58029.708    56033.381
  131    56913.068    57184.795    56610.517    56939.610
  132    56367.847    56915.987    56237.119    56902.264
  133    56317.747    56721.109    56295.440    56676.283
  134    56430.683    56563.729    56417.063    56530.177
  135    56501.167    56493.334    56486.988    56480.330
  136    56514.544    56479.974    56507.879    56478.493
  137    56508.166    56490.044    56506.743    56488.194
  138    56501.874    56496.788    56501.379    56495.203
  139    56498.625    56498.518    56497.975    56497.845
  140    56497.169    56498.214    56496.835    56498.104
  141    56496.892    56497.773    56496.807    56497.700
  142    56497.054    56497.442    56497.039    56497.368
  143    56497.232    56497.265    56497.202    56497.230
  144    56497.279    56497.217    56497.263    56497.210
  145    56497.273    56497.228    56497.268    56497.226
  146    56497.259    56497.245    56497.259    56497.241
  147    56497.252    56497.250    56497.251    56497.248
  148    56497.248    56497.250    56497.248    56497.250
  149    56497.247    56497.249    56497.247    56497.249
  150    56497.248    56497.249    56497.248    56497.249
  151    56497.248    56497.248    56497.248    56497.248
  152    56497.248    56497.248    56497.248    56497.248
  153    56497.248    56497.248    56497.248    56497.248
  154    56497.248    56497.248    56497.248    56497.248
  155    56497.248    56497.248    56497.248    56497.248

MINIMUMS
ELEMENT    126          128          126          127
VALUE    36431.718    47938.673    31574.510    46296.027

MAXIMUMS
ELEMENT    128          126          128          126
VALUE    65206.711    76537.602    62819.879    66925.096

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4     A  1   38280-PC/L1-4.4A MAY 1,1990
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    FOR SUPPORT CALL                PHONE                TWX
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Worst Case Thermal Loads for Normal Conditions 12.0687 OCT 16,1995 CP= 10.660

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
126	36431.718	76537.602	0.00000000E+00	0.00000000E+00	23008.182	29024.064
127	62811.447	50190.971	0.00000000E+00	0.00000000E+00	11052.060	9158.9889
128	65206.711	47798.713	0.00000000E+00	0.00000000E+00	2471.2401	-139.95956
129	61041.368	51958.830	0.00000000E+00	0.00000000E+00	-745.52074	-2107.9015
130	57678.224	55317.754	0.00000000E+00	0.00000000E+00	-1050.7644	-1404.8349
131	56303.036	56691.217	0.00000000E+00	0.00000000E+00	-551.80508	-493.57790
132	56105.474	56888.531	0.00000000E+00	0.00000000E+00	-144.91433	-27.455728
133	56273.105	56721.109	0.00000000E+00	0.00000000E+00	22.558665	89.759271
134	56430.683	56563.729	0.00000000E+00	0.00000000E+00	47.206860	67.163761
135	56501.167	56493.334	0.00000000E+00	0.00000000E+00	27.193295	26.018416
136	56514.544	56479.974	0.00000000E+00	0.00000000E+00	8.1468722	2.9614209
137	56508.166	56486.344	0.00000000E+00	0.00000000E+00	-0.42697290	-3.7003660
138	56500.883	56493.617	0.00000000E+00	0.00000000E+00	-2.0809714	-3.1708777
139	56497.325	56497.171	0.00000000E+00	0.00000000E+00	-1.3234263	-1.3464182
140	56496.501	56497.994	0.00000000E+00	0.00000000E+00	-0.44405201	-0.22021643
141	56496.723	56497.773	0.00000000E+00	0.00000000E+00	-0.11614650E-01	0.14588111
142	56497.054	56497.442	0.00000000E+00	0.00000000E+00	0.89665117E-01	0.14774256
143	56497.232	56497.265	0.00000000E+00	0.00000000E+00	0.63618745E-01	0.68564599E-01
144	56497.279	56497.217	0.00000000E+00	0.00000000E+00	0.23624767E-01	0.14231303E-01
145	56497.273	56497.223	0.00000000E+00	0.00000000E+00	0.21101989E-02	-0.53740273E-02
146	56497.258	56497.238	0.00000000E+00	0.00000000E+00	-0.37541175E-02	-0.67871547E-02
147	56497.249	56497.247	0.00000000E+00	0.00000000E+00	-0.30204451E-02	-0.34415279E-02
148	56497.247	56497.249	0.00000000E+00	0.00000000E+00	-0.12321632E-02	-0.85247313E-03
149	56497.247	56497.249	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
150	56497.248	56497.249	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
151	56497.248	56497.248	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
152	56497.248	56497.248	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
153	56497.248	56497.248	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
154	56497.248	56497.248	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
155	56497.248	56497.248	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

MINIMUMS						
ELEMENT	126	128	126	126	130	129
VALUE	36431.718	47798.713	0.00000000E+00	0.00000000E+00	-1050.7644	-2107.9015

MAXIMUMS						
ELEMENT	128	126	126	126	126	126
VALUE	65206.711	76537.602	0.00000000E+00	0.00000000E+00	23008.182	29024.064

155 ELEMENTS (OF 155 DEFINED) SELECTED BY EALL COMMAND.

PRINT NODAL DISPLACEMENTS
1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990
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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0688 OCT 16,1995 CP= 10.930

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1

TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
1	0.23355666E-02	-0.13127484	0.00000000E+00	-0.53733791E-04
2	0.38890091E-02	-0.13132742	0.00000000E+00	-0.65316885E-04
3	0.55656363E-02	-0.13139507	0.00000000E+00	-0.85071385E-04
4	0.72754755E-02	-0.13148171	0.00000000E+00	-0.10703649E-03
5	0.89990185E-02	-0.13158865	0.00000000E+00	-0.12991421E-03

6	0.10729534E-01	-0.13171647	0.00000000E+00	-0.15325632E-03
7	0.12464079E-01	-0.13186551	0.00000000E+00	-0.17686683E-03
8	0.14201162E-01	-0.13203595	0.00000000E+00	-0.20064641E-03
9	0.15939947E-01	-0.13222792	0.00000000E+00	-0.22453937E-03
10	0.17679929E-01	-0.13244150	0.00000000E+00	-0.24851207E-03
11	0.19420785E-01	-0.13267676	0.00000000E+00	-0.27254297E-03
12	0.21162299E-01	-0.13293374	0.00000000E+00	-0.29661764E-03
13	0.22904319E-01	-0.13321247	0.00000000E+00	-0.32072607E-03
14	0.24646738E-01	-0.13351299	0.00000000E+00	-0.34486108E-03
15	0.26389477E-01	-0.13383531	0.00000000E+00	-0.36901740E-03
16	0.28132475E-01	-0.13417945	0.00000000E+00	-0.39319104E-03
17	0.29875689E-01	-0.13454543	0.00000000E+00	-0.41737898E-03
18	0.31619082E-01	-0.13493326	0.00000000E+00	-0.44157884E-03
19	0.33362625E-01	-0.13534294	0.00000000E+00	-0.46578876E-03
20	0.35106297E-01	-0.13577449	0.00000000E+00	-0.49000723E-03
21	0.36850079E-01	-0.13622791	0.00000000E+00	-0.51423304E-03
22	0.38593957E-01	-0.13670321	0.00000000E+00	-0.53846519E-03
23	0.40337917E-01	-0.13720040	0.00000000E+00	-0.56270286E-03
24	0.42081950E-01	-0.13771948	0.00000000E+00	-0.58694536E-03
25	0.43826046E-01	-0.13826044	0.00000000E+00	-0.61119212E-03
26	0.45570199E-01	-0.13882331	0.00000000E+00	-0.63544264E-03
27	0.47314403E-01	-0.13940808	0.00000000E+00	-0.65969651E-03
28	0.49058651E-01	-0.14001475	0.00000000E+00	-0.68395337E-03
29	0.50802940E-01	-0.14064332	0.00000000E+00	-0.70821291E-03
30	0.53272786E-01	-0.14129380	0.00000000E+00	-0.73247487E-03
31	0.59423034E-01	-0.13619616	0.00000000E+00	-0.79586732E-02
32	0.69688384E-01	-0.13121908	0.00000000E+00	-0.84162245E-02
33	0.78563160E-01	-0.12637347	0.00000000E+00	-0.61664612E-02
34	0.84352880E-01	-0.12162562	0.00000000E+00	-0.35344668E-02
35	0.87301268E-01	-0.11693455	0.00000000E+00	-0.15150420E-02
36	0.88319368E-01	-0.11226831	0.00000000E+00	-0.31029901E-03
37	0.88309760E-01	-0.10760760	0.00000000E+00	0.23748402E-03
38	0.87911866E-01	-0.10294347	0.00000000E+00	0.37752591E-03
39	0.87480819E-01	-0.98273508E-01	0.00000000E+00	0.32208611E-03
40	0.87161297E-01	-0.93598475E-01	0.00000000E+00	0.20823014E-03
41	0.86976234E-01	-0.88920120E-01	0.00000000E+00	0.10493664E-03
42	0.86895632E-01	-0.84240066E-01	0.00000000E+00	0.35410724E-04

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 3B280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0688 OCT 16,1995 CP= 11.040

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
43	0.86877992E-01	-0.79559419E-01	0.00000000E+00	-0.12428691E-05
44	0.86889390E-01	-0.74878771E-01	0.00000000E+00	-0.14831994E-04
45	0.86908555E-01	-0.70198347E-01	0.00000000E+00	-0.15731191E-04
46	0.86925155E-01	-0.65518170E-01	0.00000000E+00	-0.11542766E-04
47	0.86935999E-01	-0.60838175E-01	0.00000000E+00	-0.66247063E-05
48	0.86941529E-01	-0.56158287E-01	0.00000000E+00	-0.28454044E-05
49	0.86943445E-01	-0.51478445E-01	0.00000000E+00	-0.58784700E-06
50	0.86943434E-01	-0.46798614E-01	0.00000000E+00	0.44048326E-06
51	0.86942692E-01	-0.42118777E-01	0.00000000E+00	0.70488280E-06
52	0.86941887E-01	-0.37438928E-01	0.00000000E+00	0.60237422E-06
53	0.86941289E-01	-0.32759070E-01	0.00000000E+00	0.38965443E-06
54	0.86940943E-01	-0.28079206E-01	0.00000000E+00	0.19611733E-06
55	0.86940792E-01	-0.23399339E-01	0.00000000E+00	0.65523384E-07
56	0.86940761E-01	-0.18719471E-01	0.00000000E+00	-0.34023815E-08
57	0.86940783E-01	-0.14039603E-01	0.00000000E+00	-0.28457234E-07
58	0.86940819E-01	-0.93597346E-02	0.00000000E+00	-0.28289993E-07
59	0.86940846E-01	-0.46798672E-02	0.00000000E+00	-0.16262332E-07
60	0.86940856E-01	0.00000000E+00	0.00000000E+00	0.00000000E+00
80	0.57489840E-01	-0.14204788	0.00000000E+00	-0.72419548E-03

130	0.61630899E-01	-0.14277593	0.00000000E+00	-0.68238284E-03
131	0.66117563E-01	-0.13596265	0.00000000E+00	-0.64833246E-02
132	0.76501350E-01	-0.12931208	0.00000000E+00	-0.10560043E-01
133	0.90887114E-01	-0.12287328	0.00000000E+00	-0.13199722E-01
134	0.10771329	-0.11667484	0.00000000E+00	-0.14670093E-01
135	0.12572527	-0.11072903	0.00000000E+00	-0.15214380E-01
136	0.14394410	-0.10503551	0.00000000E+00	-0.15048448E-01
137	0.16163280	-0.99584551E-01	0.00000000E+00	-0.14359713E-01
138	0.17826233	-0.94359792E-01	0.00000000E+00	-0.13307392E-01
139	0.19347835	-0.89340558E-01	0.00000000E+00	-0.12023756E-01
140	0.20707003	-0.84503725E-01	0.00000000E+00	-0.10616067E-01
141	0.21894141	-0.79825215E-01	0.00000000E+00	-0.91689645E-02
142	0.22908587	-0.75281145E-01	0.00000000E+00	-0.77470952E-02
143	0.23756367	-0.70848676E-01	0.00000000E+00	-0.63978160E-02
144	0.24448292	-0.66506608E-01	0.00000000E+00	-0.51538608E-02
145	0.24998346	-0.62235768E-01	0.00000000E+00	-0.40358729E-02
146	0.25422386	-0.58019221E-01	0.00000000E+00	-0.30547426E-02
147	0.25737095	-0.53842351E-01	0.00000000E+00	-0.22137111E-02
148	0.25959183	-0.49692834E-01	0.00000000E+00	-0.15102185E-02
149	0.26104782	-0.45560544E-01	0.00000000E+00	-0.93748962E-03
150	0.26189027	-0.41437398E-01	0.00000000E+00	-0.48586187E-03
151	0.26225776	-0.37317170E-01	0.00000000E+00	-0.14386788E-03
152	0.26227445	-0.33195291E-01	0.00000000E+00	0.10090987E-03

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0689 OCT 16,1995 CP= 11.260

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
153	0.26204937	-0.29068641E-01	0.00000000E+00	0.26119056E-03
154	0.26167636	-0.24935340E-01	0.00000000E+00	0.34952974E-03
155	0.26123443	-0.20794552E-01	0.00000000E+00	0.37801332E-03
156	0.26078848	-0.16646301E-01	0.00000000E+00	0.35808726E-03
157	0.26039008	-0.12491299E-01	0.00000000E+00	0.30050028E-03
158	0.26007830	-0.83307875E-02	0.00000000E+00	0.21533809E-03
159	0.25988048	-0.41663950E-02	0.00000000E+00	0.11212871E-03
160	0.25981276	0.00000000E+00	0.00000000E+00	0.00000000E+00
180	0.66178261E-01	-0.14333998	0.00000000E+00	-0.30751309E-03
230	0.70650353E-01	-0.14359735	0.00000000E+00	-0.16279233E-03
231	0.72667111E-01	-0.13851178	0.00000000E+00	-0.29056458E-02
232	0.77028567E-01	-0.13346814	0.00000000E+00	-0.41580173E-02
233	0.82245838E-01	-0.12848282	0.00000000E+00	-0.44059971E-02
234	0.87360816E-01	-0.12355859	0.00000000E+00	-0.40453124E-02
235	0.91831641E-01	-0.11869010	0.00000000E+00	-0.33742187E-02
236	0.95418925E-01	-0.11386786	0.00000000E+00	-0.26005413E-02
237	0.98085415E-01	-0.10908110	0.00000000E+00	-0.18560878E-02
238	0.99914911E-01	-0.10431955	0.00000000E+00	-0.12136688E-02
239	0.10105156	-0.99574376E-01	0.00000000E+00	-0.70368135E-03
240	0.10165790	-0.94838618E-01	0.00000000E+00	-0.32854023E-03
241	0.10188849	-0.90107167E-01	0.00000000E+00	-0.74217472E-04
242	0.10187560	-0.85376582E-01	0.00000000E+00	0.81210288E-04
243	0.10172353	-0.80644776E-01	0.00000000E+00	0.16172020E-03
244	0.10150842	-0.75910681E-01	0.00000000E+00	0.18973321E-03
245	0.10128152	-0.71173944E-01	0.00000000E+00	0.18420643E-03
246	0.10107378	-0.66434663E-01	0.00000000E+00	0.15992726E-03
247	0.10090088	-0.61693185E-01	0.00000000E+00	0.12758270E-03
248	0.10076793	-0.56949962E-01	0.00000000E+00	0.94268858E-04
249	0.10067331	-0.52205456E-01	0.00000000E+00	0.64196508E-04
250	0.10061171	-0.47460081E-01	0.00000000E+00	0.39429596E-04
251	0.10057631	-0.42714177E-01	0.00000000E+00	0.20558387E-04
252	0.10056014	-0.37967999E-01	0.00000000E+00	0.72580603E-05
253	0.10055698	-0.33221730E-01	0.00000000E+00	-0.12827493E-05

254	0.10056171	-0.28475484E-01	0.00000000E+00	-0.60577188E-05
255	0.10057041	-0.23729325E-01	0.00000000E+00	-0.80456906E-05
256	0.10058025	-0.18983278E-01	0.00000000E+00	-0.80988547E-05
257	0.10058934	-0.14237344E-01	0.00000000E+00	-0.68945173E-05
258	0.10059649	-0.94915059E-02	0.00000000E+00	-0.49313410E-05
259	0.10060101	-0.47457354E-02	0.00000000E+00	-0.25547340E-05
260	0.10060255	0.00000000E+00	0.00000000E+00	0.00000000E+00
280	0.73131689E-01	-0.14370489	0.00000000E+00	-0.11756975E-03
330	0.74665955E-01	-0.14378894	0.00000000E+00	-0.10229051E-03

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Worst Case Thermal Loads for Normal Conditions 12.0690 OCT 16,1995 CP= 11.430

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
331	0.64098972E-01	-0.13927955	0.00000000E+00	0.12803448E-01
332	0.50511990E-01	-0.13462008	0.00000000E+00	0.87422843E-02
333	0.43580528E-01	-0.12984760	0.00000000E+00	0.31405359E-02
334	0.41845428E-01	-0.12503112	0.00000000E+00	0.21785070E-03
335	0.42186844E-01	-0.12020951	0.00000000E+00	-0.54172889E-03
336	0.42800634E-01	-0.11539407	0.00000000E+00	-0.41681543E-03
337	0.43143634E-01	-0.11058397	0.00000000E+00	-0.16483410E-03
338	0.43242362E-01	-0.10577615	0.00000000E+00	-0.20670135E-04
339	0.43234230E-01	-0.10096870	0.00000000E+00	0.22142961E-04
340	0.43206998E-01	-0.96161007E-01	0.00000000E+00	0.19622519E-04
341	0.43190238E-01	-0.91353067E-01	0.00000000E+00	0.84982856E-05
342	0.43184808E-01	-0.86545011E-01	0.00000000E+00	0.14759484E-05
343	0.43184792E-01	-0.81736931E-01	0.00000000E+00	-0.86220317E-06
344	0.43185975E-01	-0.76928860E-01	0.00000000E+00	-0.91152731E-06
345	0.43186784E-01	-0.72120801E-01	0.00000000E+00	-0.43133783E-06
346	0.43187075E-01	-0.67312747E-01	0.00000000E+00	-0.93465681E-07
347	0.43187095E-01	-0.62504694E-01	0.00000000E+00	0.31126561E-07
348	0.43187045E-01	-0.57696642E-01	0.00000000E+00	0.41736792E-07
349	0.43187007E-01	-0.52888589E-01	0.00000000E+00	0.21585202E-07
350	0.43186991E-01	-0.48080535E-01	0.00000000E+00	0.55294583E-08
351	0.43186990E-01	-0.43272482E-01	0.00000000E+00	-0.97724879E-09
352	0.43186992E-01	-0.38464428E-01	0.00000000E+00	-0.18805884E-08
353	0.43186993E-01	-0.33656374E-01	0.00000000E+00	-0.10660477E-08
354	0.43186994E-01	-0.28848321E-01	0.00000000E+00	-0.31283797E-09
355	0.43186994E-01	-0.24040267E-01	0.00000000E+00	0.21104932E-10
356	0.43186994E-01	-0.19232214E-01	0.00000000E+00	0.83035221E-10
357	0.43186994E-01	-0.14424160E-01	0.00000000E+00	0.52063374E-10
358	0.43186994E-01	-0.96161070E-02	0.00000000E+00	0.18043744E-10
359	0.43186994E-01	-0.48080535E-02	0.00000000E+00	0.27458279E-11
360	0.43186994E-01	0.00000000E+00	0.00000000E+00	0.00000000E+00

MAXIMUMS

NODE	152	330	0	135
VALUE	0.26227445	-0.14378894	0.00000000E+00	-0.15214380E-01

***** ROUTINE COMPLETED ***** CP = 11.590

/EOF ENCOUNTERED ON FILE18

***** RUN COMPLETED ***** CP= 11.8100 TIME= 12.0691

```
FILENAME : segp2.out          DATE : 10-16-95          TIME : 12:00p                PAGE 1
TITLE    : Best Case Thermal Loads for Normal Conditions


 STORE SIT   FOR ELEMENT TYPE STIF 51  FROM ITEM   26

 STORE SIB   FOR ELEMENT TYPE STIF 51  FROM ITEM   36

 STORE SET   FOR ELEMENT TYPE STIF 51  FROM ITEM   27

 STORE SEB   FOR ELEMENT TYPE STIF 51  FROM ITEM   37

 STORE SXT   FOR ELEMENT TYPE STIF 51  FROM ITEM   11

 STORE SXB   FOR ELEMENT TYPE STIF 51  FROM ITEM   19

 STORE SYT   FOR ELEMENT TYPE STIF 51  FROM ITEM   14

 STORE SYB   FOR ELEMENT TYPE STIF 51  FROM ITEM   22

 STORE SZT   FOR ELEMENT TYPE STIF 51  FROM ITEM   16

 STORE SZB   FOR ELEMENT TYPE STIF 51  FROM ITEM   20

 USE LOAD STEP    1  ITERATION    10  SECTION   1  FOR LOAD CASE    1


 GEOMETRY STORED FOR    156  NODES    155  ELEMENTS
  TITLE =  Best Case Thermal Loads for Normal Conditions

 DISPLACEMENT STORED FOR  156 NODES

 STRESSES STORED FOR   10  SELECTED ITEMS

 ITERATION SUMMARY INFORMATION STORED

 NODAL FORCES STORED FOR  155 ELEMENTS

 ***WARNING ***                    CP =      8.960   TIME =  12.00170
 ACCUMULATED SOLUTION PHASE WARNING MESSAGES =      1.
    SEE FILE19 OR FILE06

 REACTIONS STORED FOR    8 REACTIONS

 FOR LOAD STEP =     1  ITERATION =    10  SECTION =   1
  TIME =  0.000000E+00   LOAD CASE =  1
  TITLE =  Best Case Thermal Loads for Normal Conditions

 ESEL  FOR LABEL = REAL  FROM     1 TO     1 BY   1

    35  ELEMENTS (OF    155  DEFINED) SELECTED BY  ESEL  COMMAND.

 PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4      A  1   38280-PC/L1-4.4A MAY 1,1990
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    FOR SUPPORT CALL                PHONE                TWX

 Best Case Thermal Loads for Normal Conditions                    12.0017  OCT 16,1995 CP =      9.070

       ***** POST1 ELEMENT STRESS LISTING *****

 LOAD STEP    1  ITERATION =    10  SECTION =  1
 TIME =   0.00000E+00     LOAD CASE =  1

 ELEM      SIT          SIB          SET          SEB
    1    352.52098    4035.4643    329.74105    3554.8504
    2    281.13231    3231.0478    247.59874    2865.7364
    3    260.68543    2995.4138    240.55482    2772.8408
```

4	252.05697	2895.6587	239.15613	2750.8617
5	247.62011	2844.3208	238.73371	2743.6569
6	245.04108	2814.4706	238.57097	2740.7546
7	243.41063	2795.5971	238.49747	2739.4077
8	242.31473	2782.9106	238.46031	2738.7147
9	241.54288	2773.9752	238.43987	2738.3290
10	240.97886	2767.4456	238.42788	2738.1006
11	240.55424	2762.5297	238.42046	2737.9585
12	240.22659	2758.7365	238.41567	2737.8663
13	239.96849	2755.7484	238.41247	2737.8044
14	239.76156	2753.3528	238.41026	2737.7615
15	239.59312	2751.4026	238.40870	2737.7312
16	239.45418	2749.7941	238.40757	2737.7091
17	239.33823	2748.4517	238.40673	2737.6928
18	239.24047	2747.3199	238.40611	2737.6806
19	239.15728	2746.3568	238.40563	2737.6712
20	239.08591	2745.5305	238.40526	2737.6640
21	239.02421	2744.8163	238.40497	2737.6583
22	238.97052	2744.1947	238.40474	2737.6538
23	238.92351	2743.6504	238.40455	2737.6502
24	238.88211	2743.1711	238.40440	2737.6472
25	238.84546	2742.7468	238.40428	2737.6448
26	238.81287	2742.3695	238.40418	2737.6429
27	238.78376	2742.0325	238.40410	2737.6413
28	238.75764	2741.7301	238.40403	2737.6399
29	238.73413	2741.4579	238.40397	2737.6388
30	1371.5811	3976.6610	1188.1702	3950.9633
31	3788.8693	6417.3012	3310.4961	5754.0912
32	20417.394	17527.238	17986.523	15184.093
33	10222.113	7495.1976	8885.9355	6760.6325
34	11834.239	14261.370	10401.638	13433.671
35	34480.803	38321.770	33701.130	38090.126

MINIMUMS

ELEMENT	29	29	29	29
VALUE	238.73413	2741.4579	238.40397	2737.6388

MAXIMUMS

ELEMENT	35	35	35	35
VALUE	34480.803	38321.770	33701.130	38090.126

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0018 OCT 16,1995 CP= 9.230

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB	
1	-51.657620	1367.1692	0.00000000E+00	0.00000000E+00	1841.4717	4035.4643	
2	-185.60619	2234.1456	0.00000000E+00	0.00000000E+00	1474.9577	3231.0478	
3	-213.40265	2477.1292	0.00000000E+00	0.00000000E+00	1367.3642	2995.4138	
4	-223.73272	2578.5859	0.00000000E+00	0.00000000E+00	1321.8009	2895.6587	
5	-228.72427	2630.4785	0.00000000E+00	0.00000000E+00	1298.3503	2844.3208	
6	-231.52633	2660.5517	0.00000000E+00	0.00000000E+00	1284.7148	2814.4706	
7	-233.26020	2679.5287	0.00000000E+00	0.00000000E+00	1276.0932	2795.5971	
8	-234.40929	2692.2683	0.00000000E+00	0.00000000E+00	1270.2979	2782.9106	
9	-235.21073	2701.2333	0.00000000E+00	0.00000000E+00	1266.2161	2773.9752	
10	-235.79227	2707.7804	0.00000000E+00	0.00000000E+00	1263.2334	2767.4456	
11	-236.22780	2712.7072	0.00000000E+00	0.00000000E+00	1260.9877	2762.5297	
12	-236.56252	2716.5075	0.00000000E+00	0.00000000E+00	1259.2550	2758.7365	
13	-236.82537	2719.5003	0.00000000E+00	0.00000000E+00	1257.8900	2755.7484	
14	-237.03559	2721.8993	0.00000000E+00	0.00000000E+00	1256.7956	2753.3528	
15	-237.20636	2723.8517	0.00000000E+00	0.00000000E+00	1255.9048	2751.4026	
16	-237.34699	2725.4620	0.00000000E+00	0.00000000E+00	1255.1700	2749.7941	

17	-237.46419	2726.8056	0.00000000E+00	0.00000000E+00	1254.5568	2748.4517
18	-237.56289	2727.9383	0.00000000E+00	0.00000000E+00	1254.0397	2747.3199
19	-237.64680	2728.9021	0.00000000E+00	0.00000000E+00	1253.5998	2746.3568
20	-237.71873	2729.7290	0.00000000E+00	0.00000000E+00	1253.2223	2745.5305
21	-237.78086	2730.4437	0.00000000E+00	0.00000000E+00	1252.8960	2744.8163
22	-237.83490	2731.0656	0.00000000E+00	0.00000000E+00	1252.6121	2744.1947
23	-237.88219	2731.6102	0.00000000E+00	0.00000000E+00	1252.3634	2743.6504
24	-237.92381	2732.0897	0.00000000E+00	0.00000000E+00	1252.1445	2743.1711
25	-237.96064	2732.5141	0.00000000E+00	0.00000000E+00	1251.9507	2742.7468
26	-237.99338	2732.8916	0.00000000E+00	0.00000000E+00	1251.7783	2742.3695
27	-238.02262	2733.2288	0.00000000E+00	0.00000000E+00	1251.6244	2742.0325
28	-238.04884	2733.5312	0.00000000E+00	0.00000000E+00	1251.4862	2741.7301
29	-238.07244	2733.8035	0.00000000E+00	0.00000000E+00	1251.3619	2741.4579
30	-1371.5811	3976.6610	0.00000000E+00	0.00000000E+00	1633.8210	3924.7542
31	-3788.8693	6417.3012	0.00000000E+00	0.00000000E+00	1622.1450	4699.7071
32	-20417.394	17527.238	0.00000000E+00	0.00000000E+00	729.39781	8371.6558
33	-10222.113	7495.1976	0.00000000E+00	0.00000000E+00	647.77742	5637.7475
34	-4140.2792	1846.4155	0.00000000E+00	0.00000000E+00	10977.665	14261.370
35	-1617.6026	467.59293	0.00000000E+00	0.00000000E+00	35592.485	38321.770

MINIMUMS

ELEMENT	32	35	1	1	33	29
VALUE	-20417.394	467.59293	0.00000000E+00	0.00000000E+00	647.77742	2741.4579

MAXIMUMS

ELEMENT	1	32	1	1	35	35
VALUE	-51.657620	17527.238	0.00000000E+00	0.00000000E+00	35592.485	38321.770

ESEL FOR LABEL= REAL FROM 2 TO 2 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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Best Case Thermal Loads for Normal Conditions 12.0019 OCT 16,1995 CP= 9.500

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT	SIB	SET	SEB
36	13193.619	22175.649	11609.622	19587.376
37	18282.458	17110.153	16625.283	15587.140
38	20049.615	15351.103	18837.744	14739.933
39	20043.897	15356.795	19372.050	15348.834
40	19365.228	16513.317	19111.064	16278.163
41	18625.952	17299.760	18613.070	17040.216
42	18245.794	17712.827	18161.750	17517.371
43	17952.313	17864.857	17855.738	17749.885
44	17766.522	17873.775	17692.814	17822.804
45	17675.217	17825.670	17631.395	17813.935
46	17646.160	17783.013	17626.362	17776.370
47	17649.157	17750.361	17644.231	17738.642
48	17667.811	17721.981	17665.650	17711.703
49	17686.479	17703.399	17682.243	17696.628
50	17696.024	17693.898	17692.219	17690.411
51	17699.349	17690.588	17696.803	17689.356
52	17699.350	17690.587	17698.016	17690.568
53	17698.085	17692.742	17697.597	17692.294
54	17696.704	17694.214	17696.678	17693.718
55	17695.990	17694.989	17695.833	17694.617
56	17695.441	17695.275	17695.259	17695.057
57	17695.093	17695.293	17694.954	17695.196
58	17694.922	17695.203	17694.839	17695.181
59	17694.867	17695.123	17694.830	17695.111
60	17694.873	17695.062	17694.863	17695.041

61	17694.907	17695.009	17694.903	17694.990
62	17694.943	17694.974	17694.935	17694.962
63	17694.962	17694.955	17694.955	17694.949
64	17694.970	17694.947	17694.965	17694.946
65	17694.972	17694.946	17694.969	17694.945

MINIMUMS

ELEMENT	36	38	36	38
VALUE	13193.619	15351.103	11609.622	14739.933

MAXIMUMS

ELEMENT	38	36	39	36
VALUE	20049.615	22175.649	19372.050	19587.376

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0019 OCT 16,1995 CP= 9.610

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
36	13193.619	22175.649	0.00000000E+00	0.00000000E+00	5887.5055	7234.8100
37	18282.458	17110.153	0.00000000E+00	0.00000000E+00	3894.5043	3718.6585
38	20049.615	15351.103	0.00000000E+00	0.00000000E+00	2014.5324	1309.7556
39	20043.897	15356.795	0.00000000E+00	0.00000000E+00	718.99986	15.934573
40	19365.228	16032.350	0.00000000E+00	0.00000000E+00	18.964920	-480.96686
41	18625.952	16768.236	0.00000000E+00	0.00000000E+00	-252.86749	-531.52490
42	18076.524	17315.143	0.00000000E+00	0.00000000E+00	-283.47689	-397.68398
43	17757.570	17632.634	0.00000000E+00	0.00000000E+00	-213.48295	-232.22344
44	17618.173	17771.391	0.00000000E+00	0.00000000E+00	-125.36660	-102.38382
45	17587.245	17802.178	0.00000000E+00	0.00000000E+00	-55.731936	-23.492041
46	17606.498	17783.013	0.00000000E+00	0.00000000E+00	-13.184470	13.292787
47	17639.300	17750.361	0.00000000E+00	0.00000000E+00	6.8023977	23.461482
48	17667.811	17721.981	0.00000000E+00	0.00000000E+00	12.448522	20.573886
49	17686.479	17703.399	0.00000000E+00	0.00000000E+00	11.011765	13.549861
50	17696.024	17693.898	0.00000000E+00	0.00000000E+00	7.2936831	6.9747960
51	17699.349	17690.588	0.00000000E+00	0.00000000E+00	3.7783393	2.4641787
52	17699.350	17690.587	0.00000000E+00	0.00000000E+00	1.3525571	0.38160265E-01
53	17698.085	17691.846	0.00000000E+00	0.00000000E+00	0.39990401E-01	-0.89595268
54	17696.704	17693.221	0.00000000E+00	0.00000000E+00	-0.47096386	-0.99335129
55	17695.675	17694.245	0.00000000E+00	0.00000000E+00	-0.52973711	-0.74431296
56	17695.077	17694.840	0.00000000E+00	0.00000000E+00	-0.39952143	-0.43516569
57	17694.816	17695.100	0.00000000E+00	0.00000000E+00	-0.23490012	-0.19217518
58	17694.757	17695.159	0.00000000E+00	0.00000000E+00	-0.10461839	-0.44347274E-01
59	17694.792	17695.123	0.00000000E+00	0.00000000E+00	-0.24970883E-01	0.24658394E-01
60	17694.854	17695.062	0.00000000E+00	0.00000000E+00	0.12391273E-01	0.43711473E-01
61	17694.907	17695.009	0.00000000E+00	0.00000000E+00	0.22795710E-01	0.38120643E-01
62	17694.943	17694.974	0.00000000E+00	0.00000000E+00	0.19848002E-01	0.24561329E-01
63	17694.962	17694.955	0.00000000E+00	0.00000000E+00	0.12669613E-01	0.11688805E-01
64	17694.970	17694.947	0.00000000E+00	0.00000000E+00	0.62091826E-02	0.27795280E-02
65	17694.972	17694.944	0.00000000E+00	0.00000000E+00	0.26275555E-02	-0.15818939E-02

MINIMUMS

ELEMENT	36	38	36	36	42	41
VALUE	13193.619	15351.103	0.00000000E+00	0.00000000E+00	-283.47689	-531.52490

MAXIMUMS

ELEMENT	38	36	36	36	36	36
VALUE	20049.615	22175.649	0.00000000E+00	0.00000000E+00	5887.5055	7234.8100

ESEL FOR LABEL= REAL FROM 3 TO 3 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990
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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0020 OCT 16,1995 CP= 9.890

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT	SIB	SET	SEB
66	15066.990	24646.073	13254.693	21587.697
67	11203.085	19814.257	9733.5736	17589.790
68	7614.8024	15763.641	7336.4672	14239.011
69	7235.5616	12446.623	6310.7300	11457.994
70	7123.8452	9800.2877	6507.1928	9170.9319
71	7768.1710	7752.6768	7321.9817	7310.8807
72	9359.6376	6227.7987	8258.3966	5827.5896
73	10485.011	5149.5122	9089.1650	4695.2493
74	11220.889	4444.4239	9738.3809	3915.5735
75	11638.858	4043.9436	10194.993	3502.1749
76	11804.080	3885.6343	10474.361	3436.8613
77	11774.489	3913.9874	10601.859	3641.0976
78	11600.457	4080.7376	10605.525	4009.7788
79	11324.837	4561.3738	10512.607	4457.0466
80	10983.277	5148.8126	10347.943	4927.7781
81	10604.726	5685.6991	10133.266	5389.8102
82	10212.072	6165.5159	9887.0143	5825.0361
83	9822.8454	6585.6733	9624.4158	6223.6705
84	9449.9557	6946.6060	9357.7299	6580.9949
85	9102.4194	7250.9808	9096.5634	6895.5058
86	8909.0948	7503.0160	8848.2193	7167.7973
87	8727.5864	7707.9058	8618.0478	7399.8284
88	8553.7027	7871.3443	8409.7852	7594.4048
89	8393.1500	7999.1371	8225.8717	7754.7870
90	8250.1354	8096.8917	8067.7431	7884.3861
91	8127.6672	8169.7750	7936.0963	7986.5198
92	8027.8243	8222.3270	7831.1245	8064.2204
93	7951.9861	8258.3225	7752.7223	8120.0823
94	7901.0201	8280.6705	7700.6550	8156.1475
95	7875.4245	8291.3457	7674.6908	8173.8220

MINIMUMS				
ELEMENT	70	76	69	76
VALUE	7123.8452	3885.6343	6310.7300	3436.8613

MAXIMUMS				
ELEMENT	66	66	66	66
VALUE	15066.990	24646.073	13254.693	21587.697

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990
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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0020 OCT 16,1995 CP= 10.000

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1

TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
66	9862.9285	-24646.073	0.00000000E+00	0.00000000E+00	-10380.412	-15556.762
67	4820.1157	-19814.257	0.00000000E+00	0.00000000E+00	-10078.125	-13773.281

68	592.61658	-15763.641	0.00000000E+00	0.00000000E+00	-9475.6243	-11929.063
69	-2869.2492	-12446.623	0.00000000E+00	0.00000000E+00	-8672.1676	-10108.774
70	-5631.1447	-9800.2877	0.00000000E+00	0.00000000E+00	-7749.2166	-8374.5880
71	-7768.1710	-7752.6768	0.00000000E+00	0.00000000E+00	-6771.9269	-6769.6027
72	-9359.6376	-6227.7987	0.00000000E+00	0.00000000E+00	-5790.8664	-5321.0906
73	-10485.011	-5149.5122	0.00000000E+00	0.00000000E+00	-4843.8418	-4043.5170
74	-11220.889	-4444.4239	0.00000000E+00	0.00000000E+00	-3957.7351	-2941.2653
75	-11638.858	-4043.9436	0.00000000E+00	0.00000000E+00	-3150.2803	-2011.0432
76	-11804.080	-3885.6343	0.00000000E+00	0.00000000E+00	-2431.7277	-1243.9608
77	-11774.489	-3913.9874	0.00000000E+00	0.00000000E+00	-1806.3625	-627.28733
78	-11600.457	-4080.7376	0.00000000E+00	0.00000000E+00	-1273.8578	-145.89994
79	-11324.837	-4344.8250	0.00000000E+00	0.00000000E+00	-830.45306	216.54876
80	-10983.277	-4672.0941	0.00000000E+00	0.00000000E+00	-469.95891	476.71852
81	-10604.726	-5034.8060	0.00000000E+00	0.00000000E+00	-184.59493	650.89308
82	-10212.072	-5411.0311	0.00000000E+00	0.00000000E+00	34.328640	754.48475
83	-9822.8454	-5783.9720	0.00000000E+00	0.00000000E+00	195.87032	801.70134
84	-9449.9557	-6141.2596	0.00000000E+00	0.00000000E+00	309.04196	805.34638
85	-9102.4194	-6474.2547	0.00000000E+00	0.00000000E+00	382.50147	776.72618
86	-8786.0607	-6777.3766	0.00000000E+00	0.00000000E+00	424.33677	725.63938
87	-8504.1645	-7047.4779	0.00000000E+00	0.00000000E+00	441.92486	660.42785
88	-8258.0717	-7283.2740	0.00000000E+00	0.00000000E+00	441.85061	588.07027
89	-8047.7098	-7484.8341	0.00000000E+00	0.00000000E+00	429.87158	514.30293
90	-7872.0570	-7653.1375	0.00000000E+00	0.00000000E+00	410.91632	443.75423
91	-7729.5386	-7789.6927	0.00000000E+00	0.00000000E+00	389.10541	380.08230
92	-7618.3592	-7896.2202	0.00000000E+00	0.00000000E+00	367.78592	326.10677
93	-7536.7712	-7974.3946	0.00000000E+00	0.00000000E+00	349.57142	283.92791
94	-7483.2851	-8025.6428	0.00000000E+00	0.00000000E+00	336.38134	255.02768
95	-7456.8238	-8050.9969	0.00000000E+00	0.00000000E+00	329.47474	240.34877

MINIMUMS

ELEMENT	76	66	66	66	66	66
VALUE	-11804.080	-24646.073	0.00000000E+00	0.00000000E+00	-10380.412	-15556.762

MAXIMUMS

ELEMENT	66	76	66	66	87	84
VALUE	9862.9285	-3885.6343	0.00000000E+00	0.00000000E+00	441.92486	805.34638

ESEL FOR LABEL= REAL FROM 4 TO 4 BY 1

30 ELEMENTS (OF 155 DEFINED) SELECTED BY ESEL COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0021 OCT 16,1995 CP= 10.270

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SIT	SIB	SET	SEB
96	15274.670	13346.264	13512.941	11799.383
97	16739.844	11896.452	15149.643	10858.470
98	17307.915	11334.338	16022.255	10783.896
99	17292.696	11349.397	16349.763	11200.914
100	16942.215	11946.818	16320.899	11823.503
101	16438.121	12736.889	16085.058	12474.780
102	15902.933	13372.767	15752.489	13060.746
103	15410.995	13846.825	15398.793	13540.285
104	15140.965	14173.167	15071.131	13903.779
105	14903.494	14376.837	14794.749	14159.272
106	14697.880	14486.335	14579.072	14323.579
107	14534.189	14528.899	14423.003	14416.606
108	14413.440	14527.923	14319.259	14457.842
109	14331.312	14501.903	14257.681	14464.396
110	14280.887	14464.392	14227.557	14450.102
111	14254.546	14426.167	14219.069	14425.351

112	14245.128	14406.818	14224.050	14397.362
113	14246.563	14384.058	14236.233	14370.692
114	14254.104	14361.936	14251.171	14347.836
115	14267.657	14342.719	14265.985	14329.805
116	14283.157	14327.381	14279.030	14316.631
117	14294.621	14316.038	14289.568	14307.776
118	14302.451	14308.290	14297.465	14302.429
119	14307.308	14303.484	14302.961	14299.710
120	14309.928	14300.891	14306.480	14298.798
121	14311.016	14299.815	14308.512	14298.991
122	14311.176	14299.811	14309.525	14299.734
123	14310.890	14301.289	14309.922	14300.614
124	14310.510	14302.378	14310.012	14301.347
125	14310.264	14302.951	14310.005	14301.755

MINIMUMS

ELEMENT	112	98	96	98
VALUE	14245.128	11334.338	13512.941	10783.896

MAXIMUMS

ELEMENT	98	107	99	109
VALUE	17307.915	14528.899	16349.763	14464.396

PRINT ELEMENT STRESS ITEMS PER ELEMENT

1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990

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FOR SUPPORT CALL PHONE TWX

Best Case Thermal Loads for Normal Conditions 12.0021 OCT 16,1995 CP= 10.380

***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
96	15274.670	13346.264	0.00000000E+00	0.00000000E+00	4588.9231	4299.6622
97	16739.844	11896.452	0.00000000E+00	0.00000000E+00	3245.1300	2518.6211
98	17307.915	11334.338	0.00000000E+00	0.00000000E+00	2097.5580	1201.5215
99	17292.696	11349.397	0.00000000E+00	0.00000000E+00	1194.6147	303.11979
100	16942.215	11696.203	0.00000000E+00	0.00000000E+00	536.28725	-250.61461
101	16438.121	12195.012	0.00000000E+00	0.00000000E+00	94.589413	-541.87691
102	15902.933	12724.589	0.00000000E+00	0.00000000E+00	-171.42638	-648.17793
103	15410.995	13211.369	0.00000000E+00	0.00000000E+00	-305.51251	-635.45634
104	15000.313	13617.745	0.00000000E+00	0.00000000E+00	-348.03750	-555.42274
105	14683.552	13931.184	0.00000000E+00	0.00000000E+00	-332.79740	-445.65258
106	14457.286	14155.078	0.00000000E+00	0.00000000E+00	-285.92538	-331.25661
107	14309.184	14301.627	0.00000000E+00	0.00000000E+00	-226.13817	-227.27179
108	14223.182	14386.728	0.00000000E+00	0.00000000E+00	-165.72677	-141.19484
109	14182.892	14426.595	0.00000000E+00	0.00000000E+00	-111.86392	-75.308586
110	14173.620	14435.770	0.00000000E+00	0.00000000E+00	-67.944947	-28.622494
111	14183.325	14426.167	0.00000000E+00	0.00000000E+00	-34.794625	1.6317238
112	14202.878	14406.818	0.00000000E+00	0.00000000E+00	-11.658555	18.932483
113	14225.880	14384.058	0.00000000E+00	0.00000000E+00	3.0433382	26.770136
114	14248.236	14361.936	0.00000000E+00	0.00000000E+00	11.186952	28.242044
115	14267.657	14342.719	0.00000000E+00	0.00000000E+00	14.604023	25.863410
116	14283.157	14327.381	0.00000000E+00	0.00000000E+00	14.890807	21.524463
117	14294.621	14316.038	0.00000000E+00	0.00000000E+00	13.324683	16.537181
118	14302.451	14308.290	0.00000000E+00	0.00000000E+00	10.852839	11.728593
119	14307.308	14303.484	0.00000000E+00	0.00000000E+00	8.1241557	7.5505877
120	14309.928	14300.891	0.00000000E+00	0.00000000E+00	5.5427359	4.1870946
121	14311.016	14299.815	0.00000000E+00	0.00000000E+00	3.3281634	1.6479947
122	14311.176	14299.656	0.00000000E+00	0.00000000E+00	1.5731289	-0.15475404
123	14310.890	14299.940	0.00000000E+00	0.00000000E+00	0.29322668	-1.3492895
124	14310.510	14300.315	0.00000000E+00	0.00000000E+00	-0.53336394	-2.0625404
125	14310.264	14300.558	0.00000000E+00	0.00000000E+00	-0.93681399	-2.3926989

MINIMUMS

ELEMENT	110	98	96	96	104	102
VALUE	14173.620	11334.338	0.00000000E+00	0.00000000E+00	-348.03750	-648.17793

```
MAXIMUMS
ELEMENT     98          110          96          96          96          96
VALUE    17307.915    14435.770    0.00000000E+00  0.00000000E+00  4588.9231    4299.6622

ESEL  FOR LABEL= REAL  FROM    5 TO    5 BY   1

   30  ELEMENTS (OF   155  DEFINED) SELECTED BY  ESEL  COMMAND.

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4     A  1   38280-PC/L1-4.4A MAY 1,1990
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    FOR SUPPORT CALL                PHONE                TWX

Best Case Thermal Loads for Normal Conditions                    12.0022  OCT 16,1995 CP=     10.600

      ***** POST1 ELEMENT STRESS LISTING *****

LOAD STEP    1  ITERATION=    10  SECTION=  1
TIME=   0.00000E+00     LOAD CASE=  1
```

ELEM	SIT	SIB	SET	SEB
126	36015.812	92290.038	31598.376	81086.688
127	66538.583	38766.629	57984.918	33585.060
128	70829.618	35040.166	66265.384	34763.945
129	61976.108	47764.785	61407.041	45706.214
130	56490.575	53189.183	55761.915	51799.209
131	53466.702	54087.389	52844.865	53594.177
132	52359.002	53507.165	52093.197	53485.341
133	52269.063	53104.720	52225.825	53009.932
134	52509.969	52777.641	52480.616	52708.250
135	52654.072	52633.719	52624.577	52607.271
136	52680.252	52607.572	52666.607	52604.825
137	52666.416	52629.279	52663.607	52625.335
138	52653.413	52643.127	52652.327	52639.837
139	52646.660	52646.580	52645.303	52645.206
140	52643.684	52645.890	52642.998	52645.677
141	52643.140	52644.974	52642.972	52644.817
142	52643.496	52644.282	52643.460	52644.128
143	52643.860	52643.918	52643.799	52643.848
144	52643.956	52643.823	52643.922	52643.809
145	52643.941	52643.849	52643.931	52643.843
146	52643.912	52643.883	52643.911	52643.876
147	52643.897	52643.894	52643.895	52643.890
148	52643.890	52643.894	52643.888	52643.893
149	52643.888	52643.892	52643.887	52643.892
150	52643.888	52643.890	52643.888	52643.890
151	52643.889	52643.889	52643.889	52643.889
152	52643.889	52643.889	52643.889	52643.889
153	52643.889	52643.889	52643.889	52643.889
154	52643.889	52643.889	52643.889	52643.889
155	52643.889	52643.889	52643.889	52643.889

```
MINIMUMS
ELEMENT    126          128          126          127
VALUE    36015.812    35040.166    31598.376    33585.060

MAXIMUMS
ELEMENT    128          126          128          126
VALUE    70829.618    92290.038    66265.384    81086.688

PRINT ELEMENT STRESS ITEMS PER ELEMENT
1          ANSYS - ENGINEERING ANALYSIS SYSTEM  REVISION 4.4     A  1   38280-PC/L1-4.4A MAY 1,1990
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    FOR SUPPORT CALL                PHONE                TWX

Best Case Thermal Loads for Normal Conditions                    12.0022  OCT 16,1995 CP=     10.710

      ***** POST1 ELEMENT STRESS LISTING *****
```

LOAD STEP 1 ITERATION = 10 SECTION = 1
TIME = 0.00000E+00 LOAD CASE = 1

ELEM	SXT	SXB	SYT	SYB	SZT	SZB
126	12947.933	92290.038	0.00000000E+00	0.00000000E+00	47917.128	59818.444
127	66538.583	38766.629	0.00000000E+00	0.00000000E+00	22644.900	18479.107
128	70829.618	34480.978	0.00000000E+00	0.00000000E+00	4893.1080	-559.18798
129	61976.108	43323.379	0.00000000E+00	0.00000000E+00	-1643.4966	-4441.4059
130	55003.507	50287.232	0.00000000E+00	0.00000000E+00	-2194.5096	-2901.9509
131	52200.263	53086.959	0.00000000E+00	0.00000000E+00	-1133.4346	-1000.4303
132	51823.258	53463.490	0.00000000E+00	0.00000000E+00	-289.70921	-43.674399
133	52182.479	53104.720	0.00000000E+00	0.00000000E+00	51.752271	190.08848
134	52509.969	52777.641	0.00000000E+00	0.00000000E+00	98.906206	139.05698
135	52654.072	52633.719	0.00000000E+00	0.00000000E+00	55.988254	52.935215
136	52680.252	52607.572	0.00000000E+00	0.00000000E+00	16.397387	5.4954431
137	52666.416	52621.390	0.00000000E+00	0.00000000E+00	-1.1353065	-7.8892217
138	52651.241	52636.546	0.00000000E+00	0.00000000E+00	-4.3763383	-6.5805260
139	52643.946	52643.832	0.00000000E+00	0.00000000E+00	-2.7310411	-2.7481117
140	52642.312	52645.464	0.00000000E+00	0.00000000E+00	-0.89832984	-0.42561100
141	52642.803	52644.974	0.00000000E+00	0.00000000E+00	-0.11694155E-01	0.31400276
142	52643.496	52644.282	0.00000000E+00	0.00000000E+00	0.18943327	0.30737513
143	52643.860	52643.918	0.00000000E+00	0.00000000E+00	0.13158346	0.14033981
144	52643.956	52643.823	0.00000000E+00	0.00000000E+00	0.47989340E-01	0.28036504E-01
145	52643.941	52643.837	0.00000000E+00	0.00000000E+00	0.37692662E-02	-0.11743746E-01
146	52643.910	52643.869	0.00000000E+00	0.00000000E+00	-0.79780428E-02	-0.14158796E-01
147	52643.892	52643.887	0.00000000E+00	0.00000000E+00	-0.62617232E-02	-0.70623300E-02
148	52643.886	52643.892	0.00000000E+00	0.00000000E+00	-0.25114911E-02	-0.16986082E-02
149	52643.887	52643.892	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
150	52643.888	52643.890	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.64230580E-03
151	52643.889	52643.889	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
152	52643.889	52643.889	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
153	52643.889	52643.889	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
154	52643.889	52643.889	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00
155	52643.889	52643.889	0.00000000E+00	0.00000000E+00	0.00000000E+00	0.00000000E+00

MINIMUMS

ELEMENT	126	128	126	126	130	129
VALUE	12947.933	34480.978	0.00000000E+00	0.00000000E+00	-2194.5096	-4441.4059

MAXIMUMS

ELEMENT	128	126	126	126	126	126
VALUE	70829.618	92290.038	0.00000000E+00	0.00000000E+00	47917.128	59818.444

155 ELEMENTS (OF 155 DEFINED) SELECTED BY EALL COMMAND.

PRINT NODAL DISPLACEMENTS
1 ANSYS - ENGINEERING ANALYSIS SYSTEM REVISION 4.4 A 1 38280-PC/L1-4.4A MAY 1,1990
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Best Case Thermal Loads for Normal Conditions 12.0023 OCT 16,1995 CP = 10.990

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION = 10 SECTION = 1
TIME = 0.00000E+00 LOAD CASE = 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
1	0.34552668E-02	-0.15569578	0.00000000E+00	0.56735232E-04
2	0.65097053E-02	-0.15564026	0.00000000E+00	0.68965329E-04
3	0.95787162E-02	-0.15556884	0.00000000E+00	0.89823268E-04
4	0.12651656E-01	-0.15547736	0.00000000E+00	0.11301529E-03
5	0.15726217E-01	-0.15536444	0.00000000E+00	0.13717091E-03
6	0.18801602E-01	-0.15522947	0.00000000E+00	0.16181685E-03
7	0.21877464E-01	-0.15507211	0.00000000E+00	0.18674618E-03
8	0.24953627E-01	-0.15489215	0.00000000E+00	0.21185403E-03
9	0.28029991E-01	-0.15468946	0.00000000E+00	0.23708160E-03
10	0.31106496E-01	-0.15446395	0.00000000E+00	0.26239336E-03

11	0.34183105E-01	-0.15421555	0.00000000E+00	0.28776656E-03
12	0.37259792E-01	-0.15394422	0.00000000E+00	0.31318599E-03
13	0.40336538E-01	-0.15364992	0.00000000E+00	0.33864106E-03
14	0.43413332E-01	-0.15333261	0.00000000E+00	0.36412419E-03
15	0.46490163E-01	-0.15299229	0.00000000E+00	0.38962982E-03
16	0.49567026E-01	-0.15262892	0.00000000E+00	0.41515375E-03
17	0.52643914E-01	-0.15224250	0.00000000E+00	0.44069277E-03
18	0.55720822E-01	-0.15183301	0.00000000E+00	0.46624437E-03
19	0.58797749E-01	-0.15140044	0.00000000E+00	0.49180660E-03
20	0.61874691E-01	-0.15094479	0.00000000E+00	0.51737786E-03
21	0.64951646E-01	-0.15046604	0.00000000E+00	0.54295686E-03
22	0.68028612E-01	-0.14996419	0.00000000E+00	0.56854256E-03
23	0.71105588E-01	-0.14943923	0.00000000E+00	0.59413409E-03
24	0.74182573E-01	-0.14889116	0.00000000E+00	0.61973072E-03
25	0.77259565E-01	-0.14831997	0.00000000E+00	0.64533184E-03
26	0.80336564E-01	-0.14772567	0.00000000E+00	0.67093693E-03
27	0.83413569E-01	-0.14710824	0.00000000E+00	0.69654557E-03
28	0.86490579E-01	-0.14646768	0.00000000E+00	0.72215736E-03
29	0.89567594E-01	-0.14580400	0.00000000E+00	0.74777198E-03
30	0.92644613E-01	-0.14511718	0.00000000E+00	0.77338916E-03
31	0.90955653E-01	-0.14035534	0.00000000E+00	0.17720784E-02
32	0.88838236E-01	-0.13556633	0.00000000E+00	0.16417327E-02
33	0.87167601E-01	-0.13075154	0.00000000E+00	0.11193171E-02
34	0.86148112E-01	-0.12591895	0.00000000E+00	0.59817004E-03
35	0.85670004E-01	-0.12107671	0.00000000E+00	0.22759569E-03
36	0.85535591E-01	-0.11623070	0.00000000E+00	0.21040930E-04
37	0.85570669E-01	-0.11138424	0.00000000E+00	-0.63615062E-04
38	0.85660137E-01	-0.10653874	0.00000000E+00	-0.77506451E-04
39	0.85744535E-01	-0.10169444	0.00000000E+00	-0.60470469E-04
40	0.85802696E-01	-0.96851095E-01	0.00000000E+00	-0.36572652E-04
41	0.85834125E-01	-0.92008337E-01	0.00000000E+00	-0.16946390E-04
42	0.85846329E-01	-0.87165854E-01	0.00000000E+00	-0.45978462E-05

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Best Case Thermal Loads for Normal Conditions 12.0023 OCT 16,1995 CP= 11.100

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
43	0.85847704E-01	-0.82323451E-01	0.00000000E+00	0.14250786E-05
44	0.85844562E-01	-0.77481028E-01	0.00000000E+00	0.33064422E-05
45	0.85840606E-01	-0.72638555E-01	0.00000000E+00	0.30700672E-05
46	0.85837480E-01	-0.67796033E-01	0.00000000E+00	0.20959458E-05
47	0.85835570E-01	-0.62953479E-01	0.00000000E+00	0.11216494E-05
48	0.85834673E-01	-0.58110906E-01	0.00000000E+00	0.42788177E-06
49	0.85834419E-01	-0.53268326E-01	0.00000000E+00	0.40662169E-07
50	0.85834484E-01	-0.48425745E-01	0.00000000E+00	-0.11839214E-06
51	0.85834650E-01	-0.43583166E-01	0.00000000E+00	-0.14481345E-06
52	0.85834808E-01	-0.38740589E-01	0.00000000E+00	-0.11314359E-06
53	0.85834917E-01	-0.33898014E-01	0.00000000E+00	-0.68467636E-07
54	0.85834976E-01	-0.29055440E-01	0.00000000E+00	-0.31679942E-07
55	0.85834999E-01	-0.24212867E-01	0.00000000E+00	-0.84638490E-08
56	0.85835001E-01	-0.19370294E-01	0.00000000E+00	0.28957558E-08
57	0.85834995E-01	-0.14527720E-01	0.00000000E+00	0.63895090E-08
58	0.85834987E-01	-0.96851470E-02	0.00000000E+00	0.56624847E-08
59	0.85834982E-01	-0.48425735E-02	0.00000000E+00	0.31202537E-08
60	0.85834980E-01	0.00000000E+00	0.00000000E+00	0.00000000E+00
80	0.96141433E-01	-0.14430330	0.00000000E+00	0.81250580E-03
130	0.99638852E-01	-0.14342655	0.00000000E+00	0.89479744E-03
131	0.10173551	-0.13699851	0.00000000E+00	-0.41297132E-02
132	0.10897517	-0.13068730	0.00000000E+00	-0.77164779E-02
133	0.11977313	-0.12453686	0.00000000E+00	-0.10097949E-01
134	0.13281570	-0.11857389	0.00000000E+00	-0.11492415E-01

135	0.14704024	-0.11281123	0.00000000E+00	-0.12099442E-01
136	0.16161095	-0.10725094	0.00000000E+00	-0.12097186E-01
137	0.17589229	-0.10188693	0.00000000E+00	-0.11641190E-01
138	0.18942175	-0.96707318E-01	0.00000000E+00	-0.10864341E-01
139	0.20188306	-0.91696313E-01	0.00000000E+00	-0.98776881E-02
140	0.21308079	-0.86835822E-01	0.00000000E+00	-0.87718686E-02
141	0.22291692	-0.82106716E-01	0.00000000E+00	-0.76189430E-02
142	0.23136982	-0.77489809E-01	0.00000000E+00	-0.64744540E-02
143	0.23847562	-0.72966599E-01	0.00000000E+00	-0.53795828E-02
144	0.24431238	-0.68519791E-01	0.00000000E+00	-0.43632931E-02
145	0.24898659	-0.64133644E-01	0.00000000E+00	-0.34443848E-02
146	0.25262216	-0.59794178E-01	0.00000000E+00	-0.26334045E-02
147	0.25535160	-0.55489258E-01	0.00000000E+00	-0.19343729E-02
148	0.25730910	-0.51208598E-01	0.00000000E+00	-0.13463130E-02
149	0.25862532	-0.46943693E-01	0.00000000E+00	-0.86456681E-03
150	0.25942371	-0.42687710E-01	0.00000000E+00	-0.48190603E-03
151	0.25981798	-0.38435342E-01	0.00000000E+00	-0.18944163E-03
152	0.25991052	-0.34182651E-01	0.00000000E+00	0.22651934E-04

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Best Case Thermal Loads for Normal Conditions 12.0024 OCT 16,1995 CP= 11.320

***** POST1 NODAL DISPLACEMENT LISTING *****

LOAD STEP 1 ITERATION= 10 SECTION= 1
TIME= 0.00000E+00 LOAD CASE= 1

THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTZ
153	0.25979168	-0.29926900E-01	0.00000000E+00	0.16458248E-03
154	0.25953951	-0.25666390E-01	0.00000000E+00	0.24653718E-03
155	0.25922002	-0.21400294E-01	0.00000000E+00	0.27841185E-03
156	0.25888757	-0.17128508E-01	0.00000000E+00	0.26965342E-03
157	0.25858552	-0.12851508E-01	0.00000000E+00	0.22919686E-03
158	0.25834680	-0.85702195E-02	0.00000000E+00	0.16547889E-03
159	0.25819447	-0.42858951E-02	0.00000000E+00	0.86511610E-04
160	0.25814219	0.00000000E+00	0.00000000E+00	0.00000000E+00
180	0.10355319	-0.14211770	0.00000000E+00	0.12729393E-02
230	0.10747235	-0.14048691	0.00000000E+00	0.14398346E-02
231	0.10577598	-0.13586253	0.00000000E+00	0.13594291E-02
232	0.10425793	-0.13121940	0.00000000E+00	0.11574824E-02
233	0.10301653	-0.12656039	0.00000000E+00	0.90841231E-03
234	0.10207696	-0.12188897	0.00000000E+00	0.66060465E-03
235	0.10141924	-0.11720856	0.00000000E+00	0.44187057E-03
236	0.10099961	-0.11252219	0.00000000E+00	0.26495286E-03
237	0.10076552	-0.10783225	0.00000000E+00	0.13243086E-03
238	0.10066541	-0.10314057	0.00000000E+00	0.40716803E-04
239	0.10065416	-0.98448390E-01	0.00000000E+00	-0.16929802E-04
240	0.10069554	-0.93756476E-01	0.00000000E+00	-0.48300008E-04
241	0.10076259	-0.89065249E-01	0.00000000E+00	-0.60900671E-04
242	0.10083680	-0.84374874E-01	0.00000000E+00	-0.61215782E-04
243	0.10090667	-0.79685345E-01	0.00000000E+00	-0.54396672E-04
244	0.10096603	-0.74996564E-01	0.00000000E+00	-0.44235433E-04
245	0.10101254	-0.70308389E-01	0.00000000E+00	-0.33305022E-04
246	0.10104630	-0.65620667E-01	0.00000000E+00	-0.23179638E-04
247	0.10106883	-0.60933260E-01	0.00000000E+00	-0.14676287E-04
248	0.10108229	-0.56246051E-01	0.00000000E+00	-0.80809804E-05
249	0.10108896	-0.51558949E-01	0.00000000E+00	-0.33401989E-05
250	0.10109095	-0.46871890E-01	0.00000000E+00	-0.21044165E-06
251	0.10108998	-0.42184833E-01	0.00000000E+00	0.16335071E-05
252	0.10108741	-0.37497751E-01	0.00000000E+00	0.25264809E-05
253	0.10108418	-0.32810634E-01	0.00000000E+00	0.27699131E-05
254	0.10108092	-0.28123479E-01	0.00000000E+00	0.26104792E-05
255	0.10107800	-0.23436287E-01	0.00000000E+00	0.22336533E-05
256	0.10107560	-0.18749065E-01	0.00000000E+00	0.17666190E-05
257	0.10107377	-0.14061819E-01	0.00000000E+00	0.12863217E-05
258	0.10107250	-0.93745555E-02	0.00000000E+00	0.82975361E-06

```
  259  0.10107176    -0.46872805E-02  0.00000000E+00  0.40469043E-06
  260  0.10107152     0.00000000E+00  0.00000000E+00  0.00000000E+00
  280  0.10965457    -0.13934858      0.00000000E+00  0.14697875E-02
  330  0.11091834    -0.13819741      0.00000000E+00  0.14730407E-02

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    FOR SUPPORT CALL                PHONE                TWX

 Best Case Thermal Loads for Normal Conditions                    12.0024  OCT 16,1995 CP=     11.480

      ***** POST1 NODAL DISPLACEMENT LISTING *****

 LOAD STEP    1  ITERATION=    10  SECTION=  1
 TIME=   0.00000E+00     LOAD CASE=  1

 THE FOLLOWING X,Y,Z DISPLACEMENTS ARE IN GLOBAL COORDINATES

  NODE     UX            UY            UZ            ROTZ
  331  0.87794879E-01 -0.13418235     0.00000000E+00  0.27004668E-01
  332  0.59445341E-01 -0.12984937     0.00000000E+00  0.18067885E-01
  333  0.45218960E-01 -0.12528237     0.00000000E+00  0.63711962E-02
  334  0.41759545E-01 -0.12062584     0.00000000E+00  0.36890369E-03
  335  0.42529589E-01 -0.11595977     0.00000000E+00 -0.11487543E-02
  336  0.43814194E-01 -0.11130687     0.00000000E+00 -0.86342309E-03
  337  0.44519868E-01 -0.10666504     0.00000000E+00 -0.33561010E-03
  338  0.44718192E-01 -0.10202785     0.00000000E+00 -0.38840511E-04
  339  0.44698196E-01 -0.97391395E-01  0.00000000E+00  0.47294050E-04
  340  0.44640999E-01 -0.92754414E-01  0.00000000E+00  0.40744435E-04
  341  0.44606439E-01 -0.88116916E-01  0.00000000E+00  0.17356737E-04
  342  0.44595470E-01 -0.83479182E-01  0.00000000E+00  0.28677126E-05
  343  0.44595593E-01 -0.78841399E-01  0.00000000E+00 -0.18608822E-05
  344  0.44598088E-01 -0.74203636E-01  0.00000000E+00 -0.18975032E-05
  345  0.44599760E-01 -0.69565897E-01  0.00000000E+00 -0.88339001E-06
  346  0.44600350E-01 -0.64928170E-01  0.00000000E+00 -0.18467967E-06
  347  0.44600385E-01 -0.60290445E-01  0.00000000E+00  0.68338374E-07
  348  0.44600279E-01 -0.55652720E-01  0.00000000E+00  0.87123171E-07
  349  0.44600199E-01 -0.51014994E-01  0.00000000E+00  0.44318797E-07
  350  0.44600168E-01 -0.46377268E-01  0.00000000E+00  0.11039077E-07
  351  0.44600164E-01 -0.41739541E-01  0.00000000E+00 -0.22203553E-08
  352  0.44600169E-01 -0.37101814E-01  0.00000000E+00 -0.39378793E-08
  353  0.44600172E-01 -0.32464087E-01  0.00000000E+00 -0.21940196E-08
  354  0.44600174E-01 -0.27826360E-01  0.00000000E+00 -0.62902319E-09
  355  0.44600174E-01 -0.23188634E-01  0.00000000E+00  0.53530083E-10
  356  0.44600174E-01 -0.18550907E-01  0.00000000E+00  0.17450244E-09
  357  0.44600174E-01 -0.13913180E-01  0.00000000E+00  0.10737415E-09
  358  0.44600174E-01 -0.92754535E-02  0.00000000E+00  0.36482269E-10
  359  0.44600174E-01 -0.46377267E-02  0.00000000E+00  0.51933111E-11
  360  0.44600174E-01  0.00000000E+00  0.00000000E+00  0.00000000E+00

MAXIMUMS
NODE      152          1          0          331
VALUE   0.25991052    -0.15569578     0.00000000E+00  0.27004668E-01


***** ROUTINE COMPLETED *****  CP =       11.650

/EOF ENCOUNTERED ON FILE18


***** RUN COMPLETED *****  CP=      11.9200   TIME=   12.0025
```

7.4.2 Peer Review Check Sheet

Document Checked - Number: _____ Revision: _____

Title: SECTION 7 THERMAL STRESS EVALUATION: SEG 3-82B CASK -2.1 KW Heat Load

Yes	No	N/A	
[X]	[ ]	[ ]	Problem completely defined.
[X]	[ ]	[ ]	Appropriate analytical method used.
[X]	[ ]	[ ]	Necessary assumptions are appropriate, explicitly stated, and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[ ]	[ ]	[X]	Sources of non-standard formulae/data are referenced and the correctness of the reference verified.
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[ ]	[ ]	[X]	Mathematical derivations checked including dimensional consistency of results.
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[X]	[ ]	[ ]	Hand calculations checked for errors.
[X]	[ ]	[ ]	Code run streams correct and consistent with analysis documentation.
[X]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[X]	[ ]	[ ]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[X]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[X]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.

I have checked the analysis/calculation and it is complete and accurate to the best of my knowledge.

S.L. HECHT [signature] 10-23-95

Engineer/Checker Date

COMMENT: GENERAL MEMBRANE STRESS PREDICTION IN CYLIND. SHELL REASONABLE. PEAK & ~~MEMBRANE~~ MAX STRESSES + ASSOCIATED FATIGUE EVALUATION IS ULTRA CONSERVATIVE.

8.0 THERMAL EVALUATION

This thermal evaluation is for the purpose of assessing the acceptability of changing the SEG 3-82B design basis heat load. Because this effort is not intended to replace the design basis, a number of simplifying assumptions are made consistent with the SAR (SEG 1991). The temperature limits established in SEG (1991) to ensure structural integrity of the cask include a maximum temperature of 204.4 °C (400 °F) at the silicone seals of the cask lid. A temperature limit of 326.7 °C (620 °F [Brick et al. 1977]) for the lead is imposed to prevent melting. Also, 10 CFR 71 imposes an exterior temperature limit of 82.2 °C (180 °F) when stored in the shade.

8.1 THERMAL SOURCE SPECIFICATION

The worst-case loading from RLFCM glass generates 2.1 kW of decay heat in a volume of 0.1557 m^3 (5.5 ft^3 [Jarrett 1995]). This decay heat is derived as the sum of 0.735 kW from ^{90}Sr and 1.362 kW from ^{137}Cs. The volumetric heat deposition density is 13.48 kW/m^3 (0.754 $Btu/h\text{-}in^3$).

8.2 SUMMARY OF THERMAL PROPERTIES

Emissivity of steel is taken as 0.5 for NCT. Between metal surfaces the effective emissivity for radiation heat transfer is calculated as:

$$\epsilon_{eff} = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} = 0.333.$$

The exterior emissivity is taken as 0.5 for NCT from 10 CFR 71 and as 0.8 for the HAC. The natural convection coefficient for heat transfer between two vertical surfaces is taken from Rohsenow et al. (1985) as:

$$h = \frac{k}{H}\left[1 + \left(\left[\gamma_1 \, Ra^2 \left(\frac{H}{L}\right)^8\right]^m + \left[\gamma_2 \, Ra^{1/5} \left(\frac{L}{H}\right)^{2/5}\right]^m\right)^{1/m}\right]$$

Where $m = -0.0386$

$\gamma_1 = 2.756 \times 10^{-6}$

$\gamma_2 = 0.623$

The natural convection heat transfer coefficient from the exterior of the cask to the environment is taken from Rohsenow and Choi (1964) as:

$$h = \left(\frac{k}{L}\right) 0.56 Ra^{0.25}$$

Where Ra = Rayleigh Number

k = air thermal conductivity

L = plate length

The ANSYS (SAS 1989) program's convection element allows the use of an empirical equation that is a power function of the temperature difference plus a constant of the form:

$$hf\left[(T_1 - T_2)^n + \frac{cc}{hf}\right]$$

For example, if the desire is to model the equation:

$$h = \frac{k}{H}\left[5.0\,(T_1 - T_2)^{0.25} + 1.12\right]$$

Then $hf = 5.0\,\frac{k}{H}$

$cc = 1.12\,\frac{k}{H}$

$n = 0.25$

The value for *hf* can be varied with temperature to appropriately account for the thermal conductivity of air. The values of *n* and *cc* must be constant. This neglects the variation of thermal conductivity of air with temperature. Three empirical relationships of the form, as shown above, are developed to match the Rohsenow et al. (1985) equation, each corresponding to the three air gaps in the model. An effective height of 127 cm (50 in.) is used for the length of the vertical surfaces. The first air gap is 27.43 cm (10.8 in.) between the 55-gal drum and the grout container. The second air gap is 2.06 cm (0.8125 in.) between the grout container and the payload liner. The third air gap is 7.78 cm (3.0625 in.) between the payload liner and the SEG cask.

Because the natural convection heat transfer coefficient varies linearly with the thermal conductivity of air, *hf* is used in the model as a function of temperature, as shown in Table B-10, for the three gaps identified. The value of *hf* should not be confused with the actual heat transfer coefficient. The heat transfer coefficient can only be determined by knowing the temperature difference between the two surfaces. It also should be noted that the Prandtl number and volume expansion coefficient, β, in the Grashof number were not varied with temperature to adjust *hf*.

Table B-10. Empirical Equation Coefficient, *hf*, Temperature Variation.

Temperature (°F)	60	100	200	500	800	1500
Gaps	hf (Btu/h-in^2-°F)					
Drum-grout container	5.79E-4	6.17E-4	6.94E-4	9.65E-4	1.16E-3	1.58E-3
Grout container-liner	5.85E-4	6.24E-4	7.02E-4	9.74E-4	1.17E-3	1.60E-3
Liner-cask	5.55E-4	5.92E-4	6.66E-4	9.25E-4	1.11E-3	1.52E-3

The thermal conductivity for the glass is taken form the following equation:

$$k_{glass} = 0.00095(T) + 0.75 \left(\frac{w}{m\ °C}\right)$$

where T = in °C

The thermal conductivity for the insulation is taken from SEG (1991) as 1.4365 W/m-°C (0.83 Btu/h-ft-°F). The thermal conductivity for carbon steel, stainless steel, and lead are taken from Rohsenow and Choi (1964) as 25.0, 10.0, and 18.6 Btu/h-ft-°F, respectively. A summary of those thermal conductivities used in the model that vary with temperature are shown in Table B-11.

Table B-11. Thermal Conductivity Temperature Variation.

Air	Temperature (°F)	60	100	200	500	800	1500
	Conductivity (Btu/h-in-°F)	.0012	.0013	.0015	.0021	0.0025	.0034
Glass	Temperature (°F)	68	176	572	842	1472	3992
	Conductivity (Btu/h-in-°F)	.037	.04	.05	.057	.073	.137

The specific heat and density for the glass payload were provided by Jarrett (1995) as 0.16 Btu/lb-°F and 168.5 lb/ft^3, respectively. The specific heat and density were taken from Rohsenow and Choi (1964) for the solid cask materials (carbon steel, stainless steel, lead), as shown in Table B-12.

Table B-12. Specific Heat and Density.

Solid cask material	Stainless steel	Carbon steel	Lead
Specific heat (Btu/lb-°F)	0.11	0.113	0.031
Density (lb/ft^3)	488	485	710

The specific heat and density for the insulation was unavailable. Therefore, it was assumed conservatively small. This is conservative for the fire transient and inconsequential for the steady-state conditions.

8.3 THERMAL EVALUATION FOR NCT

The NCT used in the SEG 3-82B SAR are slightly different from those that govern the requirements for transport offsite as delineated in 10 CFR 71. The NCT stated in 10 CFR 71 are applied in this evaluation. These conditions include an ambient temperature of 37.8 °C (100 °F), and solar heat deposition of 400 cal/cm^2 in a 12-hour period. The solar absorptivity is taken from SEG (1991) as 0.95, resulting in a heat flux of 0.811 Btu/h-in^2. Conservatively assuming that the cask reaches steady-state within the 12-hour period, this heat flux can be taken as a steady-state heat flux.

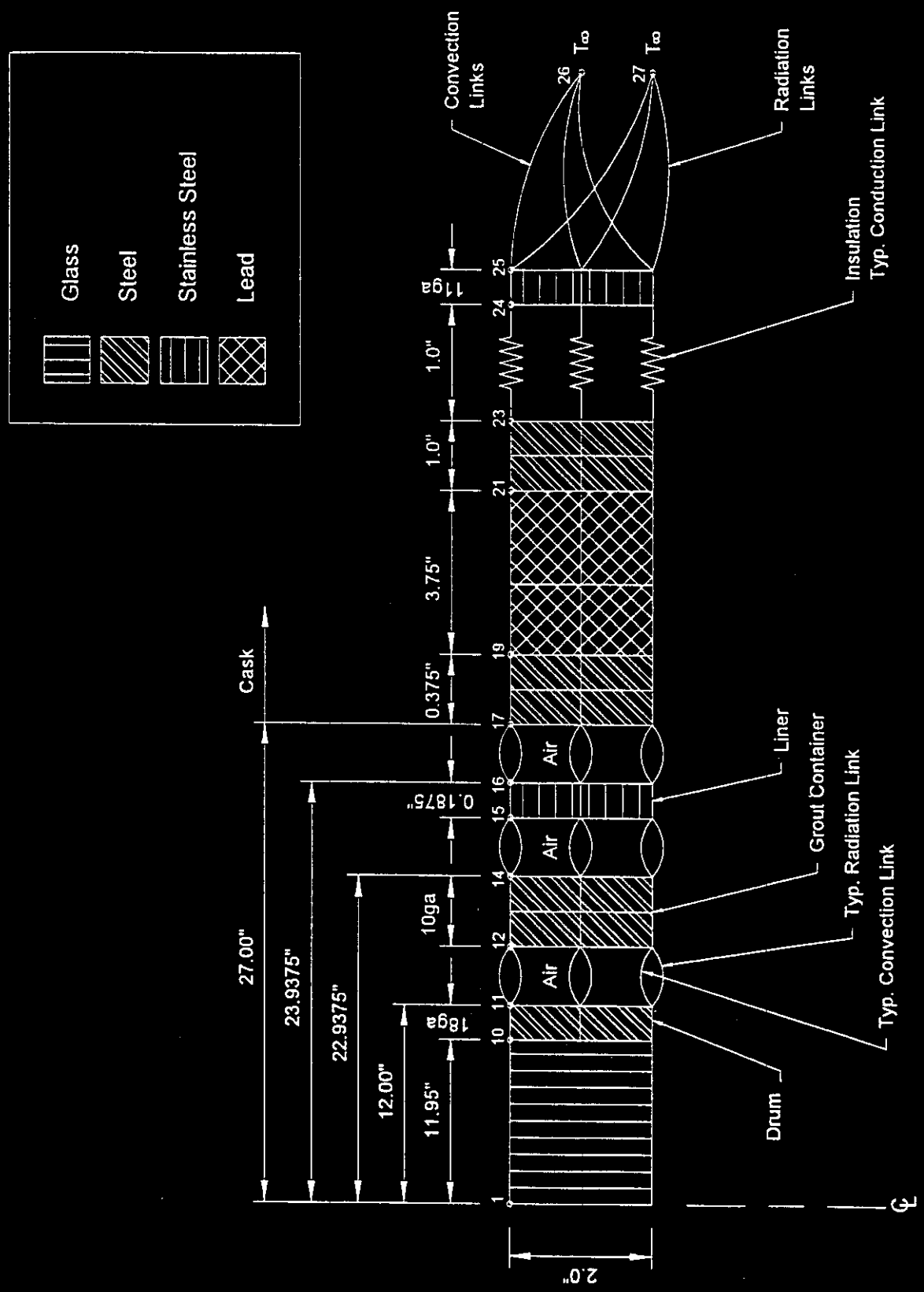
8.3.1 Thermal Model for NCT

The finite-element model used in this evaluation is consistent with the original design basis for the SEG 3-82B cask, as documented in the SAR (SEG 1991). A one-dimensional model (radial) is used to approximate the thermal behavior of the cask and its payload. A schematic of this model is shown in Figure B-3. The model comprises a series of thermal resistances and capacitances at a location near the center of the cask where the impact limiters do not cover the outside cask liner. The payload is modeled concentrically within the cask.

The general-purpose finite-element program, ANSYS (SAS 1989), was used to develop the thermal model. The model includes solid axisymmetric elements, one-dimensional conduction elements, convection elements and radiation elements. The solid axisymmetric elements are used to model materials that have significant heat capacity (carbon steel, stainless steel, lead, and glass). The conduction elements are used to model the thermal insulation. The convection and radiation elements are used to model heat transfer between the solid surfaces that passes through air gaps and the heat transfer between the outside surface of the cask and the environment.

The volumetric heat deposition is imposed to the solid elements representing the glass. The 208-L (55-gal drum) is assumed to have an OD of 60.96 cm (24 in.) and a thickness of 0.13 cm (0.05 in. [18 gauge]). The model of the cask and its payload is constructed by 3 nodes in the vertical direction and 25 nodes in the radial direction. The four-node axisymmetric solid elements used in this one-dimensional axisymmetric model require no adjustments, but the one-dimensional convection, conduction, and radiation elements require an adjustment to the heat transfer to account for the per unit radian dimensions. For radial areas, the average radius between the gap of air or insulation is taken as the area per unit radian per unit axial length. The model represents a 5.08-cm (2-in.) strip in length, which translates into a 2.54-cm (1-in.) tributary length for the middle node and 1.27-cm (0.5-in.) tributary length for the top and bottom nodes.

Figure B-3. SEG 3-82B Finite-Element Model Schematic.



8.3.2 Thermal Analysis Results for NCT

The NCT, as stated in 10 CFR 71, include insolation based on a 12-hour period. It is conservative to assume that the cask, when subjected to the solar heat load, reaches a steady-state condition within this 12-hour period. It was further assumed that the glass payload would be of small compact pieces, such that it occupied the minimum volume. Under these assumptions, Figure B-4 shows the temperature profile from the center of the payload to the exterior surface of the cask. The cask surface temperature is predicted to be approximately 144.4 °C (292 °F). This temperature exceeds the 82.2 °C (180 °F) limit for commercial transport. The temperature on the inside of the insulation is approximately 276.7 °C (530 °F). This temperature exceeds the 204.4 °C (400 °F) limit placed on the silicone seal of the cask lid. However, the temperature of the seal during NCT is expected to be closer to the surface temperature of the cask (excluding the impact limiters) because, at the location of the seals, the thermal insulation is replaced with carbon steel. The relatively high thermal conductivity of carbon steel will act as a fin to conduct heat away from the seals. The difference between the seal location and the surface temperature is expected to be much less than 37.8 °C (100 °F). This provides a comfortable margin to the limit of 204.4 °C (400 °F). The lead temperature is essentially the same as the inside of the insulation (276.7 °C [530 °F]). This leaves at least a 32.2 °C (90 °F) margin to the lead melting point.

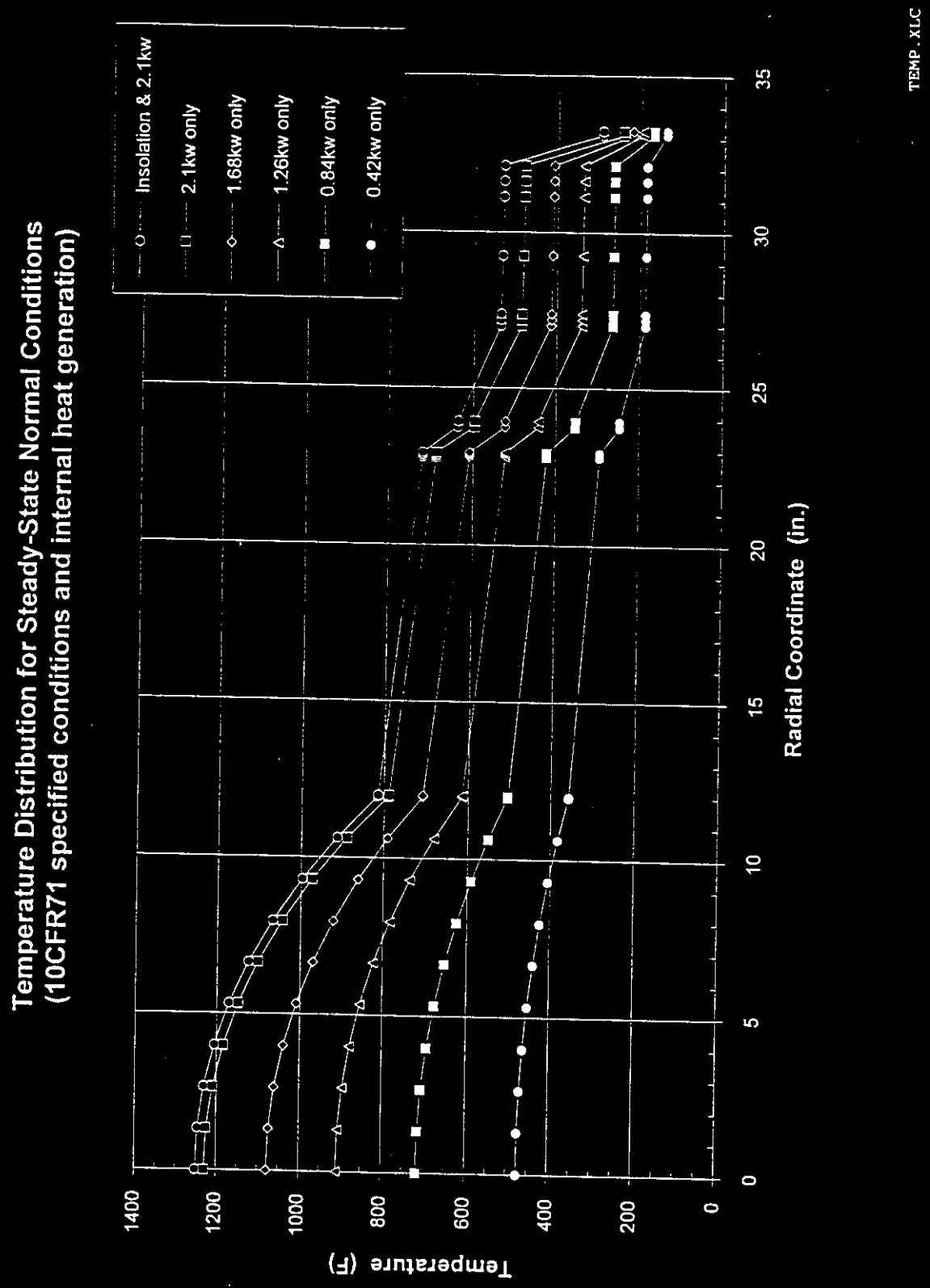
Also shown in Figure B-4 is the temperature profile for the steady-state load cases, which exclude insolation. It is clear from this figure that the internal heat generation is the dominating factor in determining the temperature distribution. Temperature distributions for other heat generation rates are also illustrated in this figure. The heat generation rates shown can be interpreted as variations in volumetric heat deposition, but with the same total heat generation rate. If the volumetric heat deposition can be reduced to 60% of the specified value, then none of the cask metal temperatures exceed 204.4 °C (400 °F).

The most significant heat load for NCT is clearly the internal heat generation. The volumetric heat deposition essentially drives the thermal solution. The assumption that the glass payload is compact (or solid) and the fact that the heat transfer model takes only a radial slice through this solid glass section are very conservative. A less conservative approach is to assume that the glass payload is uniformly distributed within a 208-L (55-gal) drum with a radius of 30.35 cm (11.95 in.). The volumetric heat deposition would be reduced by 25%. As shown in the Appendix to this section, the wall temperature for NCT would reduce to 102.8 °C (217 °F). Based on the heat flow from the 2.1-kW internal heat generation, the temperature drop across the insulation layer will result in a temperature of 201.7 °C (395 °F) at the inside surface of the insulation. This is clearly a conservative temperature to assign to the seal gap, and this temperature is less than the design basis, as stated in the SEG (1991).

8.4 THERMAL EVALUATION FOR HAC

The thermal environment for HAC includes a 30-minute fire test. The cask is required to be subjected to a fire with an effective temperature of

Figure B-4. SEG 3-82B Steady-State Temperature Profile.



801.7 °C (1,475 °F) for 30 minutes. The surface emissivity for the cask is taken in accordance with 10 CFR 71 as 0.8. The initial conditions to the fire test does not require previous exposure to solar heating. The analysis exposes the cask without its impact limiters to the 801.7 °C (1,475 °F) temperature gradually from an ambient condition of 37.8 °C (100 °F) over 2 minutes. The temperature is held for 30 minutes, then the environmental temperature is reduced over an additional 2-minute period. The 2-minute ramps are included for numerical stability. After the 30-minute fire test, the cask is allowed to cool by radiation and natural convection.

8.4.1 Thermal Model for HAC

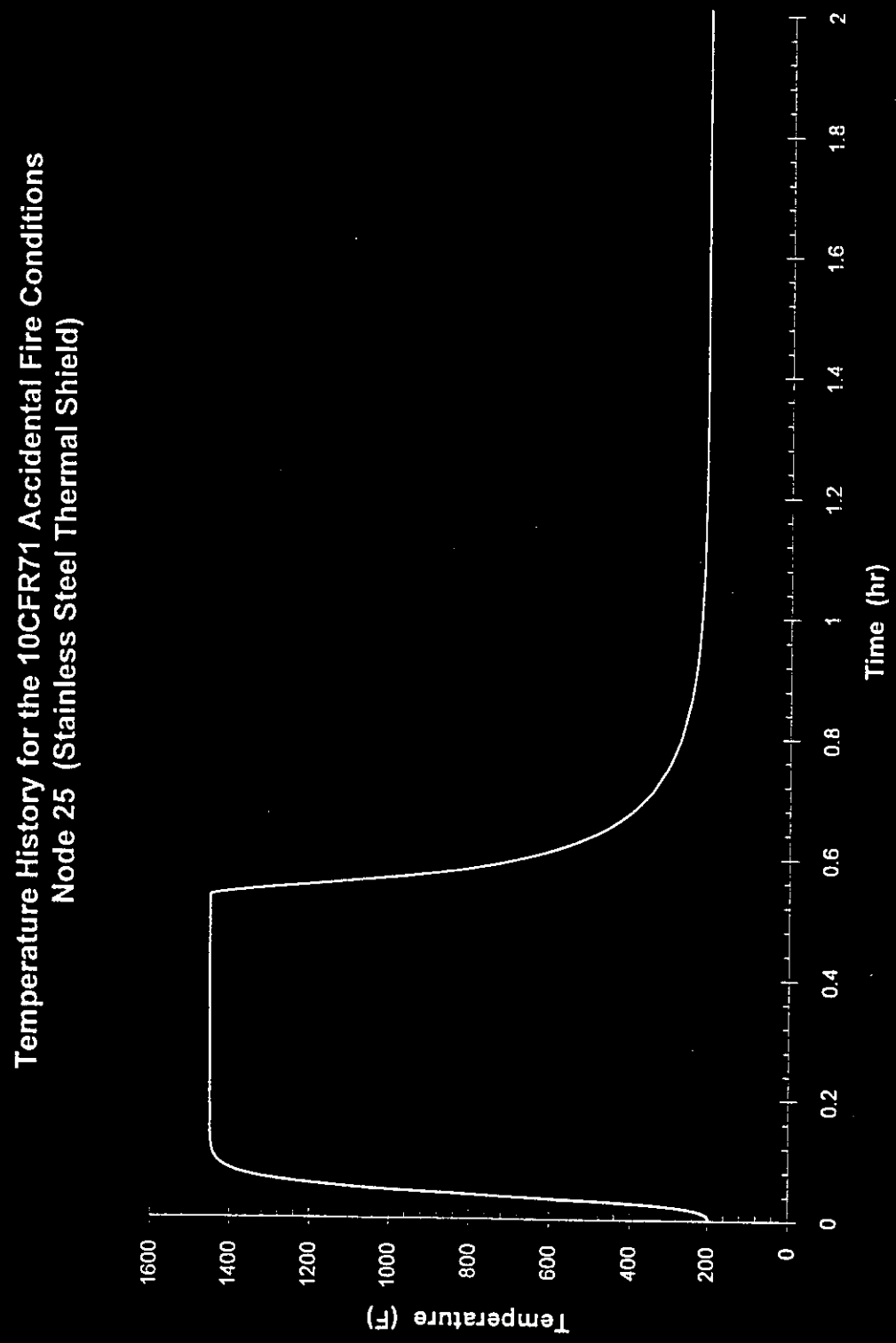
The only difference between the model used to simulate the fire HAC and the model used to simulate the NCT is that the cask surface emissivity for radiation heat transfer to the environment is 0.5 for the NCT and 0.8 for the fire HAC. A temperature varying emissivity (0.5 for temperatures below 93.3 °C [200 °F], and 0.8 for temperatures above 93.3 °C [200 °F]) is used to distinguish between the conditions before and during the fire test. The insolation heat load is not applied in the fire accident simulation.

8.4.2 Thermal Analysis Results for HAC

The outside surface of the cask's 11-gauge thermal shield responds quickly to the fire heat load to 787.8 °C (1,450 °F), as shown in Figure B-5. After the 30-minute fire, the temperature drops less quickly, but is under 121.1 °C (250 °F) in less than one hour after the start of the test. The inside surface of the insulation (node 23) also responds rapidly, but peaks at less than 257.2 °C (495 °F) within the first hour of the test, as shown in Figure B-6. In fact, the lowest peak temperature for the entire cask can be observed to be just over 254.4 °C (490 °F) by comparing Figures B-5 through B-8. This is less than the lead melting temperature, but larger than the silicone seal design basis temperature limit of 204.4 °C (400 °F). Unlike the NCT, for which the cask outside surface is the lowest temperature of the cask, during the fire test, the outside temperature of the cask is at times the highest temperature. Under these circumstances, the seal temperature will more closely follow the inside surface of the insulation. The reason the temperature of the seal will not closely follow the cask outside temperature during the fire test is because the impact limiter will act as a thermal shield against the radiation heat transfer of the fire. However, heat transfer by natural convection will be continuous. As a result, the seal temperature is expected to exceed its design basis by 35 °C (95 °F).

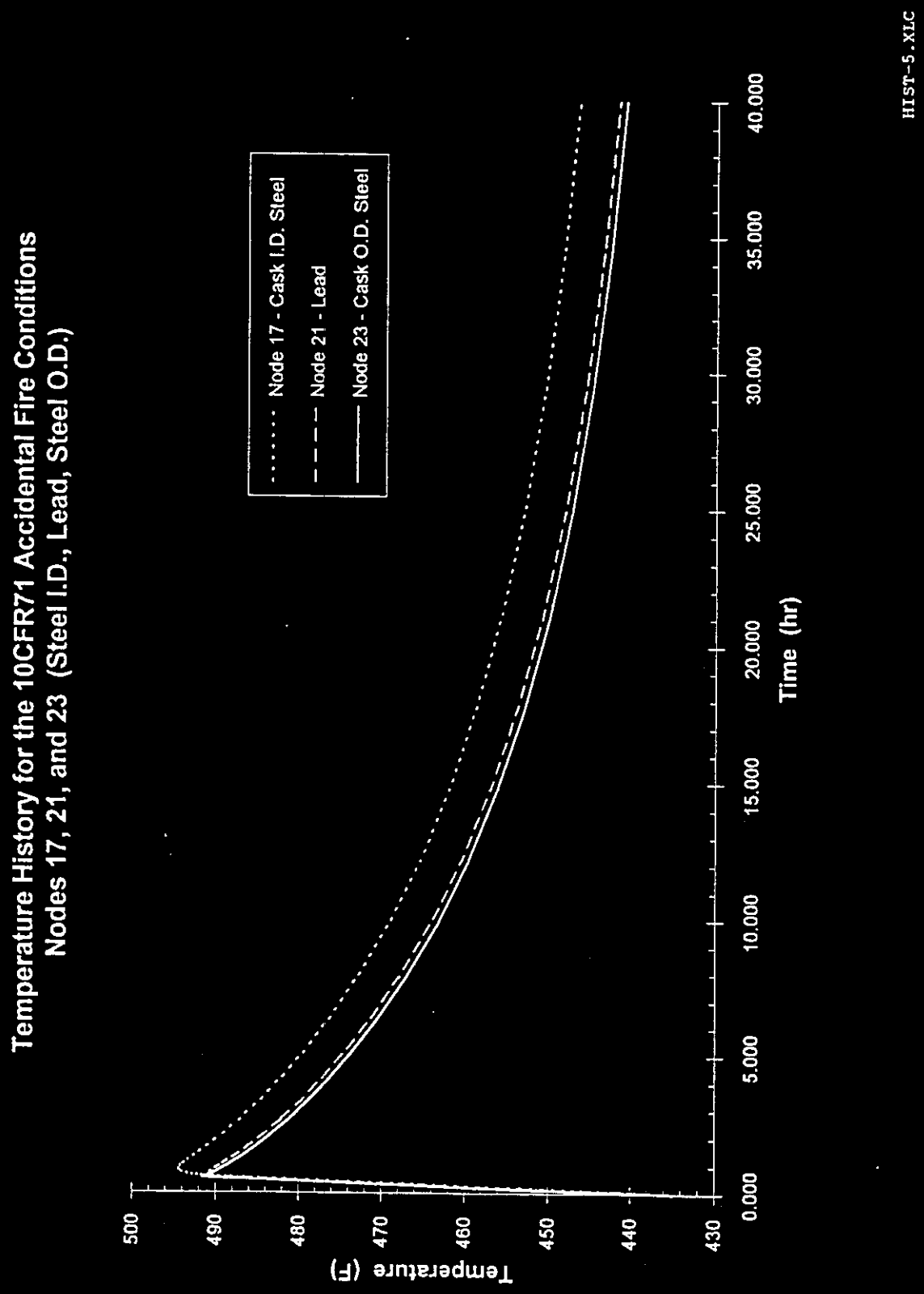
The lead temperature during the fire test peaks at just over 254.4 °C (490 °F), which leaves a comfortable margin to its melting point. It should be noted that the peak temperatures for the cask payload are for the fire test and are less than the steady-state temperatures for NCT with insolation.

Figure B-5. SEG 3-82B Surface Temperature History for the Fire Test.



HIST-6.XLC

Figure B-6. SEG 3-82B Cask Through-Wall Temperature History for the Fire Test.



HIST-5.XLC

Figure B-7. SEG 3-82B Cask Payload Container Temperature History for the Fire Test.

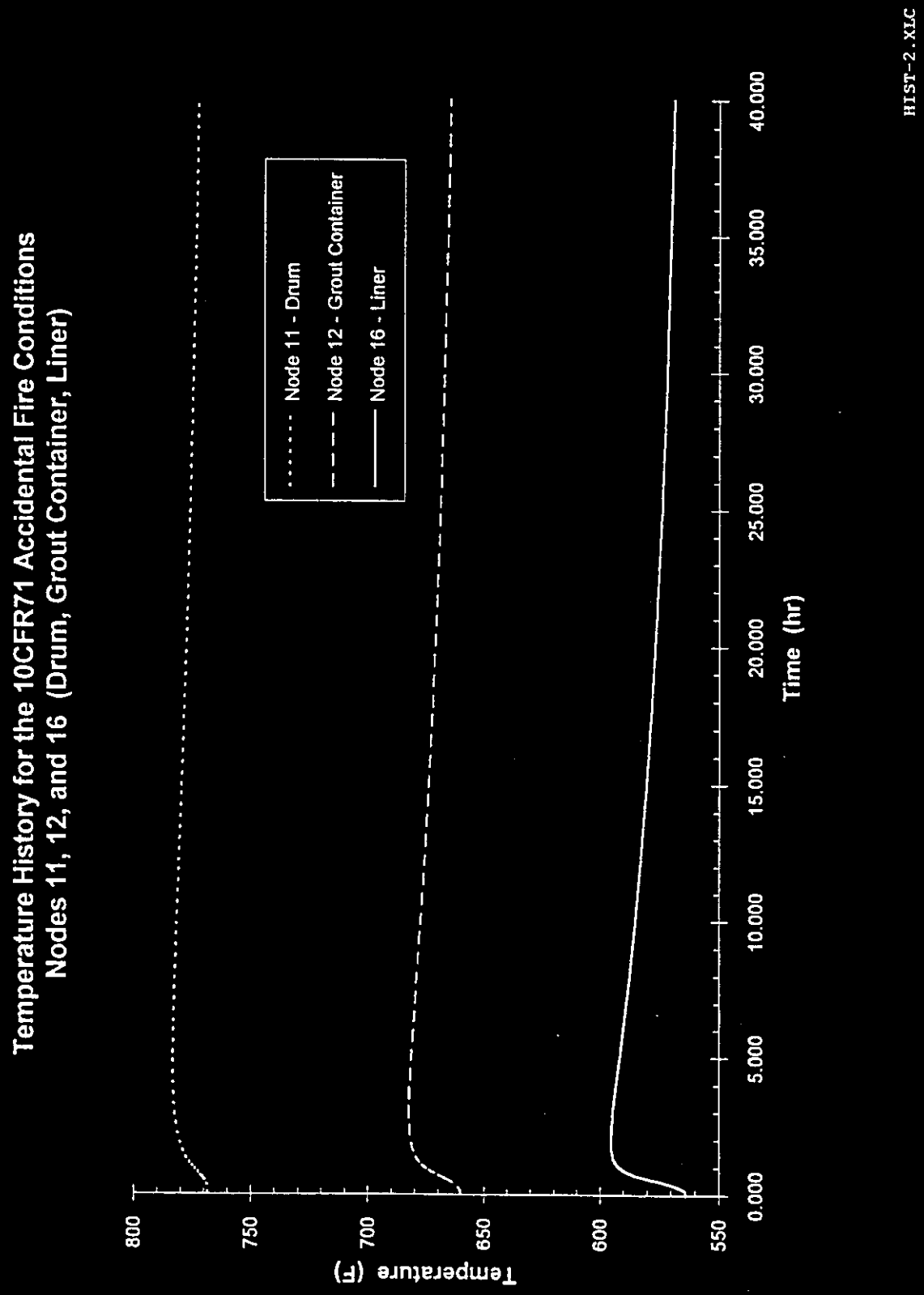
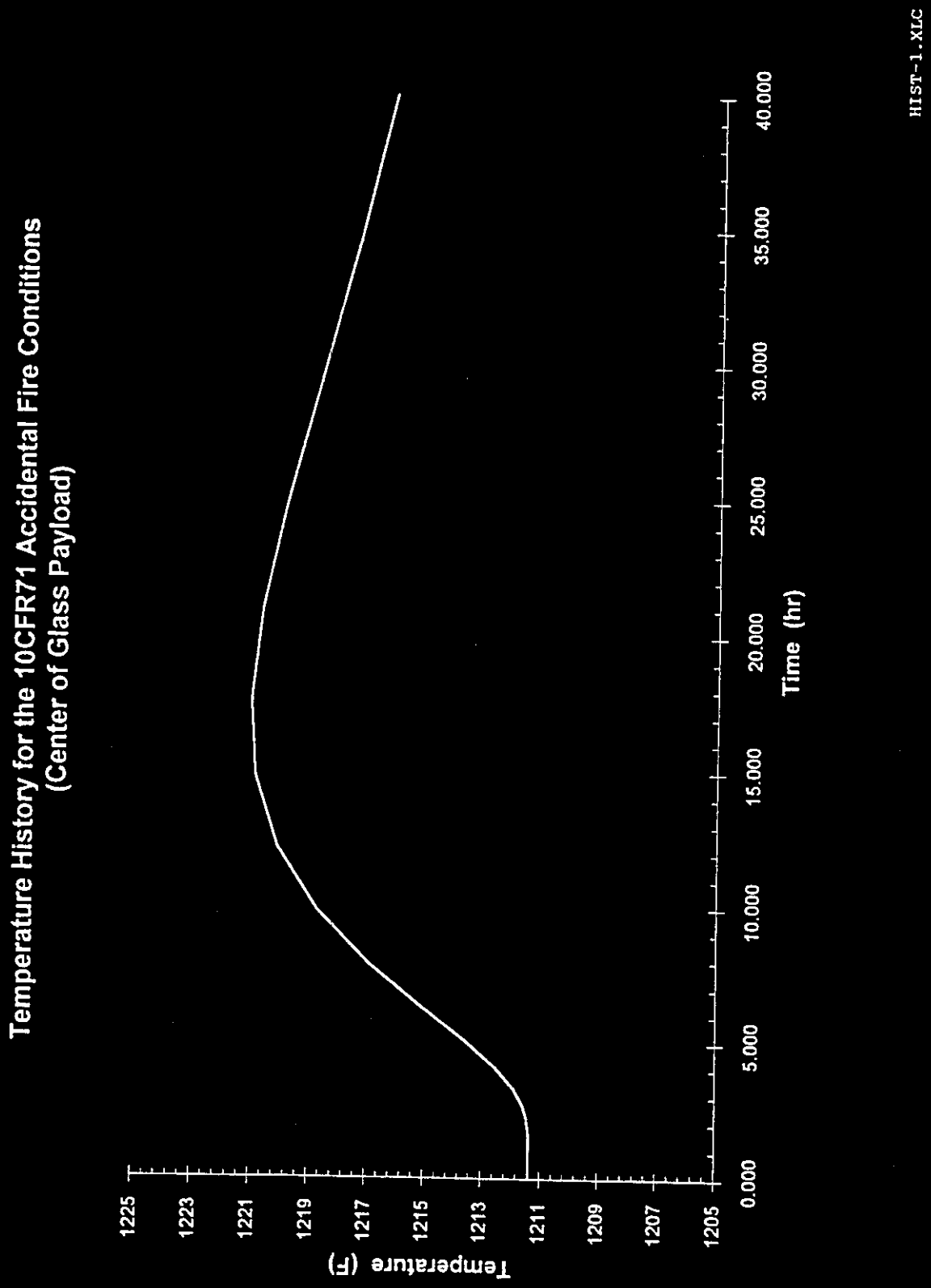


Figure B-8. SEG 3-82B Center Payload Temperature History for the Fire Test.



8.5 THERMAL EVALUATION CONCLUSION

Because the 82.2 °C (180 °F) surface temperature limit is exceeded for NCT, administrative precautions should be taken to prevent personnel injuries from accidental contact during transport or handling. The silicone seal temperature is estimated to be less than 204.4 °C (400 °F) for NCT. Therefore, the seal design basis is not expected to be exceeded. In fact, with less conservative assumptions regarding the distribution of heat deposition of the glass payload, the 204.4 °C (400 °F) limit can be shown to be unbreached. The predicted lead temperature of 276.7 °C (530 °F) is not high enough to cause melting. However, it is significantly higher than the design basis for NCT. Thermal stresses should be reevaluated with consideration of this higher temperature.

The fire test was not governing except in those areas near the cask surface. However, the seal temperature is expected to exceed the SEG (1991) operating limit of 204.4 °C (400 °F). In all cases, the cask temperatures are higher than those reported in SEG (1991). This is of concern for the thermal stress evaluation and the behavior of the payload contents (Part B, Section 7.0).

8.6 APPENDICES

8.6.1 Peer Review Check Sheet

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed Thermal Evaluation of SEG Cask

Author A. Dyrness/Advent Engineering Services, Inc.

Yes	No	N/A	
[✓]	[ ]	[ ]	Problem completely defined.
[✓]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files documented.
[✓]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[✓]	[ ]	[ ]	Data checked for consistency with original source information as applicable.
[✓]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results.
[✓]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified.
[✓]	[ ]	[ ]	Hand calculations checked for errors.
[✓]	[ ]	[ ]	Code run streams correct and consistent with analysis documentation.
[✓]	[ ]	[ ]	Code output consistent with input and with results reported in analysis documentation.
[✓]	[ ]	[ ]	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
[✓]	[ ]	[ ]	Safety margins consistent with good engineering practices.
[✓]	[ ]	[ ]	Conclusions consistent with analytical results and applicable limits.
[✓]	[ ]	[ ]	Results and conclusions address all points required in the problem statement.

MANDATORY Software QA Log Number _____

Reviewer _____ Date 10/9/95

10/09/95

8.6.2 Thermal Analysis

Thermal Properties of Air (Rohsenow and Choi (1964)

Air @ 130 F: $T_\infty = (100 + 460)\cdot R$

Conductivity	Density	Specific Heat	Viscosity
$k_a = .0166\cdot\frac{BTU}{hr\cdot R\cdot ft}$	$\rho_a = .06766\cdot\frac{lb}{ft^3}$	$c_a = .2413\cdot\frac{BTU}{lb\cdot R}$	$\mu_a = .0478\cdot\frac{lb}{ft\cdot hr}$

Kinematic Viscosity	Thermal Diffusivity	Prandtl Number	Volume Expansion Coefficient
$\nu_a = \frac{\mu_a}{\rho_a}$	$\alpha_a = \frac{k_a}{\rho_a\cdot c_a}$	$Pr_a = \frac{\nu_a}{\alpha_a}$	$\beta_a = \frac{1}{T_\infty}$
$\nu_a = 0.706\cdot\frac{ft^2}{hr}$	$\alpha_a = 1.017\cdot\frac{ft^2}{hr}$	$Pr_a = 0.695$	$\beta_a = 0.002\cdot R^{-1}$

Definition of Grashof and Rayleigh Numbers:

$$Gr(T_w, L) := \frac{g\cdot\beta_a\cdot(T_w - T_\infty)\cdot L^3}{\nu_a^2} \qquad Ra(T_w, L) := Gr(T_w, L)\cdot Pr_a$$

For vertical surfaces within enclosed cavities, Rohsenow et al. (1985) provides an expression for the natural convection Nusselt Number as a function of the Rayleigh Number and gap to length ratio as shown below.

$$Nu(H, L, T_w) := 1 + \left[\left[\left(2.756\cdot 10^{-6}\right)\cdot Ra(T_w, L)^2\cdot\left(\frac{H}{L}\right)^8\right]^{-0.386} + \left[0.623\cdot Ra(T_w, L)^{\frac{1}{5}}\cdot\left(\frac{L}{H}\right)^{\frac{2}{5}}\right]^{-0.386}\right]^{\frac{1}{-0.386}}$$

For vertical surfaces exposed to the environment, Rohsenow and Choi (1964) provides an expression for the natural convection Nusselt Number as a function of the Rayleigh Number.

$$Nu2(T_w, L) := 0.56\cdot Ra(T_w, L)^{0.25}$$

A-1

Because the ANSYS program requires input of a simpler form of the convective heat transfer coefficient the following ad hoc empirical equations are derived for the specific gaps under consideration.

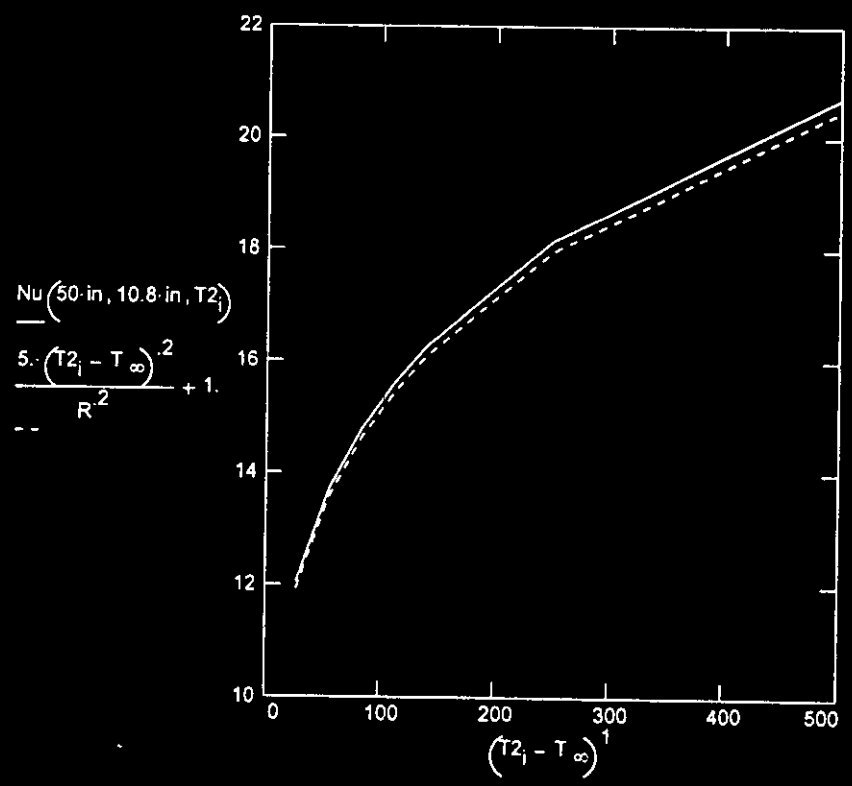
The characteristic length is taken as roughly equal to the height of a 55 gal. drum. $H1 := 50 \cdot in$

Temperature Range

$i := 0..6$ $T2_i :=$

460·R + 150·R
460·R + 200·R
460·R + 250·R
460·R + 300·R
460·R + 350·R
460·R + 550·R
460·R + 1000·R

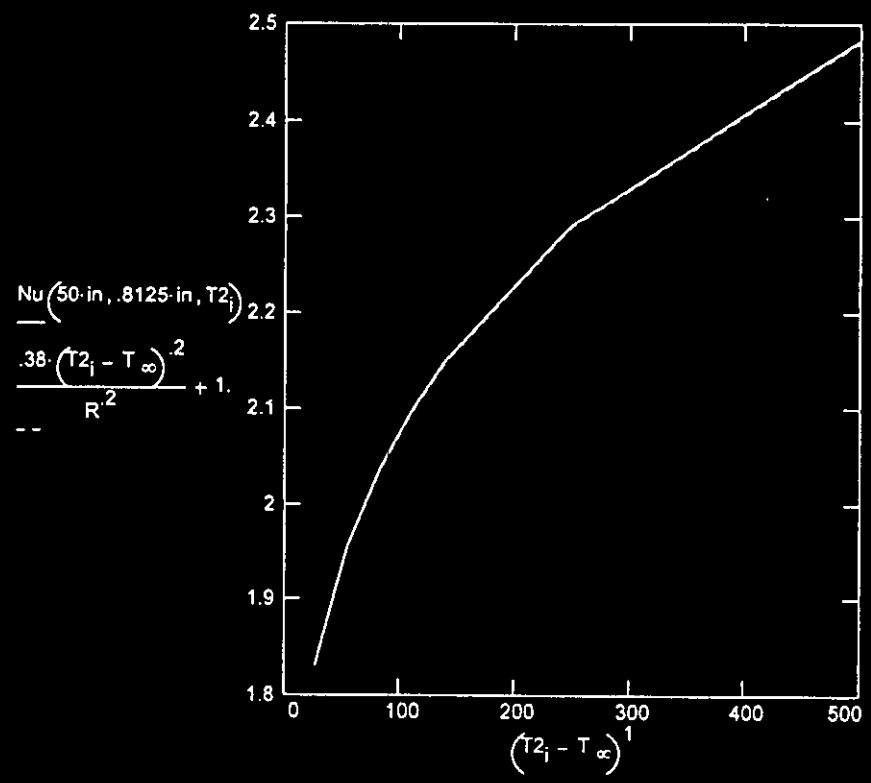
The first gap is 10.8 in. The ad hoc correlation is compared to the rigorous expression below.



$\frac{T2_i - T_\infty}{R}$	$Nu(50 \cdot in, 10.8 \cdot in, T2_i)$	$\frac{5 \cdot (T2_i - T_\infty)^{.20}}{R^{.20}} + 1.12$
50	12.059	12.054
100	13.704	13.679
150	14.777	14.74
200	15.593	15.547
250	16.259	16.205
450	18.162	18.087
900	20.714	20.61

A-2

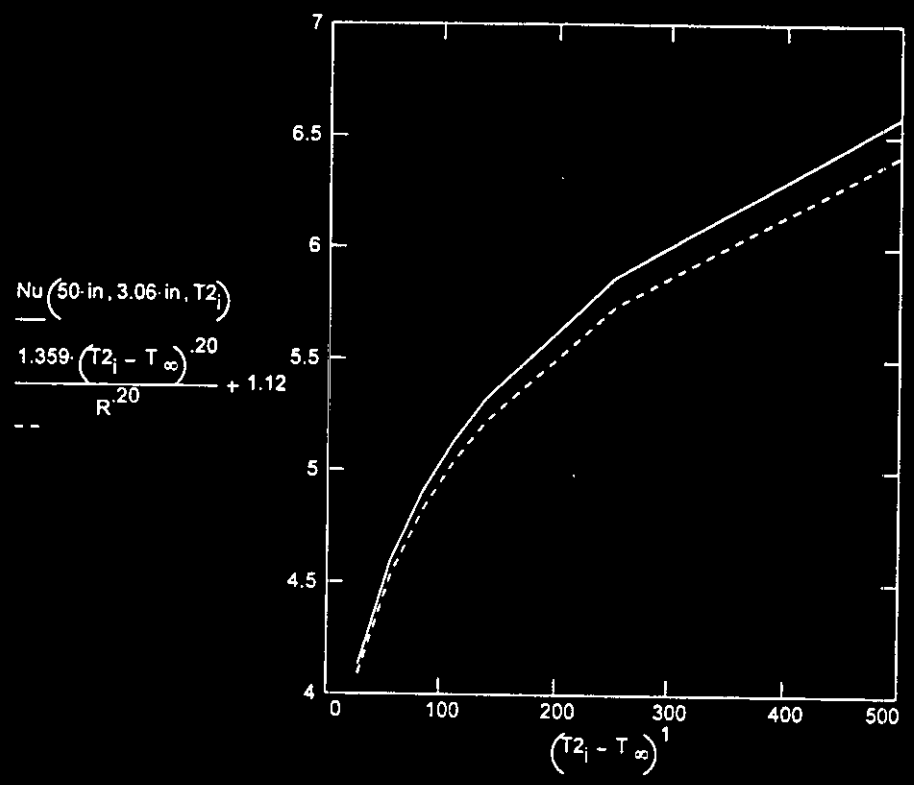
The second gap is 0.8125 in.



$\frac{T2_i - T_\infty}{R}$	$Nu(50\cdot in, .8125\cdot in, T2_i)$	$\frac{.38\cdot(T2_i - T_\infty)^{.2}}{R^{.2}} + 1.$
50	1.832	1.831
100	1.956	1.955
150	2.036	2.035
200	2.098	2.096
250	2.148	2.146
450	2.291	2.29
900	2.483	2.481

A-3

The third gap is 3.06 in.



$\frac{T2_i - T_\infty}{R}$	$Nu(50 \cdot in, 3.06 \cdot in, T2_i)$	$\frac{1.359 \cdot (T2_i - T_\infty)^{.20}}{R^{.20}} + 1.12$
50	4.133	4.092
100	4.599	4.534
150	4.903	4.822
200	5.135	5.041
250	5.323	5.22
450	5.863	5.732
900	6.586	6.417

A-4

The natural convection heat transfer coefficient for the exterior of the cask to the environment is taken from Rohsenow and Choi (1964) and is compared to that used in the SEG 3-82B SARP.

From the SEG SARP

$$\frac{T2_i - T_\infty}{R} \qquad .21\cdot\left(\frac{T2_i - T_\infty}{R}\right)^{\frac{1}{3}}$$

50	0.774
100	0.975
150	1.116
200	1.228
250	1.323
450	1.609
900	2.028

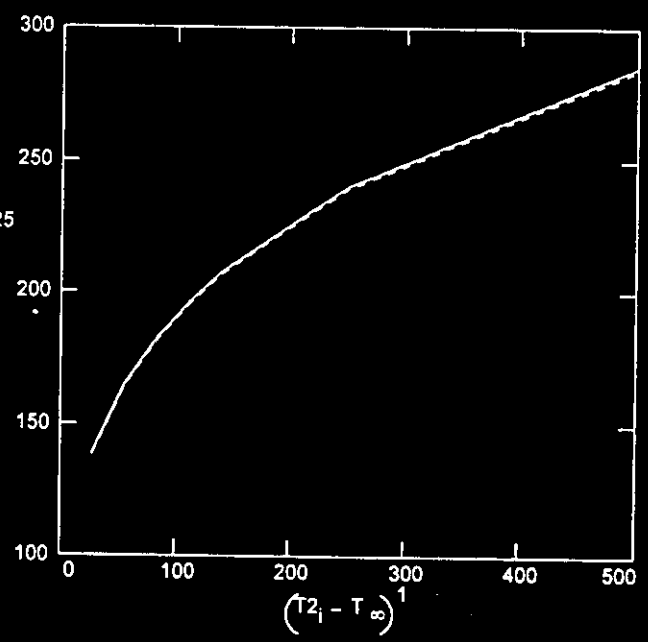
From Rohsenow and Choi (1964)

$$\frac{\frac{k_a}{50\cdot in}\cdot 0.56\cdot Ra\left(T2_i, 50\cdot in\right)^{\frac{1}{4}}}{\left(\frac{BTU}{ft^2\cdot R\cdot hr}\right)}$$

0.552
0.657
0.727
0.781
0.826
0.956
1.137

The expression used in the SEG SARP provides a larger heat transfer coefficient over the range of temperatures differences examined. The difference between these two correlations is primarily a function of the Rayleigh Number, or more specifically the choice of the characteristic length. The uncertainty associated with determining the characteristic length, L, motivates a the conservative position of taking the Rohsenow and Choi equation for normal conditions. This assumption is not expected to be design limiting because the heat transfer by radiation will dominate during the fire test. The correlation of the form that is consistent with the ANSYS input is shown below.

$$\frac{0.56\cdot Ra\left(T2_i, 50\cdot in\right)^{.25}}{\frac{51.9\cdot\left(T2_i - T_\infty\right)^{.25}}{R^{.25}}}$$



A-5

$\frac{T2_i - T_\infty}{R}$	Rohsenow and Choi $0.56 \cdot Ra\left(T2_i, 50 \cdot in\right)^{\frac{1}{4}}$	Ad Hoc Correlation $\frac{51.9 \cdot \left(T2_i - T_\infty\right)^{.25}}{R^{.25}}$
50	138.572	138.01
100	164.79	164.122
150	182.37	181.631
200	195.97	195.175
250	207.213	206.373
450	240.013	239.04
900	285.425	284.268

The following calculations use a heat balance to verify the finite-element model.

Heat Balance based on SARP calculation for steady state.

$$q_{solar} := \frac{0.95 \cdot 400}{12} \cdot \frac{cal}{hr \cdot cm^2} \qquad q_{solar} = 0.811 \cdot \frac{BTU}{hr \cdot in^2}$$

$$q_{payload} := \frac{2.1 \cdot 10^3 \cdot \frac{joule}{sec}}{127.8 \cdot ft^2} \qquad q_{payload} = 56.068 \cdot \frac{BTU}{hr \cdot ft^2}$$

$$q_{total} := q_{solar} + q_{payload} \qquad q_{total} = 172.813 \cdot \frac{BTU}{hr \cdot ft^2}$$

$$q(T) := .18 \cdot \frac{BTU}{hr \cdot ft^2} \cdot (T - 130)^{.333} \cdot (T - 130) + 0.8 \cdot .1738 \cdot 10^{-8} \cdot \frac{BTU}{hr \cdot ft^2} \cdot \left[(T + 460)^4 - (130 + 460)^4\right] - 59.2 \cdot \frac{BTU}{hr \cdot ft^2}$$

$$x := 1000 \qquad root(q(x), x) = 162.618$$

A-6

Based on 10CFR71 with new heat load but with SARP heat transfer coefficient:

$$q_{new} := \frac{\frac{2.1\cdot 10^3\cdot\frac{joule}{sec}}{5.5\cdot ft^3}\cdot 2\cdot in\cdot\pi\cdot(11.95\cdot in)^2}{2\cdot\pi} + \frac{q_{solar}\cdot 33.25\cdot in\cdot 2\cdot in}{2\cdot\pi} \qquad q_{new} = 116.246\cdot\frac{BTU}{hr}$$

$$q_n(T) := .18\cdot\frac{BTU}{hr\cdot ft^2}\cdot(T-100)^{.333}\cdot(T-100) + 0.5\cdot .1738\cdot 10^{-8}\cdot\frac{BTU}{hr\cdot ft^2}\cdot\left[(T+460)^4-(100+460)^4\right] - \frac{q_{new}}{33.25\cdot in\cdot 2\cdot in}$$

$$x := 1000 \qquad root(q_n(x), x) = 239.137$$

Based on new heat load, 10CFR71 and new heat transfer model used in finite element model:

$$Q_i := \frac{2.1\cdot 10^3\cdot\frac{joule}{sec}}{5.5\cdot ft^3}\cdot 2\cdot in\cdot\pi\cdot\frac{(11.95\cdot in)^2}{2\cdot\pi} \qquad Q_i = 107.665\cdot\frac{BTU}{hr}$$

$$Q_s := \frac{q_{solar}\cdot 33.62\cdot in\cdot\pi\cdot 2\cdot 2\cdot in}{\pi\cdot 2} \qquad Q_s = 54.514\cdot\frac{BTU}{hr}$$

$$q_{new} := Q_i + Q_s \qquad q_{new} = 162.179\cdot\frac{BTU}{hr}$$

Heat balance for conditions with insolation

$$q_n(T) := \left[\begin{array}{l} 51.9\cdot\frac{.0015}{50}\cdot\frac{BTU}{hr\cdot in^2}\cdot(T-100)^{.25}\cdot(T-100)\cdot 2\cdot in\cdot 33.25\cdot in \ldots \\ +0.5\cdot .119\cdot 10^{-10}\cdot\frac{BTU}{hr\cdot in^2}\cdot\left[(T+460)^4-(100+460)^4\right]\cdot 2\cdot in\cdot 33.25\cdot in \end{array}\right] - q_{new}$$

$$x := 262$$

$$root(q_n(x), x) = 292.481$$

A-7

Heat balance for conditions before fire starts

$$q_n(T) := \left[\begin{array}{l} 51.9 \cdot \frac{.003416}{50} \cdot \frac{BTU}{hr \cdot in^2} \cdot (T - 100)^{.25} \cdot (T - 100) \cdot 2 \cdot in \cdot 33.25 \cdot in \ldots \\ + 0.5 \cdot .119 \cdot 10^{-10} \cdot \frac{BTU}{hr \cdot in^2} \cdot \left[(T + 460)^4 - (100 + 460)^4 \right] \cdot 2 \cdot in \cdot 33.25 \cdot in \end{array} \right] - 107.665 \cdot \frac{BTU}{hr}$$

$x := 300$

$root(q_n(x), x) = 197.782$

The new heat load (2.1kw/5.5ft^3) is the maximum volumetric heat deposition possible. This assumes that the glass is essentially solid throughout the drum. If at the other extreme it is assumed that the 2.1kw is uniformly distributed inside the 55 gallon drum, then the volumetric heat deposition would result in the following:

$V := 55 \cdot gal$ $\qquad \frac{V}{(11.95 \cdot in)^2 \cdot \pi} = 2.36 \cdot ft$

$$Q_u := \frac{2.1 \cdot 10^3 \cdot \frac{joule}{sec}}{V} \cdot 2 \cdot in \cdot \pi \cdot \frac{(11.95 \cdot in)^2}{2 \cdot \pi} \qquad Q_u = 80.539 \cdot \frac{BTU}{hr}$$

Adding the insolation:

$q_u := Q_u + Q_s$ $\qquad q_u = 135.053 \cdot \frac{BTU}{hr}$

$$q_n(T) := \left[\begin{array}{l} 51.9 \cdot \frac{.003416}{50} \cdot \frac{BTU}{hr \cdot in^2} \cdot (T - 100)^{.25} \cdot (T - 100) \cdot 2 \cdot in \cdot 33.25 \cdot in \ldots \\ + 0.5 \cdot .119 \cdot 10^{-10} \cdot \frac{BTU}{hr \cdot in^2} \cdot \left[(T + 460)^4 - (100 + 460)^4 \right] \cdot 2 \cdot in \cdot 33.25 \cdot in \end{array} \right] - q_u$$

$x := 300$

$root(q_n(x), x) = 217.078$

A-8

Taking the wall temperature as 217F, and the heat flow as 80.539 Btu/hr, the temperature drop across the insulation layer is computed below.

$l := 2 \cdot in$ for 2 in. strip

$r_2 := 33.125 \cdot in$

$r_1 := 32.125 \cdot in$

$k := 0.083 \cdot \frac{BTU}{ft \cdot hr \cdot R}$

Thermal resistance across a cylidrical wall: $R_c := \frac{\ln\left(\frac{r_2}{r_1}\right)}{2 \cdot \pi \cdot l \cdot k}$

$\Delta T := Q_U \cdot 2 \cdot \pi \cdot R_c$ $\Delta T = 178.47 \cdot R$

Therefore, the temperature on the inside of the inuslation is: $217 + 178.47 = 395.47$

The thermal conductivity of borosilicate glass is given by the following expression. The temperature variation is in degrees Celsius, but reported with the symbol K as in Kevin. Because the units of the conductivity are include temperature as in incremental measure, it does not matter which unit is used.

$k(TK) := 0.00095 \cdot \frac{watt}{m \cdot K^2} \cdot (TK) + .75 \cdot \frac{watt}{m \cdot K}$

	Temperature in F
$k(20 \cdot K) = 0.037 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(20) \cdot \frac{9}{5} + 32 = 68$
$k(80 \cdot K) = 0.04 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(80) \cdot \frac{9}{5} + 32 = 176$
$k(130 \cdot K) = 0.042 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(130) \cdot \frac{9}{5} + 32 = 266$
$k(300 \cdot K) = 0.05 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(300) \cdot \frac{9}{5} + 32 = 572$
$k(450 \cdot K) = 0.057 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(450) \cdot \frac{9}{5} + 32 = 842$
$k(800 \cdot K) = 0.073 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(800) \cdot \frac{9}{5} + 32 = 1.472 \cdot 10^3$
$k(2200 \cdot K) = 0.137 \cdot \frac{BTU}{hr \cdot R \cdot in}$	$(2200) \cdot \frac{9}{5} + 32 = 3.992 \cdot 10^3$

A-9

Coefficient for ANSYS input to the natural convection heat transfer correlation as a function of temperature.

HF for 10.8 in. gap	Temperature (F)	Air Thermal Conductivity (Btu/hr-in-F)
$5.0 \cdot \frac{.015}{12 \cdot 10.8} = 0.000579$	60	$\frac{.015}{12} = 0.00125$
$5.0 \cdot \frac{.016}{12 \cdot 10.8} = 0.000617$	100	$\frac{.016}{12} = 0.001333$
$5.0 \cdot \frac{.018}{12 \cdot 10.8} = 0.000694$	200	$\frac{.018}{12} = 0.0015$
$5.0 \cdot \frac{.025}{12 \cdot 10.8} = 0.000965$	500	$\frac{.025}{12} = 0.002083$
$5.0 \cdot \frac{.03}{12 \cdot 10.8} = 0.001157$	800	$\frac{.03}{12} = 0.0025$
$5.0 \cdot \frac{.041}{12 \cdot 10.8} = 0.001582$	1500	$\frac{.041}{12} = 0.003417$

HF for 0.8125 in. gap	HF for 3.06 in. gap	Temperature (F)
$0.38 \cdot \frac{.015}{12 \cdot 0.8125} = 0.000585$	$1.359 \cdot \frac{.015}{12 \cdot 3.06} = 0.000555$	60
$0.38 \cdot \frac{.016}{12 \cdot 0.8125} = 0.000624$	$1.359 \cdot \frac{.016}{12 \cdot 3.06} = 0.000592$	100
$0.38 \cdot \frac{.018}{12 \cdot 0.8125} = 0.000702$	$1.359 \cdot \frac{.018}{12 \cdot 3.06} = 0.000666$	200
$0.38 \cdot \frac{.025}{12 \cdot 0.8125} = 0.000974$	$1.359 \cdot \frac{.025}{12 \cdot 3.06} = 0.000925$	500
$0.38 \cdot \frac{.03}{12 \cdot 0.8125} = 0.001169$	$1.359 \cdot \frac{.03}{12 \cdot 3.06} = 0.00111$	800
$0.38 \cdot \frac{.041}{12 \cdot 0.8125} = 0.001598$	$1.359 \cdot \frac{.041}{12 \cdot 3.06} = 0.001517$	1500

8.6.3 ANSYS Files

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FILENAME : segfire.inp                DATE : 10-03-95              TIME :  3:49p                    PAGE  1
TITLE    : seg fire test analysis

/PREP7
/TITLE, NEW MATERIAL DEF. SEG CASK  STEADY-STATE
KAN,-1
C**** ELEMENT TYPES

ET,1,55,,,1                          * ISO-PARA SOLID (AXI SYMMETRIC)
ET,2,34                              * CONVECTION LINK
ET,3,31                              * RADIATION LINK
ET,4,32                              * CONDUCTION LINK
ET,5,55,,,1                          * ISO-PARA SOLID (NON-PAYLOAD)
C**** MATERIAL PROPERTIES

KXX,1,(10.0/12.)                     * STAINLESS STEEL (BTU/HR F IN.)
DENS,1,(488.0/1728.)                 * LBM/IN.^3
C,1,0.11                             * BTU/LBM  F

KXX,2,(18.6/12.)                     * LEAD    (BTU/HR F IN.)
DENS,2,(710.0/1728.)                 * LBM/IN.^3
C,2,0.031                            * BTU/LBM F

KXX,3,(0.083/12.)                    * INSULATION (C)   BTU/HR F IN.
DENS,3,(1./1728.)                    * ASSUMES VERY LIGHT
C,3,.001                             * ASSUMES VERY LITTLE HEAT CAPACITY
R,7,(32.8725/2)                      * AREA FOR INSULATION
R,8,32.8725

KXX,6,(25.0/12.)                        * CARBON STEEL, BTU/HR F IN.
DENS,6,(485/1728.)                      * LBM/IN.^3
C,6,0 113                               * BTU/LBM F

C***HF,24,(51.9*1.5E-3/50.)            * ASSUMES k @ 200F
HF,24,(51.9*3.416E-3/50.)              * ASSUMES k @ 1500F
MPTEMP , 1    ,60    ,100   ,200   ,500   ,800   ,1500      * AIR (T)
MPDATA,KXX,4,1,0.0012,0.0013,0.0015,0.0016,0.0018,0.0019

MPTEMP,1,68,176,572,842,1472,3992.0
MPDATA,KXX,5,1 ,.037 ,.04 ,.05 ,.057  ,.073 ,.137
C***KXX,5,(.51/12.)                              * PAYLOAD GLASS  BUT/HR F IN.
DENS,5,(62.4*2.7/1728.)                 * SG=2.7  LBM/IN.^3
C,5,0.16                                * FOR WINDOW GLASS  BTU/LBM F

C**** FREE CONVECTION COEFFICIENTS

MPTEMP,1,60,100,200,500,800,1500

MPDATA,HF,20,1,.000579,.000617,.000694,.000965,.001157,.001582
C***HF,20,(5.0*1.5E-3/10.8)
R,1,(17.4/2),.2,(1.12*1.5E-3/10.8)    * ASSUMES k @ 200F
R,2,17.4    ,.2,(1.12*1.5E-3/10.8)    * ASSUMES k @ 200F

MPDATA,HF,21,1,.000585,.000624,.000702,.000974,.001169,.001598
C***HF,21,(0.401*1.5E-3/0.8125)
R,3,(23.343/2),.2,(1.0*1.5E-3/0.8125)  * ASSUMES k @ 200F
R,4,23.343    ,.2,(1.0*1.5E-3/0.8125)  * ASSUMES k @ 200F

MPDATA,HF,22,1,.000555,.000592,.000666,.000925,.001110,.001517
C***HF,22,(1.359*1.5E-3/3.06)
R,5,(25.469/2),.2,(1.12*1.5E-3/3.06)   * ASSUMES k @ 200F
R,6,25.469    ,.2,(1.12*1.5E-3/3.06)   * ASSUMES k @ 200F

R,9,(33.25/2),0.25,0.
R,10,33.25   ,0.25,0.

R,11,(17.4/2),1.,0.333,0.119E-10
R,12,17.4    ,1.,0.333,0.119E-10

R,13,(23.343/2),1.,0.333,0.119E-10
R,14,23.343    ,1.,0.333,0.119E-10

R,15,(25.469/2),1.,0.333,0.119E-10
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R,16,25.469    ,1.,0.333,0.119E-10


R,19,(33.25/2),1.,-25,0.119E-10        * 0.8 for fire conditions
R,20,33.25    ,1.,-25,0.119E-10

MPTEMP,25  ,60.,100.,200.,201.,1500.,2000.
MPDATA,EMIS,25,1,.5 ,.5  ,.5  ,.8,.8 ,.8

C********************** NODAL GEOMETRY ******************
N,1 ,0.,1.
N,10,11.95,1.
FILL
N,11,12.0,1.
N,12,(22.9375-0.14),1.
N,14,22.9375,1.
FILL
N,15,(23.9375-0.1875),1.
N,16,23.9375,1.
N,17,27.,1.
N,19,(27.+0.375),1.
FILL
N,21,(27.+0.375+3.75),1.
FILL
N,23,(27.+0.375+3.75+1.),1.
FILL
N,24,(27.+0.375+3.75+1.+1.),1.
N,25,(27.+0.375+3.75+1.+1.+0.125),1.
NGEN,3,100,1,25,1,0.,-1.
N,26,35.,1.
N,27,35.,-1.

TYPE,1                    * SOLID
MAT,5
E,1,2,102,101
EGEN,9,1,1
EGEN,2,100,1,9,1

TYPE,5                    * STEEL DRUM
MAT,6
E,10,11,111,110
E,110,111,211,210

TYPE,2                    * CONVECTION
MAT,20
REAL,1      $E,11,12
REAL,2      $E,111,112
REAL,1      $E,211,212

TYPE,3                    * RADIATION
REAL,11     $E,11,12
REAL,12     $E,111,112
REAL,11     $E,211,212

TYPE,5                    * GROUT CONTAINER
MAT,6
E,12,13,113,112
E,13,14,114,113
E,112,113,213,212
E,113,114,214,213

TYPE,2                    * CONVECTION
MAT,21
REAL,3      $E,14,15
REAL,4      $E,114,115
REAL,3      $E,214,215

TYPE,3                    * RADIATION
REAL,13     $E,14,15
REAL,14     $E,114,115
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REAL,13      $E,214,215

TYPE,5
MAT,1                          * STAINLESS
E,15,16,116,115
E,115,116,216,215

TYPE,2                         * CONVECTION
MAT,22
REAL,5       $E,16,17
REAL,6       $E,116,117
REAL,5       $E,216,217

TYPE,3                         * RADIATION
REAL,15       $E,16,17
REAL,16       $E,116,117
REAL,15       $E,216,217

TYPE,5
MAT,6                          * STEEL
E,17,18,118,117
E,18,19,119,118
E,117,118,218,217
E,118,119,219,218

MAT,2                          * LEAD
E,19,20,120,119
E,20,21,121,120
E,119,120,220,219
E,120,121,221,220

MAT,6                          * STEEL
E,21,22,122,121
E,22,23,123,122
E,121,122,222,221
E,122,123,223,222

TYPE,4                         * CONDUCTION
MAT,3                          * INSULATION
REAL,7       $E,23,24
REAL,8       $E,123,124
REAL,7       $E,223,224

TYPE,5
MAT,1
E,24,25,125,124
E,124,125,225,224

TYPE,2
MAT,24                         * CONVECTION
REAL,9     $E,25,26
REAL,10    $E,125,26
REAL,9     $E,225,26

TYPE,3                         * RADIATION
REAL,19    $E,25,27
REAL,20    $E,125,27
REAL,19    $E,225,27

C****************************** HEAT LOAD **************
QSH = ((1475./12.)/144.)       * 400/12 cal/m-hr
ABS = 0.4
H1 = (33.62*(QSH*ABS))

C***** INTERNAL HEAT GENERATION
QGEN = (7165.4/9504.)                    * 2.1KW/5.5FT^3

ESEL,MAT,5
QE,ALL,(.1*QGEN)
EALL
```

```
C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 1

ESEL,MAT,5
QE,ALL,(.2*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 2

ESEL,MAT,5
QE,ALL,(.3*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 3

ESEL,MAT,5
```

```
QE,ALL,(.4*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 4

ESEL,MAT,5
QE,ALL,(.5*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 5

ESEL,MAT,5
QE,ALL,(.6*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 6
```

```
ESEL,MAT,5
QE,ALL,(.7*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 7
ESEL,MAT,5

QE,ALL,(.8*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 8

ESEL,MAT,5
QE,ALL,(.9*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
```

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NT,27,TEMP,100.
LWRITE                    **** STEP 9

ESEL,MAT,5
QE,ALL,QGEN
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 10

/TITLE,SEG TRANSIENT (FIRE WITH 2.1kw)
TIME,(2.0/60.)             *** UNITS REQUIRE  TIME IN HOURS
ITER,30,,2
KBC,0
CONV,1
CNVR,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

NT,26,TEMP,1475.
NT,27,TEMP,1475.

LWRITE                    *** STEP 11
TIME,(10.0/60.)            *** UNITS REQUIRE  TIME IN HOURS
ITER,60,,2
KBC,0
CONV,1
CNVR,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1


LWRITE                    *** STEP 12
TIME,(32.0/60.)            *** UNITS REQUIRE  TIME IN HOURS
ITER,60,,2
KBC,0
CONV,1
CNVR,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1
LWRITE                    *** STEP 13

TIME,(34.0/60.)            *** UNITS REQUIRE  TIME IN HOURS
ITER,20,,2
KBC,0
CONV,1
CNVR,1,1
```

```
FILENAME : segfire.inp              DATE : 10-03-95          TIME :  3:49p              PAGE  8
TITLE    : seg fire test analysis

PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1
NT,26,TEMP,100.
NT,27,TEMP,100.

LWRITE                    *** STEP 14
TIME,(60.0/60.)            *** UNITS REQUIRE  TIME IN HOURS
ITER,600,,2
KBC,0
CONV,1
CNVR,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1
NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    *** STEP 15

TIME,(2400.0/60.)            *** UNITS REQUIRE  TIME IN HOURS
ITER,1200,,1
KBC,0
CONV,1
CNVR,1,1
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1
NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    *** STEP 16

APWRITE
FINI
C***/OUT,SOLU,OUT
/INPUT,27
FINI
/EOF
```

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FILENAME : segth.inp                DATE : 10-03-95            TIME :  3:50p                PAGE  1
TITLE    : seg normal thermal analysis

/PREP7
/TITLE, NEW MATERIAL DEF. SEG CASK  STEADY-STATE
KAN,-1
C**** ELEMENT TYPES

ET,1,55,,,1                         * ISO-PARA SOLID (AXI SYMMETRIC)
ET,2,34                             * CONVECTION LINK
ET,3,31                             * RADIATION LINK
ET,4,32                             * CONDUCTION LINK
ET,5,55,,,1                         * ISO-PARA SOLID (NON-PAYLOAD)
C**** MATERIAL PROPERTIES

KXX,1,(10.0/12.)                    * STAINLESS STEEL (BTU/HR F IN.)
DENS,1,(488.0/1728.)                * LBM/IN.^3
C,1,0.11                            * BTU/LBM  F

KXX,2,(18.6/12.)                    * LEAD    (BTU/HR F IN.)
DENS,2,(710.0/1728.)                * LBM/IN.^3
C,2,0.031                           * BTU/LBM F

KXX,3,(0.083/12.)                   * INSULATION (C)   BTU/HR F IN.
DENS,3,(1./1728.)                   * ASSUMES VERY LIGHT
C,3,.001                            * ASSUMES VERY LITTLE HEAT CAPACITY
R,7,(32.8725/2)                     * AREA FOR INSULATION
R,8,32.8725

KXX,6,(25.0/12.)                        * CARBON STEEL, BTU/HR F IN.
DENS,6,(485/1728.)                      * LBM/IN.^3
C,6,0.113                               * BTU/LBM F

HF,24,(51.9*1.5E-3/50.)             * ASSUMES k @ 200F
C***HF,24,(51.9*3.416E-3/50.)               * ASSUMES k @ 1500F
MPTEMP , 1    ,60    ,100   ,200   ,500   ,800   ,1500      * AIR (T)
MPDATA,KXX,4,1,0.0012,0.0013,0.0015,0.0016,0.0018,0.0019

MPTEMP,1,68,176,572,842,1472,3992.0
MPDATA,KXX,5,1 ,.037 ,.04 ,.05 ,.057  ,.073 ,.137
C***KXX,5,(.51/12.)                             * PAYLOAD GLASS  BUT/HR F IN.
DENS,5,(62.4*2.7/1728.)                 * SG=2.7  LBM/IN.^3
C,5,0.16                                * FOR WINDOW GLASS  BTU/LBM F

C**** FREE CONVECTION COEFFICIENTS

MPTEMP,1,60,100,200,500,800,1500

MPDATA,HF,20,1,.000579,.000617,.000694,.000965,.001157,.001582
C***HF,20,(5.0*1.5E-3/10.8)
R,1,(17.4/2),.2,(1.12*1.5E-3/10.8)   * ASSUMES k @ 200F
R,2,17.4    ,.2,(1.12*1.5E-3/10.8)   * ASSUMES k @ 200F

MPDATA,HF,21,1,.000585,.000624,.000702,.000974,.001169,.001598
C***HF,21,(0.401*1.5E-3/0.8125)
R,3,(23.343/2),.2,(1.0*1.5E-3/0.8125)  * ASSUMES k @ 200F
R,4,23.343    ,.2,(1.0*1.5E-3/0.8125)  * ASSUMES k @ 200F

MPDATA,HF,22,1,.000555,.000592,.000666,.000925,.001110,.001517
C***HF,22,(1.359*1.5E-3/3.06)
R,5,(25.469/2),.2,(1.12*1.5E-3/3.06)   * ASSUMES k @ 200F
R,6,25.469    ,.2,(1.12*1.5E-3/3.06)   * ASSUMES k @ 200F

R,9,(33.25/2),0.25,0.
R,10,33.25   ,0.25,0.

R,11,(17.4/2),1.,0.333,0.119E-10
R,12,17.4    ,1.,0.333,0.119E-10

R,13,(23.343/2),1.,0.333,0.119E-10
R,14,23.343    ,1.,0.333,0.119E-10

R,15,(25.469/2),1.,0.333,0.119E-10
```

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FILENAME : segth.inp                    DATE : 10-03-95              TIME :  3:50p                    PAGE  2
TITLE    : seg normal thermal analysis

R,16,25.469     ,1.,0.333,0.119E-10

R,19,(33.25/2),1.,0.5,0.119E-10          * 0.5 for normal conditions
R,20,33.25     ,1.,0.5,0.119E-10

C********************* NODAL GEOMETRY ******************
N,1 ,0.,1.
N,10,11.95,1.
FILL
N,11,12.0,1.
N,12,(22.9375-0.14),1.
N,14,22.9375,1.
FILL
N,15,(23.9375-0.1875),1.
N,16,23.9375,1.
N,17,27.,1.
N,19,(27.+0.375),1.
FILL
N,21,(27.+0.375+3.75),1.
FILL
N,23,(27.+0.375+3.75+1.),1.
FILL
N,24,(27.+0.375+3.75+1.+1.),1.
N,25,(27.+0.375+3.75+1.+1.+0.125),1.
NGEN,3,100,1,25,1,0.,-1.
N,26,35.,1.
N,27,35.,-1.

TYPE,1                    * SOLID
MAT,5
E,1,2,102,101
EGEN,9,1,1
EGEN,2,100,1,9,1

TYPE,5                    * STEEL DRUM
MAT,6
E,10,11,111,110
E,110,111,211,210

TYPE,2                    * CONVECTION
MAT,20
REAL,1      $E,11,12
REAL,2      $E,111,112
REAL,1      $E,211,212

TYPE,3                    * RADIATION
REAL,11     $E,11,12
REAL,12     $E,111,112
REAL,11     $E,211,212

TYPE,5                    * GROUT CONTAINER
MAT,6
E,12,13,113,112
E,13,14,114,113
E,112,113,213,212
E,113,114,214,213

TYPE,2                    * CONVECTION
MAT,21
REAL,3      $E,14,15
REAL,4      $E,114,115
REAL,3      $E,214,215

TYPE,3                    * RADIATION
REAL,13      $E,14,15
REAL,14      $E,114,115
REAL,13      $E,214,215

TYPE,5
MAT,1                     * STAINLESS
```

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FILENAME : segth.inp                DATE : 10-03-95              TIME :  3:50p                PAGE  3
TITLE    : seg normal thermal analysis

E,15,16,116,115
E,115,116,216,215

TYPE,2                          * CONVECTION
MAT,22
REAL,5       $E,16,17
REAL,6       $E,116,117
REAL,5       $E,216,217

TYPE,3                          * RADIATION
REAL,15       $E,16,17
REAL,16       $E,116,117
REAL,15       $E,216,217

TYPE,5
MAT,6                           * STEEL
E,17,18,118,117
E,18,19,119,118
E,117,118,218,217
E,118,119,219,218

MAT,2                           * LEAD
E,19,20,120,119
E,20,21,121,120
E,119,120,220,219
E,120,121,221,220

MAT,6                           * STEEL
E,21,22,122,121
E,22,23,123,122
E,121,122,222,221
E,122,123,223,222

TYPE,4                          * CONDUCTION
MAT,3                           * INSULATION
REAL,7       $E,23,24
REAL,8       $E,123,124
REAL,7       $E,223,224

TYPE,5
MAT,1
E,24,25,125,124
E,124,125,225,224

TYPE,2
MAT,24                          * CONVECTION
REAL,9     $E,25,26
REAL,10    $E,125,26
REAL,9     $E,225,26

TYPE,3                          * RADIATION
REAL,19    $E,25,27
REAL,20    $E,125,27
REAL,19    $E,225,27

C****************************** HEAT LOAD **************
QSH = ((1475./12.)/144.)      * 400/12 cal/m-hr
ABS = 0.95
H1 = (33.62*(QSH*ABS))

C***** INTERNAL HEAT GENERATION
QGEN = (7165.4/9504.)                    * 2.1KW/5.5FT^3

ESEL,MAT,5
QE,ALL,(.1*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
```

```
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 1

ESEL,MAT,5
QE,ALL,(.2*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1

C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 2

ESEL,MAT,5
QE,ALL,(.3*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 3

ESEL,MAT,5
QE,ALL,(.4*QGEN)
EALL
```

```
FILENAME : segth.inp                DATE : 10-03-95            TIME :  3:50p                PAGE  5
TITLE    : seg normal thermal analysis


C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 4

ESEL,MAT,5
QE,ALL,(.5*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 5

ESEL,MAT,5
QE,ALL,(.6*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
```

```
FILENAME : segth.inp                DATE : 10-03-95          TIME :  3:50p                PAGE  6
TITLE    : seg normal thermal analysis

LWRITE                    **** STEP 6

ESEL,MAT,5
QE,ALL,(.7*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 7
ESEL,MAT,5

QE,ALL,(.8*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 8

ESEL,MAT,5
QE,ALL,(.9*QGEN)
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1
```

```
FILENAME : segth.inp                DATE : 10-03-95          TIME :  3:50p                PAGE  7
TITLE    : seg normal thermal analysis


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 9

ESEL,MAT,5
QE,ALL,QGEN
EALL

C**** FIRST LOAD CASE (2.1 kw)

/TITLE,SEG STEADY-STATE (2.1KW)
KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

TOFFST,460.
TUNIF,100.
KBC,1


C**** CONSTANT TEMPERATURE SINK

NT,26,TEMP,100.
NT,27,TEMP,100.
LWRITE                    **** STEP 10


KTEMP,-1
ITER,-80,,80
PRDISP,-1
PRNF,-1
PRRF,-1
PRSTR,-1

C*********************** HFLOW
/TITLE,SEG (INSOLATION AND 2.1KW)
HFLOW,25,HEAT,(H1/2.)
HFLOW,125,HEAT,H1
HFLOW,225,HEAT,(H1/2.)
ESEL,MAT,5
QE,ALL,QGEN
EALL
LWRITE
AFWRITE
FINI
/INPUT,27
FINI
```

```
FILENAME : segp26.inp                DATE : 10-03-95              TIME :  4:02p                PAGE  1
TITLE    : post processing for temperature time history

/post26
numvar,14

disp,2,101,temp,g1
disp,3,110,temp,g10
disp,4,111,temp,d11
disp,5,112,temp,g12

disp,6,114,temp,g14
disp,7,115,temp,L15
disp,8,116,temp,L16
disp,9,117,temp,s17
disp,10,119,temp,p19

disp,11,121,temp,p21
disp,12,123,temp,i23
disp,13,124,temp,s24
disp,14,125,temp,s25

/out,hist,out
prval,2,3,4,5
prval,6,7,8,9,10
prval,11,12,13,14
fini
/eof
```

```
FILENAME : segp26h.inp               DATE : 10-03-95              TIME :  4:02p                PAGE  1
TITLE    : seg post processing for heat transfer coefficient history

/post26
numvar,13

estr,2,21,2,h21
estr,3,22,2,h22
estr,4,23,2,h23

estr,5,31,2,h31
estr,6,32,2,h32
estr,7,33,2,h33

estr,8,39,2,h39
estr,9,40,2,h40
estr,10,41,2,h41

estr,11,62,2,h62
estr,12,63,2,h63
estr,13,64,2,h64

/out,h-hist,out
prvar,2,3,4
prvar,5,6,7
prvar,8,9,10
prvar,11,12,13

fini
/eof
```

```
FILENAME : segplt.inp                DATE : 10-03-95              TIME :  4:04p                PAGE  1
TITLE    : seg post processing for temperature profile

/post1
/out,segplt,out

set,11

prdisp,temp

fini
/eof
```

```
FILENAME : segplh.inp                DATE : 10-03-95              TIME :  4:04p                PAGE  1
TITLE    : seg post processing for heat tranfer coefficient distribution

/post1
/out,segplh,out

store,stres
stress,H,34,2

set,11

esel,type,2
prstrs,H

fini
/eof
```

9.0 PRESSURE AND GAS GENERATION EVALUATION

Gas generation is not a concern for vitrified glass payloads. All other payloads' gas generation shall be controlled in accordance with the cask's NRC CoC USA/6574/B( ).

Pressure rise due to the increased heat load (Part B, Section 8.0) is calculated as follows.

The pressure increase due to a change in gas temperature for a closed system can be determined by an application of the ideal gas law:

$$P_2 = P_1 \times T_2/T_1$$

Where T = absolute temperature

P = absolute pressure

Conservatively taking T_2 as the maximum payload temperature with P_1 = 14.7 psi (101.35 kPa), T_1 = 70 °F (21.1 °C), and T_2 = 1,250 °F (676.7 °C)

$$P_2 = 14.7 \times (1{,}250 + 460)/(70 + 460) = 47.43 \text{ psi } (327.02 \text{ kPa})$$

This corresponds to a gauge pressure of 225.46 kPa (32.7 psig). Based upon the safety factor of 57 determined on page 2-18 of SEG (1991) for an internal pressure of 50.68 kPa (7.35 psi), the safety factor (including a 21% degradation in material strength) for 225.46 kPa (32.7 psig) is 10.11.

10.0 PACKAGE TIEDOWN SYSTEM EVALUATION

The angles and materials of the tiedown cable system shall be identical to that used by SEG for highway transport. Description and analysis of the tiedown system are available in Chapter 2.0, Appendix D, of SEG (1991). The analysis shows that the tiedown system meets the following conditions (combined into a single concurrent force) with a factor of safety of three to breaking on the tiedown cables:

- Horizontal longitudinal load of 0.683*g* (for braking)
- Horizontal transverse load of 0.4*g* (from a calculation of hard cornering)
- Vertical (up) load of the weight of the trailer
- Vertical (down) load of 1.5 times the weight of the cask plus reaction loads.

Design of the tiedown cable system for these loading conditions (without credit for the base blocking) is adequate for controlled shipment of the railcar. No humping will be allowed when the cask is on the railcar to eliminate unnecessary loading on the tiedown system.

Blocking the base of the cask on the railcar will differ from that on the SEG trailer. On the SEG trailer, a shear ring that circumferentially blocks the base of the cask is used. On the railcar, eight equally spaced kickblocks will be welded to the deck to block the base of the cask (see drawings in Part A, Section 9.0).

Of note, SEG (1991) does not take credit for the blocking of the cask base in the tiedown analysis; thus, the tiedowns alone (without blocking) are adequate to restrain the cask. Also, inspection of the SEG trailer indicates that the shear ring is not fully welded to the trailer deck. Therefore, the fully welded kickblock system on the railcar is an improvement over the old blocking system.

11.0 REFERENCES

10 CFR 71, 1994, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.

49 CFR 173, 1994, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ASME, 1992, *ASME 1992 Boiler and Pressure Vessel Code*, Section VIII, "Pressure Vessels," Division 2, "Alternative Rules," American Society of Mechanical Engineers, New York, New York.

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Carter, L. L., 1995, *Certification of MCNP Version 4A for WHC Computer Platforms*, WHC-MP-SD-30001, Rev. 5, Westinghouse Hanford Company, Richland, Washington.

Jarrett, J., 1995, *Technical Bases for SEP and SARP* (Memo to J. G. Field, Westinghouse Hanford Company, October 17), Pacific Northwest Laboratory, Richland, Washington.

NRC, 1991, *Certificate of Compliance for Radioactive Materials Packages* (Model No. 3-82B), Package ID No. USA/6574/B( ), Rev. 22, U.S. Nuclear Regulatory Commission, Washington, D.C.

Rittman, P. D., 1995, *ISO-PC Version 1.98 User's Guide*, WHC-SD-WM-UM-030, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Rohsenow, W. M., and H. Choi, 1964, *Heat Mass and Momentum Transfer*, Prentice-Hall, Englewood Cliffs, New Jersey.

DISTRIBUTION SHEET

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Distribution	Packaging Engineering	Date Jan. 2, 1996
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