SEP 15 1997 Sta. 37 (20)

ENGINEERING DATA TRANSMITTAL

1. EDT 621893

2. To: (Receiving Organization) Packaging Engineering	3. From: (Originating Organization) Packaging Engineering	4. Related EDT No.: NA
5. Proj./Prog./Dept./Div.: 03E00	6. Design Authority/ Design Agent/Cog. Engr.: J. C. McCoy	7. Purchase Order No.: NA
8. Originator Remarks: For approval.		9. Equip./Component No.: NA
		10. System/Bldg./Facility: NA
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No		12. Major Assm. Dwg. No.: NA
		13. Permit/Permit Application No.: NA
		14. Required Response Date:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-SD-TP-SEP-065		0	Safety Evaluation for Packaging (Onsite) for Cesium Chloride Capsules with Type W Overpacks	SQD lmh	1 lmh	1 lmh	

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	1	Design Authority: MM Pereira	[signature]	9/11/97	S6-51	1	1	RL Clawson	[signature]	9/11/97	H1-14
1	1	Design Agent: WW Smyth	[signature]	9/11/97	H1-15	1	1	PC Ferrell	[signature]	9/11/97	H1-15
1	1	Cog.Eng.: WW Smyth	[signature]	9/11/97	H1-15	1	1	JC McCoy	[signature]	9/11/97	H1-15
1	1	Cog. Mgr.: JG Field	[signature]	9/11/97	H1-15						
1	1	QA: CR Hoover	[signature]	9/11/97	H1-15						
1	1	Safety: DW McNally	[signature]	9/11/97							
		Env.									

18.	19.	20.	21. DOE APPROVAL (if required)
JC McCoy [signature] 9/11/97 Signature of EDT Originator / Date	Authorized Representative for Receiving Organization / Date	JG Field [signature] 9/11/97 Design Authority/ Cognizant Manager / Date	Ctrl. No. [X] Approved [] Approved w/comments [] Disapproved w/comments [signature] 9/11/97

BD-7400-172-2 (05/96) GEF097

Safety Evaluation for Packaging (Onsite) for Cesium Chloride Capsules with Type W Overpacks

J. C. McCoy
Waste Management Federal Services, Inc., Northwest Operations,
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: EDT 621893 UC: 513
Org Code: 03E00 Charge Code: KW64B
B&R Code: EW7002010 Total Pages: ~~130~~ ~~132~~ 130

Key Words: BUSS Cask, Type W Overpack, onetime onsite shipment

Abstract: This Safety Evaluation for Packaging (SEP) documents the evaluation of a new basket design and overpacked cesium chloride capsule payload for the Beneficial Uses Shipping System (BUSS) Cask in accordance with the onsite transportation requirements of the *Hazardous Material Packaging and Shipping* manual, WHC-CM-2-14. This design supports the onetime onsite shipment of 16 cesium chloride capsules with Type W overpacks from the 324 Building to the 224T Building at the Waste Encapsulation and Storage Facility (WESF). The SEP is valid for a onetime onsite shipment or until August 1, 1998, whichever occurs first.

Janis Bishop 9/15/97
Release Approval Date

SEP 15 1997
DATE: HANFORD RELEASE
STA: 37 ID: 20
Release Stamp

Approved for Public Release

CONTENTS

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PART B: PACKAGE EVALUATION

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CONTENTS (cont)

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LIST OF TERMS

ANSI	American National Standards Institute
BUSS	Beneficial Uses Shipping System
Ci	curie
CoC	Certificate of Compliance
DOE	U.S. Department of Energy
ft	feet
HAC	hypothetical accident conditions
HRCQ	highway route controlled quantity
in.	inch
kg	kilogram
lb	pound
MCNP	Monte Carlo N-Particle
NCT	normal conditions of transport
QA	quality assurance
QC	quality control
SARP	Safety Analysis Report for Packaging
SEP	Safety Evaluation for Packaging
W	Watt
WESF	Waste Encapsulation and Storage Facility
WMNW	Waste Management Federal Services, Inc., Northwest Operations

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SAFETY EVALUATION FOR PACKAGING (ONSITE) FOR CESIUM CHLORIDE CAPSULES WITH TYPE W OVERPACKS

PART A: PACKAGE DESCRIPTION AND OPERATIONS

1.0 INTRODUCTION

This Safety Evaluation for Packaging (SEP) documents the evaluation of a new basket design and overpacked cesium chloride capsule payload for the Beneficial Uses Shipping System (BUSS) Cask in accordance with the onsite transportation requirements of WHC-CM-2-14, *Hazardous Material Packaging and Shipping*. This design will support the onetime onsite shipment of 16 cesium chloride capsules with Type W overpacks from building 324, in the Hanford 300 Area, to building 224T, the Waste Encapsulation and Storage Facility (WESF), in the Hanford 200 East Area.

1.1 REVIEW AND UPDATE CYCLES

This SEP is valid for a onetime shipment or until August 1, 1998, whichever occurs first. An update or upgrade to this document is required beyond that date.

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2.0 PACKAGING SYSTEM

This SEP supports the onetime onsite shipment of 16 cesium chloride capsules in Type W overpacks. As the Type W overpacked capsules will not fit into the original BUSS Cask basket, a new basket design will be used for this shipment.

The BUSS Cask is certified by the U.S. Department of Energy (DOE) to transport up to 16 doubly encapsulated, special form, cesium chloride capsules. The BUSS Cask Safety Analysis Report for Packaging (SARP) (SNL 1994) and Certificate of Compliance (CoC) (DOE 1996) allow shipment of up to 850,000 Ci of ^{137}Cs, with a thermal load of 4,000 W. The BUSS payload weight (including basket) is limited to 907 kg (2,000 lb). The fully loaded cask will weigh no more than 15,310 kg (33,700 lb). Although overpacked capsules and new basket design meet the BUSS Cask SARP parameters, the SARP will not be amended for this payload.

The 16 capsules to be shipped, as described in Part A, Section 3.0, have compromised containment boundaries due to swelling or broken welds and as such do not meet special form criteria. Therefore, these capsules will be repackaged in Type W overpacks. The Type W overpack, as detailed in drawing H-3-307504 (Part A, Section 10.0), will be tested to the requirements of 49 CFR 173 for special form class 7 (radioactive) material and American National Standards Institute (ANSI) N43.6, *Sealed Radioactive Sources, Classification* (ANSI 1989). The overpacked capsules will not be certified as special form materials; however, they do meet all other conditions required by the BUSS SARP, as shown in Part B of this SEP. With the Type W overpacks, each capsule will weigh no more than 13.31 kg (29.35 lb), for a total of 213 kg (469.6 lb). The activity and thermal limits for the payload are described in Part A, Section 3.0, and are within the limits allowed for the BUSS Cask..

The new 16 capsule basket (drawing H-2-828979 [Part A, Section 10.0]) will be used to transport the overpacked capsules in the BUSS Cask in place of the original basket. The new basket weighs approximately 90.7 kg (200 lb.)

The total weight of the payload and basket, estimated to be approximately 304 kg (670 lb), is well within the limits of the BUSS Cask SARP (SNL 1994).

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3.0 PACKAGE CONTENTS

Table A3-1 lists the capsules that will be transported:

Table A3-1. Capsule Activity and Thermal Data.

Capsule Serial Number		Activity (^{137}Cs)		Estimated Power (W)
Outer Capsule	Inner Capsule	TBq	Ci	
C-105	C-283	1,843	49,816	234.14
C-1093	C-1245	1,652	44,639	209.8
C-287	C-237	1,539	41,590	199.58
C-913	C-1035	1,554	42,010	197.45
C-1600	C-1631	1,517	40,998	192.69
C-1368	C-1544	1,530	41,362	194.4
C-1562	C-1585	1,514	40,922	192.33
C-849	C-784	1,478	39,939	187.71
C-930	C-914	1,477	39,929	187.67
C-1504	C-1560	1,443	38,993	183.27
C-1592	C-1636	1,411	38,130	183.01
C-1507	C-1622	1,430	38,653	181.67
C-1553	C-1581	1,413	38,179	179.44
C-1196	C-1263	1,387	37,498	176.24
C-811	C-992	1,380	37,297	175.3
C-1503	C-1596	1,301	35,150	173.64
Total		23,869	645,105	3,048
Average		1,492	40,319	190.52
Standard deviation				14.70
Maximum		1,843	49,816	234.14
SARP limit, per capsule		2,590	70,000	250

[1]Activity limit of 2,590 Tbq (70,000 Ci) is based on shielding.
[2]Estimated activity is given as Tbq (Ci) of ^{137}Cs.
[3]This shipment is highway route controlled quantity (HRCQ), 49 CFR 173.
[4]Capsule data is from the WESF Encapsulation Data Base System

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

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4.0 TRANSPORT SYSTEM

The BUSS Cask, handling fixtures, and its dedicated transport trailer shall be used. These are detailed in the BUSS Cask SARP (SNL 1994). All SARP procedures, radiation, and contamination limits shall be adhered to. As this shipment does not comply with all SARP and CoC requirements for offsite shipment, the public access roads shall be barricaded during transportation.

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5.0 ACCEPTANCE FOR USE

5.1 BUSS CASK

Prior to use, all maintenance requirements shall be documented in accordance with the requirements of the SARP (SNL 1994) as shown in Part A, Section 6.0.

5.2 BASKET

The basket will be inspected as part of the fabrication process to ensure conformance with drawing H-2-828979 (Part A, Section 7.0). Prior to each use, the basket will inspected in accordance with WESF procedures.

5.3 TYPE W OVERPACKS

Prior to transportation of the Type W overpacked capsules to WESF, the overpack design shall have passed the special form testing requirements of 49 CFR 173 and ANSI N43.6.

The Type W overpacks shall be inspected as part of the fabrication process for conformance with drawing H-3-307504 (Part A, Section 10.0). After installation, the overpacks shall be inspected in accordance with WESF procedures.

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6.0 OPERATING REQUIREMENTS

The using facilities (WESF and building 324) will write detailed operating procedures in order to use the BUSS Cask and the transport system. The requirements listed below shall be incorporated into the operating procedures in order to maintain compliance with this SEP.

1. New seals will be installed on the BUSS Cask prior to shipment (SNL 1994).

2. The BUSS Cask shall satisfy the requirements of Chapter 7, "Operating Procedures," and Chapter 8, "Acceptance Tests and Maintenance Program," of the SARP (SNL 1994).

3. Prior to shipment, the Type W overpacked capsules shall have been demonstrated to meet the requirements for special form materials (49 CFR 173, ANSI N43.6). The capsules will not be certified as special form material.

4. The shipper shall ensure that the transit and wait period between loading and unloading the BUSS Cask will not exceed 30 days.

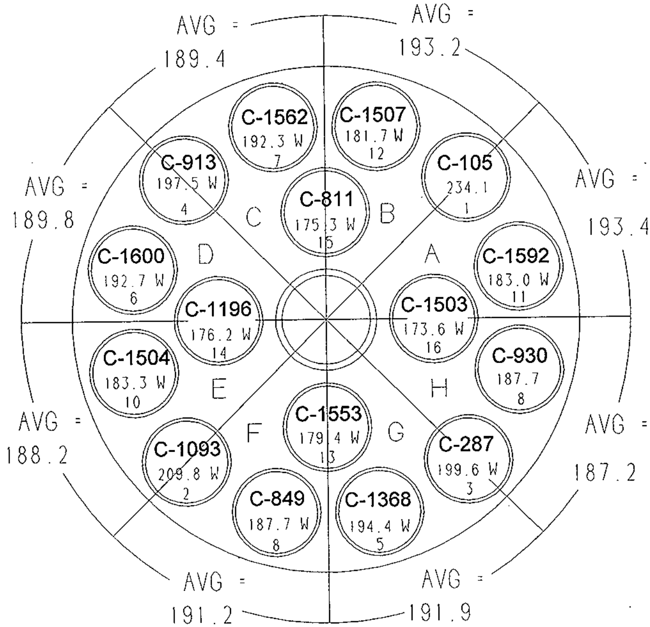
5. Overpacked capsules shall be marked externally so they are identifiable. Records shall be maintained cross referencing the Type W overpack serial number to the capsule it contains.

6. Prior to shipment, the 16 capsules will be cleaned and tested for external contamination to confirm that no capsule is leaking.

7. The overpacked capsules shall be placed in the basket in the relative positions shown in Figure A6-1. This arrangement ensures that the temperature of any capsule remains below 462 °C (864 °F).

   Note that the power, position number, and outer capsule serial number are shown in Figure A6-1 for each capsule. Refer to Table A3-1 to cross-reference inner and outer capsule serial numbers.

Figure A6-1. Relative Position of Cesium Chloride Capsules in Basket.



7.0 QUALITY ASSURANCE

7.1 GENERAL

This section describes the quality assurance (QA) requirements for the onetime onsite transportation of 16 cesium chloride capsules overpacked in Type W overpacks in the BUSS Cask.

7.2 GENERAL REQUIREMENTS

The BUSS Cask has been demonstrated to contain a nearly identical payload in accordance with the requirements of 10 CFR 71 and documented in the SARP (SNL 1994). Therefore, no transportation hazard index (THI) or quality level (QL) (WHC-CM-2-14) is assigned to the BUSS Cask. As the BUSS Cask is a packaging that is certified (DOE 1996), the SARP (SNL 1994) will be the guiding document for all QA activities that pertain directly to the cask. The new basket and Type W overpack QA requirements are described below.

7.3 ORGANIZATION

The organizational structure and the assignment of responsibility shall be such that quality is achieved and maintained by those who have been assigned responsibility for performing work. Quality achievement is to be verified by persons or organizations not directly responsible for performing the work.

Packaging Engineering of Waste Management Federal Services, Inc., Northwest Operations (WMNW), WESF, and building 324 personnel are responsible for the quality of the work performed by their respective organizations and for performing the following activities.

- Follow current requirements of this SEP; the requirements of the BUSS Cask SARP (SNL 1994); WHC-CM-4-2, *Quality Assurance Manual*; and WHC-CM-2-14.

- Provide instructions for implementing QA requirements.

The responsible facility Quality Assurance manager is responsible for establishing and administering the Fluor Daniel Hanford, Inc. QA program as stated in WHC-CM-4-2.

7.4 QA ACTIVITIES

7.4.1 Design Control

All engineering change notices (ECNs) to the basket or Type W overpack design shall be approved by WESF and Packaging Engineering of WMNW as part of the process to verify the SEP is valid for the new configuration.

7.4.2 Procurement and Fabrication Control

Procurement and fabrication of the basket and Type W overpacks shall be in accordance with drawings H-2-828979 and H-3-307504, respectively. Requirements of WHC-CM-4-2 shall be followed as required by QA personnel performing the acceptance inspections after fabrication and the packaging Quality Assurance engineer.

7.4.3 Control of Operation/Processes

Processes affecting the quality of package items or services shall be controlled by instructions, procedures, drawings, checklists, or other appropriate means. These means shall ensure that process parameters are controlled within defined limits and that specified environmental conditions are maintained. Methods for defining how process controls will be applied are defined in WHC-CM-4-2.

7.4.4 Control of Inspection and Testing

Fabrication and acceptance inspections shall be performed to the following guidelines.

7.4.4.1 Inspection Personnel. Inspection for acceptance of items fabricated onsite shall be performed by qualified quality control (QC) personnel. Inspection for acceptance of items fabricated offsite shall be performed by qualified QC personnel from Procurement Quality Assurance.

7.4.4.2 In-Process Inspection. Fabrication and acceptance inspections shall be performed by qualified QC personnel.

7.4.5 Control of Operations and Maintenance

Loading/unloading procedures shall be written by the user with appropriate reference to this SEP, the BUSS Cask SARP (SNL 1994) and WESF documentation to ensure adequate loading and operation of packaging. The loading/unloading procedure identifies actions required by loading personnel to safely and properly handle the BUSS Cask, its components, and the overpacked cesium chloride capsules. The loading/unloading procedures shall also identify which steps, as defined in this SEP (Part A, Section 6.0), are important to transportation safety.

The BUSS Cask maintenance shall be documented as required by the SARP. As this is a onetime shipment, no maintenance of the basket is anticipated.

7.4.6 Test Control

Leakage rate testing shall be done as required by the BUSS Cask SARP. Special form testing of the Type W overpacks shall be documented separately. Any other testing required incident to fabrication shall be documented as required by WHC-CM-4-2.

7.4.7 Control of Measuring and Test Equipment

The requirements for measuring and test equipment contained in WHC-CM-4-2 shall apply to operations and maintenance activities, as described in Part A, Sections 6.0 and 8.0.

7.4.8 Control of Nonconforming Items

Identification, documentation, evaluation, and disposition of nonconforming items and activities shall be accomplished per WHC-CM-4-2.

Items procured or fabricated for the packaging or used in the packaging shall be QC inspected as required by the BUSS Cask SARP. Other items shall be QC inspected prior to use for compliance with the purchase order, specification, and/or fabrication drawing. The cognizant engineer, with QA concurrence, shall define the acceptance criteria.

7.4.9 Corrective Action

Nonconformance or conditions adverse to quality are evaluated as described in Part A, Section 7.4.8, and the need for corrective action is determined in accordance with WHC-CM-4-2.

7.4.10 QA Records and Document Control

Records that furnish documentary evidence of quality shall be specified, prepared, and maintained per WHC-CM-4-2 and WHC-CM-3-5, *Document Control and Records Management Manual*. Controlled documents include (but are not limited to) the following: drawings, specifications, purchase orders, plans, procedures to inspect and test, reports, quality verification reports, nonconformance reports, corrective action reports, the SEP, and operational and maintenance procedures.

7.4.11 Independent Assessments

The Hanford independent assessment process is addressed in, and shall comply with, WHC-CM-4-2.

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8.0 MAINTENANCE

All maintenance required by the BUSS Cask SARP (SNL 1994) shall be completed prior to transporting the capsules (Part A, Section 6.0).

No maintenance is anticipated for the basket to support this onetime use. If future uses are anticipated, the basket should be stored in a manner that precludes degradation of the basket structure.

Maintenance of the Type W overpacks and capsules, except as required prior to transportation, is the responsibility of WESF and is beyond the scope of this document.

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9.0 REFERENCES

10 CFR 71, 1992, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ANSI, 1989, *Sealed Radioactive Sources, Classification,* N43.6-1977 (formerly ANSI N542-1977), revised 1989, American National Standards Institute, New York, New York.

DOE, 1996, *U.S. Department of Energy Certificate of Compliance for Radioactive Materials Packages*, USA/9511/B(U) (DOE), Rev. 3, U.S. Department of Energy, Germantown, Maryland, August 27, 1996.

FDH-MD-001, *Adoption of WHC Documents*, Fluor Daniel Hanford, Inc., Richland, Washington

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-3-5, *Document Control and Records Management Manual*, Westinghouse Hanford Company, Richland, Washington.

WHC-CM-4-2, *Quality Assurance Manual*, Westinghouse Hanford Company, Richland, Washington.

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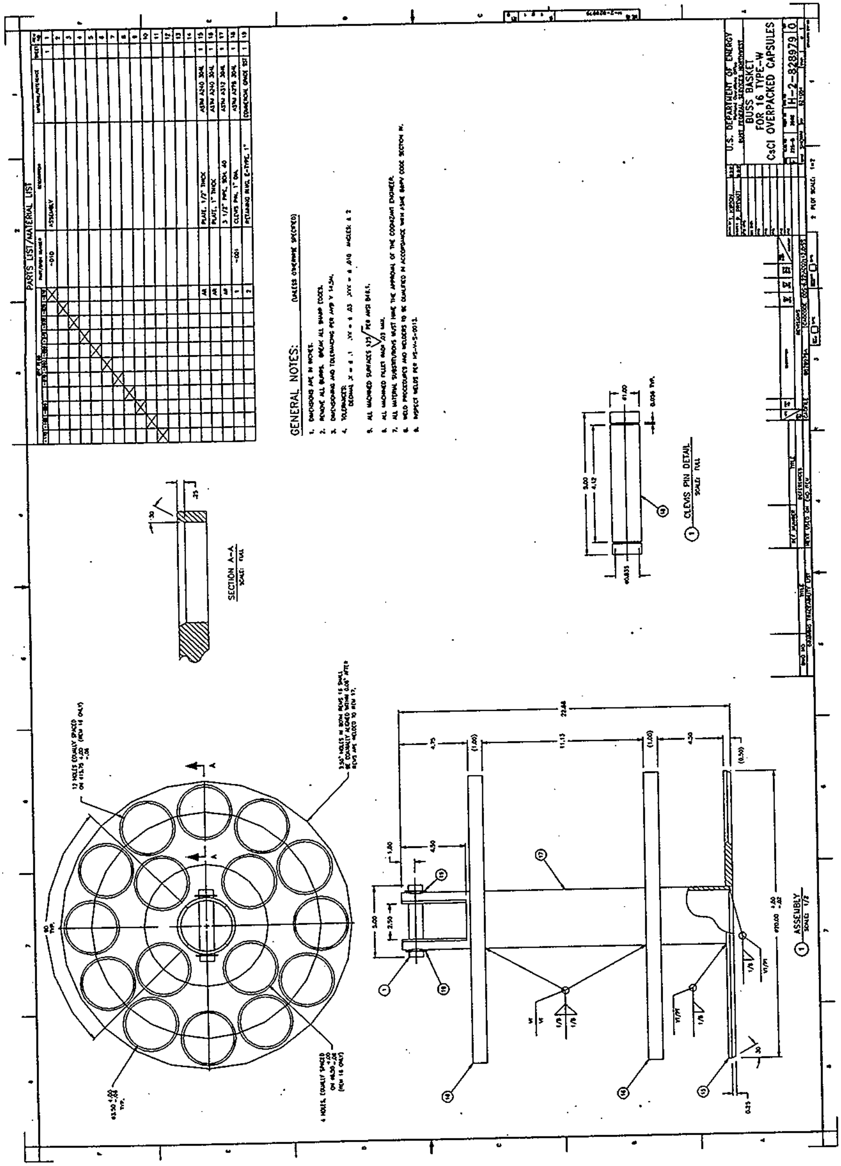
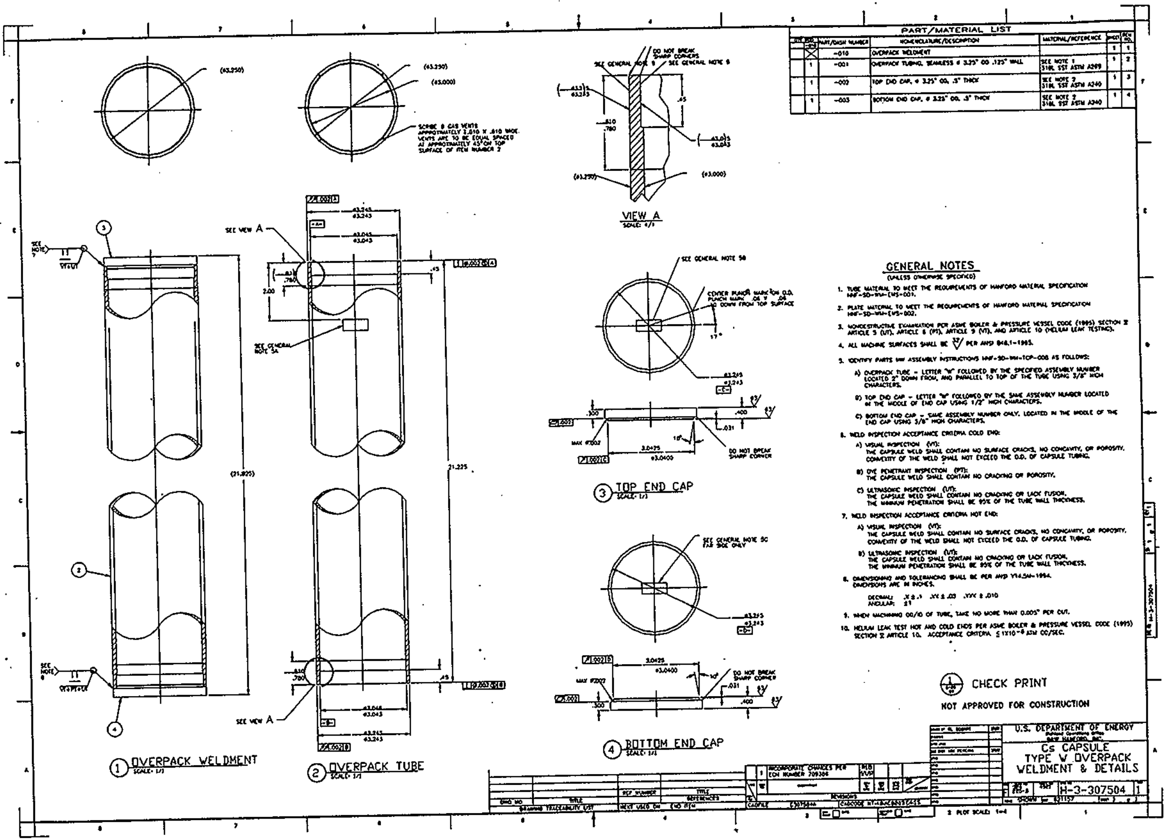
10.0 APPENDIX: DRAWINGS

Drawings H-3-307504, Cs Capsule Type W Overpack, and H-2-828979, BUSS Basket for 16 Type W CsCl Overpacked Capsules, are attached for reference only. At the writing of this SEP, several outstanding ECNs were not posted to these drawings.


PARTS LIST/MATERIAL LIST
-010 ASSEMBLY
PLATE, 1/2" THICK ASTM A240 304L 15
PLATE, 1" THICK ASTM A240 304L 16
3 1/2" PIPE, SCH. 40 ASTM A312 304L 17
-001 CLEVIS PIN, 1" DIA. ASTM A276 304L 18
RETAINING RING, E-TYPE, 1" COMMERCIAL GRADE SST 19
GENERAL NOTES: (UNLESS OTHERWISE SPECIFIED)
1. DIMENSIONS ARE IN INCHES.
2. REMOVE ALL BURRS. BREAK ALL SHARP EDGES.
3. DIMENSIONING AND TOLERANCING PER ANSI Y 14.5M.
4. TOLERANCES: DECIMAL .X = ± .1 .XX = ± .03 .XXX = ± .010 ANGLES: ± 2
5. ALL MACHINED SURFACES 125 PER ANSI B46.1.
6. ALL MACHINED FILLET RADII .03 MAX.
7. ALL MATERIAL SUBSTITUTIONS MUST HAVE THE APPROVAL OF THE COGNIZANT ENGINEER.
8. WELD PROCEDURES AND WELDERS TO BE QUALIFIED IN ACCORDANCE WITH ASME B&PV CODE SECTION IX.
9. INSPECT WELDS PER HS-V-S-0013.
SECTION A-A
SCALE: FULL
CLEVIS PIN DETAIL
SCALE: FULL
ASSEMBLY
SCALE: 1/2
12 HOLES EQUALLY SPACED
4 HOLES, EQUALLY SPACED
U.S. DEPARTMENT OF ENERGY
BUSS BASKET
FOR 16 TYPE-W
CsCl OVERPACKED CAPSULES
H-2-828979 0


PART/MATERIAL LIST
QTY REQD -010 | PART/DASH NUMBER | NOMENCLATURE/DESCRIPTION | MATERIAL/REFERENCE | SHEET | ITEM NO.
-010 OVERPACK WELDMENT 1 1
1 -001 OVERPACK TUBING, SEAMLESS ø 3.25" OD .125" WALL SEE NOTE 1 316L SST ASTM A269 1 2
1 -002 TOP END CAP, ø 3.25" OD, .5" THICK SEE NOTE 2 316L SST ASTM A240 1 3
1 -003 BOTTOM END CAP, ø 3.25" OD, .5" THICK SEE NOTE 2 316L SST ASTM A240 1 4
GENERAL NOTES
(UNLESS OTHERWISE SPECIFIED)
1. TUBE MATERIAL TO MEET THE REQUIREMENTS OF HANFORD MATERIAL SPECIFICATION HNF-SD-WM-EMS-001.
2. PLATE MATERIAL TO MEET THE REQUIREMENTS OF HANFORD MATERIAL SPECIFICATION HNF-SD-WM-EMS-002.
3. NONDESTRUCTIVE EXAMINATION PER ASME BOILER & PRESSURE VESSEL CODE (1995) SECTION V ARTICLE 5 (UT), ARTICLE 6 (PT), ARTICLE 9 (VT), AND ARTICLE 10 (HELIUM LEAK TESTING).
4. ALL MACHINE SURFACES SHALL BE 32 PER ANSI B46.1-1985.
5. IDENTIFY PARTS WM ASSEMBLY INSTRUCTIONS HNF-SD-WM-TCP-008 AS FOLLOWS:
A) OVERPACK TUBE - LETTER "W" FOLLOWED BY THE SPECIFIED ASSEMBLY NUMBER LOCATED 2" DOWN FROM, AND PARALLEL TO TOP OF THE TUBE USING 3/8" HIGH CHARACTERS.
B) TOP END CAP - LETTER "W" FOLLOWED BY THE SAME ASSEMBLY NUMBER LOCATED IN THE MIDDLE OF END CAP USING 1/2" HIGH CHARACTERS.
C) BOTTOM END CAP - SAME ASSEMBLY NUMBER ONLY, LOCATED IN THE MIDDLE OF THE END CAP USING 3/8" HIGH CHARACTERS.
6. WELD INSPECTION ACCEPTANCE CRITERIA COLD END:
A) VISUAL INSPECTION (VT): THE CAPSULE WELD SHALL CONTAIN NO SURFACE CRACKS, NO CONCAVITY, OR POROSITY. CONVEXITY OF THE WELD SHALL NOT EXCEED THE O.D. OF CAPSULE TUBING.
B) DYE PENETRANT INSPECTION (PT): THE CAPSULE WELD SHALL CONTAIN NO CRACKING OR POROSITY.
C) ULTRASONIC INSPECTION (UT): THE CAPSULE WELD SHALL CONTAIN NO CRACKING OR LACK FUSION. THE MINIMUM PENETRATION SHALL BE 95% OF THE TUBE WALL THICKNESS.
7. WELD INSPECTION ACCEPTANCE CRITERIA HOT END:
A) VISUAL INSPECTION (VT): THE CAPSULE WELD SHALL CONTAIN NO SURFACE CRACKS, NO CONCAVITY, OR POROSITY. CONVEXITY OF THE WELD SHALL NOT EXCEED THE O.D. OF CAPSULE TUBING.
B) ULTRASONIC INSPECTION (UT): THE CAPSULE WELD SHALL CONTAIN NO CRACKING OR LACK FUSION. THE MINIMUM PENETRATION SHALL BE 95% OF THE TUBE WALL THICKNESS.
8. DIMENSIONING AND TOLERANCING SHALL BE PER ANSI Y14.5M-1994. DIMENSIONS ARE IN INCHES.
DECIMAL: .X ± .1 .XX ± .03 .XXX ± .010
ANGULAR: ±1°
9. WHEN MACHINING OD/ID OF TUBE, TAKE NO MORE THAN 0.005" PER CUT.
10. HELIUM LEAK TEST HOT AND COLD ENDS PER ASME BOILER & PRESSURE VESSEL CODE (1995) SECTION V ARTICLE 10. ACCEPTANCE CRITERIA ≤ 1X10⁻⁸ ATM CC/SEC.
CHECK PRINT
NOT APPROVED FOR CONSTRUCTION
VIEW A
TOP END CAP
BOTTOM END CAP
OVERPACK WELDMENT
OVERPACK TUBE
SEE VIEW A
21.225
(21.825)
U.S. DEPARTMENT OF ENERGY
Cs CAPSULE
TYPE W OVERPACK
WELDMENT & DETAILS
H-3-307504

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PART B: PACKAGE EVALUATION

1.0 INTRODUCTION

This Safety Evaluation for Packaging (SEP) documents the evaluation of a new basket design and Type W overpacked cesium chloride capsules for transport in the Beneficial Uses Shipping System (BUSS) Cask in accordance with the onsite transportation requirements of WHC-CM-2-14, *Hazardous Material Packaging and Shipping*. This design will support the onetime onsite shipment of 16 overpacked cesium chloride capsules from building 324, in the Hanford 300 Area, to building 224T, the Waste Encapsulation and Storage Facility (WESF), in the Hanford 200 East Area.

1.1 EVALUATION SUMMARY AND CONCLUSIONS

The BUSS Cask with a new basket is safe for the onsite shipment of 16 overpacked cesium chloride capsules, as described in Part A, Section 3.0 of this SEP, in accordance with the requirements of WHC-CM-2-14.

1.1.1 Contents

The contents shown in Part A, Section 3.0, were evaluated and found to be acceptable for transport using the basket shown in drawing H-2-828979 (Part A, Section 10.0) and the Type W overpacks shown in drawing H-3-307504 (Part A, Section 10.0).

1.1.2 Radiological Risk

A complete radiological risk analysis is not required since the SEP demonstrates that the contents will be contained during both normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined by 10 CFR 71. The BUSS Safety Analysis Report for Packaging (SARP) demonstrates compliance with 10 CFR 71 and 49 CFR 173. Therefore, Part B, Section 3.0 of this SEP only demonstrates that the probability of a serious accident during transportation is sufficiently low to be considered incredible.

1.1.3 Containment

Containment is maintained by the payload throughout all NCT and HAC events. The containment evaluation is presented in Part B, Section 4.0.

1.1.4 Shielding

The shielding evaluation demonstrates that the 16 overpacked capsules can be transported in a manner consistent with as low as reasonably achievable (ALARA) practices. The shielding evaluation is presented in Part B, Section 5.0.

Subcriticality is not addressed since no fissile material is being transported.

1.1.5 Structural

The structural adequacy of the cask, basket, and contents is demonstrated in Part B, Section 7.0, of this SEP.

1.1.6 Thermal

The thermal analysis presented in Part B, Section 8.0, of this SEP demonstrates that the overpacked capsules meet the thermal requirements for the BUSS Cask as defined in the SARP (SNL 1994).

1.1.7 Gas Generation

Gas generation is not addressed since no gas can be generated within the capsules or the cask. Additionally, as shown in Part B, Section 10.0, the pressure due to temperature increases is less than that analyzed in the HAC portion of the SARP (SNL 1994).

1.2 REFERENCES

10 CFR 71, 1992, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Westinghouse Hanford Company, Richland, Washington.

2.0 CONTENTS EVALUATION

The radioactive contents considered for this evaluation are listed in Part A, Section 3.0. These contents are well within the activity limits approved for transportation in the BUSS Cask SARP (SNL 1994).

2.1 REFERENCE

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

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3.0 RADIOLOGICAL RISK EVALUATION

The containment boundary for the cesium chloride capsules which will be shipped in the BUSS Cask will be provided by the encapsulation of the capsules in Type W overpacks as discussed in Part B, Section 4.0. However, as an additional demonstration of safety, a discussion is presented in this section which addresses the radiological risks associated with the shipment of the BUSS Cask containing singly-encapsulated cesium chloride capsules.

Onsite transportation safety requirements are outlined in WHC-CM-2-14 and Mercado (1994). The acceptability of risks associated with onsite shipments can be determined by a radiological risk evaluation which evaluates the probability and consequences of release. The potential consequences of a postulated release of the BUSS Cask contents, which may contain up to 31,450 Tbq (850,000 Ci) of ^{137}Cs, would clearly be unacceptable in any scenario. The potential consequences, therefore place the BUSS Cask shipments in the highest hazard category as outlined in Mercado (1994). The highest hazard category results in the most restrictive annual release frequency acceptance criterion of 10^{-7}. As long as a risk evaluation demonstrates that the packaging will prevent release of the contents for any accident that occurs with a release frequency of greater than 10^{-7} per year, a detailed risk analysis is not performed. The radiological risk evaluation presented in this section demonstrates that the shipments meet the required criterion.

The BUSS Cask is a certified Type B packaging which is approved for the shipment of highway route controlled quantity (HRCQ) nonfissile radioactive material. The BUSS Cask provides shielding and confinement (as defined in the BUSS Cask SARP [SNL 1994]), as well as impact, puncture, and thermal protection for doubly-encapsulated special form contents during NCT and HAC as defined in 10 CFR 71. Compliance with these requirements is documented in the BUSS Cask SARP (SNL 1994).

The SARP demonstrates that the cask body, lid, and impact limiters are virtually unaffected by being subjected to the NCT and HAC events specified in 10 CFR 71.71 and 10 CFR 71.73. Those conditions include a 30 ft drop onto a hard unyielding surface, a puncture test, and immersion in an 800 °C fire for 30 minutes. The BUSS Cask SARP relies on the special form encapsulated materials to provide containment. However, because the BUSS Cask structural members withstand HAC, protection of the payload is also being provided by the BUSS Cask body, lid, and impact limiters.

In a radiological risk evaluation the total conditional probability of failure of the packaging is multiplied by the frequency of accidents per year to arrive at an annual accident release frequency. If the annual accident release frequency is below the required criteria, which in this case is a frequency of 10^{-7} accident releases per year, the shipment meets onsite transportation safety requirements (Mercado 1994).

The Hanford Site truck accident rate for all trucks including vans and light-weight pick-up trucks is equal to 2.0×10^{-7} accidents per mile (Green et al. 1996). The BUSS Cask will be used for one shipment of 25 miles which, when multiplied by the accident rate and reduction factor, gives a frequency of 5.0×10^{-6} accidents per year. The accident frequency of 5.0×10^{-6} is very conservative in that it does not take credit for the reduction factors which apply to accident rates for onsite transport. Such reduction factors are normally applied in detailed risk analyses.

The conditional release probabilities are based on the performance of the packaging and are taken from a study performed by Sandia National Laboratory (SNL) on the response of large casks to severe accidents (Dennis et al. 1976). The BUSS Cask is 12 in. thick and the probability of a release given a puncture event is approximately equal to zero. The cask will withstand a 30 minute

800 °C fire; therefore the probability of a fire failure on the Hanford Site, where emergency responders have a 15 minute response time and are trained in the handling of radioactive material, is also approximately zero. In addition, based on the analysis presented in the BUSS Cask SARP, the BUSS Cask would not fail from the crush force of the trailer (16,000 lb) should a rollover accident occur. Therefore, the probability of failure from the crush force would also be approximately equal to zero.

The only conditional release probability that will affect the annual accident release frequency is related to impact. The BUSS Cask SARP demonstrates that the cask will survive a 30 ft drop onto a hard unyielding surface. If the very conservative assumption is made that the cask fails a 30 mph velocity change onto concrete, given that the system has a gross vehicle weight of 35 tons, the corresponding total conditional release probability is 0.00612 (Dennis et al. 1976). When multiplied by the annual accident frequency of 5.0×10^{-6}, the resulting annual probability of release from failure by impact is 3.0×10^{-8} which is below the required 10^{-7}. In fact, 3 shipments can be made in one year and still meet the accident criterion of less than 10^{-7}. Therefore, the BUSS Cask meets onsite transportation safety requirements and shipments of singly-encapsulated cesium chloride capsules in the BUSS Cask present no unacceptable risks to the worker or the public.

3.1 REFERENCES

10 CFR 71, 1992, "Packaging and Transportation of Radioactive Materials," *Code of Federal Regulations*, as amended.

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

Dennis, A. W., J. T. Foley, W. F. Hartman, and D. W. Larson, 1978, *Severities of Transportation Accidents Involving Large Packages*, SAND77-0001, Sandia National Laboratories, Albuquerque, New Mexico.

Green, J. R., B. D. Flanagan, and H. W. Harris, 1996, *Hanford Site Truck Accident Rate, 1990-1995*, WHC-SD-TP-RPT-021, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

H&R, 1995, *Recommended Onsite Transportation Risk Management Methodology*, H&R522-1, H&R Technical Associates, Inc., Oak Ridge, Tennessee.

Mercado, J. E., 1994, *Report on Equivalent Safety for Transportation and Packaging of Radioactive Materials*, WHC-SD-TP-RPT-001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

WHC-CM-2-14, *Hazardous Material Packaging and Shipping*, Flour Daniel Hanford, Inc., Richland, Washington.

4.0 CONTAINMENT EVALUATION

The containment boundary for this shipment is the Type W overpack. Prior to shipment, additional testing will be conducted to demonstrate that capsules in the Type W overpacks meet the special form requirements of 49 CFR 173 and American National Standards Institute (ANSI) N43.6, *Sealed Radioactive Sources, Classification* (ANSI 1989). The Type W overpacked capsules will not be certified as special form material.

The assembled Type W overpacks and capsules will be tested after assembly and must have demonstrate a leakage rate of less than or equal to 10^{-8} atm-cc/sec for acceptance.

The cask seal is designed to be leak-tight to 10^{-4} atm-cc/sec to retain the helium atmosphere during normal transportation. After an accident, the SARP (SNL 1994) demonstrates that there will be no permanent deformation of the cask seal and the cask will contain the capsules, but no leak-tightness was demonstrated since helium does not have to be retained after an accident. As the overpacked capsules shall be leakage rate tested when assembled with the Type W overpacks and the overpack design shall be tested to the special form criteria of 49 CFR 173 and ANSI N43.6, no leakage rate criteria is required for the BUSS Cask seal.

4.1 REFERENCES

49 CFR 173, 1997, "Shippers--General Requirements for Shipments and Packagings," *Code of Federal Regulations*, as amended.

ANSI, 1989, *Sealed Radioactive Sources, Classification,* N43.6-1977 (formerly ANSI N542-1977), revised 1989, American National Standards Institute, New York, New York.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

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5.0 SHIELDING EVALUATION

5.1 INTRODUCTION

This shielding evaluation supports the shipment of overpacked cesium chloride capsules in the BUSS Cask. Although the BUSS Cask has already been approved for use for this application, this analysis was required due to the new basket design that will be used for this shipment.

This section also includes an evaluation of the fraction of heat deposited in various regions of the cask to support the thermal analysis for the cask.

5.2 DIRECT RADIATION SOURCE SPECIFICATION

5.2.1 Gamma Source

The BUSS SARP (SNL 1994) activity limit is 70 kCi of ^{137}Cs per capsule, or a total of 1,120 kCi when 16 capsules are loaded in the cask. The main radiological hazard associated with the capsules involves the 0.662 MeV photon emitted during the decay of ^{137m}Ba. ^{137m}Ba is produced during 94.6% of the decays of ^{137}Cs. A 0.662 MeV photon is emitted during 90% of the decays of ^{137m}Ba. This results in a photon emission rate of 3.53×10^{16} photons/s for 1,120 kCi of ^{137}Cs, as shown below.

Photon Emission Rate = 1,120,000 (Ci) x 3.7 E10 (decays/s/Ci of ^{137}Cs) x 0.946 (^{137m}Ba atoms/decay of ^{137}Cs) x 0.9 (photons/decay of ^{137m}Ba)

Photon Emission Rate = 3.53×10^{16} photons/s (0.662 MeV)

5.2.2 Beta Source

The beta source leads to an insignificant dose rate outside of the cask because of the shielding provided by the cask. This shielding is described in Part B, Section 5.4.3.

5.2.3 Neutron Source

The WESF capsules contain no neutron emitters. Therefore, the neutron dose rates are not reported.

5.3 SUMMARY OF SHIELDING PROPERTIES OF MATERIALS

The shielding attenuation properties for the bulk materials used in this analysis were obtained from the Monte Carlo N-Particle (MCNP) computer code data library (Breismeister 1993, Carter 1995). A description of the configuration and densities of the shielding materials used in the calculational models is given in Part B, Section 5.4.3.

5.4 NORMAL CONDITIONS OF TRANSPORT

5.4.1 Conditions to be Evaluated

Dose rates will be evaluated at the cask surface and 2 m from the cask. The dose rate at 2 m is conservatively assumed to be the driver position and conservatively used for the dose rate at 2 m from the vehicle surface.

5.4.2 Acceptance Criteria

The BUSS Cask is normally shipped using the exclusive use criteria of 49 CFR 173; therefore, the same criteria shall be applied to this evaluation. The exclusive use criteria is a maximum of 10 mSv/h (1000 mrem/h) on any surface of the cask, 2 mSv/h (200 mrem/h) at the vehicle surface, 0.1 mSv/h (10 mrem/h) at 2 m from the vehicle surface, and 0.02 mSv/h (2 mrem/h) in any normally occupied space for non-radiological workers.

5.4.3 Shielding Model

The MCNP computer code (Breismeister 1993, Carter 1995) was used for the gamma-ray dose rate calculations. MCNP is a three-dimensional monte carlo computer code and uses Evaluated Nuclear Data Files (ENDF/B) for cross sections (BNL 1991). The ENDF/B system is maintained by the National Nuclear Data Center at Brookhaven National Laboratory under contract from the U.S. Department of Energy (DOE). The quality assurance (QA) documentation of MCNP for use at the Hanford Site is given in Carter (1996). Fluence-to-dose conversion factors were conservatively based on an anterior-to-posterior irradiation pattern (ANSI/ANS 1991) and are listed in Table B5-1.

The gamma source term (see Part B, Section 5.2.1) was assumed to be homogeneously distributed throughout the volume of the 16 capsules. The capsules were modeled as cesium chloride with a density of 2.6 g/cc. Note that no credit was taken for the 10.2 cm (4 in.) fins on the side of the cask. Tables B5-2 and B5-3 summarize the radial and axial geometry and material composition, respectively. Figures B5-1 and B5-2 are simplified radial and axial models, respectively.

5.4.4 Shielding Calculations

Table B5-4 summarizes the gamma dose rate estimates from MCNP for various distances from the BUSS Cask.

Table B5-1. ANSI/ANS (1991) Photon Fluence to Dose Conversion Factors.

Energy (MeV)	Flux to dose rate (mrem/h)/(photon/cm^2/s)	Energy (MeV)	Flux to dose rate (mrem/h)/(photon/cm^2/s)
1.00 E-02	2.232 E-05	5.00 E-01	9.144 E-04
1.50 E-02	5.625 E-05	6.00 E-01	1.076 E-03
2.00 E-02	8.568 E-05	8.00 E-01	1.379 E-03
3.00 E-02	1.184 E-04	1.00 E+00	1.656 E-03
4.00 E-02	1.314 E-04	1.50 E+00	2.246 E-03
5.00 E-02	1.382 E-04	2.00 E+00	2.758 E-03
6.00 E-02	1.440 E-04	3.00 E+00	3.672 E-03
8.00 E-02	1.624 E-04	4.00 E+00	4.500 E-03
1.00 E-01	1.919 E-04	5.00 E+00	5.292 E-03
1.50 E-01	2.797 E-04	6.00 E+00	6.012 E-03
2.00 E-01	3.708 E-04	8.00 E+00	7.488 E-03
3.00 E-01	5.616 E-04	1.00 E+01	8.892 E-03
4.00 E-01	7.416 E-04	1.20 E+01	1.040 E-02

ANS = American Nuclear Society.
ANSI = American National Standards Institute.

ANSI/ANS, 1991, *Neutron and Gamma-ray Fluence-to-dose Factors*, ANSI/ANS-6.1.1-1991, American National Standards Institute/American Nuclear Society, New York, New York.

Table B5-2. BUSS Cask Radial Geometry and Material Composition.

Zone (material)	Outer radius (cm)	Material density (g/cc)
Source (cesium chloride)	2.512	2.6
Inner capsule (steel)	2.858	8.0
Gap (air)	2.990	1.22 E-3
Outer capsule (steel)	3.335	8.0
Gap (helium)	3.896	1.78 E-4
Type S overpack (steel)*	4.445	8.0
BUSS Cask inner radius	25.718	NA
BUSS Cask (steel)	58.738	8.0

BUSS = Beneficial Uses Shipping System.

*The Type S overpack was used for the shielding model. The configuration of this overpack is functionally equivalent to the Type W overpack for shielding.

Table B5-3. BUSS Axial Geometry and Material Composition.

Zone (material)	Thickness (cm)	Material density (g/cc)
BUSS Cask top (steel)	32.893	8.0
Overpack top (steel)	0.691	8.0
Gap (helium)	2.261	1.78 E-4
Outer capsule top (steel)	1.016	8.0
Gap (air)	0.319	1.22 E-3
Inner capsule top (steel)	1.016	8.0
Source (cesium chloride)	48.068	2.6
Inner capsule bottom (steel)	1.016	8.0
Gap (air)	0.319	1.22 E-3
Outer capsule bottom (steel)	1.016	8.0
Gap (helium)	2.261	1.78 E-4
Overpack bottom (steel)	0.691	8.0
BUSS Cask bottom (steel)	32.893	8.0

BUSS = Beneficial Uses Shipping System.

Figure B5-1. Simplified Radial Sketch of BUSS Cask.
(Note: all dimensions in inches)

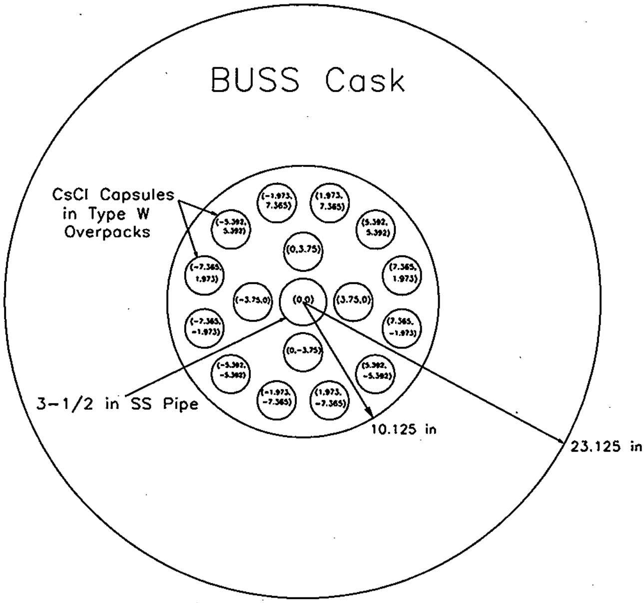

Figure B5-2. Simplified Axial Sketch of BUSS Cask.
(Note: all dimensions in inches)

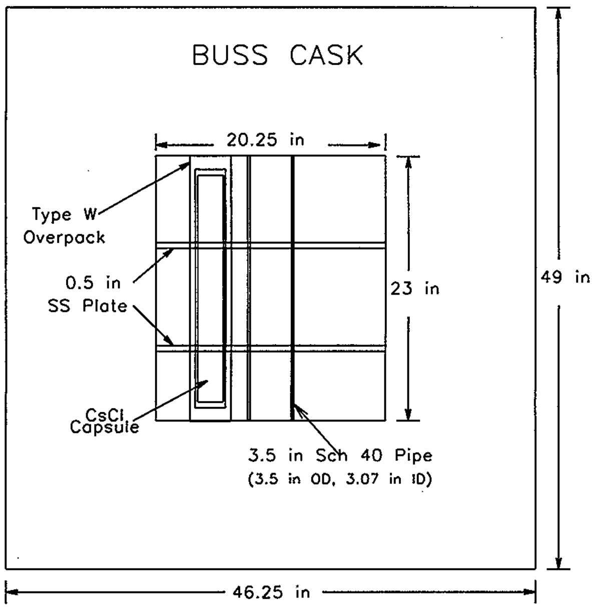

Table B5-4. Dose Rates for the BUSS Cask.

Detector location		Limit, mSv/h (mrem/h)	mSv/h (mrem/h)
Cask surface	Side	2 (200)	0.21 (21)
	Top	2 (200)	0.42 (42)
2 m from side of cask		0.1 (10)	0.0081 (0.81)
Driver position (assumed to be at 2 m)		0.02 (2)	0.0081 (0.81)

1 Sievert = 100 rem.
BUSS = Beneficial Uses Shipping System.

5.5 ACCIDENT CONDITIONS

5.5.1 Conditions to be Evaluated

Testing was performed on the BUSS Cask and it was found that there was no permanent deformation even after a 9 m (30 ft) drop test. Therefore, there is no credible scenario that could occur during onsite shipment of the BUSS Cask that would result in the loss of the cask lid or the loss of any shielding provided by the cask.

5.5.2 Acceptance Criteria

The external dose rate shall not exceed 10 mSv/h (1000 mrem/h) at 1 m from the surface under accident conditions, as directed by the onsite transportation safety program.

5.5.3 Shielding Model

No credible accident scenario was identified; therefore, no shielding model was developed.

5.6 SHIELDING EVALUATION AND CONCLUSIONS

Table B5-5 summarizes the results of the shielding analysis along with the dose rate limits. The calculated dose rates are all well within the dose rate limits assuming the worst-case cask inventory of 16 capsules with 70 kCi per capsule. Note that the dose rate at 2 m from the side of the cask was conservatively used for the dose rate at 2 m from the vehicle surface and the driver position.

Table B5-5. Dose Rates for the BUSS Cask.

Detector location		Limit, mSv/h (mrem/h)	mSv/h (mrem/h)
Cask surface	Side	2 (200)	0.21 (21)
	Top	2 (200)	0.42 (42)
2 m from side of cask		0.1 (10)	0.0081 (0.81)
Driver position (assumed to be at 2 m)		0.02 (2)	0.0081 (0.81)

1 Sievert = 100 rem.
BUSS = Beneficial Uses Shipping System.

5.7 EVALUATION OF THE THERMAL DEPOSITION FRACTIONS FOR THE CASK

The redesigned basket required a reevaluation of the fraction of the heat deposited in various regions of the cask/contents. The MCNP computer code was used to estimate the fraction of energy deposited in various regions in the cask that is associated with the gamma rays emitted by the cesium chloride capsules. The energy associated with beta particles and internal conversion electrons during decay of ^{137}Cs and ^{137m}Ba must also be accounted for. These items are discussed below.

^{137}Cs decays to ^{137m}Ba 94.6% of the time by emission of a beta particle with a maximum energy of 0.5116 MeV and an average energy of 0.173 MeV (ICRP 1983). ^{137}Cs decays directly to ^{137}Ba (stable) the other 5.4% of the time by emission of a beta particle with a maximum energy of 1.1732 MeV and an average energy of 0.425 MeV (ICRP 1983). ^{137m}Ba decays to ^{137}Ba (stable) 90% of the time by emission of a 0.662 MeV gamma ray, and by internal conversion the other 10% of the time (ICRP 1983). Therefore, each decay of ^{137}Cs results in the production of 0.85 gamma rays with an energy of 0.662 MeV, the deposition of 0.187 MeV (0.946 x 0.173 MeV + 0.054 x 0.425 MeV) of energy from beta decay, and the deposition of 0.063 MeV of energy from internal conversion. It is assumed that all of the energy associate with beta decay and internal conversion electrons is absorbed in the cesium chloride capsule. The remaining energy from the 0.662 MeV gamma rays is distributed throughout the cask, although a small portion escapes the cask. The energy from the beta particles and internal conversion (0.25 MeV per ^{137}Cs decay) must be added to the energy deposited in the cesium chloride by the gamma rays to obtain the total amount of energy deposited in the cesium chloride.

Small modifications were made to the MCNP model developed for the shielding analysis to estimate the thermal deposition fractions for various regions of the cask. The MCNP tally 6 option was used to estimate the energy deposition (MeV/g) averaged over a cell. The mass of the cell (g), as calculated by MCNP, was then multiplied by the energy deposition for the cell to determine the total energy deposited in that cell. Table B5-6 summarizes the results along with the fraction of the total energy deposited in each of the cask regions. This table indicates that approximately 2.4% of the total energy is deposited outside of the BUSS Cask.

Note that in Table B5-6, the energy deposited in the cesium chloride from beta decay and internal conversion electrons was added to the energy deposited by the gamma rays as calculated by MCNP. This information will be used in the thermal analysis for the cask.

Table B5-6. Summary of Energy Deposition in the BUSS Cask.

Region	MCNP Cell No.	Mass (g)	Average energy deposition (MeV/g)	Energy deposition (MeV)	Percent deposited in region (%)
Cesium chloride source[a]	1	2.5 E+03	8.0 E+11	1.2 E+16	36.5
Inner capsule[a]	2	2.7 E+03	5.2 E+11	1.4 E+15	4.1
Outer capsule[a]	4	3.4 E+03	5.7 E+11	1.9 E+15	5.7
Overpack[a]	6	7.3 E+03	7.0 E+11	5.1 E+15	15.1
Center pipe	23	7.9 E+03	7.7 E+10	6.1 E+14	1.8
Top support plate	24, 25	1.1 E+04	7.1 E+10	7.9 E+14	2.3
Bottom support plate	26, 27	1.1 E+04	7.1 E+10	7.8 E+14	2.3
Cask top	34	2.6 E+06	5.3 E+08	1.4 E+15	4.1
Cask side	35	3.7 E+06	2.0 E+09	7.2 E+15	21.4
Cask bottom	36	2.6 E+06	5.3 E+08	1.4 E+15	4.1
Total				3.3 E+16	97.6

BUSS = Beneficial Uses Shipping System.

[a]Includes all 16 cesium chloride capsules.

5.8 REFERENCES

ANSI/ANS, 1991, *Neutron and Gamma-ray Fluence-to-dose Factors*, ANSI/ANS-6.1.1-1991, American National Standards Institute/American Nuclear Society, New York, New York.

Breismeister, J. F., Editor, 1993, *MCNP--A General Monte Carlo Code N-Particle Transport Code, Version 4a*, LA-12625, Los Alamos National Laboratory, Los Alamos, New Mexico.

Carter, L. L., 1995, *Certification of MCNP Version 4A for WHC Computer Platforms,* WHC-SD-MP-SWD-30001, Rev. 7, Westinghouse Hanford Company, Richland, Washington.

ICRP, 1987, *International Commission on Radiological Protection, Data for Use in Protection Against External Radiation*, Publication 57, International Commission on Radiological Protection, New York, New York.

ICRP, 1983, *Radionuclide Transformations Energy and Intensity of Emissions*, Publication 38, International Commission on Radiological Protection, New York, New York.

Nelson, J. V., 1996, *Estimation of Neutron Dose Rates from Nuclear Waste Packages*, (internal memo 8M730-JVN-96-007 to J. R. Green, March 8), Westinghouse Hanford Company, Richland, Washington.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

5.9 APPENDICES

5.9.1 MCNP Input File for Shielding Model

```
Photon dose for BUSS Cask (16 CsCl Capsules)
c
c  Define the Generic Capsule Cells as Universe 1
c  mat#  mat den   surfaces
1   2 -2.6 -1 206 -205    u=1      $ CsCl - Source
2   3 -8.0 (-2 205 -204):(1 -2 206 -205):(-2 207 -206)  u=1
              $ Inner Capsule - union of top/side/bottom
3   1 -0.00122 (-3 204 -203):(2 -3 207 -204):(-3 208 -207)  u=1
              $ Air Gap around Inner & outer Capsule
4   3 -8.0   (-4 203 -202):(3 -4 208 -203):(-4 209 -208)  u=1
              $ Outer Capsule - union of top/side/bottom
5   4 -0.000178 (-5 202 -201):(4 -5 209 -202):(-5 210 -209)  u=1
              $ He Gap between Outer Capsule and Overpack
6   3 -8.0   (-6 201 -200):(5 -6 210 -201):(-6 211 -210)  u=1
              $ Overpack - union of top/side/bottom
c
c  Now Define the Cell to be filled with Universe 1 - the capsule
c
7   0  -7 213 -212     fill=1 trcl=1    $ Capsule 1
8   like 7 but trcl=2               $ Capsule 2
9   like 7 but trcl=3               $ Capsule 3
10   like 7 but trcl=4              $ Capsule 4
11   like 7 but trcl=5              $ Capsule 5
12   like 7 but trcl=6              $ Capsule 6
13   like 7 but trcl=7              $ Capsule 7
14   like 7 but trcl=8              $ Capsule 8
15   like 7 but trcl=9              $ Capsule 9
16   like 7 but trcl=10             $ Capsule 10
17   like 7 but trcl=11             $ Capsule 11
18   like 7 but trcl=12             $ Capsule 12
19   like 7 but trcl=13             $ Capsule 13
20   like 7 but trcl=14             $ Capsule 14
21   like 7 but trcl=15             $ Capsule 15
22   like 7 but trcl=16             $ Capsule 16
c
c  Define a cell for the central pipe.
c
23   3 -8.0  8 -9 211 -200
c
c  Define a cell for the top support plate.
c
24  3 -8.0 -252 -10 #7 #8 #10 #11 #12 #13
       #20 #21 #22 #23 -253 254
25  3 -8.0  252 -10 #8 #9 #10 #14 #15 #16
       #17 #18 #19 #23 -253 254
c
c  Define a cell for the bottom support plate.
c
26  3 -8.0 -252 -10 #7 #8 #10 #11 #12 #13
```

```
        #20 #21 #22 #23 -255 256
27   3 -8.0  252 -10 #8 #9 #10 #14 #15 #16
        #17 #18 #19 #23 -255 256
c
c   Define a cell for air inside the cask source region.
c
28   1 -0.00122 -252 -10 #7 #8 #10 #11 #12 #13
     #20 #21 #22 #23 253 -200 $ Air around overpacks - Above top plate
29   1 -0.00122 252  -10 #8 #9 #10 #14 #15 #16
     #17 #18 #19 #23 253 -200 $ Air around overpacks - Above top plate
30   1 -0.00122 -252 -10 #7 #8 #10 #11 #12 #13
     #20 #21 #22 #23 255 -254
               $ Air around overpacks - Between top/bottom plates
31   1 -0.00122 252  -10 #8 #9 #10 #14 #15 #16
     #17 #18 #19 #23 255 -254
               $ Air around overpacks - Between top/bottom plates
32   1 -0.00122 -252 -10 #7 #8 #10 #11 #12 #13
     #20 #21 #22 #23 211 -256 $ Air around overpacks-Below bottom plate
33   1 -0.00122 252  -10 #8 #9 #10 #14 #15 #16
     #17 #18 #19 #23 211 -256 $ Air around overpacks-Below bottom plate
c
c   Now define cells for the cask.
c
34   3  -8.0  -26 200 -235      $ Cask top
341  3  -8.0  -26 235 -234      $ Cask top
35   3  -8.0  -26 234 -233      $ Cask top
36   3  -8.0  -26 233 -232      $ Cask top
37   3  -8.0  -26 232 -231      $ Cask top
38   3  -8.0  -26 231 -230      $ Cask top
39   3  -8.0  -26 230 -229      $ Cask top
40   3  -8.0  -26 229 -228      $ Cask top
41   3  -8.0  -26 228 -227      $ Cask top
42   3  -8.0  -26 227 -226      $ Cask top
43   3  -8.0  -26 226 -225      $ Cask top
44   3  -8.0  -26 225 -224      $ Cask top
45   3  -8.0  -26 224 -223      $ Cask top
46   3  -8.0  -26 223 -222      $ Cask top
47   3  -8.0  -26 222 -221      $ Cask top
48   3  -8.0  -26 221 -220      $ Cask top
49   3  -8.0  -26 236 -211      $ Cask bottom
50   3  -8.0  -26 237 -236      $ Cask bottom
51   3  -8.0  -26 238 -237      $ Cask bottom
52   3  -8.0  -26 239 -238      $ Cask bottom
53   3  -8.0  -26 240 -239      $ Cask bottom
54   3  -8.0  -26 241 -240      $ Cask bottom
55   3  -8.0  -26 242 -241      $ Cask bottom
56   3  -8.0  -26 243 -242      $ Cask bottom
57   3  -8.0  -26 244 -243      $ Cask bottom
58   3  -8.0  -26 245 -244      $ Cask bottom
59   3  -8.0  -26 246 -245      $ Cask bottom
60   3  -8.0  -26 247 -246      $ Cask bottom
61   3  -8.0  -26 248 -247      $ Cask bottom
62   3  -8.0  -26 249 -248      $ Cask bottom
63   3  -8.0  -26 250 -249      $ Cask bottom
```

```
64  3 -8.0 -26 251 -250        $ Cask bottom
65  3 -8.0 10 -11 -200 211     $ Cask side
66  3 -8.0 11 -12 -200 211     $ Cask side
67  3 -8.0 12 -13 -200 211     $ Cask side
68  3 -8.0 13 -14 -200 211     $ Cask side
69  3 -8.0 14 -15 -200 211     $ Cask side
70  3 -8.0 15 -16 -200 211     $ Cask side
71  3 -8.0 16 -17 -200 211     $ Cask side
72  3 -8.0 17 -18 -200 211     $ Cask side
73  3 -8.0 18 -19 -200 211     $ Cask side
74  3 -8.0 19 -20 -200 211     $ Cask side
75  3 -8.0 20 -21 -200 211     $ Cask side
76  3 -8.0 21 -22 -200 211     $ Cask side
77  3 -8.0 22 -23 -200 211     $ Cask side
78  3 -8.0 23 -24 -200 211     $ Cask side
79  3 -8.0 24 -25 -200 211     $ Cask side
791  3 -8.0 25 -26 -200 211     $ Cask side
c
c  Finally define cells for the air outside cask and the universe.
c
80   1 -0.00122 220 -257 -10       $ 1 cm Air above cask - tally cell
801  1 -0.00122 258 -259 -10       $ 1 m Air above cask - tally cell
802  1 -0.00122 260 -261 -10       $ 2 m Air above cask - tally cell
803  1 -0.00122 -1000 220 #80 #801 #802 $ Rest of Air outside cask - top
81   1 -0.00122  -1000 26 -27 255 -254 $ 1 cm Air side - tally cell
811  1 -0.00122  -1000 28 -29 255 -254 $ 1 m Air side - tally cell
812  1 -0.00122  -1000 30 -31 255 -254 $ 2 m Air side - tally cell
813  1 -0.00122  -1000 26 251 -220 #81 #811 #812 $ Rest of Air - side
82   1 -0.00122  -1000 -251       $ Air outside cask - bottom
83   0  1000                      $ Void - outside universe

c
c   Radial surfaces for Capsule
c
1   cz  2.512    $ Capsule - source/outside radius
2   cz  2.858    $ Capsule - inner capsule - outer radius
3   cz  2.990    $ Capsule - outer capsule - inner radius
4   cz  3.335    $ Capsule - outer capsule - outer radius
5   cz  3.896    $ Capsule - overpack - inner radius
6   cz  4.445    $ Capsule - overpack - outer radius
7   cz  4.444    $ Outer radius for capsule universe to fill
8   cz  4.406    $ Inner radius center pipe - changed to prevent clash
9   cz  4.980    $ Outer radius center pipe - changed to prevent clash
c 8    cz  4.506    $ Inner radius for center pipe
c 9    cz  5.080    $ Outer radius for center pipe
c
c   Radial surfaces for Cask
c
10   cz 25.7175   $ Inner radius of Cask
11   cz 27.7      $ Intermediate radius of Cask - biasing
12   cz 29.7      $ Intermediate radius of Cask - biasing
13   cz 31.7      $ Intermediate radius of Cask - biasing
14   cz 33.7      $ Intermediate radius of Cask - biasing
15   cz 35.7      $ Intermediate radius of Cask - biasing
```

```
16  cz 37.7     $ Intermediate radius of Cask - biasing
17  cz 39.7     $ Intermediate radius of Cask - biasing
18  cz 41.7     $ Intermediate radius of Cask - biasing
19  cz 43.7     $ Intermediate radius of Cask - biasing
20  cz 45.7     $ Intermediate radius of Cask - biasing
21  cz 47.7     $ Intermediate radius of Cask - biasing
22  cz 49.7     $ Intermediate radius of Cask - biasing
23  cz 51.7     $ Intermediate radius of Cask - biasing
24  cz 53.7     $ Intermediate radius of Cask - biasing
25  cz 55.7     $ Intermediate radius of Cask - biasing
26  cz 58.738   $ Outer radius of Cask
27  cz 59.738   $ 1 cm from cask - tally cell
28  cz 158.238  $ 0.95 m from cask - tally cell
29  cz 159.238  $ 1.05 m from cask - tally cell
30  cz 258.238  $ 1.95 m from cask - tally cell
31  cz 259.238  $ 2.05 m from cask - tally cell
c
c  Axial surfaces for Capsule
c
200  pz  29.337    $ Top of Overpack
201  pz  28.646    $ Inside Bottom of Overpack Cap
202  pz  26.385    $ Top of outer capsule
203  pz  25.369    $ Inside Top of outer capsule
204  pz  25.050    $ Top of inner capsule
205  pz  24.034    $ Top of source
206  pz -24.034    $ Bottom of source
207  pz -25.050    $ Bottom of inner capsule
208  pz -25.369    $ Inside Bottom of outer capsule
209  pz -26.385    $ Bottom of outer capsule
210  pz -28.646    $ Inside Bottom of Overpack Bottom Plug
211  pz -29.337    $ Bottom of Overpack Plug
212  pz  29.336    $ Top plane for capsule universe to fill
213  pz -29.336    $ Bottom plane for capsule universe to fill
c
c  Axial surfaces for Cask
c
220  pz  62.230    $ Cask Top
221  pz  60.230    $ Cask Top
222  pz  58.230    $ Cask Top
223  pz  56.230    $ Cask Top
224  pz  54.230    $ Cask Top
225  pz  52.230    $ Cask Top
226  pz  50.230    $ Cask Top
227  pz  48.230    $ Cask Top
228  pz  46.230    $ Cask Top
229  pz  44.230    $ Cask Top
230  pz  42.230    $ Cask Top
231  pz  40.230    $ Cask Top
232  pz  38.230    $ Cask Top
233  pz  36.230    $ Cask Top
234  pz  34.230    $ Cask Top
235  pz  32.230    $ Cask Top
236  pz -32.230    $ Cask Bottom
237  pz -34.230    $ Cask Bottom
```

```
238  pz -36.230     $ Cask Bottom
239  pz -38.230     $ Cask Bottom
240  pz -40.230     $ Cask Bottom
241  pz -42.230     $ Cask Bottom
242  pz -44.230     $ Cask Bottom
243  pz -46.230     $ Cask Bottom
244  pz -48.230     $ Cask Bottom
245  pz -50.230     $ Cask Bottom
246  pz -52.230     $ Cask Bottom
247  pz -54.230     $ Cask Bottom
248  pz -56.230     $ Cask Bottom
249  pz -58.230     $ Cask Bottom
250  pz -60.230     $ Cask Bottom
251  pz -62.230     $ Cask Bottom
252  px  0.0       $ Misc plane
253  pz  15.27      $ Top of top support plate
254  pz  14.00      $ Bottom of top support plate
255  pz  -14.00     $ Top of bottom support plate
256  pz  -15.27     $ Bottom of bottom support plate
257  pz   63.23     $ Plane 1 cm above cask for tally
258  pz  157.23     $ Plane 0.95 m above cask for tally
259  pz  167.23     $ Plane 1.05 m above cask for tally
260  pz  257.23     $ Plane 1.95 m above cask for tally
261  pz  267.23     $ Plane 2.05 m above cask for tally
1000  so  1000.     $ air universe

tr1  -9.525    0.000  0      $ Capsule 1 Position
tr2   0.000    9.525  0      $ Capsule 2 Position
tr3   9.525    0.000  0      $ Capsule 3 Position
tr4   0.000   -9.525  0      $ Capsule 4 Position
tr5  -18.707   5.011  0      $ Capsule 5 Position
tr6  -13.696  13.696  0      $ Capsule 6 Position
tr7  -5.011   18.707  0      $ Capsule 7 Position
tr8   5.011   18.707  0      $ Capsule 8 Position
tr9  13.696   13.696  0      $ Capsule 9 Position
tr10  18.707   5.011  0      $ Capsule 10 Position
tr11  18.707  -5.011  0      $ Capsule 11 Position
tr12  13.696 -13.696  0      $ Capsule 12 Position
tr13   5.011 -18.707  0      $ Capsule 13 Position
tr14  -5.011 -18.707  0      $ Capsule 14 Position
tr15 -13.696 -13.696  0      $ Capsule 15 Position
tr16 -18.707  -5.011  0      $ Capsule 16 Position
mode p                 $ photon
c ********************************************************
c            SOURCE
c
c Srce Wgt = 1.12e6 Ci x 0.946 x 0.9 x 3.7e10 Bq/Ci= 3.528e16 phot/s
c (17 capsules Max Ci Cs137)(Branch Frct)(phot/decay)
c
c ********************************************************
sdef   cel=d1  wgt=3.528E16 erg=0.662 pos fcel d4
     rad= d2  ext= d3  axs=0 0 1
sc1  Source Cells
c
```

```
c      Capsule Cell #
c     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
si1 l 7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
sp1    1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
sc2  Source radius
si2  0 2.512  $ Source inner radius to outer radius = 0 to 2.512
c   sb2  -21 1  $ Source bias, -21 means radial power law p(x)=c|x|^a
c            $ a = 1
sc3  Source axial distribution
si3  24.034 $ Distances of the ends of the cylinder from POS
c   sp3  -21 1  $ Source axial bias prob, -21 again means p(x)=c|x|^a
c            $ a = 1
sc4  Source location
sp4  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
c        x       y       z
ds4  l  -9.525   0.000   0.000
        0.000   9.525   0.000
        9.525   0.000   0.000
        0.000  -9.525   0.000
      -18.707   5.011   0.000
      -13.696  13.696   0.000
       -5.011  18.707   0.000
        5.011  18.707   0.000
       13.696  13.696   0.000
       18.707   5.011   0.000
       18.707  -5.011   0.000
       13.696 -13.696   0.000
        5.011 -18.707   0.000
       -5.011 -18.707   0.000
      -13.696 -13.696   0.000
      -18.707  -5.011   0.000
c
c     ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
c
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
e0     .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.
c
c     Material Definitions
c
m1       7000.01p -0.765     $ air - Nitrogen
         8000.01p -0.235     $ air - Oxygen
```

```
m2    35000.01p  1        $ Source - Cl
     55000.01p  1       $ Source - Cs
m3    26000.01p -64.38   $ Steel
     24000.01p -19.08
     28000.01p -13.05
     25000.01p -1.80
     42000.01p -1.47
     6000.01p  -0.22
m4    2000.01p  1    $ He
print
c
phys:p j 1 1         $ Brems off & Coherent Scattering Off
fc05  1 cm dose rate - side of cask
f05:p  0  59.7 0 0
pd05  0 73r 0.1 2r 1 3r 0 9r
fc15  1 m dose rate - side of cask
f15:p  0 158.7 0 0
pd15  0 73r 0.1 2r 1 3r 0 9r
fc25  2 m dose rate - side of cask
f25:p  0 258.7 0 0
pd25  0 73r 0.1 2r 1 3r 0 9r
fc35  1 cm dose rate - top center of cask
f35:p  0  0 63.23 0
pd35  0 42r 0.1 2r 1 2r 0 41r
fc45  1 m dose rate - top center of cask
f45:p  0  0 162.23 0
pd45  0 42r 0.1 2r 1 2r 0 41r
fc55  2 m dose rate - top center of cask
f55:p  0  0 262.23 0
pd55  0 42r 0.1 2r 1 2r 0 41r
fc65  1 cm dose rate - side - ring detector
f65z:p  0  59.7 0
pd65  0 73r 0.1 2r 1 3r 0 9r
fc75  1 m dose rate - side - ring detector
f75z:p  0 158.7 0
pd75  0 73r 0.1 2r 1 3r 0 9r
fc85  2 m dose rate - side - ring detector
f85z:p  0 258.7 0
pd85  0 73r 0.1 2r 1 3r 0 9r
fc04  1 cm - side cell
f04:p  81
fc14  1 m  - side cell
f14:p  811
fc24  2 m  - side cell
f24:p  812
fc34  1 cm - top cell
f34:p  80
fc44  1 m  - top cell
f44:p  801
fc54  2 m  - top cell
f54:p  802
c  fc2  1 cm dose rate - top surface over sources
c  f2:p  257
c  f2s  -10
```

```
c  sd2   2.0778e3 1e20
c  fc12  1 m dose rate - top surface over sources
c  f12:p 258
c  fs12  -10
c  sd12   2.0778e3 1e20
c  fc22  2 m dose rate - top surface over sources
c  f22:p 259
c  fs22  -10
c  sd22   2.0778e3 1e20
c
c  Cell Importances
c
c  Cell 1   2   3   4   5   6   7   8   9   10
imp:p   1   1   1   2   2   4   4   4   4   4
c
c  Cell 11   12   13   14   15   16   17   18   19   20
      4   4   4   4   4   4   4   4   4   4
c
c  Cell 21   22   23   24   25   26   27   28   29   30
      4   4   4   4   4   4   4   4   4   4
c
c  Cell 31   32   33   34   341  35   36   37   38   39   40
      4   4   4   8   25  75  225  675 2000  6000 18000
c
c Cell  41    42    43    44    45    46    47    48    49  50
    5.4E4 1.6E5 4.8E5 1.4E6  4.2E6 1.3E7 3.9E7 1.2E8   8   8
c
c  Cell 51   52   53   54   55   56   57   58   59   60
      8   8   8   8   8   8   8   8   8   8
C       75  225  675 2000  6000 18000 5.4E4 1.6E5 4.8E5 1.4E6
c
C  Cell 61   62    63   64   65   66  67   68   69   70
      8   8     8    8   16   50  150  450 1800  6000
c
c  Cell 71   72    73  74   75   76   77   78    79    791
    18000 55000 1.7e5 5e5  1.5e6 4.5e6 1.3e7 4e7   1.2e8   3.6e8
c
c  Cell 80   801   802   803   81    811   812   813   82    83
    1.2E8 1.2E8 1.2e8 1.2e8 3.6E8 3.6e8 3.6e8 3.6e8  8    0
c
c  Cell Volumes
c
c
c     Cell  24         25         26         27
vol   23j 6.89051e2  6.89051e2  6.89051e2 6.89051e2
c
c  Cell  28          29        30        31
    7.63165e3 7.63165e3  1.51917e4  1.51917e4
c
c  Cell  32        33
    7.63165e3 7.63165e3  58j
nps    100000  $history
```

5.9.2 MCNP Input File for Energy Deposition Model

```
Thermal Deposition Model for BUSS Cask (16 CsCl Capsules)
c
c   Define the Generic Capsule Cells as Universe 1
c   mat#  mat den   surfaces
1    2  -2.6 -1 206 -205     u=1        $ CsCl - Source
2    3  -8.0 (-2 205 -204):(1 -2 206 -205):(-2 207 -206)   u=1
               $ Inner Capsule - union of top/side/bottom
3    1  -0.00122 (-3 204 -203):(2 -3 207 -204):(-3 208 -207)  u=1
               $ Air Gap around Inner & outer Capsule
4    3  -8.0    (-4 203 -202):(3 -4 208 -203):(-4 209 -208)  u=1
               $ Outer Capsule - union of top/side/bottom
5    4  -0.000178 (-5 202 -201):(4 -5 209 -202):(-5 210 -209)  u=1
               $ He Gap between Outer Capsule and Overpack
6    3  -8.0    (-6 201 -200):(5 -6 210 -201):(-6 211 -210)  u=1
               $ Overpack - union of top/side/bottom
c
c   Now Define the Cell to be filled with Universe 1 - the capsule
c
7    0  -7 213 -212      fill=1 trcl=1     $ Capsule 1
8    like 7 but trcl=2                    $ Capsule 2
9    like 7 but trcl=3                    $ Capsule 3
10    like 7 but trcl=4                   $ Capsule 4
11    like 7 but trcl=5                   $ Capsule 5
12    like 7 but trcl=6                   $ Capsule 6
13    like 7 but trcl=7                   $ Capsule 7
14    like 7 but trcl=8                   $ Capsule 8
15    like 7 but trcl=9                   $ Capsule 9
16    like 7 but trcl=10                  $ Capsule 10
17    like 7 but trcl=11                  $ Capsule 11
18    like 7 but trcl=12                  $ Capsule 12
19    like 7 but trcl=13                  $ Capsule 13
20    like 7 but trcl=14                  $ Capsule 14
21    like 7 but trcl=15                  $ Capsule 15
22    like 7 but trcl=16                  $ Capsule 16
c
c   Define a cell for the central pipe.
c
23    3 -8.0  8 -9 211 -200
c
c   Define a cell for the top support plate.
c
24   3 -8.0 -222 -10 #7 #8 #10 #11 #12 #13
         #20 #21 #22 #23 -223 224
25   3 -8.0  222 -10 #8 #9 #10 #14 #15 #16
         #17 #18 #19 #23 -223 224
c
c   Define a cell for the bottom support plate.
c
26   3 -8.0 -222 -10 #7 #8 #10 #11 #12 #13
         #20 #21 #22 #23 -225 226
27   3 -8.0  222 -10 #8 #9 #10 #14 #15 #16
         #17 #18 #19 #23 -225 226
```

```
c
c  Define a cell for air inside the cask source region.
c
28  1 -0.00122 -222 -10 #7 #8 #10 #11 #12 #13
    #20 #21 #22 #23 223 -200 $ Air around overpacks - Above top plate
29  1 -0.00122 222  -10 #8 #9 #10 #14 #15 #16
    #17 #18 #19 #23 223 -200 $ Air around overpacks - Above top plate
30  1 -0.00122 -222 -10 #7 #8 #10 #11 #12 #13
    #20 #21 #22 #23 225 -224
             $ Air around overpacks - Between top/bottom plates
31  1 -0.00122 222  -10 #8 #9 #10 #14 #15 #16
    #17 #18 #19 #23 225 -224
             $ Air around overpacks - Between top/bottom plates
32  1 -0.00122 -222 -10 #7 #8 #10 #11 #12 #13
    #20 #21 #22 #23 211 -226 $ Air around overpacks-Below bottom plate
33  1 -0.00122 222  -10 #8 #9 #10 #14 #15 #16
    #17 #18 #19 #23 211 -226 $ Air around overpacks-Below bottom plate
c
c  Now define cells for the cask.
c
34   3  -8.0  -11 200 -220      $ Cask top
35   3  -8.0  10 -11 -200 211    $ Cask side
36   3  -8.0  -11 221 -211      $ Cask bottom
c
c  Finally define cells for the air outside cask and the universe.
c
37  1 -0.00122  (-1000 220):(-1000 11 221 -220):(-1000 -221)
            $ Air outside cask - union of top/side/bottom
38  0  1000                  $ Void - outside universe

c
c  Radial surfaces for Capsule
c
1   cz  2.512   $ Capsule - source/outside radius
2   cz  2.858   $ Capsule - inner capsule - outer radius
3   cz  2.990   $ Capsule - outer capsule - inner radius
4   cz  3.335   $ Capsule - outer capsule - outer radius
5   cz  3.896   $ Capsule - overpack - inner radius
6   cz  4.445   $ Capsule - overpack - outer radius
7   cz  4.444   $ Outer radius for capsule universe to fill
8   cz  4.406   $ Inner radius center pipe - changed to prevent clash
9   cz  4.980   $ Outer radius center pipe - changed to prevent clash
c 8   cz  4.506   $ Inner radius for center pipe
c 9   cz  5.080   $ Outer radius for center pipe
c
c  Radial surfaces for Cask
c
10  cz 25.7175  $ Inner radius of Cask
11  cz 56.198   $ Outer radius of Cask
c
c  Axial surfaces for Capsule
c
200  pz  29.337     $ Top of Overpack
201  pz  28.646     $ Inside Bottom of Overpack Cap
```

```
202  pz  26.385      $ Top of outer capsule
203  pz  25.369      $ Inside Top of outer capsule
204  pz  25.050      $ Top of inner capsule
205  pz  24.034      $ Top of source
206  pz -24.034      $ Bottom of source
207  pz -25.050      $ Bottom of inner capsule
208  pz -25.369      $ Inside Bottom of outer capsule
209  pz -26.385      $ Bottom of outer capsule
210  pz -28.646      $ Inside Bottom of Overpack Bottom Plug
211  pz -29.337      $ Bottom of Overpack Plug
212  pz  29.336      $ Top plane for capsule universe to fill
213  pz -29.336      $ Bottom plane for capsule universe to fill
c
c  Axial surfaces for Cask
c
220  pz  62.230     $ Top of Cask
221  pz -62.230     $ Bottom of Cask
222  px  0.0      $ Misc plane
223  pz  15.27     $ Top of top support plate
224  pz  14.00     $ Bottom of top support plate
225  pz  -14.00    $ Bottom of bottom support plate
226  pz  -15.27    $ Top of bottom support plate
1000  so  300.     $ air universe

tr1  -9.525   0.000  0       $ Capsule 1 Position
tr2   0.000   9.525  0       $ Capsule 2 Position
tr3   9.525   0.000  0       $ Capsule 3 Position
tr4   0.000  -9.525  0       $ Capsule 4 Position
tr5  -18.707   5.011  0      $ Capsule 5 Position
tr6  -13.696  13.696  0      $ Capsule 6 Position
tr7  -5.011  18.707  0       $ Capsule 7 Position
tr8   5.011  18.707  0       $ Capsule 8 Position
tr9  13.696  13.696  0       $ Capsule 9 Position
tr10  18.707   5.011  0      $ Capsule 10 Position
tr11  18.707  -5.011  0      $ Capsule 11 Position
tr12  13.696 -13.696  0      $ Capsule 12 Position
tr13   5.011 -18.707  0      $ Capsule 13 Position
tr14  -5.011 -18.707  0      $ Capsule 14 Position
tr15 -13.696 -13.696  0      $ Capsule 15 Position
tr16 -18.707  -5.011  0      $ Capsule 16 Position
mode p                $ photon
c ***********************************************************
c            SOURCE
c
c Srce Wgt = 1.12e6 Ci x 0.946 x 0.9 x 3.7e10 Bq/Ci= 3.528e16 phot/s
c  (17 capsules Max Ci Cs137)(Branch Frct)(phot/decay)
c
c ***********************************************************
sdef   cel=d1  wgt=3.528E16 erg=0.662 pos fcel d4
      rad= d2  ext= d3  axs=0 0 1
sc1  Source Cells
c
c     Capsule Cell #
c     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
```

```
si1 l 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
sp1    1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
sc2 Source radius
si2 0 2.512 $ Source inner radius to outer radius = 0 to 2.512
c   sb2 -21 1 $ Source bias, -21 means radial power law p(x)=c|x|^a
c            $ a = 1
sc3 Source axial distribution
si3 24.034 $ Distances of the ends of the cylinder from POS
c   sp3 -21 1 $ Source axial bias prob, -21 again means p(x)=c|x|^a
c            $ a = 1
sc4 Source location
sp4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
c       x       y      z
ds4 l  -9.525   0.000   0.000
        0.000   9.525   0.000
        9:525   0.000   0.000
        0.000  -9.525   0.000
      -18.707   5.011   0.000
      -13.696  13.696   0.000
       -5.011  18.707   0.000
        5.011  18.707   0.000
       13.696  13.696   0.000
       18.707   5.011   0.000
       18.707  -5.011   0.000
       13.696 -13.696   0.000
        5.011 -18.707   0.000
       -5.011 -18.707   0.000
      -13.696 -13.696   0.000
      -18.707  -5.011   0.000
c
c    ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
c
c  de0   log .01 .015 .02 .03 .04 .05
c            .06 .08 .10 .15 .20 .30
c            .40 .50 .60 .80 1.0 1.5
c            2.0 3.0 4.0 5.0 6.0 8.0
c            10. 12.
c  df0   log 2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
c            1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
c            7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
c            2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
c            8.892e-3 1.040e-2
c
c    Material Definitions
c
m1      7000.01p -0.765     $ air - Nitrogen
        8000.01p -0.235     $ air - Oxygen
m2     35000.01p  1         $ Source - Cl
       55000.01p  1         $ Source - Cs
m3     26000.01p -64.38     $ Steel
       24000.01p -19.08
       28000.01p -13.05
       25000.01p -1.80
       42000.01p -1.47
```

```
     6000.01p  -0.22
m4     2000.01p  1     $ He
print
c
phys:p j 0 1          $ Brems off & Coherent Scattering Off
e0  8.700e-02 1.090e-01 1.360e-01 1.700e-01 2.130e-01 2.660e-01
    3.330e-01 4.160e-01 5.200e-01 6.500e-01 6.620e-01
c   f05:p  0 64.2 0 0.0   $ 2 cm from Cask surface - axial center
c   fc05   2 cm from Cask surface - axial center
fc06   Energy depos avg over CsCl source
f06:p  1
fc16   Energy depos avg over inner capsule
f16:p  2
fc26   Energy depos avg over capsule air gap
f26:p  3
fc36   Energy depos avg over outer capsule
f36:p  4
fc46   Energy depos avg over He
f46:p  5
fc56   Energy depos avg over overpack
f56:p  6
fc66   Energy depos avg over center pipe
f66:p  23
fc76   Energy depos avg over top plate
f76:p  (24 25)
fc86   Energy depos avg over bottom plate
f86:p  (26 27)
fc96   Energy depos avg over air inside cask
f96:p  (28 29 30 31 32 33)
fc106  Energy depos avg over cask top
f106:p 34
fc116  Energy depos avg over cask side
f116:p 35
fc126  Energy depos avg over cask bottom
f126:p 36
fc136  Energy depos avg over air outside cask
f136:p 37
imp:p
c
c  Cell Importances
c
c  Cell 1   2   3   4   5   6   7   8   9   10
        1   1   1   1   1   1   1   1   1   1
c
c  Cell 11  12  13  14  15  16  17  18  19  20
        1   1   1   1   1   1   1   1   1   1
c
c  Cell 21  22  23  24  25  26  27  28  29  30
        1   1   1   1   1   1   1   1   1   1
c
c  Cell 31  32  33  34  35  36  37  38  39  40
        1   1   1   1   1   1   1   0
c
c  Cell Volumes
```

```
c
c
c     Cell 24        25        26        27
vol   23j 6.89051e2 6.89051e2  6.89051e2 6.89051e2
c
c  Cell 28        29       30       31
    7.63165e3 7.63165e3  1.51917e4  1.51917e4
c
c  Cell 32       33
    7.63165e3 7.63165e3  5j
nps   50000  $history
```

5.9.3 Checklist for Peer Review

CHECKLIST FOR PEER REVIEW

Document Reviewed: Shielding and Energy Deposition Analysis for the BUSS Cask SEP

Scope of Review: Entire shielding and energy deposition analysis - Section 5.0

Yes	No	NA	
[✓]	[ ]	[ ]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[✓]	[ ]	[ ]	Problem completely defined.
[✓]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner.
[✓]	[ ]	[ ]	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. Spreadsheet results should be treated exactly the same as hand calculations.
[✓]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[✓]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[✓]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[✓]	[ ]	[ ]	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.
[✓]	[ ]	[ ]	Format consistent with appropriate NRC Regulatory Guide or other standards
[✓]		[ ]	Review calculations, comments, and/or notes are attached.
[✓]	[ ]	[ ]	Document approved.

RA Schwarz *R A Schwarz* 3/12/97

Reviewer (Printed Name and Signature) Date

6.0 CRITICALITY EVALUATION

No fissile materials are being transported so no criticality analysis is required.

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7.0 STRUCTURAL EVALUATION

7.1 INTRODUCTION

The BUSS Cask is currently licensed (DOE 1996) to carry 16 special form cesium chloride capsules based on an analysis in the SARP (SNL 1994). The structural differences between this shipment and the SARP configuration (SNL 1994) are the slightly smaller combined weight of the overpacked capsules in the new basket. In the shipment covered by this SEP, the cask weight will be less than the weight of the SARP configuration, so the cask will experience lower forces during the various accident scenarios. The thermal analysis (Part B, Section 8.0) shows that temperatures and temperature differences in this shipment are lower than those of the SARP configuration, so thermal stresses are bounded by the SARP analysis. Since the structural loading is bounded by those considered in the SARP, no analysis of the cask is necessary for this SEP. The cask will maintain confinement during all normal and accident conditions of transportation.

The Type W overpacked capsules are tested to the requirements for special form certification. Since the cask limits the peak acceleration of the cask body to 105*gs*, which is an order of magnitude lower than that experienced by the overpack during its test, no structural analysis of the contents is required. The overpacked capsules will maintain containment during all normal and accident conditions of transportation.

7.2 WEIGHT OF BASKET AND CONTENTS

The BUSS Cask SARP (SNL 1994) evaluated the cask with a total package weight of 14,923 kg (32,900 lb). The estimated package weight for this shipment will be 576 kg (1,270 lb) less than this. The package weight for the shipment covered by this SEP will be 14,347 kg (31,630 lb).

The SARP estimated the basket to weigh 726 kg (1,600 lb) and the 16 capsules to weigh 136 kg (300 lb); combined, the basket and contents weigh 862 kg (1,900 lb) in the SARP analysis. The table below shows that the combined contents weight for this shipment is 287 kg (632 lb), or 576 kg (1,270 lb) less than the SARP used in its evaluation.

Components	Stainless steel (unit weight = 0.289 lb/in^3)	Weight (lb)
Basket		
Bottom plate	½ in., 20 in. diameter	45.4
Upper plates (2)	1 in., 20 in. diameter	181.6
Deduction for holes in upper plates	32 holes, 3.5 in. diameter 2 holes, 4 in. diameter	89.0 3.6 -92.6
Support pipe	3.5 in. schedule 40 pipe, area = 2.68 in^2, 22.88 in. long	17.2
Basket total		151.6
Overpacked Capsules (16)		480
Total Contents		632

7.3 REFERENCES

DOE, 1996, *U.S. Department of Energy Certificate of Compliance for Radioactive Materials Packages*, USA/9511/B(U) (DOE), Rev. 3, U.S. Department of Energy, Germantown, Maryland.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

8.0 THERMAL EVALUATION

8.1 INTRODUCTION

The heat generation rate for the capsules in this shipment is significantly less than that assumed in the SARP (SNL 1994), but there are two significant configuration changes that cause the need for a thermal analysis. For this shipment, heat is conducted to the cask wall through helium rather than a solid stainless steel basket, and there is an additional gap in the heat path due to the new Type W overpack. A thermal analysis is needed to demonstrate that the temperatures within the capsules and the cask are acceptable. The ANSYS finite element program was used for this purpose; its input is attached as Part B, Section 8.8.5 and the results summarized in Part B, Section 8.5.1. It demonstrates that temperatures during normal and accident conditions are within their limits, and that the SARP thermal stress analysis bounds the stresses for this shipment.

The thermal analysis in Part B, Section 8.8.5 is based on the SARP analysis, and is not completely independent of it. The SARP's configuration was analyzed using ANSYS and checked to ensure that the answers were similar to the SARP's results, then the finite element model was modified to the configuration of this shipment. This procedure acts as a test of the modeling methods and data. It is necessary due to differences in the analysis programs and the SARP having omitted data.

After modeling the SARP configurations, four new configurations were modeled to determine the best basket design. The configuration selected was the simplest and least costly of the four and met the temperature requirements for normal and accident conditions of transportation.

After selecting the basket design, the analytical model was run with more conservative parameters and an updated basket design to determine the maximum temperatures. Case 1a of Table B8-8 presents these results: all temperatures are less than their limits, except the cesium chloride maximum temperature is at its arbitrary limit. Additional cases were run with modified parameters to test their effects, and these results are shown in Table B8-8.

8.2 THERMAL SOURCE SPECIFICATION

Table B8-1 gives the temperature limits and the calculated NCT temperatures used as limits for this SEP.

The temperature limits in this SEP are the limits used for the SARP. However, since the SARP did not limit the maximum cesium chloride temperature at the center of a capsule, this SEP uses the maximum calculated cesium chloride temperature (462 °C [864 °F]) as a limit. This temperature has been reviewed and accepted for shipments in the BUSS Cask based on serviceability limits; higher temperatures were acceptable for safety considerations, but the capsule could then not be used in a commercial facility.

Table B8-1. SARP Results and Allowable Temperatures.

Location	Calculated temperature, 16 capsules °C (°F)	Calculated temperature, 12 capsules °C (°F)	SARP allowable temperature °C (°F)
Cesium chloride	438 (820)	462 (864)	N/A[1]
Inner cladding	398 (748)	407 (765)	450 (842)[2]
Outer cladding	371 (700)	369 (696)	800 (1472)[3]
Basket	356 (673)	348 (658)	800 (1472)
Lid or port seals	202 (396)	202 (396)	450 (842)[4]
Inner cask wall seal limit	202 (396)	202 (396)	800 (1472) 450 (842)[4]
Outer cask wall	140 (284)	140 (284)	800 (1472)[5]

DOT = U.S. Department of Transportation
SARP = Safety Analysis Report for Packaging.

[1]Cesium chloride melts at 646 °C (1195 °F), and it undergoes a phase change between 350 - 470 °C (662 - 878 °F) (SNL 1984).

[2]The inner cladding temperature limit was based on testing for long-term geologic disposal. Below 450 °C (842 °F), there is no anticipated corrosion of the cladding material in contact with cesium chloride.

[3]The stainless steel temperature limits other than the inner cladding was based on reducing the potential for significant corrosion. The capsules were initially tested at a temperature of 800 °C (1472 °F) without loss of contents.

[4]Seal temperature limits are the maximum operating temperatures (SARP) provided by the manufacturer. (Helicoflex copper-lined inner seal with a section diameter of 0.58 cm. Helicoflex defines this temperature as the point the seal no longer resists pressure.) The SARP shows that the seal temperatures are less than the cask inner wall temperatures; this analysis did not model the seal areas since the inner wall temperature was less than the long-term seal limit in all cases.

[5]The outer wall temperature is significantly higher than the DOT limit of 85 °C (185 °F); a protective barrier is provided around the cask for personal protection.

SNL, 1984, *WESF ^{137}Cs Gamma Ray Sources*, SAND82-1492, Sandia National Laboratories, Albuquerque, New Mexico.

Helicoflex is a trademark of the Helicoflex Corporation.

8.3 THERMAL PROPERTIES OF MATERIALS

8.3.1 T304 Stainless Steel Properties

Density = 7900 kg/m^3 (White 1991)
= 493 lbf/ft^3
= 0.285 lbf/in^3

Heat capacity c_p = 477 J/kg • °K = 0.114 Btu/lb • F (White 1991)

Thermal conductivity, K (ASME 1992) is given in Table B8-2.

Table B8-2. Stainless Steel Thermal Conductivity.

°F	70	100	150	200	250	300	350	400
K, BTU/h/ft/°F	8.6	8.7	9	9.3	9.6	9.8	10	10.4
K, BTU/h/in/°F	0.72	0.73	0.75	0.78	0.80	0.80	0.80	0.87
°F	450	500	550	600	650	700	750	800
K, BTU/h/ft/°F	11	10.9	11	11	11.6	12	12	12.2
K, BTU/h/in/°F	0.90	0.91	0.93	0.94	0.97	0.98	1.00	1.02

8.3.2 Helium Properties (White 1991)

Density = 0.1627 Kg/m3 at 300 °K = 5.88 lb • 10^{-6}/in3 at 80 °F

Heat capacity = 5197 J/kg • °K = 1.24 Btu/hr/lb • °F

Conductivity and unit conversion is given in Table B8-3.

Table B8-3. Helium Conductivity, K.

T °K	300	350	400	450	500	550	600	700
K W/m-K	0.150	0.165	0.180	0.195	0.211	0.229	0.247	0.278
T °F	81	171	261	351	441	531	621	801
K, Btu/h/in/F	0.0072	0.0079	0.0087	0.0094	0.0102	0.0110	0.0119	0.0134

8.3.3 Properties of Cesium Chloride

The following properties were used in this analysis due to their use in the SARP (SNL 1994). The SARP stated that there was a wide range in conductivity values in the literature, and that the SARP used the minimum value, which will maximize the cesium chloride temperature.

Density = 0.0939 lbf/in^3 (Sp.G. of 2.6)

Heat capacity, C_p = 8400 J/kg*K

Thermal conductivity = 0.45 W/m*K

8.3.3.1 Heat Generation. Part A, Section 3.0 shows that the average heat generation for all 16 overpacked capsules is 191 W per capsule. However, since the finite element model considered only a 45° segment of the cask due to symmetry, an average must be found for each octant. Part B, Section 8.8.3 shows with the most favorable capsule arrangement, the highest average in one octant is 193.4 W and this analysis uses 195 W for a margin. The capsule arrangement within the package must be controlled using the sketch shown in Part A, Section 6.0.

8.3.3.2 Heat Distribution. Heat generation is caused by absorption of radiation by the package's materials and occurs throughout the package, including the cesium chloride salt. The BUSS Cask SARP's shielding analysis (SNL 1994) calculated a thermal energy distribution that was used in the SARP thermal analysis, but this distribution is not valid for this package due to the third encapsulation layer (the Type W overpack) and the new basket design. The shielding analysis in Part B, Section 5.0 of this SEP calculated a heat distribution which is compared to the SARP results in Table B8-4. The SEP analysis found a heat deposition in the cesium chloride that is much less than was found in the SARP, and a higher deposition in the encapsulation. The higher percentage of thermal power in the encapsulation is explained by the increased thickness of encapsulation in this package compared to the SARP, but this is overstated because the SEP shielding analysis uses a Type S overpack (5 mm [0.21 in.] thick) rather than the Type W overpack (3 mm [0.13 in.]) actually being used. For conservatism, the SARP heat deposition to the cesium chloride, 50% of the thermal power, was used in this analysis. Since the heating of the encapsulation is linearly dependent on the thickness, and the overpack adds a third layer as thick as each of the two inner layers of steel, the total heat absorption in the encapsulation should be 1.5 times the SARP's value. The SARP used 13% distribution in the encapsulation, so this SEP uses 20%. The remainder of the capsule's thermal energy, 30%, is deposited in the BUSS Cask walls.

Table B8-4. Heat Distribution within the BUSS Cask.

Package component	SARP shielding analysis % power	SEP shielding analysis % power	SEP thermal analysis % power
Cesium chloride	50	37	50
Steel capsule (and overpack)	13	24	20
Basket	30		
Cask wall	7	21	30
Central support		2	
Other basket components		15	

SARP = Safety Analysis Report for Packaging.
SEP = Safety Evaluation for Packaging.

8.3.4 Properties of Air and the Convection Rate at the Cask Surface

The SARP used a convection film factor of 5 W/m^2*K on the surface of the horizontal cylinder without stating the assumed temperature range it was valid for. This SEP uses a variable coefficient that is calculated in Part B, Section 8.8.2. At the surface temperature calculated by the SEP (141 °C), the film coefficient is 5.38. The lower temperature resulting from the higher convection is balanced by the SEP's using an environmental temperature 8 °C (15 °F) higher than the SARP. The SARP multiplies the convection rate by 4.7 and the radiation heat transfer rate by 1.5 to account for the 10 cm (4 in.) deep fins on the cask surface. Both of these factors were formulated in the SARP, but the calculated numbers were not shown; they are calculated in Part B, Section 8.8.1.

Table B8-5. Thermal Properties of Air. (White 1991)

Temp °K	K W/m*K	Pr	$g\beta/v^2 = Gr/(D^3 \bullet \Delta T)$
200	1.81 E-02	0.740	8.57 E+08
250	2.23 E-02	0.724	3.02 E+08
300	2.61 E-02	0.712	1.33 E+08
350	2.97 E-02	0.706	6.60 E+07
400	3.31 E-02	0.703	3.63 E+07
450	3.63 E-02	0.700	2.16 E+07
500	3.95 E-02	0.699	1.36 E+07

density = 1.177 kg/m³ at 27 °C
C_p = 1005 J/kg °C at 27 °C

8.4 INITIAL CONDITIONS

8.4.1 Normal Conditions of Transportation

The SARP used the (NCT) specified by 10 CFR 71.71, including still air, ambient temperature of 38 °C (100 °F) and 200 g-cal/cm² (over 12 hours) insolation. This SEP uses the Hanford maximum of 46 °C (115 °F) ambient temperature and an insolation of 50 BTU/h/ft² (Irwin 1996). This insolation value is less than that used in the SARP:

$$1\ BTU = 251.98\ g\text{-}cal,\ so\ 50\ Btu/hr/ft^2 = 151{,}200\ g\text{-}cal/ft^2\ over\ 12\ hours$$

$$and\ since\ 1\ ft^2 = 929\ cm^2,\ the\ insolation\ is\ \frac{151{,}200}{929} = 163\ g\text{-}cal/12\ hours$$

8.4.2 Hypothetical Accident Conditions

The SARP analyzed the BUSS Cask with 12 or 16 cesium chloride capsules under HAC that included a 30 ft drop, puncture, and a 30 minute fire with a temperature of 800 °C, a surface emissivity of 0.8 and environmental emissivity of 0.9. Under these conditions, and using the temperature distribution resulting from the NCT model, the SARP reported no temperature rise in the capsules during the 30 minute fire. The maximum temperature rise in the capsules was 25 °C (45 °F) for the 12 capsule case and 14 °C (25 °F) for the 16 capsule case hours later. The SARP's temperature limit for the capsules is 800 °C (1472 °F), and the maximum initial temperature of a capsule is 462 °C (864 °F) in this shipment. The SARP's temperature limit for accident conditions will not be approached in this shipment since it will experience about the same temperature rise as the SARP case, and no thermal analysis is necessary.

8.5 THERMAL ANALYSES

A finite element thermal analysis was done in three stages:

1. Model the SARP's shipping configuration to confirm some thermal properties and test the modeling method. Three key pieces of information were missing from the SARP, and had to be calculated in this analysis: the heat transfer film coefficient, the fin efficiency factor, and heat source length. The film coefficient and fin factors are calculated in Part B, Section 8.8.1. The length of the heat source within the capsule is needed to find the heat generation per unit area, and this was not provided in the SARP. The minimum length, and the highest two-dimensional heat generation, can be found from the following: The inside height is 48.0 cm (18.9 in.) and the cesium chloride underwent a 17% volume reduction (SNL 1984) after the capsule was filled. Since the diameter of the salt had to remain the same, the length of the salt column reduced by 17% to 39.8 cm (15.7 in.). Any subsequent volumetric change will lead to a lower heat generation density, so using this length will produce conservative results. The SARP configuration model found that the SARP results could be approximated with a two-dimensional model if the heat-generating length of the capsules was 16 in. The ANSYS input file is provided in Part B, Section 8.8.4 and the results are shown in Table B8-6.

2. Various basket designs were studied to find the simplest one that provided acceptable temperatures. Four configurations, one shown in Figure B8-1, with temperatures in Table B8-7. While the configurations with fins reduced the temperatures, the simplest basket (Case 1) resulted in acceptable temperatures and the least cost.

3. A final model was produced form the results of step 2 by raising the capsule's power level from 191 W to 195 W, lowering the stainless steel emissivity from 0.5 to a more conservative value of 0.3, and moving the capsule's position within the cask. These results are Case 1a in Table B8-8, and demonstrate that the normal condition temperatures of the cask and contents will remain at or below the temperatures calculated in the SARP. The effect of lowering the emissivity alone was about an 11 °C (20 °F) temperature rise in the cesium chloride.

4. Additional runs were made with changed parameters: increased power levels, more realistic heat distribution within the package, reduced fin effectiveness, and reduced conduction within the cask. The results of this study, shown in Table B8-8, show that the model is most sensitive to the capsule power.

8.5.1 Model of the Original Configuration

The ANSYS solid modeling processor was used to model a 45° segment of the basket and cask wall. This is a two-dimensional model using ANSYS PLANE55, 4-node elements for conduction areas, LINK31 2-node elements for radiation links between capsule layers, and SURF19 surface effect elements for convection and radiation to an atmosphere node outside of the cask. Internal gaps are assumed to be concentric, conservatively neglecting surface-to-surface contacts.

The model included one complete capsule and two half capsules of 250 W thermal power per capsule. The total power in the segment was divided by 41 cm (16 in.) to find the power per unit length, and divided by the cross-section area to find the heat generation per unit area. The resulting heat generation density is distributed through the various regions of the model using the SARP assumptions (50% in the cesium chloride and the remainder in the capsule layers, basket, and cask walls.

The cask fins convection rate was 5 $W/m^2 \cdot {}^\circ C$ (per SARP) multiplied by a fin convection factor of 4.7, as calculated in Part B, Section 8.8.1. The SARP's environmental temperature (100 °F) and the emissivity (0.5) were used. The input and output files are in Part B, Section 8.8.4, and the results are summarized below. There was close enough agreement between the ANSYS model and the SARP results to use the model as a starting point for the overpacked capsule analysis, and have confidence in the results.

Table B8-6. Results of the SARP Model; Temp, °F.

Location	SARP	tmax	tmin
Cesium chloride	820	834	680
Inner capsule	748	738	679
Outer capsule	699	684	598
Basket	673	659	536
Cask inner surface	396	403	401
Cask outer surface	284	285	285

8.5.2 Modeling 16 Overpacked Capsules

The model used for the first analysis was changed to account for the open basket and the overpack. The basket's horizontal plates are neglected and heat is conducted through the helium using the properties given above. The only feature of the basket in the model is the central support pipe, which was modeled as a solid element to account for the radiation from it to the cask wall. In reality, the 3 cm (1 in.) thick plates will conduct a significant amount of heat and lessen the temperature difference between the hottest and coldest capsules. All gaps were modeled as concentric, and no convection inside the cask was modeled, which adds to the conservatism.

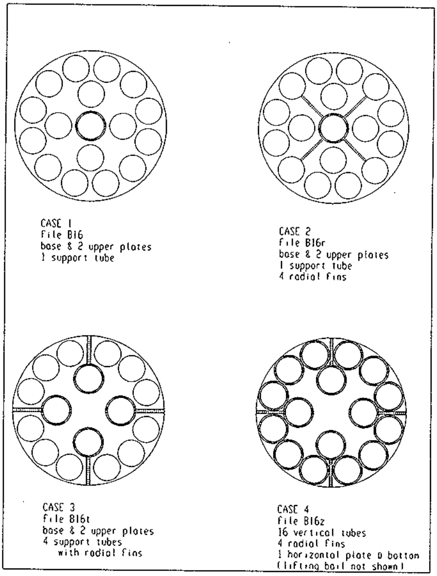
The following results were obtained by running four basket configurations to select the best one. The contents are 16 overpacked capsules with a power level of 191 W, and are compared to the SARP 16-250 W capsule case. The conclusion is that in all cases, the cesium chloride temperatures are less than those reported in the SARP, so additional heat paths are not necessary and Case 1 is the best basket design.

Table B8-7. Temperature Results, °F.

Location	SARP file b0	Case 1 file: b16		Case 2 file: b16r		Case 3 file: b16t		Case 4 file: b16z	
		max	min	max	min	max	min	max	min
Cesium chloride	820	803	614	775	583	777	597	737	591
Inner capsule	748	731	614	701	582	705	597	670	591
Outer capsule	699	693	542	651	512	666	525	624	526
Overpack	----	674	480	632	452	646	459		
Support pipe*	673	648	646	609	586	637	469	592	417
Cask inner surface	396	317	311	297	291	312	305	311	305
Cask outer surface	284	238	237	220	220	227	226	227	226

SARP = Safety Analysis Report for Packaging.
*Basket temperature for SARP.

Figure B8-1. Preliminary Models.



Case 1: Bottom plate, two upper plates with holes for the capsules, and a central support pipe.

Case 2: Central tube with four small fins, three horizontal plates.

Case 3: Four support tubes with fins, three horizontal plates.

Case 4: Sixteen vertical tubes, one horizontal plate.

The following results are variations of Case 1, the selected design. Case 1a is the analysis on which this evaluation rests. It differs from Case 1, above, by using a variable convection rate, higher capsule power, lower emissivity for the stainless steel, and a different heat generation distribution.

Case 1a: Base case. Fin factor (model parameter Fn) = 4.7 multiplies the convection rate; fin efficiency factor (parameter = F_{eff}) = 1.5; overpack thickness (thk3) = 0.13; Power (W) = 195; Capsules located as close to the cask walls as possible (Rad5 = 4.25, Rad6 = 7.88); conservative power distribution (50% power in cesium chloride, 20% power in capsule layers). Stainless steel emissivity = 0.3.

Case 1b: Reduced the heat deposition within the cesium chloride and increase the encapsulation heating to match this SEP's shielding analysis (37% power in cesium chloride, 24% in the capsule layers). This reduces the cesium chloride maximum temperature by 40 °C (72 °F), and is more realistic than Case 1a.

Case 1c: Cut the fin convection factor in half (Fn = 2.35) and use a fin efficiency factor of 1.0. This produced a cesium chloride temperature 19 °C (35 °F) higher than Case 1a and would result if the fin factors were grossly overstated. Their formulation was reviewed in the SARP; however, so using them in this analysis is not unconservative.

Case 1d: Increase capsule power (W) to 215 W, the average of the three highest power capsules. This produced cesium chloride temperatures 26 °C (47 °F) higher than Case 1a. It demonstrates the necessity of controlling the position of the capsules within the cask.

Case 1e: Replace the He conductivity in the cask with air conductivity, simulating SARP accident conditions, in which He is assumed to leak out. The cesium chloride temperature rises 18 °C (32 °F) over the base case.

Table B8-8. Maximum Temperatures in Base Case and Variations.

	Case 1a	Case 1b	Case 1c	Case 1d	Case 1e	Limit	SARP (max)
Cesium chloride	864	792	899	911	896	864	864
Inner cladding	790	738	825	829	822	842	765
Outer cladding	741	698	779	778	776	1472	700
Overpack	718	679	756	754	754	1472	
Support pipe	692	658	731	726	719	1472	673
Cask inner surface	338	332	418	356	338	842 (for seals)	396
Cask outer surface	253	254	337	264	253	284	284

These variations show that the model is behaving reasonably, and is not unduly sensitive to any one parameter. The model is most sensitive to the thermal power of the capsules and the heat deposition within the package. The power is well known, but the distribution is not well defined so a conservative heat deposition is used for this analysis. This conservatism, and the fact that the two-dimensional model neglects heat loss through the capsules ends and conduction through the two plates of the basket assure that the results are conservative. Even if improbable errors produced the results of Cases 1c, 1d, or 1e, no thermal limits of the SARP would be exceeded.

The primary check of a finite element model is to reduce the element size and rerun it to see if the temperatures at key locations converge. This was easily done since element size was a model parameter. In the final run, the element sizes were halved and the cesium chloride temperatures rose only 1 °C. Another check is to note that the equilibrium temperatures of the outer cask surface varies only when the power level is increased or the surface heat transfer parameters are changed. A third check is to verify that all of the input energy is accounted for. This was done by summing the energy input:

$$\textit{Capsule heat generation} = \frac{195\ W}{16} \times 2\ \textit{caps/segment} = 24.38\ W$$

$$24.38 \times 3.412\ \frac{Btu/h}{W} = 83.2\ Btu/h$$

$$\textit{Insolation} = \frac{50\ Btu/h/ft^2}{144} = .347\ Btu/h/in^2 \textit{ on a 52 in. diam cylinder with } \varepsilon = .3$$

$$.3 \times .347 \times 52 = 5.4\ \textit{Btu/h on the entire upper half cylinder, or } 2.1 \textit{ on } 45° \textit{ segment}$$

$$83.2 + 2.1 = 85.3$$

and comparing this to the nodal "reaction" at the environment node. Over 98% of the input energy is accounted for.

As a last check, the base model (file B16a) was run with the number of elements inside of the cask walls doubled. A plot of the thermal energy error was checked for both runs: it showed that the energy error is fairly uniform for all of the various materials, with a local maximum error in the Helium, between the cask wall and the lower capsule. In doubling the number of elements, this maximum error dropped from 0.36 to 0.09, and the temperatures inside of the cask were raised by 1 °C. The size of the error is not significant, but the fact that it is uniform, with a local maximum in an area that is not thermally significant, and the small temperature change for a halving of the element size indicates that the model is working correctly.

ANSYS geometry plots are provided at the end of this chapter to aid in reviewing the results of the analysis.

8.6 CONCLUSIONS

Under normal conditions of transportation, the calculated cask walls and the cesium chloride temperatures are less than the SARP allowables. The inner cladding is about the same temperature as the SARP maximum, and the overpack wall is only 18 °F higher than the SARP-predicted outer cladding temperature. The temperature difference between the inner and outer walls is 338 - 253

= 85 °F, which is less than the SARP's 396 - 284 = 112 °F, so the thermal stresses will be bounded by the SARP's predictions and a new structural analysis is not required.

Under HAC, this shipment will behave similar to the SARP's conclusions since the cask and overpacks are unchanged. Part B, Section 8.3.2 of the SARP notes that, starting from the NCT, the 800 °C (1470 °F) fire temperature will cause 15 °C (25 °F) rise in the maximum cesium chloride temperature for the 16 capsule case, resulting in a temperature of 889 °F. Even if an accident causes a loss of helium in the cask, thermal analysis Case 1e shows that the maximum cesium chloride temperature will be 18 °F higher than the SARP's maximum NCT temperature.

Figure B8-2. B16a Plots. (4 sheets total)

B16a, plot 1

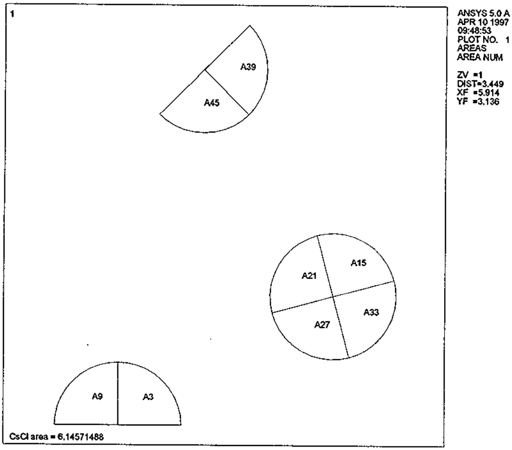
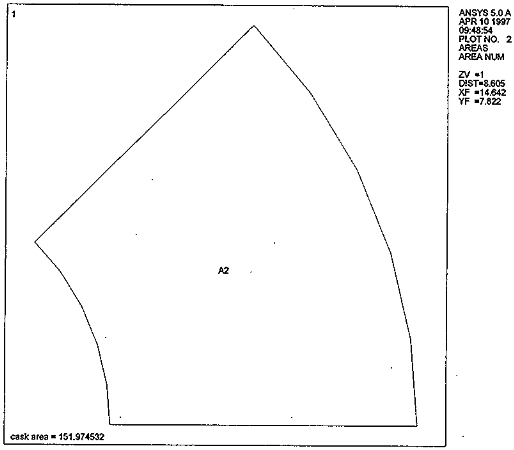


Figure B8-2. B16a Plots. (4 sheets total)

B16a, plot 2



B16a, plot 3

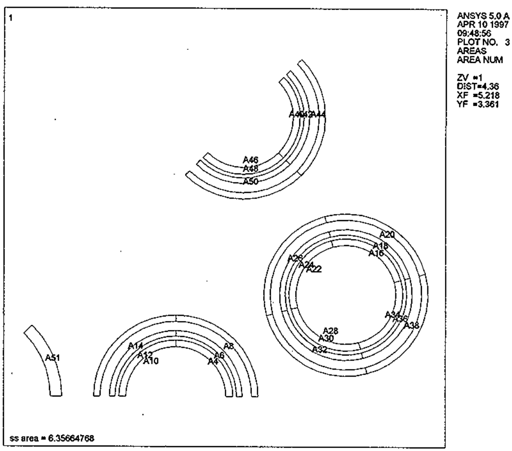
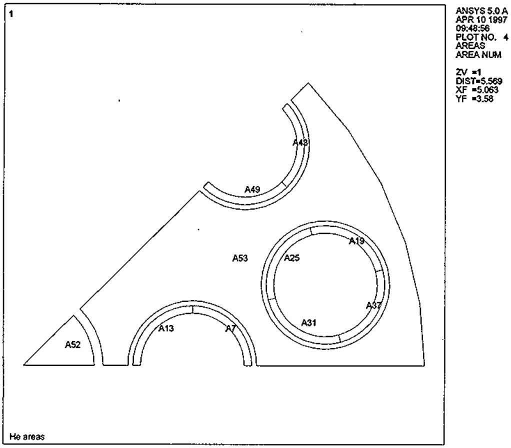


Figure B8-2. B16a Plots. (4 sheets total)

B16a, plot 4



B16a, plot5

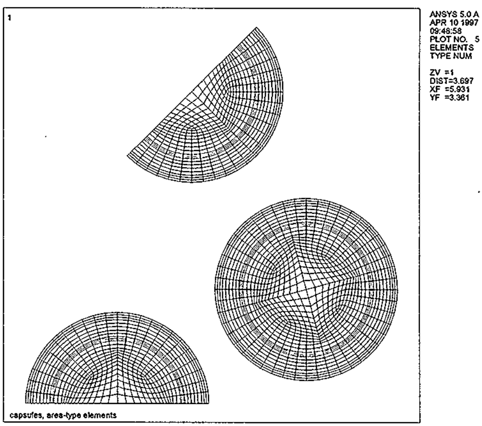
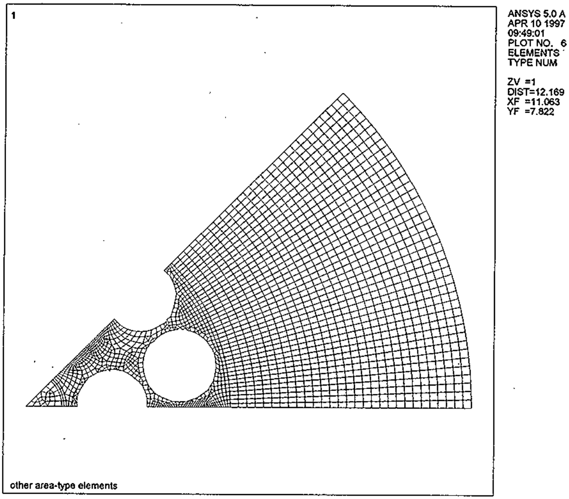
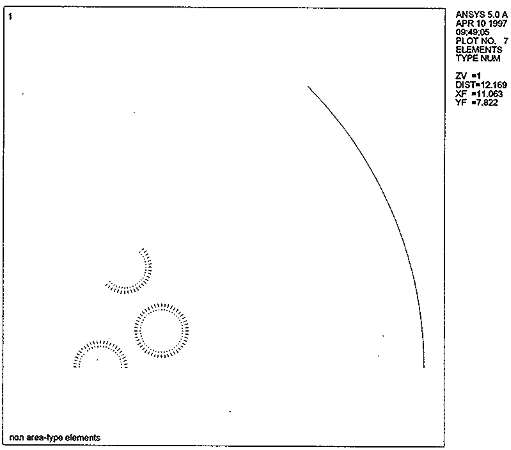


Figure B8-2. B16a Plots. (4 sheets total)

B16a, plot 6



B16a, plot 7



8.7 REFERENCES

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

ANSYS, Version 5.2, copyright by SAS IP, 1995, as an unpublished work.

ASME, 1992, *Boiler and Pressure Vessel Code,* Section II, Part D, American Society of Mechanical Engineers, New York, New York.

Irwin J. J., 1996, *Thermal Analysis Methods for Safety Analysis Reports For Packaging*, WHC-SD-TP-RPT-005, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

SNL, 1984, *WESF ^{137}Cs Gamma Ray Sources*, SAND82-1492, Sandia National Laboratories, Albuquerque, New Mexico.

White F. M., 1991, *Heat and Mass Transfer,* Addison-Wesley Publishing Company, New York, New York.

8.8 APPENDICES

8.8.1 Convection and Radiation Calculations

ENGINEERING SAFETY EVALUATION

Subject BUSS Cask Heat Transfer Calculations Page 1 of 3
Originator J. S. Boettger Date 03/21/97
Checker Wm. W. Smyth Date 03/21/97

I. **Objectives:**

It is desired to find equivalent heat transfer coefficients for the BUSS cask so that it may be modelled as a cylinder. The actual BUSS cask has 11 equally spaced fins. The approach used will be to find the ratio of heat transfer coefficients, h_1 for the finned case and h_2 for the unfinned case, which produce equal heat transfer rates. Also, a comparison of radiation heat transfer rates is made to determine an equivalent radiation heat transfer rate for the unfinned case.

II. **References:**

SNL, 1994, *Beneficial Uses Shipping System Cask (BUSS), Safety Analysis Report for Packaging (SARP), Rev. 5*, Sandia National Laboratories, Albuquerque, New Mexico.

III. **Results and Conclusions:**

A multiplier of 4.72 should be used for the convective heat transfer coefficient when modelling the cask without fins.

The radiation heat transfer rate is 50% more efficient for the finned, case, therefore a multiplier of 1.5 should be used when modelling the cask without fins.

IV. **Engineering Evaluation:**

Use the SARP (SNL, 1994) methodology for all calculations:

Convection

With Fins

The convective heat transfer rate, q_c, is:

$$q_c = q_f + q_o$$

where, q_f = heat transfer rate from finned surfaces
q_o = heat transfer rate from unfinned surfaces

The heat transfer rate from the finned surfaces is:

$$q_f = N\,\eta\, q_{max},$$

where, q_{max} = heat transfer rate assuming entire fin is at base temperature and is defined as:

$$q_{max} = 2\pi h_1(r_c^2 - r_o^2)(T_b - T_\infty)$$

where,
r_c = equivalent fin radius = $r_e + t/2$, (27.375 in.)
r_e = radius at fin edge, (27.125 in.)
r_o = radius at fin base, (23.125 in.)
t = fin thickness, (0.5 in.)
T_b = Temperature at base of fin
T_∞ = Temperature of the environment

ENGINEERING SAFETY EVALUATION

Subject BUSS Cask Heat Transfer Calculations	Page 2 of 3
Originator J. S. Boettger [signature]	Date 03/21/97
Checker Wm. W. Smyth [signature]	Date 03/21/97

Thus, $q_f = 2\pi N\eta h_1(r_c^2 - r_o^2)(T_b - T_\infty)$

The heat transfer rate from the unfinned surfaces is:

$q_o = hA_o(T_b - T_\infty)$, where $A_o = 2\pi r_o(H-Nt)$, and H = 20.5 in.

$q_c = 2\pi h_1(T_b - T_\infty)\{N\eta(r_c^2 - r_o^2) + r_o(H-Nt)\}$

Without fins

The heat transfer rate without fins is:

$q_w = 2\pi r_o H h_2(T_b - T_\infty)$

Equating q_w and q_c and solving for h_2 gives:

$$h_2 = h_1\left\{\frac{N\eta(r_c^2 - r_o^2) + r_o(H-Nt)}{r_o H}\right\}$$

$h_2 = 4.72\ h_1$

Thus, when modelling the BUSS Cask as a cylinder, a multiplication factor of 4.72 should be used with the heat transfer coefficient.

Radiation

Comparing radiation heat transfer rate with fins to heat transfer rate without fins.

With Fins

With fins, the heat transfer rate is given as:

$q_R = q_{enc} + q_{fin\text{-}tip}$

q_{enc} = heat transfer rate from enclosed portion of fin
$q_{fin\text{-}tip}$ = heat transfer rate from end of fin

$$q_{enc} = \frac{\sigma(T_b^4 - T_\infty^4)}{R_{1\text{-}\infty}} + \frac{\sigma(T_b^4 - T_\infty^4)}{R_{2\text{-}\infty}}$$

ENGINEERING SAFETY EVALUATION

Subject BUSS Cask Heat Transfer Calculations Page 3 of 3
Originator J. S. Boettger Date 03/21/97
Checker Wm. W. Smyth Date 03/21/97

$$R_{m-n} = \frac{(1-e_m)}{e_m A_m} + \frac{1}{A_m F_{m-n}} + \frac{(1-e_n)}{e_n A_n}$$

and

σ = Stefan-Boltzman constant = 1.190×10^{-11} Btu/h · in² · °R⁴
T_b = Fin temperature (assumed to be temperature at base of fin)
T_∞ = Temperature of the environment
ϵ_m = emissivity of surface m
A_m = surface area of surface m
F_{m-n} = shape factor from surface m to surface n

Surface 1 is the area between fins, and surface 2 is the surface area of the fin sides. Therefore,

$A_1 = N(2\pi r_o l)$ = 2400 in₂, where l = distance between fins = 1.5 in.
$A_2 = 2N\pi(r_c^2 - r_o^2)$ = 13900 in₂

$F_{1-\infty} = 0.0894$, and
$F_{2-\infty} = 0.1294$, as given in the BUSS SARP.

$\epsilon_1 = \epsilon_2 = 0.5$

$R_{1-\infty} = 0.0051\ in^{-2}$
$R_{2-\infty} = 0.00063\ in^{-2}$

$q_{conc} = 2.12 \times 10^{-8} (T_b^4 - T_\infty^4)$

$q_{fin-tip} = \sigma\epsilon A(T_b^4 - T_\infty^4)$, where

$A = N(2\pi r_c t) = 937\ in^2$
$\epsilon = 0.5$

$q_{fin-tip} = 5.60 \times 10^{-9} (T_b^4 - T_\infty^4)$

$q_R = 2.68 \times 10^{-8} (T_b^4 - T_\infty^4)$

Without Fins

$q_{no-fin} = \sigma\epsilon A(T_b^4 - T_\infty^4)$, where

$A = 2\pi r_o H = 3000\ in^2$
$\epsilon = 0.5$

$q_{no-fin} = 1.79 \times 10^{-8} (T_b^4 - T_\infty^4)$

The ratio $q_R/q_{no-fin} = 1.5$

8.8.2 BUSS Cask Heat Transfer Calculations

ENGINEERING EVALUATION

SUBJECT	Convection and Radiation Calcs	PAGE	1 of 9
ORIGINATOR	Wm. W. Smyth	DATE	4/10/97
CHECKER	J. S. Boettger	DATE	~~5/21/91~~ 7/1/97

I. Objective: Find the convection film coefficient for a horizontal cylinder in air, with the air temperature between 100 and 120 °F.

II. References:

White: *Heat and Mass Transfer*, 1991, Frank M. White
ASME: 1992

III. Results and Conclusions:

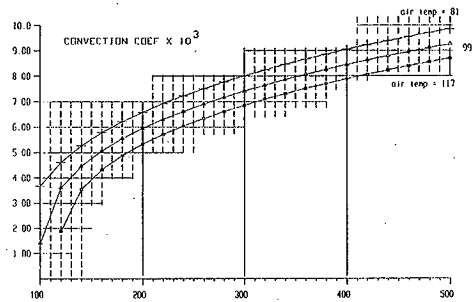
The free convection rate for a 1.12 m (44″) horizontal cylinder, in air, using the properties and methods from White, are given in the following table. For comparison, the SARP's value of 5 W/m² • °K is equivalent to 6.1210^{-3} Btu/hr •in² •°F which requires a surface temperature of about 250 °F in 117 °F air.

	air temp T_∞ =81 (°F)		air temp T_∞= 99(°F)		air temp T_∞ =117 (°F)	
surface temp	ΔT	h	ΔT	h	ΔT	h
T_w °F	°F	BTU/hr /in² °F	°F	BTU/hr /in² °F	°F	BTU/hr /in² °F
100	19	3.674e-03	1	1.402e-03		
120	39	4.613e-03	21	3.610e-03	3	1.877e-03
140	59	5.263e-03	41	4.462e-03	23	3.545e-03
160	79	5.776e-03	61	5.062e-03	43	4.321e-03
180	99	6.208e-03	81	5.541e-03	63	4.878e-03
200	119	6.585e-03	101	5.945e-03	83	5.325e-03
220	139	6.921e-03	121	6.299e-03	103	5.705e-03
240	159	7.225e-03	141	6.615e-03	123	6.038e-03
260	179	7.505e-03	161	6.902e-03	143	6.336e-03
280	199	7.765e-03	181	7.166e-03	163	6.607e-03
300	219	8.008e-03	201	7.411e-03	183	6.856e-03
320	239	8.236e-03	221	7.640e-03	203	7.088e-03
340	259	8.452e-03	241	7.856e-03	223	7.305e-03

ENGINEERING EVALUATION

SUBJECT Convection and Radiation Calcs PAGE 2 of 9
ORIGINATOR Wm. W. Smyth WWS DATE 4/10/97
CHECKER J. S. Boettger JSB DATE ~~6/23/91~~ 7/1/97

	air temp T_∞ =81 (°F)		air temp T_∞= 99(°F)		air temp T_∞ =117 (°F)	
surface temp	ΔT	h	ΔT	h	ΔT	h
T_w °F	°F	BTU/hr /in² °F	°F	BTU/hr /in² °F	°F	BTU/hr /in² °F
360	279	8.656e-03	261	8.060e-03	243	7.509e-03
380	299	8.851e-03	281	8.253e-03	263	7.702e-03
400	319	9.038e-03	301	8.438e-03	283	7.886e-03
420	339	9.217e-03	321	8.614e-03	303	8.061e-03
440	359	9.388e-03	341	8.783e-03	323	8.228e-03
460	379	9.554e-03	361	8.946e-03	343	8.389e-03
480	399	9.714e-03	381	9.103e-03	363	8.543e-03
500	419	9.868e-03	401	9.254e-03	383	8.692e-03



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SUBJECT	Convection and Radiation Calcs	PAGE	3 of 9
ORIGINATOR	Wm. W. Smyth WWS	DATE	4/10/97
CHECKER	J. S. Boettger JSB	DATE	~~6/31/91~~ WWS 7/1/97

IV. Evaluation:

Calculate the free convection rate for a 1.12 m (44") horizontal cylinder, in air, using the properties and methods from White's text. In the following table, K and Pr are interpolated linearly and Gr is interpolated as a function of T^5: White provides values every 50 °K. Curves follow this table to show the reasonablness of the interpolations. The tables that follow use Pr, K, and Gr to calculate h.

air Temp		K W/m*K	Pr	$g\beta/\nu^2$ = Gr/(D3*ΔT)	Gr/ΔT
°K	°F				
200	-99	1.81e-02	0.740	8.57e+08	1.20e+09
210	-81	1.89e-02	0.737	6.78e+08	9.53e+08
220	-63	1.98e-02	0.734	5.44e+08	7.64e+08
230	-45	2.06e-02	0.730	4.42e+08	6.21e+08
240	-27	2.15e-02	0.727	3.63e+08	5.10e+08
250	-9	2.23e-02	0.724	3.02e+08	4.24e+08
260	9	2.31e-02	0.722	2.52e+08	3.54e+08
270	27	2.38e-02	0.719	2.12e+08	2.97e+08
280	45	2.46e-02	0.717	1.80e+08	2.53e+08
290	63	2.53e-02	0.714	1.54e+08	2.16e+08
300	81	2.61e-02	0.712	1.33e+08	1.87e+08
310	99	2.68e-02	0.711	1.14e+08	1.60e+08
320	117	2.75e-02	0.710	9.86e+07	1.39e+08
330	135	2.83e-02	0.708	8.57e+07	1.20e+08
340	153	2.90e-02	0.707	7.50e+07	1.05e+08
350	171	2.97e-02	0.706	6.60e+07	9.27e+07
360	189	3.04e-02	0.705	5.80e+07	8.15e+07
370	207	3.11e-02	0.705	5.12e+07	7.19e+07

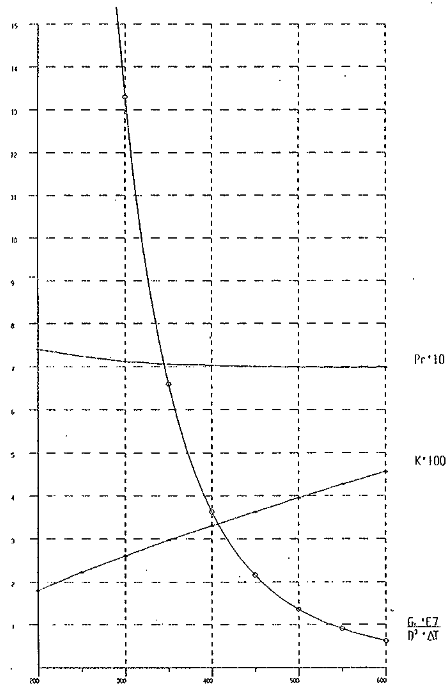
ENGINEERING EVALUATION

SUBJECT Convection and Radiation Calcs PAGE 4 of 9
ORIGINATOR Wm. W. Smyth WS DATE 4/10/97
CHECKER J. S. Boettger JSB DATE ~~6/31/91~~ 7/1/97 WWS

air Temp		K W/m*K	Pr	$g\beta/\nu^2$ = Gr/(D3*ΔT)	Gr/ΔT
°K	°F				
380	225	3.17e-02	0.704	4.54e+07	6.38e+07
390	243	3.24e-02	0.704	4.05e+07	5.69e+07
400	261	3.31e-02	0.703	3.63e+07	5.10e+07
410	279	3.37e-02	0.702	3.25e+07	4.56e+07
420	297	3.44e-02	0.702	2.92e+07	4.10e+07
430	315	3.50e-02	0.701	2.63e+07	3.69e+07
440	333	3.57e-02	0.701	2.38e+07	3.34e+07
450	351	3.63e-02	0.700	2.16e+07	3.03e+07
460	369	3.69e-02	0.700	1.96e+07	2.75e+07
470	387	3.76e-02	0.700	1.78e+07	2.50e+07
480	405	3.82e-02	0.699	1.62e+07	2.28e+07
490	423	3.89e-02	0.699	1.48e+07	2.08e+07
500	441	3.95e-02	0.699	1.36e+07	1.91e+07

ENGINEERING EVALUATION

SUBJECT	Convection and Radiation Calcs	PAGE	5 of 9
ORIGINATOR	Wm. W. Smyth WWS	DATE	4/10/97
CHECKER	J. S. Boettger JSB	DATE	~~6/31/91~~ 7/1/97 ws



ENGINEERING EVALUATION

SUBJECT	Convection and Radiation Calcs	PAGE	6 of 9
ORIGINATOR	Wm. W. Smyth	DATE	4/10/97
CHECKER	J. S. Boettger	DATE	~~6/31/91~~ 7/1/97

Using White's methodology (chapter 7) and material properties, find the convection coefficient at various air temperatures and temperature differences.

q is the heat transfer rate over A
A is the wall area
T_w = the wall temperature
T_∞ = the environment temperature.
k = conductivity of air, W/m-K

$$q = A \cdot h \cdot (Tw - T_\infty)$$

$$h = \frac{k \cdot N_u}{D}$$

$$\sqrt{N_u} = .6 + \frac{0.387 R_{aD}^{1/6}}{[1+(.\frac{559}{P_r})^{9/16}]^{8/27}}$$

$$R_{aD} = G_{rD} \cdot P_r$$

N_u = Nusselt Number
R_{aD} = Rayleigh number for cylinder

The following tables were generated by a spreadsheet. The air temperature is taken from the data in the tables above, since they are convenient. The Grashoff number

air temp, T_w, (°F) = 81							
surface temp	ΔT	ΔT	G_{rD}	Ra	N_{uD}	h	h
T_w °F	°F	°C				W/m^2-°C	BTU/hr/in²°F
100	19	10.6	1.97e+09	1.40e+09	128.90	3.00	0.0037
120	39	21.7	4.05e+09	2.88e+09	161.87	3.77	0.0046
140	59	32.8	6.12e+09	4.36e+09	184.66	4.30	0.0053
160	79	43.9	8.20e+09	5.84e+09	202.67	4.72	0.0058
180	99	55.0	1.03e+10	7.32e+09	217.83	5.08	0.0062

ENGINEERING EVALUATION

SUBJECT Convection and Radiation Calcs — PAGE 7 of 9
ORIGINATOR Wm. W. Smyth — DATE 4/10/97
CHECKER J. S. Boettger — DATE ~~6/31/91~~ 7/1/97

air temp, T_w, (°F) = 81							
surface temp	ΔT	ΔT	G_{rD}	Ra	N_{uD}	h	h
T_w °F	°F	°C				W/m^2-°C	BTU/hr/in²°F
200	119	66.1	1.24e+10	8.80e+09	231.04	5.38	0.0066
220	139	77.2	1.44e+10	1.03e+10	242.83	5.66	6.92e-03
240	159	88.3	1.65e+10	1.18e+10	253.52	5.91	7.23e-03
260	179	99.4	1.86e+10	1.32e+10	263.35	6.14	7.51e-03
280	199	110.6	2.07e+10	1.47e+10	272.46	6.35	7.77e-03
300	219	121.7	2.27e+10	1.62e+10	280.97	6.55	8.01e-03
320	239	132.8	2.48e+10	1.77e+10	288.98	6.73	8.24e-03
340	259	143.9	2.69e+10	1.91e+10	296.55	6.91	8.45e-03
360	279	155.0	2.90e+10	2.06e+10	303.73	7.08	8.66e-03
380	299	166.1	3.10e+10	2.21e+10	310.57	7.24	8.85e-03
400	319	177.2	3.31e+10	2.36e+10	317.12	7.39	9.04e-03
420	339	188.3	3.52e+10	2.51e+10	323.39	7.54	9.22e-03
440	359	199.4	3.73e+10	2.65e+10	329.42	7.68	9.39e-03
460	379	210.6	3.93e+10	2.80e+10	335.23	7.81	9.55e-03
480	399	221.7	4.14e+10	2.95e+10	340.83	7.94	9.71e-03
500	419	232.8	4.35e+10	3.10e+10	346.25	8.07	9.87e-03

air temp, T_w, (°F) = 99							
surface temp	ΔT	ΔT				h	h
T_w °F	°F	°C	G_{rD}	Ra	N_{uD}	W/m²°C	BTU/hr/in²°F
100	1	0.6	8.91e+07	6.33e+07	49.21	1.15	1.40e-03
120	21	11.7	1.87e+09	1.33e+09	126.67	2.95	3.61e-03
140	41	22.8	3.65e+09	2.60e+09	156.55	3.65	4.46e-03
160	61	33.9	5.43e+09	3.86e+09	177.62	4.14	5.06e-03
180	81	45.0	7.22e+09	5.13e+09	194.42	4.53	5.54e-03
200	101	56.1	9.00e+09	6.40e+09	208.61	4.86	5.95e-03
220	121	67.2	1.08e+10	7.66e+09	221.01	5.15	6.30e-03

ENGINEERING EVALUATION

SUBJECT Convection and Radiation Calcs
ORIGINATOR Wm. W. Smyth
CHECKER J. S. Boettger

PAGE 8 of 9
DATE 4/10/97
DATE ~~6/31/91~~ 7/1/97

air temp, T_v, (°F) = 99							
surface temp	ΔT	ΔT				h	h
T_w °F	°F	°C	G_{rD}	Ra	N_{uD}	W/m²°C	BTU/hr/ in²°F
240	141	78.3	1.26e+10	8.93e+09	232.10	5.41	6.61e-03
260	161	89.4	1.43e+10	1.02e+10	242.17	5.64	6.90e-03
280	181	100.6	1.61e+10	1.15e+10	251.44	5.86	7.17e-03
300	201	111.7	1.79e+10	1.27e+10	260.04	6.06	7.41e-03
320	221	122.8	1.97e+10	1.40e+10	268.08	6.25	7.64e-03
340	241	133.9	2.15e+10	1.53e+10	275.64	6.42	7.86e-03
360	261	145.0	2.33e+10	1.65e+10	282.79	6.59	8.06e-03
380	281	156.1	2.50e+10	1.78e+10	289.59	6.75	8.25e-03
400	301	167.2	2.68e+10	1.91e+10	296.06	6.90	8.44e-03
420	321	178.3	2.86e+10	2.03e+10	302.25	7.04	8.61e-03
440	341	189.4	3.04e+10	2.16e+10	308.19	7.18	8.78e-03
460	361	200.6	3.22e+10	2.29e+10	313.90	7.32	8.95e-03
480	381	211.7	3.39e+10	2.41e+10	319.40	7.44	9.10e-03
500	401	222.8	3.57e+10	2.54e+10	324.71	7.57	9.25e-03

air temp (°F) = 117							
surface temp	ΔT	ΔT	Gr_D	Rad	Nud	h	h
T_w°F	°F	°C				W/m²-°C	BTU/hr/ in²°F
120	3	1.7	2.31e+08	1.64e+08	65.85	1.53	1.877e-03
140	41	22.8	3.16e+09	2.24e+09	149.33	3.48	4.256e-03
160	61	33.9	4.70e+09	3.33e+09	169.41	3.95	4.828e-03
180	81	45.0	6.23e+09	4.42e+09	185.41	4.32	5.284e-03
200	101	56.1	7.77e+09	5.52e+09	198.93	4.64	5.669e-03
220	121	67.2	9.31e+09	6.61e+09	210.74	4.91	6.006e-03
240	141	78.3	1.09e+10	7.70e+09	221.31	5.16	6.307e-03
260	161	89.4	1.24e+10	8.79e+09	230.90	5.38	6.581e-03
280	181	100.6	1.39e+10	9.89e+09	239.73	5.59	6.832e-03

HQJLQHHULQJ#HYDOXDWLRQ

SUBJECT Convection and Radiation Calcs PAGE 9 of 9
ORIGINATOR Wm. W. Smyth DATE 4/10/97
CHECKER J. S. Boettger DATE ~~6/31/97~~ 7/1/97

air temp (°F) = 117							
surface temp	ΔT	ΔT	Gr_D	Rad	Nud	h	h
T_w°F	°F	°C				W/m²-°C	BTU/hr/in²°F
300	201	111.7	1.55e+10	1.10e+10	247.92	5.78	7.066e-03
320	221	122.8	1.70e+10	1.21e+10	255.58	5.96	7.284e-03
340	241	133.9	1.85e+10	1.32e+10	262.78	6.12	7.489e-03
360	261	145.0	2.01e+10	1.43e+10	269.59	6.28	7.683e-03
380	281	156.1	2.16e+10	1.53e+10	276.06	6.43	7.868e-03
400	301	167.2	2.32e+10	1.64e+10	282.23	6.58	8.044e-03
420	321	178.3	2.47e+10	1.75e+10	288.13	6.71	8.212e-03
440	341	189.4	2.62e+10	1.86e+10	293.78	6.85	8.373e-03
460	361	200.6	2.78e+10	1.97e+10	299.22	6.97	8.528e-03
480	381	211.7	2.93e+10	2.08e+10	304.46	7.10	8.677e-03
500	401	222.8	3.09e+10	2.19e+10	309.52	7.21	8.821e-03
520	421	233.9	3.24e+10	2.30e+10	314.40	7.33	8.961e-03

Note that the SARP's convection coefficient of 5 W/m² K requires a surface temperature of about 230 °F when the air temperature is 117 °F and 210 in 100 °F air. This is approximately what is found for the analysis results, but a variable convection rate was used in the SEP analysis based on the results for 117°F air.

8.8.3 Capsule Arrangement in Cask

ENGINEERING SAFETY EVALUATION

Subject	CAPSULE ARRANGEMENT FOR 16 CsCl CAPSULES IN BUSS	Page	1 of 1
Originator	Wm. W. SMYTH *WWS*	Date	4/11/97
Checker	J. S. Boettger *J Boettger*	Date	7/1/97

I. **Objective:** Determine the best capsule arrangement in the BUSS to minimize the average temperate in a 45° segment. This will be the temperature used in the thermal analysis, and the arrangement will be controlled in the operations section.

II. **References:**

III. **Results and Conclusions:** The maximum average is 193.4 W per segment. This will require administrative controls to assure this is not exceeded.

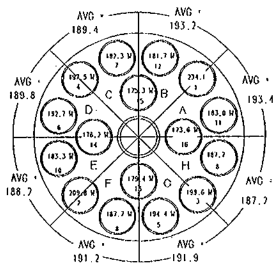
IV. **Evaluation:**

AVERAGE THERMAL POWER IN OCTANT A:

$$\frac{\frac{234.1+173.6}{2}+183.0}{2}=193.4$$

AVERAGE THERMAL POWER IN OCTANT B:

$$\frac{\frac{234.1+175.3}{2}+181.7}{2}=193.2$$



8.8.4 Finite Element Analysis of SARP Configuration

```
*--------------------------------------------------------------------------*
|                                                                          |
|         W E L C O M E   T O   T H E   A N S Y S   P R O G R A M          |
|                                                                          |
*--------------------------------------------------------------------------*



      *****  ANSYS COMMAND LINE ARGUMENTS  *****
 BATCH MODE REQUESTED


      *****  ANSYS DYNAMIC MEMORY ALLOCATION  *****
 WORK SPACE REQUESTED               =    8388608       32.000  MB  DEFAULT
 MINIMUM WORK SPACE REQUIRED        =    4718592       18.000  MB
 MINIMUM WORK SPACE RECOMMENDED     =    6702496       25.568  MB
 WORK SPACE OBTAINED                =    8388606       32.000  MB
 BYTES PER WORD                     =          4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   RESULTS SHOULD BE IMMEDIATELY BROUGHT TO OUR ATTENTION.


 ENTER  /SHOW,device TO SET THE GRAPHICS DISPLAY TO device(e.g. VGA,HALO,ETC.)
 ENTER  /MENU,ON     TO START THE ANSYS MENU SYSTEM
 ENTER  HELP         FOR GENERAL ANSYS HELP INFORMATION
        /file, b0
        /show, b0,grp
        /PREP7
        /com
        /com  16 capsules in solid basket - try to match SARP analysis
        /com
        /com  adjust the capsule length and fin convection factor to match these:
        /com
```

```
/com      CsCl     inner      outer    basket   cask inner   cask outer
/com       max    capsule    capsule   max        temp          temp
/com      820 °F    778        699     673        396           284
/com     from SARP p 3-3, 16 capsules @ 250 W
/com
mp, dens, 1, .2854  * 18-8 stainless steel,  lbf/cu
mp, dens, 2, .1627*.062428  *  Helium @ 81°F
mp, dens, 3, .0939   * CsCl
mp, dens, 4, 1.177*.1627 * air @ 81°F
rad1 = 2.250/2  * outer radius, inner capsule
thk1 = (2.250 - 1.978)/2
rad2 = 2.625/2  * outer radius, outer capsule
/com  thk2 =  (2.625-2.353)/2 * per dwg
thk2 =  (2.625-2.402)/2 * per SARP  p 3-11
rad3 =  1.437     * basket radius
thk3 = 0
/com  ********************************************
/com    250 W per capsule.
/com    capsule len 19 in, rad 1.978, volume 58.38 cu.in.
/com    specific power W/58.30 * 3.412 Btu/hr/W = 13.4
/com    but adjust length to match SARP results ( 16 found to work)
/com  ********************************************
pwr = 2*250*3.412/16   * Btu/hr-in of 2 CsCl capsules
pc = 0.50  * % power absorbed in CsCl per SARP
pcp = 0.13 * % in capsule steel
pcb = .3   * % in basket
pcsk =  .07  * % in cask
hf =  5.0  *(W) convection film constant, horiz cyl in air (5 in SARP)
etemp = 100  *  match SARP envirnmental temp
cv = hf*4.7*.1761/144   * 4.7 factor for fins from SARP
/com   mat 1 = stainles steel
/com   mat 2 = He
/com   mat 3 = CsCl
/com   mat 4 = air
/com   mat 5 = dummy surface material
mp, c, 1, 460*2.39e-4
mp, c, 2, 5197*2.39e-4
mp, C, 3, 8400*2.39E-4
mp, C, 4, 1020*2.39E-4
mp, emis, 4, 0.5
mp, kxx,3, .45*.578/12
mp, emis, 1, 0.5
mp, dens,5,.001
mp,emis,5,  0.5
MPTEMP,1,  100, 200, 300, 400, 500, 600 * 18-8 stainless
MPTEMP,7,  700,800
MPDATA,ALPX,1,1,   8.63e-6,  9.08e-6,  9.46e-6,  9.80e-6,  10.10e-6, 10.38e-6
MPDATA,ALPX,1,7, 10.60e-6, 10.79e-6
mpdata, kxx,1,1,  0.73, 0.78, 0.82, 0.87, 0.91,  0.94
mpdata, kxx,1,7,  0.98, 1.02
mptemp,1,  81, 171, 261, 351, 441, 531
mptemp,7, 621, 801
mpdata, kxx, 2, 1, 0.00722, 0.00794, 0.00867, 0.00939, 0.0102, 0.0110
mpdata, kxx, 2, 7, 0.0119,  0.0134
```

```
mpdata, kxx, 4, 1, 0.00126, 0.00143, 0.00159, 0.00175, 0.0019, 0.0021
mpdata, kxx, 4, 7, 0.0022,  0.0025
MPLIST,ALL
csys, 1
/triad,off
k,1
k,2, 9.975,0
k, 3, 10.125,0  * inner cask wall
k, 4, 22.125,0  * outer cask wall
KGEN,2,2,4,,,45 * k 5,6,7
a,1,2,5  * basket
a, 2,3,6,5  * He, basket-cask
a,3,4,7,6   * Al, cask wall
CLOCAL,11,1,3.75,0,,0  * start first capsule
k     * center, k8
k,, rad1-thk1 * k9
k,, rad1      * k10
k,, rad2-thk2  * k11
k,, rad2      * k12
k,, rad3  * k13
KGEN,2,9,13,,,90
a,8,9,14
a,9,10,15,14
a,10,11,16,15
a,11,12,17,16
a,12,13,18,17
AGEN,2,4,8,,,90
NUMmrg,ALL
NUMcmp,ALL
csys,1
CLOCAL,12,1,7.625,15,,0  * start capsule # 2
k     * center, k24
k,, rad1-thk1 * k25
k,, rad1      * k26
k,, rad2-thk2  * k27
k,, rad2      * k28
k,, rad3  * k29
KGEN,2,24,29,,,90
A, 24, 25,  31
A,25,26,32,31
A, 26, 27, 33, 32
A, 27, 28, 34, 33
A, 28, 29, 35, 34
AGEN,4,14,18,,,90
nummrg,all
numcmp,all
csys,1
CLOCAL,13,1,7.625,45
k           * k 45
k,, rad1-thk1 * k46
k,, rad1      * k47
k,, rad2-thk2  * k48
k,, rad2      * k49
k,, rad3  * k50
```

```
KGEN,2,46,50,,,-90
a,45,51,46
a,51,52,47,46
a,52,53,48,47
a,53,54,49,48
a,54,55,50,49
AGEN,2,34,38,,,-90
nummrg,all
numcmp,all
asel,u,area,,2,3
aovl,all
/pnum,mat,1
aplot
/pnum,mat,0
/pnum,area,1
aplot
et,1,plane55,1  * mesh the plane elements -
asel,s,area,,4,9,5  * CsCl
asel,a,area,,14,29,5
asel,a,area,,34,39,5
aatt,3,,1
ndiv = 12
eshape,2
ESIZE,,ndiv
amesh,all   * CsCl
asel,s,area,,5,10,5  * SS
asel,a,area,,15,30,5
asel,a,area,,35,40,5
AATT,1,,1
ESIZE,,2
amesh,all
asel,s,area,,6,11,5   * air
asel,a,area,,16,31,5
asel,a,area,,36,41,5
AATT,4,,1
ESIZE,,3
amesh,all
asel,s,area,,7,12,5   * SS
asel,a,area,,17,32,5
asel,a,area,,37,42,5
AATT,1,,1
ESIZE,,2
amesh,all
asel,s,area,,8,13,5   * He
asel,a,area,,18,33,5
asel,a,area,,38,43,5
AATT,2,,1
ESIZE,,3
amesh,all
asel,s,area,,3  * cask
cdiv = 12
esize,,cdiv
aatt,1, ,1
amesh,all
```

```
asel,s,area,,2  * cask-basket gap
esize,,2
aatt,2,,1
amesh,all
asel,s,area,,44 * mesh basket
aatt,1,,1
pi = 3.14159
s = rad3*pi/2/cdiv  * match mesh at He gap
esize,s
eshap,0
amesh,all
/pnum,mat,1
eplot
csys,1
N,,40,22.5 * atmosphere radiation node
*GET,nmax,NODE,,num,MAX
ET,2,surf19,1, , ,1,1   * exterior surface, xtra node, no mid-side node
KEYOPT,2,8,2            * hf calc at avg temp
KEYOPT,2,9,1           * form factor from reals
r,3,1,,4               * form fact = 1, 2nd mat = 4, unit thick
csys,1
kpsel,s,loc,x,22.125
LSLK,s,1
TYPE,2
MAT, 5
REAL, 3
lmesh,all
esel,s,type,,2
EMODIF,ALL,-3,nmax
esel, all
kpsel,all
lsel,all
asel,s,mat,,3
ASUM
*GET,Acap,AREA,0,area  * total capsule area
asel,s,area,,44
asum
*GET,Abas,AREA,0,area  * total basket steel area
asel,s,area,,3
asum
*GET,Acsk,AREA,0,area  * total cask area
asel,s,area,,5,40,5
asel,a,area,,7,42,5
asum
*GET,Acpp,AREA,0,area  * total ss area in capsule
asel,all
et,3,link31   * radiation links between elements of concentric cylinders
type, 3
mat, 1
csys,1
nsel,s,loc,x,9.975
nsel,a,loc,x,10.125 * radiation between basket and cask
ar1 = 10*pi/4/cdiv * radiating area of 1 element
R,1,ar1,1,-1, 11.89e-12
```

```
real,1
:GLink1
*GET,n1,NODE,,num,Min
*GET,y1,node,n1,LOC,y
n2 = node(9.975,y1,0)
e,n1,n2
nsel,u,node,,n1
nsel,u,node,,n2
*GET,n,NODE,,count
*IF,n,ne,0,:GLink1
ar4 = rad1*pi/2/ndiv
R,4,ar4,1,-1, 11.89e-12         * area of unit height of cylindrical capsule
ar5 = rad2*pi/2/ndiv
R,5,ar5,1,-1, 11.89e-12
*use,rlink,11  * radiation links between capsule layers, using
*use,rlink,12  *   the coordinate system as the parameter
*use,rlink,13
list, rlink
esel,all
nsel,all
*stat
rlist
csys,1
WSORT,x * reduce the problem size
fini
/SOLU
*stat
D,nmax,TEMP,100   * SARP environmental temp.
ANTYPE,STAT
TOFFST,460  * work in °R
TUNIF,70
CNVTOL,HEAT
esel,s,mat,,3  * apply heat generation to CsCl
BFE,ALL,HGEN,,pc*pwr/acap
asel,s,area,,44
esla,s
BFE,ALL,HGEN,,pcb*pwr/abas * heat generation rate within basket
asel,s,area,,5,40,5
asel,a,area,,7,42,5
esla,s
BFE,ALL,HGEN,,pcp*pwr/acpp * heat generation rate within capsule steel
asel,s,area,,3
esla,s
BFE,ALL,HGEN,,pcp*pcsk/acsk * heat generation rate within cask
esel,s,mat,,5  * insolation on surface elements
insl = 400 * g-cal insolation per sq cm over 12 hr
insl = insl/252/12 * Btu/hr per sq cm
BFE,all,HGEN,,insl/.394/.394 * heat gen per cubic inch
csys,1
LSEL,s,LOC,X,22.125
SFL,all,CONV,cv,,etemp
nsel,all
esel,all
lsel,all
```

```
asel,all
kpsel,all
*stat
save
solve
fini
/post1
set,last
esel,s,mat,,3  * CsCl capsules
/title,  CsCl capsule mat'l
nsle,s
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, inner SS capsule
csys,11
nsel,s,loc,x,rad1-thk1-.01, rad1+.01
csys,12
NSEL,a,LOC,x,rad1-thk1-.01,rad1+.01
csys,13
NSEL,a,LOC,x,rad1-thk1-.01,rad1+.01
esln,s
esel,r,type,,1
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min


/title, outer SS capsule
csys,11
nsel,s,loc,x,rad2-thk2-.01, rad2+.01
csys,12
NSEL,a,LOC,x,rad2-thk2-.01,rad2+.01
csys,13
NSEL,a,LOC,x,rad2-thk2-.01,rad2+.01
esln,s
esel,r,type,,1
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, basket
asel,s,area,,44 * basket
esla,s
nsle,s
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, inner cask wall
```

```
csys,1
nsel,s,loc,x,10.125
esln,s
esel,a,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, outer cask wall
nsel,s,loc,x,22.125
esln,s
esel,a,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
fini
/exit

```

CURRENT JOBNAME REDEFINED AS b0

/SHOW SWITCH PLOTS TO FILE B0.grp - RASTER MODE.

8.8.5 Finite Element Analysis of 16 Overpacked Capsules in an Open Basket

```
Running ANSYS 5.2 on workstation: sgi3   on: Thu Jul 10 09:04:04 PDT 1997
 ANSYS 5.2 has been verified by ICF KH
 Class 3 Error Reports are in the directory: /apps/ansys/class3_errors.
Executing /apps/ansys/sgi/ansys52/bin/ansys.e52


*---------------------------------------------------------------------------*
|                                                                           |
|          W E L C O M E   T O   T H E   A N S Y S   P R O G R A M          |
|                                                                           |
*---------------------------------------------------------------------------*
```

AFTER YOU HAVE READ AND UNDERSTOOD THE PREVIOUS DISCLAIMER,
PRESS <CR> OR <ENTER> TO CONTINUE

```
        *****  ANSYS COMMAND LINE ARGUMENTS  *****
 NONE

*** NOTE ***                            CP=       3.680   TIME= 09:04:14
There are no parameters and no abbreviations defined.

32207            VERSION=SGI IRIS4D     REVISION= 5.2
FOR SUPPORT CALL K McMillian 373-  PHONE JLR 206-353-8089  FAX FAX 509-373-6975
CURRENT JOBNAME=file  09:04:14  JUL 10, 1997 CP=      3.690


RUN SETUP PROCEDURE FROM FILE= /apps/ansys/sgi/ansys52/docu/start.ans


/INPUT FILE= /apps/ansys/sgi/ansys52/docu/start.ans  LINE=       0
```

```
BEGIN:
/BATCH,list
/file, b16a
/show, b16, g
/TYPE,ALL,hidp
/PREP7
/com
/com  STATIC ANALYSIS
/com  16 capsules in overpacks,  no basket
/com  CsCl temp limit is 842 °F at ss interface
/com  CsCl melt temp 1195 °F
/com  phase change between 350 - 470 °C = 662 - 878 °F
/com test temperature 800 °C = 1472 °F
/com  model 45° arc containing 1 complete + 2 half capsules
/com
mp, dens, 1, .2854  * 18-8 stainless steel,  lbf/cu in
mp, dens, 2, .1627*.062428/1728  *  Helium @ 81°F
mp, dens, 3, .0939   * CsCl
mp, dens, 4, 1.177*.1627/1728 * air @ 81°F
rad1 = 2.250/2  * outer radius, inner capsule
thk1 = (2.250 - 1.978)/2  * thickness of inner capsule
rad2 = 2.625/2  * outer radius, outer capsule
/com  thk2 =  (2.625-2.353)/2 * per dwg
thk2 =  (2.625-2.402)/2 * per SARP  p 3-11, thinner
rad3 =  1.625    * outer radius, type W overpack
thk3 = 0.125    * W overpack nominal thickness
/com  thk3 = .11    * thinnest overpack
rad4 = 2.0     * 3.5 in pipe central support
thk4 = 0.226  * schd 40  central support thickness
rad5 = 4.25   * radius of inner row of capsules
rad6 = 7.88   * radius of outer row of capsules
/com  rad5 = 4.0   * radius of inner row of capsules  * parametric variation
/com  rad6 = 7.63   * radius of outer row of capsules * parametric variation
ang1 = 15  * angular spacing in outer row
/com  W = 205  * watts per capsule
W = 195   * watts per capsule
NC = 2  * capsules per model
pwr = NC*W*3.412/16   * Btu/hr-in of #NC capsules per inch length
/com   power per cu in will be calculated using power/total CsCl area
pc = 0.50  * % in CsCl, increase slightly from SARP 0.48
pcp = 0.2 * % in capsule steel & overpack
/com try parametric variation:
/com  pc = .37   * based on shielding calc
/com  pcp = .24
pcsk = 1-pc-pcp  * % in cask
fn = 4.7  * fin factor, multiplies cylinder convection film constant
/com  fn = 2.35 * parametric variation
/com  vfac = 1   * radiation view factor for external surface
vfac = 1.5      * per SARP, due to fins
/com  ****  use temperature table for convection film coefficient
/com  hf =  5.0  * (W) convection film constant, horiz cyl in air (in SARP)
/com  cv = hf*fn*.1761/144   * convection rate including fins
/com  ******  see hf material property for air
etemp = 115   * max Hanford day avg = 94
```

```
/com   ** if etemp changes, you must also change hf table for air
/com  insl = 400 * g-cal insolation per sq cm over 12 hr
/com  insl = insl*2.54*2.54/252/12 * Btu/hr per sq in
insl = 100 * BTU/hr per sq. ft - Hanford value for flat surface (use 100)
insl = 0.5*insl/144  * BTU/hr per sq in for cylinder
/com  emss = 0.5   * stainless steel emissivity
emss = 0.3   * stainless steel emissivity
/com   mat 1 = stainles steel
mp, c, 1, 460*2.39e-4
mp, emis, 1, emss
MPTEMP,1,  100, 200, 300, 400, 500, 600 * 18-8 stainless
MPTEMP,7,  700,800
MPDATA,ALPX,1,1,   8.63e-6,  9.08e-6,  9.46e-6,  9.80e-6,  10.10e-6, 10.38e-6
MPDATA,ALPX,1,7, 10.60e-6, 10.79e-6
mpdata, kxx,1,1,  0.73, 0.78, 0.82, 0.87, 0.91,  0.94
mpdata, kxx,1,7,  0.98, 1.02
/com   mat 2 = He
mp, c, 2, 5197*2.39e-4
mptemp,1,  81, 171, 261, 351, 441, 531
mptemp,7, 621, 801
mpdata, kxx, 2, 1, 0.00722, 0.00794, 0.00867, 0.00939, 0.0102, 0.0110
mpdata, kxx, 2, 7, 0.0119,  0.0134
/com   mat 3 = CsCl
mp, C, 3, 8400*2.39E-4
mp, kxx,3, .45*.578/12
/com   mat 4 = air
mp, C, 4, 1020*2.39E-4
mp, emis, 4, emss
mptemp,1,  81, 171, 261, 351, 441, 531
mptemp,7, 621, 801
mpdata, kxx, 4, 1, 0.00126, 0.00143, 0.00159, 0.00175, 0.0019, 0.0021
mpdata, kxx, 4, 7, 0.0022,  0.0025
/com    ******* convection film coef, 44" cyl in 99 °F air
/com  mptgen,1, 20, 100, 20
/com  mpdata,hf,4,1,  fn*3.674E-03,fn*4.613E-03,fn*5.263E-03,fn*5.776E-03,fn*6.20
/com  mpdata,hf,4,6,  fn*6.585E-03,fn*6.921E-03,fn*7.225E-03,fn*7.505E-03,fn*7.76
/com  mpdata,hf,4,11,fn*8.008E-03,fn*8.236E-03,fn*8.452E-03,fn*8.656E-03,fn*8.85
/com  mpdata,hf,4,16,fn*9.038E-03,fn*9.217E-03,fn*9.388E-03,fn*9.554E-03,fn*9.71
/com  *******   convection film coef, 44" cyl in 99 °F air
/com  mptgen,1, 20, 100, 20
/com  mpdata,hf,4,1,  fn*1.402E-03,fn*3.610E-03,fn*4.462E-03,fn*5.062E-03,fn*5.54
/com  mpdata,hf,4,6,  fn*5.945E-03,fn*6.299E-03,fn*6.615E-03,fn*6.902E-03,fn*7.16
/com  mpdata,hf,4,11,fn*7.411E-03,fn*7.640E-03,fn*7.856E-03,fn*8.060E-03,fn*8.25
/com  mpdata,hf,4,16,fn*8.438E-03,fn*8.614E-03,fn*8.783E-03,fn*8.946E-03,fn*9.10
/com   *******   convection film coef, 44" cyl in 117 °F air
mptgen,1, 20, 120, 20
mpdata,hf,4,1,  fn*1.877E-03,fn*3.545E-03,fn*4.321E-03,fn*4.878E-03,fn*5.325E-03
mpdata,hf,4,6,  fn*5.705E-03,fn*6.038E-03,fn*6.336E-03,fn*6.607E-03,fn*6.856E-03
mpdata,hf,4,11,fn*7.088E-03,fn*7.305E-03,fn*7.509E-03,fn*7.702E-03,fn*7.886E-03
mpdata,hf,4,16,fn*8.061E-03,fn*8.228E-03,fn*8.389E-03,fn*8.543E-03,fn*8.692E-03
MPLIST,ALL
csys, 1
/triad,off
k, 1
```

```
k, 2, 10.125,0  * inner cask wall
k, 3, 22.125,0  * outer cask wall
KGEN,2,2,3,,,45 * k 4,5
a,1,2,4  * A1  He fill
a,2,3,5,4   * A2, cask wall
CLOCAL,11,1,rad5,,,0  * start first capsule   (half capsule)
k     * center, k6
k,, rad1-thk1 * k7
k,, rad1      * k8
k,, rad2-thk2  * k9
k,, rad2      * k10
k,, rad3-thk3  * k11
k,, rad3
KGEN,2,7,12,,,90
l, 6, 13      * make lesize work
A, 6, 7, 13
A, 7, 8, 14, 13
A, 8, 9, 15, 14
A, 9, 10, 16, 15
A, 10, 11, 17, 16
A, 11, 12, 18, 17
AGEN,2,3,8,,,90
NUMMRG,KP
NUMCMP,KP
csys,1
CLOCAL,12,1,rad6,ang1,,0  * start capsule # 2 (full capsule)
k     * center, k25
k,, rad1-thk1 * k26
k,, rad1      * k27
k,, rad2-thk2  * k28
k,, rad2      * k29
k,, rad3-thk3  * k30
k,, rad3    * k31
KGEN,2,26,31,,,90
l, 25, 32  * make lesize work for meshing
A, 25, 26, 32
A, 26, 27, 33, 32
A, 27, 28, 34, 33
A, 28, 29, 35, 34
A, 29, 30, 36, 35
a, 30, 31, 37, 36
AGEN,4,15,20,,,90
csys,1
CLOCAL,13,1,rad6,45,,0  * start capsule # 3   (half capsule)
k     * center, k77
k,, rad1-thk1 * k78
k,, rad1      * k79
k,, rad2-thk2  * k80
k,, rad2      * k81
k,, rad3-thk3  * k82
k,, rad3    * k83
KGEN,2,78,83,,,-90
l, 77,84
a, 77,78,84
```

```
a, 78,79,85,84
a, 79,80,86,85
a, 80,81,87,86
a, 81,82,88,87
a, 82,83,89,88
agen,2,39,44,,,-90
NUMMRG,KP
NUMCMP,KP
csys,1                * build in central support to see if
k,,2                 * it radiates some heat to the cask
k,,2-thk4             * inner wall
KGEN,2,69,70,,,45
a,70,69,71,72
asel,u,area,,2
boptn, keep,yes  * keep areas
aovl,all
adel, 1    *
asel,all
et,1,plane55  * mesh the plane elements
asel,s,area,,3,45,6  * CsCl
aatt,3,,1
/com  ndiv = 8  * max terr in He was .36
ndiv = 12 *  max terr in He is .08 with + 2° increase over ndiv = 8
eshape,2
ESIZE,,ndiv
csys,11
ksel,s,loc,x,0  * find center points of all capsules
csys,12
ksel,a,loc,x,0    * so we can put the right "space" on lines
lslk,s
csys,13
ksel,a,loc,x,0
lslk,s
LESIZE,ALL,,,ndiv,.2  * this makes areas larger towards center of capsules
lsel,all                  * and they grow larger towards outside of capsule
amesh,all          * CsCl
asel,s,area,,4,46,6  * inner capsule ss
AATT,1,,1
ESIZE,,2
amesh,all
asel,s,area,,5,47,6 * air gap
AATT,4,,1
ESIZE,,3
amesh,all
asel,s,area,,6,48,6 * outer capsule ss
AATT,1,,1
ESIZE,,2
amesh,all
asel,s,area,,7,49,6 * He filled gap
aatt,2,,1
ESIZE,,3
amesh,all
asel,s,area,,8,50,6 * overpack  SS
AATT,1,,1
```

```
ESIZE,,3
amesh,all
pi = 3.14159
s = rad3*pi/2/ndiv  * match mesh
asel,s,area,,2  * cask
esize,s*2
aatt,1, ,1
amesh,all
asel,s,area,,52 * inner helium fill space
idiv = 5
esize,,idiv
aatt,2,,1  * this is He in cask
/com  aatt,4,,1  * lets say He leaks out
eshape, 0
amesh,52
asel,s,area,,51 * inner support pipe
aatt,1,,1
esize,,2
eshape, 2
amesh,51
asel,s,area,,53 * He-filled cask
aatt,2,,1
/com  aatt,4,,1  * lets say He leaks out
eshape,0
esize, s/2   * this is a trial and error sort of thing
amesh,53
asel,all
csys,1
N,,40,15 * atmosphere radiation node
*GET,nmax,NODE,,num,MAX
ET,2,surf19,1, , ,0,1   * exterior surface, xtra node, mid-side node
KEYOPT,2,8,3            * hf calc at surface temp
KEYOPT,2,9,1           * form factor from reals
r,3,vfac,,4               * form fact = 1, 2nd mat = 4, unit thick
csys,1
nsel,s,loc,x,22.125
TYPE,2
MAT, 1
REAL, 3
esurf, nmax
esel, all
asel,s,mat,,3
ASUM
*GET,Acap,AREA,0,area  * total capsule area
/title, CsCl area = %Acap%
/pnum, area, 1
/number, 2
lsla,s
aplot                * plot 1
asel,s,area,,2
asum
*GET,Acsk,AREA,0,area  * total cask area
/title, cask area = %acsk%
lsla,s
```

```
aplot                * plot 2
asel,s,area,,4,50,2
asel,a,area,,51  * include support
asum
*GET,Acpp,AREA,0,area  * total ss area in capsule
/title, ss area = %acpp%
lsla,s
aplot                  * plot 3
asel,s,mat,,2
lsla,s
/title, He areas
aplot             * plot 4
asel,all
lsel,all
et,3,link31   * radiation links between elements of concentric cylinders
type, 3
mat, 1
ar4 = rad1*pi/2/ndiv
R,4,ar4,1,-1, 11.89e-12         * area of unit height of cylindrical capsule
ar5 = rad2*pi/2/ndiv
R,5,ar5,1,-1, 11.89e-12
*use,rlink,11
*use,rlink,12
*use,rlink, 13
*stat
rlist
et,4,link32  * computed radiation matrix uses link32's
csys,1
nsel,s,loc,x,10.125
nsel,a,loc,x,rad4
csys,11
nsel,a,loc,x,rad3
csys,12
nsel,a,loc,x,rad3
csys,13
nsel,a,loc,x,rad3
esel,s,type,,1
esel,r,mat,,1
esln,r
type,4
esurf
fini
/aux12
emis,emss
geom,1
vtype
mprint,1
write
fini
/prep7
nsel,all
esel,s,type,,4
edel,all
esel,all
```

```
et,5,matrix50,1
type,5
se
csys,1
WSORT,x
esel,s,type,,1  * lets plot the "area" elements
/title, area-type elements
nsle,s
eplot
esel,s,type,,2
esel,a,type,,3
csys,1
nsel,s,loc,x,0,24
eplot
esel,all
nsel,all
save
fini
/SOLU
antype, stat
autots,on
nsubst, 3, 10, 3
kbc, 0
outres,all,1
D,nmax,TEMP,etemp
TOFFST,460
tref, 70   * structure starts at tref
CNVTOL,HEAT
esel,s,type,,2   * convection bc
nsle,s
SF,all,CONV,-4
nsel,all
esel,s,mat,,3
p1= pc*pwr/acap
BFE,ALL,HGEN,,p1 * heat generation rate within CsCl
asel,s,area,,4,50,2
asel,a, area,,51
esla,s
p2 = pcp*pwr/acpp
BFE,ALL,HGEN,,p2 * heat generation rate within capsule steel
asel,s,area,,2
esla,s
p3 = pcsk*pwr/acsk
BFE,ALL,HGEN,,p3 * heat generation rate within cask steel
esel,s,type,,2  * insolation on surface elements
p4 = 52*insl*emss/(pi*22) * insolation on 1" len of cask
BFE,all,HGEN,,p4 * heat gen per cubic inch
esel,all
*stat
solve  * static soln
save
fini
/post1
/number,0
```

```
/pnum,area,0
csys,1
set,last
PRRSOL,HEAT
esel,s,mat,,2
nsle,s
/title, He
plns,temp
ples,terr  * plot thermal error
esel,s,mat,,1
esel,r,type,,1
nsle,s
/title, SS
plns,temp
ples,terr  * plot thermal error
esel,s,type,,2
etable, hf, nmisc, 5  * convection film
etable, tavg, nmisc, 6   * surface temp
etable, tblk, nmisc, 7  * bulk temp
ETABLE,vol,NMIS,15       * area (unit thick)
ETABLE,hgt,smisc,19     * heat gen rate
ETABLE,hc,SMIS,20   * convection heat flow rate over entire element
ETABLE,hr,SMIS,21   * radiation heat flow rate over entire element
pret
SSUM
/title,  CsCl capsule mat'l
esel,s,mat,,3  * CsCl capsules
nsle,s
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min

/title, inner SS capsule
csys,11
nsel,s,loc,x,rad1-thk1-.01, rad1+.01
csys,12
NSEL,a,LOC,x,rad1-thk1-.01,rad1+.01
csys,13
NSEL,a,LOC,x,rad1-thk1-.01,rad1+.01
esln,s
esel,r,type,,1
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, outer SS capsule
csys,11
nsel,s,loc,x,rad2-thk2-.01, rad2+.01
csys,12
NSEL,a,LOC,x,rad2-thk2-.01,rad2+.01
csys,13
NSEL,a,LOC,x,rad2-thk2-.01,rad2+.01
```

```
esln,s
esel,r,type,,1
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, SS overpack
csys,11
nsel,s,loc,x,rad3-thk3-.01, rad3+.01
csys,12
NSEL,a,LOC,x,rad3-thk3-.01,rad3+.01
csys,13
NSEL,a,LOC,x,rad3-thk3-.01,rad3+.01
esln,s
esel,r,type,,1
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, inner support pipe
csys,1
nsel,s,loc,x,0,rad4+.01
esln,s
esel,r,mat,,1
plns,TEMP
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, inner cask wall
csys,1
nsel,s,loc,x,10.125
esln,s
esel,a,mat,,1
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, outer cask wall
nsel,s,loc,x,22.125
esln,s
esel,a,mat,,1
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
/title, cask wall
asel,s, area,,2
esla,s
nsle,s
plns,temp
nsort, temp,,0
*get, tmax, sort, 0, max
*get, tmin, sort, 0, min
fini
```

```
/exit
```

... include input listing of macro RLINK ...

```
csys,arg1
nsel,s,loc,x,rad2-thk2  * nodes across capsule gaps
nsel,a,loc,x,rad1
real,4
:RLink1
*GET,n1,NODE,,num,Max
*GET,y1,node,n1,LOC,y
n2 = node(rad1,y1,0)
e,n1,n2
nsel,u,node,,n1
nsel,u,node,,n2
*GET,n,NODE,,count
*IF,n,ne,0,:RLink1
nsel,s,loc,x,rad3-thk3  * nodes across outer gap
nsel,a,loc,x,rad2
type, 3
mat, 1
real,5
:RLink2
*GET,n1,NODE,,num,Max
*GET,y1,node,n1,LOC,y
n2 = node(rad2,y1,0)
e,n1,n2
nsel,u,node,,n1
nsel,u,node,,n2
*GET,n,NODE,,count
*IF,n,ne,0,:RLink2
nsel,all
```

... END OF MACRO FILE RLINK ...

... OUTPUT OMITTED ...

```
        ***** ANSYS RESULTS INTERPRETATION (POST1) *****

*** NOTE ***                          CP=    461.310   TIME= 09:21:55
An active coordinate system is not zero.
 RSYS= 0 CSYS= 1 DSYS= 0.

NUMBER KEY SET TO  0  -1=NONE  0=BOTH  1=COLOR  2=NUMBER
```

```
AREA NUMBERING KEY =  0

ACTIVE COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     3  CUMULATIVE ITERATION=    12
  TIME/FREQUENCY=  1.0000
TITLE=  area-type elements

PRINT HEAT REACTION SOLUTIONS PER NODE


 area-type elements


 ***** POST1 TOTAL REACTION SOLUTION LISTING *****

 LOAD STEP=     1  SUBSTEP=     3
  TIME=    1.0000      LOAD CASE=   0

   NODE      HEAT
   4174  -84.224

TOTAL VALUES
VALUE   -84.224

SELECT       FOR ITEM=MAT  COMPONENT=
 IN RANGE       2 TO         2 STEP        1

   997  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

  1226 NODES (OF   4174  DEFINED) SELECTED FROM
   997 SELECTED ELEMENTS BY NSLE COMMAND.

TITLE=
 He


DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER   7 WRITTEN TO FILE b16.g           - RASTER MODE.
DISPLAY TITLE=
 He

DISPLAY ELEMENT SOLUTION,  ITEM=TERR  COMP=

CUMULATIVE DISPLAY NUMBER   8 WRITTEN TO FILE b16.g           - RASTER MODE.
DISPLAY TITLE=
 He
```

```
SELECT       FOR ITEM=MAT  COMPONENT=
 IN RANGE       1 TO        1 STEP        1

  2109  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

RESELECT     FOR ITEM=TYPE COMPONENT=
 IN RANGE       1 TO        1 STEP        1

  1871  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

  2258 NODES (OF   4174  DEFINED) SELECTED FROM
  1871 SELECTED ELEMENTS BY NSLE COMMAND.

TITLE=
 SS


DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER   9 WRITTEN TO FILE b16.g          - RASTER MODE.
DISPLAY TITLE=
 SS

DISPLAY ELEMENT SOLUTION,  ITEM=TERR  COMP=

CUMULATIVE DISPLAY NUMBER  10 WRITTEN TO FILE b16.g          - RASTER MODE.
DISPLAY TITLE=
 SS

SELECT       FOR ITEM=TYPE COMPONENT=
 IN RANGE       2 TO        2 STEP        1

    41  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

STORE HF        FROM ITEM=NMIS COMP=   5  FOR ALL SELECTED ELEMENTS

STORE TAVG      FROM ITEM=NMIS COMP=   6  FOR ALL SELECTED ELEMENTS

STORE TBLK      FROM ITEM=NMIS COMP=   7  FOR ALL SELECTED ELEMENTS

STORE VOL       FROM ITEM=NMIS COMP=  15  FOR ALL SELECTED ELEMENTS

STORE HGT       FROM ITEM=SMIS COMP=  19  FOR ALL SELECTED ELEMENTS

STORE HC        FROM ITEM=SMIS COMP=  20  FOR ALL SELECTED ELEMENTS

STORE HR        FROM ITEM=SMIS COMP=  21  FOR ALL SELECTED ELEMENTS

PRINT ELEMENT TABLE ITEMS PER ELEMENT

 SS
```

***** POST1 ELEMENT TABLE LISTING *****

STAT ELEM	CURRENT HF	CURRENT TAVG	CURRENT TBLK	CURRENT VOL	CURRENT HGT	CURRENT HC	CURRENT HR
4021	0.29284E-01	252.93	115.00	0.42382	0.33216E-01	1.7119	0.33822
4022	0.29284E-01	252.93	115.00	0.42382	0.33216E-01	1.7119	0.33822
4023	0.29284E-01	252.93	115.00	0.42382	0.33216E-01	1.7119	0.33823
4024	0.29285E-01	252.94	115.00	0.42382	0.33216E-01	1.7120	0.33824
4025	0.29285E-01	252.94	115.00	0.42382	0.33216E-01	1.7121	0.33826
4026	0.29285E-01	252.95	115.00	0.42382	0.33216E-01	1.7122	0.33828
4027	0.29286E-01	252.96	115.00	0.42382	0.33216E-01	1.7123	0.33831
4028	0.29287E-01	252.96	115.00	0.42382	0.33216E-01	1.7124	0.33833
4029	0.29287E-01	252.97	115.00	0.42382	0.33216E-01	1.7126	0.33837
4030	0.29288E-01	252.98	115.00	0.42382	0.33216E-01	1.7128	0.33840
4031	0.29289E-01	253.00	115.00	0.42382	0.33216E-01	1.7130	0.33844
4032	0.29290E-01	253.01	115.00	0.42382	0.33216E-01	1.7132	0.33848
4033	0.29291E-01	253.02	115.00	0.42382	0.33216E-01	1.7134	0.33852
4034	0.29291E-01	253.04	115.00	0.42382	0.33216E-01	1.7136	0.33857
4035	0.29292E-01	253.05	115.00	0.42382	0.33216E-01	1.7139	0.33861
4036	0.29294E-01	253.06	115.00	0.42382	0.33216E-01	1.7141	0.33866
4037	0.29295E-01	253.08	115.00	0.42382	0.33216E-01	1.7144	0.33871
4038	0.29296E-01	253.10	115.00	0.42382	0.33216E-01	1.7146	0.33876
4039	0.29297E-01	253.11	115.00	0.42382	0.33216E-01	1.7149	0.33882
4040	0.29298E-01	253.13	115.00	0.42382	0.33216E-01	1.7151	0.33887
4041	0.29299E-01	253.14	115.00	0.42382	0.33216E-01	1.7154	0.33892
4042	0.29300E-01	253.16	115.00	0.42382	0.33216E-01	1.7156	0.33897
4043	0.29301E-01	253.17	115.00	0.42382	0.33216E-01	1.7159	0.33902
4044	0.29302E-01	253.19	115.00	0.42382	0.33216E-01	1.7162	0.33907
4045	0.29303E-01	253.20	115.00	0.42382	0.33216E-01	1.7164	0.33912
4046	0.29304E-01	253.22	115.00	0.42382	0.33216E-01	1.7166	0.33917
4047	0.29305E-01	253.23	115.00	0.42382	0.33216E-01	1.7169	0.33922
4048	0.29306E-01	253.25	115.00	0.42382	0.33216E-01	1.7171	0.33926
4049	0.29307E-01	253.26	115.00	0.42382	0.33216E-01	1.7173	0.33930
4050	0.29308E-01	253.27	115.00	0.42382	0.33216E-01	1.7175	0.33934
4051	0.29309E-01	253.28	115.00	0.42382	0.33216E-01	1.7177	0.33938
4052	0.29309E-01	253.29	115.00	0.42382	0.33216E-01	1.7179	0.33941
4053	0.29310E-01	253.30	115.00	0.42382	0.33216E-01	1.7180	0.33944
4054	0.29311E-01	253.31	115.00	0.42382	0.33216E-01	1.7182	0.33947
4055	0.29311E-01	253.32	115.00	0.42382	0.33216E-01	1.7183	0.33950
4056	0.29312E-01	253.32	115.00	0.42382	0.33216E-01	1.7184	0.33952
4057	0.29312E-01	253.33	115.00	0.42382	0.33216E-01	1.7185	0.33954
4058	0.29312E-01	253.33	115.00	0.42382	0.33216E-01	1.7185	0.33955
4059	0.29313E-01	253.34	115.00	0.42382	0.33216E-01	1.7186	0.33956
4060	0.29313E-01	253.34	115.00	0.42382	0.33216E-01	1.7186	0.33957
4061	0.29313E-01	253.34	115.00	0.42382	0.33216E-01	1.7187	0.33957

***** POST1 ELEMENT TABLE LISTING *****

STAT ELEM	CURRENT HF	CURRENT TAVG	CURRENT TBLK	CURRENT VOL	CURRENT HGT	CURRENT HC	CURRENT HR

```
MINIMUM VALUES
ELEM       4021         4021         4021         4021         4021         4021         4021
VALUE   0.29284E-01  252.93       115.00       0.42382     0.33216E-01  1.7119       0.33822

MAXIMUM VALUES
ELEM       4061         4061         4021         4061         4061         4061         4061
VALUE   0.29313E-01  253.34       115.00       0.42382     0.33216E-01  1.7187       0.33957

SUM ALL THE ACTIVE ENTRIES IN THE ELEMENT TABLE

TABLE LABEL     TOTAL
HF          1.20125
TAVG        10378.7
TBLK        4715.00
VOL         17.3767
HGT         1.36184
HC          70.3284
HR          13.8952

TITLE=
 CsCl capsule mat'l


SELECT      FOR ITEM=MAT  COMPONENT=
 IN RANGE       3 TO        3 STEP        1

   864  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

   939 NODES (OF   4174  DEFINED) SELECTED FROM
   864 SELECTED ELEMENTS BY NSLE COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  11 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 CsCl capsule mat'l

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR    939 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX       VALUE=  863.833883

*GET  tmin      FROM  SORT  ITEM=MIN       VALUE=  667.540466

TITLE=
 inner SS capsule


ACTIVE COORDINATE SYSTEM SET TO      11  (CYLINDRICAL)

SELECT      FOR ITEM=LOC  COMPONENT=X     BETWEEN 0.97900     AND    1.1350
```

```
  KABS=  0.  TOLERANCE= 0.000000E+00

    75  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     12  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X     BETWEEN 0.97900     AND    1.1350
  KABS=  0.  TOLERANCE= 0.000000E+00

   219  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     13  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X     BETWEEN 0.97900     AND    1.1350
  KABS=  0.  TOLERANCE= 0.000000E+00

   294  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT       ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

   482 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
   294 SELECTED NODES BY  ESLN COMMAND.

RESELECT      FOR ITEM=TYPE COMPONENT=
 IN RANGE         1 TO          1 STEP          1

   384  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

RESELECT      FOR ITEM=MAT  COMPONENT=
 IN RANGE         1 TO          1 STEP          1

   192  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  12 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 inner SS capsule

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR   294 VALUES.

*GET  tmax       FROM  SORT  ITEM=MAX        VALUE=  789.816666

*GET  tmin       FROM  SORT  ITEM=MIN        VALUE=  666.839346

TITLE=
 outer SS capsule


ACTIVE COORDINATE SYSTEM SET TO     11  (CYLINDRICAL)

SELECT        FOR ITEM=LOC  COMPONENT=X     BETWEEN  1.1910     AND    1.3225
```

```
  KABS=  0.  TOLERANCE= 0.000000E+00

    75  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     12  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X     BETWEEN  1.1910     AND    1.3225
  KABS=  0.  TOLERANCE= 0.000000E+00

   219  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     13  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X     BETWEEN  1.1910     AND    1.3225
  KABS=  0.  TOLERANCE= 0.000000E+00

   294  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT       ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

   580 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
   294 SELECTED NODES BY  ESLN COMMAND.

RESELECT      FOR ITEM=TYPE COMPONENT=
 IN RANGE         1 TO          1 STEP          1

   384  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

RESELECT      FOR ITEM=MAT  COMPONENT=
 IN RANGE         1 TO          1 STEP          1

   192  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  13 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 outer SS capsule

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR   294 VALUES.

*GET  tmax       FROM  SORT  ITEM=MAX        VALUE=  741.476202

*GET  tmin       FROM  SORT  ITEM=MIN        VALUE=  578.804906

TITLE=
 SS overpack


ACTIVE COORDINATE SYSTEM SET TO     11  (CYLINDRICAL)

SELECT       FOR ITEM=LOC  COMPONENT=X     BETWEEN  1.4900     AND    1.6350
```

```
 KABS= 0.  TOLERANCE= 0.000000E+00

  100  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     12  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X    BETWEEN  1.4900    AND   1.6350
 KABS= 0.  TOLERANCE= 0.000000E+00

  292  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

ACTIVE COORDINATE SYSTEM SET TO     13  (CYLINDRICAL)

ALSO SELECT  FOR ITEM=LOC  COMPONENT=X    BETWEEN  1.4900    AND   1.6350
 KABS= 0.  TOLERANCE= 0.000000E+00

  392  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT      ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

  584 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
  392 SELECTED NODES BY  ESLN COMMAND.

RESELECT     FOR ITEM=TYPE COMPONENT=
 IN RANGE        1 TO         1 STEP        1

  486  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

RESELECT     FOR ITEM=MAT  COMPONENT=
 IN RANGE        1 TO         1 STEP        1

  288  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  14 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 SS overpack

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR   392 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX       VALUE=  718.487115

*GET  tmin      FROM  SORT  ITEM=MIN       VALUE=  504.814929

TITLE=
 inner support pipe


ACTIVE COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)

SELECT       FOR ITEM=LOC  COMPONENT=X    BETWEEN 0.00000E+00 AND   2.0100
```

```
  KABS=  0.  TOLERANCE= 0.000000E+00

    33  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT      ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

    29 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
    33 SELECTED NODES BY  ESLN COMMAND.

RESELECT     FOR ITEM=MAT  COMPONENT=
 IN RANGE        1 TO         1 STEP        1

    10  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  15 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 inner support pipe

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR    33 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX        VALUE=  692.054103

*GET  tmin      FROM  SORT  ITEM=MIN        VALUE=  689.331748

TITLE=
 inner cask wall


ACTIVE COORDINATE SYSTEM SET TO      1  (CYLINDRICAL)

SELECT       FOR ITEM=LOC  COMPONENT=X     BETWEEN  10.125     AND    10.125
  KABS=  0.  TOLERANCE= 0.506250E-01

    42  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT      ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

    82 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
    42 SELECTED NODES BY  ESLN COMMAND.

ALSO SELECT  FOR ITEM=MAT  COMPONENT=
 IN RANGE        1 TO         1 STEP        1

  2150  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR    42 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX        VALUE=  337.804347
```

```
*GET  tmin      FROM  SORT  ITEM=MIN       VALUE=  330.914929

TITLE=
 outer cask wall


SELECT       FOR ITEM=LOC  COMPONENT=X     BETWEEN  22.125     AND   22.125
  KABS=  0.  TOLERANCE= 0.110625

    42  NODES (OF   4174  DEFINED) SELECTED BY  NSEL  COMMAND.

SELECT      ALL ELEMENTS HAVING ANY NODE IN NODAL SET.

    82 ELEMENTS (OF   4258  DEFINED) SELECTED FROM
    42 SELECTED NODES BY  ESLN COMMAND.

ALSO SELECT  FOR ITEM=MAT  COMPONENT=
 IN RANGE       1 TO        1 STEP        1

  2109  ELEMENTS (OF   4258  DEFINED) SELECTED BY  ESEL  COMMAND.

SORT ON ITEM=TEMP  COMPONENT=      ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR    42 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX       VALUE=  253.340705

*GET  tmin      FROM  SORT  ITEM=MIN       VALUE=  252.929050

TITLE=
 cask wall


SELECT       FOR ITEM=AREA COMPONENT=
 IN RANGE       2 TO        2 STEP        1

    1  AREAS (OF    52  DEFINED) SELECTED BY  ASEL  COMMAND.

SELECT      ELEMENTS CREATED FROM SELECTED AREAS.

  1189  ELEMENTS (OF   4258  DEFINED) SELECTED FROM
     1 SELECTED AREAS BY  ESLA  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

  1260 NODES (OF   4174  DEFINED) SELECTED FROM
  1189 SELECTED ELEMENTS BY NSLE COMMAND.

DISPLAY NODAL SOLUTION,  ITEM=TEMP  COMP=

CUMULATIVE DISPLAY NUMBER  16 WRITTEN TO FILE b16.g            - RASTER MODE.
DISPLAY TITLE=
 cask wall
```

```
SORT ON ITEM=TEMP  COMPONENT=     ORDER= 0  KABS= 0  NMAX=  4174

SORT COMPLETED FOR  1260 VALUES.

*GET  tmax      FROM  SORT  ITEM=MAX       VALUE=  337.804347

*GET  tmin      FROM  SORT  ITEM=MIN       VALUE=  252.929050

EXIT THE ANSYS POST1 DATABASE PROCESSOR


***** ROUTINE COMPLETED *****  CP =       510.710



PURGE ALL SOLUTION AND POST DATA
SAVE ALL MODEL DATA

ALL CURRENT ANSYS DATA WRITTEN TO FILE NAME= b16a.db
 FOR POSSIBLE RESUME FROM THIS POINT


NUMBER OF WARNING MESSAGES ENCOUNTERED=          4
NUMBER OF ERROR   MESSAGES ENCOUNTERED=          0


*---------------------------------------------------------------------------*
|                                                                           |
|                          ANSYS RUN COMPLETED                              |
|                                                                           |
|---------------------------------------------------------------------------|
|                                                                           |
|            REV. 5.2                           SGI IRIS4D                  |
|                                                                           |
|      CP TIME      (sec) =       514.590       TIME  =  09:23:55           |
|      ELAPSED TIME (sec) =      1191.000       DATE  =  07/10/97           |
|                                                                           |
*---------------------------------------------------------------------------*
487.2u 27.4s 19:50 43% 0+0k 903+17801io 286pf+0w
  Ran ANSYS 5.2 on workstation: sgi3   on: Thu Jul 10 09:23:55 PDT 1997
   ANSYS 5.2 has been verified by ICF KH
   Class 3 Error Reports are in the directory: /apps/ansys/class3_errors.
```

8.8.6 Peer Review Checklist

CHECKLIST FOR PEER REVIEW

Document Reviewed: Thermal Analysis for the BUSS Cask SEP, HNF-SD-TP-SEP-065

Scope of Review: Entire thermal analysis - Chapter B 8

Yes	No	NA	
[ ]	[ ]	[X]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
[X]	[ ]	[ ]	Problem completely defined.
[ ]	[ ]	[X]	Accident scenarios developed in a clear and logical manner.
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[X]	[ ]	[ ]	Computer codes and data files documented.
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document.
[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. Spreadsheet results should be treated exactly the same as hand calculations.
[X]	[ ]	[ ]	Software input correct and consistent with document reviewed.
[X]	[ ]	[ ]	Software output consistent with input and with results reported in document reviewed.
[X]	[ ]	[ ]	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
[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.
[ ]	[ ]	[X]	Format consistent with appropriate NRC Regulatory Guide or other standards
[ ]		[X]	Review calculations, comments, and/or notes are attached.
[X]	[ ]	[ ]	Document approved.

Harold E. Adkins Jr. (signature) Harold E. Adkins, Jr. 7/17/97

Reviewer (Printed Name and Signature) Date

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9.0 PRESSURE AND GAS GENERATION

As no liquid is shipped in the package, so the only source of pressure will be due to the increase in temperature. Even if the temperature were to rise to a uniform 800 °C (the maximum fire temperature), the pressure would be:

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}$$

$$\textit{assume } T_1 = 20°C \textit{ and } P_1 = 1 \textit{ atm}$$

$$\textit{then } P_2 = \frac{273+800}{273+20} = 3.66 \textit{ atm absolute}$$

$$P_2 = (3.66-1)14.7 = 39 \textit{ psig}$$

As demonstrated in the BUSS Cask SARP (SNL 1994), this is below the maximum allowed pressure of 50 psig and no further analyses is required.

9.1 REFERENCE

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

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10.0 TIEDOWN EVALUATION

The package will be transported in its normal highway configuration as shown in the BUSS Cask SARP (SNL 1994). As a part of this, the cask as secured to a skid which is permanently attached to the trailer. The skid attachment is inspected annually as a part of routine maintenance.

10.1 REFERENCE

SNL, 1994, *Beneficial Uses Shipping System (BUSS) Cask Safety Analysis Report for Packaging (SARP)*, Volumes I and II, SAND83-0698 (TCC-0430), Rev. 5, Sandia National Laboratories, Albuquerque, New Mexico.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Packaging Engineering	Date 09/10/97
Project Title/Work Order		EDT No. 621893
Safety Evaluation for Packaging (Onsite) for Cesium Chloride Capsules with Type W Overpacks (HNF-SD-TP-SEP-065)		ECN No. NA

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
J. G. Field	H1-15	X			
C. R. Hoover	H1-15	X			
D. W. McNally	G1-15	X			
M. M. Pereira (2 copies)	S6-51	X			
HNF-SD-TP-SEP-065 File	H1-15	X			
Central Files (1 copy + original)	A3-88	X			