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APPROVED FOR PUBLIC RELEASE

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WHC Information Release Administration Specialist:

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1.0 INTRODUCTION

The purpose of this document is to compile, present and document the formal design review of the NRF TRIGA packaging.

The contents of this document include: the briefing meeting presentations, package description, design calculations, package review drawings, meeting minutes, action item lists, review comment records, final resolutions, and released drawings.

This design review required more than two meeting to resolve comments. Therefore, there are three meeting minutes and two action item lists. There was a briefing meeting (July 6, 1994), a meeting reviewing the comments (July 20, 1994), and a final close-out meeting (August 12, 1994). The drawings were released on August 18, 1994.

August 24, 1994

[23] From: Ivan L Metcalf at -WHC44 6/29/94 11:42AM (3729 bytes: 64 ln)
 To: Randall R Ames at -WHC180, James D (Jim) Anderson at -WHC212,
 Richard W Barker at -WHC217, Leland L (Lee) Carter at -WHC71,
 Michael W Clayton at -WHC118, Mary D (Denise) Clements at -WHC217,
 Richard R Cruz at -WHC217, Thomas A Delucchi at -WHC76, James O Dittmer at
 -WHC293, Satya B Dutta at -WHC149, Patrick C Ferrell at -WHC217, Gary W Lanham
 at -WHC293, E M (Magdy) Megahed at -WHC228, George W Mettler at -WHC217,
 Frank A Schmittroth at -WHC71, William W (Bill) Smyth at -WHC217,
 Jim M Steffen, Paul F Stevens at -WHC217, Douglas B Teachout at -WHC212,
 James W Thornton at -WHC217, Muhammad K Ullah at -WHC145
 cc: J G (Greg) Field at -WHC217, Ivan L Metcalf
 Subject: NRF TRIGA IRRADIATED FUEL CASK/OVERPACK DESIGN REVIEW NOTICE

----- Message Contents -----

Hard copy provided to Scott Shiraga.

From: Packaging Safety Engineering/Project Support
 Phone: 376-0781/376-7675 G2-02/N1-40
 Date: June 29, 1994
 Subject: NRF TRIGA IRRADIATED FUEL CASK AND OVERPACK FINAL DESIGN
 REVIEW NOTICE

To:	R. R. Ames	N3-13	G. W. Lanham	N1-40
	J. D. Anderson	T3-04	E. M. Megahed	T4-03
	R. W. Barker	G2-03	G. W. Mettler	G2-03
	L. L. Carter	H0-35	F. A. Schmittroth	H0-35
	M. W. Clayton	L6-57	S. S. Shiraga	N1-40
	M. D. Clements	G2-02	W. W. Smyth	G2-02
	R. R. Cruz	G2-03	J. M. Steffen	N1-47
	T. A. Delucchi	L6-38	P. F. Stevens	G2-02
	J. O. Dittmer	N1-40	D. B. Teachout	T3-04
	S. B. Dutta	L6-35	J. W. Thornton	G2-03
	P. C. Ferrell	G2-03	M. K. Ullah	L6-57

cc: JGF File/LB
 ILM File/LB

A formal review of the NRF TRIGA irradiated fuel cask and overpack designs is scheduled for Wednesday, July 20, 1994, at 8 a.m. in rooms 272-273 in the 1163 building. The review committee members and their areas of responsibility are as follows:

I. L. Metcalf	Chairman
M. D. Clements	Secretary
T. A. Delucchi	Fabrication
R. W. Barker	Fabrication
P. C. Ferrell	Fabrication/Analysis
J. D. Anderson	CWC Interface
D. B. Teachout	CWC Interface
R. R. Ames	CWC Safety Analysis
G. W. Mettler	Packaging Safety
S. B. Dutta	Quality Assurance
E. M. Megahed	CWC Operations
M. K. Ullah	NRF Facility Safety
J. O. Dittmer	NRF Facility/Customer Representative

G. W. Lanham

NRF Operations

A design review briefing will be conducted at the same location July 6, 1994, at 1 p.m. At that time, copies of the assembly drawing, description of the planned operations, analysis results, the design review checklist, etc., will be provided. Should the designated board member be unable to attend either the briefing or the design review, they should appoint a senior staff substitute from within their organization.

Questions about the design review can be addressed by M. D. Clements (376-3501) or I. L. Metcalf (376-7675).

J. G. Field, Manager
Packaging Safety Engineering

I. L. Metcalf, Manager
Project Support

dc

AGENDA**NRF TRIGA FORMAL DESIGN REVIEW****JULY 20, 1994 8:00 AM**

- **QUESTIONS FROM BRIEFING MEETING**
- **BRIEFING MEETING ACTION ITEMS**
- **RCR COMMENTS**
- **CHECKLIST**
- **NEW ACTION ITEMS**
- **CLOSURE**

AGENDA**NRF TRIGA PACKAGING FORMAL DESIGN REVIEW****DRAWING SIGN-OFF MEETING****AUGUST 12, 1994 10:00 AM**

- **INTRODUCTION**
- • **PREVIOUS MEETING MINUTES/ACTION ITEMS**
- **CHECKLIST**
- **QUESTIONS**
- **SIGN-OFF RCR'S/DRAWINGS**

2.0 PRESENTATION OF NRF TRIGA CASK METHODOLOGY/ANALYSES RESULTS/CRITERIA

BRIEFING MEETING AGENDA - JULY 6, 1994

Final Design of the NRF TRIGA Irradiated Fuel Cask and Overpack

- **Introduction** **IL Metcalf**
 - Individual Introductions
 - Design Scope and Objectives
 - Meeting Objectives and Structure
- **Background Information** **IL Metcalf**
- **Design and Analysis Presentations** **MD Clements**
- **Open Discussion**
- **Review Assignments** **IL Metcalf**
- **Action Items/Meeting Closure** **IL Metcalf**

DESIGN REVIEW SCOPE AND OBJECTIVES

Scope: Final design of the NRF Irradiated Fuel Cask and Overpack

Objective: Evaluate the overall process and equipment designs to determine if they meet the requirements for fabrication, fuel loading, facility interface, transportation and storage at the Hanford Complex

MEETING OBJECTIVES AND STRUCTURE

- Provide information supporting the designs
- Distribute review material, checklist, and review comment record (RCR)
- Review assignments and any new action items
- Provide written questions to secretary by July 18, 1994, on the RCR forms
- Informal Meeting
- Limit discussion until open discussion session

PRESENTATION OF NRF TRIGA CASK METHODOLOGY/ANALYSES RESULTS/CRITERIA

INTRODUCTION - DENISE CLEMENTS

- Explanation of Documentation
- Design Review Checklist
- Agenda for Analyses Presentation

DESIGN - RICH CRUZ

- Description of Design
- Lifting Calculations
- Operational Sequence

STRUCTURAL - BILL SMYTH

- Structural Analysis Criteria
- Structural Analysis Results

THERMAL - PAUL STEVENS

- Model Assumptions
- Design Criteria
- Results on Cask

SHIELDING - FRANK SCHMITTROTH (LEE CARTER)

- Design Criteria
- Model Assumptions
- Results for Side, Bottom, and Top for Above Conditions

CRITICALITY - LEE CARTER

- Design Criteria
- Model Assumptions
- Results for Above Conditions

PDC REQUIREMENT CRITERIA LIST - DENISE CLEMENTS

VECTRA OVERPACK PRESENTATION

TRIGA Fuel Cask Configuration

TRIGA Fuel Cask – Loading Sequence

STEP 1

-- All equipment present and accounted for

TRIGA Fuel Cask – Loading Sequence

STEP 2

- Load inner container into cask vessel
- Remove eyebolt from inner container and install in inner container lid
- Remove stiffener from inner container
- Install elastomer O-ring in inner container
- Install basket alignment pin onto inner container locking bar

TRIGA Fuel Cask – Loading Sequence

STEP 3

– Lower basket into pool

TRIGA Fuel Cask – Loading Sequence

STEP 4

– Load fuel elements into basket

TRIGA Fuel Cask – Loading Sequence

STEP 5

– Remove fuel bundle from pool and allow to dry

TRIGA Fuel Cask — Loading Sequence

STEP 6

— Align fuel bundle over cask

TRIGA Fuel Cask – Loading Sequence

TRIGA Fuel Cask — Loading Sequence

STEP 8

- Attach cask lifting beam/eyebolts to cask lid and align lid over cask

TRIGA Fuel Cask – Loading Sequence

STEP 9

- Lower lid onto cask
- Remove lid alignment pins
- Fasten lid with (12) cap screws and torque to specified preload
- Perform seal leak check

TRIGA Fuel Cask – Loading Sequence

STEP 10

- Attach lift beam to forklift and remove crane connection
- Transfer loaded cask out of building

DESIGN CALCULATIONS LIFTING DEVICES

Minimum Factors of Safety (F.S.) are 3 against yield and 5 against ultimate for lifting load

- **Cask - weight of the assembled cask lifted by two eyebolts
F.S. = 3.32 against yield and 5.47 against ultimate**
- **Basket - weight of loaded basket lifted by one center lifting collar
F.S. = 6.31 against yield and 7.57 against ultimate**
- **Inner Container - weight of assembled inner container lifted by center eyebolt
F. S. = 3.46 against yield and 8.65 against ultimate**

STRUCTURAL EVALUATION CRITERIA

The NRF TRIGA cask must maintain containment, shielding, and criticality control under the following conditions:

Normal Conditions of Transport (NCT)

- Heat/Cold effects on material:
 - Temperature of 115°F with insolation
 - Temperature of -27°F in shade
- Increased/Reduced external pressure:
 - External pressure of 20 psia
 - External pressure of 3.5 psia
- Vibration normal incident to transport

STRUCTURAL EVALUATION CRITERIA (con't)

- **Water Spray**
- **Compression of 5 x its own weight or 1.85 psi over its projected area**
- **4 ft free drop onto unyielding surface in a position to cause maximum damage**
- **Penetration of 13 lbf steel cylinder dropped 40 in.**

STRUCTURAL EVALUATION CRITERIA (con't)

Hypothetical Accident Conditions (HAC)

- Ambient temperature effects on cask
- 30 ft free drop on unyielding surface in a position to cause maximum damage
- Puncture of cask dropping 40 inches onto a vertical rod 6 in. in diameter

Storage Accident Condition

- 6 ft drop onto concrete

STRUCTURAL ANALYSIS RESULTS

NCT Results

- Cask temperatures are maintained between -27°F and 200°F. Material allowable stresses constant in this range. 304L stainless steel is not subject to brittle fracture
- 3.5 psia reduced external pressure causes 82 psi on containment vessel wall. 20 psia increase external pressure causes 184 psi on containment vessel wall. Allowable stresses are 16,700 psi
- Vibration cyclic forces less than loading evaluated for 30 ft free drop
- Water spray has no effect, cask is leaktight and materials are stainless steel

STRUCTURAL ANALYSIS RESULTS (con't)

- 5 times its own weight causes a stress of 10,600 psi when analyzing the outer shell alone. Allowable stresses are 16,700 psi
- 4 ft free drop causes acceleration less than 40 g due to overpack. Stresses below allowables from ASME B&PV Section III, Service Level A. Negligible effect on cask as compared to 30 ft drop
- Cask protected from penetration by overpack, but will resist puncture without the overpack

HAC Results

- Ambient temperatures have no effect on cask structurally

STRUCTURAL ANALYSIS RESULTS (con't)

- 30 ft drop is limited to less than 95 g loading by overpack. The bolting ring has inelastic deformation limited by the stepped lid. All stresses are below ASME B&PV Code Section III, Service Level D allowables. No loss of containment, shielding, or criticality control will occur
- The lead-backed outer shell can withstand puncture when dropped 200 in. onto a 6 in. round bar. No loss of containment, shielding, or criticality control will occur due to puncture
- Initial calculations from EPRI NP-4830, October 1986, and ACI manual of Concrete Practice 1989, show that the g-loading from 6 ft. drop will be significantly lower

THERMAL ANALYSIS

- **Fire Shield/Overpack Thermal Requirements**
 - Maximum cask temperature of 350°F necessary to maintain cask structural, shielding, and containment capabilities
 - Maximum accessible surface temperature of 180°F without insolation
- **Analysis used HEATING7 Finite Difference Heat Transfer Code, which was developed at ORNL**
- **Model Assumptions**
 - Two-dimensional, axially symmetric model used
 - 12 watt payload heat generation
 - Payload conservatively assumed to have material properties similar to air
 - Impact limit assumed crushed prior to fire incident
 - Hanford specific conditions were evaluated in addition to 10 CFR 71 conditions

CASES ANALYZED

10 CFR 71 Normal Conditions of Transport

- Evaluation of maximum surface temperature for cask in 100°F ambient environment without solar insolation (180°F limit)
- Determine cask temperatures for 100°F ambient environment with maximum solar insolation (must be no degradation of packaging shielding, containment or structural capability)

Hanford Specific Normal Conditions of Transport

- Maximum surface temperature with 115°F ambient environment and no insolation (180°F limit)

CASES ANALYZED (con't)

- Cask temperatures for 115°F ambient environment and maximum Hanford insolation (no degradation of cask shielding, containment or structural capability)

Fire Case Accident Condition

- Prior to fire, cask was assumed to suffer damage similar to that of a 30 foot drop
- Prior and subsequent to the fire, the cask is assumed to be in a 100 °F environment with no insolation
- Fire temperature is 1475 °F and lasts for 1/2 hour

RESULTS

Normal Conditions of Transport

- Without insolation, maximum accessible surface temperature 122°F (limit 180°F)
- With insolation, maximum cask temperature is 190°F, overpack surface temperature is 195°F (no degradation of package capabilities predicted)

Accident Conditions (Fire)

- Charring will occur in the outer 2 - 3 inches of the overpack, but it will not penetrate to the cask
- Maximum cask temperature is 197°F, maximum lead temperature is 195°F (350°F limit)
- Maximum cask temperatures occur approximately one hour after the end of the fire.

SHIELDING

Acceptance Criteria

Normal Conditions:

- 200 mR/h contact and 10 mR/h at 2 meters

Hypothetical Accident Conditions:

- 1000 mR/h at 1 meter

Shielding Model

18 High Burnup Pins

Fuel Composition

U	192 gm
Zr	2030 gm
H	32 gm

Total 2258 gm/pin

Density of Fuel 2.3 g/cm³

Source Term

- Assume 18 GA assemblies all irradiated in central TRIGA location
- Assume an additional prior irradiation
- Based on ORIGEN2 source term calculations in EDT 603581

RESULTS

Table A. ISOSHLD contact dose for 18 maximally exposed TRIGA fuel pins with an assumed prior irradiation

Dose Point	Steel Build-up Dose, mR/h	Lead Build-up
Side	92	32* *
Top*	81	
Bottom*	38	
1 m from side	5.17	
2 m from side	1.53	

* The "Top" value is a combination of two runs used to assess the effect of a notch in the top plate. The "Bottom" value is based on the "Top" calculation with no notch

* * Dose rates will be between the lead and steel build-up results

Eyebolt Cavity Calculation

MCNP VERIFICATION

1 m dose at the side

MCNP	2.0 mrem/h
ISOSHLD	5.2 mR/h (based on conservative iron buildup)

Top of Cask

MCNP	22 mrem/h (Point kernel contact)
ISOSHLD	38 mR/h (Bottom calculation without eyebolt cavity)

CRITICALITY EVALUATION

METHOD OF SOLUTION -- MONTE CARLO (MCNP)

Normal Conditions

- **Infinite Array of Close-Packed Casks (dry)**
- **Infinite Array of Close-Packed Casks (water)**

Accident Conditions

- **Fuel Elements Crushed Together (no clad)**
- **Infinite Arrays**

Figure 1. Plan View of Cask Showing
Fuel Elements and Materials

Figure 2.
Elevation View of Cask
Showing Materials

Figure 3. Plan View of Cask for
Accident Conditions

CALCULATED RESULTS

Normal Conditions

<u>Configuration</u>	<u>k-eff</u>
One Cask	0.420 (0.54%)
Infinite Array, Dry	0.664 (0.35%)
Infinite Array, Half Density Water	0.563 (0.46%)
Infinite Array, Full Density Water	0.527 (0.35%)
Infinite Array, Twice Density Water	0.495 (0.47%)
One Cask (Al clad fuel)	0.309 (0.58%)

CALCULATED RESULTS (con't)

Accident Conditions

Configuration k-eff

One Cask 0.499 (0.59%)
Infinite Array, Dry 0.742 (0.31%)

PDC CRITERIA REVIEW LIST

Design cask per ASME B&PV Code, Section VIII or III, as required by NRC Regulatory Guides. (4.2)

- The NRF TRIGA Cask classification by the Packaging Review Guide and NUREG/CR3854 is a Category III package (7 A₂'s). The PDC required the design and analysis per ASME B&PV Code, Section VIII, based on this category. Category III requires, as a minimum, ASME B&PV Code, Section VIII, Division 1, for fabrication and Division 2 for design and analysis. ASME B&PV Code, Section VIII and Section III, were used for the design and analysis of this cask.

Design the cask as a reusable, single containment with inner confinement vessel. (4.2)

- The NRF TRIGA package has an inner confinement vessel and an outer containment vessel.

Both vessels shall be top loading. (4.2)

- Both vessels are top loading and the inner container is already inside the outer container during loading of the fuel.

PDC CRITERIA REVIEW LIST (con't)

Materials of construction shall be of 300 Series stainless steel. (4.2.1)

- The inner vessel and outer vessel will be fabricated from 304L stainless steel.

The outer packaging seal design shall be of a material that can meet a transport life of 20 years and storage life of at least 30 years. (4.2.1)

- The outer vessel seal is metallic (Inconel and Aluminum) and will have a lifetime of greater than 30 years. The metallic seal lifetime is virtually unlimited in low pressure applications and in the absence of deleterious materials.

All materials shall be ASME/ASTM certified materials. (4.2.1)

- All materials (pipe/tubing, cap screws, lead, and plate) are either ASME or ASTM materials.

All welds shall be sufficiently rounded and smooth to enable easy decontamination. (4.2.2)

- All welds shall be rounded or machined flush. The ability to decontaminate was kept in mind during the design.

PDC CRITERIA REVIEW LIST (con't)

Inspect all welds per the ASME requirements.
(4.2.2)

- All containment boundary welds can be radiographed and all other welds can be inspected as required by ASME B&PV code Section VIII.

The inner container shall be less than 16-in. in diameter and the outer container shall be less than 30-in. (4.2.3)

- The inner container OD is 10.5 in. and the outer container OD is 16 in.

The weight of the fuel elements and basket shall be less than 500 lb. (4.2.4)

- The weight of the fuel elements and the basket is 166 lb.

The gross weight of the package without overpack shall not exceed 7000 lb. (4.2.5)

- The gross weight of the package without the overpack is 2013 lb.

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PDC CRITERIA REVIEW LIST (con't)

All tiedown devices shall incorporate a minimum safety factor of three for yield strength and five for ultimate strength. (4.2.7)

- The following chart gives the safety factors for each lifting attachment.

Lift Attachment	Minimum Safety Factor	
	Yield	Ultimate
Cask	3.32	5.47
Basket	6.31	7.57
Inner Container	3.46	8.65

Each closure for the inner and outer vessel shall have a positive fastening device that cannot be opened unintentionally. (4.2.9)

- The inner vessel closure consists of a positive bolted closure to ensure adequate pressure is placed upon the O-ring seal. The outer vessel closure consists of 12 closure cap screws. Neither closure can be opened unintentionally.

PDC CRITERIA REVIEW LIST (con't)

The NRF TRIGA Cask shall be designed as leaktight, 1×10^{-7} atm cc/sec, air, for all NCT and HAC. (4.2.10)

- **Helicoflex seals are impermeable and vendor tested to leaktight (as little as 1×10^{-10} atm cc/sec, He). Stresses in the area of the seal for both NCT and HAC are less than the ASME B&PV Code, Section VIII, Division 2 and Section III, Service Level D allowables. The cap screws will maintain the lid in position and the O-ring will not move during either the NCT or HAC. Therefore, the leaktight seal will stay intact.**

Both containers provide shielding such that the maximum surface dose rate is no greater than 200 mR/h and 10 mR/h, 2 m. from the surface. (5.1.1.5)

- **The most conservative source term of 18 worst case elements results in the following dose rates: bottom - 38 mR/h, side - 92 mR/h, and top - 81 mR/h. These rates are higher than what will occur because there are not 18 elements of this worst case source term. Also, the side rate is significantly high because the analysis used the buildup factor for iron instead of lead. Use of the more realistic lead buildup factor yields a dose rate of 32 mR/h.**
- **Actual dose measurements will be preformed for verification of the lower dose rate.**

PDC CRITERIA REVIEW LIST (con't)

Maintain containment (stresses below Section VIII NCT allowables) when exposed to an external pressure of 3.5 psi. (5.1.1.1)

- **3.5 psia external pressure causes a maximum principal stress of 82 psi in the containment vessel wall. The allowable stress for that wall is $< 16,700$ psi.**

Maintain containment (stresses below Section VIII NCT allowables) when exposed to increase external pressure of 20 psi. (5.1.1.1)

- **External pressure combined with lead shrinkage stresses will produce compressive stresses of 184 psi. The allowable stress again is $< 16,700$ psi.**

Maintain containment (stresses below Section VIII NCT allowables) when exposed to vibration normally incident to transport. (5.1.1.1)

- **Vibratory impacts recommended by ANSI N14.23 are 84 lbf. for packages less than 3500 lbs. This is insignificant compared to the NCT free drop requirements, and will not cause significant effects due to the protective overpack.**

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PDC CRITERIA REVIEW LIST (con't)

Demonstrate containment through water spray for at least one hour. (5.1.1.1)

- The cask design is not vulnerable to the water spray test. Leak check of the primary cask seal will confirm water tightness. The water in-leakage rate is 1×10^{-3} atm cc/sec, air, and the cask is leaktight (1×10^{-7} atm cc/sec, air).

Maintain containment (stresses below Section VIII NCT allowables) for a 24 hour compressive load equivalent to five times the weight of the package. (5.1.1.1)

- The maximum stress intensity under a concentrated load of 5 x its own weight is 10,600 psi in the outer shell alone. The allowable stress intensity is 16,700 psi.

Maintain containment (stresses below Section VIII NCT allowables) after the impact of the hemispherical end of a vertical steel cylinder, 1.25 in. in diameter and 13 lb, dropped from a height of 40 in. onto the most vulnerable exposed surface of the package.

- This case is shown by the overpack analysis. The bar does not puncture the overpack and therefore, does not effect the cask.

PDC CRITERIA REVIEW LIST (con't)

All cask components shall be of materials that assure that there will be no significant chemical, galvanic, or other reaction among The packaging components or between packaging components and contents. (5.1.1.2)

- All cask components are stainless steel, Inconel, or coated to prevent chemical, galvanic or other reactions.

Criticality control shall be such that the two casks transported shall have a $K_{\text{eff}} < 0.95$ when arranged in the most reactive array that is closely and fully reflected by water for both NCT and HAC. (5.1.1.6)

- For NCT an infinite array of casks without water was the worst case, $K_{\text{eff}} = 0.644$. For HAC, assuming no infiltration of water into cask (leaktight) but assuming the basket and cladding disintegrates, $K_{\text{eff}} = 0.742$. Therefore, there are no restrictions for criticality or spacing of these casks.

PDC CRITERIA REVIEW LIST (con't)

The cask shall maintain containment (stresses below Section III Service Level D HAC allowables) for a 30-ft drop onto an essentially unyielding horizontal surface. (5.1.2.1)

- **Stresses are dependant upon the tolerance in the lid step. All stresses in the area of the seal and bolts are below the Service Level D allowables.**

The cask shall maintain containment (stresses below Section VIII HAC allowables) after a 40-in. cask free drop onto the upper end of a mild steel bar 6-in. in diameter. (5.1.2.1)

- **A drop height of less than 200-in. would not damage the outer shell of the cask, therefore a 40-in. drop has no consequence on the cask. Also, the overpack encloses the cask and provides further protection from this drop. There will be no damage occurring to the overpack from this scenario and therefore, no damage to the cask.**

PDC CRITERIA REVIEW LIST (con't)

The cask and overpack shall withstand a 1475 °F heat flux with an emissivity of 0.9 for 30 minutes and shall maintain containment, shielding, and criticality control. (5.1.2.1)

- The normal and accident thermal analyses show that the maximum cask temperature is 197 °F under any condition. This temperature is well below allowables for the seal or lead.

STORAGE REQUIREMENTS

Provide shielding such that the maximum surface dose rate is 100 mR/hr or less. (5.2.1)

- The conservative source term from 18 worst case elements yields the following dose rates: bottom - 38 mR/h, side - 92 mR/h, and top - 81 mR/h. These rates are higher than what will occur because there are not 18 elements of this worst case source term. Also, the side rate is significantly high because the analysis used the buildup factor for iron instead of lead. Use of the more realistic lead buildup factor yields a dose rate of 32 mR/h.

PDC CRITERIA REVIEW LIST (con't)

The packages shall provide at least two storage containment barriers that are equivalent to two transportation confinement barriers. (5.2.2)

- **The inner and outer containers provide these two barriers.**

Packages of TRU waste shall not contain compressed gases. (5.2.6)

- **The fuel is non-pyrophoric, non-water reactive and encapsulated in stainless steel or aluminum cladding and therefore, will not release any type of gas to cause pressurization of the cask.**

Packages shall meet a 30 year lifetime requirement

- **The package containers and containment seals are metallic with an unlimited lifetime in low pressure applications and in the absence of deleterious materials**

Criticality spacing for storage shall not restrict spacing

- **K_{eff} for normal conditions of an infinite array of casks is 0.644. Therefore, there is no spacing restrictions**

PDC CRITERIA REVIEW LIST (con't)

The cask shall maintain containment after a 6 ft drop onto concrete

- Initial calculations from the EPRI document show the g-loading from this scenario is less than the 30 ft drop g-loading

3.0 DESIGN REVIEW ASSIGNMENTS

DESIGN REVIEW ASSIGNMENTS

IL Metcalf	Chairman
MD Clements	Secretary
TA Delucchi	Fabrication
RW Barker	Fabrication
PC Ferrell	Fabrication/Analysis
JD Anderson	CWC Interface
DB Teachout	CWC Interface
RR Ames	CWC Safety Analysis
GW Mettler	Packaging Safety
SB Dutta	Quality Assurance
EM Megahed	CWC Operations
MK Ullah	NRF Facility Safety
JO Dittmer	NRF Facility/Customer Representative
GW Lanham	NRF Operations

FINAL DESIGN REVIEW

TIME: 8 a.m.

DATE: July 20, 1994

LOCATION: Room 272-273, 1163 Bldg

4.0 NRF TRIGA CASK PACKAGING, ACCEPTANCE AND OPERATIONS DESCRIPTION AND FABRICATION SPECIFICATION

4.1 PACKAGING SYSTEM

4.1.1 Configuration and Dimensions

The NRF TRIGA cask consists of a stainless steel basket structure housed inside a single wall stainless steel container which is housed inside a composite stainless steel/lead vessel. During transport, the entire cask assembly is enclosed in an overpack, which serves as a shock absorber and thermal insulator during hypothetical accident conditions.

The basket, as shown in Figure 4-1, is a welded assembly of 304 stainless steel tube segments of 1.69 in. outer diameter (OD), and varying inner diameters (ID). A 1.13 in. ID tube segment at the center of the assembly runs the entire length of the basket, and serves as the primary lifting and structural component of the basket. The top of the center tube is appropriately machined to interface with basket handling equipment. Welded to the center tube are two hexagonal arrays of 6.00 in. and 4.00 in. long, 1.63 in. ID, tube segments (18 per array). These segments serve as insertion guides and lateral support members for the fuel elements, and are positioned such that the chance of hang-up of a fuel element, once it has cleared the upper guide, and until it becomes seated, is minimized. To the very bottom of the basket is welded another array of 18, 2.57 in. long, 1.13 in. ID, tube segments. This array, with each tube segment ID being smaller than each fuel element OD, serves as the seating surface for the fuel, and is designed to bear the load of all 18 elements during cask loading.

Figure 4-1. NRF TRIGA Fuel Cask Basket.

The inner container (shown in Figure 4-2), although it provides a single elastomer seal at the lid interface, is not designed to specific leak rate

criteria for normal or accident conditions, and therefore serves as a "confinement" barrier only. The container contributes considerably to the total shielding capability of the cask. The shell of the inner container is a 29.13 in. long, 10.25 in. OD x 8.88 in. ID 304 stainless steel tube section, and has a machined O-ring groove at the upper face to accommodate a 9.12 in. diameter elastomer

[Fluorocarbon (e.g. Viton)] seal. Welded to the lower end of the shell is the base of the container, which is a 0.50 in. thick, 9.50 in. diameter 304 stainless steel plate. The lid is a 1.00 in. thick, 9.63 in. diameter 304 stainless steel plate. As part of the closure system, a 0.31 in. diameter hole, countersunk on both sides, is tapped through the center of the lid. The closure system consists of a 1.00 in. OD x 0.25 in. ID x 28.94 in. long 304 stainless steel locking bar, and a single eyebolt. The locking bar, with a tapped thread in its upper end, is welded to the center of the interior side of the container base. In this position, the bar protrudes partially through the container lid when the lid is properly seated. To achieve closure, the eyebolt is inserted through the center of the lid, and threaded into the upper portion of the locking bar until the proper seal compression is achieved. A teflon-coated metallic seal (which resists damage due to threading) is used at the eyebolt/lid interface.

NRF TRIGA Cask Inner Container

Figure 4-2. NRF TRIGA Cask Inner Container.

The outer vessel, shown in Figure 4-3, contains a double seal at the lid interface, is designed to meet leak rate criteria for normal and accident conditions, ($\leq 1 \times 10^{-7}$ scc/s air, and $\leq A_2$ /week, respectively), and provides leak test capability. The outer vessel therefore constitutes the "containment" barrier, or system, as defined by 10 CFR 71.4, *Containment System*. The vessel consists of a 29.11 in. long, 12.00 in. OD x 10.50 in. ID 304L stainless steel inner shell, which serves as primary containment, and a 33.87 in. long, 16.00 in. OD x 15.00 in. ID 304L stainless steel outer shell. Both shells are welded at the lower end to a 4.00 in. thick, 16.00 in. diameter machined 304L stainless steel plate. The annulus between the two shells is filled with lead. This composite wall construction provides the necessary shielding for 18 TRIGA fuel elements. Welded to the upper portion of both shells is a 2.50 in. thick, 16.00 in. OD x 10.50 in. ID machined 304L

stainless steel ring, which serves to encapsulate the lead, and provides the required seating/sealing surface for the outer vessel lid. The seating surface has 12 evenly-spaced 0.50 in. diameter tapped holes for securing the lid. The lid consists of a 3.50 in. thick, 16.00 in. diameter 304L stainless steel plate, with a machined step on the underside to facilitate remote placement of the lid onto the vessel, and to restrict lateral movement of the lid during normal and accident drop test scenarios. The seating surface of the lid has a machined O-ring groove which accommodates a leak-testable, double seal arrangement.

Figure 4-3. NRF TRIGA Cask Outer Container.

This double seal arrangement includes a metallic seal which is comprised of an Inconel[™], helically-wound spring encased in an aluminum C-shaped section outer jacket, and a larger diameter elastomer [Fluorocarbon (e.g. Viton)] O-ring. The two seals are separated at a fixed distance from each other by a stainless steel bracket. The spring-energized metallic seal design provides for maximum resiliency of the seal, which is an ideal property for joints which experience external loading, and which require sealing for long periods of time. The elastomer seal, by creating an isolated annulus between the two seals, allows the performance of a leak test on the metallic seal, which is required after the cask lid has been secured, and prior to transport. At the appropriate location on the top side of the lid, a 4.00 in. diameter, countersunk "port" is machined, into which a pair of Swagelok[™] quick-disconnect fittings is installed; one to provide a backfill of helium to the inner volume of the cask, and the other to connect the proper equipment to detect and measure the leak rate of the helium into the seal annulus. To protect the fittings, and to displace the removed shielding material, a 3.97 in. diameter 304L stainless steel blind flange is installed, with 8 ASTM F-837, Type 304 cap screws, into the port. The blind flange has an O-ring groove machined on its underside which contains a spring-energized (as

described above) seal. The lid assembly is secured to the cask vessel with 12 ASTM F-837, Type 410 cap screws, to a torque specification of at least that necessary to properly seat the metallic spring-energized seal.

4.2 ACCEPTANCE OF PACKAGING FOR USAGE

4.2.1 New Packaging

The following applies to a new NRF TRIGA Package that has never been used to transport radioactive materials. The below tests shall have been performed within 12 months prior to shipment of radioactive materials.

4.2.1.1 Acceptance Requirements. The new NRF TRIGA Packagings shall be inspected prior to first use as described in Section 4.2.1.2. Each inspection shall be documented as stated in Section 4.2.1.4. The inspections shall be performed to ensure that the packaging has maintained the original fabricated configuration.

Each new NRF TRIGA packaging shall also be leak tested per Section 4.2.1.3 prior to first use (Section 4.2.1.3.1) and prior to transport (Section 4.2.1.3.2). The acceptance criteria for the leak tests are based upon the type of test. The fabrication leak test, prior to first use, requires a leak rate equal to or less than leaktight, as defined in ANSI N14.5 (1.0×10^{-7} scc/s, air). The assembly leak test, prior to transport, requires a leak rate, equal to or less than, 1.0×10^{-4} scc/s.

The following are recommended guidelines for the inspection and testing of the packaging. Specific procedures with appropriate Quality Control hold points, shall be written by the user and approved by Packaging Safety Engineering, prior to use, to ensure the packaging is not damaged during inspection and testing operations.

3.2.1.2 Inspection and Testing. The first use inspections shall consist of:

- Visually examining the NRF TRIGA cask and overpack for damage due to storage or transport from the fabricator.
- All seals shall be visually inspected for damage, the elastomeric shall be inspected for hardening and the packaging shall be cleaned of any dirt or dust.
- The cask shall be leak tested per Section 4.2.1.3 procedures and meet the above acceptance criteria.
- Helium leak testing prior to loading.
- Pressure rise leak testing after loading.
- Dose rate readings for acceptance.

- Contamination levels for acceptance.

4.2.1.3 Leak Testing. There shall be two stages of leak testing prior to transport of the NRF TRIGA package. The first will consist of a helium mass spectrometer leak test to ensure that the cask meets the leak tight design criteria prior to shipment. The second will be a pressure rise leak test which is performed after loading to verify assembly of the containment components was performed accurately. Leak tests shall be in accordance with ANSI N14.5, *American National Standard for Radioactive Materials - Leakage Test on Packages for Shipment*.

4.2.1.3.1 Helium Mass Spectrometer Leak Test (Fabrication Verification). The purpose of the fabrication leak tests is to ensure that the leaktight containment acceptance criteria of $(1.7 \times 10^{-7}$ scc/s, air) is met. A mass spectrographic helium-tuned leak detector and calibrated leak standard should be available for these measurements. This test shall be performed on each cask prior to loading to ensure proper fabrication of the leak tight container was performed.

The following are steps that are required for leak testing the package. Specific leak test procedures with appropriate Quality Control hold points, shall be written by the user and approved by Packaging Safety Engineering, prior to use, to ensure the packaging is not damaged during testing.

1. Assemble package per Section 4.3.
2. Remove leak-test port lid.
3. Calibrate the Mass Spectrometer Leak Detector (MSLD) using a calibrated leak standard in accordance with the manufacturer's instructions. Connect the MSLD to the leak detector port (Location 1, Figure 4-4). Evacuate the inner seal space.
4. Attach a helium supply and a vacuum pump to the swagelock fitting helium fill port (Location 2, Figure 4-4). Evacuate the cask cavity to 0.01 atm or less and then backfill with helium to a pressure of 1 atm.
5. After appropriate dwell time, record the leak rate and ensure it meets the leak rate criteria. If the leak rate exceeds the allowable specified above, disassemble the outer container, remove the metallic seal and thoroughly clean the seal surface on the lid and container.

Replace the metallic seal with a new one, reassemble the package, and repeat the leakage rate test. If it becomes apparent that the system cannot be made to pass the test, prepare a non-conformance report for disposition per the requirements of the Quality Assurance section of the SARP.

Figure 4-4. Helium Leak Test Configuration.

6. Disconnect leak detector and helium supply and vacuum pump appropriately relieving the pressure within the cask.

4.2.1.3.2 Pressure Rise Leak Test (Assembly Verification).

The purpose of the assembly verification leak tests is to ensure that the seal system is functional prior to shipment. This test requires a sum leakage rate of less than or equal to 1.0×10^{-3} scc/s, air, per ANSI N14.5. This test shall be performed on each cask prior to shipment per ANSI N14.5. The recommended test method is an air pressure rise test of the metallic seal. A vacuum pump, a resolution calibrated pressure gauge, and a timer shall be used. See Figure 4-5 for test locations. The leak test system should have a minimum sensitivity of 1.5×10^{-4} scc/s, air. The following are steps that shall be part of the leak test procedures developed by the user.

Figure 4-5. Pressure Rise Leak Test Configuration.

1. Connect the vacuum pump and pressure gauge to the leak test port as shown in Figure 4-5.

2. Evacuate the test cavity (seal interspace) to a pressure of 0.001 atm or less and valve off the vacuum pump. Wait approximately 10 minutes for the system to stabilize.
3. Measure and record the change in pressure and temperature for a precise time period.
4. Calculate the leakage rate by using the following equation:

$$L = \frac{VT_s}{3600H} \left(\frac{P_2}{T_2} - \frac{P_1}{T_1} \right)$$

where:

L = scc/s, air at 25 °C

V = volume of test space in cm³ (seal interspace + test system volume)

T_s = standard temperature, 298 K

H = test duration in hours

P₂ = gas pressure at end of test, atm abs

P₁ = gas pressure at start of test, atm abs

T₂ = gas temperature at end of test, K

T₁ = gas temperature at start of test, K

5. Disconnect the test system and plug the test port.

4.2.1.4 Documentation. Leak test verification and results shall be documented, with Quality Control verification and maintained for the life of the package or 5 years, whichever is longer.

4.2.2 Packaging for Reuse

The following applies to NRF TRIGA Casks which have been previously used to transport and stored radioactive materials.

4.2.2.1 Acceptance Requirements. For reuse of a NRF TRIGA Cask, the fuel elements shall have been remotely removed and placed in alternative storage. Visual inspections shall be performed on both the inner and outer container. Visual acceptance criteria shall be; no weld degradation, container material degradation, dents or damage to the outer container greater than 0.25 in. in depth that could affect the containment of package. The cask shall be cleaned to non-fixed internal contamination levels and external contamination levels are shown in Table 4-1. The closure bolts shall be inspected for degradation with acceptance based on condition of the threads. Also, bolts shall be inspected for suspects or counterfeit parts. The empty cask shall be

leak tested as stated in Section 4.2.1.3.1 to the original leak tight acceptance criteria of 1.0×10^{-7} scc/s prior to loading and 1.0×10^{-3} scc/s prior to transport.

Table 4-1. Empty Cask Re-Use Contamination Limits.

Contaminant	External Maximum Permissible Limits		Internal Maximum Permissible Limits	
	uCi/cm ²	dpm/cm ²	uCi/cm ²	dpm/cm ²
Beta-gamma	10^{-5}	22	10^{-3}	220
Alpha	10^{-6}	2.2	10^{-4}	22

4.2.2.2 Inspection and Testing. For reuse, the NRF TRIGA Package shall be:

- Disassembled and the package cleaned and decontaminated to Table 4-1 limits, if necessary.
- The metallic O-ring on the lid shall be removed and replaced.
- The elastomeric O-rings in the leak test ports shall be removed and replaced.
- An inspection of the external surface of the casks to the above acceptable limits shall be performed.
- Inspection of the closure lid and sealing surface shall be performed to ensure a smooth surface has been maintained.
- Inspection of the closure bolts shall be performed to ensure degradation of the threads has not occurred.
- Inspection of all bolts for suspects/counterfeit parts.
- A smear test shall be performed to ensure contamination levels on the inside and outside of the empty cask are acceptable (Table 4-1).

The lid shall be replaced on the cask and the bolts tightened as required in Section 4.3.2 and all required acceptance testing for a new package shall be performed (i.e., helium leak testing, pressure rise leak testing, etc.).

4.2.2.3 Documentation. All inspections shall be documented in procedures and/or inspection checklists and verified by Quality Control. The

documentation shall be maintained for the life of the package or 5 years, whichever is longer.

4.3 OPERATING REQUIREMENTS

4.3.1 General Requirements

The following operating requirements are denoted to ensure that operations that could adversely affect the integrity of the NRF TRIGA packaging are not performed. The following are recommended guidelines for the use of the packaging. Specific operating procedures with appropriate Quality Control/Quality Assurance hold points, shall be written by the user and approved by Packaging Safety Engineering, prior to use, to ensure the packaging is not damaged during transfer and loading operations.

For loading/unloading operations, the following shall be inspected:

1. Visually inspect Helicoflex and elastomeric seals for damage.
2. Visually inspect sealing surfaces for damage.
3. Visually inspect cask and welds for any damage.
4. Helium leak test to acceptance criteria listed in Section 4.2 prior to loading.
5. Visually inspect overpack for dents or damage.
6. Visually inspect lifting and tiedown attachments for loose connections, cracks, or damage.
7. Helium leak test prior to loading per Section 4.2.
8. Visually inspect fuel element basket prior to loading.
9. Pressure rise leak test cask after loading and prior to transport per acceptance criteria listed in Section 4.2.
10. Verify accurate loading and closure of overpack.
11. Verify accurate lifting of cask onto trailer.
12. Verify accurate tiedown of NRF TRIGA package to transporter.
13. Verify accurate lifting for removal from transporter.
14. Verify location of storage.

4.3.2 Loading Package

Prior to initial loading, the cask shall have been helium leak tested per Section 4.2.1.3.1.

1. Prepare the NRF TRIGA cask for fuel element loading by removing both the outer and inner container lids. Inspect the metallic and elastomeric O-rings visually to ensure integrity of both seals.
2. Load the fuel elements into the handling basket and allow the elements to dry within the reactor.
3. Once the elements are dry, transfer the handling basket by crane to the cask and lower the basket into the inner container.
4. Place the inner container lid onto the container and tighten closure bolt with remote tooling.
5. Remotely place the outer container closure lid onto the container. Lubricate the stainless steel bolts and insert the lid closure bolts. Torque bolts according to the bolt pattern shown in Figure 4-6 to 41 ± 5 ft-lb.
6. Pressure rise leak test the package per ANSI N14.5 leak testing requirements (Section 3.2.1.3.2) to assure proper assembly.
7. Use a forklift to remove the package from the User Facility and prepare for loading onto the transporter.

Figure 4-6. Lid Bolt Torque Pattern.

4.3.3 Unloading Package

The NRF TRIGA Casks will be used for interim storage in the Central Waste Complex (CWC) until disposition of irradiated fuel is determined.

Therefore, the unloading procedures, for NRF TRIGA fuel element purposes, will consist only of removing the cask from the transporter and placing the cask into the assigned storage location, not removing the contents from the package. Should, at a later date, the contents be required to be removed, additional unloading procedures will be required.

1. Open overpack.

2. Attach lifting attachments to cask.
3. Remove cask from overpack and transporter.
4. Transfer cask to storage location.

4.3.4 Empty Package (Packaging)

Empty packages shall be prepared for transport per 49 CFR 173.427 under the conditions that the smearable contamination levels are acceptable per 49 CFR 173.443 (see Table 3-1, Section 3.2.2.1). Otherwise, the package shall be re-assembled and transported per Section 3.3.2.

5.0 CASK DESIGN CALCULATIONS

5.1 WEIGHTS AND CENTER OF GRAVITY (C.G.) CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cask Weight & C.G. calculation
 (8) Originator K.P. Gury Date 5/25/94
 (9) Checker Harold E. O'Brien, P.E. Date 6-25-94

(10) Weights and weight-distances about the x-axis (cask base) will be calculated for each component of the cask system.

① Outer Vessel

Outer Shell, $\rho = .2837 \text{ lb/in}^3$

$$W = .2837 \frac{\pi}{4} (16.00^2 - 15.00^2) (33.87) = \underline{233.95 \text{ lb}}$$

$$M_x = 233.95 (20.94) = \underline{4898.95 \text{ lb}\cdot\text{in}}$$

Inner Shell, $\rho = .2837 \text{ lb/in}^3$

$$W = .2837 \frac{\pi}{4} (12.00^2 - 10.50^2) (29.11) = \underline{218.91 \text{ lb}}$$

$$M_x = 218.91 (18.56) = \underline{4062.97 \text{ lb}\cdot\text{in}}$$

Lead Shield, $\rho = .4079$

$$W = .4079 \frac{\pi}{4} (15.00^2 - 12.00^2) (29.11) = \underline{755.39 \text{ lb}}$$

$$M_x = 755.39 (18.56) = \underline{14,020.02 \text{ lb}\cdot\text{in}}$$

Bottom Plate, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (16.00)^2 (4.00) = \underline{228.17 \text{ lb}}$$

$$M_x = 228.17 (2.00) = \underline{456.33 \text{ lb}\cdot\text{in}}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cast Weights + C.G.
 (8) Originator KK Cow Date 5/25/94
 (9) Checker WLD/LL Date 6-27-94

(10) Top Ring*, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (15.00^2 - 10.50^2) (2.13) = \underline{54.46 \text{ lb}}$$

$$M_x = 54.46 (34.18) = \underline{1861.46 \text{ lb}\cdot\text{in}}$$

Lid*, $\rho = .2837 \Rightarrow 124.33 \text{ lbs} \Rightarrow 24.42 \text{ lbs}$

$$W = .2837 \frac{\pi}{4} ((14.94^2)(2.50) + (10.47^2)(1.00)) = \underline{148.72 \text{ lbs.}}$$

$$M_x = 124.33 (36.50) + 24.42 (34.75) = \underline{5385.55 \text{ lb}\cdot\text{in}}$$

$$\text{Vessel Weight Subtotal} = \underline{1,639.56 \text{ lbs}}$$

② Inner Container

Shell, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (10.25^2 - 8.85^2) (29.13) = \underline{170.02 \text{ lb}}$$

$$M_x = 170.02 (19.07) = \underline{3242.32 \text{ lb}\cdot\text{in}}$$

Bottom Plate, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (9.50^2) (.50) = \underline{10.05 \text{ lb}}$$

$$M_x = 10.05 (4.25) = \underline{42.71 \text{ lb}\cdot\text{in}}$$

Lid, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (9.63^2) (1.00) = \underline{20.65 \text{ lb}}$$

$$M_x = 20.65 (33.63) = \underline{694.56 \text{ lb}\cdot\text{in}}$$

* Although the geometries of these components have changed slightly since Rev. 0, the overall geometry of the outer vessel, hence the weight, has not changed.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Core Weights + C.G.
 (8) Originator K.R. Gar Date 5/25/94
 (9) Checker [Signature] Date 6-27-94

(10) Locking Bar, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (1.00^2 - .25^2) (28.94) = \underline{6.04 \text{ lb.}}$$

$$M_x = 6.04 (18.97) = \underline{114.62 \text{ lb} \cdot \text{in}}$$

Inner Container Weight Subtotal = 206.76 lbs

③ Basket

Center Tube, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (1.688^2 - 1.126^2) (28.50) = \underline{10.04 \text{ lb}}$$

$$M_x = 10.04 (18.75) = \underline{188.25 \text{ lb} \cdot \text{in}}$$

Upper Guides, $\rho = .2837$

$$W = 18 (.2837) \frac{\pi}{4} (1.688^2 - 1.632^2) (6.00) = \underline{4.47 \text{ lb}}$$

$$M_x = 4.47 (26.20) = \underline{117.16 \text{ lb} \cdot \text{in}}$$

Lower Guides, $\rho = .2837$

$$W = 4.47 (4/6) = \underline{2.98 \text{ lbs}}$$

$$M_x = 2.98 (11.50) = \underline{34.27 \text{ lb} \cdot \text{in}}$$

Studs, $\rho = .2837$

$$W = .2837 \frac{\pi}{4} (1.688^2 - 1.126^2) ((6)(2.57) + (12)(2.06)) = \underline{14.14 \text{ lbs}}$$

$$M_x = 14.14 (6.01) = \underline{84.98 \text{ lb} \cdot \text{in}}$$

Basket Weight Subtotal = 31.64 lbs

④ Fuel, $w = 3.4 \text{ kg} = 7.48 \text{ lb}$

$$W = 18 (7.48) = \underline{134.64 \text{ lb}}$$

$$M_x = 134.64 (18.81) = \underline{2532.58 \text{ lb} \cdot \text{in}}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 4
(4) Building _____ (5) Rev. 1 (6) Job No. _____
(7) Subject TRIGA Cask Weights - C.G.
(8) Originator R.R. Garg Date 5/25/94
(9) Checker W.D. L. Date 6-27-94

(10)

$$\begin{aligned}\text{Total Weight, } W_T &= \sum W \\ &= \underline{\underline{2,012.34}} \approx \underline{\underline{2,013}} \text{ lbs}\end{aligned}$$

$$\begin{aligned}\text{C.G. (from base of cask)} &= \frac{\sum M_x}{W_T} \\ &= \frac{37,735.88 \text{ lb in}}{2,012.34 \text{ lb}} \\ &= \underline{\underline{18.75}} \text{ in}\end{aligned}$$

5.2 CASK MOMENTS OF INERTIA CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 6
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject TRIGA Cask Moments of Inertia
 (8) Originator R. R. Purr Date 5/23/94
 (9) Checker Phil G. Date 6-28-94

- (10) The mass moments of inertia of each cask component^{*} will be calculated. The same geometries used to calculate weights and CG's will be used here. To obtain minimum and maximum total values, it is assumed that the lead shielding is the only component to which minimum and maximum cask weights are attributed. Maximum cask weight is 2100 lb. Minimum cask weight is 1400 lb. C.G. from cask base = 18.75

① Outer Vessel

Outer shell $w = 233.95 \text{ lb}$, $h = 33.87 \text{ in}$, $\rho = .2837 \text{ lb/in}^3$

Weight of major cylinder = $.2837 \frac{\pi}{4} (16.00)^2 (33.87) = 1431.99 \text{ lbs.} = W_1$

Weight of minor cylinder = $1431.99 - 233.95 = 1198.04 \text{ lb} = W_2$

$r_1 = 8.00 \text{ in}$ $r_2 = 7.50 \text{ in}$

$$\begin{aligned} I_{xx} &= \frac{1}{12} (W_1 (3r_1^2 + h^2) - W_2 (3r_2^2 + h^2)) \\ &= \frac{1}{12} (1431.99 (3(8)^2 + (33.87)^2) - 1198.04 (3(7.50)^2 + (33.87)^2)) \\ &= \underline{29,398.32 \text{ lb-in}^2} \end{aligned}$$

$$I_{x'x'} = 29,398.32 + 233.95 (20.44 - 18.75)^2 = \boxed{30,520.37 \text{ lb-in}^2}$$

Inner Shell

$w = 218.91 \text{ lb}$, $h = 29.11 \text{ in}$

$W_1 = .2837 \frac{\pi}{4} (12.00)^2 (29.11) = 934.02 \text{ lb}$

$W_2 = 934.02 - 218.91 = 715.11 \text{ lb}$

$$I_{xx} = \frac{1}{12} (934.02 (3(6)^2 + (29.11)^2) - 715.11 (3(5.25)^2 + (29.11)^2)) = 18,937.18$$

$$I_{x'x'} = 18,937.18 + 218.91 (18.75 - 18.56)^2 = \boxed{18,945.08 \text{ lb-in}^2}$$

* about an axis through the c.g. of the cask, and perpendicular to the longitudinal axis of the cask.

DESIGN CALCULATION

(1) Drawing	(2) Doc. No.	(3) Page 2 of 6
(4) Building	(5) Rev. 0	(6) Job No.
(7) Subject	Rigid Fast Mounts of Inertia	
(8) Originator	S.E. Ryan	
(9) Checker	Date 5/24/94	

(10) Lead Shield

$$W_{min} = 755.39 - (2013 - 1900 - 8(7.48)) = 702.23 \text{ lb}$$

$$W_{max} = 755.39 + (2100 - 2013) = 842.39 \text{ lb}$$

$$h = 29.11 \text{ in}$$

Inertia for minimum lead weight

$$I_{xx} = \frac{1}{12} (1949.63 (3(7.50)^2 + (29.11)^2) - 1247.77 (3(6.50)^2 + (29.11)^2))$$

$$W_1 = \frac{4}{\pi} (15.00^2) (29.11) = 1949.63 \text{ lb}$$

$$W_2 = \frac{12.00^2}{15.00^2} (1949.63) = 1247.77 \text{ lb}$$

$$I_{xx}' = 65,749.29 \text{ lb} \cdot \text{in}^2$$

$$I_{xx}' = 65,749.29 + 702.23 (18.75 - 18.56)^2 = 65,774.64 \text{ lb} \cdot \text{in}^2 \text{ (min)}$$

Inertia for maximum lead weight

$$I_{xx}' = 842.39 \text{ lb} \cdot \text{in}^2$$

$$I_{xx}' = 842.39 + 702.23 (18.75 - 18.56)^2 = 842.39 \text{ lb} \cdot \text{in}^2 \text{ (max)}$$

$$I_{xx} = \frac{1}{12} (2340.59 (3(7.50)^2 + (29.11)^2) - 1497 (3(6.50)^2 + (29.11)^2))$$

$$W_1 = 1949.63 \text{ lb}$$

$$W_2 = 1247.77 \text{ lb}$$

Bottom Plate $W = 228.17 \text{ lb}$ $h = 4.00 \text{ in}$

$$I_{xx}' = \frac{1}{12} (228.17 (3(8.00)^2 + (4.00)^2) + 228.17 (18.75 - 2.00)^2)$$

$$= 67,970.89 \text{ lb} \cdot \text{in}^2$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3 of 6
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject RIGA Cask Moments of Inertia
 (8) Originator R.R. Long Date 5/24/94
 (9) Checker W.H. G. Date 6-25-94

(10) Top Ring $W = 54.46 \text{ lb}$ $h = 2.13 \text{ in}$
 $W_1 = .2837 \frac{\pi}{4} (15.00)^2 (2.13) = 106.79 \text{ lb}$
 $W_2 = 106.79 \left(\frac{10.50^2}{15.00^2} \right) = 52.33 \text{ lb}$

$$I_{xx} = \frac{1}{12} \left(106.79 (3(7.50)^2 + (2.13)^2) - 52.33 (3(5.25)^2 + (2.13)^2) \right)$$

$$= 1161.74 \text{ lb} \cdot \text{in}^2$$

$$I_{x'x'} = 1161.74 + 54.46 (34.18 - 18.75)^2 = \boxed{14,127.84 \text{ lb} \cdot \text{in}^2}$$

Lid Upper Portion : $W = 124.33 \text{ lb}$ $h = 2.50 \text{ in}$
 $I_{x'x'} = \frac{1}{12} (124.33) (3(7.47)^2 + (2.50)^2) + 124.33 (36.50 - 18.75)^2$
 $= \boxed{40,461.02 \text{ lb} \cdot \text{in}^2}$

Lower Portion : $W = 24.42 \text{ lb}$ $h = 1.00 \text{ in}$
 $I_{x'x'} = \frac{1}{12} (24.42) (3(5.24)^2 + (1.00)^2) + 24.42 (34.75 - 18.75)^2$
 $= \boxed{6,421.18 \text{ lb} \cdot \text{in}^2}$

② Inner Container

Shell $W = 170.02 \text{ lb}$ $h = 29.13 \text{ in}$
 $W_1 = .2837 \frac{\pi}{4} (10.25)^2 (29.13) = 681.93 \text{ lb}$
 $W_2 = 681.93 - 170.02 = 511.91 \text{ lb}$

$$I_{xx} = \frac{1}{12} (681.93 (3(5.125)^2 + (29.13)^2) - 511.91 (3(4.438)^2 + (29.13)^2))$$

$$= 13,979.84 \text{ lb} \cdot \text{in}^2$$

$$I_{x'x'} = 13,979.84 + 170.02 (19.07 - 18.75)^2 = \boxed{13,997.25 \text{ lb} \cdot \text{in}^2}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 6
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject RIGA Cask Moments of Inertia
 (8) Originator R.P. Perry Date 5/24/94
 (9) Checker WES Date 6-28-94

(10) Bottom Plate $w = 10.05 \text{ lb}$ $h = .50 \text{ in}$

$$I_{x'x'} = \frac{1}{12} (10.05) (3(4.75)^2 + (.50)^2) + 10.05 (18.75 - 4.75)^2$$

$$= \boxed{2169.91 \text{ lb} \cdot \text{in}^2}$$

Lid $w = 20.65 \text{ lb}$ $h = 1.00$

$$I_{x'x'} = \frac{1}{12} (20.65) (3(4.82)^2 + (1.00)^2) + 20.65 (33.63 - 18.75)^2$$

$$= \boxed{4643.87 \text{ lb} \cdot \text{in}^2}$$

Locking Bar $w = 6.04 \text{ lb}$ $h = 28.94 \text{ in}$

$$w_1 = .2837 \frac{\pi}{4} (1.00^2) (28.94) = 6.45 \text{ lb}$$

$$w_2 = 6.45 - 6.04 = .41 \text{ lb}$$

$$I_{xx} = \frac{1}{12} (6.45 (3(.50)^2 + (28.94)^2) - .41 (3(.125)^2 + (28.94)^2))$$

$$= 421.96 \text{ lb} \cdot \text{in}^2$$

$$I_{x'x'} = 421.96 + 6.04 (18.97 - 18.75)^2 = \boxed{422.25 \text{ lb} \cdot \text{in}^2}$$

③ Basket

Center Tube $w = 10.04 \text{ lb}$ $h = 28.50 \text{ in}$

$$w_1 = .2837 \frac{\pi}{4} (1.688)^2 (28.50) = 18.04 \text{ lb}$$

$$w_2 = 18.04 - 10.04 = 8.05 \text{ lb}$$

$$I_{xx} = \frac{1}{12} (18.04 (3(.844)^2 + (28.50)^2) - 8.05 (3(.563)^2 + (28.50)^2))$$

$$= 682.17 \text{ lb} \cdot \text{in}^2$$

$$I_{x'x'} = 682.17 + 10.04 (18.75 - 18.75)^2 = \boxed{682.17 \text{ lb} \cdot \text{in}^2}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 5 of 6
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject TRIGA Cask Moments of Inertia
 (8) Originator R.R. Gurr Date 5/24/94
 (9) Checker HEA/JO Date 6-27-94

(10) Upper Guides* $w = .248$ each $h = 6.08$

$$I_{x'x'} = 18 \left(\frac{1}{2} (.248) (.816)^2 + .248 (26.20 - 18.75)^2 \right) = \boxed{249.25 \text{ lb} \cdot \text{in}^2}$$

Lower Guides* $w = .166$ lb each $h = 4.00$

$$I_{x'x'} = 18 \left(\frac{1}{2} (.166) (.816)^2 + .166 (18.75 - 11.50)^2 \right) = \boxed{153.05 \text{ lb} \cdot \text{in}^2}$$

Stops $w = .785$ lb. each $h = 2.06$ in

$$w_1 = .2837 \frac{\pi}{4} (1.698)^2 (2.06) = 1.31 \text{ lb}$$

$$w_2 = 1.31 - .785 = .525 \text{ lb}$$

$$I_{xx} = \frac{1}{12} \left(1.31 (3(.844)^2 + (2.06)^2) - .525 (3(.563)^2 + (2.06)^2) \right) \\ = .469 \text{ lb} \cdot \text{in}^2$$

$$I_{x'x'} = 18 (.469 + .166 (18.75 - 6.01)^2) = \boxed{493.42 \text{ lb} \cdot \text{in}^2}$$

Fuel* $w = 7.48$ lb $h = 23.11$ in

$$I_{x'x'} = \frac{1}{12} \left(7.48 (3(.72)^2 + (23.11)^2) + 7.48 (18.81 - 18.75)^2 \right)$$

$$= 333.90 \text{ lb} \cdot \text{in}^2 \text{ for each pin}$$

$$10 (333.90) = 3390.00 \text{ lb} \cdot \text{in}^2 \text{ for 10 pins (min. cask wt.)}^{**}$$

$$18 (333.90) = 6,010.20 \text{ lb} \cdot \text{in}^2 \text{ for 18 pins (max. cask wt.)}$$

* Because of symmetry, the three arrays of tubes are translated by only the "E" distance to the cask C.G.

** The 10 fuel pins must be arranged symmetrically about the E-axis of the basket.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 6 of 6
(4) Building _____ (5) Rev. 0 (6) Job No. _____
(7) Subject TRIGA Cask Moments of Inertia
(8) Originator R.R. Perry Date 5/24/94
(9) Checker W.H. Perry Date 6-28-94

(10) Totals

Minimum Cask Weight (10 fuel pins, minimum lead)

$$I_{x'x'}(\text{total}) = \sum I_{x'x'} = \underline{\underline{270,426 \text{ lb-in}^2}}$$

Maximum Cask Weight (18 fuel pins, maximum lead)

$$I_{x'x'}(\text{total}) = \sum I_{x'x'} = \underline{\underline{286,787 \text{ lb-in}^2}}$$

5.3 BASKET/WELD CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 1
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject Basket Weld Integrity
 (8) Originator R. R. Gann Date 6/17/94
 (9) Checker [Signature] Date 6-29-94

(10) The only aspect of the basket warranting structural analysis is the weld stress, at the step-to-center tube joint, due to the weight of the fuel elements. The design does not attempt to prevent failure of basket members/welds due to accident conditions.

The welds will be analyzed at the joint between the center tube and the array of 18 steps. The array is welded to the tube at 6 locations. Essentially, this requires, on average, each weld to bear the weight of 3 fuel elements. By inspection, this is clearly the enveloping situation.

$$\text{Weld Shear Stress, } \tau = \frac{P}{A_w}$$

$$P = 134.64 \times 14.14$$

$$= 148.78 \text{ lbs}$$

$$A_w = 707 \left(\frac{1}{16} \right) (2.00) (6)$$

$$= 53 \text{ in}^2$$

$$\tau = \frac{148.78}{53} = 280.72 \text{ psi}$$

$$30.4 \text{ SST} = S_y = 30,000 \text{ psi}$$

$$S_u = 75,000 \text{ psi}$$

$$F.S. (S_y) = \frac{1/2(30,000)}{280.72} = 53.43$$

$$F.S. (S_u) = \frac{1/2(75,000)}{280.72} = 133.59$$

5.4 CASK CLOSURE CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 2
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject TRIGA Cask Seal/Closure Calculations
 (8) Originator R.P. Gray Date 4/20/94
 (9) Checker H.H. Jr. Date 6-27-94

- (10) The seal designed for the outer containment vessel is a leak-tight double seal. The appropriate seating load, applied by the (12) .50-13UNC cap screws, must be sufficient to properly seat both seals.

Determine Seating Loads (P):

① Helicoflex Seal

Per manufacturer's specification
for Aluminum outer jacket:

$$W = 210 \frac{\text{daN}}{\text{cm}} \left(5.696 \frac{\text{lb/in}}{\frac{\text{daN}}{\text{cm}}} \right) = 1196.2 \text{ lb/in}$$

Call it 1200 lb/in

② Viton Seal

Per manufacturer's specification:

$$W = 200 \text{ lb/in}$$

Determine seating
loads per the
code.

Since the two seals are seated in parallel, their required seating loads are additive.

$$\begin{aligned} \therefore P &= 1200 \text{ lb/in} (\pi)(11.149 \text{ in}) + 200 \text{ lb/in} (\pi)(12.573) \\ &= 42,030.74 \text{ lb} + 7,899.84 \text{ lb} = 49,930.58 \text{ lb} \\ &\text{Call it } \underline{49,931 \text{ lb}} \end{aligned}$$

Determine total preload required:

Because the cask lift (from the lid) requires the total weight of the cask to bear on the lid cap screws, the weight of the cask must be added to the preload. This will assure that the seal remains properly seated during cask lifts.

$$\text{Total preload, } F, = 49,931 + 2013 = \underline{51,944 \text{ lbs}}$$

$$\text{Preload required by each cap screw} = \frac{51,944}{12} = 4328.67 \text{ lb}$$

Call it 4329 lb

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 2
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject TRIGA Cock Seal/Closure Calculations
 (8) Originator R.R. Gurr Date 4/30/94
 (9) Checker W.A. Gurr Date 5-27-94

(10) Total bolt preload = 4329 lb. = F

Per ASTM F-837, Table 4, minimum tensile strength
 for a .50-13 cap screw (Alloy Group 5, type 410) = 22,700 lb.

Determine minimum engagement length

The threads in the vessel will fail first, in shear.

Assume allowable stress of $\frac{2}{3} S_y$, or for shear,

$\frac{1}{2}(\frac{2}{3} S_y)$. For 304L SST, $S_y = 25,000$ psi

$\therefore \tau_{all} = \underline{8,333 \text{ psi}}$, solve for the minimum engagement:

$$\tau_{all} = \frac{F}{A}$$

$$A = \pi D_p \frac{L_e}{2}$$

$$F = 4329 \text{ lb}$$

$$D_p = \text{Pitch Dia.} = .4500 \text{ in}$$

$$L_e = \text{engagement length}$$

$$\therefore 8,333 = \frac{4329(2)}{\pi(.4500)(L_e)} \Rightarrow L_e = .735 \text{ in}$$

make it .750 in

Determine Torque required to develop required preload:

$$T = F(kD) \quad D = .50 \text{ in} \quad k = .2 \text{ (statistically)}$$

$$\therefore T = 4329(.2)(.50) = 432.9 \text{ in-lb} / 12 = \underline{36 \text{ ft-lbs}}$$

5.5 LEAK TEST CLOSURE CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 2
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject TRIGA Cost Leak-check Port Closure Analysis
 (8) Originator R. E. Gung Date 4/20/94
 (9) Checker W. J. Gung Date 6-24-94

(10) Each blind flange, used to cover the quick-disconnect fittings in the outer vessel lid, contains a standard Helicoflex (Type HN) seal in a machined groove.

The seal is compressed by (6) 1/4-20 UNC ASTM F-837, alloy group 1, type 304 socket head cap screws.

Determine seating load (P)

Per manufacturer's specification:

$$w = 1,054 \text{ lb/in}$$

$$\therefore P = 1,054 (\pi) (1.173) = 3,884.08 \text{ lb} \Rightarrow \text{call it } 3,884$$

$$\text{Load per cap screw} = \frac{3,884}{6} = 647.33 \quad \text{call it } 648 \text{ lb.}$$

Per ASTM F-837, Table 4, minimum tensile strength for a 1/4-20 cap screw (Alloy Group 1, ^{Annealed} Type 304), = 2,700 lb

Determine minimum engagement length

The threads in the lid will fail first, in shear.

Assume allowable stress of $\frac{2}{3} S_y$, or for shear, $\frac{1}{2} (\frac{2}{3} S_y)$. For 304L SST, $S_y = 25,000 \text{ psi}$

$\therefore \tau_{all} = 8333 \text{ psi}$, solve for the minimum engagement:

$$\tau = \frac{P}{A} \quad A = \pi D_p \frac{L_e}{2} \quad D_p = \text{pitch dia.} = 2.175 \text{ in}$$

$L_e = \text{engagement length}$

$$\therefore 8333 = \frac{648 (2)}{\pi (2.175) (L_e)} \Rightarrow L_e = 2.28 \text{ in}$$

make it 2.50 in (1/4)

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 2
(4) Building _____ (5) Rev. 0 (6) Job No. _____
(7) Subject TSK Cask Leak-check Port Closure Analysis
(8) Originator R. K. Gung Date 4/20/94
(9) Checker W. H. Jr. Date 6-29-94

(10) Determine torque required to develop required preload:

$$T = F(kD) \quad D = .25 \text{ in} \quad k = .2 \text{ (statistically)}$$

$$\therefore T = 648 (.2)(.25) = 32.40 \text{ in-lb} / 12 = \underline{\underline{2.70 \text{ ft-lb}}}$$

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5.6 INNER CONTAINER CLOSURE CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject Tanger Container Closure Analysis
 (8) Originator RR Perry Date 6/17/94
 (9) Checker WJH Date 6-21-94

(10) The purpose of this analysis is to determine the adequacy of using a single threaded eyebolt at the center of the inner container to lock the lid in place. The preload provided by the eyebolt must be adequate to properly seat both the container elastomer O-ring, and metal C-ring at the eyebolt/lid interface. The analysis will also ^{evaluate} the adequacy of the thread engagement length.

Components: ① Viton O-ring, Durometer-60 hardness

O.D.: 9.262 in.

I.D.: 8.984 in.

See Reference 1

Mean ϕ : 9.12 in

% compression: 30% *

Required loading: 10¹⁵ lb/in

② Teflon-coated Inconel X-750 C-ring seal

O.D.: .375 in

I.D.: .293 in

See Reference 2

Mean ϕ : .334 in

% compression: 24%

Required loading: 150¹⁵ lb/in

③ Type 304 SST Eyebolt

$S_y = 30,000$ psi

$S_u = 75,000$ psi

Thread: 5/16-18 UNC-2

See Reference 3

Thread length: 13/32 in. min

Min. shank $\phi = 1/4" - 1/64" = .234$ in

* 30% compression is used, conservatively, to enable obtaining compression loading requirements directly from Figure A4-14 of Reference 1. actual compression will be 25%.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject Inner Container Closure
 (8) Originator R.R. Gurr Date 6/17/94
 (9) Checker W.D. D. Date 6-21-94

(10) Since the two seals are loaded in series, and not in parallel, the total force exerted on each, by the eyebolt, will be the same. Therefore, when the proper seating load is applied to ^{the} seal requiring the greater compression, the other seal (requiring the lesser compression) will automatically become properly seated.

A. Determine minimum compression loads for each seal.

$$\textcircled{1} P_1 = \pi D_1 w_1 \quad \begin{array}{l} P_1 = \text{compression load, lbs.} \\ D_1 = \text{mean } \phi = 9.12 \text{ in} \\ w_1 = \text{linear compression} = 10 \text{ lb/in} \end{array}$$

$$P_1 = \pi(9.12)(10) = \underline{286.51 \text{ lbs}}$$

$$\textcircled{2} P_2 = \pi D_2 w_2 \quad \begin{array}{l} D_2 = .375 - .047 = .328 \text{ in} \\ w_2 = 150 \text{ lb/in} \end{array}$$

$$P_2 = \pi(.328)(150) = \underline{154.57 \text{ lbs}}$$

Conclusion: The preload requirement of the eyebolt will be based on the required seating load of the elastomer seal. This applied preload will also seat the metal C-ring properly.

B. Determine the total tensile load in the eyebolt

Because it is possible that the entire inner container, with its contents, could be lifted by the eyebolt, the eyebolt could experience additional loading. This additional loading would be the weight of the loaded container itself, which is 373.03 lbs. This is greater than the tensile load due to seal compression.

C. Determine ^{tensile} stress in eyebolt shank

$$\sigma = \frac{P}{A} = \frac{373.04}{\frac{\pi}{4}(.234)^2} = \underline{8,674.29 \text{ psi}}$$

$$F.S. (s_u) = \frac{30,000}{8,674.29} = \underline{3.46}$$

$$F.S. (s_w) = \frac{75,000}{8,674.29} = \underline{8.65}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject Seal Compression Closure
 (8) Originator R.R. Gray Date 6/20/94
 (9) Checker W.H. P. Date 6-29-94

(10) D. Determine strength of thread

From equation 2.8 of Reference 4:

$$F = S \times A_{TS}$$

F = Allowable load

A_{TS} = thread shear stress area

S = Allowable shear stress =

$$\frac{1}{2} \left(\frac{1}{3} \right) (30,000) = 5,000 \text{ psi}$$

From equation 2.13 of Reference 4:

$$A_{TS} = \pi E_p \frac{L_e}{2}$$

E_p = Pitch $\phi = .276 \text{ in}$

L_e = engagement length = $\frac{7}{16} \text{ in} - \frac{1}{32} \text{ in} = .406 \text{ in}$

$$A_{TS} = \pi (.276) \left(\frac{.406}{2} \right) = .176 \text{ in}^2$$

$$\therefore F_{\text{allowable}} = 5,000 (.176) = \underline{880.0 \text{ lbs.}} \Rightarrow \text{OK; will only see } 373 \text{ lbs.}$$

$$F.S. (s_y) = \frac{\frac{1}{2} (30,000) (.176)}{373} = \underline{7.08} \quad F.S. (s_u) = \frac{\frac{1}{2} (75,000) (.176)}{373} = \underline{17.69}$$

E. Determine Torquing requirement (Torquing will develop the seal compression)

From Equation 5.4 of Reference 4:

$$T = P(KD)$$

P = 286.51 lbs

K = .2

D = Nominal $\phi = \frac{5}{16} \text{ in} = .3125 \text{ in}$

$$T = 286.51 (.2) (.3125)$$

$$= \frac{17.9116 \text{ lb-in}}{12} = \underline{1.49 \text{ ft-lb}}$$

F. Determine shear stress in eyebolt due to torque

$$\tau = \frac{Tc}{J}$$

T = applied torque

c = radius = $\frac{5}{32} \text{ in} = .1563 \text{ in}$

J = polar moment of inertia = $\frac{1}{2} \pi (.1563)^4 = 9.36 \times 10^{-4} \text{ in}^4$

$$\tau = \frac{17.91 (.1563)}{9.36 \times 10^{-4}} = \underline{2,990.74 \text{ psi}}$$

$$\tau_{\text{all}} = \frac{2}{3} \left(\frac{1}{2} \right) (30,000) = 10,000 \text{ psi}$$

$$M.S. = \frac{10,000}{2,990.74} - 1 = \underline{2.34}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 4
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject Inner Container Closure
 (8) Originator R.R. Craig Date 6/20/94
 (9) Checker [Signature] Date 6-27-94

(10) References:

1. Parker O-Ring Design Handbook, Parker Seals, Inc., Lexington, Kentucky, 1991
2. Ener-Ring™ Resilient Metal Seals Design Manual, Advanced Products, Inc., North Haven, Conn., 1992
3. Catalog 90, McMaster-Carr Supply Co., Los Angeles, Calif., 1987.
4. "An Introduction to the Design and Behavior of Bolted Joints", John H. Bickford, 1990.

G. Determine stresses in center tube due to lifting and bottom weldment

$$\text{Tensile stress in tube} = \frac{P}{A} \quad P = 664.51 \text{ lbs}$$

$$A = \frac{\pi}{4} (1.00^2 - .25^2) = .74 \text{ in}^2$$

$$\sigma = \frac{664.51}{.74} = \underline{902.94 \text{ psi}}$$

Shear stress in tube-to-plate weld

$$\tau = \frac{P}{A} \quad A = .707 \left(\frac{3}{16} \right) \pi (1.00) = .42 \text{ in}^2$$

$$\tau = \frac{664.51}{.42} = \underline{1,596.21 \text{ psi}}$$

Shear stress in bottom plate-to-shell weld

$$\tau = \frac{P}{A} \quad A = .707 \left(\frac{3}{16} \right) \pi (9.50) = 3.95 \text{ in}^2$$

$$\tau = \underline{168.02 \text{ psi}}$$

5.7 LIFTING BEAM ASSEMBLY DESIGN AND CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 6
(4) Building _____ (5) Rev. 1 (6) Job No. _____
(7) Subject TRIGA Cask Lifting Beam Assembly
(8) Originator R.K. Cross Date 6/21/94
(9) Checker W.H. Ho Date 6-27-94

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3 of 6
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cock Lift Room Analysis
 (8) Originator R. P. Gurn Date 6/21/94
 (9) Checker W. A. R. Date 6-27-94

- (10) The lift beam will be analyzed for both forklift and crane lifting modes. For conservatism in the forklift mode, it will be assumed that the load at each fork is concentrated at the outer edge of each structural tubing member. A dynamic load factor of 2.00 will also be used.

Assembly members

$$c = 1.50, A = 2.21 \text{ in}^2$$

Beam: S 3x7.5, $I_{xx} = 2.93 \text{ in}^4$, ASTM A-36 $S_y = 36,000 \text{ psi}$
 $S_u = 58,000 \text{ psi}$

Tubing: 6.00 O.D. x 2.00 O.D x 3/16 wall

Lugs: 1/2 Thk. Plate, ASTM A-36

Links: 3.3-ton Double clevis link, CROSBY S-247

① Lift by Crane

$$\text{Max load @ crane hook} = 2.00 W_c = F$$

$$W_c = \text{Cast weight} = 2,013 \text{ lb}$$

$$\therefore F = 2.00 (2,013) = 4,026 \text{ lb}$$

$$\text{Max Shear} = \frac{4,026}{2} = 2,013 \text{ lb} = P$$

$$\begin{aligned} \text{Max Moment} &= 2,013 (6.81 \text{ in}) \\ &= 13,708 \text{ lb} \cdot \text{in} = M \end{aligned}$$

$$\text{Max shear stress} = \tau = \frac{P}{A}$$

$$\tau = \frac{2,013 \text{ lb}}{2.21 \text{ in}^2} = 911 \text{ psi}$$

$$\text{Max Bending Stress} = \sigma = \frac{Mc}{I}$$

$$\sigma = \frac{13,708 (1.50)}{2.93} = 7,018 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 6
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cask Lift Beam Analysis
 (8) Originator R.R. Cunn Date 6/21/94
 (9) Checker Wendell Date 6-27-94

(10) A 3:1 safety factor to yield, and 5:1 safety factor to ultimate, will apply to stresses in the beam assembly.

$$\therefore \text{for shear stress, } F.S. (s_u) = \frac{\frac{1}{2}(36,000)}{911} = \underline{\underline{19.76}}$$

$$F.S. (s_u) = \frac{\frac{1}{2}(58,000)}{911} = \underline{\underline{31.83}}$$

$$\text{for bending stress, } F.S. (s_u) = \frac{36,000}{7,018} = \underline{\underline{5.13}}$$

$$F.S. (s_u) = \frac{58,000}{7,018} = \underline{\underline{8.26}}$$

② Lift by Forklift

$$\text{Max Shear} = \frac{4026}{2} = \underline{\underline{2013 \text{ lb}}}$$

$\therefore$ Shear stress will not exceed that of the crane lift.

$$\begin{aligned} \text{Max Moment, } M &= 2013 \text{ lb}(7.75 \text{ in}) \\ &= \underline{\underline{15,601 \text{ lb}\cdot\text{in}}} \end{aligned}$$

$$\sigma = \frac{15,601 (1.50)}{2.93} = \underline{\underline{7,987 \text{ psi}}}$$

$$F.S. (s_u) = \frac{36,000}{7,987} = \underline{\underline{4.51}}$$

$$F.S. (s_u) = \frac{58,000}{7,987} = \underline{\underline{7.26}}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 5 of 6
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA 1.24 Room Analysis
 (8) Originator R R Perry Date 6/21/94
 (9) Checker W H W Date 6-24-94

(10)

③ Determine stresses in Lugs + Welds: Analysis of the lugs and welds will be the same for both lifting modes.

Main Lug: Failure will be by shear tear-out of the eye, or by failure of the weld.

Shear tear-out

For conservatism, the section under stress is assumed to be at the minimum membrane between the eye and the edge, t .

$$t_{\min} = (1\frac{3}{8} - \frac{1}{32}) - \frac{1}{2}(1\frac{1}{32} + \frac{1}{32}) = .81 \text{ in}$$

$$\tau_{\max} = \frac{P}{A} \quad A = 2(.50)(.81) = .81 \text{ in}^2$$

$$\tau_{\max} = \frac{4,026}{.81} = \underline{\underline{4970 \text{ psi}}}$$

$$F.S. (s_u) = \frac{\frac{1}{2}(36,000)}{4970} = \underline{\underline{3.62}}$$

$$F.S. (s_u) = \frac{\frac{1}{2}(58,000)}{4970} = \underline{\underline{5.84}}$$

Weld

$$\tau = \frac{P}{A} \quad A = .707\left(\frac{3}{16}\right)(2(4.00 + .50)) = 1.19$$

$$\tau = \frac{4026}{1.19} = \underline{\underline{3383 \text{ psi}}}$$

$\therefore$ Safety Factors are enveloped by those above.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc No. _____ (3) Page 6 of 6
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject RIGA Rack Lift Room Analysis
 (8) Originator R. L. Fawcett Date 6/21/94
 (9) Checker W. H. H. H. Date 6-29-94

(10)

Lifting LugsShear tear-out

$$t_{min} = (3/4 - 1/32) - \frac{1}{2}(21/32 + 1/32) = .38 \text{ in}$$

$$\tau_{max} = \frac{P}{A} = \frac{2013}{2(.50)(.38)} = 5297 \text{ psi}$$

$$F.S. (s_u) = \frac{\frac{1}{2}(36,000)}{5297} = 3.40$$

$$F.S. (s_u) = \frac{\frac{1}{2}(58,000)}{5297} = 5.47$$

Weld

$$\tau = \frac{P}{A} = \frac{2013}{707(3/16)(2(2.00 + .50))} = 3,037 \text{ psi}$$

∴ Safety Factors are enveloped by those above

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5.8 CASK LIFT CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 1
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cask Lift - Strength of Threads
 (8) Originator R.R. Jany Date 6/24/94
 (9) Checker [Signature] Date 6-27-94

- (10) The cask will be lifted by two ^{3/8-16UNC} eyebolts located on the same bolt circle as the closure cap screws. Each eyebolt has a 1,200 lb working load limit. The ultimate load of each eyebolt is 5 times the working load.

In this application, the nut (lid) material, 304L SST, is weaker than the bolt material. Equation 2.12 of Reference 1 will therefore be used to determine the minimum length of engagement of the eyebolt ^{required} to develop full strength of the eyebolt.

$$L_e = \frac{S_{st}(2A_s)}{S_{nt} \cdot \pi \cdot n \cdot D_{smin} [(1/2n) + 0.57735(D_{smin} - E_{nmax})]}$$

D_{smin} = minimum OD of bolt threads = .3643 in.

E_{nmax} = maximum PD of nut .3401

S_{st} = tensile strength of the bolt material (psi, MPa) = 80,000 psi

n = threads per inch = 16

A_s = stress area of bolt threads - See below

S_{nt} = ultimate tensile strength of the nut material = 70,000 psi

From Equation 2.1 of Reference 1:

$$A_s = \frac{\pi}{4} \left(.375 - \frac{.9743}{16} \right)^2 = .0775 \text{ in}^2$$

$$\therefore L_e = \frac{80,000(2)(.0775)}{70,000\pi(16)(.3643) \left(\frac{1}{2(16)} + .57735(.3643 - .3401) \right)} = .214 \text{ in} \quad (\text{o.k. - will ally be.})$$

Determine actual shear stress in the tapped thread:

$$\tau = \frac{P}{A} \quad P = \frac{2013 \text{ lb}}{2} = 1006.50 \text{ lb} \quad A = \pi E_p \left(\frac{.50}{2} \right) \quad E_p = \text{pitch } \phi = .3401$$

$$\tau = \frac{1006.50}{.27} = 3768.06 \text{ psi}$$

$$\therefore A = .27 \text{ in}^2$$

$$F.S. (s_y) = \frac{\frac{1}{2}(25,000)}{3768} = 3.32$$

$$F.S. (s_u) = \frac{\frac{1}{2}(70,000)}{3768} = 9.29$$

5.9 BASKET LIFT CALCULATIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 3
 (4) Building _____ (5) Rev. 1 (6) Job No. _____
 (7) Subject TRIGA Cask - Bucket Lift Analysis
 (8) Originator R R Cam Date 6/24/94
 (9) Checker [Signature] Date 6-27-94

(10) This analysis will consist of determining shear and tensile stresses induced in the lifting collar, and the shear stress induced in the device pin. Safety factors of 3:1 to yield, and $\infty:1$ to ultimate, will apply to this lift.

① Lifting Collar: Material - 6061-T6 Aluminum
 $S_y = 35,000 \text{ psi}$
 $S_u = 42,000 \text{ psi}$

→ Shear stress in collar

For conservatism, the shear line is assumed to be at the minimum membrane distance.

$$\tau = \frac{P}{A} \quad P = \text{Loaded basket weight} = 166.03 \text{ lb}$$

$$A = 2 \left(\frac{13}{32} - \frac{1}{32} \right) \left(\frac{1}{8} \right) = .044 \text{ in}^2$$

$$\tau = \frac{166.03}{.044} = 1771 \text{ PSI} \Rightarrow \text{combined with bending stresses on page 2}$$

Tensile stresses, due to bending, are also experienced at this section. See page 2 for the analysis and associated safety factors.

→ Tensile stress in collar

The maximum tensile stress, σ , will occur at either the slotted section of the collar (see Figure), or at the threaded section at the major diameter of the thread.

$$\sigma = \frac{P}{A}$$

$$A = \frac{1}{2} \left(\frac{\pi}{4} \right) (1.75^2 - 1.50^2) - 4 \left(.125 \right) \left(\frac{1}{64} \right)$$

$$A = .25 \text{ in}^2$$

continue on page 2

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 3
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA Cask Basket Lift Analysis
 (8) Originator R. K. Four Date 6/24/94
 (9) Checker [Signature] Date 6-27-94

(10) Bending Stress at Shear Section

$$\sigma_B = \frac{Mc}{I}$$

$$M = F \cdot l \quad l = \frac{9}{64} + \frac{1}{64} = \frac{10}{64} = .1563 \text{ in}$$

$$F = \frac{166.03}{2} = 83.015 \text{ lb}$$

$$\therefore M = 83.015 (.1563) = \underline{12.98 \text{ lb} \cdot \text{in}}$$

$$c = \frac{(\frac{13}{32} + \frac{1}{32})}{2} = \underline{.2031 \text{ in}}$$

$$I = \frac{1}{12} (.125) \left(\frac{13}{32} - \frac{1}{32} \right)^3 = \underline{7.0 \times 10^{-4} \text{ in}^4}$$

$$\sigma_B = \underline{3,774.64 \text{ psi}}$$

Combining shear and bending,

$$\tau + \sigma_B = 1771 + 3,774.64 = \underline{5546 \text{ psi}}$$

$$S.F. (s_u) = \frac{35,000}{5546} = \underline{6.31}$$

$$S.F. (s_y) = \frac{42,000}{5546} = \underline{7.57}$$

(Return to page 1, "Tensile Stress in Collar")

DESIGN CALCULATION

(1) Drawing (2) Doc No. (3) Page 3 of 3
 (4) Building (5) Rev. 1 (6) Job No.
 (7) Subject TRIGA CAST - Reactor Core Assembly
 (8) Originator R. R. Ryan Date 6/24/94
 (9) Checker H. H. H. Date 6-12-94

(10)

$$A = \frac{\pi}{4} (1.75^2 - 1.625^2) = .331 \text{ in}^2$$

The weakest (smallest) tensile stress section is therefore the threaded section.

$$S = \frac{P}{A} = \frac{166.03}{.25} = 664.12 \text{ psi}$$

$$F.S. (S_y) = \frac{35,000}{664.12} = 52.70$$

$$F.S. (S_u) = \frac{42,000}{664.12} = 63.24$$

$$Z = \frac{P}{A} = \pi E_p \frac{L_e}{L}$$

$E_p = \text{min pitch dia.} = 1.5709 \text{ in}$
 $L_e = \text{min. engagement length} = 7/16 \text{ in (.4375)}$

$$A = \pi (1.5709) (.4375) = 1.08 \text{ in}^2$$

$$Z = \frac{166.03}{153.73 \text{ psi}} = 1.08$$

$$F.S. (S_y) = \frac{153.73}{113.84} = 1.36$$

$$F.S. (S_u) = \frac{153.73}{136.60} = 1.13$$

Material - Type 304 SST
 $S_y = 30,000 \text{ psi}$
 $S_u = 75,000 \text{ psi}$

$$Z_{\text{allowable}} = \frac{Z (S_y)}{3} = \frac{5,000 \text{ psi}}{3} = 1,666.67 \text{ psi}$$

$$Z = \frac{P}{A}$$

$$Z = \frac{166.03}{1698.17 \text{ psi}} = .098$$

5-38

$$F.S. (S_y) = \frac{1698.17}{22.08} = 77.08$$

$$F.S. (S_u) = \frac{1698.17}{8.83} = 192.32$$

5.10 NORMAL CONDITIONS OF TRANSPORT

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2 MCT
 (7) Subject TRIGA CASK
 (8) Originator W. W. Smyth Date 30 June '94
 (9) Checker [Signature] Date 6/30/94

(10) Containment material properties

Type 304 L steel [ASME SA-240] [ASME, 1989, SECTION III]

min yield $S_y = 25.0 \text{ ksi} \leq 100^\circ\text{F}$, $21.3 \text{ ksi} \leq 200^\circ\text{F}$
 $19.1 \text{ ksi} \leq 300^\circ\text{F}$, $17.5 \text{ ksi} \leq 400^\circ\text{F}$

min ult. tensile strength $S_u = 70.0 \text{ ksi}$

design strength $S_m = 16.7 \text{ ksi} \leq 300^\circ\text{F}$
 $15.8 \text{ ksi} \leq 400^\circ\text{F}$
 $14.8 \text{ ksi} \leq 500^\circ\text{F}$

Thermal expansion coefficient α

$\alpha_{70} = 9.11 \times 10^{-6} \text{ in/in} - \text{absolute expansion @ } 70^\circ$

$\alpha_{100} = 9.21 \times 10^{-6}$

$\alpha_{200} = 9.50 \times 10^{-6}$

$\alpha_{300} = 9.73 \times 10^{-6}$

Modulus of Elasticity $E = 29.1 \times 10^6 \text{ psi @ } -100^\circ\text{F}$, $22.3 \times 10^6 \text{ psi @ } 70^\circ\text{F}$

Lead [AISC, misc. prop]

density = 710 lb/ft^3

$\alpha = .00059 \text{ in/in/}^\circ\text{F} = 15.9 \times 10^{-6} \text{ in/in/}^\circ\text{F}$

$E = 136,000 \text{ psi}$, $S_y = 680 \text{ psi}$, $E = 20,400$ for $\sigma > 680 (1.5\% E)$

[M.H.-1A SARP] - refers to Tietz, 1958, bilinear approx.

The usual numbers to use for mechanical properties are

$E = 2,000,000 \text{ psi}$, $\mu = .40 \text{ to } .45$

[Cask Designer's Guide]

[ASM, 1961] gives : $E = 2,000,000$, $\mu = .40 \text{ to } .45$,

tensile yield = 800 psi

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W-W Smyth Date 30 June 94
 (9) Checker Scott J. Moore Date 6/30/94

(10)

BOLTS : ASTM F-837, Alloy group 5, heat-treated

tensile strength = 160 KSI min

yield strength = 120 KSI min, 12% elongation

Alloy group 5 is Alloy 410, S41000,

Martensitic, 11.5-13.5 % Chromium

Using NUREG/CR-6007 = 27% table 6.1,

$$S_m = \frac{2}{3} S_y = 80 \text{ KSI}$$

STRESS ACCEPTANCE

SINCE THERE ARE $< 30 A_2$ IN THE CASK, ASME SECTION VIII COULD BE USED. HOWEVER, SINCE THIS IS A SPENT FUEL CASK, THAT MAY BE MORE HEAVILY LOADED IN THE FUTURE, SECTION III NB WILL BE USED FOR STRESS ACCEPTANCE. NORMAL CONDITIONS WILL BE "SERVICE LEVEL A", HYPOTHETICAL ACCIDENT WILL BE "SERVICE LEVEL D"

UNDER SERVICE LEVEL A RULES, $P_m \leq S_m$, $P_{m+b} \leq 1.5 S_m$

$$1.5 S_m = 1.5 (16,700) = 25,050 \text{ psi} \leq 300^\circ \text{F for 304L}$$

for bolts, $1.5 S_m = 120 \text{ KSI}$

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DESIGN CALCULATION

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 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W.E. W. Smith Date 30 June '94
 (9) Checker [Signature] Date 6/30/94

(10)

PDC § 5.1.1.1(a) Heat - normal conditions of transport

The preliminary analysis conservatively calculated a max. temp. due to solar insolation + internal heat generation of 160° .

[Letter, R.F. Stevens, April 20 1994]. This included the protective overpack. More importantly, the maximum temperature difference was 4°F , & occurred in the lid.

A 4°F temperature will cause essentially no stress within the cask.

The minimum temperature during transportation will be -27°F . Assuming a σ -stress state at 70°F , the temp.

change is about -100°F for normal transport conditions. Lead has a greater coef. of thermal expansion than stainless steel, so a temperature drop of 100°F causes the lead to shrink more than the stainless steel containment. If the containment is rigid under the shrinkage forces in the lead, find the pressure on lead-steel interface:

assume the 1.5" thick lead shrinks freely due to 100°F ΔT .

$$\Delta b = 100 (\alpha_{pb} - \alpha_{ss}) b$$

$$\Delta b = 100 (15.9 - 9.1) \cdot 10^{-6} \cdot 6 = .0041"$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject _____
 (8) Originator Wm W Smith Date 30 June 94
 (9) Checker /// Date 6/30/94

- (10) Now assume this change of radius is prevented by the containment. Using a standard soln for a thick cylinder under internal pressure [Roark, p 504, case 1a]

$$\Delta b = \frac{q b}{E} \left(\frac{a^2 + b^2}{a^2 - b^2} + \nu \right) \quad q = \text{internal pressure}$$

for $E_{pb} = 136,000$ psi, $\nu = .4$

$$\Delta b = \frac{6 q}{136,000} \left(\frac{7.5^2 + 6^2}{7.5^2 - 6^2} + .4 \right) = .000219 q \quad \frac{\text{in}}{\text{psi}}$$

equat thermal $\Delta b \equiv$ pressure Δ_b

$$.0041 = .000219 q$$

$$q = 19 \text{ psi}$$

$$\text{max tensile lead stress } \sigma_2 = 19 \cdot \frac{7.5^2 + 6^2}{7.5^2 - 6^2} = 87 \text{ psi}$$

no cracking in Pb.

add 19 psi to Δ external pressure for § (c)

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 5 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 82MCT
 (7) Subject TRIGA CASE
 (8) Originator W. W. Smith Date 30 June 94
 (9) Checker ADD Date 6/30/94

(10) SECTION 5.1.1.1 (b) (Reduced external pressure)

Assuming an absolute internal pressure of 14.5 psia, the internal pressure will be $14.5 - 3.5 = 11$ psig when the external pressure drops to 3.5 psia.

For a thin-walled cylinder,

$$\sigma_1 = \frac{pR}{t}$$

$$\sigma_2 = \frac{pR}{t}$$

$$R = \frac{1}{2}(6 + 5.25) = 5.63 \quad t = .75$$

$$\sigma_1 = \frac{11 \times 5.63}{.75 \times 2} = 41.3 \text{ psi}$$

$$\sigma_2 = \frac{11 \times 5.63}{.75} = 82.3$$

$$\sigma_3 = 0$$

$$\text{stress intensity} = \sigma_2 - \sigma_3 = 82.3 \text{ psi} < S_m$$

Section 5.1.1.1 (c) (increased external pressure)

for external pressure of 20 psia,

$$p = 20 - 14.5 = 5.5 \text{ psig (inward)}$$

add 19 psi due to temperature-induced local shrinkage for a total external

$$\text{pressure} = 19 + 5.5 = 24.5 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 6 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W.D. W. Smyth Date 30 June 94
 (9) Checker MS Date 6/30/94

$$(10) \quad \sigma_1 = - \frac{24.5 \times 5.63}{2 \times 7.5} = -92 \text{ psi (compression)}$$

$$\sigma_2 = - \frac{24.5 \times 5.63}{.75} = -184 \text{ psi}$$

$$\text{STABILITY: } \frac{r}{t} = \frac{5.63}{.75} = 7.5 < 10 \quad \text{so ROARK}$$

Table 35, case 20a must be used cautiously -

recommended minimum critical pressure is .8 σ_1

$$\text{critical pres.} = .8 \times .92 E = \frac{.8 \times .92 \times 28.3 \text{ EG}}{\left(\frac{2}{r}\right) \left(\frac{r}{t}\right)^{2.5}} = \frac{.8 \times .92 \times 28.3 \text{ EG}}{\left(\frac{2}{5.63}\right) (7.5)^{2.5}}$$

$$= 25,400 \text{ psi} \gg 24.5$$

The top & bottom of the cylindrical containment are prevented from radial expansion by the ring & bottom R. Check for any local bending stresses

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 7 of _____
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 (7) Subject TRIGA CASK
 (8) Originator N. W. Smith Date 30 June '94
 (9) Checker SS Date 6/30/94

(10)

Follow Roark, example on
P. 465

$$R = 6" \quad l = 30" \quad D = \frac{Et^3}{12(1-\nu^2)} = \frac{28.3 \times 10^6 (1.75)^3}{12(1-.3^2)}$$

$$= 1.093 \times 10^9 \text{ in}^3$$

$$\lambda = \left[\frac{3(1-\nu^2)}{R^2 t^2} \right]^{1/4} = \left[\frac{3(1-.3^2)}{5.63^2 \times 1.75^2} \right]^{1/4} = .6255 / \text{in}$$

$\lambda L = .6255 \times 30" = 19 > 6$ so cylinder is long.

ΔR due to pressure is

$$-\frac{qR^2(1-\frac{\nu}{2})}{Et} = -\frac{24.5(5.63)^2}{28.3 \times 10^6 \times 1.75} \left(1 - \frac{.3}{2}\right) = -31.1 \times 10^{-6} \text{ in}$$

(+ outside, - inside)

table 30, case 8: $\phi = \frac{V_0}{2D\lambda^2}$ $\Delta R = \frac{V_0}{2D\lambda^3}$

table 30, case 10 $\phi = \frac{M_0}{D\lambda}$ $\Delta R = -\frac{M_0}{2D\lambda^2}$

Combine the 3 loads so $\Delta R = 0$ & $\phi = 0$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 8 of _____
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 (7) Subject TRIGA CASK
 (8) Originator Wm W Smith Date 30 June 94
 (9) Checker /// Date 6/30/94

(10)

$$-31.1 \times 10^{-6} + \frac{V_0}{2D\lambda^3} - \frac{M_0}{2D\lambda^2} = 0$$

$$\frac{-V_0}{2D\lambda^3} + \frac{M_0}{D\lambda} = 0 \Rightarrow M_0 = \frac{V_0}{2\lambda}$$

$$\frac{V_0}{2D\lambda^3} - \frac{V_0/2\lambda}{2D\lambda^2} = \frac{V_0}{4\lambda^3 D} = 31.1 \times 10^{-6} \text{ in}$$

$$V_0 = 33.3 \times 10^{-6} \times 4 \cdot (.6255)^3 (1.093 \times 10^6) \frac{\text{in}}{\text{in}^3} = 33.3 \text{ #/in}$$

$$M_0 = \frac{33.3}{2 \times .6255} = 26.6 \frac{\text{#-in}}{\text{in}}$$

$$\text{bending stress } \sigma_1 = \frac{6M}{t^2} = \frac{6 \times 26.6}{.75^2} = 284 \text{ psi}$$

uniform circumferential stress $\sigma_2 =$

$$\left(\text{use } M_0 = \frac{V_0}{2\lambda} \right) \frac{2V_0\lambda R}{t} - \frac{2M_0\lambda^2 R}{t} = \frac{V_0\lambda R}{t}$$

$$\sigma_2 = \frac{33.3 \times .6255 \times 5.63}{.75} = 156 \text{ psi}$$

It is evident that all load combinations have stresses below their limits.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 9 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. W. Smyth Date 30 June '94
 (9) Checker SLD Date 6/30/94

(10)

PDC § 5.1.1.1 (h) (Compression) - subject the cask to a concentrated load of 5 times its own weight.
 (Assume no overpack)

Total Weight:

CASK = 1640	} USE RICH CRUZ'S DESIGN CALCS
inner Cont. = 207	
Basket = 32	
Fuel = 135	
<u>2014</u>	

Considering just the outer pipe of the cask as a simply supported beam ~

$$P = 5 \times 2014 = 10,070$$

considering only the outer pipe (16" OD, 1/2" wall)

$$S_x = \frac{\pi(d^4 - d_i^4)}{32d} = \frac{\pi(16^4 - 15^4)}{32 \times 16} = 91.5 \text{ in}^3$$

longitudinal bending stress $\sigma_l = \frac{M}{S_x}$, $M = PL/4$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 10 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MGT
 (7) Subject TRIGA CASE
 (8) Originator Wm Smyth Date 30 June '94
 (9) Checker MM Date 6/30/94

(10)

$$\sigma_1 = \frac{10,070 \times 32.38 / 4}{91.5} = \pm 891 \text{ psi}$$

for σ_2 , see Roark, p 496, Case 9b:

$$\sigma_2 = -1.3 B P R^{3/4} b^{-3/2} t^{-5/4}$$

$$B = [12(1-\nu^2)]^{1/8} = [12(1-.3^2)]^{1/8} = 1.348$$

$$P = 10,070, R = 5.63, b = 1" (\text{say}), t = .5"$$

$$\sigma_2 = -1.3 (1.35) (10,070) (5.63)^{3/4} (1) (.5)^{-5/4} = -15,360 \text{ psi}$$

$$\text{stress intensity } SI = \sigma_2 - \sigma_1 = -16250 \text{ psi} < 16,700 \text{ [Sm]}$$

THE RING STRESSES ARE INVESTIGATED UNDER "FREE DROP" CONDITIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 11 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 32 MCT
 (7) Subject TRIGA CASE
 (8) Originator W. Smith Date 30 June 94
 (9) Checker /// Date 6/30/94

(10) PDC § 5.1.1.1 (g) (4' FREE DROP)

Assume the protective overpack limits the deceleration to 60g. Assume the outer shell & lead take no load & find the max. stress in the containment.

$$R = \frac{2014}{2} \times 60 = 60,420^{\#}$$

$$\text{end shear} = 60,420^{\#}$$

$$\text{moment} = \frac{wL^2}{2}$$

$$L = 32.38$$

$$wL = 40g \times 2014 = 120,800^{\#}$$

$$M = \frac{120,800 \times 32.38}{2} = 489,100^{\#}$$

$$\text{max bending stress (2, top & bottom)} f_b = \frac{M}{S}$$

$$S = \frac{\pi(d_o^4 - d_i^4)}{32d_o} = \frac{\pi(12^4 - 10.5^4)}{32 \times 12} = 70.2 \text{ in}^3$$

$$f_b = \frac{489,100}{70.2} = 6967 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 12 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. W. Smyth Date 30 June 94
 (9) Checker /// Date 4/30/94

(10)

Find the shear flow $q = t \cdot \text{shear stress}$
 in a thin-wall pipe

by elementary beam theory,

$$\tau_v = \frac{VQ}{Ib}$$

V = applied shear
 I = moment of inertia
 b = section width

Q = statical moment from y_0 to the top of the section

$$Q = \int y dA$$

τ_v is the vertical component of the shear stress

$$I = \frac{\pi(d_o^4 - d_i^4)}{64}$$

d_o = outer } diameter
 d_i = inner }

for thin walls, $d_o - d_i = 2t$
 $d_o + d_i \approx 2d$ (avg)

$$I \approx \frac{\pi d^3 t}{8} = \pi r^3 t$$

$$Q = 2 \int_0^{\pi/2} (r \sin \theta)(r d\theta)t = 2r^2 t \cos \theta$$

total shear $\tau = \tau_v / \cos \theta$

$$\tau = \frac{V(2tr^2 \cos \theta)}{\pi r^3 t (2t / \cos \theta)} / \cos \theta = \frac{2V \cos \theta}{2\pi r}$$

$$\tau = 2 \times \frac{V}{A} \cos \theta = 2 \times \text{avg shear stress @ center}$$

$$\tau_{\max} = 2 \times \frac{60,420}{\pi(6^2 \cdot 5.25^4)} = 4559 \text{ psi}$$

no combination of 6967 psi tension & 4559 shear
 can approach 16,800 psi S_m since max
 τ occurs at points with $\tau = 0$ & max τ occurs
 at points of $\sigma = 0$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 13 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. W. SMYTH Date 7/13/94
 (9) Checker /// Date 8/5/94

- (10) INVESTIGATE THE UPPER RING & LID WITH A CONCENTRATED LOAD OF 60,420 # (static equivalent of 60 g impact)

The overpack is very soft compared to the cask & will crush uniformly. The lid will slip up to bear on the ring, then will distribute its load to the ring.

60,420 # distributed to RING & LID proportional to their length.

$$\text{Force on bottom of ring} = \frac{2.5}{4.625} \times 60,420 = 32,660$$

$$\text{Force on lid} = \frac{2.125}{4.625} \times 60,420 = 27,760 \text{ #} - \text{this}$$

force is transferred through the lid to the upper part of the ring. Assume the inertial forces are uniformly distributed to the ring's circumference by the two shells -

$$W = \frac{60,420}{2\pi \times 6.625} = 1451 \text{ #/inch}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 14 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator W. Smith Date 7/13/94
 (9) Checker J/P Date 8/5/94

- (10) USE ROARK (5th ed) CASE 13 on p.231 for forces in the ring & CASE 1 on p.210 for stresses in the ring (curved beam stresses)

$$\frac{h}{c} = \frac{R}{c} - \frac{2}{\ln\left(\frac{R/c+1}{R/c-1}\right)}$$

$$C = 2.75/2 = 1.375$$

$$\frac{R}{c} = \frac{6.625}{1.375} = 4.818$$

$$\frac{h}{c} = .0700 \Rightarrow \text{neutral axis is } .07 + C = .0963'' \text{ below the centroid}$$

$$\text{beam properties: } A = 2.5 \times 2.75 = 6.875$$

$$S = \frac{1}{6} (2.5)(2.75)^2 = 3.151$$

$$I = \frac{1}{12} (2.5)(2.75)^3 = 4.333$$

STRESS CORRECTION FACTORS

$$K_i = \frac{1}{3^{h/c}} \cdot \frac{1 - h/c}{R/c - 1} = 1.16$$

$$K_o = \frac{1}{3^{h/c}} \cdot \frac{1 + h/c}{R/c + 1} = 0.876$$

$$f_b = \frac{\text{Moment}}{S} \times \begin{cases} K_o, \text{ outside} \\ K_i, \text{ inside} \end{cases}$$

BOTTOM LOADED
PROBLEM

$$R = 32660$$

$$W = \frac{R}{2\pi} = 784.6$$

TOP LOAD
PROBLEM

$$R = 27760$$

$$W = \frac{27760}{2\pi \cdot 6.625} = 666.9 \text{ lb/in}$$

COMBINE THE FORCES

AS:
RING FORCE @ $\theta =$

BOTTOM-LOAD FORCE @ θ

(-)
TOP-LOAD FORCE @ $(180^\circ - \theta)$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 15 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2 MCT
 (7) Subject TRIGA CASK
 (8) Originator W. Smyth Date 20 June 94
 (9) Checker /// Date 6/30/94

(10)

from p.220: $M = M_A - T_A \cdot R(1 - \cos\theta) + V_A \cdot R \cdot \sin\theta - WR^2(\theta \sin\theta + \cos\theta - 1)$
 & p.231

$$T = T_A \cos\theta + V_A \sin\theta - WR\theta \sin\theta$$

$$V = -T_A \sin\theta + V_A \cos\theta - WR\theta \cos\theta$$

at any section, the stress intensity due to primary stresses (excludes bending) can be found by combining $\frac{3}{2} \times \text{avg shear} + \text{avg } T/A$ using

Mohr's circle

$$(SI)^2 = \left[\left(\frac{T}{2A} \right)^2 + \left(\frac{3}{2} \frac{V}{A} \right)^2 \right] : \text{compare to } S_m$$

then consider the bending stresses by finding
 SI due to bending + primary & compare to $1.5 S_m$

from p.220: $\alpha = \frac{I}{AR^2} = \frac{4.333}{6.875 \cdot 6.625^2} = .01436$

$\beta = \frac{FEI}{GAR^2}$ $F = \text{shear shape factor} = 6/5 \text{ for rectangle}$
 $G = \frac{E}{2(1+\mu)}$ $E/G = 2(1.3) = 2.6$

$$\beta = \frac{6}{5} \times \frac{2.6 \times 4.333}{6.625^2 \times 6.875} = .04481$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 16 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. Smith Date 7/13/94
 (9) Checker /// Date 8/5/94

(10) $k_1 = 1 + \alpha + \beta = 1.059$ $k_2 = 1 - \alpha + \beta = 1.030$
 $k_3 = 1 + \alpha - \beta = .9696$ $k_4 = k_2/k_1 = .9729$

For both problems, $M_A = k_4 \frac{\omega R^2}{2} = .9729 \omega (6.625)^2/2$

Bottom: $M_A = 784.6 \times 21.35 = 16,750 \text{ #}$

Top: $M_A = 666.9 \times 21.35 = 14,240 \text{ #}$

$T_A = K_4 \frac{\omega R}{2} = \omega (3.223)$

Bottom: $T_A = 2529 \text{ #}$

Top: $T_A = 2149 \text{ #}$

"point A" is 180° away from concentrated force.
 measure θ from A; @ $\theta = 180^\circ =$ point C

USE $\theta = 180^\circ$ & FIND M_C, T_C, V_C :

$M_C = M_A = M_A - 2RT_A + 2\omega R^2$

"Bottom" $M_C = 16750 - 2(6.625)(2529) + 2(784.6)(6.625)^2$
 $= 52110 \text{ #}$

"Top" $M_C = \frac{666.9}{784.6} \times 52110 = 44300$ by proportion

$T_C = -T_A$ "Bottom" $T_C = -2529$
 "Top" $T_C = -2149$

$V_C = \omega R T$ "Top" $V_C = 784.6(6.625)\pi = 16,330$
 "Bottom" $V_C = 666.9(6.625)\pi = 13,880$

AT THE TOP OF THE RING,

$T = + \text{Bottom } T_A (-) \text{ Top } T_C$
 $= 2529 - 2149 = 4678 \text{ #}, \sigma = \frac{T}{A} = \frac{4678}{6.875} = 680 \text{ psi}$

$V = 0 - 13880$

avg $\tau = \frac{-13880}{6.875} = -2019 \text{ psi}$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 17 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. SMITH Date 7/12/94
 (9) Checker SSS Date 8/5/94

(10)

$$M = +M_A(\text{bottom}) - M_C(\text{top}) = 16,750 - 44,300 = -27,550$$

$$\text{inside } F_b = -1.16 \times \frac{27,550}{3.151} = -10,140 \text{ psi compression}$$

$$\text{outside } F_b = + \frac{.876 \times 27,550}{3.151} = +7,659 \text{ psi tension}$$

CHANGE IN VERTICAL DIAMETER

$$D_v = -\frac{WR^2}{EI} \left(\frac{\pi^2}{4} R_1 - 2 \right)$$

$$W = +784.6 - 666.9 = +117.7$$

$$EI = 28.3 \text{ EG} \times 4.33 = 122.5 \text{ EG} \cdot \text{in}^2$$

$$D_v = \frac{-117.7 (6.625)^2}{122.5 \text{ EG}} \left(\frac{\pi^2}{4} \cdot 1.059 - 2 \right) = -.00114" \text{ (diam. shortens)}$$

CHANGE IN HORIZONTAL DIAMETER

$$D_h = \frac{+WR^2}{EI} \left(2 - \frac{\pi^2}{2} R_1 \right) = \frac{117.7 (6.625)^2}{122.5 \text{ EG}} \left(2 - \frac{\pi^2}{2} \cdot .9625 \right) = -.000882" \text{ (increases)}$$

THE LID-RING DIAMETER TOLERANCES ARE $+.002$ (max), -0.000
 IF IT IS $> .00114$, THEN THE ANALYSIS ABOVE GIVES THE MAX.
 σ IN THE RING.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 18 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 525ACT
 (7) Subject TRIGA CORE
 (8) Originator W. Smith Date 7/14/94
 (9) Checker JW Date 8/5/94

(10)

COMBINED STRESSES

PRIMARY MEMBRANE STRESS: COMBINE $\sigma + \frac{3}{2}\tau$ AVG
 USING MOHR'S CIRCLE

$$P_1 = \frac{680}{2} + \sqrt{340^2 + 3029^2}$$

$$= 3388 \text{ psi}$$

$$P_2 = 0$$

$$P_3 = 340 - 3029 = -2708$$

$$P_m = 3388 - (-2708) = 6096 \text{ psi} < 16,800 \text{ OK}$$

Primary + bending: combine $(F_b + T/A)$ with τ_{avg}

$$\text{inside: } (-10,140 + 680) + \sqrt{4730^2 + 2019^2} = +413 \text{ psi} = P_1$$

$$P_3 = -4730 - 5143 = -9873$$

$$P_2 = 0$$

$$P_{m+b} = 413 - (-10,530) = 10,940 < 1.5 \times 16,800$$

Find the combined stresses & margins with a spread-sheet on the following pages - use the above to verify the spreadsheet

DESIGN CALCULATION

Drawing	_____	Doc. No.	_____	Page	19	of	_____
Building	_____	Rev	_____	Job	B2MCT		
Subject	_____						
Originator	Wm. W. Smyth	WWS		Date	12 July 1994		
Checker	_____ 111			Date	8/1/94		

Combine 2 ring loads using Roark case 13 on p. 231 (5th ed.)

Geometry: Radius = 6.625
 height = 2.75
 width = 2.5

Calc'd properties: I = 4.333
 S = 3.151
 A = 6.875
 c = 1.375
 h/c = 0.07000 (curved beam properties, p. 210)
 ko = 0.875796
 ki = 1.159944 (Fb multiplier for inside of beam)

Mat'l properties: E = 2.83E+07
 G = 1.09E+07
 Sm = 16,700
 α = 0.014359
 β = 0.044799

Hoop stress k1 = 1.059157
 corrections: k2 = 1.03044
 k3 = 0.96956
 k4 = 0.972887

Load: g = 60

Drawing	_____	Doc. No.	_____	Page	20	of	_____
Building	_____	Rev	_____	Job	B2MCT		
Subject	_____						
Originator	Wm. W. Smyth	_____		Date	12 July 1994		
Checker	_____	_____		Date	8/1/94		

Reaction = 32,659 at $\theta = 180^\circ$
 uniform load = 785 vertical #/in on circumference
 calc'd δ diameter = -0.00756 (vertical)
 0.00588 (horizontal)

Θ	Tension force	stress	avg force	Shear stress	moment	inside Fb	outside Fb
0	2,528	368	0	0	16,751	6,166	-4,656
5	2,479	361	-672	-98	16,557	6,095	-4,602
10	2,333	339	-1,332	-194	15,976	5,881	-4,440
15	2,090	304	-1,969	-286	15,021	5,529	-4,175
20	1,755	255	-2,570	-374	13,707	5,046	-3,810
25	1,333	194	-3,124	-454	12,058	4,439	-3,351
30	829	121	-3,621	-527	10,105	3,720	-2,809
35	250	36	-4,051	-589	7,884	2,902	-2,191
40	-396	-58	-4,405	-641	5,435	2,001	-1,511
45	-1,099	-160	-4,675	-680	2,807	1,033	-780
50	-1,850	-269	-4,853	-706	48	18	-13
55	-2,637	-384	-4,933	-718	-2,786	-1,025	774
60	-3,450	-502	-4,911	-714	-5,636	-2,075	1,567
65	-4,276	-622	-4,784	-696	-8,444	-3,108	2,347
70	-5,103	-742	-4,548	-662	-11,147	-4,103	3,098
75	-5,918	-861	-4,203	-611	-13,682	-5,037	3,803
80	-6,708	-976	-3,750	-546	-15,986	-5,885	4,443
85	-7,462	-1,085	-3,191	-464	-17,998	-6,625	5,002
90	-8,165	-1,188	-2,528	-368	-19,656	-7,236	5,463
95	-8,806	-1,281	-1,768	-257	-20,903	-7,695	5,810
100	-9,373	-1,363	-915	-133	-21,682	-7,982	6,026
105	-9,856	-1,434	23	3	-21,944	-8,078	6,099
110	-10,242	-1,490	1,037	151	-21,641	-7,966	6,015
115	-10,524	-1,531	2,118	308	-20,732	-7,632	5,762
120	-10,692	-1,555	3,254	473	-19,182	-7,061	5,331
125	-10,740	-1,562	4,433	645	-16,961	-6,244	4,714
130	-10,660	-1,551	5,644	821	-14,050	-5,172	3,905
135	-10,448	-1,520	6,872	1,000	-10,432	-3,840	2,899
140	-10,101	-1,469	8,104	1,179	-6,103	-2,247	1,696
145	-9,616	-1,399	9,325	1,356	-1,064	-392	296
150	-8,994	-1,308	10,521	1,530	4,675	1,721	-1,299
155	-8,234	-1,198	11,676	1,698	11,094	4,084	-3,083
160	-7,341	-1,068	12,775	1,858	18,165	6,687	-5,049
165	-6,317	-919	13,804	2,008	25,852	9,516	-7,185
170	-5,168	-752	14,749	2,145	34,110	12,556	-9,481
175	-3,903	-568	15,595	2,268	42,887	15,787	-11,920
180	-2,528	-368	16,330	2,375	52,121	19,187	-14,486

DESIGN CALCULATION

Drawing	_____	Doc. No.	_____	Page	21	of	_____
Building	_____	Rev	_____	Job	B2MCT		
Subject	_____						
Originator	Wm. W. Smyth <i>WWS</i>			Date	12 July 1994		
Checker	<i>1/1</i>			Date	7/5/94		

stresses in "TOP LOADED" ring

Reaction = 27,761 at $\Theta = 180^\circ$
 uniform load = 667 vertical #/in on circumference
 calc'd δ diameter = 0.00643 (vertical)
 -0.00500 (horizontal)

Θ	Tension force	stress	avg force	Shear stress	moment	inside Fb	outside Fb
0	2,149	313	0	0	14,239	5,241	-3,957
5	2,107	307	-604	-88	14,073	5,181	-3,911
10	1,983	288	-1,198	-174	13,580	4,999	-3,774
15	1,777	258	-1,772	-258	12,767	4,700	-3,549
20	1,492	217	-2,314	-337	11,651	4,289	-3,238
25	1,133	165	-2,816	-410	10,249	3,773	-2,849
30	705	102	-3,268	-475	8,589	3,162	-2,387
35	212	31	-3,661	-533	6,701	2,467	-1,863
40	-336	-49	-3,988	-580	4,620	1,701	-1,284
45	-934	-136	-4,242	-617	2,386	878	-663
50	-1,572	-229	-4,415	-642	41	15	-11
55	-2,241	-326	-4,504	-655	-2,368	-872	658
60	-2,932	-427	-4,503	-655	-4,791	-1,764	1,332
65	-3,634	-529	-4,410	-641	-7,178	-2,642	1,995
70	-4,337	-631	-4,222	-614	-9,475	-3,488	2,633
75	-5,030	-732	-3,939	-573	-11,630	-4,281	3,232
80	-5,702	-829	-3,561	-518	-13,588	-5,002	3,777
85	-6,342	-923	-3,090	-449	-15,298	-5,631	4,252
90	-6,940	-1,009	-2,528	-368	-16,708	-6,150	4,644
95	-7,485	-1,089	-1,880	-274	-17,767	-6,540	4,938
100	-7,967	-1,159	-1,151	-167	-18,430	-6,784	5,122
105	-8,377	-1,219	-347	-50	-18,652	-6,866	5,184
110	-8,706	-1,266	525	76	-18,395	-6,771	5,113
115	-8,945	-1,301	1,456	212	-17,622	-6,487	4,898
120	-9,088	-1,322	2,437	354	-16,304	-6,002	4,532
125	-9,129	-1,328	3,458	503	-14,417	-5,307	4,007
130	-9,061	-1,318	4,507	656	-11,942	-4,396	3,319
135	-8,881	-1,292	5,573	811	-8,867	-3,264	2,465
140	-8,586	-1,249	6,645	967	-5,187	-1,910	1,442
145	-8,174	-1,189	7,709	1,121	-904	-333	251
150	-7,645	-1,112	8,753	1,273	3,974	1,463	-1,104
155	-6,999	-1,018	9,764	1,420	9,430	3,471	-2,621
160	-6,239	-908	10,729	1,561	15,440	5,684	-4,291
165	-5,369	-781	11,636	1,692	21,974	8,089	-6,107
170	-4,393	-639	12,471	1,814	28,994	10,673	-8,058
175	-3,317	-482	13,223	1,923	36,454	13,419	-10,132
180	-2,149	-313	13,880	2,019	44,303	16,309	-12,314

DESIGN CALCULATION

Drawing	_____	Doc. No.	_____	Page 22 of _____
Building	_____	Rev	_____	Job B2MCT
Subject	_____			
Originator	Wm. W. Smyth <i>W-7</i>			Date 12 July 1994
Checker	<i>111</i>			Date <i>8/1/94</i>

COMBINED STRESSES

δ diameter = -0.0011 (vertical)
 0.00088 (horizontal)

	axial stress	shear stress	P1	P2	Pm	margin
0	680	-2,019	3,388	-2,707	6,095	64%
5	843	-2,021	3,482	-2,639	6,122	63%
10	978	-2,008	3,540	-2,562	6,102	63%
15	1085	-1,979	3,560	-2,475	6,035	64%
20	1163	-1,934	3,541	-2,378	5,919	65%
25	1212	-1,875	3,482	-2,271	5,753	66%
30	1233	-1,800	3,386	-2,153	5,539	67%
35	1225	-1,711	3,251	-2,025	5,276	68%
40	1191	-1,607	3,079	-1,888	4,967	70%
45	1132	-1,491	2,872	-1,740	4,613	72%
50	1049	-1,361	2,633	-1,584	4,217	75%
55	944	-1,220	2,363	-1,418	3,781	77%
60	820	-1,069	2,065	-1,245	3,310	80%
65	679	-908	1,743	-1,064	2,806	83%
70	524	-738	1,400	-875	2,275	86%
75	358	-561	1,039	-681	1,720	90%
80	183	-378	666	-483	1,149	93%
85	3	-191	288	-284	572	97%
90	-178	0	-0	-178	178	99%
95	-358	192	160	-519	679	96%
100	-534	385	369	-903	1,272	92%
105	-702	576	582	-1,284	1,866	89%
110	-859	765	796	-1,655	2,450	85%
115	-1002	949	1,009	-2,011	3,019	82%
120	-1129	1,128	1,220	-2,348	3,568	79%
125	-1236	1,300	1,427	-2,664	4,091	76%
130	-1322	1,463	1,631	-2,953	4,584	73%
135	-1384	1,617	1,830	-3,214	5,043	70%
140	-1420	1,759	2,022	-3,442	5,464	67%
145	-1430	1,889	2,207	-3,637	5,844	65%
150	-1411	2,006	2,385	-3,795	6,180	63%
155	-1363	2,108	2,553	-3,916	6,469	61%
160	-1285	2,195	2,712	-3,997	6,709	60%
165	-1177	2,266	2,860	-4,038	6,898	59%
170	-1040	2,320	2,998	-4,038	7,036	58%
175	-874	2,356	3,124	-3,999	7,123	57%
180	-680	2,375	3,239	-3,919	7,158	57%

DESIGN CALCULATION

Drawing	_____	Doc. No.	_____	Page	23	of	_____
Building	_____	Rev	_____	Job	B2MCT		
Subject	_____						
Originator	Wm. W. Smyth			Date	12 July 1994		
Checker	_____ 111			Date	8/1/94		

COMBINED STRESSES: primary membrane + bending stresses

Θ	inside Fb	outside Fb	P1	inside P3	Pb+Pm SI	margin	outside P1	P3	SI	margin
0	-10,142	7,658	413	-9,875	10,287	59%	8,801	-463	9,264	63%
5	-7,324	5,530	579	-7,060	7,639	70%	6,960	-587	7,547	70%
10	-4,792	3,618	862	-4,676	5,538	78%	5,350	-754	6,103	76%
15	-2,560	1,933	1,374	-2,849	4,223	83%	3,997	-980	4,977	80%
20	-638	482	2,215	-1,690	3,904	84%	2,924	-1,280	4,204	83%
25	968	-731	3,258	-1,079	4,337	83%	2,131	-1,649	3,780	85%
30	2,257	-1,704	4,252	-762	5,014	80%	1,579	-2,051	3,631	86%
35	3,235	-2,442	5,041	-580	5,621	78%	1,207	-2,424	3,631	86%
40	3,910	-2,952	5,566	-464	6,030	76%	952	-2,713	3,665	85%
45	4,297	-3,245	5,812	-382	6,194	75%	771	-2,883	3,654	85%
50	4,414	-3,333	5,783	-320	6,104	76%	635	-2,919	3,554	86%
55	4,282	-3,233	5,497	-271	5,768	77%	529	-2,817	3,346	87%
60	3,927	-2,965	4,977	-230	5,206	79%	442	-2,587	3,028	88%
65	3,379	-2,551	4,252	-194	4,445	82%	368	-2,240	2,607	90%
70	2,668	-2,014	3,354	-162	3,517	86%	304	-1,794	2,097	92%
75	1,830	-1,381	2,323	-135	2,458	90%	248	-1,271	1,519	94%
80	900	-679	1,202	-119	1,321	95%	204	-700	904	96%
85	-85	64	154	-236	390	98%	227	-160	387	98%
90	-1,085	819	-0	-1,263	1,263	95%	641	-0	641	97%
95	-2,063	1,558	15	-2,437	2,452	90%	1,229	-30	1,260	95%
100	-2,979	2,250	42	-3,555	3,597	86%	1,798	-82	1,880	92%
105	-3,797	2,867	73	-4,571	4,644	81%	2,309	-144	2,453	90%
110	-4,478	3,381	107	-5,445	5,552	78%	2,736	-214	2,950	88%
115	-4,990	3,767	147	-6,139	6,285	75%	3,060	-295	3,354	87%
120	-5,297	4,000	192	-6,618	6,811	73%	3,261	-390	3,652	85%
125	-5,372	4,056	247	-6,855	7,101	72%	3,328	-508	3,836	85%
130	-5,187	3,916	314	-6,823	7,136	72%	3,253	-658	3,911	84%
135	-4,718	3,563	402	-6,504	6,906	72%	3,039	-860	3,899	84%
140	-3,947	2,980	525	-5,893	6,418	74%	2,704	-1,144	3,848	85%
145	-2,858	2,158	713	-5,001	5,715	77%	2,288	-1,559	3,847	85%
150	-1,441	1,088	1,035	-3,887	4,922	80%	1,851	-2,173	4,024	84%
155	311	-235	1,647	-2,698	4,345	83%	1,455	-3,053	4,508	82%
160	2,398	-1,810	2,821	-1,708	4,529	82%	1,138	-4,233	5,371	79%
165	4,816	-3,637	4,726	-1,086	5,812	77%	899	-5,712	6,611	74%
170	7,557	-5,706	7,259	-741	8,000	68%	721	-7,467	8,188	67%
175	10,607	-8,008	10,273	-540	10,814	57%	586	-9,469	10,055	60%
180	13,945	-10,529	13,677	-412	14,090	44%	483	-11,692	12,174	51%

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 25 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2 MCT
 (7) Subject TRUCK CASE
 (8) Originator W. W. Smith Date 20 June '94
 (9) Checker /// Date 5/24/94

(10)

PUNCTURE - § 5.1.1.1(c) and § 5.2.1.1(c)

For both Normal Conditions of Transport and Hypothetical Accident Conditions, the cask is protected by the overpack. Since the cask will be handled without the overpack & stored for a long period without the overpack, the outer cylinder should be checked for puncture resistance.

USING THE CASK DESIGNERS GUIDE [Shappert, 1970], which refers to Nelms (ORNL-TM-1312 Vol 3),

$$E/S = 39t^{1.4} \quad E = \text{drop energy} = \text{height} \times Wt$$

lb ft x inches

$S = \text{ultimate strength, psi}$
 $t = \text{min thickness to resist puncture.}$

The eqn was based on the 10CFR71 req't: a 6" diam. bar & a 40" drop. The text noted that the formula applied directly to a cylinder > 30" in diameter, & was not conservative for smaller cylinders. It recommends multiplying the weight by 1.3

$$\frac{1.3 \times 2014 \times h}{70,000} = 39(.5)^{1.4}, \quad h = 395"$$

Since the req'd drop height of 40" is much less than 395", puncture is unlikely.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 26 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. R2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. W. Smyth Date 30 June 94
 (9) Checker [Signature] Date 6/30/94

(10)

A second puncture resistance analysis is cited in the SCANS backup [NUREG/CR-4554, Vol 7], p. 13

$$(5) T_d = 1.61 e^{[-.681 + .685 \ln(Y) + \ln(d)]}$$

T_d = design thickness such that there is a 100% chance that the probability of puncture is less than 1% (inches)

E_i = incipient energy of puncture

d = diameter of puncture pin (6")

S_u = ultimate strength of the R

$$Y = \frac{E_i}{S_u d^3}$$

the range of valid t/d ratios is

$$.045 < t/d < 0.4$$

for TRIGA, $t/d = .5/6 = .083$ - which is valid.

find E_i for $t = .5$; $S_u = 70,000$

$$.5 = 1.61 e^Z, \quad Z = -1.169$$

$$-.681 + .685 \ln(Y) + \ln(6) = -1.169$$

$$Y = e^{-3.328} = .03586$$

$$E_i = 2014 \cdot h = .03586 \cdot 70,000 \cdot 6^3$$

$$h = 269'' \gg 40''$$

The unprotected cast will meet the 10CFR71 puncture resistance req't.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 27 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. Smith Date 30 June 94
 (9) Checker /// Date 6/30/94

(10)

LIFTING WITH 2 EYE-BOLTS - EACH BOLT IS LOADED
 WITH $2014/2 = 1007$ - $3/8"$ BOLT

FOR A $1/2"$ DEEP THREAD (IN $2 1/8"$ MAT'L), SHEAR
 STRESS IN THE LID @ EYE BOLT IS

$$\frac{1007}{\pi (3/8) \times 1/2} = 1710 \text{ psi} = S_i < P_m$$

$$r = \text{BOLT CIRCLE DIAM} \div 2 \\ = \frac{13 5/8}{2} = 6.81"$$

$$c = \text{chord of } 30^\circ \text{ angle @ } 6.81" \text{ radius} \\ = 2(6.81) \sin(30/2) = 3.53"$$

$$w = \text{rim of lid width} = \frac{1}{2}(16" - 10.5") = 2.75" \\ \text{use effective beam width} = 1" \text{ to}$$

ignore the stiffening effect of the lid's center, & treating
 the lid's rim as a fixed end beam lifted @
 its center

$$P = \frac{1}{2} \text{ of cask wt} = 1007"$$

$$f_b = \frac{1}{8} \frac{PL}{S} = \frac{1007 \times 3.53}{8 \times \frac{1}{6} (1)(2.5)^2} \\ = 427 \text{ psi}$$

lifting the cask @ 2 points on the lids bolt
 circle will not cause significant stresses or deformation

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 28 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. W. Smyth Date 30 June
 (9) Checker /// Date 6/30/64

(10)

BOLT LOADING USE NUREG/CR-6007 "STRESS ANALYSIS
 OF CLOSURE BOLTS FOR SHIPPING CASKS"

TABLE 4.1 & 4.2 preload force per bolt is 4329"/bolt,
 determined by the gasket seating requirements.

$$F_a = F_{ar} = 6240^* \text{ from Rich Cruz design calcs} \\ @ 52 \pm 5 \text{ #-ft Torque}$$

Table 4.3 : Pressure difference

internal pressure is + 11 psig gasket diam

$$\text{non-prying } F_2 = \frac{\pi (12.75)^2}{4} \times \frac{11 \text{ psi}}{12 \text{ bolts}} = 117^* / \text{bolt}$$

$$\text{shear } F_3 = \frac{\pi E_{lid} t_{lid} (\Delta \text{ pressure}) (\text{Diam-bolt})^2}{2 \cdot 2 \text{ bolts} \cdot E_{cask} t_{cask wall} (1 - \nu)}$$

$$F_3 = \frac{\pi (2.125)(11)(13.625)^2}{2 \cdot 12 \cdot .75 (1 - \nu)} = 1082^*$$

derivation unclear $\rightarrow$ it is conservative to use
 the pressure-boundary thickness rather than the
 ring width

$$\text{prying } F_4 = \frac{\text{bolt-circle diam}}{4} \times \Delta p = \frac{13.625 \times 11}{4} = 37.16 \text{ f}$$

$$\text{prying } M_f = \frac{13.625^2 \times 11 \text{ psi}}{32} = 64^* \text{ in}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 29 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 22 MCT
 (7) Subject TRICA CASK
 (8) Originator W. Smith Date 30 June 94
 (9) Checker /// Date 1/30/94

(10)

Table 4.4 : temperature is not considered since the temperature difference between the cask & lid is ≈ 0

Table 4.5 (impact) This is a protected lid since the stepped lid will bear on the ring before there is lid-bolt bearing.

non-prying
axial : $F_a = \frac{1.34 \sin \phi \cdot DLF \cdot a \cdot (W_l + W_c)}{N_b}$

shear : $F_s = \frac{\cos \phi \cdot a \cdot W_l}{N_b}$

$W_c =$ inner container : 207
 basket : 32
 fuel : 135
374
 } Rich Cruz
 design Calc.

N_b : number of bolts
 W_l : lid weight
 W_c : wt. of contents
 a : rigid body deceleration
 ϕ : drop angle
 [for side drop, $\phi = 0$]
 [for top drop $\phi = 90$]

unit wt from design calcs $W_l : .2837 \text{ lb/in}^3 \cdot \frac{\pi}{4} (2'8'' \times 16^2 + 1'8'' \times 10.49^2)$
 $= 155 \text{ lb}$

DLF = dynamic load factor

$DLF = 1$
 $a = 60g$
 $N_b = 12$

$F_a = \frac{1.34 (1) (1) (60) (374 + 155)}{12} = 3544 \text{ lb}$

for top drop

$F_s = \frac{60 \times 155}{12} = 755 \text{ lb/bolt}$ - side drop

prying : $F_p = \frac{1.34 \times 60 (529)}{\pi (13.625)} = 993.6 \text{ lb/in}$

BOLT CIRCLE DIAM = 13.625

$M_c = \frac{1.34 \times 60 (529)}{8 \pi} = 1692 \text{ lb/in}$

both for top drop

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 30 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. W. Smyth Date 30 June 94
 (9) Checker /// Date 6/30/94

(10)

Table 4.7 (Puncture)

Puncture is not considered since the over-packs provide protection, and the free-fall envelopes this case

Table 4.8 (vibration)

overpack provides protection from vibration force loading - ANSI N14.33 suggests an $84 \text{ RMS} \times 2' = 168 \text{ shock @ } 2 \text{ Hz}$. This is much less than the max. drop load evaluated for.

Table 4.9 (Load combinations)

preload + temp : $F_{a-pt} = 6240$
 all others $\Delta p + \text{impact} = 117 + 3544 = 3661^* = F_{a-dl}$

$F_{a-c} = \text{larger of } F_{a-pt}, F_{a-dl} = 6240$

total prying force $F_{f-c} = 37 + 994 = 1031$

prying moment $M_{f-c} = 64 + 1692 = 1756$

Table 2.1

$$F_{a-p} = \pi \left(\frac{D_{ab}}{N_b} \right) \left[\frac{\frac{2M_c}{D_{ab}} - C_1(3-F_c) - C_2(3-P)}{C_1 + C_2} \right]$$

$$C_1 = 1$$

$$C_2 = \frac{8}{3(D_{ab} - D_{ab})} \left[\frac{E \cdot t_a^3}{1-\nu} + \frac{(D_{ab} - D_{ab}) E t_f^3}{D_{ab}} \right] \left(\frac{L_b}{N_b D_b^2 E} \right)$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 31 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W = Smith Date 30 June 94
 (9) Checker /H Date 6/30/94

(10)

$$D_{e0} = \text{outer lid diam.} = 16''$$

$$D_{eb} = \text{bolt circle diam} = 13.625''$$

$$D_{ei} = \text{inside lid diam} = \text{cask opening} = 10.5''$$

$$V = 0.3 \quad t_e = 3\frac{1}{2}'' \quad t_f = \text{flange thickness} = 2\frac{1}{8}''$$

$$L_b = \text{bending length of bolt} = 2\frac{1}{8}'' \text{ less counterbore depth}$$

$$D_b = .5'' \quad L_b = 2\frac{1}{8}'' - \frac{1}{2}'' = 1.625''$$

$$C_2 = \frac{8}{3(16-13.625)^2} \left[\frac{3.5^3}{1-.3} + \frac{16-10.5}{13.625} (2.125)^3 \right] \left[\frac{1.625}{12 \times 0.5} \right]$$

$$C_2 = 8.338$$

$$P = \text{bolt preload per unit length} = \frac{12 \times 6240}{\pi \times 13.625} = 1749 \text{ lb/in}$$

$$F_f = 994 < P \quad \text{so} \quad B = P = 1749$$

additional load due to bolt prying

$$F_{op} = \frac{\pi (13.625)}{12} \left[\frac{2 \times 1756}{16-13.625} - (1749 - 1031) - 0 \right] = 291 \frac{\text{lb}}{\text{in}}$$

$$1 = 8.34$$

Bending moment per bolt

$$M_{bb} = \frac{\pi D_{eb}}{N_b} \left[\frac{K_b}{K_b + K_e} \right] M_c$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 32 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. Smyth Date 30 June 94
 (9) Checker /// Date 6/30/94

(10)

$$K_b = \frac{N_b}{L_b} \left(\frac{E_b}{D_{eb}} \right) \left(\frac{D_b^4}{64} \right) \quad E_b \sim \text{say } 30E6 \text{ for cask body}$$

$$K_b = \frac{12}{1.63} \left(\frac{30E6}{13.625} \right) \left(\frac{.5^4}{64} \right) = 15,830$$

$$K_2 = \frac{E_2 t_e^3}{3 \left[(1-.3^4) + (1-.3)^2 \left(\frac{D_{eb}}{D_{eo}} \right)^2 \right] D_{eb}}$$

$$= \frac{28.356(3.5)^3}{3 \left[.91 + .49 \left(\frac{13.625}{16} \right)^2 \right] \cdot 13.625} = 23.46E6$$

$$M_{bb} = \frac{\pi(13.625)}{12} \left[\frac{15,830}{(.0158 + 23.46) E6} \right] 1756 = 4.2 \text{ "}$$

Table S.1Bolt stress : tensile area = $D_b - .9743 \cdot \text{pitch}$

$$= .5 - .9743 \left(\frac{1}{13} \right) = .425 \text{ " DIAM}$$

$$S_{ba} = \frac{6240 + 291}{\pi(.425^2/4)} = 46,030 \text{ psi} \quad \text{tensile stress}$$

$$S_{bb} = \frac{10,186 M_{bb}}{D_b^3} \quad \sim \text{say } D_b = .425 \text{ "}$$

$$S_{bb} = \frac{10,186 \cdot 4.2}{.425^3} = 560 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 33 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 32MCT
 (7) Subject TRIGA CASE
 (8) Originator W. W. Smith Date 30 June
 (9) Checker W. W. Smith Date 4/30/64

(10)

^{OP} ^{60% drop} impact, side drop
 Bolt shear = $1082 + 755 = 1837$

considering an axial drop, bolt shear = 0

$$S_{bs} = \text{bolt shear stress} = \frac{1082}{.425} \times 1.2732 = 7627 \text{ psi}$$

axial-end-drop

from table 4.1, residual bolt torsion = .5 × applied torque

$$M_t = .5 \times (52 \times 5) \times 12 = 342 \text{ in-lb}$$

$$S_{bt} = \text{torsional shear stress} = 5.093 \times \frac{M_t}{D^3}$$

$$= \frac{5.093 \times 342}{.425^3} = 22,690 \text{ psi}$$

$$\text{max stress intensity, } S_{bi} = \sqrt{(S_{bs} + S_{bt})^2 - 4(S_{bs} + S_{bt})^2} = 30,320$$

(46,030 + 560) = 46,590
(22,690 + 7627) = 30,320

$$S_{bi} = \sqrt{46,590^2 - 4(30,320)^2} = 76,470$$

$$S_m = 80,000 > 76,470$$

30LTS OK @ 60%

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 34 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. 32MCT
 (7) Subject TRIGA CASIC
 (8) Originator Wm Smith Date 30 June 94
 (9) Checker /// Date 6/30/94

(10) LEAD SLUMP UNDER 100g DECELERATION & END DROP & NO
 SS-Pb BONDING

THE LEAD ANNULUS IS CONTAINED BY THE
 SS PIPE

Pb height h = o'all length less
 bottom P, less lead thickness t
 outside, less ring thickness

$$h = 37\frac{3}{4} - 4 - 2\frac{1}{2} - 2\frac{1}{8} = 29\frac{1}{8}" = 29.13"$$

$$\gamma = 710 \text{ PCF} = .411 \text{ lb/in}^3$$

$$\text{vert stress } \sigma_z = \gamma h$$

$$\max \sigma_z = 29.13 \times .411 = 12.0 \text{ psi}$$

$$\max \sigma_z @ 100g = 1200 \text{ psi}$$

Treating a column of lead as uniformly stressed in a horizontal plane, & confined perfectly by the pipes, find the vertical deformation due to a 100g load

$$\begin{cases} \epsilon_x = \frac{1}{E} \sigma_x - \frac{\mu}{E} (\sigma_y + \sigma_z) = 0 \\ \epsilon_y = \frac{1}{E} \sigma_y - \frac{\mu}{E} (\sigma_x + \sigma_z) = 0 \\ \epsilon_z = \frac{1}{E} \sigma_z - \frac{\mu}{E} (\sigma_x + \sigma_y) \end{cases} \quad \begin{cases} \sigma_x = \mu \sigma_y + \mu \sigma_z \\ \sigma_y = \mu \sigma_x + \mu \sigma_z \\ \sigma_x + \sigma_y = \mu (\sigma_x + \sigma_y) + 2\mu \sigma_z \\ \sigma_z = \frac{(1-\mu)(\sigma_x + \sigma_y)}{2\mu} \\ \sigma_x - \sigma_y = -\mu (\sigma_x - \sigma_y) \end{cases}$$

→ Hooke's law for linear, isotropic mat'l.

$$\begin{aligned} \text{so } \sigma_x &= \sigma_y \\ \text{and } \sigma_z &= \frac{1-\mu}{\mu} \sigma_x \\ \therefore \sigma_z &= -41.1 \times z \end{aligned}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 35 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2 MCT
 (7) Subject TRIGA CASK
 (8) Originator W. Smith Date 20 June 94
 (9) Checker [Signature] Date 6/20/94

(10)

Find the total vertical strain for a confined column of mat'l :

$$\epsilon_z = \frac{\sigma_z}{E} - \frac{\mu}{E} (\sigma_x + \sigma_y) \quad \sigma_x + \sigma_y = \frac{2\mu\sigma_z}{1-\mu}$$

$$\epsilon_z = \frac{\sigma_z}{E} \left[1 - \frac{\mu}{1-\mu} \cdot \frac{2\mu}{1-\mu} \right] = \frac{\sigma_z}{E} (1-2\mu)(1+\mu)$$

$$\frac{\epsilon_z}{\sigma_z} = \frac{(1-2\mu)(1+\mu)}{(1-\mu)E}$$

for the range $.4 \leq \mu \leq .45$,

$\frac{\epsilon_z}{\sigma_z}$ is maximized by using $\mu = .4$

$$\frac{\epsilon_z}{\sigma_z} = \frac{.467}{E} \quad \text{for } \mu = .4$$

use $E = 136,000 \text{ psi}$ to envelope the maximum strain

$$\epsilon_z = \frac{.467}{136,000} \cdot (-41.1 \bar{z}) = -141 E-6 \bar{z}$$

$$\text{total change of height } \Delta = \int_0^h \epsilon(\bar{z}) d\bar{z}$$

$$\text{shortening is } -141 E-6 \int_0^{29.13} \bar{z} d\bar{z}$$

$$\Delta = -141 E-6 \cdot \frac{\bar{z}^2}{2} \bigg|_0^{29.13} = .0599 \text{ in}$$

$$\text{at the base, } \sigma_z = -1200 \text{ psi}, \quad \sigma_x = \sigma_y = \frac{-\mu}{1-\mu} \sigma_z$$

$$\sigma_x = \sigma_y = \frac{-.4}{1-.4} \cdot 1200 = -800 \text{ psi}$$

$$\text{max. shear stress } \tau = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

$$= \frac{1}{2} (200 - 800) = 200 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 36 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASK
 (8) Originator W. Smyth Date 30 June 94
 (9) Checker [Signature] Date 6/30/94

(10)

The "maximum shear stress" failure criteria predicts initiation of plastic behavior when $\tau_{max} \geq \frac{1}{2} \sigma_y$ using the lower of the 2 cited yield values,

$$\frac{1}{2} \sigma_y = \frac{1}{2} (680) = 340 \text{ psi}$$

in this case, $\tau_{max} < \frac{1}{2} \sigma_y$ so the lead deformation is elastic.

Now find the effects on the inner & outer shells - Uniform horizontal stresses were assumed for the lead, both stresses were equal, so one is a tangential (hoop) stress in the lead and the other horizontal stress is a pipe pressure.

ON THE INNER & OUTER PIPE, THE MAX PRESSURE DUE TO LEAD SLUMP IS 800 psi FOR A 100g ACEL.

ADD A HOOP STRESS TO OTHER LOAD CASES: $\sigma = \frac{p r}{t}$

INNER PIPE: $\sigma = \frac{800 \times 6}{.75} = 6400 \text{ psi (compression)}$

OUTER PIPE: $\sigma = \frac{800 \times 7.5}{.5} = 12,000 \text{ psi (tension)}$

5.11 HYPOTHETICAL ACCIDENT CONDITIONS

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 37 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. E. Smith Date 7/12/94
 (9) Checker AAA Date 8/5/94

- (10) § 5-1.2.1 (b) 30' drop to unyielding surface -
 For Hypothetical Accident Condition, use
 ASME III, service level D criteria
 (used to be called "FAULTED" conditions)

The overpack limits the free-body acceleration to less than 100g. The preliminary design review stated that the maximum loading was 89.4g at a drop angle of 10° from horizontal.

drop angle	deceleration	
	nose	tail
0°	76	76
10°	86.1	89.4
20°	74.1	54.8
90°	43.9	-

Ref: VECTRA OVERPACK CALCULATION PACKAGE
 FILE # 252-59.0200

P 37/200

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3.5 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. B2MCT
 (7) Subject TRIGA CASE
 (8) Originator W. S. Smith Date 7/13/94
 (9) Checker /// Date 8/5/94

(10)

look at a 100 g side drop

use the results of the 4' drop, 60g loading, from p. 12

100g loading is $\frac{100}{60} \times 60g$ load

assuming the outer $\frac{1}{2}$ " shell takes all bending loads,

peak bending stress $F_b = \frac{100}{60} \times 6967 = 11,610 \text{ psi}$

peak $\tau = 1.67 \times 4559 = 7614$

$$F_b = \frac{Y}{8} \times 11,150$$

$$F_s = 7294 \sqrt{1 - Y/8}$$

The outer shell by itself will resist the effects of 100 g load with very low stresses

$$\begin{aligned} \text{stress intensity} &< 2.4 \times 16,800 \\ &< -7 \times 70,000 \end{aligned}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 29 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASK
 (8) Originator WE Smith Date 7/18/94
 (9) Checker 1/1 Date 7/5/94

- (10) IN THE RING, LOOKING AT THE POINT OF MINIMUM MARGIN @ 60°
 MULTIPLY SI BY 1.67 & USE 2.4 Sm AS THE ACCEPTANCE.
 Primary Membrane @ Bottom: $P_m = 1.67 \times 7158 = 11,950 < 2.4 \times 16,200$
OK

Bolt loading: bolt preload & residual torsion is the same
 as on p. 33 - other loads are scaled up by $\frac{100}{60}$

$$F_a = 1.67 \times 3544 = 5918^{\pm} < \text{Preload force/bolt (6240)}$$

$$F_s = \frac{100 \times 155}{12} = 1292^{\pm} / \text{bolt for side drop.}$$

$$F_f = 1.67 \times 993.6 = 1659^{\pm}, M_f = 1.67 \times 1692 = 2826^{\pm} \text{ in}$$

$$F_{a-c} = 117 + 5918 = 6035 - \text{based on drop} + \Delta p$$

Total prying force $F_{f-c} = 37 + 1659 = 1696$
 $M_{f-c} = 64 + 2826 = 2890$

$$\text{from p 31: } B = 1749$$

$$F_{ap} = \pi \left(\frac{13.625}{12} \right) \left[\frac{2 \times 2826^{2380}}{16 - 13.625} - (1749 - 1696)^{53} - 0 \right] \\ = 889^{\pm}$$

$$M_{bb} = 1.67 \times 4.1 = 6.8$$

$$S_{ba} = \frac{F_{a-c}}{\text{area}} = \frac{6240 + 889}{\pi (1.425)^2 / 4} = 50,520 \text{ psi based on } 100 \text{ g drop load} + \Delta p$$

$$S_{bb} = \frac{10.186 \times 6.8}{.425^3} = 909 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 40 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASK
 (8) Originator Wm W. Smyth Date 19 July 94
 (9) Checker /// Date 8/5/94

(10)

Residual bolt torsional stress - based on the nominal +
 tolerance - is $S_{bt} = 22960$ from p 33
 applied shear $S_{bs} = 17627$ psi from Δp (no impact shear)

$$\begin{aligned} \text{max stress intensity is } & \sqrt{(S_{bs} + S_{bt})^2 + 4(S_{bt} + S_{bs})^2} \\ & = \sqrt{(50,520 + 709)^2 + (22,960 + 7627)^2 \cdot 4} \\ & = 79,920 \end{aligned}$$

for the 100g accident, the allowable
 bolt stress intensity is the smaller
 of $2.4 S_m = 2.4 (80,000) = 192,000 \text{ psi}$
 or $.7 S_u = .7 (160) = 112 \text{ ksi}$

$112,000 > 79,920$ so bolts are OK

5.12 SIX FOOT DROP FOR STORAGE

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 41 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASK
 (8) Originator W-E Smith Date 19 July 94
 (9) Checker / / / Date 8/1/94

- (10) USE CREDE & HARRIS, SHOCK & VIBRATION H'BOOK, 1961, p 41-3
 TO CALC. A MAX g-load on the cask due to a
 6' drop to a rigid surface - they assume a sine pulse
 and find an acceleration a_r to stop a falling object.

$$a_r = \frac{\pi \sqrt{2gh}}{2td}$$

use a rise-time of .002 sec

$$a_r = \frac{\pi \sqrt{2(386.4)72}}{2(.002)} = 185,200 \text{ in/sec}^2$$

$$= 480g$$

Now use EPRI NP-4830, "The effects of Target
 Hardness on the Structural Design of Concrete
 Storage Pads for Spent Fuel Casks",
 by BNATECH INT'L, 1986

The dimensionless parameter $S \equiv$ hardness number
 is used to predict the max. deceleration of
 a rigid falling object.

$$S = \frac{M_u \cdot \sigma_u \cdot A}{W^2 \delta_e}$$

M_u = ultimate moment of
slab

σ_u = ultimate strength of
slab

A = target area

W = package weight

δ_e = static deflection
(due to W) of
soil

DESIGN CALCULATION

(1) Drawing (2) Doc. No. (3) Page 2 of 2
 (4) Building (5) Rev. (6) Job No.
 (7) Subject TRIGA CASE
 (8) Originator J. Smith Date 19 July 94
 (9) Checker Date 8/5/94

(10)

USE M_n ~ bending strength ~ due to an ACI terminally change - without ϕ

The slab is 8" thick & reinforced with #7 @ 12". Assume $f'_c = 4000$ psi & $f_y = 60ksi$.
 & 2" cover to the #7 bars.

$$A_s = .60 \text{ in}^2/\text{ft} \quad D = 6 \cdot \frac{1}{8} = 5.56" \quad \rho = \frac{.6}{5.56} = .009$$

$$T = 60ksi \times .60 = 36 \text{ k}/\text{ft} \quad \text{tension} \quad a = \frac{36}{.85 \times 4.12} = .882 \text{ in} \quad \text{stress block depth}$$

$$M_n = 36(5.56 - .882) = 184 \text{ k}/\text{ft}$$

$$E_c = 57,000 \sqrt{f'_c} \quad [8Y \text{ ACI-318}]$$

$$= 3.6E6$$

for an END DROP : $D = 16"$ (cook diameter)

$$\text{slab } M_u = \frac{16}{12} \times 184 = 246,000 \text{ lb-in}$$

$$H = \pi(16)^{3/4} = 201 \text{ in}^2$$

assume a soil elastic modulus of 20,000 psi

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 43 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASE
 (8) Originator W. L. Smith Date 7/15/94
 (9) Checker SD Date 8/5/94

(10)

$$S = \frac{244 E3 (4000 \text{ psi}) (201 \text{ in}^3)}{2014^2 + 397 E \div 6 \text{ in}} = \frac{4 \text{ in}^3}{122 E6}$$

EPRI results go to 400,000 = .4 E6

For an edge drop use $D = 10''$, $r = 5''$

$$\beta = \left[\frac{E_s}{4 E_c I_c} \right]^{1/4} \quad I_c = \frac{1}{12} (37) (8)^3 = 1579$$

$$\beta = \left[\frac{20,000}{4 \times 3.61 E6 \times 1579} \right]^{1/4} = .0306 / \text{in}$$

using the simplified expression for small β

$$\delta_e = \frac{W \beta}{2 k} \quad k = E_s$$

$$\delta_e = \frac{2014 (.0306)}{2 \times 20,000} = .0015''$$

$\delta_e = 1541 E-6$
 For a small compact case, δ_e should be the same for edge & end drop.

$$-M_U = \frac{10}{12} \times 183,000 = 153,000 \text{ in}^2, \quad A = 10 \times 37 = 370 \text{ in}^2$$

$$S = \frac{M_U \delta_e A}{W^2 \delta_e} = \frac{153 E3 (4000) (370)}{2014^2 + .0015} = 37.1 E6$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 44 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASC
 (8) Originator W. L. Small Date 7/15/90
 (9) Checker /// Date 5/5/94

(10)

$$\text{find } \beta = (E_s / 4D_c)^{1/3} \leftarrow$$

EFRI INCORRECT
 See Timoshenko
 in R. Shell
 P. _____

$$\text{USE } E_s = 20,000 \text{ psi [Assume]}$$

$$D_c = \frac{E_c h^3}{12(1-\nu_c^2)}$$

$$E_c = 57,000 \sqrt{f'_c} = 3.61 \text{ EG psi}$$

$$\nu_c = .17$$

$$D_c = \frac{3.61 \text{ EG} (8)^3}{12(1-.17^2)} = 158 \text{ EG}$$

$$\beta = \left[\frac{20,000}{4 \times 158 \text{ EG}} \right]^{1/3} = .03161 / \text{inch}$$

$$k = \frac{\pi E_s}{1-\nu_s^2} = \frac{\pi (20,000)}{1-.45^2} \quad \left[\text{say } \nu_s = .45 \right]$$

$$k = 78,790 \text{ psi}$$

$$r = 8'' \text{ cask radius}$$

$$\beta r = .253 \text{ no units}$$

$$\beta r \cdot 180^\circ / \pi = 14.5^\circ$$

$$\delta_e \text{ static deflection} = \frac{W}{2r k} (1 - e^{-\beta r} \cos \beta r)$$

$$W = 2014 \text{ lb cask wt}$$

$$\delta_e = \frac{2014}{2 \times 8 \times 78,790} \left(1 - e^{-.248} \cos(14.5^\circ) \right) = 397 \text{ E-6 in.}$$

$$A = \pi (8)^2 = 201 \text{ in}^2$$

$$M_u = 183,000 \times \frac{16''}{12} = 244,000 \text{ in-lb}$$

Figure 27. Force vs. Target Hardness Number for 70" Drop Height

$$z = A \sqrt{S}$$

DESIGN CALCULATION

Drawing	_____	Doc. No.	_____	Page	46 of _____
Building	_____	Rev	_____	Job	B2MCT
Subject	_____				
Originator	Wm. W. Smyth	Date	12 July 1994		
Checker	///	Date	3/5/94		

Upper bound g-load for rigid body falling 70" onto 8 R/C slab. S & g are from EPRI, p. 2-40. Extrapolate with a general power function: $g = A \cdot S^b$ using linear between $\log(S)$ and b : $\log(g) = \log(A) + b \cdot \log(S)$

S	g	log S	log g	$A \cdot S^b$	err ²
10,000	18.50	4.0000	1.2672	20.24	3.011
20,000	26.00	4.3010	1.4150	26.24	0.056
30,000	30.25	4.4771	1.4807	30.54	0.084
40,000	34.50	4.6021	1.5378	34.02	0.234
50,000	37.75	4.6990	1.5769	36.98	0.590
60,000	40.75	4.7782	1.6101	39.60	1.330
70,000	44.00	4.8451	1.6435	41.95	4.199
80,000	46.00	4.9031	1.6628	44.10	3.598
90,000	47.50	4.9542	1.6767	46.09	1.980
100,000	49.25	5.0000	1.6924	47.95	1.693
110,000	50.75	5.0414	1.7054	49.69	1.119
120,000	52.25	5.0792	1.7181	51.34	0.830
130,000	53.50	5.1139	1.7284	52.90	0.358
140,000	54.90	5.1461	1.7396	54.39	0.259
150,000	56.00	5.1761	1.7482	55.82	0.034
160,000	57.00	5.2041	1.7559	57.18	0.033
180,000	59.00	5.2553	1.7709	59.76	0.580
200,000	61.00	5.3010	1.7853	62.17	1.364
250,000	65.75	5.3979	1.8179	67.59	3.382
300,000	69.75	5.4771	1.8435	72.37	6.852
350,000	74.25	5.5441	1.8707	76.67	5.858
400,000	78.00	5.6021	1.8921	80.60	6.780
					$\Sigma = 44.22247$

extrapolate

37,100,000	439.97
122,000,000	687.32

Regression Output:

Constant	-0.19259	= $\log(A)$ so, $A = 0.641817$
Std Err of Y Est	0.014093	
R Squared	0.991771	
No. of Observations	22	
Degrees of Freedom	20	
X Coefficient(s)	0.374674	= b
Std Err of Coef.	0.007631	

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 47 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject True Case
 (8) Originator W. W. Smith Date 7/15/94
 (9) Checker LL Date 8/5/94

(10)

The extrapolation was for S values considerably beyond EPRI's valid range, and are not influenced by the curves' upper bound @ the slab failure.

In both cases, the predicted " g " values are greater than the rigid target value of $\frac{3089}{480}$ ~~172~~.

Find slab failure loads based on punching shear.

For an end drop, assume a failure area $d/2$ outside of the loaded area (radius = $8 + \frac{5.56}{2} = 10.8"$)

$$V_c = 2\pi(10.8)(5.56) + 4\sqrt{4000} = 95,450 \text{ lb}$$

IN ORDER FOR THE SLAB TO FAIL, THE UNDERLYING SOIL MUST FAIL ALSO. THE PRESUMED DESIGN STRENGTH FOR SANDY SOIL WITH 1' OF OVER-BURDEN IS 2000 PF, WITH A FACTOR OF SAFETY OF 4

$$\frac{4 \times 2000 \text{ #/ft}^2}{144 \text{ in}^2/\text{ft}^2} = 55.6 \text{ psi}$$

USE 100 psi SOIL FAILURE STRENGTH - THIS $g^{(10)}$
 a resistance of $100\pi(8+5.56)^2 = 57,770 \text{ lb}$ ON
 THE BASE OF THE ROUND AREA. THE MAX resistance
 is $95,450 - 57,770 = 153,200 \text{ lb}$

$$\text{or } \frac{153,200}{2014} = 76 \text{ g avg acceleration}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 48 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Trac Cask
 (8) Originator W. L. Smith Date 15 July 94
 (9) Checker /// Date 8/5/94

(10) CORNER DROP

Find an upper bound for cask loading for 2014" cask falling 6' onto an 8" R/C slab. Reinforcing is #7 @ 12".

USE THE ACI-318-79 appendix B approach to find the punch-out failure strength - assume a 1'Ø area is loaded & the failure cone is on a 45° plane, with nominal "tensile stress" of $4\sqrt{f_c}$ on the cone's base. Assume a soil failure pressure of 100 psi (4x2000 PSF FDN DESIGN LOAD) $\div 144 = 55.6$

$$\text{Failure force} = \frac{353 \text{ psi}}{(100 + 4\sqrt{f_c})} \left(\frac{\pi \cdot 17^2}{4} \right) = 80,130$$

$$\text{This corresponds to a } \frac{80,130}{2014} = \underline{40 \text{ g load}}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 49 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASK
 (8) Originator W.W. Smyth Date 15 July 94
 (9) Checker 111 Date 8/5/94

(10)

For a side drop, assuming the shear failure area is a rectangle 16" x 37", the concrete shear strength

$$V_c = 4\sqrt{4000} (37 + 5.56 + 16 + 5.56) 2 \times 5.56 = 180,400$$

The soil loading is 100psi $(37 + 2 \times 5.56)(16 + 2 \times 5.56) = 130,500$

$$\Sigma = 310,900$$

$$\text{deceleration is } \frac{310,900}{2014} = 155g$$

This is not as severe a load for the ring & lid as the 100g acceleration in the overpack - when the cask is dropped on a near-rigid surface, the cask body is loaded. When dropped in the overpack, the overpack yields to allow the cask body to deform & the cask ends are loaded.

The ring & lid will experience a load of

$$155 \times (\text{weight of ring} + \text{lid})$$

$$wt = \left[\pi \left(\frac{16}{4} \right)^2 (3.5) + 1.13 \left(\frac{16^2 - 10.5^2}{4} \right) \pi \right] \frac{49}{12}$$

$$h = 4.63 - 3.5 = 1.13" = 236 \#$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 50 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject Truss Cask
 (8) Originator W. W. Smyth Date 7/15/90
 (9) Checker 1/1 Date 8/5/94

(10)

$$\text{Ring/Lid load} = 155 \times 236 = 36,580^{\#}$$

load used in 60 g analysis was 60,420[#]

The cask body is loaded uniformly with
 $155 \times (\text{cask wt} + \text{contents}) / \text{cask length}$

$$\begin{aligned} \text{cask wt} &= \pi [(8^2 - 7.5^2 + 6^2 - 5.25^2) 490 \\ &\quad + (7.5^2 - 6^2) 710] \cdot \frac{1}{1728} \\ &= \frac{\pi}{1728} [5798 + 4134 + 14380] \\ &= 40.56 \text{ \#/in} \end{aligned}$$

USE ROARK RING RESULTS (TABLE 17) WITH TABLE 16,
 CASE 9 circular beam:

$$P = 155 \times 40.56 = 6287^{\#}$$

$$\omega = \frac{P}{2\pi R}$$

DESIGN CALCULATION

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 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASE
 (8) Originator W. L. Smith Date 7/15/94
 (9) Checker 1/1 Date 7/5/94

(10)

$$cg \text{ loc} : \frac{(-.75)^2/2 + (2.25 + .25)(.5)}{.75 + .5} = 1.225''$$

$$= C$$

$$A = 1.25 \text{ m}^2$$

$$I = \frac{1}{12}(1)(.75)^3 + (.75)(2.5 - 1.225)^2$$

$$+ \frac{1}{12}(1)(.5)^3 + .5(1.225 - .5)^2 = 1.528 \text{ m}^3$$

$$S_{outside} = \frac{1.528}{2.75 - 1.225} = 1.136$$

$$S_{inside} = \frac{1.528}{1.225} = 1.247$$

$$R = 5.25 + 1.225 = 6.475$$

$$\frac{R}{C} = \frac{6.475}{1.225} = 5.286$$

$$\frac{d}{C} = \frac{2.75}{1.225} = 2.245$$

$$\frac{A}{bd} = \frac{1.25}{2.75} = .4545$$

$$\frac{I}{C} = \frac{.75}{1.225} = .6122$$

$$\frac{C_1}{C} = \frac{2.75 - 1.225}{1.225} = .3878$$

$$\frac{t_1}{C} = \frac{.5}{1.225} = .4082$$

$$\frac{h}{C} = \frac{R}{C} - \frac{(A/bd)(d/C)}{\ln\left[\frac{R/C - t_1/C - 1}{R/C - 1}\right]} + \frac{b_1}{b} \ln\left[\frac{R/C + C_1/C}{R/C + C_1/C - t_1/C}\right]$$

$$= 5.286 - \frac{(.4545)(2.245)}{\ln\left[\frac{5.286 + .6122 - 1}{4.286}\right]} + \ln\left[\frac{5.286 + .3878}{5.286 + .3878 - .4082}\right]$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 52 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator W. L. Smith Date 7/15/94
 (9) Checker W. L. Date 8/5/94

(10)

$$\frac{h}{c} = 5.286 - \frac{4.389}{L_n(1.143) + L(1.078)} = .3968$$

$$\frac{I_c}{A_c^2} = \frac{1.528}{1.25 + 1.225^2} = .8146$$

$$k_i = \frac{.8146}{4.286} \left[\frac{1 - .3968}{.3968} \right] = .289$$

$$k_o = \frac{.8146}{.3968} + \frac{2.245 - .3968 - 1}{5.286 - 2.245 - 1} + \frac{1}{2.245 - 1}$$

$$k_o = 2.053 + .2514 + .803 = .4145$$

$$\text{use } k_o = k_i = 1 \quad \omega = \frac{6287}{2\pi(6.475)} = 155 \text{ #/in.}$$

$$\text{MAX MOMENT} = \frac{3}{2} \omega R^2 = \frac{3}{2} (155) (6.475)^2 = 9748 \text{ #}$$

$$f_{b-\text{inside}} = \frac{9748}{1.247} = 7817 \text{ psi}$$

$$f_{b-\text{outside}} = \frac{9748}{1.136} = 8581 \text{ psi}$$

$$T = \frac{\omega R}{2} = \frac{155 \cdot 6.475}{2} = 502 \text{ #}$$

$$T/A = \frac{502}{1.25} = 402 \text{ psi}$$

$$V = P/2 = \frac{6287}{2} = 3144 \text{ #} \quad \tau = \frac{3144}{1.25} = 2515 \text{ psi}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 53 of _____
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject TRIGA CASK
 (8) Originator W. W. Smyth Date 17 July 94
 (9) Checker JS Date 8/5/94

(10)

For the 6' drop onto an 8" slab, the cask body will have the following stresses:

3/4" containment: $f_b = 7817 \text{ psi}$
 $f_a = -402 \text{ psi}$
 $\tau = 2515 \text{ psi (avg)}$

primary bending + shear stress intensity

$$P_1 = \sqrt{402^2 + \left(\frac{2}{3} \cdot 2515\right)^2} - 402$$

$$= 3392 \text{ psi}$$

$$P_3 = -402 - 3794 = -4196 \text{ psi}$$

$$P_2 = 0$$

$$P_m = 0 - 4196 = 4196 \text{ psi}$$

allowable for accident (level D) is

$$2.4 S_m = 2.4(16,800) = 40,320$$

No load combination in the steel inner or outer shells will approach $2.4 S_m$

The lead stress intensity will be about $\frac{E_{sh}}{E_{ss}} \times 4196$

$$\approx \frac{2}{28.3} \times 4196 = 297 \text{ psi} < \text{yield stress}$$

DESIGN CALCULATION

Drawing _____ Doc. No. _____ Page _____ of _____
Building _____ Rev. _____ Job No. _____
Subject TRIGA CASK FIGURE
Originator N/A mdc Date _____
Checker N/A mdc Date _____

TRIGA CASK
STRUCTURAL MODEL

6.0 CASK REVIEW DRAWINGS

PARTS/MATERIAL LIST			QUANTITY		REVISION		DATE	
ITEM NO.	DESCRIPTION	QTY	REV	DATE	BY	CHKD	APP'D	REMARKS
1	OUTER VESSEL	1	1					
2	OUTER VESSEL LID ARRANGEMENT	1	1					
3	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
4	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
5	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
6	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
7	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
8	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
9	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
10	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
11	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
12	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
13	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
14	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
15	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
16	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
17	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					
18	OUTER VESSEL LID PLATE 3 1/2" ASTN 2400 S&W SET	1	1					

GENERAL NOTES (UNLESS OTHERWISE NOTED)

1. ALL PARTS SHALL BE MANUFACTURED TO THE DRAWING NUMBER AND ITEM NUMBER IN LOCATION INDICATED USING 5/16" HIGH CHROME VANADIUM STEEL UNLESS OTHERWISE SPECIFIED.
2. WELD AND INSPECT FOR ASME SECTION V, ARTICLE 2, RADIOGRAPHIC EXAMINATION. INSPECTION PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE SECTION II.
3. DIMENSIONS AND TOLERANCES PER ASME Y14.5-92 UNLESS OTHERWISE SPECIFIED. DIMENSIONS: FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1, 1 1/4, 1 1/2, 1 3/4, 2, 2 1/4, 2 1/2, 2 3/4, 3, 3 1/4, 3 1/2, 3 3/4, 4, 4 1/4, 4 1/2, 4 3/4, 5, 5 1/4, 5 1/2, 5 3/4, 6, 6 1/4, 6 1/2, 6 3/4, 7, 7 1/4, 7 1/2, 7 3/4, 8, 8 1/4, 8 1/2, 8 3/4, 9, 9 1/4, 9 1/2, 9 3/4, 10, 10 1/4, 10 1/2, 10 3/4, 11, 11 1/4, 11 1/2, 11 3/4, 12, 12 1/4, 12 1/2, 12 3/4, 13, 13 1/4, 13 1/2, 13 3/4, 14, 14 1/4, 14 1/2, 14 3/4, 15, 15 1/4, 15 1/2, 15 3/4, 16, 16 1/4, 16 1/2, 16 3/4, 17, 17 1/4, 17 1/2, 17 3/4, 18, 18 1/4, 18 1/2, 18 3/4, 19, 19 1/4, 19 1/2, 19 3/4, 20, 20 1/4, 20 1/2, 20 3/4, 21, 21 1/4, 21 1/2, 21 3/4, 22, 22 1/4, 22 1/2, 22 3/4, 23, 23 1/4, 23 1/2, 23 3/4, 24, 24 1/4, 24 1/2, 24 3/4, 25, 25 1/4, 25 1/2, 25 3/4, 26, 26 1/4, 26 1/2, 26 3/4, 27, 27 1/4, 27 1/2, 27 3/4, 28, 28 1/4, 28 1/2, 28 3/4, 29, 29 1/4, 29 1/2, 29 3/4, 30, 30 1/4, 30 1/2, 30 3/4, 31, 31 1/4, 31 1/2, 31 3/4, 32, 32 1/4, 32 1/2, 32 3/4, 33, 33 1/4, 33 1/2, 33 3/4, 34, 34 1/4, 34 1/2, 34 3/4, 35, 35 1/4, 35 1/2, 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[illegible]

[illegible]

GENERAL NOTES (UNLESS OTHERWISE NOTED)

- [illegible]

12 LIFTING/CLOSURE EYEBOLT (MODIFIED)
SCALE: 2X

5 INNER CONTAINER LID

DETAIL F

DETAIL A

1 INNER CONTAINER ASSY

DETAIL C

DETAIL D

[illegible]

1		2		3		4		5	
DATE	TIME	LOCATION	WIND	WAVE	SEA	WIND	WAVE	SEA	WIND
1964-11-10	10:00	1000	10	10	10	1000	10	10	10
1964-11-10	11:00	1000	10	10	10	1000	10	10	10
1964-11-10	12:00	1000	10	10	10	1000	10	10	10
1964-11-10	13:00	1000	10	10	10	1000	10	10	10
1964-11-10	14:00	1000	10	10	10	1000	10	10	10
1964-11-10	15:00	1000	10	10	10	1000	10	10	10
1964-11-10	16:00	1000	10	10	10	1000	10	10	10
1964-11-10	17:00	1000	10	10	10	1000	10	10	10
1964-11-10	18:00	1000	10	10	10	1000	10	10	10
1964-11-10	19:00	1000	10	10	10	1000	10	10	10
1964-11-10	20:00	1000	10	10	10	1000	10	10	10
1964-11-10	21:00	1000	10	10	10	1000	10	10	10
1964-11-10	22:00	1000	10	10	10	1000	10	10	10
1964-11-10	23:00	1000	10	10	10	1000	10	10	10
1964-11-11	00:00	1000	10	10	10	1000	10	10	10
1964-11-11	01:00	1000	10	10	10	1000	10	10	10
1964-11-11	02:00	1000	10	10	10	1000	10	10	10
1964-11-11	03:00	1000	10	10	10	1000	10	10	10
1964-11-11	04:00	1000	10	10	10	1000	10	10	10
1964-11-11	05:00	1000	10	10	10	1000	10	10	10
1964-11-11	06:00	1000	10	10	10	1000	10	10	10
1964-11-11	07:00	1000	10	10	10	1000	10	10	10
1964-11-11	08:00	1000	10	10	10	1000	10	10	10
1964-11-11	09:00	1000	10	10	10	1000	10	10	10
1964-11-11	10:00	1000	10	10	10	1000	10	10	10
1964-11-11	11:00	1000	10	10	10	1000	10	10	10
1964-11-11	12:00	1000	10	10	10	1000	10	10	10
1964-11-11	13:00	1000	10	10	10	1000	10	10	10
1964-11-11	14:00	1000	10	10	10	1000	10	10	10
1964-11-11	15:00	1000	10	10	10	1000	10	10	10
1964-11-11	16:00	1000	10	10	10	1000	10	10	10
1964-11-11	17:00	1000	10	10	10	1000	10	10	10
1964-11-11	18:00	1000	10	10	10	1000	10	10	10
1964-11-11	19:00	1000	10	10	10	1000	10	10	10
1964-11-11	20:00	1000	10	10	10	1000	10	10	10
1964-11-11	21:00	1000	10	10	10	1000	10	10	10
1964-11-11	22:00	1000	10	10	10	1000	10	10	10
1964-11-11	23:00	1000	10	10	10	1000	10	10	10
1964-11-12	00:00	1000	10	10	10				

Technical drawing of a structural member, likely a beam or column, showing dimensions and callouts. The drawing includes a vertical dimension line on the left with a value of 10'-0" (9'-11 1/2" max). A horizontal dimension line at the bottom indicates a length of 10'-0" (9'-11 1/2" max). The drawing is divided into three sections by vertical lines, labeled 1, 2, and 3. Section 1 is labeled "DETAIL A" and "SCALE 1/2\".

PARTS/MATERIAL LIST				PART NUMBER		DESCRIPTION		QUANTITY		UNIT		REMARKS		
ITEM	QTY	UNIT	DESCRIPTION	QTY	UNIT	DESCRIPTION	QTY	UNIT	DESCRIPTION	QTY	UNIT	DESCRIPTION	QTY	UNIT
1	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
2	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
3	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
4	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
5	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
6	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
7	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
8	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
9	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
10	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
11	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
12	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
13	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
14	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
15	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
16	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
17	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
18	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
19	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
20	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
21	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
22	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
23	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
24	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB	PCB	1	PCB
25	2	3	2-3	2	3	2-3	2	3	2-3	2	3	2-3	2	3
26	4	5	4-5	4	5	4-5	4	5	4-5	4	5	4-5	4	5
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
33	1	1	1	1	1	1	1	1	1	1	1	1	1	1
34	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1	1	1	1	1
36	1	1	1	1	1	1	1	1	1	1	1	1	1	1
37	1	1	1	1	1	1	1	1	1	1	1	1	1	1
38	1	1	1	1	1	1	1	1	1	1	1	1	1	1
39	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GENERAL NOTES

- [illegible]

MAIN LIFTING PLATE

LIFTING ASSEMBLY

⑥ LIFTING LUG

[illegible][illegible]

7.0 VECTRA PRESENTATION METHODOLOGY/RESULTS/CRITERIA

NRF TRIGA[®] Cask Final Design Review

- Introduction
- Description of Preliminary Overpack and Tie-Down Design
- Structural Analyses
- Thermal Analyses
- Overpack Handling Scenarios
- Design Requirement Review Checklist
- Deliverables

NRF TRIGA[®] Cask

Final Design Description

Overpacks

- Stainless Steel Shell
 - 11 ga Sheet on Sides
 - 1/4 and 3/16 Inch Plate on Ends
- Energy Absorbing Material
 - Closed Cell Polyurethane Foam Material
 - Seven lb/ft³ Density
- Ceramic Fiber Thermal Insulation
 - Fiberfrax[™] Durablanket S Material
 - Two Inches Thick
- Bolted Closure Ring
- Lifting Eyes

NRF TRIGA[®] Cask Final Overpack Assembly

DETAIL 1
Tamper Indicator

NRF TRIGA[®] Cask Final Overpack Hardware

NRF TRIGA[®] Cask

Final Design Description

Tie-Downs

- **Tube Steel Pallet**
 - 10 x 4 x 1/4 Inch Tubes for Forklift Interface
 - 4 x 4 x 1/4 Inch Tube Supports
 - Four Lifting and Tie-Down Lugs
 - Conical Cup Support for Overpack
- **Stainless Steel Collar**
 - Seated Over Top Overpack
 - Four Lifting and Tie-Down Lugs
- **Turnbuckle Tie-Down Assemblies**
- **Attachment to Transport Vehicle**
 - Straps Across Pallet
 - Bolted to Deck
 - Other

NRF TRIGA[®] Cask Tie-Down Assembly

NRF TRIGA[®] Overpack Final Drop Analysis

NCT Drop Orientations

- Overpack Evaluated Only for Transport Orientation (90° End Drop) to Satisfy Intent of 10CFR71 Regulations

HAC Drop Orientations

- 0° Side Drop
- 90° End Drop
- Slapdown Drop Orientations
 - 5°, 10°, 15°, 20°, and 25° Primary Impact Angles and Subsequent Secondary Impacts (Slapdown)
- C.G. over Corner Drops
 - 32.2° & 80.6° Drop Angles
 - All Drop Energy Absorbed at Primary Impact

NRF TRIGA[®] Overpack Final Drop Analysis

Predicted Foam Behavior

- Foam Stress-Strain Relationships Parallel and Perpendicular to Direction of Foam Rise
 - Temperature Variations (-20°F and 180°F)
 - Strain Rate Effects ($\sigma_D = 1.32\sigma_S + 0.00015\sigma_S^2$)
 - Manufacturing Tolerances ($\pm 10\%$)
- Crush Behavior
 - Outside-In Crush - overpack crush on exterior surface at beginning of impact
 - Inside-Out Crush - cask thrusts through foam from inside when internal foam resistance force is exceeded by external force

NRF TRIGA[®] Overpack Final Drop Analysis

Force-Deflection Curves

- Curves Developed for 0°, 15°, 30°, 80.6°, and 90° Impact Orientations
- 0° F-D Curves used for 0° & 5° Drop
15° F-D Curves used for 10°, 15°, & 20° Drops
30° F-D Curves used for 25° & 32.2° Drops
- $\text{Force} = \text{Area} \times \text{Crush Strength}$

NRF TRIGA[®] Overpack Final Drop Analysis

Drop Analysis

- "SLAPDOWN" computer program developed by Sandia National Lab used to determine rigid body response of cask
- Model geometry based on impact orientation
 - Round end properties used for nose
 - Square end properties used for tail
- Worst case mass properties assumed for cold and heat drop conditions
 - Min. weight & M.O.I. for Cold
 - Max. weight & M.O.I. for Heat

NRF TRIGA[®] Overpack Final Drop Analysis

NCT Predicted G-loads & Deformation

- Cold Pre-Drop Condition
 - Peak Deceleration: 39.5 g's
 - Total Crush Depth: 2.9 inches
- Heat Pre-Drop Condition
 - Peak Deceleration: 15.6 g's
 - Total Crush Depth: 4.9 inches

NRF TRIGA[®] Overpack Final Drop Analysis

HAC Drop Conditions

- Cold Pre-Drop Condition
 - Peak Deceleration: 89.3 g's
 - Total Crush Depth: 10.2 inches
- Heat Pre-Drop Condition
 - Peak Deceleration: 88.2 g's
 - Total Crush Depth: 20.3 inches

NRF TRIGA[®] Overpack Final Structural Analysis

Normal Conditions of Transport

- Vibration
 - Stresses in overpack shell less than $S_y/3$ and $S_u/5$
 - Tie-Down design minimizes overpack shell contact stresses and isolates cask.
- 4 Foot Free Drop
 - Maximum G-Load of 39.5 g's is less than 50g Limit
 - Overpack remains intact

NRF TRIGA[®] Overpack Final Structural Analysis

Lifting Devices

- Minimum Factors of Safety (F.S.) are 3 against yield and 5 against ultimate for lifting load
- Lower Impact Limiter - weight of lower impact limiter lifted by two attachments
- Upper Impact Limiter/Package - weight of overpack, cask and tie-down lifting by three attachments
- Package & Tie-Down Device - weight of package and tie-down device (including pallet) lifted by two attachments

NRF TRIGA[®] Overpack Final Structural Analysis

Tie-Down Devices

- Designed for 1.5g forward, lateral, and vertical accelerations, applied non-simultaneously
- Failure due to shear tear-out occurs in the upper attachment bracket at 8.1 g's horizontal forward or lateral, or 5.7 g's horizontal diagonal
- Tie-Down device failure has no adverse affect on overpack performance

NRF TRIGA[®] Cask Final Thermal Results

Normal Operation

- Maximum Cask Temperature is 202°F *includes emissivity increase Hanford Specific*
- Maximum Overpack Surface Temperature is 117°F (in Shade)

Hypothetical Accident Conditions

- Undamaged Overpack is Bounding
- Cask Temperature During Fire Less Than 145°F
- Cask During Temperature After Fire Less Than 173°F

NRF TRIGA[®] Cask Sequence of Operations

Preparation of Packaging

- Inspect Overpack and Tie-Downs for Damage
- Place Bottom Overpack Onto Tie-Down Pallet
- Install Holddown Slings Between Bottom Overpack and Pallet
- Install Turnbuckle Attachment Ring on Top Overpack

Placement of Cask in Overpack

- Place Cask Into Bottom Overpack
- Verify that Cask is Properly Seated
- Remove Cask Lifting Hardware

NRF TRIGA[®] Cask Sequence of Operations

Installation of Top Overpack and Tie-Downs

- Place Top Overpack Over Cask
- Verify that Overpack Halves are Properly Seated
- Connect Turnbuckle Assemblies Between Attachment Ring and Pallet
- Install Overpack Closure Bolts
- Remove Lifting Slings
- Install Tamper Seal Wire
- Tighten Turnbuckle Assemblies
- Disconnect Temporary Holddown Straps
- Remove Lifting Shackles and Install Disabling Bolts

NRF TRIGA[®] Cask

Sequence of Operations

Installation of Package on Transport Vehicle

- Lift Pallet and Place on Transport Vehicle
- Attach Pallet to Vehicle Using Suitable Tie-Down Device
- Monitor Package Radiation Levels

NRF TRIGA[®] Cask

Preliminary Review Comments

- Check Steel Emissivity
- Four Foot Drop Orientations
- Improve Stability During Loading
- Design Top Lifting Eyes for Entire Package Weight
- Design Tamper Seal Using Two Washers and Place Seals on Both Sides of Overpack
- Use Detent Pins in Turnbuckles
- Analyze Chains Through Pallet Tubes
- Justify Phase Change Conductivity of Foam

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Maximum Allowable Hypothetical Accident Condition (HAC) g-load < 95g (3.2.1)

- The drop analysis shows that the maximum HAC g-load is 89.3g's.

Maximum Allowable Normal Condition g-load < 50g (supplemental)

- The drop analysis shows that the maximum normal condition g-load is 39.5 g's.

Maximum Cask Surface Temperature < 350°F (3.2.1)

- The normal and accident thermal analyses show that the maximum cask temperature is 202°F under any conditions.

NRF TRIGA[®] Cask

Specification Requirement Review

Checklist

Overpack Design to Minimize Cask Stresses (3.2.1)

- The cask does not experience any loads due to the presence of the overpack.
- A nominal gap exists between the overpack and the cask.
- The only loads on the cask are the normal transport and HAC loads.

Tie-Down Load of 1.5g Forward, Lateral or Vertical (3.2.2)

- The tie-down design and analysis has been provided.

Tie-Downs Shall Break Without Affecting Overpack (3.2.2)

- The tie-down failure point is the turnbuckle attachment point on the collar.
- Failure at this point prevents damage to overpack during the HAC.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Incorporate Lifting Attachments for Forklifts/Cranes (3.2.3)

- The support structure is designed for lifting by forklift or crane.
- The tie-down collar and the overpack halves include lifting lugs for handling by crane.

Lifting Attachments Designed for 3 Times Load for Yield and 5 Times Load for Ultimate (3.2.3)

- The lifting attachments are designed for 3 times the package weight for yield and 5 times the weight for ultimate as described in the structural evaluation.

Cask Dimensions 16 in dia., 37.87 in lq, 2100 lbs (3.2.4.1.1)

- The overpack allows for 16.25 in diameter and 38 in length.
- Design allows for a maximum cask weight of 2100 lbs.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Necessary Lifting Attachments for Forklift or Crane (3.2.4.1.2)

- The support structure is designed for lifting by forklift or crane.
- The tie-down collar and the overpack halves include lifting lugs for handling by crane.

Necessary Tie-Down Attachments for 49CFR393 (3.2.4.1.3)

- The overpack frame can be tied to the trailer using bolts through pallet or slings across the frame.
- Either attachment technique can meet 49CFR393.

Two Overpacks Fit on Trailer 24ft by 8ft (3.2.4.1.4)

- The overall footprint of each overpack and tie-down is seven feet square.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Tamper Evident Closure System (3.2.4.1.5)

- Lock wire installed between washers in two locations 180° apart.

Easy Opening Closure System (3.2.4.1.6)

- The two halves of the overpack are connected using sixteen 1/2 inch bolts.
- Substantial lead-ins and two alignment pins facilitate assembly of the overpacks around the cask.

Minimum of Crevices and Joints (3.2.4.1.7)

- The overpack halves have no crevices that would prevent decontamination.
- All joints will be seal welded to facilitate decontamination.

NRF TRIGA[®] Cask

Specification Requirement Review

Checklist

Overpack Shall be Watertight (3.2.4.1.8)

- The bolted flange provides the primary seal preventing intrusion of water.
- The backing ring provides an additional barrier to water.

Dissipate 12 W of Decay Heat (3.2.4.2.1 and supplements)

- The normal and accident thermal analyses show maximum cask temperature is less than 350°F under any conditions with a decay heat load of 12 watts.

Normal Thermal for 10CFR71 and Hanford (3.2.4.2.2)

- The thermal analysis has been provided.

Normal Overpack Surface Temperature in Shade Less Than 180°F (3.2.4.2.3)

- The maximum normal operation overpack surface temperature is 117°F.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Structural Design to 10CFR71 (3.2.4.4.1)

- The structural design described in structural analysis and drop analysis packages complies with 10CFR71 for the overpack design.

Overpack Structural Integrity for Normal Loads (3.2.4.4.2)

- The overpack structural integrity is maintained for all normal and accident loads as describe in the structural analysis.

Overpack Loads from Tie-Downs (3.2.4.5.1.1)

- The overpack loads from the tie-downs are addressed in the structural evaluation.

Overpack Loads from Vibration Designed for 3/5 Safety Factor on Yield/Ultimate (3.2.4.5.1.2)

- The vibration analysis is provided in the structural ebaluation.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

30 Foot Free Drop < 95g's (3.2.4.5.2.1)

- The maximum deceleration from the free drop is 89.3g's.
- The post drop configuration of the overpack is accounted for in the accident thermal analysis.

40 Inch Drop Onto Bar (3.2.4.5.2.2)

- The maximum deceleration is bounded by the 30 foot drop.
- The overpack shell is designed with sufficient thickness for puncture integrity.
- The post-drop configuration of the overpack is accounted for in the accident thermal analysis.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

30 Minute 1475°F Fire and Postfire Transient (3.2.4.5.2.3)

- The accident thermal analysis combines both fire and drop damage.
- The maximum cask temperature during and after the fire is 173°F.

Materials Compatible with Operating Conditions (3.2.5)

- The overpack materials include stainless steel (304), ASTM A490 bolts, polyurethane foam, and Fiberfrax[™] insulation.
- Each of these materials is suitable for use in a package of this type.

NRF TRIGA[®] Cask

Specification Requirement Review

Checklist

Painting and Sealing (3.2.5.1)

- The overpacks do not require painting or sealing.
- The overpacks are sealed by welds during fabrication.
- The tie-down painting specifications are called-out on the detail drawings and the fabrication specification.

Corrosion (3.2.5.2)

- No galvanic reactions will occur between overpack components.
- The shell materials are stainless steel and closed cell foam, neither of which absorbs moisture.
- The overpacks will be sealed during fabrication so no electrolyte will be present.
- Closure bolts will be treated to prevent corrosion and the tie-down structure will be painted.

NRF TRIGA[®] Cask Specification Requirement Review Checklist

Interface Control Requirements (3.2.6)

- The tie-down frame measures 7 feet square.
- Two frames can easily fit on an 8 foot by 24 foot trailer bed.
- The cavity of the overpacks is 16.25 inches in diameter by 38.0 inches long allowing adequate space for the TRIGA[®] cask.

NRF TRIGA[®] Cask Deliverables

- Drawings
- Structural and Drop Analyses
- Thermal Analysis
- Design Analysis Report
 - Narrative Description
 - Analysis
 - Operating Procedures
 - Maintenance Requirements
 - Spare Parts
- Overpack and Tie-Down Fabrication Specifications and Drawings
- Design Review Checklist

**8.0 VECTRA DRAWINGS/PACKAGING AND OPERATIONS DESCRIPTION/
FABRICATION SPECIFICATION**

1. GENERAL INFORMATION

This section of the Neutron Radiography Facility (NRF) Training Reactor, Isotopes, General Atomic (TRIGA[®]) Cask Overpack Design Analysis Report (DAR) presents a general introduction to and a description of the overpack and its tie-down assembly. The overpack is used to transport the NRF TRIGA[®] Cask and TRIGA[®] Reactor fuel elements on the Hanford Site from the TRIGA[®] Reactor to the Central Waste Complex. The design of the NRF TRIGA[®] Cask is performed by others and is beyond the scope of this report. The NRF TRIGA[®] Cask and Overpack design criteria are equivalent to the requirements of 10CFR71 [1.1] as supplemented by the Westinghouse Hanford Company design specification [1.2]. The terminology used throughout this DAR is presented in Table 1-1. An illustration of the overpack and tie-down assembly is provided in Figure 1-1. This report documents the design, analysis, and use of the overpack and the tie-down assembly.

1.1 Introduction

The NRF TRIGA[®] Cask Overpack and Tie-Down Assembly has been developed by VECTRA to provide a safe and efficient means of transporting the cask and its payload on the Hanford Site in accordance with Reference 1.2. The overpack is composed of two impact limiters and a thermal shield. The overpack completely encloses the cask and protects it from impact and thermal loads that may arise due to a postulated accident. The tie-down assembly is comprised of a pallet and a collar that secures the package to the pallet. The pallet supports the package during loading and transportation and provides a means for lifting the package using either forklift or crane and tie-down points for the transport vehicle. The overpack and tie-down assembly are shown in Figure 1-1 and Section 1.3.2.

The NRF TRIGA[®] Cask and Overpack are designed as a type B fissile package. Two packages may be transported in a single shipment.

1.2 Package Description

This section provides a basic description of the NRF TRIGA[®] Cask Overpack and Tie-Down Assembly. The overpack has been designed to meet the requirements of the ASME Code, Section VIII, Division 1. The description of the cask and payload are beyond the scope of this report. Defining general arrangement drawings are presented in Section 1.3.2.

1.2.1 Packaging

The overpack consists of two impact limiters and a thermal shield, described below. The tie-down assembly consists of a tube steel pallet and a collar with associated hardware. The gross weights of the overpack and the tie-down assembly are about 1500 lbs and 1150 lbs, respectively.

The impact limiter shells are fabricated from stainless steel and filled with a closed-cell polyurethane foam. Carbon steel attachment bolts are used to hold the top and bottom impact

limiters together. The material properties of the foam are provided in Chapter 2. The top impact limiter includes a thermal shield that extends between the impact limiters when assembled. The thermal shield includes a layer of ceramic fiber insulation sandwiched between two stainless steel sheets. The properties of the insulation are provided in Chapter 3. A closure flange is welded to the bottom of the thermal shield to provide a means of bolting the impact limiters together. The dimensions and configuration of the impact limiters and thermal shield are provided in Section 1.3.2. Lifting lugs are provided at the top of the top impact limiter for lifting the top impact limiter alone or for lifting the entire package and tie-down device. Additional lifting lugs are provided at the top of the bottom impact limiter for installation of the limiter on the pallet and as a temporary attachment point for stability during installation of the cask and the top impact limiter. The weight of the top impact limiter (with thermal shield) is about 840 lbs and the weight of the bottom impact limiter is about 660 lbs.

The tie-down pallet consists of a tube steel frame supporting a stainless steel conical support cup and four carbon steel turnbuckle attachment plates. The conical cup supports the package during transport. The collar is a stainless steel rolled plate that slides onto the top impact limiter. Four turnbuckles secure the collar to the overpack and the tie-down pallet and provide lateral support during transport. The pallet can be lifted by a forklift through its frame or by a crane through the turnbuckle attachment plates.

1.2.2 Operational Features

The overpack and tie-down assembly are not considered to be operationally complex and are similar to other licensed transportation packages. All operational features are readily apparent from inspection of the Drawing provided in Section 1.3.2. Operational procedures are provided in Chapter 4.

1.2.3 Contents of Package

As described above, the contents of the overpack consist of one NRF TRIGA[®] Cask and its payload. The cask is a cylindrical stainless steel vessel with a diameter of 16.0 inches and a height of 37.87 inches. The maximum weight of the cask and payload is 2100 lbs. The maximum decay heat in the cask cavity is 12 watts. The overpack is not designed as a pressure retaining vessel although it has been designed to meet the intent of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

Table 1-1
Terminology and Notation

Overpack:	The structure external to the cask which protects the cask and payload by minimizing the impact and thermal loadings in the event of an accident.
NRF TRIGA [®] Cask:	A top-loaded, lead shielded package that contains, isolates, transports, and stores irradiated fuel material.
Cask:	The NRF TRIGA [®] Cask.
Payload:	The irradiated fuel material within the Cask.
Packaging:	The Cask along with its Overpack.
Package:	The Packaging with its Payload as it is presented for transport.
Tie-Down Assembly	The support frame and cradle that support the Package during transport and provides a means for attachment to the Transport Vehicle.
Tie-Down	The actual binding used to secure the Tie-Down Assembly to the Transport Vehicle.
Transport Vehicle	The transportation system used for the transfer of the Package on the Hanford Site.

Figure 1-1
NRF TRIGA[®] Cask Overpack Layout

1.3 Appendix1.3.1 References

- 1.1. U.S. Government, Packaging and Transportation of Radioactive Material, Title 10, Code of Federal Regulations, Part 71, Office of the Federal Register, Washington D.C.
- 1.2. Westinghouse Hanford Company, "Specification for the NRF TRIGA[®] Cask Overpack," WHC-S-0275, Revision 0, February 22, 1994.

1.3.2 Drawings

The following drawings are provided in this appendix:

1. H-3-302836, TRIGA Cask Overpack Arrangement and Interface Control, Sheet 1, Revision 0.
2. H-3-302837, TRIGA Cask Overpack Arrangement and Interface Control, Sheet 2, Revision 0.
3. H-3-302838, TRIGA Cask Overpack Overpack Details, Sheet 1, Revision 0.
4. H-3-302839, TRIGA Cask Overpack Overpack Details, Sheet 2, Revision 0.
5. H-3-302840, TRIGA Cask Overpack Overpack Details, Sheet 3, Revision 0.
6. H-3-302841, TRIGA Cask Overpack Pallet and Tie Down Hardware, Revision 0.
7. H-3-302842, TRIGA Cask Overpack Main Assembly, Revision 0.

4. OPERATING PROCEDURES

Loading the NRF TRIGA[®] Cask Overpack for transport involves (1) preparation of the overpack for use, (2) placement of the cask into the overpack, (3) installing the top overpack and tie-down hardware, and (4) installing the package on the transport vehicle.

The procedures provided below assume that the cask is loaded into the overpack on the ground and then loaded onto the transport vehicle. The cask may instead be loaded into the overpack directly on the transport vehicle with no effect on operations.

4.1 Preparing the Packaging for Transportation

- a. Take contamination smears as necessary on the overpack and cask surfaces. Decontaminate if necessary.
- b. Inspect the overpack and tie-down hardware (including bolts and turnbuckles) for damage that may have occurred during transportation. Repair or replace as required.
- c. Remove the bolts from the top overpack lifting points and install the three lifting shackles.
- d. Remove the bolts from the bottom overpack lifting points and install the four lifting shackles.
- e. Lift the bottom overpack by the shackles and place it in the conical cup on the tie-down pallet.
- f. Install the temporary holddown slings between the bottom overpack shackles and the pallet turnbuckle attachment plates.
- g. Install the collar on the top overpack.
- h. The four turnbuckle assemblies may be pre-installed on either the pallet or the attachment ring at the user's option.

4.2 Procedures for Loading the Package

4.2.1 Placement of the NRF TRIGA[®] Cask into Overpack

- a. Lift the NRF TRIGA[®] Cask using suitable slings and place it into the bottom overpack.
- b. Verify that the cask is evenly seated in the bottom overpack.
- c. Remove the lifting hardware from the cask.

4.2.2 Installation of the Top Overpack and Tie-Down Hardware

- a. Using suitable slings and the top overpack lifting lugs, lift the top overpack and the turnbuckle attachment ring and place them on the bottom overpack and cask. Use the closure flange alignment pins to align the overpack halves during assembly.
- b. Verify that the overpack halves are properly seated.
- c. Connect the four turnbuckle assemblies between the tie-down pallet and the turnbuckle attachment ring to provide lateral support. Do not tighten the turnbuckles.
- d. Install the sixteen 1/2 inch screws in the overpack closure flange and torque 1/4 turn beyond snug tight.
- e. Disconnect the lifting slings from the top overpack lifting shackles.
- f. Install the two tamper seal wires between the washers provided on the top and bottom overpacks.
- g. Tighten the turnbuckles 1/4 turn beyond snug tight.
- h. Disconnect the temporary holddown straps from the bottom overpack and the tie-down pallet.
- i. Remove the lifting shackles from the top and bottom overpacks and install disabling bolts in their place.

4.2.3 Installation of the Package on the Transport Vehicle

- a. Using a suitable forklift or crane, lift the package and tie-down assembly and place it onto the transport vehicle. Package may be lifted using shackles in the collar or the pallet.
- b. Attach the tie-down pallet to the transport vehicle using hold down bolts through the pallet members or suitable chains or straps stretched over the pallet assembly.
- c. For offsite use, monitor the package radiation levels per 49 CFR 173.441 [4.1] and 10 CFR 71.47 [4.2] requirements.

4.3 Procedures for Unloading the Package

Unloading the package following transport involves removing the tie-down pallet from the transport vehicle and removing the cask from the overpack. The necessary procedures for these tasks are essentially the reverse of those described in Section 4.2.

4.4 Maintenance Requirements

4.4.1 Maintenance Program

This section describes the maintenance program used to ensure the continued performance of the overpack and tie-down hardware.

4.4.1.1 Structural and Pressure Tests

The overpack and tie-down lifting points will be visually inspected annually and after each use for plastic deformation or cracking. Any indication of cracking or distortion shall be repaired prior to further use of the overpack or tie-down. The locations to be inspected include the top and bottom overpack lifting locations, the tie-down turnbuckle attachment plates, and the contact surfaces between the overpack and the tie-down. Because the overpack and tie-downs do not serve as a containment boundary, no pressure tests are necessary to ensure their continued performance.

4.4.1.2 Leak Tests

Because the overpack does not serve as a containment boundary, no leak tests of the overpack are necessary to ensure its continued performance.

4.4.1.3 Subsystems Maintenance

Fasteners All threaded parts, including the closure bolts, Helicoil thread inserts, and the turnbuckles, will be inspected annually and after each use for deformed or stripped threads. The closure bolt coating will also be inspected for chips or corrosion. Any damaged parts shall be replaced prior to further use. As a minimum, the closure bolts shall be replaced annually if the overpack has been in use during the preceding year.

Paint The carbon steel tie-down components have been painted to prevent corrosion. The paint will be inspected annually for chips or corrosion. Touch-up paint shall be applied to any locations where the coating has deteriorated. The inside surfaces of the 10x4 tie-down beams, painted with a primer coat, will experience wear due to lifting by forklift. These surfaces shall be touched-up annually.

Wear Pads Neoprene wear pads have been installed in the tie-down pallet and collar to minimize wear during overpack installation and shipment. These pads shall be replaced annually if the overpack has been in use during the preceding year.

4.4.2 Spare Parts

The following spare parts are recommended for the NRF TRIGA[®] Cask Overpack and Tie-Downs. Complete descriptions of the recommended spare parts are listed on the drawings in Section 1.3.2.

- 4.4.2.1 Closure Bolts and Washers (16), Drawing: H-3-302838, Item 15
- 4.4.2.2 Turnbuckles (4) , Drawing: H-3-302842, Item 4
- 4.4.2.3 Top Overpack Lifting Shackles (3) , Drawing: H-3-302842, Item 6
- 4.4.2.4 Bottom Overpack Lifting Shackles (4) , Drawing: H-3-302842, Item 8
- 4.4.2.5 Temporary Holddown Slings (4) , Drawing: H-3-302842, Item 5
- 4.4.2.6 Neoprene Wear Pads (8), Drawing: H-3-302841, Item 11

4.5 Appendix

4.5.1 References

- 4.1. U.S. Government, Shippers - General Requirements for Shipments and Packaging, Title 49, Code of Federal Regulations, Part 173, Office of the Federal Register, Washington D.C.
- 4.2. U.S. Government, Packaging and Transportation of Radioactive Material, Title 10, Code of Federal Regulations, Part 71, Office of the Federal Register, Washington D.C.

ITEM/REV	PART OR IDENTIFYING NO.	DESCRIPTION OR IDENTIFYING NO.	MATERIAL SPECIFICATION	QUANTITY	DATE	BY
PARTS LIST						
<p>ALL DIMENSIONS ARE APPLICABLE TO NET AND ALL DIMENSIONS APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.</p> <p>DIMENSIONS ARE IN INCHES AND DECIMALS UNLESS NOTED OTHERWISE. DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH T1.4M-1983.</p> <p>FRACTIONS DECIMALS ANGLES N/A .001 N/A 2 N/A N/A .001 N/A 2 N/A</p> <p>BREAK AND CHAMFER ALL SHARP EDGES N/A</p> <p>3RD ANGLE PROJECTION</p> <p>DO NOT SCALE DRAWING</p>						
<p>VECTRA Fuel Services - San Jose, California</p> <p>TRIGA CASK OVERPACK ARRANGEMENT AND INTERFACE CONTROL</p> <p>252-59.1000 M-3-302837 1/2 OF 2 1/2</p>

OVERPACK ASSEMBLY

DETAIL 1

DETAIL 2
(TYPE AS APPROPRIATE 15 AND 185)

NOTES:

1. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH ASME CODE SECTION 9. ALTERNATIVELY, WELDERS AND PROCEDURES SHALL BE QUALIFIED TO AWS OR SUPPLEMENTED BY THE FACTORY TRAINING PROGRAM TO MEET ASME SECTION 9. WELDING PROCEDURES AND WELDER QUALIFICATIONS SHALL BE AVAILABLE FOR AUDIT OR REVIEW PER VECTRA FABRICATION SPECIFICATION NO. 232-59-101.
2. ALL WELLS SHALL BE VISUALLY EXAMINED IN ACCORDANCE WITH AWS D9.1. VISUAL WELDING INSPECTION SHALL BE QUALIFIED PER AWS D11.1. IT IS IMPORTANT THAT WELDS BE WELDED TO THE NOMINAL SIZE WITH NO EXCESS REINFORCEMENT. EXCESS WELD DEPOSITS SHALL BE REMOVED BY GRINDING.
3. POLYURETHANE FOAM SHALL HAVE NOMINAL DENSITY AS SPECIFIED. INSTALLATION OF REINFORCING AND WELDS SHALL BE VERIFIED FOR DEFLECTIONS IN PROPORTION PER VECTRA FABRICATION SPECIFICATION NO. 232-59-101.
4. PRIOR TO POURING FLOW (ITEM 17), APPLY CONSUMABLE PASTE WAX (ITEM 22) TO ALL INTERIOR SURFACES OF SMALL SUBASSEMBLY.
5. IDENTIFY ALL COMPLETED FABRICATED COMPONENTS AND SUBASSEMBLIES USING "1" HIGH LOW STRESS STAMP OR MARKER PENCIL AS APPROPRIATE TO IDENTIFY COMPONENTS. APPLICATION, IDENTIFICATION SHALL CONSIST OF: DRAWING NUMBER, APPROVAL DATE, NAME, DRAWING NUMBER, DRAWING NUMBER AND A PROJECT UNLESS OTHER NUMBER PROVIDED BY PURCHASER.
6. IF "1" 5/16" SLOT UNLESS "2" CENTERS MAY BE USED TO CONNECT REINFORCING AND WELDS TO PLATES. SLOTS MAY BE IN SAME CENTERS ON EACH SIDE OF JOINT OR STAGGERED BY 1" AT FABRICATOR'S OPTION.
7. BOLT HOLES IN ITEM 10 AND TAPPED HOLES IN ITEM 13 SHALL BE WAX DRILLED.
8. FABRICATOR SHALL PROVIDE A QUANTY CAGE #1820 X 37.57 L3 TO DEMONSTRATE THE FABRICATOR'S CAPABILITY TO PRODUCE A CAGE TO (MILITARY) SPEC. SHALL REST ON BOTTOM SUPPORT LAMINER SHALL WITHOUT ANY BOLT OR SCREW.
9. QUALITY CATEGORY FOR "IMPORTANT TO SAFETY" ITEMS AS DEFINED IN VECTRA FABRICATION SPECIFICATION NO. 232-59-101. "WHT" IS NOT IMPORTANT TO SAFETY.
10. LENGTH OF TYPICAL SHEED SHALL BE ADJUSTED TO ENSURE A MINIMUM DENSITY THICKNESS OF 36.00.
11. SHEED SHALL LOCATE FROM 12 TO PROVIDE A MINIMUM GAP OF .05 AND A MAXIMUM GAP OF .13 FROM ITEM 15.

[illegible]

ALL DIMENSIONS ARE APPROXIMATE
AT GRT AND ALL TOLERANCING
APPLIES AFTER WELDING
AND FINAL MACHINING
UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES
 UNLESS NOTED OTHERWISE.
 DIMENSIONING AND TOLERANCING
 IN ACCORDANCE WITH
 Y14.5M-1982.

FRACTIONS	DECIMALS	ANGLES
N/A	$\pm .010$ N/A	$\pm .1$ N/A
	$\pm .005$ N/A	

BREAK AND DEBURR ALL SHARP EDGES N/A
3/4" ANGLE PROJECTION

DO NOT SCALE DRAWING

VECTRA
Fuel Services - San Jose, California

TRIGA CASK OVERPACK
OVERPACK DETAILS
DAR DRAWINGS

252-591001	W-1-107833	MOUSE	1 OF 2	REV. 26
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(USE SHEET 1 FOR PARTS LIST) PARTS LIST	INTERNAL PREPARATION QUALITY / INSPECTION CONTROL	DATE OF INSPECTION OR ACCEPTANCE DATE	PARTS LIST	VECTRA Fuel Services - San Jose, California	TRIGA CASK OVERPACK OVERPACK DETAILS DRAWINGS	DATE 22-58-1001 4-3-201840 INVOICE 3 OF 3 8 1/2 X 11
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NOTES:

1. ALL WELDING PROCEDURES AND PERSONNEL SHALL BE QUALIFIED IN ACCORDANCE WITH AWS D1.1.
2. ALL WELDS SHALL BE VISUALLY EXAMINED IN ACCORDANCE WITH SECTION 5.1.1 OF AWS D1.1. VISUAL ACCEPTANCE SHALL BE REQUIRED FOR ALL WELDS.
3. ALL WORK SHALL BE PERFORMED IN ACCORDANCE WITH VECTRA FABRICATION SPECIFICATION NO. 251-55-102.
4. IDENTIFY ALL QUALIFIED ASSEMBLED COMPONENTS AND SUBASSEMBLIES USING A "P" AND THE LETTERS "THRU" OR "VIA" FOLLOWED BY THE DRAWING NUMBER, PART OR SUB-ASSEMBLY NUMBER, DRAWING NUMBER, AND A PART OR SUB-ASSEMBLY NUMBER (SUPPLIED BY PURCHASER).
5. QUALITY CONTROL FOR "IMPORTANT TO SAFETY" ITEMS AS DEFINED IN VECTRA FABRICATION SPECIFICATION NO. 251-55-102 SHALL BE NOT SUBJECT TO SAFETY.

COLLAR ASSEMBLY

DETAIL 1
TOP VIEW
(AT BOTH ENDS OF 2 ONLY)

ITEM 7
TURNBUCKLE ATTACHMENT PLATE

PALETT ASSEMBLY

SECTION A-A

ITEM	DESCRIPTION	QTY	UNIT	REMARKS
1	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg
2	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg
3	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg
4	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg
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99	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg
100	TURNBUCKLE ATTACHMENT PLATE, 50 THK	1	PC	AS PER Dwg

VECTRA
Fuel Services - San Jose, California

TRIGA CASK OVERPACK
PALLET AND TIE DOWN HARDWARE
DAR DRAWING

DATE	201-55-1002	REV	1	DATE	201-55-1002	REV	1
BY	1002	CHKD	1002	BY	1002	CHKD	1002
APP'D	1002	APP'D	1002	APP'D	1002	APP'D	1002

252-59-101

Revision 0

July, 1994

FABRICATION SPECIFICATION
FOR
NRF TRIGA® CASK OVERPACKS

**UNCONTROLLED COPY
FOR INFORMATION ONLY**

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Richland, Washington

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1. SCOPE OF WORK

This document defines the requirements for supply of the NRF TRIGA[®] Cask Overpack. The Overpack is a foam-filled, steel shell impact limiter that encases the NRF TRIGA[®] Cask during transportation. The scope of work includes the materials, fabrication, welding, inspection, examination, quality assurance, and shipping of one complete, Safety Related Overpack.

1.1 Work Included

The work set forth by this Specification shall include the following:

- A. The preparation and submittal of an Overpack manufacturing plan, schedule, and shop detail and assembly drawings to the Buyer for approval in accordance with this Specification. Submittals shall be made in accordance with Section 8 of this Specification.
- B. The preparation and submittal of overpack material certificates, fabrication procedures, inspection and examination procedures, welding procedures, checklists, dimensional certificates, and other documentation as required by this Specification to verify that the materials and completed Work conforms to the requirements of this Specification.
- C. The furnishing of materials, fabrication, welding, foam installation, insulation installation, shop testing, inspection, documentation, quality assurance, and shipping of one complete NRF TRIGA[®] Cask Overpack as described by the Design Drawings and this Specification.

1.2 Related Work by Others

The following items related to the NRF TRIGA[®] Cask Overpack are not included and will be furnished by Others:

- A. Design and licensing of the Overpack.
- B. Design and fabrication of the Overpack lifting and tie-down skid.

2. TECHNICAL TERMINOLOGY

The following definitions and abbreviations shall apply as used within this Specification.

2.1 Definitions

The following definitions of terms shall apply throughout this document.

- A. **Buyer** is hereby defined as meaning VECTRA Technologies, Inc., San Jose, California.
- B. **Seller** is hereby defined as meaning the entity awarded the contract for furnishing the equipment specified herein.
- C. **Owner** is hereby defined as the Westinghouse Hanford Company, Richland, Washington.
- D. **The Work** is hereby defined as meaning collectively any and all equipment, material, apparatus, item, process, and parts or portions thereof to be supplied by the Seller under the Contract.

2.2 Abbreviations

The abbreviations applicable to this Specification are defined as follows.

AISC	American Institute of Steel Construction, Inc.
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASME Code	ASME Boiler and Pressure Vessel Code
ASNT	American Society for Nondestructive Testing
ASTM	American Society of Testing and Materials
AWS	American Welding Society
Cask	The NRF TRIGA [®] Cask
CFR	Code of Federal Regulations
NRF TRIGA [®]	Neutron Radiography Facility, Training Reactor, Isotopes, General Atomic
Overpack	The NRF TRIGA [®] Cask Overpack

3. SPECIFYING DOCUMENTS

3.1 Codes and Standards

Equipment and services furnished in accordance with this Specification shall comply with the following codes and standards to the extent referenced herein. Unless otherwise noted, the document with addenda, amendments, and revisions in effect on the date of the purchase contract will apply. Any conflicting requirements shall be brought to the attention of the Buyer for resolution prior to proceeding with the Work.

- 3.1.1 ASME Code, Section VIII, Division 1, "Pressure Vessels."
- 3.1.2 CFR, Title 10, Part 21, "Reporting of Defects and Noncompliance."
- 3.1.3 CFR, Title 10, Part 71, Subpart H, "Quality Assurance."
- 3.1.4 CFR Title 14, Part 25, "Airworthiness Standards: Transport Category Airplanes."
- 3.1.5 ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Fabrication Phase of Nuclear Power Plants."
- 3.1.6 ANSI N45.2.2 (1972), "Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants."
- 3.1.7 ANSI/ASME N45.2.6-1978, "Qualifications of Inspection, Examination, and Testing Personnel for Nuclear Power Plants."
- 3.1.8 ANSI Y14.5M-82, "Dimensioning and Tolerancing."
- 3.1.9 AWS A2.4-86, "Weld Symbols."
- 3.1.10 AWS D1.1, "Structural Welding Code - Steel."
- 3.1.11 AWS D9.1, "Sheet Metal Welding Code."
- 3.1.12 ASTM D1622, "Method of Test for Apparent Density of Rigid Cellular Plastics."
- 3.1.13 ASTM C177-76, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Guarded Hot Plate."
- 3.1.14 ASTM A380, "Standard Recommended Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems."
- 3.1.15 Federal Specification QQ-P-416E Amendment 1, "Plating, Cadmium (Electrodeposited)."

3.2 Reference Drawings

The Design Drawings listed below are hereinafter referred to as Drawings and set forth the extent of the Work to be performed under this contract. These Drawings are hereby expressly made a part of this Specification.

Drawing

Title

252-59-2001

TRIGA Cask Overpack, Overpack Details
Fabrication Drawing

4. MANUFACTURING REQUIREMENTS

4.1 General Requirements

Overpack fabrication, welding, and inspection shall comply with the applicable requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, ASME Section IX. The materials shall meet the applicable ASTM requirements specified herein. An ASME U stamp is not required on finished overpacks.

All work specified herein is nuclear safety related and requires the application of the provisions of the Code of Federal Regulations, Title 10, Part 21 (10CFR21), "Reporting of Defects and Noncompliance." It is the responsibility of the Seller to implement the provisions of 10CFR21 and to pass these requirements on to his subcontractors. The Seller shall notify the Buyer concurrent with any notice to the NRC pursuant to 10CFR21 requirements.

The Seller shall accept complete responsibility for all Work performed in compliance with this Specification. Review or approval of data or procedures by the Buyer with regard to Work performed to accomplish the requirements of this Specification does not constitute acceptance of any materials or components which will not fulfill the requirements established by this Specification. The requirements of this Specification shall be met.

Alternative fabrication details proposed by the Seller shall be submitted to the Buyer in writing. These shall not be made part of the purchase contract without written approval from the Buyer.

4.2 Materials

4.2.1 General

All materials used for the fabrication of the Overpack shall be in accordance with the Drawings. Material purchase specifications shall be prepared and submitted to the Buyer for approval prior to placing the material order. The Seller may propose to supply alternative materials, components, or parts other than those specified, if in the opinion of the Seller, the substitution is more economical, better qualified for the performance requirements, and is equivalent to and in accordance with the applicable requirements. All proposed substitutions shall be clearly defined in the Seller's proposal with a complete description including supporting data establishing equivalence to the specified item.

4.2.2 Overpack Structural Materials

All structural materials of the Overpack are required to meet the applicable ASTM specification as designated on the Drawings. These materials shall be purchased in accordance with the requirements of the applicable ASTM specifications.

4.2.3 Welding Materials

All welding filler metals and fluxes used in the fabrication and repair of the Overpack in accordance with the requirements of ASME Section VIII, Division 1, and ASME Section IX. Materials need not be purchased from an ASME material supplier.

4.2.4 Foam

A. Type

The finished foam product shall be a closed cell polyurethane plastic foam of the self-extinguishing variety such as the General Plastics type FR-3700 series. An equivalent polyurethane foam meeting all of the nominal properties listed below is an acceptable substitute.

B. Density

The rigid polyurethane foam shall have a nominal density of 7 lbs/ft³. The density shall be determined in accordance with ASTM D1622.

C. Mechanical Properties

The foam shall conform to the compressive stress/strain properties shown in Table 1. The foam shall also exhibit the following nominal ($\pm 15\%$) properties at an ambient temperature of 75°F.

1. Nominal Tensile Strength

Perpendicular to Rise	220 psi
Parallel to Rise	280 psi

2. Nominal Shear Strength

Perpendicular to Rise	170 psi
Parallel to Rise	150 psi

D. Water Absorption

The foam shall be a "closed-cell" type which will absorb less than 20.0 grams of water per square foot of surface area in 96 hours of continuous

immersion. Data supporting the water absorption criteria shall be submitted to the Buyer for review and approval.

E. Flame Retardant Characteristics

A test to validate the flame retardant characteristics shall be performed in accordance with Section 5.2.2 (C). Data from previous tests performed on the same material may substitute for the testing required in Section 5.2.2 (C).

F. Thermal Properties

The foam shall be certified to have nominal thermal properties at 70°F consistent with the manufacturer's published literature.

G. Notification Regarding Changes

No changes in approved product formulation, critical raw materials, basic methods of manufacture, or plant site shall be made without notification to and prior written approval by the Buyer. Requalification of the revised material may be required.

4.2.5 Thermal Insulation

A. Type

The thermal insulation shall be a flexible ceramic fiber blanket such as Fiberfrax® Durablanket™ S

B. Continuous Use Temperature Limit

The thermal insulation shall have a minimum continuous temperature limit of 1500°F.

C. Thermal Properties

The thermal insulation shall be certified to have nominal thermal properties consistent with the published Fiberfrax Durablanket manufacturer's published literature as measured in accordance with ASTM C177.

4.2.6 Other Materials

Standard products incorporated into the Overpack design have been designated on the Drawings as ASTM materials or by the manufacturer's callout as applicable. These materials shall be purchased in accordance with the applicable requirements or the manufacturer's standard specifications.

4.3Fabrication

All cutting, forming, machining, and fitting operations shall be performed in accordance with approved shop drawings, the provisions of this specification, the recommendations of the ASME Code section VIII, Division 1, and manufacturer's practices, as applicable.

Temporary welded attachments shall be removed flush with the base material without encroaching on the specified minimum thickness. All areas from which temporary attachments have been removed shall be examined by the Liquid Penetrant method after the surface has been restored. Repair procedures and documentation are required.

4.3.1

Cutting

Preparation for welds shall be by non-thermal methods where practical. Thermally cut surfaces shall be ground to provide slag-free metal and fit-up equivalent to machining. Thermal cutting of austenitic stainless steel shall not be permitted without the Buyer's approval of the process to be used. All grinding wheels used on the overpack shall be new and shall not be used on any carbon steel material.

4.3.2

Forming

All plates used in the cylindrical and conical Overpack walls shall be rolled to final form in the direction of mill rolling, and shall be accurately cut to size before welding. Plates shall be formed to true shape with curvature continuous from the edges of the plate. Flat spots shall meet the tolerances specified on the Drawings. Corrections, if required, shall be made by the pressure process and not by hammer blows.

4.3.3

Machining

Machining of the Overpack shall be performed using tooling suitable for the task and capable of producing the required dimensional control and surface finishes as specified on the Drawings.

4.3.4

Fitting and Aligning

Fitting and aligning of all parts is to be performed in accordance with the component tolerances specified on the Drawings.

4.3.5

Piece-Part Tolerancing

Where piece-part tolerances are not specified on the Drawings, the Seller shall establish piece-part tolerances that provide a finished product meeting the overall

tolerances specified on the Drawings. The piece-part tolerances shall be stated on the shop drawings.

The Seller may recommend variations in the piece-part tolerances established by the Drawings, provided a system is established that ensures the critical Overpack cavity dimensions and closure ring position tolerances are maintained. Any modifications to the Drawing tolerances shall be approved, in writing, by the Buyer prior to use in the shop.

4.3.6 Dimensional Verification

The Seller shall establish a system with his quality control program that shall verify critical dimensions of all piece parts and subassemblies prior to and during fit-up and welding. This program shall be identified in the Seller's manufacturing plan.

4.4 Welding

All Overpack welding shall conform to the requirements of Section VIII, Division 1 of the ASME Code and this Specification unless noted otherwise on the Drawings. Non-structural attachments and minor welds may be performed in accordance with AWS D9.1. The Seller shall submit all welding procedures to the Buyer in accordance with the schedule given in Section 8. All welding shall be performed by welders and welding operators qualified in accordance with Section IX of the ASME Code.

4.4.1 Welding Processes

Welding shall be performed in accordance with Section VIII, Division 1 of the ASME Code.

4.4.2 Welding Procedures and Qualifications

The Seller shall prepare written welding procedures. Each procedure shall be prepared in accordance with ASME Section IX and this Specification. Procedures and procedure qualification records shall be in the form of clear, sharp, reproducible prints and shall be submitted on forms QW-482 and QW-483, or equivalent, as shown in the ASME Code, Section IX or similar forms or formats.

Approved welding procedure identifications and designations shall be shown on the Seller's shop drawings for each weld. The Seller shall submit to the Buyer the Welding Procedure Specifications (WPSs) and copies of the Procedure Qualification Records (PQRs) in accordance with the schedule in Section 8. The welding and quality control procedures shall include the limitation that no welder shall have in his possession more than one type of filler metal at any one time, except that a welder may have both bare wire and covered electrodes that deposit weld metal of the same A-number class.

4.4.3 Preheat and Interpass Temperatures

Preheat and interpass temperatures shall be in accordance with the recommendations of Section VIII of the ASME Code.

4.4.4 Workmanship and Visual Quality

- A. Each weld shall be essentially uniform in width and size throughout its full length. Each layer of welding shall be visually free of slag, inclusions, cracks, porosity, and lack of fusion.
- B. Fillet welds shall be of the specified size with full throat thickness as required. Excessive convexity or concavity shall be avoided. Fillet welds shall always develop the minimum size required by the Drawing, but may vary in size above the minimum as long as a reasonably uniform appearance is maintained.
- C. Elimination of defects and surface preparation of welds by chipping, grinding, or gouging shall be done in such a manner as not to gouge, groove, or reduce the adjacent base-material thickness below the specified thickness. Buyer approved repair procedures and verification reports shall be used for this Work.
- D. All weld spatter and arc strikes shall be removed in accordance with Buyer approved procedures.

4.4.5 Non-destructive Examination

All welds shall be 100 percent visually examined in accordance with Section 8.15.1 of AWS D1.1.

4.4.6 Repair by Welding

Repair of defects in either the base metal or in completed welds shall be performed in accordance with Section VIII of the ASME Code.

4.5 Installation of Foam Material

4.5.1 Liquid Foam Pouring

The liquid foam material shall be "poured in place" within surrounding walls made of stainless steel. The liquid components must react to form the rigid foam and rise in such a way that the entire volume of the single foamed assembly is filled with expanded foam. The Overpack shells shall be inspected to ensure that a compatible release agent has been applied to all stainless steel surfaces to prevent bonding of the foam to the shells.

4.5.2 Foam Temperature

Maintain mixed foam components temperatures at a minimum pour point of 60°F.

4.5.3 Surrounding Wall Temperature

The surrounding walls of the assembly being foamed shall be maintained between 55°F and 85°F prior to foam installation. Insulation of the package walls from concrete floors shall be considered if temperatures are below the 55°F minimum value.

4.5.4 Timing of Multiple Pours

The time between multiple pours into a single container shall be not less than 20 hours.

4.5.5 Shoring

Bracing and shoring for all surrounding assembly walls shall be provided as necessary to prevent distortion due to internal foam pressure. The method used must allow the container to meet its required dimensions and dimensional tolerances. Bracing shall be performed prior to transferring the shells to the foaming location to prevent shell distortion.

4.6 Cleaning, Coating, and Surface Preparation

Cleaning, coating, and surface preparation for the Overpack shall be as specified on the Drawings and the following:

4.6.1 Cleaning

- A. All metal surfaces shall have a surface cleanliness classification C or better as defined in Section 2 of ANSI N45.2.1.
- B. All welding by-products such as slag, spatter, or smoke stains shall be removed.
- C. The use of any mechanical method which produces excessive roughness, or cleaning agents which may have corrosive effects or affect the performance of the material is prohibited. Products containing measurable amounts of chlorides or halides shall not be used on stainless steel.

4.6.2 Bolt Coatings

The Overpack closure bolts shall be cadmium plated per Federal Specification QQ-P-416E 1987, Class 1, Type 1. The bolts shall be baked immediately after plating at 375°F ± 25°F for a minimum of six hours. The cadmium plating is non-safety related and no preproduction or destructive tests are required.

5.INSPECTION AND TESTING REQUIREMENTS

The Overpack shall undergo dimensional inspections. The purpose of these inspections is to ensure the quality of workmanship and to guarantee that the Overpack meets the dimensional requirements. The Seller shall furnish all shop inspection and test facilities, materials, and labor necessary for performance of inspections, or for any modifications resulting from the inspections. The Seller shall repair or replace any portion of the Work which is not in compliance with the Purchase Contract as determined by these inspections.

The Buyer shall be notified in writing at least two weeks in advance of designated hold points or witness points. In addition, three days prior to these hold or witness points, the seller shall notify the Buyer by telephone. Hold or witness points may not be waived without specific written consent of the Buyer.

5.1Shop Test and Inspection

- A. The Seller shall submit to the Buyer documentation identifying the QA inspection, witness and hold points which will occur during the manufacturing, assembly, and testing activities for the Overpack. This list will be used to designate the Buyer surveillance hold and witness points.
- B. The Buyer reserves the right to make arrangements with a qualified inspection firm, or provide his own representative, to be present during the required hold or witness point activities. The presence of a representative from such a firm or the Buyer's representative does not relieve the Seller from performing his required in-house quality control functions. The Seller is responsible for first line inspection and verification of items and services within the contractual scope of work. The Seller shall furnish the representative all necessary documents and records to perform the required surveillance during hold and witness point activities.
- C. The Buyer will review the work to ensure that all items have been fabricated and tested in accordance with the Specification.

5.2Performance Tests

The Seller shall complete the following functional performance tests for the Overpack:

5.2.1Dimensional and Weight Checks

Prior to foaming, subsequent to foaming, and upon completion of all overpack fabrication, the Seller shall perform the necessary dimensional checks to verify that the critical dimensions and surface finishes have been achieved in accordance

with the Drawings and a 100 percent visual examination shall be performed on all welds. Upon completion of the Overpack fabrication, the following dimensional and weight tests shall be performed:

- A. The internal cavity dimensions of the Overpack shall be verified to ensure that the cavity envelope is within the tolerance specified in the drawings. This check shall be performed using an accurate full length gauge. The performance of this test shall be designated as a fabrication hold point in the Seller's manufacturing plan.
- B. The Seller shall completely assemble the Overpack halves to demonstrate that the halves fit and that the attachment bolts can be readily inserted without the need to exert undue force or effort with the full length gage in the cavity. The performance of this test shall be designated a fabrication hold point in the Seller's manufacturing plan.
- C. Following completion of the Overpack fabrication, the Seller shall weigh the components and record the weights. The weighing device shall be calibrated.

5.2.2

Foam Testing

The following tests shall be performed on the polyurethane foam material:

A. Sample Pours

All sample pours shall be formed in test boxes or containers at the same time as the actual production pour they represent. A portion of the actual production pour stream shall be used for the corresponding samples.

B. Compressive Testing

- 1. A minimum of three test specimens shall be taken from each test sample box prepared during production as described in Section A above. In the case of multiple pours into a single foamed assembly, samples shall be tested prior to installation of the next pour.
- 2. The samples shall be sectioned and tested for compressive strength within the parameters shown in Table 1. Stress-strain plots shall be prepared for each sample in the parallel to foam-rise orientation. The density shall be measured in accordance with ASTM D1622.
- 3. The test data shall be recorded and reviewed by the Buyer to verify that the following acceptance criteria are met:

- a. At 10 percent, 40 percent, and 70 percent foam strain, the average stress of all production pour samples from a single Overpack shell shall not exceed ± 10 percent of the corresponding nominal stress specified in Table 1.
 - b. At 10 percent, 40 percent, and 70 percent foam strain, the stress value of any single tested specimen from a single pour samples shall not exceed ± 15 percent of the corresponding nominal stress specified in Table 1.
4. The foregoing production pour sample testing criteria will result in a minimum total of three test plots being required for each pour into a single, fully foamed assembly.

C. Flame Retardancy Testing

1. A minimum of one test specimen shall be taken from the sample boxes prepared during the production foam pours.
2. The sample shall be sectioned and tested for flame retardancy per the requirements of Section 853 (a) and Part I (d), Appendix F, of 14 CFR 25. The test data shall be recorded and reviewed by the Buyer to verify the following acceptance criteria are met:
 - a. The average burn length shall not exceed six inches.
 - b. The average flame time after removal of the flame source shall not exceed fifteen seconds.
 - c. After falling, drippings from the test specimen shall not continue to flame for more than an average of three seconds.

6.QUALITY ASSURANCE REQUIREMENTS

The Seller is required to have an acceptable Quality Assurance Program which shall be in effect throughout the fabrication, assembly and testing of the Overpack. This program shall meet the applicable requirements of CFR, Title 10, Part 71, Subpart H. The Quality Assurance Program must be accepted by the Buyer prior to initiation of procurement of materials or fabrication.

Procurement of material, items, and components may be in accordance with a Graded Quality Quality approach in accordance with CFR Title 10 Part 71, Regulatory Guide 7.10.

If the Seller procures items from sub-suppliers not audited to the requirements of 10CFR71, Subpart H (or equivalent), the supplier's QA Program or implementing procedures must address the control of the items. This program must meet the intent of EPRI NP-5652, "Guidelines for the Utilization of Commercial Grade Items in Nuclear Safety Related Applications (NCIG-07)", dated June 1988 as amended by NRC Generic Letter 89-02 dated 3/21/89.

6.1Quality Control

An inspection point plan shall be prepared by the Seller for the Buyer's approval. This plan shall include a description of all inspection points and hold points which may impact the quality of the Overpack.

The Seller's and the Seller's subcontractor QC procedures shall include the use of fabrication travelers. Fabrication travelers shall reference or describe the procedures used in accomplishing the tasks, the inspection, the test requirements and any inspection hold points. Fabrication travelers shall include hold and witness points for review by the Buyer.

All critical dimensions, as indicated on the referenced Drawings, shall be measured and actual measurements shall be recorded in accordance with the Seller's inspection procedures.

The Buyer and the Owner shall have full access to the Seller's or the Seller's subcontractor's facilities for reviewing progress and determining acceptability of quality control activities.

The Buyer shall have full access to the Seller's or Seller's subcontractor's facilities for auditing the implementation of the Seller's Quality Assurance Program and for performing QC Surveillance of the Overpack. Any findings resulting from audit or surveillance of the Seller's or subcontractor's facilities shall be addressed and promptly corrected to the Buyer's satisfaction.

Any nonconformance with purchase documents, drawings, approved procedures, or material selection shall be promptly submitted in writing to the Buyer both upon initial issuance and after closure. Nonconformances dispositioned as "Repair" or "Use-as-is" shall also be submitted prior to implementation of corrective action.

6.2

Quality Requirements for Shipping Release

The Seller shall not ship the Overpack until all the tests and inspections have been performed and the Overpack documentation package is complete and approved by the Buyer's quality representative.

The Seller shall notify the Buyer three weeks prior to the intended shipping date and shall allow the Buyer one week prior to shipment to review the documentation package as described in Section 8.2. The documentation package shall be complete and final prior to submission to the Buyer.

Along with the documentation package, the Seller shall submit to the Buyer a Certificate of Compliance to this Specification and the applicable Drawings. As a minimum the Certificate shall include but not limited to the following information:

- A. Purchase Order number.
- B. Procurement Specification and drawing numbers, including any approved changes, waivers, or deviations applicable to the equipment.
- C. A certification by the person who is responsible for Seller's the quality assurance function.
- D. Provisions for the signature of the Buyer Quality representative. The Buyer signature is to indicate an agreement that the equipment and the accompanying documentation is ready for shipment, and does not constitute acceptance by the Buyer.

7.PACKAGING AND SHIPPING REQUIREMENTS

All packaging and shipping shall be in accordance with Level D of ANSI N45.2.2. "Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants." On the date of the shipment, the Seller shall provide the Buyer with the following: the carrier bill of lading number, the routing and destination instructions, a list of the items being shipped. The Seller shall be totally responsible for the safe delivery of the Overpack. Any damage to the Overpack as a result of improper packaging, in transit handling, or shipping, shall be repaired at the expense of the Seller.

Delivery of the Overpack shall be F.O.B to the location specified in the Buyer's purchase order. Unloading will be the responsibility of the Owner. Unloading may occur within the plant protected area at a location to be designated by the Owner. The overpack shall be shipped intact using the tie-down hardware to be provided by the Buyer.

8. DOCUMENT AND RECORD SUBMITTAL REQUIREMENTS

This section contains the requirements for document and record submittals for the Overpack. Table 2 summarizes the required documents to be submitted for review and approval. Table 3 summarizes the required records to be submitted at the time of shipment.

8.1 Documents

8.1.1 Shop Drawings

The Seller shall prepare shop drawings required for normal shop practice for all assembly, sub-assembly, and piece parts associated with the Overpack. The Seller shall prepare and submit one reproducible of all shop drawings to the Buyer.

The shop drawings are to be full-size and legible with uniform background density suitable for microfilming and subsequent reproduction from microfilm.

The shop drawings will be reviewed and, if satisfactory, will be approved and one print, so marked, will be returned to the Seller. If not satisfactory, the reproducible will be appropriately marked and one print returned to the Seller for correction; after which, one reproducible of the drawings as corrected shall again be submitted for approval. The Seller shall make any corrections required and appropriately note any changes by dated revisions on the drawing.

All shop drawings shall be checked for accuracy prior to submission for approval. The approval of shop drawings shall not be construed as a complete check. Approval of such drawings will not relieve the Seller of the responsibility for any error which may exist on the shop drawings. Approval of the shop drawings does not relieve the Seller of the responsibility for meeting the design drawing requirements which are part of this specification.

8.1.2 Drawing Standards

Weid symbols shall be in accordance with the requirements of AWS A2.4-86.

The following Drafting Lettering Standards shall apply:

- A. Minimum character height (A, B, C, size drawings):
0.125 in. (1/8)
- B. Minimum character height (D and E size drawings):
0.156 in. (5/32)
- C. Minimum spacing between lines of characters:
height of characters

- D. Machine and guide generated characters:
12 point size minimum
- E. Density of characters and lines:
dense, sharp, and uniform

8.1.3 Inspection and Test Procedures

Inspection and test procedures shall include identification of each characteristic or attribute evaluated, the measuring and test equipment used, the inspection/ testing set-up for each characteristic/attribute evaluated and other requirements as required by Code, Standard and Contract.

8.2

Records

The Seller shall assemble and submit to the Buyer, two copies of the final records package. The package shall include but not limited to the items identified in Table 3.

- A. The Seller shall prepare and submit for approve by the Buyer, an Index of Records. The Index of Records shall include the records identified in Table 3 as well as any documents used by the Seller's QA Program to trace the record to the equipment.
- B. All test reports and test results shall be compared to the acceptance criteria. These reports shall contain the signature of the authorized representative or the agency performing the tests.
- C. Functional test results including signed-off copies of foam material acceptance tests and test report data. Signatures on this report data shall be by authorized representatives or by the agency personnel performing the tests.
- D. Certified material test reports with actual chemical and physical properties for each heat number for all material; i.e., piece traceability shall be provided. Certificates of compliance may be provided in place of CMTRs for quality category grade B and C items as specified on the Drawings.
- E. Records of all repairs as required by Section VIII of the ASME Code.
- F. Visual inspection reports in accordance with this Specification.
- G. Record of all deviations affecting the Seller's approved drawings, if any.

Table 1
Allowable Foam Static Compressive Stress at 75°F (Parallel to Rise)

Strain	Minimum [individual pour] (-15%) (psi)	Minimum [average of all pours] (-10%) (psi)	Nominal (psi)	Maximum [average of all pours] (+10%) (psi)	Maximum [individual pour] (+15%) (psi)
10%	553	190	211	232	243
40%	672	202	224	246	258
70%	1833	480	533	586	674

Note: Test results shall be determined using samples which are 1.75 inch cubes.

Table 2
Document Submittal List

Item	Type of Document Required	Reference Spec. Sect.	Timing ⁽¹⁾
1	Detailed Manufacturing Schedule	1.1	15 days AC
2	Manufacturing Plan Including Key Inspection and Test Witness Points	1.1, 5	30 days AC
3	Shop Drawings	8.1.1	30 days AC
4	QA Manual with Implementing Procedures and Instructions	6	Submit with Bid
5	Material Purchase Specifications. Foam and Insulation Data	4.2.1, 4.3.6	2 weeks MO
6	Shop Procedures (machining, fabrication, cleaning, shipping, etc.)	4.3	30 days AC
7	Process Specifications (welding, NDE, etc.)	4.4	30 days AC
8	Inspection and Test Procedures	5	30 days AC
9	Non-Conformance Reports	6.1	Prior to implementation
10	Shipment Bill of Lading	7	On date of shipment
11	Index of Records	8.2	1 week PS

1. AC = after award of contract; MO = prior to material order; PS = prior to shipment.

Table 3
Records Submittal List

Item	Type of Document Required	Reference Spec. Sect
1	Index of Records	8.2
2	Certified Material Test Reports and/or Certificates of Compliance	8.2
3	Welding Material Qualification Reports	4.4.2
4	Repair Records	4.4.6
5	Inspection Records and Reports	8.2
6	Foam Compressive Testing Reports	5.2.2(B)
7	Foam Flame Retardancy Reports	5.2.2 (C)
8	Non-Conformance Reports	6.1
9	Dimensional and Weight Test Reports	5.2.1
10	Certificate of Compliance	6.2
11	As-Built Documents	8.2

252-59-102
Revision 0
June, 1994

FABRICATION SPECIFICATION

FOR

NRF TRIGA® CASK OVERPACK

TIE-DOWN HARDWARE

UNCONTROLLED COPY

FOR INFORMATION ONLY

Prepared for

Westinghouse Hanford Company
Richland, Washington

Issued by:

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Project Manager

Date: 6/30/94

Reviewed by:

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Approved by:

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REVISION CONTROL SHEET

FILE NO.: 252-59.0102

TITLE: Fabrication Specification for NRF TRIGA® Cask Overpack Tie-Down Hardware

K. B. Jones, P.E. / Project Engineer

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1. SCOPE OF WORK

The Scope of Work includes the materials, documentation, fabrication, welding, cleaning, painting, assembly, inspection, packaging, and shipping of the NRF TRIGA[®] Cask Overpack Tie-Down hardware. The work specified herein is non-safety related for non-QA condition hardware. All items in the scope of supply shall be shipped to the location specified on the Purchase Order.

1.1 Work Included

The following equipment, documentation, and services are to be provided by the Seller:

- A. One overpack tie-down pallet assembly fabricated in accordance with the Drawings (refer to Paragraph 3.2).
- B. One overpack tie-down collar assembly fabricated in accordance with the Drawings.
- C. Four overpack tie-down turnbuckle assemblies fabricated in accordance with the Drawings.
- D. Assembly and inspection of the assemblies listed above. The assemblies shall be subjected to all inspections and tests specified herein.
- E. All documentation required herein. Documentation includes all packaging and shipping documents.
- F. Packaging and shipment of all items in the scope of supply to the jobsite.

1.2 Related Work by Others

The following services and items of equipment will be provided by others:

- A. Design, licensing, and fabrication of the Overpack.
- B. Unloading of the tie-downs at the jobsite.

2.TECHNICAL TERMINOLOGY

The following definitions and abbreviations shall apply as used within this Specification.

2.1Definitions

The following definitions of terms shall apply throughout this document.

- A. **Buyer** is hereby defined as meaning VECTRA Technologies, Inc., San Jose, California.
- B. **Seller** is hereby defined as meaning the entity awarded the contract for furnishing the equipment specified herein.
- C. **Owner** is hereby defined as the Westinghouse Hanford Company, Richland, Washington.
- D. **The Work** is hereby defined as meaning collectively any and all efforts made by the Seller to provide components, materials, items, processes, and parts or portions thereto to be supplied by the Seller under the Contract.
- E. **Equipment** is hereby defined to mean collectively any and all components, materials, items, and parts or portions thereto to be supplied by the Seller under the Contract.

2.2Abbreviations

The abbreviations applicable to this Specification are defined as follows.

AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
AWS	American Welding Society
Overpack	The NRF TRIGA [®] Cask Overpack
SSPC	Steel Structure Painting Council
Tie-Down	The NRF TRIGA [®] Cask Overpack Tie-Down Pallet, Collar, and Turnbuckle Assemblies

3. SPECIFYING DOCUMENTS

3.1 Codes and Standards

Equipment and services furnished in accordance with this Specification shall comply with the following codes and standards to the extent referenced herein. Unless otherwise noted, the document with addenda, amendments, and revisions in effect on the date of the purchase contract will apply. Any conflicting requirements shall be brought to the attention of the Buyer for resolution prior to proceeding with the Work.

3.1.1 American National Standards Institute (ANSI) Standards:

Y14.5M-1982, "Dimensioning and Tolerancing"

3.1.2 American Institute of Steel Construction (AISC) Standards

"Code of Standard Practice for Steel Buildings and Bridges," 1986

3.1.3 American Welding Society (AWS) Specifications:

D1.1, "Structural Welding Code - Steel"

3.1.4 Steel Structures Painting Council (SSPC) Specifications:

A. SP 6, "Commercial Blast Cleaning"

B. PS 13.01, "Epoxy-Polyamide Painting System"

C. Paint 22, "Epoxy-Polyamide Paints (Primer, Intermediate, and Topcoat)"

D. PA 1, "Shop, Field and Maintenance Painting"

3.2 Reference Drawings

The Design Drawings listed below are hereinafter referred to as Drawings and set forth the extent of the Work to be performed under this contract. These Drawings are hereby expressly made a part of this Specification.

Drawing

Title

252-59-2002

TRIGA Cask Overpack Pallet and Tie Down Hardware

252-59-2003

TRIGA Cask Overpack Main Assembly

1 MANUFACTURING REQUIREMENTS4.1 Materials

The materials selected for the fabrication of components to be provided under this Specification shall be in accordance with the Drawings and suitable for the service conditions and performance requirements specified herein. Any variance from the Drawing requirements require written approval from the Buyer.

4.2 Fabrication

All fabrication shall be in accordance with the Drawings and the AISC Code of Standard Practice for Steel Buildings and Bridges. The drawings specify all required dimensions, tolerances, and surface finishes. Any variance from the drawing requirements must be preceded by written approval from the Buyer.

Good shop practices shall be followed during the performance of the Work.

4.3 Welding Requirements

All fabrication processes involving welding shall be performed in accordance with AWS D1.1. Welders shall be qualified in accordance with the Requirements of Section 5 of AWS D1.1.

Prior to painting, all welds shall be inspected in accordance with the Seller's standard methods by an AWS Certified Welding Inspector to ensure that welds meet the visual acceptance standards listed in Section 9.25.1 of AWS D1.1. All welds that do not meet these acceptance standards shall be repaired by methods established in AWS D1.1, Section 3.7. After repair, the welds shall be re-examined.

4.4 Surface Finishes4.4.1 General Requirements

The requirements for cleaning and painting are as follows:

- A. All welding by-products such as slag, spatter, or smoke stains shall be removed. All surfaces shall be free of dirt and oil prior to coating. Surfaces shall be cleaned by manual swabbing, dip washing, or spray cleaning with a compatible solvent such as mineral spirits oil.
- B. Machined surfaces shall be finished as indicated on the Drawings and will be subject to the approval of the Buyer.

- C. Surfaces shall not be coated until completion of all tests and inspections specified in Section 5, Inspection and Check-Out Requirements.
- D. All blast-cleaned surfaces, with the exception of threaded and/or moving parts, shall be coated per Paragraph 4.4.2 of this Specification.
- E. Any elastomeric materials or stainless steel surfaces shall not be coated.

4.4.2

Protective Coatings

Exterior steel surfaces to be coated shall be commercially blast cleaned (per SSPC-SP-6) and painted per SSPC-PS-13.01 using a two part, three coat epoxy-polyamide system (SSPC-Paint 22). The color of the coatings shall be ANSI #70 light gray. The interior of the 10x4 pallet tubes shall be coated with the SSPC-Paint 22 primer coat only.

4.5Assembly

4.5.1

Tolerancing

All dimensional tolerancing shall be in accordance with the Drawings and with this Specification.

4.5.2

Dimensional Verification

- A. The Seller shall establish a system with his quality control program which shall verify dimensions of all piece parts prior to welding and fit-up.
- B. All operational features shall be verified and witnessed by the Buyer. Refer to Section 5, Inspection and Check-Out Requirements.

4.5.3

Component Assembly

- A. All Equipment provided per this specification shall be shipped to the location specified on the Purchase Order fully assembled and ready for installation.
- B. After assembly of the tie-down hardware, all inspections and tests shall be performed in accordance with Section 5.

5.INSPECTION AND CHECK-OUT REQUIREMENTS5.1Component Check-Outs and Inspections

- A. The Work may be rejected by the Buyer if the Equipment does not conform to the Drawings or to this Specification.
- B. The Seller shall notify the Buyer in writing at least 10 days in advance of final inspection.
- C. Following successful completion of the inspection, the Seller shall submit to the Buyer a Certificate of Compliance to this Specification.
- D. Dimensional Verification: Upon completion of the overpack tie-down fabrication, the Seller shall perform the necessary dimensional checks to verify that the critical dimensions and surface finishes have been achieved. The dimensional and weight tests required are:
 - 1. The interface dimensions between the pallet and collar shall be verified to ensure that they are within the tolerances shown on the Drawings. The interface dimensions include the interior surfaces of the pallet conical cup and the collar. The Seller shall plan for the Buyer to witness the dimensional inspection in his manufacturing / inspection plan.
 - 2. Following completion of the tie-down fabrication, the Seller shall weigh the components and record the weights. Weights shall be recorded for the pallet assembly (including turnbuckles) and the collar assembly.
- E. The Seller shall perform a fit-up test of the turnbuckle assemblies to verify that all connections between the turnbuckles and the tie-down pallet and the tie-down collar can be made smoothly without undue force.

5.2Acceptance

Final acceptance of the Equipment will be made following successful completion of all inspections and following review and approval by the Buyer of all documentation required of the Seller.

6.QUALITY ASSURANCE REQUIREMENTS

The fabrication and inspection of the overpack tie-down hardware specified herein shall be performed in accordance with the Seiler's commercial Quality Assurance and Quality Control Programs. The Seiler shall maintain his standard Quality Assurance Program throughout the manufacture of the tie-down hardware. The tie-down equipment is not-important-to-safety and is designated as non-QA condition.

7PACKAGING AND SHIPPING REQUIREMENTS

- A. Items, just before packaging, shall have been inspected for cleanness according to the requirements specified in Section 4.4. Dirt, oil residue, metal chips, or other forms of contamination shall have been removed by approved cleaning methods. Any entrapped water shall have been removed.
- B. All openings into items shall be capped, plugged, and sealed. Weld end preparations shall be protected from corrosion and physical damage.
- C. Items subject to detrimental corrosion, either internal or external, or contamination shall be suitably protected.
- D. Items packed in containers shall be blocked, braced, and/or cushioned to prevent physical damage.
- E. The identity of the item shall be maintained by marking or other appropriate means.
- F. On the date of shipment, the Seller shall inform the Buyer of the following: the motor carrier and a list of the items being shipped and shall forward a copy of the carrier's Bill of Lading to the Buyer.
- G. The Seller shall be totally responsible for the safe delivery of the Equipment. Any damage to the Equipment as a result of improper packaging, in-transit handling, or shipping, shall be repaired at the Seller's expense.

8. DOCUMENT SUBMITTAL REQUIREMENTS

Table 1 lists the required technical document submittals and schedule.

8.1 Drawings

All weld symbols shall be in accordance with the requirements of AWS A2.4.

The following drafting standards shall apply (per ANSI Y14.2):

- A. Minimum character height (A, B, C, size drawings): 0.125 inch (1/8")
- B. Minimum character height (D and E size drawings): 0.156 inch (5/32")
- C. Minimum spacing between lines of characters: Height of characters
- D. Machine and guide generated characters: 12 point size minimum.
- E. Density of characters and lines: dense, sharp, and uniform.

8.2 Document Submittals

8.2.1 Submittals with Bid

The Seller shall supply the Buyer with the following documents for the overpack tie-down hardware proposal:

- A. Manufacturer's data sheets for the turnbuckles, shackles, and pins.
- B. Manufacturing plan including work schedule and inspection plan.

8.2.2 Submittals After Award of Contract

The Seller shall provide the following information for review and approval by the Buyer after award of contract:

- A. Shop drawings (if prepared) for tie-down components. All dimensioning shall be in accordance with ANSI Y14.5M and with the requirements of this specification. Shop drawings may not be required for the scope of work; however, in the event of rework, shop drawings may be necessary.
- B. Cut sheets, brochures, technical information, etc., for all off-the-shelf items.
- C. Shipping Plan

The Seller shall prepare and submit one reproducible and two copies of any shop drawings of the Equipment for review and approval by the Buyer. These prints are to be a minimum of 8-1/2" x 11" and legible with uniform background density suitable for microfilming and subsequent reproduction from microfilm.

These prints will be reviewed by the Buyer, and, if satisfactory, will be approved and one copy of each print, so marked, will be returned to the Seller. If not satisfactory, the prints will be appropriately marked and one copy of each print returned to the Seller for correction; after which, one reproducible and two prints of the drawings as corrected shall again be submitted to the Buyer for approval. The Seller shall make any corrections required by the Buyer and appropriately note any changes by dated revisions on the drawing.

Any work done by the Seller prior to receipt of the drawings approved by the Buyer shall be at the Seller's own risk.

Approval of shop drawings will not relieve the Seller of the responsibility for providing equipment which meets the requirements of this Specification.

8.3

Certificate of Compliance

The Seller shall provide a certificate of compliance with this Specification providing the following information:

- A. Identification of the purchased material or equipment by the Buyer's purchase order number.
- B. Identification of any procurement requirements that have not been met, together with a written explanation of the means for resolving the nonconformances.
- C. Signature by an authorized person who is responsible for the quality assurance of the purchased equipment.

Table 1
Document Submittal Requirements

	<u>Item</u>	<u>Submitted For</u>	<u>Due</u>
1.	Manufacturing Plan	Approval	With Bid
2.	Shop Drawings (if prepared)	Approval	30 days after award
3.	Hardware Data Sheets	Approval	30 days after award
4.	Inspection Report	Approval	10 days prior to shipping
5.	Certificate of Compliance	Review	10 days prior to shipping
6.	Shipping Plan	Approval	10 days prior to shipping
7.	Bill of Lading	Information	Date of shipment

9.0 MEETING MINUTES

MEETING MINUTES

Subject: NRF TRIGA Formal Design Review Meeting

TO: Ivan Metcalf

BUILDING: N1-40

FROM: Denise Clements *Denise*

CHAIRMAN: Ivan Metcalf

Dept-Operation-Component	Area	Shift	Meeting Date	Number Attending
Packaging Safety Engineering	1100	A	July 20, 1994	17

DISTRIBUTIONATTENDERS*

R. R. Ames	T3-04	R. A. Moore	G1-66
R. W. Barker*	G2-03	W. W. Smyth*	G2-02
L. L. Carter*	H0-35	P. F. Stevens*	G2-02
R. R. Cruz*	G2-03	F. A. Schmittroth*	H0-35
J. O. Dittmer*	N1-40	D. Teachout*	T3-04
S. B. Dutta*	L6-35	J. W. Thornton*	G2-03
P. C. Ferrell*	G2-03	M. K. Ullah*	L6-57
J. G. Field	G2-02	K. B. Jones*	VECTRA
G. W. Lanham*	N1-40	S. Sisley*	VECTRA
G. W. Mettler	G2-03	MDC File/PSE Route/LB	
E. M. Megahed	T4-03		

PURPOSE:

The purpose of this meeting was to resolve all of the Review Comment Records (RCR's) and review the Formal Design Review checklist to determine if the NRF TRIGA cask and overpack design meet the Packaging Design Criteria (PDC) and specification. The overall objective of the Formal Design Review is to evaluate the overall process and equipment designs to determine if they meet the requirements for fabrication, fuel loading, facility interface, transportation and storage on the Hanford site.

AGENDA:

The following was discussed:

- Questions from Briefing Meeting - Ivan Metcalf
- Briefing Meeting Action Items - Denise Clements
- RCR Comments - Denise Clements
- Checklist - Ivan Metcalf
- New Action Items - Denise Clements
- Closure - Ivan Metcalf

DISCUSSION:

The meeting agenda was reviewed and agreed upon. Any previous questions from the briefing meeting were requested to be brought forward and there were none. The briefing meeting action items were reviewed and are attached as Appendix A. All seven resolutions to the action items were reviewed. A short discussion on the method VECTRA used for establishing the worst case four foot drop was held. The worst case g-loading ended up being 56.3 g's. The specification will be revised to have an allowable g-loading for

four foot drop of 60 g's (Action Item #1). This was allowed to be raised from the original 50 g's by refining the model and redoing the calculations performed to ensure that an appropriate amount of conservatism was used instead of excessive conservatism.

The Review Comment Records (RCR's) were then reviewed (Attachment 2). The first RCR was from Solid Waste pertaining to the galvanic reactions due to the dissimilar metals in the Helicoflex metallic O-ring. A vacuum dry process will be used to ensure there is no moisture within the cask prior to transport. This was agreed upon.

The second RCR was from Quality Assurance. All comments were agreed to be incorporated into both VECTRA and WHC fabrication specifications.

The third RCR reviewed was from R. W. Barker. All comments were agreed to be incorporated and included changing the material call-outs, adding call-outs for surface flatness, and recommending that more information is called-out for the lead pouring.

The fourth RCR reviewed was from P. C. Ferrell. He recommended that only two permanent guide pins be used instead of four removable ones. The two instead of four was agreed on prior to the meeting and the permanent or removable was discussed with operations during the meeting. Operations agreed that they would like to have them permanent to prevent loss and maintain ALARA limits. Also, a short explanation on the additional elastomeric O-ring to account for the transportation accident scenario was given. A discussion of the VECTRA welding requirements from this RCR was held. This comment involved welding of the overpacks to be performed by VECTRA. VECTRA agreed to perform Dye Penetrant testing (PT) on the structural welds for the overpack and the tie-down lugs. They explained that they feel the visual examination is better than PT. They also explained that the skid is a non-safety item for the cask and thus, they felt the visual examinations were sufficient for the welds on the skid and on the collar. Since these items are carbon steel, they requested to use AWS requirements. Tom Delucchi asked what type of welding procedures would be used for the skid and a conference call was going to be held at the end of the meeting (Action Item #2). However, at the end of the meeting the welding agreements were made and an ECN will be incorporated including the above welding inspections. The end agreement was that they will PT the structural welds of the overpack and the tie-down and lifting lugs. The skid and tie-down collar only require visual examination. All other comments were accepted and will be incorporated.

The fifth RCR reviewed was from T. A. Delucchi. His comments were based on the fabricability of the cask. He explained that the outer vessel was not fabricable and the basket would be very difficult to fabricate. The basket re-design sketch was presented and agreed upon except that the length of the tubes for the plate circular array needed to be smaller with possibly several of them instead of 6 in. and 3 in. pieces. The fabricability of the cask was decided upon after the meeting was completed (Action Item #3). Several suggestions were made during the meeting however, to come up with an organized solution, a separate meeting was held after the completion of the design review. The change agreed to after the meeting involved moving the top inner wall weld up so that it is only 2 1/2 in. below the opening of the container. The weld will be turned around so that it is an inner weld. This solution eliminates any affect that other changes could have had on the structural capability of the cask and does not require any additional analysis. This weld will be UT inspected instead of radiographed which is acceptable by the ASME B&PV code.

A question was raised on the fissile classification of the cask. This is a fissile class I cask and requires no additional controls than the analysis showing the cask is still below the limits with an infinite array. It was agreed that the fissile classification will be added to the SARP (Action Item #4). Also, it was asked why the drop scenario listed in 10 CFR 71.71 (8) was not performed. The explanation that the regulation states this test is only for wood or fiberboard containers was given. It was requested that a statement be added into the design review information that the design complies with 10 CFR 71 except for receiving a Certificate of Compliance (Action Item #5). A statement will be added explaining that the NRF TRIGA package was designed and analyzed to meet the intent of 10 CFR 71 requirements but will not be certified by the NRC or DOE. This statement will be found in section 4.1 of the Design Review Report.

The Design Review Checklist was then reviewed (Attachment 3). Although there will be one more meeting when this checklist will be reviewed, it was reviewed during this meeting to make sure there were no surprises at the last meeting. Attachment 3 has the original checklist with the appropriate responses and redline changes.

The new action items as listed above were reviewed with an additional action being to send out the matrix comparing the NRF TRIGA design to 10 CFR 72 requirements (Action Item #6).

If there are any further questions, or comments please contact me at 376-3501. Thank you for your time and a notice will be sent out for the final drawing sign-off meeting.

ACTION ITEM LIST JULY 6, 1994
FORMAL DESIGN REVIEW
NRF TRIGA PACKAGE

1. Determine the definition of dry. The purpose of this action item was to determine how to ensure the fuel elements were dry prior to transport of the cask. Water in the cask is not allowed by DOT and water in the cask could cause hydrogen generation, which could become a safety problem in storage.

The solution will not only be the vacuum dry for any moisture from the inner container but will also be determined by a test to be performed on dummy elements that will determine how long it takes to dry them. That time will then be used, although the heat generating elements will not require as much time.

2. How will the inner lid withstand torquing the closure eye-bolt and will it move?

The attached calculations and information from Parker show that the lid sufficiently will withstand the torquing of the bolt without unseating the seal and the lid will not rotate when the eye-bolt is being tightened based upon the friction of the elastomeric O-ring on the stainless steel. Calculations are attachment 1.

3. What is the temperature of the cask without the overpack and with a solar load?

The maximum cask temperature occurs in the center of the cask lid and is 184°F. Calculations are Attachment 2.

4. Were all the stress combinations from the Regulatory Guides considered for the NCT drop?

They were not originally looked at in combination however, the additional pressure and temperature change stress combinations are so small there was not a significant change.

5. If the sealing surface moves, the metallic seal cannot be proven to maintain containment. How will containment be maintained?

An additional elastomeric bore seal will be added which will be considered the "transportation seal". Elastomeric seals have been tested and can tolerate movement and still maintain containment. The changes to the drawings have been incorporated.

6. Explain why VECTRA used the temperature criteria -20°F to 180°F for their drop analysis instead of the Hanford ambient temperatures.

The temperature range for evaluating an accident drop scenario that is required by Regulatory Guide 7.8 is -20°F to 100°F. They state that in the contiguous U.S., there is a 99.7 percent probability that any hourly temperature reading will fall within this range. However, there is a difference between these temperatures and evaluating the package for the

ambient temperature affects on the package. The ambient temperature effects on the package shall be evaluated for:

- A hot environment with maximum insolation, maximum decay heat, maximum internal pressure, and fabrication stresses. VECTRA performed this evaluation for both 10 CFR 71 (100°F) and Hanford temperatures (115°F).
- A cold environment with minimum insolation, minimum decay heat, minimum internal pressure, and fabrication stresses. VECTRA performed this evaluation for 10 CFR 71 only because the temperature is -40°F which is worse than the -27°F Hanford environment.

The above two analyses considering the temperature environment are different from the drop scenario hot and cold temperatures. The -20°F and 100°F were temperatures set by the NRC to evaluate the drop scenario's. The drops must be evaluated at both hot and cold however, these hot and cold temperatures are based upon the country's averages not based upon the area's maximum and minimum. VECTRA did evaluate the cask for the -27°F by evaluating the -40°F, as required by the WHC specification.

7. The four foot drop scenario for the overpack should be performed in the worst case orientation.

VECTRA performed the worst case four foot drop which ended up being the side drop. The g-loading was 56.3 g's. An ANSYS analysis was performed on the cask to ensure that this g-loading did not adversely affect the package past normal conditions of transport criteria.

REVIEW COMMENT RECORD (RCR)	1. Date July 18, 1994	2. Review No. 1
	3. Project No.	4. Page 1 of 1

5. Document Number(s)/Title(s)	6. Program/Project/ Building Number	7. Reviewer	8. Organization/Group	9. Location/Phone
NRF TRIGA Cask Design Review	NRF/Building 308	Douglas B. Teachout	Solid Waste Disposal/Generator Services	MO279/A107/200W, 373-6688

17. Comment Submittal Approval:	10. Agreement with indicated comment disposition(s)	11. CLOSED
_____ Organization Manager (Optional)	_____ Reviewer/Point of Contact	_____ Reviewer/Point of Contact
_____ Date	_____ Author/Originator	_____ Author/Originator

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[illegible]

REVIEW COMMENT RECORD (RCR)		1. Date 7/12/94	2. Review No. 0
		3. Project No. triga	4. Page 1 of 2
5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer S. B. Dulla	8. Organization/Group QA
		9. Location/Phone 300 Area/376-6789	

17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

Date

Reviewer/Point of Contact

Date

Reviewer/Point of Contact

Author/Originator

Author/Originator

9-8

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.1-B, Line 3: dimensional certificates - needs clarification.			
2.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.2.A: VECTRA's function in designing the overpack? This is a confusing section although it is explaining that the designer is different from the Fab shop.			
3.	VECTRA Overpack Fabrication Specification: Page 10, Paragraph 4.4.5, needs to be clarified.			
4.	WHC Fabrication Specification: Page 4-11, Section 4.4.1 - Correct drawing numbers.		Accepted and incorporated.	
5.	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.2, line 3, Typo - American Society of Mechanical Engineers.		Accepted and incorporated.	
	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.3, DOE 5700.6B needs to be 5700.6C.		Accepted and incorporated.	
	WHC Fabrication Specification: Page 4-12, Section 4.4.4.1, SARP number to be assigned.		Accepted and will be incorporated.	

REVIEW COMMENT RECORD (RCR)

1. Date	7/12/94
3. Project No.	Triga
4. Page	2 of 2
2. Review No.	0

12.	Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	WHC Fabrication Specification: Page 4-18, Section 4.4.7.3, Line 4, Typo - QA shall define the acceptance and nonconformance criteria.
14.	Hold Point	14.	
15.	Disposition (Provide justification if NOT accepted.)	15.	Accepted, changed and to or.
16.	Status	16.	

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REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 2

5. Document Number(s)/Title(s) NRF TRIGA Package Formal Design Review	6. Program/Project/ Building Number TRIGA	7. Reviewer R. W. Barker	8. Organization/Group PDE	9. Location/Phone 376-5235
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

Date

Reviewer/Point of Contact

Date

Reviewer/Point of Contact

Author/Originator

Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
9-10 1.	Drawing II-2-822938 Sht. 1 - Item 7 Need to look at different specification. A249 is a tubing call-out. Possibly A312 per ANSI A36.19.		Accepted. Being incorporated.	
2.	Drawing II-2-822938 Sht. 1 - Item 8 Look at possibly A358 or A511 availability.		Accepted. Being incorporated.	
3.	Drawing II-2-822938 Sht. 1 - Note 5 Surface finish should be 63 instead of 125.		Accepted. Being incorporated.	
4.	Drawing II-2-822938 Sht. 1 - Note 9 Need to add in a reference to a procedure for radiographing lead and acceptance criteria.		Accepted. Being incorporated.	
5.	Drawing II-2-822938 Sht. 1 - Note 12 Awkward wording in last line.		Accepted. Being incorporated.	
6.	Drawing II-2-822938 Sht. 1 - Note 13 As-rolled should be as-received. Revised wording.		Accepted. Being incorporated.	
7.	Drawing II-2-822938 Sht. 1 - Surface call-outs on top seal surface need to be incorporated.		Accepted. Being incorporated.	

REVIEW COMMENT RECORD (RCR)		1. Date 7/18/94	2. Review No.
		3. Project No.	4. Page 2 of 2
12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)
8.	Drawing II-2-822938 Sht. 1 - General note: Need to have more information on lead pouring and include fill and vent in the drawing. Preheat temp, Pouring temp., and zoned heat tracing should be called out or referred to.		Accepted. Being incorporated.
9.	Drawing II-2-822938 Sht. 2 - Fabrication of leak test port hole should be noted that leak test port be drilled first and then seal location second.		Accepted. Being incorporated.
10.	Drawing II-2-822938 Sht. 2 - The metallic seal needs to have a vacuum dry performed to ensure absence of moisture.		Accepted. Being incorporated.
11.	Drawing II-2-822938 Sht. 3 - Outer Vessel lid seal surface call-outs need to be added.		Accepted. Being incorporated.
12.	Drawing II-2-822938 Sht. 3 - Detail II Seal groove should have limits and dimensions.		Accepted. Being incorporated.
13.	Drawing II-2-822936 Sht. 1 - Bottom container weld detail either needs to be changed to a code weld or the Note #2 needs to be revised because it isn't a code weld.		

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
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5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer P. C. Ferrell	8. Organization/Group Packaging Design Engineering	9. Location/Phone 376-2846
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

Date

Reviewer/Point of Contact

Date

Reviewer/Point of Contact

Author/Originator

Author/Originator

9-12

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	<p>Cask Lid Alignment Pins.</p> <p>a) Why are four alignment pins used? Most casks use only two. The RTG packaging uses only two alignment pins for each of its closure systems and the alignment/closure process works smoothly.</p> <p>b) Why are the alignment pins not permanently installed in the cask upper closure ring plate? Alignment pins could be located on the same circle diameter as the closure bolts.</p> <p>c) The alignment pins should not be made of stainless steel; especially if the removable-type alignment pins are used. Threading the stainless steel alignment pins into the stainless steel upper ring plate can cause galling. A more commonly used material for alignment pins is Nitronic 50 or 60.</p> <p>d) The main reason for using fewer and permanent type alignment pins is to help keep operator dose ALARA.</p>		<p>a) Only two alignment pins will be used.</p> <p>b) The guide pins will be permanent based on design review discussion.</p> <p>c) The guide pins will not be threaded and can remain stainless.</p>	

REVIEW COMMENT RECORD (RCR)

1. Date

7/18/94

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2 of 3

12.
(Item

13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)

14.
Hold
Point

15. Disposition (Provide justification if NOT accepted.)

16.
Status

2. The current cask design uses a metallic O-ring seal as the main containment boundary closure. The metallic O-ring seals will not tolerate much movement and still retain a leak tight seal. If the structural analysis indicates that there is not movement in the closure seal area, then the metallic O-ring may be acceptable. The enclosure seal must be examined carefully to ensure a leak tight seal is maintained during all 10CFR71 tests.

An additional elastomeric O-ring was added as a bore seal to the cask lid for transportation purposes. The metallic O-ring will ensure the greater than 30 year storage life only not provide transportation containment.

3. The worst case four foot drop orientation needs to be developed and defended.

The worst case 4 foot drop is the side drop under cold conditions. The g-loading is 56.3. The original 50 g criteria stated in the specification will be revised to 60 g's after a review of the actual stress distribution shows that 60g is acceptable.

4. All welding and inspection should be performed to ASME eight and nine. The following welds need to be dye penetrant tested (PT):

- All main (structural) impact limiter welds
- Lifting and tiedown lug welds
- Tiedown collar welds
- All structural welds on shipping skid

The design review agreement is that the structural overpack welds and the lifting and tie-down lugs will be PT inspected. The tie-down collar and skid were agreed to be only visually inspected.

5. The lid closure bolt torque of 41+/- 5 ft-lb appears to be low. Standard torque for a 1/2" bolt is 50+/- 5 ft-lb.

The bolt torque is 52 +/- 5 ft-lb

6. The leak test port for the area between the metallic seal and the cask cavity needs to be inside of the seal area.

Accepted and incorporated.

9-13

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
1.	Have assumptions necessary to perform the design task been adequately described and are they reasonable?	Yes	
2.	Have the appropriate Quality Assurance requirements been specified?	Yes	
3.	Does the design meet the established requirements or design criteria?	Yes	
4.	Have the site and facility interface requirements been met?	Yes	New requirements possibly now with FFTF.
5.	Are there any interface problems?	No	Assuming no problems with FFTF.
6.	Has appropriate consideration been given to use of standardized parts, materials and processes, and have engineering standards and criteria been specified properly in the design?	Yes	With incorporation of all RCR comments.
7.	Does the design represent the simplest design consistent with functional requirements and expected service conditions?	Yes	With incorporation of all RCR comments.
8.	Can the equipment be readily assembled/disassembled as designed?	Yes	With incorporation of all RCR comments.
9.	Does the design minimize the overall cost to the extent practicable?	Yes	
10.	Have qualified and certified parts been specified?	Yes	

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
11.	Are the applicable codes, standards and requirements, including revisions, properly identified and are their design requirements provided for?	Yes	
12.	Have available data on similar designs been used?	Yes	
13.	Is the design producible by conventional means?	Yes	With incorporation of all RCR comments.
14.	Have non-corrosive materials been used where required?	Yes	
15.	Does the design avoid any materials unproven for use in the anticipated environment?	Yes	
16.	Can the assembly be stored for extended periods of time without degrading effects?	Yes	
17.	Does the design meet functional requirements? a. Stresses are within design limits? b. Steady-state and transient conditions? c. Have actual and "worst case" condition stresses been considered rather than nominal average stresses?	a. Yes b. Yes c. Yes	

9-18

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
18.	Will the design meet the following environmental conditions? a. Temperature (steady-state and transient) b. Flow (steady-state and transient) including induced vibration c. Pressure (steady-state and transient)	a. Yes b. Yes c. Yes	
19.	Are the specified construction materials resistant to the following as applicable: a. Moisture b. Radiation	a. Yes b. Yes	
20.	Has the design appropriately considered maintenance operation and reliability, including maintenance procedures and techniques, unique maintenance requirements and frequencies?	Yes	
21.	Are required tolerances, fabrication techniques, processes, etc., consistent with standard practices?	Yes	With the incorporation of all the RCR comments.
22.	Has adequate accessibility been provided for in-service/storage inspection?	?	Doug Teachout will make sure these have been incorporated.
23.	Does the design meet all established safety and SAR requirements?	Yes	Yes, for CMC need to look at the new possibility of going to FFTF.

84100-94-MDC-228
Attachment 3
Page 3 of 3

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
24.	Have personnel radiation protection requirements been considered and identified?	Yes	
25.	Have nuclear criticality safety considerations been incorporated?	Yes	
26.	Have necessary features been provided to maintain personnel radiation exposure as low as reasonably achievable?	Yes	
27.	Have requirements for receiving and storing the equipment item been defined?	Yes	Assuming FFTF receiving is same as CWC.
28.	Have any locking devices, that are critical to operation or that will be inaccessible after assembly, been sufficiently evaluated to assure their adequacy?	Yes	
29.	Have human operability been considered?	Yes	
30.	Does the design utilize engineered safety and operational protections to avoid an excessive risk-taking dependence on administrative actions?	Yes	
31.	Is the equipment operable?	Yes	
32.	Has the drawing traceability been provided?	Yes	
33.	Have welding, bolting, joining methods been adequately specified?	Yes	With incorporation of all RCR comments.

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
34.	Does the design match the intended (and possible abnormal) methods of operation of the facility or site?	Yes	
35.	Is the design in compliance with applicable regulatory requirements and/or WMC regulatory commitments?	Yes	
36.	Are the specified materials compatible with each other and the environmental condition to which the material will be exposed?	Yes	

MEETING MINUTES

Subject: NRF TRIGA Cask and Overpack Formal Design Review

TO: Ivan Metcalf

BUILDING: G2-02

FROM: Denise Clements *Denise*

CHAIRMAN: Ivan Metcalf

Dept-Operation-Component	Area	Shift	Meeting Date	Number Attending
Packaging Safety Engineering	1100	A	July 6, 1994	17

DISTRIBUTIONATTENDERS*

J. D. Anderson*	T3-04
R. R. Ames*	N3-13
R. W. Barker*	G2-03
L. L. Carter*	H0-35
R. R. Cruz*	G2-03
J. O. Dittmer*	N1-40
S. B. Dutta*	L6-35
P. C. Ferrell*	G2-03
J. G. Field*	G2-02
G. W. Lanham*	N1-40
G. W. Mettler*	G2-03
R. A. Moore*	G1-66
W. W. Smyth*	G2-02
P. F. Stevens*	G2-02
F. A. Schmittroth	H0-35
D. Teachout*	T3-04
J. W. Thornton	G2-03
M. K. Ullah*	L6-57
K. Jones (VECTRA)	
MDC File/PSE Route/LB	

PURPOSE:

This was the Formal Design Review briefing meeting for the NRF TRIGA cask and overpack. The objective of this briefing meeting was to distribute the design review packages and present the checked results received from analysts in support of the design. The objective of the design review is to evaluate the overall process and equipment designs to determine if they meet the requirements for fabrication, fuel loading, facility interface, transportation and storage at the Hanford Complex.

AGENDA:

The following was discussed:

- Introduction - Ivan Metcalf
- Design Scope and Objectives
- Meeting Objectives and Structure
- Individual Introductions
- Background Information - Jim Dittmer

Design and Analysis Presentations
Introduction - Denise Clements
Design and Operations - Rich Cruz
Structural - Bill Smyth
Thermal - Paul Stevens
Shielding - Lee Carter for Frank Schmittroth
Criticality - Lee Carter
PDC Requirements Criteria List
VECTRA Overpack Presentation
Open Discussion
Review Assignments
Action Items/Meeting Closure

DISCUSSION:

This meeting was the briefing meeting for the design review. It was discussed that the objective of this meeting was to distribute the review package and drawings, discuss review assignments, and limit discussion until the open discussion session held on July 20, 1994.

Background information on the requirement of the NRF TRIGA cask was discussed. The cask is necessary to transport the TRIGA fuel elements from the shutdown, 308 Building to interim storage on the Hanford site. The TRIGA Reactor supported examination of the FFTF fuel and since the closure of FFTF, the TRIGA Reactor is no longer necessary. The NRF TRIGA cask and overpack criteria consisted of; designing the cask per 10 CFR 71 for transportation and meeting the storage requirements of the Central Waste Complex.

The following are questions and discussions that were held during the presentations. The unresolved questions were noted as action items to resolve prior to the final design review meeting.

- Is there enough water shielding provided when the fuel elements are lifted into the fuel basket during loading? Yes, there will be approximately 15 feet left between the technician and the fuel element.
- How will the fuel elements be dried? Do we have a definition of dry? The requirement for dry comes from storage requirements to eliminate any hydrogen build-up within the cask. The elements will be dried by forced air and a mock-up will be performed to determine the amount of time it will take to dry.
Action Item #1 - Determine the definition of dry.
- Were the welds on the fabrication drawings reviewed by a welding engineer? Yes, Mike Palm reviewed them as a recommendation from Tom Delucchi.
- Is there a galling problem with the lifting device for the basket. No, with inspection of the lifting device there will only be an aluminum/stainless steel interface.
- Did we receive any information from the Helicoflex seal vendor on deformation of the seals? Yes, the information can be reviewed if desired.

- Will there be a battery effect between the metallic seals and the cask surface? No, this seal was recommended by the vendor for this cask and there is also an absence of an electrolyte to provide any reaction.
- Once the seals are crushed due to the closure, is the tolerance so small that the seals get stuck and cannot be removed? Tolerances will be reviewed but were recommended by the seal manufacturer. All operations at this point will be hands on and the seals should not be difficult to remove.
- Is the seal formed from the crush force? Yes.
- Can the inner lid move when torquing the closure eye-bolt? Action Item #2
- What is meant when reference is made to an "allowable stress"? The allowable stress is from the ASME B&PV code. The code states that all stresses in the cask from the NCT and HAC conditions must be below these allowables.
- Does the seal maintain it's properties over the allowable temperature range? Yes, the Helicoflex seal temperature range at Hanford is from below -40°F to 530°F.
- What is the temperature of the cask without the overpack and with a solar load? Action Item #3.
- What is the design basis for the temperatures? Why is -27° F and 200°F used when the ambient temperature range is -27°F to 115°F? Are the temperatures used at the same time? The -27°F to 200°F are not used simultaneously but are looked at as the extremes that the material will reach. These temperatures were determined and reviewed structurally to ensure that the stainless steel does not structurally degrade at the two extreme temperatures it will reach.
- Is the cask Type A without the overpack? Yes.
- Were all of the stress combinations from the Regulatory Guides considered for the NCT drop? Action Item #4.
- With metallic seals, you cannot have movement of the seals and prove that containment is maintained per 10 CFR 71. This seal needs to be looked at because the metallic is needed for storage but will not meet transportation requirements. Action Item #5.
- Has the effects of the fire on the cask structurally been reviewed. Since the temperatures in the cask do not exceed 200°F during the fire no structural effects will occur. Also, the temperature variation between the cask surface and the inner cask surface is essentially uniform, so there will not be an extreme temperature gradient in the cask.
- What is the maximum fissile content in the cask? 663 gm.
- Explain why VECTRA used the temperature criteria -20°F to 180°F for their drop analysis instead of the Hanford ambient temperatures. Action Item #6.

- The 4 foot drop scenario for the overpack should be performed in the worst case orientation. Action Item #7.

The open discussion section of the meeting was very short since the majority of the questions were asked during the presentations. The list of review assignments was discussed and a request made that the RCR forms be used to transmit comments to the secretary, Denise Clements, as soon as possible, and at least by July 18, 1994. The final meeting will be held on July 20, 1994 in the same location, starting at 8:00 am. The actions listed above will be resolved and the resolutions discussed in the final meeting.

If there are any further questions, please contact me or Ivan Metcalf. Thank you all for coming and for your time in reviewing the package.

MEETING MINUTES

Subject: NRF TRIGA Formal Design Review Meeting

TO: Ivan Metcalf

BUILDING: N1-40

FROM: Denise Clements

CHAIRMAN: Ivan Metcalf

Dept-Operation-Component	Area	Shift	Meeting Date	Number Attending
Packaging Safety Engineering	1100	A	August 12, 1994	9

DISTRIBUTIONATTENDERS*

R. R. Ames	T3-04	G. W. Lanham	N1-40
R. W. Barker*	G2-03	G. W. Mettler	G2-03
R. R. Cruz	G2-03	E. M. Megahed	T4-03
J. O. Dittmer*	G2-03	D. Teachout	T3-04
S. B. Dutta	N1-40	J. W. Thornton	G2-03
P. C. Ferrell*	L6-35	M. D. Ullah	L6-57
J. G. Field*	G2-03	MDC File*/PSE Route/LB	

PURPOSE:

The purpose of this meeting was to close out the Formal Design Review by resolving all of the Review Comment Records (RCR's) and reviewing the Formal Design Review checklist to determine if the NRF TRIGA cask and overpack design meet the Packaging Design Criteria (PDC) and specification. The overall objective of the Formal Design Review is to evaluate the overall process and equipment designs to determine if they meet the requirements for fabrication, fuel loading, facility interface, transportation and storage on the Hanford site.

AGENDA:

The following was discussed:

- Introduction
- Previous Meeting Minutes/Action Items
- Review of RCR's
- Checklist
- Drawing Sign-off

DISCUSSION:

The meeting agenda was reviewed and agreed upon. The final plotted drawings of the cask were not complete for the meeting to sign them off. Therefore, the action items and RCR's were closed out and resolved to close the design review and it was agreed that the designer would take the drawings and EDT around to everyone for signature and release.

The previous action items were discussed and all were completed prior to the meeting. See attachment 1 for the items and their resolutions.

All of the new comments received from the second design revision on the drawings were reviewed and resolved. The RCR's (Attachment 2) were signed off and will all be included in the Design Review Report (DRR).

The checklist was reviewed one last time and it was agreed by all in attendance that the design meets the requirements. The checklist was agreed upon with a few minor changes from when it was reviewed initially.

The release of the drawings will be accomplished by taking the drawings to all the design review team for approval and sign-off of the EDT. Rich Cruz will be bringing the drawings around. The whole design review team will be on the EDT requiring approval for release of the drawings. The SARP drawings for the overpack that were included in the VECTRA Design Analysis Report submitted for review at the first design review meeting will also be released with the same approval signatures.

If there are any further questions, please contact Denise Clements. Otherwise, Rich Cruz will be getting signatures and Denise will be releasing the DRR.

ACTION ITEM LIST
JULY 20, 1994 DESIGN REVIEW MEETING

84100-94-MDC-262
Attachment 1

1. The specification for the procurement of the overpack is required to be revised to reflect the 60 g loading for Normal Conditions instead of 50 g's.

The specification was revised and released on July 28, 1994.

2. Conference call between VECTRA welding engineer and WHC welding engineering will be held after design review meeting.

The conference call was not necessary. The welding agreement was made between VECTRA representatives and WHC design reviewers.

3. The current cask design is not fabricable.

The cask design was modified to ensure the cask was fabricable. The top inner weld was raised closer to the opening of the cask and turned around to an inside weld.

4. Fissile classification of the package was requested to be stated in the documentation.

The fissile classification, Class I, was added to the SARP.

5. It was requested that a statement be added to the documentation mentioning that the NRF TRIGA cask does not meet 10 CFR 71 in the area of licensing.

A statement was added to the SARP mentioning that the design of the NRF TRIGA casks meets the intent of 10 CFR 71, excepting licensing.

6. A matrix for comparing storage requirements to the cask was developed and needs to be cc:mailed to the design review team members.

The matrix comparing storage requirements to the NRF TRIGA cask was developed and cc:mailed to everyone on the Design Review Team.

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 1

5. Document Number(s)/Title(s) NRF TRIGA Package Formal Design Review	6. Program/Project/ Building Number TRIGA	7. Reviewer T. A. Delucchi	8. Organization/Group ED & F	9. Location/Phone 306E/376-3116
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17. Comment Submittal Approval:

10. Agreement with Indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/16/94
Date

T.A. Delucchi
8/16/94
Reviewer/Point of Contact
M.D. Clements
Author/Originator

8/16/94
Date

T.A. Delucchi
8/16/94
Reviewer/Point of Contact
M.D. Clements
Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	Drawing II-2-822938 sht. 1 - Outer vessel cannot be fabricated as designed.		Accepted. A revision to the fabrication welding will be incorporated per final review meeting.	C
2.	Drawing II-2-822937 sht. 1 - The fuel basket will be difficult to fabricate by welding. Suggest the grid assembly's be machined from aluminum bar and keyed to the center shaft.		Accepted. Basket configuration will be revised and fabricated from aluminum bar or plate with machined holes.	C
3.	Drawing II-2-822938 sht. 1 - Part #7 should be made from tubing not pipe.		Accepted. Tubing A511 is being used.	C
4.	Drawing II-2-822938 sht. 1 - Lead fill and vent holes are not shown. Are plugs to be installed and welded after filling?		Accepted. Note was added to have fabricator specify.	C
5*	Drawing II-2-822937 - Basket welds should all be 1/8".		Incorporated.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 2

5. Document Number(s)/Title(s) NRF TRIGA Package Formal Design Review	6. Program/Project/ Building Number TRIGA	7. Reviewer R. W. Barker	8. Organization/Group PDE	9. Location/Phone 376-5235
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17. Comment Submittal Approval: 10. Agreement with indicated comment disposition(s) 11. CLOSED

Organization Manager (Optional)

Date

R. W. Barker
Reviewer/Point of Contact

M. D. Clements
Author/Originator

Date

8-12-1994

R. W. Barker
Reviewer/Point of Contact

M. D. Clements
Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	Drawing II-2-822938 Sht. 1 - Item 7 Need to look at different specification. A249 is a tubing call-out. Possibly A312 per ANSI A36.19.		Accepted. The call-out is now tubing on the Bill of Materials also - A511.	C
2.	Drawing II-2-822938 Sht. 1 - Item 8 Look at possibly A358 or A511 availability.		Accepted. A511 being used.	C
3.	Drawing II-2-822938 Sht. 1 - Note 5 Surface finish should be 63 instead of 125.		Accepted. Being incorporated.	C
4.	Drawing II-2-822938 Sht. 1 - Note 9 Need to add in a reference to a procedure for radiographing lead and acceptance criteria.		Accepted. Being incorporated.	C
5.	Drawing II-2-822938 Sht. 1 - Note 12 Awkward wording in last line.		Accepted. Being incorporated.	C
6.	Drawing II-2-822938 Sht. 1 - Note 13 As-rolled should be as-received. Revised wording.		Accepted. Being incorporated.	C
7.	Drawing II-2-822938 Sht. 1 - Surface call-outs on top seal surface need to be incorporated.		Accepted. Being incorporated.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 2 of 2

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
8.	Drawing II-2-822938 Sht. 1 - General note: Need to have more information on lead pouring and include fill and vent in the drawing. Preheat temp, Pouring temp., and zoned heat tracing should be called out or referred to.		Accepted. Will be incorporated into a fabrication specification in more detail. Placement will be up to fabricator	C
10.	Drawing II-2-822938 Sht. 2 - The metallic seal needs to have a vacuum dry performed to ensure absence of moisture.		Accepted. Being incorporated.	C
9-30 11.	Drawing II-2-822938 Sht. 3 - Outer Vessel lid seal surface call-outs need to be added.		Accepted. Being incorporated.	C
12.	Drawing II-2-822938 Sht. 3 - Detail II Seal groove should have limits and dimensions.		Accepted. Being incorporated.	C
13.	Drawing II-2-822936 Sht. 1 - Bottom container weld detail either needs to be changed to a code weld or the Note #2 needs to be revised because it isn't a code weld.		Accepted. The weld does not have to be code so the note will be revised.	C
14*	Drawing II-2-822938 Sht 1 - Lower containment weld should refer to machining on inside of container.		Incorporated.	C
15*	Drawing II-2-822938 Sht 1 - Flatness call-out on top ring inner surface should have a B instead of and A first.		Incorporated.	C
16*	Drawing II-2-822939 Sht 2 - Radius on Item 4 View A-A need to be called-out.		Incorporated.	C

Item (2) 2x should be 4x

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 3

5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer P. C. Ferrell	8. Organization/Group Packaging Design Engineering	9. Location/Phone 376-2846
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/12/94
Date
P. C. Ferrell
Reviewer/Point of Contact
M. D. Clements
Author/Originator

8/12/94
Date
P. C. Ferrell
Reviewer/Point of Contact
M. D. Clements
Author/Originator

9-31

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	<p>Cask lid Alignment Pins.</p> <p>a) Why are four alignment pins used? Most casks use only two. The RTG packaging uses only two alignment pins for each of its closure systems and the alignment/closure process works smoothly.</p> <p>b) Why are the alignment pins not permanently installed in the cask upper closure ring plate? Alignment pins could be located on the same circle diameter as the closure bolts.</p> <p>c) The alignment pins should not be made of stainless steel; especially if the removable-type alignment pins are used. Threading the stainless steel alignment pins into the stainless steel upper ring plate can cause galling. A more commonly used material for alignment pins is Nitronic 50 or 60.</p> <p>d) The main reason for using fewer and permanent type alignment pins is to help keep operator dose ALARA.</p>		<p>a) Only two alignment pins will be used.</p> <p>b) The guide pins will be permanent based on design review discussion.</p> <p>c) The guide pins will be Nitronic 50 or 60.</p>	<p>C</p> <p>C</p> <p>C</p>

REVIEW COMMENT RECORD (RCR)

1. Date 7/18/94	2. Review No.
3. Project No.	4. Page 2 of 3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
2.	The current cask design uses a metallic O-ring seal as the main containment boundary closure. The metallic O-ring seals will not tolerate much movement and still retain a leak tight seal. If the structural analysis indicates that there is not movement in the closure seal area, then the metallic O-ring may be acceptable. The enclosure seal must be examined carefully to ensure a leak tight seal is maintained during all 10CFR71 tests.		An additional elastomeric O-ring was added as a bore seal to the cask lid for transportation purposes. The metallic O-ring will ensure the greater than 30 year storage life only not provide transportation containment.	C
3.	The worst case four foot drop orientation needs to be developed and defended.		The worst case 4 foot drop is the side drop under cold conditions. The g-loading is 56.3. The original 50 g criteria stated in the specification will be revised to 60 g's after a review of the actual stress distribution shows that 60g is acceptable.	C
4.	All welding and inspection should be performed to ASME eight and nine. The following welds need to be dye penetrant tested (PT): <ul style="list-style-type: none"> All main (structural) impact limiter welds Lifting and tiedown lug welds Tiedown collar welds All structural welds on shipping skid 		The design review agreement is that the structural overpack welds and the lifting and tie-down lugs will be PT inspected. The tie-down collar and skid were agreed to be only visually inspected.	C
5.	The lid closure bolt torque of 41+/- 5 ft-lb appears to be low. Standard torque for a 1/2" bolt is 50+/- 5 ft-lb.		The bolt torque was changed to 52 +/- 5 ft-lb based on additional stresses from drop analyses.	C
6.	The leak test port for the area between the metallic seal and the cask cavity needs to be inside of the seal area.		Accepted and incorporated.	C

9-32

REVIEW COMMENT RECORD (RCR)	1. Date <u>7/18/94</u>	2. Review No.
	3. Project No.	4. Page 3 of 3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
7.	Unless a well controlled process is used the lead will not be bonded to the cask wall. A gap of 0.002" can be assumed to make the thermal analysis conservative. With a low heat load, using a gap should not be a problem.		A calculation was performed with the air gap. Currently the maximum temperature drop across the lead during the fire is 0.2. Adding the air gap changes this temperature drop 0.32°F.	C
8*.	Alignment pins should be placed so that they are 15 - 30° offset.		Incorporated.	C
9-33 9*.	There should be an alignment stripe painted on the outside of the lid and body to facilitate assembly.		Not required with above incorporation	C
10*	Drawing II-2-822939; Item 4 and 5 are not referred to correctly. Is there an item 5?		Item 4 is 6 and item 5 is 7.	C
11*	Do not place alignment pins directly under lifting bolt holes.		Incorporated.	C

MHC-SD-TP-DRR-003

Rev. 0

August 24, 1994

REVIEW COMMENT RECORD (RCR)	1. Date July 18, 1994	2. Review No. 1
	3. Project No.	4. Page 1 of 1

5. Document Number(s)/Title(s) NRF TRIGA Cask Design Review	6. Program/Project/ Building Number NRF/Building 308	7. Reviewer Douglas B. Teachout	8. Organization/Group Solid Waste Disposal/Generator Services	9. Location/Phone M0279/A107/200W, 373-6688
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17. Comment Submittal Approval:

Organization Manager (Optional)

10. Agreement with indicated comment disposition(s)

8/12/94
Date

Douglas B. Teachout
Reviewer/Point of Contact
M. D. Munn
Author/Originator

11. CLOSED

8/12/94
Date

Douglas B. Teachout
Reviewer/Point of Contact
M. D. Munn
Author/Originator

9-34

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	We still have some concern over the possibility of a battery effect between the metallic seals and the cask surface. The fuel will be loaded at room temperature (probably at or near 75F). It is feasible that water will be present as the cask and cools down and some of the water condenses. Subsequent heating of the cask would cause the moisture to be distributed throughout the cask. If so, an electrolyte will be present and a battery effect could occur.		Accepted. The cask will be vacuum dried to assure prior to shipment that it is dry. The inner-seal space can also be vacuum dried.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/12/94	2. Review No. 0
	3. Project No. triga	4. Page 1 of 2

5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer S. B. Dutta	8. Organization/Group QA	9. Location/Phone 300 Area/376-6789
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8-12-94
DateS.B. Dutta
Reviewer/Point of Contact8-12-94
DateS.B. Dutta
Reviewer/Point of ContactM.D. Clements
Author/OriginatorM.D. Clements
Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
9-35 1.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.1-B, Line 3: dimensional certificates - needs clarification.		Accepted and Incorporated.	C
2.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.2.A: VECTRA's function in designing the overpack? This is a confusing section although it is explaining that the designer is different from the Fab shop.		Accepted and Incorporated.	C
3.	VECTRA Overpack Fabrication Specification: Page 10, Paragraph 4.4.5, needs to be clarified.		Accepted and Incorporated.	C
4.	WHC Fabrication Specification: Page 4-11, Section 4.4.1 - Correct drawing numbers.		Accepted and incorporated.	C
5.	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.2, line 3, Typo - American Society of Mechanical Engineers.		Accepted and incorporated.	C
6.	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.3, DOE 5700.6B needs to be 5700.6C.		Accepted and incorporated.	C
7.	WHC Fabrication Specification: Page 4-12, Section 4.4.4.1, SARP number to be assigned.		Accepted and will be incorporated.	C

10.0 ACTION ITEM LISTS

ACTION ITEM LIST JULY 6, 1994
FORMAL DESIGN REVIEW
NRF TRIGA PACKAGE

1. Determine the definition of dry. The purpose of this action item was to determine how to ensure the fuel elements were dry prior to transport of the cask. Water in the cask is not allowed by DOT and water in the cask could cause hydrogen generation, which could become a safety problem in storage.

The solution will not only be the vacuum dry for any moisture from the inner container but will also be determined by a test to be performed on dummy elements that will determine how long it takes to dry them. That time will then be used, although the heat generating elements will not require as much time.

2. How will the inner lid withstand torquing the closure eye-bolt and will it move?

The attached calculations and information from Parker show that the lid sufficiently will withstand the torquing of the bolt without unseating the seal and the lid will not rotate when the eye-bolt is being tightened based upon the friction of the elastomeric O-ring on the stainless steel. Calculations are attachment 1.

3. What is the temperature of the cask without the overpack and with a solar load?

The maximum cask temperature occurs in the center of the cask lid and is 184°F. Calculations are Attachment 2.

4. Were all the stress combinations from the Regulatory Guides considered for the NCT drop?

They were not originally looked at in combination however, the additional pressure and temperature change stress combinations are so small there was not a significant change.

5. If the sealing surface moves, the metallic seal cannot be proven to maintain containment. How will containment be maintained?

An additional elastomeric bore seal will be added which will be considered the "transportation seal". Elastomeric seals have been tested and can tolerate movement and still maintain containment. The changes to the drawings have been incorporated.

6. Explain why VECTRA used the temperature criteria -20°F to 180°F for their drop analysis instead of the Hanford ambient temperatures.

The temperature range for evaluating an accident drop scenario that is required by Regulatory Guide 7.8 is -20°F to 100°F. They state that in the contiguous U.S., there is a 99.7 percent probability that any hourly temperature reading will fall within this range. However, there is a

difference between these temperatures and evaluating the package for the ambient temperature affects on the package. The ambient temperature effects on the package shall be evaluated for:

- A hot environment with maximum insolation, maximum decay heat, maximum internal pressure, and fabrication stresses. VECTRA performed this evaluation for both 10 CFR 71 (100°F) and Hanford temperatures (115°F).
- A cold environment with minimum insolation, minimum decay heat, minimum internal pressure, and fabrication stresses. VECTRA performed this evaluation for 10 CFR 71 only because the temperature is -40°F which is worse than the -27°F Hanford environment.

The above two analyses considering the temperature environment are different from the drop scenario hot and cold temperatures. The -20°F and 100°F were temperatures set by the NRC to evaluate the drop scenario's. The drops must be evaluated at both hot and cold however, these hot and cold temperatures are based upon the country's averages not based upon the area's maximum and minimum. VECTRA did evaluate the cask for the -27°F by evaluating the -40°F, as required by the WHC specification.

7. The four foot drop scenario for the overpack should be performed in the worst case orientation.

VECTRA performed the worst case four foot drop which ended up being the side drop. The g-loading was 56.3 g's. An ANSYS analysis was performed on the cask to ensure that this g-loading did not adversely affect the package past normal conditions of transport criteria.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 2
 (4) Building _____ (5) Rev. 0 (6) Job No. _____
 (7) Subject 2 1/2" Gasket Seals - For Tank
 (8) Originator E.K. Perry Date 7/13/94
 (9) Checker CHECK VERIFICATION ATTACHED PAGE 10-6 Date _____

(10)

② Determine the amount of lid displacement at the seal seating area. This amount, Δ , at the seal centerline is:

$$\Delta = (4.560 - 4.438) \tan(1.76 \times 10^{-4})$$

$$\Delta = \underline{\underline{3.75 \times 10^{-7} \text{ in}}}$$

This amount of displacement will have no appreciable effect on the container seal.

Reference 1 - Rank's Formulas for Stress & Strain,
6th Edition, 1989

POOR COPY RECEIVED
DOCUMENT PROCESSING

TRIGA CASK INNER CONTAINER LID DEFLECTION.

CHECK BY: HAROLD ATKINS

$$r_0 = .285''$$

$$E = 30 \times 10^6 \text{ psi}$$

$$a = 4.438''$$

$$t = 7/32 = .219''$$

$$b = (5/16)/2 = .156''$$

$$\nu = 0.3$$

$$W = \frac{286.5116}{2 \cdot \pi \cdot (.285)} = 160 \text{ lb/in}$$

$$D = \frac{(30 \times 10^6) \left(\frac{7}{32}\right)^3}{12(1 - 0.3^2)} = 61,119 \text{ in} \cdot \text{lb}$$

$$C_4 = \frac{1}{2} \left[(1 + 0.3) \left(\frac{.156}{4.438} \right) + (1 - 0.3) \left(\frac{4.438}{.156} \right) \right] = 4.98$$

$$C_7 = \frac{1}{2} \left[(1 - 0.3^2) \left(\frac{4.438}{.156} - \frac{.156}{4.438} \right) \right] = 12.93$$

$$L_6 = \frac{.285}{4(4.438)} \left[\left(\frac{.285}{4.438} \right)^2 - 1 + 2 \ln \left(\frac{4.438}{.285} \right) \right] = 7.22 \times 10^{-2}$$

$$L_7 = \left(\frac{.285}{4.438} \right) \left\{ \frac{1 + 0.3}{2} \ln \left(\frac{4.438}{.285} \right) + \frac{1 - 0.3}{4} \left[1 - \left(\frac{.285}{4.438} \right)^2 \right] \right\} = 0.126$$

$$\theta_a = \frac{W a^2}{D} \left(\frac{C_4 L_7}{C_7} - L_6 \right)$$

$$= \frac{(160)(4.438)^2}{(61,119)} \left(\frac{(4.98)(0.126)}{(12.93)} - 7.22 \times 10^{-2} \right)$$

$$\theta_a = 1.27 \times 10^{-3} \text{ radians}$$

$$\theta_a = 7.4 \times 10^{-2} \text{ degrees}$$

$$\tan \theta = \frac{dy}{dx}$$

$$\Delta L = 1.58 \times 10^{-4} \text{ in.}$$

$$\Delta L = \left(\frac{9.12 - 8.876}{2} \right) \tan \theta$$

August 24, 1994

ATTACHMENT 2

DON'T SAY IT — *Write It!*

DATE: July 12, 1994

TO: MD Clements

G2-02

FROM: Paul F. Stavens

G2-02

Telephone: 372-3747

cc: WW Smyth
RR CruzG2-02
G2-03SUBJECT: Storage Pad Solar Insolation Temperatures

During the design review, the question arose as to what the maximum temperatures that the TRIGA cask would experience on a storage pad without its protective overpack. I have reevaluated my model of the TRIGA cask to assess this issue. I evaluated the model at steady state, using an average value for the maximum daily Hanford insolation and the maximum ambient temperature (115 °F). I also evaluated my model using Vectra's values for maximum insolation, which were slightly higher than mine.

The maximum cask temperature occurs in the center of the cask lid and is 184 °F using the insolation values I derived and 190 °F using Vectra's values. Both of these values are under the 200 °F assumed for Bill's structural analysis.

I have attached copies of the HEATING7 input and output for record purposes and/or for Vectra review, if that is necessary.

Paul

Solar Insolation Values

From *Thermal Analysis Methods for Safety Analysis Reports for Packaging*, (WHC-SD-TP-RPT-005) the worst case solar insolation for a vertical surface facing east and a horizontal surface are as follows:

Time	Vertical Surface Facing East (Btu/hr-ft ²)	Horizontal Surface (Btu/hr-ft ²)
4:00 am	0	0
6:00 am	211	64
8:00 am	258	127
10:00 am	177	281
12:00 pm	49	314
2:00 pm	42	281
4:00 pm	32	127
6:00 pm	17	64
8:00 pm	0	0

From 6:00 am to 6:00 pm the average insolation values are 179.7 Btu/hr-ft² for horizontal surfaces and 131.7 Btu/hr-ft² for vertical surfaces. This assumes that the surface of the cask will act as a black body.

From Vectra's *TRIGA Cask Overpack Thermal Analysis* Table 4.1, Summary of Solar Insolation at Various Operating Conditions, horizontal and vertical surfaces will experience maximum solar insulations of 184.3 Btu/hr-ft² and 128.3 Btu/hr-ft² respectively.

HEATING7 Input File for TRIGA Cask Analysis Using Average Value for Maximum Daily Insolation

Heating 7 model of TRIGA Cask sans Overpack

8000 3 0 0

0 0 1

1 1

regions

1 1 0.0 8.0 0.0 0.000 0.0 4.0

1 0 0 4 0 0

2 1 0.0 4.5 0.0 0.000 4.0 4.5

1 0 0 0 0 0

3 1 4.5 5.00 0.0 0.000 4.0 4.5

1 0 0 0 0 0

4 4 5.0 5.125 0.0 0.00 4.0 4.5

1 0 0 0 0 0

5 1 5.125 5.375 0.0 0.000 4.0 4.5

1 0 0 0 0 0 0

6 1 5.375 7.5 0.0 0.000 4.0 4.50

1 0 0 0 0 0

7 1 7.5 8.00 0.0 0.000 4.0 4.5

1 0 0 4 0 0

8 3 0.0 4.5 0.0 0.000 4.5 34.25

1 1 0 0 0 0

9 1 4.5 5.00 0.0 0.000 4.5 34.25

1 0 0 0 0 0

10 4 5.0 5.125 0.0 0.00 4.5 34.25

1 0 2 2 0 0

11 1 5.125 5.375 0.0 0.000 4.5 34.25

1 0 0 0 0 0 0

12 2 5.375 7.5 0.0 0.000 4.5 34.25

1 0 0 0 0 0

13 1 7.5 8.00 0.0 0.000 4.5 34.25

1 0 0 4 0 0

14 3 0.0 4.5 0.0 0.000 34.25 34.75

1 1 0 0 0 0

15 1 4.5 5.00 0.0 0.000 34.25 34.75

1 0 0 0 0 0

16 4 5.0 5.125 0.0 0.00 34.25 34.75

1 0 2 2 0 0

17 1 5.125 5.375 0.0 0.000 34.25 34.75

1 0 0 0 0 0 0

18 1 5.375 7.5 0.0 0.000 34.25 34.75

1 0 0 0 0 0

19 1 7.5 8.00 0.0 0.000 34.25 34.75

1 0 0 4 0 0

20 1 0.0 5.0 0.0 0.000 34.75 35.75

1 0 0 0 0 0

21 4 5.0 5.125 0.0 0.00 34.75 35.75

1 0 2 2 0 0

22 1 5.125 5.375 0.0 0.000 34.75 35.75

1 0 0 0 0 0 0

23 1 5.375 7.5 0.0 0.000 34.75 35.75

1 0 0 0 0 0

24 1 7.5 8.00 0.0 0.000 34.75 35.75

```

1 0 0 4 0 0
25 4 0.0 5.125 0.0 0.000 35.75 35.875
1 0 0 0 0 0 2 2
26 1 5.125 5.375 0.0 0.000 35.75 35.875
1 0 0 0 0 0 0 0
27 1 5.375 7.5 0.0 0.000 35.75 35.875
1 0 0 0 0 0
28 1 7.5 8.00 0.0 0.000 35.75 35.875
1 0 0 4 0 0
29 1 0.0 5.0 0.0 0.000 35.875 36.875
1 0 0 0 0 0
30 1 5.0 5.125 0.0 0.00 35.875 36.875
1 0 0 0 0 0
31 1 5.125 5.375 0.0 0.000 35.875 36.875
1 0 0 0 0 0 0 0
32 1 5.375 7.5 0.0 0.000 35.875 36.875
1 0 0 0 0 0
33 1 7.5 8.00 0.0 0.000 35.875 36.875
1 0 0 4 0 0
34 1 0.0 7.5 0.0 0.000 36.875 39.375
1 0 0 0 0 0 0 1
35 1 7.5 8.00 0.0 0.000 36.875 39.375
1 0 0 4 0 0 0 1
materials
1 stainless 1.08 0.2810 0.11 0 0 0 0
2 leadshld 1.68 0.4094 0.031 0 0 0 1
620.0 10.5
3 payloads 0.0108 0.0733 0.23 0 0 0 0
4 airgapzz 0.00125 0.0733 0.23 0 0 0 0
initial temperatures
1 100.0
heat generations
1 0.00106
boundary conditions
1 1 1.0 -1
0.0 8.33e-12 0.00125 0.333 1.248
2 3
.00 5.83e-12 0.0
3 3
.00 5.83e-12
4 1 1.0 -1
0.0 8.33e-12 0.00125 0.333 0.790
xgrid
0.0 4.5 5.0 5.125 5.375 7.5 8.00
3 2 1 1 3 2
ygrid
zgrid
0.0 4.0 4.5 34.25 34.75 35.75 35.875 36.875 39.375
3 2 5 1 2 1 2 3
tabular functions
1
0.0 115.0 0.01 1475.0 0.51 1475.0 0.52 100.0 2.0 115.0
printout times
0.02 0.04 0.06 0.08 0.1 0.2 0.3 0.4 0.5 0.75 1.0 1.25 1.5
nodes monitored

```

1
steady state
1 10000
%

and assumed that the cask would experience maximum Hanford insolation and ambient temperatures.

HEATING7 Output for TRIGA Cask Analysis Using Average Value for Maximum Daily Insolation

Heating 7 model of TRIGA Cask sans Overpack

Steady-State Temperature Distribution at Time .0000E+00

Tue Jul 12 08:39:59 1994

20	39.38	185.59	185.54	185.42	185.24	185.21	185.18	185.16	185.13	185.04	184.96	184.89	184.87	184.84
19	38.54	185.34	185.30	185.17	184.98	184.94	184.91	184.89	184.86	184.77	184.69	184.61	184.59	184.57
18	37.71	185.16	185.11	184.97	184.74	184.70	184.66	184.64	184.60	184.49	184.41	184.33	184.31	184.29
17	36.88	185.03	184.98	184.81	184.53	184.48	184.42	184.39	184.33	184.21	184.12	184.04	184.02	184.00
16	36.38	184.98	184.93	184.76	184.44	184.36	184.28	184.24	184.16	184.03	183.94	183.87	183.84	183.82
15	35.88	184.96	184.90	184.73	184.39	184.28	184.14	184.05	183.95	183.83	183.75	183.68	183.66	183.64
14	35.75	183.37	183.35	183.31	183.25	183.25	183.25	183.92	183.88	183.77	183.70	183.64	183.62	183.60
13	35.25	183.36	183.35	183.30	183.24	183.23	183.23	183.62	183.61	183.56	183.50	183.45	183.44	183.42
12	34.75	183.36	183.34	183.30	183.22	183.21	183.20	183.37	183.37	183.34	183.31	183.27	183.25	183.24
11	34.25	183.40	183.37	183.30	183.14	183.14	183.14	183.15	183.15	183.13	183.11	183.09	183.08	183.06
10	28.30	182.73	182.67	182.51	182.23	182.23	182.23	181.85	181.84	181.84	181.83	181.81	181.80	181.78
9	22.35	181.96	181.91	181.73	181.44	181.44	181.44	181.01	181.00	181.00	180.99	180.97	180.97	180.96
8	16.40	181.37	181.31	181.14	180.35	180.35	180.35	180.43	180.43	180.43	180.42	180.41	180.40	180.40
7	10.45	180.36	180.31	180.66	180.40	180.40	180.40	180.11	180.11	180.10	180.10	180.09	180.08	180.08
6	4.50	179.98	179.98	179.98	179.99	179.99	179.99	179.96	179.96	179.96	179.95	179.94	179.94	179.93
5	4.25	179.98	179.98	179.98	179.99	179.99	179.98	179.96	179.96	179.95	179.95	179.94	179.93	179.93
4	4.00	179.98	179.98	179.98	179.98	179.98	179.97	179.97	179.96	179.95	179.94	179.93	179.93	179.92
3	2.67	179.97	179.97	179.96	179.96	179.96	179.95	179.95	179.95	179.94	179.93	179.91	179.91	179.90
2	1.33	179.96	179.96	179.96	179.95	179.94	179.94	179.94	179.94	179.93	179.92	179.90	179.90	179.89
1	.00	179.96	179.96	179.95	179.94	179.94	179.94	179.94	179.93	179.92	179.91	179.90	179.89	179.89
		.00	1.50	3.00	4.50	4.75	5.00	5.13	5.38	6.08	6.79	7.50	7.75	8.00
		1	2	3	4	5	6	7	8	9	10	11	12	13

HEATING7 Input File for TRIGA Cask Analysis Using Vectra Insolation

Heating 7 model of TRIGA Cask sans Overpack with Vectra Insolation

8000 3 0 0

0 0 1

1 1

regions

```
1 1 0.0 8.0 0.0 0.000 0.0 4.0
1 0 0 4 0 0
2 1 0.0 4.5 0.0 0.000 4.0 4.5
1 0 0 0 0 0
3 1 4.5 5.00 0.0 0.000 4.0 4.5
1 0 0 0 0 0
4 4 5.0 5.125 0.0 0.00 4.0 4.5
1 0 0 0 0 0
5 1 5.125 5.375 0.0 0.000 4.0 4.5
1 0 0 0 0 0 0
6 1 5.375 7.5 0.0 0.000 4.0 4.50
1 0 0 0 0 0
7 1 7.5 8.00 0.0 0.000 4.0 4.5
1 0 0 4 0 0
8 3 0.0 4.5 0.0 0.000 4.5 34.25
1 1 0 0 0 0
9 1 4.5 5.00 0.0 0.000 4.5 34.25
1 0 0 0 0 0
10 4 5.0 5.125 0.0 0.00 4.5 34.25
1 0 2 2 0 0
11 1 5.125 5.375 0.0 0.000 4.5 34.25
1 0 0 0 0 0 0
12 2 5.375 7.5 0.0 0.000 4.5 34.25
1 0 0 0 0 0
13 1 7.5 8.00 0.0 0.000 4.5 34.25
1 0 0 4 0 0
14 3 0.0 4.5 0.0 0.000 34.25 34.75
1 1 0 0 0 0
15 1 4.5 5.00 0.0 0.000 34.25 34.75
1 0 0 0 0 0
16 4 5.0 5.125 0.0 0.00 34.25 34.75
1 0 2 2 0 0
17 1 5.125 5.375 0.0 0.000 34.25 34.75
1 0 0 0 0 0 0
18 1 5.375 7.5 0.0 0.000 34.25 34.75
1 0 0 0 0 0
19 1 7.5 8.00 0.0 0.000 34.25 34.75
1 0 0 4 0 0
20 1 0.0 5.0 0.0 0.000 34.75 35.75
1 0 0 0 0 0
21 4 5.0 5.125 0.0 0.00 34.75 35.75
1 0 2 2 0 0
22 1 5.125 5.375 0.0 0.000 34.75 35.75
1 0 0 0 0 0 0
23 1 5.375 7.5 0.0 0.000 34.75 35.75
1 0 0 0 0 0
24 1 7.5 8.00 0.0 0.000 34.75 35.75
1 0 0 4 0 0
```

25 4 0.0 5.125 0.0 0.000 35.75 35.875
1 0 0 0 0 0 2 2
26 1 5.125 5.375 0.0 0.000 35.75 35.875
1 0 0 0 0 0 0 0
27 1 5.375 7.5 0.0 0.000 35.75 35.875
1 0 0 0 0 0
28 1 7.5 8.00 0.0 0.000 35.75 35.875
1 0 0 4 0 0
29 1 0.0 5.0 0.0 0.000 35.875 36.875
1 0 0 0 0 0
30 1 5.0 5.125 0.0 0.00 35.875 36.875
1 0 0 0 0 0
31 1 5.125 5.375 0.0 0.000 35.875 36.875
1 0 0 0 0 0 0 0
32 1 5.375 7.5 0.0 0.000 35.875 36.875
1 0 0 0 0 0
33 1 7.5 8.00 0.0 0.000 35.875 36.875
1 0 0 4 0 0
34 1 0.0 7.5 0.0 0.000 36.875 39.375
1 0 0 0 0 0 0 1
35 1 7.5 8.00 0.0 0.000 36.875 39.375
1 0 0 4 0 0 0 1
materials
1 stainless 1.08 0.2810 0.11 0 0 0 0
2 leadshld 1.68 0.4094 0.031 0 0 0 1
620.0 10.5
3 payloads 0.0108 0.0733 0.23 0 0 0 0
4 airgapzz 0.00125 0.0733 0.23 0 0 0 0
initial temperatures
1 100.0
heat generations
1 0.00106
boundary conditions
1 1 1.0 -1
0.0 8.33e-12 0.00125 0.333 1.280
2 3
.00 5.83e-12 0.0
3 3
.00 5.83e-12
4 1 1.0 -1
0.0 8.33e-12 0.00125 0.333 0.891
xgrid
0.0 4.5 5.0 5.125 5.375 7.5 8.00
3 2 1 1 3 2
ygrid
zgrid
0.0 4.0 4.5 34.25 34.75 35.75 35.875 36.875 39.375
3 2 5 1 2 1 2 3
tabular functions
1
0.0 115.0 0.01 1475.0 0.51 1475.0 0.52 100.0 2.0 115.0
printout times
0.02 0.04 0.06 0.08 0.1 0.2 0.3 0.4 0.5 0.75 1.0 1.25 1.5
nodes monitored
1

steady state

1 10000

2

HEATING7 Input File for TRIGA Cask Analysis Using Vectra Insulation

Heating 7 model of TRIGA Cask same Overpack with Vectra Insulation
Jul 11 16:46:57 1994

Steady-State Temperature Distribution at Time .0000E+00

20	29.38	190.95	190.92	190.81	190.66	190.63	190.61	190.59	190.57	190.55	190.54	190.52	190.49	190.43	190.35	190.33
19	28.54	190.75	190.71	190.60	190.44	190.41	190.38	190.37	190.34	190.32	190.30	190.26	190.25	190.19	190.11	190.10
18	27.71	190.59	190.55	190.43	190.26	190.20	190.17	190.15	190.12	190.03	189.90	189.96	189.90	189.88	189.86	189.86
17	26.38	190.43	190.43	190.30	190.06	190.02	189.97	189.94	189.90	189.80	189.72	189.56	189.49	189.47	189.46	189.46
16	26.38	190.44	190.39	189.25	189.99	189.82	189.75	189.76	189.76	189.50	189.43	189.32	189.51	189.49	189.47	189.47
15	25.28	190.42	190.37	190.23	189.95	189.85	189.74	189.66	189.58	189.48	189.41	189.36	189.34	189.32	189.32	189.32
14	25.75	189.12	189.10	189.07	189.02	189.01	189.01	189.56	189.52	189.43	189.37	189.32	189.30	189.29	189.29	189.29
13	25.25	189.11	189.10	189.06	189.01	189.00	189.00	189.30	189.25	189.21	189.17	189.15	189.13	189.13	189.13	189.13
12	24.75	189.11	189.09	189.06	188.99	188.98	188.98	189.10	189.08	189.04	189.01	189.00	188.98	188.98	188.98	188.98
11	24.25	189.16	189.14	189.07	188.93	188.93	188.93	188.92	188.91	188.90	188.88	188.87	188.85	188.84	188.84	188.84
10	23.30	188.54	188.58	188.42	188.15	188.15	188.15	187.32	187.32	187.31	187.30	187.28	187.27	187.27	187.27	187.27
9	22.35	188.01	187.95	187.78	187.49	187.49	187.49	187.09	187.08	187.08	187.07	187.06	187.05	187.05	187.05	187.05
8	16.40	187.51	187.45	187.28	187.00	187.00	187.00	186.65	186.65	186.62	186.62	186.62	186.62	186.62	186.62	186.62
7	10.45	187.09	187.04	186.89	186.63	186.63	186.63	186.35	186.35	186.34	186.34	186.34	186.34	186.34	186.34	186.34
6	4.50	186.27	186.27	186.27	186.28	186.28	186.28	186.24	186.24	186.23	186.23	186.22	186.22	186.22	186.22	186.22
5	4.25	186.27	186.27	186.27	186.27	186.27	186.27	186.24	186.24	186.23	186.23	186.22	186.22	186.22	186.22	186.22
4	4.50	186.24	186.24	186.24	186.24	186.24	186.24	186.23	186.23	186.23	186.23	186.22	186.22	186.22	186.22	186.22
3	3.00	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25
2	1.50	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25
1	.00	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25	186.25

ACTION ITEM LIST
JULY 20, 1994 DESIGN REVIEW MEETING

1. The specification for the procurement of the overpack is required to be revised to reflect the 60 g loading for Normal Conditions instead of 50 g's.

The specification was revised and released on July 28, 1994.

2. Conference call between VECTRA welding engineer and WHC welding engineering will be held after design review meeting.

The conference call was not necessary. The welding agreement was made between VECTRA representatives and WHC design reviewers.

3. The current cask design is not fabricable..

The cask design was modified to ensure the cask was fabricable. The top inner weld was raised closer to the opening of the cask and turned around to an inside weld.

4. Fissile classification of the package was requested to be stated in the documentation.

The fissile classification, Class I, was added to the SARP.

5. It was requested that a statement be added to the documentation mentioning that the NRF TRIGA cask does not meet 10 CFR 71 in the area of licensing.

A statement was added to the SARP mentioning that the design of the NRF TRIGA casks meets the intent of 10 CFR 71, excepting licensing.

6. A matrix for comparing storage requirements to the cask was developed and needs to be cc:mailed to the design review team members.

The matrix comparing storage requirements to the NRF TRIGA cask was developed and cc:mailed to everyone on the Design Review Team.

11.0 REVIEW COMMENT RECORDS - CASK AND OVERPACK

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 1

5. Document Number(s)/Title(s) NRF TRIGA Package Formal Design Review	6. Program/Project/ Building Number TRIGA	7. Reviewer T. A. Delucchi	8. Organization/Group ED &F	9. Location/Phone 306E/376-3116
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/16/94
Date

Reviewer/Point of Contact

Author/Originator

8/16/94
Date

Reviewer/Point of Contact

Author/Originator

11-2

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	Drawing H-2-822938 sht. 1 - Outer vessel cannot be fabricated as designed.		Accepted. A revision to the fabrication welding will be incorporated per final review meeting.	C
2.	Drawing H-2-822937 sht. 1 - The fuel basket will be difficult to fabricate by welding. Suggest the grid assembly's be machined from aluminum bar and keyed to the center shaft.		Accepted. Basket configuration will be revised and fabricated from aluminum bar or plate with machined holes.	C
3.	Drawing H-2-822938 sht. 1 - Part #7 should be made from tubing not pipe.		Accepted. Tubing A511 is being used.	C
4.	Drawing H-2-822938 sht. 1 - Lead fill and vent holes are not shown. Are plugs to be installed and welded after filling?		Accepted. Note was added to have fabricator specify.	C
5*.	Drawing H-2-822937 - Basket welds should all be 1/8".		Incorporated.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 2

5. Document Number(s)/Title(s) NRF TRIGA Package Formal Design Review	6. Program/Project/ Building Number TRIGA	7. Reviewer R. W. Barker	8. Organization/Group PDE	9. Location/Phone 376-5235
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17. Comment Submittal Approval: 10. Agreement with indicated comment disposition(s) 11. CLOSED

Organization Manager (Optional)

Date

R. W. Barker
Reviewer/Point of Contact
M. D. Clement
Author/Originator

R. W. Barker
Reviewer/Point of Contact
8-12-1994
Date
M. D. Clement
Author/Originator

11-3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	Drawing II-2-822938 Sht 1 - Item 7 Need to look at different specification. A249 is a tubing call-out. Possibly A312 per ANSI A36.19.		Accepted. The call-out is now tubing on the Bill of Materials also - A511.	C
2.	Drawing II-2-822938 Sht. 1 - Item 8 Look at possibly A358 or A511 availability.		Accepted. A511 being used.	C
3.	Drawing II-2-822938 Sht. 1 - Note 5 Surface finish should be 63 instead of 125.		Accepted. Being incorporated.	C
4.	Drawing II-2-822938 Sht. 1 - Note 9 Need to add in a reference to a procedure for radiographing lead and acceptance criteria.		Accepted. Being incorporated.	C
5.	Drawing II-2-822938 Sht. 1 - Note 12 Awkward wording in last line.		Accepted. Being incorporated.	C
6.	Drawing II-2-822938 Sht. 1 - Note 13 As-rolled should be as-received. Revised wording.		Accepted. Being incorporated.	C
7.	Drawing II-2-822938 Sht. 1 - Surface call-outs on top seal surface need to be incorporated.		Accepted. Being incorporated.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 2 of 2

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
8.	Drawing II-2-822938 Sht. 1 - General note: Need to have more information on lead pouring and include fill and vent in the drawing. Preheat temp, Pouring temp., and zoned heat tracing should be called out or referred to.		Accepted. Will be incorporated into a fabrication specification in more detail. Placement will be up to fabricator	C
10.	Drawing II-2-822938 Sht. 2 - The metallic seal needs to have a vacuum dry performed to ensure absence of moisture.		Accepted. Being incorporated.	C
11.	Drawing II-2-822938 Sht. 3 - Outer Vessel lid seal surface call-outs need to be added.		Accepted. Being incorporated.	C
12.	Drawing II-2-822938 Sht. 3 - Detail II Seal groove should have limits and dimensions.		Accepted. Being incorporated.	C
13.	Drawing II-2-822936 Sht. 1 - Bottom container weld detail either needs to be changed to a code weld or the Note #2 needs to be revised because it isn't a code weld.		Accepted. The weld does not have to be code so the note will be revised.	C
14*	Drawing II-2-822938 Sht 1 - Lower containment weld should refer to machining on inside of container.		Incorporated.	C
15*	Drawing II-2-822938 Sht 1 - Flatness call-out on top ring inner surface should have a B instead of and A first.		Incorporated.	C
16*	Drawing II-2-822939 Sht 2 - Radius on Item 4 View A-A need to be called-out.		Incorporated.	C

Item (2) 2x should be 4x

11-4

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 1 of 3

5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer P. C. Ferrell	8. Organization/Group Packaging Design Engineering	9. Location/Phone 376-2846
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/12/94
DateP.C. Ferrell
Reviewer/Point of ContactM.D. Clement
Author/Originator8/12/94
DateP.C. Ferrell
Reviewer/Point of ContactM.D. Clement
Author/Originator

11-5

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	<p>Cask Lid Alignment Pins.</p> <p>a) Why are four alignment pins used? Most casks use only two. The RTG packaging uses only two alignment pins for each of its closure systems and the alignment/closure process works smoothly.</p> <p>b) Why are the alignment pins not permanently installed in the cask upper closure ring plate? Alignment pins could be located on the same circle diameter as the closure bolts.</p> <p>c) The alignment pins should not be made of stainless steel; especially if the removable-type alignment pins are used. Threading the stainless steel alignment pins into the stainless steel upper ring plate can cause galling. A more commonly used material for alignment pins is Nitronic 50 or 60.</p> <p>d) The main reason for using fewer and permanent type alignment pins is to help keep operator dose ALARA.</p>		<p>a) Only two alignment pins will be used.</p> <p>b) The guide pins will be permanent based on design review discussion.</p> <p>c) The guide pins will be Nitronic 50 or 60.</p>	<p>C</p> <p>C</p> <p>C</p>

REVIEW COMMENT RECORD (RCR)

1. Date

7/18/94

2. Review No.

3. Project No.

4. Page

2 of 3

12.
Item

13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)

14.
Hold
Point

15. Disposition (Provide justification if NOT accepted.)

16.
Status

2. The current cask design uses a metallic O-ring seal as the main containment boundary closure. The metallic O-ring seals will not tolerate much movement and still retain a leak tight seal. If the structural analysis indicates that there is not movement in the closure seal area, then the metallic O-ring may be acceptable. The enclosure seal must be examined carefully to ensure a leak tight seal is maintained during all 10CFR71 tests.

An additional elastomeric O-ring was added as a bore seal to the cask lid for transportation purposes. The metallic O-ring will ensure the greater than 30 year storage life only not provide transportation containment.

C

3. The worst case four foot drop orientation needs to be developed and defended.

The worst case 4 foot drop is the side drop under cold conditions. The g-loading is 56.3. The original 50 g criteria stated in the specification will be revised to 60 g's after a review of the actual stress distribution shows that 60g is acceptable.

C

4. All welding and inspection should be performed to ASME eight and nine. The following welds need to be dye penetrant tested (PT):

- All main (structural) impact limiter welds
- Lifting and tiedown lug welds
- Tiedown collar welds
- All structural welds on shipping skid

The design review agreement is that the structural overpack welds and the lifting and tie-down lugs will be PT inspected. The tie-down collar and skid were agreed to be only visually inspected.

C

5. The lid closure bolt torque of 41+/- 5 ft-lb appears to be low. Standard torque for a 1/2" bolt is 50+/- 5 ft-lb.

The bolt torque was changed to 52 +/- 5 ft-lb based on additional stresses from drop analyses.

C

6. The leak test port for the area between the metallic seal and the cask cavity needs to be inside of the seal area.

Accepted and incorporated.

C

11-6

MHC-SD-TP-DRR-003

Rev. 0

August 24, 1994

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 3 of 3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
7.	Unless a well controlled process is used the lead will not be bonded to the cask wall. A gap of 0.002" can be assumed to make the thermal analysis conservative. With a low heat load, using a gap should not be a problem.		A calculation was performed with the air gap. Currently the maximum temperature drop across the lead during the fire is 0.2. Adding the air gap changes this temperature drop 0.32°F.	C
8*.	Alignment pins should be placed so that they are 15 - 30° offset.		Incorporated.	C
9*.	There should be an alignment stripe painted on the outside of the lid and body to facilitate assembly.		Not required with above incorporation	C
10*	Drawing II-2-822939; Item 4 and 5 are not referred to correctly. Is there an item 5?		Item 4 is 6 and item 5 is 7.	C
11*	Do not place alignment pins directly under lifting bolt holes.		Incorporated.	C

11-7

REVIEW COMMENT RECORD (RCR)	1. Date July 18, 1994	2. Review No. 1
	3. Project No.	4. Page 1 of 1

5. Document Number(s)/Title(s) NRF TRIGA Cask Design Review	6. Program/Project/ Building Number NRF/Building 308	7. Reviewer Douglas B. Teachout	8. Organization/Group Solid Waste Disposal/Generator Services	9. Location/Phone M0279/A107/200W, 373-6688
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/12/94
DateDouglas B. Teachout
Reviewer/Point of Contact8/12/94
DateDouglas B. Teachout
Reviewer/Point of ContactM. D. Clement
Author/OriginatorM. D. Clement
Author/Originator

11-8

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	We still have some concern over the possibility of a battery effect between the metallic seals and the cask surface. The fuel will be loaded at room temperature (probably at or near 75F). It is feasible that water will be present as the cask and cools down and some of the water condenses. Subsequent heating of the cask would cause the moisture to be distributed throughout the cask. If so, an electrolyte will be present and a battery effect could occur.		Accepted. The cask will be vacuum dried to assure prior to shipment that it is dry. The inner-seal space can also be vacuum dried.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/12/94	2. Review No. 0
	3. Project No. triga	4. Page 1 of 2

5. Document Number(s)/Title(s) NRF TRIGA Package Design Review Report	6. Program/Project/ Building Number TRIGA	7. Reviewer S. B. Dutta	8. Organization/Group QA	9. Location/Phone 300 Area/376-6789
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17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8-12-94
Date

S.B. Dutta
Reviewer/Point of Contact
M.D. Clement
Author/Originator

8-12-94
Date

S.B. Dutta
Reviewer/Point of Contact
M.D. Clement
Author/Originator

11-9

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
1.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.1-B, Line 3: dimensional certificates - needs clarification.		Accepted and Incorporated.	C
2.	VECTRA Overpack Fabrication Specification: Page 1, Paragraph 1.2.A: VECTRA's function in designing the overpack? This is a confusing section although it is explaining that the designer is different from the Fab shop.		Accepted and Incorporated.	C
3.	VECTRA Overpack Fabrication Specification: Page 10, Paragraph 4.4.5, needs to be clarified.		Accepted and Incorporated.	C
4.	WHC Fabrication Specification: Page 4-11, Section 4.4.1 - Correct drawing numbers.		Accepted and incorporated.	C
5.	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.2, line 3, Typo - American Society of Mechanical Engineers.		Accepted and incorporated.	C
6.	WHC Fabrication Specification: Page 4-12, Section 4.4.3.1.3, DOE 5700.6B needs to be 5700.6C.		Accepted and incorporated.	C
7.	WHC Fabrication Specification: Page 4-12, Section 4.4.4.1, SARP number to be assigned.		Accepted and will be incorporated.	C

REVIEW COMMENT RECORD (RCR)	1. Date 7/12/94	2. Review No. 0
	3. Project No. triga	4. Page 2 of 2

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
8.	WHC Fabrication Specification: Page 4-18, Section 4.4.7.3, Line 4, Typo - QA shall define the acceptance and nonconformance criteria.		Accepted, changed and to or.	C
9*.	Drawing II-2-822939 Sht 1 - Should be sheet 1 of 2 not 1 of 1.		Incorporated.	C
10*	Drawing II-2-822939 Sht 1 - Item 4 should be item 6, Item 5 should be item 7.		Incorporated.	C
11*	Drawing II-2-822939 Sht 2 - Should Item #3 be the lifting collar instead of the locking collar and #4 vice versa?		Incorporated.	C

11-10

WHC-SD-TP-DRR-003 Rev. 0 August 24, 1994

REVIEW COMMENT RECORD (RCR)

1. Date

7/18/94

2. Review No.

3. Project No.

4. Page

1 of 3

5. Document Number(s)/Title(s)

NRF TRIGA Cask Overpack Design
Analysis Report/Overpack Fabrication
Specification/Tie-down Fabrication
Specification/Letter from VECTRA to
WHC on Welding Requirements

6. Program/Project/
Building Number

TRIGA Package

7. Reviewer

Westinghouse
Hanford Company

8. Organization/Group

9. Location/Phone

(509) 376-3501

17. Comment Submittal Approval:

10. Agreement with indicated comment disposition(s)

11. CLOSED

Organization Manager (Optional)

8/16/94
Date

M.D. Clements
Reviewer/Point of Contact
See VECTRA
Author/Originator
Letter

8/16/94
Date

M.D. Clements
Reviewer/Point of Contact
See VECTRA LTR
Author/Originator

12.
Item

13. Comment(s)/Discrepancy(s) (Provide technical justification for the
comment and detailed recommendation of the action required to correct/
resolve the discrepancy/problem indicated.)

14.
Hold
Point

15. Disposition (Provide justification if NOT accepted.)

16.
Status

1. July 2, 1994 Letter from Moses Taylor to Beverly Johnston. Based upon the specification and AWS information, the specification cannot be changed as requested. The following is WHC's allowable change:

The specification shall require fabrication per the following requirements:

1. All materials will be either ASME or ASTM.
2. All welders and welding procedures shall be qualified to ASME Section IX.
3. All welding and inspection* should be performed to ASME Section VIII and IX. The following welds shall be dye penetrant tested (PT):
 - All main (structural) impact limiter welds.
 - Lifting and tiedown lug welds
 - Tiedown Collar welds
 - All structural welds on shipping skid.

* Visual examinations for non-structural welds may be performed per AWS, Dynamically Loaded Structures.

REVIEW COMMENT RECORD (RCR)

1. Date

7/18/94

2. Review No.

3. Project No.

4. Page

2 of 3

12.
Item

13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)

14.
Hold
Point

15. Disposition (Provide justification if NOT accepted.)

16.
Status

2. Overpack Fabrication Specification: Section 1, last sentence. This should be written for 2 overpacks not one as specified in the Purchase Order from WHC. Follow this through in the specification.

3. Section 1.1-B, Line 3: define what is meant by dimensional certificates.

4. Section 1.2-A: please remove reference to licensing. This cask will not be licensed. In first sentence, instead of saying Others, please state VECTRA and/or WHC.

5. Section 4.4.5, page 10. See #1 above for welding inspection requirements.

6. Section 5.2.1, page 13, first sentence: revise the statement about 100 percent visual examination of welds to reflect above comment #1.

7. Overpack Tie-Down Hardware Fabrication Specification: Page 1, Section 1.1 - There should be two overpack tiedown assemblies fabricated.

8. Page 1, Section 1.2 - Please take out reference to licensing.

11-12

WHC-SD-TP-DRR-003

Rev. 0

August 24, 1994

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 3 of 3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
9.	Page 4, Section 4.3 - Add that all structural welds shall be dye penetrant tested.			
10.	Design Analysis Report: Page 1-1, Section 1.2.1 - Please provide more details to Package Description.			
11.	Overall - Please perform spell check on the document again.			
12.	Page 2-32, Section 2.6.5 - Please determine the worst case 4 foot drop and defend. The specification g-loading allowable for this case will be revised to 60 g's.			
13.	Page 2-40, Section 2.7.1.2 - Does brittle fracture of the overpack carbon steel closure bolts need to be considered?			
14.	Page 2-39 and Presentation - Why is 180°F used as the hot drop temperature? It is only required to be 100°F per 10 CFR 71 and Reg Guide 7.8.			

11-13

REVIEW COMMENT RECORD (RCR)	1. Date 7/18/94	2. Review No.
	3. Project No.	4. Page 4 of 3

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
15.	<p>Section 1.3.2 - Please change drawing number from H-3 number to the following H-9 numbers and discard the H-3 numbers.</p> <p>For the 2 TRIGA Cask Overpack Arrangement and Interface Control Drawings, number them H-9-5011 sht. 1 and sht. 2.</p> <p>For the 3 TRIGA Cask Overpack, Overpack Details DAR Drawings, number them H-9-5012 sht. 1, 2, and 3.</p> <p>For the 1 TRIGA Cask Overpack Pallet and Tie Down Hardware DAR Drawing, number it H-9-5013.</p> <p>For the 1 TRIGA Cask Overpack Main Assembly DAR Drawing, number it H-9-5014.</p>			

11-14

WHC-SD-TP-DRR-003 Rev. 0 August 24, 1994

August 24, 1994

VECTRA

July 27, 1994
252-59-94-008

R. A. Moore
Westinghouse Hanford Company
P. O. Box 1970
Richland, WA 99352

Subject: NRF TRIGA[®] Cask Overpack Design and Analysis Project - Response to Final Design Review Comments

Reference: 1. Purchase Order No. MFJ-XVV-375226
2. WHC Fax (Denise Clements to Moses Taylor/Kyle Jones) dated July 14, 1994

Dear Mr. Moore:

Reference 2 forwarded WHC final design review comments to VECTRA for resolution. Attached are the VECTRA responses to the final review comments.

If you have any questions, please contact me.

Sincerely,

Moses Taylor, Jr., P.E.
Project Manager

Attachment

cc: M. D. Clements

FAXED

FAXED

VECTRA

Attachment to
252-59-94-008
Page 1 of 3

Responses to WHC Final Design Review Comments

1. The specification shall require fabrication per the following requirements: (1) All materials will be either ASME or ASTM; (2) All welders and welding procedures shall be qualified to ASME Section IX; (3) All welding and inspection should be performed to ASME Section VIII and IX with all main structural impact limiter welds, lifting and tie-down lug welds, tiedown collar welds, and structural welds on shipping skid dye penetrant tested. Visual examinations for non-structural welds may be performed per AWS, Dynamically loaded Structures.

As discussed in the final design review meeting on 7/20, the resolution to this comment is as follows:

- 1) All materials are specified as ASME or ASTM. The current drawings specify ASTM materials for all structural components. Off-the-shelf rigging hardware is provided using the manufacturer's standard materials.
- 2) All welders and welding procedures for the overpack are qualified in accordance with ASME Section IX. All welders and welding procedures for the non-safety-related tie-down collar and pallet are qualified in accordance with ASME Section IX or AWS D1.1.
- 3) All overpack welding and inspection will be performed to ASME Section IX and ASME Section V. The overpack seam, flange and lifting lug welds will also be dye penetrant tested per ASME Section V and ASME Section VIII. Welds joining the backing plates to the overpack sheet will not be dye penetrant tested. All overpack welds will be visually inspected per AWS D1.1.
- 4) Because the tie-down collar and pallet are non-safety-related hardware, all welding and inspection will be performed in accordance with AWS D1.1 or ASME Section IX. All welds will be visually inspected per AWS D1.1 and no PTs will be performed. A visual inspection is suitable for the pallet and collar because they contain no pressure retaining welds.

The overpack fabrication specification will be revised to define the requirements for dye penetrant testing and to clarify the code criteria for welding and inspection. The overpack drawings will be revised to call out the welds that require dye penetrant testing. The tie-down fabrication specification will be revised to allow qualification per AWS D1.1 or ASME Section IX.

VECTRA

Attachment to
252-59-94-008
Page 2 of 3

2. **Overpack Fabrication Specification:** Section 1, last sentence. This should be written for 2 overpacks not one as specified in the Purchase Order from WHC. Follow this through in the specification.

The fabrication specification is written to define the requirements for one overpack. The purchase order for the overpacks that is provided to the Seller will define the required number of overpacks (2).

3. **Section 1.1-B, Line 3:** define what is meant by dimensional certificates.

The reference to dimensional certificates in Section 1.1 will be deleted because the documentation requirements defined in Section 8 do not require dimensional certificates. A dimensional verification is required by Section 5.2.1 of the specification and the documentation requirements are defined in Sections 8.1.3, 8.2(B), and 8.2(C).

4. **Section 1.2-A:** please remove reference to licensing. This cask will not be licensed. In first sentence, instead of saying Others, please state VECTRA and/or WHC.

The specification will be modified accordingly. The term "Others" will be replaced with "the Buyer and/or the Owner" for consistency with the remainder of the specification.

5. **Section 4.4.5, page 10.** See #1 above for welding inspection requirements.

As discussed in the response to comment #1, this section will be revised to add dye penetrant testing in accordance with ASME Section V for the welds shown on the Drawings that require PT.

6. **Section 5.2.1, page 13, first sentence:** revise the statement about 100 percent visual examination of welds to reflect above comment #1.

The reference to visual inspections will be deleted from this section. Section 5.2.1 defines the performance testing requirements. The NDE requirements for both visual and dye penetrant examinations are defined in Section 4.4.5.

7. **Overpack tie-down Hardware Fabrication Specification:** Page 1, Section 1.1 - There should be two overpack tie-down assemblies fabricated.

The fabrication specification is written to define the requirements for one tie-down assembly. The purchase order for the tie-downs that is provided to the Seller will define the required number of tie-downs (2).

VECTRA

Attachment to
252-59-94-008
Page 3 of 3

8. Page 1, Section 1.2 - Please take out reference to licensing.

Comment will be incorporated.

9. Page 4, Section 4.3 - Add that all structural welds shall be dye penetrant tested.

As discussed in the response to comment #1 and agreed upon at the final design review meeting, the tie-down collar and pallet welds do not require dye penetrant testing.

10. Design Analysis Report: Page 1-1, Section 1.2.1 - Please provide more details to Package Description.

The package description will be expanded in the Design Analysis Report.

11. Overall - Please perform spell check on the document again.

Comment will be incorporated.

12. Page 2-32, Section 2.6.5 - Please determine the worst case 4 foot drop and defend. The specification g-loading allowable for this case will be revised to 60 g's.

Comment will be incorporated.

13. Page 2-40, Section 2.7.1.2 - Does brittle fracture of the overpack carbon steel closure bolts need to be considered?

The carbon steel ASTM A490 bolts will be replaced with ASTM A564 Type 630 precipitation hardened bolts that are not susceptible to brittle fracture at the temperatures of interest.

14. Page 2-39 and Presentation - Why is 180°F used as the hot drop temperature? It is only required to be 100°F per 10CFR71 and Reg. Guide 7.8.

180°F was selected for the evaluation of the hot drop impact limiter material properties because it bounds the predicted temperature of the foam for the pre-drop conditions. The 10CFR71 thermal boundary conditions for the pre-drop case are taken from the normal conditions of transport and include an ambient temperature of 100°F and full solar insolation. The maximum overpack surface temperature for this case was calculated to be 170°F.

12.0 DESIGN REVIEW CHECKLIST

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
1.	Have assumptions necessary to perform the design task been adequately described and are they reasonable?	Yes	
2.	Have the appropriate Quality Assurance requirements been specified?	Yes	
3.	Does the design meet the established requirements or design criteria?	Yes	
4.	Have the site and facility interface requirements been met?	Yes	
5.	Are there any interface problems?	No	
6.	Has appropriate consideration been given to use of standardized parts, materials and processes, and have engineering standards and criteria been specified properly in the design?	Yes	
7.	Does the design represent the simplest design consistent with functional requirements and expected service conditions?	Yes	
8.	Can the equipment be readily assembled/disassembled as designed?	Yes	
9.	Does the design minimize the overall cost to the extent practicable?	Yes	
10.	Have qualified and certified parts been specified?	Yes	

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
11.	Are the applicable codes, standards and requirements, including revisions, properly identified and are their design requirements provided for?	Yes	
12.	Have available data on similar designs been used?	Yes	
13.	Is the design producible by conventional means?	Yes	
14.	Have non-corrosive materials been used where required?	Yes	
15.	Does the design avoid any materials unproven for use in the anticipated environment?	Yes	
16.	Can the assembly be stored for extended periods of time without degrading effects?	Yes	
17.	Does the design meet functional requirements? a. Stresses are within design limits? b. Steady-state and transient conditions? c. Have actual and "worst case" condition stresses been considered rather than nominal average stresses?	a. Yes b. Yes c. Yes	

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
18.	Will the design meet the following environmental conditions? a. Temperature (steady-state and transient) b. Flow (steady-state and transient) including induced vibration c. Pressure (steady-state and transient)	a. Yes b. Yes c. Yes	
19.	Are the specified construction materials resistant to the following as applicable: a. Moisture b. Radiation	a. Yes b. Yes	
20.	Has the design appropriately considered maintenance operation and reliability, including maintenance procedures and techniques, unique maintenance requirements and frequencies?	Yes	
21.	Are required tolerances, fabrication techniques, processes, etc., consistent with standard practices?	Yes	
22.	Has adequate accessibility been provided for in-service/storage inspection?	Yes	
23.	Does the design meet all established safety and SAR requirements?	Yes	Preliminary Safety Evaluation currently being developed for 10 CFR 72 storage.

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
24.	Have personnel radiation protection requirements been considered and identified?	Yes	
25.	Have nuclear criticality safety considerations been incorporated?	Yes	
26.	Have necessary features been provided to maintain personnel radiation exposure as low as reasonably achievable?	Yes	
27.	Have requirements for receiving and storing the equipment item been defined?	Yes	
28.	Have any locking devices, that are critical to operation or that will be inaccessible after assembly, been sufficiently evaluated to assure their adequacy?	Yes	
29.	Have human operability been considered?	Yes	
30.	Does the design utilize engineered safety and operational protections to avoid an excessive risk-taking dependence on administrative actions?	Yes	
31.	Is the equipment operable?	Yes	
32.	Has the drawing traceability been provided?	Yes	
33.	Have welding, bolting, joining methods been adequately specified?	Yes	

Project	System/Component	Design Phase	Cognizant Engineer
Item	Review Consideration	Yes/No/NA	Remarks
34.	Does the design match the intended methods of operation of the facility or site?	Yes	
35.	Is the design in compliance with applicable regulatory requirements and/or WMC regulatory commitments?	Yes	
36.	Are the specified materials compatible with each other and the environmental condition to which the material will be exposed?	Yes	

DISTRIBUTION SHEET

To Distribution	From Packaging Safety Engineering	Page 1 of 1
		Date 8/26/94
Project Title/Work Order NRF TRIGA Package Design Review Report		EDT No. 603611
		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
R. R. Ames	N3-13	X			
R. W. Barker	G2-03				X
M. D. Clements	G2-02	X			
R. R. Cruz	G2-03				X
T. A. Delucchi	L6-36	X			
J. O. Dittmer	N1-40	X			
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AUG 26 1994

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 603611

35 Station 21

2. To: (Receiving Organization) Packaging Safety Engineering		3. From: (Originating Organization) Packaging Safety Engineering		4. Related EDT No.: NA	
5. Proj./Prog./Dept./Div.: 84100		6. Cog. Engr.: M. D. Clements		7. Purchase Order No.: NA	
8. Originator Remarks: The purpose of this EDT is to approve the design review material compiled for the review of the NRF TRIGA package. This documents the design review process for the NRF TRIGA package and states the approval of the design.				9. Equip./Component No.: NA	
				10. System/Bldg./Facility: NA	
11. Receiver Remarks:				12. Major Assm. Dwg. No.: H-2-822935, Rev. 0	
				13. Permit/Permit Application No.: NA	
				14. Required Response Date: August 26, 1994	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-TP-DRR-003		0	NRF TRIGA Package Design Review Report	SQ	1	1	

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	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)												(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.		
1	1	Cog.Eng.: MD Clements	<i>M.D. Clements</i>	8/24/94	2-02	RR Ames	<i>R. Ames</i>	8-25-94	N3-13	1	1		
1	1	Cog. Mgr.: JG Field	<i>J.G. Field</i>	8/24/94	2-02	RW Barker	<i>R.W. Barker</i>	8-24-94	G2-03	1	1		
1	1	QA: SB Dutta	<i>S.B. Dutta</i>	8/24/94	6-35	TA Delucchi	<i>T.A. Delucchi</i>	8/25/94	L6-36	1	1		
1	1	Safety: GW Mettlen	<i>G.W. Mettlen</i>	8/24/94	2-03	PC Ferrell	<i>P.C. Ferrell</i>	8/24/94	G2-03	1	1		
1	1	IL Metcalf	<i>I.L. Metcalf</i>	8/24/94	1-40	DB Teachout	<i>D.B. Teachout</i>	8/25/94	T3-04	1	1		
1	1	JO Dittmer	<i>J.O. Dittmer</i>	8/24/94	1-40	MK Ullah	<i>M.K. Ullah</i>	8/26/94	L6-57	1	1		
1	1	GW Lanham	<i>G.W. Lanham</i>	8/24/94	1-40	RR Cruz	<i>R.R. Cruz</i>	8/24/94	G2-03	1	1		
1	1	JW Thornton	<i>J.W. Thornton</i>	8/24/94	2-03								

18. Signature of EDT Originator <i>M.D. Clements</i> 8/24/94		19. Authorized Representative Date for Receiving Organization <i>J.G. Field</i> 8/24/94		20. Cognizant Manager Date <i>J.G. Field</i> 8/24/94		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
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