spec
SOURCE OF QUALITY

January 9, 2015

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U.S. Nuclear Regulatory Commission
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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Director, Division of Spent Fuel Management
Office of Nuclear Material Safety and
Safeguards
Washington DC, 20555-0001

Dear Sirs,

Attached please find the consolidated SAR for the SPEC-300 transport package, USA/9282/B(U)-96 per NRC's request. There is no change to the package design, operating and maintenance procedures other than those already approved by the NRC staff in all of the supplements of the original application and in some clarifications and edits previously approved by staff during the last amendment request of the SPEC-150 package as applicable to the SPEC 300. The SAR includes all previously approved changes from Supplements dated October 6, November 4, November 22 and December 15, 1999; February 29 and March 27, 2000; March 14, 2005; and October 28, 2009.

Drawings 19B000 and B190700 were be revised to reflect previously approved changes. These changes included:

1. B190700: Eliminated recording the QA Classification on the drawing and changed our (internally used) QA Classification to Category B.
2. 19B000: Removed part numbers from parts list.
3. 19B000: Changed drawing fabrication notes to clarify that all welding processes and weld inspection activities for each SPEC-300 will be performed in accordance with the 2007 edition of either the ASME or the AWS welding code.

Should you need any additional information please do not hesitate to contact me.

Sincerely,

Kelley Richardt

Kelley Richardt
Regulatory and Quality Manager

NMSS01

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APPLICATION
for
NRC CERTIFICATE OF COMPLIANCE

Consolidated SAR, 01/09/2015

Model SPEC-300
Type B(U) Radioactive Material Package

Table of Contents

1. GENERAL INFORMATION

1.1 Introduction

The SPEC-300 is a Cobalt-60 industrial radiography device that also serves as a type B transport package. The SPEC-300 is designed for a maximum quantity of 11.1 TBq (300 Ci) of Cobalt-60 in the form of a sealed source. It is anticipated that the SPEC-300 will be transported both domestically and internationally by authorized users in private carriage and by common carriers.

1.2 Package Description

1.2.1 Packaging

Maximum Gross Weight: 354 kg (780 lb)

Materials of construction:
Enclosure: 316/316L stainless steel
Lock box: 316/316L stainless steel
Shield: depleted Uranium, 98% pure with a Titanium or Titanium alloy or zircalloy S-tube.
Foam fill: polyurethane
Nameplates: 316/316L stainless steel
Lock module: Titanium, 316/316L stainless steel, polyacetal resin, bronze, Buna rubber
Lock cap: Titanium, Tungsten, 316/316L stainless steel
Safety plug: 316/316L stainless steel, Tungsten

Materials used as neutron absorbers or moderators: Not applicable. The SPEC-300 is not intended for use with fissionable or neutron-producing materials.

External dimensions: 66 cm (26 in) long, 35.6 cm (14 in) wide, and 38.1 cm (15.0 in) high, 41.9 cm (16.5 in) high including lifting eye blocks.

Cavity size: 13 mm (0.50 in) I.D. S-shaped tube running through the depleted Uranium shield between the lock end and outlet end bulkheads.

Internal structures: Refer to appendix 1.3 for a general arrangement drawing and a shield drawing. The major internal structure is the depleted Uranium shield. The depleted Uranium shield is secured in the SPEC-300 by two supports welded to the lock-end and outlet-end bulkheads. These support the "ears" cast into the shield and transmit reaction forces from the shield to the device enclosure. Four tubular structural posts are welded between the outlet and lock end bulkheads. Attached to these structural posts are a hot top ring support and, on the opposite side, a dome top support. These provide additional shield support. Polyurethane foam fills the void between the depleted Uranium shield and the device enclosure. The foam provides some supplementary support to the depleted Uranium shield although the design of the device is not dependent on this supplementary support. The foam is expected to enhance the thermal performance of the package, particularly during the thermal test, where the foam would significantly reduce radiant heat transfer to the depleted Uranium shield and prevent convective

heat transfer to the depleted Uranium shield. The foam does not provide any significant increase in radiation shielding.

External structures: Refer to appendix 1.3 for a general arrangement drawing. An outlet panel is attached to the outlet-end bulkhead to provide a means of attaching a safety plug to the package. This plug is required for transport. A lock box is attached to the lock end bulkhead. This lock box houses the automatic securing mechanism/lock module and the transport lock. The automatic securing mechanism/lock module employed on the SPEC-300 is interchangeable with the SPEC-150, an Iridium-192 industrial radiography device of which hundreds are currently employed in various industries and environments, and has maintained an excellent safety record.

Receptacles, valves, sampling ports, means of heat dissipation, volumes and types of coolant, outer and inner protrusions: Not applicable. The SPEC-300 is a simple package and these components are not needed.

Lifting and tie down devices: Refer to appendix 1.3 for a general arrangement drawing. Hinged lifting rings are provided on top of the device. These fold down when not in use. They are rated to carry 3 times the weight of the device. Four tie-down holes are provided at the upper corners of the device. Since they could possibly be used to lift the device, they also are rated to carry 3 times the weight of the device.

Pressure relief system: Not applicable. The SPEC-300 enclosure is vented to the atmosphere; a change in ambient pressure would not result in a pressure differential within the device.

Closures: Not applicable. Structural closures of openings are not employed to contain the radioactive material within the packaging.

Means of containment: The primary containment means preventing release of radioactive material is the sealed source capsule, which meets the requirements of special form radioactive material in 10 CFR 71.75. Source assemblies consist of the sealed source capsule swaged onto a flexible cable to which is also swaged two locking balls and a source cable connector. See appendix 1.3 for a general arrangement drawing showing the source assembly.

1.2.2 Operational Features

Features for Securing the Source in the Device:
The source assembly is held in the secured position by the following features:

Automatic securing mechanism housing design:

The locking ball is larger than the hole at the lock end of the automatic securing mechanism housing. This prevents the source assembly from being pulled out of the device toward the lock end even when the source assembly and device locks are not engaged.

The source assembly is automatically secured by the automatic securing mechanism

when it is retracted to the fully shielded position inside the device. This prevents movement of the source assembly toward the outlet end unless the release plunger is in the depressed and latched position.

Source Assembly Lock:

The source assembly is locked in the secured position by the manually operated source assembly lock which prohibits movement of the source assembly in both directions when engaged.

Safety Plug and Lock Cap:

During transportation and storage, the lock cap and safety plug provide additional means to prohibit movement of the source assembly in either direction in the event of an accident.

Transport Lock:

The package is fitted with a transport lock that must be engaged during transport and storage. The transport lock provides another securing method for the source assembly preventing movement in either direction during transport and storage. The design of the source model and transport lock is such that even in a catastrophic accident condition that would be severe enough to cause the lock box to be completely separated from the device, the transport lock would still retain the source assembly in the fully shielded position. The locking ball that engages the transport lock has a higher pull-off strength than the connector at the end of the source assembly. If the lock box were to be separated from the package, the connector at the end of the source assembly would be pulled off, but the source assembly would be retained in the fully shielded position.

Tamper Seal:

The SPEC-300 lock cap is designed to accept a wire tamper seal that secures the lock cap to the lock box. This tamper seal must be removed in order to remove the lock cap. Since the radioactive source assembly cannot be accessed without removing the lock cap, the tamper seal, when intact, provides evidence that the package has not been opened by unauthorized persons.

1.2.3 Contents of Packaging

The contents of the packaging is an industrial radiography source assembly which includes a sealed source capsule which meets the requirements of special form radioactive material stated in 10 CFR 71.75. The Special form capsule contains a maximum output activity of 11.1 tBq (300 Ci) of Cobalt-60, which is also the maximum activity the SPEC-300 is designed to hold. Output activity is determined in accordance with American National Standard N432, issued January 1981, Paragraph 8.1.2, Note 1.

Appendix 1.3

<u>Drawings</u>

CONTROLLED COPY NO

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
1	INCORPORATED ECR #990712-1	7/14/99 7/14/99 7/14/99	RAM PW RCD
2	INCORPORATED ECR # 990930-2	10/1/99 10/5/99 10/5/99	S. BYRD PW RCD
3	INCORPORATED ECR #991103-1	11/3/99 11/4/99 11/4/99	RAM PW RCD
4	INCORPORATED ECR #991122-1	11/22/99 11/22/99 11/22/99	SRB [illegible] RCD
5	SEE MQI	MQI	MQI

Security-Related Information
Figure Withheld Under 10 CFR 2.390

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FINISH NONE	QA CLASS Q-B	

SOURCE PRODUCTION & EQUIPMENT CO., INC.
113 TEAL ST, ST ROSE, LA 70087

GENERAL ARRANGEMENT,
SPEC-300 EXPOSURE DEVICE

SIZE C | DWG NO. 198000 | REV 5

SCALE: NTS | M 00085205 | SHEET 1 OF 8

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APPROVED MQ1	SCALE: 1/2	M 00085205	SHEET 2 OF 8

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SOURCE PRODUCTION & EQUIPMENT CO INC	SIZE C	DWG NO 198000	REV 5
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REV	DESCRIPTION	DATE	APPROVED

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APPROVED MQI	SCALE: 1/2	M 00085205	SHEET 6 OF 8

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REV	DESCRIPTION	DATE	APPROVED

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SOURCE PRODUCTION & EQUIPMENT CO INC	SIZE C	DWG NO 198000	REV 5
APPROVED MQ1	SCALE: 1/2	M 00035205	SHEET 7 OF 8

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REV	DESCRIPTION	DATE	APPROVED

Security-Related Information
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SOURCE PRODUCTION & EQUIPMENT CO INC	SIZE C	DWG NO 198000	REV 5
APPROVED MQ1	SCALE: 1/2	M 00085205	SHEET 8 OF 8

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REV	DESCRIPTION	DATE	APPROVED
1	ECR #990621-6. CHANGED NOTE 2 FROM AN APPROXIMATE WEIGHT OF 500 POUNDS TO A MAXIMUM WEIGHT OF 525 POUNDS.	6/24/99 6/24/99 6/24/99	RAM PW RDD
2	INCORPORATED ECR# 990930-1.	10/1/99 10/6/99 10/6/99	S. BYRD PW RDD
2	INCORPORATED ECR# 991103-2	11/3/99 11-4-99 11/4/99	RAM PW RDD

Security-Related Information
Figure Withheld Under 10 CFR 2.390

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DO NOT SCALE DRAWING

TREATMENT NONE

FINISH NONE

APPROVALS	DATE
DRAWN SJ	1/7/15
CHECKED MQ1	MQ1
ISSUED MQ1	MQ1
DU CLASS N/A	

SOURCE PRODUCTION & EQUIPMENT CO., INC.
113 TEAL ST, ST ROSE, LA 70087

DU SHIELD-
CO-60,
SPEC-300 EXPOSURE DEVICE

SIZE C | DWG NO. B190700 | REV 4

SCALE: 1/2 | M 00058104 | SHEET 1 OF 1

2. STRUCTURAL EVALUATION

2.1 Structural Design

2.1.1 Discussion

The principal structural elements of the SPEC-300 consist of the depleted Uranium shield, shield supports, lock end and outlet end bulkheads, structural posts, and the enclosure.

The depleted Uranium shield is a single solid casting surrounding a small Titanium, Titanium alloy, or zircalloy S-shaped tube. The spherical primary shape of the shield is extraordinarily strong and tough. A SPEC depleted Uranium shield has never been damaged as a result of normal conditions or hypothetical accident conditions testing. The thick "ears" cast into the shield transfer the reaction forces from the shield to the shield supports welded onto the lock-end and outlet-end bulkheads. During hypothetical accident condition testing, the first drop was made at -40° C (-40° F) since depleted Uranium exhibits a ductile-brittle transition at a temperature of about 0° C (32° F). Shielding efficiency was unaffected after the drop.

The shield supports are solid 316/316L stainless steel, continuously welded to the lock-end and outlet-end bulkheads. Copper eutectic barrier strips prevent the shield from contacting the shield supports. A two-component chocking compound fills the gap between the shield supports and the shield "ears".

The lock end and outlet end bulkheads transmit the reaction forces from the shield supports to the package enclosure. The bulkheads are 7.9 mm (0.31 in) thick 316/316L stainless steel, and are continuously welded around the perimeter to the package enclosure cover and base. Welds typically equal the thickness of the thinnest member joined.

The structural posts, made of 316/316L stainless steel pipe, connect the lock-end and outlet-end bulkheads and are continuously welded to both. During a significant impact to the lock-end or outlet-end of the package, the structural posts transfer a portion of the shock load from the loaded bulkhead (the one the shield is reacting against) to the unloaded bulkhead at the other end of the package. This effect was demonstrated during hypothetical accident condition testing. The structural posts are also used to attach the shield hot top support ring and on the opposite side of the shield, the dome top support. Reaction forces from these supports are transmitted through the structural posts to the lock-end and outlet-end bulkheads.

The outer enclosure consists of the enclosure base and enclosure cover. These parts are made from 6.4 mm (0.25 in) thick 316/316L stainless steel and are continuously welded at the two joining seams. The joint design allows for a full penetration weld, including a backing bar in areas where the back side of the weld is inaccessible (between the bulkheads). The lock-end and outlet-end bulkheads are continuously welded to the enclosure base and cover. The result is a monolithic shell that, if not for miscellaneous small penetrations, would act as a pressure vessel. The lock-end and outlet-end bulkheads are recessed, creating a protective flange. Hypothetical accident condition testing proved this protective flange highly effective; the lock box and automatic securing mechanism/lock module were undamaged after four nine meter (30 foot) drops.

2.1.2 Design Criteria

See Appendix 2.10 for the SPEC-300 design criteria matrix.

2.2 Weights and Centers of Gravity

The SPEC-300 weighs a maximum of 354 kg (780 lb). The center of gravity is approximately the geometric center of the package. There are no major subassemblies of any significant weight relative to the total weight of the package.

2.3 Mechanical Properties of Materials

2.3.1 Materials List

316/316L stainless steel:
Yield stress: 206,840 kPa (30,000 psi)
Ultimate stress: 517100 kPa (75,000 psi)
Poisson's ratio: 0.3
Coefficient of thermal expansion: $1.8*10^{-5}$ m/m*degree C ($9.9*10^{-6}$ in/in*degree F)
Data taken from Mark's Standard Handbook for Mechanical Engineers 10^{th} edition.

Depleted Uranium:
Yield stress: 172370 kPa (25,000 psi)
Ultimate stress: 365420 kPa (53,000 psi)
Density: 18.3 g/cm^3 (0.661 lb/in^3) minimum
Coefficient of thermal expansion: $1.1*10^{-5}$ m/m*degree C ($6*10^{-6}$ in/in*degree F)
Data taken from Mark's Standard Handbook for Mechanical Engineers 10^{th} edition.

Two-component chocking compound:
Compressive strength ASTM D695: 1336 kg/cm^2 (19,000 psi)
Temperature Resistance: 100 °C (212 °F)
Data taken from manufacturer's data sheet

Epoxy adhesive:
Temperature Resistance: 120 °C (250 °F)
Compressive Strength ASTM D695: 592 kg/cm^2 (8,420 psi)
Adhesive Tensile Shear ASTM D1002: 180 kg/cm^2 (2600 psi)
Data taken from manufacturer's data sheet

2.4 General Standards for All Packages

The SPEC-300 meets the general standards for all packages in accordance with the provisions of 10 CFR Sections 71.43, 71.45 and 71.47 as demonstrated below:

2.4.1 Chemical and Galvanic Reactions

316/316L stainless steel contacts Titanium in the automatic securing mechanism/lock module of the SPEC-300. Galvanic reaction is not expected since these two metals are relatively close on the electromotive scale and both are cathodic. Other packages produced by SPEC with this material combination have not demonstrated galvanic reaction.

The depleted Uranium shield is prevented from contacting 300 series CRES by the use of Copper pads. These pads also act as a barrier to possible eutectic alloying at elevated temperatures. The shield is subject to corrosion when exposed to moisture. It is protected in the SPEC-300 by a coat of paint and by the closed-cell polyurethane foam completely surrounding it. This protection method has been used on other SPEC designs and has proven adequate, even in offshore applications. A SPEC-150 package was accidentally dropped into the Gulf of Mexico and was recently recovered after being submerged in seawater for several weeks. The package was cleaned, inspected, and returned to service showing no evidence of chemical or galvanic reaction.

2.4.2 Positive Closure

For the purpose of this discussion, "opened" will be defined as release of radioactive material from the source assembly capsule. The primary containment system preventing the direct release of radioactive material from the package is the special form sealed source capsule which can only be opened destructively.

Regarding release of the radioactive source assembly from the package; when configured for transport the SPEC-300 cannot be inadvertently opened. The transport lock is positioned in the locked position and secured by a commercially available padlock. Even if this lock was defeated, a specific sequence of operations must be performed before the source can be removed from the shielded position. Since the equipment required to accomplish this is not readily available to unauthorized persons, and since untrained persons would not know how to use it, inadvertent release of the source assembly from the SPEC-300 is unlikely.

2.4.3 Lifting Devices

See Appendix 2.10 for design criteria and regulatory requirements of lifting devices.
See Appendix 2.10 for a general arrangement drawing of the SPEC-300 showing lifting devices.
See Appendix 2.10 for SPEC-300 design Calculations. This includes design calculations for the strength of lifting devices.

In summary, the lifting eyes and tie-down holes (since it is conceivable that the tie-down points could be used as lifting points) are rated to carry 3 times the weight of the package with a significant margin of safety.

2.4.4 Tiedown devices

See Appendix 2.10 for design criteria and regulatory requirements of tie-down devices.
See Appendix 2.10 for a general arrangement drawing of the SPEC-300 showing tie-down devices.
See Appendix 2.10 for SPEC-300 design Calculations. This includes design calculations for the

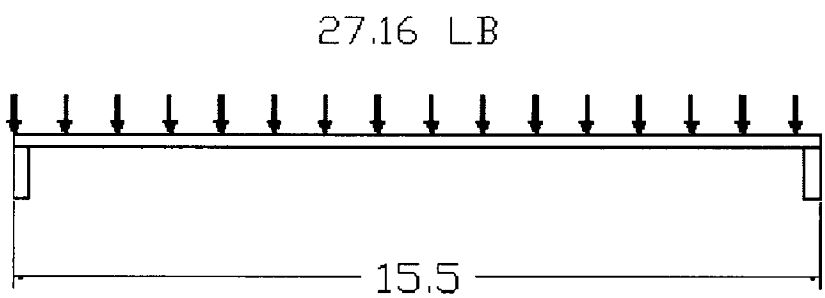
strength of tie-down devices.
In summary, the tie-down holes and lifting eyes (since it is conceivable that the lifting eyes could be used as tie-down points) holes are rated to carry 3 times the weight of the package with a significant margin of safety.

2.5 Standards for Type B Packaging

2.5.1 Load Resistance

A load resistance test was not performed on the SPEC-300. The following analysis considers the enclosure cover as a flexible plate with a uniformly distributed load. The regulation requires a compressive force of 5 times the package weight or 1814 kg (4000 lb) to be uniformly distributed across the top of the package. The SPEC-300 consists of a 6 mm (0.25 in) thick steel housing with 8 mm (0.31 in) thick steel bulkheads. The housing is joined to the bulkheads by continuous (0.25 in) fillet welds. This configuration does not have the potential for failure under the load specified, as proven below:

Cross-sectional view of the SPEC-300 enclosure



The following formulas are taken from Roark's Formulas for Stress and Strain 6th ed., published by McGraw-Hill and copyrighted in 1989:

$$Max\sigma = \frac{-\beta q b^2}{t^2}$$

where:

q = unit load = $\frac{W(5)}{ab} = 27.16$

β = ratio of a / b, (value given in book) for a / b = 1.6) then β =.4872

a = length of the long side = 15.5 in

b = length of the short side = 9.5 in

t = thickness of the material = .25 in

$$\sigma = \frac{-.4872)(27.16)(9.5)^2}{(25)^2}$$

$$\sigma = -19107.51 psi(131 MPa)$$

This stress will not cause the package to fail because the stress is less than 30,000 psi, the yield strength of the steel.

The bottom plate will experience similar loads.

This loading will also cause in-plane stress in the four sides. The long side plates will be the worst case, therefore the other two plates will not need to be analyzed.

This plate is ¼" thick and 15.5" long. Since the load is uniformly distributed across the top of the plate, then each side will only see 1000 lb of downward force.

Therefore the stress is:

$$\sigma = \frac{F}{A} = \frac{1000}{(15.5)(.25)} = 258.06\,psi\,(1.78\,MPa)$$

While this stress will not cause any problems, to be complete, the consideration of buckling must also be analyzed.

Using Euler's formula,

$$Pcr = \frac{\pi^2 EI}{L^2}$$

where:

Pcr = the critical load, that load where the plate will buckle

E = Modulus of Elasticity = $30 \times 10^6\,psi$

I = Moment of Inertia = $\frac{1}{12}a^3b$ (a = .25", b = 15.5")

L = height of the plate = 10.396"

$$\text{Pr} = \frac{\pi^2(30000000)(.021)}{(10.396)^2} = 57531.77\,lbs\,(256\,kN)$$

With the load being applied at 1000 lbs, the device meets the corresponding CFR.

2.5.2 External Pressure

An external pressure test was not performed on the SPEC-300 containment vessel. The SPEC-300 containment vessel is the special form capsule. This capsule consists of a cylindrical welded

316/316L stainless steel capsule with a minimum wall thickness of 0.8 mm (0.030 in). The capsule must resist a 172 kPa (25 lb/in^2) external pressure. For this exercise, the capsule is considered to be a thick walled vessel under uniform external loading.

Maximum circumferential stress is calculated as:

$$MaxCircumferentialStress = -Pressure \times 2 \times Outsidediameter^2 \div Outsidediameter^2 - Insidediameter^2$$

$$MaxCircumferentialStress = -172000Pa \times 2 \times 0.010^2 M^2 \div 0.010^2 M^2 - 0.008^2 M^2$$

Maximum Circumferential Stress = -956 *KPa* (-138 *lb/inch*^{2})

Maximum radial stress is calculated as:

Max Radial Stress = -pressure

Maximum Radial Stress = -172 *KPa* (-25 *lb/inch*^{2})

These stress levels are negligible.

Equations taken from Roark's Formulas for Stress and Strain, 6th edition, page 638, table 32.

2.6 Normal Conditions of Transport

The SPEC-300, when subjected to the normal conditions of transport specified in 10 CFR part 71, meets the standards specified in paragraph 71.35 of 10 CFR part 71, as demonstrated in the following paragraphs.

10 CFR 71.71(c) requires consideration of heat input due to insolation and maximum ambient temperature. This regulation ensures that the stresses in the material that are caused by temperature changes will not allow the package to fail any of the Normal Conditions tests.

To determine the stress caused by insolation, the temperature effects of insolation must first be considered. These calculations were performed by a finite element analysis program. The program utilized for this application is EMRC NISA II Version 7.0, a product of EMRC, Troy, Michigan. Benchmark and verification problems for these types of analysis are numerous and are provided in the software documentation. In addition many aerospace companies such as Boeing, Primex, Rocket Research, Pacific ElectroDynamics, GTE Astrospace, and thousands of other commercial companies use NISA as their primary analysis code so the reliability of the software is well proven. The model was meshed using a structured meshing technique, Display III, a proprietary product of EMRC, Troy Michigan. Localized adjustments were made to improve the mesh accuracy, such as the area where the structural posts join to the bulkhead. The model uses 8 node brick elements to model the structure, and was "skinned" with 4 node plate elements of thickness 2.5 e-5 mm (1.0 e-6 in). The model was "skinned" in order to simplify the application of the convection coefficients, and to facilitate surface

radiation and view factor calculations. The types of analysis performed on the structure include non-linear steady state thermal analysis, non-linear transient thermal analysis, and linear static and thermal stress analysis. No corners were rounded out in the modeling and the welds were modeled as full penetration continuous welds without including the effect of the fillet area. This results in a conservative stress result. Several features were not included in the analysis to simplify the modeling. These include the lock box, and several small round bolt-holes, which were considered insignificant. The mechanical and thermal properties were obtained from matweb, an online materials database, www.matweb.com for AISI Type 316 stainless steel. Those properties were:

CTE	16.2 um/m-°C (9 uin/in-°F)
Heat capacity	0.5 J/g-°C (.12 BTU/lb-°F)
Thermal Conductivity	16.3 W/M-°K (113 BTU-in/hr-ft^2-°F)
Young's Modulus	193 Gpa (28 ksi)
Poisson's Ration	.3
Density	8 g/cc (.289 lb/in^3)
Yield Strength	290 MPa (42.05 ksi)
Ultimate Strength	580 MPa (84.1 ksi)

The absorptivity value, .37, was obtained from JP Holman, Heat Transfer, 5th ed., McGraw-Hill, 1981. Another value for absorptivity of .28 was found in Marks Handbook for Mechanical Engineers, however the high value was used in order to be conservative.

The finite element program used includes a check in the solver during the solution generation. The check revealed no convergence errors, warnings, or anomalies. This concludes that the model was properly prepared and represents the best possible solution to this model, and gives a high degree of confidence that the model is not inordinately sensitive to a small change in any input parameter.

To determine the temperature changes in the package, the time required to reach steady state conditions must be determined. The derivation of the temperature profile is obtained through finite element analysis. Figure 1 is a graphical representation of temperature versus time for insolation at 38 °C (100 °F). From this graph, it can be seen that steady is reached in approximately 5 hours. Figure 2 is a graphical representation of temperature versus time for insolation at -29 °C (-20 °F) ambient. This graph also depicts that it takes 5 hours for the package to reach steady state.

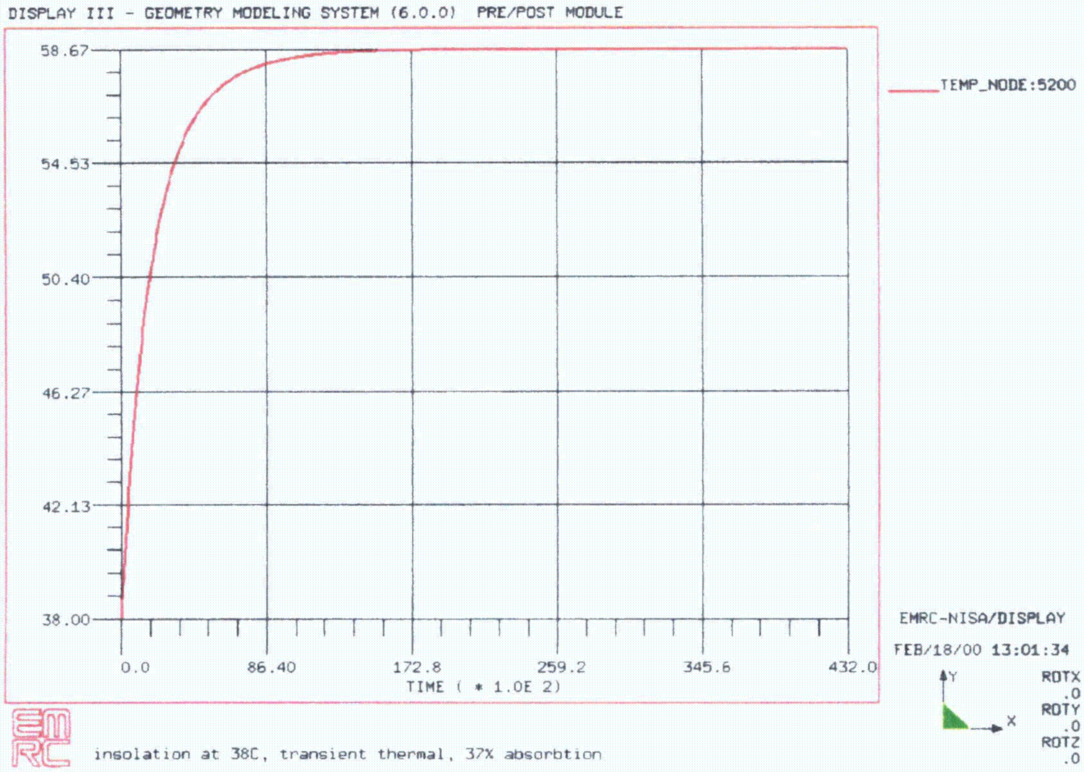


Figure 1

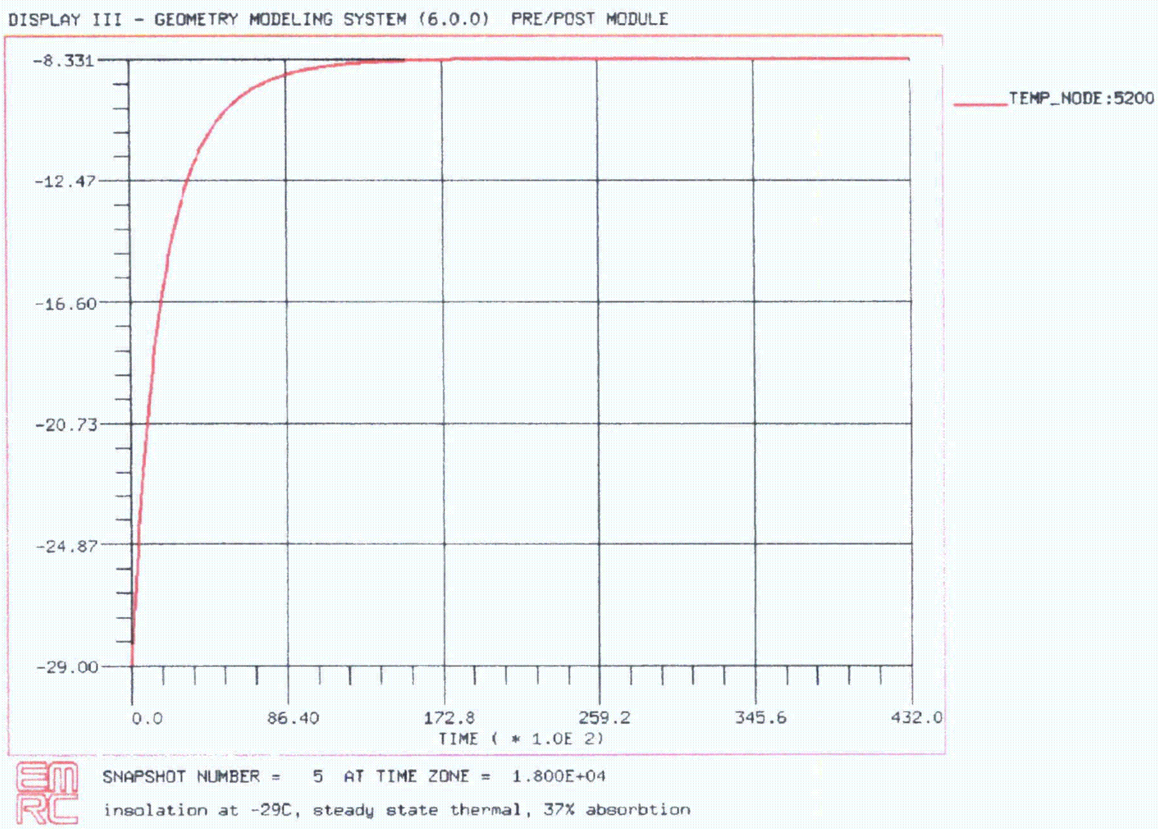


Figure 2

After the package reaches steady state, the maximum temperature of the package was determined for each loading condition. The first loading condition was insolation with an ambient temperature of 38 °C (100 °F). Figure 3 and 4 show the temperature distribution across the package when the package is subjected to insolation. Figure 3 is the temperature distribution after one hour, while figure 4 is the temperature distribution after five hours. (Figure 4 also represents the steady state condition). The maximum temperature of the package under these conditions is 58.67 °C (138 °F). The location of the maximum temperature occurs directly in the middle of the package.

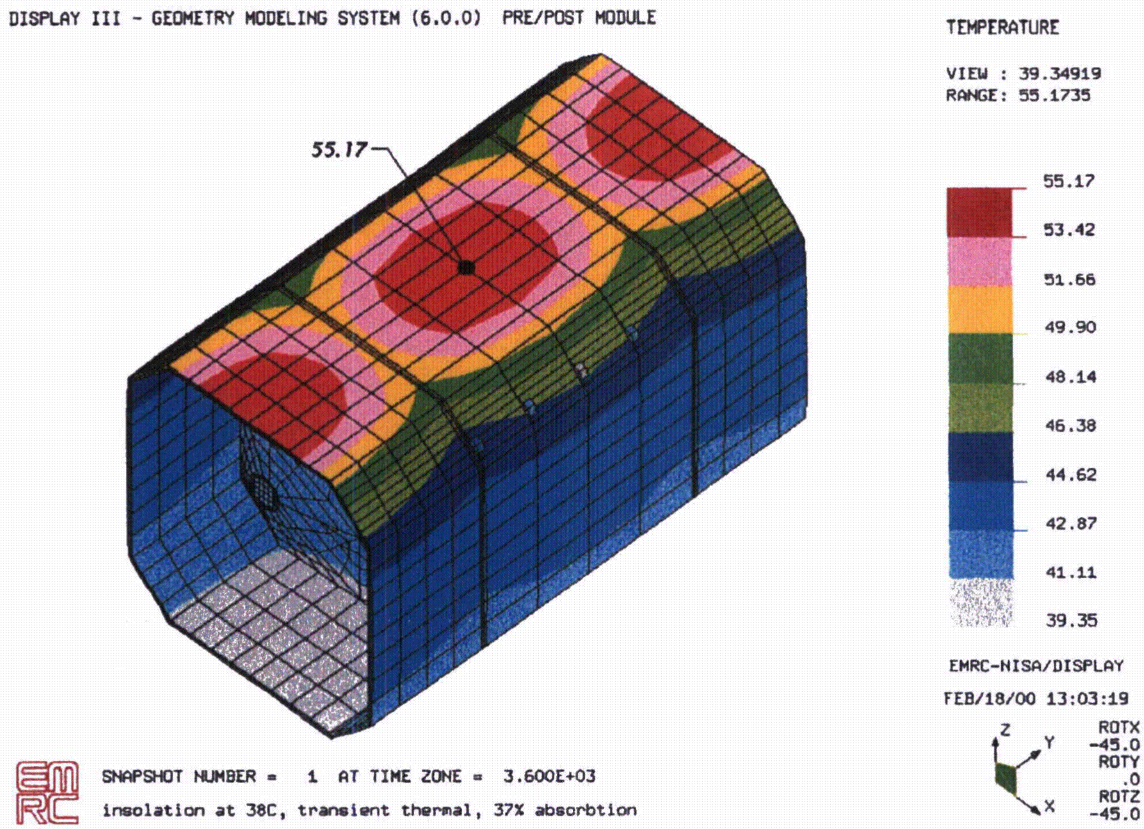


Figure 3

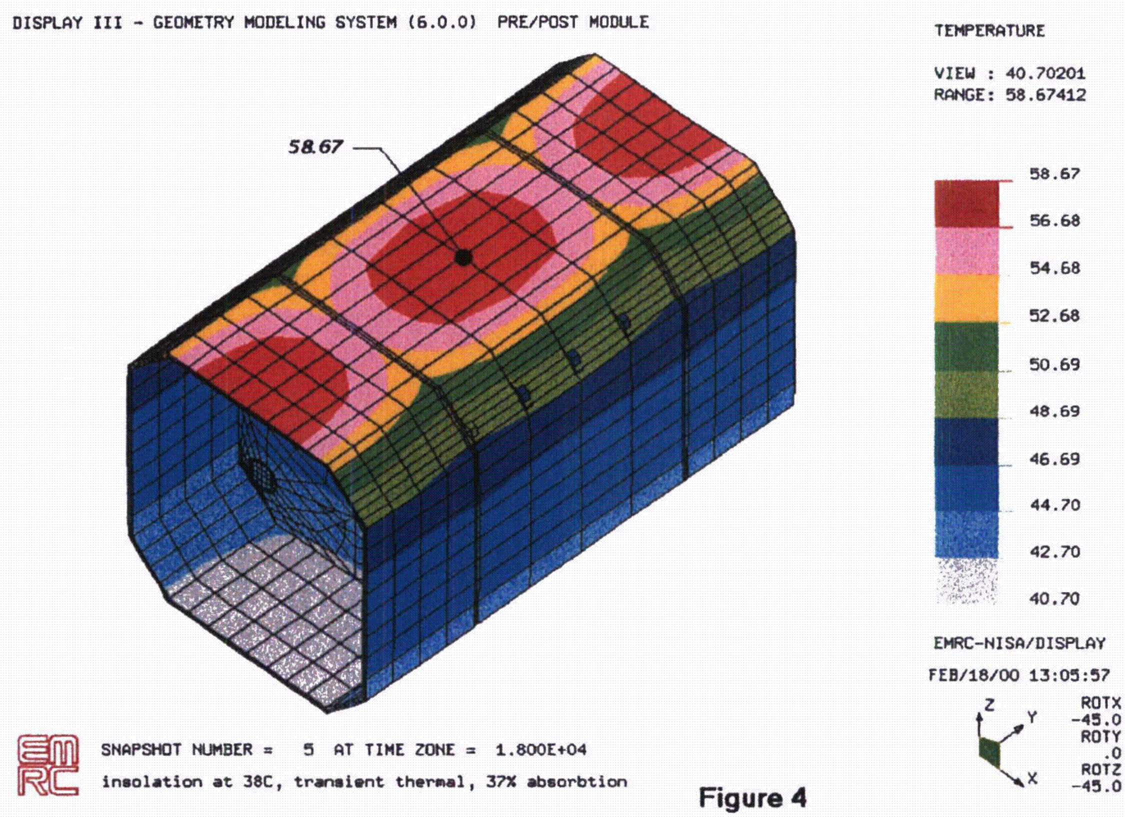


Figure 4

The second loading condition was insolation with an ambient temperature of -29 °C (-20 °F). Figure 5 and 6 show the temperature distribution across the package when the package is subject to the insolation load. Figure 5 is the temperature distribution after one hour, while figure 6 is the temperature distribution after five hours. (Figure 6 also represents the steady state conditions). The maximum temperature of the package under these conditions is -8.32 °C (17 °F). The location of the maximum temperature occurs directly in the middle of the package.

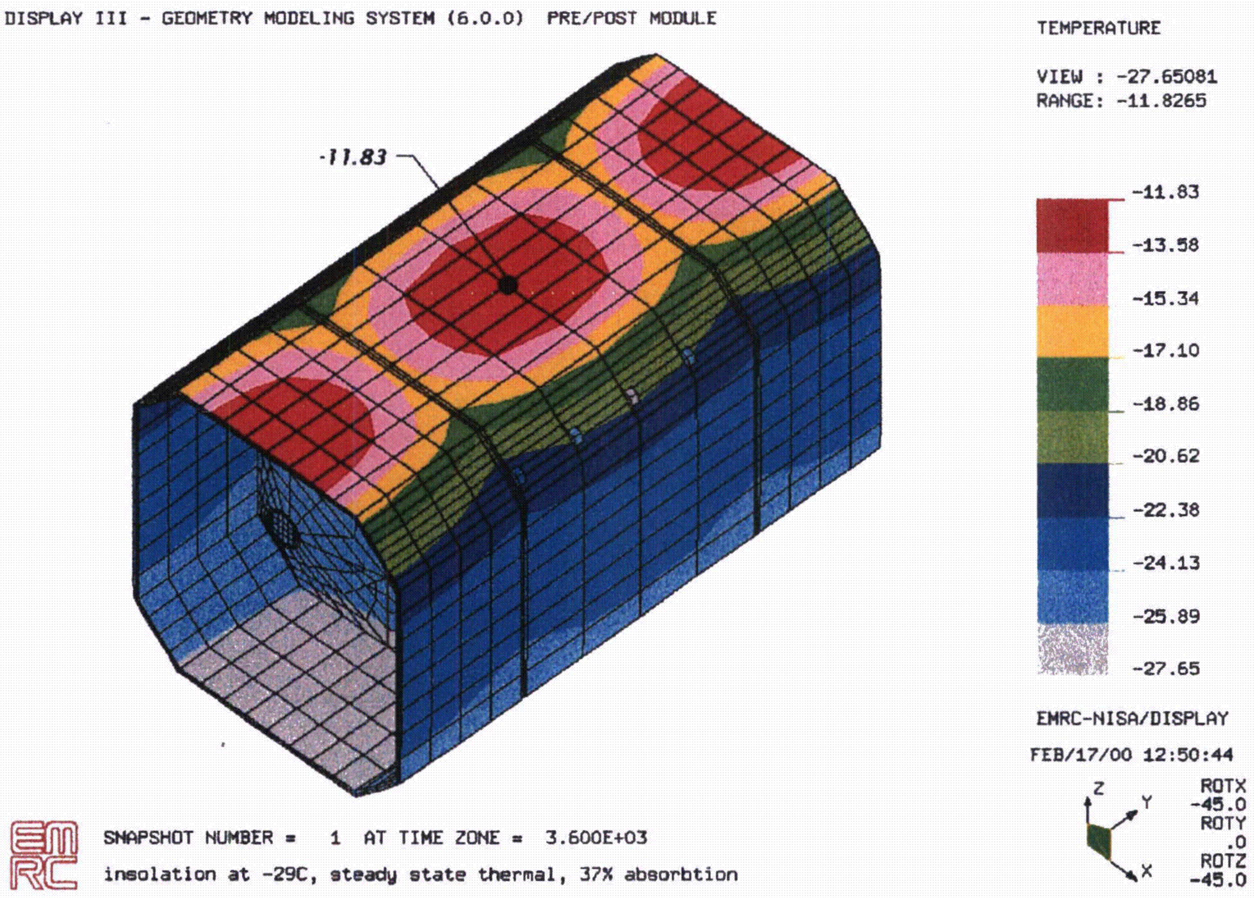


Figure 5

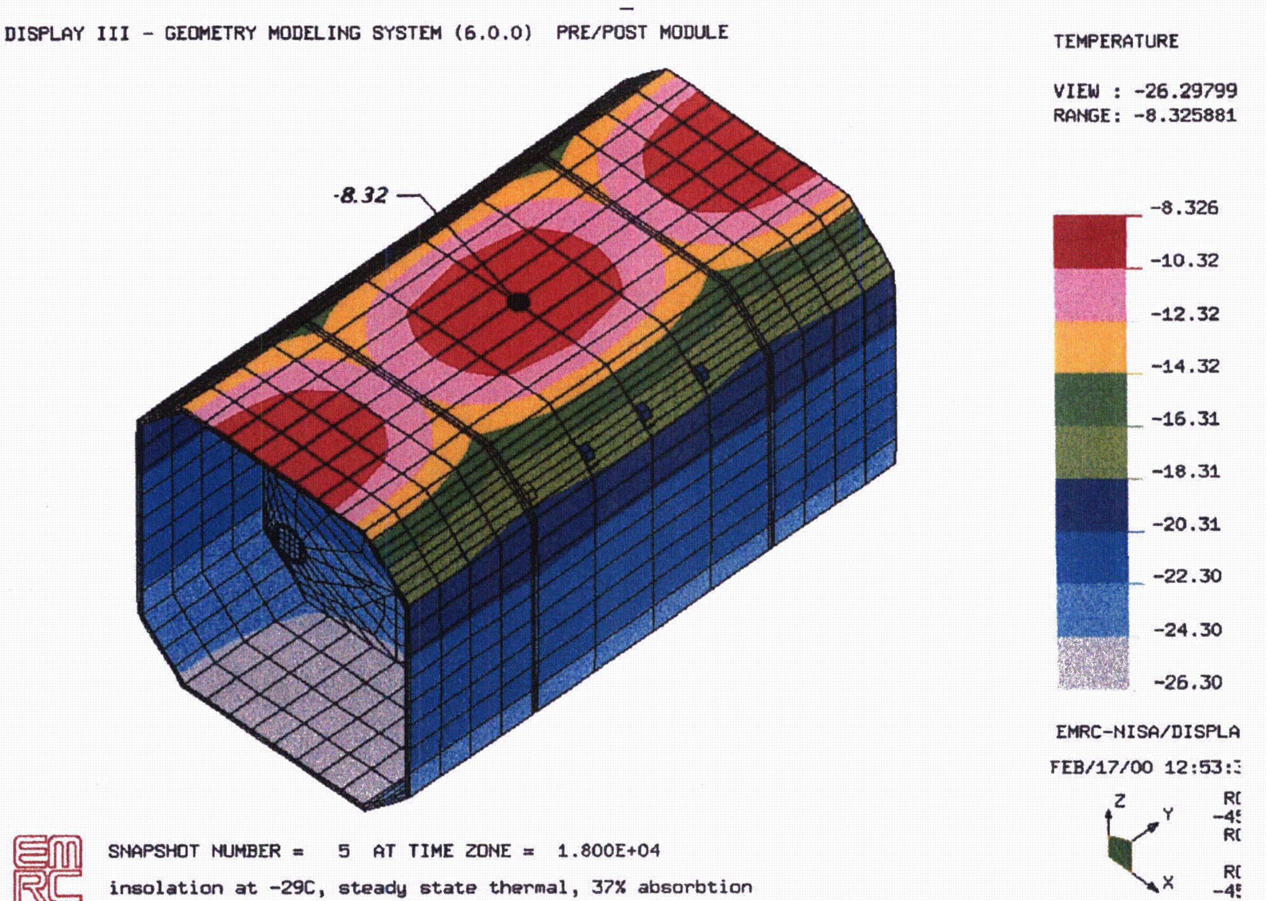


Figure 6

Once the temperature distribution is calculated, thermal stress on the package can be evaluated. Finite element analysis is also used to determine these stresses. The stresses shown are for both the package and the internal structure of the package. This analysis is done for both 38 °C (100 °F) and -29 °C (-20 °F) ambient temperature. The evaluation includes stress calculations at 1 hour intervals until steady state is achieved.

For the -29 °C (-20 °F) and 38 °C (100 °F) ambient temperatures, the maximum stress on the outside of the package occurs on the bottom flange near the ends. See figures 7 and 8 for the first hour at 38 °C (100 F°) and figures 9 and 10 for the first hour at -29 °C (-20 °F). See figures 11 and 12 for the last hour at 38 °C (100 °F) and figures 13 and 14 for the last hour at -29 °C (-20 °F). The reason the highest stresses are on the bottom and not the top where the high temperatures exist is due to expansion of the hotter parts. The hotter an area, the more it will expand. The cooler areas will not expand as much as the hotter areas; however, the cooler areas are constraining the hotter areas. This phenomenon causes the cooler areas to carry more load, thus having more stress. The maximum stress value is approximately 712 MPa (103 ksi) on the bottom edge of the flange in figure 12. This high stress is extremely localized. Also, the finite element analysis performed on this was linear, meaning any values over the yield strength of the material are not appropriate to consider. If the stress values were to reach the yield limit, the material would deform slightly and relieve the stress. This high stress is also located in a non-critical area. The highest stress in the weld between the bulkhead and the enclosure shown on figure 11 is only 94 Mpa (13 ksi). This is well below the yield limit for stainless steel.

The values calculated for this stress analysis are conservative due to the nature of the analysis; for example, the analysis does not consider any of the components inside the package. The components inside the package will absorb some of the heat and lower the stresses generated.

The finite element analysis for insolation of the SPEC-300 reveals that there will not exist an adverse condition due to insolation. The stresses generated by the thermal load will not affect the package's ability to function properly.

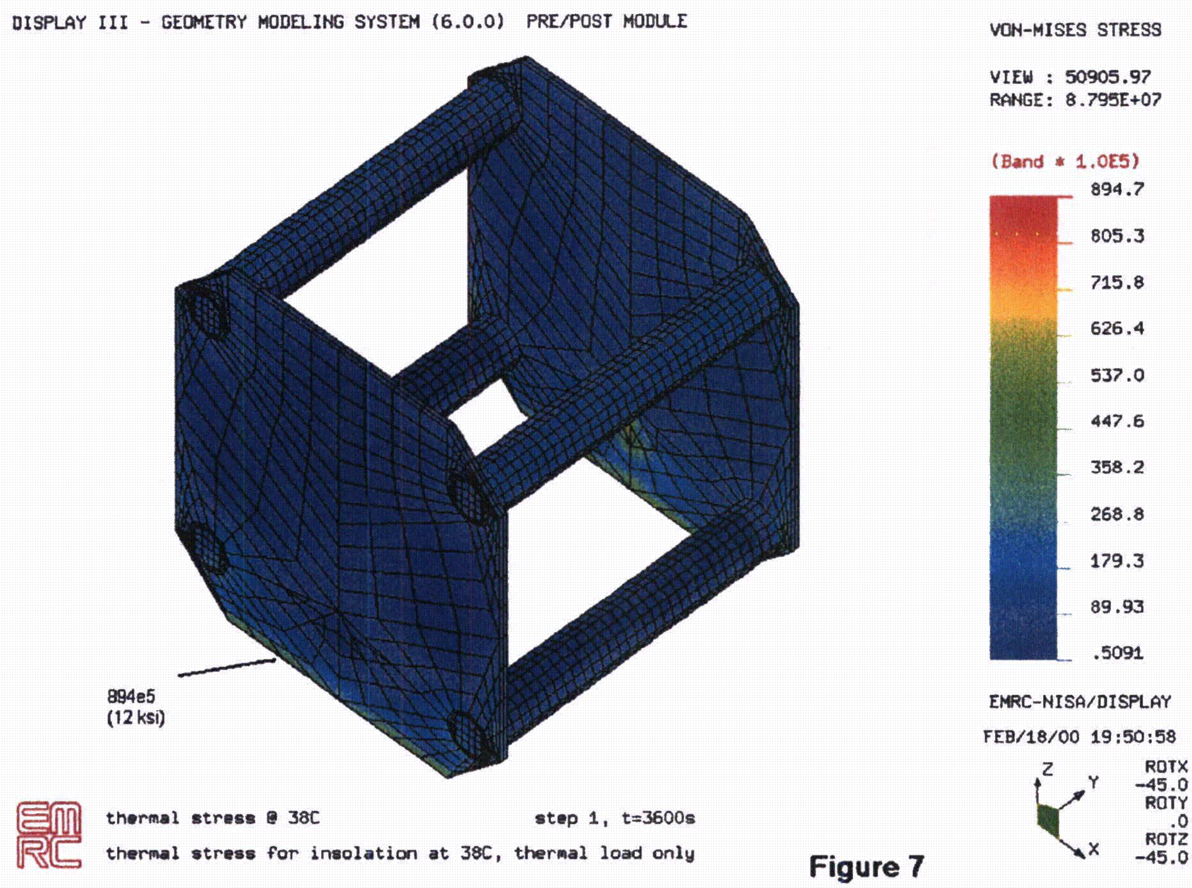


Figure 7

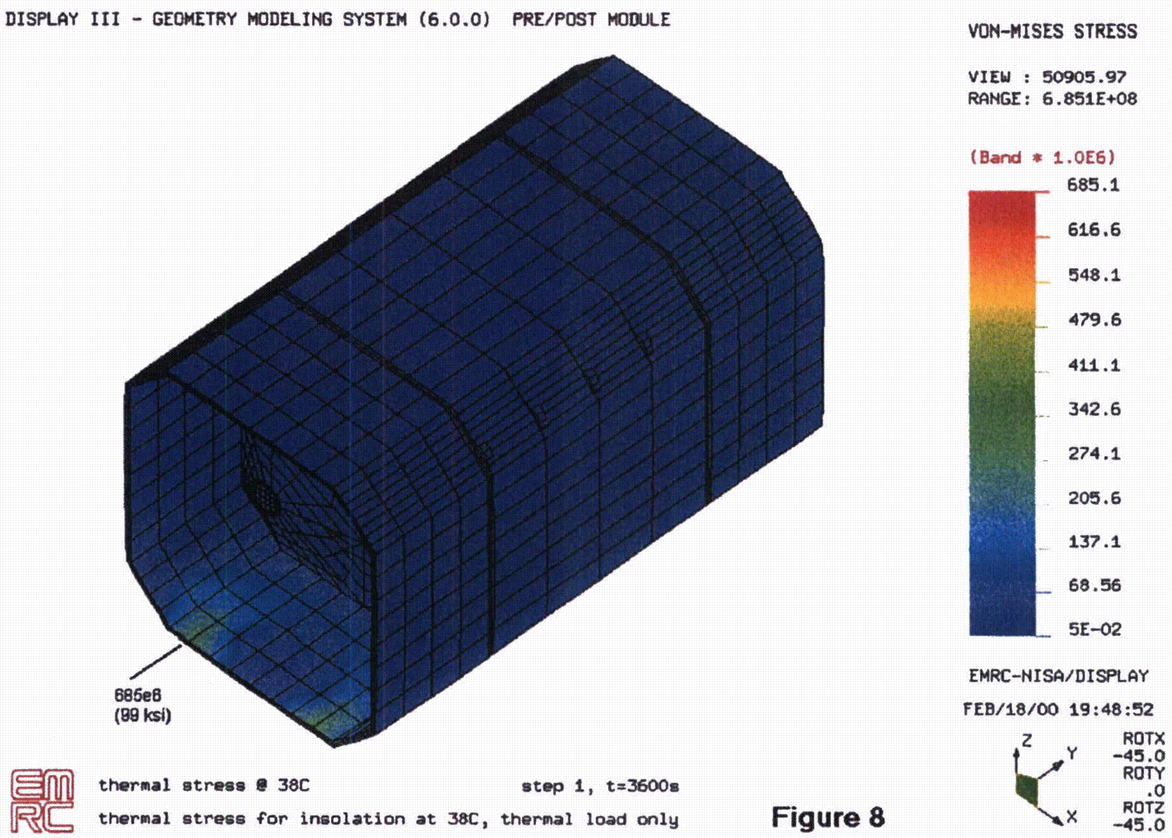


Figure 8

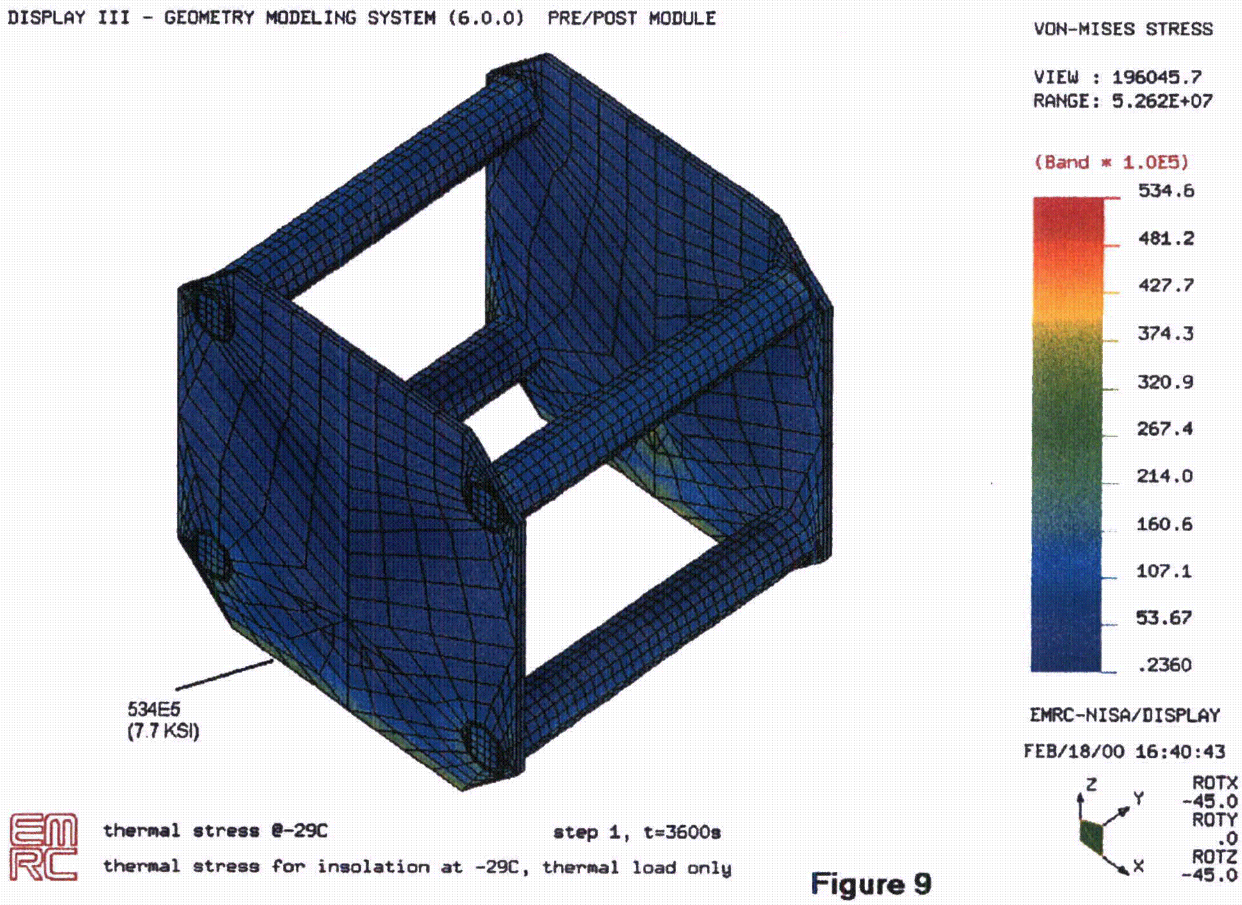


Figure 9

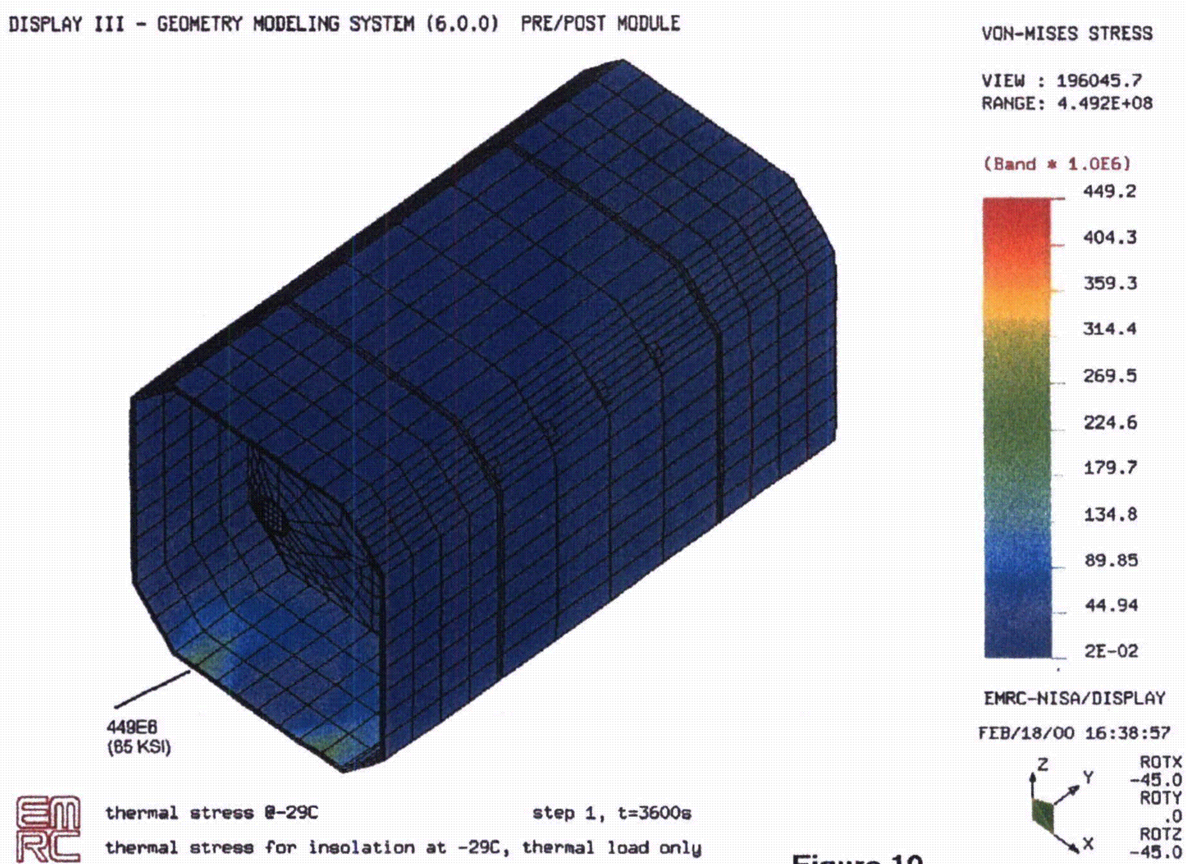


Figure 10

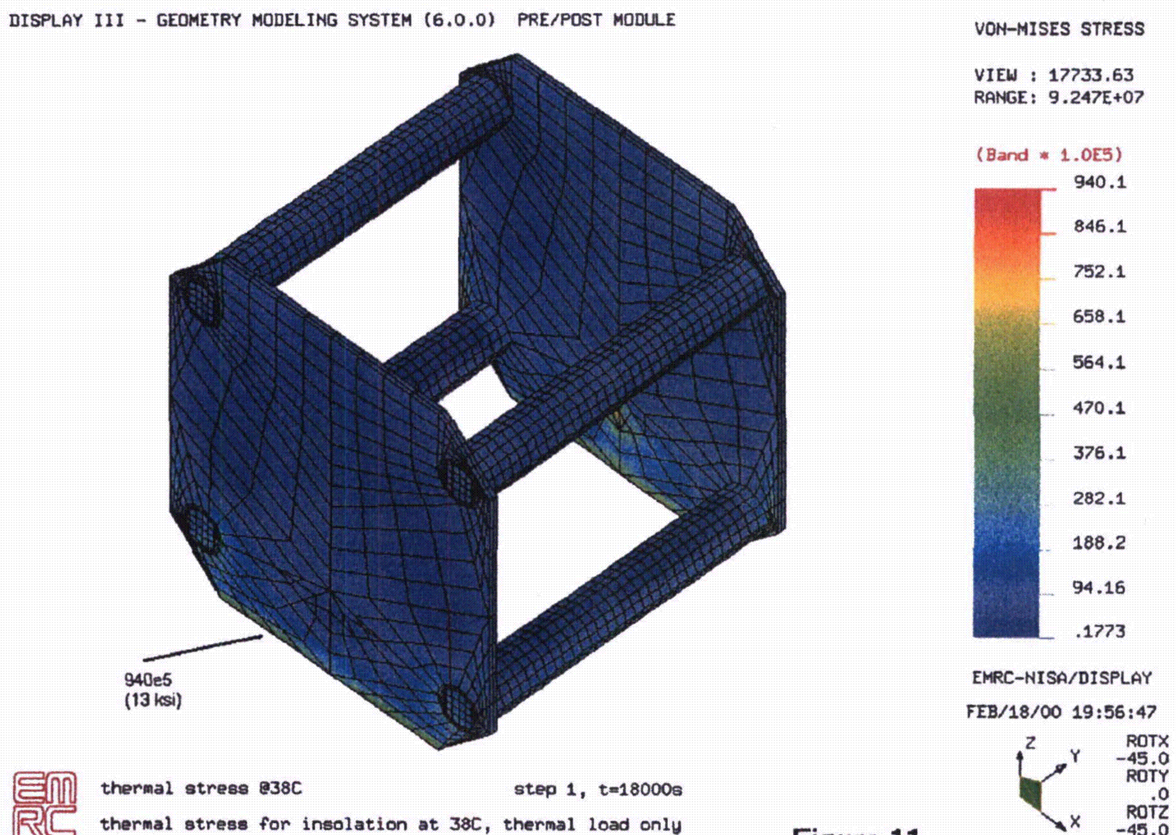


Figure 11

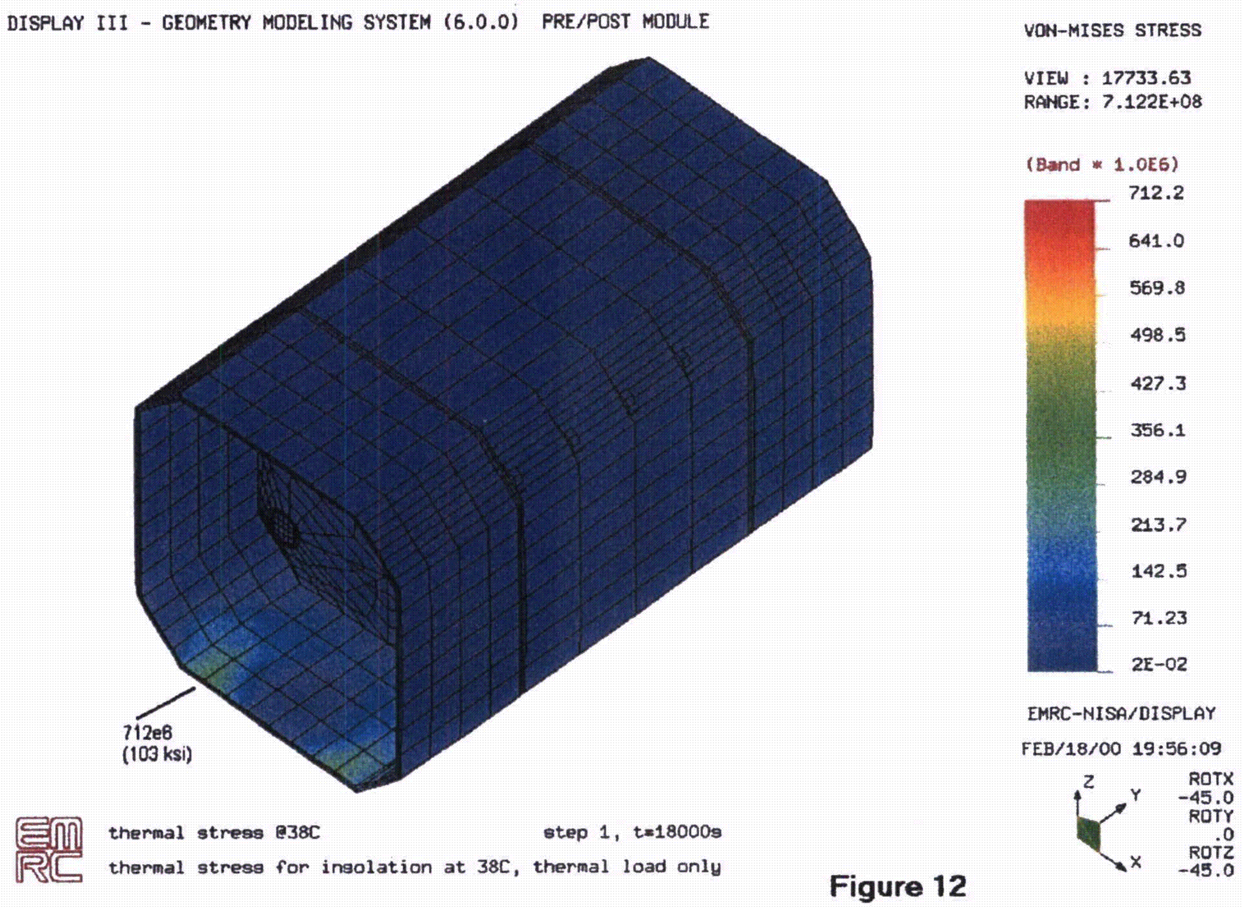


Figure 12

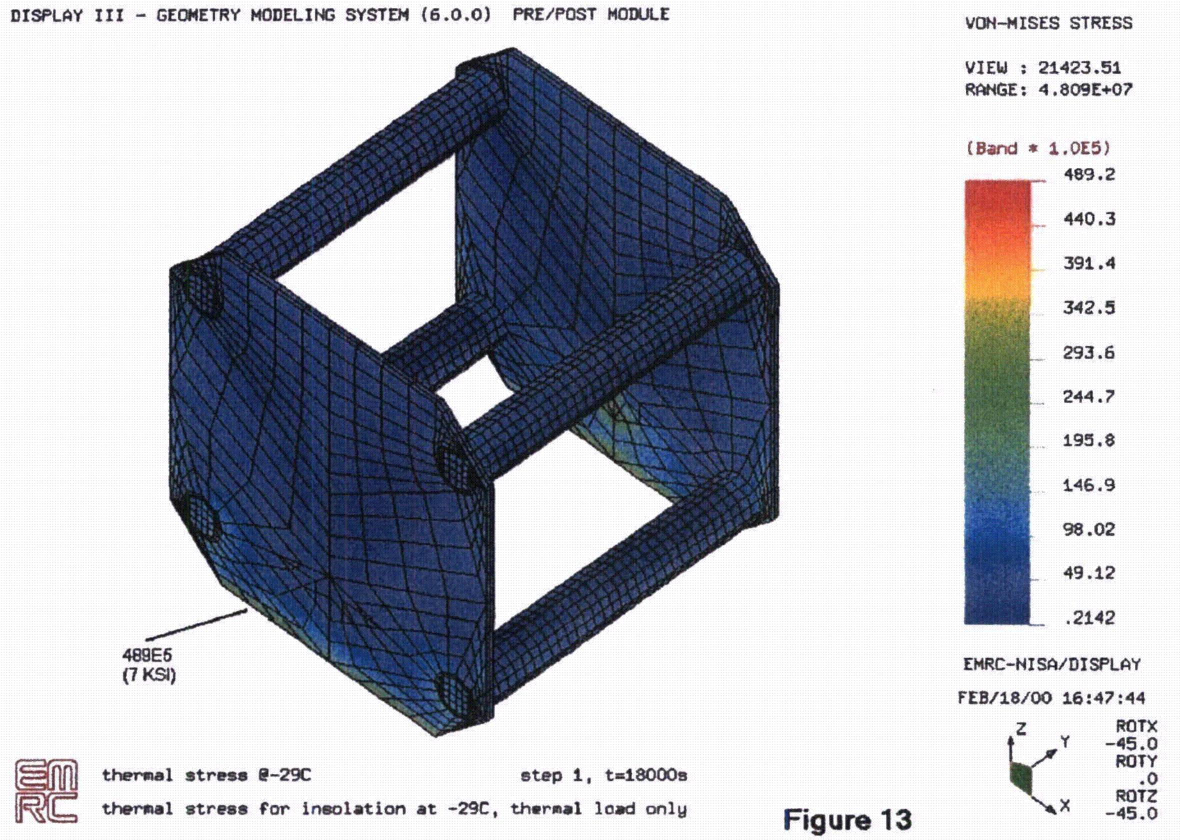


Figure 13

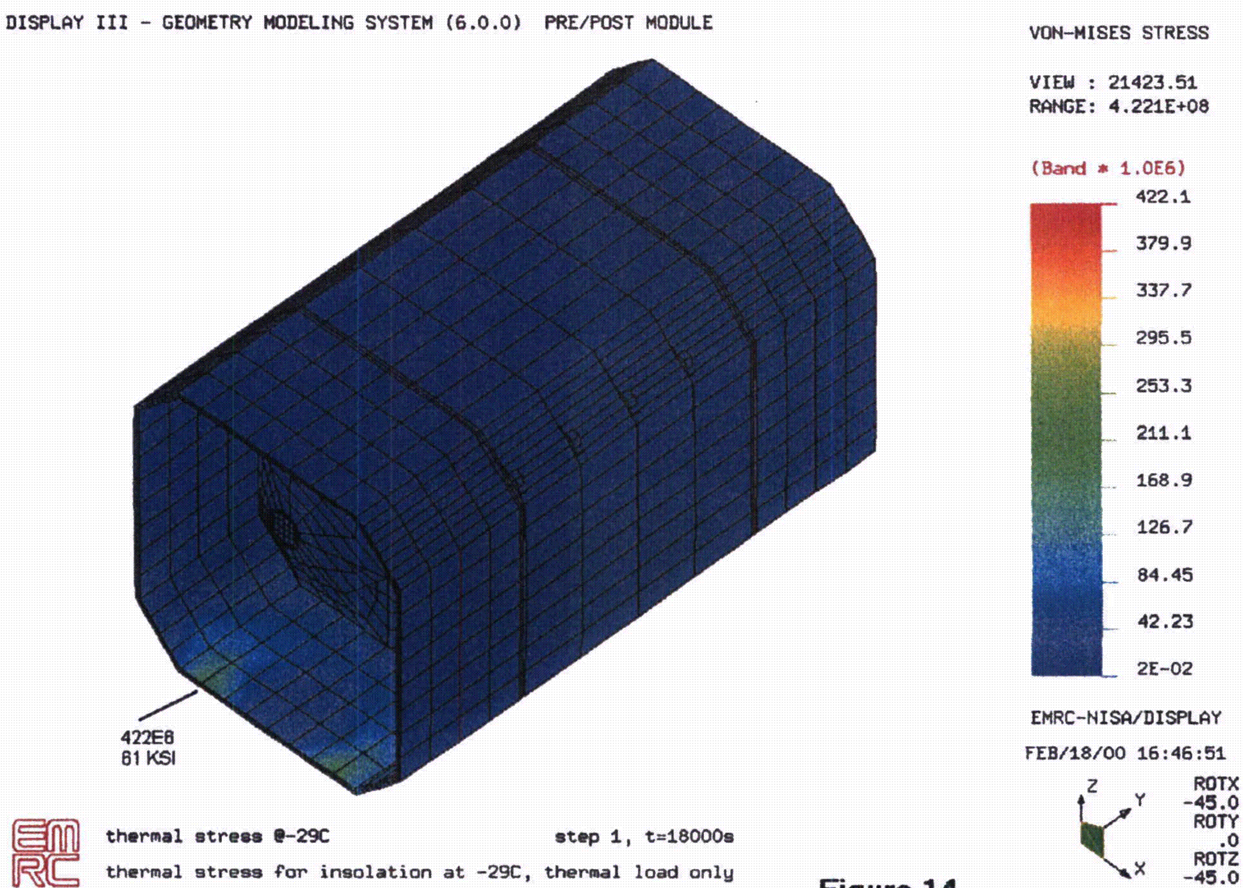


Figure 14

2.6.1 Heat

The thermal evaluation for the heat test is reported in section 3.4.

2.6.1.1 Summary of Pressures and Temperatures

Approximate temperature at which the package was constructed: 27°C (80°F)
Minimum operating temperature: -40 deg.C (-40 deg.F) per 10 CFR 71.71 (c) (2)
Maximum operating temperature: +66 deg.C (+150 deg.F) per SPEC criterion
Minimum operating pressure: 25 kPa (absolute) (3.5 psia) per 10 CFR 71.71 (c) (3).
Maximum operating pressure: 140 kPa (absolute) (20 psia) per 10 CFR 71.71 (c) (4).

2.6.1.2 Differential Thermal Expansion.

The SPEC-300 enclosure is made of 316/316L stainless steel. The shield is made of depleted Uranium. The coefficient of thermal expansion of these two materials differs slightly. The only possible significant result of this is a binding condition at low temperature if the enclosure shrinks more than the shield. This is calculated below. The shield is 350mm (13.875 in) long. The thermal expansion coefficients in the equations below are for 316/316L stainless steel and for depleted Uranium, respectively.

$$\Delta ThermalExpansion = \Delta Temperature \times \Delta CoefficientOfThermalExpansion$$

$$\Delta ThermExp = 350mm \times (27°C - (-40°C)) \times (1.8 \times 10\text{-}5\ mm/mm \times °C) - (1.1 \times 10\text{-}5\ m/m \times °C)$$

$$\Delta ThermExp = -0.16mm\ (-0.006inch)$$

This differential thermal expansion is negligible.

2.6.1.3 Stress Calculations

During normal conditions, the only significant stress is bearing stress of the depleted Uranium shield resting on the two shield supports welded to the lock-end and outlet-end bulkheads. The interface between the shield and the shield support is filled with a two-component chocking compound, a material intended for this purpose. Contact area for each of the two supports is approximately 10.5 cm^2 (1.6 in^2) for a total contact area of approximately 21 cm^2 (3.2 in^2). The two-component chocking compound has a compressive strength of 1336 kg/cm^2 (19,000 psi). Bearing stress can then be calculated as:

$BearingStress = 238kg / 21cm^2$

$BearingStress = BearingLoad / BearingArea$

$BearingStress = 11kg/cm^2$ $(156lb/inch^2)$

2.6.1.4 Comparison with allowable stresses.

The bearing stress is orders of magnitude below the compressive strength of the material it rests on. This analysis was based on the worst case orientation of the SPEC-300; that is, the orientation where the weight of the shield bears on the smallest area. This happens to be the normal orientation of the package, with the lifting rings at the top.

2.6.2 Cold

The test at an ambient temperature of -40° C (-40° F) in still air and isolation was not performed because the materials and methods of construction would not be adversely affected in a manner that would cause a loss or dispersal of the radioactive contents or a loss of shielding integrity. A greater than 20% increase in the radiation level at any external surface of the package would not be expected. Incidentally, as part of the preparation for the first hypothetical accident condition 9 m (30 ft) free drop test, the SPEC-300 was chilled in dry ice to a temperature below -40° C (-40° F). No adverse effect resulted either before or after the free drop test.

The effects of cold were considered during the design of the SPEC-300. The 316/316L stainless steel chosen for the package enclosure is a face centered cubic metal. Metals of this type are preferred for cryogenic equipment because they do not exhibit a ductile to brittle transition at low temperatures. In general, the mechanical properties of these materials improve with lower temperatures:

-Young's modulus at 22°K (-420° F) is 5% to 20% greater than at 294° K (69.5° F).

-Yield strength at 22°K (-420° F) is considerably greater than at 294° K (69.5° F).

-Fatigue properties at low temperatures are also improved.

This information was taken from Mark's Mark's Standard Handbook for Mechanical Engineers 10th edition, Page 19-32, 33.

The depleted Uranium shield does exhibit a ductile to brittle transition at approximately 0° C (32°F). For this reason the SPEC-300 was chilled in dry ice to a core temperature below -40° C (-40° F) prior to and during the first 9 m (30 ft) free drop test. A radiation survey performed after this test showed no measurable increase in radiation levels, indicating no significant damage to the shield. Incidentally, three additional 9 m (30 ft) free drop tests were subsequently performed. Had fracture or other damage related to the ductile to brittle transition occurred during the first free drop, it is likely the remaining three free drop tests would have caused some increase in post-test radiation levels. This did not occur.

Information relating to the ductile to brittle transition temperature of depleted Uranium was taken from Physical Metallurgy of Uranium Alloys, Proceedings of the Third Army Materials Technology Conference, Held at Vail, Colorado, February 12-14, 1974. Sponsored by Army Materials and Mechanics Research Center, Watertown, Massachusetts. Pages 315-317.

Effect of freezing liquids:
Not applicable. There are no liquids present in the SPEC-300 under normal conditions.

2.6.3 Pressure

The enclosure of the SPEC-300 is vented to the atmosphere. Venting of the SPEC-300 enclosure occurs through the hollow bodies of 20 rivets distributed among the top, left, and right sides of the packaging. Each of these rivets has an open internal diameter of approximately 2mm (0.080 in), for a cumulative vent area of approximately 65 mm^2 (0.1 in^2). The mandrels in the rivets are driven out after installation to ensure that each rivet acts as a vent. Even though the package is vented through the rivet holes, a finite element analysis was performed treating the package as a sealed container. The input parameters for the finite element analysis are given in section 2.6. The analysis considered the effects of insolation at -29° C (-20° F) and 38° C (100° F) with reduced and increased external pressure as specified in 10 CFR Part 71.71(c)(3) and 10 CFR Part 71.71(c)(4). This analysis assumed that the package did not vent through the rivet holes.

Figures 15 and 16 show the stresses generated from insolation and pressure at an ambient temperature of 38 °C (100 °F) with increased external pressure. The maximum stress generated, 712 MPa (103 ksi), occurs at a very localized area on the very edge of the enclosure cover flange as seen in figure 16. This high stress is extremely localized. Also, the finite element analysis performed on this was linear, meaning any values over the yield strength of the material are not appropriate to consider. If the stress values were to reach the yield limit, the material would deform slightly and relieve the stress. This high stress is also located in a non-critical area. The

highest stress in the weld between the bulkhead and the enclosure, shown on figure 11, is only 94 MPa (13 ksi). This is well below the yield limit for stainless steel. The stress generated with an increased pressure with insolation at 38 °C (100 °F) is similar to the stress generated with an insolation temperature of -29 °C (-20 °F). Since the stress generated is similar, the graphs and discussion for ambient insolation at -29 °C (-20 °F) with the addition of pressure are not included.

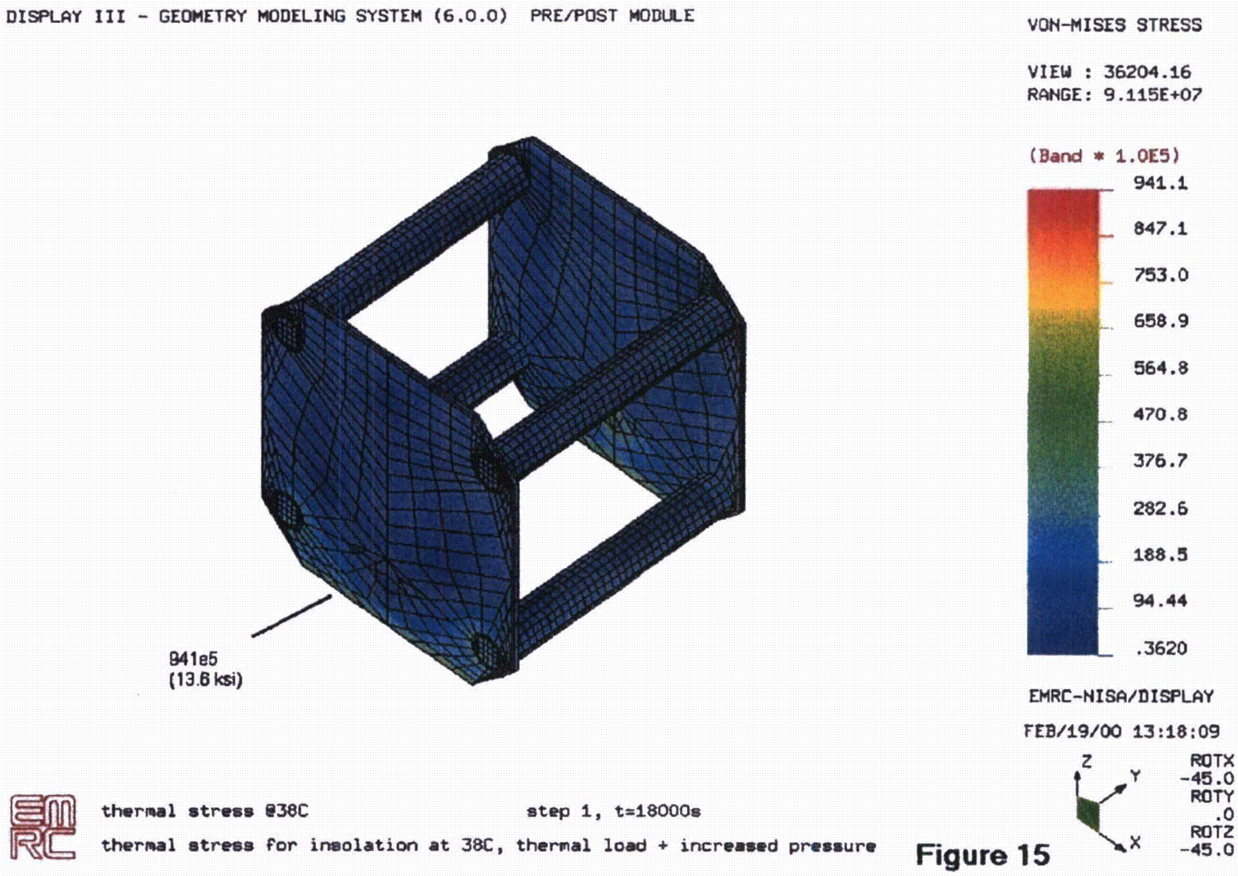


Figure 15

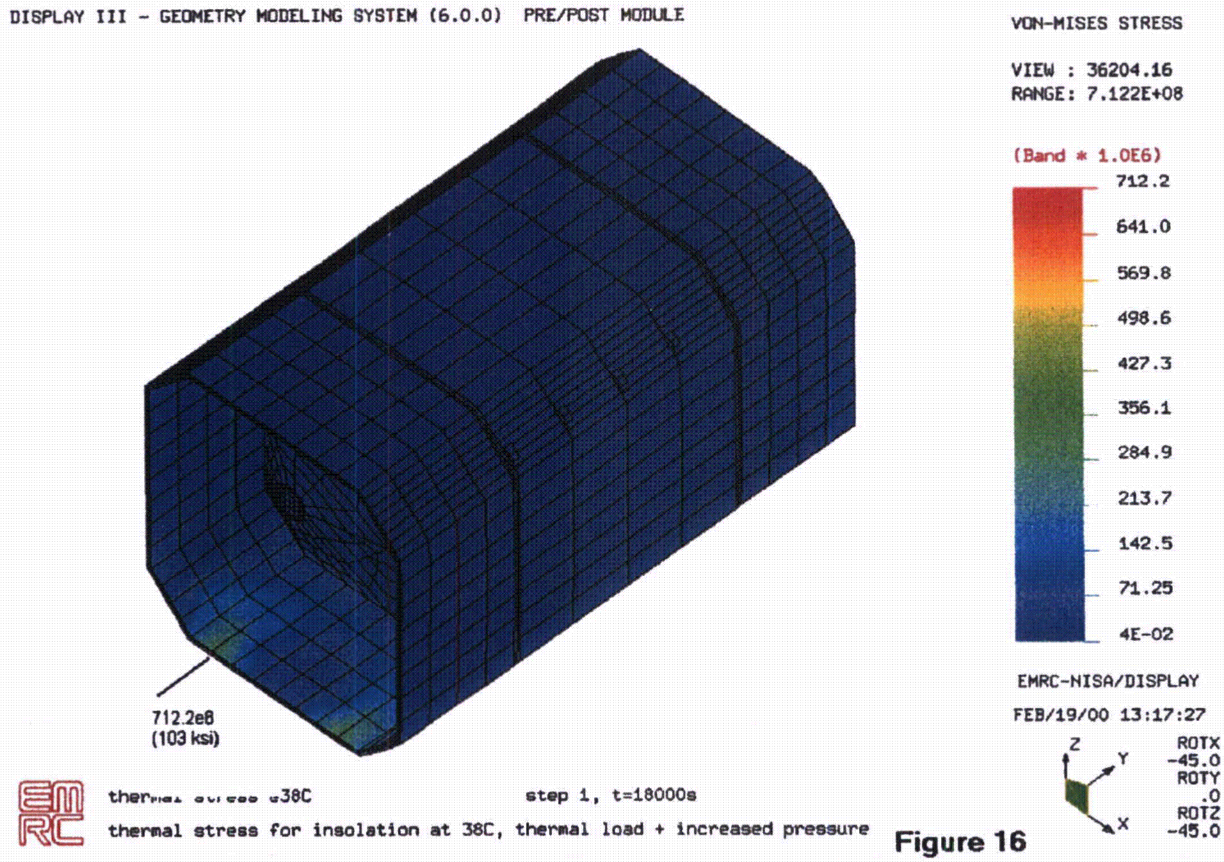


Figure 16

Figures 17 and 18 consider a reduced pressure with an ambient insolation temperature of 38 °C (100 °F). In this condition the maximum stress generated is approximately 712 MPa (103 ksi). This high stress is located at the very edge of the outer enclosure cover. This stress does not present a problem for the package because it is extremely localized in only one node of the package. The highest stress in the weld area is only 95 MPa (14 ksi). This stress value is located approximately in the center of the bottom edge on the bulkhead. This value is much lower than the yield strength of the material, and thus would not have an adverse effect on the package. This loading situation uses the same assumptions as before. Since the stresses generated for reduced pressure at an ambient insolation temperature of 38 °C (100 °F) are similar to those with an ambient insolation temperature of -29 °C (-20 °F), the results for the -29 °C (-20 °F) insolation are not included in this application.

The finite element analysis for insolation with increased and reduced pressure of the SPEC-300 reveals that there will not exist an adverse condition on the package or the welds on the package. The stresses generated by the thermal load and pressure will not affect the package's ability to function properly.

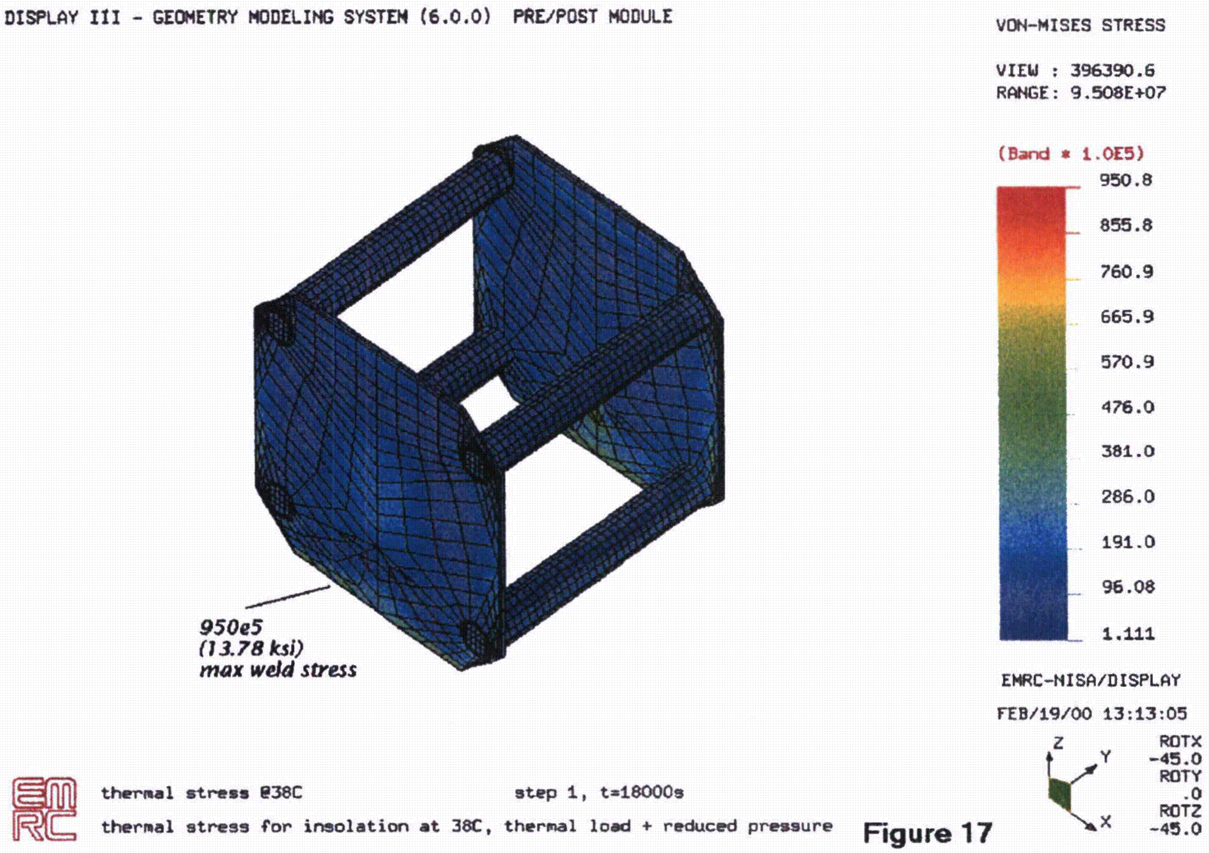


Figure 17

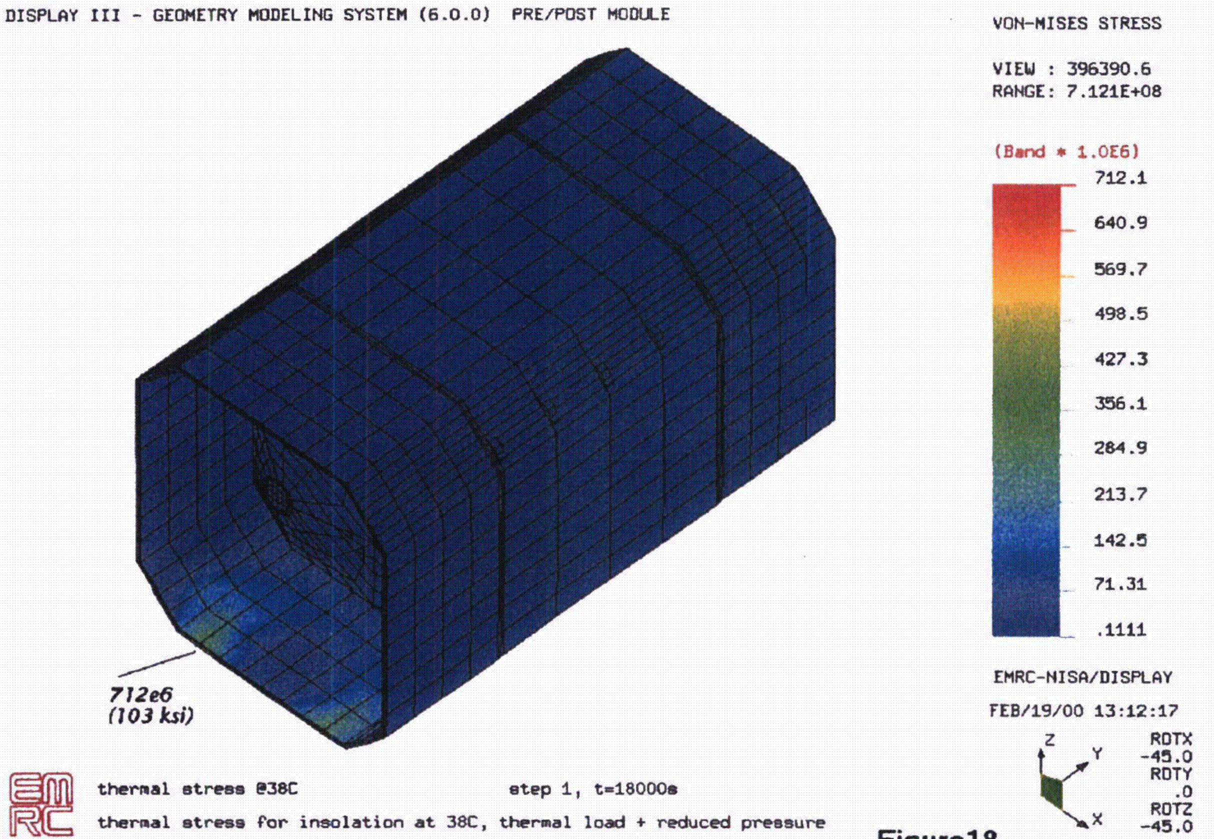


Figure18

2.6.4 Vibration

The effect of vibration on the package and materials of constructions incident to normal transportation is negligible. Many similar SPEC packages have been transported over a period of 20 years via all common modes of private and common transportation on water, highway and air without vibration-induced damage. The SPEC-300 enclosure is stiff and rigid. Its natural frequency is estimated to be above 500 Hz. The package is also damped by the high density polyurethane foam filling the cavity between the shield and the enclosure. Vibration incident to normal transportation will not reduce the effectiveness of the packaging.

2.6.5 Water Spray

A water spray test was not conducted on the SPEC-300. The enclosure, lock box, transport lock, and automatic securing mechanism/lock module are all made of corrosion resisting materials. The depleted Uranium shield is protected by the enclosure, by the polyurethane foam surrounding it, and by a layer of paint. No materials of construction in the SPEC-300 would be affected by water spray.

2.6.6 Free Drop

A SPEC-300 prototype package was dropped from a distance of 4 feet onto an essentially unyielding surface, striking the surface in a position for which maximum damage is expected. SPEC's drop target consists of a solid steel plate measuring 77 cm x 90 cm x 4.4 cm thick (30.25 in x 35.25 in x 1.8 in thick) weighing 239 kg (528 lb). The steel plate was wet floated onto the top surface of a flat horizontal concrete block weighing approximately 4491 kg (9,900 pounds). No damage or separation of the steel plate from the concrete block occurred as a result of any test. The total weight of the drop target is over 4763 kg (10,500 lb) which exceeds ten times the mass of the 354 kg (780 lb) package. The concrete block is metal reinforced and rests in firm soil. A 12 meter (40 ft) tall structure was erected over the drop target and used to raise and release the test package over the top surface of the target. See Appendix 2.10 for a drawing of the drop target.

The point of impact for the SPEC 300 was flat on the lock end flange. See Appendix 2.10 for a justification of the impact point and for photos of the test (photos #1 through #7). There was no effect on the operation or the shielding capability of the package. The four foot free drop did not result in loss of radioactive contents from the package, increased radiation levels or reduction in the effectiveness of the package.

2.6.7 Corner Drop

Not applicable. The package is not constructed of wood or fiberboard.

2.6.8 Penetration

As required by 10 CFR 71.71, Section (c)(10), a SPEC-300 prototype was subjected to the impact of a 1-1/4 inches diameter steel cylinder weighing 13 lbs falling a distance of 40 inches. The point of impact was directly on the safety plug which is located at the outlet end of the package. See Appendix 2.10 for a justification of the impact point and for photos of the test

(photos #8 through #13). The safety plug is the weakest structural point on the package that would also cause the most significant increase in radiation level if it were to break off. The impact caused the outlet nipple on the outlet end panel to bend downward. The safety plug and outlet nipple remained intact. There was no increase in radiation levels. The penetration test did not result in loss of radioactive contents from the package, increase radiation levels, or reduce the effectiveness of the SPEC-300 package. The penetration test shows that the safety plug can be expected to remain attached to the package during normal conditions of transport. In addition, SPEC safety plugs of this type have been in continuous use for over 20 years with no tendency to come adrift during normal transport.

A second penetration test was performed on the lock end cap. The impact caused only minor damage to the lock end cap. There was no increase in radiation levels. The penetration test did not result in loss of radioactive contents from the package, increase radiation levels, or reduce the effectiveness of the SPEC-300 package.

2.6.9 Compression

This test was not performed on the SPEC-300. The regulation requires a compressive force of 1769 kg (3900 lb) to be uniformly distributed across the top of the package. The SPEC-300 is constructed of 6 mm (.25 in) 316/316L stainless steel with 8 mm (.31 in) thick bulkheads. The enclosure and bulkheads are continuously joined with 6 mm (0.25 in) fillet welds. This configuration would not be affected by the compression load specified. In addition, paragraph 2.5.1 of this application describes a load resistance analysis where an identical load is concentrated at the ends of the package. Calculated stresses are well within limits.

2.7 Hypothetical Accident Conditions

2.7.1 Free Drop

The technique used to assess the SPEC-300 was prototype testing. The SPEC-300 prototype was subjected to four successive free drops from a height of 9 meters (30 feet) onto the drop test target described in paragraph 2.6.6 of this application. A 0.55 tBq (14.9 Ci) source was loaded in the package during testing. Although not required under the test criteria, multiple drops were made with the same prototype package to thoroughly demonstrate the durability of the package and to address any questions concerning the proper selection of the impact point and orientation for which maximum damage is expected. See Appendix 2.10 for a justification of the impact points and for photos of the test, as noted below.

1st 9 Meter Drop Test

The point of impact for this test was flat on the dome top side of the package (when looking at the lock-end of the package, this would be the left side). The package was suspended from the opposite side and adjusted to ensure a flat impact. See appendix 2.10, photos #14 through #16.

1st drop damage assessment: The shield shifted slightly toward the dome top, warping the lock-end bulkhead approximately 6 mm (0.25 in). One outlet panel screw was slightly bent. The shackle on the padlock securing the transport lock was pulled through the hole in the side of the

package, opening the lock. The transport lock remained engaged on the source assembly. Some paint was transferred from the drop test target to the housing. There was no measurable increase in radiation levels at 1 meter. All weld joints remained intact. See appendix 2.10, photos #17 through #20. Photo #21 depicts the package core temperature, -53.7° C (-47.6° F).

2nd 9 Meter Drop Test

The point of impact for this test was flat on the outlet end. The package was suspended from the lock end and adjusted to ensure a flat impact. See appendix 2.10, photos #22 and #23.

2nd drop damage assessment

The flange around the package was bent slightly inward, except for the left side which was bent outward. The shield pushed the outlet-end bulkhead slightly outward, approximately 6 mm (0.25 in) at the highest point. There was no measurable increase in radiation levels at 1 meter. All weld joints remained intact. See appendix 2.10, photos #24 through #28.

3rd 9 Meter Drop Test

The point of impact for this test was flat on the lock end. The package was suspended from the outlet-end and adjusted to ensure a flat impact. See appendix 2.10, photos #29 through #31.

3rd drop damage assessment

The lock-end bulkhead was pushed out approximately 12 mm (0.5 in). This caused the lock box flange to bend outward slightly. The reaction from the automatic securing mechanism/lock module pushed the lock box slightly outward. The transport lock jammed in the locked position. The outlet nipple broke off of the outlet end of the package (opposite end from the impact). The radiation level at the outlet end at the broken-off outlet nipple increased to 1.2 mSv/hr (120 mR/hr). When extrapolated to 11.1 TBq (300 Ci), this equates to 24.2 mSv/hr (2.4 r/hr). At 1 meter, the radiation level increased to .03 mSv/hr (2.8 mR/hr). When extrapolated to 11.1 TBq (300 Ci), this equates to 0.57 mSv/hr (57 mR/hr). The outlet-end bulkhead returned almost to its original position. All weld joints remained intact. See appendix 2.10, photos #32 through #36.

Note that the outlet nipple was bent by the normal conditions penetration test (see paragraph 2.6.8). It is unlikely that the outlet nipple would have broken off if it had not been already damaged.

4th 9 Meter Drop Test

The point of impact for this test was on the edge formed by the top of the package and the lock-end. The package was suspended from the opposite corner and adjusted to ensure that the center of gravity was above the impact point. See appendix 2.10, photos #37 through #39.

4th drop damage assessment

The edge of the package striking the drop target was significantly deformed, almost to the point where the lock box would contact the drop target. The side flanges bent inward and the top corners bent outward. The welds securing the doubler plates to the tie-down holes cracked. All other weld joints remained intact. There was no measurable increase in radiation levels at 1 meter. See appendix 2.10, photos #40 through 42.

Performance Requirements
10 CFR 71.51 (a) (2) specifies that as a result of testing, the radiation dose rate will not exceed one REM/hr at one meter from the external surface of the package. The four damage assessments above confirm that the SPEC-300 meets this requirement.

2.7.2 Puncture

Following the 9 meter (30 ft) free drop tests, the SPEC-300 prototype was dropped from a distance of 1 meter (40 inches) onto the center of a 15 cm (6 in) diameter by 36 cm (14 in) high steel cylindrical bar. The bar was bolted to the drop test target described in paragraph 2.6.6 of this application. The same 0.55 TBq (14.9 Ci) sealed source installed in the SPEC-300 for the series of drop tests remained in the package for the puncture test. The point of impact was on the lock cap. The SPEC-300 was suspended from the outlet end and oriented with the long axis of the package vertical. See Appendix 2.10 for a justification of the impact point and photos #43 through #46 for the test setup, as noted below.

Damage assessment
The lock cap was scratched and bent. The release plunger on the automatic securing mechanism/lock module was stuck in the up (auto-securing) position. There was no other effect on the overall package. There was no measurable increase in radiation levels at 1 meter. See appendix 2.10, photos #47 and #49.

Performance Requirements
10 CFR 71.51 (a) (2) specifies that as a result of testing, the radiation dose rate will not exceed one REM/hr at one meter from the external surface of the package. The damage assessments above confirm that the SPEC-300 meets this requirement.

2.7.3 Thermal

See section 3.5 for the thermal analysis.

2.7.3.1 Summary of Pressures and Temperatures.
Pressure: Not applicable. The SPEC-300 is vented to the atmosphere. Pressure buildup inside the package will not occur due to increased ambient temperature.
Temperature: 800°C (1475° F)

2.7.3.2 Differential Thermal Expansion.
The coefficient of linear thermal expansion of the 316/316L stainless steel enclosure is greater than that of the depleted Uranium shield. For this reason, no binding condition would exist between the enclosure and the shield at elevated temperature.

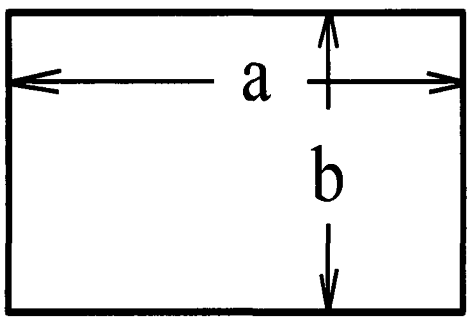
2.7.3.3 Stress Calculations.
Not applicable. See paragraph 2.7.3.2 above.

2.7.3.4 Comparison with allowable stresses.
Not applicable. See paragraph 2.7.3.2 above.

2.7.4 Water immersion.

The following analysis predicts the maximum stresses induced on the SPEC-300 packaging if it were to be subjected to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For the purpose of this analysis an external pressure of water of 150 kPa (21.7 psi) gauge will be used.

Each face of the SPEC-300 can be considered as a uniformly loaded rectangular plate with all edges fixed. Maximum stress in each face can be calculated from the following equation.



$$Max\sigma = -\frac{\beta \times q \times b^2}{t^2}$$

The following chart is used to calculate ß

a/b	1.0	1.2	1.4	1.6	1.8
ß	0.3078	0.3834	0.4356	0.4680	0.4872

q = distributed load
t = plate thickness

For the top and bottom surfaces of the SPEC-300:

a = 37.8 cm (14.9 in) = distance between bulkheads
b = 35.6 cm (14.0 in) = overall width of SPEC-300
t = 0.64 cm (0.25 in) = top and bottom plate thickness
q = distributed load = 150,000 pa (21.7 psi)
a/b = 1.1, so ß = 0.34 (interpolating)

$$Max\sigma = -\frac{\beta \times q \times b^2}{t^2}$$

$$Max\sigma = -\frac{0.34 \times 150{,}000 \times 35.6^2}{0.64^2}$$

$$Max\sigma = -157{,}800 kPa$$

$$(-22{,}887 psi)$$

For the left and right sides of the SPEC-300:

a = 38.1 cm (15.0 in) = overall width of SPEC-300
b = 37.8 cm (14.9 in) = distance between bulkheads
t = 0.64 cm (0.25 in) = top and bottom plate thickness
q = distributed load = 150,000 pa (21.7 psi)
a/b = 1.0, so ß = 0.3078

$$Max\sigma = -\frac{\beta \times q \times b^2}{t^2}$$

$$Max\sigma = -\frac{0.3078 \times 150{,}000 \times 37.8^2}{0.64^2}$$

$$Max\sigma = -161{,}058 kPa$$

$$(-23{,}360 psi)$$

For the inlet-end and outlet-end bulkheads of the SPEC-300:

a = 38.8 cm (14.5 in) = overall width of SPEC-300
b = 34.3 cm (13.5 in) = distance between bulkheads
t = 0.79 cm (0.31 in) = top and bottom plate thickness
q = distributed load = 150,000 pa (21.7 psi)
a/b = 1.1, so ß = 0.34 (interpolating)

$$Max\sigma = -\frac{\beta \times q \times b^2}{t^2}$$

$$Max\sigma = -\frac{0.34 \times 150{,}000 \times 34.3^2}{0.79^2}$$

$$Max\sigma = -96{,}140 kPa$$

$$(-13{,}944 psi)$$

All of these stresses are below the material yield point of the material:
316/316L stainless steel:
Yield stress: 206,840 kPa (30,000 psi)

2.7.5 Summary of Damage

Damage as a result of hypothetical accident condition testing was remarkably minor. The transport lock moved as a result of one of the 9m (30 ft) free drop tests, but remained engaged. The ends of the enclosure buckled as a result of the cumulative damage of the 4 9m (30 ft) free drop tests. The depleted Uranium shield also shifted slightly and the safety plug on the outlet nipple came adrift when the outlet nipple broke off. The puncture test caused the release plunger

on the automatic securing mechanism/lock module to stick. None of this damage defeated the redundant safety systems of the SPEC-300. The source always remained secured in the package. Radiation levels remained well below the requirement.

2.7.6 Overall Summary of Prototype Testing

All prototype testing was performed in accordance with written work instructions. These work instructions are summarized below:

DAY 1 - TEST#1 10 CFR PART 71 NORMAL CONDITIONS PENETRATION TEST OF THE SPEC-300 TYPE B(U) TRANSPORT PACKAGE

1. Install the source into the package in the secured and locked position. Engage the transport lock and install the safety plug and lock cap. Install a lead wire tamper seal to the lock cap.
2. Record Sealed Source Data.
3. Measure and record radiation levels. Record levels and locations where the reading was taken.
4. Place the package on a flat surface and elevate (chock) the outlet end upward to expose the safety plug such that when the 1 1/4" diameter penetration bar is dropped in a vertical position, the hemispherical end is able to impact directly on the safety plug. *Note: This orientation allows the penetration bar to strike the safety plug without interference of the housing "flange".*
5. Record ambient temperature (87.2F) and conditions (calm wind). SPEC-300 surface temperature 82.6F.
6. Start the video camera (showing package orientation).
7. Hold the hollow tube vertically with the open end (bottom) just above and directed at the safety plug.
8. Insert the penetration bar into the top of the hollow tube with the hemispherical end down and the lower end of the penetration bar 40 inches (minimum) above the safety plug.
9. Using the hollow tube to guide the penetration bar, release the bar allowing it to free fall and impact the safety plug.
10. Perform a "safety survey" to verify that radiation levels have not elevated to an unsafe level and stop the video.
11. Perform and record visual damage assessment, observations, etc.
RESULTS: The first outlet end drop struck the safety plug collar, slightly bending it. The bar was dropped again on the outlet end. After the second outlet end drop, the safety plug was bent down approximately 20 degrees. The safety plug could not be removed.
12. Place the package on its right side (hot top side) and elevate (chock) the lock end upward to expose the lock cap such that when the 1 1/4" diameter penetration bar is dropped in a vertical position, the hemispherical end is able to impact directly on the left side of the lock cap. *Note: This orientation allows the penetration bar to strike the lock cap without interference of the housing "flange".*
13. Record ambient temperature (84.8F) and conditions (calm wind).
14. Start the video camera (showing package orientation).
15. Hold the hollow tube vertically with the open end (bottom) just above and directed at the lock cap.
16. Insert the penetration bar into the top of the hollow tube with the hemispherical end down and the lower end of the penetration bar 40 inches (minimum) above the lock cap.

17. Using the hollow tube to guide the penetration bar, release the bar allowing it to free fall and impact the lock cap.
18. Perform a "safety survey" to verify that radiation levels have not elevated to an unsafe level and stop the video.
19. Perform and record visual damage assessment, observations, etc.
RESULTS: After the penetration bar was dropped on the lock end there was a slight indentation / marking on the lock cap marking the point of impact. The lock cap was bent and jammed. Upon removing the lock cap, it appeared to have no internal damage. The boss was slightly separated on the left side, to a degree that the left side of the lock cap can override the stop pin. The connector did not appear to be damaged.
20. Perform a radiation survey of the same marked spots as recorded on pre-test survey to determine if any loss of shielding integrity in excess of 20% has occurred. Record the radiation levels.

DAY 1 - TEST #2 10 CFR PART 71 NORMAL CONDITIONS DROP TEST OF THE SPEC-300 TYPE B(U) TRANSPORT PACKAGE

1. Perform a radiation survey, record the highest reading on each side and mark the location.
2. Attach a harness to the package such that when suspended in air and then dropped, the impact will be on the lock end flange. Using the drop tower, hoist and release mechanism, verify the orientation at ground level. Ensure that the center of gravity is directly over the desired point of impact. *Note: The point of impact was predetermined prior to actual test set up. See "Justification of Package Orientation for Normal Conditions Free Drop Test.*
3. Record ambient temperature (87.0F) and conditions (calm wind).
4. Verify emergency procedure preparations and post surveillance personnel.
5. Start the video camera (showing package orientation).
6. Lift the package to four (4) feet (minimum). Verify that the distance is measured from the top of the target (steel plate surface) to the lowest point on the package.
7. Clear all personnel from the target location and drop the package.
8. Perform the safety survey and stop video.
9. Perform and record visual damage assessment, observations, etc.
RESULTS: The pattern of the flange edge was imprinted in the paint on the target pad. There were no cracked welds. The only damages were superficial scratches on the flange edges. The transport lock was fully functional. The release plunger was fully functional. On impact, the camera rolled over onto the top. One lifting eye would not move to the middle easily. The eye was able to be moved from the jammed position by hand.
10. Perform a radiation survey to determine if any loss of shielding integrity in excess of 20% has occurred. Measure the radiation levels on each side of the package's surface in the same marked location as pre-test. Record on the Post test survey illustration.

DAY 1 - TEST #3 HYPOTHETICAL ACCIDENT CONDITIONS, 30 FOOT DROP TEST OF THE SPEC-300 TYPE B(U) TRANSPORT PACKAGE/RADIOGRAPHIC EXPOSURE DEVICE

1. Using the following formula, determine maximum allowable radiation level at 1 meter following the drop test (extrapolated to 300 curies)
300 / actual activity = REF. 1000 / REF = max allowable radiation level.

2. Place dry ice on the bottom (floor) of the freezer.
3. Lower the SPEC-300 into the freezer and on top of the dry ice.
4. Remove the safety plug and install thermocouple wire inside the SPEC-300's interior (through the s-tube opening at the outlet end) and plug the s-tube opening.
5. Place ice around (in contact with) the SPEC-300.
6. Close the freezer and record time (1145 6/11/99).
7. Allow the SPEC-300 to freeze to -40F or colder. *Note: Do not freeze the safety plug. Rationale: An unfrozen safety plug offers worst case conditions for test.*
8. Record ambient temperature (87.2F) and conditions (light rain).
9. Record SPEC-300 core temperature (-48.8F). *Note: Should be colder than -40F to accommodate additional "warming" time to required to reach point of impact.*
10. Verify emergency procedure preparations and post surveillance personnel.
11. Start the video camera.
12. Open the freezer, start the stopwatch and remove the SPEC-300 from the freezer.
13. Attach the SPEC-300 harness to the release mechanism such that when suspended in air and then dropped, the impact will be flat on the left side (opposite the hot top). Using the drop tower, hoist and release mechanism, verify the orientation at ground level. Ensure that the center of gravity is directly over the desired point of impact. *Note: The point of impact was predetermined prior to actual test set up. See "Justification of SPEC-300 Orientation for Hypothetical Accident Conditions, 30' Free Drop Test.*
14. Again, record the SPEC-300 temperature (-48.0F) and remove the thermocouple from the unit's interior and install the unfrozen safety plug into the SPEC-300. *(Note: Temperature must be -40F or colder.)*
15. Attach the 30' line to the lowest surface of the SPEC-300 and lift the unit to 30 feet, minimum. Verify that the distance is measured from the top of the target (steel plate surface) to the lowest point on the SPEC-300 and remove the line.
16. Clear all personnel from the target location and drop the SPEC-300.
17. Record time elapsed. Time elapsed: 14.39 minutes
18. Perform the safety survey (at the package's surface). If the surface survey reveals radiation levels greater than 500 mR/hr, immediately discontinue the test and inform the RSO and Project Manager. The Project Manager (or designate) will determine if the radiation levels at 1 meter exceed the maximum allowable radiation level as previously established. *Note: 500 mR/hr at the surface should provide a generous safety margin before the extrapolated 1 meter readings exceed Type B requirements.*
19. Stop video.
20. Once safe radiation levels are verified, perform and record visual damage assessment, observations, etc.

    RESULTS: After drop #1, flat on left side: The shield shifted slightly toward the dome top bending the inlet bulkhead slightly. One outlet end plate screw was slightly bent and a new screw was installed. The transport lock operates normally. The padlock was replaced because the drop caused damage to the shackle which allowed the lock to unlock. Paint was marked evenly along the two lengths of the housing. The core temperature after the drop was still below -40F. No cracked welds were evident.

DAY 2 - TEST #3 HYPOTHETICAL ACCIDENT CONDITIONS, 30 FOOT DROP TEST OF THE SPEC-300 TYPE B(U) TRANSPORT PACKAGE/RADIOGRAPHIC EXPOSURE DEVICE

21. Attach a drop harness to the SPEC-300 such that when suspended in air and then dropped, the impact will be flat on the outlet end (see illustration) as predetermined. Using the drop tower, hoist and release mechanism, verify the orientation at ground level. Ensure that the center of gravity is directly over the desired point of impact and lower the SPEC-300 to the ground. *Note: The SPEC-300 will not be refrozen for the remainder of the drop tests. See "Justification of SPEC-300 Orientation for Hypothetical Accident Conditions, 30' Free Drop Test for rationale.*
22. Attach the thermocouple to the surface of the SPEC-300 and record the surface temperature (82.4F).
23. Record ambient temperature (81.2F) and conditions (fog).
24. Verify emergency procedure preparations and post surveillance.
25. Start the video camera.
26. Re-verify the orientation of the SPEC-300 (at ground level) to ensure that when dropped the impact will be flat on the outlet end, as predetermined.
27. Attach the 30' line to the lowest surface of the SPEC-300 and lift the unit to 30 feet, minimum. Verify that the distance is measured from the top of the target (steel plate surface) to the lowest point on the SPEC-300 and remove the line.
28. Clear all personnel from the target location and drop the SPEC-300.
29. Perform the safety survey (at the package's surface). If the surface survey reveals radiation levels greater than 500 mR/hr, immediately discontinue the test and inform the RSO and Project Manager. The Project Manager (or designate) will determine if the radiation levels at 1 meter exceed the maximum allowable radiation level as previously established. *Note: 500 mR/hr at the surface should provide a generous safety margin before the extrapolated 1 meter readings exceed Type B requirements.*
30. Stop video.
31. Once safe radiation levels are verified, perform and record visual damage assessment, observations, etc.
    RESULTS: After drop #2, flat on outlet end: No cracked welds were evident. The flanges were bent inward except for the left flange which was bent outward. The shield pushed the bulkhead out around the outlet end panel, approximately 1/4" at highest point. The transport lock was operational. The release plunger was operational. No cracks in welds or visible damage on lock side.
32. Attach a drop harness to the SPEC-300 such that when suspended in air and then dropped, the impact will be flat on the lock end as predetermined. Using the drop tower, hoist and release mechanism, verify the orientation at ground level. Ensure that the center of gravity is directly over the desired point of impact and lower the SPEC-300 to the ground.
33. Attach the thermocouple to the surface of the SPEC-300 and record the surface temperature (89.6F).
34. Record ambient temperature (82.6F) and conditions.
35. Verify emergency procedure preparations and post surveillance personnel.
36. Start the video camera.
37. Re-verify the orientation of the SPEC-300 (at ground level) to ensure that when dropped the impact will be flat on the lock end, as predetermined.

38. Attach the 30' line to the lowest surface of the SPEC-300 and lift the unit to 30 feet, minimum. Verify that the distance is measured from the top of the target (steel plate surface) to the lowest point on the SPEC-300 and remove the line.
39. Clear all personnel from the target location and drop the SPEC-300.
40. Perform the safety survey (at the package's surface). If the surface survey reveals radiation levels greater than 500 mR/hr, immediately discontinue the test and inform the RSO and Project Manager. The Project Manager (or designate) will determine if the radiation levels at 1 meter exceed the maximum allowable radiation level as previously established. *Note: 500 mR/hr at the surface should provide a generous safety margin before the extrapolated 1 meter readings exceed Type B requirements.*
41. Stop video.
42. Once safe radiation levels are verified, perform and record visual damage assessment, observations, etc.
    RESULTS: After drop #3, flat on lock end: No cracked welds were evident. The bulkhead was pushed out approximately 1/2" on the lock side which caused the lock box flange to bend and the lock box was pushed out. None of the bolts were broken. The flange is slightly dented in on all 4 sides. The padlock was still intact. The transport lock was jammed but the release plunger still works. There is no physical damage to the outside face of the lock box, tamper seal or lock cap. The outlet end no longer protrudes as much as it did prior to drop #3, not past normal. The outlet nipple broke off, 80 mr/hr radiation stream.
43. Attach a drop harness to the SPEC-300 such that when suspended in air and then dropped, the impact will be on the edge formed by the top of the device and the lock end (see illustration) as predetermined. Using the drop tower, hoist and release mechanism, verify the orientation at ground level. Ensure that the center of gravity is directly over the desired point of impact and lower the SPEC-300 to the ground.
44. Attach the thermocouple to the surface of the SPEC-300 and record the surface temperature (88.8F).
45. Record ambient temperature (84.0F) and conditions.
46. Verify emergency procedure preparations and post surveillance personnel.
47. Start the video camera.
48. Re-verify the orientation of the SPEC-300 (at ground level) to ensure that when dropped the impact will be on the edge formed by the top of the device and the lock end, as predetermined.
49. Attach the 30' line to the lowest surface of the SPEC-300 and lift the unit to 30 feet, minimum. Verify that the distance is measured from the top of the target (steel plate surface) to the lowest point on the SPEC-300 and remove the line.
50. Clear all personnel from the target location and drop the SPEC-300.
51. Perform the safety survey (at the package's surface). If the surface survey reveals radiation levels greater than 500 mR/hr, immediately discontinue the test and inform the RSO and Project Manager. The Project Manager (or designate) will determine if the radiation levels at 1 meter exceed the maximum allowable radiation level as previously established. *Note: 500 mR/hr at the surface should provide a generous safety margin before the extrapolated 1 meter readings exceed Type B requirements.*
52. Stop video.
53. Once safe radiation levels are verified, perform and record visual damage assessment, observations, etc.

RESULTS: After drop #4, on the edge formed by the top and lock end: No cracked bulkhead or lock box welds were evident. The release plunger is operational. The top flange is pushed in almost to the top of the lock box. The side flanges are bent inward, the top corners are pointed outward. The tamper seal is intact. The flange doubler welds are broken on both sides. Neither the padlock nor the transport lock were broken. The shield may have shifted slightly.

54. Re-evaluate the unit orientation (impact point) for the ensuing Puncture Test with rationale based on the cumulative damage caused by the four 30 foot drop tests.

DAY 2 - TEST #4 HYPOTHETICAL ACCIDENT CONDITION, PUNCTURE TEST OF THE SPEC-300 TYPE B(U) TRANSPORT PACKAGE/RADIOGRAPHIC EXPOSURE DEVICE

1. Install the Puncture Test Pin to the steel test pad and verify that the pin is rigidly mounted to prevent lateral movement or tipping of the pin caused by the SPEC-300 drop impacts on the pin.
2. Attach the drop harness to the SPEC-300 such that when suspended in air and then dropped, the impact will be directly on the lock box. Using the drop tower, hoist and release mechanism, verify the orientation at pin level. Ensure that the center of gravity is directly over the desired point of impact. Note: The point of impact was predetermined prior to actual test set up and re-evaluated after 30' drops. See "Justification of SPEC-300 Orientation for Hypothetical Accident Conditions, Puncture Test.
3. Record ambient temperature (83.6F) and conditions.
4. Verify emergency procedure preparations and post surveillance personnel.
5. Start the video camera (showing SPEC-300 orientation).
6. Lift the SPEC-300 to 40 inches, minimum. Verify that the distance is measured from the top of the test pin to the lowest point on the SPEC-300.
7. Clear all personnel from the test area and drop the SPEC-300.
8. Perform the safety survey and stop video.
9. Once safe radiation levels are verified, perform and record damage assessment, observations, etc. RESULTS: The pin remained mounted securely to the test pad. An imprint of the SPEC-300 lock cap was visible on the top of the pin, approximately ½ way between the center and edge of the puncture pin. The lock cap was scratched and bent. The release plunger was stuck in the up position. The tamper seal is still intact. There were no visible cracks in the bulkhead and lock housing welds.
10. Perform a Part 71 survey by measuring the highest radiation levels of each side at 1 meter from the surface of the SPEC-300. Record the actual readings.
11. Extrapolate the actual radiation levels to 300 curies and record.

2.7.7 Prototype Test Package Deviations

This section describes the differences between the prototype test package and the package design defined in the engineering drawings.

2.7.7.1 Part Number 190600: Package ID plates blank, no source tag.

The Package ID plates were blank because information needed to complete them will not be available until the package is issued a Certificate of Compliance. The source tag was not

installed because it was not deemed necessary to do so for testing. The blank id plates and the absence of the source tag in no way affect the safety conclusions of the test.

2.7.7.2 Part Number 190640: 3 lock box mounting holes oversize

Of the 13 holes used to attach the lockbox to the SPEC-300, 3 holes were misaligned slightly, so their diameter was increased from 9.5mm (0.375 in) to 11.9 mm (0.469 in). This deviation, (holes oversize) weakens the lock box slightly. Any affect on testing caused by this deviation would be conservative, that is, a part in compliance with the engineering drawing would be expected to perform better than the part tested.

2.7.7.3 Part Number 150007: 4 small screws not installed in lock module cover plate

The lock module is attached and to the lockbox of the SPEC-300 by 4 large screws in the face of the lock module. The lock module has a sheet metal cover plate approximately 100 mm (4 in) square that is attached to the lock box by 6 small (12-24) flat head screws. During the assembly process it was noted that 4 of the 6 screw holes did not align perfectly with the lock module cover plate. It was decided to test the unit with only two screws holding the cover plate in place. This deviation, (4 small screws not installed) weakens the connection between the lock module cover plate and the lock box. Any affect on testing caused by this deviation would be conservative, that is, an assembly in compliance with the engineering drawing would be expected to perform better than the part tested.

2.7.7.4 Part Number 190753: The thru hole in the control attachment boss is 0.15mm (.006 in) over tolerance.

The control adapter boss is located on the SPEC-300 lock box. When the SPEC-300 is used as a gamma radiography device, the user attaches crank-out controls to the control attachment boss. The thru hole in the control attachment boss allows the user's drive cable to enter the SPEC-300. The deviation described, (hole oversize) would weaken the part slightly. Any affect on testing caused by this deviation would be conservative, that is, a part in compliance with the engineering drawing would be expected to perform better than the part tested.

This section also shows that all deviations in design, materials, fabrication methods, and/or quality assurance do not change the safety conclusions of the tests.

2.7.8 Evaluation of prototype testing

At the conclusion of all prototype tests, the SPEC-300 was found to meet all of the requirements set forth in 10 CFR Part 71, "Packaging and Transportation of Radioactive Material."

2.8 Special Form

See Section 4, containment for discussion of the special form capsule.

2.9 Fuel Rods

Not applicable. The SPEC-300 does not use fuel rods.

<u>Appendix 2.10</u>

Part 71 Design Criteria

Design Criteria For Part 71 Application Approval Form

Project: SPEC-300 EXPOSURE DEVICE

June 24, 1999

Revision Number: 0

Approved:	Donny Dicharry	**Title**	President	**Date**	6/24/99
Approved:	Pete Weber	**Title**	General Manager	**Date**	6.24.99
Approved:	Kelley Richardt	**Title**	QA Manager	**Date**	6/24/99
Approved:	Richie Melancon	**Title**	Engineering Manager	**Date**	6/24/99
Approved:	Kenny Carrignton	**Title**	Special Projects Mgr.	**Date**	6/24/99

Source Production & Equipment Company
St. Rose, Louisiana

Design Criteria for SPEC-300 Exposure Device

Date: 6/24/99
REV 0

CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
Requirements for Overall Dimensions	1	10 CFR PART 71 SUBPART E SECTION 71.43a	The smallest overall dimension of a package may not be less than 10 cm (4 in).	Overall dimensions are 14 x 14.15 x 26 inches	
Requirements Seals on Type B Packages	2	10 CFR PART 71 SUBPART E SECTION 71.43b	The outside of a package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.	Seal through lock cap	Not readily breakable: Requires intentional effort to remove the seal.
	3	10 CFR PART 71 SUBPART E SECTION 71.43c	Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by pressure that may arise within the package.	Welded special form capsule.	
Requirements for Materials in Type B Packages	4	10 CFR PART 71 SUBPART E SECTION 71.43d	A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among packaging contents, including possible reaction resulting from inleakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation.	Eutectic Barrier Camera Fill	This requirement will be met by suppling a eutectic barrier between the depleted uranium and the stainless steel case. This barrier will not allow for the depleted uranium to come in contact with the stainless steel, therefore, there should not be a galvanic, chemical or other type of reaction between the two dissimilar materials.

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CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
					Account must be taken: The design must ensure that the materials used in the device will not be adversely affected by radiation.
Requirements for Radiation Levels in Shipping Packages	5	10 CFR PART 71 SUBPART E SECTION 71.43f	A package must be designed, constructed, and prepared for shipment so that under the test specified in Sec. 71.71 ("Normal Conditions of Transport") there would be no loss or dispersal of radioactive contents, no significant increase in radiation levels, and no substantial reduction in the effectiveness of the packaging.	Tested	Significant increase is defined as 20%. Substantial Reduction: maximum increase of 20%.
	6	10 CFR PART 71 SUBPART E SECTION 71.47a	Each package of radioactive materials offered for transportation must be designed and prepared for shipment so that under conditions normally incident to transportation the radiation level does not exceed 2 mSv/hr (200 mrem/h) at any point on the external surface of the package, and the transport index does not exceed 10.	Tested	Transport index will not exceed five, as per ANSI N432. (5 mr/hr @ 1meter)
Temperature Requirements for Shipping Type B	7	10 CFR PART 71 SUBPART E SECTION 71.43g	A package must be designed, constructed, and prepared for transport so that in still air at 38 deg C (100 deg F) and in the shade, no accessible surface of a package would have	Engineering Analysis	

Design Criteria for SPEC-300 Exposure Device

Date: 6/24/99
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CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
Packages			a temperature exceeding 50 deg. C (122 deg. F) in a nonexclusive use shipment, or 85 deg. C (185 deg. F) in an exclusive use shipment.		
Requirements for Venting during Shipment of Type B Packages	8	10 CFR PART 71 SUBPART E SECTION 71.43h	A package may not incorporate a feature intended to allow continuous venting during transport.	Not Applicable	Donny has consulted with Dr. Parker.
Requirement for Lifting Means of Type B Packages	9	10 CFR PART 71 SUBPART E SECTION 71.45a	Any lifting attachment that is a structural part of a package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting device under excessive load would not impair the ability of the package to meet other requirements of this subpart. Any other structural part of the package that could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport, or must be designed with strength equivalent to that required for lifting attachments.	Engineering Analysis. Refer to Project #98007-02	Eye must fail before the welds fail, or eye rip out of block before block rips off of the enclosure. Also, flanges must be able to withstand 3x the weight. The intent is not to breech the case and expose the foam. Intended manner: Lifting the device by the designed lifting attachments. Any other structural part of the package that could be used to lift the package: An area on the device which is not designed to be used as a lifting means, but is reasonably

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CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
					foreseeable to be used as a lifting point. Inoperable: Must not be able to utilize as a lifting point.
Requirements for Tie down on Type B Packages	10	10 CFR PART 71 SUBPART E SECTION 71.45b1	If there is a system of tie-down that is a structural part of the package, the system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of 5 times the weight of the package with its contents.	Engineering Analysis. Refer to Project #98007-02	Tie down: places on the camera which can be utilized to tie the device down.
	11	10 CFR PART 71 SUBPART E SECTION 71.45b2	Any other structural part of the package that could be used to tie down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices.	Engineering Analysis. Refer to Project #98007-02	Lifting eyes are the only other structural part that could be used as a tie down point.
	12	10 CFR PART 71	Each tie down device that is a structural part	Excessive load to tie	

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Date: 6/24/99
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CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
		SUBPART E SECTION 71.45b3	of the package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirement of this part.	down points will cause failure outside the package critical structural. Engine-ring analysis	
Cold Requirements	13	10 CFR PART 71 SUBPART E SECTION 71.71c2 (Normal Condition Test)	Cold test. An ambient temperature of -40 degrees F. in still air and shade.	Tested	
External Pressure Requirements	14	10 CFR PART 71 SUBPART E SECTION 71.71c3 (Normal Condition Test)	Reduced external pressure. An external pressure of 25 kPa (3.5 psi) absolute.	N/A due to package open to Atsmospheric Pressure	Donny has consulted with Dr. Parker.
Internal Pressure Requirements	15	10 CFR PART 71 SUBPART E SECTION 71.71c4 (Normal Condition Test)	Increased external pressure. An external pressure of 140 kPa (20 psi) absolute.	N/A due to package open to Atsmospheric Pressure	Donny has consulted with Dr. Parker.
Vibration of Class M Devices	16	10 CFR PART 71 SUBPART E SECTION 71.71c5 (Normal Condition Test)	Vibration normally incident to transport.	Engineering Analysis	
Water Spray Requirements	17	10 CFR PART 71 SUBPART E SECTION 71.71c6	Water Spray that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour.	Engineering Analysis	Materials not subject to damage from water.

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CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
		(Normal Condition Test)			
Drop Test Requirements	18	10 CFR PART 71 SUBPART E SECTION 71.71c7 (Normal Condition Test)	Free drop between 1.5 and 2.5 hours the conclusion of the water spray test, a free drop through a distance specified below onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.	Tested	Maximum Damage: 20% increase in radiation levels.
Excessive Load	19	10 CFR PART 71 SUBPART E SECTION 71.71c9 (Normal Condition Test)	The package must be subjected to 24 hours of a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following: a. the equivalent of 5 times the weight of the package. b. the equivalent of 13 kPa (2 psi) multiplied by the vertically projected area of the package.	Engineering Analysis	
Penetration Requirements	20	10 CFR PART 71 SUBPART E SECTION 71.71c10 (Normal Condition Test)	Penetration. Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in) diameter and 6 chg. (13 lbs) mass, dropped from a height of 1 m (40 in) onto the exposed	Tested	Most Vulnerable: Position that would cause the greatest increase in radiation levels.

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REV 0

CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
			surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.		
30 Foot Free Drop	21	10 CFR PART 71 SUBPART E SECTION 71.73c1 (Hypothetical Accident Conditions)	Free drop. A free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.	Tested	Maximum damage: 1 rem/hr at 1 meter.
Puncture Test	22	10 CFR PART 71 SUBPART E SECTION 71.73c3 (Hypothetical Accident Conditions)	Puncture. A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted to an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical.	Tested	Mounted: bolted. Maximum Damage: 1rem/hr at one meter.
Thermal Test	23	10 CFR PART 71 SUBPART E SECTION 71.73c4	Thermal. Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air	Engineering Analysis	

Design Criteria for SPEC-300 Exposure Device

Date: 6/24/99
REV 0

CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
		(Hypothetical Accident Conditions)	fire of sufficient extent, and in sufficiently quiescent ambient temperatures, to provide an average emisstivity coefficient of 0.9, with an average flame temperature of 800 C (1475 F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800 C. The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1 m (40 in) above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to posses if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.		
Heat Requirements	24	10 CFR PART 71 SUBPART E SECTION 71.71c1	An ambient temp. of 100 F in still air, and insolation according to the following	Engineering Analysis	

Design Criteria for SPEC-300 Exposure Device

Date: 6/24/99
REV 0

CRITERIA	#	ORIGINATOR OF CRITERIA	REQUIREMENT	IMPLEMENTATION	COMMENTS
		(Normal Condition Test)	Form and Location Total Insolation of 12 hours Flat Surface transported Horizontally: Base---------------------------------None Other surfaces -----------------800 Flat Surface not transported Horizontally --------------------200 Curved Surfaces --------------400		
Immersion Test	25	10 CFR PART 71 SUBPART E SECTION 71.73c6 (Hypothetical Accident Conditions)	Immersion. A separate, undamaged specimen must be subjected to a water pressure equivalent to immersion under a head of water of a least 15 m (50 ft).	Engineering Analysis	

Special Note: Some tests must be done in succession.

h:/spec300/appcrit0.xls

SPEC-300 Design Calculations

SPEC-300
Design Calculations
Project #98007-02

Purpose:

The design calculations are used to prove that the welds and/or designs are sufficient for the SPEC-300 exposure device. The welds are classified in four different classifications, A, B, C, and D. Classification A represents the welds on the SPEC-300 that are welded to a pre-approved welding code. These codes are included. Classification B represents those calculations that are needed to prove that the SPEC-300 can meet the criteria set forth in 10 CFR 71.45(a) and ISO 3999 Section 6.4.3.1, whichever provides for the worst case. Classification C represents those calculations that are needed to prove that the SPEC-300 can meet the criteria set forth in 10 CFR 71.45(b). Classification D represent welds that have weld sizes larger than what is required by Code A, (these welds surpass the standards). Welds which are not included in this report are not considered to be structural welds.

The following in a list of the structural welds and the classification they fall under.

Weld Size Table

Weld #	Weld Size	Description	Verification Code
1	1/4	Hot top ring support to structural post	D
2	1/4	Structural post to bulkheads	D
3	3/16	Eye mounting block to enclosure cover	B
4	3/16	Lifting doubler to enclosure cover	C
5	1/4	Enclosure cover to base and bulkheads	A
6	1/4	Base to both bulkheads	A
7	1/4	Lock end shield support to bulkhead	E
8	1/4	Outlet end shield supports to bulkhead	E
9	1/8	Outlet boss to outlet plate	E
10	1/4	Four sides of shield support together	E

Verification Codes

Code A Code A implies that the weld design complies with at least one the following standards:

UBC, 2.689, J2
UBC, 2-691, TABLE J2.4
D1.1, 2.3
UBC, 2-1.691, J2.2b
D1.1, 2.7.1.1, TABLE 2.2
AISC, 5-26, J2
D1.1, 2.7.1.1

UBC - Uniform Building Code
D1.1 - American Welding Society, D1.1 - 94
AISC - American Institute of Steel Construction, 9ed.

All the standards above are taken from the book, Welding Codes, Standards, and Specifications, published by McGraw-Hill and copyrighted 1998.

Code B Code B represents those calculations that are needed to prove that the SPEC-300 can meet the criteria set forth in 10 CFR 71.45(a). The criteria applies to lifting devices on the package. 10 CFR 71.45a requires that the lifting attachments on the device must be designed with a minimum factor of safety of three against yielding when used to lift the package. These calculations are attached.

Code C Code C represents those calculations that are needed to prove that the SPEC-300 can meet the criteria set forth in 10 CFR 71.45(b). This CFR requires that the device withstand a static force applied to the center of gravity of the package having a vertical component of 2 times the weight, a horizontal component along the direction of vehicle travel of 10 times the weight, and a horizontal component in the transverse direction of 5 times the weight of the package. These calculations are attached.

Code D Code D implies that the weld size for the particular weld is oversized for requirements given in Code A. Code A gives the maximum effective weld size for a particular weld. However, Code D will allow for a larger weld. The reasoning for the larger weld is to allow for inconsistences within the weld due to the welding process. Therefore, a Code D weld surpasses that of Code A by allowing for a larger weld.

Code E Code E welds are welds that were tested for their compliance.

SPEC-300 Weld Verification
Code B

Part I. Calculate the force in pounds required to have the eyebolt fail.

Part II. Calculate the stress applied to the SPEC-300 mounting blocks when the required load is applied to the lifting eyes. Include calculations of the stress generated in the enclosure cover from the load applied.

Part III. Calculate the stress to have the lifting eye rip out of the mounting blocks.

According to the criteria set forth by 10 CFR 71.45(a), each lifting point must withstand at least three times the weight of the device. This amount requires the eyebolt to withstand 2400 lbs, and each mounting block weld to hold 1200 lbs. The analysis also proves that the weld for the mounting block to the enclosure cover will fail before the case tears open. This feature is desirable to eliminate exposing the DU shield.

SPEC-300 Weld Verification
Code B

Part I. Calculate the force in pounds required to have the eyebolt fail.

The specifications for the eyebolt used for the SPEC-300:

Ring Type Weldable Lifting Eye
ID = 1 7/8"
Ring Thickness = 5/8"
Working Load = 7000 lbs
Ultimate Load = 28,000 lbs

Part II

Problem:

Calculate the stress applied to the SPEC-300 mounting blocks when the required load is applied to the lifting eyes. Include calculations of the stress generated in the enclosure cover from the load applied.

Analysis:

Dimensions of mounting block are 2.5" x 1.5"
Weight of Package = 800 lb
3 times the weight = 2400 lb

If load is applied to only one eyebolt, then each mounting block will have 1200 lb force.
Applied load = 1200 lb

Assumptions: Eyebolt will not tear out of mounting block

Weld size = 3/16"
Area of weld = A = 1.414h(b+d)
(Reference Mechanical Engineering Design, 5th ed. The book is authored by Shigley, Joseph and Mischke, Charles, and published by McGraw Hill 1989.)

Where: h = height of weld leg
b = length of side 1 (1.5")
d = length of side 2 (2.5")

$$A = 1.414(3/16)(1.5 + 2.5)$$

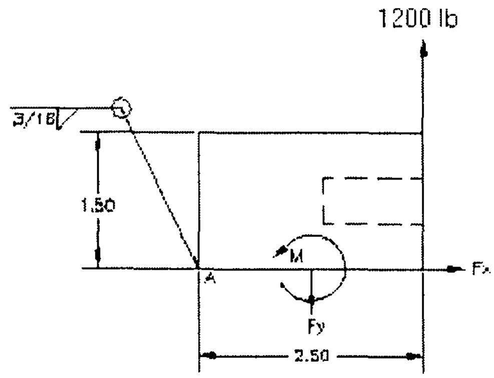
$$A = 1.0605 \text{ in}^2$$

From free body diagram

M = 1200(1.25) = 1500 lb*in

Fx = 1200 (cos 90) = 0

Fy = 1200 (sin 90) = 1200 lb



Moment ofIntertia = Iu

$$Iu = \frac{d^2}{6}(3b + d) = \frac{(2.5)^2}{6}(3(1.5) + (2.5) = 7.29in^2$$

Second Mom ent of Interia about axis = I

$$I = .707(h)(Iu) = .707(3/16)(7.29) = .9666in^4$$

A shear stress due to moment and Fy are additive. The total shear stress for the weld metal is as follo ws:

$$\tau = \frac{Fy}{A} + \frac{M}{I} = \frac{1200}{1.0606} + \frac{1500(1.25)}{.9666}$$

$$\tau = 3071.22\,psi$$

Shear stress due to Fx = 0

Properties of stainless steel

Ultim ate Streng th = Su = 75ksi

Yeild Strength = 30 kpsi

Resultant stress in weld material

$$\tau = (\tau x^2 + \tau y^2)^{1/2} = 3071.22\,psi$$

$$Factor\,of\,Safety = n = \frac{Sy}{\tau} = \frac{30000}{3071.22} = 9.72$$

Stress in the parent material (enclosure cover) is as follows:

A = l x w = 1.5 x 2.5 = 3.75 in^2

$$\tau xy = \frac{Fx}{A} = 0$$

$$Section\ Modulus = S = \frac{bd^2}{6} = \frac{(1.5)(2.5)^2}{6} = 1.5625 in^3$$

$$Tensile\ Strength = \sigma y = \frac{Fy}{A} + \frac{M}{S} = \frac{1200}{3.75} + \frac{1500}{1.5625} = 1280\ psi$$

$$Factor\ of Safety = n = \frac{30000}{1280} = 23.44$$

This analysis proves that the weld around the mounting block will not fail under a load of 3 times the weight of the package. The load does not generate stress over the yield stress limit for the parent material or the weld material. The weld metal has the same or better yield strength than the parent material. The parent material has a yield strength of 30,000 psi.

There was concern that the calculations for the enclosure cover should be treated as a flexible plate in the plate stress computation.

After an analysis, it was determined that the top plate is not a flexible plate in the loading situation. The load is being applied to the mounting blocks which are welded to the enclosure cover. The mounting blocks are located either on top of or very near to the vertical bulkheads on the device. These vertical bulkheads are fixed to the enclosure cover via a weld. The enclosure cover will not flex at these locations.

Part III.

Problem:

Calculate the stress to have the lifting eye rip out of the mounting blocks.

Analysis:

Assumptions:

1. Mounting block is fixed to cover
2. Eyebolt will not fail

d = .625 in
w = 1.5 in
d/w = .4166 in

Kt = 3.25 (Pg 749)
For safety allow Kf = Kt (Pg 291)

(d, w, Kt, and Kf are taken from the book, Mechanical Engineering Design, 5th ed. The book is authored by Shigley, Joseph and Mischke, Charles, and published by McGraw Hill 1989.)

$$\sigma = Kf\frac{Fy}{A}$$

$$\sigma = 3.25\frac{1200}{(1.5)(1.5)} = 1733.33psi$$

This solution proves that the design passes the requirements set forth in the CFR. The stress generated is below the stress limit for the parent material or the weld material. The weld metal has the same or better yield strength than the parent material. The parent material has a yield strength of 30,000 psi.

Miscellaneous Lifting Stress calculation

To remain in compliance with the criteria for this package set forth by 10 CFR 71.45, any means other than the intended means that can be used to lift the device muse be able to withstand 3 times the weight of the package. The worst case scenario that could be used includes lifting the device by the top enclosure cover at the ends of the flange. If these lifting points are utilized, the stress must not exceed the ultimate stress of the material. Unfortunately, there is no way of predicting exactly how much area will be used upon lifting. Therefore, we will assume a ½ in^2 of area. This will produce 2400 psi, which is less than 30000 psi (ultimate strength). Also, if smaller area is utilized the stress would increase. However if the plate begins to deform from the stress, the contact between the lifting means and the enclosure cover will increase thus increasing the area and decreasing the stress at the lifting point.

SPEC-300 Weld Verification
Code C

Part I. Static force applied at the center of gravity with vertical component of 2 times the weight, static force applied at the center of gravity with horizontal component along the direction of the vehicle travel at 10 times the weight, static force applied at the center of gravity with horizontal component in transverse direction of vehicle travel of 5 times the weight.

The passing criteria requires that the stress generated is below the stress limit for the parent material or the weld material. The weld metal has the same or better yield strength than the parent material. The parent material has a yield strength of 30,000 psi.

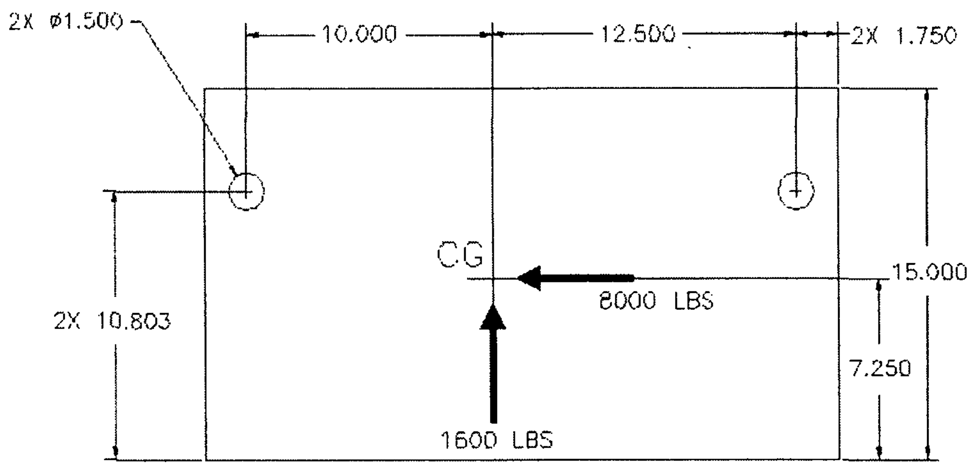
SPEC-300 Weld Verification
Code C

Part I.

Problem:

Calculate the stress generated when a static force is applied at the center of gravity with vertical component of 2 times the weight, a static force is applied at the center of gravity with horizontal component along the direction of the vehicle travel at 10 times the weight, and a static force applied at the center of gravity with horizontal component in transverse direction of vehicle travel of 5 times the weight.

Analysis:



There is a 4000 lb load applied at the center of gravity perpendicular to the plane of the page.

This calculation will evaluate the tie down system for a load combination that includes all loads specified in 10 CFR 71.45(b) acting simultaneously.

Using the load combination (3 separate forces), the following force vector can be determined:

Vector A = 4000i + 0j +ok
Vector B = 0i + 8000j + 0k
Vector C = 0i + 0j + 1600k

Sum the vectors to find the resultant vector R = 4000i + 8000j + 1600k

Calculate the magnitude and directional cosines:

$$r = \sqrt{(4000)^2 + (8000)^2 + (1600)^2}$$

$$r = 9086.25 lbs$$

Directional Cosines:

$$\lambda = \frac{R}{r} = \frac{4000i + 8000j + 1600k}{9086.25}$$

$$\lambda = .440i + .8804j + .176k$$

Therfore:

$$Cos\theta x = .440$$

$$\theta x = 63.89°$$

$$Cos\theta y = .8804$$

$$\theta y = 28.30°$$

$$Cos\theta z = .176$$

$$\theta z = 79.86°$$

For efforts of simplicity and extreme conservatism, SPEC will assume that the 9086.25 load will act fully in each direction. In other words, instead of using angular contribution in the x, y, z directions, SPEC will assume that the full load will act in each direction.

If 9086.25 lbs were acting on the x, y, z, planes, then the y plane, force pulling along the long axis, would be worst case for the holes in the enclosure cover. These holes are the worst case for tie down because the mounting blocks can withstand higher forces, as seen in code B.

In this calculation, there is no way to predict how much area will be used when tying down the device. We will assume 1/2in^2 of area. This gives the following:

$$\sigma = \frac{F}{A} = \frac{9086.25}{.5} = 18172.5 psi$$

Considering the shear stress in the plate at the edge of the hole:

Shear stress calculations will depend on the force along the long axis and the area of the hole. In this location, doubler plates are used to give an area of .625 in^2. See the following calculations for the shear stress:

$$\tau = \frac{p}{A} = \frac{8000}{(1)(.625)} = 12800 psi$$

Temperature Stresses:

There are no temperature stresses included in these calculations. Considering thermal deformation, very little would exist given the temperature requirements of 10 CFR 71.71(a). Also, according to Marks Standard Handbook for Mechanical Engineers (10^{th} ed) temperature stresses only results when a design prevents thermal deformation from happening. Since there is no prevention, the thermal stresses do not exist.

Inertia Stresses:

Evaluate the bulkheads and the enclosure for inertia forces during normal conditions of transport. The inertia forces are 10g along the direction of the travel, 5g in the lateral direction and 2g in the vertical direction. The inertia forces are specified for tie-down system design in 10 CFR 71.45(b). These forces are first transferred to the bulkheads and the enclosure. And then to the tie down systems.

The forces for the tie down systems are shown above. The inertia forces are described below.

From the above, we have the magnitude and direction of all the forces acting simultaneously. In calculating the effects on the two bulkheads, the force perpendicular to the bulkheads will cause the worst case. The force applied to perpendicular to the bulkhead plate is 8000 pounds.

From the construction of the entire package, it obvious that the shield will transfer the load into the bulkhead. However, the shield is also supported by the hot top ring enclosure. It is a conservative assumption that the hot top support will only absorb 25% of the 8000 pound load. This results in the rest of the load (6000 lbs) being applied perpendicular to the bulkhead. This 6000 lb load will have a contact area of 7.23 in^2.

In an attempt to use industry accepted formulas, SPEC will assume that this load is applied uniformly over a small concentric circle. This assumption is necessary to allow the use of a proven formula for a concentrated load applied to a rectangular plate with all of the edges fixed.

The formula places the load in the center of the plate, which is not a true representation. The load is actually applied off center, but the assumption of the load applied on center is worst case and therefore, would make this an acceptable assumption.

Using textbook, Roark's Formulas for Stress and Strain, 6th ed, the formula is (page 465):

$$\sigma b = \frac{3W}{2\pi t^2}[(1+v)\ln\frac{2b}{\pi r_0} + \beta_1]$$

where

σb = max stress at center of the plate

W= applied load

t = thickness of the plate

v = Possion's ratio (.3)

r_0 = equivalent radius of contact for the load (1.5)

β_1 = Ratio of a / b. This value is taken from a chart (.067)

a = long side of the rectangular area

b = short side of the rectangular area

Values for "a" and "b" are determined by the area utilized in the stress calculation. There is no need to consider the entire bulkhead for these calculations because the shield supports act as stiffeners as well as the structural posts. The worst case would be an area which extends from the points where the shield supports are fixed to the bulkhead. This gives a = 8.037 in and b = 4.219 in.

The variable r_0 is determined by calculating the contact area and relating it to a circular area. The actual contact area is rectangular (7.23 in^2), but the formula requires that the area be circular. Therefore, after the area was calculated, it was then converted into a radial area with radius of 1.5 in. The calculations are as follows:

$$\sigma b = \frac{3(6000)}{2\pi(5/16)^2}[(1+.3)\ln\frac{2(4.219)}{\pi(1.5)}+.067]$$
$$\sigma b = 29335.49(1.3\ln 1.79+.067)$$
$$\sigma b = 24181.65 psi$$

The inertia forces have also been tested in the four foot normal conditions test required by NRC. This test was performed by dropping the device four feet on the lock end. This drop incurred more than the g-load required by 10 CFR 71.45(b).

This solution proves that the design passes the requirements set forth in the CFR. All of the stresses generated are below the stress limit for the parent material or the weld material. The weld metal has the same or better yield strength than the parent material. The parent material has a yield strength of 30,000 psi.

SPEC-300 Weld Verification
Code E

Statement: Code E welds are welds that were tested for their compliance. The welds for the shield support together and shield supports to both bulkheads were tested extensively in the hypothetical 30 foot drop test. The SPEC-300 was dropped four times in an attempt to not only satisfy the 10 CFR requirements, but to also verify the weld strength of the fore mentioned welds. The SPEC-300 was dropped from 30 feet on the lock end, outlet end, side, and a top edge. In all of these four drops, these welds proved to hold firm. The results of all four of these tests verify the welds.

The weld of the outlet plate to the outlet boss was also tested in conjunction with the 30 foot drops. This joint does not see a load applied to it. This weld size is also used on the other SPEC device, the SPEC-150.

Drop Target Design Drawing

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	COMPLETLY REVISED & REDRAWN TO AS BUILT CONFIGURATION.	6/18/97 6/23/97	J FRYER P. WEBER

Security-Related Information
Figure Withheld Under 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE .XX±.250 .XXX±.010 DO NOT SCALE DRAWING	APPROVALS	DATE	SOURCE PRODUCTION & EQUIPMENT CO INC 113 TEAL ST, ST ROSE, LA 70087
	DRAWN JAF	6/18/97	DROP TEST TARGET
	CHECKED PW	6/23/97	
TREATMENT NA	APPROVED PW	6/23/97	SIZE C DWG NO. 50890-1 REV 1
FINISH NA	QA CLASS NA		SCALE: 1"=1" 00000242 SHEET 1 of 2

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SOURCE PRODUCTION & EQUIPMENT CO INC	SIZE C	DWG NO 50890-1	REV 1
	SCALE: 1"=1'	00000243	SHEET 2 of 2

CONTROLLED COPY NO			
REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

Security-Related Information
Figure Withheld Under 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE .XX±.03 .XXX±.010 DO NOT SCALE DRAWING	APPROVALS	DATE	SOURCE PRODUCTION & EQUIPMENT CO., INC. 113 TEAL ST, ST ROSE, LA 70087
	DRAWN RAM	3/25/99	ASSEMBLY– FUNCTURE FIXTURE, 10 CFR PART 71.73(C)(3)
TREATMENT NONE	CHECKED JRB	3/25/99	SIZE C DWG NO. 990086 REV 0
FINISH NONE	ISSUED PW	3/26/99	
	QA CLASS N		SCALE: 1/2 00074300 SHEET 1 OF 1

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REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE .XX±.03 .XXX±.010 DO NOT SCALE DRAWING	APPROVALS	DATE	SOURCE PRODUCTION & EQUIPMENT CO., INC. 113 TEAL ST, ST ROSE, LA 70087	
	DRAWN RAM	3/25/99	BASE- PUNCTURE TEST, 10 CFR PART 71.73 (C)(3)	
TREATMENT NONE	CHECKED SRB	3/25/99	SIZE C DWG NO 990084	REV 0
	APPROVED RW	3.26.99		
FINISH NONE	QA CLASS N		SCALE: 1/2 00074100	SHEET 1 OF 1

CONTROLLED COPY NO			
REVISIONS			
REV	DESCRIPTION	DATE	APPROVED

Security-Related Information
Figure Withheld Under 10 CFR 2.390

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE .XX±.03 .XXX±.030			SOURCE PRODUCTION & EQUIPMENT CO., INC. 113 TEAL ST, ST ROSE, LA 70087
	APPROVALS	DATE	PIN– PUNCTURE TEST, 10 CFR PART 71.73 (C)(3)
	DRAWN RAM	3/25/59	
DO NOT SCALE DRAWING	CHECKED SEB	3/25/99	
TREATMENT NONE	APPROVED PW	3.26.99	SIZE C · DWG NO. 990085 · REV 0
FINISH NONE	QA CLASS N		SCALE: 1/2 · 00C74200 · SHEET 1 OF 1

Impact Point Justifications

SOURCE PRODUCTION AND EQUIPMENT COMPANY
ST. ROSE, LOUISIANA

SPEC-300 Exposure Device
Justification of Package Orientation for:
4 Foot Free Drop
30 Foot Free Drop
Puncture Test

Prepared by: Kenny Carrington and Pete Weber
Date: 6/8/99
Rev: 1

Purpose:
10 CFR 71.71 (c) (7) describes a drop test consisting of a 4 foot free drop onto a flat, essentially unyielding horizontal surface striking in a position for which a maximum damage is expected.

10CFR 71.71 (c) (10) describes a penetration test consisting of an impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs) mass, dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.

10 CFR 71.73 (c) (1) describes a drop test consisting of a 30-foot free drop onto a flat, essentially unyielding horizontal surface striking in a position for which a maximum damage is expected.

10 CFR 71.73 (c) (2) describes a puncture test consisting of a 40" free drop onto a 6" diameter mild steel bar. The package should strike the bar in a position for which maximum damage is expected.

This document defines the test package orientation expected to produce maximum damage for the four tests described above, and states the rationale for the orientation chosen.

Scope:
The following radioactive material package will be considered:
SPEC-300 Exposure Device/Type B transport package.
Testing is scheduled for the week of June 7, 1999.

Maximum Damage definition:

4 foot free drop and penetration tests:

"Maximum damage" is not defined in 10CFR 71.71, but 10CFR 71.43 (f) states: A package must be designed, constructed, and prepared for shipment so that under the tests specified in Sec. 71.71 (``Normal conditions of transport") there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging. It is highly unlikely that the sealed radioactive source assembly will shift in the depleted Uranium shield as a result of these tests, and only minimum damage is expected to the device enclosure. For these tests, maximum damage will be defined as a test-induced condition that results in a 20% or greater increase in radiation level, when compared to a pre-test radiation level at the same location, and this will be attempted by trying to jar either the safety plug or the lock cap (safety cap) off of the device.

30 foot free drop and puncture tests:
"Maximum damage" is not defined in 10 CFR 71.73, but 10 CFR 71.51 (a) (2) specifies that as a result of testing, the radiation dose rate will not exceed one REM/hr at one meter from the external surface of the package. For these tests, maximum damage will be considered as the condition that provides maximum movement, or chance of movement, of the sealed radioactive source assembly away from the fully shielded position within the depleted Uranium shield. This is the condition most likely to result in increased radiation levels outside the device.

SPEC-300 construction overview:
The SPEC-300 exposure device is a depleted Uranium shield weighing approximately 500 pounds enclosed in a robust rectangular welded stainless steel enclosure. The shield is retained in the enclosure by two tabs or "ears" that are cast integrally with the shield. Each tab is fastened to the corresponding end bulkhead of the enclosure by means of a solid support welded to the bulkhead. Two additional internal brackets support the depleted Uranium shield. The interior of the enclosure is filled with a dense structural foam that further supports and cushions the depleted Uranium shield. The foam also increases the overall strength of the enclosure. Attached to the lock-end bulkhead on the outside of the enclosure is a sheet metal lock box containing a lock module and transport lock. The transport lock is the primary mechanism maintaining the radioactive pigtail assembly at the desired location in the depleted Uranium shield. Attached to the opposite-end bulkhead is a panel containing a quick connect nipple. A safety plug is attached to this nipple. The safety plug includes a length of wire rope cable that when inserted and secured to the nipple, acts to prevent the source from moving significantly in the direction of the outlet end of the device. The ends of the device are designed to act as "crumple zones". The bulkheads are recessed several inches into the ends of the device, forming a large "lip" all around, which during testing is expected to crush and deform, absorbing significant impact energy. This feature has been demonstrated on both the SPEC-150 and SPEC 2-T, which share a common design.

SPEC-300 4 foot free drop package orientation:
The failure criterion for the 4 foot free drop test is a 20% increase in radiation levels after the test. Considering that the device is designed to withstand a 30 foot drop, significant damage is not expected when the device is dropped only 4 feet. Movement of the radioactive source assembly away from the fully shielded position in the depleted Uranium shield therefore will not be a goal of this test. The most likely means of increasing radiation levels by 20% would be to cause one of the protective caps located at each end of the device to come adrift. Considering the design of the

device and end caps, it is most likely that this will occur if the device is dropped flat on the lock end. Deformation of the "crumple zone" at the lock end of the device could result in an impact to the lock cap. Such an impact could damage the boss that retains the cap in place, and cause the cap to come adrift. Removal of the lock end cap does result in an increase in radiation level at the lock end of at least 20%. SPEC has therefore decided that this concept will be used in the 4 foot free drop test.

Since the 300 series stainless steel used for the device enclosure becomes stronger and tougher as temperature is reduced, the test will be conducted with the enclosure at ambient temperature.

SPEC-300 penetration test package orientation:

The failure criterion for the penetration test is a 20% increase in radiation levels after the test. Considering that the device is designed to withstand a 30 foot drop, significant damage is not expected when the device is subjected to this test. Movement of the radioactive source assembly away from the fully shielded position in the depleted Uranium shield therefore will not be a goal of this test. The most likely means of increasing radiation levels by 20% would be to cause one of the protective caps located at each end of the device to come adrift. The most effective means of causing this failure would be to perform the test twice, impacting the device on the safety plug at the outlet end and then on the lock cap at the lock end of the device. Removal of the safety plug or lock end cap would result in a localized increase in radiation level of at least 20%. SPEC has therefore decided that this concept will be used in the penetration test.

Since the 300 series stainless steel used for the device enclosure becomes stronger and tougher as temperature is reduced, the test will be conducted with the enclosure at ambient temperature.

SPEC-300 30 foot free drop test package orientation:

In an attempt to drop the exposure device on a point that would cause maximum damage as defined above, several ideas were considered and discussed with NRC:

The first concept involves dropping the device flat on the outlet end. An impact at this point could cause the mass of the shield to deform the outlet-end bulkhead, resulting in the shield shifting toward the outlet end of the device, effectively pulling the radioactive source assembly out of the fully shielded position. An observation about this concept is that the ends of the device are designed to act as "crumple zones", and the deformation of one of these zones would absorb significant impact energy before the shield would begin to shift. In addition, the dense foam in the device would act to further absorb impact energy and prevent shifting of the shield.

The second concept involves dropping the device flat on the lock end. An impact at this point could cause the mass of the shield to deform the lock-end bulkhead, resulting in the shield shifting toward the lock end of the device. The lip around the end of the device would also be expected to crush. The combination of these two effects would potentially crush the lock box and transport lock, possibly even tearing them off. If this were to occur, the radioactive source could be pulled out of the fully shielded position. An observation about this concept is that since all of the forces expected are compression forces, it is likely that the lock box would simply be crushed, but still retain the source assembly in the fully shielded position.

The third concept involves dropping the device flat on the side opposite the hot top. The predicted failure mode would be a direct shock to the depleted Uranium casting causing failure (cracking) of the casting where the two tabs or "ears" join the spherical portion of the casting. These cast-in tabs are the thinnest and weakest part of the casting, and would bear most of the shock load. A side impact would induce significant bending stress in the tabs where they join the spherical portion of the casting. Chilling the device to -40°F or colder would cause low temperature embrittlement of the depleted Uranium casting, allowing for a worst case condition. Contrary to the first and second concepts, there exists no crumple zone to attenuate the forces resulting from the impact. An observation about this concept is that a depleted Uranium shield has never failed during testing at SPEC, even in devices containing no foam. Also, considering the configuration of the shield (no stress risers) and the mechanical properties of depleted Uranium it is not expected that an impact of this magnitude would crack the shield. It is calculated that the device will only be traveling at 44ft/s or 30MPH at the end of the 30 foot fall.

The fourth concept involves dropping the exposure device on the edge formed by the top of the device and the lock end. An impact at a similar location has caused failures in early SPEC-150 prototype devices, which share a common design. The failure mode consists of shearing the welds attaching the lock end bulkhead to the device enclosure, particularly near the impact point. Whereas failure of these welds may not cause a direct increase in radiation levels, a breach in the device enclosure would cause the device to be much more vulnerable to the thermal test, which follows the 30 foot free drop test. A second failure mode would be shearing off the lock box and transport lock. Since the lock box and transport lock are the means of retaining the radioactive source assembly in the fully shielded position, this failure could allow the radioactive source to be pulled out of the fully shielded position. An observation about this concept is that the transport lock and lock box are redundant mechanisms, and the transport lock is very securely fastened to the lock end bulkhead. The likelihood of both the transport lock and the lock box being sheared off due to this type of impact is low.

The four concepts described above each offer the possibility of maximum damage to the package. SPEC has therefore decided to perform the test 4 times, once in each orientation described above. Since the 300 series stainless steel used for the device enclosure becomes stronger and tougher as temperature is reduced, tests 1, 2, and 4 will be conducted with the enclosure at ambient temperature. Test 3 will be performed with the casting at low temperature as described above.

When the test is performed, steps will be taken to ensure that the center of gravity of the exposure device is directly above the impact point at the time of release. This will ensure that maximum energy will be focused at the desired impact point.

SPEC-300 Puncture test package orientation:

Considering the size of the puncture test pin relative to the SPEC-300 exposure device, as well as the overall design of the device, it is not expected that the puncture test pin will penetrate the device or cause internal damage. The next best chance for this test to cause maximum damage would be to damage the lock box, possibly compromising the means to position the radioactive source assembly at the fully shielded position in the depleted Uranium shield. The lock box

consists of a relatively thin sheet metal enclosure that attaches externally to the lock-end bulkhead of the device. Inside the lock box is the transport lock, a mechanism that acts as the primary means of positioning the radioactive source assembly at the fully shielded position in the depleted Uranium shield. If the lock box can be moved out of position, coupled with failure to the transport lock or the source assembly, it could drag the source assembly out from the center of the depleted uranium shield. This shift of position of the source assembly could result in abnormally high radiation levels.

Since the lock box is the only externally mounted item whose damage could result in maximum damage, SPEC has decided that this concept will be used in the puncture drop test. When the test is performed, steps will be taken to ensure that the center of gravity of the exposure device is directly above the impact point at the time of release. This will ensure that maximum energy will be focused at the desired impact point. Since the 300 series stainless steel used for the device enclosure becomes stronger and tougher as temperature is reduced, the test will be conducted with the enclosure at ambient temperature.

Assessment Conducted By: ______________________ Date 6/8/99
Kenny Carrington, Special Projects Manager

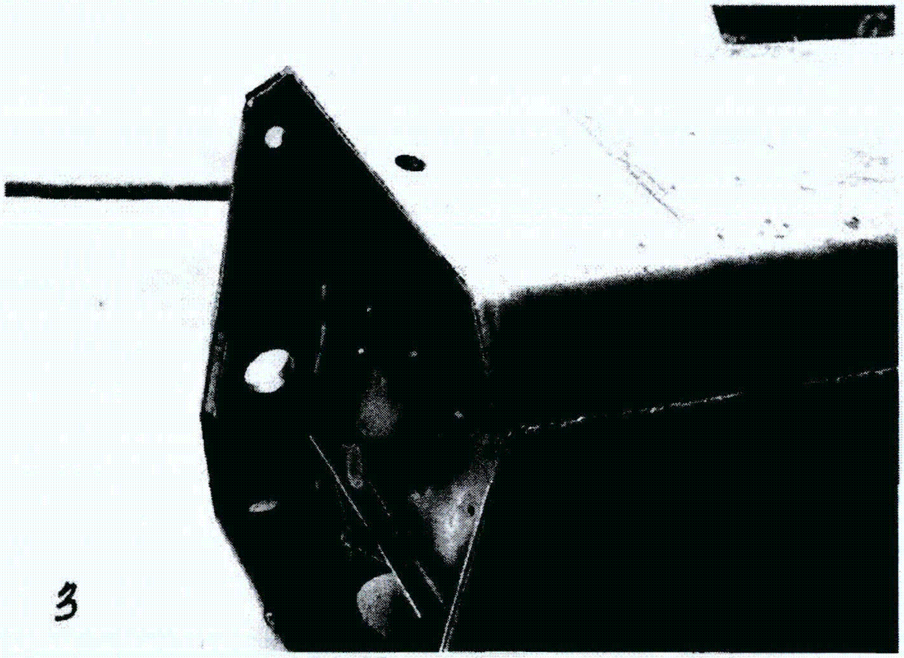
______________________ Date 6.8.99
Pete Weber, General Manager

Reviewed By: ______________________ Date 6/8/99
Richie Melancon, Engineering Manager

Approved By: ______________________ Date 6/9/99
Donny Dicharry, President

Filename: H:\WP\DOCS\IMPACT.WPD

Photographs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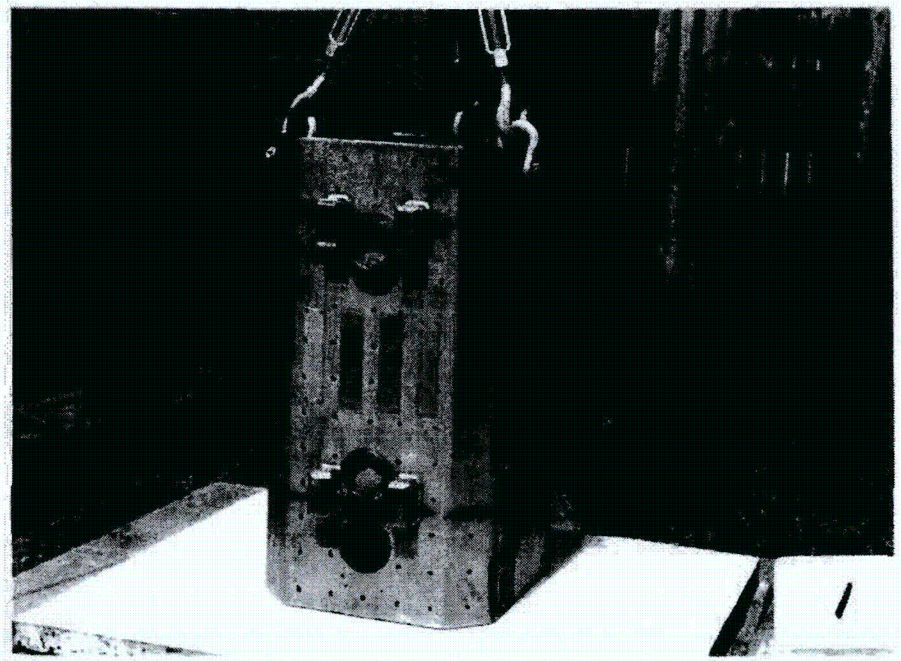
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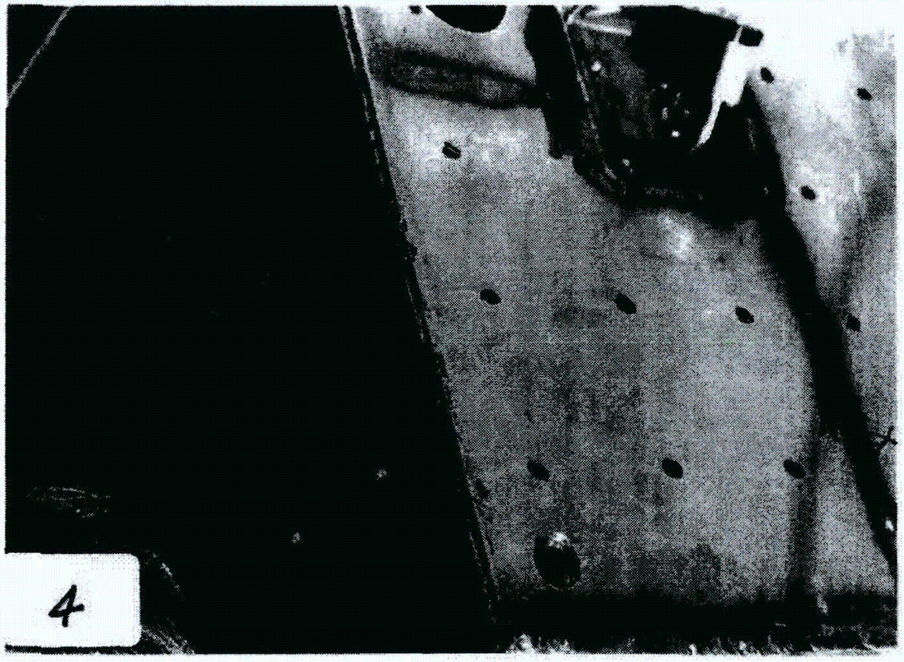
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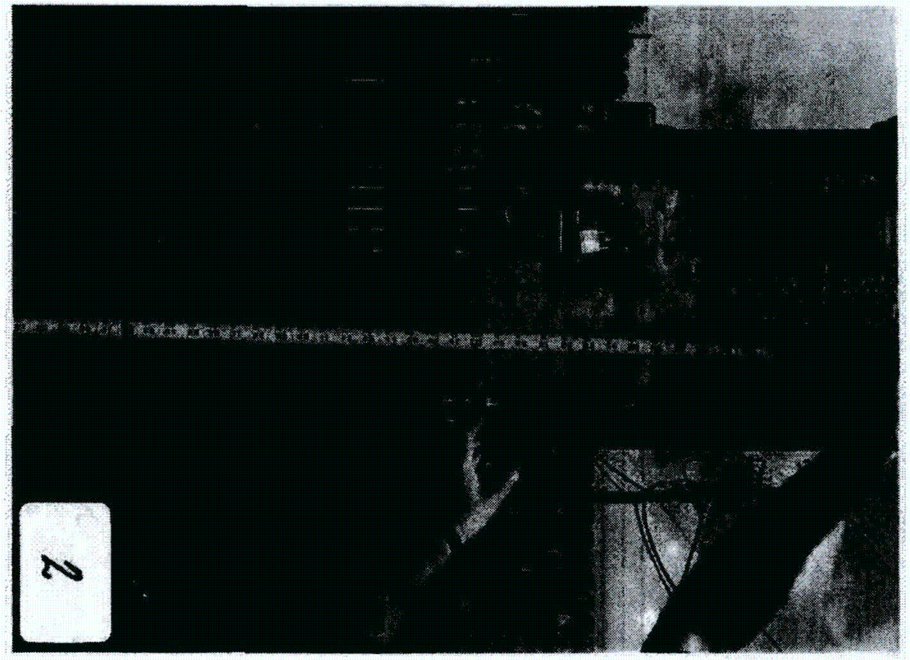
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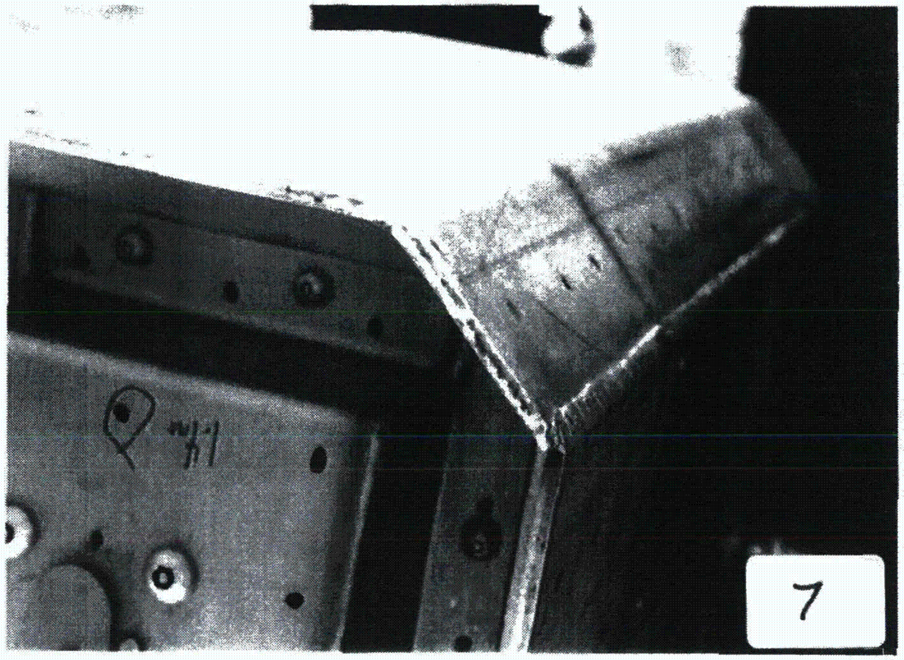

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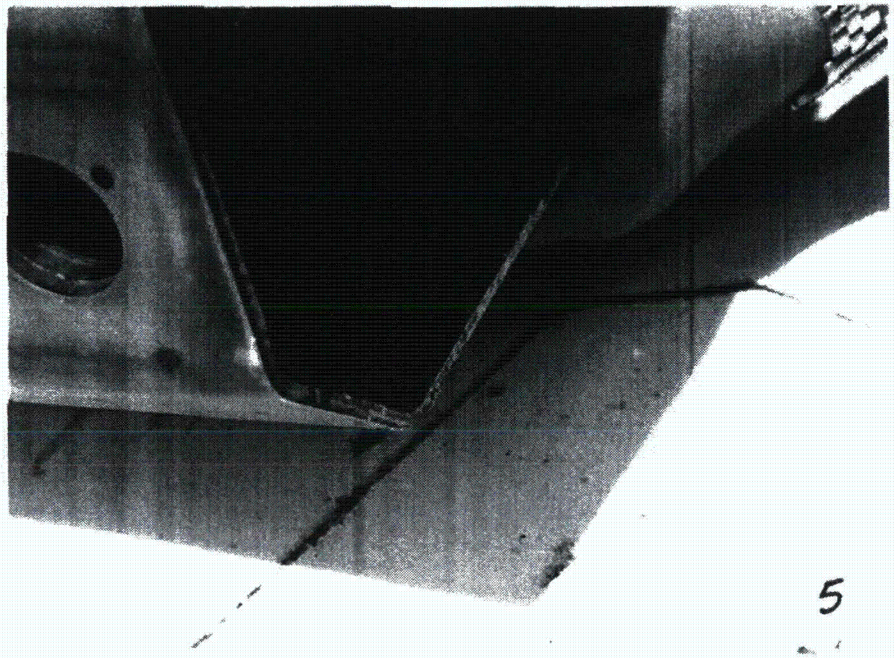

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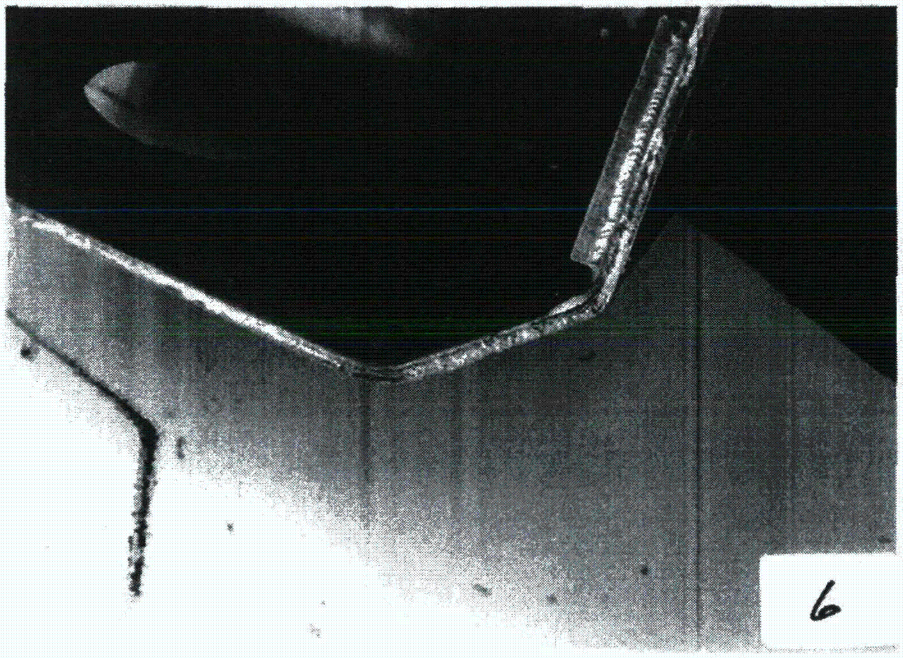

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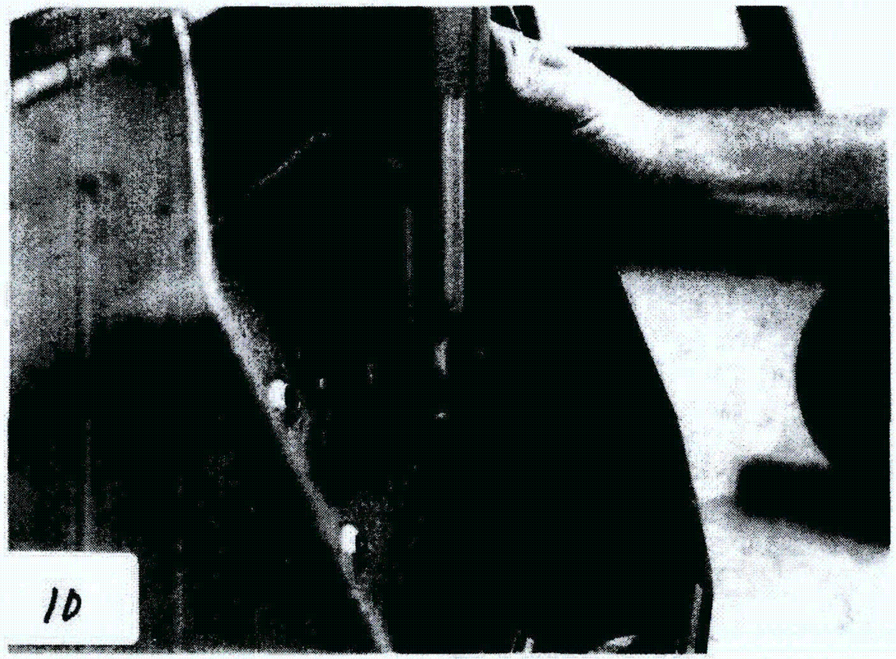

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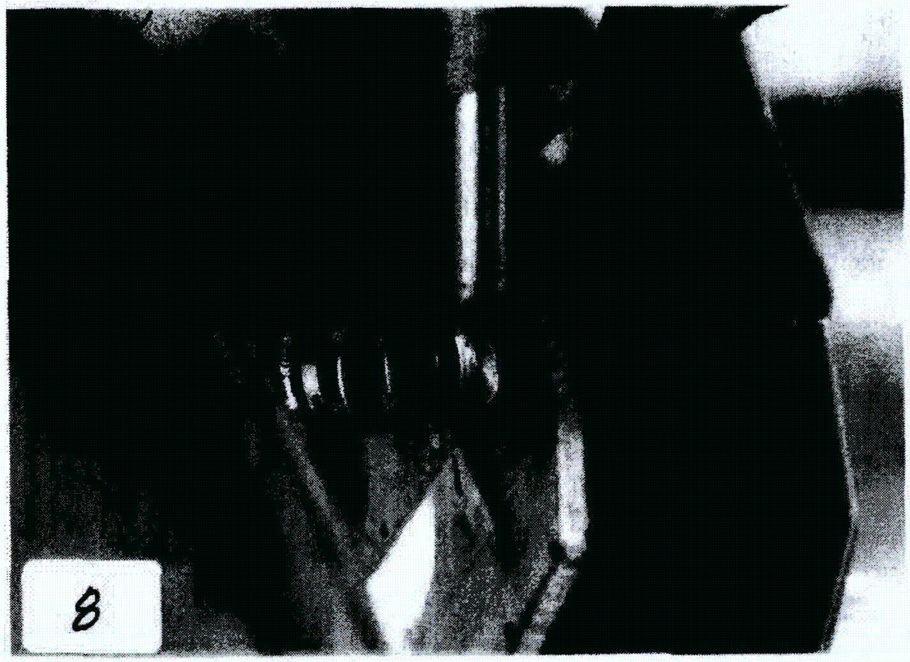

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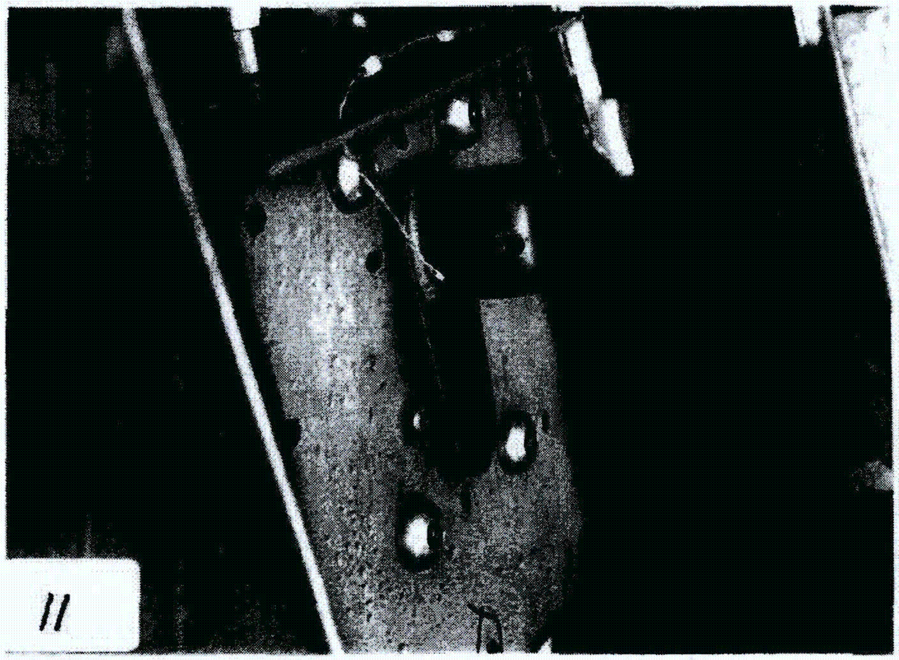

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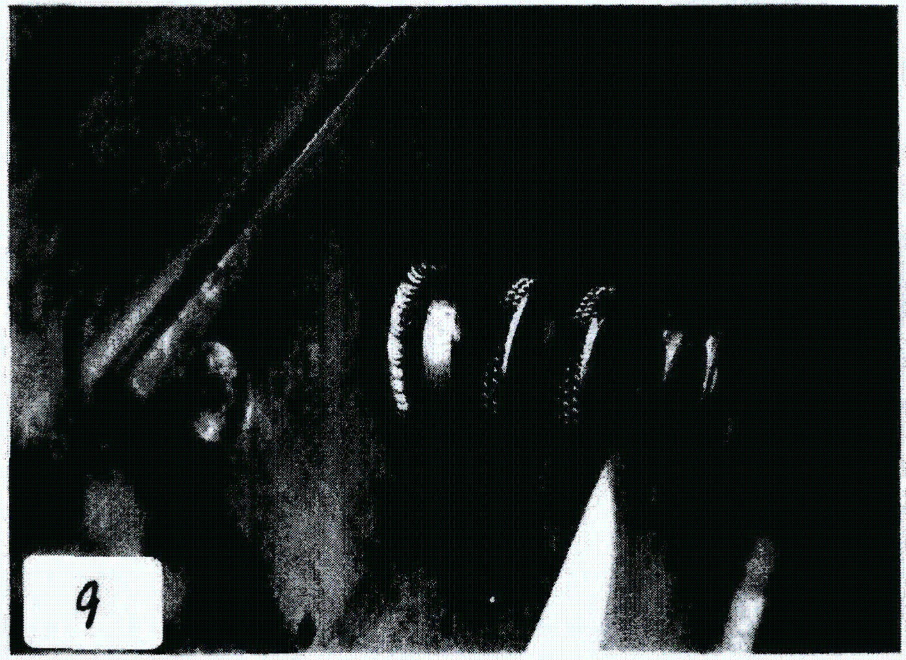

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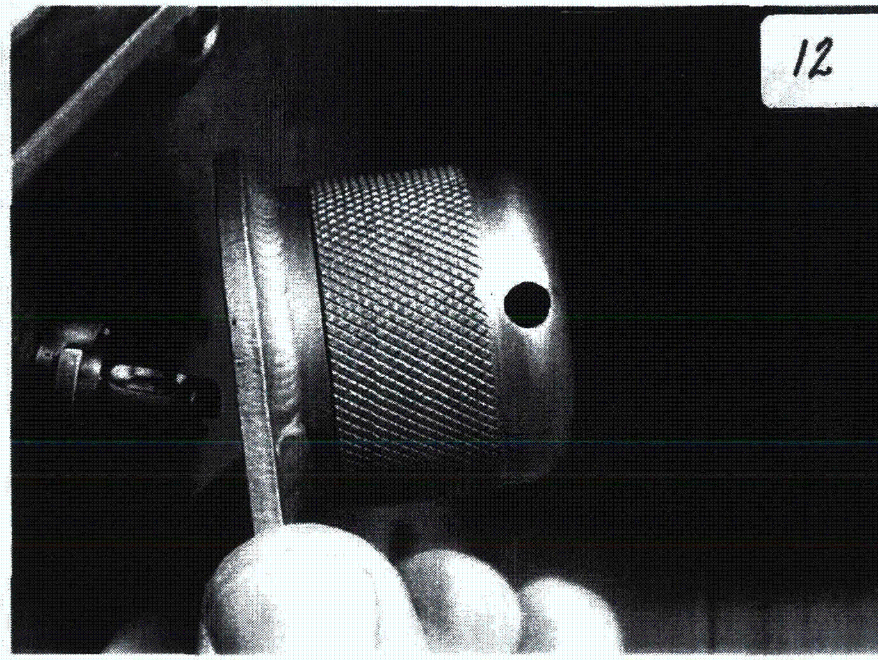
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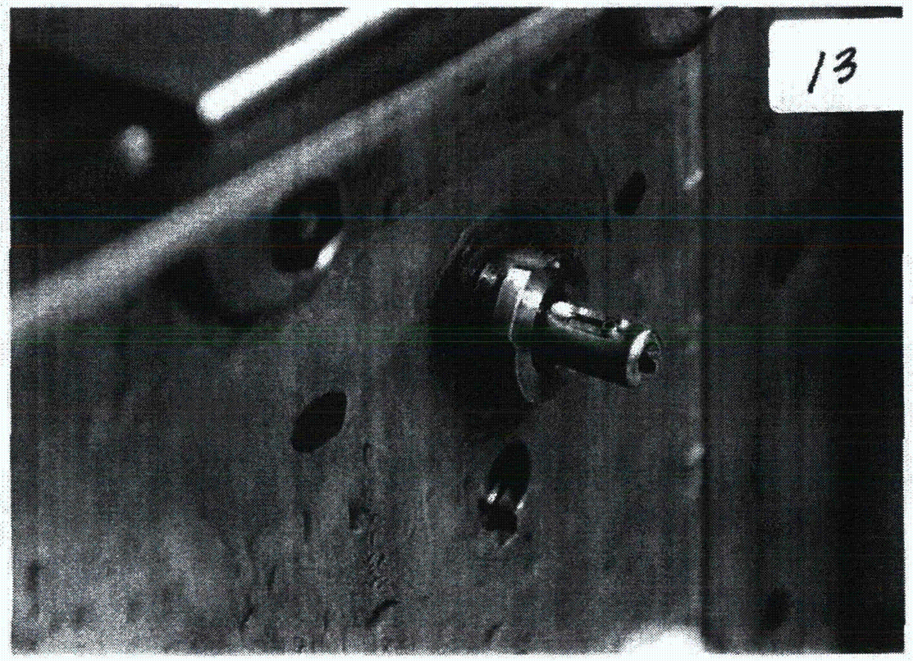
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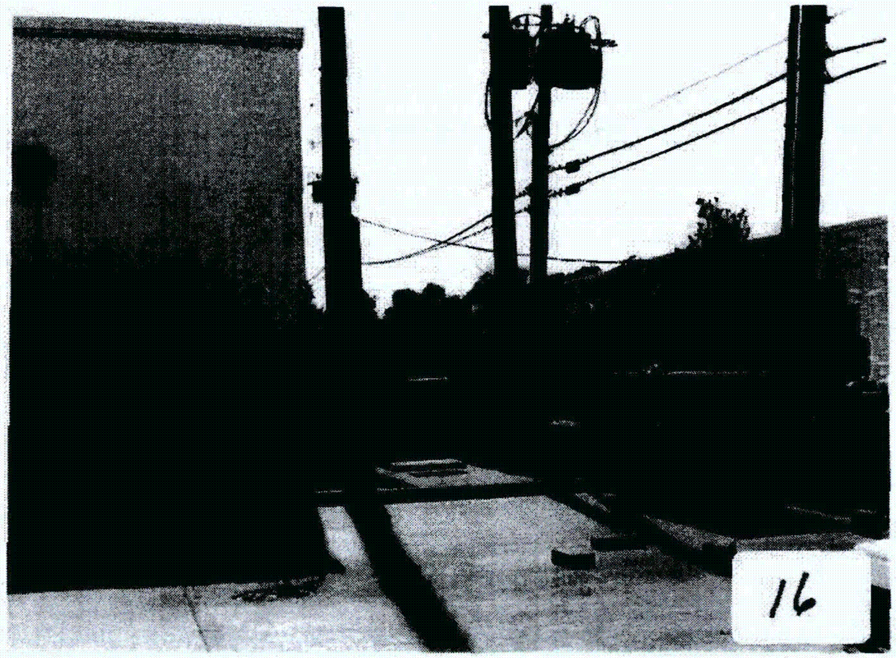
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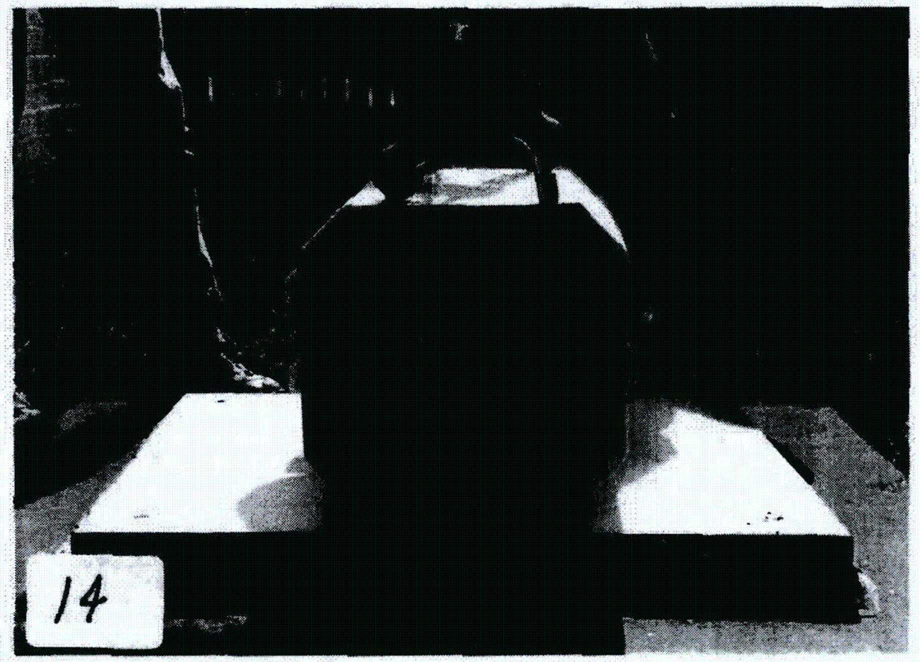
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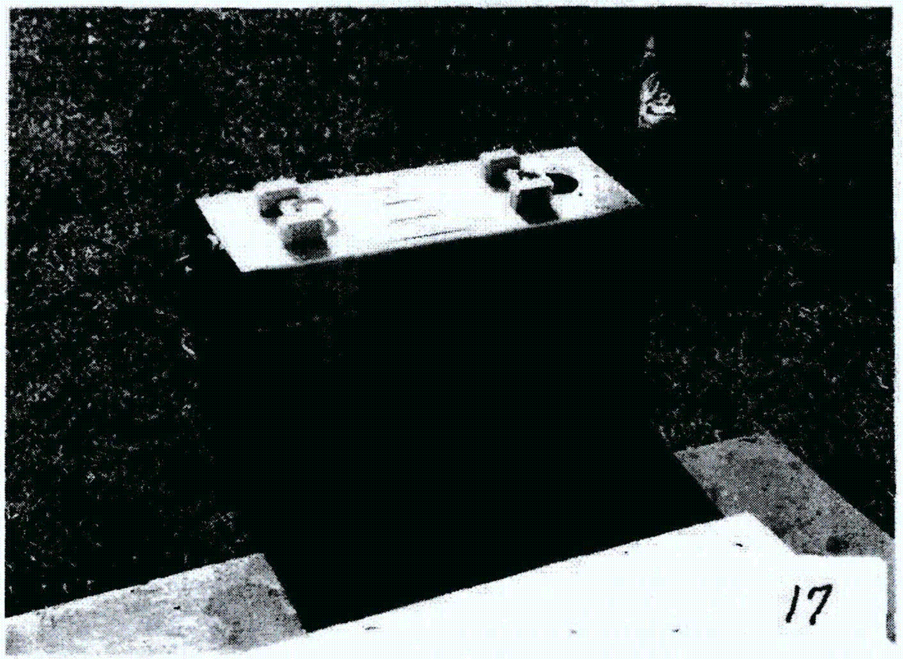
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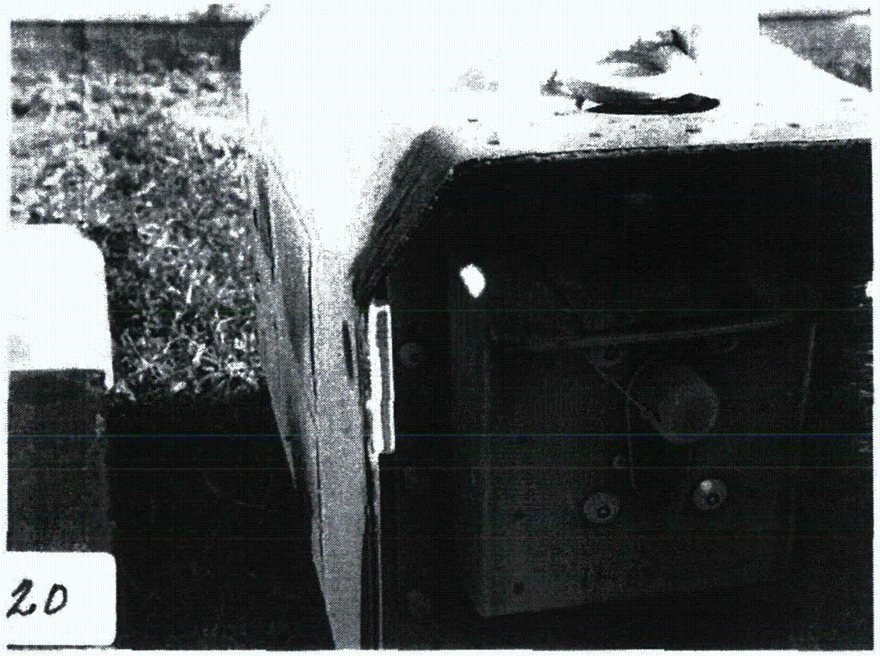

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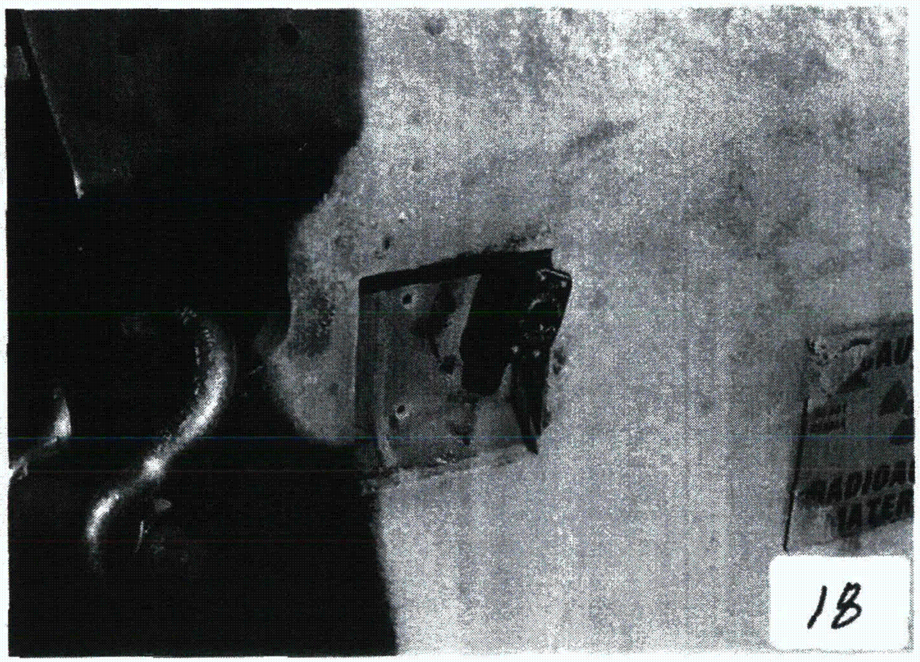

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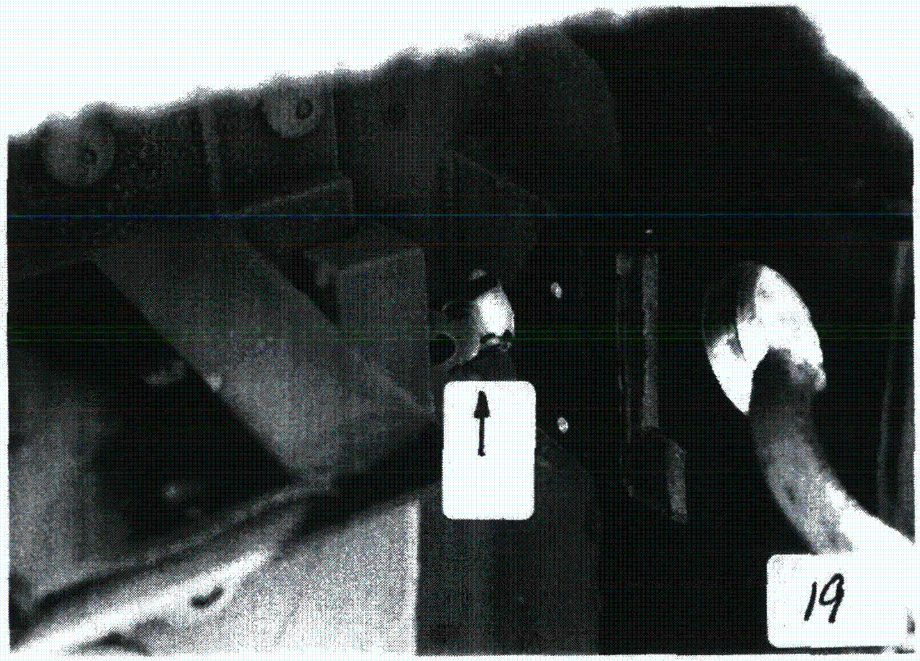

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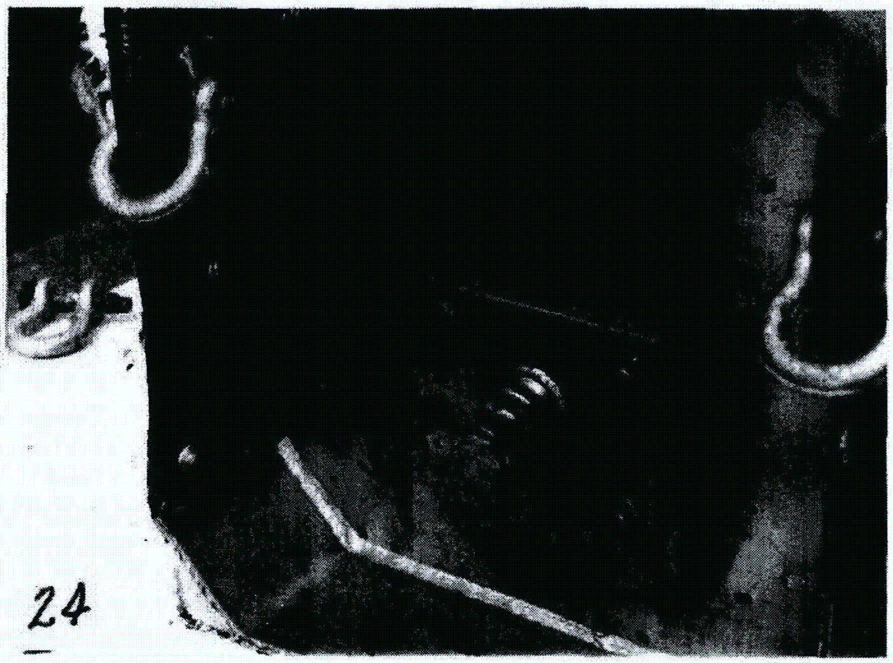

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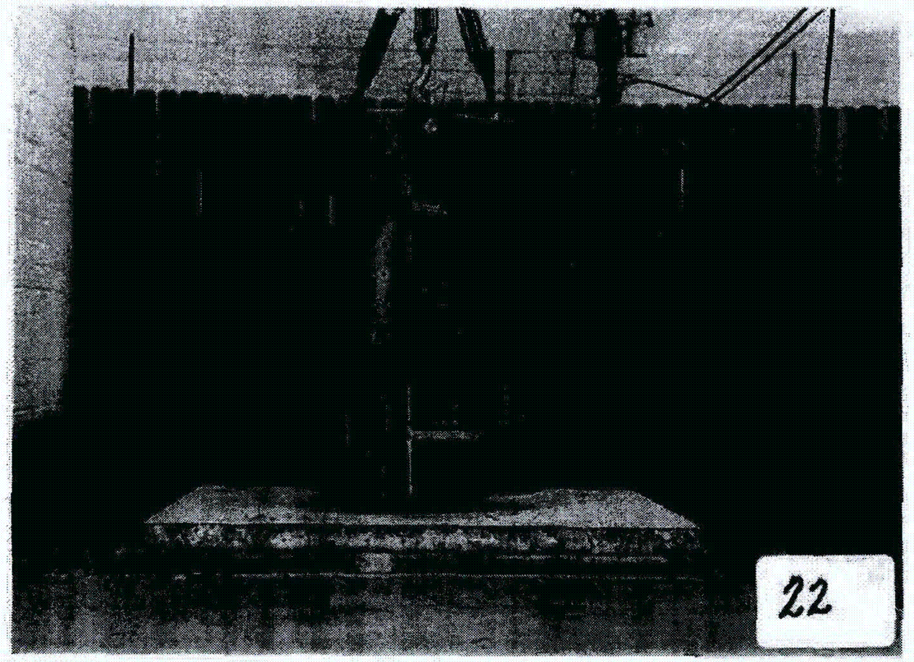

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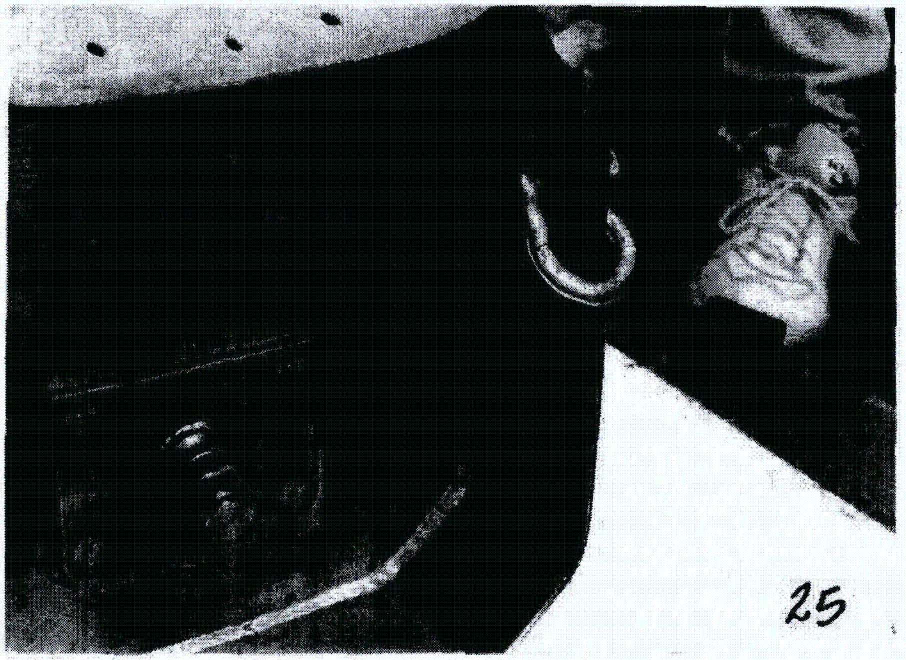

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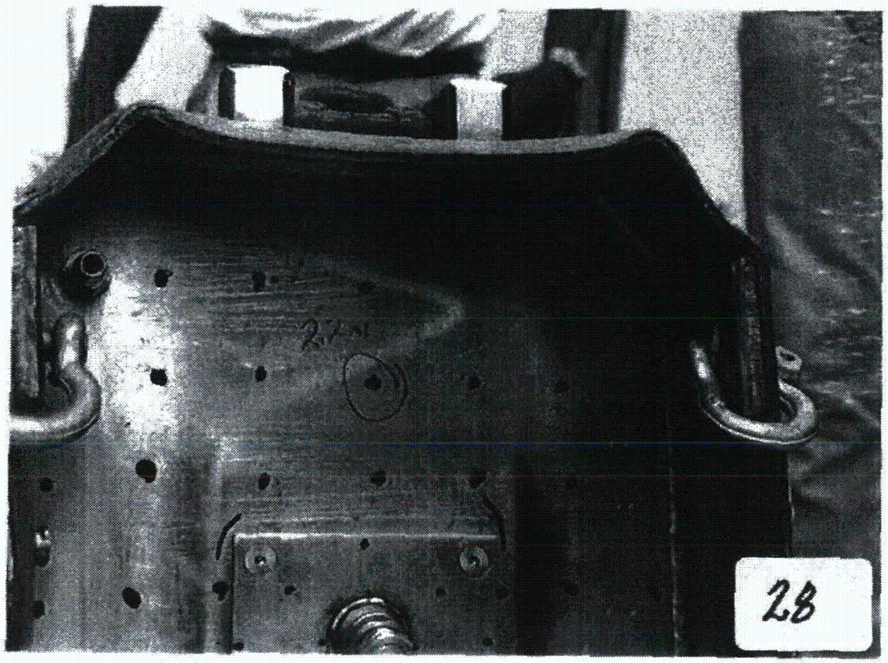
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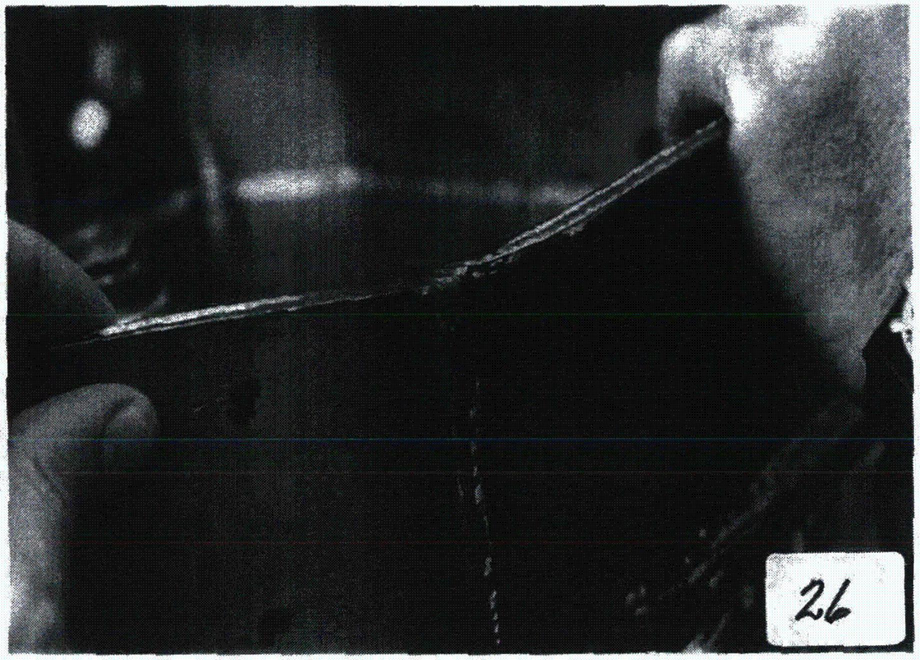
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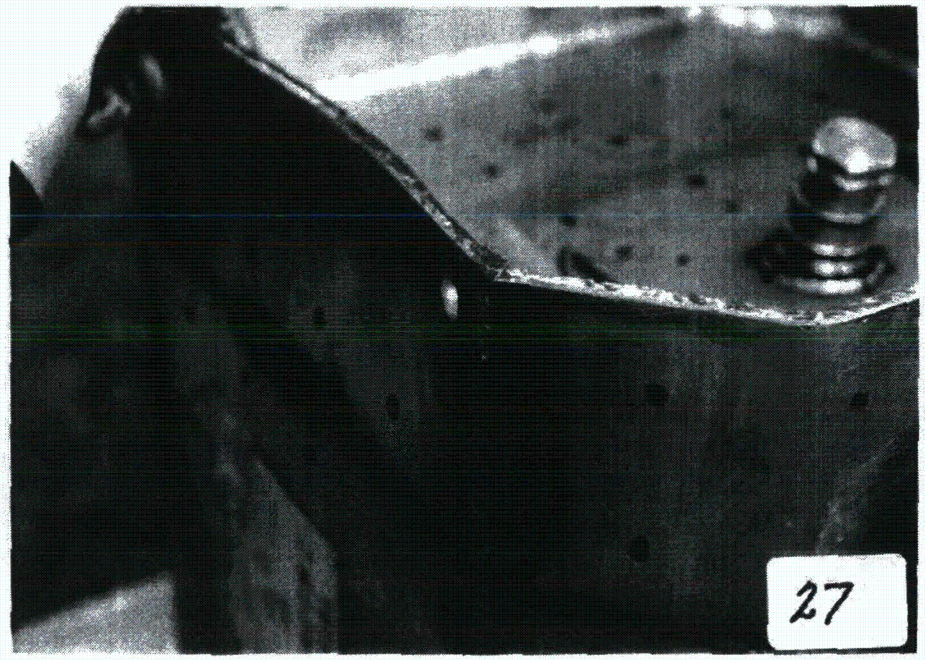
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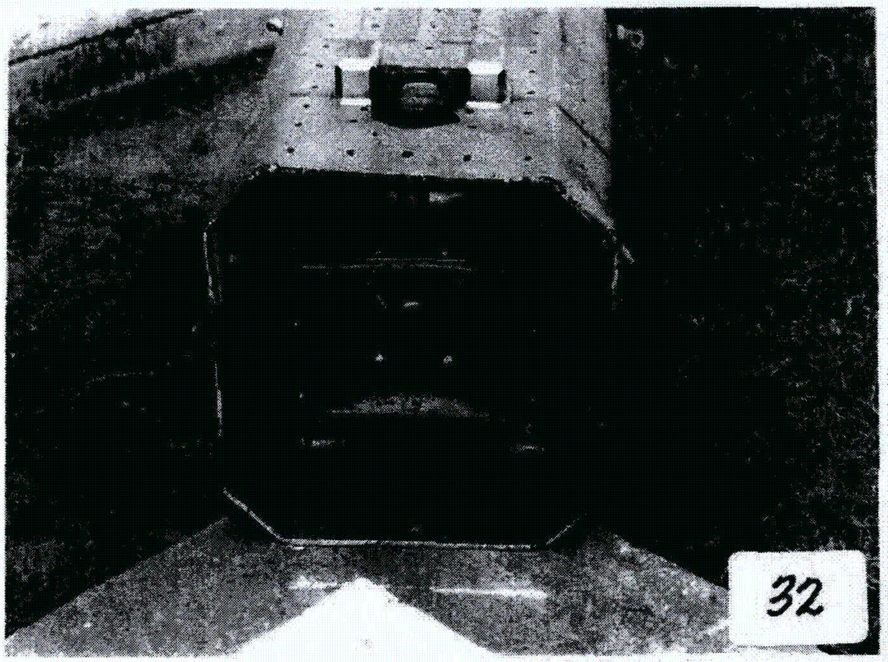
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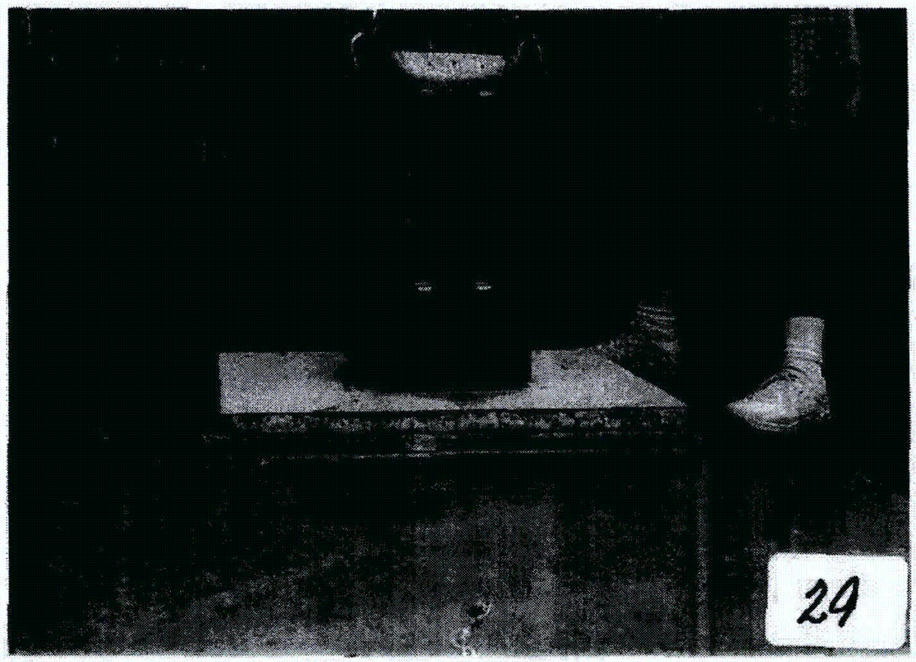
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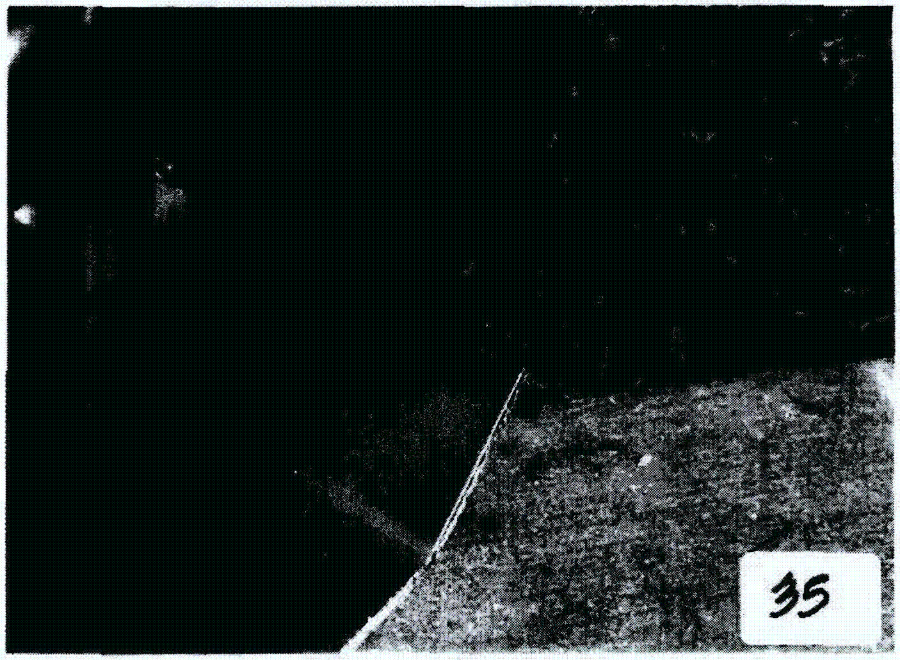
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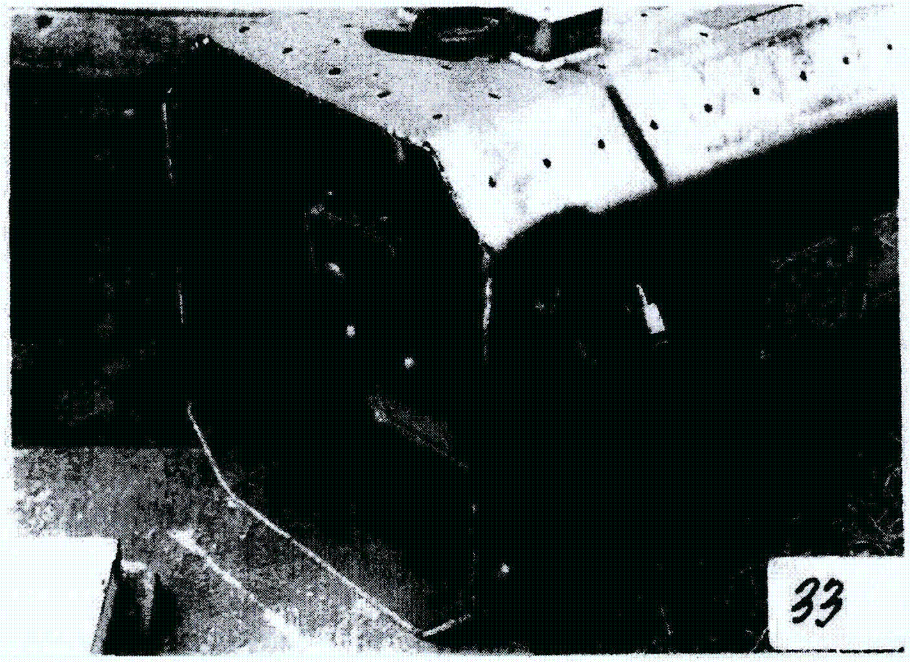
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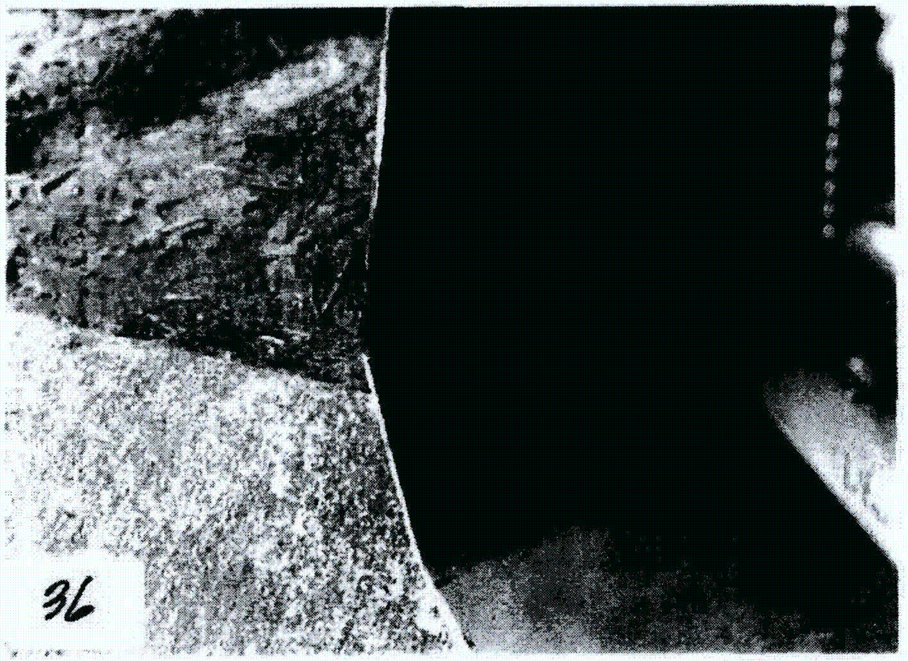
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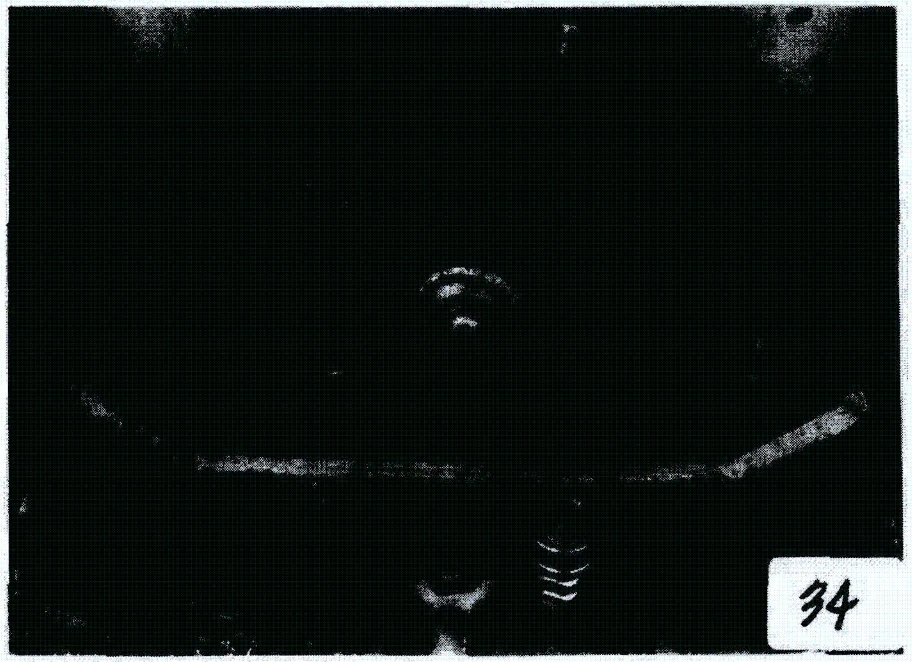
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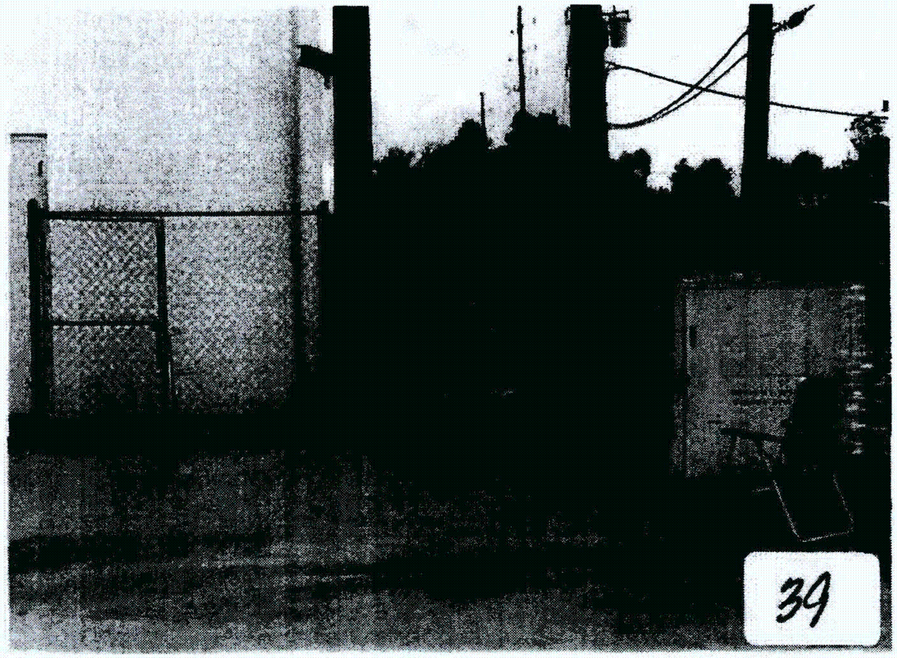
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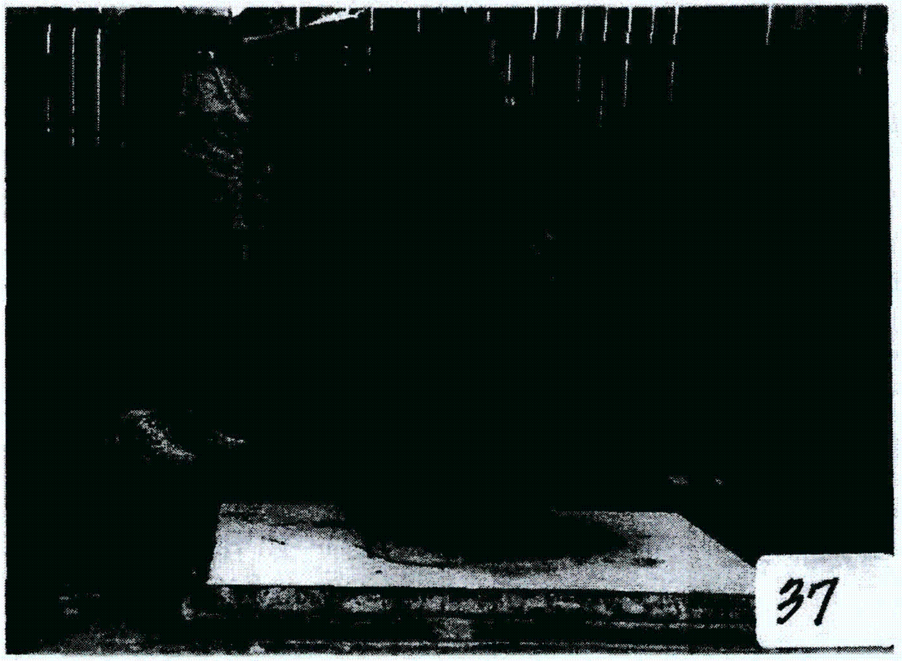
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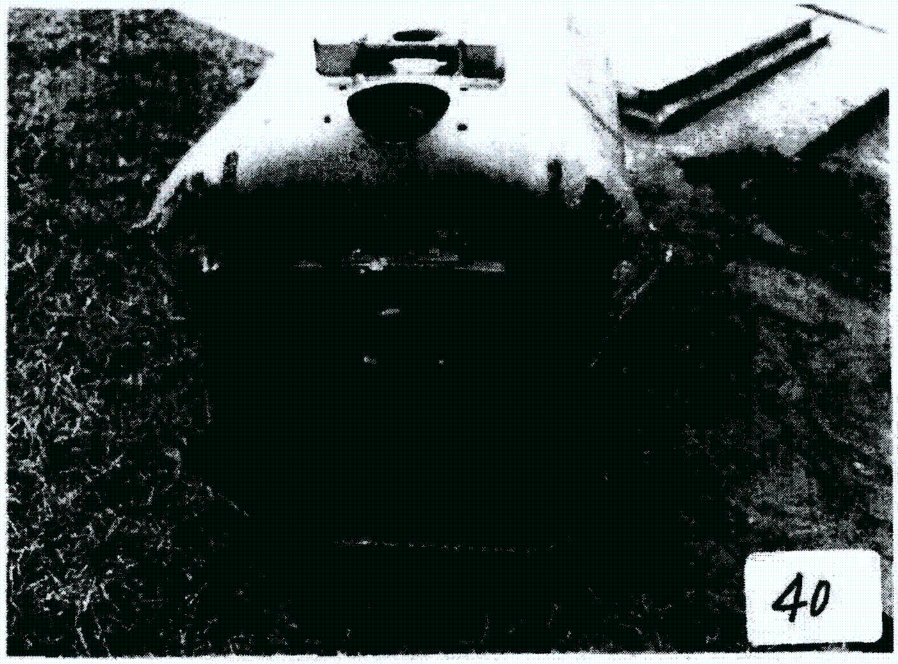
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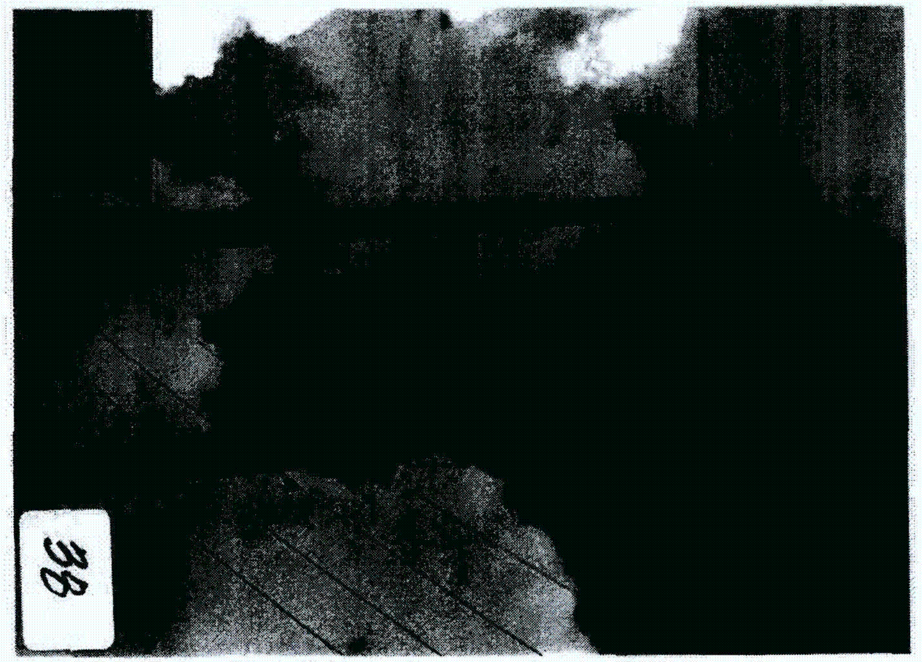
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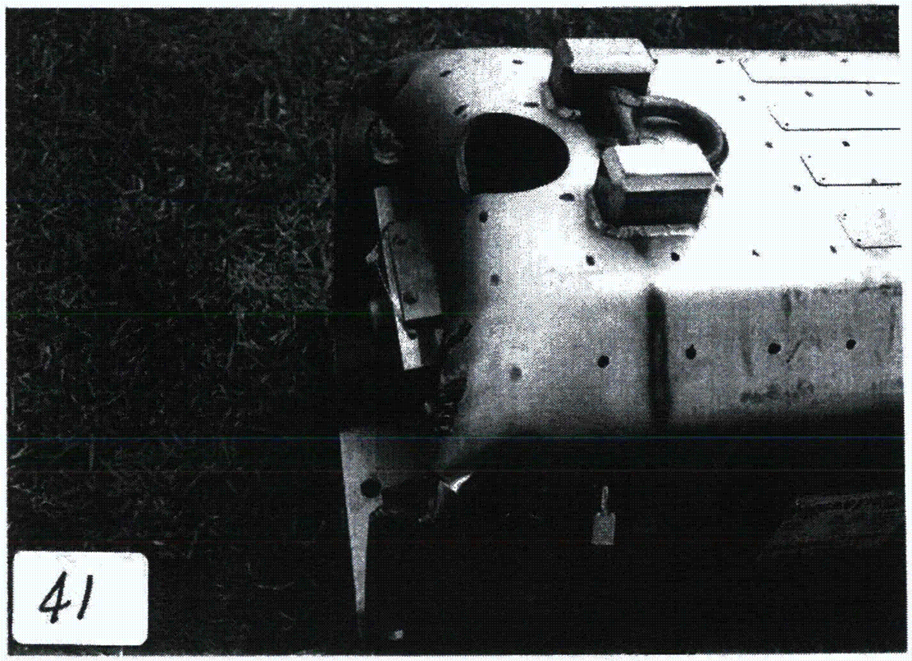
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Transport Securing System Drawing

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DO NOT SCALE DRAWING	DRAWN RAM	8/10/99	
	CHECKED SEB	8/13/99	
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3. THERMAL EVALUATION

Due to the materials of construction of the SPEC-300 which are known to have stable thermal properties and which will not be affected by the prescribed 800° C (1475° F) heat test it was not necessary to incorporate any special thermal engineering features in the package for it to comply with the normal conditions of transport and the hypothetical accident conditions.

3.1 Discussion

The heat of decay from the maximum activity 11.1 TBq (300 Ci) Cobalt-60 source is negligible. There are no fluids in the SPEC-300 package, it is not hermetically sealed, it is vented to the atmosphere, and there can be no pressure build up in the package. Venting of the SPEC-300 enclosure occurs through the hollow bodies of 20 rivets distributed among the top, left, and right sides of the packaging. Each of these rivets has an open internal diameter of approximately 2mm (0.080 in), for a cumulative vent area of approximately 65 mm^2 (0.1 in^2). The mandrels in the rivets are driven out after installation to ensure that each rivet acts as a vent. The effects of the free drop and percussion tests do not affect the thermal characteristics of the package since the individual materials of construction are not affected by a temperature of 800° C (1475° F). Buna rubber, foam and epoxy potting compound are the only materials which will be affected by the 800° C (1475° F) test temperature, but they are not critical to the safety of the packaging. Bronze has the next lowest melting point which is not lower than 704° C (1300° F). Melting of the bronze bushing in the automatic securing mechanism/lock module would only prevent unlocking the package. The hypothetical accident temperature of 800° C (1475° F) would affect the temper of the springs in the automatic securing mechanism/lock module, but it would remain in the locked position. A temperature of -40° C (-40° F) would have no adverse effect on the materials of construction since there are no moving operational parts of the package.

3.2 Summary of Thermal Properties of Materials

References: ASM International, Guide to Materials Engineering Data and Information, 1986.
Private Communication - Nuclear Metals, Incorporated.
Private Communication - Mitech Metals, Inc.

The materials of construction are as follows:

Structural Materials	Melting Temperature	
Depleted Uranium	1132° C	(2070° F)
316/316L stainless steel	1399° C	(2550° F)
Titanium Grade 2	1649° C	(3000° F)
Tungsten (alloy)	1649° C	(3000° F)
Zircalloy 2	1799° C	(3270° F)

The following non-structural materials are assumed to melt or be volatilized above 800° C (1475° F)

Epoxy adhesive
Polyurethane Foam

Rubber 70 Buna
Enamel Paint

From the above table it is apparent that a temperature of 800° C (1475° F) would have no effect on the package.

There have been reports indicating a possibility of an iron-Uranium eutectic formation at temperatures above 727° C (1340° F). Such eutectic formation has been associated with metallurgically clean surfaces and vacuum heat treatment. The depleted Uranium casting in the SPEC-300 is coated with enamel paint at the factory. Foam and two-component chocking compound would come in contact with the enamel paint on the shield exterior, but the iron-bearing SPEC-300 enclosure does not come in direct contact with the depleted Uranium shield. Copper pads are used as eutectic barriers at all locations where contact could occur. Depleted Uranium castings have employed Titanium S-tubes for years without any indication of a Titanium-Uranium eutectic.

3.3 Technical Specification of Components

This section is not applicable. The only operating component in the SPEC-300 package are the source assembly lock and the transport lock which are one piece components made of stainless steel which is not affected by an 800° C (1472° F) temperature. The SPEC-300 is locked when the package is prepared for transport. There are no operating components during transport.

3.4 Thermal Evaluation for Normal Conditions of Transport

The radiation level shielding and containment of the source assembly within the SPEC-300 is totally dependent on materials which are not adversely affected by temperatures in the range of -40° C (-40° C) to 70° C (158° F). Therefore, the SPEC-300 package will not release it contents, will not allow increased radiation levels, and will not incur any reduction in the effectiveness of the package.

3.5 Hypothetical Accident Thermal Evaluation

The purpose of the thermal test assessment is to supply information that the SPEC-300 meets thermal test requirements pursuant to 10 CFR 71.73 (c) (4). To prove that the SPEC-300 complies with the thermal requirements, there are two issues to be investigated. The first issue is the effect of temperature on the materials of construction, and the second issue is the rate of heat transfer into the package, and particularly into the depleted Uranium shield.

Issue #1:

The SPEC-300 is comprised of several different materials. The shielding material is depleted Uranium, and the support structure and enclosure are composed of 300 series stainless steel. Both of these materials have melting temperatures higher than the temperature of 800° C (1475°F) required by the thermal test in Part 71.73(c)(4). This results in no structural complications on the SPEC-300 package when exposed to the thermal test.

The other materials used in this package which are not considered structural parts, but still have a higher

melting temperature than 800° C (1475°F) are: copper, tungsten, bronze, and titanium, and the paint around the shield. These materials would neither be affected by a thermal test, nor lead to structural changes which would cause the loss of any radioactive material from the package.

The materials used in the SPEC-300 which are not structural parts and have a lower melting temperature than 800° C (1475°F) are: two-component chocking compound, polyurethane foam, epoxy adhesive, and the buna rubber. These materials are expected to melt or volatilize to some degree during a thermal test. When these materials began to melt during the test, some of them will produce gases. These gases will not increase the pressure in the SPEC-300 because the package is not hermetically sealed. The gases will naturally vent to the exterior of the package. Loss of these materials during a thermal test will neither reduce the shielding effectiveness of the package nor lead to structural changes which would cause the loss of any radioactive material from the package.

No shield movement is expected as a result of materials being consumed during the thermal test because in addition to the two-component chocking compound used to restrain the shield, the shield is held in position by a total of twelve 13 mm (0.5 in) diameter jack screws that are used to position the shield during fabrication of the package. These screws clamp directly on the Copper pads contacting the "ears" of the depleted Uranium shield. Even if the two-component chocking compound were to be completely destroyed as a result of the thermal test, the shield would remain in position relative to the device enclosure.

In addition to the statements made above, a finite element thermal analysis was performed on the package. The analysis was set up using the constraints specified in 10 CFR Part 71.73. The input parameters for the finite element analysis program are given in section 2.6 of the SAR. The heat transfer modes used for the thermal test finite element analysis were radiation and free convection. SPEC considered using forced convection, but the package heated up so quickly that forced convection was not necessary. The analysis assumes that the package is fully engulfed by the fire. Results for the analysis include the temperature distribution on the package. The analysis also includes the stresses generated on the package from the hypothetical fire test.

Figure 19 illustrates the temperature distribution over the package after two minutes of exposure to the fire test. The figure points out the temperature of the fire, 800 °C (1475° F). The highest temperature on the package is located on the flanges and is approximately 155 °C (311 °F).

Figure 20 illustrates the temperature distribution over the package after the required thirty minutes. The highest temperatures are located in the middle of the sides and on the flanges. These locations are approximately 716 °C (1320 °F) to 800 °C (1475 °F). The sides of the package near the bulkheads are approximately 630 °C (1166 F), while the top of the package ranges from 550 °C (1022 °F) to 380 °C (716 °F).

Figure 21 illustrates the temperature distribution over the internal structure after the required thirty minutes. The highest temperatures are found on the bottom and side edges of the bulkheads. These temperatures are approximately 600 °C (1112 °F) to 675 °C (1247 °F). The middle of the bulkheads reach a temperature of approximately 330 °C (626 °F). The structural post temperatures range from 460 C (860 °F) on the ends to 50 C (122 °F) in the middle.

The temperature distribution on the package is typical. The outside of the package reaches the temperature of the fire, while in inside of the package is much cooler.

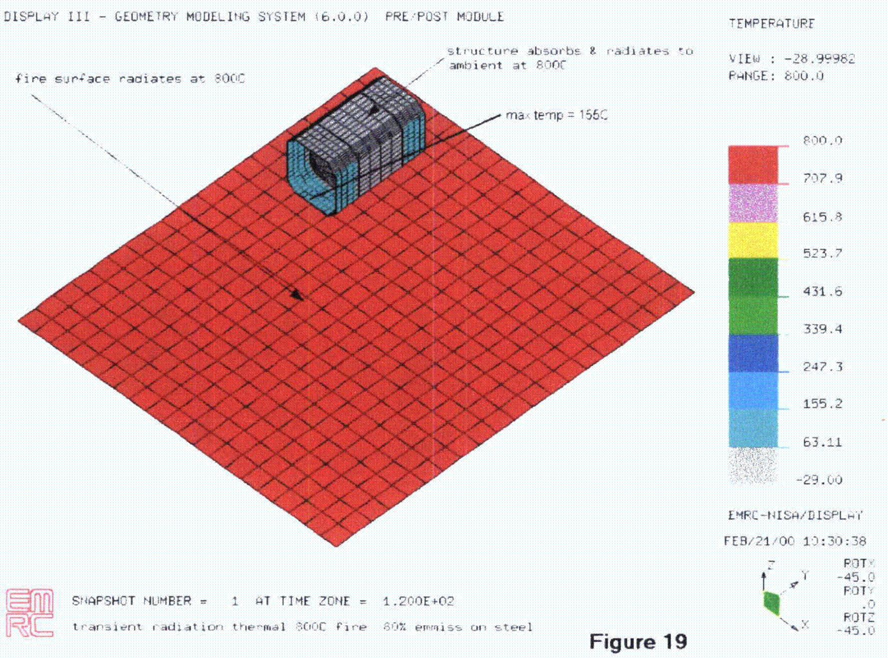

Figure 19

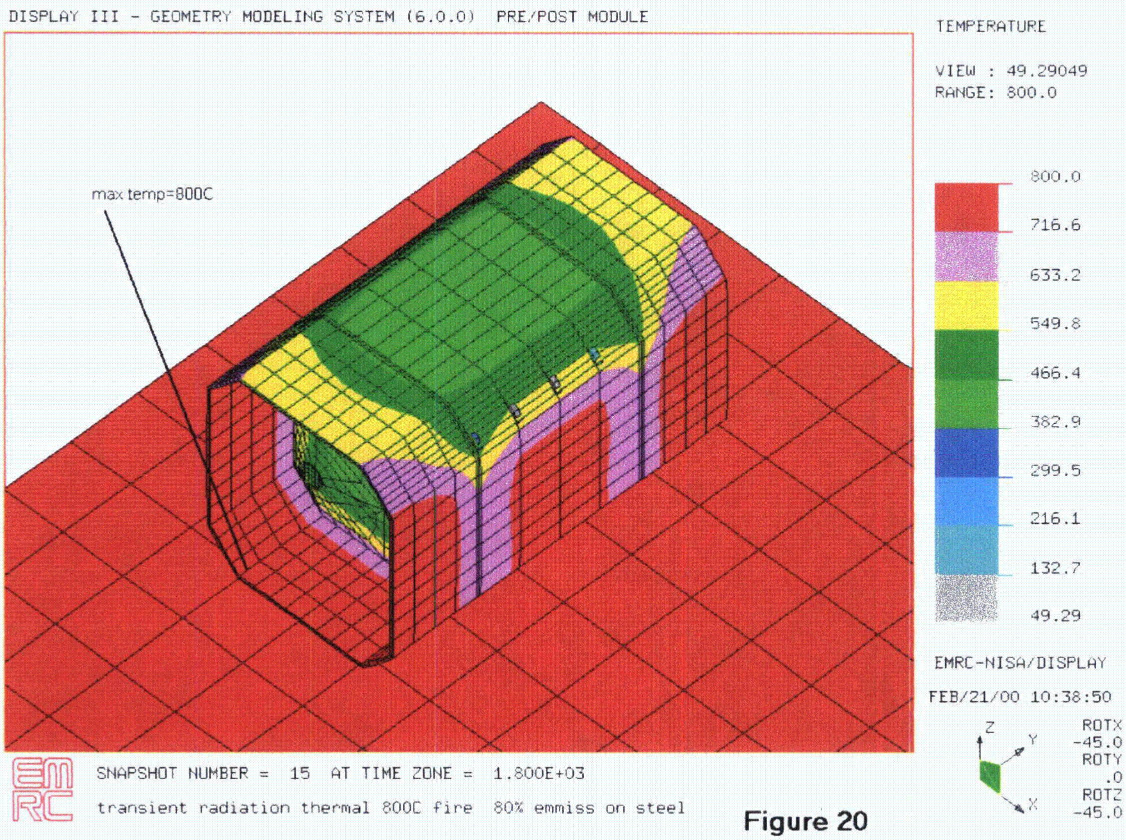

Figure 20

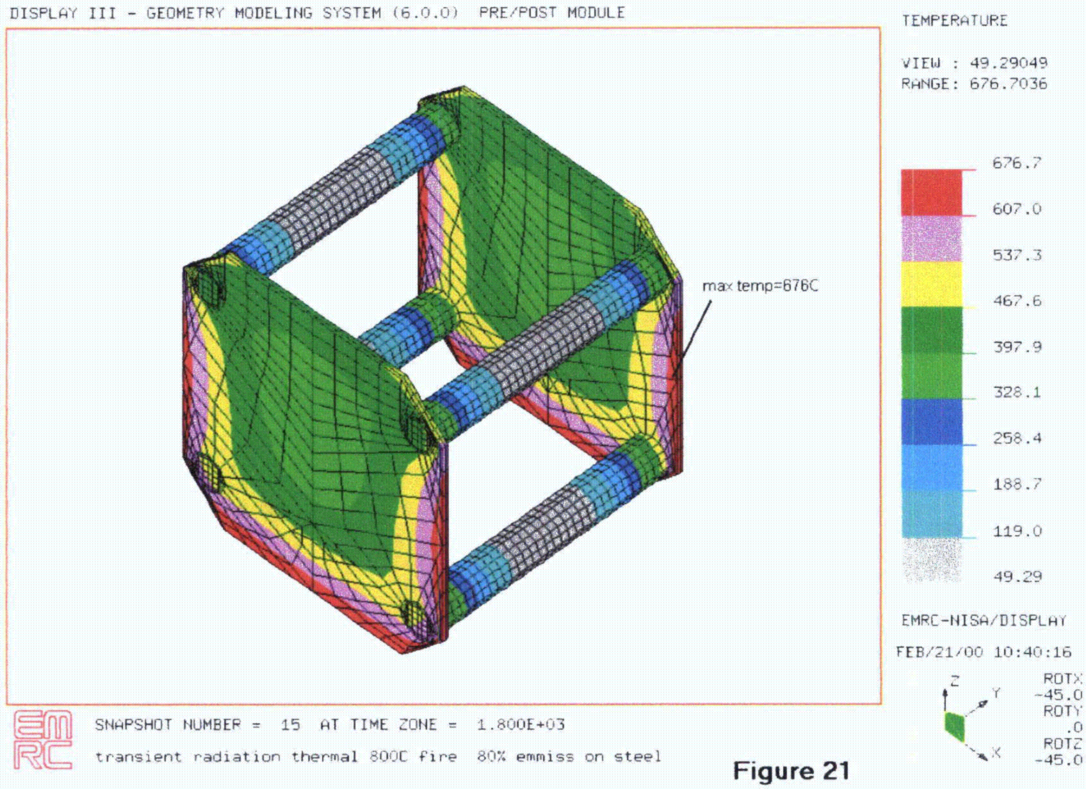

Figure 21

When considering the temperature of the package, the stresses generated must also be investigated. The finite element analysis recorded the results of the test at two minute intervals. Figure 22 demonstrates the stress generated on the outside of the package and Figure 23 demonstrates the stress generated on the internal structure after two minutes elapsed time. These two figures (22 and 23) show that the maximum stress generated is approximately 403 MPa (58 ksi).

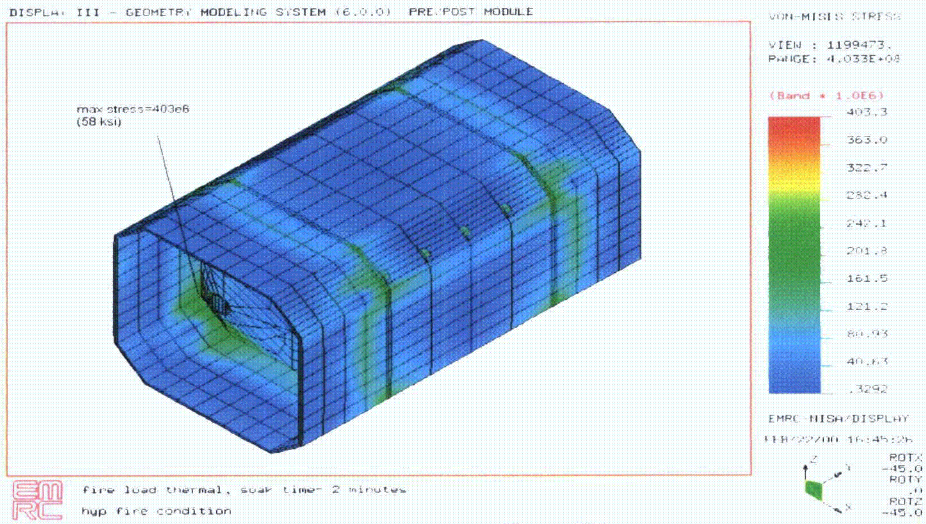

Figure 22

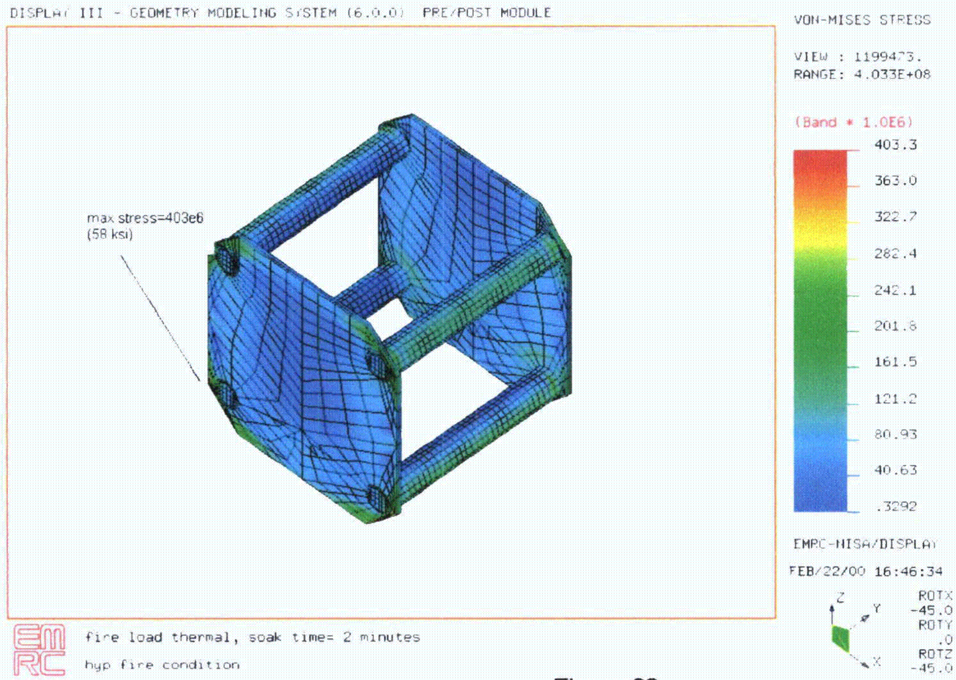

Figure 23

Figures 24 and 25 depict the stress generated on the package after being exposed to the fire test for thirty minutes. The highest stress generated is approximately 2280 MPa (330 ksi). As the package is exposed to the fire, the package slowly heats up. This heating process causes the temperature on the outside of the package to increase more than in temperature on the inside of the package. This thermal gradient causes the stress in the material.

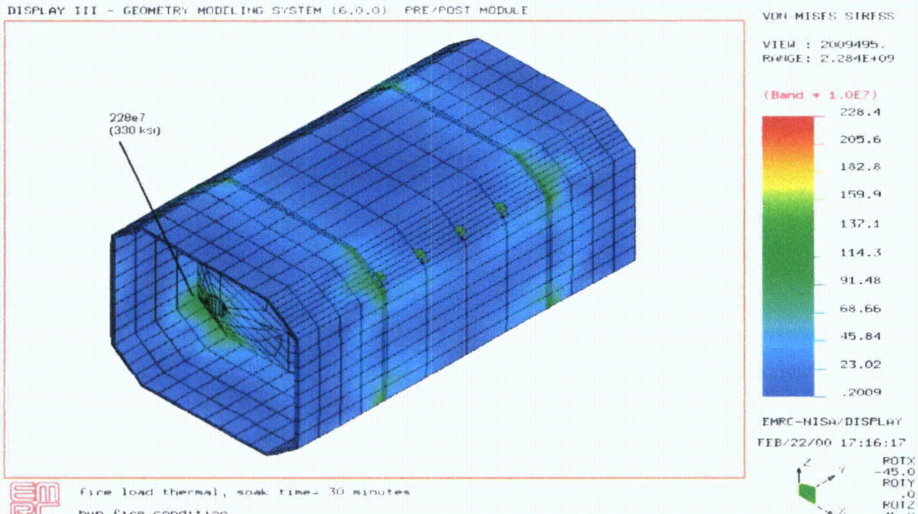

Figure 24

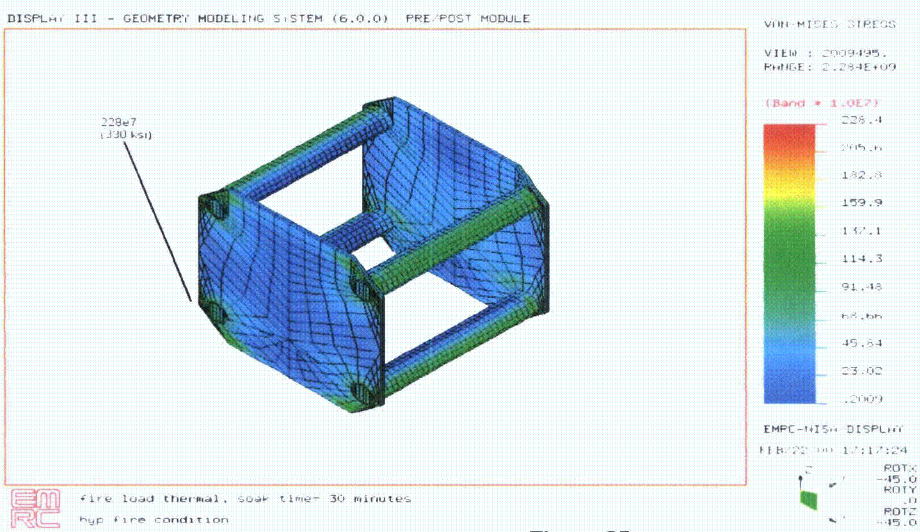

Figure 25

From the plots shown in figures 22 through 25, some stresses generated from the fire test are in excess of the yield strength of the material. However these results were generated using a linear analysis. When using a linear analysis, any stress value above the yield strength is invalid. Therefore, SPEC performed another analysis using a non-linear elasto-plastic stress technique.

The non-linear analysis predicts that certain areas of the package will have a strain over 55%. These areas are the welds between the bulkhead and the cover and between the bulkhead and the structural posts. These high stress and strain values are to be expected when heating any package to these extreme temperatures. In light of the high predicted strain values, SPEC envisions two possible scenarios.

The first possibility is deformation in the material. When the material increases in temperature, the ultimate strain value for the material will increase significantly. Thus, the stress caused by the increased temperature would result in minor deformation of the package which would relieve the stress.

The second possibility is localized cracking in the welds. If the ultimate strain is exceeded, localized cracking of the welds will occur. This cracking of the welds will relieve the stress in the material. Since the bulkheads are fitted tightly to the cover, this localized cracking would not constitute a significant broach of the housing.

If either of the two possibilities described above, do occur, the SPEC-300 package will not fail the test specified in 10 CFR Part 71.73(c)(4). Other Type B radiography packages with similar construction, have passed this test even with more damage from the preceding drop test. For example, the SPEC 2-T was tested in the fire condition specified by the CFR. The package was not completely welded before the test. The package was only half welded. (The package was welded one inch, skipped an inch, then welded an inch). This package passed the specified test. Some other packages that have been fire tested with split welds were the INC IR-100, and the AEA 650L. Both of these packages had large splits in the package before the fire test. The INC package had a gap of 4.7 mm (3/16 inch), and the AEA package had a gap that measured 76 mm (3 inches) by 12.7 mm (½ inch). Also, there was no indication of gross deformation in either of these packages after the fire test.

Issue #2:

The purpose of this assessment is to supply additional information to support our assertion that the SPEC-300 meets the 10 CFR 71.73 (c) (4) thermal test requirements, with particular emphasis placed on the effects from forced convection (high convective velocity).

The thermal analysis included in discussion #1 was mainly a comparison of the melting temperatures of package materials compared against the specified test temperature. While this analysis is valid, other effects such as high temperature oxidation of the Depleted Uranium casting were not discussed.

The primary concern is the temperature of the Depleted Uranium shield at the end of the test. A recent test on another manufacturer's design has demonstrated that shielding effectiveness can be compromised if the shield reaches a temperature where severe high temperature oxidation occurs. There are three modes by which the shield can increase in temperature during the test; conduction, convection, and radiation.

Conduction:
The means for the shield to be heated by conduction is heat transfer from the 316/316L stainless steel housing of the package through the two-component chocking compound used to constrain the shield and through the polyurethane foam encasing the shield. Assuming the temperature of the stainless steel housing of the package to be 800° C (1475°F), and considering the fact that only a small portion of the shield is in contact with the two-component chocking compound, and considering the thermal conductivity of the chocking compound, significant temperature rise is not expected. Assuming the temperature of the stainless steel housing of the package to be 800° C (1475°F), an average foam thickness of 50 mm (2 in), and considering the thermal conductivity of the foam, significant temperature rise is again not expected.

Convection:
Significant convective heat transfer is expected between the heat source and the 316/316L stainless steel housing of the package. Our analysis assumes forced convection (high convective velocity) to be the primary means of heat transfer to the housing. For this reason we assume the housing will quickly reach equilibrium temperature with the 800° C (1475°F) environment. Convective heat transfer cannot occur inside the package since there is no convective heat transfer medium. For this reason the temperature of the Depleted Uranium shield is not expected to increase due to direct convection.

Radiation:
Radiation is expected to be the primary means of heat transfer between the package enclosure and the Depleted Uranium shield. For purposes of radiative heat transfer the two-component chocking compound and the polyurethane foam are assumed not to exist. Considering the large thermal mass of the shield and the 30 minute duration of the test, it is expected that the shield temperature will remain well below the point at which oxidation or combustion could begin.

<u>Determination of internal shield temperature at the conclusion of the thermal test:</u>

<u>Conductive heat transfer</u>

Discussion:
The equation predicting conductive heat flux is:

Equation 1:

$$q_{conduction} = \frac{k \times a \times \Delta t}{l}$$

where: $q_{conduction}$ = heat flux from conduction
k = thermal conductivity
a = area
Δt = difference in temperature between environment and depleted Uranium shield.
l = length of boundary layer

The equation that predicts the temperature of the SPEC-300 shield as a result of the heat flux calculated in Equation 1 is:

Equation 2:

$$t_f = t_i + \frac{q \times time}{m \times c_p}$$

where: t_f = final temperature
t_i = initial temperature
q = heat flux
m = mass
c_p = specific heat

These equations taken from Introduction to Heat Transfer, by Frank P. Incropera and David P. Dewitt, 3rd edition, Copyright 1996, John Wiley & Sons

Equations 1 and 2 are steady-state equations. As can be seen from Equation 1, heat flux varies with Δt. The SPEC-300 undergoing the thermal test is not a steady state system. The temperature is expected to increase throughout the duration of the test. This can be compensated for by assuming that if the time interval is very short, Δt, and therefore heat flux, are constant. This assumption allows an iterative computer model to be used, employing equations 1 and 2 as simple steady-state heat flux equations solved many times to span the necessary time. The result of solving equations 1 and 2 (which gives device internal temperature) for each iteration supplies a new temperature to be used for the next iteration.

Also needed to solve Equation 1, are the area, thermal conductivity, and boundary layer length for each of the different heat flow paths into the SPEC-300 depleted Uranium shield. The SPEC-300 is far from a homogeneous structure. It contains many different materials and the internal configuration varies with location. Instead of estimating the various values for these variables, a more accurate method is to experimentally determine a thermal constant "C" by measuring the change in internal temperature of the depleted Uranium shield under controlled conditions of ambient temperature and time. Equation 1, with these variables combined, then becomes

Equation 3:

$$q_{conduction} = C \times \Delta t$$

where: $q_{conduction}$ = heat flux from conduction
C = thermal constant combining thermal conductivity, area, and length of boundary layer
Δt = difference in temperature between environment and depleted Uranium shield.

To determine the thermal constant "C", cooling data taken when the device was chilled in dry ice prior to the 9m (30 ft) free drop test was used. An iterative computer program was written that employs Equations 3 and 2 to predict final depleted Uranium shield temperature as a function of external

environment temperature, depleted Uranium shield initial internal temperature, mass, specific heat, overall time, and time iteration interval.

Cooling data for SPEC-300 package:

Ambient Temperature:	-79 °C (-110 °F), device covered on all sides with dry ice
Device initial internal temp:	30.6 °C (87 °F) (measured)
Device final internal temp:	-44.9 °C(-48.8 °F) (measured)
Chill time:	4.75 HR (measured)
Time iteration interval:	0.001 hr (3.6 sec)

The program was run multiple times using this data, along with various values for "C", until a value for C was obtained which produced the final temperature recorded when the device was chilled. A time iteration interval of 0.001 hr (3.6 sec) is short enough that further reduction in the interval does not appreciably change the result A value of C = 3.445 produced a calculated final temperature that matched the measurement taken at the end of the 4.75 hr in dry ice.

See Appendix 3.6, program 1 printout for the computer code used.
See Appendix 3.6, Results printout 1 for the program input variables and results.

Radiant heat transfer

The equation predicting radiant heat transfer is

$$q_{radiation} = \frac{\sigma(t_1^4 - t_2^4)}{\frac{1-\varepsilon_1}{\varepsilon_1 \times a_1} + \frac{1}{a_1 \times f} + \frac{1-\varepsilon_2}{\varepsilon_2 \times a_2}} \quad \text{Equation 4:}$$

where
$q_{radiation}$ = Heat flux from radiation
σ = Stefan-Boltzmann constant
ε_1 = Emmisivity of SPEC-300 enclosure
ε_2 = Emmisivity of SPEC-300 depleted Uranium shield
a_1 = Internal area of SPEC-300 enclosure
a_2 = Area of SPEC-300 depleted Uranium shield.

This equation taken from Introduction to Heat Transfer, by Frank P. Incropera and David P. Dewitt, 3rd edition, Copyright 1996, John Wiley & Sons

As can be seen from equation 4, heat flux varies with Δt. This can be compensated for by assuming that if the time interval is very short, Δt, and therefore heat flux, are constant. This assumption allows an iterative computer model to be used, employing equations 2 and 4 as simple steady-state heat flux equations solved many times to span the necessary time. The second iterative computer analysis developed allows these steady-state equations (2, and 4) to be combined with Equation 3 (conductive heat transfer) and used to calculate the overall change in depleted Uranium shield temperature as a result

of exposure to the thermal test. The analysis is basically simple. For each iteration, heat flux from conduction (Equation 3) and radiation (Equation 4) are calculated. The resulting total is used with Equation 2 to determine the incremental change in temperature of the depleted Uranium shield. This process is repeated using the new temperature resulting from solving Equation 2, until the required overall time period is spanned.

Using the experimentally derived thermal constant C = 3.445, and substituting the parameters for the Hypothetical Accident Thermal Evaluation in accordance with 10 CFR 71.73 (c) (4):

ambient temperature:	800 °C (1472 °F)
initial device temperature:	48.9 °C (120 °F) (Assume significant insolation)
Overall heating time: 0.5 hours	Time iteration interval: 0.001 hr (3.6 sec)
View Factor: 1 (worst case)	Emissivity of enclosure: 0.28 (316 Stainless steel)
Mass of shield: 500 lb	Emissivity of DU shield: 0.91 (painted surface)

Specific heat of DU shield: 0.028 btu/lb/deg f

results in a final depleted Uranium shield temperature of 434 °C (813 °F).

See Appendix 3.6, program 2 printout for the computer code used.
See Appendix 3.6, Results printout 2 for the program input variables and results.

This analysis assumes that the enclosure of the device is at ambient temperature 800 °C (1472 °F). Heat transfer from free convection inside the device is assumed not to occur due to the presence of the polyurethane foam. Even if the polyurethane foam is degraded by the test, it effectively prevents the free movement of gasses necessary for convective heat transfer to the depleted Uranium shield. Informal tests performed at SPEC on this polyurethane foam indicate that the polyurethane foam, when encased in an enclosure, is able to withstand a hydrocarbon flame for 30 minutes without being completely degraded or vaporized..

Assuming a final depleted Uranium shield temperature of 434 °C (813 °F), any Oxygen entering the device enclosure through the vents will not significantly degrade the shield.

In addition to the mathematical analysis above, a finite element thermal analysis was performed on the shield. The finite element analysis consisted of heating the package as specified in 10 CFR 71.73(c)(4). The input parameters for this analysis are in Section 2.6 of the SAR. This analysis considered all three types of heat transfer, conduction, convection, and radiation. The boundary conditions for the analysis used the temperature profile determined in earlier on figure 24. The analysis assumed that the foam in the package was not present, this allows for free convection inside the package.

The results of the finite element thermal analysis reveal that the shield does not reach a temperature where high temperature oxidation can occur. The highest temperature the shield will reach during the fire test is approximately 340 °C (644 °F). The shield may absorb some heat from the enclosure after the fire is removed, but it will not cause the temperature of the shield to increase significantly. This highest temperature occurs at the bottom edge of ear. Figure 30 is a graphical representation of the temperature distribution on the shield after thirty minutes. Figure 31 illustrates the temperature profile of the shield and the internal structural after thirty minutes in the fire test.

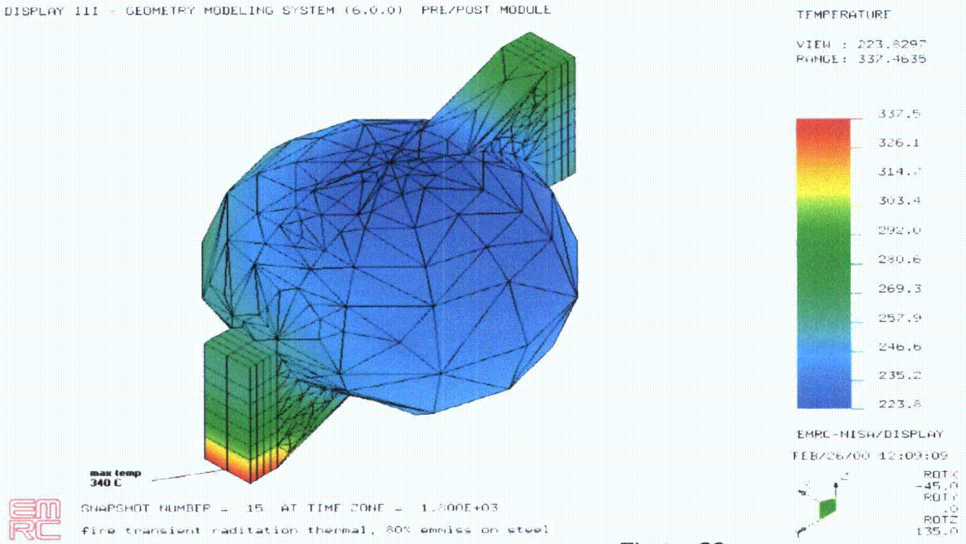

Figure 26

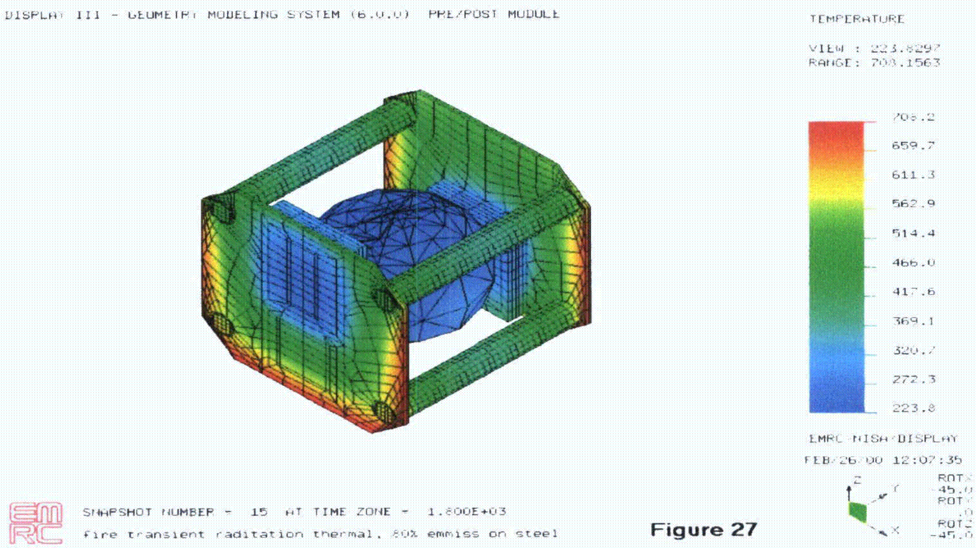

Figure 27

Summary:
To comply with the thermal requirement, the SPEC-300 package was designed such that the Depleted Uranium shield is well protected from the primary means of heat transfer from the fire to the package, convection. The package housing is robust enough not be breached as a result of the four 9 meter (30 ft) tests and a 1 meter (39.4 in) puncture test that precede the thermal test. Prototype testing proved this, and post test inspection confirmed that the welds did not crack. Analysis proves that the depleted Uranium shield will not reach temperatures that would cause loss of shielding from oxidation as a result of the Hypothetical Accident Thermal Evaluation in accordance with 10 CFR 71.73 (c) (4).

Conclusion:
The package meets the 10 CFR 71.73 (c) (4) thermal test criteria because the Depleted Uranium shield is well protected from high convective velocity heat transfer, which is the primary means of heat transfer from the fire to the packaging.

Appendix 3.6

Computer Code, Input Variables and Results

program 1 printout:

```
{ Conductive Heat transfer calculation utility
  by: Pete Weber  date: 10/1/99 }

unit Main;

interface

uses
  Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs,
  StdCtrls;

type
  TMainForm = class(TForm)
    CEdit: TEdit;
    T1Edit: TEdit;
    T2Edit: TEdit;
    IntervalEdit: TEdit;
    Label1: TLabel;
    Label4: TLabel;
    Label5: TLabel;
    Label6: TLabel;
    FinalTemperatureLabel: TLabel;
    CalcButton: TButton;
    Label7: TLabel;
    OverallTimeEdit: TEdit;
    FinalTemperatureCLabel: TLabel;
    PrintButton: TButton;
    MassEdit: TEdit;
    Label2: TLabel;
    CPEdit: TEdit;
    Label3: TLabel;
    procedure CalcButtonClick(Sender: TObject);
    procedure PrintButtonClick(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

var
  MainForm: TMainForm;
  C,                  { Thermal Constant, derived from chill rate data }
  t1,                 { Ambient temperature, degrees F }
  t2,                 { Device Initial Temperature, degrees F }
  mass,               { mass of DU shield }
  Cp,                 { Specific Heat of Uranium }
  interval,           { Time is iterated at the time interval, hr }
  Overalltime,        { Overall length of exposure to temperature t1 }
  time,               { used to keep track of the iteration }
  q  : real;

implementation

{$R *.DFM}
```

```
Procedure CalcTemperature;  { iteratively called by Procedure Iterate }
begin
  q := c * ( t1 - t2 );

  t2 := t2 + ( q * interval ) / ( mass * Cp );
end;

Procedure Iterate;
begin
  time := Interval;
  while time <= OverallTime do
    begin
      CalcTemperature;
      time := time + Interval;
    end;
end;

procedure TMainForm.CalcButtonClick(Sender: TObject);
begin
  C           := StrToFloat( Cedit.Text );  { input variables }
  T1          := StrToFloat( T1Edit.Text );
  T2          := StrToFloat( T2Edit.Text );
  Mass        := StrToFloat( MassEdit.Text );
  Cp          := StrToFloat( CPEdit.Text );
  OverallTime := StrToFloat( OverallTimeEdit.Text );
  Interval    := StrToFloat( IntervalEdit.Text );

  Iterate;{ call the procedure to iterate temperature over the time interval }

  FinalTemperatureLabel.Caption := 'Final Temperature, degrees F = ' +
                                   FloatToStrf( t2, ffFixed, 10, 2 );

  T2 := ( T2 - 32.0 ) * 5 / 9;     { convert temperature to degrees C }

  FinalTemperatureCLabel.Caption := 'Final Temperature, degrees C = ' +
                                   FloatToStrf( t2, ffFixed, 10, 2 );
end;

procedure TMainForm.PrintButtonClick(Sender: TObject);
begin
  print;  { hard copy printout of form }
end;

end.
```

Results printout 1:

Input variables:

Thermal Constant, C	3.445
Environment Temperature, T1, deg F	-110
Device Initial Temperature, T2, deg F	87
Depleted Uranium Shield Mass, lbm	500
Depleted Uranium Shield Specific Heat btu/lb/deg F	0.028
Overall Time, Hr	4.75
Time Iteration Interval, Hr	0.001

Calculated results:

Final Depleted Uranium Shield Temperature, Deg F -48.80

Final Depleted Uranium Shield Temperature, Deg F -44.89

Program 2 printout:

```
{ Combined Conduction and Radiation Heat transfer calculation utility
  by: Pete Weber date: 10/1/99 }

unit Main;

interface

uses
  Windows, Messages, SysUtils, Classes, Graphics, Controls, Forms, Dialogs,
  StdCtrls;

type
  TMainForm = class(TForm)
    FinalTemperatureLabel: TLabel;
    CalcButton: TButton;
    FinalTemperatureCLabel: TLabel;
    PrintButton: TButton;
    GroupBox1: TGroupBox;
    Label1: TLabel;
    Label2: TLabel;
    Label3: TLabel;
    Label4: TLabel;
    Label11: TLabel;
    EnclosureEmmisivityEdit: TEdit;
    ShieldEmmisivityEdit: TEdit;
    EnclosureAreaEdit: TEdit;
    ShieldAreaEdit: TEdit;
    ViewFactorEdit: TEdit;
    GroupBox2: TGroupBox;
    GroupBox3: TGroupBox;
    EnclosureTempEdit: TEdit;
    Label5: TLabel;
    ShieldInitialTempEdit: TEdit;
    Label10: TLabel;
    MassEdit: TEdit;
    Label8: TLabel;
    Label9: TLabel;
    SpecificHeatEdit: TEdit;
    CLabel: TLabel;
    CEdit: TEdit;
    GroupBox4: TGroupBox;
    Label7: TLabel;
    OverallTimeEdit: TEdit;
    IntervalEdit: TEdit;
    Label6: TLabel;
    procedure CalcButtonClick(Sender: TObject);
    procedure PrintButtonClick(Sender: TObject);
  private
    { Private declarations }
  public
    { Public declarations }
  end;

const
```

```
  StefanBoltzmann : real = 0.1714e-8;

var
  MainForm: TMainForm;
  e1, { emmisivity of enclosure }
  e2, { emmisivity of depleted Uranium shield }
  A1, { area of enclosure, sq ft }
  A2, { area of shield, sq ft }
  f,  { view factor, 1 is worst case }
  c,  { conductive thermal constant }
  t1, { Ambient temperature, degrees F }
  t2, { Device Initial Temperature, degrees F }
  m,  { mass of shield, lbm }
  cp, { Specific heat of item under consideration, btu/lb/deg f }
  Overalltime,  { Overall length of exposure to temperature t1 }
  interval,     { Time is iterated at the time interval, hr }
  time,         { used by program to iterate }
  qRad,         { heat flux from radiation, btu/hr }
  qCond : real; { heat flux from conduction, btu/hr }




implementation

{$R *.DFM}

Procedure CalcTemperature;  { iteratively called by Procedure Iterate }
begin
  qRad := StefanBoltzmann * ( sqr( sqr( t1 )) - sqr( sqr( t2 ) ) ) /
    ( ( 1 - e1 ) / (e1 * a1 ) + ( 1 / ( a1 * f ) ) + ( 1 - e2 ) / (e2 * a2 ) );

  qCond := C * (t1 - t2 );

  t2 := t2 + ( ( qRad + qCond ) * interval ) / ( m * cp );
end;

Procedure Iterate;
begin
  time := Interval;
  while time <= OverallTime do
    begin
      CalcTemperature;
      time := time + Interval;
    end;
end;

procedure TMainForm.CalcButtonClick(Sender: TObject);
begin  { input variables }
  e1 := StrToFloat( EnclosureEmmisivityEdit.Text );
  e2 := StrToFloat( ShieldEmmisivityEdit.Text );
  A1 := StrToFloat( EnclosureAreaEdit.Text );
  A2 := StrToFloat( ShieldAreaEdit.Text );
  F  := StrToFloat( ViewFactorEdit.Text );
  C  := StrToFloat( CEdit.Text );
  T1 := StrToFloat( EnclosureTempEdit.Text );
  T2 := StrToFloat( ShieldInitialTempEdit.Text );
```

```
  M  := StrToFloat( MassEdit.Text );
  cp := StrToFloat( SpecificHeatEdit.Text );
  OverallTime := StrToFloat( OverallTimeEdit.Text );
  Interval    := StrToFloat( IntervalEdit.Text );

  Iterate;  { call the procedure to iterate temperature over the time interval }

  FinalTemperatureLabel.Caption := 'Final Temperature, degrees F = ' +
                                   FloatToStrf( t2, ffFixed, 10, 2 );

  T2 := ( T2 - 32.0 ) * 5 / 9;     { convert temperature to degrees C }

  FinalTemperatureCLabel.Caption := 'Final Temperature, degrees C = ' +
                                   FloatToStrf( t2, ffFixed, 10, 2 );
end;

procedure TMainForm.PrintButtonClick(Sender: TObject);
begin
  print;  { hard copy printout of form }
end;

end.
```

Results printout 2:

Input variables:

Enclosure Emissivity, E1	0.28
Depleted Uranium Shield Emissivity, E2	0.91
Area of Enclosure, sq ft	7.8
Area of Depleted Uranium shield, sq ft	3.0
View factor, F	1
Thermal Constant, C	3.445
Depleted Uranium Shield Initial Temp, T2, deg F	120
Ambient Temperature, T1, deg F	1472
Depleted Uranium Shield Mass, lbm	500
Depleted Uranium Shield Specific Heat btu/lb/deg F	0.028
Overall Time, Hr	0.5
Time Iteration Interval, Hr	0.001

Calculated results:

Final Depleted Uranium Shield Temperature, Deg F 813.00

Final Depleted Uranium Shield Temperature, Deg F 433.89

4. CONTAINMENT

4.1 Containment Boundary

4.1.1 Containment Vessel

The sealed source capsule containing the Cobalt-60 pellets described in Section 2.8.1 represents the primary containment boundary and vessel. This capsule meets the requirements of 10 CFR 71.75 for special form radioactive material.

4.1.2 Containment Penetrations

None.

4.1.3 Seals and Welds

The sealed source capsule is fused in a thermal metal joining procedure to meet the requirements of special form radioactive material and there are no mechanical or chemical seals pertaining to the primary containment capsule.

4.1.4 Closure

The special form, sealed source capsule may only be opened destructively and there are no mechanical closure provisions.

4.2 Requirements for Normal Conditions of Transport

4.2.1 Release of Radioactive Material

The sealed source capsule containing the Cobalt-60 pellets represents the primary containment boundary and vessel. This capsule meets the requirements of 10 CFR 71.75 for special form radioactive material. Based on this, there is no release of radioactive material from the primary containment vessel during normal conditions of transport.

4.2.2 Pressurization of Containment Vessel

No gas is produced inside the sealed source capsule; the only gasses present in the capsule are those found in the atmosphere at the time the capsule is loaded and welded. The only increase in stress due to the pressure from gasses inside the capsule would result from a decrease in pressure outside the capsule. The maximum value for is pressure is one atmosphere 101 kPa (14.7 psi) if the capsule were placed in a "hard" vacuum environment. Paragraph 2.5.2 of this application demonstrates the adequacy of the sealed source capsule under this condition.

4.2.3 Coolant Contamination

Not applicable. No coolants are used in the package.

4.2.4 Coolant Loss

Not applicable. No coolants are used in the package.

4.3 Containment Requirement for the Hypothetical Accident Conditions

4.3.1 Fission Gas Products

Not applicable. No fissionable radioactive material is used in the SPEC-300 package.

4.3.2 Releases of Contents

The sealed source capsule containing the Cobalt-60 pellets represents the primary containment boundary and vessel. This capsule meets the requirements of 10 CFR 71.75 for special form radioactive material. Based on this, there is no release of radioactive material from the primary containment vessel during hypothetical accident conditions. Hypothetical accident conditions testing performed on the SPEC-300, which contained the sealed source capsule when the tests were performed, confirmed no releases of contents.

5. SHIELDING EVALUATION

Adequate shielding design for the SPEC-300 was confirmed by actual measurements of radiation profiles from the prototype shield, and by actual measurements of resulting radiation levels after the numerous tests performed for normal conditions of transport and hypothetical accident conditions. Theoretical calculations were not used.

5.1 Package Shielding

A depleted Uranium casting weighing 238 kg (525 lb) max is used for the principal shielding material. See appendix 2.10 for a drawing of the shield. A Titanium, Titanium alloy, or zircalloy S-Tube permits the source assembly to pass through the depleted Uranium shield for use as an industrial radiography exposure package. When the SPEC-300 is used as a transport package, the sealed source capsule is positioned at or very near the center of the depleted Uranium shield primarily by the transport lock mechanism. A redundant mechanism is the automatic securing mechanism/lock module which independently secures the source during transport. The transport lock and the source assembly lock must be locked in order to prepare the package for shipment. The source assembly lock cannot be locked unless the source assembly is positioned with the source capsule in the in fully shielded position. The transport lock, automatic securing mechanism, device lock, lock cap and safety plug provide mutually redundant safety systems for securing the source assembly at the proper position in the shield. The curvature of the S-Tube and the elongated shape of the depleted Uranium shield attenuate primary radiation.

Measurements were taken on the surface of the prototype before the normal conditions of transport and hypothetical accident condition tests. Radiation readings were taken at points on an approximately 50 mm (2 in) by 50 mm (2 in) grid located on each of the six sides of the package. This provided 91 points each on the top and bottom, 78 points each on the left and right sides, 67 points on the outlet end plate, and 50 points on the lock end plate, for a total of 455 measurement points. A correction factor was applied to compensate for the diameter of the detector probe. Measurements were taken with a 1.27 TBq (34.4 Ci) Cobalt-60 source and the results were extrapolated to 11.1 TBq (300 Ci) Cobalt-60.

Surface readings extrapolated to 11.1 TBq (300 Ci) Cobalt-60

Package Surface	Number of Points	Maximum mSv/hr(mR/hr)		Minimum mSv/hr(mR/hr)		Average mSv/hr(mR/hr)	
Top	91	1.98	(198)	13	(2)	53	(30)
Bottom	91	0.59	(59)	8	(2)	56	(13)
Left Side	78	0.18	(18)	21	(2)	64	(8)
Right Side	78	1.8	(180)	18	(6)	50	(38)
Lock End	50	1.2	(120)	18	(6)	34	(25)
Outlet End	67	0.9	(90)	13	(6)	25	(21)

Measurements were taken of the maximum radiation level at one meter (39.4 in) from each of the six surfaces of the prototype package using a 1.27 TBq (34.4 Ci) Cobalt-60 source and the results were extrapolated to 11.1 TBq (300 Ci) Cobalt-60.

Readings at one meter (39.4 in) from Surface extrapolated to 11.1 TBq (300 Ci) Cobalt-60:

Package Surface	Maximum mSv/hr	Maximum mR/hr
Top	0.01	1.2
Bottom	0.02	1.7
Left Side	0.02	1.7
Right Side	0.02	1.7
Lock End	0.02	1.7
Outlet End	0.04	3.5

Measurements were taken of the maximum radiation level at 30 cm (11.8 in) from each of the six surfaces of the prototype package using a 1.27 TBq (34.4 Ci) Cobalt-60 source and the results were extrapolated to 11.1 TBq (300 Ci) Cobalt-60.

Readings at 30 cm (11.8 in) from Surface extrapolated to 11.1 TBq (300 Ci) Cobalt-60:

Package Surface	Maximum mSv/hr	Maximum mR/hr
Top	0.16	16
Bottom	0.05	5.2
Left Side	0.04	3.5
Right Side	0.05	5.2
Lock End	0.07	7.0
Outlet End	0.05	5.2

Measurements were taken of the maximum radiation level at 5 cm (2 in) from each of the six surfaces of the prototype package using a 1.27 TBq (34.4 Ci) Cobalt-60 source and the results were extrapolated to 11.1 TBq (300 Ci) Cobalt-60.

Readings at 5 cm (2 in) from Surface extrapolated to 11.1 TBq (300 Ci) Cobalt-60:

Package Surface	Maximum mSv/hr	Maximum mR/hr
Top	1.22	122
Bottom	0.30	30
Left Side	0.09	9
Right Side	0.82	82
Lock End	0.37	37
Outlet End	0.24	24

5.2 Normal Conditions of Transport

See appendix 2.10 for selection and justification of package orientation for normal conditions of transport tests. Radiation surveys were performed before and after each normal conditions of transport test: free drop and penetration. Radiation levels were measured at sufficient locations to determine if there was significant change compared with the pre-test radiation level. There was no measurable change in radiation levels after the free drop test or either of the two penetration tests.

Maximum radiation level for each of the six sides was measured before the normal conditions free drop test. Post-test radiation levels were measured at the same locations. A 1.26 TBq (34.1 Ci) source was used for the tests. The results were not extrapolated since the criterion refers to a percent increase in radiation levels. The results are tabulated below:

Free drop test:

	Max pre-test mSv/hr(mR/hr)		Max post-test mSv/hr(mR/hr)	
Top	0.21	(21)	0.21	(21)
Bottom	0.06	(6.4)	0.06	(6.2)
Right Side	0.18	(18)	0.17	(17)
Left Side	0.02	(2)	0.01	(1)
Outlet End	0.04	(4)	0.04	(4)
Lock End	0.14	(14)	0.13	(13)

Penetration tests:

Radiation levels at points expected to be most affected by the penetration tests were measured before the normal conditions penetration tests. Post-test radiation levels were measured at the same points. A 1.26 tBq (34.1 Ci) source was used for the tests. The results were not extrapolated since the criterion refers to a percent increase in radiation levels. The results are tabulated below:

Penetration test #1:

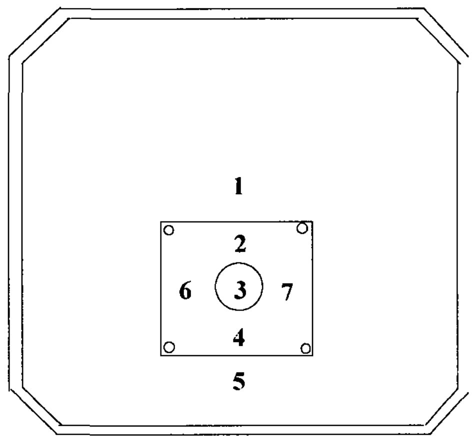

Illustration of the outlet end of the package
showing radiation measurement points

1st penetration test
(outlet end)

	pre-test mSv/hr(mR/hr)		post-test mSv/hr(mR/hr)	
Point #1	0.01	(1.2)	0.01	(1.2)
Point #2	0.04	(4.0)	0.04	(3.6)
Point #3	0.14	(14.0)	0.13	(13.0)
Point #4	0.03	(3.2)	0.02	(2.0)
Point #5	0.01	(1.2)	0.01	(1.0)
Point #6	0.02	(2.0)	0.02	(2.0)
Point #7	0.03	(3.2)	0.03	(3.0)

Penetration test #2:

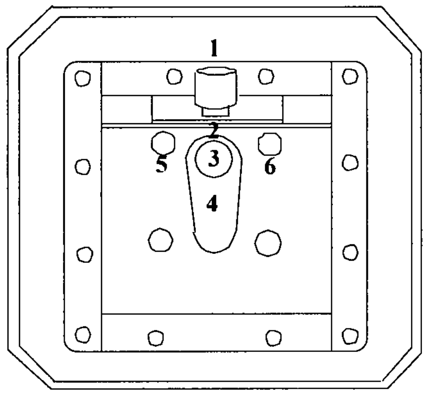

Illustration of the lock end of the package
showing radiation measurement points

2nd penetration test
(lock end)

	pre-test mSv/hr(mR/hr)		post-test mSv/hr(mR/hr)	
Point #1	0.01	(1.2)	0.01	(1.0)
Point #2	0.03	(2.6)	0.02	(2.4)
Point #3	0.02	(2.2)	0.02	(2.0)
Point #4	0.01	(1.2)	0.01	(1.2)
Point #5	0.02	(2.2)	0.02	(1.8)
Point #6	0.02	(1.6)	0.02	(1.6)

The maximum increase in surface radiation levels after the free drop and penetration tests tabulated above was 0%. Based on the low surface readings, readings at one meter (39.4 in) were not taken as they would be too low to be reliably measured.

5.3 Hypothetical Accident Conditions

Four successive 9 meter (30 ft) drop tests were conducted on the prototype package to address any questions concerning the proper selection of the impact point and orientation for which maximum damage is expected. These tests were followed by the puncture test. Safety radiation surveys were performed between each test. Damage to the package was cumulative. Maximum surface radiation levels were taken for each side of the device at the conclusion of the free drop and puncture tests. Readings were also taken at one meter (39.4 in), but with the exception of the outlet end, readings were

too low to be reliably measured. A 0.55 TBq (14.9 Ci) Cobalt-60 source was used for the hypothetical accident conditions tests. The maximum radiation level at one meter (39.4 in) from each of the six surfaces, extrapolated to 11.1 TBq (300 Ci) are tabulated below:

Post-test Radiation Levels at the surface of the package, corrected and extrapolated to 11.1 TBq (300 Ci)
Readings taken after free drop and puncture tests.

	Radiation levels	
	mSv/hr	mR/hr
Top	1.82	(182)
Bottom	0.68	(68)
Right Side	1.61	(161)
Left Side	0.28	(28)
Lock End	0.83	(83)
Outlet End	27.60	(2760)

Post-test Radiation Levels one meter (39.4 in) from the surface of the package, corrected and extrapolated to 11.1 tBq (300 Ci)
Readings taken after free drop and puncture tests.

	Radiation levels	
	mSv/hr	mR/hr
Top	0.04	(4)
Bottom	0.04	(4)
Right Side	0.04	(4)
Left Side	0.04	(4)
Lock End	0.04	(4)
Outlet End	0.56	(56)

The highest radiation level at one meter (39.4 in) is 0.56 mSv/hr (56 mR/hr), far below the allowable limit of 10 mSv/hr (1000 mR/hr) at one meter (39.4 in).

5.4 Source Specification

As noted above, the source assembly used in the normal conditions of transport testing was a SPEC model G-70 Cobalt-60 source with an activity of 1.26 TBq (34.1 Ci). The source assembly used in hypothetical accident condition testing was a SPEC model G-70 Cobalt-60 source with an activity of 0.55 TBq (14.9 Ci).

5.5 Model specification

Not applicable. Physical radiation measurements were performed on a prototype package and radiation surveys were performed on the prototype test package after the tests for normal conditions of transport

and hypothetical accident conditions. Theoretical calculations or scale models were not used.

5.6 Shielding Evaluation

Test results showed that radiation levels are within limits for a type B package. There was no significant increase in radiation levels after normal condition or hypothetical accident condition tests. The maximum radiation level of 0.56 mSv/hr (56 mR/hr) at one meter (39.4 in) from the surface of the prototype package after the conclusion of free drop tests and puncture test demonstrates the SPEC-300 meets the 10mSv/hr (1.0 R/hr) at one meter (39.4 in) criteria for hypothetical accident condition tests. The shielding evaluation of the prototype confirms that the package meets the shielding criteria for a Type-B package. The maximum radiation levels after the conclusion of the four 30-foot drop tests and puncture test on the prototype conclusively demonstrates that the SPEC-300 meets the shielding requirements for a Type B package.

6. CRITICALITY EVALUATION

This section is not applicable. The SPEC-300 does not contain and is not designed to transport fissile material.

7. OPERATING PROCEDURES

7.1 Procedures for Preparing and Loading the Package

The SPEC-300 shall be loaded and prepared for shipment in accordance with written operating procedures.

7.1.1 General Package Inspection

Visually inspect the SPEC-300 to determine if it is in unimpaired condition for shipment. The SPEC-300 should be inspected to determine that it is not damaged, that the locks operate properly, that the source assembly is securely locked in the package, and that the safety plug and lock cap are securely positioned. Verify that the package identification plate is present and legible, which identifies the package as a SPEC-300 and displays the Certificate of Compliance identification number.

7.1.2 Packaging

The user will ensure that the use of the package complies with the conditions of approval in the Certificate of Compliance, including authorized contents. There are no special controls, precautions or equipment required for loading or preparing the package for transportation other than to monitor radiation levels during the installation of the sealed source inside the SPEC-300. Installation of the source into the SPEC-300 must be performed using a calibrated and properly operating survey instrument. The user will verify that the source assembly is properly secured and locked in the SPEC-300, and that the safety plug and lock cap are firmly attached. The user will verify that a tamper seal has been properly installed from the lock cap to lock box housing.

Radiological requirements of 10 CFR 71.47 shall be met prior to transportation. The user shall measure the maximum surface and one meter radiation levels of the package. The radiation level at the surface must not exceed 2 mSv/hr (200 mR/hr). The maximum radiation level at one meter (39.4 in) from the surface must not exceed 0.1 mSv/hr (10 mR/hr).

7.1.3 Outer Package Surface Contamination

Packages may be shipped on a non-exclusive use basis only if outer surface contamination levels are less than the values given below. It is it is the shipper's responsibility to ensure that the following conditions are met.

10 CFR Part 71.87(I)(1) requires that the non-fixed (removable) contamination on the external surfaces of the outer package being shipped on a non-exclusive use basis not exceed 10^{-5} :Ci/cm^2 (0.00001 :Ci/cm^2) averaged over a 300 cm^2 (46.5 in^2)area of any part of the surface. This may be determined by measuring the activity on wipes taken from representative areas. The above criterion is met if the activity on any sample averaged over the surface area wiped does not exceed 10^{-5} :Ci/cm^2 (0.4 Bq/cm^2 or 22 dpm/cm^2).

7.1.4 Transportation Requirements

The SPEC-300 package will be properly marked, labeled and described on a shipping paper in accordance with U.S. Department of Transportation regulations. Placards will be offered to carriers transporting a Radioactive Yellow III labeled package. Shipping papers will be retained for one year in accordance with U.S. Department of Transportation regulations.

7.1.5 Type B Quantity Consignee Notification

Prior to each shipment of a SPEC-300 containing more than 0.4 TBq (10.8 Ci) Cobalt-60 the shipper shall notify the consignee of the dates of shipment and expected arrival.

The shipper shall notify each consignee of any special loading/unloading instructions prior to first shipment, as applicable.

7.2 Procedures for Receipt and Unloading the Package

7.2.1 Unloading

The consignee must establish written procedures for receiving the SPEC-300 package in accordance with applicable NRC and agreement state regulations. Such procedures should provide for inspection, monitoring, notification and records. The SPEC-300 package becomes an industrial radiography exposure device after receipt by the licensed industrial radiographer user. The source assembly is temporarily removed and then returned to the exposure device frequently throughout its use in accordance with the licensed user's procedures and in accordance with applicable NRC regulations.

7.2.2 Receiving the SPEC-300

A. Delivery, Pick Up and Acceptance from Carrier

Regulations require that the consignee must make arrangements to receive the SPEC-300 when it is offered for delivery by the carrier; or must make arrangements to receive notification from the carrier at the time of arrival for pick up at the carriers facility.

The consignee must expeditiously pick up the SPEC-300 upon receipt of notification from the carrier.

B. Receipt Survey and Inspection

Before the delivered package is opened and as soon as practicable after receiving the SPEC-300, but no later than three hours after it is received at the consignee's facility during normal working hours or within three hours beginning the next work day if received after normal working hours the package must be monitored and inspected.

The outside package, as received, should be inspected for any indication of damage to the SPEC-300, and the maximum external radiation levels at the surface of the outside package and at one meter (39.4 in) from the surface of the outside package must be measured and recorded. Dents and abrasions to any crating or other ancillary shipping materials normally encountered in handling, loading and unloading are not generally considered evidence of damage to the SPEC-300.
The package must be inspected to ensure that the tamper seal has remained intact as evidence that the package has not been opened prior to receipt. If the tamper seal has been removed the user shall investigate and determine if the contents have been tampered with. If so, the user shall notify the shipper.

Since the sealed source in the SPEC-300 is classified as special form radioactive material it is not required to monitor the external surfaces of the SPEC-300 package for removable contamination.

C. Notification

If the measured maximum radiation level at the surface of the outside package or at one meter (39.4 in) from the surface of the outside package exceeds either of the following limits:

Location	Max mSv/hr	Max mR/hr
Surface of Outside Package	2	200
One Meter from Surface of Outside Package	0.1	10

Then the consignee must immediately notify the final delivering carrier, and either the agreement state radiation control agency, if applicable, or the NRC regional office having jurisdiction over the location where the package was received. It is also recommended that the shipper be notified. Care should be exercised in performing the survey that the radiation levels are measured at the proper distances, that the survey meter is calibrated and operating properly.

D. Records

Records of the receiving survey should be maintained for a period of three years which include at least: date and time package received or picked up; date and time monitored; identification of package by serial number; identification of source by serial number, isotope and activity (includes date of measurement); identification of individual performing survey; identification of survey meter by serial number; maximum radiation levels at surface of outside package and at one meter (39.34 in) from surface of outside package; and corrective action and notification to carrier and regulatory agency, if applicable.

7.3 Preparation of an Empty Package for Transport

Test to verify that the SPEC-300 does not contain a radioactive source (authorized source, unauthorized source, modified source, or a source capsule that has been removed from the source assembly) by the following method. This test should be performed by authorized and monitored personnel who have been trained in radiation safety and equipped with a properly operating survey instrument.

First, remove the safety plug and survey the open outlet nipple. The depleted Uranium shield is radioactive and will emit radiation even when no sealed source is installed in the package, but the highest radiation level should not exceed approximately 0.02 mSv/hr (2 mR/hr). Second, remove the lock cap and visually inspect the package to verify that no source assembly connector is protruding. This will indicate that there is no source assembly installed. Third, attach a control assembly to the package and crank only the drive cable from the control assembly forward through and out of the package while monitoring the survey instrument for a radiation hazard. A detached source capsule or otherwise unauthorized source will be pushed out of the package by the drive cable being cranked through the package. An exposed source must be treated as an emergency. Fourth, attach a dummy connector or dummy source assembly to the end of the drive cable. Retract the drive cable fully, then disconnect and remove the control assembly from the package, and install the safety plug and lock cap. If a dummy connector was used it will be removed with the controls. If a dummy source assembly was used it will remain in the package and must be disconnected from the control drive cable to remove the controls. Inspect the connector of the dummy source assembly to verify that it has no serial number.

8. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

Components and materials for package construction are subject to a QA receiving inspection, in process inspections as appropriate, and final acceptance inspections. These inspections are conducted in accordance with SPEC's quality assurance program under NRC Certificate of Compliance No. 0102 prior to shipment to a customer. Prior to shipment, each packaging is conspicuously and durably marked with its model number, serial number, gross weight, and a package identification number as assigned by the NRC.

8.1.1 Visual Inspections and Measurements

Receiving, in process and final acceptance inspections are performed to verify that the packaging has been fabricated and assembled in accordance with approved engineering documents including drawings listed on the certificate of compliance. Dimensions and tolerances specified on engineering documents are confirmed by measurement. Nonconforming material is handled in accordance with SPEC's quality assurance program.

8.1.2 Weld Examinations

Internal and external weld examinations are performed to verify packaging fabrication in accordance with approved engineering documents. The location, type and size of the welds are confirmed by measurement. These visual and dye penetrant weld examinations are performed by trained and qualified personnel in accordance with SPEC quality assurance program.

8.1.3 Structural and Pressure Tests

Structural acceptance tests on the model SPEC-300 are not indicated because of the rugged design and durable materials of construction. Weld examinations and visual inspections verify structural integrity. Pressure tests are not indicated because there is no possibility of a pressure build up which would affect the structure of the containment or the integrity of the package.

8.1.4 Leak Tests

Leak tests are performed by trained personnel in accordance with a SPEC approved work instruction. Source capsules and source assemblies are tested for leakage and rejected if there is removable contamination in excess of 74 Bq (0.002 :Ci). Prior to shipment, the outer surfaces of the packaging are tested for leakage and rejected if there is removable contamination in excess of 22 dpm/cm^2 averaged over 300 cm^2.

8.1.5 Component and Material Tests

Packaging material is inspected prior to use to verify that engineering specifications are met. Appropriate tests and acceptance criteria are specified for components that affect package performance such as the automatic securing mechanism. These tests must be performed prior to

shipment to verify that components meet performance specifications.

8.1.6 Shielding Tests

Amount of shielding: The depleted Uranium shield has a maximum weight of 238 kg (525 lb) and has a spherical diameter of 25 cm (10 in). With the source assembly capsule in the fully shielded position at the center of the shield, approximately 12.5 cm (5 in) of depleted Uranium shielding is present all around the radioactive source. "Ears" cast into the shield compensate for the depleted Uranium not present in the S-shaped tube running through the shield.

Prior to shipment with a source assembly, the package is surveyed to assure compliance with transportation requirements. Radiation levels must not exceed 2 mSv/hr (200mR/hr) at the surface when readings are corrected and extrapolated to 11.1 TBq (300 Ci). Radiation levels must not exceed 0.10 mSv (10 mR/hr) at one meter (39.4 in) from the surface when readings are extrapolated to 11.1 tBq (300 Ci).

A radiation survey is performed on the SPEC-300 as part of the final inspection prior to the initial distribution. This test assures that no voids or streaming paths exist in the shielding. The final inspection survey consists of radiation measurements taken at the surface of the package and at one meter from the package surface. The highest surface readings are obtained by scanning the entire surface of each side of the package. The highest surface reading is then extrapolated to 300 curies and a correction factor is applied to compensate for the distance between the detector and the actual surface of the package 13 mm (0.5 in). The one meter readings are taken at the location of the highest surface radiation reading for each side of the package. The readings are extrapolated to 11.1 TBq (300 Ci). Correction factors for detector to package surface distance are not required for the one meter surveys because the detector itself is placed at 1 meter.

At the time of manufacture, additional shielding pads may be used to reduce radiation levels to meet the allowable radiation levels stated above. Since the radiation shielding properties of cast depleted Uranium shields can vary slightly from unit to unit, shielding pads made from Tungsten or depleted Uranium may be used to locally improve the attenuation characteristics of a given shield if necessary to meet transport radiation level requirements. Shielding pads are attached to the depleted Uranium shield with an epoxy adhesive. The pads are further secured by the high density polyurethane foam material filling the interior space between the depleted Uranium shield and the device housing. The most common need for a pad is on the hot top of the DU shield. Shielding pads are not necessary to meet accident dose limit requirements in 10 CFR 71.51 (a) (2). Shielding pads will only be used on shields that already meet type B hypothetical accident condition testing radiation level requirements.

8.1.7 Thermal Acceptance Tests

Thermal tests are not appropriate (or required) to demonstrate the heat transfer capability of the packaging because the heat of decay for the maximum permissible activity Cobalt-60 source 11.1 TBq (300 Ci) is negligible.

8.2 Maintenance Program

Licensees are required to develop procedures to ensure that the SPEC-300 package is shipped and maintained in accordance with the Certificate of Compliance.

8.2.1 Structural and Pressure Tests

There are no maintenance instructions required to ensure continued structural performance of the SPEC-300. As a normal part of package preparation and receipt, the package is routinely inspected for structural damage.

Periodic pressure tests are not required because there is no possibility of a pressure build up which would affect the structure of the containment or the integrity of the package.

The inspection and maintenance that are relevant to assure that the SPEC-300 operates properly as a Type-B package consist of visual inspections and operational tests of the lock cap, device lock, source assembly lock, safety plug, outlet nipple and transport lock. The recommended inspections, operational checks and maintenance procedures are described in the SPEC-300 users manual.

8.2.2 Leak Tests

Instructions, including frequency, for performing leak tests for removable contamination of the sealed source must be developed to verify that the sealed capsule meets the special form requirements of 10 CFR 71.75 and other current regulatory requirements, as applicable.

8.2.3 Subsystems Maintenance

Not applicable. The model SPEC-300 has no subsystems.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

Not applicable. The primary containment vessel is a small sealed source capsule.

8.2.5 Shielding

Shielding integrity is verified at the time of manufacture. There are no instructions for maintaining the integrity of the shield and/or optional shielding pads by the licensee. As a normal part of package preparation and receipt, the package is routinely inspected for excessive radiation levels.

8.2.6 Thermal

Periodic thermal tests on the model SPEC-300 are not indicated since the heat of the decay for the maximum permissible activity Cobalt-60 source (300 Ci) is negligible. There are no components which would be thermally degraded by typical use and transport.