71-9282

spec
SOURCE OF QUALITY

March 27, 2000

Mr. Michael D. Waters, Project Manager
Licensing Section
Spent Fuel Project Office
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
One White Flint North
11155 Rockville Pike
Rockville, MD 20852

Subject: Docket No.: 71-9282
Application for Model SPEC-300 Package
Supplement No. 5, dated March 27, 2000

Dear Mr. Waters:

This submittal is to provide additional information and clarification in regards to the teleconference with your staff on March 21, 2000. The submittal is identified as Supplement No. 5, dated March 27, 2000. As instructed, three (3) color copies of the supplement are being sent. To facilitate the review, a summarization of the information provided is as follows:

Section 2.6 has been revised to include all input parameters for the Finite Element Analysis which can be found on page 15. Additionally, Figures Nos. 1 through 4 previously submitted in Supplement No. 4 have been deleted due to the insignificance of the information provided. The remaining figures are renumbered accordingly. The information provided in the figures remains the same with the exception that the localized areas of the maximum temperatures or stresses on the package are indicated (labeled). Due to a significant changes in the formatting caused by figure deletion and revised text, pages 15 through 15.10 and 17 through 17.3 are revised in their entirety. Changes are indicated by a vertical line in the right margin.

Section 3.5 was revised to further explain why this package meets the requirements of 10 CFR 71.73 (c)(4) and summarizes why stress limits over the yield strength of the material will not adversely affect the shielding integrity of the package. Due to a significant changes in the formatting caused by figure deletion and revised text, pages 35 through 35.7 and 39 through 39.1 are also revised in their entirety. Changes are indicated by a vertical line in the right margin.

Please do not hesitate of contact me if further clarification is needed.

Sincerely,

Kenneth N. Carrington
Regulatory Affairs

/knc

Enclosures: Three (3) copies of Supplement No. 5, dated March 27, 2000 to Application for Model SPEC-300 Package

H:\APPLICAT\SPEC-300\TYPEB\SUPP5.WPD

Source Production & Equipment Co., Inc.
113 Teal Street St. Rose, LA 70087-9691 Phone 504/464-9471 FAX 504/467-7685 Website: www.spec150.com

NMSS01 Public

SUPPLEMENT NO. 5
to
Type B(U)-85 Transportation Package
Certificate of Compliance Application, Revision (1),
dated October 6, 1999
Model SPEC-300

March 27, 2000

REMOVE	INSERT
Table of Contents Page 2 Supplement No. 4 February 29, 2000	Table of Contents Page 2 Supplement No. 5 March 27, 2000
Page 15 through 15.10 Supplement No. 4 February 29, 2000	Page 15 through 15.10 Supplement No. 5 March 27, 2000
Page 17 through 17.3 Supplement No. 4 February 29, 2000	Page 17 through 17.4 Supplement No. 5 March 27, 2000
Page 35 through 35.5 Supplement No. 4 February 29, 2000	Page 35 through 35.7 Supplement No. 5 March 27, 2000
Page 39 through 39.1 Supplement No.4 February 29, 2000	Page 39 through 39.1 Supplement No. 5 March 27, 2000

TABLE OF CONTENTS

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)(1) 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.

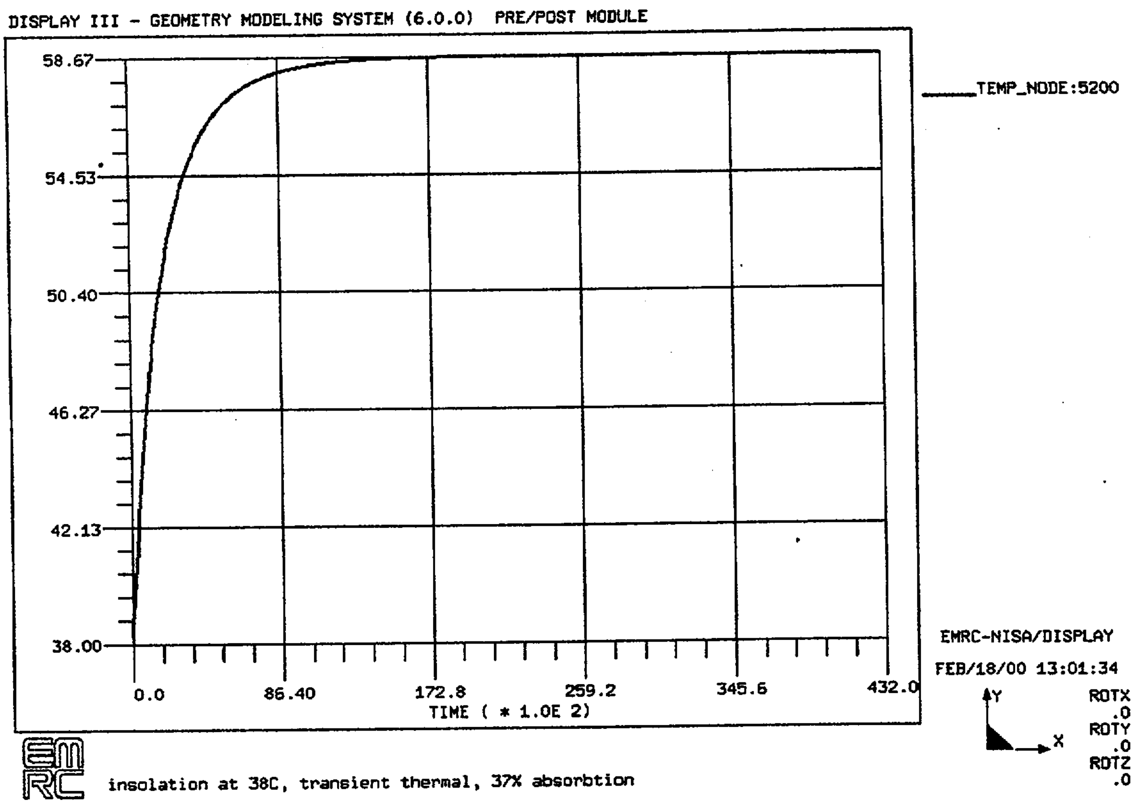


Figure 1

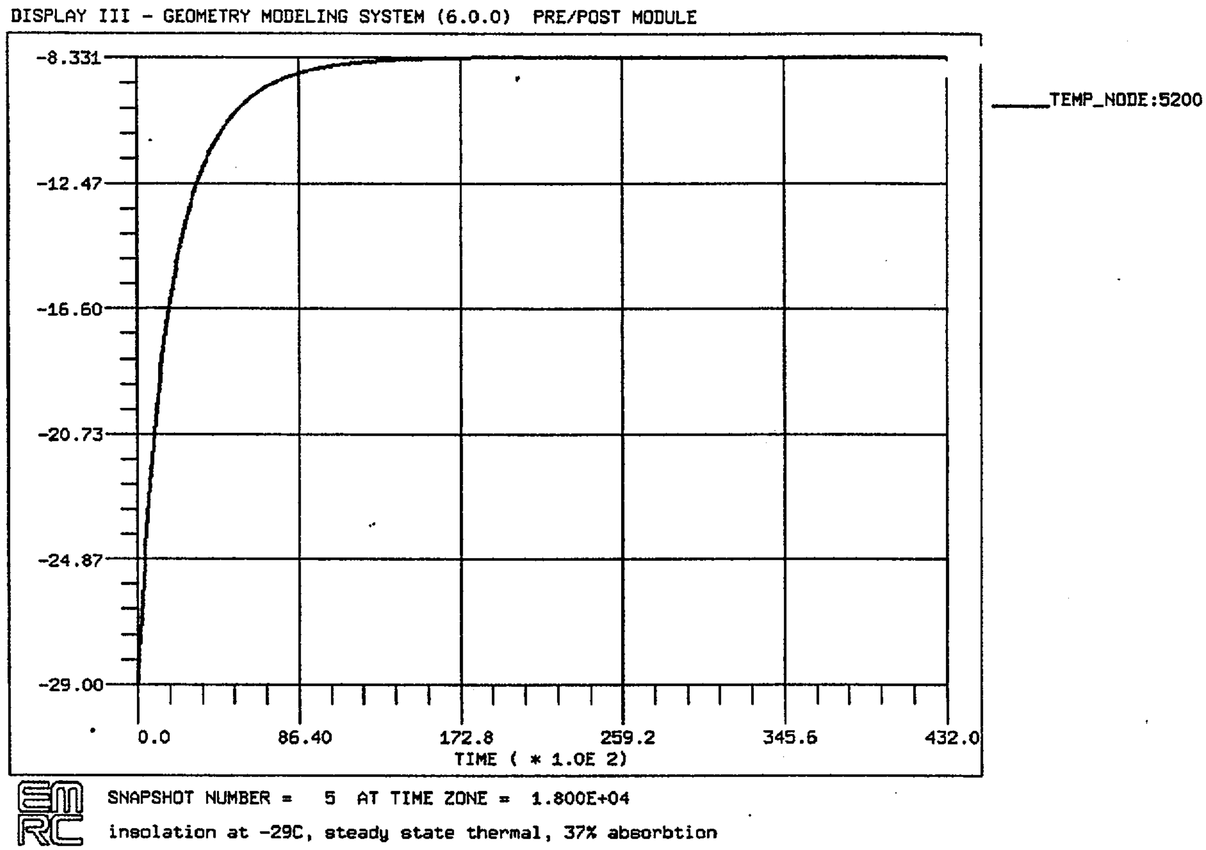


Figure 2

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.

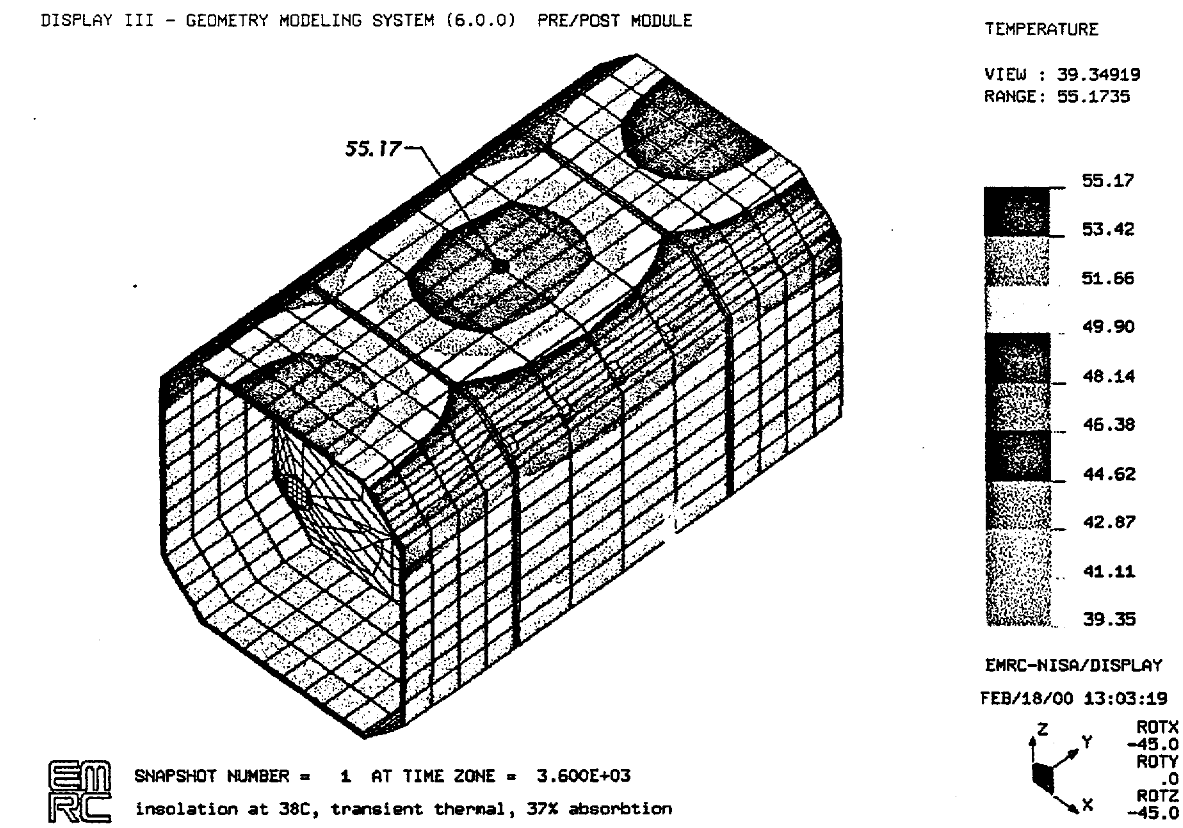


Figure 3

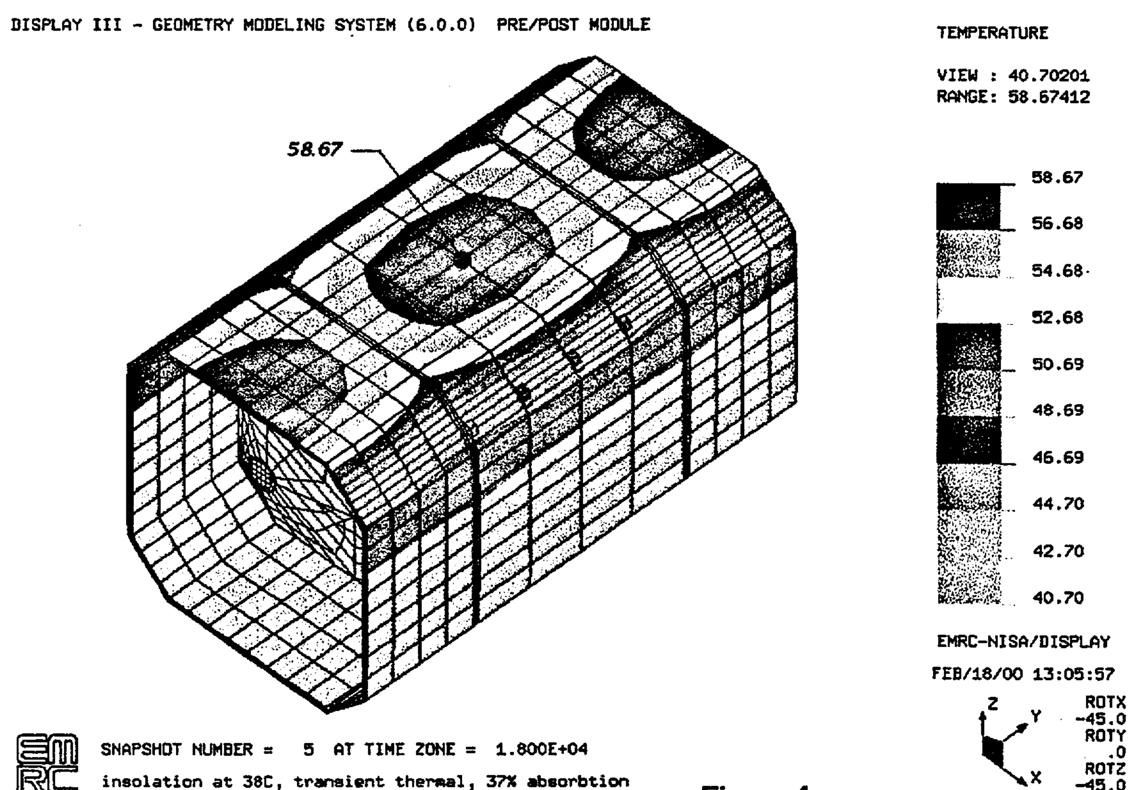


Figure 4

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.

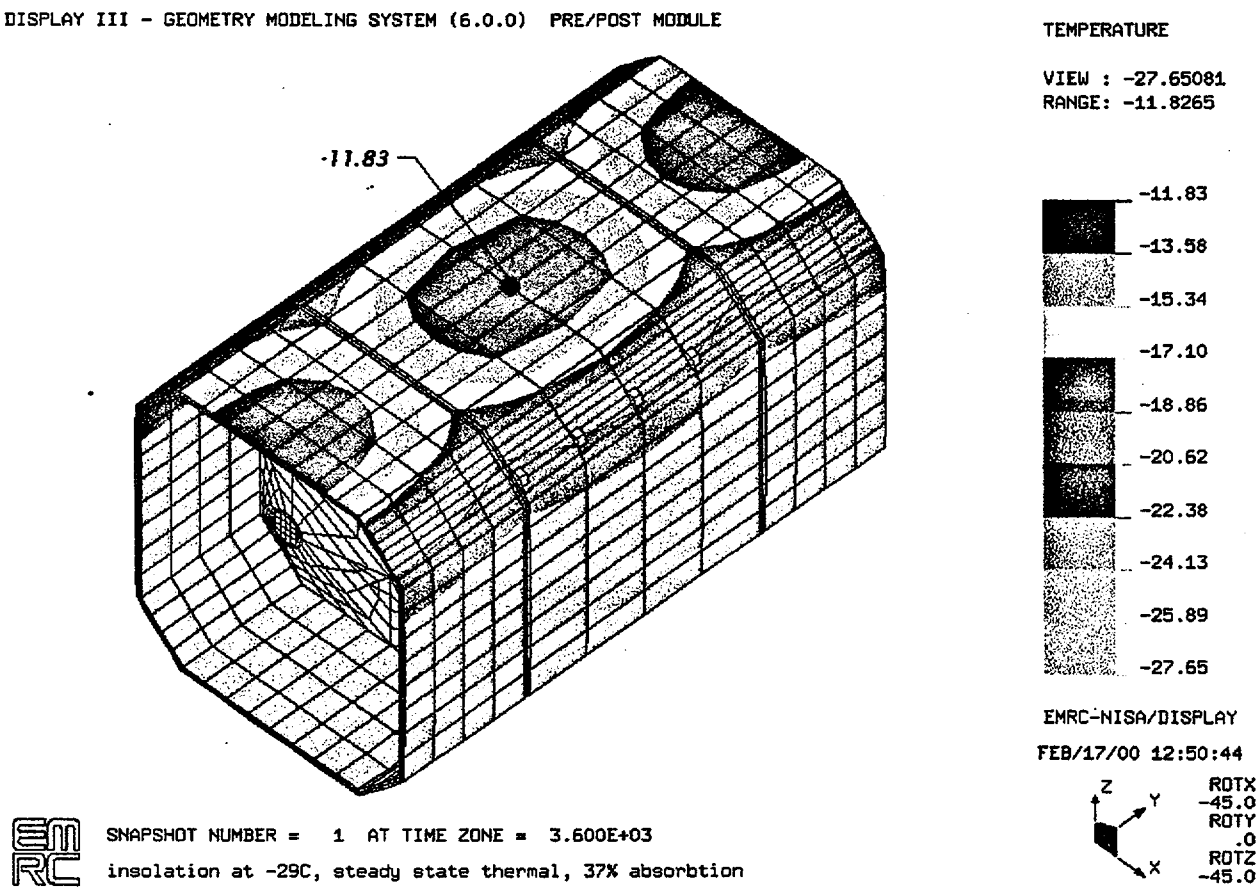


Figure 5

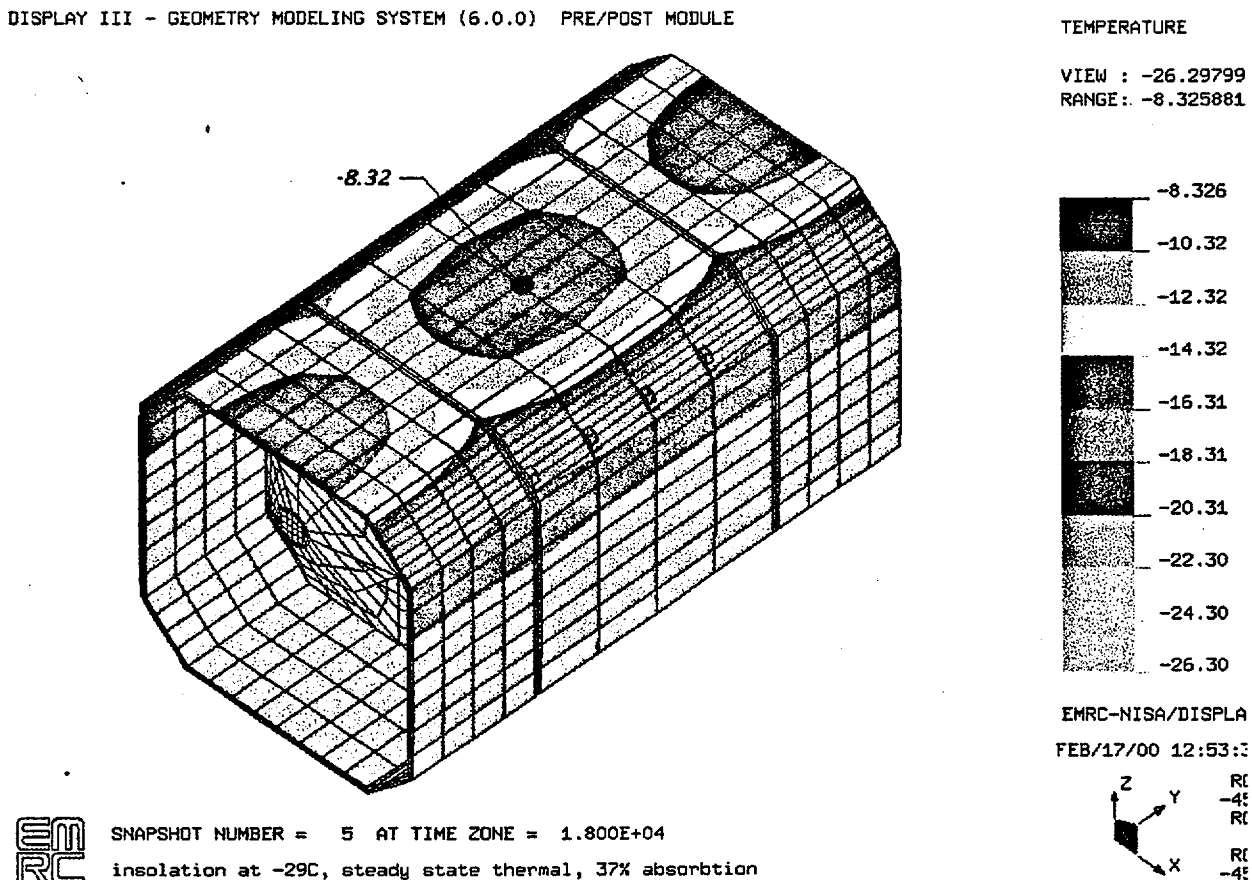


Figure 6

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.

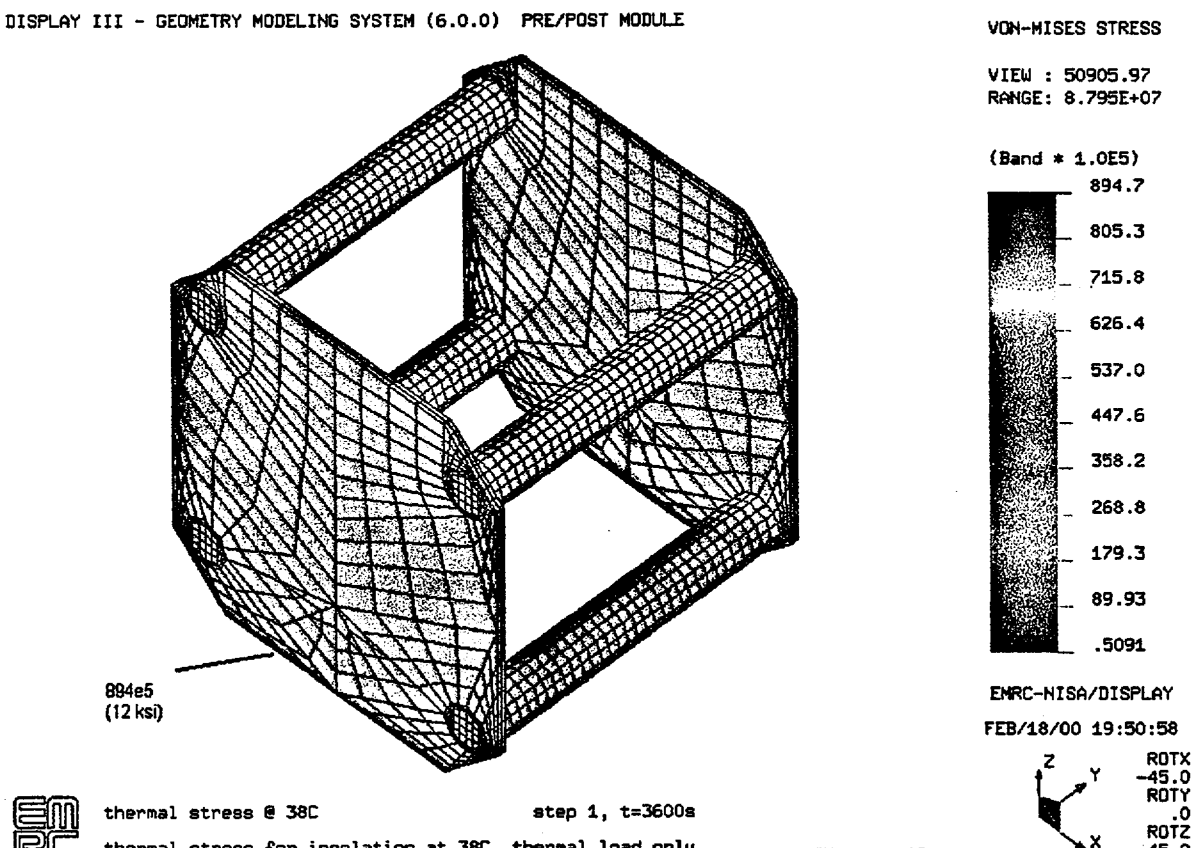
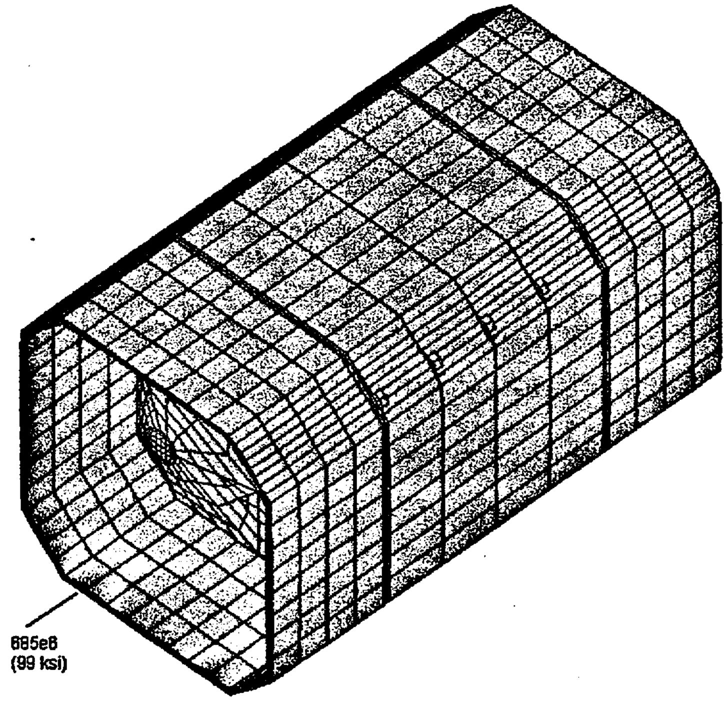


Figure 7

DISPLAY III - GEOMETRY MODELING SYSTEM (6.0.0) PRE/POST MODULE



VON-MISES STRESS

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(Band * 1.0E6)
685.1
616.6
548.1
479.6
411.1
342.6
274.1
205.6
137.1
68.56
5E-02

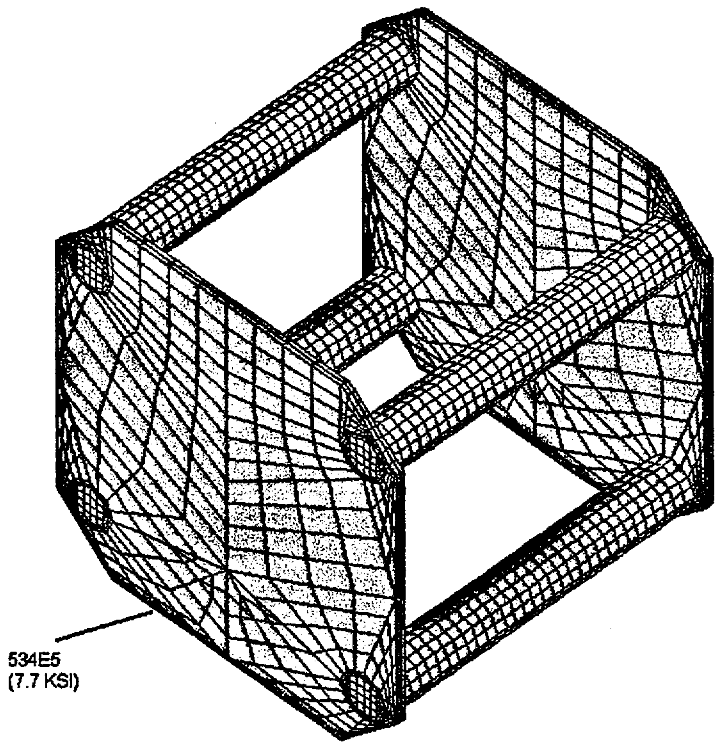
EMRC-NISA/DISPLAY
FEB/18/00 19:48:52

Z Y X
ROTX -45.0
ROTY .0
ROTZ -45.0

EMRC thermal stress @ 38C step 1, t=3600s
thermal stress for insolation at 38C, thermal load only

Figure 8

DISPLAY III - GEOMETRY MODELING SYSTEM (6.0.0) PRE/POST MODULE



VON-MISES STRESS

VIEW : 196045.7
RANGE: 5.262E+07

(Band * 1.0E5)
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481.2
427.7
374.3
320.9
267.4
214.0
160.6
107.1
53.67
.2360

EMRC-NISA/DISPLAY
FEB/18/00 16:40:43

Z Y X
ROTX -45.0
ROTY .0
ROTZ -45.0

EMRC thermal stress @-29C step 1, t=3600s
thermal stress for insolation at -29C, thermal load only

Figure 9

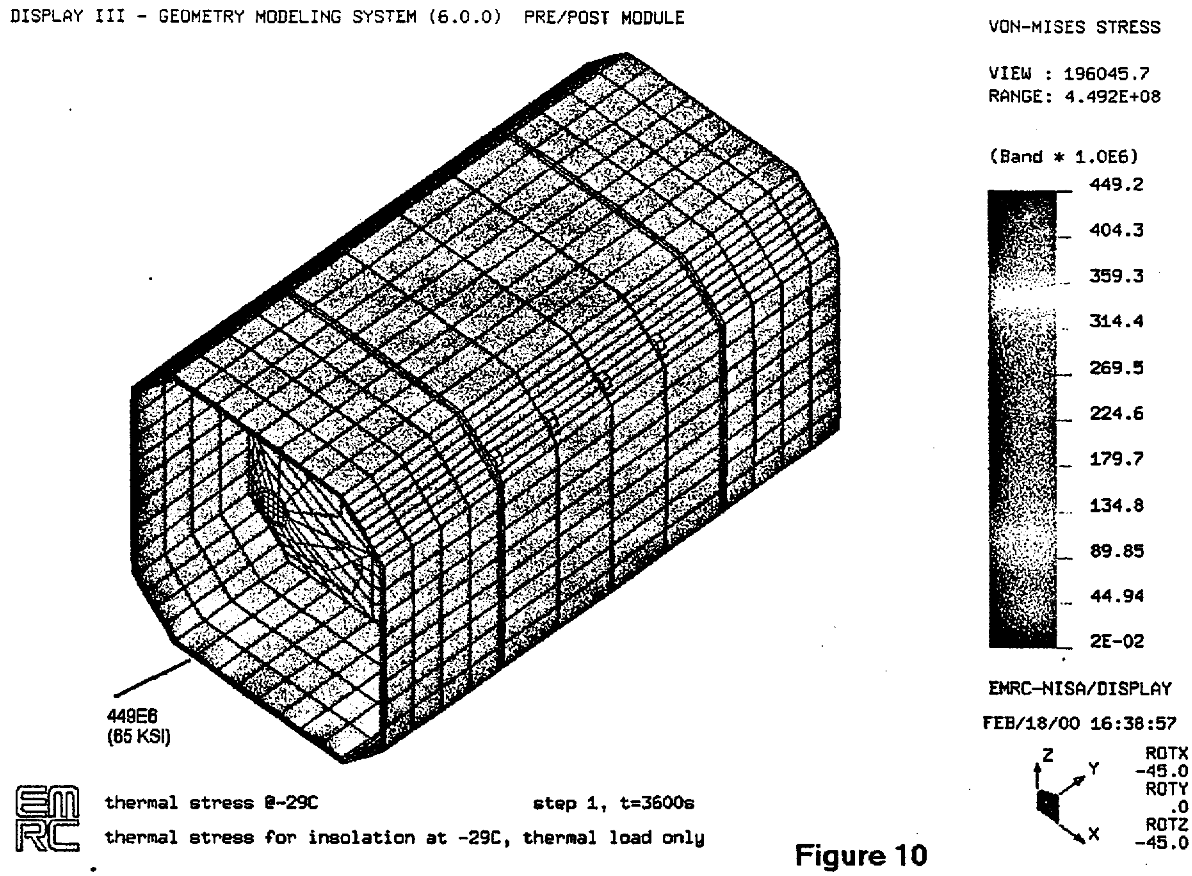

Figure 10

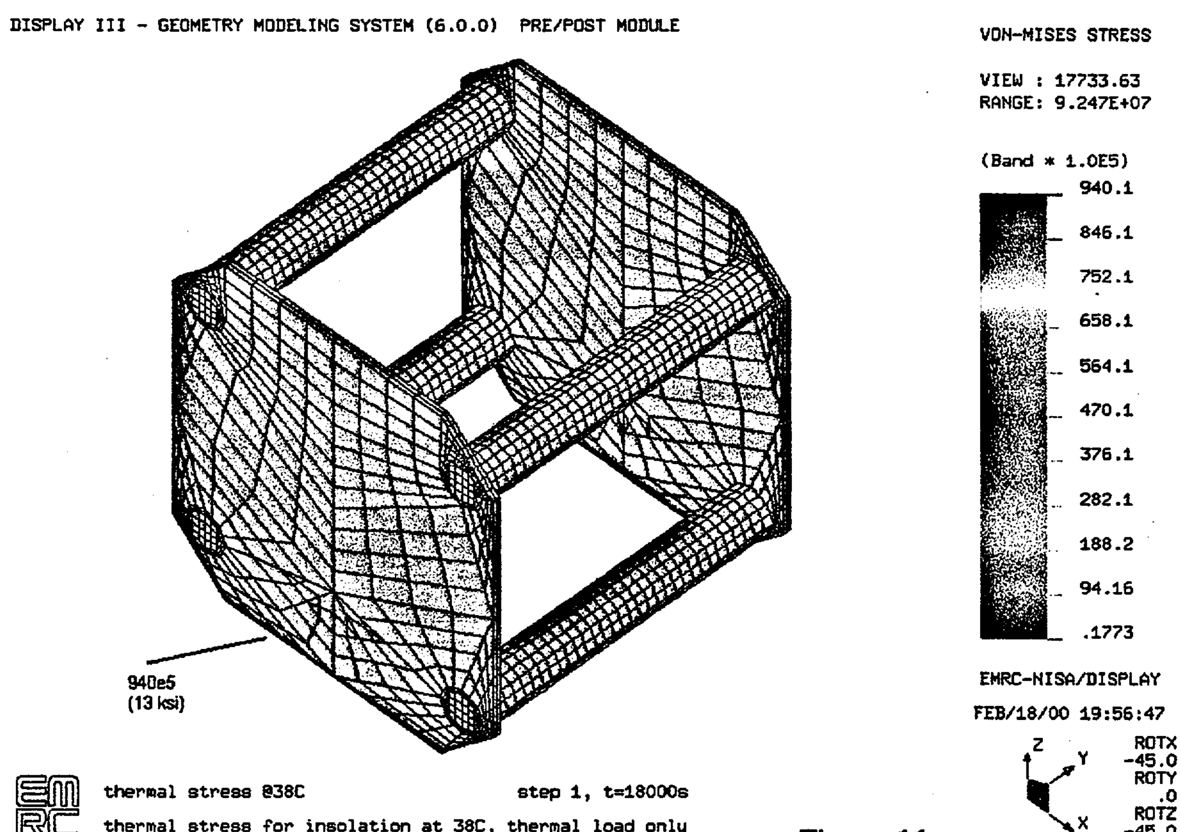

Figure 11

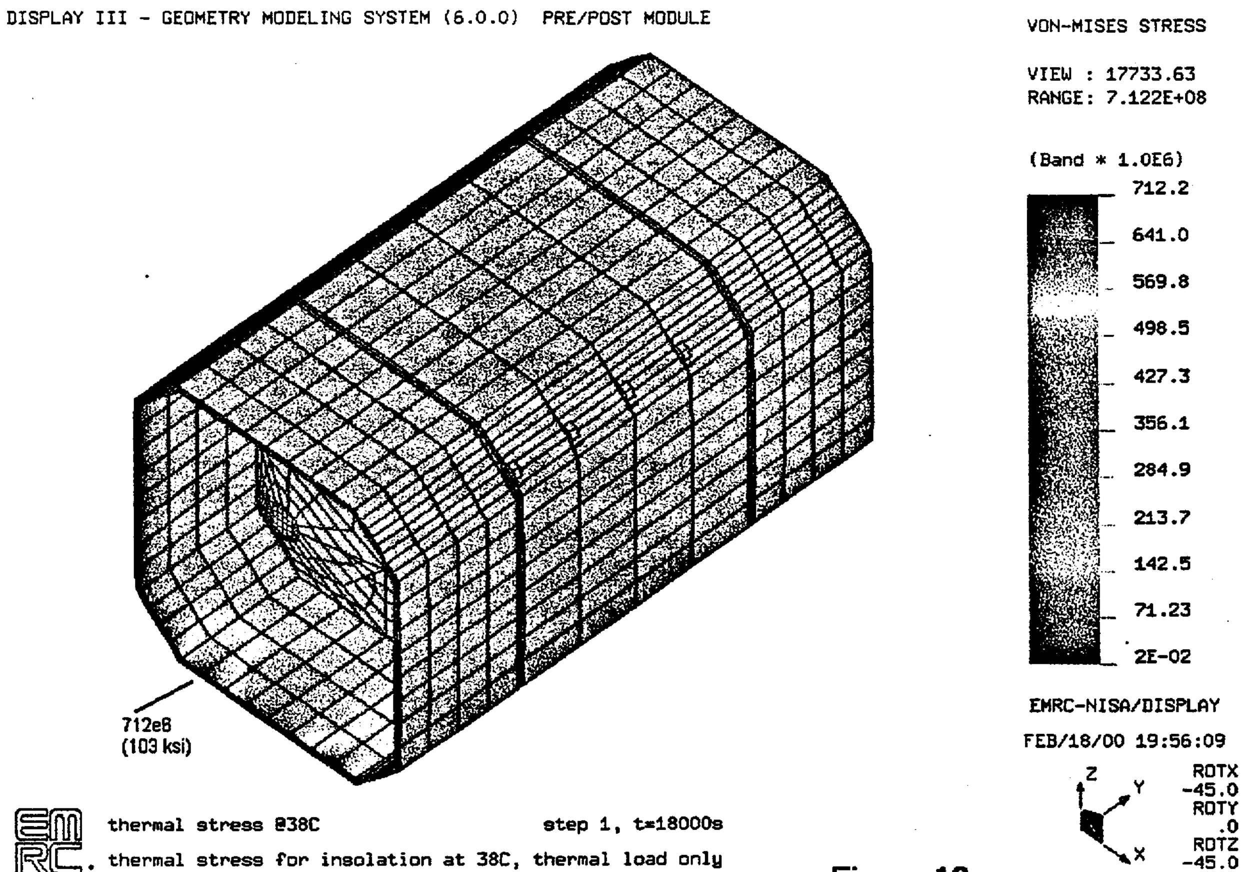

Figure 12

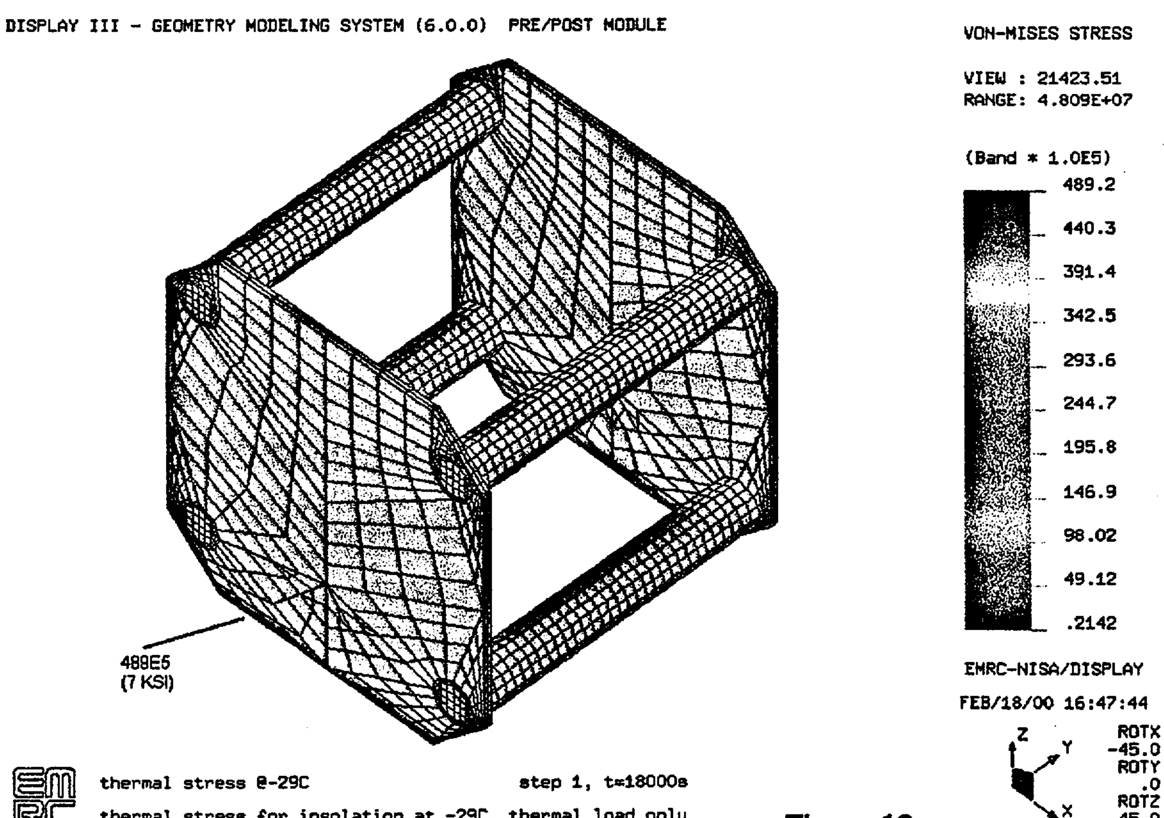

Figure 13

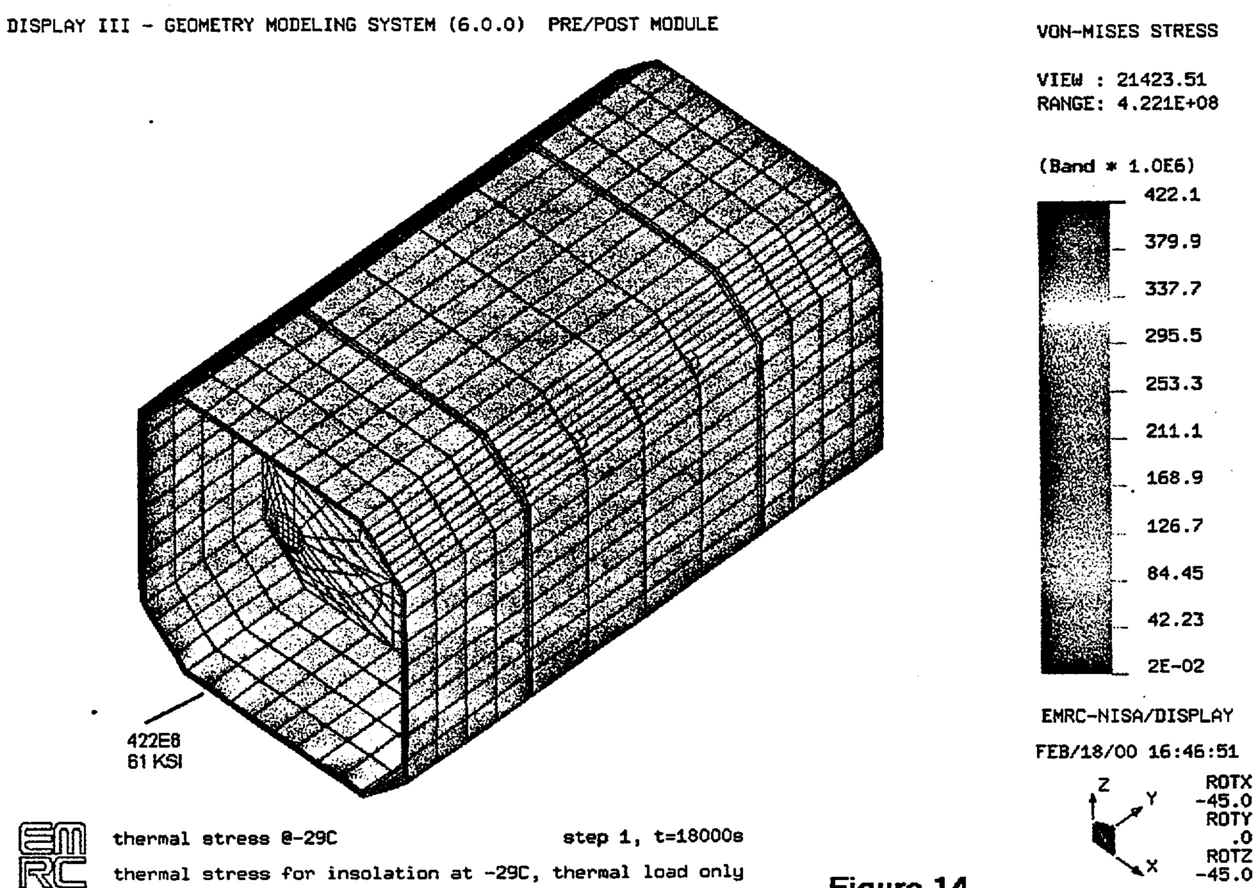
DISPLAY III - GEOMETRY MODELING SYSTEM (6.0.0) PRE/POST MODULE
VON-MISES STRESS
VIEW : 21423.51
RANGE: 4.221E+08
(Band * 1.0E6)
422.1
379.9
337.7
295.5
253.3
211.1
168.9
126.7
84.45
42.23
2E-02
EMRC-NISA/DISPLAY
FEB/18/00 16:46:51
422E8
61 KSI
thermal stress @-29C
step 1, t=18000s
thermal stress for insolation at -29C, thermal load only
Z
Y
X
ROTX
-45.0
ROTY
.0
ROTZ
-45.0

Figure 14

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

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

3. 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.

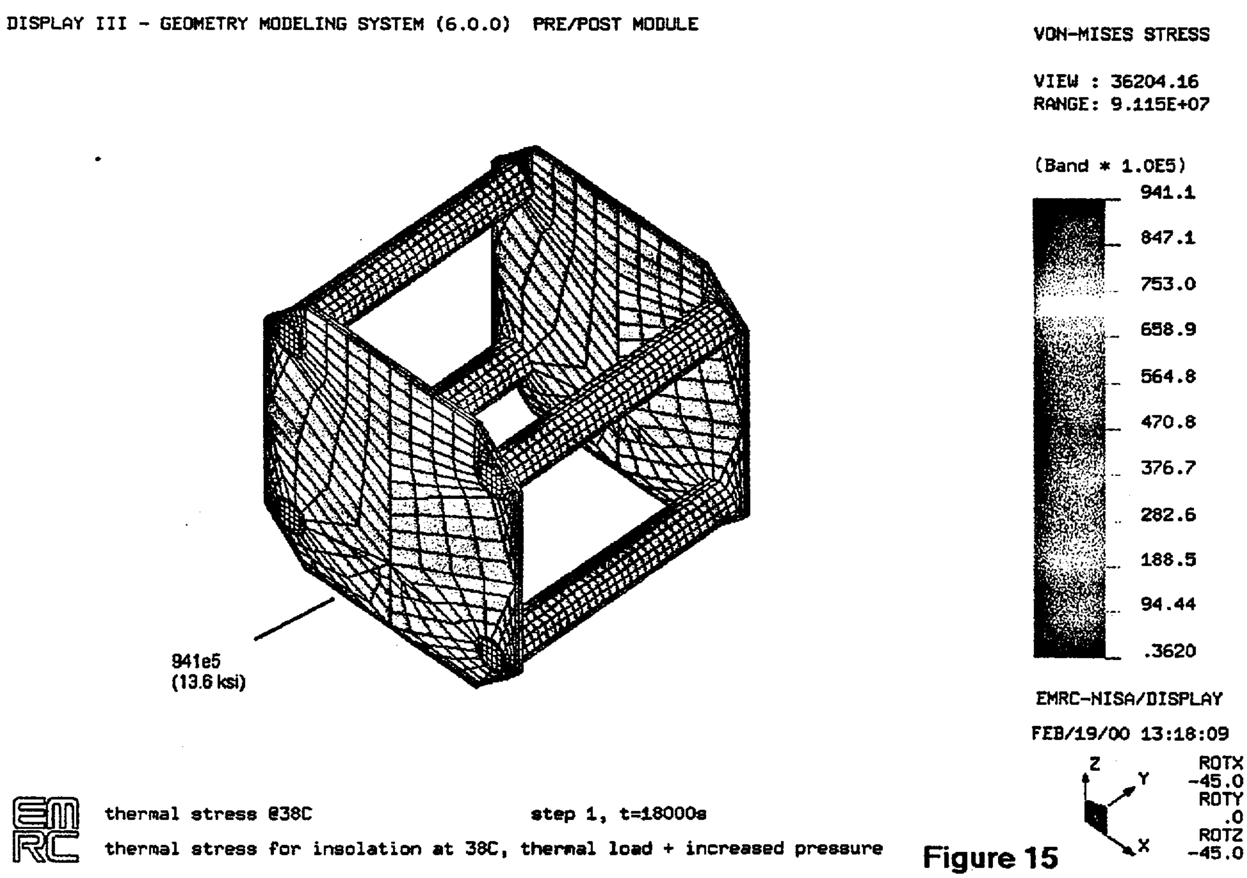

Figure 15

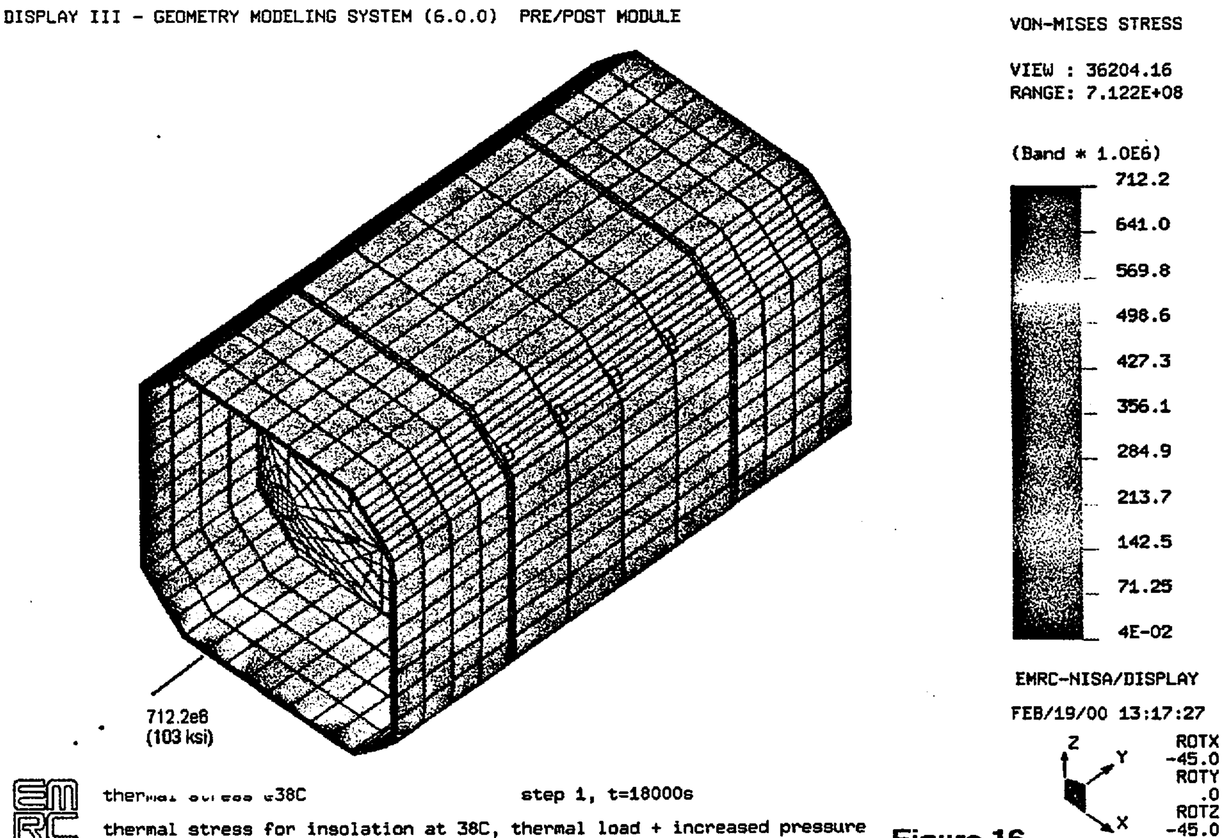

Figure 16

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.

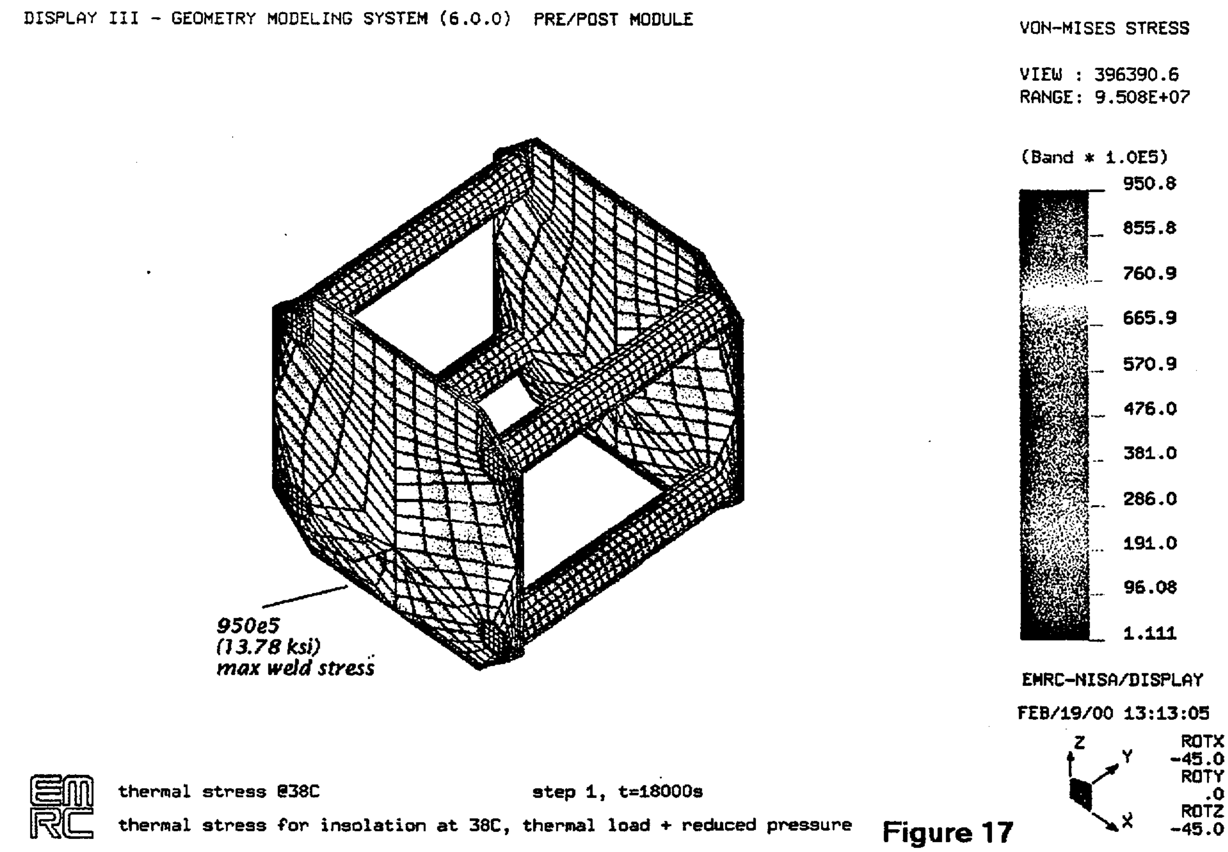

Figure 17

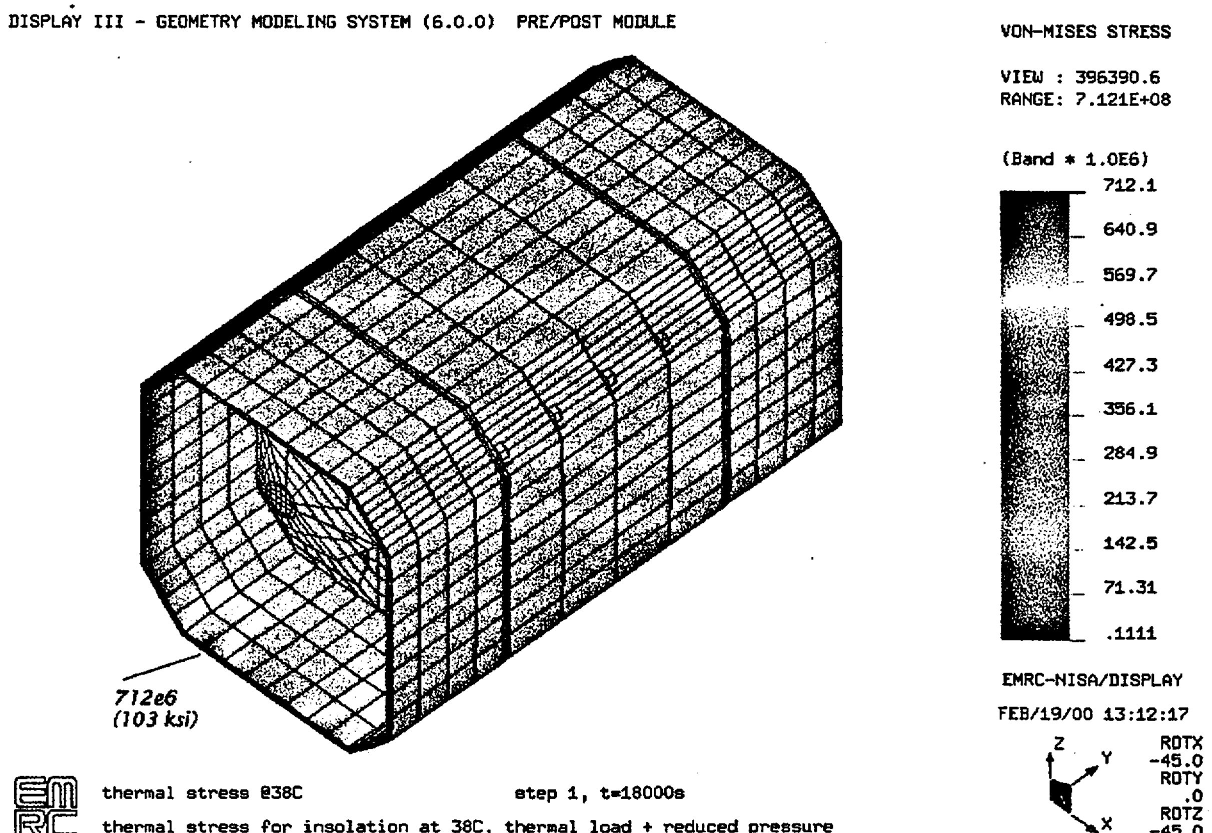

Figure18

2.6.4 Vibration

The effect of vibration on the package and materials of construction incident to normal

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. 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 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.

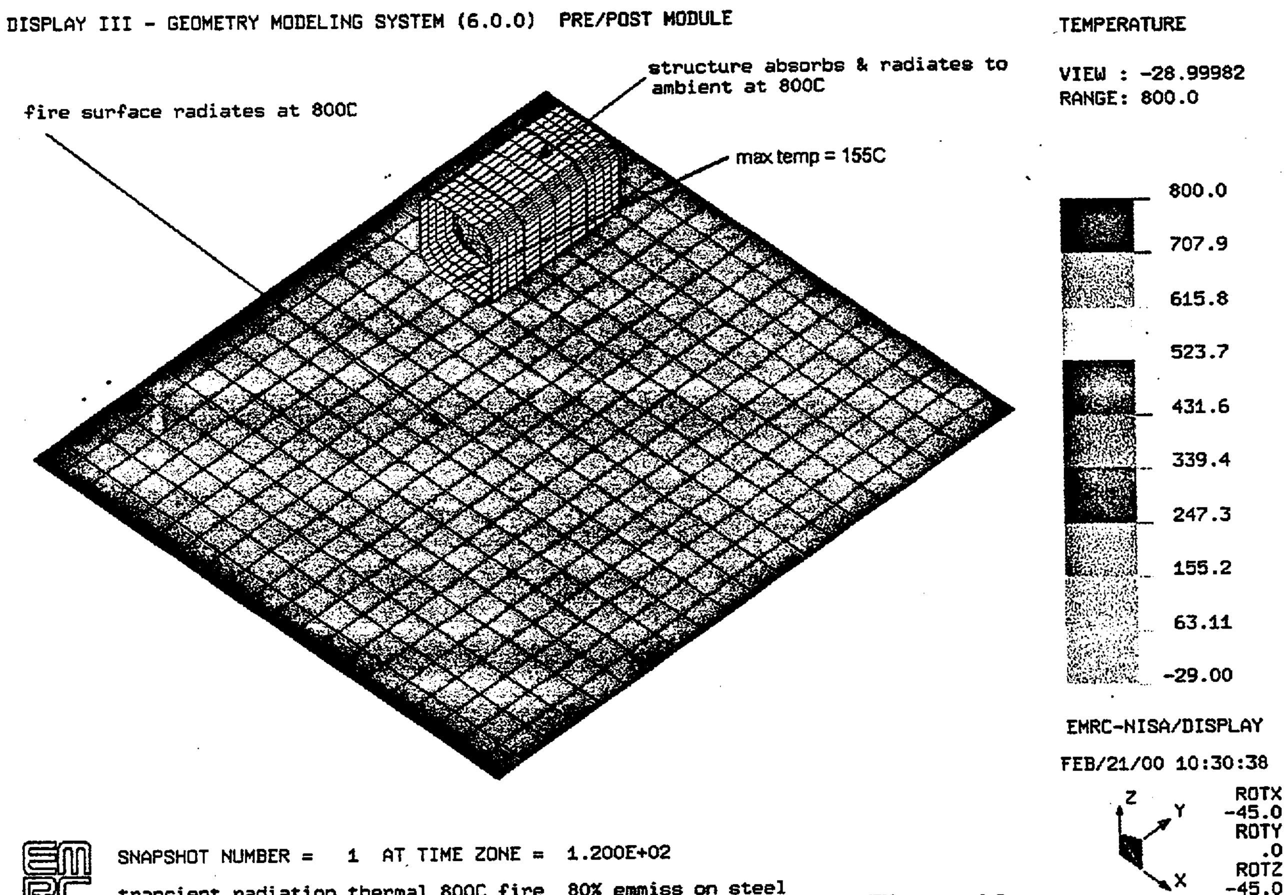

Figure 19

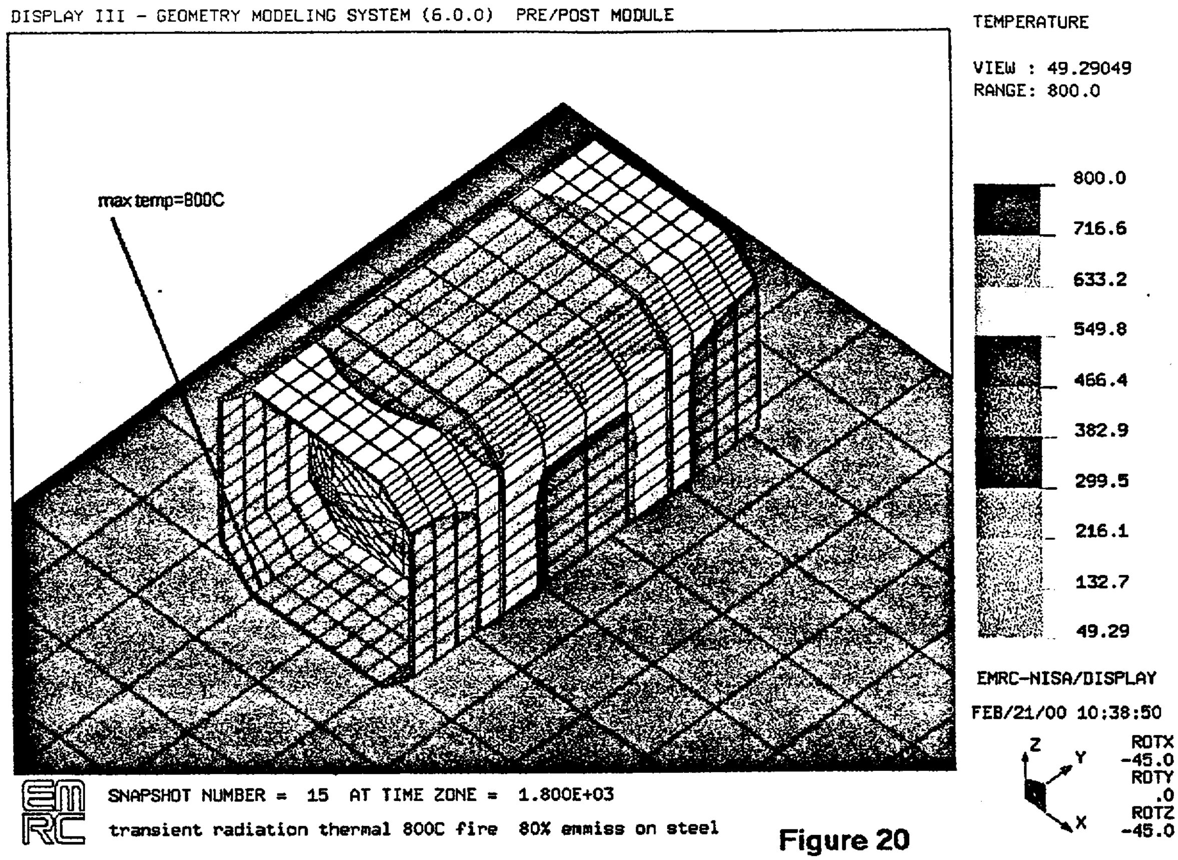

Figure 20

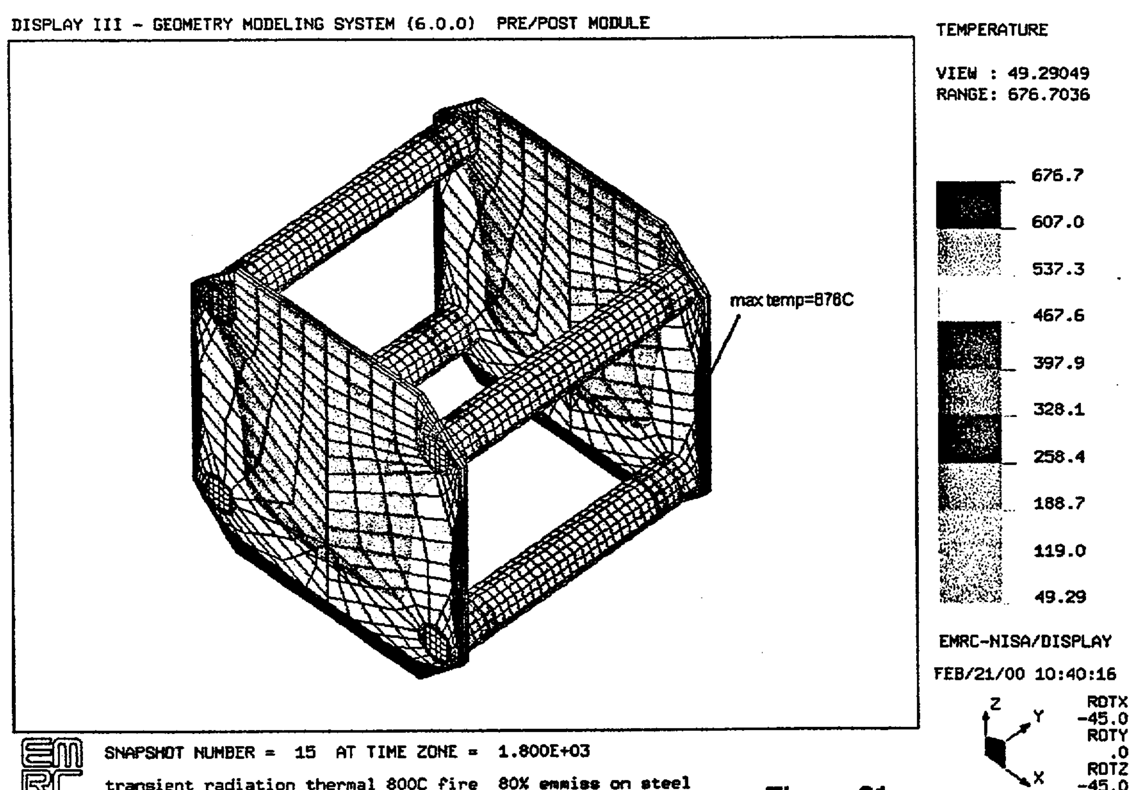

Figure 21

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).

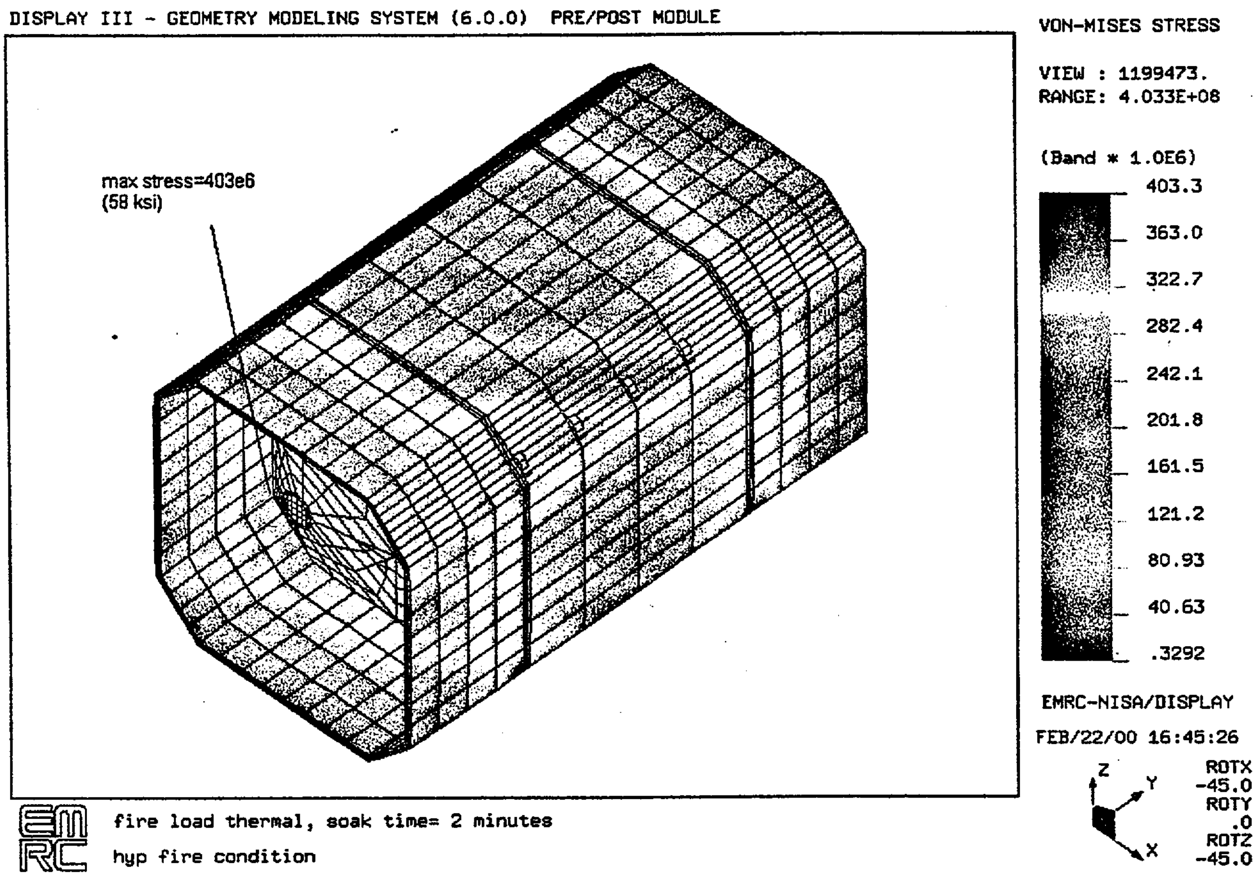

Figure 22

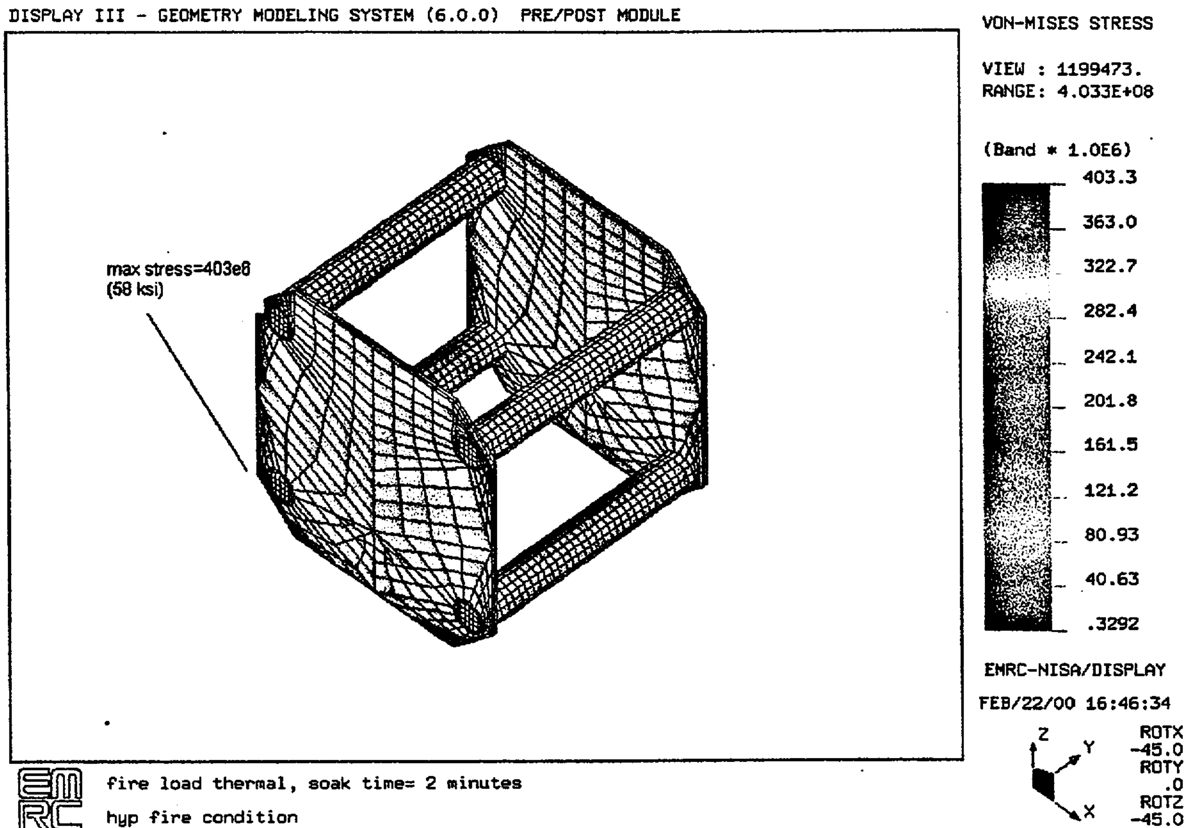

Figure 23

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.

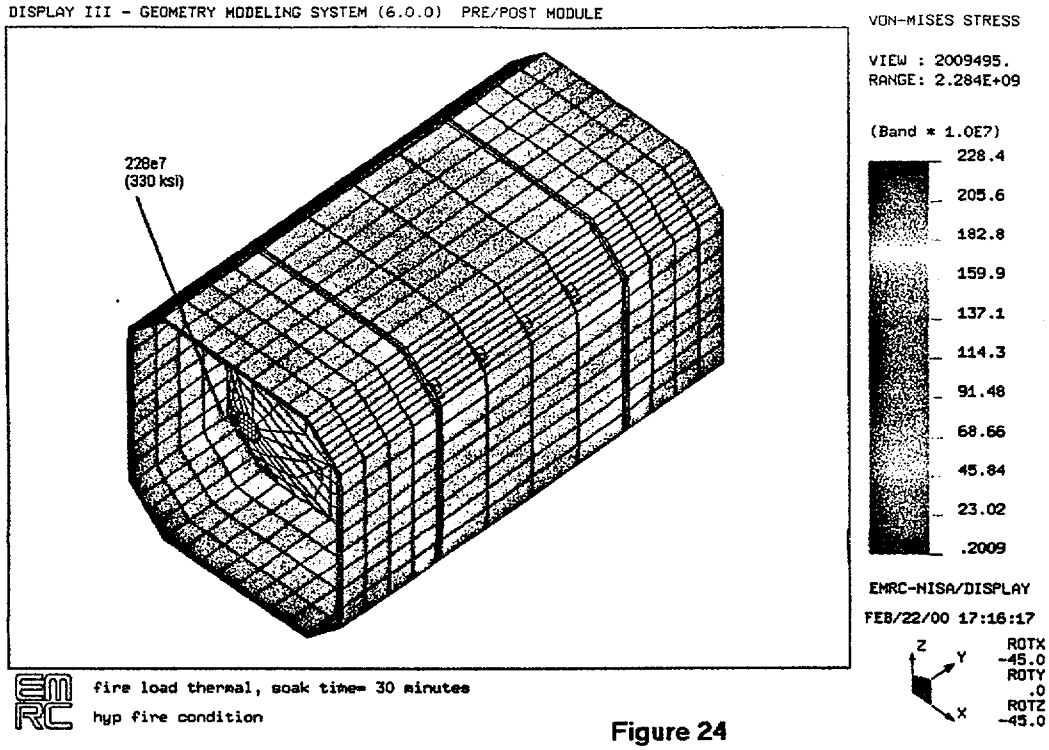

Figure 24

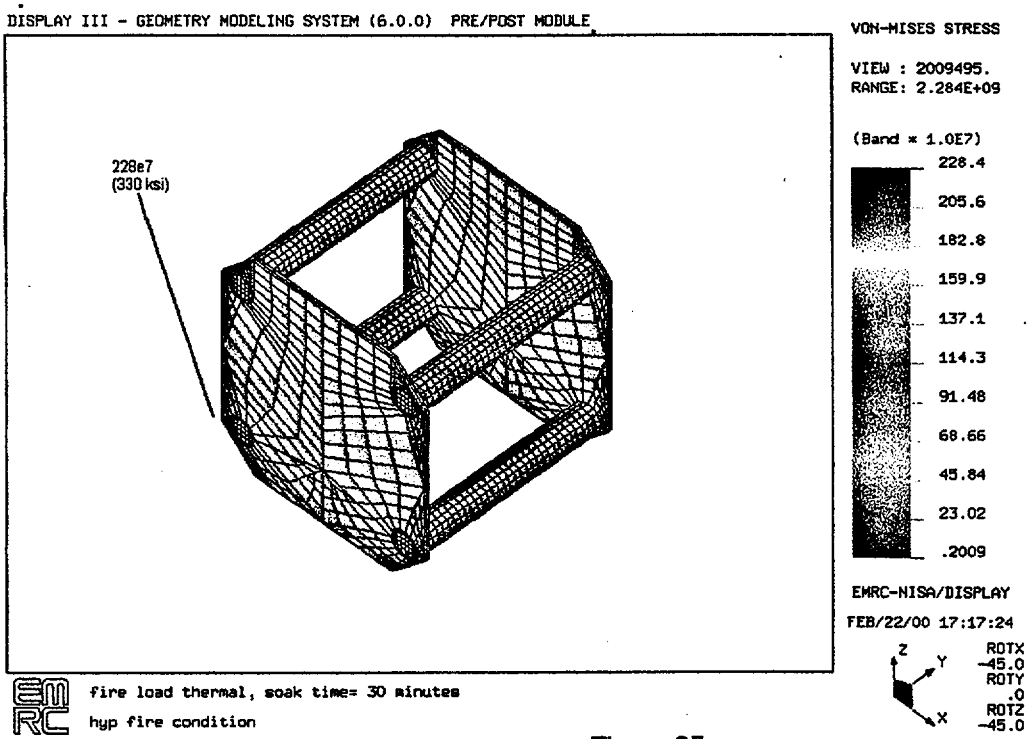

Figure 25

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 © (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

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.

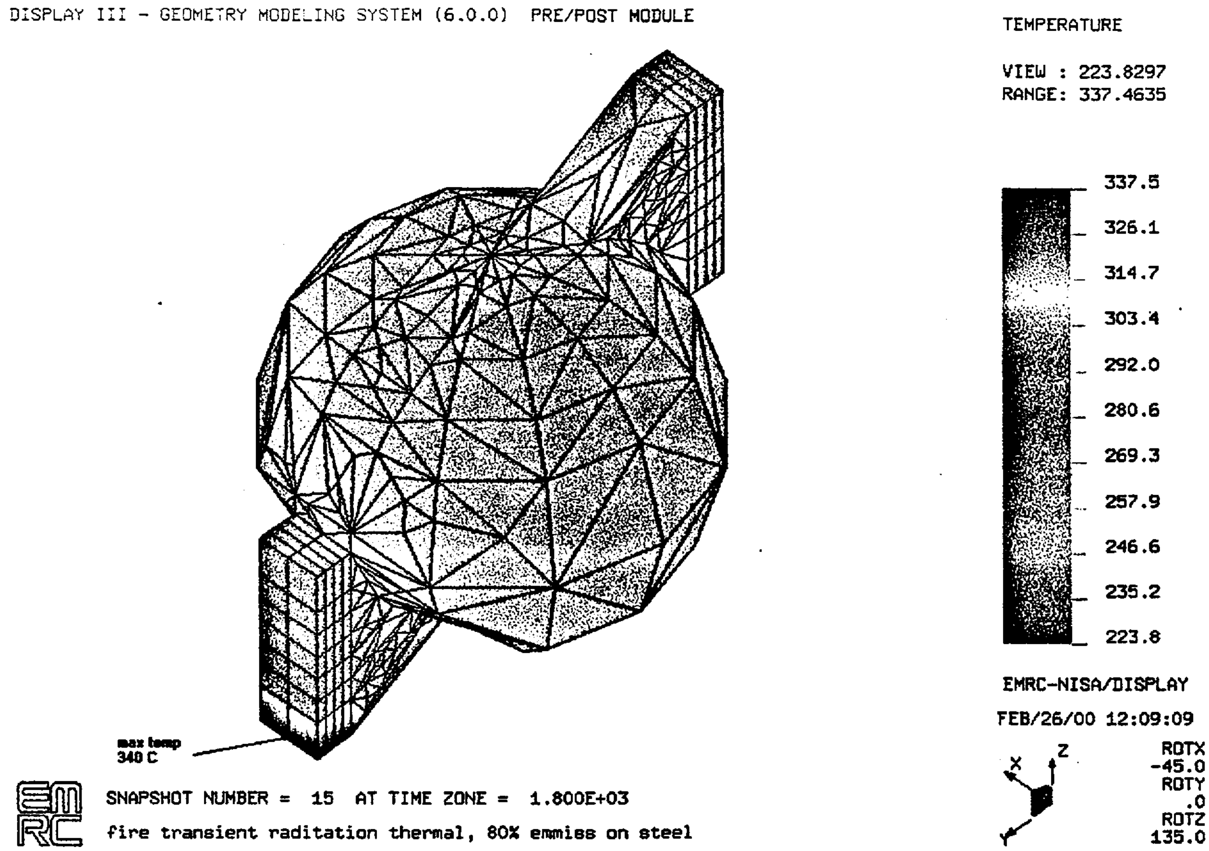

Figure 26

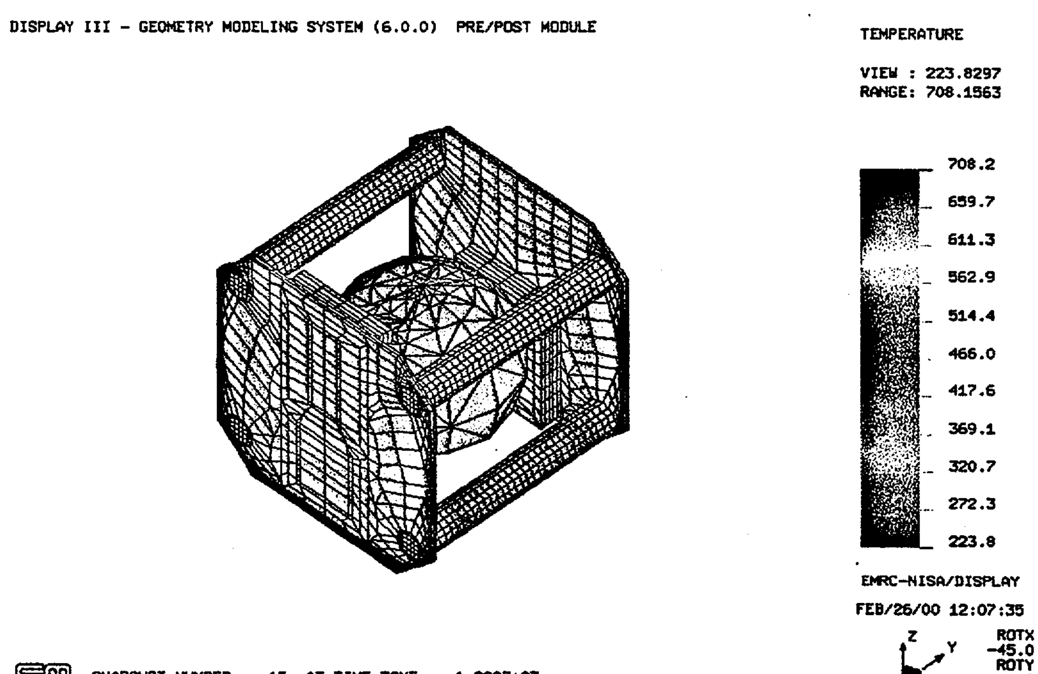

Figure 27