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REQUEST FOR A MANUFACTURING EXEMPTION FOR FABRICATION AND USE OF PACKAGING FOR TRANSPORTING USED NUCLEAR REACTOR PRESSURE VESSEL HEADS.

NON-PROPRIETARY VERSION

Duratek™

140 Stoneridge Drive
Columbia, South Carolina 29210
803-256-0450
www.duratekinc.com

September 7, 2004
E&L-030-04

Associate Administrator for Hazardous Materials Safety
Research and Special Programs Administration
U.S. Department of Transportation
400 7th St., S.W.
Washington, DC 20590-0001

Attention: Exemptions, DHM-31

SUBJECT: REQUEST FOR A MANUFACTURING EXEMPTION FOR FABRICATION AND USE OF PACKAGING FOR TRANSPORTING USED NUCLEAR REACTOR PRESSURE VESSEL HEADS.

Duratek Inc. requests a manufacturing exemption from certain requirements of 49 CFR 173.403, §173.427, and §173.465 for the Duratek Reactor Head Package (DTKHP) to allow the package to be used in the transportation in commerce of a hazardous material. Numerous utilities plan to replace their nuclear power reactor pressure vessel heads in the next few years. The used heads are both neutron activated and contaminated with radioactive materials. Duratek has designed components to enclose the activated and contaminated portions of the head that when securely fastened to the head form a package suitable for transport in commerce. Duratek requests:

- exemption from the LSA definition in §173.403,
- DOT approval that reactor heads can be classified as LSA,
- exemption from the LSA packaging requirement of §173.427,
- exemption from the drop test orientation requirement of §173.465,
- exemption from the stacking test requirement of §173.465, and
- DOT approval of the DTKHP as meeting the applicable requirements of Part 173 for transport of a reactor head.

Five attachments are included to support the request for exemption. The attachments are:

Attachment 1 – Compliance Matrix
Attachment 2 – Characteristics of a Used Reactor Pressure Vessel Head
Attachment 3 – Structural Analysis of the Duratek Head Package
Attachment 4 – Typical Transportation and Emergency Response Plan
Attachment 5 – Affidavit for Proprietary Information

If you require additional information regarding this request, please contact Scott Johnson, Project Manager, at (803) 758-1841.

Sincerely,

Mark Lewis
Regional Vice-President

Attachments 1 – 5 as noted above

Attachment 1
Compliance Matrix

EXEMPTION REQUEST FOR THE PACKAGING AND TRANSPORT OF REACTOR PRESSURE VESSEL HEADS

This document provides the basis of Duratek Services, Inc. application for a manufacturing exemption for a package to transport reactor pressure vessel heads (RPVHs) with or without attached whole or partial control rod drive mechanisms (CRDMs).

In the following text, the regulation concerning the exemption request is cited in bold, and the applicant's response is provided following the respective regulation. Supporting information is provided in other documents also included as attachments to this exemption submittal.

Title 49:	**TRANSPORTATION**
	CHAPTER 1—RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION, DEPARTMENT OF TRANSPORTATION
Subpart B:	**Exemptions**
	Source: Amdt. 107-38, 61 FR 21095, May 9, 1996, unless otherwise noted.
§107.101:	**Purpose and scope.**
	This subpart prescribes procedures for the issuance, modification and termination of exemptions from requirements of this subchapter, subchapter C of this chapter, or regulations issued under chapter 51 of 49 U.S. C.
§107.105:	**Application for exemption.**
§107.105(a)	*General.* **Each application for an exemption or modification of an exemption must be written in English and must–**
§107.105(a)(1)	**Be submitted for timely consideration, at least 120 days before the requested effective date, in duplicate to: Associate Administrator for Hazardous Materials Safety (Attention: Exemptions, DHM-31), Research and Special Programs Administration, U.S. Department of Transportation, 400 7th Street, SW., Washington, DC 20590-0001. Alternatively, the application with any attached supporting documentation submitted in an appropriate format may be sent by facsimile (fax) to: (202) 366-3753 or (202) 366-3308 or by electronic mail (e-mail) to:** ***Exemptions@rspa.dot.gov*****;**
	This application is being submitted electronically on or about October 1, 2004.
§107.105(a)(2)	**State the name, street and mailing addresses, e-mail address optional, and telephone number of the applicant; if the applicant is not an individual, state the name, street and mailing addresses, e-mail address optional, and telephone number of an individual designated as an agent of the applicant for all purposes related to the application;**

<u>Applicant</u>:

Duratek Services, Inc.
140 Stoneridge Drive
Columbia, SC 29210
Attention: Mark Lewis
Regional Vice-President
(803) 256-0450

§107.105(a)(3) **If the applicant is not a resident of the United States, a designation of agent for service in accordance with §105.40 of this part; and**

Duratek Services, Inc. (Duratek) is a United States corporation.

§107.105(a)(4) **For a manufacturing exemption, a statement of the name and street address of each facility where manufacturing under the exemption will occur.**

Duratek will only use fabricators that have been placed on the Duratek Approved Vendor's List (AVL) per the requirements of Duratek's NRC approved QA program. Two such fabrication vendors are:

American Tank and Fabricating Company
12314 Elmwood Ave., N.W.
Cleveland, OH 44111

Quality Metal Products
803 Dogwood Dr.
New Ellenton, SC 29809

Other fabrication vendors that are the Duratek AVL may be used for manufacturing the components subject to this exemption.

§107.105(b) ***Confidential treatment.* To request confidential treatment for information contained in the application, the applicant shall comply with §105.30(a).**

Per 49 CFR 105.30, Duratek is asking for confidential treatment of the package design and the structural analysis document and that its content not be made available to the public. Duratek considers it their intellectual property, containing trade secrets whose disclosure would cause the company harm in a competitive technology based business environment.

§107.105(c) ***Description of exemption proposal.* The application must include the following information that is relevant to the exemption proposal:**

§107.105(c)(1) **A citation of the specific regulation from which the applicant seeks relief;**

49 CFR 173.403 – Definitions.
(2) LSA-II:
(ii) Other radioactive material in which the activity is distributed throughout and the average specific activity does not exceed 10^{-4} A_2/g for solids and

gases, and 10^{-5} A_2/g for liquids.

49 CFR 173.427 – Transport requirements for low specific activity (LSA) Class 7 (radioactive) materials and surface contaminated objects (SCO).
(a) ...
(b) Except as provided in paragraph (c) of this section, LSA material and SCO must be packaged as follows:
(1) In an industrial package (IP-1, IP-2, Of IP-3; §173.411), subject to the limitations of Table 6

49 CFR 173.465 – Type A packaging tests
(c) Free drop test. The specimen must drop onto the target so as to suffer maximum damage to the safety feature being tested,

(d) Stacking test. (1) The specimen must be subjected for a period of at least 24 hours to a compressive load equivalent to the following:

§107.105(c)(2) **Specification of the proposed mode or modes of transportation;**

The proposed modes of transportation for this exemption request are water, rail, or highway or a combination thereof.

§107.105(c)(3) **A detailed description of the proposed exemption (e.g., alternative packaging, test, procedure or activity) including, as appropriate, written descriptions, drawings, flow charts, plans and other supporting documents;**

The definition of Low Specific Activity (LSA) material in §173.403 does not address an item, which otherwise meets the LSA definition, but also has surface contamination. NUREG-1608 states that such an item is to be considered LSA and that the level of contamination may exceed SCO limits. An RPVH, described further in Attachment 2, has areas that are activated, typically the thermal sleeves and stainless steel cladding, and areas that are contaminated, e.g., the inner head surface, the interior of the CRDM housings, and, if attached, the interior of the CRDMs. Since the RPVH with attached CRDMs is a single piece, based on the definition of LSA and the guidance of NUREG-1608, the RPVH is appropriately classified as LSA. The Applicant requests DOT concurrence that an RPVH that otherwise meets the conditions of §173.427(a) is LSA material.

The Applicant is requesting an exemption for the transportation of (RPVHs) utilizing a packaging equivalent in safety to an IP-2 package in lieu of the packaging requirements cited in §107.105(c)(1) above. In demonstrating equivalent safety, the Applicant requests modification of the IP-2 testing requirements of §173.465(c) to subject the complete component to the free drop test requirements oriented in the transport (horizontal) position, rather than the orientation that will cause the maximum damage, without benefit of any securement devices or systems. Also, the Applicant requests elimination of the stacking test of §173.465(d) as stacking of packages during transport is administratively prohibited.

The RPVH will be packaged in the Duratek Head Package (DTKHP) as shown in Attachment 3. The outside surface of the RPVH flange will be decontaminated to remove loose surface contamination to less than the limits of §173.443 and a fixative will be applied. The opening at the mating surface on the bottom of the RPVH will be sealed with a large steel closure plate; additional plates may be attached to provide shielding to meet §173.441. The top of the RPVH will be sealed using a steel cap. The steel cap will be sized, i.e., varied in radius and length, to accommodate various diameter RPVHs with whole or partial reactor control devices, as necessary.

Transport of the DTKHP will be via exclusive use conveyance and in accordance with a shipment specific Transportation and Emergency Response Plan (TERP). The TERP, prepared by Duratek, will dictate specific shipment requirements and controls including shipment routing, travel times, travel speed and weather restrictions, loading and unloading activities, stacking prohibitions, training requirements, shipment specific permit and notification requirements, and any shipment specific security requirements above and beyond those specified in Duratek's Transportation Security Plan. A typical TERP is provided as Attachment 4.

§107.105(c)(4) **A specification of the proposed duration or schedule of events for which the exemption is sought;**

The applicant requests the exemption be effective for a period of 5 years in order to facilitate transportation of the RPVHs currently planned to be replaced throughout the nuclear industry.

§107.105(c)(5) **A statement outlining the applicant's basis for seeking relief from compliance with the specified regulations and, if the exemption is requested for a fixed period, a description of how compliance will be achieved at the end of that period;**

The transport of each RPVH is a one-time event. After the end of the effective period, transport of any remaining RPVHs will be accomplished using a different package.

§107.105(c)(6) **If the applicant seeks emergency processing specified in §107.117, a statement of supporting facts and reasons;**

The applicant is not seeking emergency processing of this exemption application.

§107.105(c)(7) **Identification and description of the hazardous materials planned for transportation under the exemption;**

The hazardous material planned for transport under the requested exemption is radioactive material. The stainless steel cladding and the thermal sleeves have undergone neutron activation. In addition, the internal surfaces of an RPVH are coated with radioactive materials deposited during circulation of reactor cooling water during the course of normal operation. Additionally, small amounts of contamination may be present on the external surfaces of the RPVH. The radiological condition of a typical RPVH is discussed in Attachment 2.

An RPVH is a massive hemispherical steel shell that is normally attached to the reactor pressure vessel in order to close the system and form the pressure boundary. The shell averages a minimum of several inches in thickness, has a machined mating surface around the bottom face, has a substantial bolting flange around the periphery of the mating surface and has multiple penetrations in the top for connection of reactor instrumentation and control devices. The reactor control devices may remain attached for transport.

The DTKHP consists of the RPVH, a steel bottom closure, i.e., a flat plate over the mating surface opening (bottom), and a shaped cap enclosing the reactor control devices, or the portions remaining, on top of the RPVH. The closures will be bolted to the RPVH flange with a gasket used in the joint between the closure and the RPVH. The outer surfaces of the RPVH flange not covered by the closures will be decontaminated to remove loose surface contamination to below the limits of 49 CFR 173.443 and a fixative will be applied

In order to ensure compliance with 49 CFR 173.441, the DTKHP incorporates the use of supplemental transport shields. The thickness of the shields is determined by the RPVH dose rate. The mating surface closure supplemental transport shield is bolted directly to the closure while the supplemental transport shield for the top closure is bolted around the closure.

A drawing of the DTKHP and the structural analysis is provided in Attachment 3.

§107.105(c)(8) **Description of each packaging, including specification or exemption number, as applicable, to be used in conjunction with the requested exemption;**

The packaging will be as described in response to 49 CFR 107.105(c)(3) above.

§107.105(c)(9) **For alternative packagings, documentation of quality assurance controls, package design, manufacture, performance test criteria, in-service performance and service-life limitations;**

All Duratek activities related to the design, testing, fabrication, and use of the DTKHP will be conducted in accordance with Duratek's NRC approved Quality Assurance Program. Implementation of the following Duratek programs and procedures will control activities performed under an Exemption issued as a result of this application:

- DRTK-QA-POL-001, Quality Assurance Program

- DTK-EN-002, Engineering Design Control

The fabricated components (closure plate and cap) covered by this exemption request are single use components and thus have no service-life limitations.

§107.105(c)(10) **When a Class 1 material is forbidden for transportation by aircraft except under an exemption (see Columns 9A and 9B in the table in 49 CFR 172.101), an applicant for an exemption to transport such Class 1 material on passenger-carrying or cargo-only aircraft with a maximum certificated takeoff weight of less than 12,500 pounds must certify that no person within the categories listed in 18 U.S.C. 842(i) will participate in the transportation of the Class 1 material.**

Not applicable. This exemption is not for transport by aircraft.

§107.105(d) ***Justification of exemption proposal.* The application must demonstrate that an exemption achieves a level of safety at least equal to that required by regulation, or if a required safety level does not exist, is consistent with the public interest. At a minimum, the application must provide the following:**

§107.105(d)(1) **Information describing all relevant shipping and incident experience of which the applicant is aware that relates to the application;**

Since 1992, Duratek has completed numerous large component transportation projects involving the safe transport of over 60 large components (reactor pressure vessels, reactor pressure vessel heads, steam generators, pressurizers, reactor coolant pumps and reactor coolant loop isolation valves). Each of these projects involved the transport of the large components via water, rail, or highway or a combination thereof. Duratek was involved in the engineering and operational activities for each of the projects and is intimately familiar with the issues important to safety.

Specific to the transport of RPVHs, Duratek recently completed transporting the RPVH from Connecticut Yankee and SONGS Unit 1. The SONGS shipment was performed under DOT exemption DOT-E 13025, which is similar to that being requested in this application. Every Duratek large component shipment has been completed safely and without incident.

§107.105(d)(2) **A statement identifying any increased risk to safety or property that may result if the exemption is granted, and a description of the measures to be taken to address that risk; and**

The applicant is not aware of any increased risk to safety or property as a result of this request. The information provided in this application demonstrates that the DTKHP will maintain its integrity during handling and transportation.

§107.105(d)(3) **Either–**

§107.105(d)(3)(i) **Substantiation, with applicable analyses, data or test results, that the proposed alternative will achieve a level of safety that is at least equal to that required by the regulation from which the exemption is sought; or**

The integrity of the packaging, as shown by the analysis of the one-foot drop in Attachment 3, along with the constraints of TERP (Attachment 4) provide assurance that the DTKHP can be transported without loss or dispersal of contents under normal handling and transport scenarios.

The TERP provided in Attachment 4 details the special steps and operational controls that will be performed to provide additional safety over a routine shipment of radioactive material. The DTKHP, transported per the transportation plan, will achieve a level of safety equal to or greater than an IP-2 package in normal transport.

§107.105(d)(3)(ii) **If the regulations do not establish a level of safety, an analysis that identifies each hazard, potential failure mode and the probability of its occurrence, and how the risks associated with each hazard and failure mode are controlled for the duration of an activity or life-cycle of a packaging.**

Not applicable. This application provides a basis for equivalent safety of the alternative packaging.

Attachment 2
Characteristics of a Used Reactor Pressure Vessel Head

EXEMPTION REQUEST FOR THE PACKAGING AND TRANSPORT OF REACTOR PRESSURE VESSEL HEADS

Characteristics of a Used Reactor Pressure Vessel Head

1. Introduction

The radionuclide content of a used reactor pressure vessel head (RPVH) is determined based on isotopic and dose rate information gathered after removal of the head during an outage. This data in combination with a dose-to-curie factor determined from modeling is used to calculate the activity contained in the RPVH. The analysis process and the results of the analysis for an example RPVH are presented below.

2. Physical Description

A Reactor Pressure Vessel Head (RPVH) is a large, hemispherical steel shell that attaches to the reactor pressure vessel to close the system and form the pressure boundary. The RPVH is approximately 5 inches in thickness. It has a machined mating surface around the bottom face, a substantial bolting flange around the periphery of the mating surface, and multiple penetrations in the top for connection of reactor instrumentation and control devices. The reactor control devices (CRDMs) may remain attached to the RPVH for transport. A typical RPVH with CRDMs attached is shown in Figure 2-1.

RPVH diameters vary to match the reactor vessels. The diameters, weights, and heights of typical RPVHs are shown in Table 2-1.

The inner surface of the RPVH is clad with stainless steel, a minimum of 5/32" thick for the smaller heads and thicker for the larger heads. Stainless steel CRDM housings are welded into the penetrations of the RPVH. Stainless steel thermal sleeves are located inside the CRDM housings and extend into the interior of the RPVH to assist in positioning the control rod drives. The thermal sleeves terminate in a stainless steel guide funnel. A few penetrations are used for instrumentation to monitor various reactor parameters. CRDMs are welded to the housings above the RPVH dome and extend approximately 20 feet above the RPVH. The number of CRDMs is specific to each reactor. The typical range of the number of penetrations for the various head sizes is shown in Table 2-1.

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Figure 2-1 – Typical Reactor Pressure Vessel Head With Reactor Control Devices

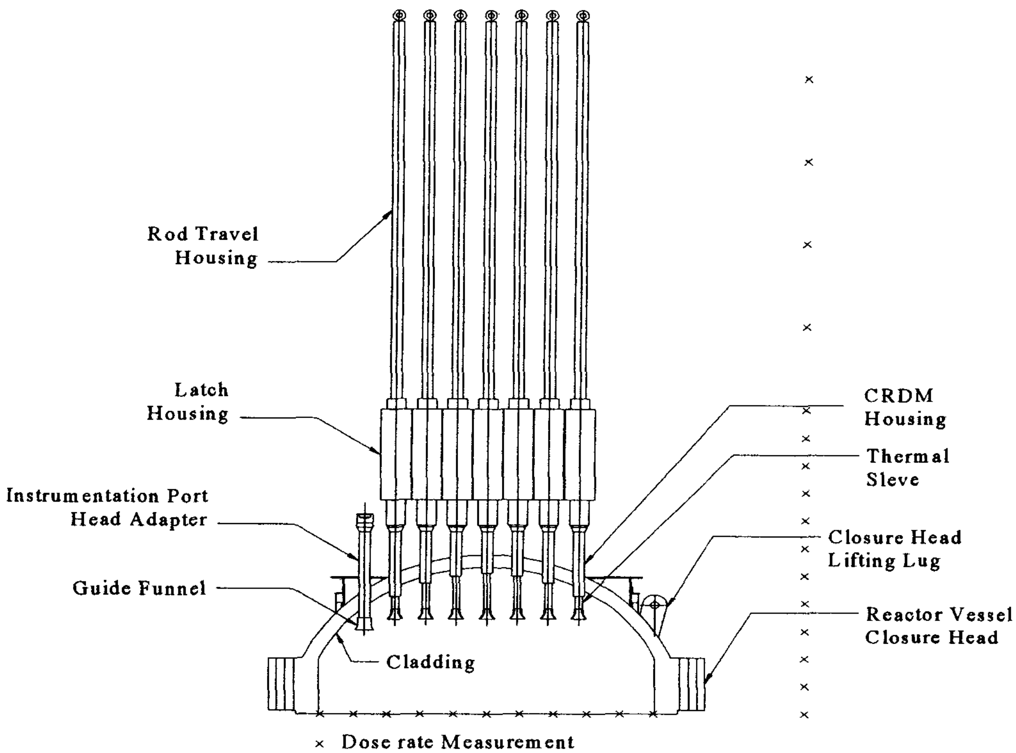


Table 2-1 – RPVH Characteristics

Head Type	Diameter (in)	Weight (lbs)	Height (in)	Penetrations
W-157	157	104,000	307	40-50
W-184	184	171,000	318	65-75
W-205	205	195,000	310	60-70

Radiological data are provided below for an example RPVH. The example RPVH is a W-157 type with 49 penetrations and 33 attached CRDMs. The example RPVH is evaluated for activity and compared to DOT transportation requirements.

3. Radioactive Source Characteristics

The inner surfaces of the RPVH and the CRDMs are coated with a layer of contamination deposited by reactor coolant. The stainless steel cladding, thermal sleeves, and guide funnels in the interior of the RPVH are activated by neutron flux from the core. To determine the isotopic distribution of the contamination layer, a contamination sample (smear), is taken from the interior of the RPVH and analyzed for radionuclide content. The results of the analysis are normalized to Co-60. The normalized distribution is applied to the Co-60 activity determined from the dose-to-curie conversion factors from the shielding models described in 5.1. Sample results and the normalized distribution for the example RPVH are provided in Table 3-1.

Table 3-1 Example Isotopic Distribution of the Contamination Layer

Isotope	Sample Results (µCi/sample)	Normalized Activity (µCi)
H-3	3.93E-05	2.50E-05
C-14	1.10E-01	7.10E-02
Cr-51	1.35E+00	1.90E-01
Mn-54	1.87E-01	1.20E-01
Fe-55	3.27E+00	2.10E+00
Co-57	2.07E-02	1.30E-02
Co-58	7.10E+00	4.60E+00
Fe-59	9.83E-02	6.40E-02
Co-60	1.54E+00	1.00E+00
Ni-63	1.74E+00	1.10E+00
Zn-65	1.40E-02	7.70E-03
Sr-90	8.10E-03	5.30E-03
Nb-94	5.08E-04	3.30E-04
Nb-95	6.77E-01	4.40E-01
Zr-95	1.11E-01	7.20E-02
Tc-99	7.59E-02	4.90E-02
Ru-103	5.13E-03	3.30E-03
Ag-108m	2.16E-02	1.40E-02
Ag-110m	5.33E-03	3.50E-03
Sb-124	2.63E-03	1.70E-03
Sb-125	2.50E-02	1.60E-02
Cs-134	2.18E-03	1.40E-03
Cs-137	4.50E-03	2.90E-03
Ba-140	1.45E-01	9.40E-02
Ce-141	8.56E-03	5.50E-03
Ce-144	3.93E-03	2.60E-03
Pu-238	1.03E-04	6.70E-05
Pu-239	3.27E-05	2.10E-05
Pu-241	9.83E-03	6.40E-03
Am-241	1.23E-04	2.20E-04
Cm-242	1.50E-05	9.70E-06
Cm-243	4.48E-05	2.90E-05

The dose rate from the RPVH, is directly proportional to the amount of activity in the RPVH, both activation and contamination. In order to quantify the activity in the RPVH interior, radiation surveys are taken across the inner diameter of the RPVH flange (see Figure 2-1). The value at the center of a typical RPVH ranges from 1 to 3 rem/hr. The center value is used in calculating the activity on the inner surfaces of the RPVH. The center value for the example RPVH is 2.5 rem/hr.

In order to quantify the activity in the CRDM array, radiation surveys are taken of the CRDM array on the exterior of the RPVH. Dose rates are measured at 1' intervals along the length of the array at a distance of 3' from the side of the array (see Figure 2-1). Dose measurements are made of the lower CRDM array (up to the top of the latch housing) and of the upper CRDM array (from the top of the latch housing to the upper end of the rod travel housing). The average values are used to calculate the activity in the CRDMs. The values for the example RPVH are 0.100 rem/hr for the lower array and 0.050 rem/hr for the upper array.

4. Characterization Assumptions

Several assumptions are made in the course of performing the characterization analyses. These assumptions are utilized to simplify the analysis, while maintaining accuracy in the overall result.

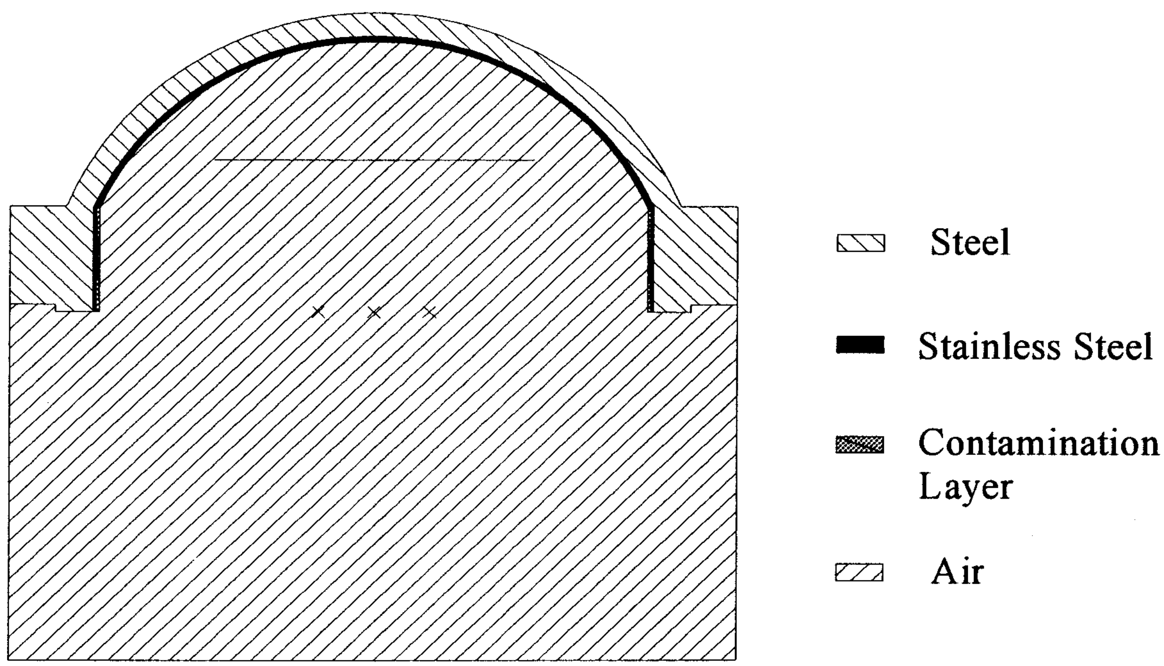
1. The activation of the cladding on the inner surface of the RPVH and the thermal sleeves and guide funnels produce a small fraction of the total activity.
2. The isotopic distribution determined from the contamination sample is assumed to apply to the activated materials in the RPVH as well as to the contamination on the RPVH inner surfaces.

   The relative ratios of activation products in the stainless steel cladding, thermal sleeves, and guide funnels are the same as in the contamination layer. The contamination layer also includes fission products and transuranics, which would not be found in activated stainless steel. Applying the isotopic distribution of the contamination layer, normalized to Co-60, to the Co-60 activity on the inner surface the RPVH will conservatively estimate the fission product and transuranic activity.
3. The activity per unit area on the inner surface of the RPVH is uniform.

5. Source Characterization

The RPVH is modeled with the SCALE [2] SAS4 monte carlo shielding code. A unit source term (1 curie of Co-60) is evenly distributed over the inner surface of the head (hemispherical and cylindrical sections), as shown in Figure 5-1. To account for the shielding provided by the thermal sleeves and guide funnels, a disk of stainless steel is inserted at the location of the funnels. The mass of the disk is conservatively set equal to the total mass of the thermal sleeves plus guide funnels (part of the thermal sleeves extend above the head hemisphere). The calculated dose rate at the center of the flange is the dose-to-curie factor.

Figure 5-1 SCALE Plot of the RPVH



The CRDM array above the RPVH is modeled using MicroShield [3] as two cylinders with the activity and mass in the CRDMs assumed to be uniformly distributed over the cylinder volume. Two cylinders are used since the lower portion of the CRDM array includes most of the mass and is surrounded by a steel cooling shroud. The steel shroud has a wall thickness of ~1/8". The first cylinder represents the lower portion of the array and has a height equal to the distance from the top of the RPVH to the top of the latch housings, i.e., ~80". The second cylinder represents the upper portion of the CRDM array and has a height of ~160". Both cylinders have a radius of ~50", the distance from the center of the RPVH to the outermost penetration.

5.1 Modeling Calculations

Analyses are performed with SCALE and Microshield using the models and source terms previously described. The SCALE calculation produces a dose rate, at the center of the plane of the flange. The measured average dose rate is then divided by the dose-to-curie factor to determine the number of curies of Co-60 in the RPVH.

The Microshield results give a dose-to-curie factor for the upper cylinder and lower cylinder, respectively. The measured average dose rate is then divided by the dose-to-curie factor to determine the number of curies of Co-60 in the CRDMs. The results of these calculations for the example RPVH and CRDMs are presented in Table 5-1.

Table 5-1 Co-60 Content

	Dose-to-Curie	**Survey Results (rem/hr)**	**Activity (Ci Co-60)**
RPVH	1.25	2.5	2.0
CRDMs (lower)	0.08	0.1	1.25
CRDMs (upper)	0.4	0.05	0.125
Total			3.375

5.2 Source Distribution

The activity calculated in Section 5.1 is utilized to determine the total activity in the RPVH and CRDMs.

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The normalized distribution, presented in Table 3.1, is used to determine the full isotopic distribution of activity in the RPVH and CRDMs, i.e., each isotope distribution factor is multiplied by the Co-60 content from Table 5-1. The resulting activity is shown in Table 5-2.

5.3 DOT Classification

The shipping classification can be performed for the RPVH and CRDMs based on the physical characteristics and the calculated radionuclide content in accordance with applicable guidance and regulatory requirements [4, 5, 6, and 7]. This information demonstrates that the shipment meets applicable requirements for transportation and disposal.

Table 5-2 shows the activity in the example RPVH, 33.7 Ci, and the A_2 evaluation. The A_2 value for the radionuclide mixture in the example RPVH is calculated to be 30.7. As shown, the example RPVH contains a greater-than-Type-A quantity of radioactive material, with a cumulative A_2 value of 1.10.

Table 5.2 Example A_2 Evaluation of RPVH and CRDMs

Isotope	Activity (Ci)	A_2 Value	Fraction A_2
H-3	8.438E-05	1.10E+03	7.67E-08
C-14	2.396E-01	8.10E+01	2.96E-03
Cr-51	6.413E-01	8.10E+02	7.92E-04
Mn-54	4.050E-01	2.70E+01	1.50E-02
Fe-55	7.088E+00	1.10E+03	6.44E-03
Co-57	4.388E-02	2.70E+02	1.63E-04
Co-58	1.553E+01	2.70E+01	5.75E-01
Fe-59	2.160E-01	2.40E+01	9.00E-03
Co-60	3.375E+00	1.10E+01	3.07E-01
Ni-63	3.713E+00	8.10E+02	4.58E-03
Zn-65	2.599E-02	5.40E+01	4.81E-04
Sr-90	1.789E-02	8.10E+00	2.21E-03
Nb-94	1.114E-03	1.90E+01	5.86E-05
Nb-95	1.485E+00	2.70E+01	5.50E-02
Zr-95	2.430E-01	2.20E+01	1.10E-02
Tc-99	1.654E-01	2.40E+01	6.89E-03
Ru-103	1.114E-02	5.40E+01	2.06E-04
Ag-108m	4.725E-02	1.90E+01	2.49E-03
Ag-110m	1.181E-02	1.10E+01	1.07E-03
Sb-124	5.738E-03	1.60E+01	3.59E-04
Sb-125	5.400E-02	2.70E+01	2.00E-03
Cs-134	4.725E-03	1.90E+01	2.49E-04
Cs-137	9.788E-03	1.60E+01	6.12E-04

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Isotope	Activity (Ci)	A_2 Value	Fraction A_2
Ba-140	3.173E-01	8.10E+00	3.92E-02
Ce-141	1.856E-02	1.60E+01	1.16E-03
Ce-144	8.775E-03	5.40E+00	1.63E-03
Pu-238	2.261E-04	2.70E-02	8.38E-03
Pu-239	7.088E-05	2.70E-02	2.63E-03
Pu-241	2.160E-02	1.60E+00	1.35E-02
Am-241	7.425E-04	2.70E-02	2.75E-02
Cm-242	3.274E-05	2.70E-01	1.21E-04
Cm-243	9.788E-05	2.70E-02	3.63E-03
TOTAL	3.370E+01		1.10E+00

The interior of the RPVH and the CRDMs are contaminated by contact with the reactor coolant. The Co-60 activity in the example CRDM array is 1.375 Ci. When the distribution of Table 3.1 is applied, the activity of the CRDM array is 1.37E+01 Ci of beta, gamma and low toxicity alpha emitters and 0.01 Ci of alpha emitters. To determine the contamination level of the CRDMs, the activity is conservatively assumed to be distributed over the interior of just the 33 CRDMs on the example RPVH. The estimated interior surface area of a CRDM including the housing is 1.55E+04 cm^2. The resulting average contamination level of the CRDMs is 27 uCi/cm^2 of beta, gamma and low toxicity alpha emitters and 0.02 uCi/cm^2 of alpha emitters. The stainless steel cladding, thermal sleeves, and guide funnels on the interior of the RPVH are activated with the activity distributed throughout the stainless steel components. If the entire activity of the RPVH, 33.7 Ci, is conservatively assumed to be distributed throughout just the cladding, which has a mass of 5.1E+05g, the specific activity is 6.6E-05 Ci/g. Evaluating the RPVH cladding against the LSA-II criteria [6], the RPVH cladding is 2% of the LSA-II limit of 1.0E-04 A_2/g. Per NUREG-1608 [7], "A contaminated, activated object may be categorized as LSA material insofar as it otherwise meets the requirements of the applicable LSA definition". The example RPVH, when packaged in the Duratek Head Packaging (DTKHP) (described in Attachment 3), meets the requirements of 49 CFR 173.427. Thus, the appropriate DOT subtype for the RPVH with attached CRDMs is LSA-II. If the CRDMs were separated from the RPVH, the RPVH packaged with the DTKHP would still qualify as LSA-II.

5.4 Bounding Radiological Values

Duratek has examined data from seven RPVH replacement projects. The activity in the removed RPVHs range from 3.8 to 60 Ci. The radionuclide distributions for these seven RPVHs have an A_2 value for the radionuclide mixture ranging from 7.08 to 39.5. If the highest activity RPVH has a distribution with the lowest A_2 value, the number of A_2 values for the RPVH is ~8.5. To ensure a wide range of

RPVHs can be accommodated, we request an A_2 limit for our alternate package of 20 times the A_2 value.

5.5 Project Specific Characterization

Each RPVH will be characterized, as described above for the example RPVH, and the characterization documented per the requirements of Duratek procedure DTK-EN-009 [1]. Only RPVHs that meet the 20 A_2 constraint and the transport requirements of 49 CFR 427(a)(1) through (a)(6) will be transported using the DTKHP. The characterization report will be provided to the customer (shipper) and a copy retained in the project file.

6. References

[1] Duratek Procedure DTK-EN-009, "Procedure for Waste Characterization of Irradiated Components or Items."

[2] SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluations, U.S. Nuclear Regulatory Commission, NUREG/CR-0200, May 2000

[3] Grove Engineering, Inc. "Microshield Computer Code," Version 6.00.

[4] NRC, "Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification," (May 1983).

[5] Code of Federal Regulations, 10CFR Part 61 and 10CFR Part 71.

[6] Code of Federal Regulations, 49CFR Parts 100 to 177.

[7] NUREG-1608, "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects," U.S. Nuclear Regulatory Commission and U.S. Department of Transportation, July 1998

Attachment 3
Structural Analysis of Duratek Head Package
Documents included:
Calculation ST-474 (Non-Proprietary)
Calculation ST-475 (Proprietary)
Calculation ST-476 (Proprietary)
Drawings C-068-952C17-001 through –006 (Non-Proprietary)
Drawings C-068-952C17-010 through –060 (Proprietary)

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DESIGN DOCUMENT COVER SHEET

DOCUMENT ID NUMBER: ST-474 REVISION NUMBER: 0

PROJECT NUMBER: 952C17

SECURITY STATUS: PROPRIETARY: ____ NON-PROPRIETARY: X

RETENTION PERIOD: Life of the Project + 1 year

TITLE: Structural Evaluation of the Duratek RPV Head Packages

PREPARED BY: [signature] DATE: 8/23/2004

TITLE: Chief Engineer

REVIEWED BY: [signature] DATE: 8/25/04

TITLE: Principal Engineer

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DESIGN DOCUMENT REVIEW CHECKLIST

Document ID No.: ST-474 Revision No.: 0

Date: 8/23/2004

	ITEM	YES	N/A *
1.	The purpose or objective is clear and consistent with the analysis.	✓	
2.	Design Inputs such as design bases, regulatory requirements, codes, and standards are identified and documented.	✓	
3.	Effect of design package on compliance with the Safety Analysis Report or Certificate of Compliance identified and documented.		✓
4.	References are complete and accurate.	✓	
5.	Latest version of the drawings is used, and the revision numbers are correct on the list of drawings.	✓	
6.	Assumptions are reasonable, and the list of assumptions is complete and appropriate.	✓	
7.	Assumptions that must be verified as the design proceeds have appropriately identified.	✓	
8.	Analysis methodology is appropriate, and correct analysis method used.	✓	
9.	Correct values used from drawings?	✓	
10.	Answers and units correct?	✓	
11.	Summary of results matches calculations?	✓	
12.	Material properties properly taken from credible references?	✓	
13.	Figures match design drawings?	✓	
14.	Computer input complete and properly identified?	✓	
15.	Conclusions are consistent with the analysis results.	✓	
16.	Documentation of all hand calculations attached?	✓	
17.	Meeting minutes of the Design Review?		✓

* Not Applicable, Explain

3. There are no SAR or C of C for these packages. The calculations form the basis for DOT exemption request.
17. The minutes of the final design review meeting are documented in E&L-029-04.

Independent Reviewer [signature]

PROPERTY OF DURATEK INC. AND ITS SUBSIDIARIES

DESIGN DOCUMENT REVIEW METHOD CHECKLIST

Document ID No.: ST-474 Revision No.: 0

Date: 8/23/2004

ITEM		
1.	Alternate or simplified computational method.	
2.	Comparison of results to other calculations of a similar nature.	
3.	Numerical repetition of the calculations.	✓
4.	Comparison of calculations with experimental results.	
5.	Other (specify)	
6.	Comments:	

Independent Reviewer [signature]

1.0 OBJECTIVE

Structural evaluation of the standard RPV Head packages to demonstrate that they will meet the applicable regulatory requirements with exceptions, if any, noted in this document.

2.0 INTRODUCTION

Duratek has developed a standard design for packaging and transporting reactor pressure vessel heads (RPVH) from the commercial nuclear power plants to disposal or decontamination sites. The package design covers an array of reactor pressure vessel heads ranging from 157-inch diameter vessels, manufactured by Westinghouse, to 205-inch diameter vessels, manufactured by Combustion Engineering. Using the standard Duratek Head Package (DTKHP) design, the RPV heads may be packaged in two different configurations; either with the control rod drive mechanisms (CRDMs) attached (Figure 1) or removed (Figure 2). The DTKHP (Figure 3) consists of a canister that is attached to the RPV head flange through the existing boltholes to close the top of the RPVH assembly and a circular endplate to close the cavity of the RPV head. Together they provide a robust package that can be transported by highway, railroad, or barge to its final destination. Reference 1 and 2 provide the assembly information of the RPVH packages. The details of the various components of these packages are provided in the proprietary drawings of References 3 through 8.

The decommissioned RPV head and the CRDM assemblies are activated and contaminated with radioactive materials. The off-site transportation of these assemblies in the United States is controlled by the U.S.D.O.T. regulations 49 CFR Part 173 (Reference 9). Depending on the level of activity, the RPV head package has to be qualified as a strong-tight container, or as a Type 2 Industrial Package (IP-2). The Duratek standard design is qualified to satisfy the more stringent requirements of the IP-2 packaging as applicable to large component shipments.

Two different size DTKHPs have been analyzed. The “large” size refers to the 205-inch diameter RPVH packages. The “small” size refers to 157-inch diameter RPVH packages. The two basic sizes were further evaluated in two configurations. The “long” configuration refers to the package used for the RPVH with the CRDM assembly attached, and “short” configuration refers to the package used for the RPVH with the CRDM assembly removed. The package design is scalable for both the diameter and the length of the canister. The results for the “long” and “short” sizes bound intermediate diameters. The results for the “long” and “short” configuration bound intermediate lengths.

This document presents the evaluation of the DTKHP for the loads encountered during the normal handling and transportation of the packages, and the free drop test requirements of § 173.465(c) of Reference 9. Since the IP-2 packages may be secured in a variety of ways during the handling and transportation, representative loading scenarios, which are reasonably conservative, are analyzed for each loading condition.

The "long" configuration packages will be transported in a horizontal orientation (RPVH axis horizontal) by road or by barge. References 10 and 11 give conceptual schemes for the road transportation that may be employed for these packages. The "short" configuration packages will be transported in a vertical orientation (RPVH axis vertical) by road, barge or railroad. Reference 12 gives a conceptual scheme for the road transportation that may be employed for these packages. Because of the limitation on width of the load transported on the railroad, only short configuration DTKHP can be transported by the railroad. The packages on the railroad can be shipped with their axis horizontal and pointing in the lateral direction. Reference 13 shows a conceptual scheme of the DTKHP shipment on the railroad. Supplemental shielding may be used in conjunction with any of these tie down support systems. The tie down support system, used for transporting these packages, must be analyzed on a case-by-case basis to confirm that they meet the allowable values established in this document.

The IP-2 packages, per § 173.411 need to meet the free drop test requirements of §173.465(c). This states that the package must withstand a free drop onto an unyielding surface in the most damaging orientation from a height based on their mass. For the packages weighing more than 33,000 lbs, this height is established at 1-foot. The acceptance criteria for this drop test are established in 49 CFR 173.411(b)(2)(i) and (ii), which require that the packages must prevent the loss or dispersal of radioactive contents and significant increase in radiation level.

Analyses have been performed using an explicit dynamic finite element program – ANSYS/LS-DYNA (Reference 14), to show that the RPVH packages, without the help of any securement system, will maintain their integrity during a 1-foot free drop onto an unyielding surface. Since due to their large size, and controlled handling process, the RPVH packages will maintain their horizontal orientation throughout the entire transportation period, the drop orientation for the analyses is assumed to be that of the shipping orientation. It has been shown that all size RPVH packages in all configurations will maintain their integrity with no loss of shielding, thereby satisfying the regulatory acceptance criteria of 49 CFR 173.411(b)(2)(i) and (ii).

3.0 REFERENCES

(1) Duratek Drawing No. C-068-952C17-001, Rev.0, "Duratek Standard RPV Head (Long) - Packages" (Non-Proprietary).

(2) Duratek Drawing No. C-068-952C17-002, Rev.0, "Duratek Standard RPV Head (Short) - Packages" (Non-Proprietary).

(3) Duratek Drawing No. C-068-952C17-010, Rev.0, "RPV Head Packages - Canister Details" (Proprietary).

(4) Duratek Drawing No. C-068-952C17-020, Rev.0, "RPV Head Packages – Closure Endplate Details" (Proprietary).

(5) Duratek Drawing No. C-068-952C17-030, Rev.0, "RPV Head Packages – Supplemental Shielding (Closure Endplate)" (Proprietary).

(6) Duratek Drawing No. C-068-952C17-040, Rev.0, "RPV Head Packages (Short) – Supplemental Shielding (Canister End)" (Proprietary).

(7) Duratek Drawing No. C-068-952C17-050, Rev.0, "RPV Head Packages – Closure Gasket Details" (Proprietary).

(8) Duratek Drawing No. C-068-952C17-060, Rev.0, "RPV Head Packages – Closure Hardware Details" (Proprietary).

(9) Code of Federal Regulations, Title 49, Part 173.

(10) Duratek Drawing No. C-068-952C17-003, Rev.0, "RPV Head Packages (Large-Long) - Road Transportation General Arrangement" (Non-Proprietary).

(11) Duratek Drawing No. C-068-952C17-004, Rev.0, "RPV Head Packages (Small-Long) - Road Transportation General Arrangement" (Non-Proprietary).

(12) Duratek Drawing No. C-068-952C17-005, Rev.0, "RPV Head Packages (Short) - Road Transportation General Arrangement" (Non-Proprietary).

(13) Duratek Drawing No. C-068-952C17-006, Rev.0, "RPV Head Packages (Short) - Rail Transportation General Arrangement" (Non-Proprietary).

(14) ANSYS Release 7.1 (including the LS-DYNA module), Ansys Inc., Canonsburg, PA.

(15) AISC, *Steel Construction Manual*, Ninth Edition.

(16) Code of Federal Regulations 49 CFR 393, Federal Motor Carrier Safety Regulations.

(17) ANSI N14.24-1985, American National Standard for Highway Route Controlled Quantities of Radioactive Materials - Domestic Barge Transport.

(18) AAR Manual, Rev.9, Section No.1, General Rules, 1993.

(19) ANSI N 14.6-1993, Special Lifting Devices for Shipping Containers Weighing 10,000 lbs. (4,500 kg) or More, American National Standard Institute, New York.

(20) Duratek Document ST-475, Structural Analyses of the DTKHP for the Large Size RPV Heads (Proprietary).

(21) Duratek Document ST-476, Structural Analyses of the DTKHP for the Small Size RPV Heads (Proprietary).

4.0 MATERIAL PROPERTIES

Fabricated Components

Specification: ASTM A-516 Gr. 70

Minimum Yield Strength, S_y = 38,000 psi

Minimum Ultimate Strength, S_u = 70,000 psi

Welds

Rod Specification: E-70xx Electrodes

Minimum Ultimate Strength, S_u = 70,000 psi

Studs & Bolts

Specification: ASTM A-193 Gr. B7

Minimum Yield Strength, S_y = 105,000 psi

Minimum Ultimate Strength, S_u = 125,000 psi

Stud Size: 2 " – 4½ UNC

Bolt Size: 1½" – 6 UNC

5.0 ALLOWABLE STRESSES

Transportation Conditions

Stresses in the fabricated components of the DTKHP are based on the AISC (Reference 15) allowable values.

Steel

Allowable bending stress = 0.66 S_y = 25,080 psi

Allowable shear stress = 0.4 S_y = 15,200 psi

Welds

Full penetration welds are employed in the fabrication of the canisters. Therefore, the base metal allowable is also applicable to the welds. No separate evaluation of the welds has, therefore, been performed.

Bolts & Studs

The bolts and studs used in the DTKHPs are specified to be A-193 Gr. B7. The allowable tensile and shear loads in these components are conservatively taken to be the same as A-325 bolts, which have lower specified yield and tensile stresses.

Allowable Tensile Stress = 44,000 psi (Reference 15)

Allowable Shear Stress = 21,000 psi (Reference 15)

For 2"- 4½ UNC studs,

Allowable axial load, P $= (\pi/4)\times 2.0^2\times 44{,}000 = 138{,}230$ lb

Allowable shear load, V $= (\pi/4)\times 2.0^2\times 21{,}000 = 65{,}973$ lb

For 1½" - 6UNC bolts,

Allowable axial load, P $= (\pi/4)\times 1.5^2\times 44{,}000 = 77{,}754$ lb

Allowable shear load, V $= (\pi/4)\times 1.5^2\times 21{,}000 = 37{,}110$ lb

Free Drop Test

The DTKHPs must maintain their integrity during the one-foot free drop test. Minor deformation in the structure is permissible. The acceptance criteria for the stresses are set in such a way that the rupture of the material is prevented. Since the free drop analyses are performed using nonlinear finite element analyses techniques, where the accumulated plastic strains can be calculated, the failure criteria is established based on the material ductility. Duratek proprietary documents References 20 and 21 provide the details of the allowable values, which are summarized below for reference purpose.

Fabricated Components

Maximum Accumulated Plastic Strain = 17%

Bolts & Studs

Bolt Maximum Tensile Load = 175,000 lb

Bolt Maximum Shear Load = 105,000 lb

Stud Maximum Tensile Load = 310,000 lb

Stud Maximum Shear Load = 235,000 lb

Lifting and Handling

ANSI N-14.6 (Reference 19) requires that lifting attachments provide a factor of safety of three on yield strength and five on the ultimate strength of the material of construction.

Fabricated components

Allowable bending stress = Smaller of (1/3 S_y & 1/5 S_u) = 12,667 psi

Allowable shear stress, $= 0.6 \times 12,667 = 7,600$ psi

Welds

The allowable stresses in the welds should conservatively meet the values established for the base metal.

6.0 ESTIMATED MASS & C.G.

Based on the maximum mass of 195,000 lbs (large) and 104,250 lbs (small) RPV heads, the masses of different size DTKHPs in different configurations are summarized in Table 1. The location of the C.G. for all these configurations is estimated from the finite element model used in the analyses of these packages. The C.G. locations provided in Table 1 can be used in evaluating the support reactions during shipping and handling process.

7.0 LOADING & LOAD CASES

For the highway transportation of the DTKHPs, under the Federal Motor Carrier Safety Regulations, 49 CFR 393.102(a) and 49 CFR 393.102(d) (Reference 16), the packages are subjected to the following loading:

- 0.8g in rearward direction,
- 0.5g in forward direction,
- 0.5g in lateral direction, and,
- 0.2g in vertical direction.

For the barge transportation, based on the requirements of ANSI N-14.24 (Reference 17), the packages are subjected to the following accelerations:

- 1.5g in longitudinal direction,
- 1.6g in lateral direction,
- 3.0g in vertical upwards, and,
- 1.0g in vertical downward direction.

For the railroad transportation, based on the AAR general rules (Reference 18), the packages are subjected to the following accelerations:

- 3g in longitudinal direction,
- 2g in lateral direction, and,
- 2g in vertical direction.

To envelop the loading experienced by the DTKHPs during any mode of transportation, a maximum acceleration of 3g is assumed to occur in all directions. Two load cases are analyzed to incorporate this loading (Load Cases 1 & 2)

As described in Section 2.0 of this document, the RPV head packages may be supported in a variety of ways during the shipping and handling processes. The support system must be analyzed on a case-by-case basis to confirm that they do not impart stresses in the DTKHPs larger than those listed under the allowable stresses. To demonstrate that the DTKHPs are capable of supporting typical shipment and handling loadings, two load cases are analyzed in this document (Load Cases 3 & 4). In both load cases one support is located at the RPV head. The other support is located at two extreme locations.

The load cases analyzed in this document encompass the loading described above.

Load Case 1 - 3g lateral/vertical loading

Load Case 2 - 3g axial loading

Load Case 3 - 3g vertical loading with one support located at approximately the same distance as the distance between the combined C.G. and the other support located at the RPV head (Figures 4 & 5 support location 1).

Load Case 4 - 3g vertical loading with one support located at approximately 3 time the distance as the distance between the combined C.G. and other the support located at the RPV head (Figures 4 & 5 support location 2).

8.0 EVALUATION OF THE PACKAGE

Handling & Transportation

The analyses of the DTKHP is performed using the finite element analysis code ANSYS (Reference 14). The large and small size packages in the long configuration have been analyzed. The short configuration packages, used for the shipment of the RPV heads without the CRDM attached, have identical geometry as the corresponding long configuration packages except that they have much shorter length of the canister. Therefore, the stresses in short packages are conservatively enveloped with those of the corresponding long configuration packages and have not been exclusively analyzed. The finite element models of the packages include the canister, the RPV head, and the endplates including the supplemental shielding. The canister, endplate and the supplemental shielding plates are modeled using 3-dimensional shell elements (ANSYS

SHELL181) and the RPV head is modeled using 3-dimensional solid elements (ANSYS SOLID185). The CRDMs are modeled with a shell that has the length approximately equal to the length of the longest CRDM and an equivalent thickness that results in total mass of the CRDMs. The interfaces between the canister flange and the RPV head flange, and between the RPV head seal surface and the endplate are made with 3-dimensional target and contact elements, ANSYS TARGET170 and ANSYS CONTACT174, respectively. The bolted connection between the supplemental shielding and the endplate is modeled by coupling the nodes at the bolt locations in the radial, tangential and the axial translational directions. Figure 6 shows a typical finite element model.

The finite element models are analyzed for load cases 1 and 2 assuming that the RPV head is fixed and the canister and the endplate are subjected to the 3g inertia loadings in the vertical/lateral and axial directions, respectively, without any other support. For load cases 3 and 4 the RPV head is supported at the mid-plane of the flange on the lower 60° segment length and over a width of approximately 12" over the canister shell at the two support locations described in Section 7.0 of this document.

The summary of the analyses results for the large and small size packages are presented in Tables 2 and 3, respectively. The stress intensities reported in tables are directly obtained from the finite elements model analyses results. The stud tensile and shear loads are calculated from the interface reaction. The total shear load is distributed over the number of studs. The tensile loads in the studs are calculated by assuming a linear load distribution that results in a moment equal to the interface moment obtained from the finite element analyses. The tensile and shear load ratio with their corresponding allowable values are combined together using the following relation to obtain the interaction coefficient.

$$I.C. = \left[\frac{P}{P_{allow}}\right]^2 + \left[\frac{V}{V_{allow}}\right]^2 < 1.0$$

Where, P = Tensile load, lb

P_{allow} = Allowable tensile load, lb

V = Shear load, lb

V_{allow} = Allowable shear load, lb

The bolt loads are obtained from the finite element analyses results. The tensile and shear loads in the bolts are combined the same way as described above for the stud loads.

The tables also give the moment at the interface between the canister and the RPV head flange. These moments are provided here to facilitate the DTKHP user in designing the support system. If the moment arising at the interface from a particular support system design is smaller than those indicated in these tables, the support system should be considered to be within the bounds of the analyses performed in this document.

Figures 7 and 8 show the plot of stress intensities in the large DTKHP for load cases 1 and 2, respectively. Figures 9 and 10 show those for small DTKHP. The stress intensity plots for load cases 3 and 4 are shown in Figures 11 and 12, for large DTKHP, and, in Figures 13 and 14 for the small DTKHP.

The summary printout from the ANSYS finite element analyses for load cases 1 through 4 is included in Appendix 1 of this document.

Free Drop Test

To show the compliance with the free drop test requirement of §173.465(c) (Reference 9) finite element analyses of various size DTKHP in both long and short configurations have been performed using the LS-DYNA module of the ANSYS program (Reference 14). This program specializes in solving short duration dynamic problems using explicit scheme for formulating the problems. The details of these analyses are provided in Duratek proprietary documents References 20 and 21.

For satisfying the requirements of §173.465(c) (Reference 9) for IP-2 packages, the drop orientation must be such that it should cause maximum damage to the package. For a large package like DTKHP this orientation may be such that it is never encountered during its controlled shipment. Therefore, an exemption from the initial drop orientation that causes maximum damage to the package needs to be taken. Instead an initial drop orientation that is most likely to occur during the off-site transportation of the package is employed in evaluating the free drop test requirement of DTKHPs. Based on the shipment orientation, the initial drop orientation used in the analyses of the Long packages is shown in Figure 15. Figure 16 shows the initial drop orientation of the short packages, employed in the free drop analyses.

To perform the free drop analyses, finite element models of DTKHPs using ANSYS/LS-DYNA (Reference 14) software are created. The models include all the components of the DTKHP – the canister, the RPV head, the closure plate, the supplemental shielding, and the attachment studs. They are constructed using a combination of 4-node explicit shell elements (SHELL 163) and 8-node explicit 3-D structural solid (SOLID 164) elements. The rigid target surface is also constructed with the SOLID 164 elements. The details of the model are provided in References 20 and 21.

Recognizing that for long packages, the initial drop may not cause the maximum damage, the finite element models are run for long enough duration so that the subsequent impacts (slap-down) are also included in the analyses. For example, the long packages go through three impacts as shown in Figure 15.

From the finite element model analyses, the results are animated and the maximum stress intensities and the maximum accumulated plastic strains are obtained for all size DTKHPs in all configurations. Results are presented in Figures 17 through 28 and have been summarized in Table 4.

Lifting

The DTKHPs have flexibility in design so that the lifting components such as a pair of trunnions or lugs may be welded to the canister for lifting and handling purpose. These components must meet the ANSI N-14.6 (Reference 19) loading criteria. They must, also, be located outside the free drop strike zone, which is conservatively specified to be the area within 30° from the vertical plane on both sides of the strike-plane. For lifting and handling purposes holes and notches may be made in the can flange and the endplate to expose unused RPV head bolting holes, provided these holes and notches are located outside of the sealing surface and are well outside the free drop strike-zone. The lifting and handling components must be analyzed on case-by-case basis to confirm that they meet the allowable values established in this document. A typical trunnion that may be used for lifting the empty small size container is analyzed below.

The trunnion geometry is as follows:

Trunnion outside diameter = 6.625 in.
Trunnion wall thickness = 0.432 in.
Trunnion length = 4.25 in.

Load on each trunnion,

Shear Load = 34,000/2 = 17,000 lb

Bending Moment = 17,000×4.25/2 = 36,125 in-lb

The trunnion is made of ASTM A-53 steel (S_y = 25,000 psi and S_u = 45,000 psi)

Allowable stresses per ANSI N14.6 (Reference 19),

Allowable bending stress = Smaller of (1/3 S_y & 1/5 S_u) = 8,333 psi

Allowable shear stress, = 0.6 × 8,333 = 5,000 psi

$S_{trunnion} = \pi \times 6.625/[32\times(6.625^4 - 5.761^4)] = 12.224\ in^3$

$S_{weld} = \pi \times 6.625^2 \times 0.432 / 4 = 14.892\ in^3$

$A_{weld} = \pi \times 6.625 \times 0.432 = 8.991\ in^2$

Trunnion bending stress:

$\sigma_b = M / S_{trunnion} = 36,125 / 12.224 = 2,955$ psi

Trunnion maximum shear stress:

$$\tau = V / A$$

$$= 17{,}000 / (\pi \times (6.625^2 - 5.761)^2 / 4) = 2{,}023 \text{ psi} < 5{,}000 \text{ psi} \qquad \text{O.K.}$$

Combined stress in trunnion:

$$\sigma_{tot} = (2{,}955^{\,2} + 2{,}023^{\,2})^{1/2} = 3{,}581 \text{ psi} < 8{,}333 \text{ psi} \qquad \text{O.K.}$$

Trunnion weld bending shear:

$$\tau_b = M / S_{weld} = 36{,}125 / 14.892 = 2{,}426 \text{ psi}$$

Trunnion Weld Shear:

$$\tau = V / A_{weld} = 17{,}000 / 8.991 = 1{,}891 \text{ psi}$$

Combined stress in trunnion weld:

$$\tau_{tot} = 2{,}426 + 1{,}891 = 4{,}317 \text{ psi} < 8{,}333 \text{ psi} \qquad \text{O.K.}$$

It should be noted that any structural component employed for lifting and handling of the DTKHP components – canister, endplate, supplemental shielding, need to be rendered inoperable before the shipment so that them may not be used for lifting the entire package.

9.0 CONCLUSIONS

The calculations presented in this document demonstrate that the DTKHP design satisfies the requirements of the IP-2 packages for the normal transportation and handling loading with sufficient margin of safety (see Tables 2 and 3). An initial drop orientation that is most likely to occur during the off-site transportation of the package is employed in evaluating the free drop test of the DTKHPs. With this orientation, the DTKHPs in all configurations are shown to undergo some permanent deformation during the free drop test but in each case, there is no rupture or detachment of any component of the package. Therefore, it is concluded that during the free drop test, all size RPVH packages, in all configurations, will maintain their integrity with no loss of shielding. Thus, the regulatory acceptance criteria of 49 CFR 173.411(b)(2)(i) and (ii) are satisfied.

Table 1
Summary of Weight & C.G. of RPV Head Packages in Various Configurations

Large Size Package			
Configuration	Item	Calculated Value[1]	Design Value
Long	Canister Weight, lb	52,028	53,000
	C.G. from the Canister Flange Face, inch	124.37	124.4
	Package Weight, lb	290,880	305,000[2]
	C.G. from the RPVH Flange Face, inch	81.63	81.5
Short	Canister Weight, lb	37,887	39,000
	C.G. from the Canister Flange Face, inch	49.65	49.5
	Package Weight, lb	215,425	240,000[2]
	C.G. from the RPVH Flange Face, inch	36.56	36.5
Small Size Package			
Configuration	Item	Calculated Value[3]	Design Value
Long	Canister Weight, lb	33,630	34,000
	C.G. from the Canister Flange Face, inch	126.58	126.5
	Package Weight, lb	159,852	160,000[2]
	C.G. from the RPVH Flange Face, inch	72.83	73
Short	Canister Weight, lb	20,356	21,000
	C.G. from the Canister Flange Face, inch	41.94	42
	Package Weight, lb	117,903	125,000[2]
	C.G. from the RPVH Flange Face, inch	26.6	26.5

Notes:

(1) From Reference 20.

(2) Includes endplate and extra shield plates.

(3) From Reference 21.

Table 2
Summary of Finite Element Model Analyses of the RPV Head Large Packages
Handling & Transportation Loading Conditions

Quantity		Load Case 1	Load Case 2	Load Case 3	Load Case 4
Canister	Maximum Stress, psi	1,761	5,608	15,597	6,893
	Allowable Stress, psi	25,080	25,080	25,080	25,080
	Factor of Safety	14.2	4.47	1.61	3.64
Endplate	Maximum Stress, psi	240	958	1,036	1,433
	Allowable Stress, psi	25,080	25,080	25,080	25,080
	Factor of Safety	104.5	26.2	24.2	17.5
Studs	Interaction Coefficient	0.02	0.002	0.02	0.02
	Allowable Interaction Coefficient	1.0	1.0	1.0	1.0
	Factor of Safety	50	500	50	50
Bolts	Interaction Coefficient	0.011	0.002	0.011	0.011
	Allowable Interaction Coefficient	1.0	1.0	1.0	1.0
	Factor of Safety	91	500	91	91
Interface	Moment, in-lb	1.965×10^7	0	1.966×10^7	1.965×10^7
	Allowable, in-lb	7.78×10^7	7.78×10^7	7.78×10^7	7.78×10^7
	Factor of Safety	3.96	n/a	3.96	3.96

NOTES:

(1) Load Case 1 – package subjected to 3×Inertia in the lateral/vertical direction.

(2) Load Case 2 – package subjected to 3×Inertia in the axial direction.

(3) Load Case 3 – package supported on the RPV head and Support 1 (see Figure 4).

(4) Load Case 4 – package supported on the RPV head and Support 2 (see Figure 4).

Table 3
Summary of Finite Element Model Analyses of the RPV Head Small Packages
Handling & Transportation Loading Conditions

Quantity		Load Case 1	Load Case 2	Load Case 3	Load Case 4
Canister	Maximum Stress, psi	2,398	3,132	9,751	4,129
	Allowable Stress, psi	25,080	25,080	25,080	25,080
	Factor of Safety	10.5	8	2.6	6.1
Endplate	Maximum Stress, psi	281	561	481	1,132
	Allowable Stress, psi	25,080	25,080	25,080	25,080
	Factor of Safety	89	44.7	52	22.2
Studs	Interaction Coefficient	0.0155	0.001	0.022	0.017
	Allowable Interaction Coefficient	1.0	1.0	1.0	1.0
	Factor of Safety	64.5	1000	45.5	58.8
Bolts	Interaction Coefficient	0.0033	0.001	0.003	0.003
	Allowable Interaction Coefficient	1.0	1.0	1.0	1.0
	Factor of Safety	303	1,000	333	333
Interface	Moment, in-lb	1.278×10^7	0	1.347×10^7	1.527×10^7
	Allowable, in-lb	5.23×10^7	5.23×10^7	5.23×10^7	5.23×10^7
	Factor of Safety	4.09	n/a	3.88	3.43

NOTES:

(1) Load Case 1 – package subjected to 3×Inertia in the lateral/vertical direction.

(2) Load Case 2 – package subjected to 3×Inertia in the axial direction.

(3) Load Case 3 – package supported on the RPV head and Support 1 (see Figure 5).

(4) Load Case 4 – package supported on the RPV head and Support 2 (see Figure 5).

Table 4
Summary of Finite Element Model Analyses of the RPV Head Packages
Free Drop Loading Conditions

Size	Configuration	Maximum S.I. (psi)	Maximum Plastic Strain (%)	Allowable Plastic Strain (%)	Factor of Safety
Large[1]	Long	60,979	9.59	17	1.77
	Short Orientation 1	67,041	12.33	17	1.38
	Short Orientation 2	31,592	0.14	17	121
Small[2]	Long	54,438	9.97	17	1.71
	Short Orientation 1	55,419	12.31	17	1.38
	Short Orientation 2	30,963	0.24	17	70.8

NOTES:

(1) From Reference 20.

(2) From Reference 21.

Figures

(28 pages)

Appendix 1

(18 Pages)

ANSYS Finite Element Model Analyses Result Summary

Large Size Package – Load Case 1

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls1.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=    15
  TIME/FREQUENCY=  1.0000
TITLE= Large-Long - 3W Later/Vertical Inertia

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    2011  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    2033 NODES (OF     8793  DEFINED) SELECTED FROM
    2011 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       4971        5104        4988        6217        6217
VALUE   -47.627     -981.40     -1756.1     0.52118     0.49298

MAXIMUM VALUES
NODE       4726        4770        4610        4726        4704
VALUE    1763.0      978.00      47.718      1761.3      1608.5

c*** Interface Moment Print-Out


NODE FOR MOMENT SUMMATION=        0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       29.2500
```

```
*** NOTE ***                            CP=     153.875   TIME= 11:19:07
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  = -0.1204370E-10
 FY  =  -160150.3
 FZ  = -0.1111999E-11
 MX  =  0.1964975E+08
 MY  = -0.3533001E-01
 MZ  =  -28.93980

SUMMATION POINT=  0.0000      0.0000      29.250

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY       1

     648  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1432 NODES (OF     8793  DEFINED) SELECTED FROM
     648 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   2

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       7012        7084        7052        7695        7695
VALUE   -4.0779     -27.771     -125.98     0.75802     0.66003

MAXIMUM VALUES
NODE       7151        7147        7028        6910        6910
VALUE    127.93      28.984      3.8119      239.52      207.51

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     438  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       -2.50000
```

```
*** NOTE ***                              CP=     154.000   TIME= 11:19:07
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX   = -0.1420133E-05
 FY   =  -60887.53
 FZ   = -0.1872354E-03
 MX   =  -91392.94
 MY   = -0.3618674E-03
 MZ   = -0.4797033E-01

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Large Size Package – Load Case 2

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls2.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=    12
  TIME/FREQUENCY=  1.0000
TITLE= Large-Long - 3W Axial Inertia

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    2011  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    2033 NODES (OF     8793  DEFINED) SELECTED FROM
    2011 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
```

```
NODE       4794         6217         6083         4984         4984
VALUE   -3.7290      -2802.8      -5380.9       13.280       11.531

MAXIMUM VALUES
NODE       6083         6217         4795         6083         6083
VALUE    5607.6       4013.1       12.791       5607.6       5103.4

c*** Interface Moment Print-Out


NODE FOR MOMENT SUMMATION=        0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       29.2500

*** NOTE ***                            CP=     260.188   TIME= 11:28:53
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  0.4497791E-11
 FY  =  0.8299139E-11
 FZ  =   160150.0
 MX  =   13.34535
 MY  =  -29.17328
 MZ  =  0.3339542E-01

SUMMATION POINT=  0.0000      0.0000      29.250

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY       1

     648  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1432 NODES (OF     8793  DEFINED) SELECTED FROM
     648 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   2

   NODE    S1           S2           S3           SINT         SEQV

MINIMUM VALUES
NODE       6644         7072         6430         6543         6543
VALUE   -56.619      -253.95      -566.88       5.5790       5.1716

MAXIMUM VALUES
NODE       7147         7523         6512         7147         7147
VALUE    409.06       41.074      -38.187       957.85       833.76
```

```
c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     438  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=      0
MOMENT SUMMATION LOCATION=   0.00000      0.00000     -2.50000

*** NOTE ***                           CP=    260.297   TIME= 11:28:53
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL   FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  0.2072292E-05
 FY  = -0.6548367E-05
 FZ  =   60887.25
 MX  =  0.1830751
 MY  =  0.2027184
 MZ  =  0.3187445E-03

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Large Size Package – Load Case 3

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls3.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=    12
  TIME/FREQUENCY=  1.0000
TITLE= Large-Long - Support at Location 1

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    2011  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    2033 NODES (OF     8793  DEFINED) SELECTED FROM
    2011 SELECTED ELEMENTS BY NELE COMMAND.
```

```
PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       5064        5665        5665        4705        4705
VALUE   -132.76     -7179.1     -15652.      40.806      35.394

MAXIMUM VALUES
NODE       5607        5608        4970        5665        5665
VALUE    8181.4      6502.5      126.34      15597.      13524.

c*** Interface Moment Print-Out


NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000        0.00000        29.2500

*** NOTE ***                            CP=     377.891   TIME= 11:34:39
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX   =  0.1223839E-09
 FY   =  -160150.4
 FZ   = -0.1119105E-09
 MX   =  0.1966153E+08
 MY   = -0.4141523
 MZ   =  -438.6669

SUMMATION POINT=  0.0000      0.0000      29.250

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY        1

     648  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1432 NODES (OF     8793  DEFINED) SELECTED FROM
     648 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
```

```
 TIME=    1.0000       LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   2

   NODE     S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       6524        6460        6466        6841        6841
VALUE   -22.471     -81.010     -763.67      5.4409      4.7334

MAXIMUM VALUES
NODE       6532        6538        6530        6466        6466
VALUE    330.01      143.41      10.495      1035.4      964.81

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     438  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000      -2.50000

*** NOTE ***                             CP=     378.000   TIME= 11:34:39
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  0.1868131E-01
 FY  =  -60887.51
 FZ  =  -9.921026
 MX  =  -86994.03
 MY  =  -5.014402
 MZ  =  -18.44499

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Large Size Package – Load Case 4

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls4.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=    11
  TIME/FREQUENCY=  1.0000
TITLE= Large-Long - Support at Location 2
```

```
c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    2011  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    2033 NODES (OF     8793  DEFINED) SELECTED FROM
    2011 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

*** NOTE ***                            CP=    487.750   TIME= 11:39:43
Page file used.

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       4769        5476        5675        4807        4807
VALUE   -103.11     -2960.5     -6918.3      31.160      27.666

MAXIMUM VALUES
NODE       5103        5103        5103        5675        5675
VALUE    4300.5      3609.7      140.49      6893.4      6040.3

c*** Interface Moment Print-Out


NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       29.2500

*** NOTE ***                            CP=    488.031   TIME= 11:39:43
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  = -0.2092548E-10
 FY  =  -160150.4
 FZ  = -0.5329071E-10
 MX  =  0.1965470E+08
 MY  =  0.1128845
 MZ  =  -274.7232

SUMMATION POINT=  0.0000      0.0000      29.250

c*** Endplate Stress Intensity Print-Out
```

```
ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY       1

     648  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1432 NODES (OF     8793  DEFINED) SELECTED FROM
     648 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   2

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE      6801        6809        6466        6499        6499
VALUE   -84.025     -141.63     -1114.4      18.814      16.458

MAXIMUM VALUES
NODE      6906        6538        6499        6466        6466
VALUE    514.89      174.91      2.3764      1433.3      1341.6

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     438  ELEMENTS (OF     7003  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       -2.50000

*** NOTE ***                           CP=     488.172   TIME= 11:39:43
Summations based on final geometry and will not agree with solution
reactions.

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  0.4013585E-03
 FY  =  -60887.51
 FZ  = -0.3162037
 MX  =  -89599.36
 MY  = -0.9304960E-01
 MZ  = -0.2788333

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Small Size Package – Load Case 1

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls1.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=     5
  TIME/FREQUENCY=  1.0000
TITLE= Small-Long - 3W Lateral/Vertical Inertia

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

ERSE  FOR LABEL= TYPE  FROM       2 TO       2 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ERSE  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1453 NODES (OF     7638  DEFINED) SELECTED FROM
    1437 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1           S2           S3           SINT         SEQV

MINIMUM VALUES
NODE       5602         5602         5602         6551         6551
VALUE   -115.06      -1870.1      -2259.6      0.67657      0.58721

MAXIMUM VALUES
NODE       5399         5399         5344         5399         5399
VALUE    2397.5       1987.4       108.00       2397.5       2221.1

c*** Interface Moment Print-Out
```

```
NRSE  FOR LABEL= Z     BETWEEN  24.000    AND  25.000       KABS=  0.
 TOLERANCE=  0.00000

     126  NODES (OF     7638  DEFINED) SELECTED BY  NRSE  COMMAND.

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       24.0000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  = -0.4421331E-08
 FY  =  -102616.5
 FZ  =  0.7739303E-09
 MX  =  0.1277830E+08
 MY  = -0.8956708E-06
 MZ  =   12.79391

SUMMATION POINT=  0.0000      0.0000      24.000

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY       1

     948  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1918 NODES (OF     7638  DEFINED) SELECTED FROM
     948 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV
MINIMUM VALUES
NODE        4582        4360        4537        5140        5140
VALUE   -4.0419     -25.036     -149.43     0.33093     0.28839

MAXIMUM VALUES
NODE        4525        4340        4566        4525        4525
VALUE    149.59      24.971      4.0942      280.53      243.06

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     492  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS
```

```
NODE FOR MOMENT SUMMATION=        0
MOMENT SUMMATION LOCATION=   0.00000       0.00000      -2.50000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 (Excludes contact elements; issue FSUM,,both to include them)
 FX   =  0.3234398E-08
 FY   =  -34192.74
 FZ   = -0.1792912E-09
 MX   =  -51323.30
 MY   = -0.5307766E-07
 MZ   = -0.1438130E-06

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Small Size Package – Load Case 2

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls2.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=     5
  TIME/FREQUENCY=  1.0000
TITLE= Small-Long - 3W Axial Inertia

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

ERSE  FOR LABEL= TYPE  FROM       2 TO       2 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ERSE  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1453 NODES (OF     7638  DEFINED) SELECTED FROM
    1437 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1
```

```
   NODE     S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE        5872        6551        5971        5701        5701
VALUE   -1.7749     -2377.7     -3040.3      8.4415      8.2777

MAXIMUM VALUES
NODE        5971        6551        5425        5971        5971
VALUE     3132.4      2475.1      24.070      3132.4      2813.9

c*** Interface Moment Print-Out


NRSE  FOR LABEL= Z     BETWEEN  24.000    AND  25.000       KABS=  0.
 TOLERANCE=  0.00000

     126  NODES (OF     7638  DEFINED) SELECTED BY  NRSE  COMMAND.

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       24.0000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  0.1493277E-09
 FY  =  0.2596607E-09
 FZ  =   102616.5
 MX  =  -16.36825
 MY  =   12.79391
 MZ  =  0.3681635E-08

SUMMATION POINT=  0.0000      0.0000      24.000

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       10 TO       13 BY        1

     948  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1918 NODES (OF     7638  DEFINED) SELECTED FROM
     948 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=      1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE     S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE        5140        4959        4552        4026        4026
```

```
VALUE   -33.859     -107.31      -320.36      7.9885       7.4389

MAXIMUM VALUES
NODE       4371        4541        4163        4371         4371
VALUE   251.59      28.117      -23.596      561.09       486.16

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     492  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000        0.00000      -2.50000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 (Excludes contact elements; issue FSUM,,both to include them)
 FX  =  0.3756185E-08
 FY  = -0.5534901E-08
 FZ  =   34192.74
 MX  = -0.2171742E-06
 MY  = -0.5476977E-07
 MZ  = -0.1341079E-05

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Small Size Package – Load Case 3

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls3.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0

SET COMMAND GOT LOAD STEP=     1  SUBSTEP=     5  CUMULATIVE ITERATION=     5
  TIME/FREQUENCY=  1.0000
TITLE= Small-Long - Support at Location 1

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

ERSE  FOR LABEL= TYPE  FROM       2 TO       2 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ERSE  COMMAND.
```

```
SELECT       ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1453 NODES (OF      7638  DEFINED) SELECTED FROM
    1437 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S     NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=      1  SUBSTEP=      5
  TIME=     1.0000       LOAD CASE=    0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL    1

   NODE     S1           S2           S3           SINT         SEQV

MINIMUM VALUES
NODE        5474         6079         6079         5333         5333
VALUE    -166.63      -4299.3      -9799.6       9.5321       8.4303

MAXIMUM VALUES
NODE        5976         5977         5602         6079         6079
VALUE     5890.8       4843.1       200.77       9751.4       8468.1

c*** Interface Moment Print-Out


NRSE  FOR LABEL= Z      BETWEEN  24.000    AND  25.000       KABS=  0.
 TOLERANCE=  0.00000

     126  NODES (OF      7638  DEFINED) SELECTED BY  NRSE  COMMAND.

NODE FOR MOMENT SUMMATION=        0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       24.0000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX   =  -3645.571
 FY   =   150593.6
 FZ   =  0.7032668E-08
 MX   = -0.1347313E+08
 MY   =  -374940.8
 MZ   =   12.79372

SUMMATION POINT=  0.0000      0.0000      24.000

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       10 TO       13 BY       1

     948  ELEMENTS (OF      6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT       ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1918 NODES (OF      7638  DEFINED) SELECTED FROM
     948 SELECTED ELEMENTS BY NELE COMMAND.
```

```
PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE       3757        3756        4080        4159        4159
VALUE   -18.108     -90.895     -308.92      5.7971      5.2072

MAXIMUM VALUES
NODE       4509        4080        4566        4509        4509
VALUE    215.65      46.351      1.8424      481.39      420.99

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     492  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=  0.00000       0.00000      -2.50000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 (Excludes contact elements; issue FSUM,,both to include them)
 FX   =  0.4752592E-06
 FY   =  -34192.74
 FZ   = -0.6408455E-07
 MX   =  -51323.30
 MY   = -0.2605032E-05
 MZ   = -0.3422656E-04

SUMMATION POINT=  0.0000      0.0000     -2.5000
```

Small Size Package – Load Case 4

```
c*** Specify Result Filename for Reading


SET DATABASE INPUT CONTROL TO ACCESS RESULTS FILE DATA FOR :
 ALL

DATA FILE CHANGED TO FILE= ls4.rst


USE LAST SUBSTEP ON RESULT FILE  FOR LOAD CASE 0
```

```
SET COMMAND GOT LOAD STEP=      1  SUBSTEP=      5  CUMULATIVE ITERATION=      5
  TIME/FREQUENCY=  1.0000
TITLE= Small-Long - Support at Location 2

c*** Canister Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM       2 TO       7 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

ERSE  FOR LABEL= TYPE  FROM       2 TO       2 BY       1

    1437  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ERSE  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1453 NODES (OF     7638  DEFINED) SELECTED FROM
    1437 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL    1

   NODE    S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE        5344        5399        6089        5378        5378
VALUE    -134.00     -2888.1     -4148.9      19.180      19.118

MAXIMUM VALUES
NODE        5602        5602        5602        6089        6089
VALUE     4056.8      3461.4      209.01      4128.9      3629.8

c*** Interface Moment Print-Out


NRSE  FOR LABEL= Z     BETWEEN  24.000    AND  25.000       KABS=  0.
 TOLERANCE=  0.00000

     126  NODES (OF     7638  DEFINED) SELECTED BY  NRSE  COMMAND.

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000       24.0000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 FX  =  -862.7178
 FY  =   14946.23
 FZ  =  0.4031335E-08
 MX  = -0.1527397E+08
 MY  =  -201888.5
 MZ  =   12.79380
```

```
SUMMATION POINT=  0.0000       0.0000       24.000

c*** Endplate Stress Intensity Print-Out


ESEL  FOR LABEL= REAL  FROM      10 TO      13 BY       1

     948  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      ALL NODES HAVING ANY ELEMENT IN ELEMENT SET.

    1918 NODES (OF     7638  DEFINED) SELECTED FROM
     948 SELECTED ELEMENTS BY NELE COMMAND.

PRINT S    NODAL SOLUTION PER NODE

 ***** POST1 NODAL STRESS LISTING *****
 PowerGraphics Is Currently Enabled

 LOAD STEP=     1  SUBSTEP=     5
  TIME=    1.0000      LOAD CASE=   0
 SHELL NODAL RESULTS ARE AT TOP/BOTTOM FOR MATERIAL   1

   NODE     S1          S2          S3          SINT        SEQV

MINIMUM VALUES
NODE      4565        4533        4328        3881        3881
VALUE   -5.2102     -45.828     -609.60      8.6721      7.8940

MAXIMUM VALUES
NODE      4509        4322        5306        4509        4328
VALUE    529.09      98.015     -5.2447      1131.9      984.06

c*** Endplate Attachment Bolt Load Print-Out


ESEL  FOR LABEL= REAL  FROM      11 TO      13 BY       1

     492  ELEMENTS (OF     6069  DEFINED) SELECTED BY  ESEL  COMMAND.

SELECT      COMPONENT BOLTS

NODE FOR MOMENT SUMMATION=       0
MOMENT SUMMATION LOCATION=   0.00000       0.00000      -2.50000

***** SUMMATION OF TOTAL    FORCES AND MOMENTS IN GLOBAL COORDINATES *****
 (Excludes contact elements; issue FSUM,,both to include them)
 FX  =  0.2564853E-06
 FY  =  -34192.74
 FZ  = -0.5146769E-07
 MX  =  -51323.30
 MY  = -0.7733814E-06
 MZ  = -0.1838059E-04

SUMMATION POINT=  0.0000       0.0000      -2.5000
```

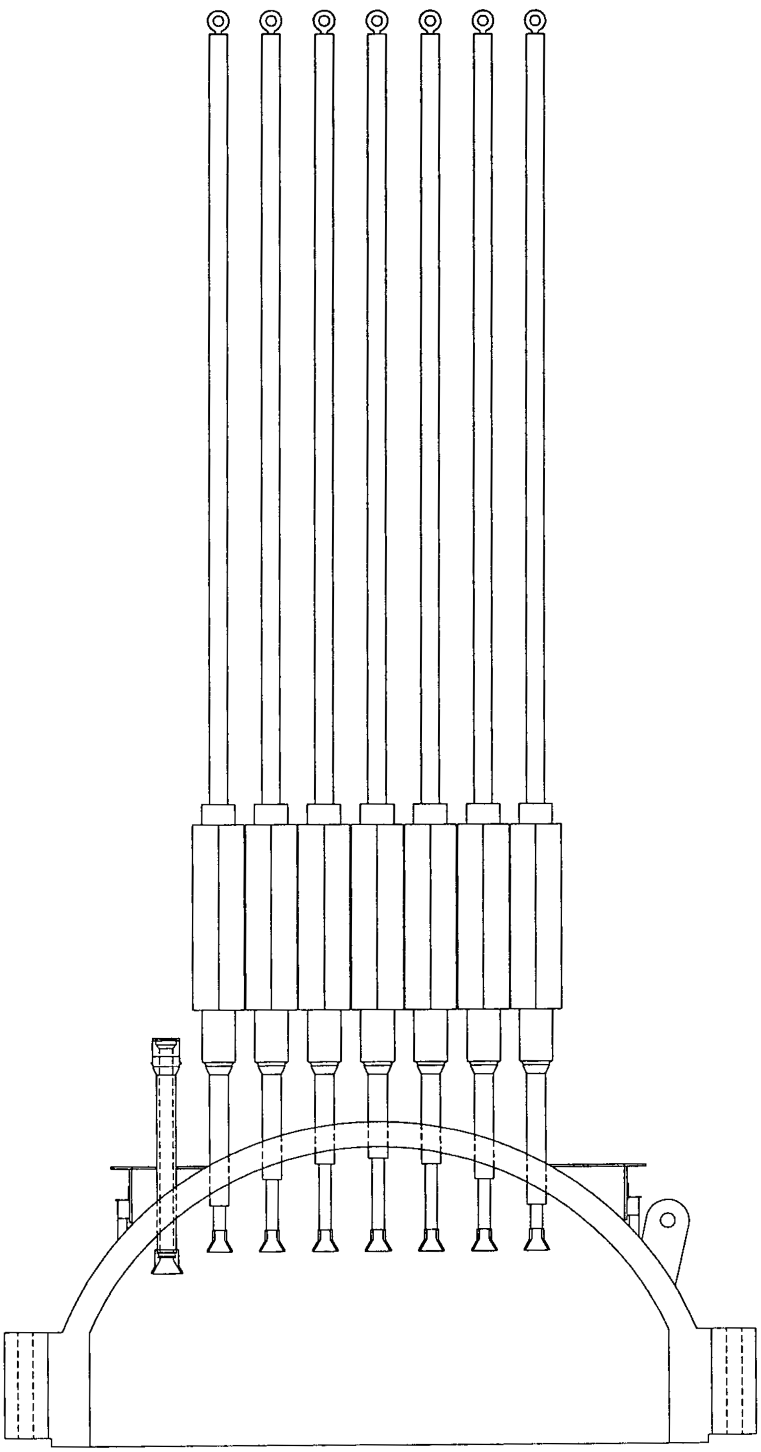

Figure 1
A Typical RPV Head with CRDM Assembly, Packaged in Duratek Long Canister

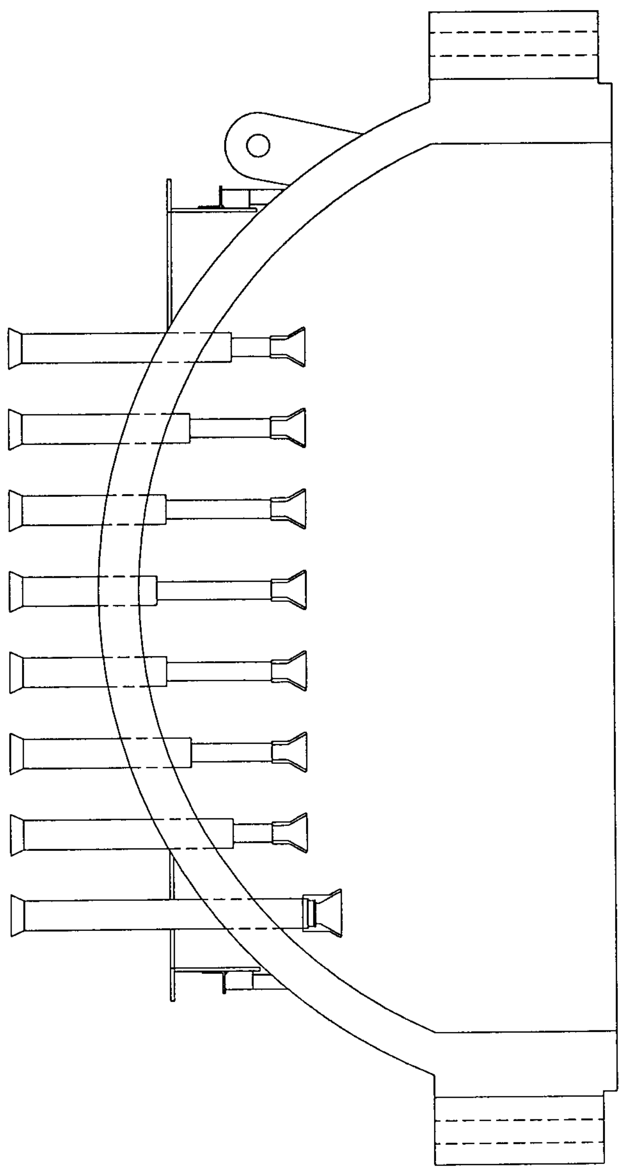

Figure 2
A Typical RPV Head without CRDM Assembly, Packaged in Duratek Short Canister

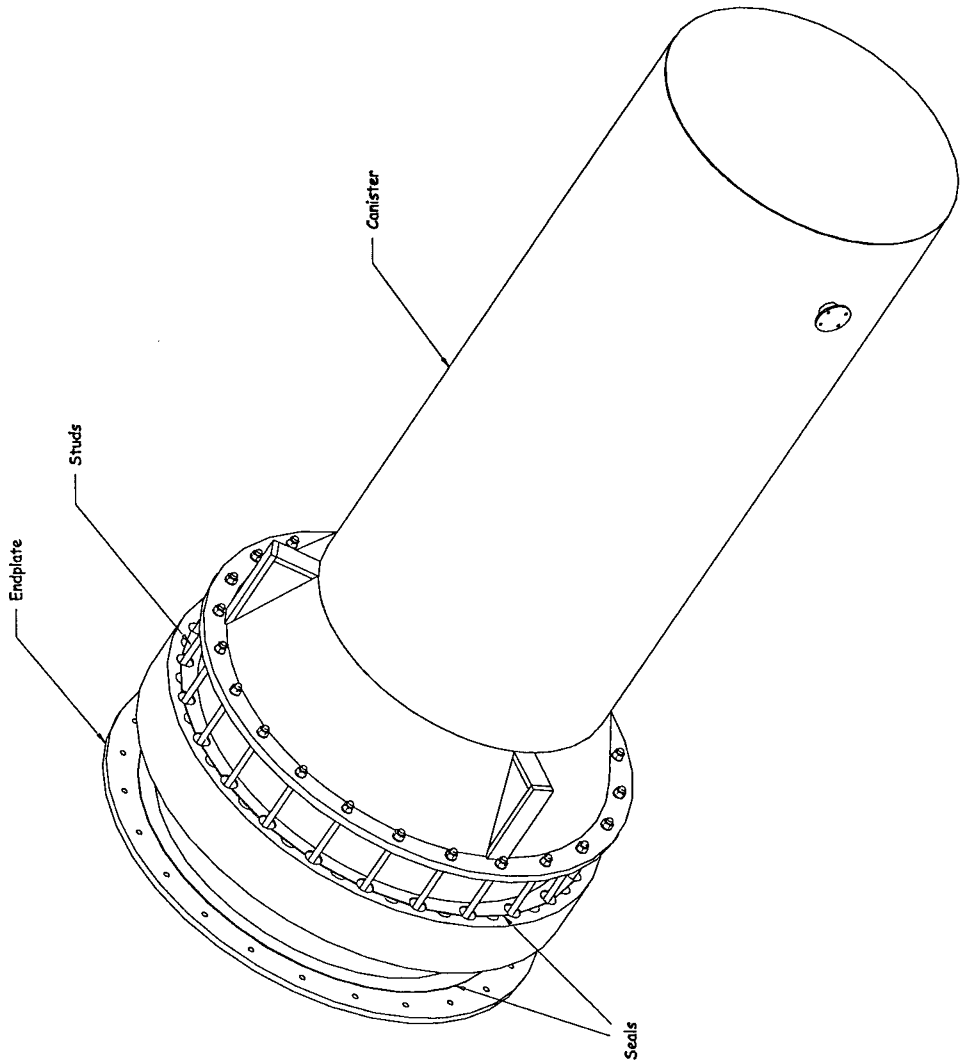

Figure 3
A Typical RPV Head Package

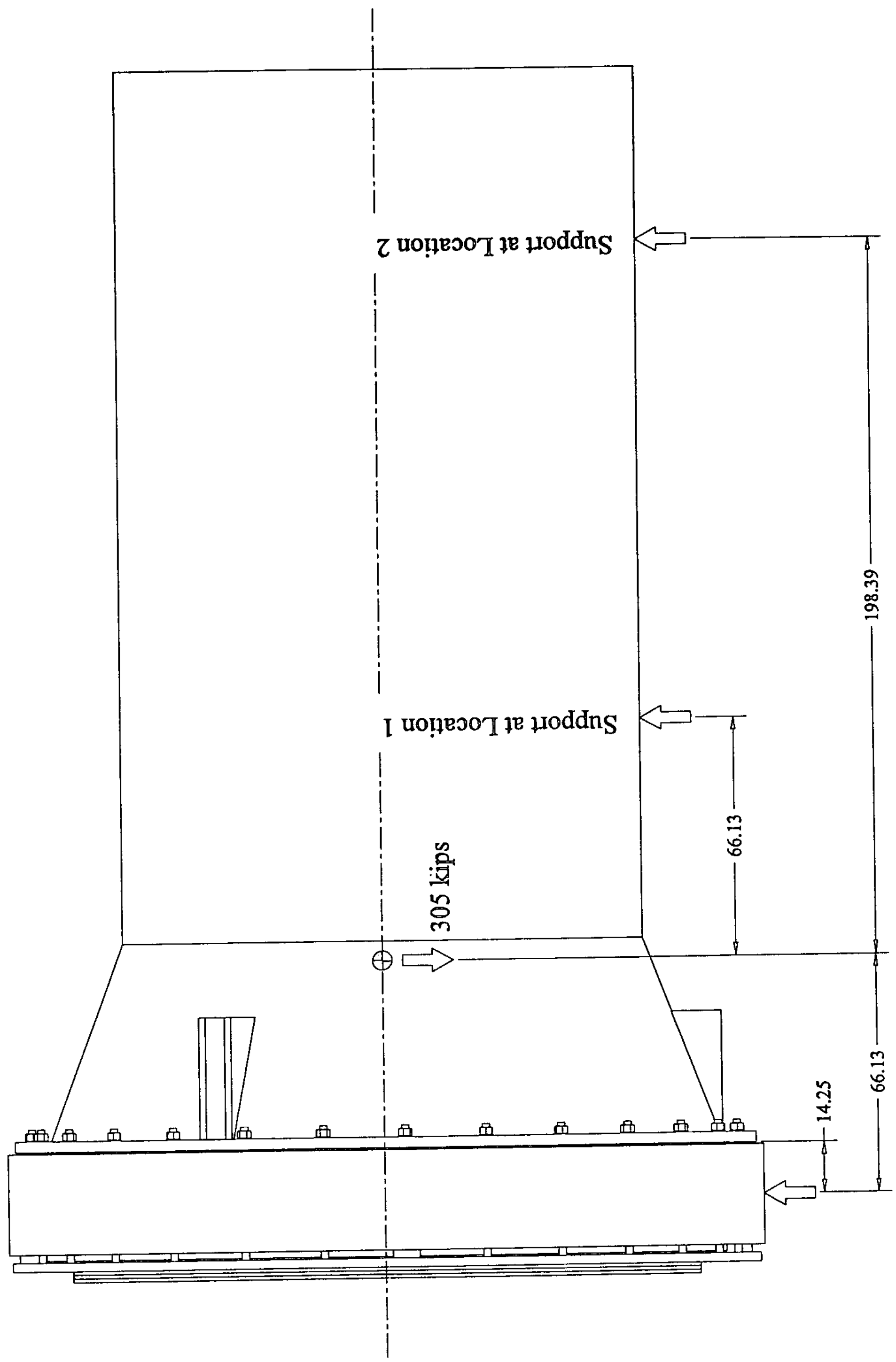

Figure 4
A Typical Support Scenario for Large Head Package

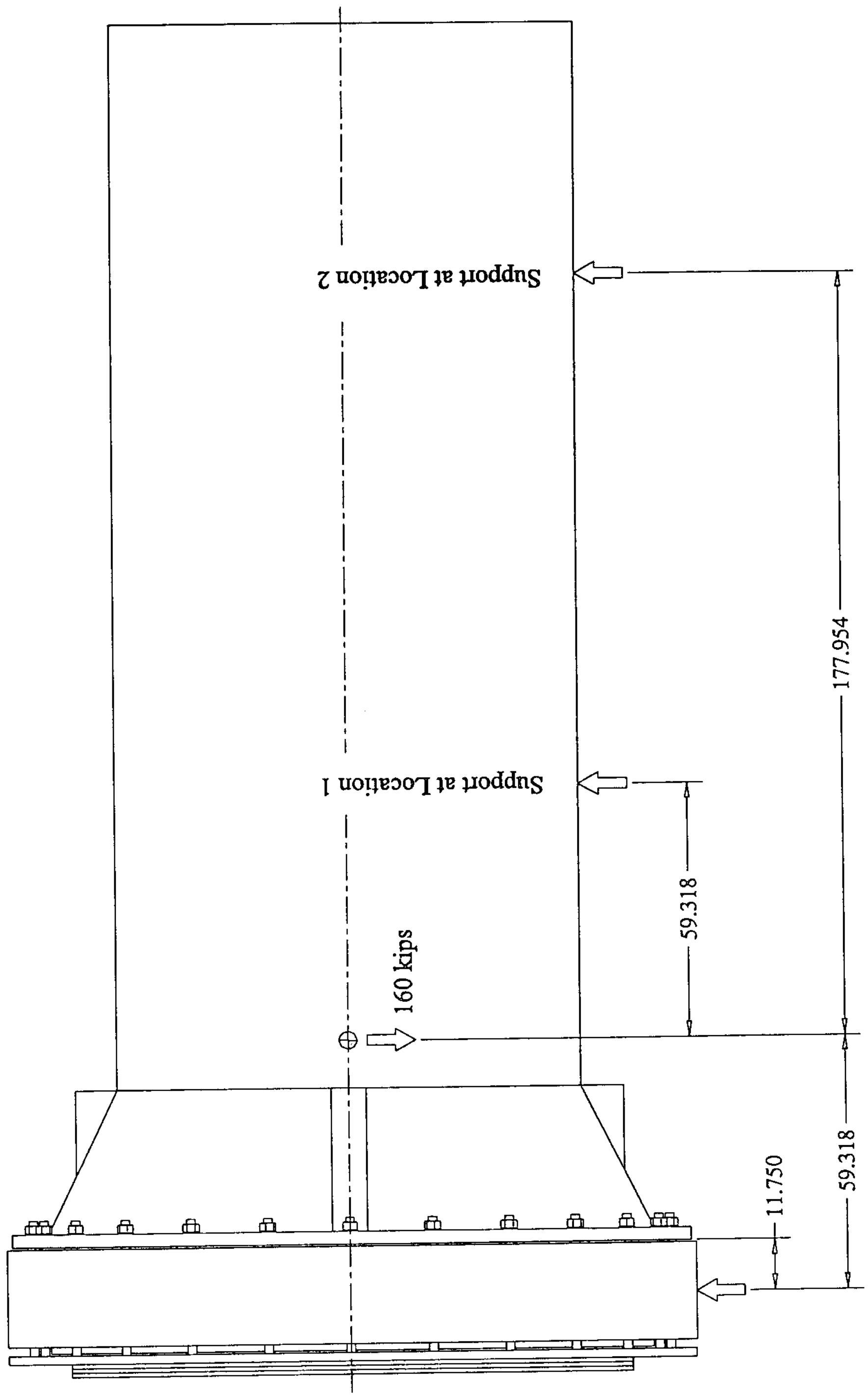

Figure 5
A Typical Support Scenario for Small Head Package

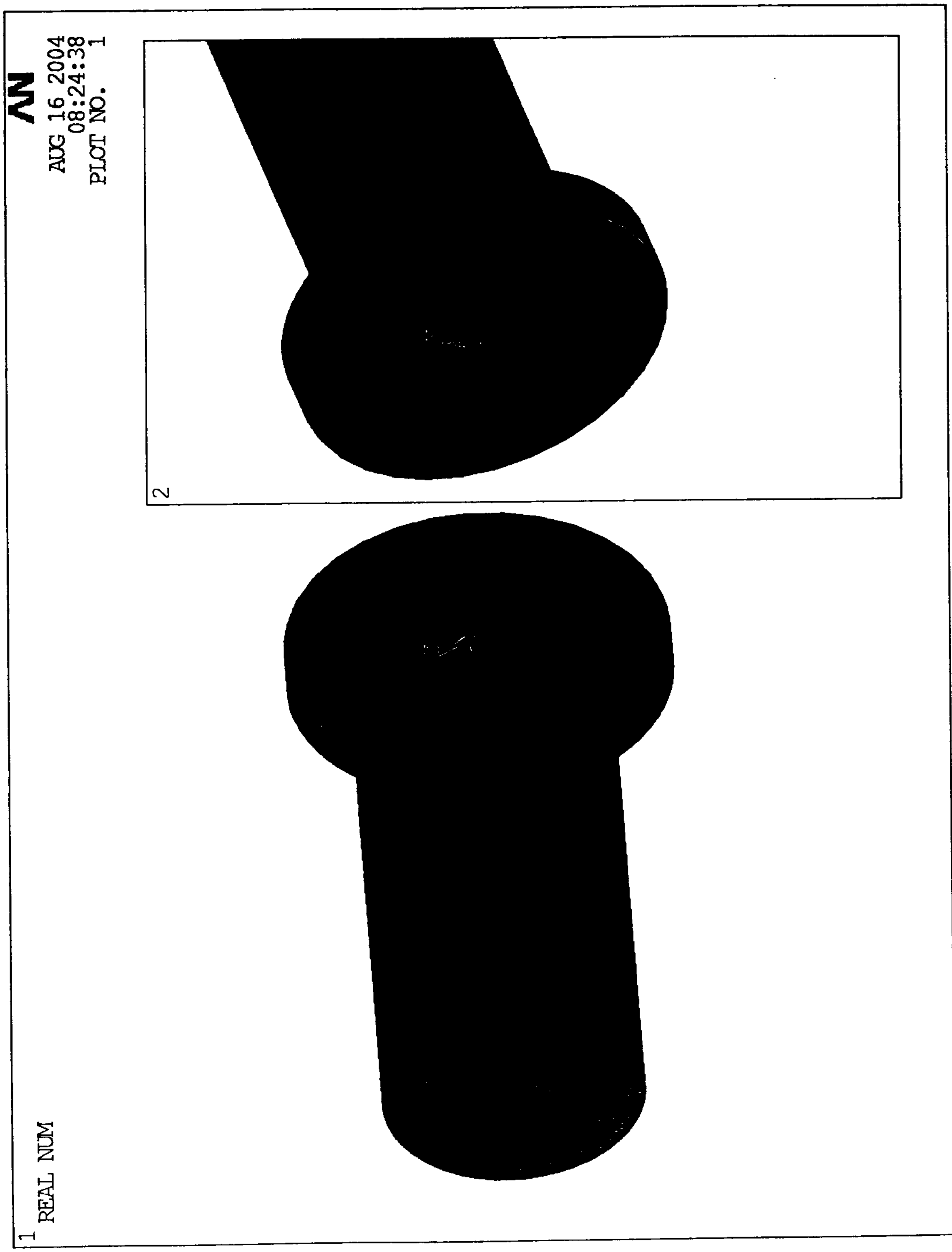

Figure 6
A Typical Finite Element Model of a RPV Head Package

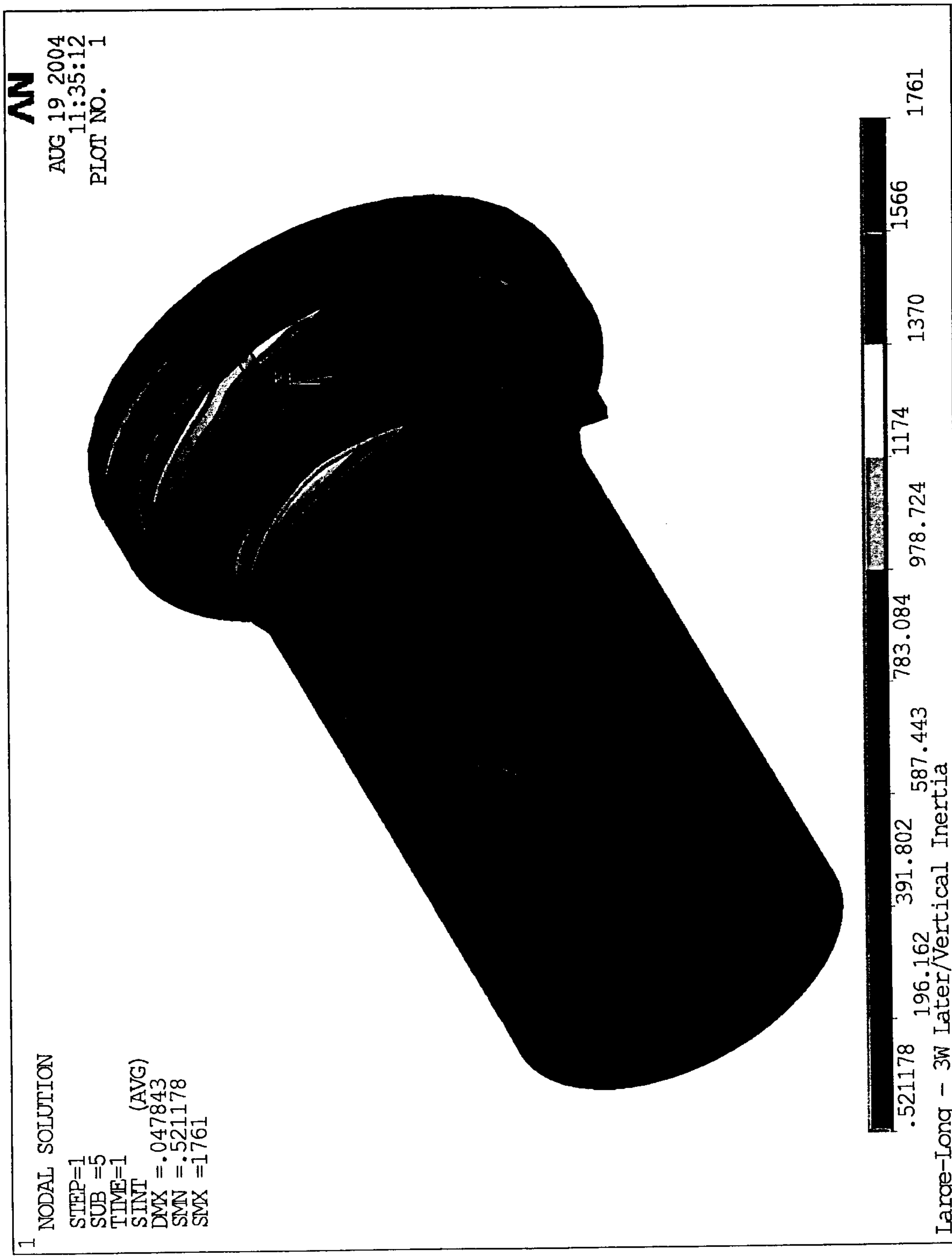

Figure 7

Stress Intensity Contour Plot in the Large Package Under 3g Lateral Loading

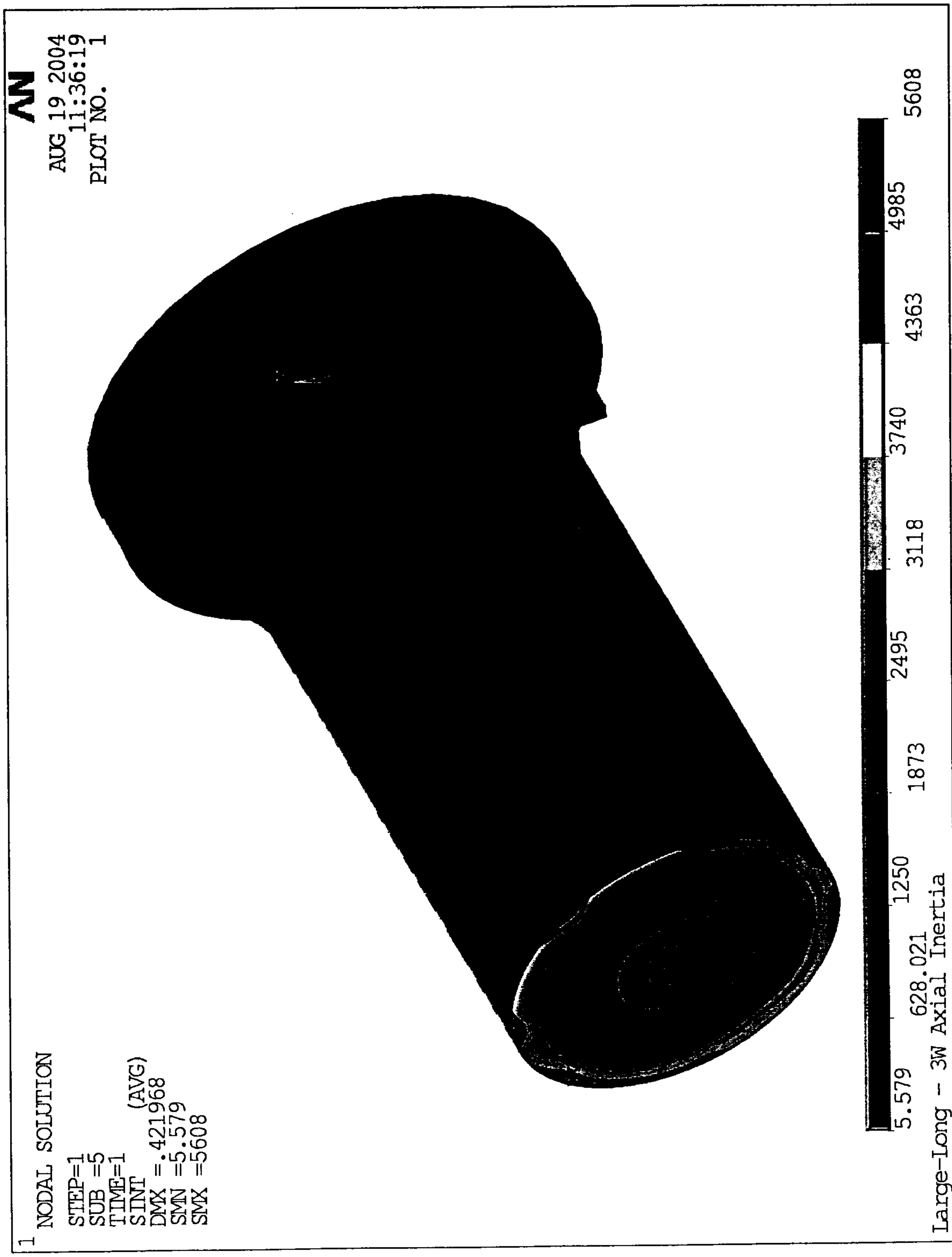

Figure 8
Stress Intensity Contour Plot in the Large Package Under 3g Axial Loading

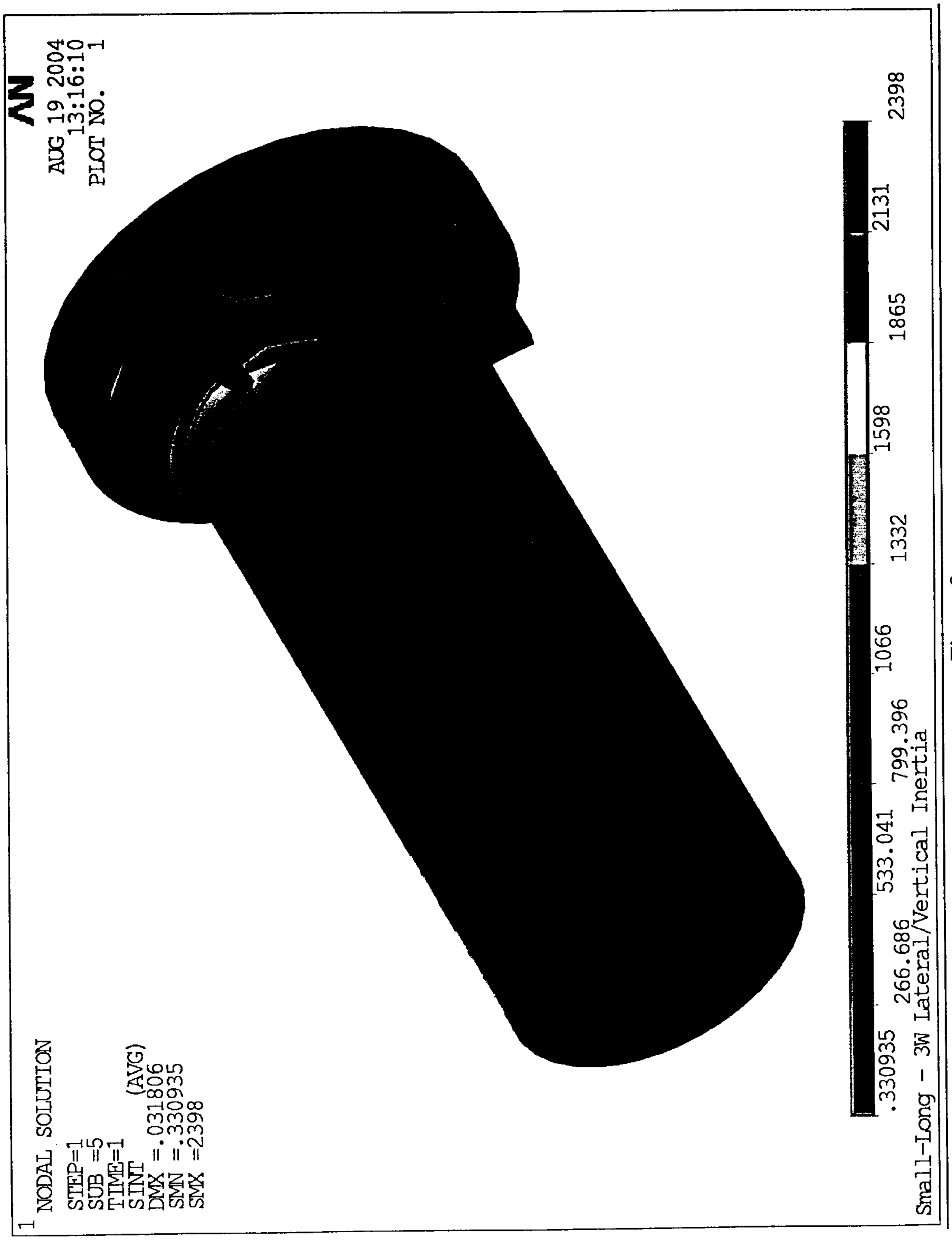

Figure 9
Stress Intensity Contour Plot in the Small Package Under 3g Lateral Loading

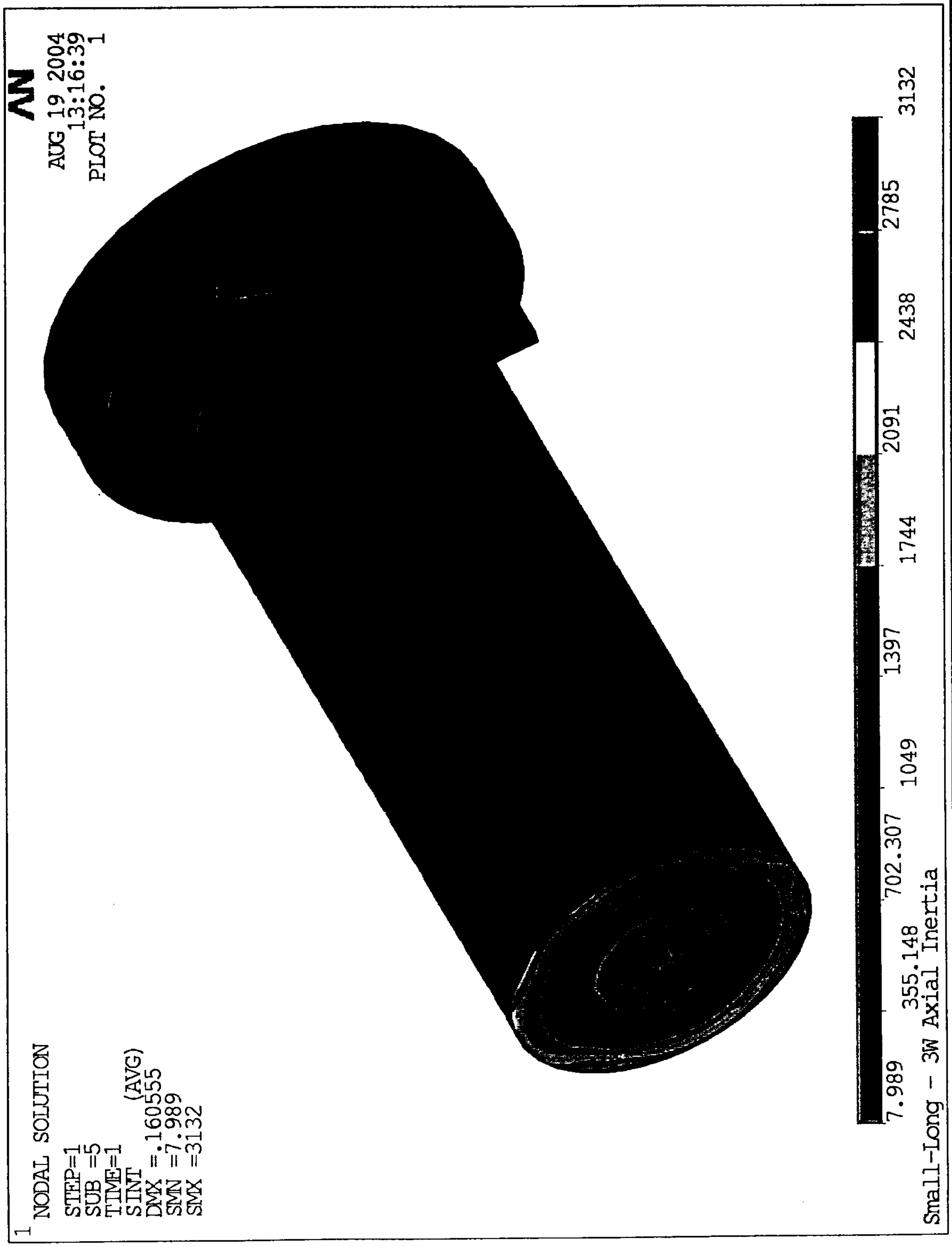

Figure 10
Stress Intensity Contour Plot in the Small Package Under 3g Axial Loading

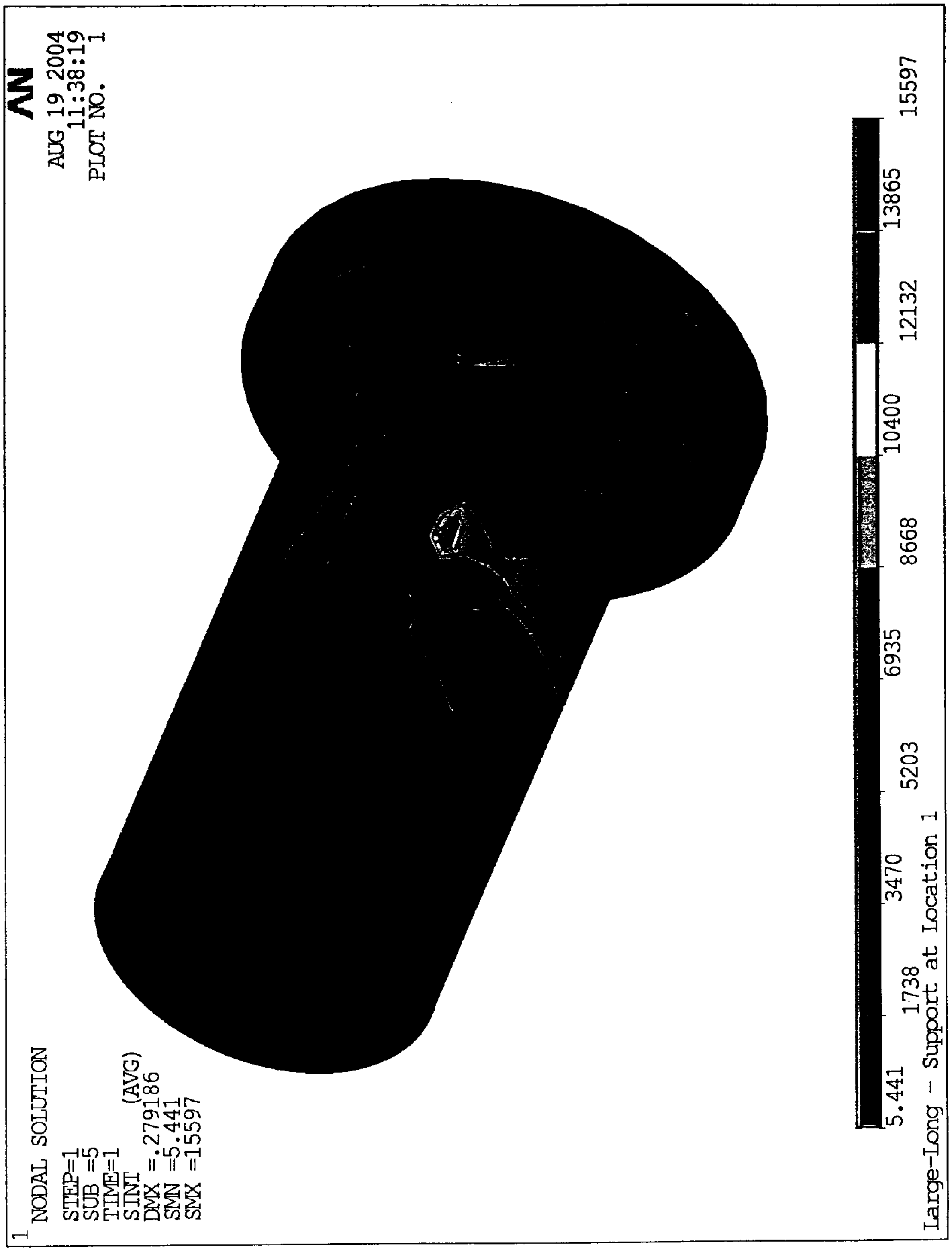

Figure 11

Stress Intensity Contour Plot in the Large Package with Support at Location 1

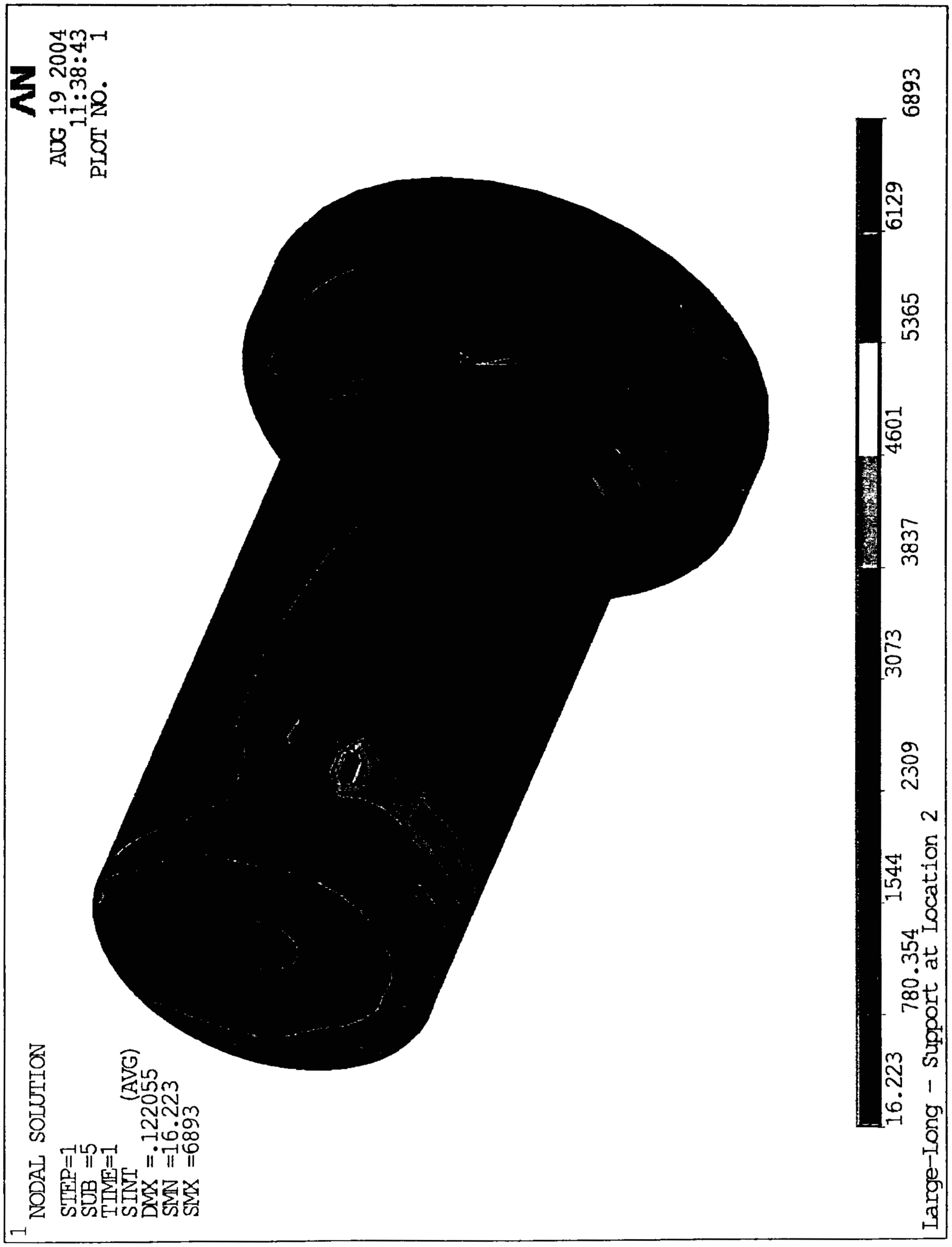

Figure 12
Stress Intensity Contour Plot in the Large Package with Support at Location 2

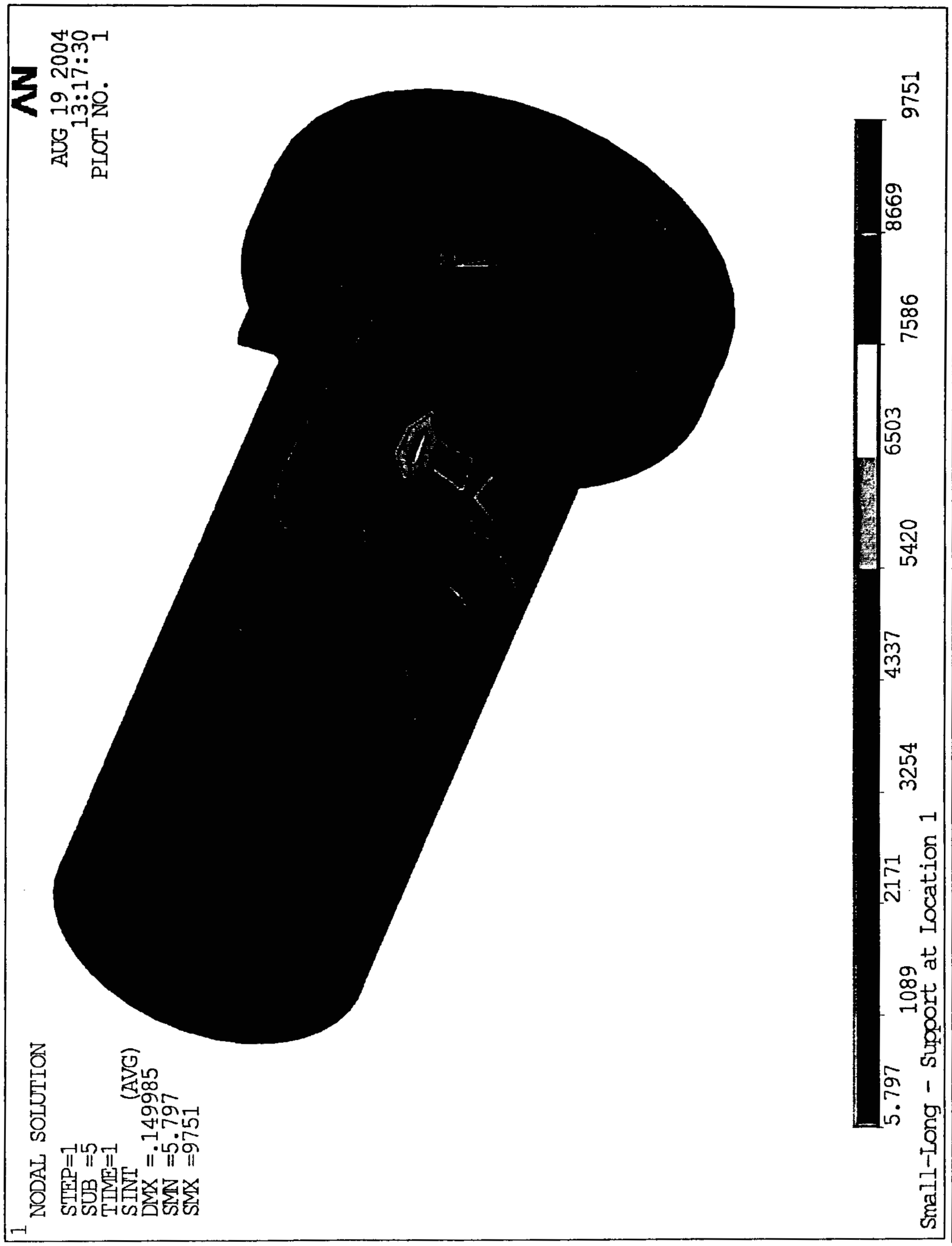

Figure 13

Stress Intensity Contour Plot in the Small Package with Support at Location 1

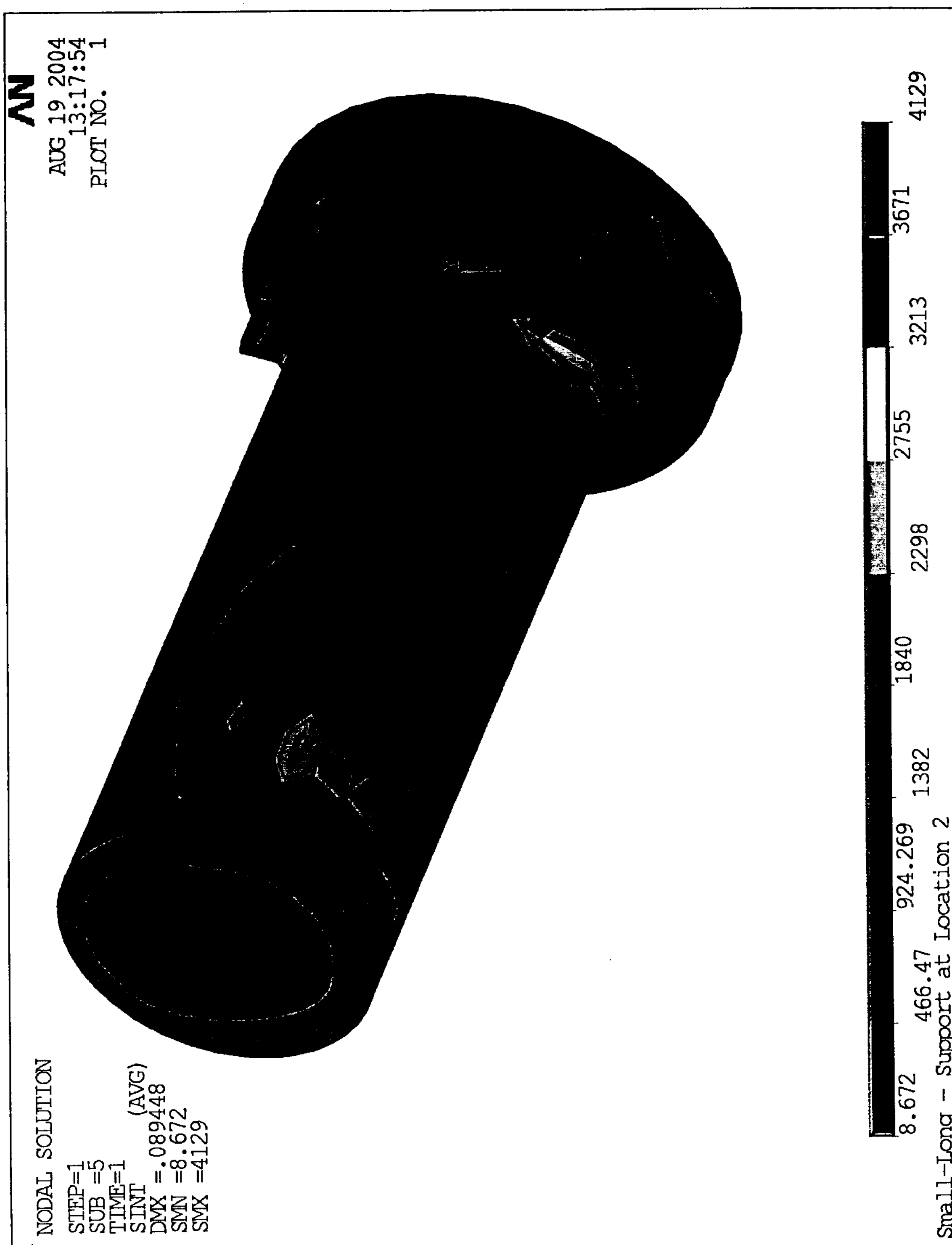

Figure 14

Stress Intensity Contour Plot in the Small Package with Support at Location 2

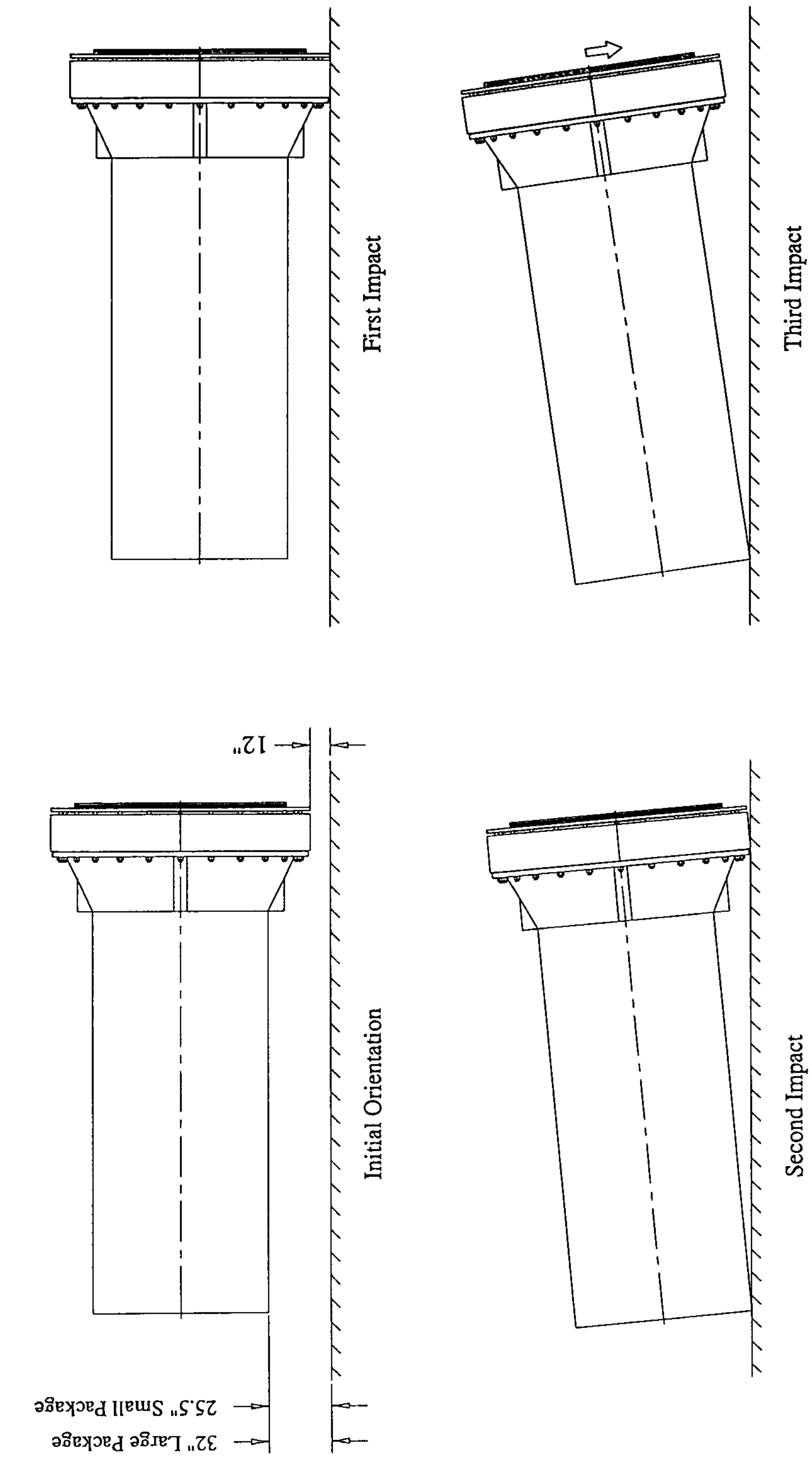

Figure 15
Free Drop Scenario for Long Packages

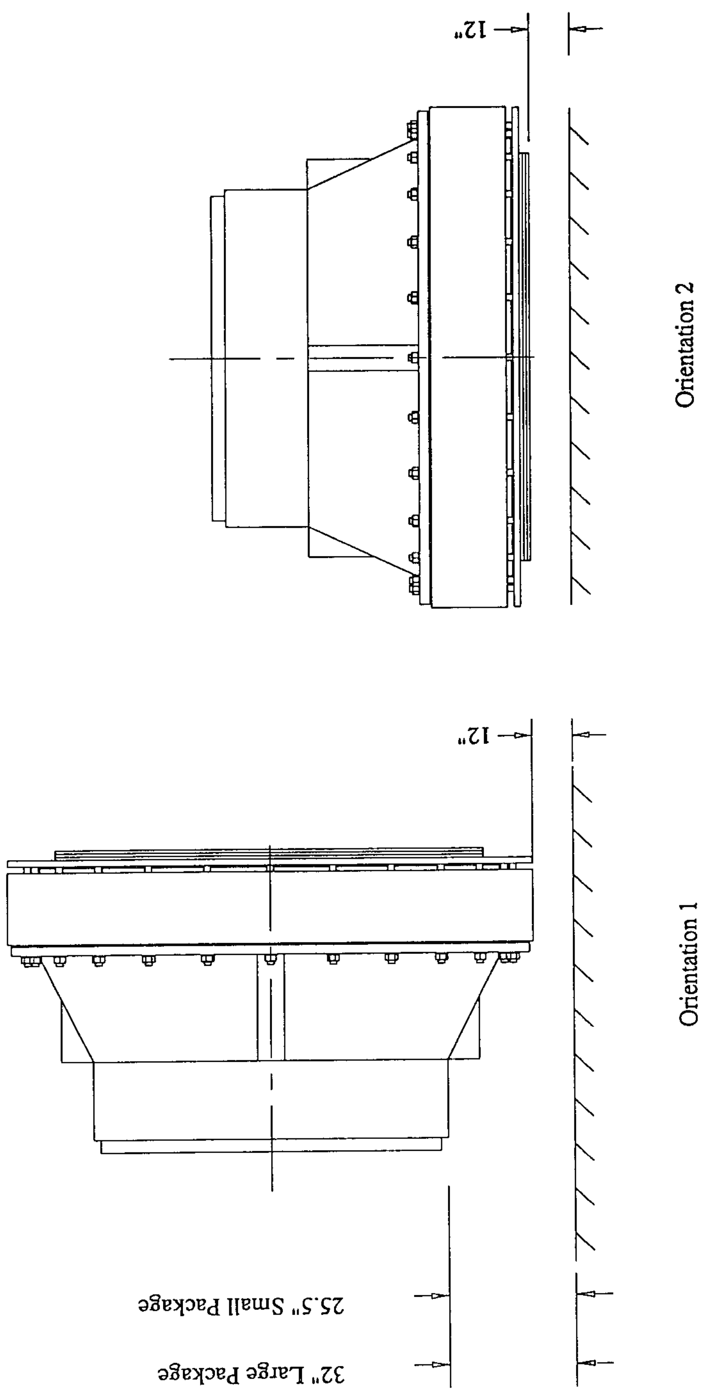

Figure 16
Free Drop Scenario for Short Packages

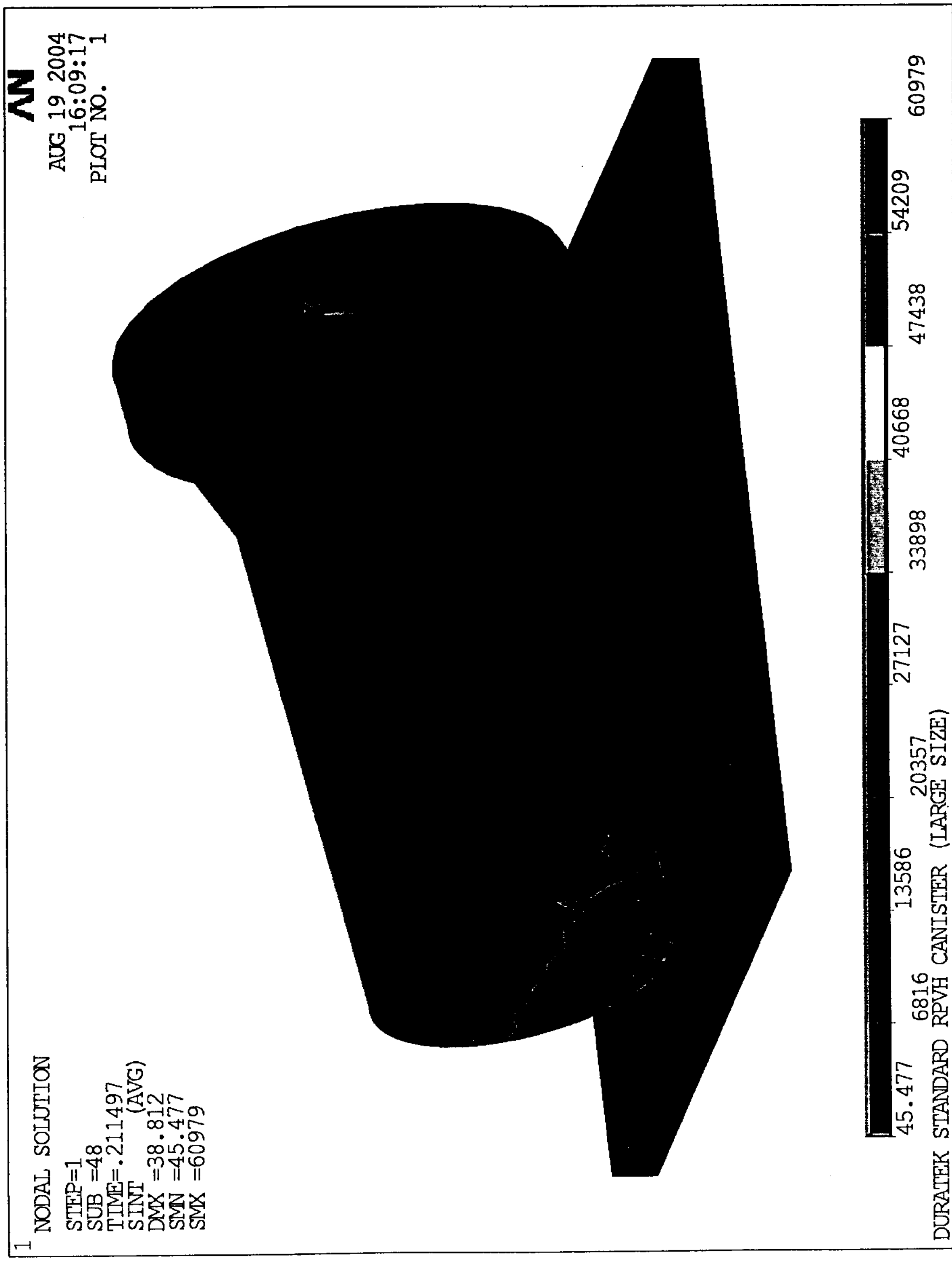

Figure 17
Maximum Stress Intensity Contour Plot in Large Package (Long Configuration) Under Free Drop

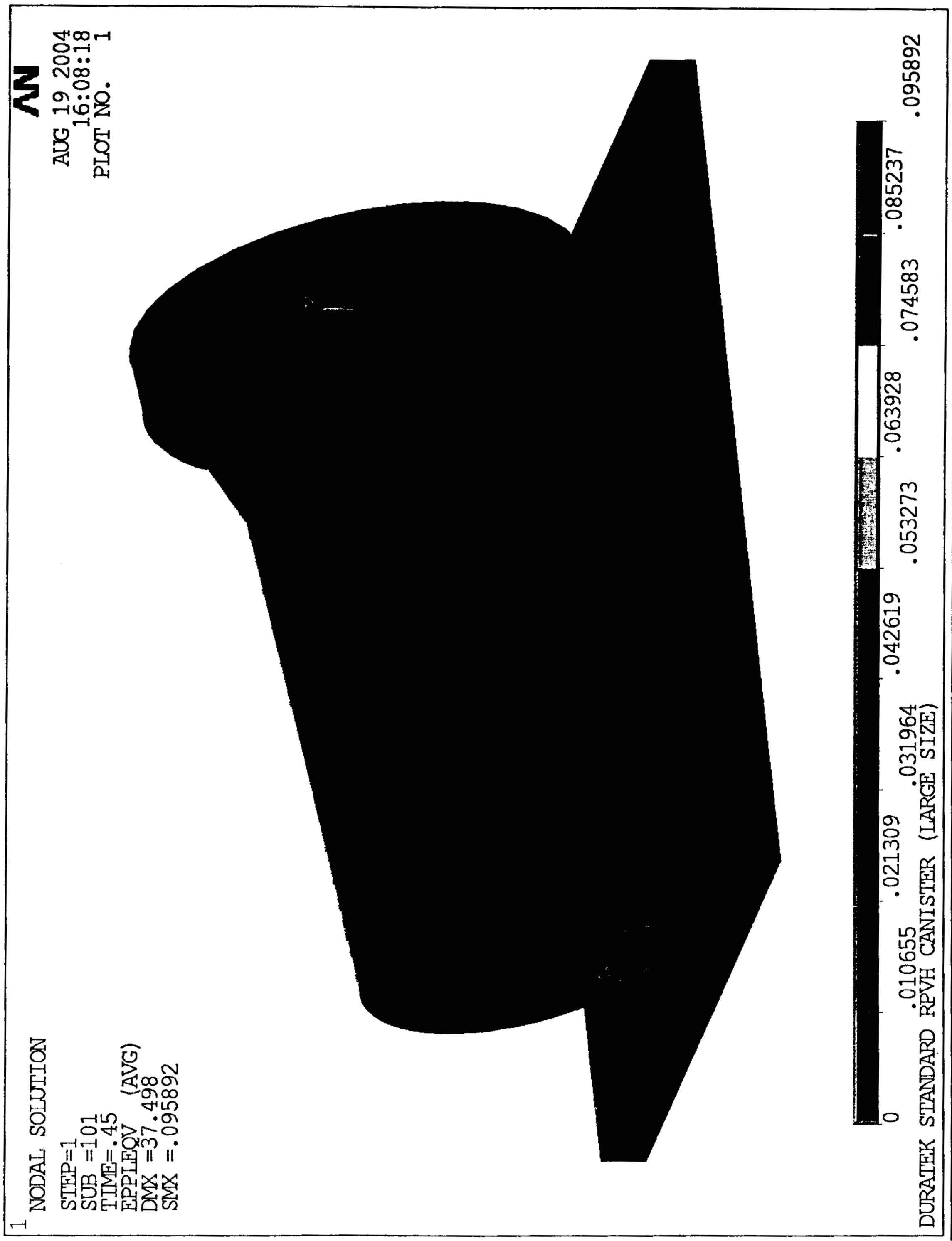

Figure 18

Maximum Plastic Strain Contour Plot in Large Package (Long Configuration) Under Free Drop

Figure 19

Maximum Stress Intensity Contour Plot in Large Package (Short Configuration) Under Free Drop Scenario 1
(Supplemental can shielding removed from the plot for clarity)

Figure 20
Maximum Plastic Strain Contour Plot in Large Package (Short Configuration) Under Free Drop Scenario 1
(Supplemental can shielding removed from the plot for clarity)

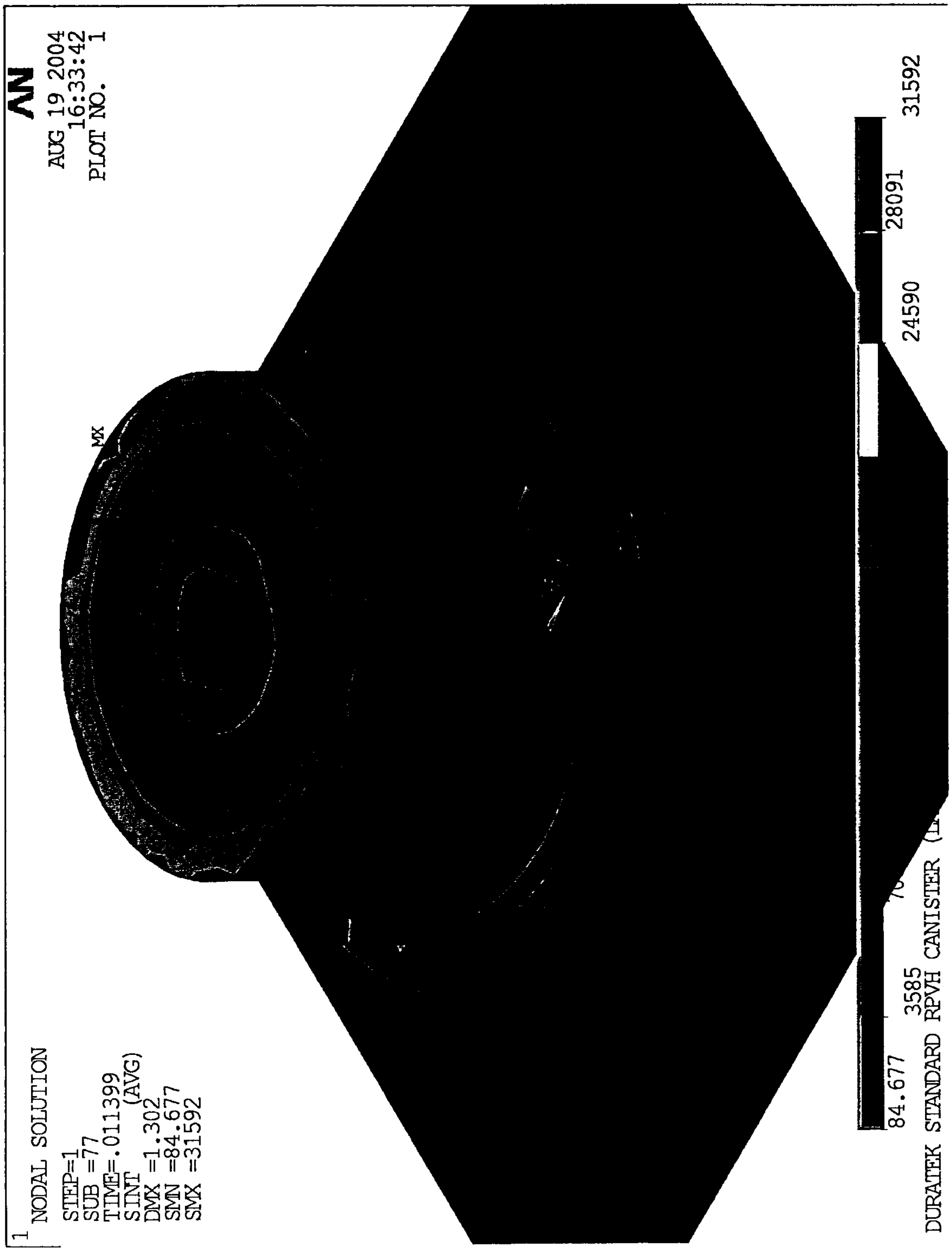

Figure 21

Maximum Stress Intensity Contour Plot in Large Package (Short Configuration) Under Free Drop Scenario 2

(Supplemental can shielding removed from the plot for clarity)

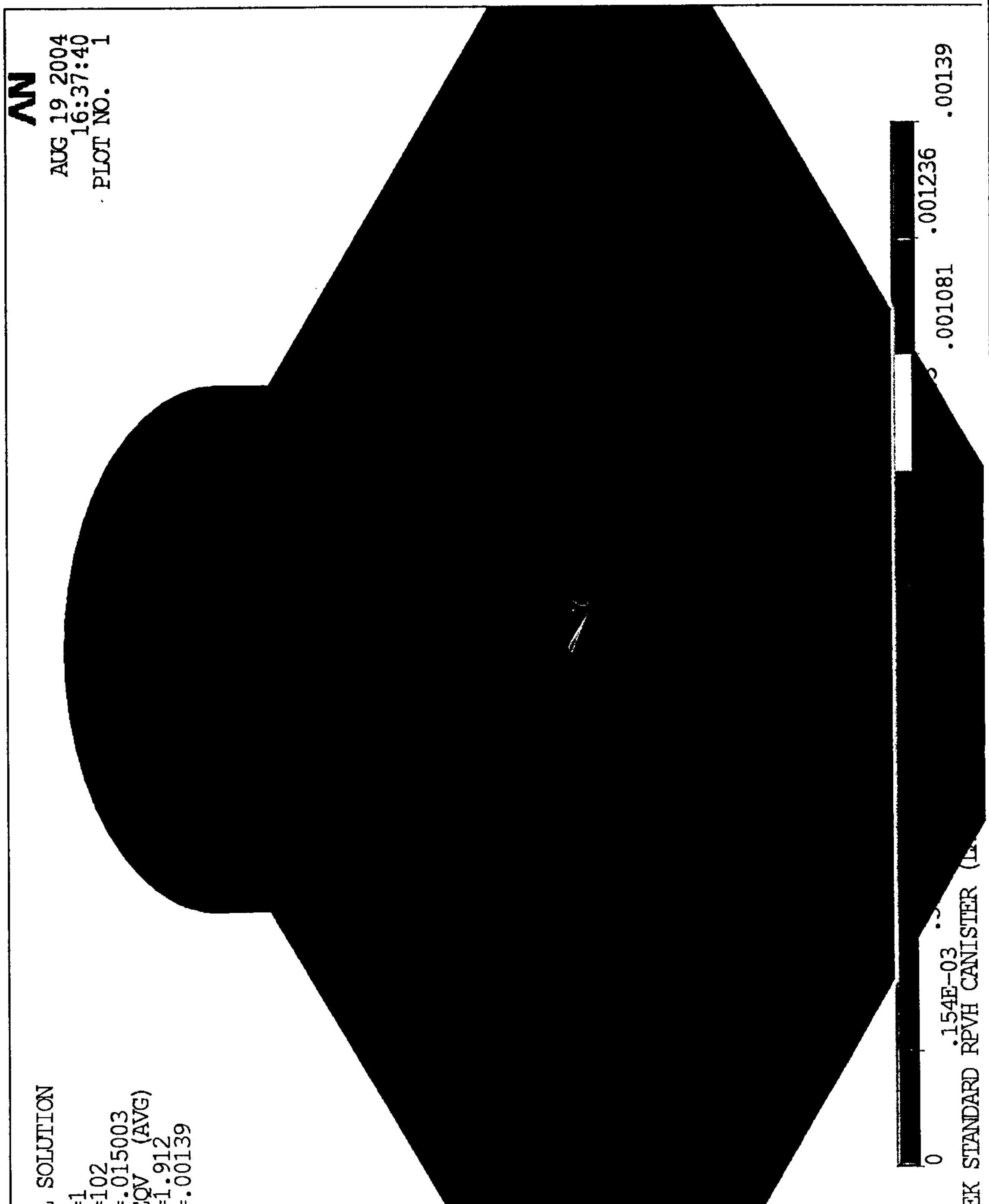

Figure 22
Maximum Plastic Strain Contour Plot in Large Package (Short Configuration) Under Free Drop Scenario 2
(Supplemental can shielding removed from the plot for clarity)

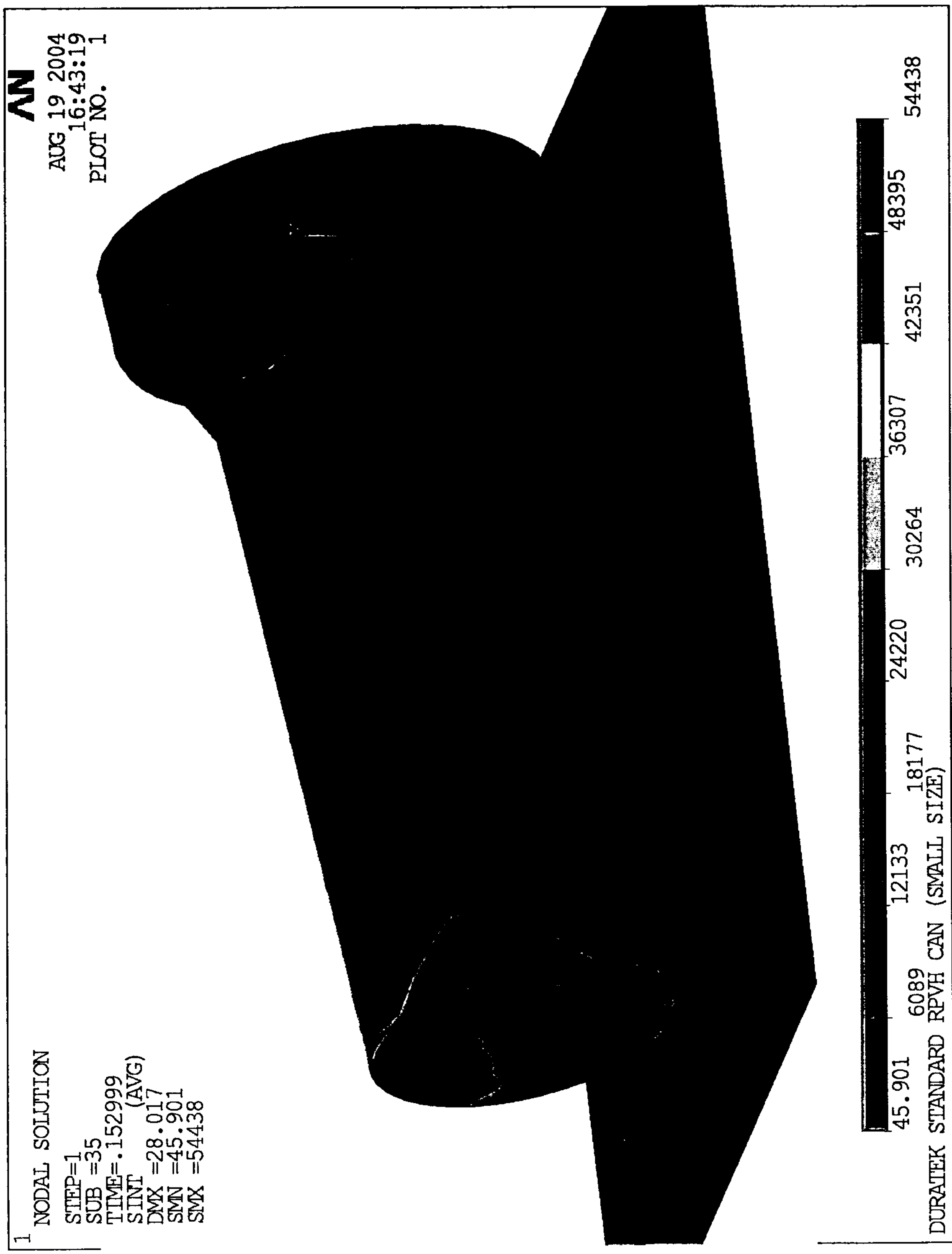

Figure 23
Maximum Stress Intensity Contour Plot in Small Package (Long Configuration) Under Free Drop

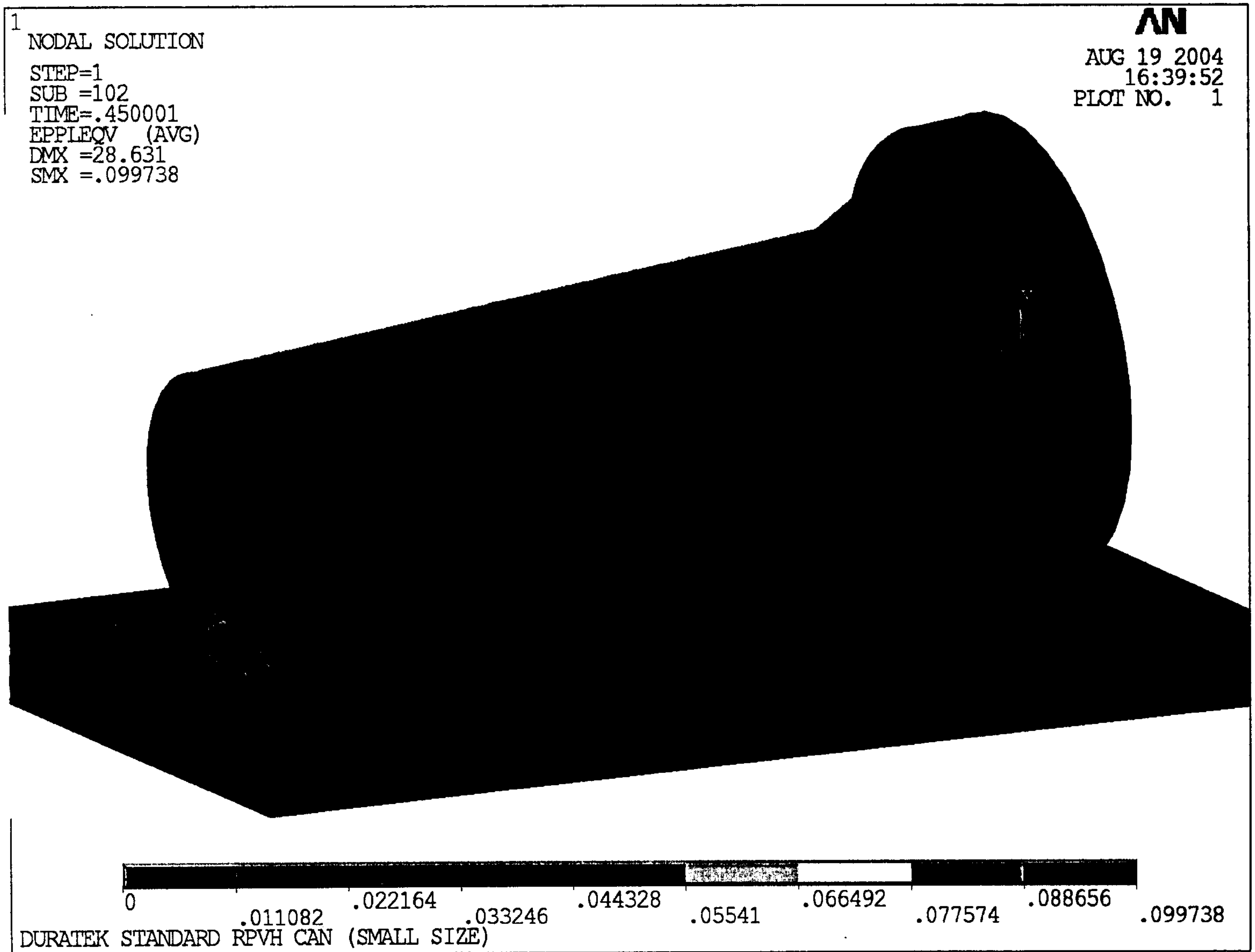

Figure 24

Maximum Plastic Strain Contour Plot in Small Package (Long Configuration) Under Free Drop

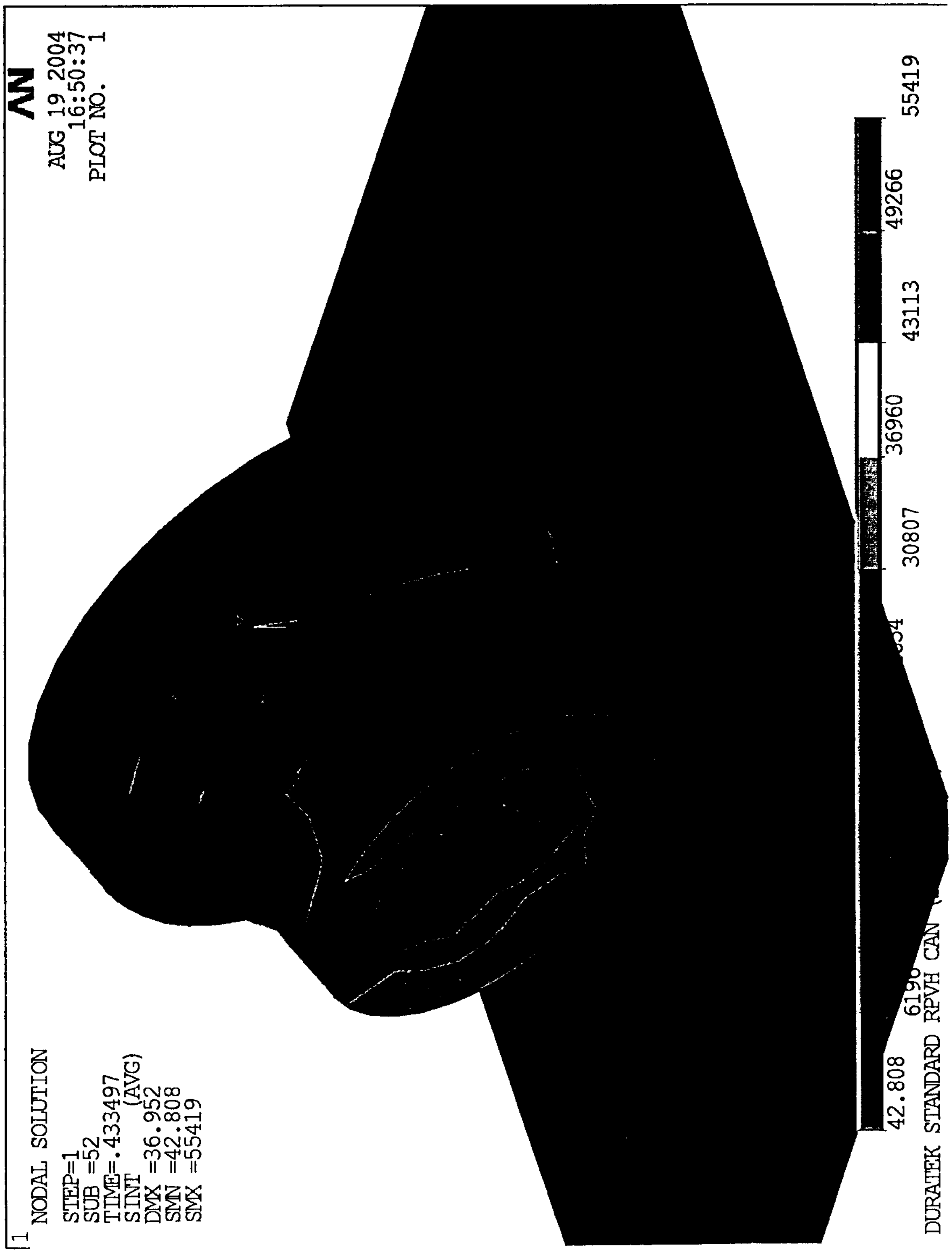

Figure 25

Maximum Stress Intensity Contour Plot in Small Package (Short Configuration) Under Free Drop Scenario 1 (Supplemental can shielding removed from the plot for clarity)

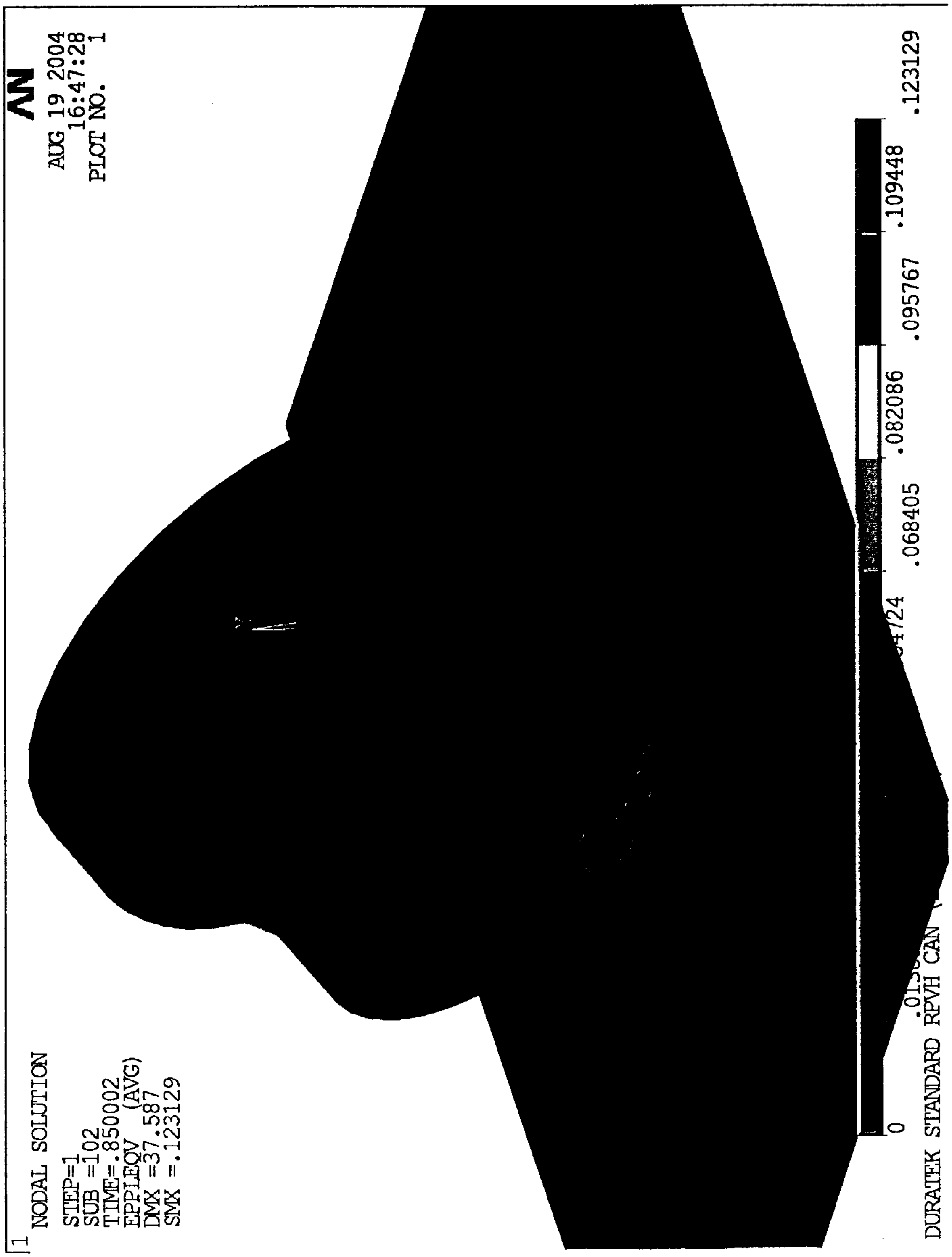

Figure 26

Maximum Plastic Strain Contour Plot in Small Package (Short Configuration) Under Free Drop Scenario 1

(Supplemental can shielding removed from the plot for clarity)

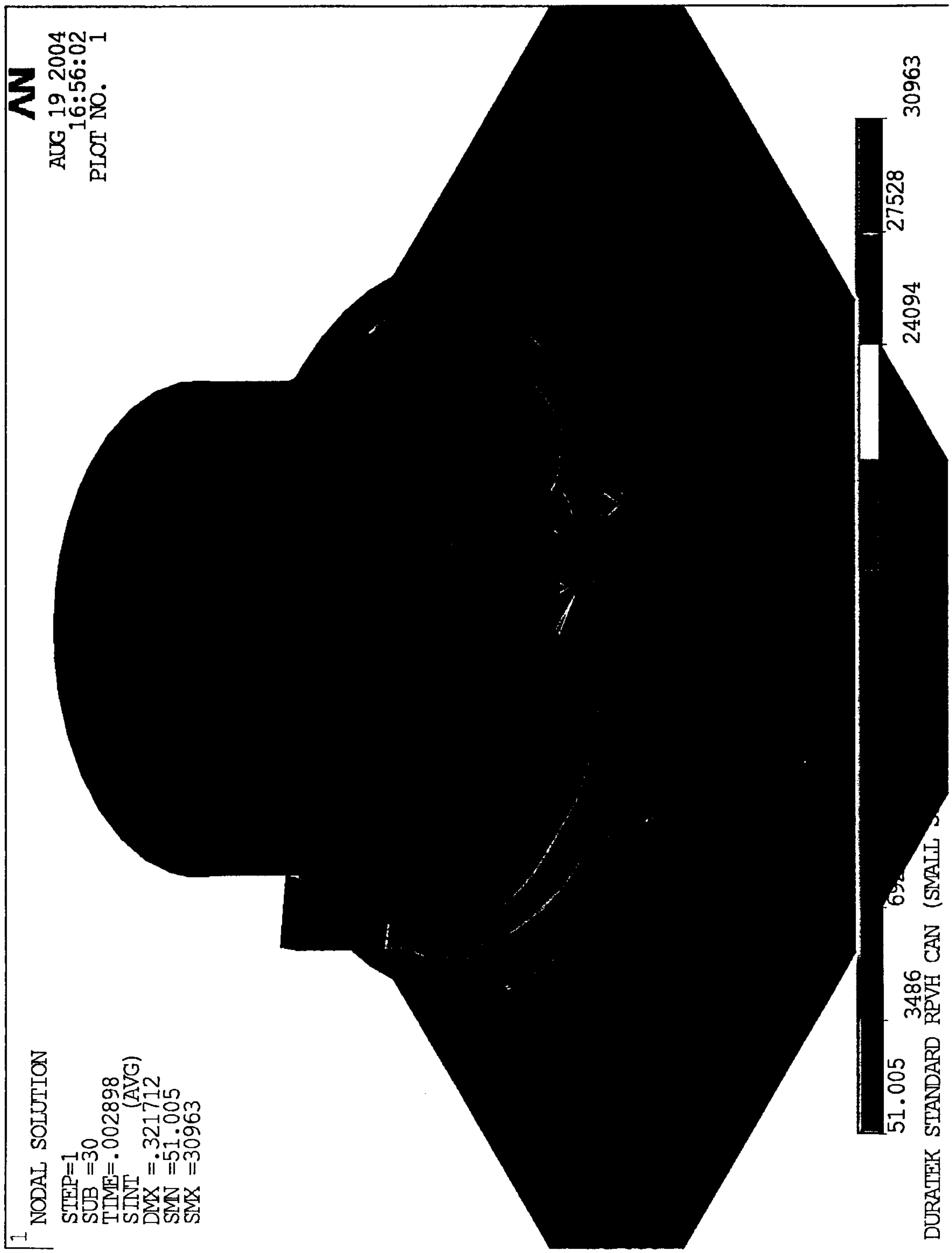

Figure 27

Maximum Stress Intensity Contour Plot in Small Package (Short Configuration) Under Free Drop Scenario 2

(Supplemental can shielding removed from the plot for clarity)

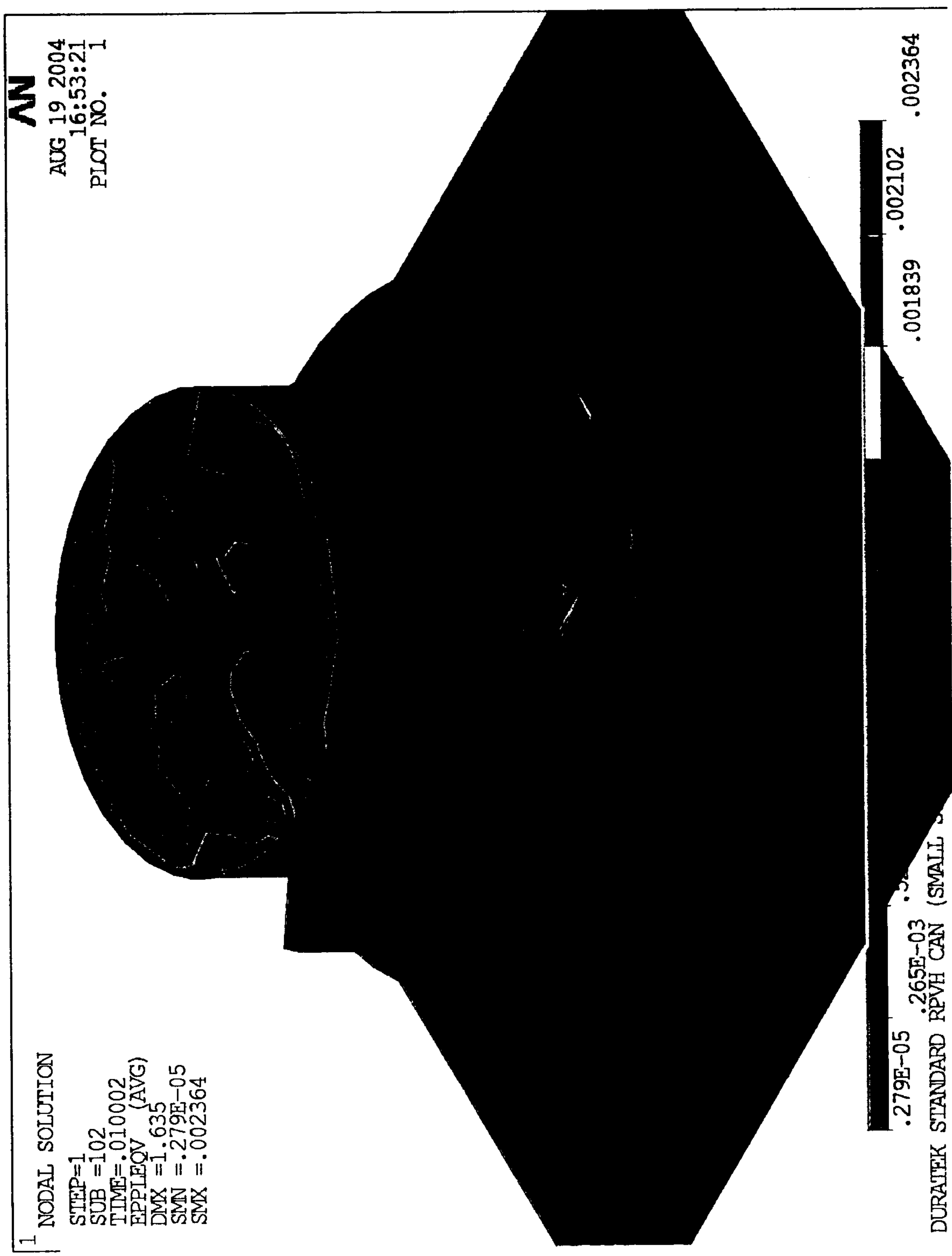

Figure 28

Maximum Plastic Strain Contour Plot in Small Package (Short Configuration) Under Free Drop Scenario 2

(Supplemental can shielding removed from the plot for clarity)

AVAILABILITY OF NON-SCANNABLE ITEMS

Docket / Document Number

13963-N

Old Docket Number, If any

Drawings

Name / Description of Item(s) non-scannable

MAY BE VIEWED IN Room 810, RSPA/Records Center

Agency / Office Name / Room Number / Contact Person {if any)

during the hours of 8:30 am - 5:30 p.m. .

(WPS.x;\ R:\nscanwp)