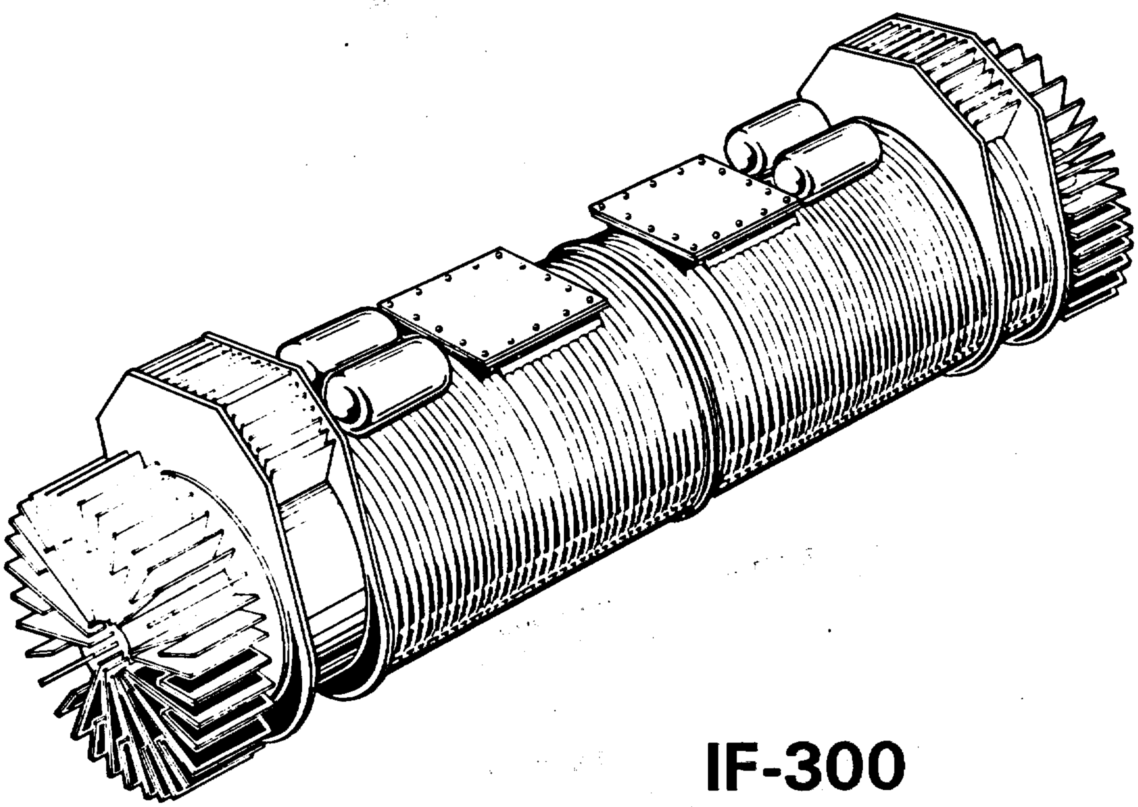
71-9001

VECTRA

NEDO-10084-4
MARCH 1995



IF-300 SHIPPING CASK

CONSOLIDATED SAFETY ANALYSIS REPORT

VOLUME 3

NOTICE AND DISCLAIMER

See Volume 1

VECTRA

March 30, 1995
CJT-95-011

Docket No. 71-9001

United States Nuclear Regulatory Commission
Office of Nuclear Materials Safety and Safeguards
Division of Industrial and Medical Nuclear Safety
Washington, D.C. 20555

ATTENTION: C. R. Chappell, Section Leader
Cask Certification Section
Storage and Transportation Systems Branch

SUBJECT: IF-300 Shipping Cask
Certificate of Compliance No. 9001
Application for Renewal

ENCLOSURE: Pages to Update VECTRA IF-300 Shipping Cask Consolidated Safety Analysis Report (CSAR) from NEDO-10084-3 (September 1984) to NEDO-10084-4 (March 1995) (10 copies)

Dear Mr. Chappell:

In accordance with the provisions of 10CFR71 and 10CFR §170.31 10.A, VECTRA Technologies, Inc. requests the renewal of the Subject Certificate of Compliance. Attachments A, B, and C of this letter present the following:

Attachment A - Requested modifications and revisions to the existing certificate. These modifications and revisions are related to the deletion of Shoreham-specific fuel details and all supplements referenced by the existing certificate.

Attachment B - The disposition of all supplements to the existing certificate.

Attachment C - Instructions for the insertion of enclosed IF-300 shipping cask CSAR revised pages to update NEDO-10084-3 (September 1984) to NEDO-10084-4 (March 1995).

The enclosed pages to update NEDO-10084-3 to NEDO-10084-4 include the following:

VECTRA Technologies, Inc. · 6203 San Ignacio Ave., Suite 100 · San Jose, CA 95119 · Tel: (408) 629-9800
Fax: (408) 281-6186 Engineering · Fax: (408) 281-6202 Fuel Services

1) New Tables of Contents for existing CSAR Volumes 1 and 2.

2) Revised CSAR Volume 1 pages to provide references to the appendices of new Volume 3.

3) New CSAR Volume 3 which incorporates the Channelled BWR Fuel Basket, High Burnup PWR Fuel, and Outer Plastic Wrap "standalone" SAR amendments referenced by the existing certificate into new Appendices A, B, and C, respectively (see Attachment B).

Text revised by VECTRA in CSAR Volume 1 is indicated by a vertical line in the left-hand margin and all pages containing these revisions have headers reading "NEDO-10084-4 / March 1995". All unrevised CSAR Volume 1 pages have headers reading "NEDO-10084-3" with either September 1984 or February, April, or May 1985 revision dates. NEDO-10084-3 Volume 1 and 2 text revised by the original IF-300 primary License holder (General Electric Company) is indicated by a vertical line in the right-hand margin with an "E" or an "N" to indicate an "Editorial" or "New" change, respectively.

Written communications and questions should be directed to the undersigned.

Respectfully submitted,

VECTRA Technologies, Inc.

James W. Cyliui for C. Temus

Charles J. Temus, P.E.
Licensing Manager
Transportation Products

Attachments:

A) Requested Modifications and Revisions to Existing Certificate of Compliance No. 9001, Revision No. 29

B) Disposition of Certificate of Compliance No. 9001, Revision No. 29 Referenced Supplements

C) Page Insertion Instructions to Update NEDO-10084-3 to NEDO-10084-4

cc: R. K. Kunita - CP&L (w/ Atts. & 1 Encl.)
D. C. Poteralski - CP&L (w/o Atts. or Encl.)
R. Heatherington - CP&L (w/o Atts. or Encl.)
T. E. Tehan - VECTRA/Morris (w/ Atts. & 2 Encls.)
K. A. Hoedeman - VECTRA/San Jose (w/ Atts. & 1 Encl.)
C. H. Froehlich - VECTRA/San Jose (w/ Atts. & 1 Encl.)
File: 0132-00163.000

Attachment A

REQUESTED MODIFICATIONS AND REVISIONS TO EXISTING CERTIFICATE OF COMPLIANCE NO. 9001, REVISION NO. 29

(Crossed-out text [~~text~~] to be deleted and italicized text [*text*] to be added.)

1. **Page 2, Paragraph 5.(a)(2):** Revise as follows:

   "The cask has ~~four~~ *three* types of fuel baskets which can be interchanged to accommodate various fuels. The PWR basket holds seven assemblies, the unchannelled BWR basket holds eighteen assemblies, *and* the channelled BWR basket holds seventeen assemblies~~, and the Shoreham BWR fuel basket holds seventeen Shoreham BWR fuel assemblies. The channelled and unchannelled BWR fuel baskets may be provided with supplementary shielding (depleted uranium) near the cask closure.~~"

2. **Page 2, Paragraph 5.(a)(3):** Revise as follows:

   "... 420-11-3006, Sheet 1, Rev. 0~~; 2045.3000, Sheets 1 to 4, Rev. 1; 2045.3001, Sheets 1 and 2, Rev. 1; 2045.3002, Sheet 1, Rev. 1; and 2045.30003, Sheet 1, Rev. 0~~."

3. **Page 4, Paragraph 5.(b)(1)(ii):** Delete this paragraph completely.

4. **Page 5, Paragraph 5.(b)(1)(iii):** Renumber this paragraph 5.(b)(1)(ii).

5. **Page 5, Paragraph 5.(b)(2)(ii):** Revise as follows:

   "Seven PWR fuel assemblies, seventeen channelled BWR assemblies, *or* eighteen unchannelled BWR fuel assemblies~~, or seventeen Shoreham BWR fuel assemblies~~.

6. **Page 5, Paragraph 5.(b)(2)(iii):** Revise as follows:

   "Above fuel assemblies to be contained in their respective fuel baskets as shown in GE Drawing No. 159C5238 - Sheet 6, Rev. 8, *or* PNSI Drawing No. 420-111-3000, Sheet 1 through 9, Rev. 0~~, or PNSI Drawing No. 2045.3002, Sheet 1, Rev. 1~~.

7. Page 6, Paragraph 20: Delete this paragraph completely.

8. Page 6, Paragraphs 21 and 22: Renumber as paragraphs 20 and 21, respectively, and revise expiration date in new Paragraph 21.

9. Page 7, REFERENCES: Revise as follows:

"~~General Electric Uranium Corporation consolidated application dated September 24, 1984.~~

~~General Electric supplements dated: February 8, April 4, and May 10, 1985, and March 12, 1990.~~

~~Pacific Nuclear Systems, Inc. supplements dated: July 26, 1990; March 28, April 12, July 19, and August 30, 1991; January 3, 1992; and February 25, April 9, July 29, and August 10, 1993.~~

~~VECTRA Technologies, Inc. supplement dated: April 25, 1994.~~

VECTRA Technologies, Inc. consolidated application dated March 30, 1995."

Attachment B

DISPOSITION OF CERTIFICATE OF COMPLIANCE NO. 9001, REVISION NO. 29 REFERENCED SUPPLEMENTS

1. General Electric supplements dated:

    a. February 8, 1985: Incorporated into NEDO-10084-3.

    b. April 4, 1985: Incorporated into NEDO-10084-3.

    c. May 10, 1985: Incorporated into NEDO-10084-3.

    d. March 12, 1990: 1990 license renewal request.

2. Pacific Nuclear Systems, Inc. supplements dated:

    a. July 26, 1990: See August 30, 1991.

    b. March 28, 1991: See August 30, 1991.

    c. April 12, 1991: See August 30, 1991.

    d. July 19, 1991: Incorporated as Appendix C in NEDO-10084-4 (Outer Plastic Wrap).

    e. August 30, 1991: Incorporated as Appendix A in NEDO-10084-4 (Channelled BWR Fuel Basket).

    f. January 3, 1992: Deleted (Shoreham basket).

    g. Feb. 25, 1993: Deleted (Shoreham basket).

    h. April 9, 1993: Deleted (Shoreham basket).

    i. July 29, 1993: Deleted (Shoreham basket and tarpaulin).

    j. August 10, 1993: Deleted (Shoreham tarpaulin).

3. VECTRA Technologies, Inc. supplement dated:

    a. April 25, 1994: Incorporated as Appendix B in NEDO-10084-4 (High Burnup PWR Fuel).

Attachment C

PAGE INSERTION INSTRUCTIONS TO UPDATE NEDO-10084-3 TO NEDO-10084-4

A. Volume 1 (in front cover inside pocket of new Volume 3 binder)

1. Replace existing outside binder cover insert (1 sheet) with new binder cover insert (1 sheet).

2. Replace existing binder spine (1 piece) with new binder spine (1 piece).

3. Replace existing title/NOTICE AND DISCLAIMER pages (1 sheet) with new title/NOTICE AND DISCLAIMER pages (1 sheet).

4. Replace existing REVISION SUMMARY (1 sheet) with new REVISION CONTROL SHEETs (2 sheets).

5. Replace existing TABLE OF CONTENTS (1 sheet) with new TABLE OF CONTENTS (2 sheets).

6. Section I

   Replace existing pages 1-1 & 1-2 (1 sheet) with new pages 1-1 & 1-2 (1 sheet).

7. Section II

   a. Replace existing pages 2-1 & 2-2 (1 sheet) with new pages 2-1 & 2-2 (1 sheet).

   b. Replace existing pages 2-3 & 2-3a (1 sheet) with new pages 2-3 & 2-3a (1 sheet).

   c. Replace existing pages 2-4 & 2-5 (1 sheet) with new pages 2-4 & 2-5 (1 sheet).

   d. Replace existing pages 2-8 & 2-9 (1 sheet) with new pages 2-8 & 2-9 (1 sheet).

A. Volume 1 (Continued)

7. Section II (Concluded)

e. Replace existing pages 2-10 & 2-11 (1 sheet) with new pages 2-10 & 2-11 (1 sheet).

f. Replace existing pages 2-14 & 2-15 (1 sheet) with new pages 2-14 & 2-15 (1 sheet).

8. Section III

a. Replace existing pages 3-1 & 3-2 (1 sheet) with new pages 3-1 & 3-1a (1 sheet) and 3-2 & 3-2a (1 sheet).

b. Replace existing pages 3-15 & 3-16 (1 sheet) with new pages 3-15 & 3-16 (1 sheet).

9. Section IV

a. Replace existing pages 4-1 & 4-2 (1 sheet) with new pages 4-1 & 4-2 (1 sheet).

b. Replace existing pages 4-3 & 4-4 (1 sheet) with new pages 4-3 & 4-4 (1 sheet).

c. Replace existing pages 4-5 & 4-6 (1 sheet) with new pages 4-5 & 4-6 (1 sheet).

d. Replace existing pages 4-9 & 4-10 (1 sheet) with new pages 4-9 & 4-10 (1 sheet).

10. Section V

a. Replace existing pages 5-1 & 5-2 (1 sheet) with new pages 5-1 & 5-2 (1 sheet).

b. Replace existing pages 5-3 & 5-4 (1 sheet) with new pages 5-3 & 5-4 (1 sheet).

c. Replace existing pages 5-5 & 5-6 (1 sheet) with new pages 5-5 & 5-6 (1 sheet).

A. Volume 1 (Continued)

10. Section V (Concluded)

d. Replace existing pages 5-101 & 5-102 (1 sheet) with new pages 5-101 & 5-102 (1 sheet).

e. Replace existing pages 5-269 & 5-270 (1 sheet) with new pages 5-101 & 5-102 (1 sheet).

11. Section VI

a. Replace existing pages 6-1 & 6-2 (1 sheet) with new pages 6-1 & 6-1a (1 sheet) and 6-2 & 6-2a (1 sheet).

b. Replace existing pages 6-33 & 6-34 (1 sheet) with new pages 6-33 & 6-34 (1 sheet).

c. Replace existing pages 6-35 & 6-36 (1 sheet) with new pages 6-35 & 6-36 (1 sheet).

12. Section VII

Replace existing pages 7-1 & 7-2 (1 sheet) with new pages 7-1 & 7-2 (1 sheet).

13. Section VIII

a. Replace existing pages 8-1 & 8-2 (1 sheet) with new pages 8-1 & 8-2 (1 sheet).

b. Replace existing pages 8-3 & 8-4 (1 sheet) with new pages 8-3 & 8-4 (1 sheet).

c. Replace existing pages 8-19 & 8-20 (1 sheet) with new pages 8-19 & 8-20 (1 sheet).

A. Volume 1 (Concluded)

14. Section IX

a. Replace existing pages 9-1 & 9-2 (1 sheet) with new pages 9-1 & 9-2 (1 sheet).

b. Replace existing pages 9-5 & 9-6 (1 sheet) with new pages 9-5 & 9-6 (1 sheet).

15. Section X

Replace existing pages 10-3 & 10-4 (1 sheet) with new pages 10-3 & 10-4 (1 sheet).

B. Volume 2 (inside back cover sleeve of new Volume 3)

1. Replace existing outside binder cover insert (1 sheet) with new binder cover insert (1 sheet).

2. Replace existing binder spine (1 piece) with new binder spine (1 piece).

3. Replace existing title/NOTICE AND DISCLAIMER pages (1 sheet) with new title/NOTICE AND DISCLAIMER pages (1 sheet).

4. Replace existing REVISION SUMMARY (1 sheet) with new REVISION CONTROL SHEET (1 sheet).

5. Replace existing TABLE OF CONTENTS (1 sheet) with new TABLE OF CONTENTS (2 sheets).

C. Volume 3 - Completely new binder with new Appendices A, B, and C.

REVISION CONTROL SHEET

See Volume 1

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VOLUME 2

TABLE OF CONTENTS
(Concluded)

VOLUME 3

Appendix A

CHANNELLED BWR FUEL BASKET

Except for pagination and editorial revisions, this appendix is identical in content to Pacific Nuclear (now VECTRA) document titled, "Safety Analysis Report for the IF-300 Shipping Cask Channelled BWR Fuel Basket", Revision 2, dated August 1991. This addendum was originally submitted as an attachment to or as the subject of the July 26, 1990 and March 28, April 12, and August 30, 1991 references in USNRC Certificate of Compliance No. 9001, Revision No. 29.

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(Concluded)

A-1.0 GENERAL INFORMATION

This chapter of the IF-300 Cask Channelled BWR Fuel Basket appendix presents a general introduction to and a description of the IF-300 Cask Channelled BWR Fuel Basket. Terminology used throughout this appendix is presented in Table A-1.0-1. Drawings of the subject basket are included in Section A-1.3.2.

Table A-1.0-1

Terminology and Notation

Package:	The packaging with its radioactive contents. Within this SAR, the Package is the IF-300 Cask with basket and fuel.
Packaging:	The assembly of components necessary to ensure compliance with the packaging requirements (10CFR71.4). Within this SAR, the Packaging is the IF-300 Cask.
IF-300 Cask:	The Packaging as described in the "Consolidated Safety Analysis Report for the IF-300 Shipping Cask" [A-1.3.1-1].
Channelled BWR Fuel Basket:	The assembly which supports the irradiated BWR fuel assemblies with the flow channels, spacers, and fasteners intact within the IF-300 Cask.

A-1.1 Introduction

The IF-300 Cask Channelled BWR Fuel Basket has been developed by Pacific Nuclear Systems, Inc. (PNSI) (currently VECTRA Technologies, Inc. [VECTRA]) as a means to transport irradiated BWR fuel with the flow channels intact in the IF-300 Shipping Cask (Model IF-300, Certificate of Compliance No. 9001 [A-1.3.1-2]). The design utilizes nearly identical interfaces with the IF-300 Cask body as the BWR fuel basket authorized for use by the NRC under the Certificate of Compliance No. 9001 [A-1.3.1-2]. No modification to the IF-300 Cask containment boundary is required to accommodate the Channelled BWR Fuel Basket. As such, this modification to the package has no significant effect on the design, operating characteristics, and safe performance of the IF-300 Cask containment system.

Prior to 1991, the IF-300 Cask was licensed for transport of seven (7) pressurized water reactor (PWR) or eighteen (18) boiling water reactor (BWR) irradiated fuel assemblies [A-1.3.1-1]. The IF-300 Cask Channelled BWR Fuel Basket is designed to accommodate seventeen (17) irradiated BWR fuel assemblies, with the associated flow channels, spacers, and fasteners intact.

This appendix presents the information provided in 1991 for authorization of the IF-300 Cask Channelled BWR Fuel Basket for shipment of irradiated channelled BWR fuel assemblies under the provisions for modifications of contents of a Type B package of 10CFR71.13 [A-1.3.1-3].

A-1.2 Package Description

A-1.2.1 Packaging

1. Summary Description of IF-300 Cask

   The IF-300 Cask is a stainless steel cased, depleted uranium shielded cask. The cask is cylindrical in shape, 64 inches in diameter with a maximum length of 210 inches. The cavity dimensions are 37.5 inches in diameter by 180.25 inches long. Shielding is provided by four (4) inches of depleted uranium, 2.13 inches of stainless steel, and a minimum of 4.5 inches of a water/ethylene glycol mixture. The closure heads are secured to the cask body by means of thirty-two 1-3/4 inch studs and nuts, and is sealed with a metallic ring gasket. The cavity is penetrated by a vent line at the top and a drain line at the bottom, which are sealed with stainless steel globe valves and valved quick-disconnect couplings or stainless steel pipe caps. The vent line is equipped with a rupture disk.

All valves are housed in protective boxes on the cask exterior.

The cask is shipped horizontally on a 37.5 foot long by 8 foot wide skid. The cask is covered by a retractable aluminum enclosure. The cask is primarily designed for shipment by rail, however it may be transported for short distances by heavy haul truck. The gross weight of the cask is approximately 140,000 pounds, The skid and other external components weigh approximately 45,000 pounds.

No modifications are made to the cask body, support skid, or hold down restraints for use of the Channelled BWR Fuel Basket.

2. Summary Description of IF-300 Cask 18-Cell BWR Fuel Basket

The IF-300 Cask BWR Fuel Basket licensed prior to 1991 accommodates up to eighteen (18) BWR fuel assemblies. The basket consists of nine (9) 1.00 inch thick spacer disks and one (1) 0.50 inch thick top plate made of AISI 200 Type 216 stainless steel. A 4.0 inch wide by 0.50 inch thick type 216 stainless steel flange is welded to the outside edge of each spacer disk. The spacer disks and top plate are supported in position by four (4) 2.25 inch diameter Type 216 stainless steel support rods. Each basket cell is formed of 16 gage sheet Type 304 stainless steel with slotted walls. The bottom of each cell is closed with a 0.38 inch thick Type 304 stainless steel end plate which supports the fuel assemblies 0.50 inch from the bottom of the cask cavity.

Neutron absorption and moderation is accomplished by use of poison rods consisting of 0.50 inch diameter stainless steel tubes filled with boron carbide. A total of 112 rods are positioned between each set of spacer disks.

Additional gamma shielding is provided in the top end of the basket by use of 1.00 inch thick depleted uranium shield blocks. The depleted uranium blocks are encased in Type 304 stainless steel, and are supported in position by a series of Type 304 stainless steel support plates welded to the top spacer disk and by 0.38 inch diameter stainless steel pins passing through and welded to the top plate.

Two Type 304 stainless steel lifting lugs are provided for handling of the basket, which are attached to the top spacer disk and top plate. The bottom spacer disk is notched to fit around a lug located at the bottom of the cask cavity, preventing rotation of the basket within the cask during shipment and handling and ensuring proper alignment of the basket within the cask.

The IF-300 18-Cell BWR Fuel Basket is 179.25 inches long and 37.38 inches in diameter. The basket with fuel weighs 16,925 pounds, the empty basket weighs 5,675 pounds [A-1.3.1-1].

3. Description of Channelled BWR Fuel Basket

The gross shipping weight of the IF-300 Cask is defined in the Certificate of Compliance as 140,000 lb, and the maximum gross weight of the cavity contents is limited to 21,000 pounds. The gross weight of the contents utilizing the IF-300 Cask Channelled BWR Fuel Basket is 17,890 pounds. A detailed summary of this weight is provided in Table A-2.2-1.

The major basket components, i.e. the spacer disks and the support rods, are fabricated from ASME SA240 and SA479 Type XM-19 stainless steel. The shielding blocks located at the top end of the basket are fabricated from depleted uranium, cased in ASTM A240 Type 304 stainless steel, with ASTM A479 Type XM-19 stainless steel support pins. The fuel assembly supports located at the bottom of the basket are fabricated from ASME SA240 Type 304 stainless steel. The neutron poison plates are fabricated from ASTM A887 Grade 304B5 Type A borated stainless steel. The borated stainless steel sheets are supported by ASME SA240 Type 304 guide bars. All other components of the basket are fabricated from ASME SA240 Type 304 stainless steel.

The general configuration of the Channelled BWR Fuel Basket is nearly identical to that of the 18-Cell BWR Fuel Basket. The basket consists of nine (9) individual 2.00 inch thick spacer disks and one (1) 1.25 inch thick top plate with seventeen (17) 5.96 inch fuel cell openings. The spacer disks and top plate are supported in place by four (4) 3.00 inch diameter support rods. The shielding blocks are supported between the top spacer disk and the top plate, and are secured by means of pins, which are integral with the shield block assembly, which pass through the spacer disk and top plate and are welded to the top plate. The lifting lugs and support plates are welded to the top spacer disk and the top plate.

Fuel support plates, consisting of 0.375 inch end plates supported by 11 gage side plates attached to the bottom spacer disk, maintain the location of the fuel assemblies 1/2 inch off the bottom of the cask, as is the case for the 18-Cell BWR Fuel Basket design. This assures that the fuel assemblies are properly positioned within the cask such that the fuel grid straps are aligned with the spacer disks, and so that the gap of the fuel assembly at the top of the cask is identical to the gap for fuel shipped in the 18-Cell BWR Fuel Basket. As is the case for the 18-cell baskets, a spacer assembly is placed in the top head of the cask to minimize the gap between the top of the fuel assemblies and the cask. The spacer assembly used in the IF-300 cask BWR head for the Channelled BWR Fuel Basket is identical in design to the spacer assembly used with the 18-Cell BWR Fuel Basket, except the spacer assembly is drilled to accommodate 17 spacer plates instead of the 18 used for the existing basket.

Neutron moderation and absorption is achieved by use of ASTM A887 borated stainless steel plates. The plates are 26 inches and 33 inches wide and 0.25 and 0.31 inches thick, and 6.25 inches and 6.5 inches wide and 0.25, 0.31, 0.38, and 0.44 inches thick. Further discussion of neutron absorption and moderation is provided in Chapter A-6.0.

The overall basket dimensions are 179.25 inches long and 37.310 inches in diameter.

There are no special devices utilized on the IF-300 Cask for dissipation of heat, and none is required for use of the Channelled BWR Fuel Basket. There are no coolants utilized other than the normal inert transportation atmosphere of helium, nitrogen, or argon. The maximum heat load for the package is 40,000 Btu/hour. A more detailed discussion of the thermal characteristics of the basket and package is provided in Chapter A-3.0.

Lifting of the IF-300 Cask Channelled BWR Fuel Basket is accomplished by use of two lifting lugs located at the top of the basket assembly. As previously stated, the lifting lugs are welded to the top spacer disk and top plate. The lifting lug features are identical to those of the 18-Cell BWR Fuel Basket, and will interface with the same lifting and handling equipment. The lifting lugs are only used for handling the basket without fuel.

The bottom spacer disk is notched to fit around a lug located in the bottom of the cask cavity. This arrangement prevents rotation of the basket within the cask during handling and shipment, and assures proper orientation of the basket within the cask. Again, this is identical to the 18-Cell BWR Fuel Basket arrangement.

As in the IF-300 Cask 18-Cell BWR Basket design, the IF-300 Channelled BWR Fuel Basket design provides gamma shielding in addition to that in the cask body. This shielding consists of depleted uranium blocks encased in stainless steel located at the top end of the basket. The uranium blocks are 1.00 inch thick, and 7.50 inches high. The blocks in the Channelled BWR Fuel Basket are located at the perimeter of the basket between the top spacer disk and top plate. Further detail regarding shielding is provided in Chapter A-5.0.

A-1.2.2 <u>Operational Features</u>

The operational features of the IF-300 Cask are unaffected by the Channelled BWR Fuel Basket.

A-1.2.3 <u>Contents of Packaging</u>

The IF-300 Channelled BWR Fuel Basket is designed to ship up to seventeen (17) intact, undamaged BWR fuel assemblies with flow channels which meet the constraints imposed in this appendix.

1. Fuel Acceptance Parameters

   Fuel acceptance parameters are established to assure that no regulatory limits are exceeded during normal or accident conditions of transport. The fuel acceptance parameters are summarized in Table A-1.2-1. By limiting the package contents to the specifications herein, the analytical parameters used in the structural, thermal, shielding, and criticality analyses documented by this appendix can be presumed to be bounding conditions.

   The list of fuel types qualified for shipment is shown in Table A-1.2-2. These fuel designs are shown in this document to be bounded or equivalent to the reference fuel design used in each analytical discipline. There is therefore no restriction on mixing different fuel designs within a single shipment.

   The shipment of fuel assemblies, or other material, which do not meet these acceptance parameters is not addressed in this appendix. Fuels which have peak enrichments higher than the design basis, or fuels which are not included in the list of qualified fuel types may be acceptable for shipment pending qualification and a license amendment.

2. Defective Fuel

Fuel defects may range from pin hole sized leaks in a single rod to gross cladding failure resulting in total rod separation or gross assembly distortion. The IF-300 Certificate of Compliance No. 9001 [A-1.3.1-2] prohibits the shipment of known or suspected failed fuel assemblies (rods) and fuel with cladding defects greater than pin holes and hairline cracks.

In the event of fuel failure during shipment utilizing the IF-300 Channelled BWR Fuel Basket, the thermal, shielding, structural and criticality control performance of the package would not be affected. There would be no impact on thermal analyses since defective fuel has no more heat load than design basis fuel. The shielding analysis would not be affected by defective fuel since the neutron and gamma ray source terms would be unaffected (in fact, there is a likelihood of a very small percentage decrease in activity due to the prior leakage of gaseous fission products from the fuel-clad gap). The structural analysis would not be affected by defective fuel since the overall fuel assembly size and weight would be unaffected. Adequacy for criticality is not impacted unless the fuel/moderator volume ratio is significantly altered, or gross loss of pellet confinement within the fuel cladding has occurred. It is shown in Chapter A-6.0 of this SAR that fuel rod distortions tend to drive reactivity downward. The only limitation on defective fuel with regard to criticality is therefore that no assemblies with gross cladding failure (sufficient to release pellets or fuel shards) may be transported. Partial assemblies may be shipped providing that dummy rods are inserted to preserve the fuel/moderator volume ratio.

3. Radionuclide Inventory

The IF-300 Cask, when fitted with the IF-300 Channelled BWR Fuel Basket, may contain substantial quantities of radionuclides in the form of irradiated fuel pellets, fuel-clad free volume fission products, and surface contamination on the payload itself. This inventory has been estimated using the assumption that the cask is fully loaded with seventeen (17) design basis channelled BWR fuel assemblies.

The estimated radionuclide inventory for shielding design basis fuel is presented in Chapter A-5.0 of this appendix. Chapter A-3.0 addresses the estimated amount of fission gases which are presumed to be available for release from the fuel-cladding free volume. The effects of fuel crud are discussed in Chapter A-4.0.

Table A-1.2-1

Fuel Qualification Acceptance Parameters

Parameter	Value
Number of Assemblies	≤ 17
Fuel Design	See Table A-1.2-2
Initial Enrichment, w/o U235	≤ 4.0
Burnup	0-35 GWd/MTIHM
Decay Time	120 days (1)
Fuel Channels	Intact

NOTE:

1. Decay time is limited to a minimum of 120 days by the Certificate of Compliance. Required decay time for shipment will be as required to meet the head load and source terms as documented in Sections A-3.1.1 and A-5.2, respectively.

Table A-1.2-2

Qualified Fuel Designs

Fuel Design [A-1.3.1-4] (1)	Reactor Class
GE 7x7 GE-3, V1	GE BWR/2,3
GE 7x7 GE-3, V2a	GE BWR/4,5,6
GE 7x7 GE-3, V2b	GE BWR/4,5,6
GE 8x8 GE-4, V1	GE BWR/2,3
GE 8x8 GE-4, V2a	GE BWR/4,5,6
GE 8x8 GE-4, V2b	GE BWR/4,5,6
GE 8x8 GE-5, V1	GE BWR/2,3
GE 8x8 GE-5, V2	GE BWR/4,5,6
GE 8x8 Pres., V1	GE BWR/2,3
GE 8x8 Pres., V2	GE BWR/4,5,6
GE 8x8 Barrier, V1	GE BWR/2,3
GE 8x8 Barrier, V2	GE BWR/4,5,6
GE 8x8 GE-8, V1a	GE BWR/2,3
GE 8x8 GE-8, V1b	GE BWR/2,3
GE 8x8 GE-8, V2a	GE BWR/4,5,6
GE 8x8 GE-8, V2b	GE BWR/4,5,6

NOTE:

1. Other BWR fuel types matching the physical characteristics of the GE BWR fuel types listed above are also acceptable.

A-1.3 Appendix

A-1.3.1 References

[1] Consolidated Safety Analysis Report for IF-300 Shipping Cask, NEDO-10084-3, Volumes 1 & 2, General Electric Company, Docket No. 71-9001, May 1985.

[2] "Certificate of Compliance for Radioactive Materials Packages," Model No. IF-300, Certificate No. 9001, Revision 23, Package Identification No. USA/9001/B( )F, Dated May 1990.

[3] "Packaging and Transportation of Radioactive Materials," Title 10, Code of Federal Regulations, Part 71 (10CFR71), USNRC, 5/31/88.

[4] Moore, R.S., Notz, K.J., "Physical Characteristics of GE BWR Fuel Assemblies," Oak Ridge National Laboratory, June, 1989, ORNL/TM-10902.

A-1.3.2 Drawings

[A] IF-300 Shipping Cask Channelled BWR Fuel Basket Assembly, Drawing No. 420-11-3000, Rev. 1.

[B] IF-300 Shipping Cask Channelled BWR Fuel Basket Poison Plates, Drawing No. 420-11-3001, Rev. 1.

[C] IF-300 Shipping Cask Channelled BWR Fuel Basket Shield 1 Assy, Drawing No. 420-11-3002, Rev. 1.

[D] IF-300 Shipping Cask Channelled BWR Fuel Basket Shield 2 Assy, Drawing No. 420-11-3003, Rev. 1.

[E] IF-300 Shipping Cask Channelled BWR Fuel Basket Shield 3 Assy, Drawing No. 420-11-3004, Rev. 1.

[F] IF-300 Shipping Cask Channelled BWR Fuel Basket Shield 4 Assy, Drawing No. 420-11-3005, Rev. 1.

[G] IF-300 Shipping Cask Spacer Assembly for Channelled BWR Fuel Basket, Drawing No. 420-11-3006, Rev. 1.

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-01

(PARTS LIST CONTINUED ON SHEET 2)

ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
24	2		FUEL SUPPORT SIDE PLATE MID-OUTER, .1196 THK (11 GAGE) X 8 5/16 X [illegible]	ASME SA240 TYPE 304
23	4		FUEL SUPPORT SIDE PLATE OUTER, .1196 THK (11 GAGE) X 6 7/8 X [illegible]	
22	2		FUEL SUPPORT SIDE PLATE INNER, .1196 THK (11 GAGE) X 30 X [illegible]	
21	2		FUEL SUPPORT SIDE PLATE MIDDLE, .1196 THK (11 GAGE) X 19 X [illegible]	
20	4		FUEL SUPPORT END PLATE OUTER, 3/8 X 8 5/8 X 6 5/16	
19	1		FUEL SUPPORT END PLATE INNER, 3/8 X 20 X 7 1/8	
18	2		FUEL SUPPORT END PLATE MIDDLE, 3/8 X 20 X 6 13/16	ASME SA240 TYPE 304
17	128		RETAINER BLOCK, 3/4 X 1 1/2 X 3 3/8	ASME SA-240 TYPE 304
16	4		GUIDE TYPE 3, BAR 3/4 X 3/4 X 33 1/2	ASME SA-240 TYPE 304
15	24		GUIDE TYPE 2, BAR 3/4 X 3/4 X 33 1/2	
14	24		GUIDE TYPE 1, BAR 3/4 X 3/4 X 33 1/2	
13	2		TOP SUPPORT, PLATE 3/4 X 3 X 8 1/2	
12	2		LIFTING LUG, 3/4 X 3 X 14 13/16	ASME SA-240 TYPE 304
11	4		SUPPORT ROD, 60 OF	ASME SA-479 TYPE 304-H
10	1		TOP PLATE, 1 1/4 THK	ASME SA-240 TYPE 304-H
9	1		SPACER DISC TOP, PLATE 1 THK	
8	1		SPACER DISC BOTTOM, PLATE 1 THK	
7	7		SPACER DISC, PLATE 1 THK	ASME SA-240 TYPE 304-H
6	2	420-11-3005-02	SHIELD 4 ASSEMBLY, LH	
5	2	420-11-3005-01	SHIELD 4 ASSEMBLY, RH	
4	2	420-11-3004-02	SHIELD 3 ASSEMBLY, LH	
3	2	420-11-3004-01	SHIELD 3 ASSEMBLY, RH	
2	2	420-11-3003	SHIELD 2 ASSEMBLY	
1	[illegible]	420-11-3002	SHIELD 1 ASSEMBLY	

PARTS LIST

DIMENSIONS ARE IN INCHES AND DECIMALS UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES

3RD PROJECTION

DO NOT SCALE DRAWING

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San Jose, CA

TITLE SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

PART NO.	DWG NO.	SHEET	REV NO.
420-11-3000	420-11-3000	1 OF 1	1

2 1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-02

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
42	28		GUIDE TYPE 5, BAR 3/4 X 3/4 X 8 1/2	ASME SA-240 TYPE 304
41	28		GUIDE TYPE 4, BAR 3/4 X 3/4 X 8 3/4	ASME SA-240 TYPE 304
40	2	420-11-3000-116	POISON PLATE TYPE 16	
39	2	420-11-3000-115	POISON PLATE TYPE 15	
38	12	420-11-3000-114	POISON PLATE TYPE 14	
37	12	420-11-3000-113	POISON PLATE TYPE 13	
36	2	420-11-3000-112	POISON PLATE TYPE 12	
35	2	420-11-3000-111	POISON PLATE TYPE 11	
34	2	420-11-3000-110	POISON PLATE TYPE 10	
33	2	420-11-3000-109	POISON PLATE TYPE 9	
32	2	420-11-3000-108	POISON PLATE TYPE 8	
31	2	420-11-3000-107	POISON PLATE TYPE 7	
30	2	420-11-3000-106	POISON PLATE TYPE 6	
29	18	420-11-3000-105	POISON PLATE TYPE 5	
28	2	420-11-3000-104	POISON PLATE TYPE 4	
27	2	420-11-3000-103	POISON PLATE TYPE 3	
26	2	420-11-3000-102	POISON PLATE TYPE 2	
25	2	420-11-3000-101	POISON PLATE TYPE 1	

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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TITLE

SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK CHANNELLED BWR FUEL BASKET ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
420-11.3000	420-11-3000		2 OF 8	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-03

(SEE SHEET 1 & 2 FOR PARTS LIST)

ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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San Jose, CA

TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3500	420-11-3500		3 OF 8	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-04

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

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BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV. NO.
420-11.3000	420-11-3000		4 OF 8	1

2 1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-05

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

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BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV. NO.
420-11.3000	420-11-3000		5 OF 9	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-06

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

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BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK CHANNELLED BWR FUEL BASKET ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3000	420-11-3000		6 OF 9	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-07

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

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3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

P/F NO.	DWG NO.	SCALE	SHEET	REV NO.
420-11.3000	420-11-3000		7 OF 1	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-08

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3000	420-11-3000		8 OF 9	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-09

(SEE SHEET 1 AND 2 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M–1982.

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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Pacific Nuclear Fuel Services, Inc.
San Jose, CA

TITLE
SAFETY ANALYSIS REPORT
IF–300 SHIPPING CASK
CHANNELLED BWR FUEL
BASKET ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420–11.3000	420–11–3000		9 OF 9	1

2 1 A

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-10

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.	Pacific Nuclear Fuel Services, Inc. San Jose, CA
BREAK AND DEBURR ALL SHARP EDGES .02	TITLE: SAFETY ANALYSIS REPORT IF-300 SHIPPING CASK CHANNELLED BWR FUEL BASKET POISON PLATE
3D PROJECTION	
DO NOT SCALE DRAWING	FILE NO. 420-11.3001 / DWG. NO. 420-11-3001 / SCALE / SHEET 1 OF 1 / REV. NO. 1

FIGURE WITHHELD UNDER 10 CFR 2.390

9508020436-11

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
7	8		STUD TOP, #3/8 X 2 1/16 LG	A479 TYPE XM-19
6	8		STUD BOTTOM, #3/8 X 3 3/16 LG	A479 TYPE XM-19
5	1		COVER BACK PLATE, .060 THK (16 GA) X 7 LG	A240 304 SS
4	1		COVER FRONT PLATE, .060 THK (16 GA) X 7 LG	A240 304 SS
3	2		COVER END, 3/16 THK X 7 1/4 LG	A276 304 SS
2	2		TOP/BOTTOM BAR, 1/2 THK X 14 9/16 LG	A276 304 SS COLD DRAWN
1	1		DEPLETED URANIUM SHIELDING	(SEE NOTE 8)

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

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TITLE
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 1 ASSEMBLY

REF NO.	DWG NO.	SCALE	SHEET	REV NO.
420-11.3002	420-11-3002		1 OF 2	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9605020436 - 12

(SEE SHEET 1 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M–1982.

BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

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TITLE: SAFETY ANALYSIS REPORT

IF–300 SHIPPING CASK CHANNELLED BWR FUEL BASKET SHIELD 1 ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
420–11.3002	420–11–3002		2 OF 2	1

2 1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436 -13

7	[illegible]		STUD TOP, [illegible]	[illegible]
6	[illegible]		STUD BOTTOM, [illegible]	[illegible]
5	1		COVER BACK PLATE, [illegible]	A240 304 SS
4	1		COVER FRONT PLATE, [illegible]	A240 304 SS
3	2		COVER END, [illegible]	A240 304 SS
2	2		TOP/BOTTOM BAR, [illegible]	A479 304 SS [illegible]
1	1		[illegible] URANIUM SHIELDING	[illegible]
ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

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Pacific Nuclear Fuel Services, Inc.

SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 2 ASSEMBLY

FSCM NO.	DWG NO.	SCALE	SHEET	REV NO.
420-91.3003	420-91-3043		1 OF 2	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-14

(SEE SHEET 1 FOR PARTS LIST)

PARTS LIST

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BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

DO NOT SCALE DRAWING

SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK

CHANNELLED BWR FUEL BASKET

SHIELD 2 ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3003	420-11-3003		2 OF 2	1

A

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-15

ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
8	[illegible]		STUD TOP, [illegible]	A479 TYPE [illegible]
7	[illegible]		STUD BOTTOM, [illegible]	A479 TYPE [illegible]
6	1		COVER BACK PLATE, .060 THK (16 GA) X 7 LG	A240 304 SS
5	1		COVER FRONT PLATE, .060 THK (16 GA) X 7 LG	A240 304 SS
4	1		COVER END LH, 3/16 THK X 7 1/4 LG	A276 304 SS
3	1		COVER END RH, 3/16 THK X 7 1/4 LG	A276 304 SS
2	2		TOP/BOTTOM BAR, RH/LH [illegible]	A276 304 SS COLD DRAWN
1	1		DEPLETED URANIUM SHIELDING	(SEE NOTE 4)

PARTS LIST

Pacific Nuclear Fuel Services, Inc.

SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 3 ASSEMBLY

420-11-3004 | 420-11-3004 | SHEET 1 OF 3 | REV 1

3RD PROJECTION

DO NOT SCALE DRAWING

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436-16

(SEE SHEET 1 FOR PARTS LIST)

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

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TITLE SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 3 ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3004	420-11-3004		2 OF 2	1

FIGURE WITHHELD UNDER 10 CFR 2.390

VERSION CHART

9505020436-17

ITEM NO.	QTY REQ'D	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
8	2		STUD TOP, ø3/8 X 3 [illegible]/16 LG	A479 TYPE XM-19
7	2		STUD BOTTOM, ø3/8 X 3 5/16 LG	A479 TYPE XM-19
6	1		COVER BACK PLATE, .090 THK (16 GA) X 8 1/8 X 7 LG	A240 304 SS
5	1		COVER FRONT PLATE, .090 THK (16 GA) X 7 LG	A240 304 SS
4	1		COVER END LH, 3/16 THK X 7 1/4 LG	A276 304 SS
3	1		COVER END RH, 3/16 THK X 7 1/4 LG	A276 304 SS
2	2		TOP/BOTTOM BAR, RH/LH 1/2 THK X 4 13/16 LG	A276 304 SS COLD DRAWN
1	1		DEPLETED URANIUM SHIELDING	(SEE NOTE [illegible])

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .010

3D PROJECTION

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TITLE SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 4 ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV. NO.
420-11.3005	420-11-3005		1 OF 2	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436 -18

(SEE SHEET 1 FOR PARTS LIST)

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .03

3D PROJECTION

DO NOT SCALE DRAWING

Pacific Nuclear Fuel Services, Inc.

SAFETY ANALYSIS REPORT

IF-300 SHIPPING CASK
CHANNELLED BWR FUEL BASKET
SHIELD 4 ASSEMBLY

FILE NO.	DWG. NO.	SCALE	SHEET	REV NO.
420-11.3005	420-11-3005		2 OF 2	1

FIGURE WITHHELD UNDER 10 CFR 2.390

9505020436 -19

3

ITEM NO.	QTY REQD	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
2	6		LUG, PLATE 3/8 THK	ASTM A240 TYPE 304
1	1		SPACER, PLATE 7/8 THK	ASTM 240 TYPE 304

PARTS LIST

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS OTHERWISE NOTED. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ANSI Y14.5M-1982.

BREAK AND DEBURR ALL SHARP EDGES .02

3D PROJECTION

DO NOT SCALE DRAWING

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San Jose, CA

TITLE:
SAFETY ANALYSIS REPORT
IF-300 SHIPPING CASK
SPACER ASSY FOR CHANNELLED
BWR FUEL BASKET

FILE NO.	DWG NO.	SCALE	SHEET	REV. NO.
420-11.3006	420-11-3006		1 OF 1	1

A-2.0 STRUCTURAL EVALUATION

This chapter presents the structural evaluation of the IF-300 Cask Channelled BWR Fuel Basket and its conformance with all applicable structural criteria. Normal and hypothetical accident condition evaluations are performed in accordance with 10CFR71 [A-2.10.1-1] requirements.

The results of the detailed analyses are presented which demonstrate that the IF-300 Channelled BWR Fuel Basket will remain functional under normal transport and hypothetical accident conditions, and as such will maintain the configuration of the contained fuel assemblies and neutron absorption media to assure criticality safety. Much of the detailed analysis is included in Section A-2.10.3 in which computer analytical model input and output listings have been provided.

A-2.1 Structural Design

A-2.1.1 Discussion

The IF-300 Cask Channelled BWR Fuel Basket consists of nine 37.31 inch diameter by 2 inch thick spacer disks, one 37.31 inch diameter by 1¼ inch thick top plate, four 3 inch diameter support rods, neutron poison plates between the spacer disks, and depleted uranium (D.U.) shield block assemblies between the top spacer disk and the top plate.

In order to accommodate BWR fuel assemblies with channels intact, the Channelled BWR Fuel Basket has been designed. The configuration and structural elements of the Channelled BWR Fuel Basket are very similar to that of the IF-300 cask 18-Cell BWR Fuel Basket [A-2.10.1-2]. Care has been taken to maintain as closely as possible the basket to cask body interface and the loaded basket weight to ensure minimal differences in the cask body loading. Compared to the 18-Cell BWR Fuel Basket, the Channelled BWR Fuel Basket design provides:

- Reduced capacity from 18 to 17 fuel assemblies,
- Larger spacer disk fuel cell openings,
- Thicker spacer disks with no perimeter flange,
- No guide sleeves,
- No poison rods,
- Borated stainless steel neutron poison plates,
- Larger diameter axial support rods,
- Higher strength support rod and spacer disk materials, and
- Modified D.U. shield blocks.

The Channelled BWR Fuel Basket design is shown in detail in the drawing included in Section A-1.3.2. The basket is designed to maintain the fuel and neutron poison plate positions during all normal and accident conditions.

The spacer disks are positioned at the BWR fuel grid strap locations, as shown in Figure A-2.1-1. During normal transportation and postulated side drop accident conditions, the fuel weight is transferred through the spacer disks to the cask body. During postulated end drop accident conditions, the fuel weight is carried by the cask body top or bottom and the basket support rods carry the weight of the basket and maintain the basket configuration. The positions of the spacer disks are maintained by the support rods. The load from the poison plates and D.U. is carried by the spacer disks and transferred through the spacer disk to the support rods by attachment welds. The support rod loads are transferred directly to the cask body through the cask end plates.

The D.U. is attached to the spacer disk and top plate by connection pins extending through the D.U. into the top spacer disk and the top plate. The pins support the D.U. blocks between the top plate and top spacer disk during normal transport and postulated side drop accident conditions. The poison plates are attached to the spacer disks by guide bars which are welded to the spacer disks. The guide bars support the poison plates during normal and accident loads but permit the poison plates to thermally expand.

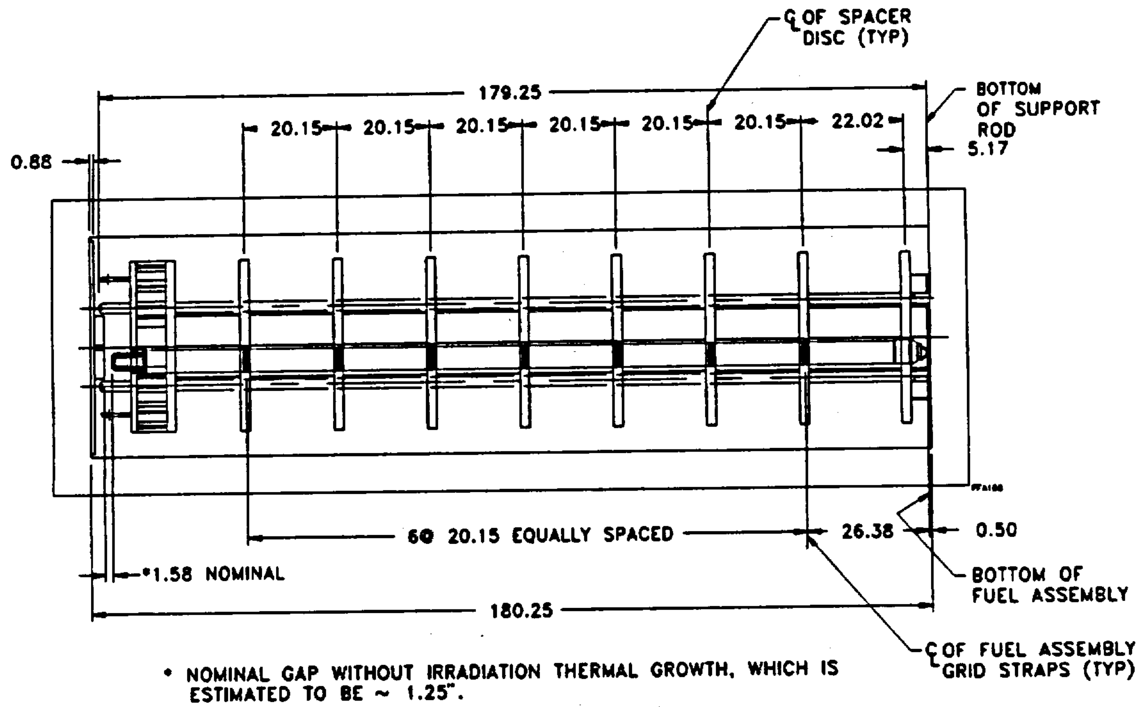


Figure A-2.1-1

Fuel Grid Strap and Spacer Disk Locations

A-2.1.2 Design Criteria

1. Allowable Stresses

   1. Allowable Stress Limits for ASME Materials

      This section defines the allowable limits for primary membrane, primary bending, secondary, bearing, and shear stresses and the required factor of safety against instability (i.e. buckling) for all components in the Channelled BWR Fuel Basket assembly. The basket is designed in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NG and Appendices, 1986 through 1988 Addenda [A-2.10.1-3]. Table A-2.1-1 summarizes the allowable criteria used in this analysis.

   2. Allowable Stress Limits For Non-ASME Materials

      The Channelled BWR Fuel Basket assembly consists entirely of ASME accepted materials except for the poison plates and depleted uranium. The poison plates are required only to be self-supporting for the applicable load combinations and perform no other structural function. Bending stress and buckling are the controlling design factors for the poison plates as shown in Sections A-2.7.1.1.4 and A-2.7.1.2.8. The allowable stress limit for the poison plate in bending is taken as the material yield stress for all load combinations and service limits. The allowable buckling load is $0.67P_{cr}$ where P_{cr} is the elastic buckling load. The depleted uranium in the Channelled BWR Fuel Basket assembly is used to provide additional radiation shielding and not as a structural material. The stainless steel cover sheets maintain the integrity of the shield blocks and meet all the allowable stress limits. No credit is taken for the structural strength of the depleted uranium.

2. Load Combinations

   The load combinations used in the Channelled BWR Fuel Basket assembly analysis are developed in accordance with Regulatory Guide 7.8 [A-2.10.1-4] for the applicable basket loads. The resulting load combinations are shown in Table A-2.1-2.

3. Miscellaneous Structural Criteria

1. Brittle Fracture

With the exception of the depleted uranium shield blocks, all components of the Channelled BWR Fuel Basket are fabricated from austenitic stainless steels. The spacer disks, support rods, and depleted uranium shield block connection pins are fabricated from Type XM-19 austenitic stainless steel, and the handling attachments and poison plate guide bars are fabricated of Type 304 austenitic stainless steel. The poison plate material has ductile to brittle properties similar to Type 304 stainless steel. Since these materials do not undergo a ductile to brittle transition in the temperature range of interest (down to -40°F), they are not subject to brittle fracture. Brittle fracture of the depleted uranium shield blocks is not a concern as the load of the blocks is carried by the Type 304 cover sheets which are not subject to brittle fracture.

2. Fatigue

A fatigue analysis of the basket assembly is required to evaluate the effects of cyclic loads. The fatigue analysis is performed in accordance with the requirements of NG-3222.4(e) [A-2.10.1-3]. All significant cyclic loads, including thermal cycling and vibration, are evaluated to determine the cumulative usage factor.

Table A-2.1-1

Allowable Stress Limit Criteria [A-2.10.1-3]

STRESS CONDITION	ALLOWABLE STRESS[1]
Normal Condition - Service Level A	
P_m	S_m
P_l	$1.5S_m$
$P_l + P_b$	$1.5S_m$
$P_l + P_b + Q$	$3S_m$
Bearing Stress	S_y
Pure Shear	$0.6S_m$
Accident Condition - Service Level D	
P_m	The lesser of $2.4S_m$ and $0.7S_u$
$P_l + P_b$	150% of P_m allowable
$P_l + P_b + Q$	Need not be evaluated
Bearing Stress	Need not be evaluated
Pure Shear	$0.42S_u$
Buckling - The buckling load shall not exceed $0.67P_{CR}$ where P_{CR} represents the elastic collapse load	

NOTE:

1. These allowable limits apply to all basket structural components. The poison plates shall be limited to S_y for bending for all conditions, and shall meet the requirement that the maximum load be less than 0.67 times the critical elastic buckling load.

Table A-2.1-2

Load Combination Definitions[A-2.10.1-4] [1]

Load Combination Number [1]	Description	ASME Code Service Level [A-2.10.1-3]
1.	One Foot Drop + Normal Thermal	A
2.	Thirty Foot Drop	D
3.	Accident Thermal	N/A [2]
4.	Vibration & Shock + Normal Thermal	A [3]

Notes:

1. All other load combinations specified by Regulatory Guide 7.8 [A-2.10.1-4] are not applicable for the Channelled BWR Fuel Basket assembly.

2. Accident thermal need not be evaluated per ASME Code [A-2.10.1-3] Service Level D (accident condition) requirements. Evaluation of the accident thermal (fire accident) case is performed to demonstrate it has no adverse effect on the Channelled BWR Fuel Basket.

3. Evaluated for fatigue.

A-2.2 Component Weights

The total weight of the Channelled BWR Fuel Basket assembly without fuel is 6,415 lbs. The total weight with 17 channelled BWR fuel assemblies is 17,890 lbs. A summary of the basket assembly component weights is provided in Table A-2.2-1.

Table A-2.2-1

Channelled BWR Fuel Basket Assembly Component Weights

COMPONENT	WEIGHT[1] (lbs)
Top Plate (1 total)	157
Spacer Disks (9 total)	2,357
Support Rods (4 total)	1,445
Depleted Uranium Shield Blocks	518
Poison Plates	1,670
Guide Bars	241
Lifting Lugs/Support Plates	27
Empty Basket Weight	6,415
Channelled Fuel Assemblies (17 total)	11,475[2]
Loaded Basket Weight	17,890

Notes:

1. Component weights are calculated based on the dimensions shown on the drawings in Section A-1.3.2 and the material densities discussed in Section A-2.3.

2. Channelled BWR fuel weight is based on a per assembly weight of 675 lbs [A-2.10.1-5] for 17 fuel assemblies.

A-2.3 Mechanical Properties of Materials

The Channelled BWR Fuel Basket assembly is fabricated from austenitic stainless steels Type 304 and Type XM-19 (ASME SA-240 and SA-479), borated Type 304 stainless poison plates and Type 304 stainless cased depleted uranium. A brief description of the materials follows. A listing of the material properties used in the analysis is included in Table A-2.3-1.

A-2.3.1 Types 304 and XM-19 Stainless Steels

Type 304 and XM-19 stainless steels are ASME Code approved materials with high corrosion resistance. None of these materials experience a ductile to brittle transition in the design basis temperature ranges of interest and therefore are not subject to brittle fracture. The density of these stainless steels used in the analysis is 0.285 lb/in^3 [A-2.10.1-6].

A-2.3.2 Borated Type 304 Stainless Steel Poison Plates

The poison plates are a borated version of Type 304 stainless steel meeting the requirements of ASTM A887 Grade 304B5 Type A [A-2.10.1-7]. Tests of borated stainless materials have demonstrated high corrosion resistance and ductility [A-2.10.1-8]. The material exhibits good impact toughness, with Charpy impact values of about 25 ft-lbs at -20°F (29°C) [A-2.10.1-8]. The temperatures of the loaded basket, even for an ambient air temperature of -40°F (-40°C), are well above this temperature. Therefore, it is concluded that brittle fracture of the borated stainless steel material is not a concern. The density of borated stainless steel used in the analysis is 0.280 lb/in^3 [A-2.10.1-9].

A-2.3.3 Depleted Uranium

Depleted uranium (D.U.) is used in the shield blocks in the top end of the basket assembly. The depleted uranium is cased in Type 304 stainless steel. The density of depleted uranium used in the analysis is 0.673 lb/in^3 [A-2.10.1-10].

Table A-2.3-1

Mechanical Properties of Materials

STEEL MATERIAL SPEC.	TYPE OR GRADE	TEMP (°F)	STRESS (ksi) YIELD S_Y	STRESS (ksi) ULTIMATE S_U	STRESS (ksi) ALLOWABLE S_M	ELASTIC MODULUS (10^6 psi)	COEF. OF THERMAL EXPANSION (10^{-6} in/in·°F)
SA 240[1]	304	100	30.0	75.0	20.0	28.3	8.55
		300	22.5	66.0	20.0	27.0	9.00
		500	19.4	63.5	17.5	25.8	9.37
		650	17.9	63.5	16.2	24.8	9.61
SA 240[1] and SA 479[1]	XM-19	100	55.0	100.0	33.3	28.3	8.30
		300	43.4	94.3	31.4	27.0	8.65
		500	38.8	89.1	29.7	25.8	8.92
		650	36.8	87.1	29.0	24.8	9.09
A887[2]	304B5 Grade A	500	35.0	75.0	N/A[6]	25.8[4]	9.69[5]
Depleted Uranium[3]		300	28.5	N/A[6]	N/A[6]	26.5	8.34

Notes:

1. Reference A-2.10.1-3 Tables, I-1.2, I-2.2, I-3.2, I-5.0, and I-6.0.
2. References A-2.10.1-7, 8, and 9.
3. Reference A-2.10.1-11.
4. Values of SA 240 Type 304 are used.
5. Value at 650°F.
6. Not Available.

A-2.4 General Standards for All Packages

The IF-300 Cask CSAR [A-2.10.1-2] provides justification that the general standards for the packaging are met. Additional information specifically applicable to the Channelled BWR Fuel Basket is provided in the following sections.

A-2.4.1 Minimum Package Size

The Channelled BWR Fuel Basket has no effect on package size.

A-2.4.2 Tamperproof Feature

Since the Channelled BWR Fuel Basket is contained within the cask body, it does not effect the tamperproof features of the packaging.

A-2.4.3 Positive Closure

Since the Channelled BWR Fuel Basket is contained within the cask body, it does not effect the positive closure of the packaging.

A-2.4.4 Chemical and Galvanic Reactions

The cask body surfaces and the fuel baskets are constructed of stainless steel. This material does not react with steam or water either chemically or galvanically. The fuel is designed to be chemically nonreactive in water filled systems. The uranium shield blocks are completely cased in stainless steel. A potential for reaction of the D.U. with the 304 stainless steel casing and the XM-19 stainless steel connection studs exists in that a low melting point eutectic can form between the steel and uranium. However this phase change does not occur until 714°C (1317°F) [A-2.10.1-12] which is significantly higher than the basket temperatures as reported in Chapter A-3.0. No additional measures are required to prevent reaction between these materials since the entire package is chemically and galvanically inert.

A-2.5 Lifting and Tiedown Standards for All Packages

The payload weight of the Channelled BWR Fuel Basket assembly is well below the maximum payload weight of 21,000 lbs. specified by the Certificate of Compliance [A-2.10.1-13]. The existing cask lifting devices and tiedowns are not affected by the Channelled BWR Fuel Basket and are therefore not addressed herein.

A-2.6 Normal Conditions of Transport

The Channelled BWR Fuel Basket Assembly, when subjected to the normal conditions of transport as specified in 10CFR71.71, meets the performance requirements specified in Subpart E of 10CFR71 [A-2.10.1-1]. This is demonstrated in the following sections where each normal condition is addressed and shown to meet the applicable design criteria.

A-2.6.1 Heat

The thermal evaluation for the normal and off-normal events is performed in Chapter A-3.0. The structural evaluation of the resulting thermal distributions is presented later in this section.

1. Summary of Pressures and Temperatures

   The basket assembly is not a pressure boundary. Therefore, pressure loads need not be addressed in the structural analysis. The controlling design temperatures for normal conditions of transport used in the structural analysis are listed in Table A-2.6-1.

2. Differential Thermal Expansion

   1. Spacer Disk Differential Thermal Expansion

      The spacer disk differential thermal expansion is evaluated in the spacer disk thermal stress analysis in Section A-2.6.1.3.1.

   2. Support Rod Thermal Expansion

      The maximum design temperature of the support rods from Table A-2.6-1 is 300°F. The nominal length of the support rods is 179.25 inches. The maximum thermal growth of the support rods can be calculated as:

      $$\begin{aligned}\delta_t &= \alpha L \Delta T \\ &= 8.65(10^{-6})(179.25)(300 - 70) \\ &= 0.357 \text{ inches}\end{aligned}$$

      The nominal internal cavity length of the cask cavity is 180.25 inches [A-2.10.1-2]. The gap which exists between the cask interior end plates and the support rods δ_d, is:

      $$\begin{aligned}\delta_d &= 180.25 - 179.25 \\ &= 1.00 \text{ inches}\end{aligned}$$

This exceeds the maximum thermal growth of the support rods. Therefore the support rods will expand freely and will not experience thermal stresses. This calculation conservatively assumes no thermal growth in the cask body.

3. Depleted Uranium Thermal Expansion

The shield block assembly differential thermal expansion is calculated in conjunction with the shield block assembly thermal stress analysis in Section A-2.6.1.3.3.

4. Poison Plate Thermal Expansion

The poison plate design temperature is 500°F (Table A-2.6-1). The thermal growth of the poison plate will only result in stress occurring in the poison plate if the gap between the poison plates and spacer disks attachment guide bars is closed. The support rods of the spacer disks will also expand as the poison plates expand. Differential growth between the support rods and poison plates greater than the available gap will result in thermal stresses in the poison plates. Using a conservative length of the support rod between spacer disks of 20 inches, the thermal growth of the support rods based on a design temperature of 300°F is:

$$\begin{aligned} \delta_r &= \alpha L \Delta T \\ &= 8.65(10^{-6})(20)(300 - 70) \\ &= 0.040 \text{ inches} \end{aligned}$$

Also using a 20 inch length of poison plate and a design temperature of 500°F, the thermal growth of the poison plates is:

$$\begin{aligned} \delta_p &= \alpha L \Delta T \\ &= 9.69(10^{-6})(20)(500 - 70) \\ &= 0.083 \text{ inches} \end{aligned}$$

The differential thermal growth is then:

$$\begin{aligned} \Delta &= 0.083 - 0.040 \\ &= 0.043 \text{ inches} \end{aligned}$$

The gap minimum specified between the poison plate and the guide bars is 0.06 inch. The poison plate will therefore expand freely and will not experience thermal stress.

3. Stress Calculations

1. Spacer Disk Thermal Stress Analysis

The temperature distribution of the spacer disk for normal conditions, calculated in Chapter A-3.0, is applied to a finite element analytic model by specifying nodal temperature values. The nodal temperatures are applied at the spacer disk outer edge and the interior nodes of the fuel cell openings. The thermal stresses are evaluated only for radial thermal gradients (plane stress evaluation). The out-of-plane (through-thickness) thermal stresses are negligible. The radial differential thermal growth due to the non-uniform temperature distribution results in membrane stresses in the spacer disk. Node and element plots of the analytical model used for this analysis are shown in Figures A-2.6-1 and A-2.6-2, respectively.

The maximum membrane stress intensity due to the normal temperature distribution is 45.1 ksi. The results of the spacer disk thermal stress analysis are included in Section A-2.10.3.

2. Spacer Disk Thermal Fatigue Analysis

The fatigue analysis of the basket assembly is performed in accordance with NG-3222.4(e) [A-2.10.1-3]. A fatigue strength reduction factor of 2.0 is conservatively assumed to account for any imperfections which may exist in the spacer disk plates. The value of S_{alt} is adjusted by the ratio of the fatigue curve modulus of elasticity (Figure I-9.2.1 [A-2.10.1-3]) to the material modulus of elasticity as required by the ASME Code [A-2.10.1-3].

The maximum normal thermal stress for the spacer disk is:

$$\sigma = 45.1 \text{ ksi}$$

The maximum alternating stress intensity, S_{alt}, is then:

$$S_{alt} = 1/2(45.1)(2.0)(28.3/25.8)$$
$$= 49.5 \text{ ksi}$$

The permissible number of cycles for S_{alt} = 49.5 ksi is 35,000 cycles (Figure I-9.2.1

[A-2.10.1-3]). Conservatively assuming 24 shipments per year for an assumed design life of 25 years, the total number of thermal cycles would be 600. The usage factor for this would be:

$$U = 600/35{,}000 = 0.017$$

The cumulative fatigue usage factor is addressed in Section A-2.6.5.

3. Shield Block Thermal Stress Analysis

The D.U. shield block assemblies are fabricated at room temperature. The D.U. coefficient of thermal expansion is less than the coefficient of thermal expansion for the stainless steel casing. The coefficient of thermal expansion of the XM-19 stainless steel support rods is less than the coefficients of thermal expansion for the stainless steel casing.

The free thermal growth of the D.U., stainless steel casing sheets and the support rods, δ_{du}, δ_{ss} and δ_r can be calculated as:

$$\delta = \alpha \ell \Delta t$$

$$\begin{aligned} \delta_{du} &= 8.34(10^{-6})(7.0)(300 - 70) \\ &= 0.0134 \text{ inches} \end{aligned}$$

$$\begin{aligned} \delta_{ss} &= 9.00(10^{-6})(7.5)(300 - 70) \\ &= 0.0155 \text{ inches} \end{aligned}$$

$$\begin{aligned} \delta_{r} &= 8.65(10^{-6})(7.5)(300 - 70) \\ &= 0.0149 \text{ inches} \end{aligned}$$

Conservatively assuming no strain in the D.U., the strain and resulting stress in the D.U. shield block stainless steel casing due to differential thermal expansion is:

$$\begin{aligned} \epsilon_{ss} &= (\delta_{ss} - \delta_{du})/\ell \\ &= (0.0155 - 0.0149)/7.5 \\ &= 8.00\ (10^{-5}) \end{aligned}$$

$$\begin{aligned} \sigma_{ss} &= E\epsilon \\ &= 27.0(10^{6})(8.00)(10^{-5})/1000 \\ &= 2.2 \text{ ksi} \end{aligned}$$

To allow sufficient differential thermal growth between the D.U. shield blocks and the support rods, a nominal gap of 0.18 inch is provided between the D.U. shield blocks and the top spacer disk.

4. Poison Plate Thermal Stress Analysis

Thermal stress for the poison plates is addressed in Section A-2.6.1.2.4.

4. Comparison with Allowable Stresses

The controlling normal conditions of transport load combination is:

Normal Thermal + One Foot Drop

Table A-2.6-2 lists the normal thermal and one foot cask drop stresses for the basket assembly major components. Also shown are the combined stresses and their comparison to allowable limits. The stresses for a postulated one foot cask drop are calculated in Section A-2.6.7.

A-2.6.2 Cold

For the cold condition, a -40°F steady state ambient temperature is specified [A-2.10.1-1]. This temperature in conjunction with no fuel load in the cask will result in a minimum temperature throughout the cask of -40°F. The materials of construction for the Channelled BWR Fuel Basket are not adversely affected by the -40°F condition.

A-2.6.3 Reduced External Pressure

The basket assembly is not a pressure boundary and the effects of external pressure on the cask body have no effect on the Channelled BWR Fuel Basket.

A-2.6.4 Increased External Pressure

The basket assembly is not a pressure boundary and the effects of external pressure on the cask body have no effect on the Channelled BWR Fuel Basket.

A-2.6.5 Vibration

The stresses induced by vibration normally incident to handling and transportation of the package are considered to be negligible. The basket loads resulting from the normal vibration accelerations will conservatively be less than 10g's [A-2.10.1-14]. When compared to the stresses resulting from the normal condition one foot drop loads (Section A-2.6.7), it is obvious that stresses due to a 10g or less vibration load will be enveloped by those due to the drop condition.

The fatigue analysis of the basket assembly is performed in accordance with NG-3222.4(e) [A-2.10.1-3]. The evaluation is performed for the vibration loads, and for the cumulative effects of vibration and thermal loads for the expected life of the basket.

An analysis of the spacer disk is performed using the analytical model shown in Figure A-2.6-4 and A-2.6-5 to determine dead weight stress. The results of this analysis are provided in Section A-2.10.3. The resulting maximum dead weight stress in the spacer disk is 441 psi. The maximum expected acceleration of a transport vehicle bed is a 10g [A-2.10.1-14]. The maximum normal operation vibration stress intensity can then be conservatively calculated as:

σ = 10(441)
= 4410 psi (conservatively using peak accelerations, ignoring direction of acceleration)

The range of the vibration stress is then:

$$\sigma = (4.41)(2.0) = 8.82 \text{ ksi}$$

Using the applicable fatigue strength reduction factor and modulus of elasticity adjustment as discussed in Section A-2.6.1.3.2, the resulting alternating stress is:

$$S_{alt} = 1/2(8.82)(2.0)(28.3/25.8) = 9.7 \text{ ksi}$$

The allowable number of cycles for this alternating stress exceeds 10^{11} cycles (Figure I-9.2.2 [A-2.10.1-3]). Conservatively assuming 1,000,000 cycles per shipment, the total number of cycles is 600,000,000 and the resulting usage factor is:

$$U1 = 600{,}000{,}000/10^{11} = 0.006$$

The fatigue usage factor for thermal loads as calculated in Section A-2.6.1.3.2 is:

$$U2 = 0.017$$

The cumulative usage factor is then:

$$U = U1 + U2$$
$$= 0.017 + 0.006 = 0.023 << 1.0$$

For the normal conditions of transport, all Channelled BWR Fuel Basket components except the spacer disks have maximum vibration stress for the vertical or lateral accelerations of the cask on the transport vehicle. The maximum expected acceleration in these directions is 4g, which is less than half of the 10g value used in the above evaluation. Since the spacer disk fatigue evaluation resulted in a very small usage factor (<3%), and the controlling accelerations for the remaining basket components are less than 50% of those used in the spacer disk evaluation, no fatigue evaluation of the remaining basket components is necessary.

It is concluded that fatigue in the Channelled BWR Fuel Basket is not a concern.

A-2.6.6 Water Spray

The Channelled BWR Fuel Basket need not be subject to the water spray test.

A-2.6.7 Free Drop

The regulations [A-2.10.1-1] include a one-foot drop as part of the normal conditions of transport. Since the IF-300 Cask is transported solely in a horizontal orientation, an analysis of the package (cask body and basket) postulated to be dropped one foot need only be performed for the horizontal orientation to satisfy the intent of the regulations.

The one foot horizontal side drop load definition is taken from Reference A-2.10.1-2, page 5-294, paragraph 2, which states "*The peak deceleration was 210 g's with the total time from zero to peak and back to zero being about 0.0005 second ....*". This load results from the cask postulated to be dropped one foot while restrained in the skid. Consistent with the currently approved design basis for the package, this load definition represents an enveloping design basis for the Channelled BWR Fuel Basket.

1. Spacer Disk One Foot Side Drop

   A finite element analysis is used for the spacer disk one foot horizontal side drop evaluation. The loads and reactions considered in the spacer disk one foot side drop analysis are illustrated in Figure A-2.6-3 and described in detail in this section. The associated dynamic analyses of the spacer disk are carried out using the finite element program ANSYS [A-2.10.1-15]. The corresponding spacer disk analytical model node and element geometry is shown in Figures A-2.6-4 and A-2.6-5. Mass elements are included in the analytical model at the nodes representing the contact surface between the fuel and the spacer disk cells to account for the weight of the fuel. The one foot drop acceleration time history loads taken from Reference A-2.10.1-2 are applied to the analytical models. The spacer disk contact with the cask body is modeled with radial gap elements. Due to the symmetric nature of the 0° orientation drop, a half symmetry model is used in the analysis. The spacer disk cell openings are modeled as 6.0 inch square openings. The modeled ligament widths which result are the minimum thicknesses permissible for the worst case tolerance deviations during fabrication.

The spacer disk one foot drop analysis is a small displacement theory linear elastic analysis with geometric nonlinearities performed using direct integration. The time steps used in the analyses are based on guidelines set by the ANSYS program and evaluation of the results to establish the refinement required in the time step size and response duration.

Appropriate boundary conditions are utilized in the spacer disk analytical model. Symmetric boundary conditions are included along the vertical centerline of the model. The boundary along the lower contact surface of the spacer disk with the cask body is modelled with gap elements which model the effects of the non-uniform radial gap between the smaller spacer disk outer diameter and the larger inside diameter of the cask. Initial contact is assumed at the bottom location.

The spacer disk computer evaluation input and output listings for the one foot drop analysis are provided in Section A-2.10.3. Maximum displacement and stress time history results are presented graphically in Figures A-2.6-6 through A-2.6-8. The maximum spacer disk one foot drop primary membrane (P_m), local primary membrane plus primary bending ($P_l + P_b$), and primary plus secondary ($P_l + P_b + Q$) stress intensities are calculated to be:

P_m = 15.3 ksi
$P_l + P_b$ = 23.8 ksi
$P_l + P_b + Q$ = 23.8 ksi

2. Top Plate One Foot Side Drop

Although no credit is taken for the 1¼ inch thick top plate during the side drop accident for support of the fuel, it will carry half of the depleted uranium shielding load. All loading from the fuel is assumed to be carried by the 2 inch thick spacer disks. The weight of the depleted uranium is assumed to be carried equally by the top plate and the top spacer disk. This analysis determines the effect of the accelerated D.U. weight on the top plate during the side drop accident. Since the top plate is constructed of the same material as the spacer disks, the same material properties are used in the analysis.

The top plate side drop analysis uses the same analytical techniques used for the spacer disk. The top plate drop analysis is performed using the ANSYS model shown in Figure A-2.6-4 and A-2.6-5 for the spacer disk 0° drop analyses, with an appropriate thickness change. The one foot drop analysis of the 1¼" top plate is performed using a top plate thickness of 3/4". The stresses in the top plate result from the decelerated mass of the top plate, poison sheets and D.U. shield blocks. Since increasing the thickness of the top plate increases the inertia of the plate, and consequently the flexural stiffness, the stresses due to external loading (i.e. the decelerated mass of the poison sheets and D.U. shield blocks) are conservatively large. The stresses due to the decelerated self mass of the top plate do not change significantly since both the mass and the inertia increase linearly with the thickness. Consequently, the stress results from the 3/4" top plate side drop analyses are conservative and are used for the qualification of the modified IF-300 basket assembly. The side drop acceleration time history load from Reference A-2 is applied to the analytical model in a linear transient dynamic analysis.

The weight of the D.U. on the top plate is simulated by applying mass elements to the appropriate locations on the analytical model and applying the drop load decelerations. The boundary conditions used for the top plate side drop analysis are the same as those for the spacer disk analysis.

The one foot drop analysis results for the top plate are provided in Section A-2.10.3. Maximum displacement and stress time history results are presented graphically in Figures A-2.6-9 through A-2.6-11. The maximum top plate one foot drop primary membrane (P_m), local primary membrane plus primary bending ($P_l + P_b$), and primary plus secondary ($P_l + P_b + Q$) stress intensities are:

P_m	=	24.1 ksi
$P_l + P_b$	=	27.7 ksi
$P_l + P_b + Q$	=	30.2 ksi

3. Support Rod One Foot Side Drop

The postulated one foot side drop analysis load time history (210 g's peak load) is bounded by the 30 foot drop load time history (214 g's peak load). The stresses calculated for the 30 foot side drop analysis assuming a static 214g load are conservatively used for the one foot drop analysis (see Section A-2.7.1.2.6) of the support rod. The loads and reactions considered in the support rod 30 foot side drop analysis are illustrated in Figure A-2.7-6. The resulting one foot drop stress intensity, S.I., calculated using a DLF of 2.0, is then conservatively taken as:

$P_l + P_b \quad = \quad 19.9$ ksi

4. Depleted Uranium Shield Block One Foot Side Drop

The D.U. shield blocks are evaluated as simply supported beams. The loads and reactions considered in the shield block side drop analysis are illustrated in Figure A-2.7-14 and described in detail in the following model description. The 210g one foot drop peak loading is applied to the critical shield block as a static load with a dynamic load factor (DLF). No credit is taken for the structural strength of the D.U. Based on the evaluation results of the shield blocks for the 30 foot side drop in Section A-2.7.1.2.7, shield block Assembly No. 1 is evaluated as the critical shield block. The stress in the shield block casing due to the one foot drop loads is calculated as:

$$\sigma = (Mc/I)(DLF)$$

where,

$M = (w\ell^2/8)$
$c = h/2$
$I = bh^3/12 + ad^2$
$w =$ shield block weight per inch
$h =$ height of shield block

The moment of inertia of the casing assembly for shield block No. 1, conservatively evaluated as a 12 inch wide rectangle, is:

$$I = \{0.19(1.0)^3/12\}2 + \{12(0.06)^3/12 + 12(0.06)(.53)^2\}2$$
$$= 0.44 \text{ in}^4$$

The moment of inertia of shield block No. 1 including the D.U. is:

$$I = 0.44 + \{12-2(0.19)\}(1.0)^3/12$$
$$= 1.41 \text{ in}^4$$

The DLF is dependent on the natural frequency of the shield block assembly and the loading frequency. The frequency of the shield block assembly is determined based on the assumption that it acts on a pinned end beam. The weight of shield block No. 1 is 67.45 lbs. The fundamental frequency of a pinned end beam is defined as:

$\omega \quad = \quad A\{EI/\mu L^4\}^{1/2}$ rad/sec
([A-2.10.1-16] Appendix 1.1)

where,

$A \quad = \quad 9.87$
$E \quad = \quad 25.8(10^6)$ psi
$L \quad = \quad 7.5$ in
$\mu \quad = \quad$ mass per unit length
$\quad = \quad 67.45/(7.5)(386.4)$
$\quad = \quad 0.0233$ lb-sec^2/in

Therefore,

$\omega \quad = \quad 9.87\{25.8(10^6)(1.41)/0.0233(7.5)^4\}^{1/2}$
$\quad = \quad 6637$ rad/sec
$\quad = \quad 1004$ Hz

The loading frequency is:

$f_p \quad = \quad 1/\tau$
$\quad = \quad 1/1(10^{-3})$ (full cycle)
$\quad = \quad 1000$ hz.

The frequency ratio is:

$f_r \quad = \quad 1004/1000$
$\quad = \quad 1.0$

The resulting DLF is:

DLF = 1.6 ([A-2.10.1-16] Figure 42.13)

The shield block casing bending stresses are then calculated as:

$w \quad = \quad 67.45/7.5$
$\quad = \quad 8.993$ lbs/in (for 1g load)

$M \quad = \quad 8.993(7.5)^2/8$
$\quad = \quad 63.2$ in-lb. (for 1 g load)

$\sigma \quad = \quad 63.2(1.12/2)(210)(1.6)/0.44(1000)$
$\quad = \quad 27.0$ ksi

The maximum shear stress is calculated for the shield block assembly connection pins. The shear loads are assumed to be evenly distributed between all 16 pins. The shear stress is given by:

$\sigma \quad = \quad 4V/3A$

where:

$A \quad = \quad \pi(0.38)^2/4$
$\quad\;\; = \quad 0.11\ in^2$

and the load per stud for the Assembly No. 1 is:

$V \quad = \quad 67.45/16$
$\quad\;\; = \quad 4.22\ lbs.$

The maximum shear stress in the pins is therefore:

$\sigma \quad = \quad (5.53/0.11)(4/3)(210)(1.6)/1000)$
$\quad\;\; = \quad 22.5\ ksi$

The pins are made of 17-4 PH stainless, which has an S_m = 42.8 ksi at 500°F. Therefore the allowable shear stress is:

$\sigma_{all} \quad = \quad 0.6(42.8)$
$\quad\;\; = \quad 25.7\ ksi$

5. Poison Plates One Foot Drop

The poison plates are non-structural items and need only support their own weight under the deceleration load of the postulated drop events. The main criteria for the poison plates is that they remain in place for criticality control. The poison plates are evaluated using the simple ANSYS [A-2.10.1-15] analytical model shown in Figure A-2.6-12. The model consists of elastic beam elements. The beam properties are based on a one inch wide strip of plate. It is assumed no variation in response occurs along the width of the plates. The loads and reactions considered in the poison plate side drop analysis are illustrated in Figure A-2.7-25 and described in detail in the following model description. The ANSYS evaluation uses a linear dynamic analysis to evaluate the response of the poison plates when subjected to the one foot drop loads. This analysis is used to determine the maximum bending and deflection of the plates. The critical poison plates analyzed in the one foot drop analysis are the 7/16 inch thick plates with the acceleration applied normal to the flat surface of the plate.

The time history discussed in Section A-2.6.7 is used as the input loading to the poison plate model. The poison plate is loaded by its own mass excited by the applied acceleration time history.

The one foot drop analysis results are included in Section A-2.10.3. The maximum stress intensity of the borated stainless steel poison plate is:

$P_l + P_b \quad = \quad 6.4$ ksi

The longitudinal deflection of the poison sheet is very small. The maximum vertical deflection at the center of the poison sheet span is:

$\delta_y \quad = \quad 0.038$ in.

A-2.6.8 Corner Drop

The Channelled BWR Fuel Basket need not be evaluated for the corner drop, since this test does not apply to the IF-300 shipping cask, as the package weight is in excess of 100 kg (220 lb.) and the materials of construction do not include wood or fiber board.

A-2.6.9 Compression

The Channelled BWR Fuel Basket need not be evaluated for compression. This test does not apply to the IF-300 shipping cask, since the package weight is in excess of 5,000 kg (11,000 lbs.).

A-2.6.10 Penetration

This test does not apply to the Channelled BWR Fuel Basket. The puncture surface is the IF-300 Cask body.

Table A-2.6-1

Basket Assembly Design Temperatures

Basket Assembly Component	Design[1] Temperature (°F)
Spacer Disk	500
Support Rod	300
Depleted Uranium Shield Block	300
Poison Plate	500

Notes:

1. Design temperature based on results of normal conditions of transport thermal analysis, Section A-3.4.

Table A-2.6-2

Comparison of Normal Condition Stresses to Allowable Stresses

Basket Assembly Component	Type of stress	Load Condition Stress: Normal Thermal (Ksi)	Load Condition Stress: One Foot Drop (Ksi)	Combined Stresses	Allowable Stress	Factor of Safety
1¼" top plate	P_m	---	24.1	24.1	29.7	1.23
	$P_l + P_b$	---	27.7	27.7	44.6	1.61
	$P_l + P_b + Q$	45.1	30.2	75.3	89.1	1.18
2" Spacer Disk	P_m	---	15.3	15.3	29.7	1.94
	$P_l + P_b$	---	23.8	23.8	44.6	1.87
	$P_l + P_b + Q$	45.1	23.8	68.9	89.1	1.29
Support Rods	P_m	---	0.0	0.0	31.4	NA
	$P_l + P_b$	---	19.9	19.9	47.1	2.37
	$P_l + P_b + Q$	0.0	19.9	19.9	94.2	4.73
D.U. Shield Blocks	P_m	---	0.0	0.0	20.0	NA
	$P_l + P_b$	---	27.0	27.0	30.0	1.11
	$P_l + P_b + Q$	2.2	27.0	29.2	60.0	2.05
Poison Plates ~~45~~	P_m	---	0.0	0.0	23.3[1]	NA
	$P_l + P_b$	---	6.4	6.4	35.0[1]	5.47
	$P_l + P_b + Q$	0.0	6.4	6.4	35.0[1]	5.47

Note:

1. Allowable stress for P_m is taken as 2/3 S_y ([A-2.10.1-3] Appendix III-2110 (4)). Allowable stress for $P_l + P_b$ and $P_l + P_b + Q$ is conservatively limited to the material yield strength.

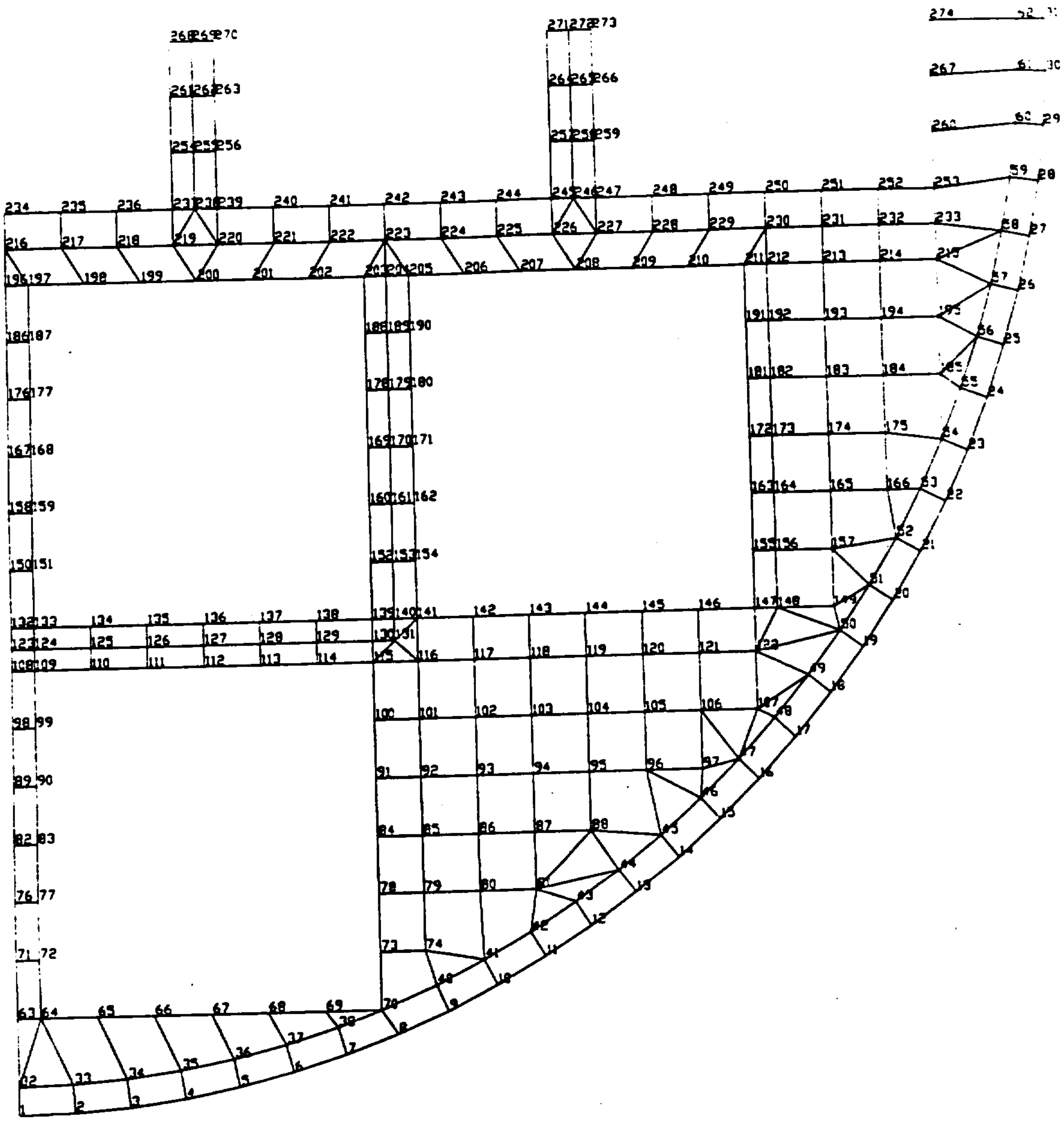


Figure A-2.6-1

Spacer Disk Thermal Stress Analytical Model Nodal Geometry

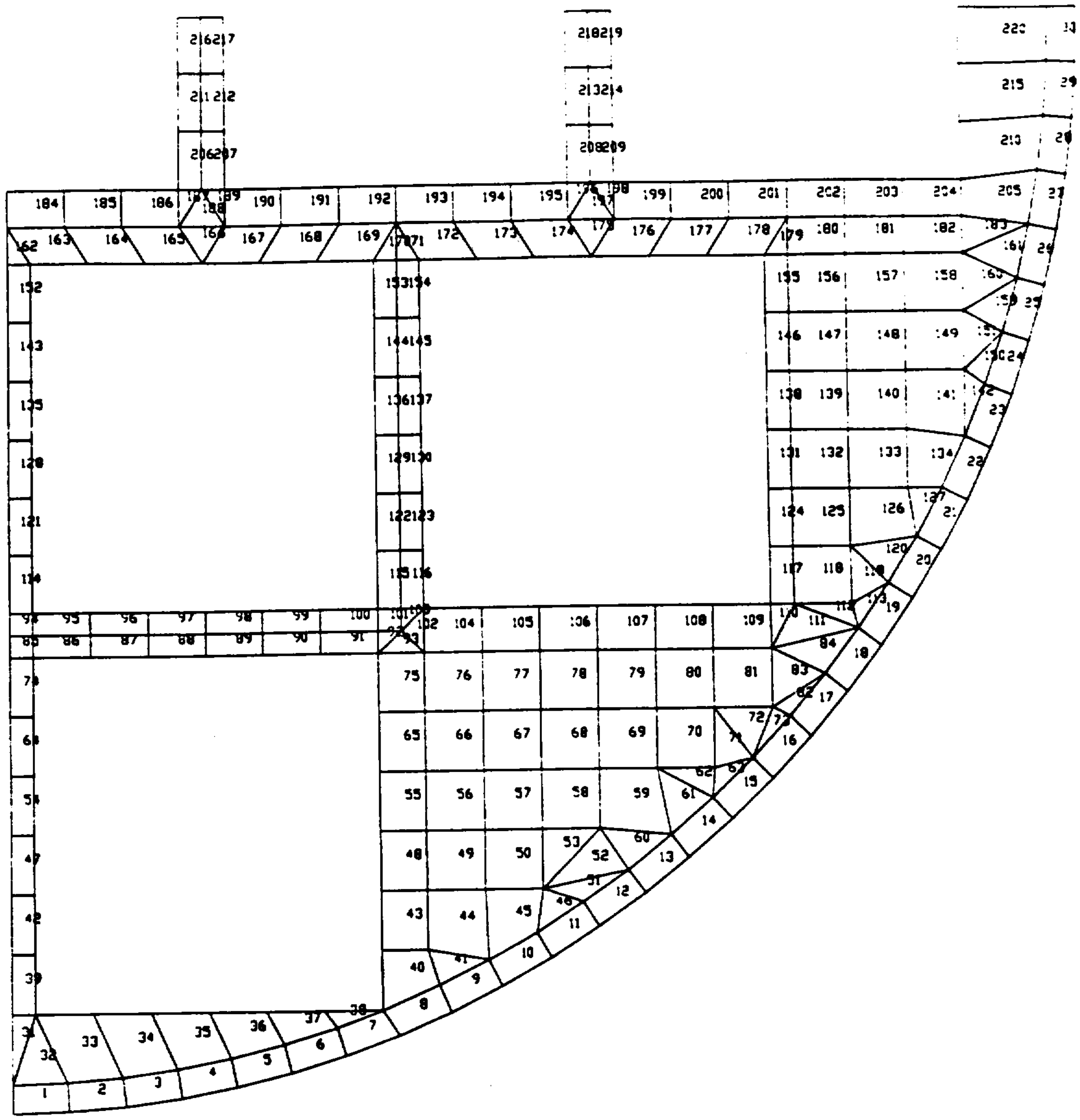


Figure A-2.6-2

Spacer Disk Thermal Stress Analytical Model Element Geometry

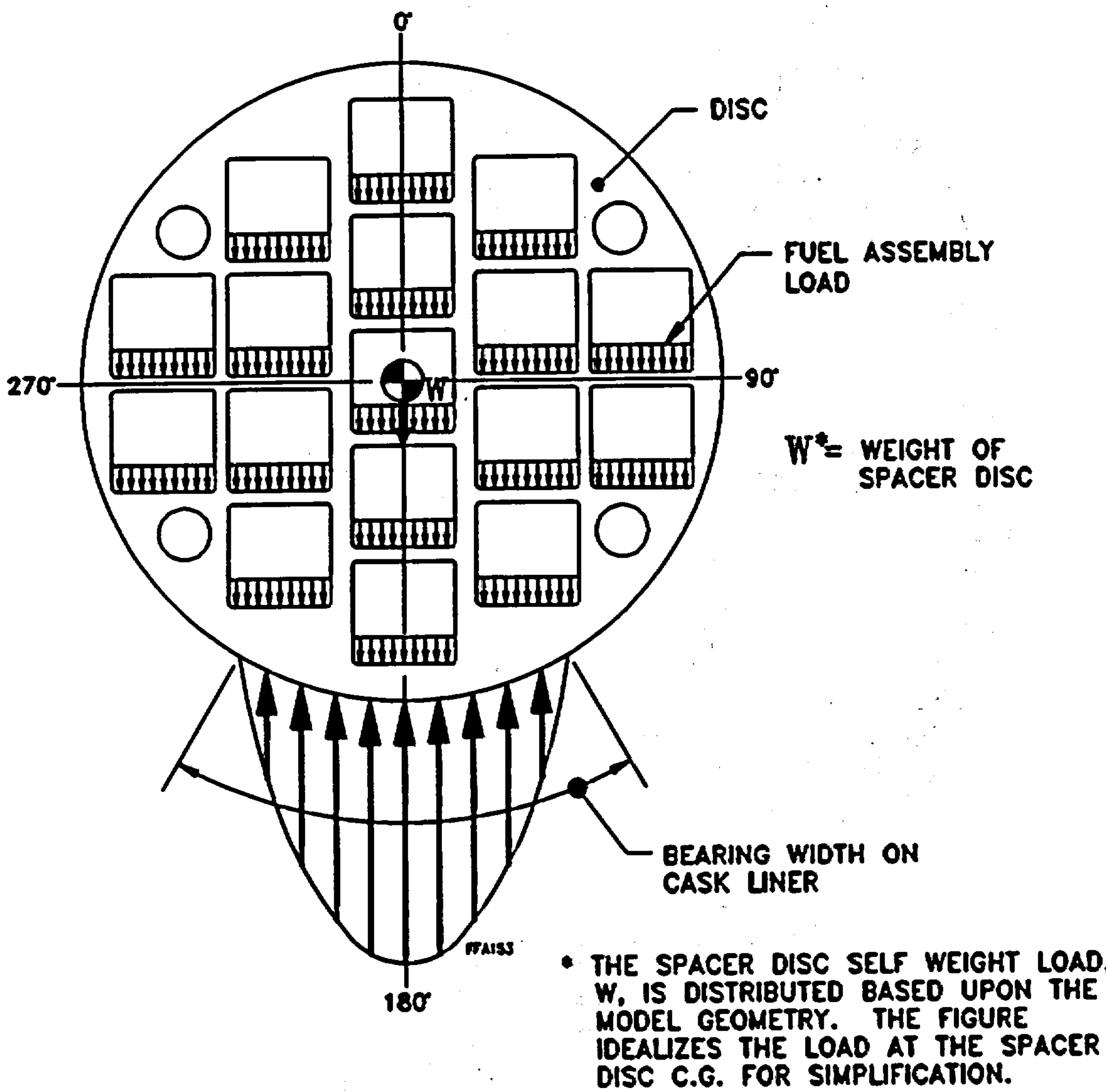


Figure A-2.6-3

Spacer Disk Side Drop Loads and Reactions

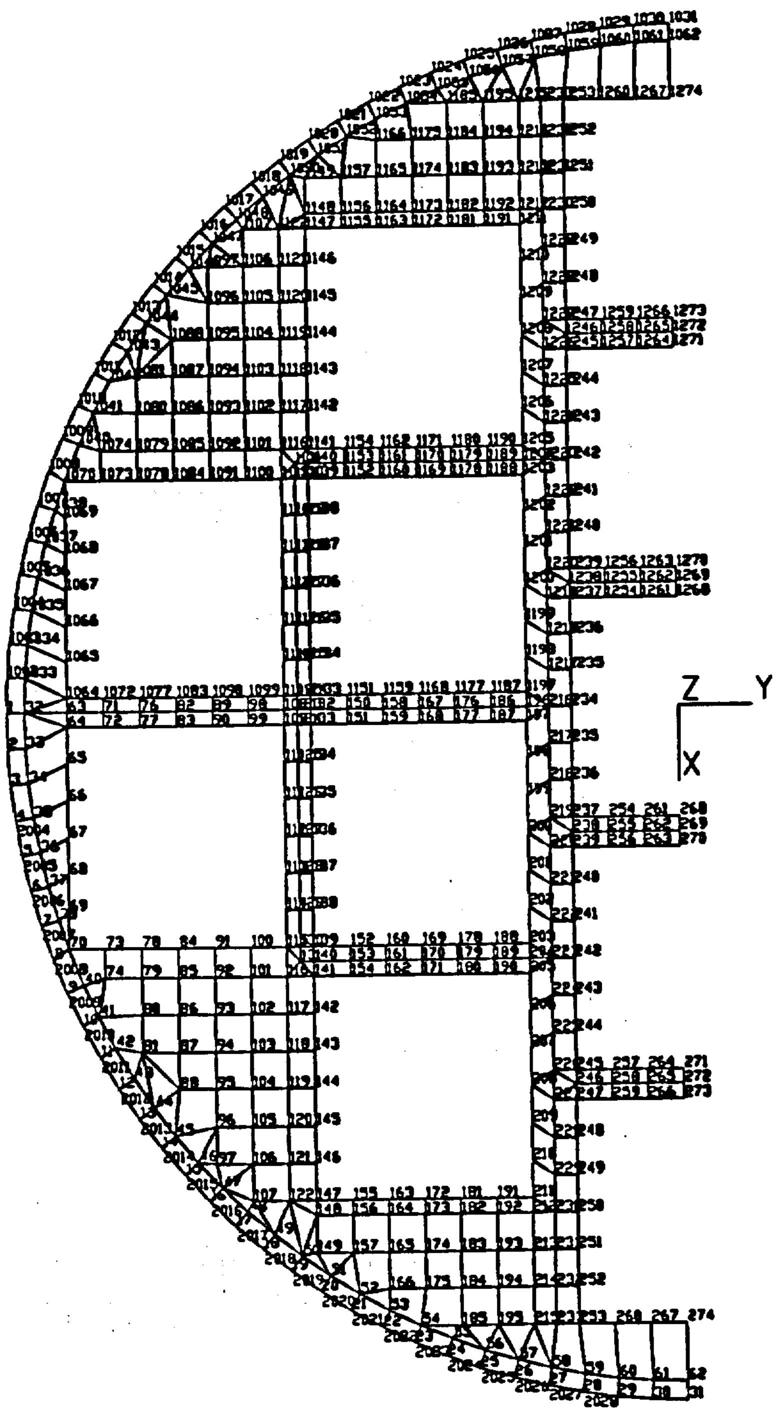


Figure A-2.6-4

Spacer Disk Side Drop Analytical Model Nodal Geometry

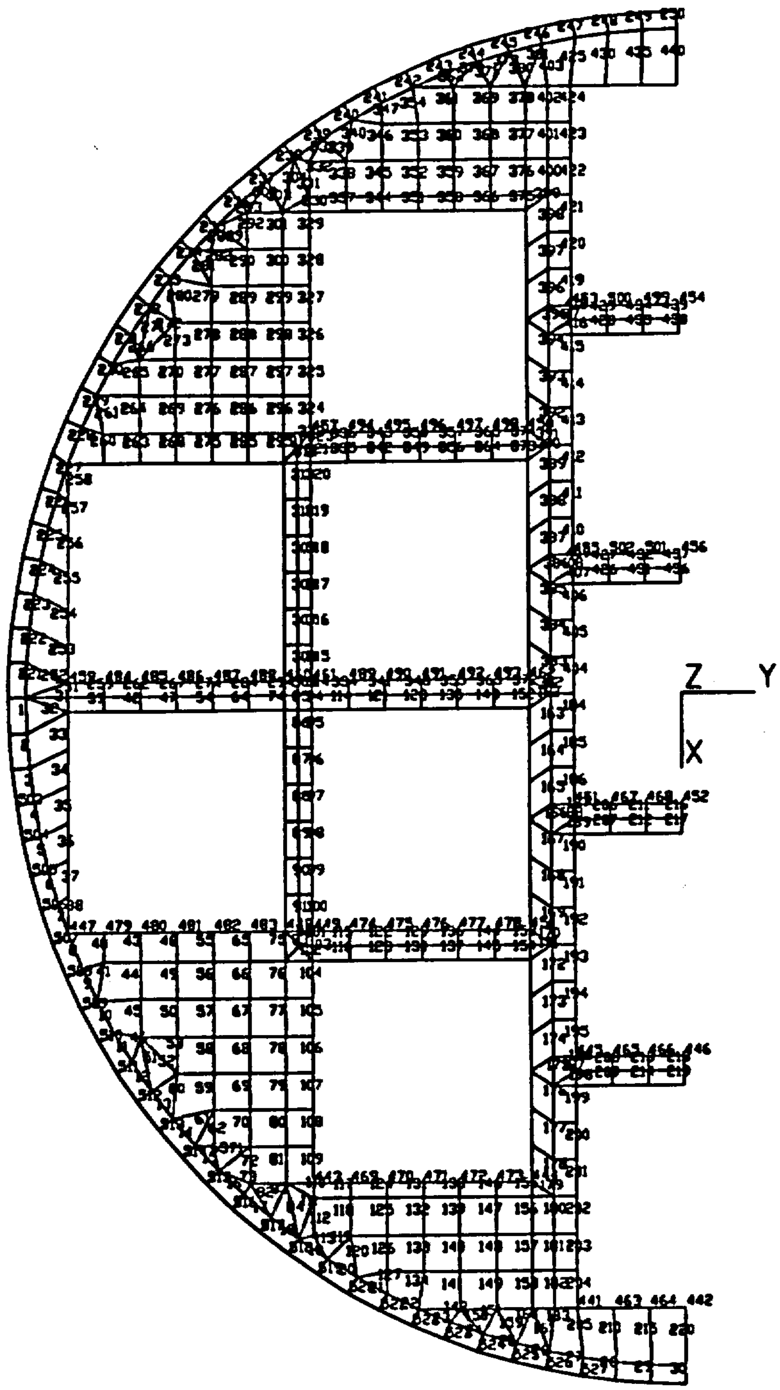


Figure A-2.6-5

Spacer Disk Side Drop Analytical Model Element Geometry

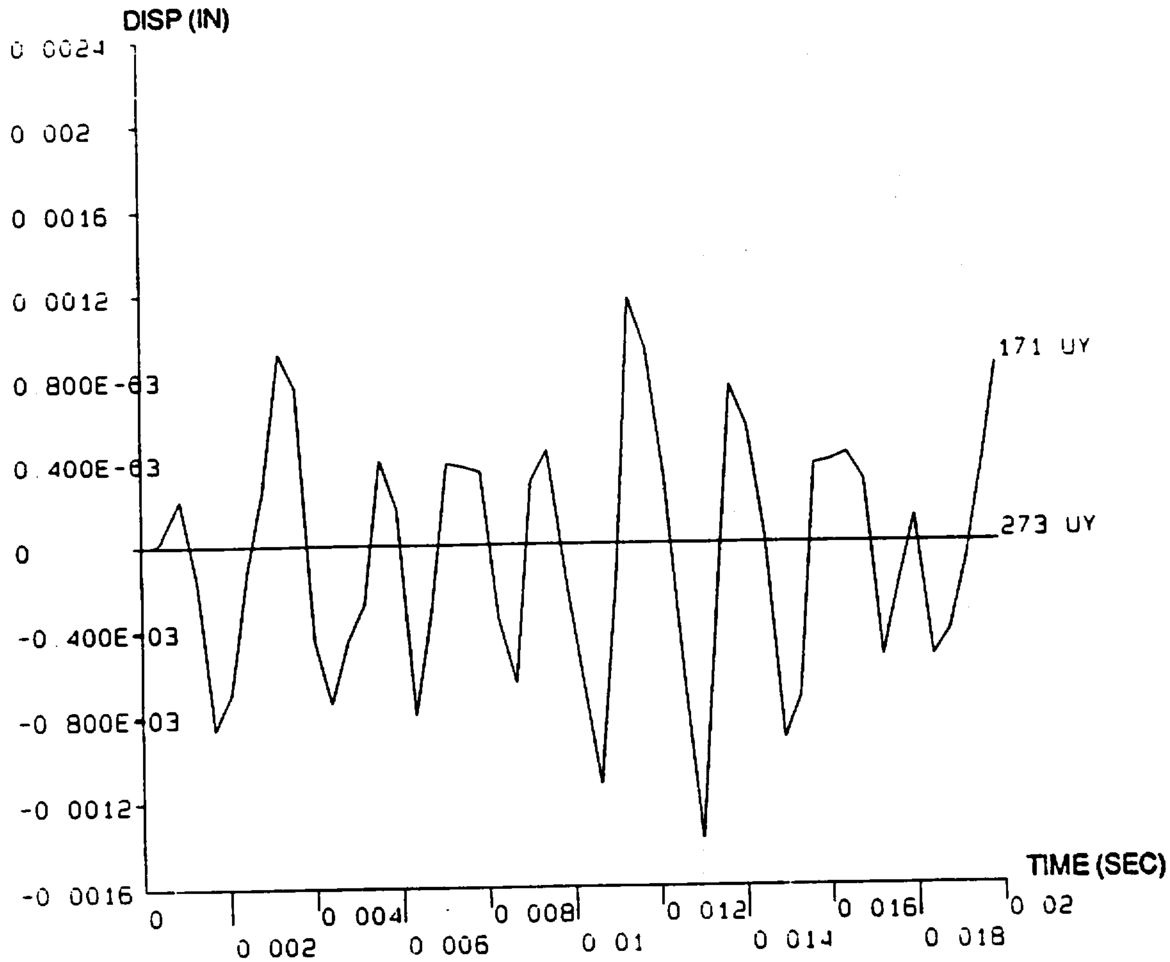


Figure A-2.6-6

Spacer Disk One Foot Drop Maximum Displacement vs. Time

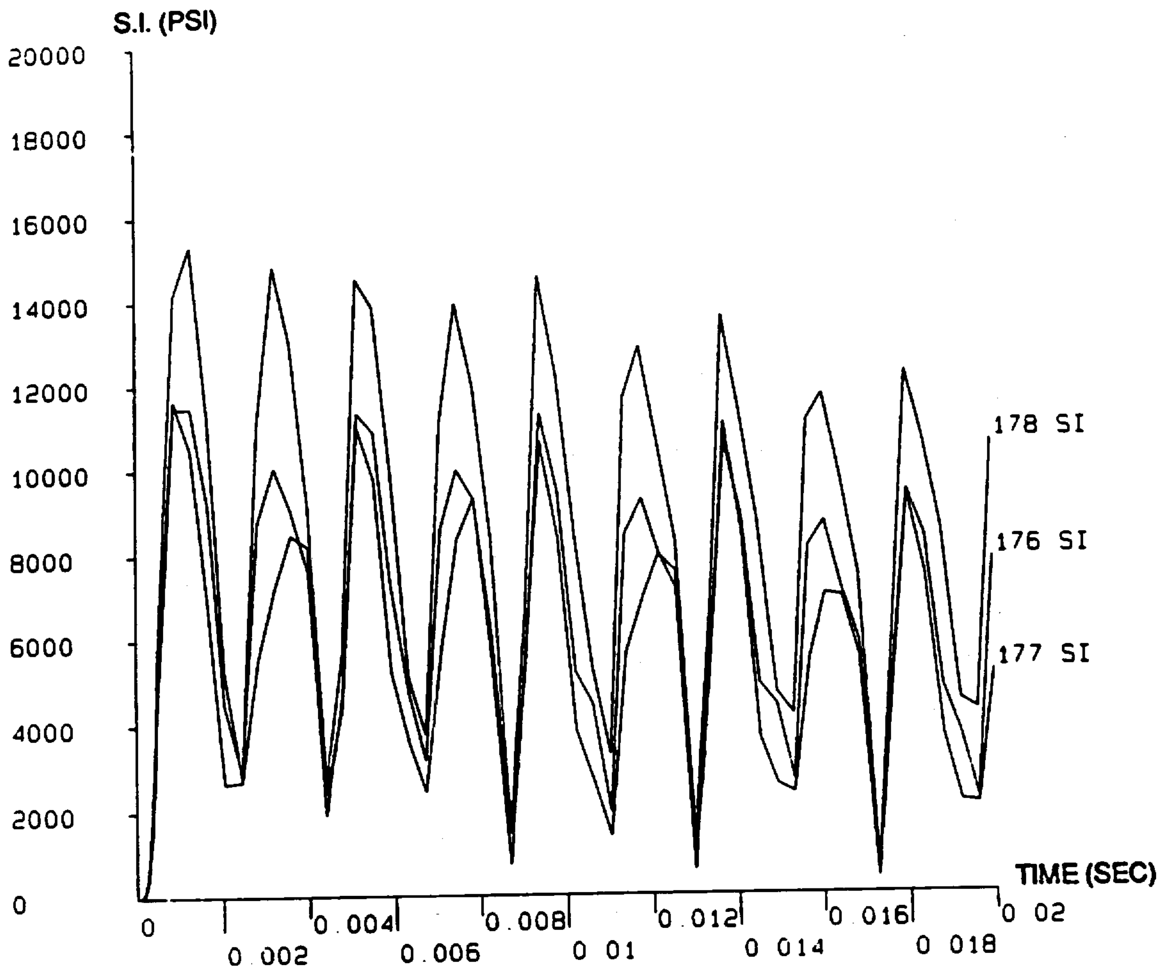


Figure A-2.6-7

Spacer Disk One Foot Drop Maximum Membrane S.I. vs. Time

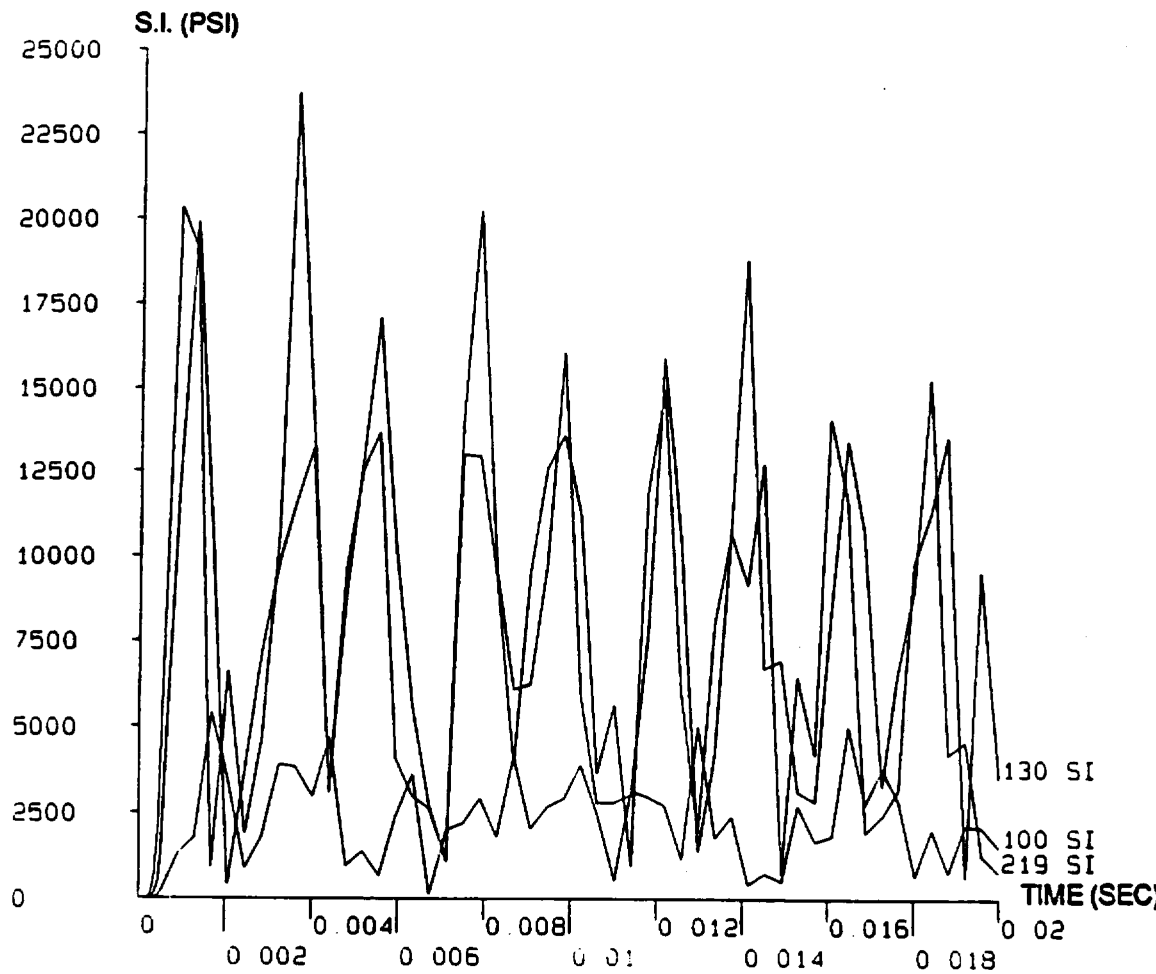


Figure A-2.6-8

Spacer Disk One Foot Drop Maximum Membrane Plus Bending S.I. vs. Time

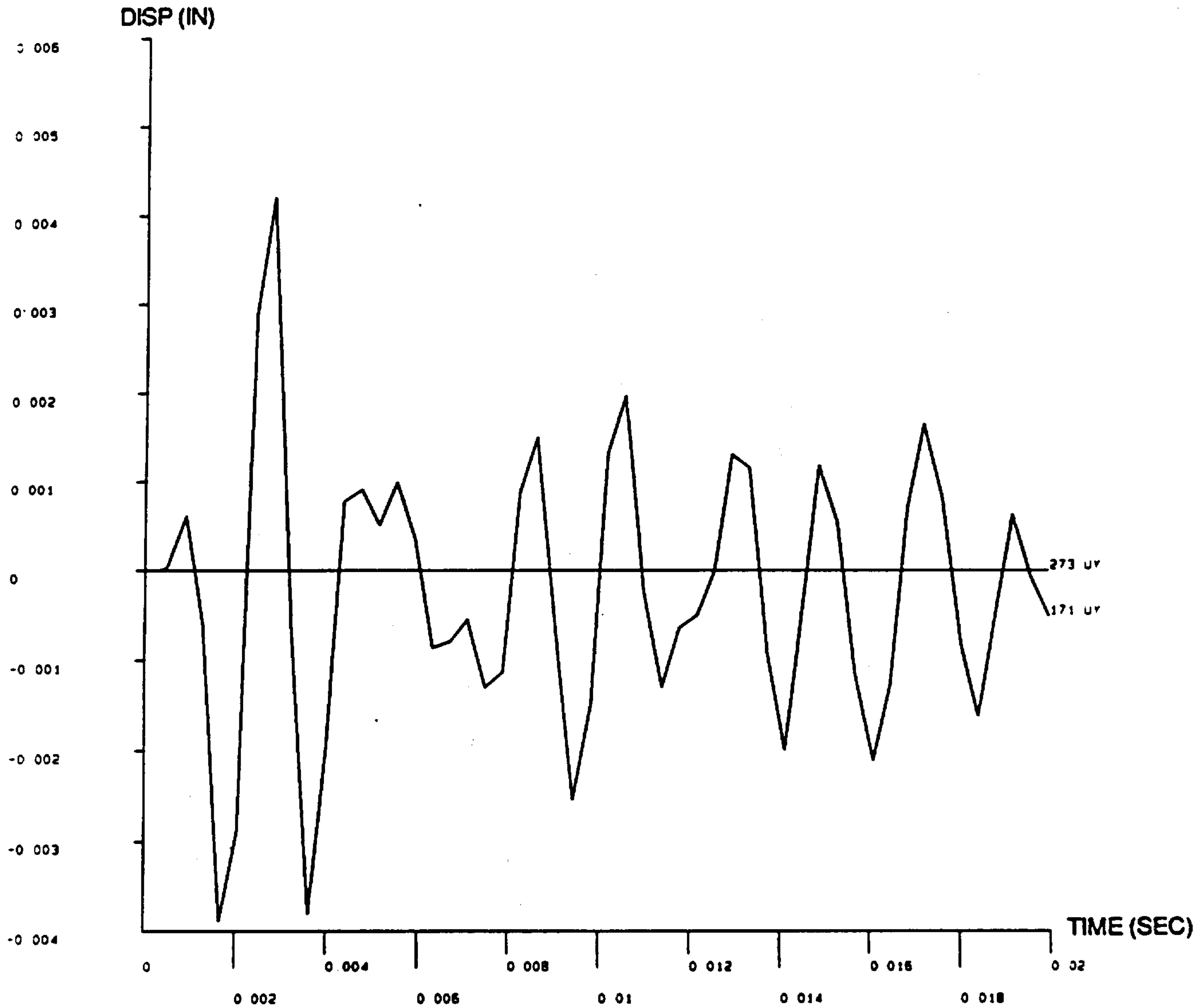


Figure A-2.6-9

Top Plate One Foot Drop Maximum Displacement vs. Time

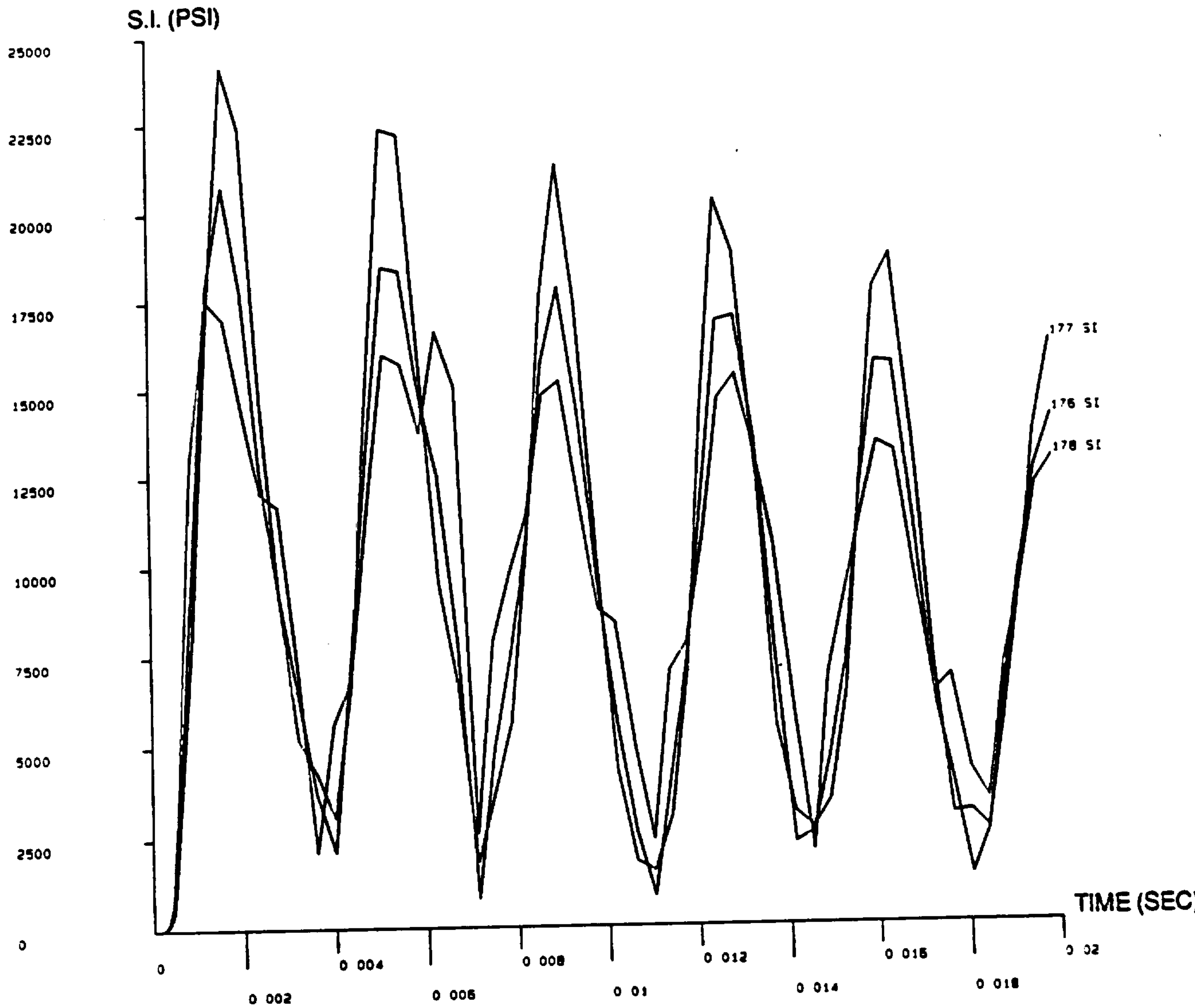


Figure A-2.6-10

Top Plate One Foot Drop Maximum Membrane S.I. vs. Time

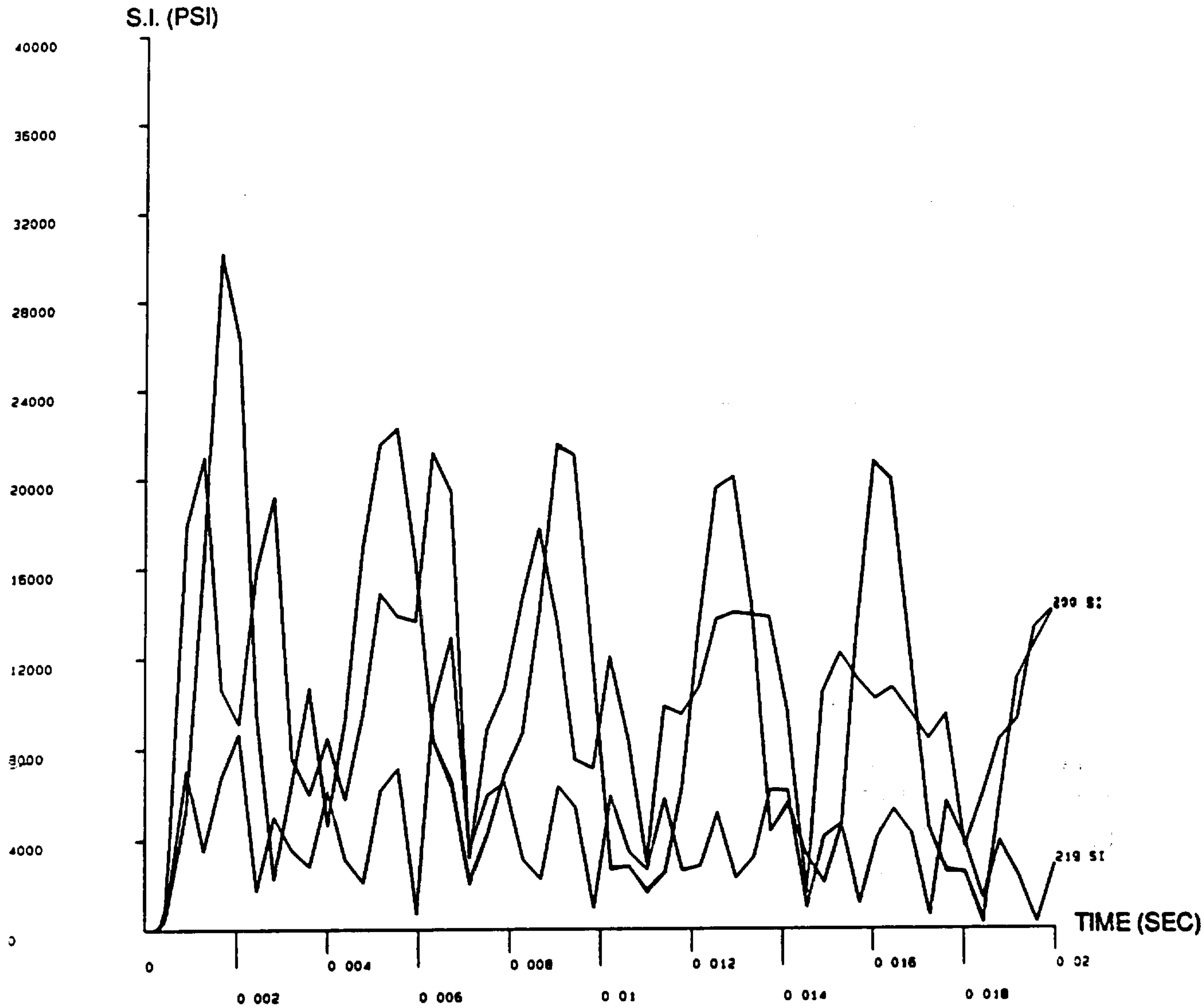
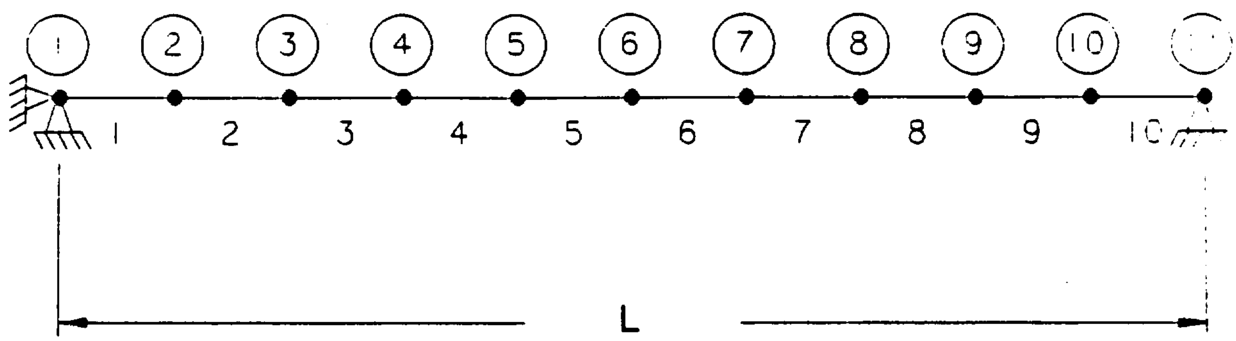


Figure A-2.6-11

Top Plate One Foot Drop Maximum Membrane Plus Bending S.I. vs. Time



t (inches)	L (inches)
0.44	19.06
0.38	17.18
0.31	19.06
0.25	17.18

Figure A-2.6-12

Borated Stainless Steel Poison Plate Side Drop Analytical Model

A-2.7 Hypothetical Accident Conditions

The IF-300 Cask Channelled BWR Fuel Basket assembly, when subjected to hypothetical accident conditions as specified in 10CFR71.73, meets the performance requirements specified in Subpart E of 10CFR71 [A-2.10.1-1]. This is demonstrated in the following sections where each accident condition is addressed and shown to meet the applicable design criteria.

A-2.7.1 Free Drop

Subpart F of 10CFR71 [A-2.10.1-1] requires that a 30 foot free drop be considered for the package, which includes the basket assembly. Consistent with the approved CSAR [A-2.10.1-2], five different load orientations are considered for the basket assembly. These include three different horizontal side drop orientations (0, 45 and 90° spacer disk orientations) and vertical end drops on the top and bottom ends of the cask. The basket loads vary in the different orientations due to differences in the cask energy absorption characteristics. A keyway is included in the basket design to maintain the orientation of the basket within the cask body. Oblique orientation drops are bounded by the horizontal and vertical drops evaluated and are not addressed, consistent with Reference A-2.10.1-2.

1. End Drop

    1. Top Plate End Drop Analysis

        Due to the symmetry of the top plate, a quarter model of the spacer disk is used in the end drop analysis. The model consists of 4 node solid elements (STIF63) with out-of-plane loading.

        To adequately capture the interaction of the D.U. shield blocks and the end spacer disk, the D.U. is also included in the analytic model. The D.U. shield blocks are modeled, using 3-D elastic beam elements (STIF4) with the flexural rigidity of the stainless steel casing only, ignoring the structural capacity of the D.U. material. The mass associated with the D.U. shield blocks is modeled using modified material densities for the elements representing the shield block casings. The D.U. connection pins are welded to the top plate. The interface between the D.U. and top plate is modeled as a pinned connection. Interface nodes between the D.U. and the top plate are coupled in the translational directions but free in all rotations. A fuel cell opening size of 6 inches is used to model the minimum size ligament widths considering allowable fabrication to tolerances. Geometry plots of the top plate vertical end drop analytical model, showing node and element numbers, are shown in Figures A-2.7-1 and A-2.7-2, respectively.

The 1¼" top plate carries the load of the poison sheets during the end drop. The 7.5" deep poison sheets are much more rigid than the spacer disk ligaments which carry the sheets in the end drop orientation. Because of the differences in rigidity, the poison tends to distribute its accelerated mass through its corners due to the differential deflection of the poison sheets and ligaments. The poison sheets are modeled using 3-D elastic beam elements (STIF4) with the appropriate geometric properties. The nodes corresponding to the assumed poison sheet/top plate contact locations are coupled in the direction of loading to reflect the distribution of the load to the poison sheet corners and other contact points. The beams are separated from the top plate at all nodes which are not assumed to be in contact with the top plate by gap elements which are initially set as closed.

The boundary conditions utilized for the top plate analytical model include:

- Symmetric boundary conditions along the horizontal and vertical centerlines of the top plate.
- Restraints at the appropriate location in the out of plane direction to represent the support rod.
- Restraints at the end points of the D.U., representing the support provided by the top spacer disk in the in-plane directions.

The analysis applies the vertical end drop loading using an acceleration time history, shown in Reference A-2.10.1-22. A more detailed description of the critical time steps is shown in Figure 5-1 Appendix V-2, Reference A-2.10.1-2. The applied acceleration time history is shown in Figure A-2.7-3.

A linear elastic transient dynamic analysis is performed for the top end drop loading. The top plate end drop analysis results are provided in

Section A-2.10.3, and indicate the top plate stresses are primarily due to bending. Membrane stresses are negligible. The maximum local primary membrane plus primary bending stress intensity is:

$P_l + P_b \quad = \quad 42.5$ ksi

The displacement and stress intensity time history results at controlling locations are shown in Figures A-2.7-4 and A-2.7-5, respectively.

2. Spacer Disk End Drop Analysis

For the end drop, the spacer disks carry the weight of the stainless steel poison plates. As discussed in Section A-2.7.1.1.1, the top plates carry the weight of the poison plates and the depleted uranium shield blocks. Since the total load on the top plate is greater than that on the spacer disks, and the top plate is significantly thinner than the spacer disk, an analysis of the spacer disks for the end drop is not required. The end drop analysis results for the top plate are considered bounding for the spacer disk end drop loads.

3. Support Rod End Drop Analysis

The spacer disk support rods' stability is of primary importance for the vertical end drop loading. This section addresses the stability of the support rods for the vertical end drop loading. The ASME Boiler and Pressure Vessel Code Section III, Subsection NG [A-2.10.1-3] is used for buckling analysis criteria.

Analyses of the support rod indicate that the rod acts as a compact section and the primary collapse mechanism for the support rod is plastic collapse. As the support rod cross-section becomes fully plastic it becomes unstable and collapses before elastic bifurcation buckling occurs. Therefore the critical segments of the support rods are those which carry the entire weight of the basket. These segments are the 4.17 inch segment at the bottom of the basket for the 287g bottom end drop, and the 7 inch segment at the top of the basket for the 280g top end drop. The longer of the two segments will be more susceptible to buckling, therefore the critical load condition for the support rod is the top end drop.

The support rods are analyzed using the ANSYS [A-2.10.1-15] analytical model shown in Figure A-2.7-8. The loads and reactions considered in the support rod end drop analysis are illustrated in Figure A-2.7-7 and described in further detail in the following analysis description. The spacer disks and top plate are included in the model in order to account for both shear and moment forces imparted to the support rods during the deceleration loading of the top end drop. A 90° segment of the basket assembly is modeled, using the appropriate symmetry boundary conditions. The spacer disks and top plate, shown in Figure A-2.7-9, are modeled using 3-D elastic beam elements, representing the ligaments, and quadrilateral shell elements for the plate area surrounding the ligaments. The support rod, shown in Figures A-2.7-10 and A-2.7-11, is modeled using elastic straight pipe elements. The model is used to determine the critical collapse load of the support rod and accounts for bifurcation buckling, plastic collapse and a range of initial eccentricities which conservatively address the range of support rod initial imperfections.

The support rods are fabricated from Type XM-19 stainless steel. The material properties used in this analysis are based on an operating temperature of 300°F, which bounds the support rod operating temperatures reported in Chapter A-3.0.

The support rods will carry the decelerated weight of the:

- Support rod (self weight)
- Spacer disks (1/4 total weight per rod)
- Depleted uranium shield blocks (1/4 total weight per rod)
- Poison material sheets (1/4 total weight per rod)

In addition to their own masses, the spacer disks and the top plate support the mass of the guide bars and (except for the bottom spacer disk) the mass of the poison sheets for the top end drop case. The poison sheets and guide bars are modeled as lumped masses. The lumped masses representing the poison sheets are distributed to those nodes nearest the location of the poison sheet edges. The poison sheets and guide bar masses used in the model are derived from the weights reported in Section A-2.1.

In addition to the mass of the adjacent poison sheets, the top plate also supports the entire mass of the D.U. shield blocks for a top end drop condition. Since the D.U. material is assumed to have no structural value, its mass is distributed to the nodes corresponding to the locations of the shield block connection pin welds. In order to account for the stiffening effect the D.U. steel casing has on the top plate, the D.U. steel casing is modeled using 3-D beam elements.

The lifting lugs and support plates are modeled using 3-D beam elements and are attached to the top plate and top spacer disk. The decelerated weight of the fuel assemblies with channels is transferred directly to the cask body.

Two cases are evaluated for the critical support rod initial eccentricities (i.e., imperfections). Case 1 conservatively assumes a straight rod with the top of the rod out of alignment with the base by 0.2 inch. The 0.2 inch eccentricity utilized is based on the maximum diametrical gap between the spacer disk outer diameter and the cask body inner diameter. Case 2 conservatively assumes a curved rod with the top and bottom ends in alignment but with an initial eccentricity at the center of 0.2 inch. To account for the initial eccentricities of the support rod, the model is physically generated as the curved rod subjected to a vertical loading. The curvature of the rod is assumed to be the deflected shape of a uniformly loaded beam.

The boundary conditions applied to the model include:

- The bottom end node (top of the support rod) is restrained against vertical and horizontal translation.
- The spacer disk symmetry planes have appropriate symmetry boundary constraints applied.

A linear elastic buckling analysis of the support rod is performed using the ANSYS [A-2.10.1-15] support rod analytical model. The maximum load permitted by F-1331.5 [A-2.10.1-3] is $0.67P_{cr}$, where P_{cr} is the critical elastic buckling load. The critical support rod buckling load is determined based on the load factor resulting from a unit acceleration applied to the analytical model. The load factor (eigenvalue) represents the load at which the support rod experiences elastic buckling. The results of the support rod buckling analysis are provided in Section A-2.10.3. The minimum load factor for linear elastic buckling, which results from the 0.2" top eccentricity basket configuration, is 1319379 in./sec^2. The factor of safety for buckling, assuming a maximum DLF of 1.6 for a triangular pulse loading [A-2.10.1-16], is:

$$F.S. = \frac{1319379\, inches/s^2}{(280g's)\,(386.4\, inches/s^2/g)\,(1.6)} = 7.6 > 1.5$$

The elastic buckling shape for the 0.2" top eccentricity configuration is shown in Figure A-2.7-12.

The maximum stresses in the support rod, due to the top end accident drop case, are determined using the same model used in the buckling analysis. A linear transient dynamic analysis is performed applying the time history shown in Figure A-2.7-3 to the model. The load sequence need not be carried out farther than the time shown as the maximum stresses in the support rod occur early in the plateau load and are converging to a static response state at the end of the plateau load.

The results of the support rod end drop stress analysis are provided in Section A-2.10.3. The maximum resulting end drop stress in the support rods is:

$P_l + P_b = 58.0$ ksi

The maximum support rod stress occurs in the 7" support rod span at the top end. Figure A-2.7-13 shows the stress intensity vs. time for the controlling stress location.

4. Poison Plate End Drop Analysis

The poison plates are non-structural items and need only support their own decelerated weight. The main criteria for the poison plates is to ensure that collapse does not occur as a result of the postulated drop accidents. The loads and reactions considered in the poison plate end drop analysis are illustrated in Figure A-2.7-25 and described below. The poison plates are evaluated using the ANSYS model shown in Figure A-2.7-26. The model consists of two dimensional elastic beams. The beam properties are based on a one inch wide strip. It is assumed that no variation in response occurs along the width of the poison plates. The material properties used in the analysis are shown in Table A-2.3-1.

A conservative height of the poison plate acting as a column is taken as 20 inches. The initial eccentricity of the poison plate is based on ASTM specifications. The maximum camber for the plate material is taken as 0.05 inch per foot. A flatness tolerance of 1/8 inch per foot or 0.21 inch for the 20 inch height is conservatively used. The camber is assumed to take the shape of a uniformly loaded beam.

The unit acceleration load is applied to the model to represent the vertical end drop loads. This loading is applied vertically to the poison plate analytical model.

The results of the poison plate analytical model analysis are provided in Section A-2.10.3. The resulting buckling load is 1105g's. The maximum 30 foot cask end drop peak loading is 287g's. The factor of safety, F.S., against buckling for the borated stainless steel poison plate is then:

$$\text{F.S.} = 1105/287(1.6)$$
$$= +\ 2.41$$

The required factor of safety is 1/0.67 = 1.5 [A-2.10.1-3].

The maximum stress in the poison plates is:

$$\sigma = P/A$$

Where:

$$P = \delta t \ell g(1)(\text{DLF})$$

$= \quad 0.280(0.25)(20)(287)(1)(1.6)$
$= \quad 642.9$ lbs. per inch of width

$A \quad = \quad t\ (1)$
$= \quad 0.25\ (1)$
$= \quad 0.25\ in^2$ per inch of width

Therefore:

$\sigma \quad = \quad 401.8(1.6)/(0.25)(1000)$
$= \quad 2.6$ ksi

5. Spacer Disk to Support Rod Attachment Weld

The support rods attachment welds are analyzed for the loads resulting from the postulated 30 foot top end drop. The maximum shear and moment forces for the critical welds are obtained from the support rod 30 foot top end drop analysis. The critical support rod attachment welds considered in this analysis are those located at the top 2" spacer disk (spacer disk #9) and the second spacer disk from bottom (spacer disk #2). The loads on the welds at the top spacer disk location are significant due to the interaction with the top plate which supports the mass of the D.U. shield blocks and poison sheets. The effective weld throats required for the maximum weld loads are calculated as described below:

From Reference A-2.10.1-3, subsection NG, Table NG-3352-1, the efficiency factor for the partial penetration weld is 0.6 for surface PT inspection on a category D or E weld. Category D or E welds are described as "connection welds" and are an appropriate classification for the support rod connection welds. The Service Level A allowable stress for pure shear is:

$\tau_{all} \quad = \quad 0.6S_m \qquad$ (Subsection NG 3227.2)

The Service Level D allowable stress for shear is:

$\tau_{all} \quad = \quad 0.42S_u \qquad$ (Subsection NG 3225)

The weld allowables are based on material properties for the support rod and spacer disks which are fabricated from Type XM-19 stainless steel material. The material properties used to analyze the welds are:

S_m = 31.4 ksi @ 300°F
S_u = 94.2 ksi @ 300°F

Therefore,

τ_{all} = 0.42(94.2)(0.6)
= 23.7 ksi (Service Level D)

Treating the weld as a line, the weld length is:

L_w = $\pi d = \pi(3.0") = 9.43$ inches

The maximum loads on the spacer disk #9/support rod weld, in the support rod local coordinate system (X-axis in support rod axial direction), are:

F_x = 29.33 kips
M_y = 84.31 in-kips
M_z = 104.00 in-kips

The resulting shear force on the weld due to the moments is:

$$F_{YZ} = \frac{\sqrt{M_Y^2 + M_Z^2}}{t_d} = \frac{\sqrt{(84.31)^2 + (104.00)^2}}{2.0} = 66.9\ kips$$

where:

t_d = distance between the welds = spacer disk thickness

The resultant force, F_R, acting on the weld is:

$$F_R = \frac{\sqrt{F_X^2 + F_{YZ}^2}}{L_w} = \frac{\sqrt{(29.33/2)^2 + (66.9)^2}}{9.43} = 7.3\ kips/inch$$

The effective weld throat required for the spacer disk #9/support rod attachment weld is:

$t_{req'd} = F_R/\sigma_{ALL} = 7.3/23.7 = 0.31$ inches

Using a double sided 3/8" groove weld with a 1/8" cover fillet weld, the effective weld throat is:

$t_{eff} = [(3/8)^2 + (1/8)^2]^{1/2} = 0.395" > 0.31"$

The maximum loads on the spacer disk #2/support rod weld, in the support rod local coordinate system (X-axis in support rod axial direction), are:

F_x = 38.11 kips
M_y = 36.46 in-kips
M_z = 52.91 in-kips

The resulting shear force on the welds due to the moments is:

$$F_{YZ} = \frac{\sqrt{M_Y^2 + M_Z^2}}{t_d} = \frac{\sqrt{(36.46)^2 + (52.91)^2}}{2.0} = 32.13\ kips$$

The resultant force, F_R, acting on the weld is:

$$F_R = \frac{\sqrt{F_X^2 + F_{YZ}^2}}{L_w} = \frac{\sqrt{(38.11/2)^2 + (32.13)^2}}{9.43} = 4.0\ kips/inch$$

This load is less than that calculated for spacer disk #9, therefore the double sided 3/8" groove weld with 1/8" cover fillet is adequate for all spacer disks.

6. Top Plate to Support Rod Attachment Weld

The top plate to support rod weld is evaluated for the end drop condition. The top plate carries the weight of the depleted uranium shield blocks, the stainless steel poison plates, the lifting lugs, the support plates, and its own weight. The maximum shear and moment forces for the critical welds are obtained from the support rod 30 foot top end drop analysis.

The top plate to support rod weld is designed as a one-sided weld for fabrication purposes. The maximum loads on the 1¼" top plate/support rod weld, in the support rod local coordinate system (X-axis in support rod axial direction), are:

F_x = 23.15 kips
M_y = 78.45 in-kips
M_z = 59.80 in-kips

$$\Sigma M = \sqrt{M_Y^2 + M_Z^2} = \sqrt{(78.45)^2 + (59.80)^2} = 98.64\ inch\text{-}kips$$

The section modulus for the weld is:

$S_w \quad = \quad \pi d^2/4$

and the length of the weld is:

$L_w \quad = \quad \pi d$

where:

d = support rod diameter = 3"

Therefore,

$S_w \quad = \quad 7.06\ in^2$

$L_w \quad = \quad 9.43\ in.$

The resultant force, F_R, acting on the weld is:

$$F_R = \frac{F_X}{L_W} \pm \frac{\Sigma M}{S_w} = \frac{23.15}{9.43} \pm \frac{98.64}{7.06} = 16.4\ kips/inch$$

The effective weld throat required for the 1¼" top plate/support rod attachment weld is:

$t_{req'd} = F_R/\sigma_{ALL} = 16.4/23.7 = 0.69$ inches

Using a 5/8" J-groove weld with a 3/8" cover fillet weld on the top side of the 1¼" top plate, the effective weld throat is:

$t_{eff} = [(5/8)^2 + (3/8)^2]^{1/2} = 0.73" > 0.69"$

7. Shield Block End Drop Analysis

A linear elastic static analysis of the D.U. shield blocks for the 30 foot bottom end drop is performed using an ANSYS [v4-2.10.1-15] finite element model, shown in Figure A-2.7-17. The analytical model consists of quadrilateral shell elements and 3-D isoparametric brick elements, representing the stainless steel casing and D.U., respectively. The stainless steel casing node and element geometry is shown in Figures A-2.7-18 thru A-2.7-21. The D.U. geometry at various heights corresponding to the nodal layers, is shown in Figure A-2.7-22. The static acceleration loads applied to the model are conservatively increased using a bounding DLF of 2.0. The shield block bottom end drop casing analysis assumes that there is no mechanical connection between the D.U. material and the connection pins. Consequently, the D.U. material acts as dead load on the bottom of the shield block assembly for the drop loading conditions. Shield block assembly #1 is used for the analyses of the stainless steel casings since it has the longest span between the end covers.

The decelerated mass of the D.U. shield blocks is supported by the 1¼" top plate in the top end drop case. The assumed loads and reactions in the D.U. shield block subjected to the top end drop loading are illustrated in Figure A-2.7-15. The assumed loads and reactions in the D.U. shield blocks subjected to bottom end drop loading are illustrated in Figure A-2.7-16. Support provided by the 2" spacer disk on the bottom side of the shield blocks, due to differential displacement between the top plate and 2" spacer disk resulting from the bottom end drop, is conservatively ignored. Consequently, the bottom end drop is the critical end drop load case. The peak acceleration loading, conservatively including a bounding DLF of 2.0, applied to the ANSYS model is:

Load = (2.0)(287g)(386.4) = 221,794 in/sec^2

The boundary conditions applied to the model include:

- The nodes nearest the locations of the connection pins attached to the top bar are restrained from translating in all directions, assuming the connection pin/top bar weld joints act as pinned connections.

- The shield assembly bottom bar is coupled with the bottom of D.U. in the vertical direction (direction of loading) since the D.U. is conservatively assumed to bear against the bottom bar in the bottom drop case.

- The front and back cover sheets and side bars of the shield assembly are coupled to the D.U. in the lateral directions to prevent the D.U. from deflecting through the casing cover sheets, while allowing the D.U. to deflect relative to the casing cover sheets in the direction of loading.

The results of the D.U. shield block 30 foot drop analysis are provided in Section A-2.10.3. The deflected shape and maximum D.U. shield block casing membrane and membrane plus bending stress intensities are shown in Figures A-2.7-23 and A-2.7-24. The resulting maximum stress intensities for the 30-foot bottom end drop in the shield blocks are:

$P_m \quad = \quad 34.3 \text{ ksi}$

$P_l + P_b \quad = \quad 1.8 \text{ ksi}$

The maximum connection pin tensile reaction force from the D.U. shield block 30 foot bottom end drop analysis is:

$F_y \quad = \quad 6901 \text{ lbs.}$

The resulting tensile stress in the connection pin is:

$\sigma \quad = \quad 6901/[\pi(0.38)^2/4](1000) \quad = \quad 60.9 \text{ ksi}$

The allowable membrane stress for Service Level D conditions is the lesser of 2.4 S_m and 0.7S_y. The allowable stress, S_m, and the yield stress, S_y, of the XM-19 connection pin material at 300°F are 31.4 ksi and 94.3 ksi, respectively. Therefore, the allowable membrane stress, σ_{all}, is:

$\sigma_{all} \quad = \quad 2.4(31.4) \text{ or } 0.7(94.3) \quad = \quad 66.0 \text{ ksi}$
$\quad\quad > \quad 60.9 \text{ ksi}$

The top end shield block connection pins are connected to the shield block casing top bars and the 1-1/4" top plate with 5/16" groove welds. The maximum tensile load on any top end shield block connection pin resulting from the 30 foot bottom end drop is 6901 pounds. The shear load on the weld is:

$f \quad = \quad 6901/[\pi(0.38")](1000) \quad = \quad 5.8 \text{ ksi}$

The allowable shear stress in the weld is:

$\tau_{all} \quad = \quad 0.42(94.2)(0.6) \quad = \quad 23.7 \text{ ksi}$

Therefore, the required weld throat is:

$\tau_{req'd} \quad = \quad 5.8/23.7 \quad = \quad 0.24" \quad < \quad 0.3125"$

2. Side Drop

1. Spacer Disk 0° Orientation Side Drop Analysis

The analysis of the 2 inch thick spacer disk oriented 0° with respect to the vertical cask centerline for the 30 foot drop loads uses the same methodology as the spacer disk one foot drop evaluation presented in Section A-2.6.7.1. The loads and reactions considered in the 0° spacer disk side drop analysis are illustrated in Figure A-2.6-3 and described below. The finite element model shown in Figure A-2.6-2 is used to evaluate the maximum stresses which result in the spacer disk. Consistent with the one foot drop evaluation, gap elements are used to model the boundary conditions and mass elements represent the fuel mass, as described in Section A-2.6.7.1. The drop load time history from Reference A-2.10.1-2 is shown in Figure A-2.7-28. The spacer disk buckling analysis is presented in Section A-2.7.1.2.4.

The 0° side drop analysis results are provided in Section A-2.10.3. Figures A-2.7-29, A-2.7-30 and A-2.7-31 show the displacements and stresses vs. time for controlling locations. The maximum 0° side drop primary membrane stress intensity is:

P_m = 37.8 ksi

And the local primary membrane plus primary bending stress intensity is:

$P_l + P_b$ = 56.6 ksi

2. Spacer Disk 90° Orientation Side Drop Analysis

The analytical model used in the 30 foot side drop analysis with the spacer disk oriented 90° with respect to the vertical cask centerline is very similar to the model used for the 0° orientation analysis. Due to geometric symmetry, only half the model is generated with the appropriate boundary conditions. Mass elements are attached to the model to represent the loading of the fuel on the spacer disk. The nodal masses calculated for the 0° side drop are also used in the 90° side drop. The spacer disk material properties are described in the one foot drop analysis presented in Section A-2.6.1.2. The 90° orientation side drop analytical model node and element geometry is shown in Figures A-2.7-33 and A-2.7-34, respectively.

The loads and reactions considered in the 90° spacer disk side drop analysis are shown in Figure A-2.7-32. An acceleration time history is applied to the finite element model for the 90° orientation 30 foot side drop loads. The corresponding 90° side drop orientation acceleration time history is shown in Figure A-2.7-35 ([A-2.10.1-2] Appendix V-1, page 30). The acceleration time history is applied to the spacer disk and the attached mass elements which represent the fuel.

The boundary conditions included in the analytical model are the same as those used in the analysis presented in Section A-2.7.1.2.1.

The 90° orientation side drop analysis results are provided in Section A-2.10.3. Figures A-2.7-36 through A-2.7-38 show the displacements and stresses vs. time for the controlling locations.

The maximum 90° side drop primary membrane stress intensity is:

P_m = 30.67 ksi

And the maximum primary membrane plus primary bending stress intensity is:

$P_l + P_b$ = 39.7 ksi

3. Spacer Disk 45° Orientation Side Drop Analysis

The loads and reactions considered in the spacer disk 45° side drop analysis are illustrated in Figure A-2.7-39 and described in further detail in this section. The side drop analysis with the spacer disk oriented 45° with respect to the vertical cask centerline uses a similar analytical model to the models shown in the 0° and 90° orientation analyses. Due to the lack of symmetry for the 45° orientation, a full spacer disk model is used. The 45° orientation analytical model nodes and elements are shown in Figure A-2.7-40 and A-2.7-41, respectively. Using the information derived in the 0° and 90° side drops, the masses from the previous analysis will be used for the 45° side drop.

One-half of the full nodal masses of both the 0° and 90° side drop models are applied for the 45° drop analysis. The spacer disk material properties are the same as those used in the 0° and 90° orientation side drop analysis presented in Section A-2.7.1.2.1 and A-2.7.1.2.2.

An acceleration time history is applied to the finite element model for the 45° orientation 30 foot side drop loads. The acceleration time history is shown in Figure A-2.7-42 ([A-2.10.2-2] Appendix V-3). The acceleration time history is applied to the model by accelerating the spacer disk and the attached mass elements which represent the fuel.

The boundary conditions included in the analytical model are the same as those used in the analysis presented in Section A-2.7.1.2.1, except symmetry boundary conditions are not required for the full model.

The 45° side drop analysis results are provided in Section A-2.10.3. Figures A-2.7-43 through A-2.7-45 show the displacements and stresses vs. time for the controlling locations.

The maximum 45° orientation side drop primary membrane stress intensity is:

P_m = 12.9 ksi

And the maximum local primary membrane plus primary bending stress intensity is:

$P_l + P_b$ = 43.4 ksi

4. Spacer Disk Side Drop Buckling Analysis

The spacer disk buckling analysis is performed for the 0° and 90° drop orientations. As shown in Sections A-2.7.1.2.1 through A-2.7.1.2.3, membrane stresses are maximum in the 0° and 90° drop orientations and will therefore bound the buckling results of the 45° drop orientation case. A full spacer disk model is used to capture the in and out-of-plane buckling behavior as shown in Figure A-2.7-40.

A linear elastic buckling analysis of the spacer disks is performed using the 0° and 90° spacer disk models described in Sections A-2.7.1.2.1 and A-2.7.1.2.2, respectively, which conservatively accounts for a range of initial eccentricities and manufacturing tolerances. The maximum load permitted by F-1331.5 [A-2.10.1-3] is $0.67P_{cr}$, where P_{cr} is the elastic instability load.

The spacer disk side drop stress analysis results show that the membrane stresses do not exceed yield during the 30 foot drops. The buckling analysis of the spacer disk is based on elastic bifurcation buckling behavior. A unit load is applied to the model and a buckling load factor is determined.

Mass elements are attached at the appropriate nodes to represent the fuel mass for the 0° and 90° side drop orientation buckling analyses. A static 1 inch/sec^2 acceleration load is applied to the model for the corresponding 0° and 90° drop orientations. The buckling load factors (eigenvalues) are then calculated.

Conservative boundary conditions are used in both drop orientation buckling analyses. A contact surface is assumed with the cask body and the corresponding nodes at the edge of the spacer disk are restrained in the radial direction.

The contact length to be used for the buckling analysis for the 0° and 90° orientation drop events is estimated by:

b = $1.6(\rho K_D C_E)^{1/2}$
([A-2.10.1-17] Table 33, Case 2c)

where:

ρ = load per unit length
= basket weight/total spacer disk thickness
= 17698(96)/(2)(9)
(17698 = basket weight)
(Conservatively using plateau load of 96g's)
= 94389 lbs/in.

K_D = $D_1D_2/(D_1 - D_2)$

D_1 = cask liner inside diameter
= 37.5 inches

D_2 = spacer disk outside diameter
= 37.31

K_D = 7363.82

C_B = $(1 - \upsilon_1^2)/E_1 + (1 - \upsilon_2^2)/E_2$
= $7.05(10^{-8})$
(for $\upsilon_1 = \upsilon_2 = 0.3$ &
$E_1 = E_2 = 25.8(10^6)$)

b = $1.6\{(94389)(7363.82)(7.05(10^{-8})\}^{1/2}$
= 11.2 inches

The contact length used in the analytical models, using the nearest modelled node is 11.7 inches.

The spacer disk 0° and 90° drop orientation buckling analysis results are provided in Section A-2.10.3. The resulting buckling load factors (based on 1 inch/sec² applied load), are:

0° Orientation = 3204g's

90° Orientation = 4103g's

It is apparent from these analysis results that buckling is not a controlling failure mode for the spacer disk. Safety margins far exceed the 1.5 factor of safety imposed by Reference A-2.10.1-3.

The resulting spacer disk buckling mode shapes are shown in Figures A-2.7-46 and A-2.7-47. The analyses show that the controlling buckling modes are in-plane. The effects of local imperfections are not explicitly included in the analysis. However, considering the high factors of safety (3204/214 = 14.97 min. for the 0° drop loads), and that the spacer disk is a precision machined item, the factor of safety vs. buckling is more than adequate and meets code requirements.

5. Top Plate 0° Orientation Side Drop Analysis

The spacer disks are designed to carry the decelerated weight of the fuel. No credit is taken for the top plate for the side drop accident for support of the fuel. The weight of the depleted uranium is carried equally by the top plate and the top spacer disk. The top plate will, therefore, carry half the depleted uranium load. The analysis presented herein determines the effect of the D.U. weight on the top plate during the postulated side drop accident. The top plate consists of the same material as the spacer disks, therefore, the same material properties are used.

The top plate side drop analysis uses the same analysis techniques as are used for the spacer disk analysis presented in Section A-2.7.1.2.1. The 0° orientation side drop acceleration time history shown in Figure A-2.7-28 is applied to the model in a linear transient dynamic analysis.

The top plate drop analysis is performed using the ANSYS [A-2.10.1-15] analytical model shown in Figure A-2.6-2. The side drop analysis of the 1¼" top plate is performed using a top plate thickness of 3/4". The stresses in the top plate result from the decelerated mass of the top plate, poison sheets and D.U. shield blocks. Since increasing the thickness of the top plate increases the inertia of the plate, and consequently the flexural stiffness, the stresses due to external loading (i.e. the decelerated mass of the poison sheets and D.U. shield blocks) are conservatively large. The stresses due to the decelerated mass of the top plate will not change significantly, since both the mass and the inertia will increase linearly with the thickness. Therefore, the stress results from the 3/4" top plate side drop analyses are conservative and are used for the qualification of the 1¼" thick top plate. The 0° orientation results bounded those of the 45° and 90° orientation results for the spacer disk, therefore only the 0° orientation loads are evaluated for the top plate.

The weight of the D.U. on the top plate is simulated by applying mass elements to the appropriate locations on the analytical model and applying the drop load decelerations.

The boundary conditions used for the top plate side drop analysis are the same as those used for the spacer disk analysis.

The ANSYS run output is included in Section A-2.10.3. The resulting maximum primary membrane stress intensity is:

P_m = 19.3 ksi

The maximum local primary membrane plus primary bending stress intensity is:

$P_l + P_b$ = 19.6 ksi

The secondary stress intensity need not be considered for the Service Level D accident conditions [A-2.10.1-3]. Key displacement and stress vs. time plots for the top plate side drop are shown in Figures A-2.7-48 through A-2.7-50.

6. Support Rod Side Drop Analysis

The support rod analysis for the postulated side drop is performed using simple beam theory. The support rods are assumed to be loaded by their own dead weight under the side drop loading. The remaining accelerated weight of the fuel, spacer disks, poison plates and D.U. shielding assemblies is transferred by the spacer disks directly to the cask body. The support rod is a continuous beam with a maximum span of 22.02 inches near the bottom end.

The 0° peak acceleration of 214g is the controlling side drop loading for the postulated 30 foot cask drop. The corresponding load duration is 0.95×10^{-3} seconds (see Figure A-2.7-28).

The support rod is conservatively analyzed as a fixed-fixed continuous beam for determination of the structural frequency in order to maximize amplification.

From Reference A-2.10.1-16, Appendix 1.1, the fundamental structural frequency is defined as:

ω = $A(EI/\mu l^4)^{1/2}$

where:

A = 22.4 (fixed end beam)

E = $25.8(10^6)$ (at 500°F)

I = $\pi d^4/64$
= 3.976 in^4

μ = γA
= $0.283(\pi(3.0^2)/4)/386.4$
= $2.02/386.4$
= 0.00522 lb-sec^2/in

ℓ = 22.02 inches

substituting,

ω = 6477 Rad/sec

The loading frequency, ω_p, is:

ω_p = π/T
= $\pi/0.95(10^{-3})$
= 3307 Rad/sec

The frequency ratio, f_r, is:

f_r = $6477/3307$
= 1.96

As seen from Figure 42.13 of Reference A-2.10.1-16, the dynamic load factor (DLF) is approximately 1.75 for an undamped system and approximately 1.62 for a 5% critically damped system. The maximum possible dynamic load factor for an undamped system shown is just under 1.8. A bounding DLF of 2.0 is conservatively used in this analysis.

The side drop bending stress is defined as:

σ_b = Mc/I

where:

M = $w\ell^2/8$
(conservatively assume simply supported beam to maximize stress)

M = $2.02(22.02)^2/8$
= 122.4 lb-in

σ_b = $122.4(3.0/2)/3.98$
= 46.1 psi

For the 214 "g" peak side drop load, the maximum support rod bending stress is:

σ_b = $46.1(214)(2.0)/1000$
= 19.7 ksi

The support rod side drop maximum shear stress is defined as:

$\tau = 4V/3A$

where:

$V = w\ell/2$
$= 2.02(22.02)/2$
$= 22.24$ lbs

$A = \pi d^2/4$
$= \pi(3.0)^2/4$
$= 7.09\ in^2$

substituting:

$\tau = 4.19$ psi per "g" load

For the 214 "g" peak side drop load, the maximum support rod shear stress is:

$\tau = 4.19(214)2.0/1000$
$= 1.8$ ksi

The support rod maximum stress intensity for the side drop loading is therefore:

$P_l + P_b = 1/2[\sigma_x + \sigma_y \pm \{(\sigma_x - \sigma_y)^2 + 4\tau^2\}^{1/2}]$
$= 1/2[19.7 + \{(19.7)^2 + 4(1.8)^2\}^{1/2}]$
$= 19.9$ ksi

This is conservative as it assumes the maximum shear and bending stress occur at the same location.

7. Shield Block Side Drop Analysis

The depleted uranium shield block assemblies between the top spacer disk and top plate are analyzed for the maximum side drop loads. Four different shield block assemblies are used. The various shield block cross-sections are shown in Section A-1.3.2.

The shield blocks are evaluated using hand calculations assuming the blocks act as simply supported beams. Each cross-section is evaluated for the maximum 30 foot side drop loading imposed on its weakest axis of bending, using the peak acceleration corresponding to the shield block orientation. The shield block connection pins are evaluated assuming direct shear. The appropriate DLF is also included.

The shield blocks consist of depleted uranium and stainless steel (SA-240 Type 304). Since the accident thermal (fire) condition is postulated to occur after the drop, the bounding temperature condition is normal thermal. As discussed in Section A-2.6, the shield block temperature for normal conditions is 300°F. The material properties for the D.U. and stainless steel based on 300°F are listed in Table A-2.3-1.

The shield block bending stress is calculated as:

σ = (Mc/I) (DLF)

where:

M	=	$w\ell^2/8$
c	=	h/2
I	=	$bh^3/12 + ad^2$ (neglecting D.U.)
w	=	W/ℓ (shield block weight per inch)
h	=	thickness of shield block assembly
	=	1.12 inch
ℓ	=	height of shield block assembly
	=	7.5 inch
W	=	weight of shield block assembly

The weights of the Channelled BWR Fuel Basket components and the methodology used to obtain the component weights are summarized in Section A-2.2. As provided therein, the total weight of the D.U. shield blocks is 518 lbs. The individual shield block assembly weights which result in this total reported weight are:

Assembly No. 1: W = 67.45 lb.
Assembly No. 2: W = 56.25 lb.
Assembly No. 3: W = 45.52 lb.
Assembly No. 4: W = 22.11 lb.

The moment of inertia for the four different shield blocks is calculated as:

Assembly No. 1 (conservatively analyzed as a 12 inch wide rectangle),

$$I = \{0.19(1.0)^3/12\}2 + \{12(0.06)^3/12 + 12(0.06)(.53)^2\}2$$
$$= 0.44 \text{ in}^4$$

Assembly No. 2 (conservatively analyzed as a 9 inch wide rectangle),

$$I = \{0.19(1.0)^3/12\}2 + \{9(0.06)^3/12 + 9(0.06)(0.53)^2\}2$$
$$= 0.34 \text{ in}^4$$

Assembly No. 3 (conservatively analyzed as a 9 inch wide rectangle),

$$I = \{0.19(1.0)^3/12\}2 + \{9(0.06)^3/12 + 9(0.06)(0.53)^2\}2$$
$$= 0.34 \text{ in}^4$$

Assembly No. 4 (conservatively analyzed as a 4 inch wide rectangle),

$$I = \{4.0(0.06)^3/12 + 4.0(0.06)(0.53)^2 + 0.19(1.0)^3/12\}2$$
$$= 0.17 \text{ in}^4$$

The DLF is evaluated by comparing the ratio of the shield block structural frequency with the load frequency. The 0° orientation peak acceleration of 214g is the critical side drop loading for the postulated 30 foot cask drop. The corresponding load duration is $0.95\text{x}10^{-3}$ seconds. The shield block assemblies have similar frequencies since the configurations are similar. Assembly No. 1 is conservatively used to determine an appropriate DLF. The structural frequency of shield block Assembly No. 1 is calculated in Section A-2.6.7.4, and is equal to 6637 rad/sec.

The loading frequency, ω_p, is:

$$\omega_p = \pi/T$$
$$= \pi/0.95(10^{-3})$$
$$= 3307 \text{ Rad/sec}$$

The frequency ratio, f_r, is:

$$f_r = 6637/3307$$
$$= 2.01$$

As seen from Figure 42.13 of Reference A-2.10.1-15, the dynamic load factor (DLF) is approximately 1.75 for an undamped system and approximately 1.62 for a 5% critically damped system. The maximum possible dynamic load factor for an undamped system shown is just under 1.8. A bounding DLF of 2.0 is conservatively used in the analysis of the shield blocks.

The bending stress in the shield blocks can then be calculated as:

Assembly No. 1 -

$$w = 67.45/7.5$$
$$= 8.993 \text{ lbs/in}$$

$$M = 8.993(7.5)^2/8$$
$$= 63.2 \text{ in-lb.}$$

$$\sigma = 63.2(1.12/2)(214)(2)/0.44(1000)$$
$$= 34.4 \text{ ksi}$$
(for 214g load w/DLF = 2.0)

Assembly No. 2 -

$$M = (56.25/7.5)(7.5)^2/8$$
$$= 52.73 \text{ in-lb.}$$

$$\sigma = \{52.73(1.12/2)/0.34\}140(2.0)/1000$$
$$= 24.3 \text{ ksi}$$
(for 140g load w/DLF = 2.0)

Assembly No. 3 -

$$M = (45.52/7.5)(7.5)^2/8$$
$$= 42.68 \text{ in-lb.}$$

$$\sigma = \{42.68(0.56)/0.34\}161(2.0)/1000$$
$$= 22.6 \text{ ksi}$$
(for 161g load w/DLF = 2.0)

Assembly No. 4 -

$$M = (22.11/7.5)(7.5)^2/8$$
$$= 20.73 \text{ in-lb.}$$

$$\sigma = \{20.73(0.56)/0.17\}161(2.0)/1000$$
$$= 22.0 \text{ ksi}$$
(for 161g load w/DLF = 2.0)

The shear stress in the shield block connection pins, due to the side drop loading, are evaluated assuming the shear loads are evenly distributed between all pins. The shear stress is given by:

$$\sigma = 4V/3A$$

where:

$$A = \pi(0.38)^2/4$$
$$= 0.11\ in^2$$

The weight per pin at a 1 "g" load for the different cross-sections is listed below:

Assembly No. 1: $V = 67.45/16 = 4.22$ lbs.

Assembly No. 2: $V = 56.25/14 = 4.02$ lbs.

Assembly No. 3: $V = 45.52/12 = 3.79$ lbs.

Assembly No. 4: $V = 22.11/4 = 5.53$ lbs.

The loads shown above will be carried by the pins on each end of the shield blocks.

The maximum shear stress in the pins, conservatively assuming a bounding DLF of 2.0, is therefore:

$$\sigma = (5.53/0.11)(4/3)(214)(2.0)/1000$$
$$= 28.7\ ksi$$

The pin material has an S_u of 94.3 ksi at 300°F. Therefore the allowable shear stress is:

$$\sigma_{all} = 0.42(94.3)$$
$$= 39.6\ ksi$$

8. Poison Plate Side Drop Analysis

The poison plates are non-structural items and need only support their own decelerated weight. The main criteria for the poison plates is to ensure that collapse does not occur during the postulated cask drop accidents. The poison sheet loads and reactions resulting from the side drop loading are shown in Figure A-2.7-25. The poison plates are evaluated using the ANSYS [A-2.10.1-15] analytical model shown in Figure

A-2.6-12. The model consists of two dimensional elastic beams. The beam properties are based on a one inch wide strip. It is assumed no variation in response occurs along the width of the poison plates. The ANSYS evaluation uses a linear dynamic analysis to evaluate the response of the poison plates when subjected to the 30 foot side drop loads. This analysis determines the maximum bending and deflection of the plates. Loads are applied normal to the flat surface of the plate to maximize the bending stresses and displacements. In plane loading of the poison plates is addressed in Section A-2.7.1.1.4.

Four configurations are evaluated in the poison plate analysis. These include:

- A 1/4 inch thick by 17-3/16 inch long plate subjected to the 90° orientation 30 foot side drop load. This analysis bounds all poison plates subjected to the 90° orientation loads except those located between the bottom two spacer disks.

- A 5/16 inch thick by 19-1/16 inch long plate subjected to the 90° orientation 30 foot side drop loads. This analysis is for the poison plates located between the bottom two spacer disks.

- A 3/8 inch thick by 17-3/16 inch long plate subjected to the 0° orientation 30 foot side drop load. This analysis bounds all poison plates subjected to the 0° orientation loads except those located between the bottom two spacer disks.

- A 7/16 inch thick by 19-1/16 inch long plate subjected to the 0° orientation 30 foot side drop loads. This analysis is for the poison plates located between the bottom two spacer disks.

The borated stainless steel material properties used in this analysis are summarized in Table A-2.3-1. The boundary conditions used in the analysis correspond to a pinned end beam with one end allowed to act as a roller in the direction normal to load application.

The same time history used for the spacer disk 0° and 90° orientation side drop analyses is used as the loading for the poison plate analysis. The poison plate is loaded by its own mass excited by the applied acceleration time history.

The linear dynamic time history ANSYS run results are included in Section A-2.10.3. The resulting maximum stress for any sheet at any orientation is:

$$\sigma = 34.8 \text{ ksi}$$

The minimum yield strength for the A887 material is 35.0 ksi at 500°F (Table A-2.3-1). The poison plates remain below yield during the 30 foot drop, therefore, permanent deformation will not occur. In addition, the maximum axial deformation due to the side drop loading is very small. The guide bars which support the poison plates extend a minimum of 0.44 inches at each end of the poison plate. Therefore, the poison plate is adequately retained by the supports and will remain in place.

The guide bars are evaluated for the accident drop load imposed by the poison plates. The guide bar loads and reactions resulting from the postulated 30' side drop loading are illustrated in Figure A-2.7-27. As discussed previously, the maximum poison plate length is 19.06 inches. The maximum poison plate thickness of 7/16 inch is used for this evaluation. The minimum guide bar thickness, accounting for manufacturing tolerances, is 0.19 inches.

The maximum poison sheet end reaction from the 30 foot drop case is:

$$V = 208.0 \text{ lbs./in. (node 1)}$$

The corresponding maximum shear stress is:

$$\begin{aligned} \tau &= (1.5)V/A \\ &= 1.5(208.0)/[((0.75 - 0.37)/2)(1)(1000)] \\ &= 1.6 \text{ ksi} \end{aligned}$$

Assuming the poison plate extends only halfway into the guide bar, the guide bar maximum bending stress is calculated as:

$$\ell = 0.63/2 = 0.31$$

$$M = V\ell = 208.0(0.31) = 64.5 \text{ in-lbs/in.}$$

$$S = bt^2/6 = (1)(0.19)^2/6 = 0.00602 \text{ in}^3\text{/in.}$$

$$\sigma_b = M/S = [64.5/0.00602(1000)] = 10.7 \text{ ksi}$$

The resulting stress intensity for the maximum shear and bending stress is 11.6 ksi. The allowable local primary membrane plus bending stress intensity for the guide bars at 500°F for ASME [A-2.10.1-3] Service Level D is:

$$\sigma_{all} = 1.5(2.4)S_m = 1.5(2.4)(17.5) = 62.6 \text{ ksi}$$

The stress in the 1/8 inch double-sided partial penetration attachment welds between the guide bar and spacer disk is evaluated using the controlling poison plate reaction force. Assuming the poison plate extends only halfway into the guide bar, the eccentricity is:

$$e = (0.63/2) + 0.12 = 0.435 \text{ in.}$$

Applying the maximum reaction force from the ANSYS [A-2.10.1-15] poison sheet side drop model, the corresponding maximum shear and moment forces acting on the weld is:

$$V = 208.0 \text{ lbs./in.}$$

$$M = V(e)$$

$$M = (208.0)(0.435) = 90.5 \text{ in-lbs/in.}$$

The section modulus is:

$$S_w = b(d) = (1)(0.5) = 0.5 \text{ in}^2$$

The bending force per inch of weld is:

f_b = M/S_w
= 181 lbs/in

The area/in. of the weld is:

A_w = L_w
= 2 in

The shear force per inch of weld is:

f_v = V/A_w
= 104 lbs/in

The resultant force on the weld is:

f_r = $[f_r^2 + f_v^2]^{1/2}$
= 209 lbs/in

The allowable stress, S_m, for Type 304 stainless steel at 500°F is 17.5 ksi. The allowable stress for a double sided partial penetration weld (0.6 efficiency factor) for service level D is:

τ_{all} = $(0.6)2.4S_m$ (NG-3225)
= $(0.6)2.4(17.5)$
= 25.2 ksi

The required weld size is:

t = $f_r/\tau_{all} = 209/25200 = 0.01$ in

Therefore, the 1/8" double-sided partial penetration welds provided are adequate.

3. Corner Drop

The corner drop deceleration magnitudes are significantly less than those of the vertical end and horizontal side drop orientation decelerations ([A-2.10.1-2] Table V-19, page 5-48). The magnitudes of the end and side drop components of the corner drop deceleration are less than those used to evaluate the end and side drop loading. Therefore, the critical loading conditions for the basket assembly are the vertical end and horizontal side drop loads which maximize the load magnitude for each load orientation. As the corner drop horizontal and vertical load magnitudes are substantially bounded by those of the end and side drop loads, the corner drop load need not be evaluated.

4. Oblique Drop

The oblique drop orientations are bounded by the end and side drop loading conditions and need not be evaluated as described in Section A-2.7.1.3. Further discussion of oblique drops is provided in Section A-2.10.4.

5. Summary of Results

The accident drop condition maximum stresses are summarized in Table A-2.7-1. As can be seen from the table, the only stresses which exceed yield are the bending stresses associated with the 0° orientation spacer disk side drop load and the top plate vertical end drop load. These stresses are well within allowable limits and will result in only slight plastic deformation. Stresses for all basket components are within allowable limits. Therefore, the integrity of the Channelled BWR Fuel Basket assembly will be maintained and will remain fully functional for all accident drop conditions.

A-2.7.2 Puncture

Puncture conditions do not apply to the Channelled BWR Fuel Basket assembly and need not be specifically addressed. The effects of the basket assembly on the cask body puncture analysis is negligible. As discussed previously in Section A-2.2, the basket loading on the cask body remains well within the currently licensed limits.

A-2.7.3 Thermal

The thermal evaluation of the Channelled BWR Fuel Basket for the accident event is presented in Chapter A-3.0. The structural evaluation of the resulting temperature distributions is presented in Section A-2.7.3.3.

1. Summary of Pressures and Temperatures

The Channelled BWR Fuel Basket is not a pressure boundary, therefore, pressure loadings need not be addressed in the structural analysis. The controlling design temperatures used in the structural thermal analysis are listed in Table A-2.7-2.

2. Differential Thermal Expansion

1. Spacer Disk Differential Thermal Expansion

The spacer disk differential thermal expansion is evaluated in the spacer disk thermal stress analysis presented in Section A-2.7.3.3.1.

2. Support Rod Thermal Expansion

The enveloping accident temperature of the support rods is 500°F. The nominal length of the support rods is 179.25 inches, which is identical to the support rod length of the 18-Cell BWR Fuel Basket. Since the design basis heat loads are identical to those used for the 18-cell design in the CSAR [A-2.10.1-2], differential thermal expansion of the basket and cask will be unchanged.

3. Depleted Uranium Thermal Expansion

The shield block assembly differential thermal expansion is addressed in conjunction with the shield block assembly thermal stress analysis presented in Section A-2.7.3.2.4.

4. Poison Plate Thermal Expansion

The enveloping poison plate accident temperature is 650°F. The support rods and the spacer disks will also expand as the poison plates expand. Thermal stresses in the poison plates are alleviated by the gap between the poison plate and spacer disks attachment guide bars. Differential growth between the support rods and poison plates greater than the available gap will result in thermal stresses in the poison plates.

Using a conservative length of support rod of 20 inches and based on a design temperature of 500°F, the thermal growth of the support rods is:

$$\begin{aligned}\delta_r &= \alpha(\Delta T)\ell \\ &= 8.92(10^{-6})(500 - 70)(20) \\ &= 0.077 \text{ inches}\end{aligned}$$

Also using a 20 inch length of poison plate and a design temperature of 650°F, the thermal growth of the poison plates is:

$$\begin{aligned}\delta_p &= \alpha(\Delta T)\ell \\ &= 9.69(10^{-6})(650 - 70)(20) \\ &= 0.112 \text{ inches}\end{aligned}$$

The differential growth is then:

$$\begin{aligned}\Delta &= \delta_p - \delta_r \\ &= 0.112 - 0.077 \\ &= 0.035 \text{ inches}\end{aligned}$$

The minimum gap specified between the poison plates and the guide bars is 0.063 inches. The poison plates, therefore, are free to expand thermally and will not experience thermal stresses.

3. Stress Calculations

1. Spacer Disk Thermal Stress Analysis

The temperature distribution for the spacer disk, presented in Chapter A-3.0, is applied to a finite element model shown in Figure A-2.6-1 using nodal temperatures. Thermal effects are evaluated for radial thermal gradients (plane stress conditions). The through-thickness thermal effects are negligible. The differential thermal growth due to the non-uniform temperature distribution results in membrane stresses in the spacer disk.

Symmetry boundary conditions are applied in the analytical model at the spacer disk centerlines. A single node is fixed to provide numerical stability. The spacer disk is allowed free thermal growth.

The analytical model results are provided in Section A-2.10.3. The resulting maximum membrane stress intensity due to the accident thermal temperature distribution is 28.7 ksi.

2. Shield Block Accident Thermal Stress Analysis

The D.U. shield block assemblies are fabricated at room temperature. The D.U. coefficient of thermal expansion is less than the coefficient of thermal expansion for the stainless steel casing. The coefficient of thermal expansion of the XM-19 support rods is less than the coefficient of thermal expansion for the stainless steel casing and slightly larger than that of the D.U.

The free thermal growth of the D.U., stainless steel casing sheets and the support rods, δ_{du}, δ_{ss} and δ_r can be calculated as:

$$\delta = \alpha \ell \Delta t$$

$$\delta_{du} = 8.34(10^{-6})(7.0)(500 - 70) = 0.0251 \text{ inches}$$

$$\delta_{ss} = 9.37(10^{-6})(7.5)(500 - 70) = 0.0302 \text{ inches}$$

$$\delta_r = 8.92(10^{-6})(7.68)(500 - 70) = 0.0295 \text{ inches}$$

Conservatively assuming no strain in the D.U., the strain and resulting stress in the D.U. shield block stainless steel casing due to differential thermal expansion is:

$$\epsilon_{ss} = (\delta_{ss} - \delta_{du})/\ell = (0.0302 - 0.0251)/7.5 = 6.80\ (10^{-4})$$

$$\sigma_{ss} = E\epsilon = 25.8(10^6)(6.80)(10^{-4})/1000 = 17.5 \text{ ksi}$$

The differential thermal growth between the D.U. shield blocks and the support rods is:

$$\delta_d = \delta_{ss} - \delta_r = 0.0007 \text{ inches}$$

To allow sufficient differential thermal growth between the D.U. shield blocks and the support rods, a minimum gap of 0.010 inch is provided between the D.U. shield blocks and the top spacer disk.

4. Comparison with Allowable Stresses

The controlling accident condition load combination is the 30 foot drop. The 30 foot drop conditions are classified as Service Level D events. Thermal loads are defined by the ASME code as secondary stresses which need not be considered for Service Level D events. Therefore for the primary stresses evaluated for compliance with the ASME Code, the accident thermal stresses need not be considered.

Table A-2.7-3 lists the accident condition stresses for the Channelled BWR Fuel Basket major components.

Also shown is their comparison to allowable limits. As can be seen from the table, all stresses are within allowable limits.

A-2.7.4 Immersion - Fissile Material

The criticality evaluation presented in Chapter 6.0 considers the effect of water in-leakage. Thus the requirement of 10CFR71 [A-2.10.1-1] Section 73(c)(4) is met.

A-2.7.5 Immersion - All Packages

A 21 psig external pressure due to immersion of the package in 50 feet of water as required by 10CFR71 [A-2.10.1-1] Section 73(c)(5) does not effect the Channelled BWR Fuel Basket assembly and need not be addressed.

A-2.7.6 Summary of Damage

As shown in this section and summarized in Table A-2.7-3, the only stresses in the Channelled BWR Fuel Basket which exceed yield are the bending stresses associated with the 0° orientation spacer disk side drop and the top plate end drop. These stresses are well within allowable limits and will result in only slight plastic deformation. Therefore, the integrity of the basket assembly will be maintained and will remain fully functional in all hypothetical accident conditions.

Table A-2.7-1

Accident Drop Load Stress Analysis Summary

COMPONENT	LOAD CONDITION	TYPE OF STRESS	MAXIMUM STRESS (Ksi)
Spacer Disk	30' Side Drop		
	0° orientation	P_m	37.8
		P_l	37.8
		$P_l + P_b$	56.6
	45° orientation	P_m	12.9
		P_l	12.9
		$P_l + P_b$	43.4
	90° orientation	P_m	30.7
		P_l	30.7
		$P_l + P_b$	39.7
Top Plate	0° Orientation 30' Side Drop	P_m	19.3
		P_l	19.3
		$P_l + P_b$	19.6
	30' End Drop	P_m	N/A
		P_l	N/A
		$P_l + P_b$	42.5
Support Rods	30' Side Drop	P_m	N/A
		$P_l + P_b$	19.9
	30' End Drop	P_m	58.0
		$P_l + P_b$	58.0
D.U. Shield Blocks Casing Plates	30' Side Drop	P_m	N/A
		$P_l + P_b$	34.4
	30' End Drop	P_m	34.3
		$P_l + P_b$	41.8
D.U. Shell Block Pins	30' Side Drop	Pure Shear	28.7
	30' End Drop	Tension	60.9
Poison Plates	30' Side Drop	P_m	0.0
		$P_l + P_b$	34.8
	30' End Drop	P_m	2.6

Table A-2.7-2

Basket Assembly Accident Condition Design Temperatures

Basket Assembly Component	Design[1] Temperature (°F)
Spacer Disks	650
Support Rods	500
Depleted Uranium Shield Blocks	500
Poison Plates	650

Note:

1. The design temperatures reported in this table are used for the thermal expansion stress evaluations for the postulated accident fire. The drop event is postulated to occur prior to the postulated accident fire [A-2.10.1-1], therefore, applicable design temperatures for the drop analysis are those given in Table A-2.6-1.

Table A-2.7-3

Comparison of Accident Condition Stresses to Allowable Stresses

Basket Assembly Component	Type of Stress	Accident Stresses	Allowable Stress (S.I.)	Factor of Safety (F.S.)
Top Plate	P_m	19.3	62.4	3.23
	$P_l + P_b$	42.5	93.6	2.20
Spacer Disk	P_m	37.8	62.4	1.65
	$P_l + P_b$	56.6	93.6	1.65
Support Rods	P_m	58.0	66.0	1.14
	$P_l + P_b$	58.0	99.0	1.71
D.U. Shield Block Casing Plates	P_m	34.3	46.2	1.35
	$P_l + P_b$	41.8	69.3	1.66
D.U. Shield Block Pins	Pure Shear	28.7	39.6	1.38
	Tension	60.9	66.0	1.08
Poison Plates	P_m	2.6	23.3(1)	9.0
	$P_l + P_b$	34.8	35.0(1)	1.01

Note:

1. Allowable stress for P_m is taken as 2/3 yield strength ([A-2.10.1-3] Appendix III-2110(4)). Allowable for P_l + P_b is conservatively limited to the material yield strength.

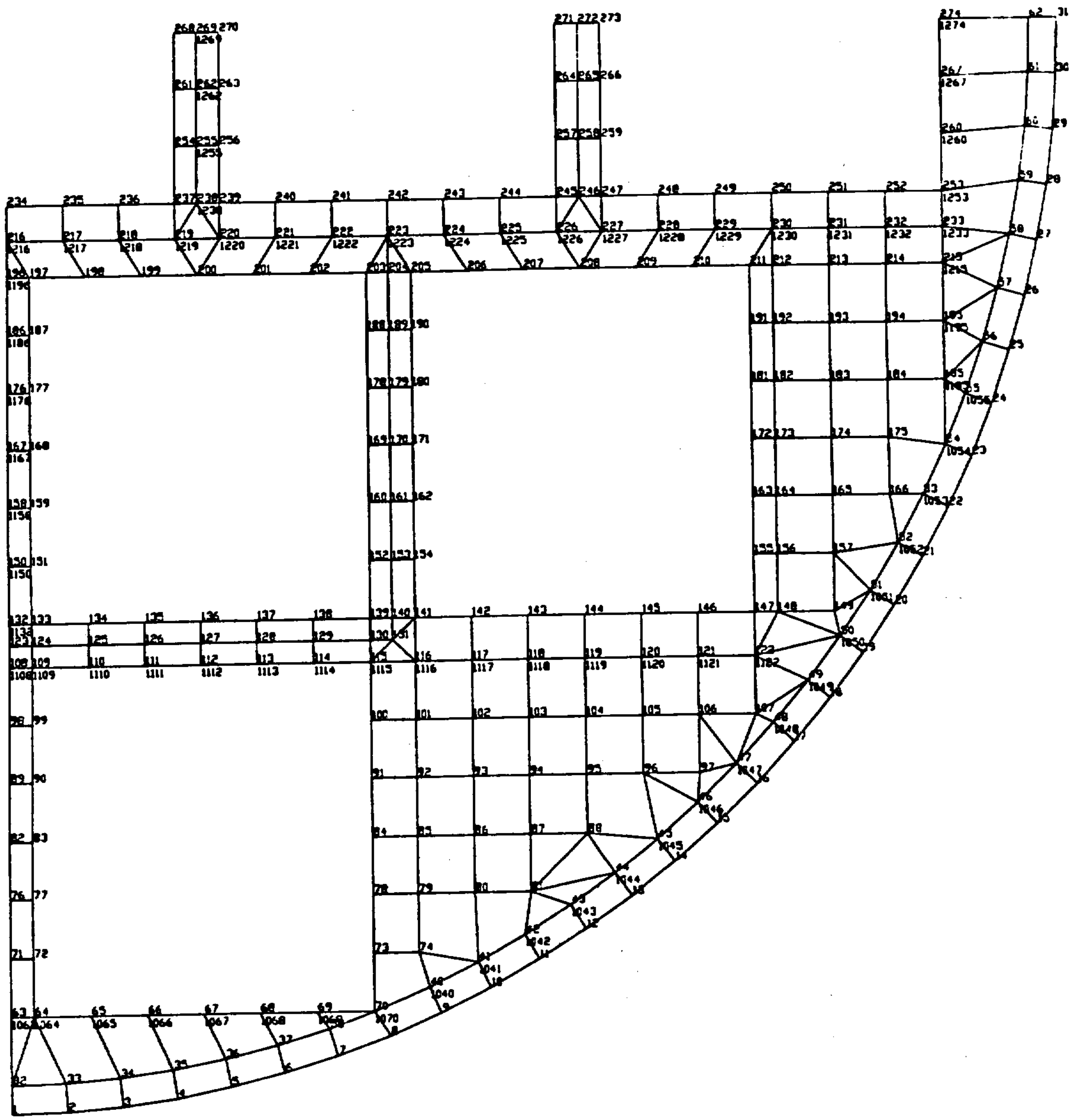


Figure A-2.7-1

<u>Top Plate End Drop Model Nodal Geometry</u>

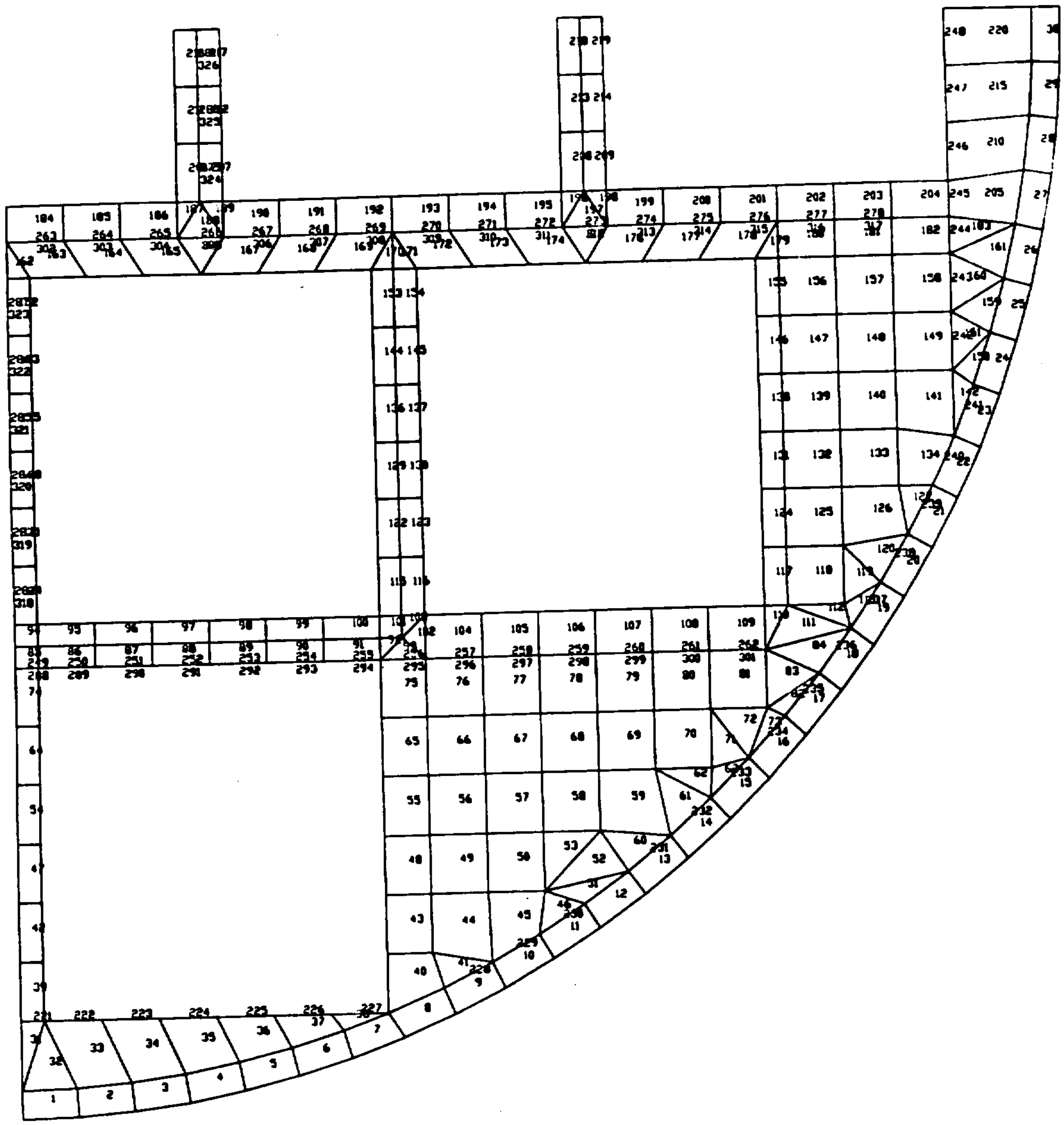


Figure A-2.7-2

Top Plate End Drop Model Element Geometry

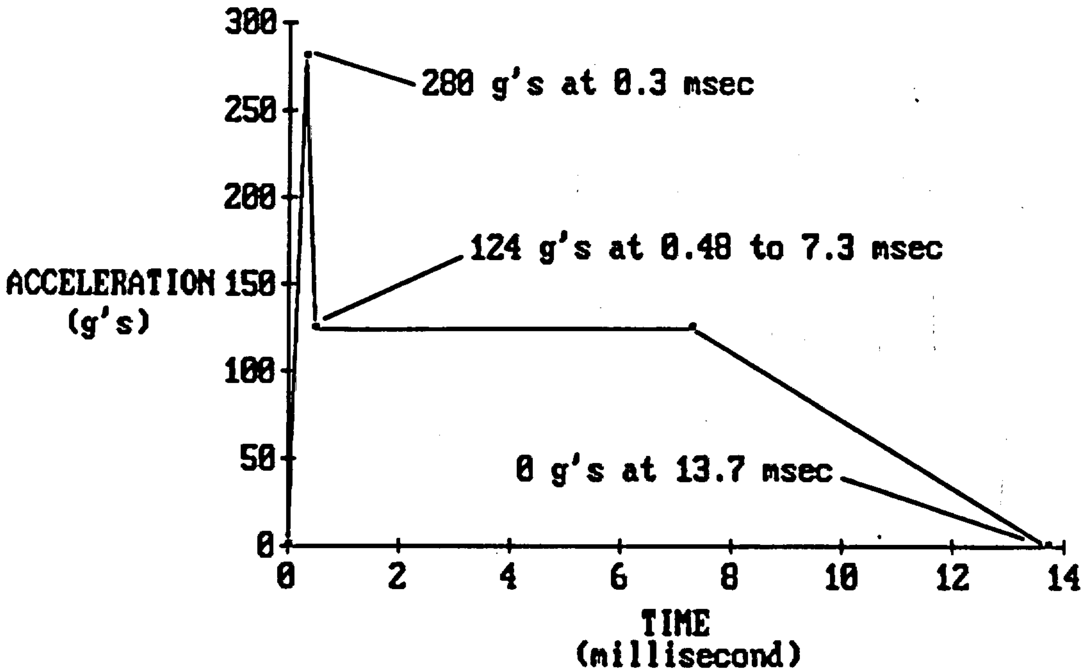


Figure A-2.7-3

Vertical End Drop Acceleration Time History

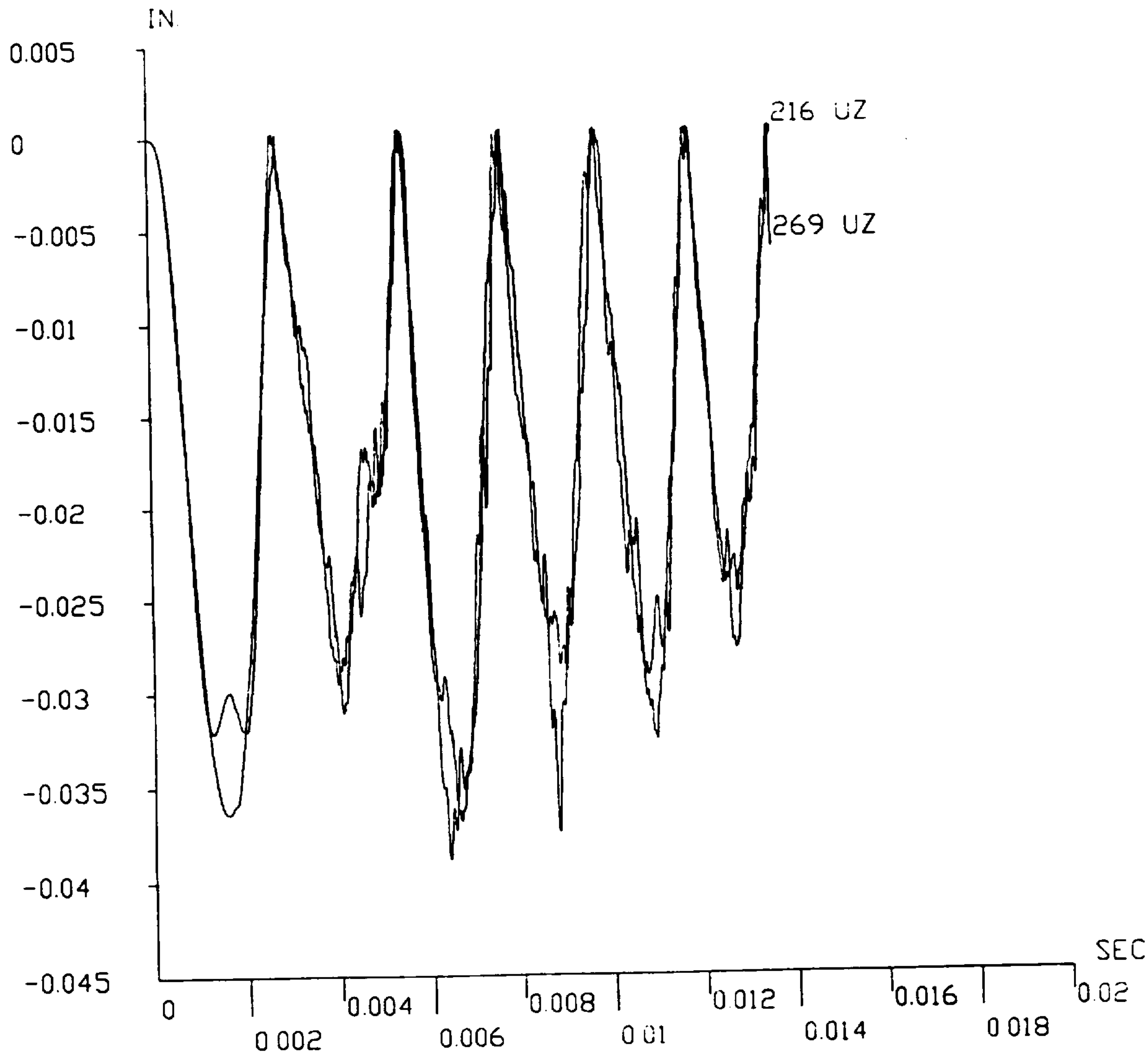


Figure A-2.7-4

Top Plate End Drop Maximum Displacements vs. Time

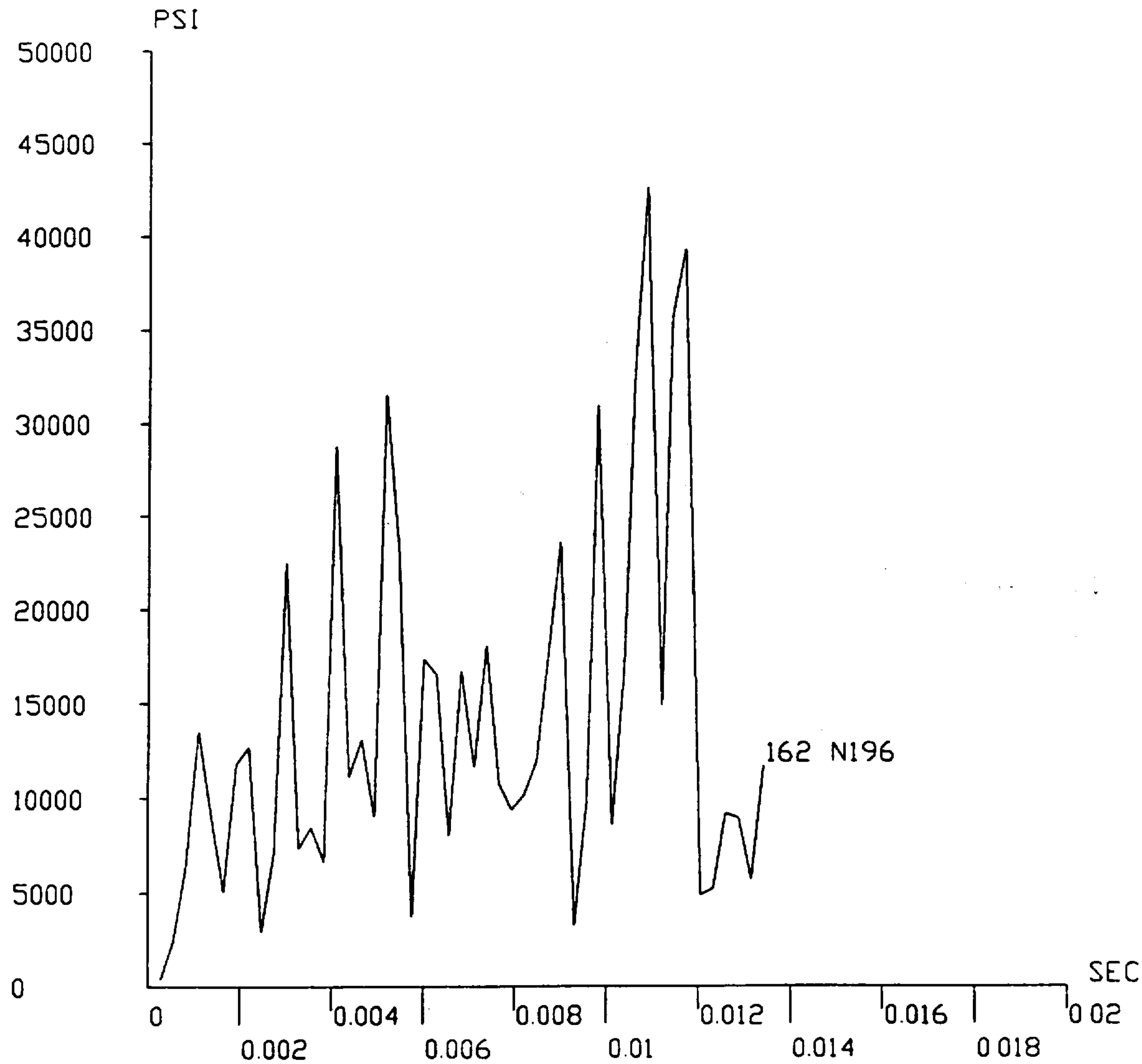


Figure A-2.7-5

<u>Top Plate End Drop Maximum S.I. vs. Time</u>

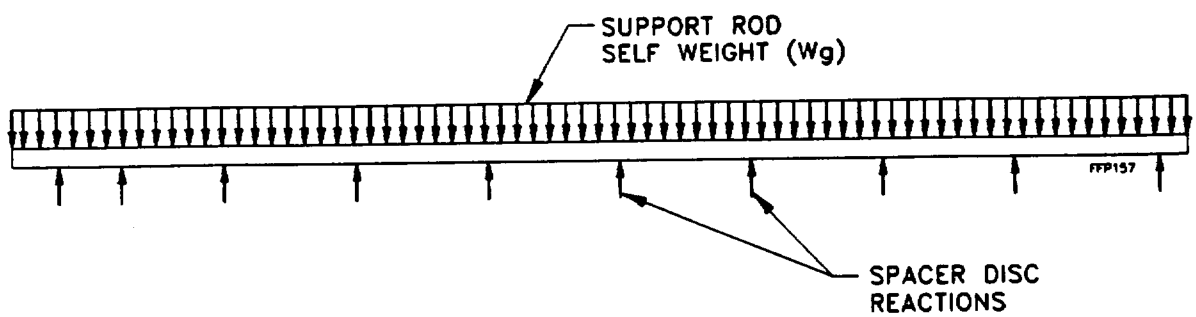
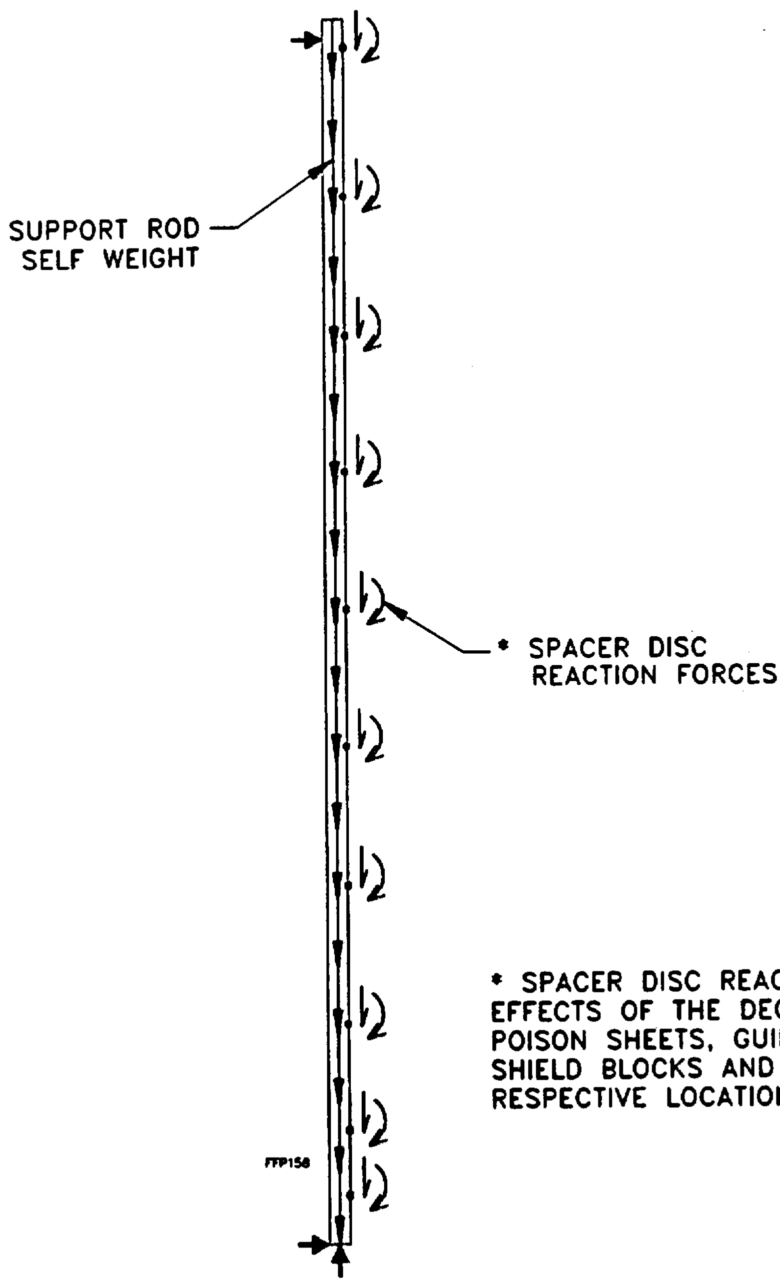


Figure A-2.7-6

Support Rod Side Drop Loads and Reactions



* SPACER DISC REACTION FORCES INCLUDE THE EFFECTS OF THE DECELERATED MASS OF THE POISON SHEETS, GUIDE BARS, DEPLETED URANIUM SHIELD BLOCKS AND LIFTING LUGS AT THEIR RESPECTIVE LOCATIONS.

Figure A-2.7-7

<u>Support Rod End Drop Loads and Reactions</u>

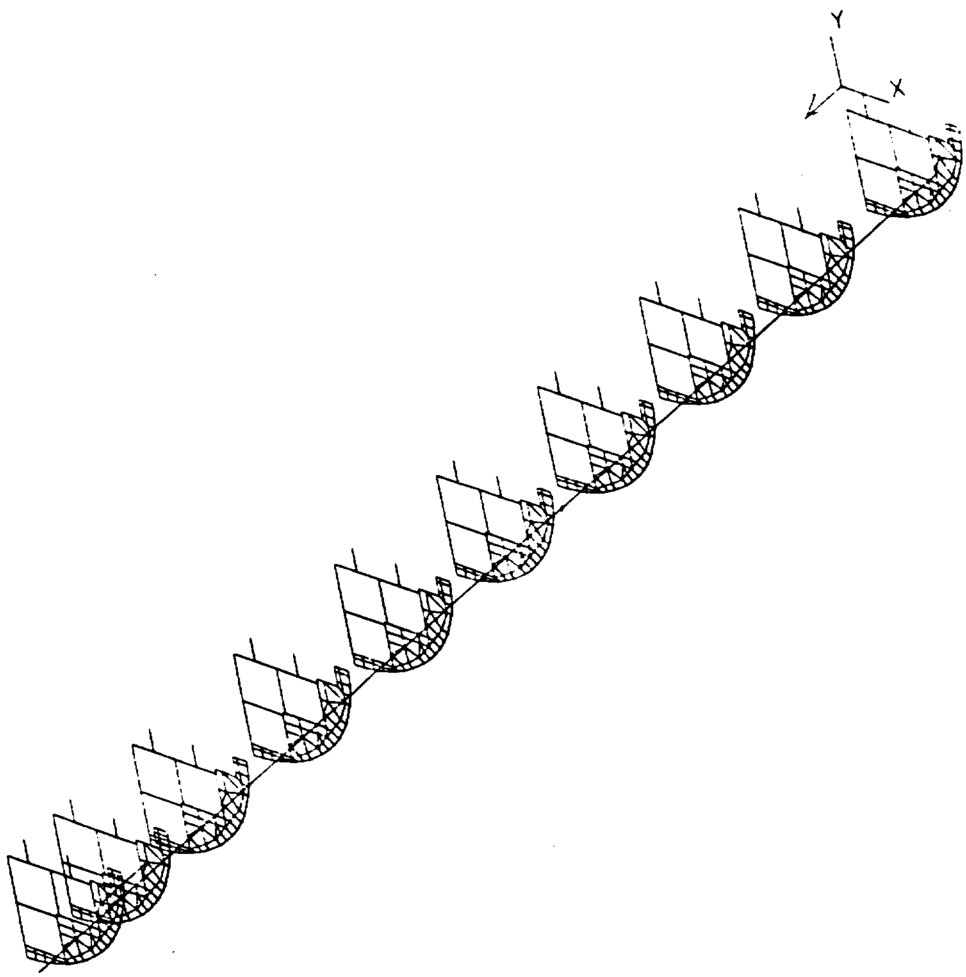


Figure A-2.7-8

Support Rod Analytical Model

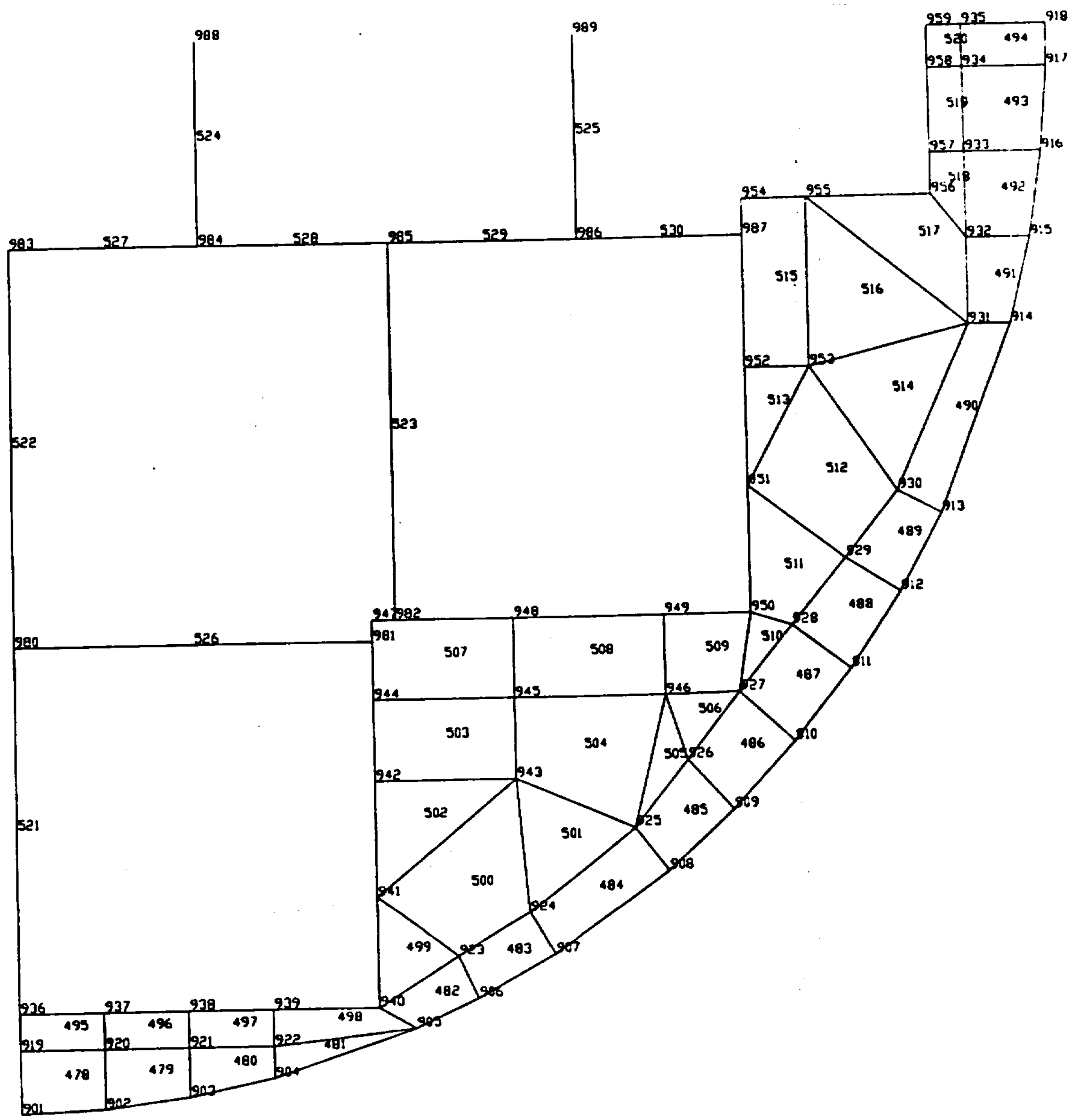


Figure A-2.7-9

Support Rod Analytical Model
Top Plate Node and Element Geometry

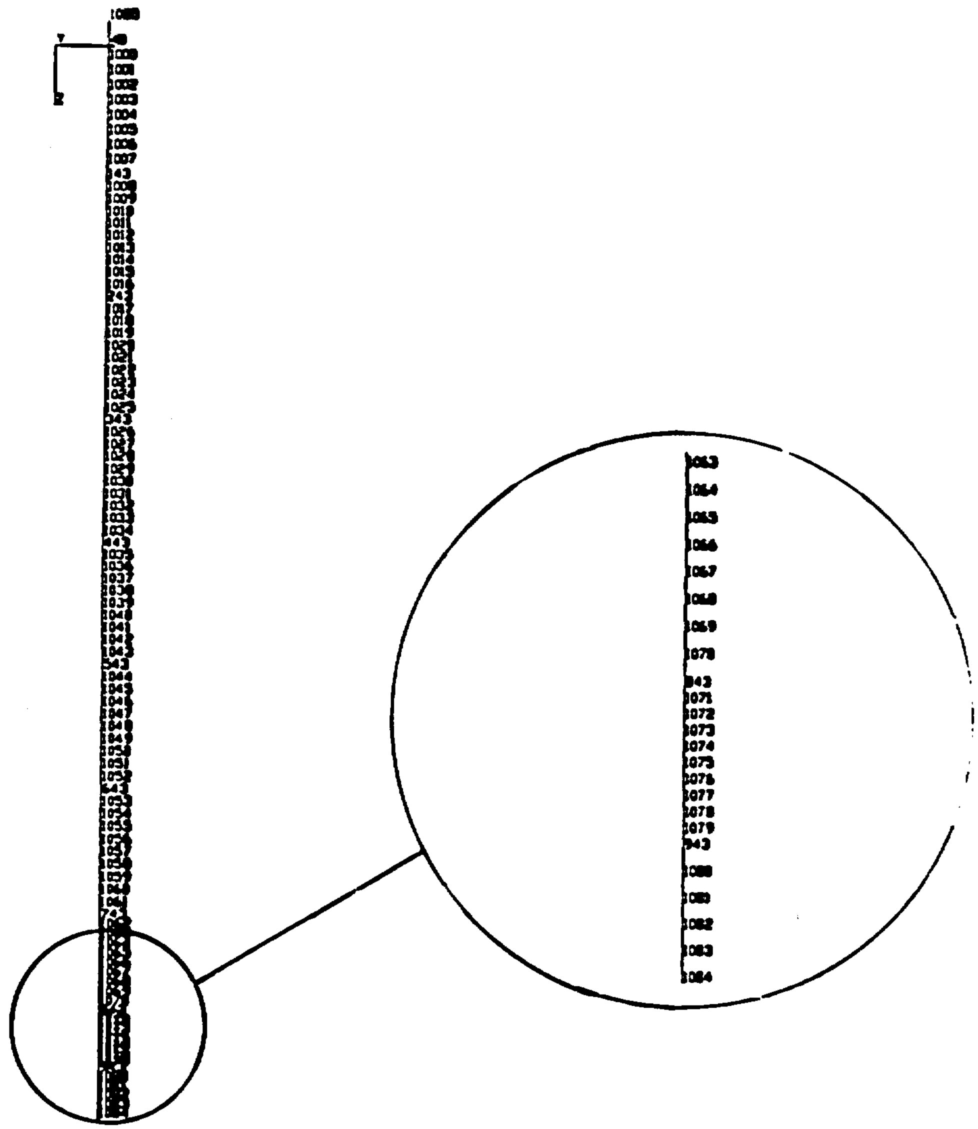


Figure A-2.7-10

Support Rod Model Nodal Geometry

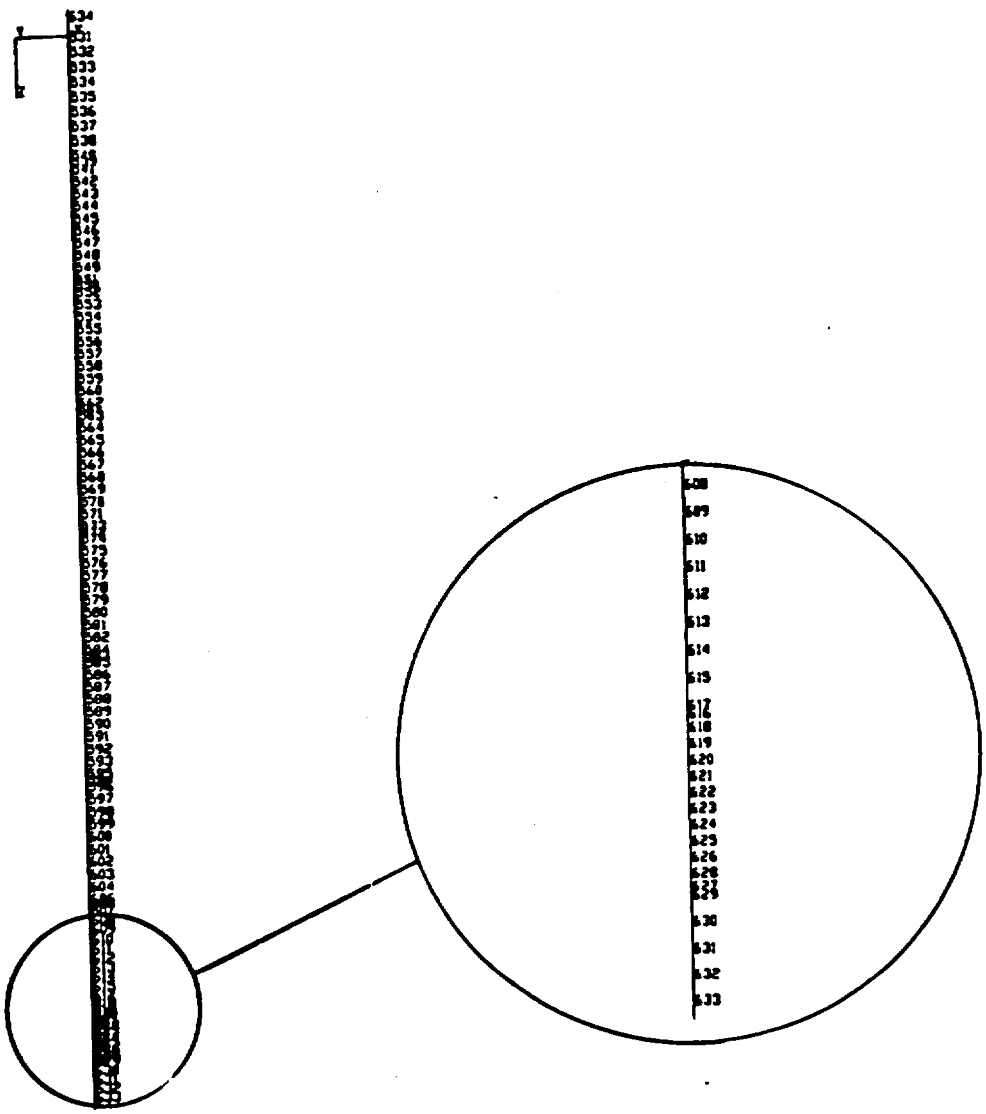


Figure A-2.7-11

Support Rod Model Element Geometry

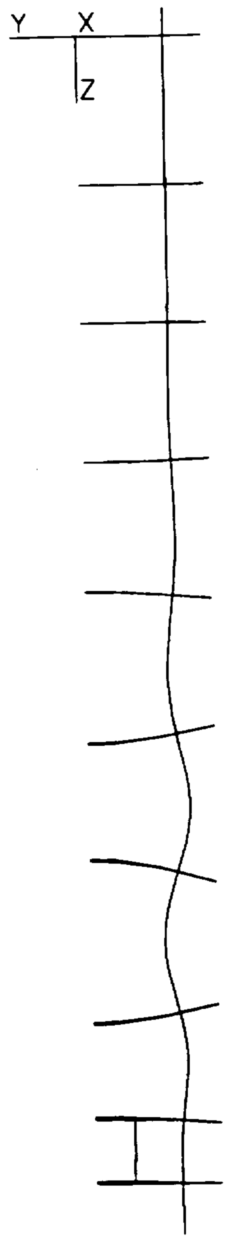


Figure A-2.7-12

Support Rod Buckled Mode Shape

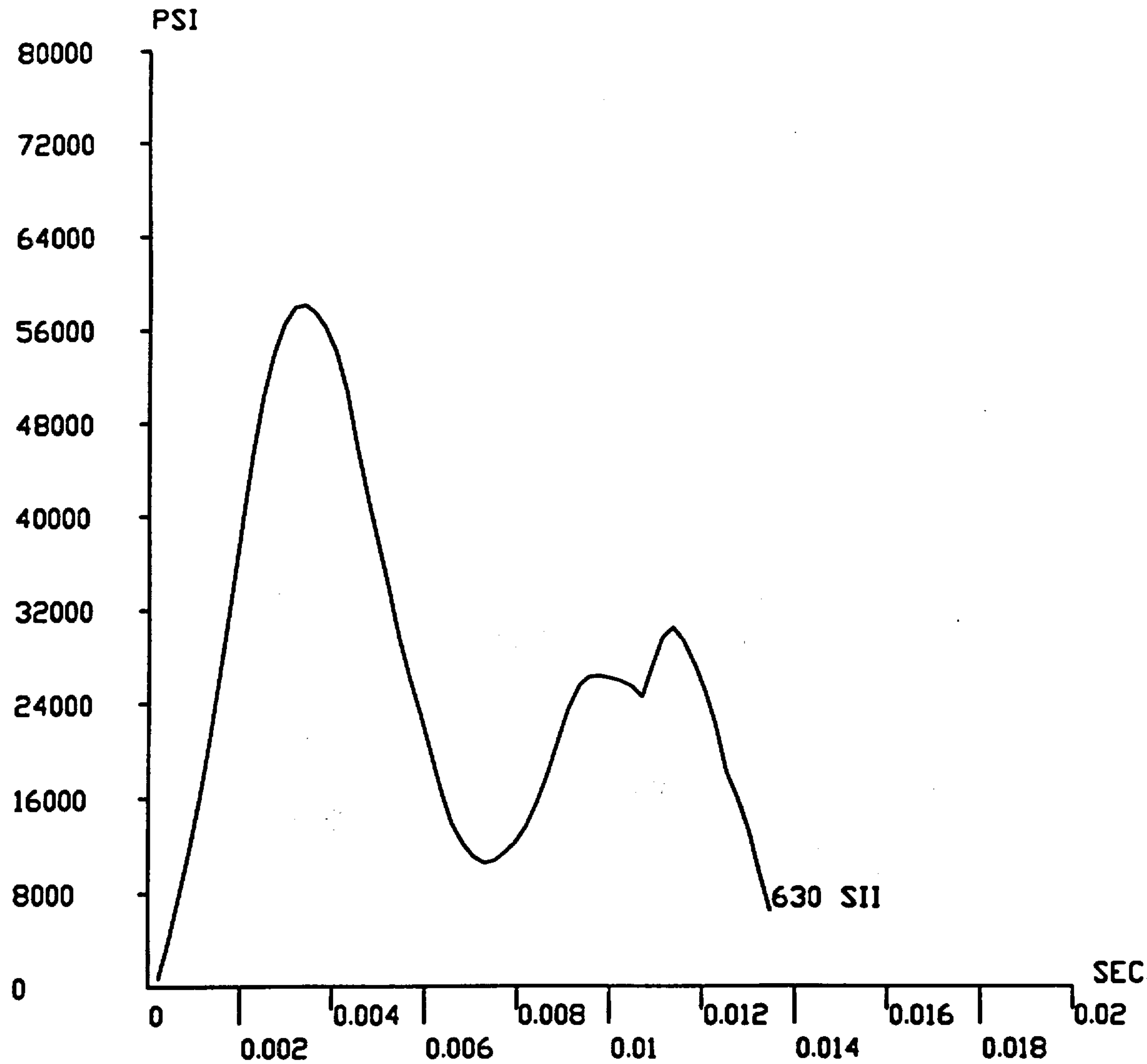


Figure A-2.7-13

Support Rod End Drop Maximum S.I. vs. Time

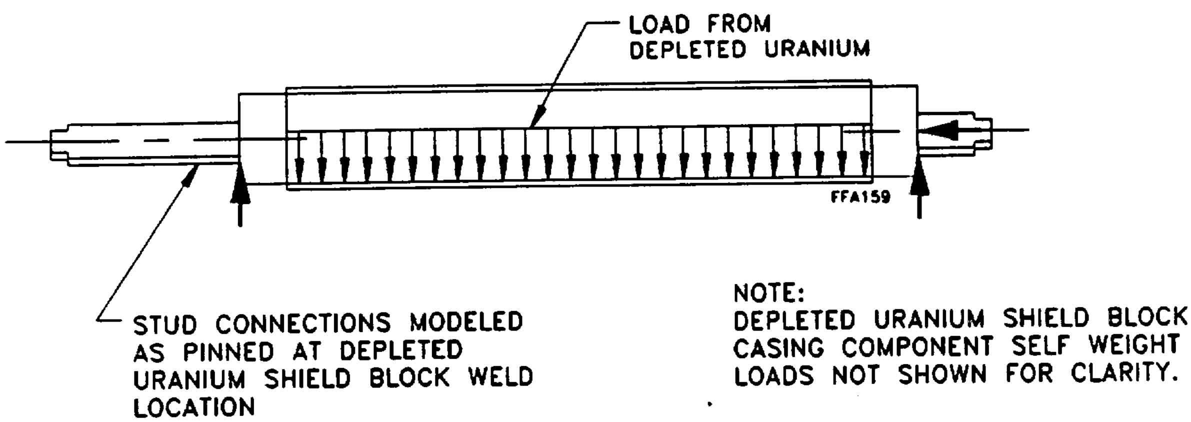


Figure A-2.7-14

Shield Block Side Drop Loads and Reactions

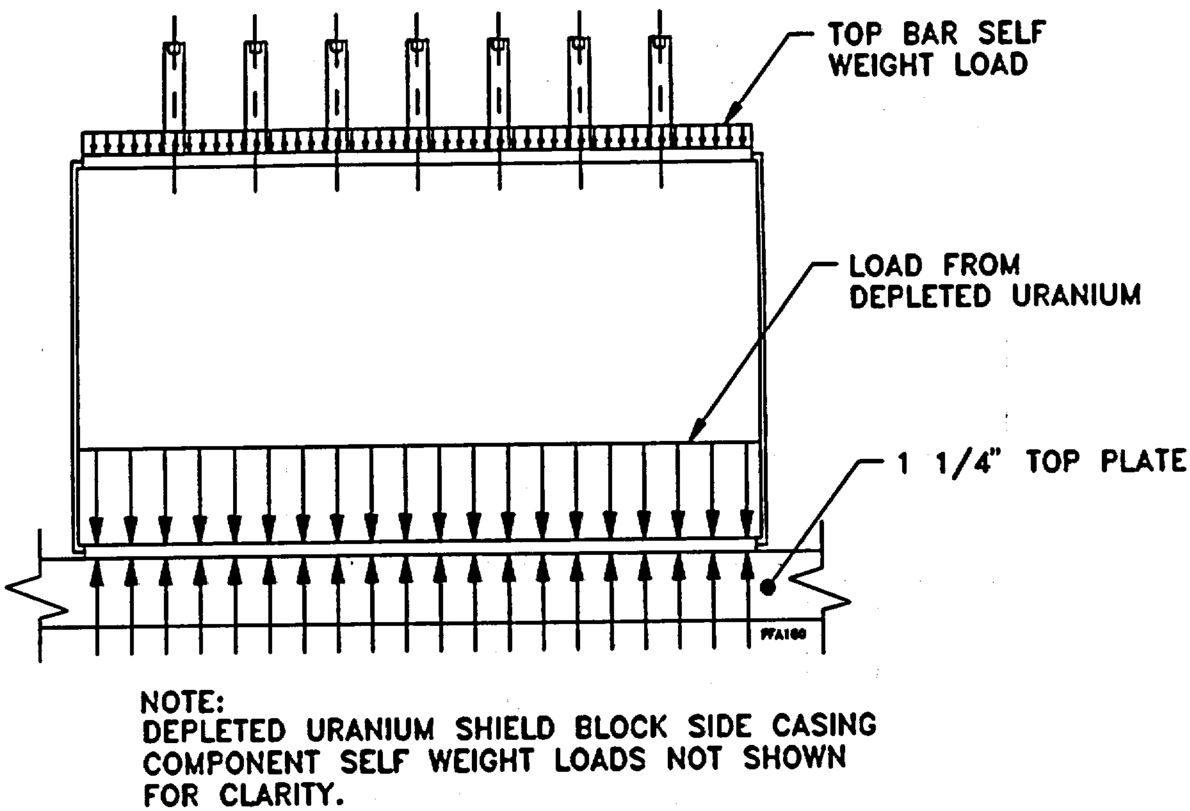


Figure A-2.7-15

Shield Block Top End Drop Loads and Reactions

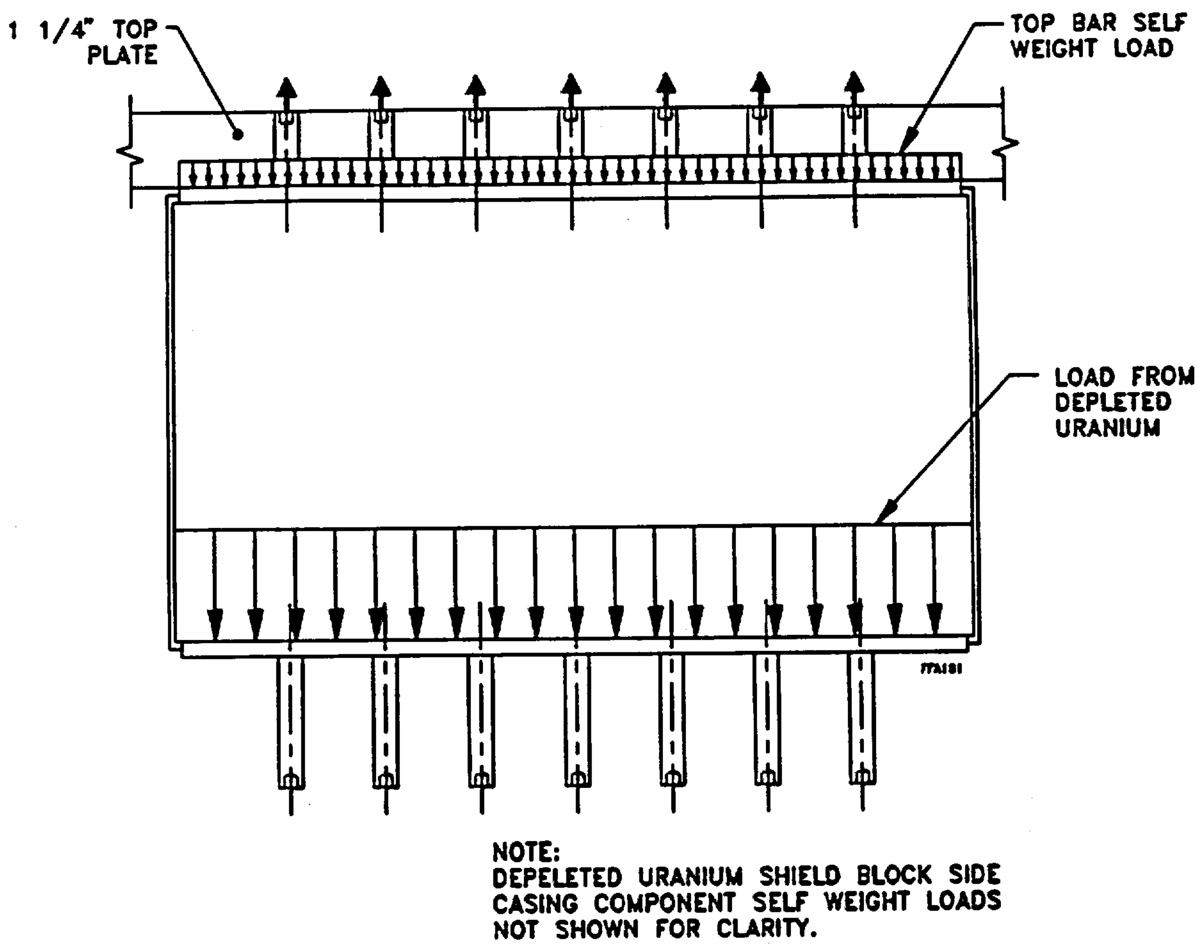


Figure A-2.7-16

Shield Block Bottom End Drop Loads and Reactions

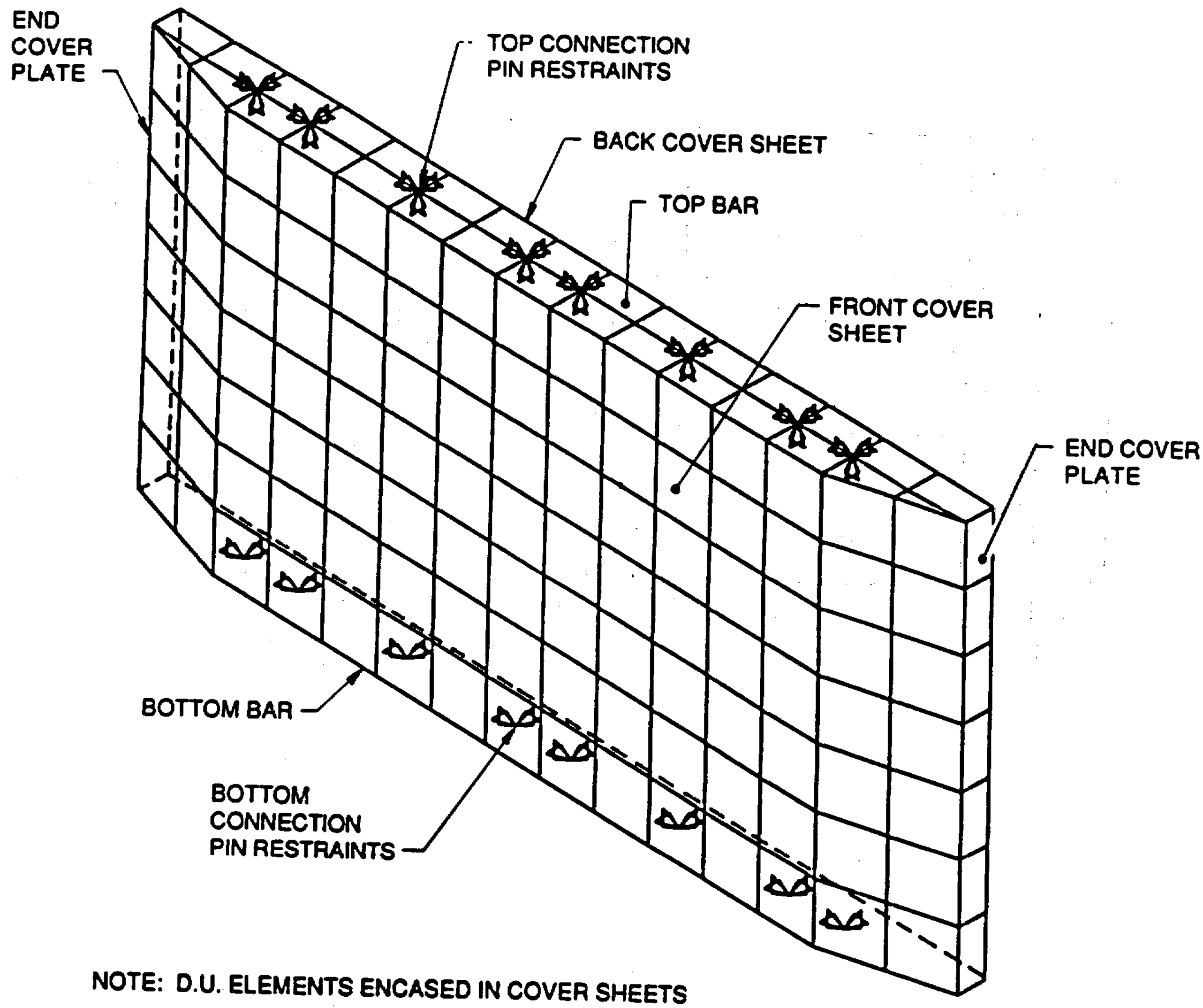
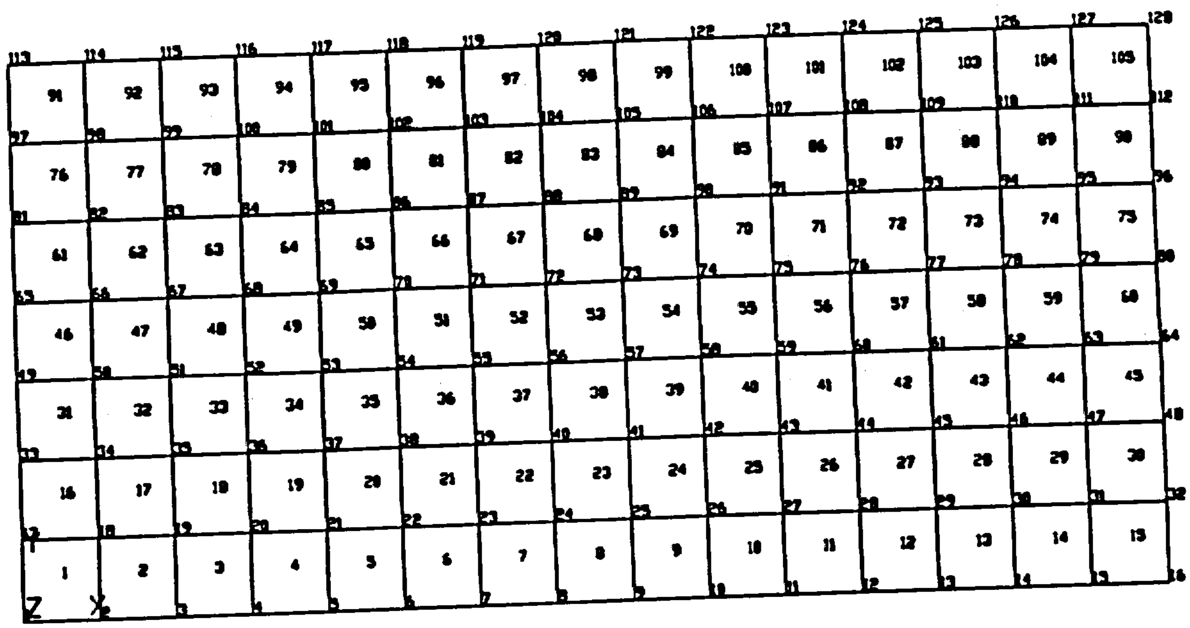


Figure A-2.7-17

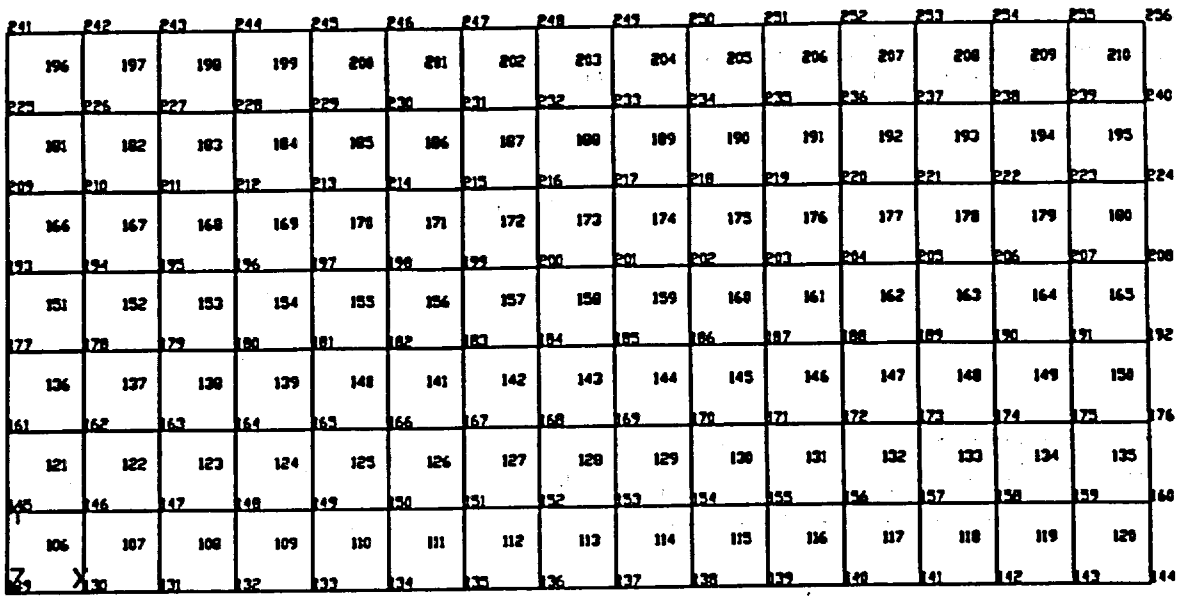
Shield Block End Drop Analytical Model



Note: See Figure A-2.7-17 for location of this plate in the analytical model.

Figure A-2.7-18

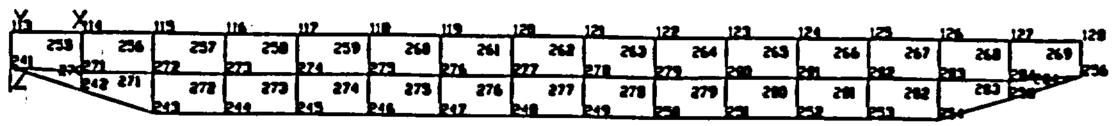
Shield Block End Drop Analytical Model
Back Cover Plate Geometry



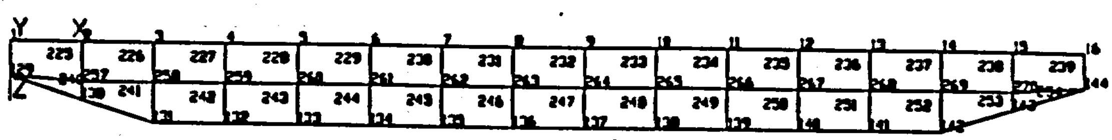
Note: See Figure A-2.7-17 for location of this plate in the analytical model.

Figure A-2.7-19

<u>Shield Block End Drop Analytical Model</u>
<u>Front Cover Plate Geometry</u>



TOP BAR GEOMETRY

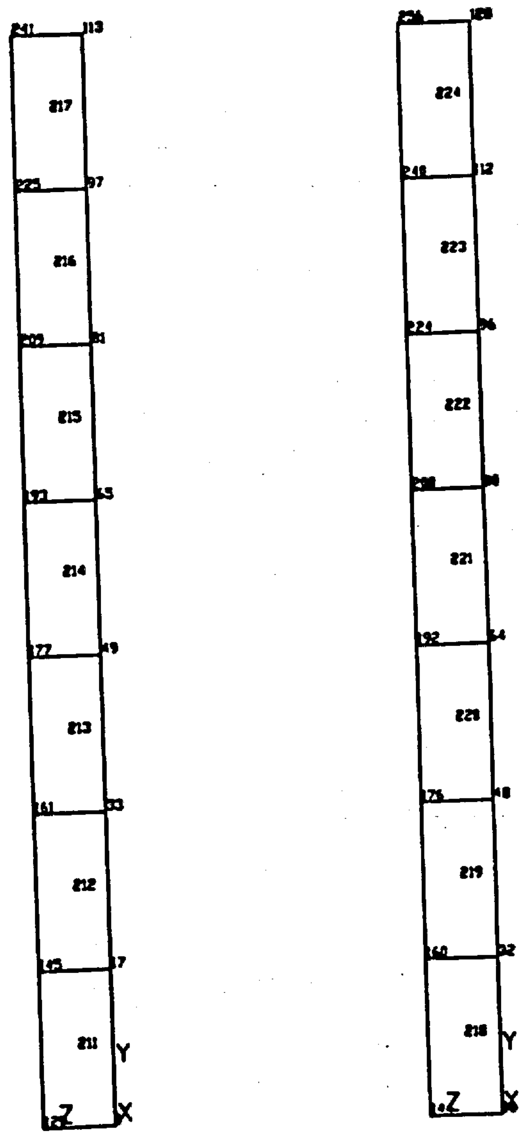


BOTTOM BAR GEOMETRY

Note: See Figure A-2.7-17 for location of this plate in the analytical model.

Figure A-2.7-20

Shield Block End Drop Analytical Model
Top and Bottom Bar Geometry

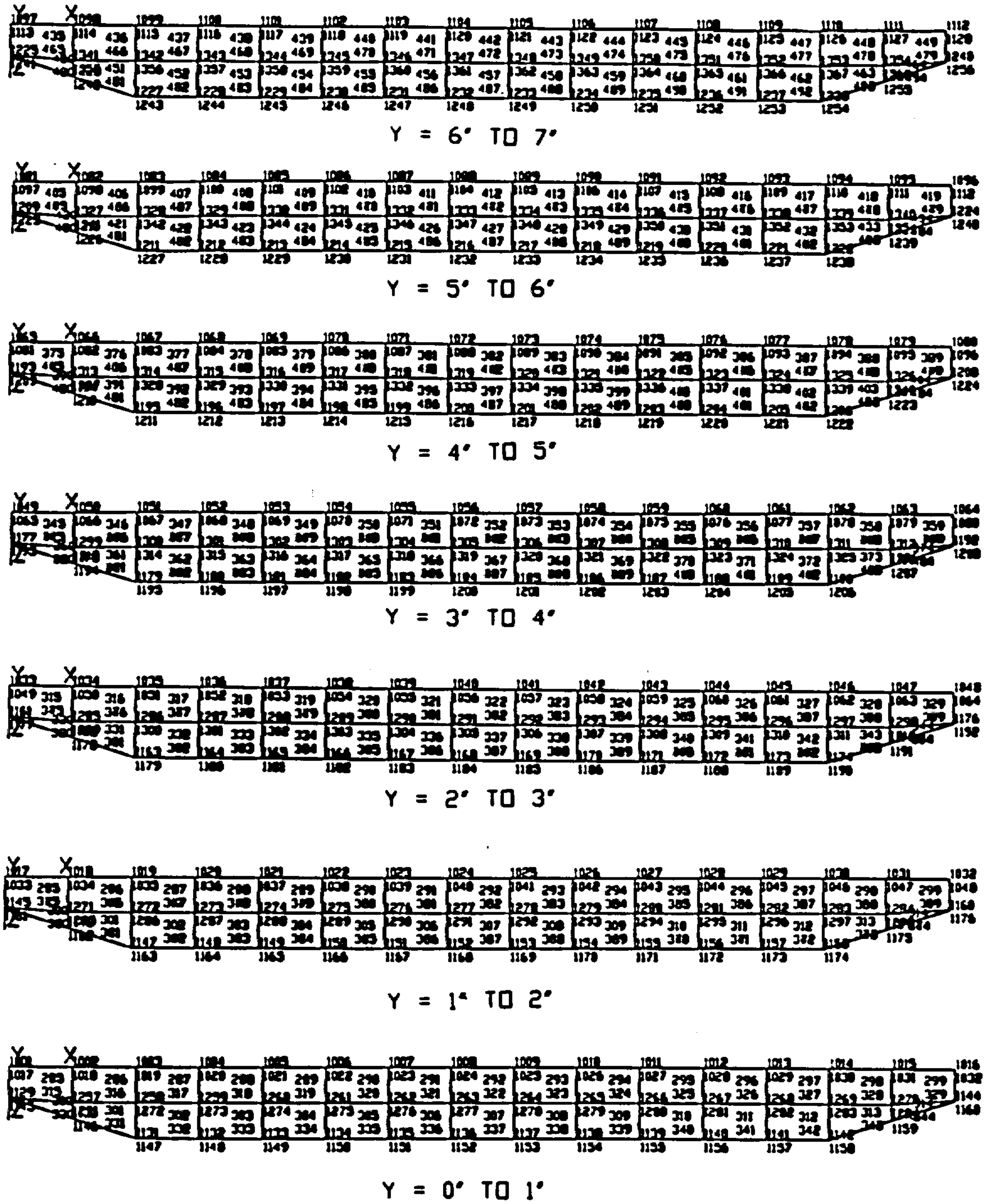


END COVER GEOMETRY

Note: See Figure A-2.7-17 for location of this plate in the analytical model.

Figure A-2.7-21

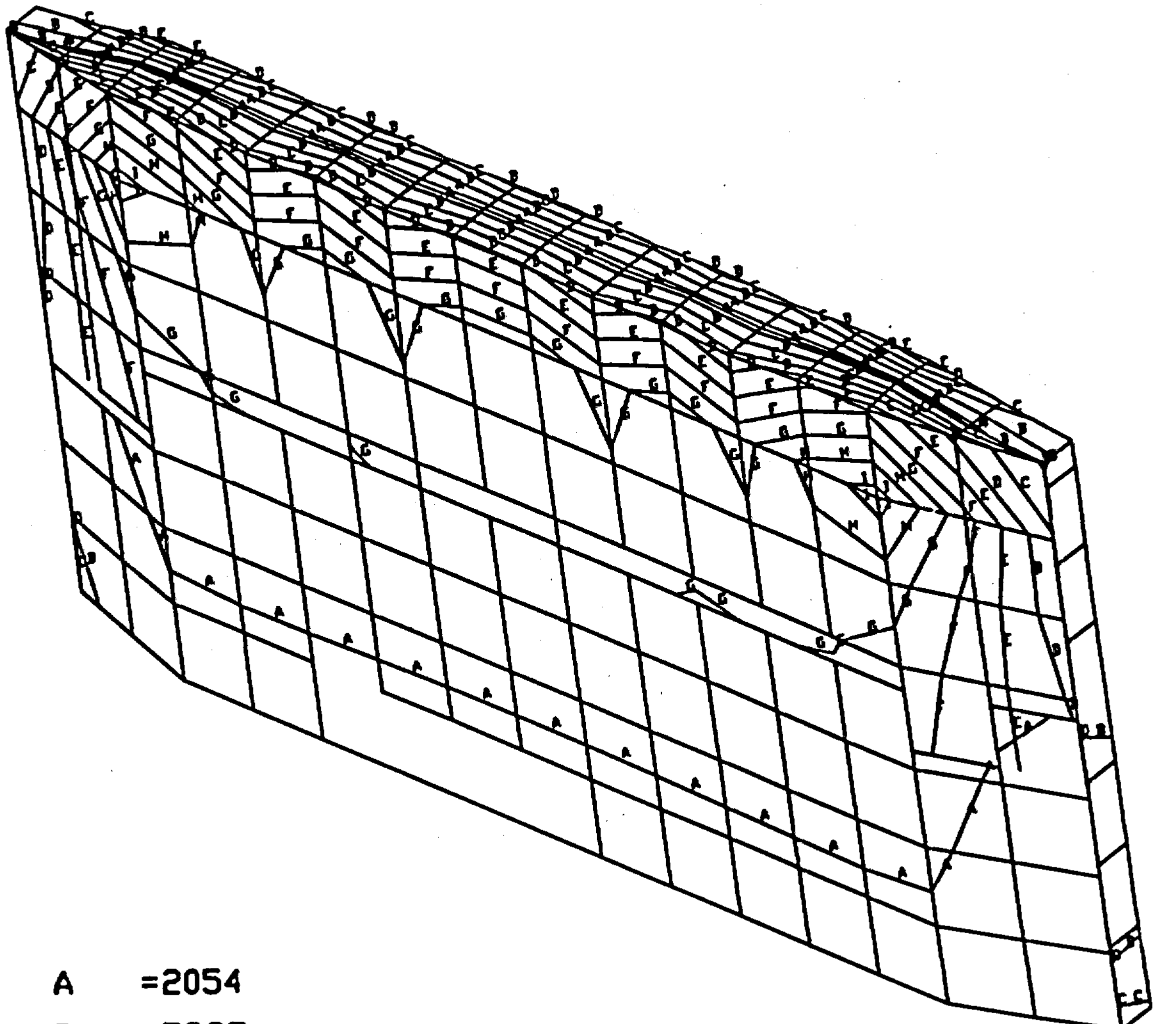
<u>Shield Block End Drop Analytical Model</u>
<u>End Cover Plate Geometry</u>



Note: See Figure A-2.7-17 for location of this plate in the analytical model.

Figure A-2.7-22

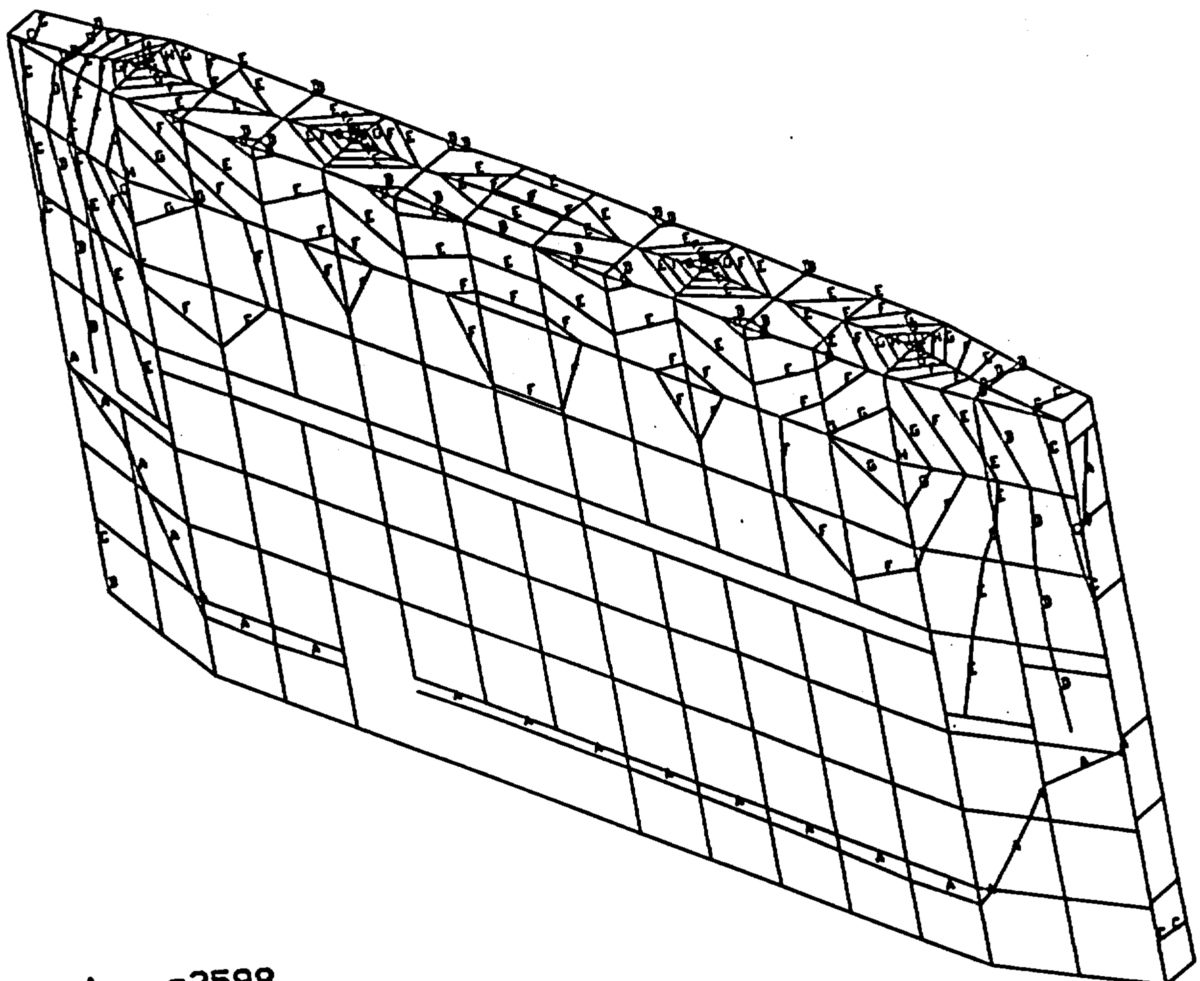
Shield Block End Drop Analytical Model
D.U. Geometry



A =2054
B =5837
C =9621
E =17188
F =20972
G =24756
I =32323

Figure A-2.7-23

Shield Block End Drop Membrane S.I.



A =2598
B =7199
C =11799
E =21000
F =25600
G =30201
I =39401

Figure A-2.7-24

Shield Block End Drop Membrane Plus Bending

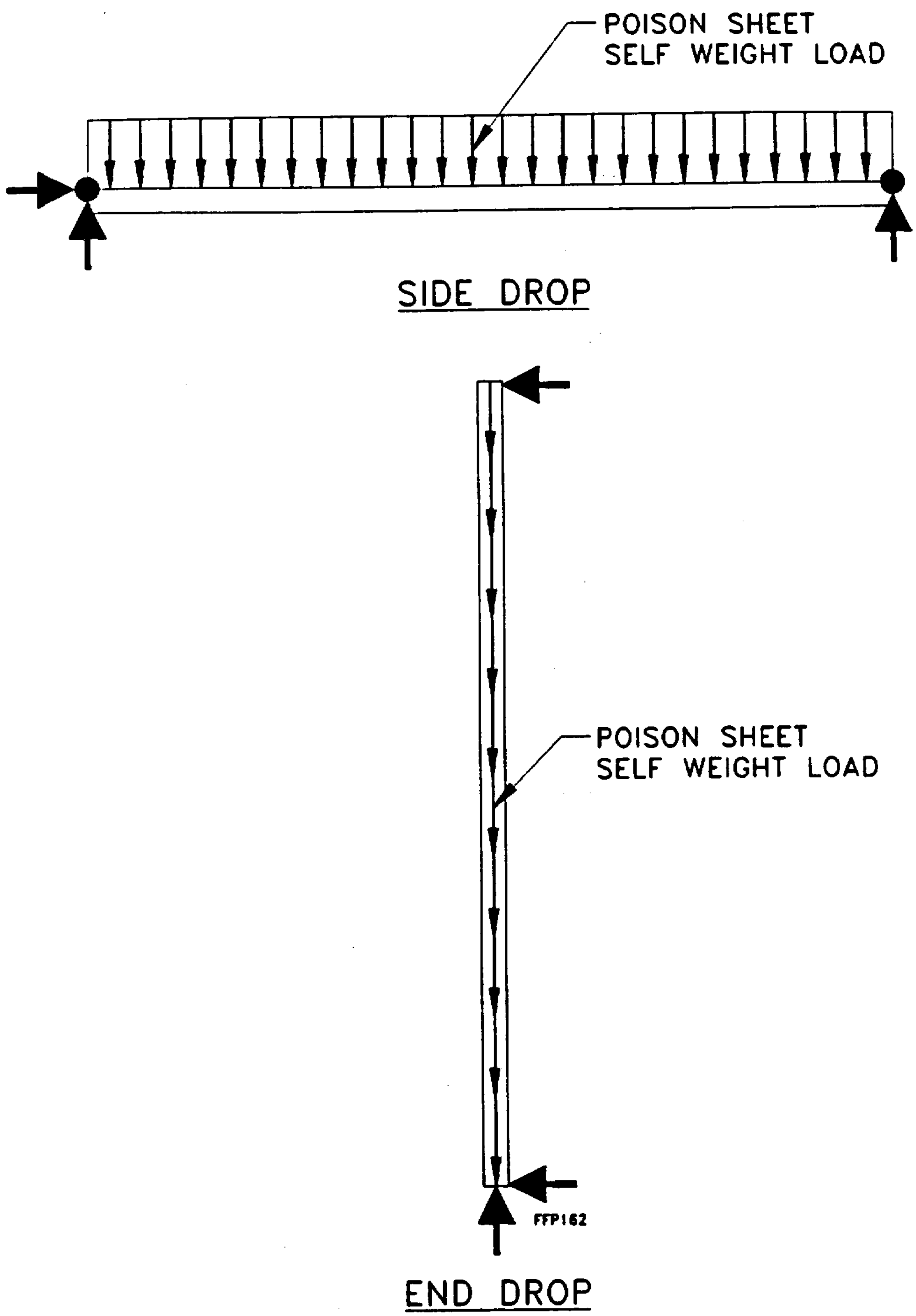


Figure A-2.7-25

Poison Plate Side and End Drop and Side Drop Loads and Reactions

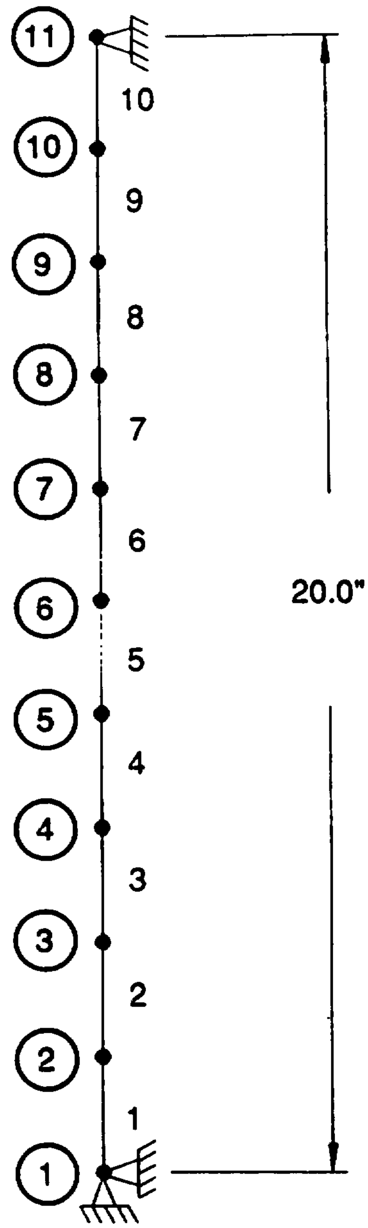


Figure A-2.7-26

Poison Plate Analytical Model

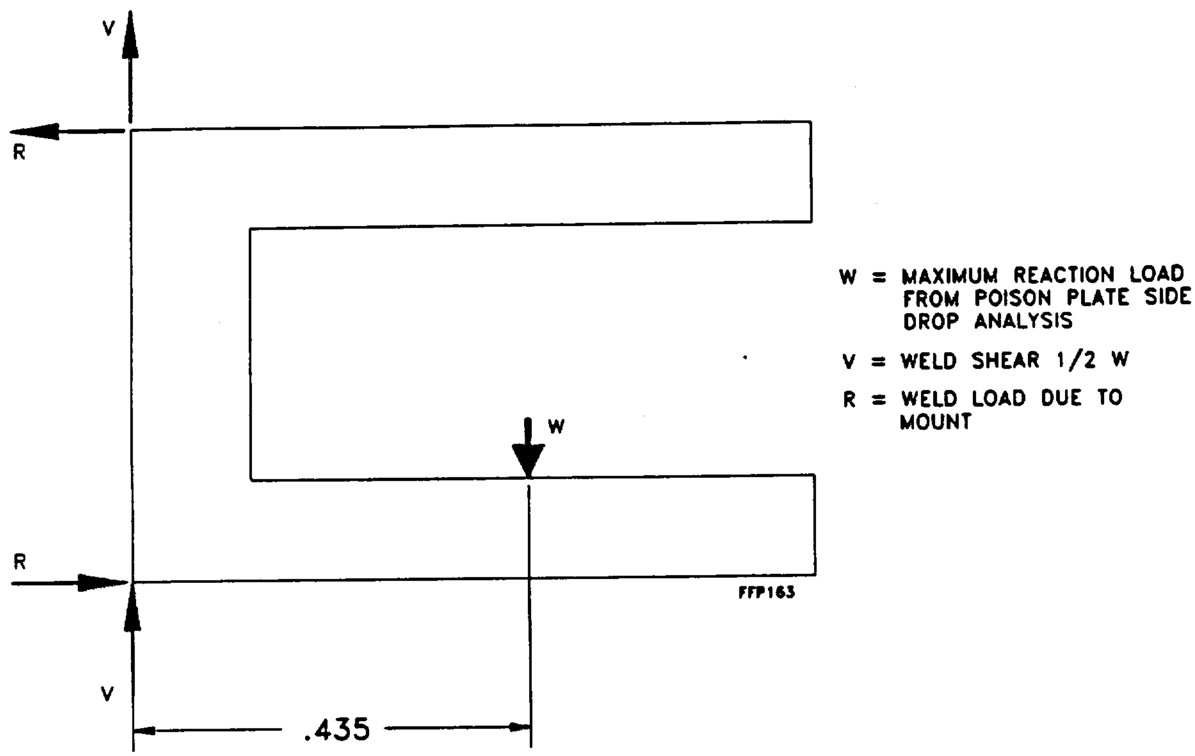


Figure A-2.7-27

Guide Bar Loads and Reactions

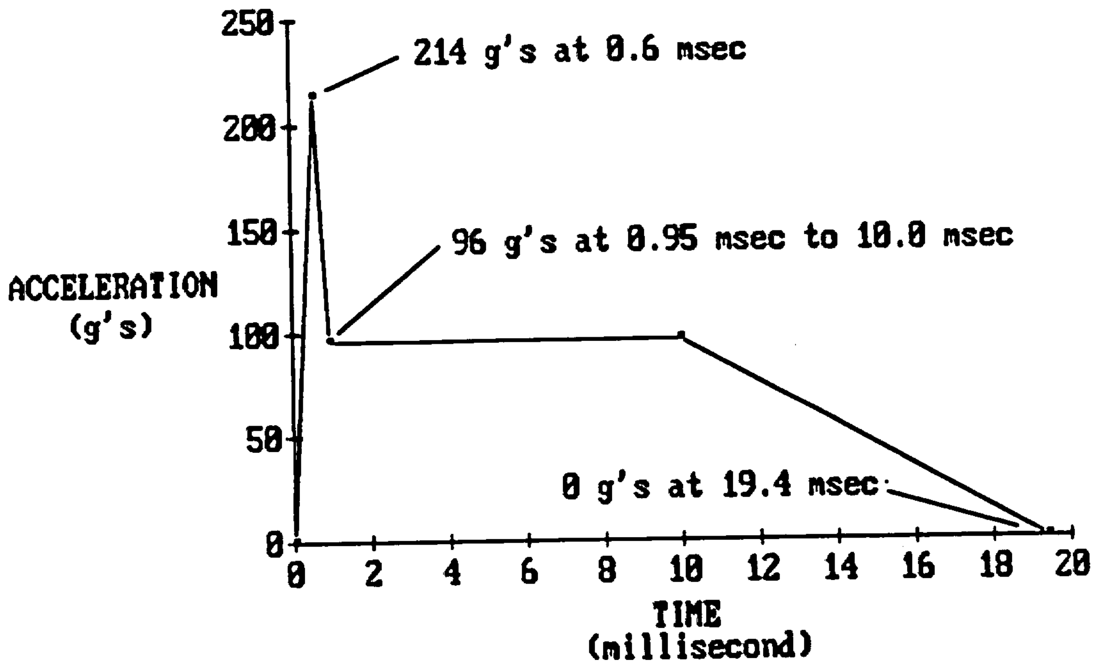


Figure A-2.7-28

<u>0° Orientation 30 Foot Side Drop Acceleration Time History</u>

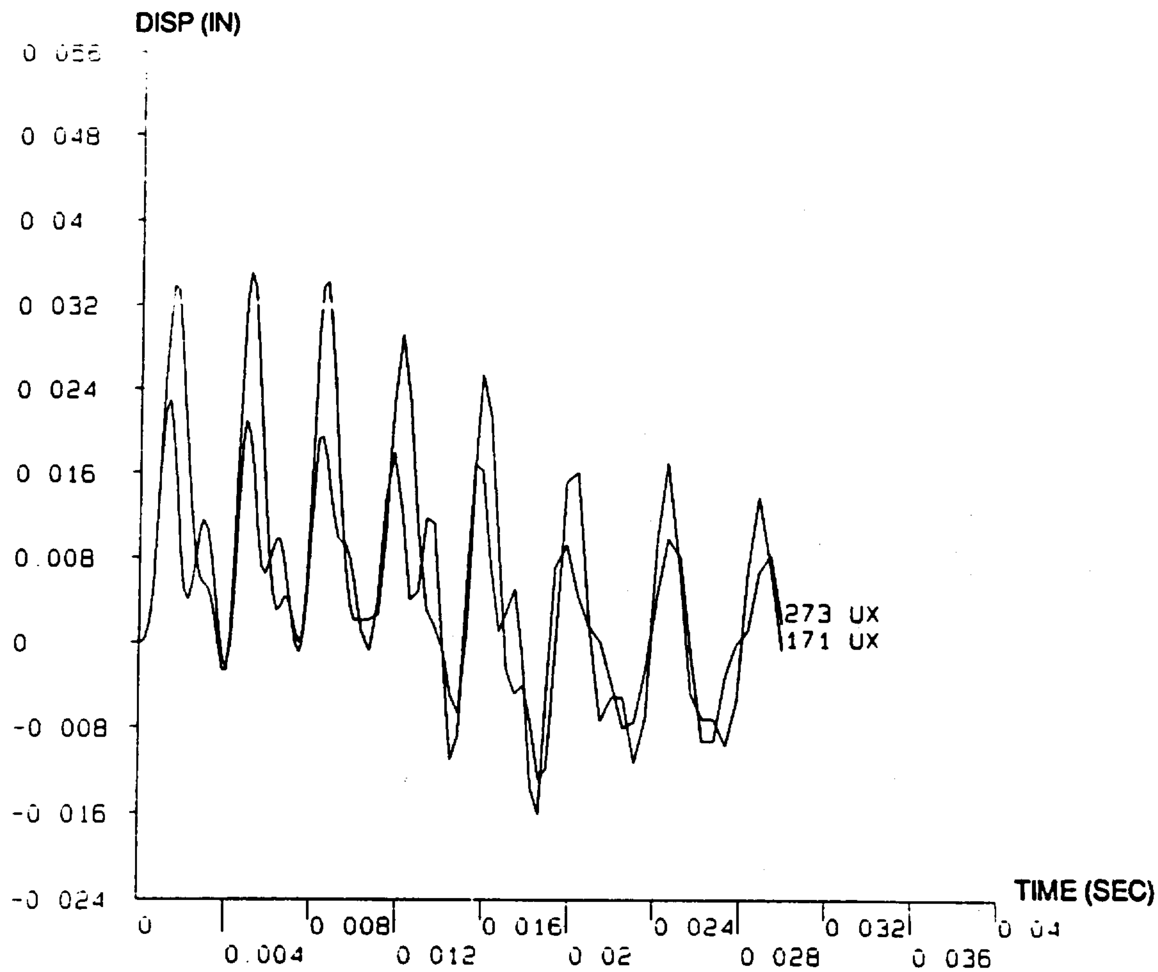


Figure A-2.7-29

Spacer Disk 0° Orientation Side Drop
Maximum Displacements vs. Time

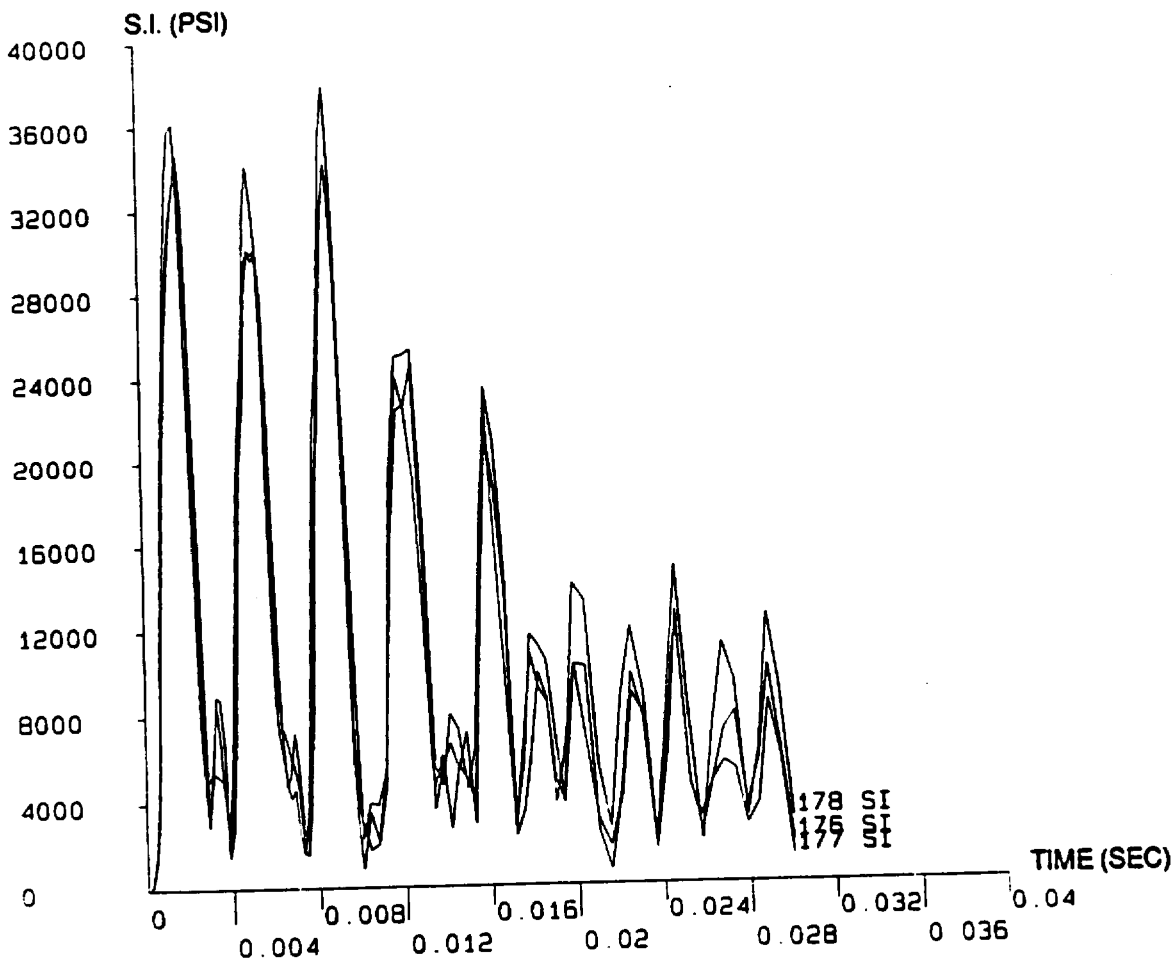


Figure A-2.7-30

Spacer Disk 0° Orientation Side Drop
Maximum Membrane S.I. vs. Time

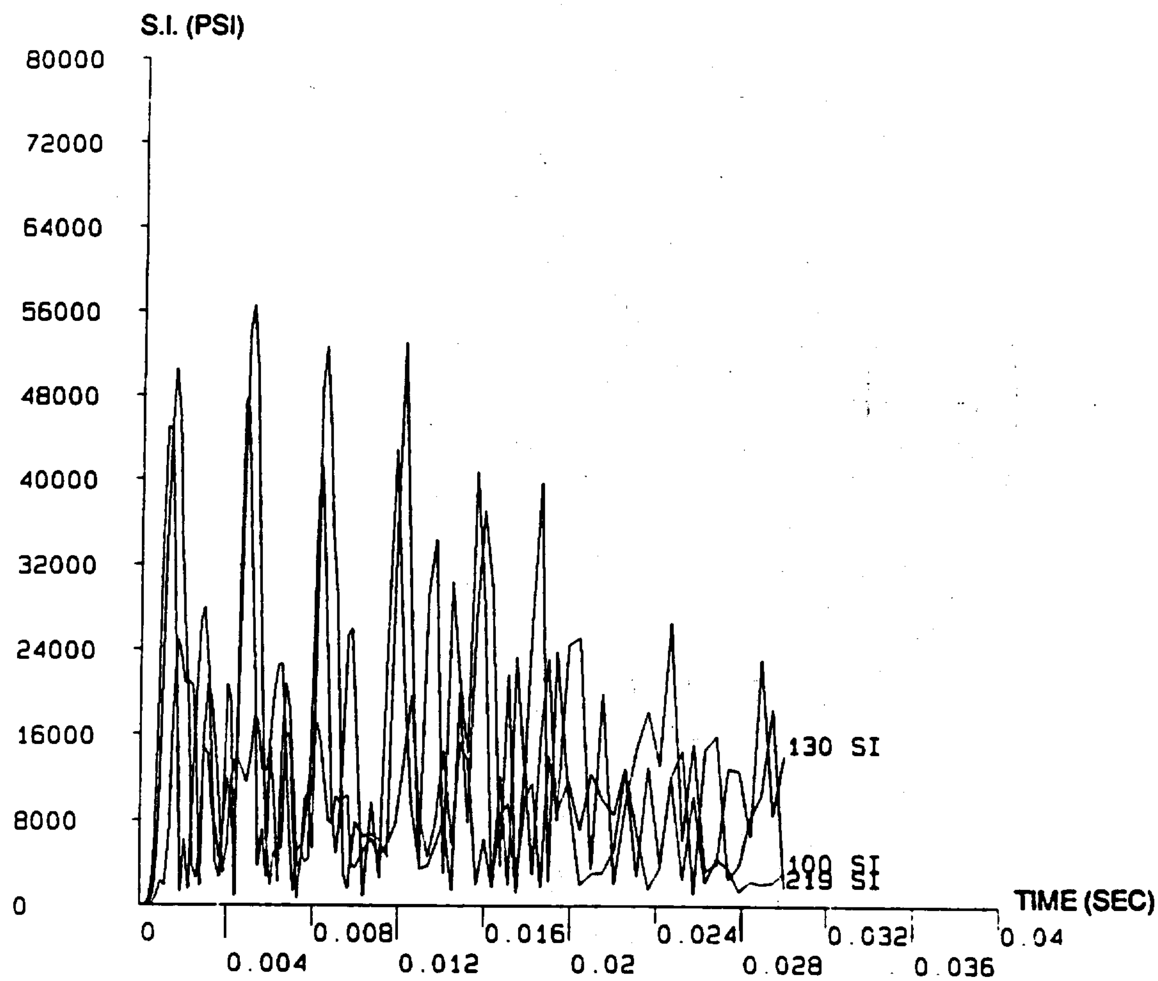


Figure A-2.7-31

Spacer Disk 0° Orientation Side Drop
Maximum Membrane + Bending S.I. vs. Time

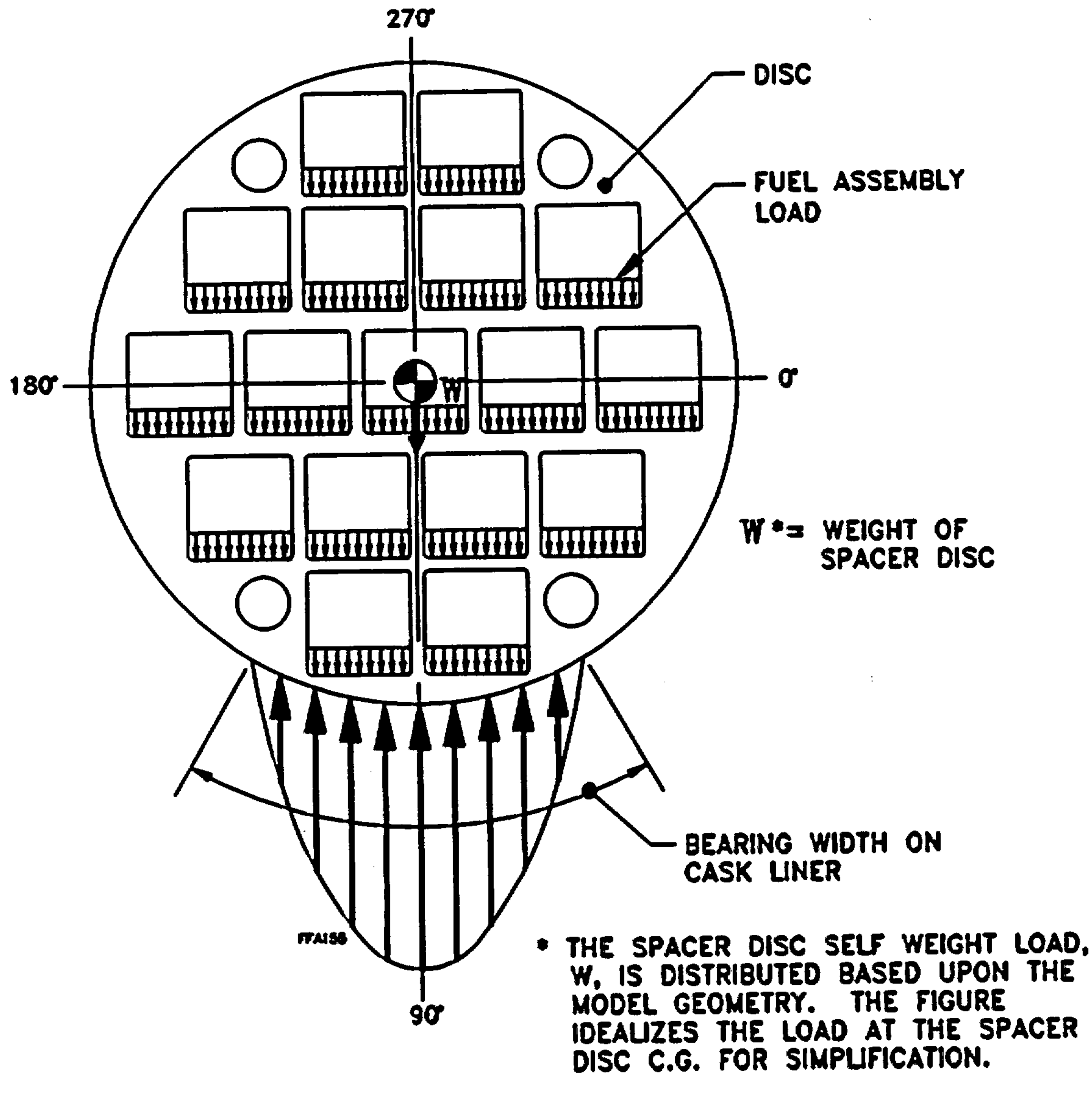


Figure A-2.7-32

Spacer Disk 90° Orientation Side Drop Loads and Reactions

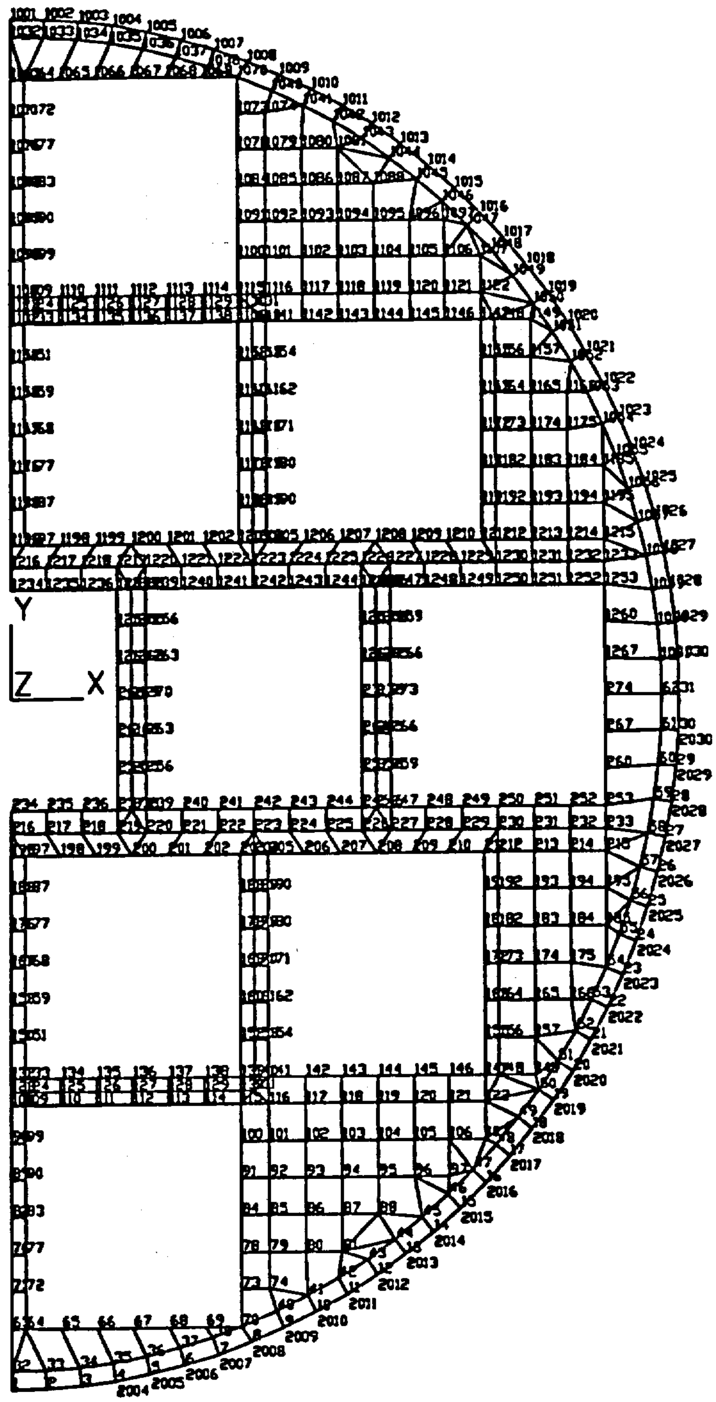


Figure A-2.7-33

Spacer Disk 90° Orientation Side Drop
Analytical Model - Nodal Geometry

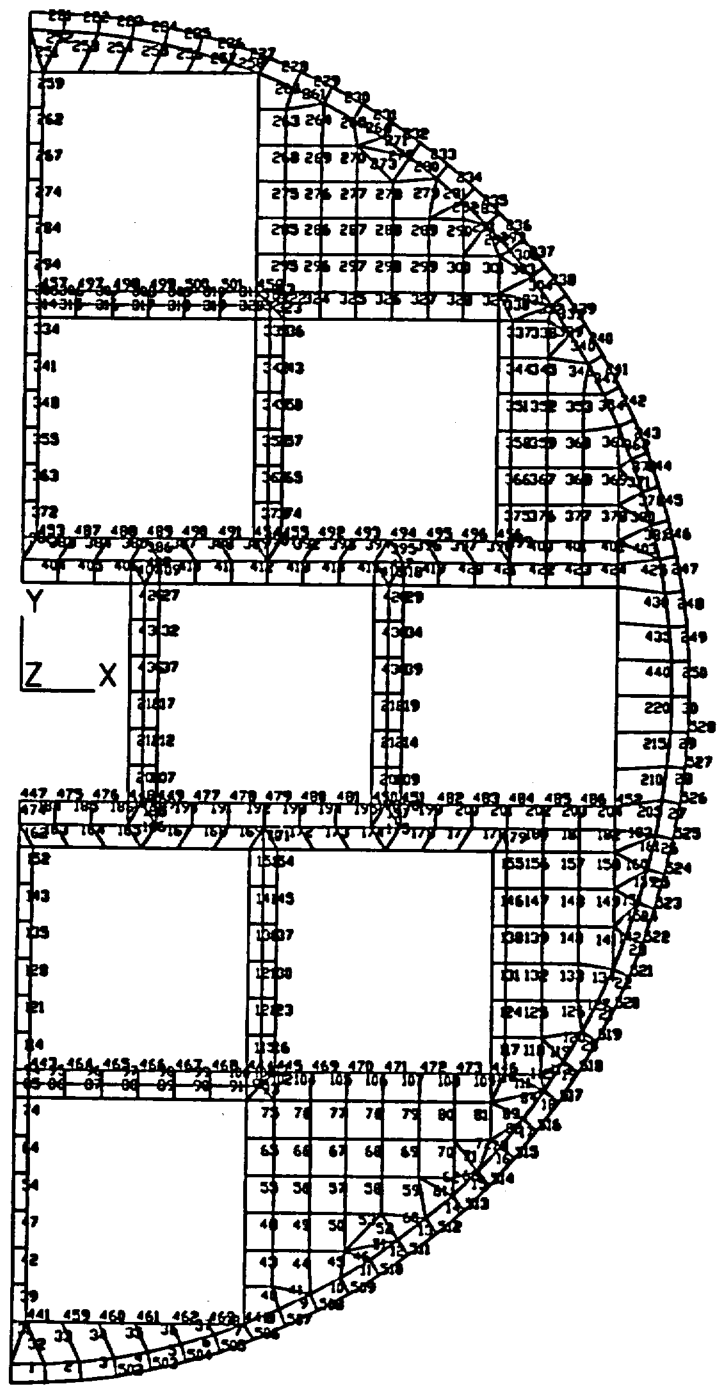


Figure A-2.7-34

Spacer Disk 90° Orientation Side Drop
Analytical Model - Element Geometry

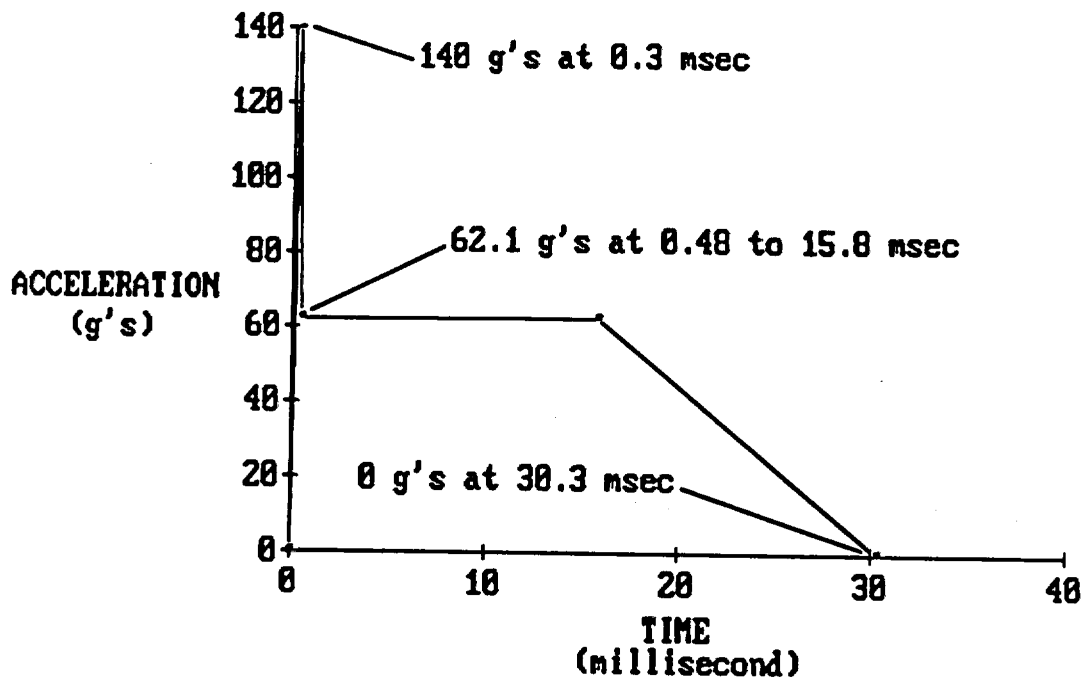


Figure A-2.7-35

90° Orientation Side Drop Acceleration Time History

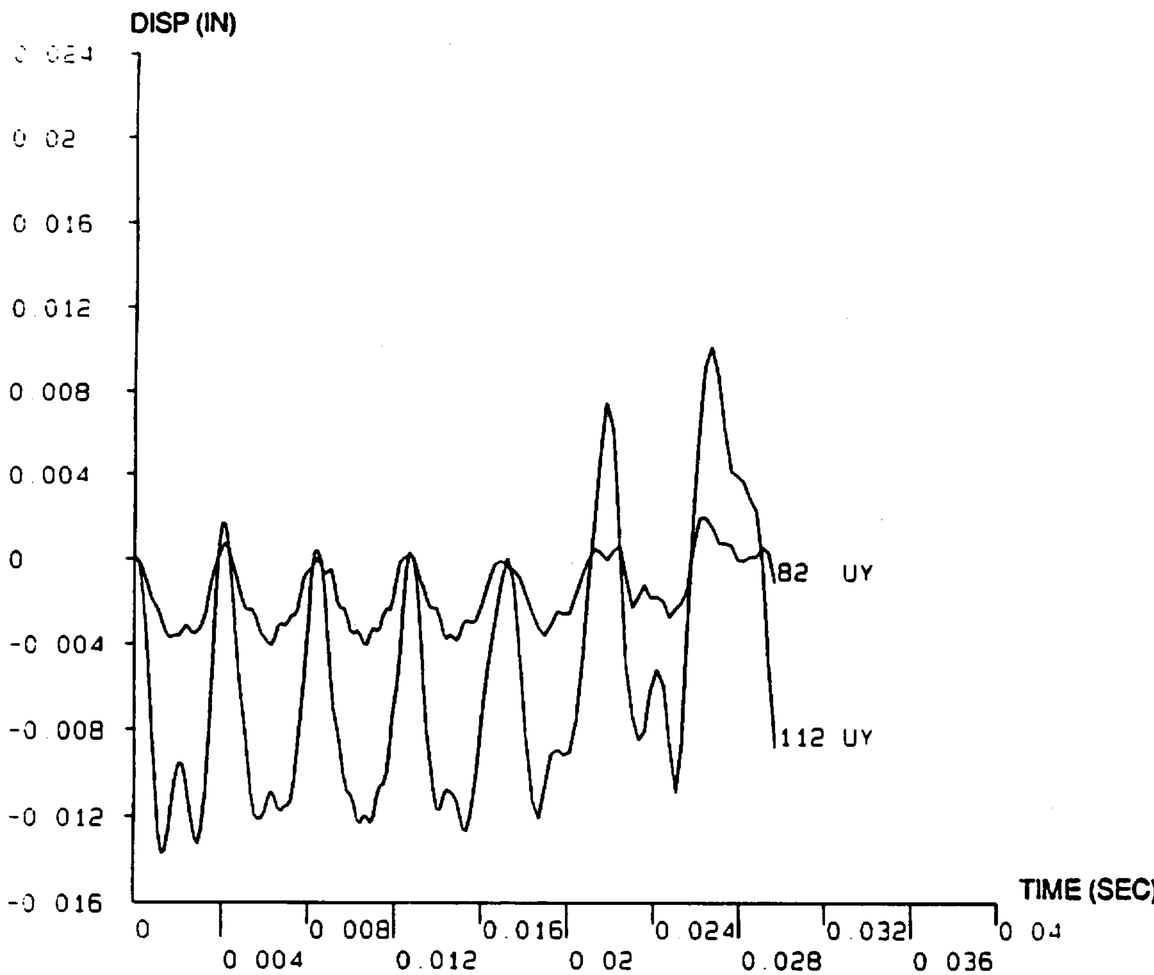


Figure A-2.7-36

<u>Spacer Disk 90° Orientation Side Drop</u>
<u>Maximum Displacements vs. Time</u>

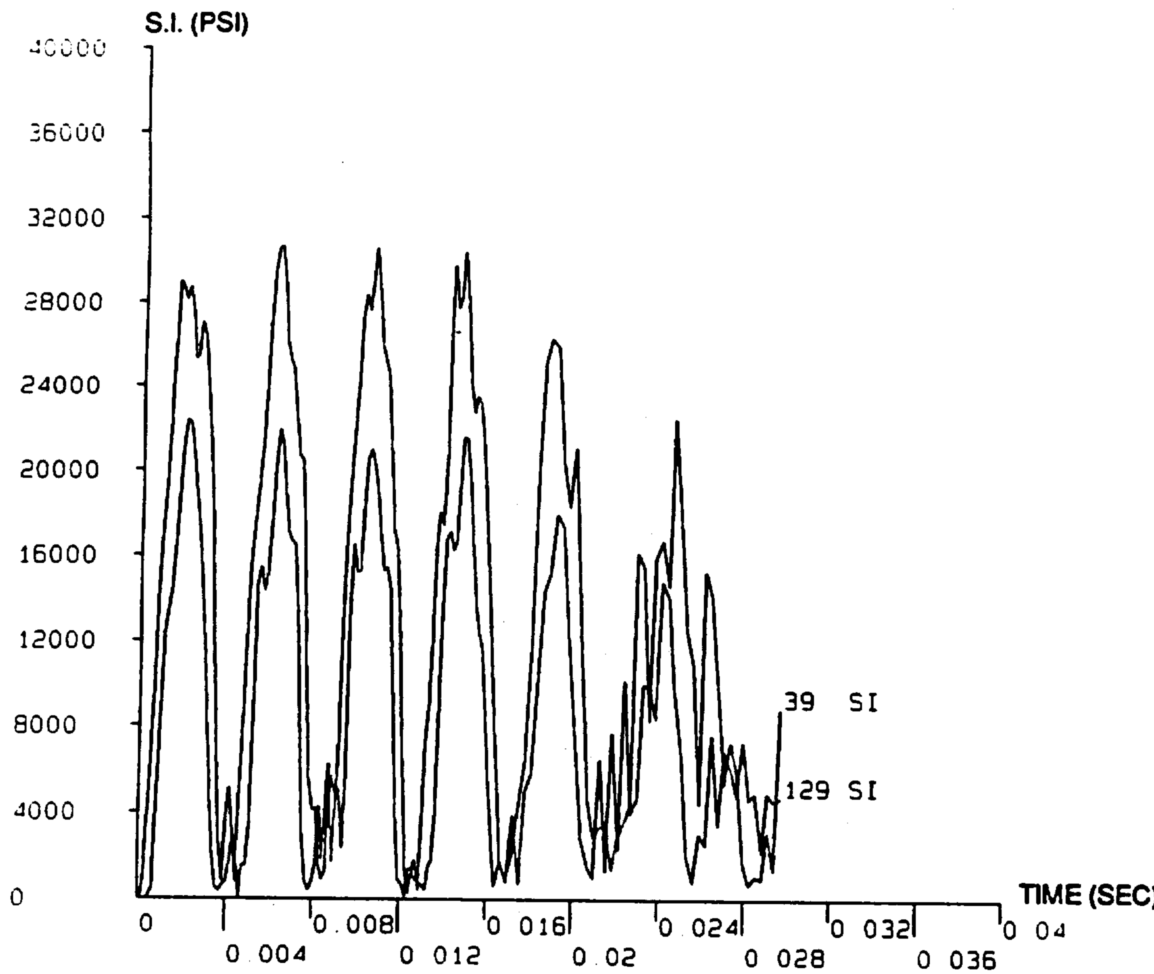


Figure A-2.7-37

Spacer Disk 90° Orientation Side Drop
Maximum Membrane S.I. vs. Time

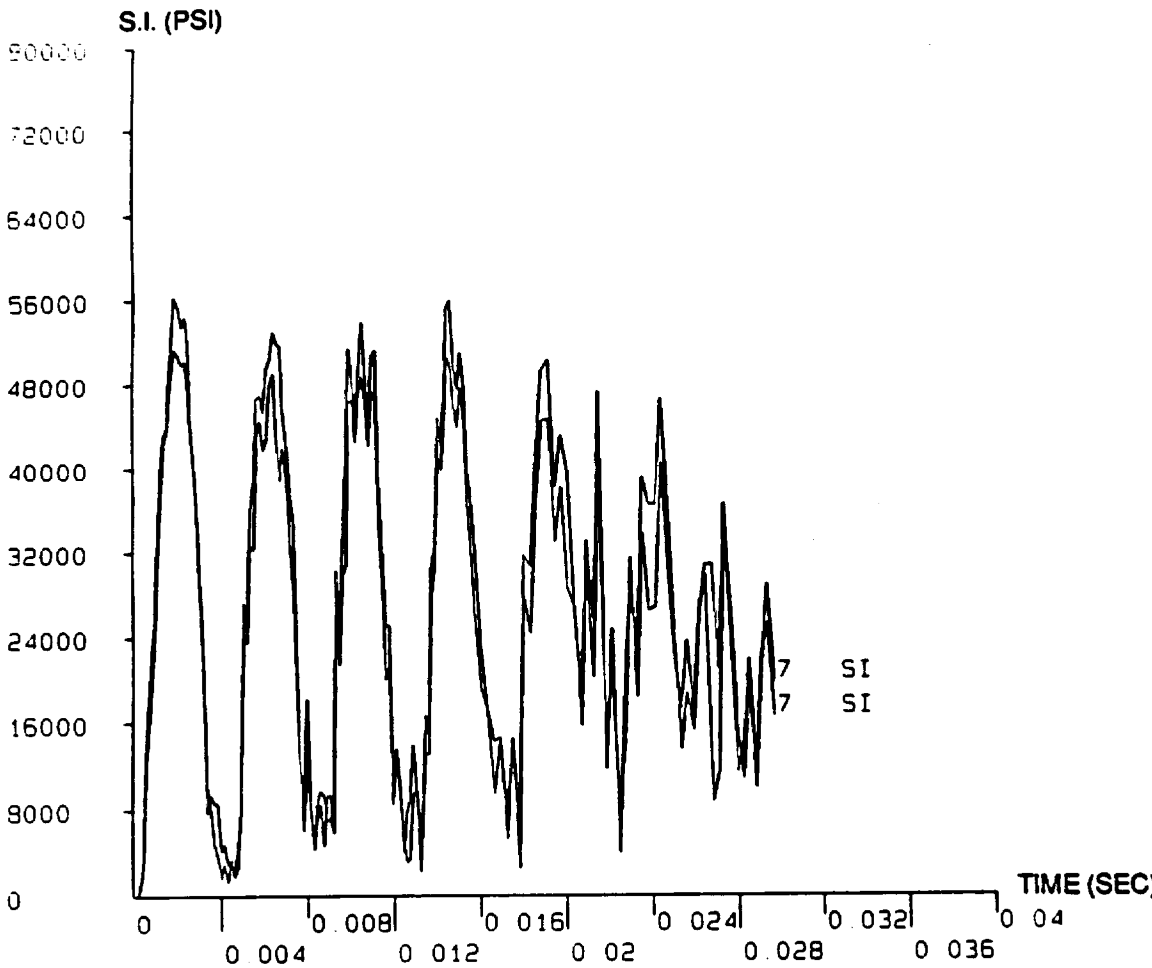


Figure A-2.7-38

Spacer Disk 90° Orientation Side Drop
Maximum Membrane + Bending S.I. vs. Time

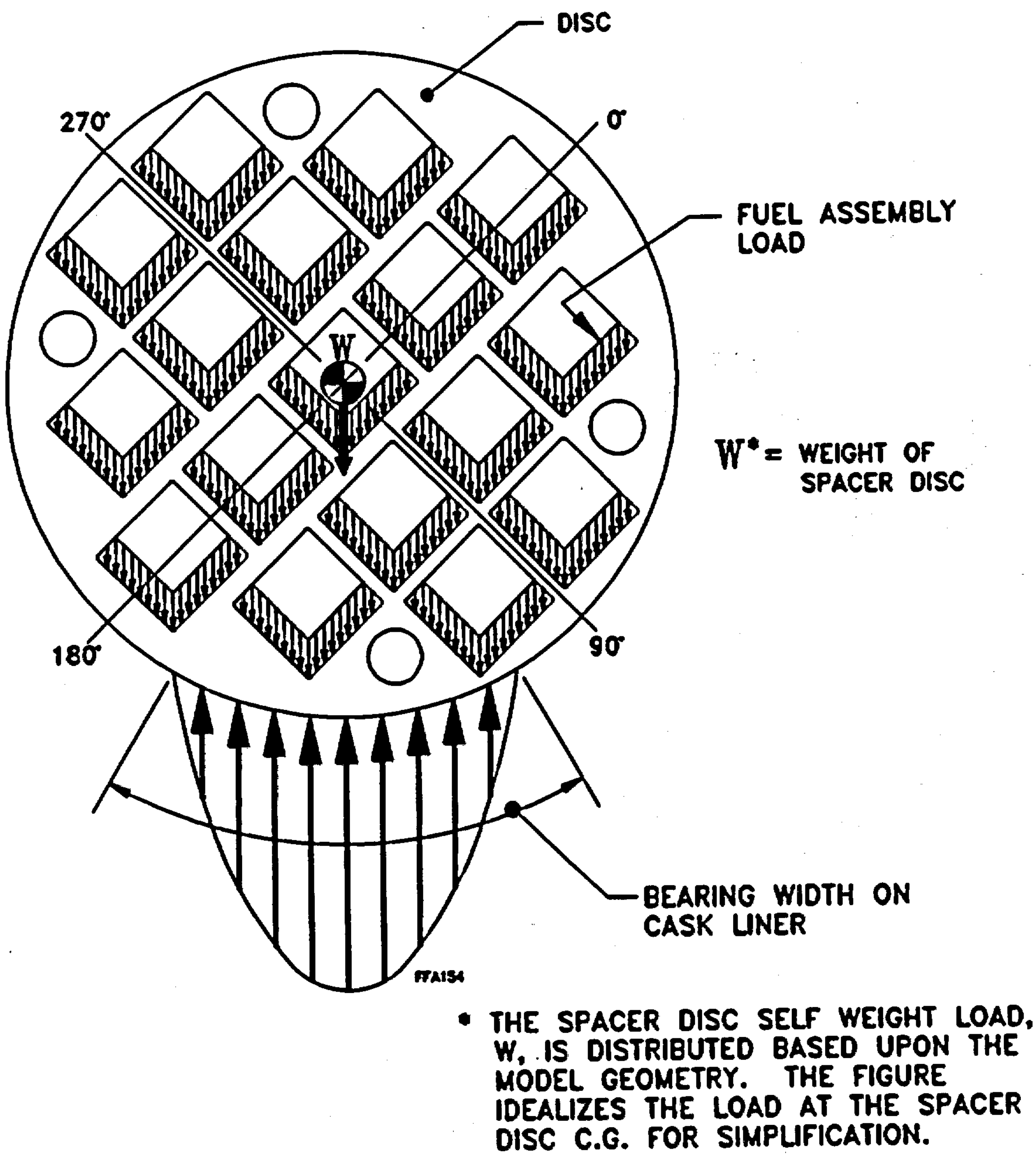


Figure A-2.7-39

Spacer Disk 45° Orientation Side Drop Loads and Reactions

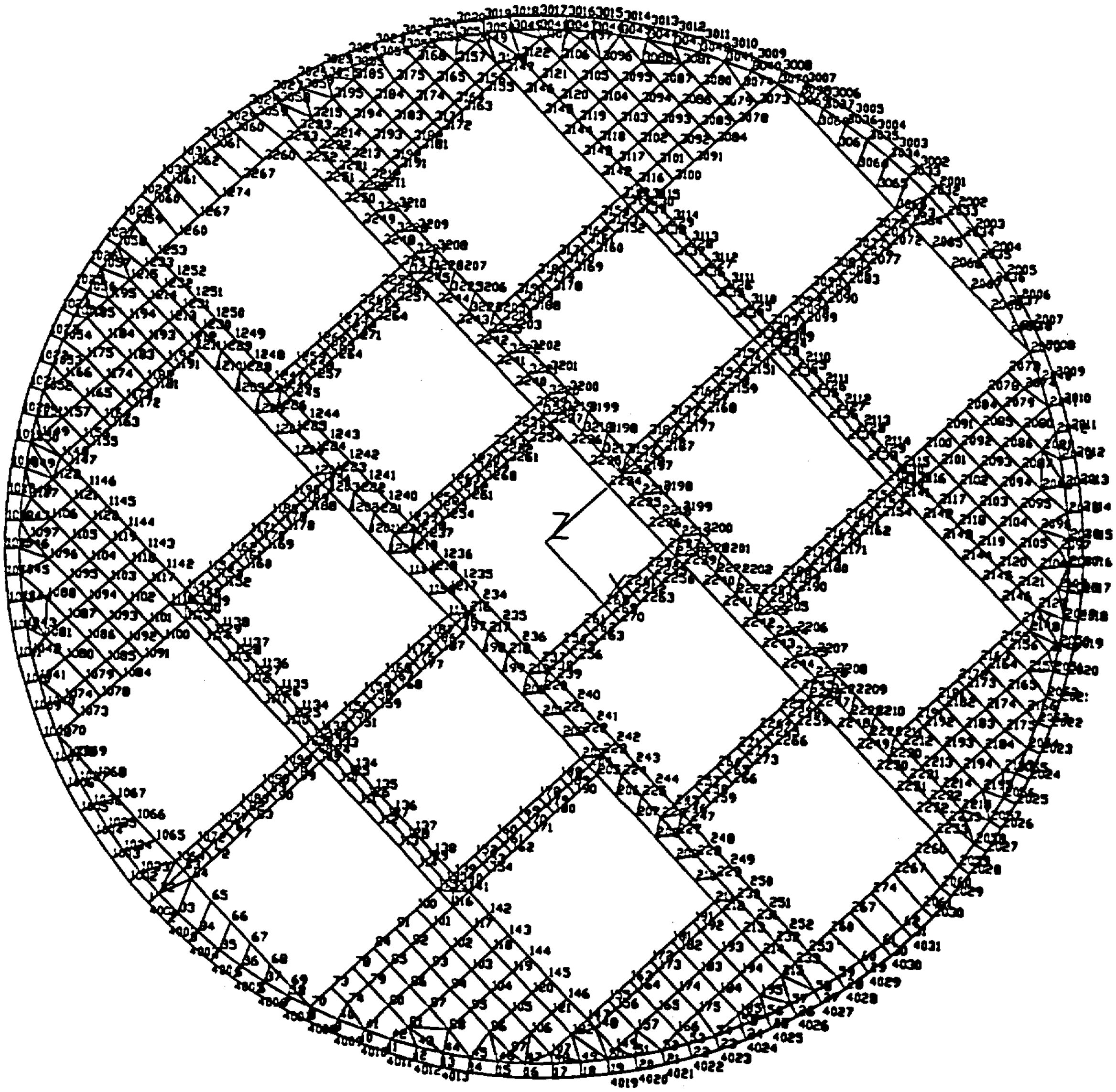


Figure A-2.7-40

Full Spacer Disk Side Drop
Analytical Model - Nodal Geometry

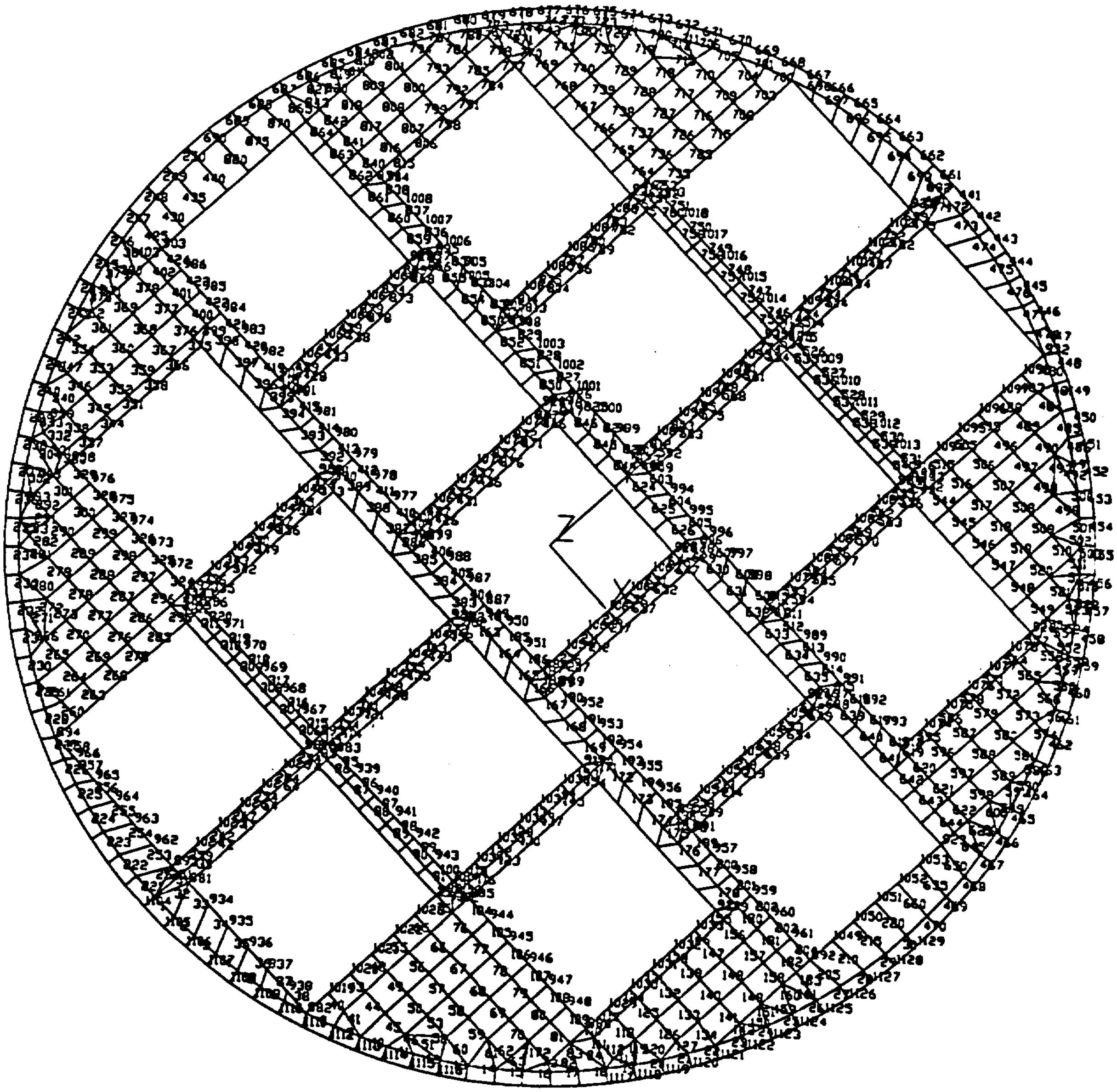


Figure A-2.7-41

Full Spacer Disk Side Drop
Analytical Model - Element Geometry

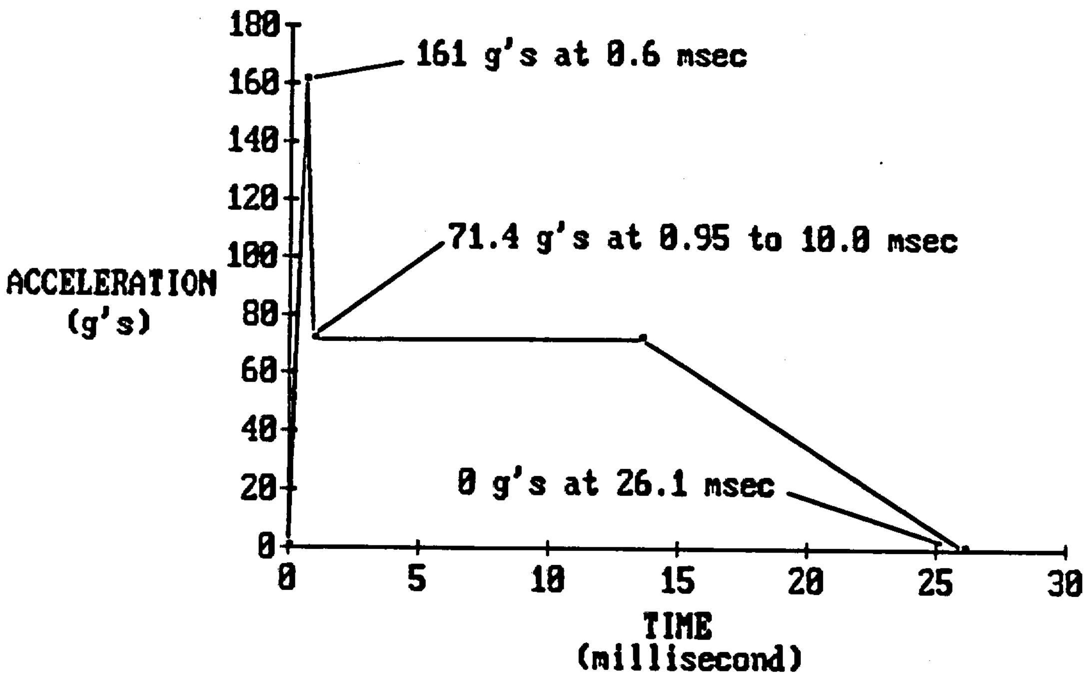


Figure A-2.7-42

45° Orientation Side Drop Acceleration Time History

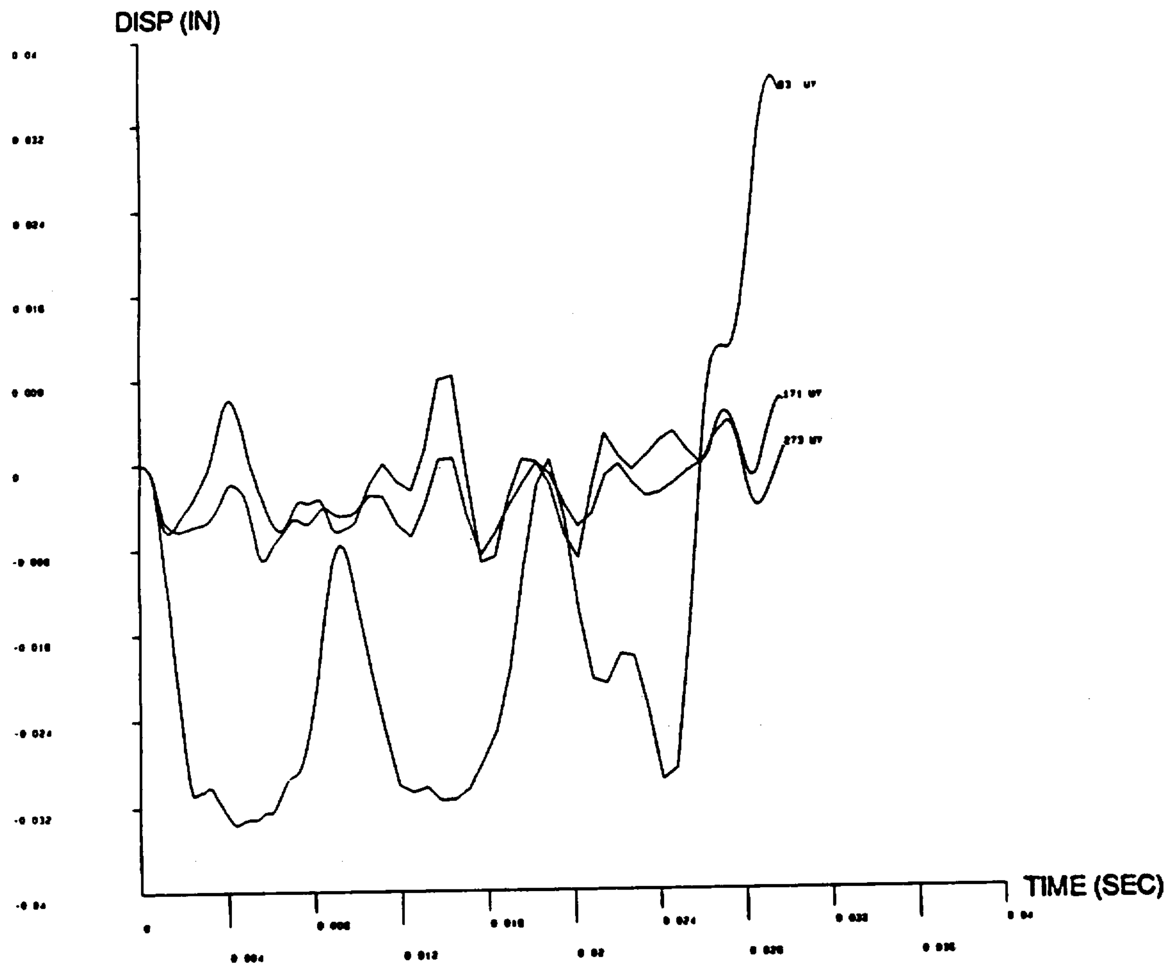


Figure A-2.7-43

Spacer Disk 45° Orientation Side Drop
Maximum Displacements vs. Time

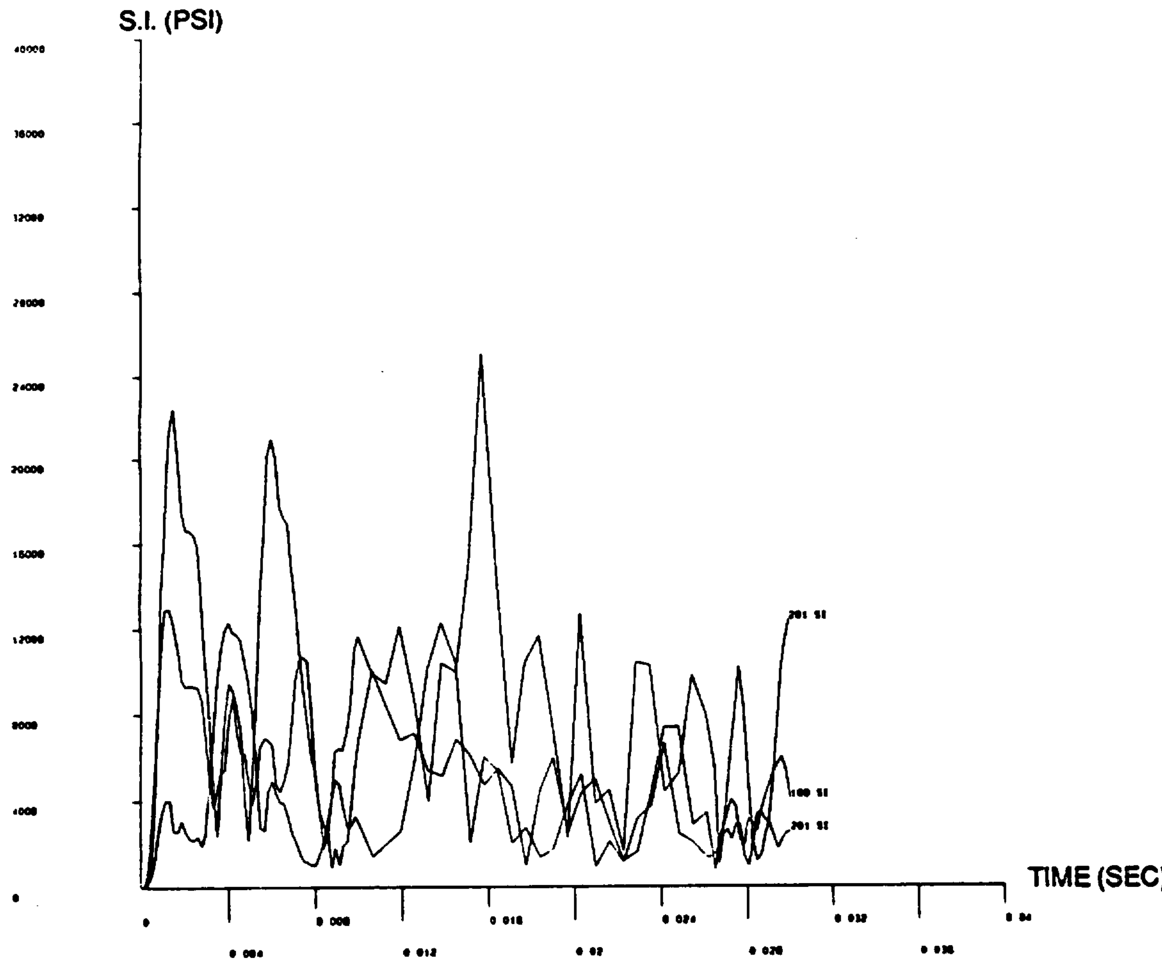


Figure A-2.7-44

Spacer Disk 45° Orientation Side Drop
Maximum Membrane S.I. vs. Time

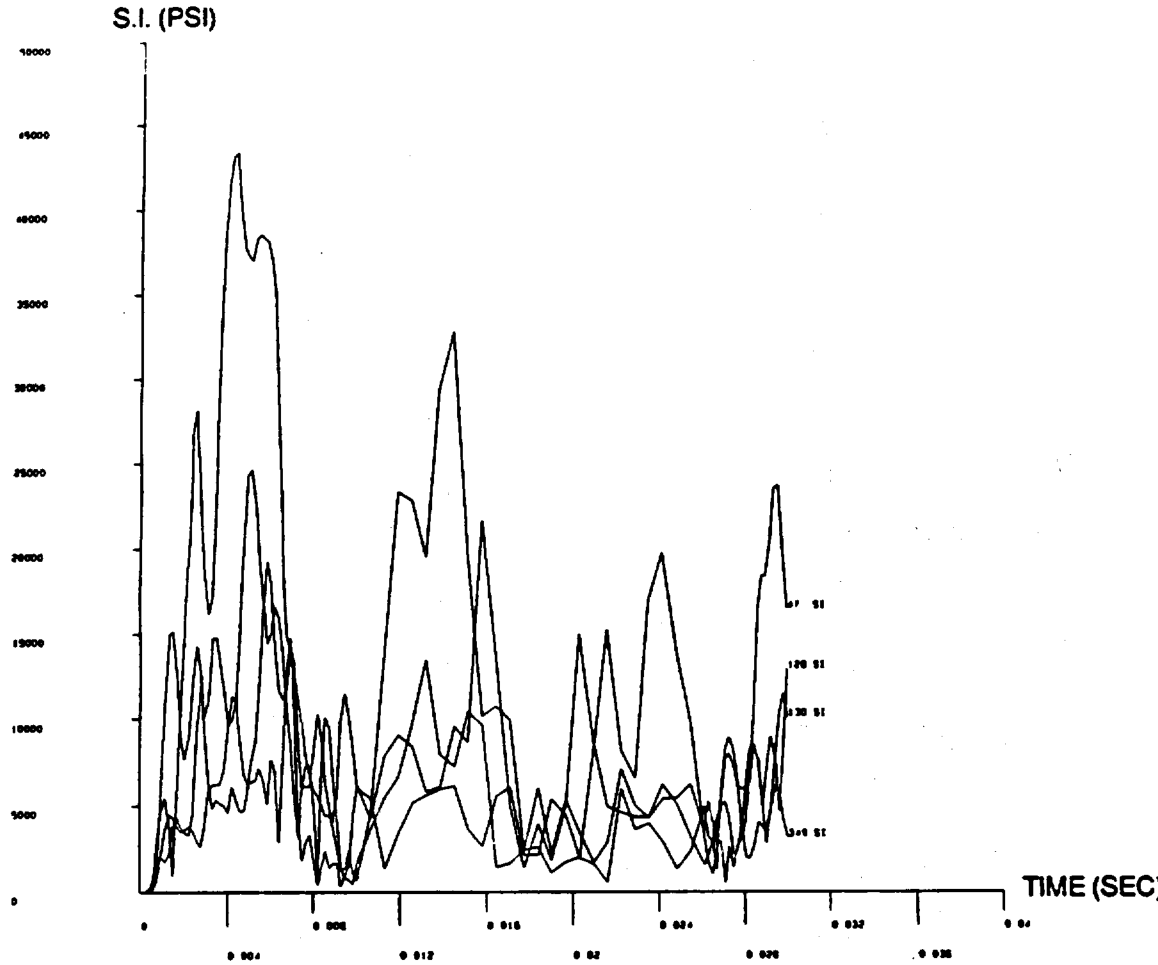


Figure A-2.7-45

Spacer Disk 45° Orientation Side Drop
Maximum Membrane + Bending S.I. vs. Time

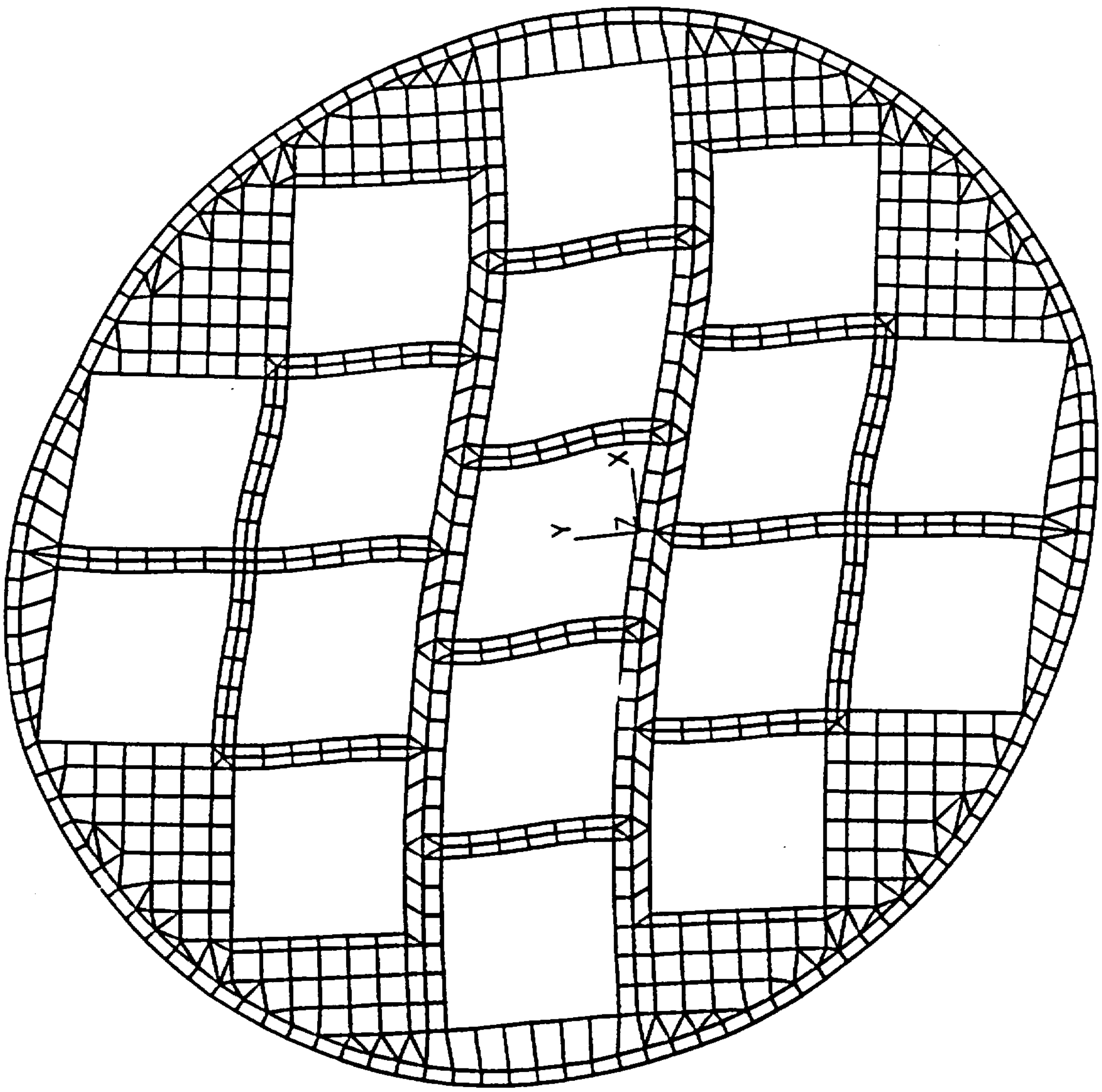


Figure A-2.7-46

Spacer Disk 0° Orientation Side Drop Buckling Mode Shape

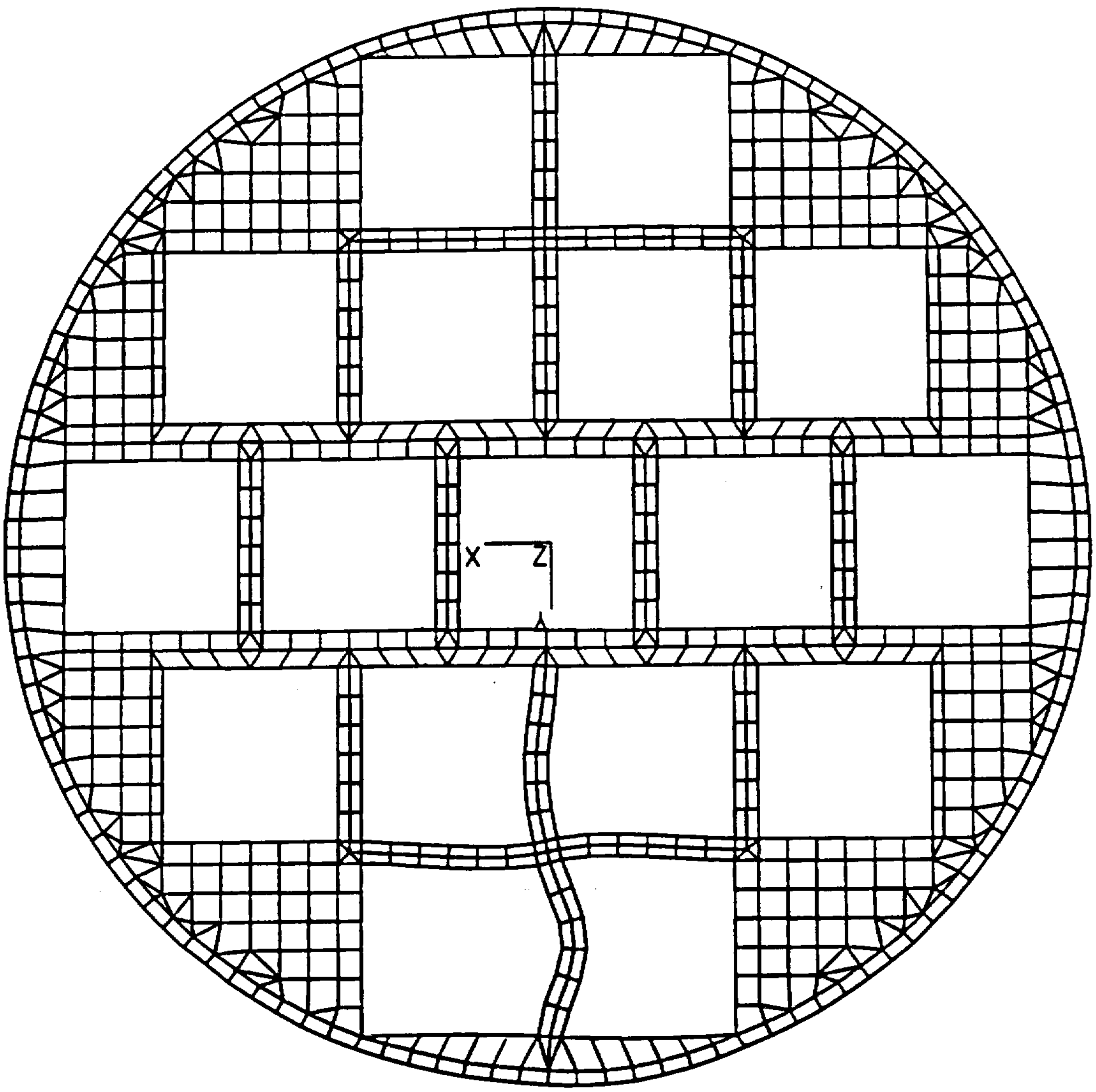


Figure A-2.7-47

Spacer Disk 90° Orientation Side Drop Buckling Mode Shape

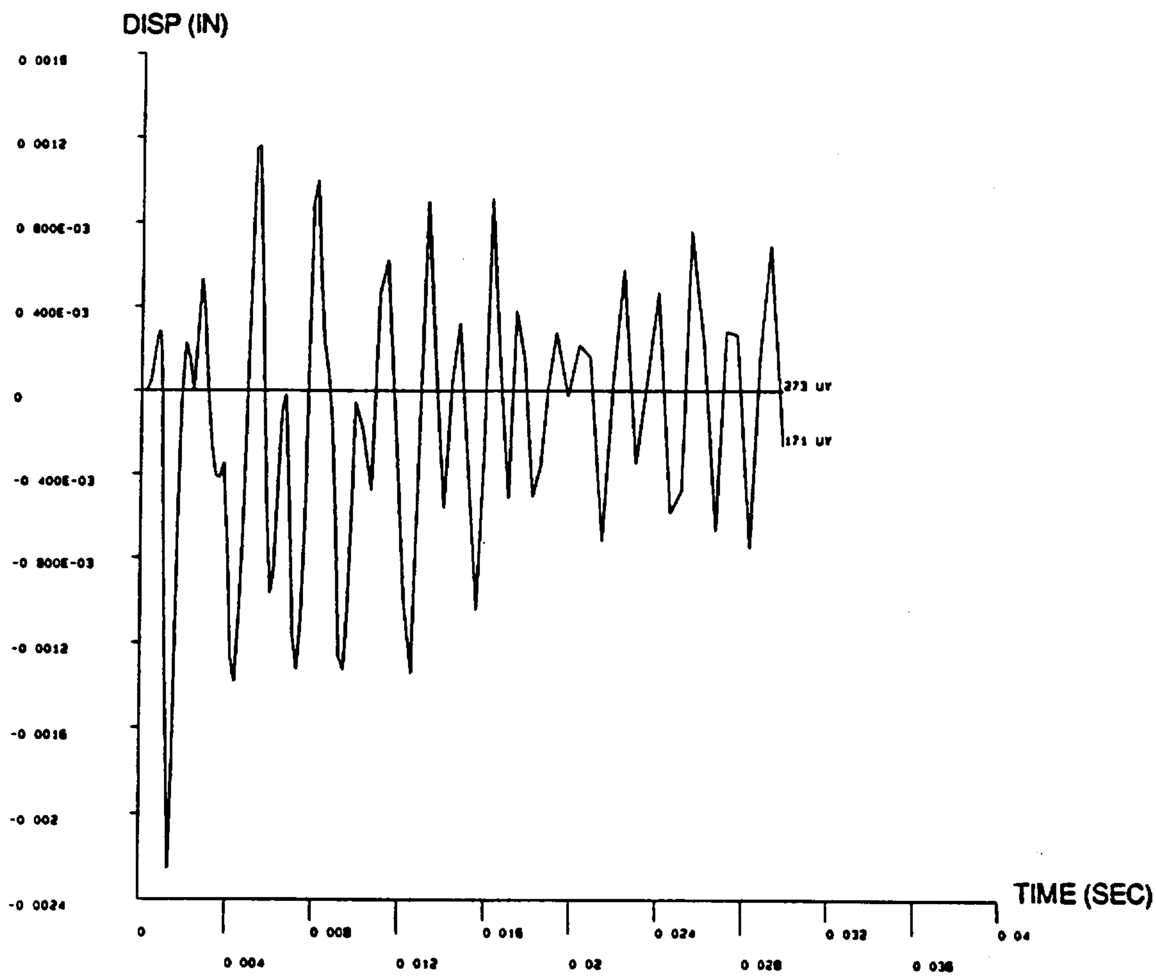


Figure A-2.7-48

Top Plate Side Drop Maximum Displacements vs. Time

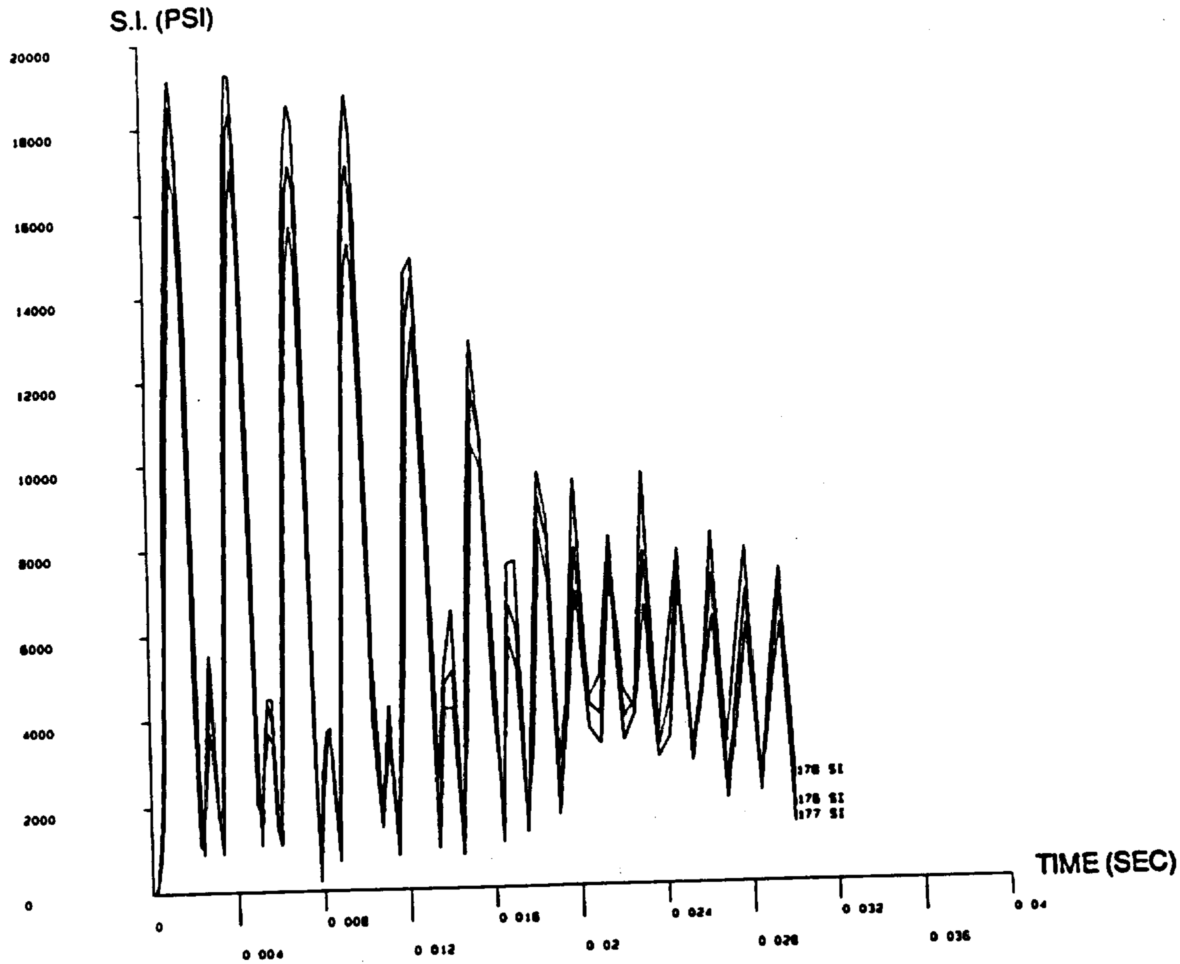


Figure A-2.7-49

Top Plate Side Drop Maximum Membrane S.I. vs. Time

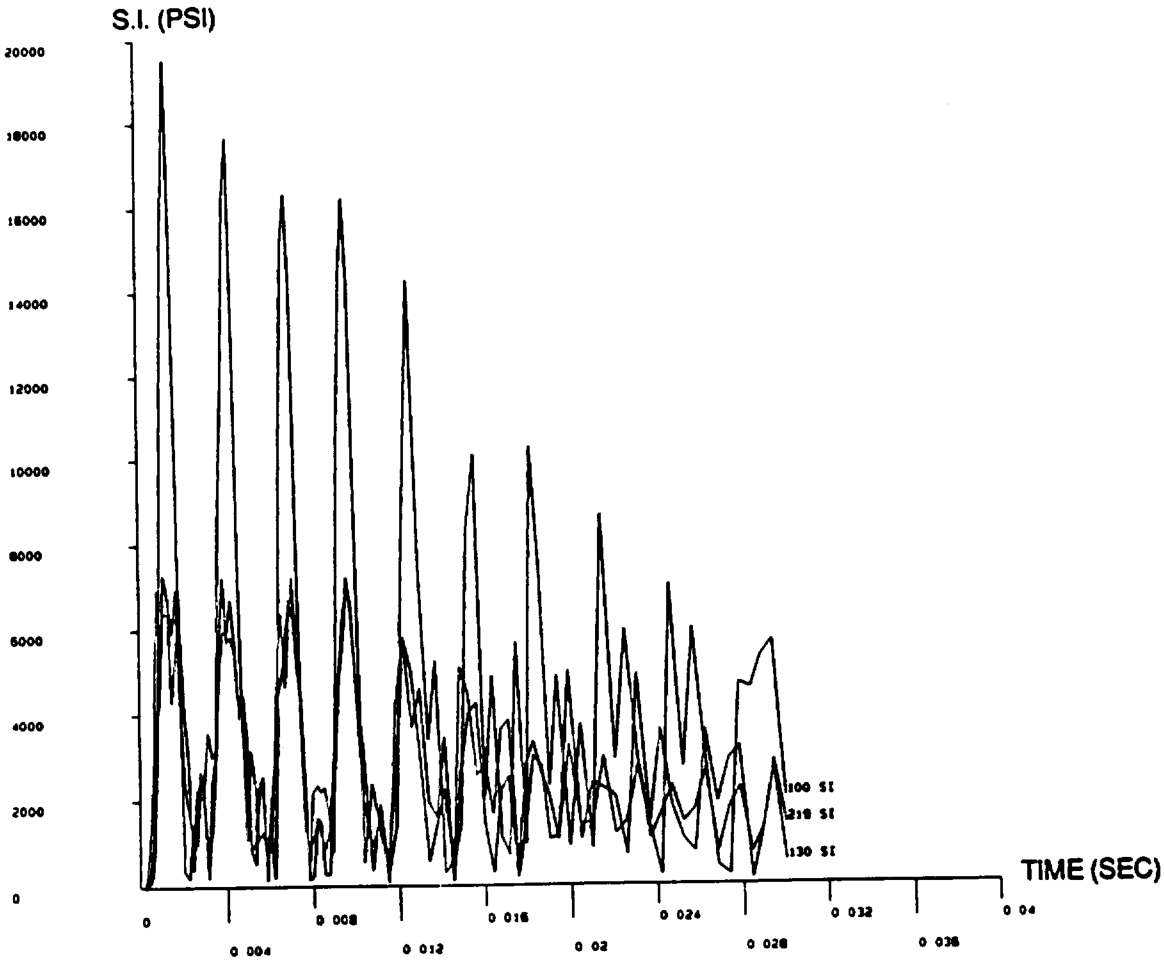


Figure A-2.7-50

Top Plate Side Drop Maximum Membrane Plus Bending S.I. vs. Time

A-2.8 Special Form

This section does not apply for the IF-300 shipping cask.

A-2.9 Fuel Rods

The Channelled BWR Fuel Basket does not affect the fuel rod assessment described in the IF-300 CSAR [A-2.10.1-2].

A-2.10 Appendix

A-2.10.1 References

[1] "Packaging and Transportation of Radioactive Materials," Title 10, Code of Federal Regulations, Part 71 (10CFR71), USNRC, 5/31/88.

[2] Consolidated Safety Analysis Report for IF-300 Shipping Cask, NEDO-10084-3, Volumes 1 & 2, General Electric Company, Docket No. 71-9001, May 1985.

[3] ASME Boiler and Pressure Vessel Code, Section III Division 1, Subsection NG and Appendices, 1986 through 1988 Addenda.

[4] Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material," Rev. 1, U. S. Nuclear Regulatory Commission, March 1989.

[5] Correspondence letter from Robert K. Kunita (CP&L) to Wallace C. Wheadon (PNSI), January 4, 1990.

[6] Baumeister, et al, Mark's Standard Handbook for Mechanical Engineers, Eighth Edition, McGraw Hill Book Company, 1979, p. 6-44.

[7] American Society for Testing and Materials, "Standard Specification for Borated Stainless Steel Plate, Sheet, and Strip for Nuclear Application," A887-88, Annual Book of ASTM Standards, Vol. 01.03, 1989.

[8] Carpenter Technology Corporation, Effect of Boron Content and Processing on Mechanical Properties and Microstructure of Borated Stainless Steels, Technical Report K86007.

[9] Carpenter Technology Corporation, Carpenter NeutroSorb™ and NeutroSorb Plus™, Alloy Data, Document No. 5-87/1M.

[10] Society of Automotive Engineers, "Depleted Uranium Castings," Aerospace Material Specification AMS 7730D, October 1987.

[11] Rust, James H., Nuclear Power Plant Engineering, Haralson Publishing Company, 1979.

[12] Hawkins, D. T. and Hultgren, R., "Constitution of Binary Alloys," Metals Handbook - Metallography, Structures and Phase Diagrams, Vol. 8, Page 307.

[13] "Certificate of Compliance for Radioactive Materials Packages," Model No. IF-300, Certificate No. 9001, Revision 23, Package Identification No. USA/9001/B( )F, dated May 1990.

[14] International Atomic Energy Agency, Advisory Material for the Application of the IAEA Transport Regulations, Second Edition, Safety Series No. 37, 1982.

[15] Swanson Analysis Systems INC., ANSYS, Engineering Analysis Users Manual Vol. 1 & 2, Revision 4.4.

[16] Harris and Crede, Shock and Vibration Handbook, McGraw-Hill Book Company, Second Edition, 1976.

[17] Young, Warren C., Roarks Formulas for Stress and Strain, McGraw-Hill Book Company, Sixth Edition, 1989.

[18] "SCANS - Shipping Cask ANalysis System", Lawrence Livermore National Laboratory, Version 1b, 06/01/89.

[19] Telecon between Stearns-Roger Corp. and the Atomic Energy Commission, "Energy Absorbing Capacity of Fins on the G.E. Shipping Cask," dated May 18, 1970.

[20] American Society of Testing and Materials, ASTM A240-88, "Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels."

A-2.10.2 Reference Calculations

[A] "IF-300 Modified BWR Fuel Basket Structural Analysis," PNFSI Calculation 420-11.0301, Revision 1.

A-2.10.3 Input/Output Listings

Summary of Computer Input/Outputs:

********** ANSYS INPUT DATA LISTING (FILE18) **********

```
/PREP7
/TITLE. SUPPORT ROD BUCKLING ANALYSIS. 0.2" CENTER OFFSET
KAN.0
KAY.8.0
ET.1.63......1
ET.2.4.......1
ET.3.16......2
ET.4.21...2....1
C**** REAL CONSTANTS (PLATE ELEMENT THICKNESS)
R.1.2.0
R.2.1.25
R.3.3.0.1.5.1.1
C**** REAL CONSTANTS (BEAM ELEMENT PROPERTIES)
C**** NO..AREA.IZZ.IYY.TKZ.TKY.THETA ****
R.5.1.63.0.0902.0.5433.2.0.0.815.
R.6.1.53.0.0746.0.51.2.0.0.765.
R.7.2.52.0.3334.0.84.2.0.1.260.
R.9.1.0188.0.0564.0.1326.1.25.0.815.
R.10.0.9563.0.0466.0.1245.1.25.0.765.
R.11.1.575.0.2084.0.2051.1.25.1.260.
R.4.0.816.0.0113.0.272.2.0.0.408.
R.8.0.510.0.0071.0.0664.1.25.0.408.
C**** LIFTING LUG BEAM ELEMENT PROPERTIES
R.12.2.25.1.6875.0.1055.0.75.3.0.157.5
C**** D.U. SHIELD BLOCK MASSES ****
R.13.0.0218
R.14.0.0104
R.15.0.0208
R.16.0.0196
R.17.0.0286
C**** LIFTING LUG MASS ****
R.18.0.0096
C**** POISON PLATE/GUIDE BAR MASSES ****
R.19.0.0647
R.20.0.0509
R.21.0.0092
R.22.0.0089
R.23.0.0589
R.24.0.0463
R.25.0.0070
R.26.0.0067
R.27.0.0454
R.28.0.0357
R.29.0.0054
R.30.0.0052
R.31.0.0265
R.32.0.0210
R.33.0.0030
R.34.0.0029
R.35.0.0053
C**** D.U. BEAM ELEMENT PROPERTIES ****
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C**** SPACER DISK PROPERTIES ****
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DENS.1.0.00073
NUXY.1.0.29
EX.1.26.2E6
C**** SUPPORT ROD PROPERTIES ****
ALPX.2.9.0
DENS.2.0.00073
NUXY.2.0.29
EX.2.27.0E6
C**** D.U. BEAM PROPERTIES ****
ALPX.3.9.0
DENS.3.0.00000
NUXY.3.0.29
EX.3.26.2E6
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N.3.3.-18.4122.0
N.4.4.5.-18.1041.0
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E.8.9.26.25
E.9.10.27.26
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REAL.5
E.82.85
E.84.88
E.86.89
REAL.6
E.80.81
REAL.7
E.83.84
E.84.85
E.85.86
E.86.87
C**** GENERATE NODES FOR SPACER DISKS
NGEN.2.100.1.59.1.0.0812.0.22.02
NGEN.2.100.80.89.1.0.0812.0.22.02
NGEN.2.100.101.159.1.0.0619.0.20.15
NGEN.2.100.180.189.1.0.0619.0.20.15
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NGEN.2.100.880.889.1.-0.0340.0.9.055
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N.1078.8.8887.-13.165.6900
N.1079.8.8853.-13.166.6000
N.1080.8.8763.-13.168.9800
N.1081.8.8707.-13.170.4600
N.1082.8.8651.-13.171.9300
N.1083.8.8596.-13.173.4100
N.1084.8.8541.-13.174.8800
C**** SUPPORT ROD ELEMENTS ****
TYPE.3
MAT.2
REAL.3
E.43.1000
E.1000.1001
EGEN.8.1.532
E.1007.143
E.143.1008
E.1008.1009
EGEN.9.1.542
E.1016.243
E.243.1017
E.1017.1018
EGEN.9.1.553
E.1025.343
E.343.1026
E.1026.1027
EGEN.9.1.564
E.1034.443
E.443.1035
E.1035.1036
EGEN.9.1.575
E.1043.543
E.543.1044
E.1044.1045
EGEN.9.1.586
E.1052.643
E.643.1053
E.1053.1054
EGEN.9.1.597
E.1061.743
E.743.1062
E.1062.1063
EGEN.9.1.608
E.1070.843
E.843.1071
E.1071.1072
EGEN.9.1.619
E.1079.943
E.943.1080
E.1080.1081
EGEN.4.1.630
E.1085.43
C**** LIFTING LUG ELEMENT ****
TYPE.2
MAT.1
REAL.11
E.853.953
C**** LIFTING LUG MASS ELEMENT ****
TYPE.4
REAL.18
E.953
C**** DEPLETED URANIUM SHEILD BLOCK MASS ELEMENTS
REAL.13
E.931
E.932
E.933
E.934
REAL.14
E.919
REAL.15
E.920
E.921
E.922
```

```
REAL,16
E,925
E,926
E,927
E,928
E,929
E,930
REAL,17
E,923
E,924
C**** POISON PLATE/GUIDE BAR MASS ELEMENTS ****
REAL,19
E,156
REAL,20
E,150
REAL,21
E,180
E,183
REAL,22
E,184
EGEN,2,100,653,657,1,,,4
EGEN,6,100,658,662,1
EGEN,2,100,683,687,1,,,4
EGEN,2,100,688,692,1,,,4
REAL,35
E,84
C**** D.U. BEAM ELEMENTS ****
TYPE,2
REAL,36
MAT,3
E,919,920
EGEN,3,1,699
E,923,924
E,925,926
EGEN,5,1,703
E,931,932
EGEN,4,1,708
C**** SPACER DISK BOUNDARY CONDITIONS ****
SYMBC,0,0,0,0,21
SYMBC,0,2,0,0,01
CP,1,UX,81,47,82
CP,2,UY,81,47,82
CP,3,UZ,81,47,82
CP,4,ROTX,81,47,82
CP,5,ROTY,81,47,82
CP,6,ROTZ,81,47,82
CP,7,UX,87,54
CP,8,UY,87,54
CP,9,UZ,87,54
CP,10,ROTX,87,54
CP,11,ROTY,87,54
CP,12,ROTZ,87,54
CPSGEN,10,100,1,12,1
C**** SUPPORT ROD BOUNDARY CONDITIONS ****
D,43,ROTX,0,0,,943,100
D,1084,UX,0,0
D,1084,UY,0,0
D,1084,UZ,0,0
D,43,UX,0,0
D,43,UY,0,0
C**** LOADING CONDITIONS ****
TOTAL,50
ACEL,,,-1.0
ITER,1,0,1
AFWRITE
FINISH
/INPUT,27
FINISH
/BUCKLE,50,,1,1,0,,1
ITER,1,1,1
END
FINISH
/OUTPUT
/EOF
```

```
********** ANSYS OUTPUT DATA LISTING **********

 *** ANSYS REV 4.4            38122-PC/LIN-4.4 CP=    7.410 ****
 FOR SUPPORT CALL ROBERT QUINN       PHONE (408) 281-6151    TWX

NEW TITLE= SUPPORT ROD BUCKLING ANALYSIS. 0.2" CENTER OFFSET

***** ANSYS BUCKLING ANALYSIS *****

TOTAL MASTER DOF= 50  (IF 0 AND NOT FULL. USE M CMDS.)
SUBSPACE SIZE=   0  (IF 0. USE HOUSEHOLDER)
EXPAND   1 SHAPE(S) FOR PLOTTING (-1 FOR NONE)
REDUCED MODE PRINT KEY= 1  (0.FIRST  1.ALL)
STRESS CALCULATE KEY= 0
FULL SUBSPACE KEY= 0  (0.REDUCED  1.FULL)
NO ROTATIONAL MASTER KEY= 1  (0.ALLOW ROTATION  1.NO)
VIRTUAL EQUATION SOLVER KEY= 0  (0.OFF 1.ON)
RUN MODE IS /EXEC

    ***** EIGENVALUE BUCKLING SOLUTION *****

 MODE    LOAD FACTOR

   1      1357283.63

         ***** EIGENVECTOR BUCKLING SOLUTION *****

 REDUCED EIGENVECTOR FOR BUCKLING MODE  1     LOAD FACTOR= 0.135728E+07
  NODE     UX              UY              UZ              ROTX            ROTY            ROTZ

  1020   0.637312E-01
  1029  -0.190156
  1031                  -0.168201E-02
  1032  -0.198432
  1037   0.362141
  1038                  -0.104312E-02
  1039   0.507274
  1040                   0.137629E-02
  1041   0.450479
  1046  -0.660939
  1047                   0.250773E-02
  1048  -0.883289
  1050                   0.504802E-03
  1051  -0.539690
  1054   0.578564
  1055                  -0.169180E-02
  1056                  -0.247103E-02
  1057   1.00000
  1058   0.926714       -0.419695E-02
  1059                  -0.491938E-02
  1060   0.519063
  1064  -0.373500       -0.298928E-02
  1065  -0.420811       -0.103595E-02
  1066  -0.419090        0.114203E-02
  1067  -0.374644        0.325275E-02
  1068  -0.298721        0.505099E-02
  1069  -0.206027
  1072                   0.572031E-02
  1073   0.429100E-01    0.452771E-02
  1074   0.561763E-01    0.309127E-02
  1075   0.626958E-01    0.150726E-02
  1076   0.632116E-01   -0.615349E-04
  1077   0.589058E-01   -0.151724E-02
  1081   0.197306E-01   -0.364472E-02
  1082   0.129263E-01   -0.277457E-02
  1083   0.636468E-02   -0.149088E-02

MAXIMUMS
NODE      1057          1072              0               0               0               0
VALUE   1.00000     0.572031E-02    0.000000E+00    0.000000E+00    0.000000E+00    0.000000E+00

***** ROUTINE COMPLETED *****  CP =     3065.660
```

********** ANSYS INPUT DATA LISTING (FILE18) **********

```
/PREP7
/TITLE.SUPPORT ROD BUCKLING ANALYSIS. 0.2" TOP OFFSET
KAN.0
KAY.8.0
ET.1.63......1
ET.2.4......1
ET.3.16......2
ET.4.21...2....1
C**** REAL CONSTANTS (PLATE ELEMENT THICKNESS)
R.1.2.0
R.2.1.25
R.3.3.0.1.5.1.1
C**** REAL CONSTANTS (BEAM ELEMENT PROPERTIES)
C**** NO..AREA.IZZ.IYY.TKZ.TKY.THETA ****
R.5.1.63.0.0902.0.5433.2.0.0.815.
R.6.1.53.0.0746.0.51.2.0.0.765.
R.7.2.52.0.3334.0.84.2.0.1.260.
R.9.1.0188.0.0564.0.1326.1.25.0.815.
R.10.0.9563.0.0466.0.1245.1.25.0.765.
R.11.1.575.0.2084.0.2051.1.25.1.260.
R.4.0.816.0.0113.0.272.2.0.0.408.
R.8.0.510.0.0071.0.0664.1.25.0.408.
C**** LIFTING LUG BEAM ELEMENT PROPERTIES
R.12.2.25.1.6875.0.1055.0.75.3.0.157.5
C**** D.U. SHIELD BLOCK MASSES ****
R.13.0.0218
R.14.0.0104
R.15.0.0208
R.16.0.0196
R.17.0.0286
C**** LIFTING LUG MASS ****
R.18.0.0096
C**** POISON PLATE/GUIDE BAR MASSES ****
R.19.0.0647
R.20.0.0509
R.21.0.0092
R.22.0.0089
R.23.0.0589
R.24.0.0463
R.25.0.0070
R.26.0.0067
R.27.0.0454
R.28.0.0357
R.29.0.0054
R.30.0.0052
R.31.0.0265
R.32.0.0210
R.33.0.0030
R.34.0.0029
R.35.0.0053
C**** D.U. BEAM ELEMENT PROPERTIES ****
R.36.1.975.0.323.24.987.7.5.1.13
C**** MATERIAL PROPERTIES ****
TREF.300
TUNIF.300
C**** SPACER DISK PROPERTIES ****
ALPX.1.9.0
DENS.1.0.00073
NUXY.1.0.29
EX.1.26.2E6
C**** SUPPORT ROD PROPERTIES ****
ALPX.2.9.0
DENS.2.0.00073
NUXY.2.0.29
EX.2.27.0E6
C**** D.U. BEAM PROPERTIES ****
ALPX.3.9.0
DENS.3.0.00000
NUXY.3.0.29
EX.3.26.2E6
C*** NODE GENERATION - SPACER DISK #1
N.1.0.-18.655.0
N.2.1.50.-18.5946.0
```

```
N.3.3.-18.4122.0
N.4.4.5.-18.1041.0
N.5.7.0128.-17.2867.0
N.6.8.133.-16.7888.0
N.7.9.5161.-16.0453.0
N.8.11.5803.-14.6255.0
N.9.12.7678.-13.6012.0
N.10.13.8918.-12.451.0
N.11.14.9137.-11.2067.0
N.12.15.82.-9.8862.0
N.13.16.59.-8.5311.0
N.14.17.901.-5.25.0
N.15.18.2742.-3.75.0
N.16.18.5188.-2.25.0
N.17.18.6399.-.75.0
N.18.18.655.0.0
N.19.0.-17.55.0
N.20.1.5.-17.55.0
N.21.3.-17.55.0
N.22.4.5.-17.55.0
N.23.7.78.-16.06.0
N.24.9.08.-15.31.0
N.25.10.99.-13.88.0
N.26.11.95.-12.73.0
N.27.12.92.-11.58.0
N.28.13.88.-10.43.0
N.29.14.85.-9.28.0
N.30.15.81.-8.13.0
N.31.17.15.-5.25.0
N.32.17.15.-3.75.0
N.33.17.15.-2.25.0
N.34.17.15.-.75.0
N.35.17.15.0.0
N.36.0.-16.925.0
N.37.1.5.-16.925.0
N.38.3.-16.925.0
N.39.4.5.-16.925.0
N.40.6.3625.-16.925.0
N.41.6.3625.-15.0
N.42.6.3625.-13.0
N.43.8.875.-13.0
N.44.6.3625.-11.6.0
N.45.8.875.-11.6.0
N.46.11.58.-11.6.0
N.47.6.3625.-10.2.0
N.48.8.875.-10.2.0
N.49.11.58.-10.2.0
N.50.13.1403.-10.2.0
N.51.13.1403.-8.0
N.52.13.1403.-5.92.0
N.53.14.29.-5.92.0
N.54.13.1403.-2.98.0
N.55.14.29.-2.98.0
N.56.16.525.-2.98.0
N.57.16.525.-2.25.0
N.58.16.525.-.75.0
N.59.16.525.0.0
N.80.0.-10.5825.0
N.81.6.3625.-10.5825.0
N.82.6.77.-10.2.0
N.83.0.-3.61.0
N.84.3.388.-3.61.0
N.85.6.77.-3.61.0
N.86.10.163.-3.61.0
N.87.13.1403.-3.61.0
N.88.3.388.0.0
N.89.10.163.0.0

C*** ELEMENT GENERATION

E.1.2.20.19
E.2.3.21.20
E.3.4.22.21
E.4.5.22
E.5.6.23.40
```

```
E.6.7.24.23
E.7.8.25.24
E.8.9.26.25
E.9.10.27.26
E.10.11.28.27
E.11.12.29.28
E.12.13.30.29
E.13.14.31.30
E.14.15.32.31
E.15.16.33.32
E.16.17.34.33
E.17.18.35.34
E.19.20.37.36
E.20.21.38.37
E.21.22.39.38
E.22.5.40.39
E.40.23.41
E.23.24.43.41
E.24.25.43
E.41.43.42
E.42.43.45.44
E.43.25.46.45
E.25.26.46
E.26.27.46
E.44.45.48.47
E.45.46.49.48
E.46.27.50.49
E.27.28.50
E.28.29.51.50
E.29.30.53.51
E.51.53.52
E.30.31.53
E.52.53.55.54
E.53.31.55
E.31.32.56.55
E.32.33.57.56
E.33.34.58.57
E.34.35.59.58
TYPE.2
MAT.1
REAL.4
E.36.80
E.80.83
REAL.5
E.82.85
E.84.88
E.86.89
REAL.6
E.80.81
REAL.7
E.83.84
E.84.85
E.85.86
E.86.87
C**** GENERATE NODES FOR SPACER DISKS
NGEN.2.100.1.59.1.0.0261.0.22.02
NGEN.2.100.80.89.1.0.0261.0.22.02
NGEN.7.100.101.159.1.0.0239.0.20.15
NGEN.7.100.180.189.1.0.0239.0.20.15
NGEN.2.100.701.759.1.0.0183.0.15.53
NGEN.2.100.780.789.1.0.0183.0.15.53
NGEN.2.100.801.859.1.0.0124.0.9.055
NGEN.2.100.880.889.1.0.0124.0.9.055
C**** GENERATE ELEM. FOR SPACER DISKS
EGEN.9.100.1.53.1
EGEN.2.100.425.467.1...1
EGEN.2.100.468.477.1...4
C**** SUPPORT ROD NODES ****
FILL.43.143.8.1000.1
FILL.143.243.9.1008.1
FILL.243.343.9.1017.1
FILL.343.443.9.1026.1
FILL.443.543.9.1035.1
FILL.543.643.9.1044.1
FILL.643.743.9.1053.1
```

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FILL.743.843.9.1062.1
FILL.843.943.9.1071.1
N.1084.9.082.-13.174.88
FILL.943.1084.4.1080.1
N.1085.8.87.-13.0.-4.25
C**** SUPPORT ROD ELEMENTS ****
TYPE.3
MAT.2
REAL.3
E.43.1000
E.1000.1001
EGEN.8.1.532
E.1007.143
E.143.1008
E.1008.1009
EGEN.9.1.542
E.1016.243
E.243.1017
E.1017.1018
EGEN.9.1.553
E.1025.343
E.343.1026
E.1026.1027
EGEN.9.1.564
E.1034.443
E.443.1035
E.1035.1036
EGEN.9.1.575
E.1043.543
E.543.1044
E.1044.1045
EGEN.9.1.586
E.1052.643
E.643.1053
E.1053.1054
EGEN.9.1.597
E.1061.743
E.743.1062
E.1062.1063
EGEN.9.1.608
E.1070.843
E.843.1071
E.1071.1072
EGEN.9.1.619
E.1079.943
E.943.1080
E.1080.1081
EGEN.4.1.630
E.1085.43
C**** LIFTING LUG ELEMENT ****
TYPE.2
MAT.2
REAL.12
E.853.953
C**** LIFTING LUG MASS ELEMENT ****
TYPE.4
REAL.18
E.953
C**** DEPLETED URANIUM SHEILD BLOCK MASS ELEMENTS
REAL.13
E.931
E.932
E.933
E.934
REAL.14
E.919
REAL.15
E.920
E.921
E.922
REAL.16
E.925
E.926
E.927
E.928
```

```
E.929
E.930
REAL.17
E.923
E.924
C**** POISON PLATE/GUIDE BAR MASS ELEMENTS ****
REAL.19
E.156
REAL.20
E.150
REAL.21
E.180
E.183
REAL.22
E.184
EGEN.2.100.653.657.1...4
EGEN.6.100.658.662.1
EGEN.2.100.683.687.1...4
EGEN.2.100.688.692.1...4
REAL.35
E.84
C**** D.U. BEAM ELEMENTS ****
TYPE.2
REAL.36
MAT.3
E.919.920
EGEN.3.1.699
E.923.924
E.925.926
EGEN.5.1.703
E.931.932
EGEN.4.1.708
C**** SPACER DISK BOUNDARY CONDITIONS ****
SYMBC.0.0.0.0.21
SYMBC.0.2.0.0.01
CP.1.UX.81.47.82
CP.2.UY.81.47.82
CP.3.UZ.81.47.82
CP.4.ROTX.81.47.82
CP.5.ROTY.81.47.82
CP.6.ROTZ.81.47.82
CP.7.UX.87.54
CP.8.UY.87.54
CP.9.UZ.87.54
CP.10.ROTX.87.54
CP.11.ROTY.87.54
CP.12.ROTZ.87.54
CPSGEN.10.100.1.12.1
C**** SUPPORT ROD BOUNDARY CONDITIONS ****
D.43.ROTZ.0.0..943.100
D.1084.UX.0.0
D.1084.UY.0.0
D.1084.UZ.0.0
D.43.UX.0.0
D.43.UY.0.0
C**** LOADING CONDITIONS ****
TOTAL.50
ACEL...-1.0
ITER.1.0.1
AFWRITE
FINISH
/INPUT.27
FINISH
/BUCKLE.50..3.1.0..1
ITER.1.1.1
END
FINISH
/OUTPUT
/EOF
```

```
********** ANSYS OUTPUT DATA LISTING **********

*** ANSYS REV 4.4          38122-PC/LIN-4.4 CP=     7.410 ****
FOR SUPPORT CALL ROBERT QUINN      PHONE (408) 281-6151    TWX

NEW TITLE= SUPPORT ROD BUCKLING ANALYSIS. 0.2" TOP OFFSET

***** ANSYS BUCKLING ANALYSIS *****

TOTAL MASTER DOF=  50  (IF 0 AND NOT FULL. USE M CMDS.)
SUBSPACE SIZE=   0  (IF 0. USE HOUSEHOLDER)
EXPAND   3 SHAPE(S) FOR PLOTTING (-1 FOR NONE)
REDUCED MODE PRINT KEY=  1  (0.FIRST  1.ALL)
STRESS CALCULATE KEY=  0
FULL SUBSPACE KEY=  0  (0.REDUCED  1.FULL)
NO ROTATIONAL MASTER KEY=  1  (0.ALLOW ROTATION  1.NO)
VIRTUAL EQUATION SOLVER KEY=  0  (0.OFF 1.ON)
RUN MODE IS /EXEC

    ***** EIGENVALUE BUCKLING SOLUTION *****

 MODE    LOAD FACTOR

   1      1319378.92

 REDUCED EIGENVECTOR FOR BUCKLING MODE   1      LOAD FACTOR=  0.131938E+07
  NODE       UX               UY               UZ             ROTX            ROTY            ROTZ

  1020   0.179087E-02
  1021                    0.750055E-01
  1030  -0.271949E-02    -0.221942
  1037  -0.284860E-02
  1039  -0.174137E-02     0.527805
  1041   0.238119E-03
  1042                    0.344646
  1046   0.125962E-01    -0.710644
  1048   0.160408E-01    -0.944577
  1050   0.135495E-01    -0.793438
  1054                    0.621935
  1055  -0.236735E-01     0.872667
  1057  -0.335365E-01
  1058                     1.00000
  1059  -0.304049E-01
  1060                    0.573237
  1063                   -0.292303
  1064                   -0.401628
  1065   0.257827E-01
  1066   0.300834E-01    -0.463145
  1067   0.315099E-01    -0.421388
  1068   0.298121E-01    -0.344136
  1069   0.250845E-01    -0.246332
  1072                    0.998884E-02
  1073  -0.486019E-02     0.363387E-01
  1074  -0.846280E-02     0.549782E-01
  1075  -0.111593E-01     0.663227E-01
  1076  -0.128576E-01     0.711056E-01
  1077  -0.135090E-01     0.703464E-01
  1081  -0.440434E-02     0.358817E-01
  1082  -0.255627E-02     0.252399E-01
  1083  -0.115785E-02     0.130394E-01

MAXIMUMS
NODE       1057            1058             0              0              0              0
VALUE  -0.335365E-01     1.00000     0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00

***** ROUTINE COMPLETED *****  CP =     3221.550
```

********** ANSYS INPUT DATA LISTING (FILE18) **********

```
/PREP7
/TITLE. SUPPORT ROD TRANSIENT DYNAMIC ANALYSIS - MODAL ANALYSIS
KAN.2
KAY.3.1
KAY.8.0
TREF.300
TUNIF.300
ET.1.63.......1
ET.2.4.......1
ET.3.16......2
ET.4.21...2...1
C**** REAL CONSTANTS (PLATE ELEMENT THICKNESS)
R.1.2.0
R.2.1.25
R.3.3.0.1.5.1.1
C**** REAL CONSTANTS (BEAM ELEMENT PROPERTIES)
C**** NO..AREA.IZZ.IYY.TKZ.TKY.THETA ****
R.5.1.63.0.0902.0.5433.2.0.0.815.
R.6.1.53.0.0746.0.51.2.0.0.765.
R.7.2.52.0.3334.0.84.2.0.1.260.
R.9.1.0188.0.0564.0.1326.1.25.0.815.
R.10.0.9563.0.0466.0.1245.1.25.0.765.
R.11.1.575.0.2084.0.2051.1.25.1.260.
R.4.0.816.0.0113.0.272.2.0.0.408.
R.8.0.510.0.0071.0.0664.1.25.0.408.
C**** LIFTING LUG BEAM ELEMENT PROPERTIES
R.12.2.25.1.6875.0.1055.0.75.3.0.157.5
C**** D.U. SHIELD BLOCK MASSES ****
R.13.0.0218
R.14.0.0104
R.15.0.0208
R.16.0.0196
R.17.0.0286
C**** LIFTING LUG MASS ****
R.18.0.0096
C**** POISON PLATE/GUIDE BAR MASSES ****
R.19.0.0647
R.20.0.0509
R.21.0.0092
R.22.0.0089
R.23.0.0589
R.24.0.0463
R.25.0.0070
R.26.0.0067
R.27.0.0454
R.28.0.0357
R.29.0.0054
R.30.0.0052
R.31.0.0265
R.32.0.0210
R.33.0.0030
R.34.0.0029
R.35.0.0053
C**** D.U. BEAM ELEMENT PROPERTIES ****
R.36.1.975.0.323.24.987.7.5.1.13
C**** MATERIAL PROPERTIES ****
C**** SPACER DISK PROPERTIES ****
ALPX.1.9.0
DENS.1.0.00073
NUXY.1.0.29
EX.1.26.2E6
C**** SUPPORT ROD PROPERTIES ****
ALPX.2.9.0
DENS.2.0.00073
NUXY.2.0.29
EX.2.27.0E6
C**** D.U. BEAM PROPERTIES ****
ALPX.3.9.0
DENS.3.0.00000
NUXY.3.0.29
EX.3.26.2E6
C*** NODE GENERATION - SPACER DISK #1
N.1.0.-18.655.0
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N.2.1.50.-18.5946.0
N.3.3.-18.4122.0
N.4.4.5.-18.1041.0
N.5.7.0128.-17.2867.0
N.6.8.133.-16.7888.0
N.7.9.5161.-16.0453.0
N.8.11.5803.-14.6255.0
N.9.12.7678.-13.6012.0
N.10.13.8918.-12.451.0
N.11.14.9137.-11.2067.0
N.12.15.82.-9.8862.0
N.13.16.59.-8.5311.0
N.14.17.901.-5.25.0
N.15.18.2742.-3.75.0
N.16.18.5188.-2.25.0
N.17.18.6399.-.75.0
N.18.18.655.0.0
N.19.0.-17.55.0
N.20.1.5.-17.55.0
N.21.3.-17.55.0
N.22.4.5.-17.55.0
N.23.7.78.-16.06.0
N.24.9.08.-15.31.0
N.25.10.99.-13.88.0
N.26.11.95.-12.73.0
N.27.12.92.-11.58.0
N.28.13.88.-10.43.0
N.29.14.85.-9.28.0
N.30.15.81.-8.13.0
N.31.17.15.-5.25.0
N.32.17.15.-3.75.0
N.33.17.15.-2.25.0
N.34.17.15.-.75.0
N.35.17.15.0.0
N.36.0.-16.925.0
N.37.1.5.-16.925.0
N.38.3.-16.925.0
N.39.4.5.-16.925.0
N.40.6.3625.-16.925.0
N.41.6.3625.-15.0
N.42.6.3625.-13.0
N.43.8.875.-13.0
N.44.6.3625.-11.6.0
N.45.8.875.-11.6.0
N.46.11.58.-11.6.0
N.47.6.3625.-10.2.0
N.48.8.875.-10.2.0
N.49.11.58.-10.2.0
N.50.13.1403.-10.2.0
N.51.13.1403.-8.0
N.52.13.1403.-5.92.0
N.53.14.29.-5.92.0
N.54.13.1403.-2.98.0
N.55.14.29.-2.98.0
N.56.16.525.-2.98.0
N.57.16.525.-2.25.0
N.58.16.525.-.75.0
N.59.16.525.0.0
N.80.0.-10.5825.0
N.81.6.3625.-10.5825.0
N.82.6.77.-10.2.0
N.83.0.-3.61.0
N.84.3.388.-3.61.0
N.85.6.77.-3.61.0
N.86.10.163.-3.61.0
N.87.13.1403.-3.61.0
N.88.3.388.0.0
N.89.10.163.0.0
C*** ELEMENT GENERATION
E.1.2.20.19
E.2.3.21.20
E.3.4.22.21
E.4.5.22
E.5.6.23.40
E.6.7.24.23
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E.7.8.25.24
E.8.9.26.25
E.9.10.27.26
E.10.11.28.27
E.11.12.29.28
E.12.13.30.29
E.13.14.31.30
E.14.15.32.31
E.15.16.33.32
E.16.17.34.33
E.17.18.35.34
E.19.20.37.36
E.20.21.38.37
E.21.22.39.38
E.22.5.40.39
E.40.23.41
E.23.24.43.41
E.24.25.43
E.41.43.42
E.42.43.45.44
E.43.25.46.45
E.25.26.46
E.26.27.46
E.44.45.48.47
E.45.46.49.48
E.46.27.50.49
E.27.28.50
E.28.29.51.50
E.29.30.53.51
E.51.53.52
E.30.31.53
E.52.53.55.54
E.53.31.55
E.31.32.56.55
E.32.33.57.56
E.33.34.58.57
E.34.35.59.58
TYPE.2
MAT.1
REAL.4
E.36.80
E.80.83
REAL.5
E.82.85
E.84.88
E.86.89
REAL.6
E.80.81
REAL.7
E.83.84
E.84.85
E.85.86
E.86.87
C**** GENERATE NODES FOR SPACER DISKS
NGEN.2.100.1.59.1.0.0812.0.22.02
NGEN.2.100.80.89.1.0.0812.0.22.02
NGEN.2.100.101.159.1.0.0619.0.20.15
NGEN.2.100.180.189.1.0.0619.0.20.15
NGEN.2.100.201.259.1.0.0431.0.20.15
NGEN.2.100.280.289.1.0.0431.0.20.15
NGEN.2.100.301.359.1.0.0149.0.20.15
NGEN.2.100.380.389.1.0.0149.0.20.15
NGEN.2.100.401.459.1.-0.0108.0.20.15
NGEN.2.100.480.489.1.-0.0108.0.20.15
NGEN.2.100.501.559.1.-0.0367.0.20.15
NGEN.2.100.580.589.1.-0.0367.0.20.15
NGEN.2.100.601.659.1.-0.0581.0.20.15
NGEN.2.100.680.689.1.-0.0581.0.20.15
NGEN.2.100.701.759.1.-0.0547.0.15.53
NGEN.2.100.780.789.1.-0.0547.0.15.53
NGEN.2.100.801.859.1.-0.0340.0.9.055
NGEN.2.100.880.889.1.-0.0340.0.9.055
C**** GENERATE ELEM. FOR SPACER DISKS
EGEN.9.100.1.53.1
EGEN.2.100.425.467.1...1
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EGEN,2,100,468,477,1,,,4
C**** SUPPORT ROD NODES ****
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N,1001,8.8936,-13,4.8933
N,1002,8.9029,-13,7.3400
N,1003,8.9120,-13,9.7867
N,1004,8.9211,-13,12.2330
N,1005,8.9301,-13,14.6800
N,1006,8.9390,-13,17.1270
N,1007,8.9477,-13,19.5730
N,1008,8.9631,-13,24.0350
N,1009,8.9699,-13,26.0500
N,1010,8.9765,-13,28.0650
N,1011,8.9830,-13,30.0800
N,1012,8.9893,-13,32.0950
N,1013,8.9954,-13,34.1100
N,1014,9.0014,-13,36.1250
N,1015,9.0072,-13,38.1400
N,1016,9.0128,-13,40.1550
N,1017,9.0233,-13,44.1850
N,1018,9.0283,-13,46.2000
N,1019,9.0331,-13,48.2150
N,1020,9.0376,-13,50.2300
N,1021,9.0419,-13,52.2450
N,1022,9.0459,-13,54.2600
N,1023,9.0498,-13,56.2750
N,1024,9.0533,-13,58.2900
N,1025,9.0567,-13,60.3050
N,1026,9.0626,-13,64.3350
N,1027,9.0652,-13,66.3500
N,1028,9.0675,-13,68.3650
N,1029,9.0695,-13,70.3800
N,1030,9.0713,-13,72.3950
N,1031,9.0728,-13,74.4100
N,1032,9.0740,-13,76.4250
N,1033,9.0750,-13,78.4400
N,1034,9.0757,-13,80.4550
N,1035,9.0762,-13,84.4850
N,1036,9.0761,-13,86.5000
N,1037,9.0757,-13,88.5150
N,1038,9.0750,-13,90.5300
N,1039,9.0741,-13,92.5450
N,1040,9.0728,-13,94.5600
N,1041,9.0714,-13,96.5750
N,1042,9.0696,-13,98.5900
N,1043,9.0676,-13,100.6100
N,1044,9.0627,-13,104.6400
N,1045,9.0599,-13,106.6500
N,1046,9.0568,-13,108.6700
N,1047,9.0535,-13,110.6800
N,1048,9.0500,-13,112.7000
N,1049,9.0462,-13,114.7100
N,1050,9.0421,-13,116.7300
N,1051,9.0378,-13,118.7400
N,1052,9.0333,-13,120.7600
N,1053,9.0237,-13,124.7900
N,1054,9.0185,-13,126.8000
N,1055,9.0132,-13,128.8100
N,1056,9.0076,-13,130.8300
N,1057,9.0019,-13,132.8400
N,1058,8.9959,-13,134.8600
N,1059,8.9898,-13,136.8700
N,1060,8.9835,-13,138.8900
N,1061,8.9771,-13,140.9000
N,1062,8.9654,-13,144.4700
N,1063,8.9601,-13,146.0300
N,1064,8.9548,-13,147.5800
N,1065,8.9494,-13,149.1300
N,1066,8.9439,-13,150.6900
N,1067,8.9384,-13,152.2400
N,1068,8.9328,-13,153.7900
N,1069,8.9272,-13,155.3400
N,1070,8.9215,-13,156.9000
N,1071,8.9124,-13,159.3600
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N,1072,8.9090,-13,160.2600
N,1073,8.9057,-13,161.1700
N,1074,8.9023,-13,162.0700
N,1075,8.8989,-13,162.9800
N,1076,8.8955,-13,163.8800
N,1077,8.8921,-13,164.7900
N,1078,8.8887,-13,165.6900
N,1079,8.8853,-13,166.6000
N,1080,8.8763,-13,168.9800
N,1081,8.8707,-13,170.4600
N,1082,8.8651,-13,171.9300
N,1083,8.8596,-13,173.4100
N,1084,8.8541,-13,174.8800
C**** SUPPORT ROD ELEMENTS ****
TYPE,3
MAT,2
REAL,3
E,43,1000
E,1000,1001
EGEN,8,1,532
E,1007,143
E,143,1008
E,1008,1009
EGEN,9,1,542
E,1016,243
E,243,1017
E,1017,1018
EGEN,9,1,553
E,1025,343
E,343,1026
E,1026,1027
EGEN,9,1,564
E,1034,443
E,443,1035
E,1035,1036
EGEN,9,1,575
E,1043,543
E,543,1044
E,1044,1045
EGEN,9,1,586
E,1052,643
E,643,1053
E,1053,1054
EGEN,9,1,597
E,1061,743
E,743,1062
E,1062,1063
EGEN,9,1,608
E,1070,843
E,843,1071
E,1071,1072
EGEN,9,1,619
E,1079,943
E,943,1080
E,1080,1081
EGEN,4,1,630
E,1085,43
C**** LIFTING LUG ELEMENT ****
TYPE,2
MAT,1
REAL,11
E,853,953
C**** LIFTING LUG MASS ELEMENT ****
TYPE,4
REAL,18
E,953
C**** DEPLETED URANIUM SHEILD BLOCK MASS ELEMENTS
REAL,13
E,931
E,932
E,933
E,934
REAL,14
E,919
REAL,15
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E.920
E.921
E.922
REAL.16
E.925
E.926
E.927
E.928
E.929
E.930
REAL.17
E.923
E.924
C**** POISON PLATE/GUIDE BAR MASS ELEMENTS ****
REAL.19
E.156
REAL.20
E.150
REAL.21
E.180
E.183
REAL.22
E.184
EGEN.2.100.653.657.1...4
EGEN.6.100.658.662.1
EGEN.2.100.683.687.1...4
EGEN.2.100.688.692.1...4
REAL.35
E.84
C**** D.U. BEAM ELEMENTS ****
TYPE.2
REAL.36
MAT.3
E.919.920
EGEN.3.1.699
E.923.924
E.925.926
EGEN.5.1.703
E.931.932
EGEN.4.1.708
C**** SPACER DISK BOUNDARY CONDITIONS ****
SYMBC.0.0.0.0.21
SYMBC.0.2.0.0.01
CP.1.UX.81.47.82
CP.2.UY.81.47.82
CP.3.UZ.81.47.82
CP.4.ROTX.81.47.82
CP.5.ROTY.81.47.82
CP.6.ROTZ.81.47.82
CP.7.UX.87.54
CP.8.UY.87.54
CP.9.UZ.87.54
CP.10.ROTX.87.54
CP.11.ROTY.87.54
CP.12.ROTZ.87.54
CPSGEN.10.100.1.12.1
C**** SUPPORT ROD BOUNDARY CONDITIONS ****
D.43.ROTZ.0.0..943.100
D.1084.UX.0.0
D.1084.UY.0.0
D.1084.UZ.0.0
D.43.UX.0.0
D.43.UY.0.0
C**** LOADING CONDITIONS ****
NLIST.ALL
ELIST.ALL
RLIST.ALL
MLIST.ALL
CPLIST.ALL
DLIST.ALL
TOTAL.100
ITER.1.1.1
AFWRITE
FINISH
/INPUT.27
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FINISH
/PREP7
RESUME
/TITLE. SUPPORT ROD - DISPLACEMENT PASS
KAN.5
KAY.3
KAY.8.0
TREF.300
TUNIF.300
C**** LOADING CONDITIONS ****
TIME.0.0
ACEL...0
LWRITE
TIME.0.3E-3
ITER.40.0.1
ACEL...-108192
LWRITE
TIME.0.48E-3
ITER.40.0.1
ACEL...-47913
LWRITE
TIME.7.3E-3
ITER.200.0.1
ACEL...-47913
LWRITE
TIME.13.7E-3
ITER.80.0.1
ACEL...0.0
LWRITE
SLOAD.1
AFWRITE
FINISH
/LNFREQ.100
/INPUT.27
FINISH
/TITLE.SUPPORT ROD STRESS PASS
/STRESS...5
TIME.13.7E-3
NSTRES.60
END
FINISH
/POST26
TIME.0.13.7E-3
ESTR.2.629.26.SII
ESTR.3.630.26.SII
ESTR.4.631.26.SII
ESTR.5.632.26.SII
ESTR.6.633.26.SII
ESTR.7.628.30.SIJ
/GRAPH.LABY.SI
/TITLE.SUPPORT ROD S.I. VS. TIME. ELEM 628
/SHOW.SI628
PLVAR.7
/TITLE.SUPPORT ROD S.I. VS. TIME. ELEM 629
/SHOW.SI629
PLVAR.2
/TITLE.SUPPORT ROD S.I. VS. TIME. ELEM 630
/SHOW.SI630
PLVAR.3
/TITLE.SUPPORT ROD S.I. VS. TIME. ELEM 631
/SHOW.SI631
PLVAR.4
EXTREM.3.7.1
ESTR.2.540.7.FX
ESTR.3.541.1.FX
ADD.4.2.3..FX
/GRAPH.LABY.FX
/TITLE.SUPPORT ROD/SPACER DISK #2 WELD SHEAR - NODE 143
/SHOW.FXSD2
PLVAR.4
EXTREM.4
ESTR.2.540.11.MY
ESTR.3.541.5.MY
ESTR.4.540.12.MZ
ESTR.5.541.6.MZ
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ADD.6.2.3..MY
ADD.7.4.5..MZ
/GRAPH.LABY.MOM
/TITLE.SUPPORT ROD/SPACER DISK #2 WELD MOMENTS - NODE 143
/SHOW.MSD2
PLVAR.6.7
EXTREM.6.7
ESTR.2.617.7.FX
ESTR.3.618.1.FX
ADD.4.2.3..FX
/GRAPH.LABY.FX
/TITLE.SUPPORT ROD/SPACER DISK #9 WELD SHEAR - NODE 843
/SHOW.FXSD9
PLVAR.4
EXTREM.4
ESTR.2.617.11.MY
ESTR.3.618.5.MY
ESTR.4.617.12.MZ
ESTR.5.618.6.MZ
ADD.6.2.3..MY
ADD.7.4.5..MZ
/GRAPH.LABY.MOM
/TITLE.SUPPORT ROD/SPACER DISK #9 WELD MOMENTS - NODE 843
/SHOW.MSD9
PLVAR.6.7
EXTREM.6.7
ESTR.2.628.7.FX
ESTR.3.629.1.FX
ADD.4.2.3..FX
/GRAPH.LABY.FX
/TITLE.SUPPORT ROD/TOP PLATE WELD SHEAR - NODE 943
/SHOW.FXTP
PLVAR.4
EXTREM.4
ESTR.2.628.11.MY
ESTR.3.629.5.MY
ESTR.4.628.12.MZ
ESTR.5.629.6.MZ
ADD.6.2.3..MY
ADD.7.4.5..MZ
/GRAPH.LABY.MOM
/TITLE.SUPPORT ROD/TOP PLATE WELD MOMENTS - NODE 943
/SHOW.MTP
PLVAR.6.7
EXTREM.6.7
/OUTPUT
/EOF
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