MOL.20000202.0192

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: QA

2. Calculation Title
Structural Calculation of an Emplacement Pallet Statically Loaded by a Waste Package

MOL.20000202.0192

3. Document Identifier (including Revision Number)
CAL-WER-ME-000003 REV 00

4. Total Attachments	5. Attachment Numbers - Number of pages in each
3	I-3, II-10, III-3

	Print Name	Signature	Date
6. Originator	Sreten Mastilovic	[signature]	02/01/2000
7. Checker	Zekai Ceylan	[signature]	2/1/00
8. Lead	Scott M. Bennett	[signature]	02/02/00

9. Remarks
TBV-3982 applies to this calculation

Revision History

10. Revision No.	11. Description of Revision
00	Initial issue

CONTENTS

1. PURPOSE

The purpose of this calculation is to determine the structural response of the emplacement pallet (EP) subjected to static load from the mounted waste package (WP). The scope of this document is limited to reporting the calculation results in terms of stress intensity magnitudes. This calculation is associated with the waste emplacement systems design; calculations are performed by the Waste Package Design group. AP-3.12Q, Revision 0, ICN 0, Calculations, is used to perform the calculation and develop the document.

2. METHOD

The finite element solutions are performed by using the commercially available ANSYS Version (V) 5.4 finite element code. The results of these calculations are provided in terms of maximum stress intensity magnitudes.

3. ASSUMPTIONS

In the course of developing this document, the following assumptions are made regarding the EP structural calculation.

3.1 Some of the temperature-dependent material properties were not available for SB-575 N06022 (Alloy 22) and SA-240 S31603 (316L stainless steel [SS]). Therefore, room-temperature (20 °C) material properties are assumed for both materials. The impact of using room-temperature material properties is anticipated to be small. The basis for this assumption is that the mechanical properties of said materials do not change significantly at the temperatures experienced during handling and lifting operations. This assumption is used in Section 5.2.

3.2 The magnitudes of the contact stiffness between the WP and the EP is assumed to be $1 \cdot 10^8\ N/m$. The basis for this assumption is explained below:

The magnitude of the contact stiffness between surfaces is one of the parameters that affects the results. If the contact stiffness value is very large, stiffness matrix ill-conditioning and divergence occur. On the other hand, an extremely small contact stiffness value results in compatibility violations. Therefore, an optimum value for the contact stiffness is one that is in between and is arrived at iteratively. This assumption is used in Section 5.3.

3.3 The Poisson's ratio of 316L SS was not available in literature. Therefore, the Poisson's ratio of 316 SS is assumed for 316L SS. The impact of this assumption is anticipated to be negligible. The basis for this assumption is the similar chemical composition of these two stainless steels (see Ref. 9, Table 1). This assumption is used in Section 5.2.

3.4 The Poisson's ratio of Alloy 22 was not available in literature. Therefore, the Poisson's ratio of Alloy 625 is assumed for Alloy 22. The impact of this assumption is anticipated to be negligible. The basis for this assumption is that the chemical compositions of Alloy 22 and Alloy 625 are similar (see Ref. 6, Table 1 and Ref. 5, p. 143). This assumption is used in Section 5.2.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE (QA) WORK

The finite element analysis computer code used for this calculation is ANSYS V5.4 that is identified with the Computer Software Configuration Item (CSCI) 30040 V5.4 and was obtained from Software Configuration Management in accordance with appropriate procedures. ANSYS V5.4 is a commercially available finite element analysis code and is appropriate for structural calculations of waste packages as performed in this calculation. The calculations using the ANSYS V5.4 software were executed on the Hewlett-Packard (HP) workstation identified with Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) tag number 115288. The software qualification of the ANSYS V5.4 software is summarized in the Software Qualification Report for ANSYS V5.4 (Ref. 2). Qualification of ANSYS V5.4 on the Waste Package Operations (WPO) HP UNIX workstations is documented in Reference 7. The ANSYS evaluations performed for this design are fully within the range of the validation performed for the ANSYS V5.4 code. Access to and use of the code for the calculation were granted by Software Configuration Secretariat in accordance with the appropriate procedures.

4.2 SOFTWARE ROUTINES

Industry standard software used in this calculation is Pro/Engineer Version 20.0. This software is executed on the HP workstation. Pro/Engineer Version 20.0 is not controlled computer software, and it has not been qualified under the Office of Civilian Radioactive Waste Management (OCRWM) procedures.

Attachment II contains the input/output data obtained from Pro/Engineer Version 20.0. The mass densities given in Section 5.2 are used as inputs to Pro/Engineer Version 20.0 and corresponding masses of WP components are obtained for the use in structural evaluations. There are no user-operated equations of mathematical models, algorithms, or numerical solution techniques applicable to the software routine since Pro/Engineer Version 20.0 is an engineering drawing software package and the subject mass calculations are performed by the source code, based on the dimensions of structural components and the mass density of materials. Verification of this software is accomplished by a test case, as described in Section 5.1. The range of input parameter values is limited to the dimensions of the structural components used in those cases; all mass calculations depend on specific geometry of the subject components. No limitations are identified on software routine applications or validity.

4.3 MODELS

None used.

5. CALCULATION

5.1 MASS AND GEOMETRIC DIMENSIONS OF WASTE PACKAGE

To provide the bounding set of results for all waste packages, this calculation is performed using mass and geometric dimensions of the heaviest WP: the single-CRM (corrosion resistant material) naval SNF (spent nuclear fuel) long WP.

To provide the bounding results for possible slight design modifications, the total mass of the single-CRM naval SNF long WP emplaced on the EP, $72643\,kg$ (page II-2), is expressed with two significant digits, i.e.:

Total mass of the loaded WP $= 73000\,kg$
Length of WP $= 6.525\,m$ (see p. II-2)
Outer diameter of outer shell $= 1.869\,m$ (see p. II-2)

The outer shell lid of the single-CRM naval SNF long WP is selected for verification of the mass obtained from Pro/Engineer Version 20.0. The mass of this component is determined as product of the mass density (see Section 5.2) and the volume, using the dimensions provided on page II-2:

Mass = $8690 \cdot 0.025 \cdot 1.822^2 \pi/4 = 566.43021\,kg$

The mass obtained by the preceding calculation is identical to the mass provided on page II-9.

5.2 MATERIAL PROPERTIES

Material properties used in the calculations are listed in this section. Some of the temperature-dependent material properties were not available for Alloy 22 and 316L SS; therefore, room-temperature material properties were used in calculations (Assumption 3.1).

SB-575 N06022 (ASTM B 575) (Alloy 22):

- Density = 8690 kg/m^3 (0.314 lb/in^3) (Ref. 6, p. 2)
- Yield strength = 310 *MPa* (45 *ksi*) (Ref. 6, Table 3)
- Tensile strength = 690 *MPa* (100 *ksi*) (Ref. 6, Table 3)
- Poisson's ratio = 0.278 (Ref. 5, p. 143; see Assumption 3.4)
- Modulus of elasticity = 206 *GPa* ($29.9 \cdot 10^6\ psi$) (Ref. 3, p. 14)

SA-240 S31603 (316L SS):

- Density = 7980 kg/m^3 (Ref. 1, p. 7)
- Yield strength = 172 *MPa* (25 *ksi*) (Ref. 4, Table Y-1)
- Tensile strength = 483 *MPa* (70 *ksi*) (Ref. 4, Table U)
- Poisson's ratio = 0.3 (Ref. 5, p. 755, Fig. 15; see Assumption 3.3)
- Modulus of elasticity = 195 *GPa* $(28.3 \cdot 10^6\ psi)$ (Ref. 4, Table TM-1)

5.3 FINITE ELEMENT REPRESENTATION

Three-dimensional finite element representation (FER) is developed using the dimensions provided in Attachment II and Section 5.1. A two-plane-symmetry FER is developed for the EP (see p. III-1). Furthermore, a one-eighth-symmetry FER is constructed for the WP mounted on the EP, by making use of its three-plane symmetry. Since the contact zones of the WP and EP are the only regions of interest as far as WP is concerned, its FER is reduced to a cylinder of uniform mass density. The overall mass and the geometric dimensions of WP (Section 5.1) define this density, and it is appropriately modified to take into account its one-eighth-symmetry FER. The benefit of using this approach is to reduce the computer execution time while preserving all features of the problem relevant to the structural calculation.

Contact elements are used to represent contact between the WP and the EP. The magnitude of the contact stiffness is one of the parameters that affects the results. If the stiffness value is very large, stiffness matrix ill-conditioning and divergence occur. On the other hand, an extremely small stiffness value results in compatibility violations. Thus, an optimum value for the contact stiffness that works best, $1 \cdot 10^8\ N/m$, is determined as a result of succesive iterations (see Assumption 3.2).

The bottom plate (plate #1 on page II-1) of the emplacement pallet is supported by three, 12-*in*-wide longitudinal beams (Ref. 10). Displacement constraints are placed on the corresponding locations of the plate.

The mesh of the FER is appropriately generated, and refined in the contact region according to standard engineering practice. Thus, the accuracy and representativeness of the results of this linear calculation are deemed acceptable.

6. RESULTS

In accordance with AP-3.15Q, Revision 1, ICN 0, *Managing Technical Product Inputs*, the following statement is made: "This document and its conclusions may be affected by technical product input information that requires confirmation. Any changes to the document or its conclusions that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database." Note that in accordance with AP-3.12Q, Revision 0, ICN 0, *Calculations*, calculations shall not provide any conclusions.

The results show that the maximum stress intensities among Alloy 22, and 316L SS components are 98 *MPa* (see Reference 8, Attachment V, line # 393), and 22 *MPa* (see Reference 8, Attachment V, line # 398), respectively. These stress intensity magnitudes are less than one-third of the yield strength and one-fifth of the tensile strength for the corresponding materials (see Section 5.2).

The design of the naval WP has been changed (compare p. II-2 with pp. II-3 and II-4) while this document was in check. Since the mass of naval canister and the dimensions of the outer and inner shells remained intact, while the mass of loaded WP assembly is even smaller than in the original design, the calculation results are not affected. Thus, it is not necessary to repeat the calculation.

7. ATTACHMENTS

Attachment I (3 pages): Document Input Reference Sheets

Attachment II (10 pages): Design sketches (Emplacement Pallet [SK-0144 REV 01], Single-CRM Naval SNF Long Waste Package Assembly [SK-0146 REV 00], and Naval SNF Long Waste Package Configuration for Site Recommendation [SK-0194 REV 01, two sheets]), and component masses of the WP

Attachment III (3 pages): Figures obtained from ANSYS V5.4

Attachments IV and V have been moved to Reference 8. The following is the list of electronic files including names, dates, times and sizes available in that reference. Note that these are no longer attachments to this document; they are listed for information only.

Description	Date	Time	Size
Attachment IV: pall3.at4	12/20/1999	11:26 am	348 KB
Attachment V: pall3.at5	12/20/1999	11:28 am	16 KB

Note: the file sizes may vary with operating system.

8. REFERENCES

1. ASTM G 1-90 (Reapproved 1999). 1990. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 238771.

2. CRWMS M&O 1998. *Software Qualification Report for ANSYS V5.4, A Finite Element Code.* CSCI: 30040 V5.4. DI: 30040-2003, REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980609.0847.

3. Haynes International 1997. *Hastelloy C-22 Alloy.* Kokomo, Indiana: Haynes International. TIC: 238121.

4. ASME (American Society of Mechanical Engineers) 1995. "Materials." Section II of *1995 ASME Boiler and Pressure Vessel Code.* New York, New York: American Society of Mechanical Engineers. TIC: 245287.

5. American Society for Metals 1980. *Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals. Volume 3 of Metals Handbook.* 9th Edition. Metals Park, Ohio: American Society for Metals. TIC: 209801.

6. ASTM B 575-97. 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.

7. Doering, T.W. 1998. "Qualification of ANSYS V5.4 on the WPO HP UNIX Workstations." Interoffice correspondence from T.W. Doering (CRWMS M&O) to G. Carlisle, May 22, 1998, LV.WP.SMB.05/98-100. ACC: MOL.19980730.0147.

8. CRWMS M&O 1999. *Electronic Files for Structural Calculation of an Emplacement Pallet Statically Loaded by a Waste Package.* CAL-WER-ME-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991220.0380.

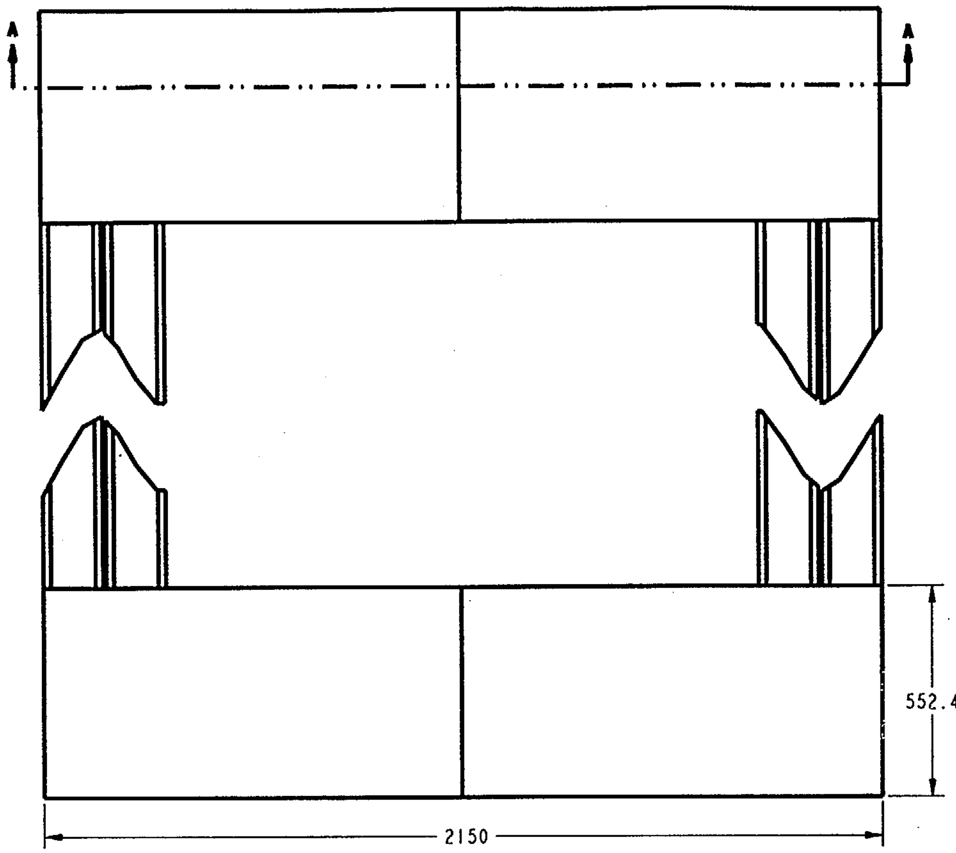
9. ASTM A 240/A 240M-97a. 1997. *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 239431.

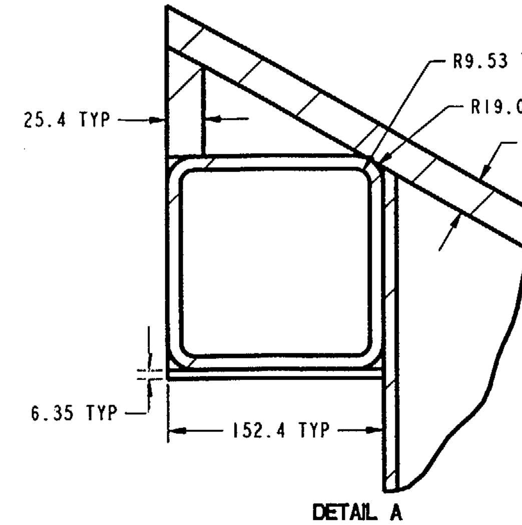
10. CRWMS M&O 2000. *Emplacement Pallet Support.* WP-SSR-99426.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000105.0145.

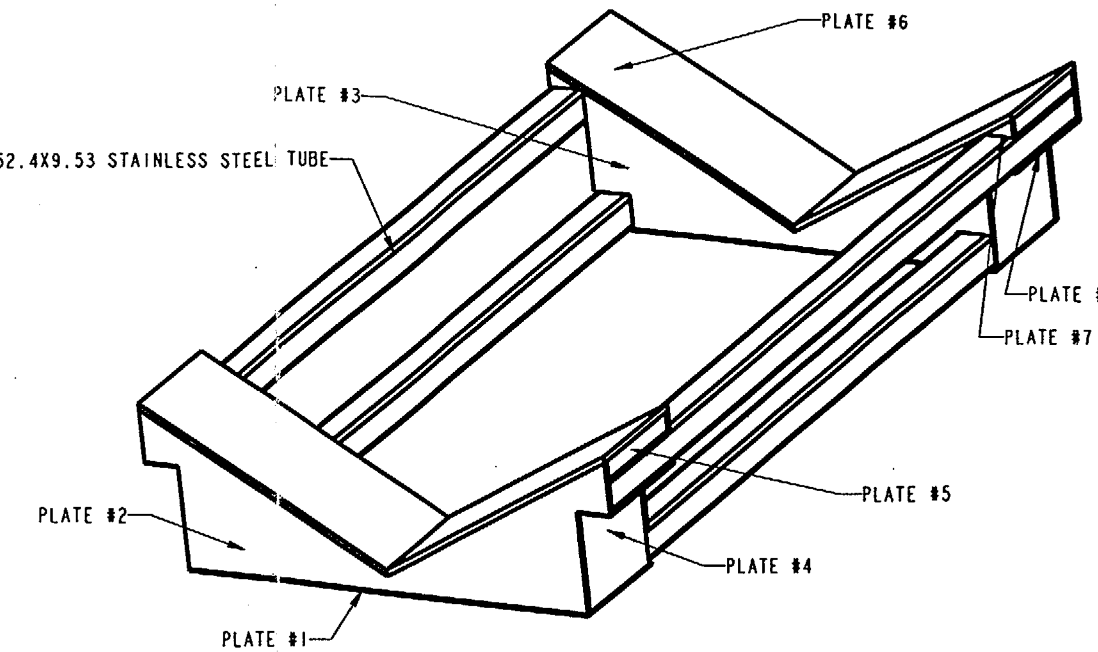
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT **DOCUMENT INPUT REFERENCE SYSTEM**										
1. Document Identifier No./Rev.: CAL-WER-ME-000003 Rev. 00		Change: N/A	Title: STRUCTURAL CALCULATION OF AN EMPLACEMENT PALLETT STATICALLY LOADED BY A WASTE PACKAGE							
Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/ TBD Priority	8. TBVDue To			
2a.	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncon trolled Source	Un-Confirmed
1	ASTM G 1-90 (Reapproved 1999). 1990. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 238771.	Page 7	N/A - Accepted Data (Fact)	5.2	Density of SA-240 S31603	N/A	N/A	N/A	N/A
2	CRWMS M&O 1998. *Software Qualification Report for ANSYS V5.4, A Finite Element Code.* CSCI: 30040 V5.4. DI: 30040-2003, REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980609.0847.	Entire	N/A - Reference Only	4.1	Qualification report for ANSYS V5.4	N/A	N/A	N/A	N/A
3	Haynes International 1997. *Hastelloy C-22 Alloy.* Kokomo, Indiana: Haynes International. TIC: 238121.	Page 14	N/A - Accepted Data (AMOPE approved)	5.2	Modulus of elasticity of SB-575 N06022	N/A	N/A	N/A	N/A
4	ASME (American Society of Mechanical Engineers) 1995. "Materials." Section II of *1995 ASME Boiler and Pressure Vessel Code.* New York, New York: American Society of Mechanical Engineers. TIC: 245287.	Table TM-1	N/A - Accepted Data (Fact)	5.2	Modulus of elasticity of SA-240 S31603	N/A	N/A	N/A	N/A
		Table Y-1	N/A - Accepted Data (Fact)	5.2	Yield strength of SA-240 S31603	N/A	N/A	N/A	N/A
		Table U	N/A - Accepted Data (Fact)	5.2	Tensile strength of SA-240 S31603	N/A	N/A	N/A	N/A

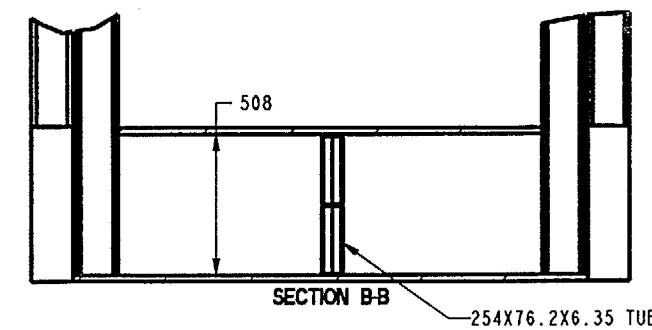
5	American Society for Metals 1980. *Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals.* Volume 3 of *Metals Handbook.* 9th Edition. Metals Park, Ohio: American Society for Metals. TIC: 209801.	Page 143	N/A - Accepted Data (Fact)	3	Chemical composition of Alloy 625	N/A	N/A	N/A	N/A
		Page 143	N/A - Accepted Data (Fact)	5.2	Poisson's ratio of Alloy 625 to be used for SB-575 N06022	N/A	N/A	N/A	N/A
		Figure 15, page 755	N/A - Accepted Data (Fact)	5.2	Poisson's ratio of 316 stainless steel to be used for SA-240 S31603	N/A	N/A	N/A	N/A
6	ASTM B 575-97. 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.	Page 2	N/A - Accepted Data (Fact)	5.2	Density of SB-575 N06022	N/A	N/A	N/A	N/A
		Table 1	N/A - Accepted Data (Fact)	3	Chemical composition of SB-575 N06022	N/A	N/A	N/A	N/A
		Table 3	N/A - Accepted Data (Fact)	5.2	Yield strength of SB-575 N06022	N/A	N/A	N/A	N/A
		Table 3	N/A - Accepted Data (Fact)	5.2	Tensile strength of SB-575 N06022	N/A	N/A	N/A	N/A
7	Doering, T.W. 1998. "Qualification of ANSYS V5.4 on the WPO HP UNIX Workstations." Interoffice correspondence from T.W. Doering (CRWMS M&O) to G. Carlisle, May 22, 1998, LV.WP.SMB.05/98-100. ACC: MOL.19980730.0147.	Entire	N/A - Reference Only	4.1	Qualification of ANSYS V5.4 on HP UNIX workstations	N/A	N/A	N/A	N/A
8	CRWMS M&O 1999. *Electronic Files for Structural Calculation of an Emplacement Pallet Statically Loaded by a Waste Package.* CAL-WER-ME-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991220.0380.	Entire	N/A - Reference Only	6	Stress intensity magnitudes	N/A	N/A	N/A	N/A

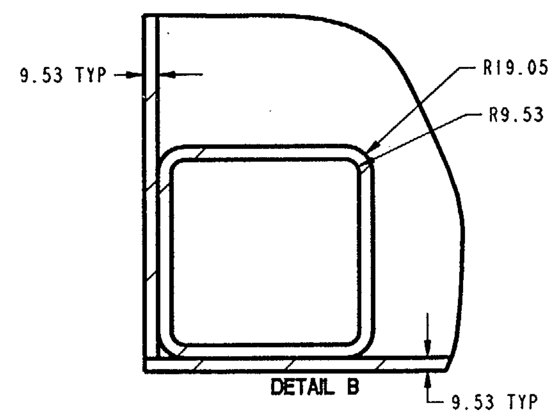
9	ASTM A 240/A 240M-97a. 1997. *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 239431.	Table 1	N/A - Accepted Data (Fact)	3	Chemical compositions of 316 and 316L stainless steels	N/A	N/A	N/A	N/A
10	CRWMS M&O 2000. *Emplacement Pallet Support.* WP-SSR-99426.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000105.0145.	Page 1	TBV -3982	5.3	Number and width of the longitudinal beams supporting the emplacement pallet	1	X	N/A	N/A

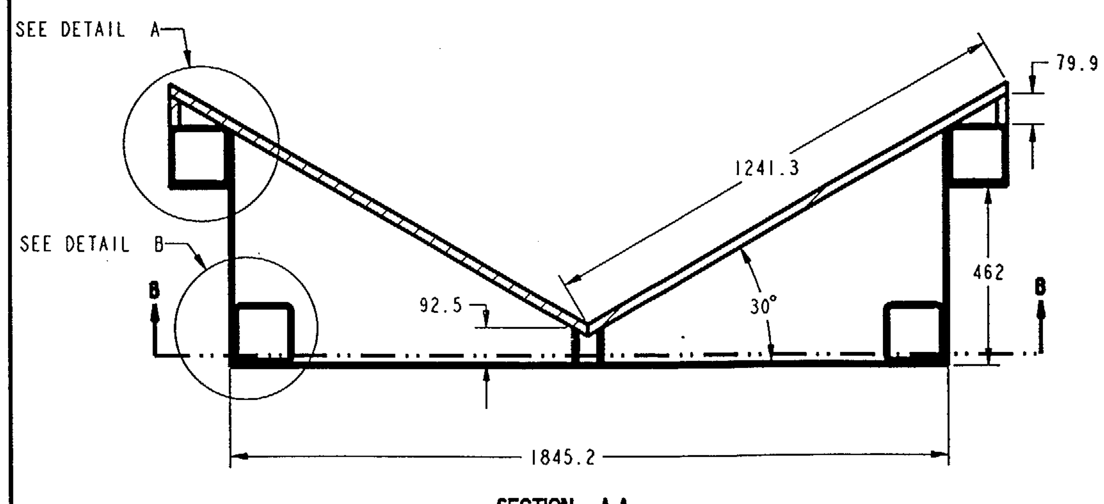


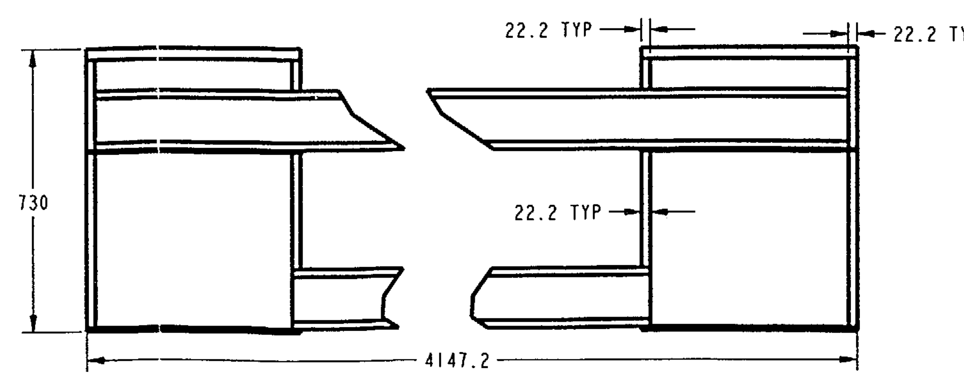












COMPONENT NAME	MATERIAL	THICKNESS	MASS (kg)	QTY REQ
PLATE #1	SB-575 N06022	9.53	84.4	2
PLATE #2	SB-575 N06022	22.2	131	2
PLATE #3	SB-575 N06022	22.2	110	2
PLATE #4	SB-575 N06022	9.53	25.2	4
PLATE #5	SB-575 N06022	25.4	8.14	4
PLATE #6	SB-575 N06022	25.4	151	4
PLATE #7	SB-575 N06022	22.2	1.07	4
PLATE #8	SB-575 N06022	6.35	4.70	4
152.4X152.4X9.53 STAINLESS STEEL TUBE	SA-240 S31603	9.525	171	4
254X76.2X6.35 TUBE	SB-575 N06022	6.35	3.02	4
PALLET ASSEMBLY	--	--	2108	1

"FOR INFORMATION ONLY"

REVISION 01

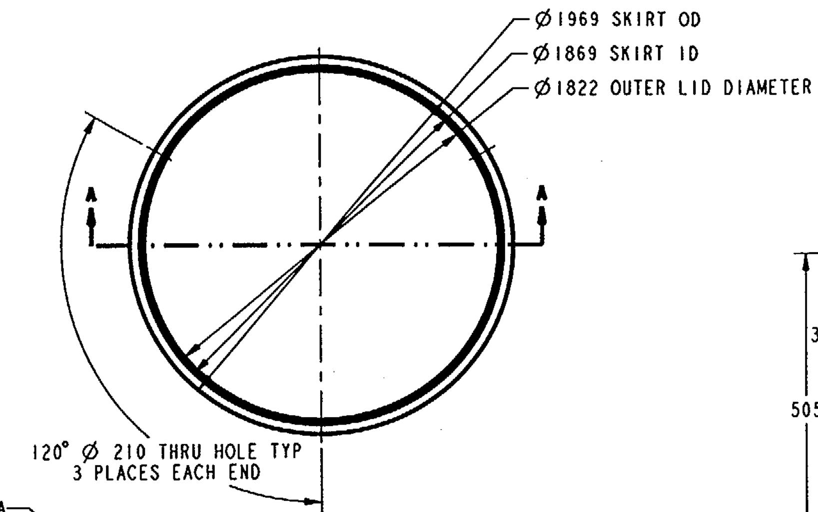
ITEM NUMBER	ITEM
1	PLATE #1 MATERIAL CHANGE TO SB-575 N06022
2	84.4 PLATE #1 MASS WAS 77.5 ON DATA TABLE
3	2108 PALLET MASS WAS 2094 ON DATA TABLE

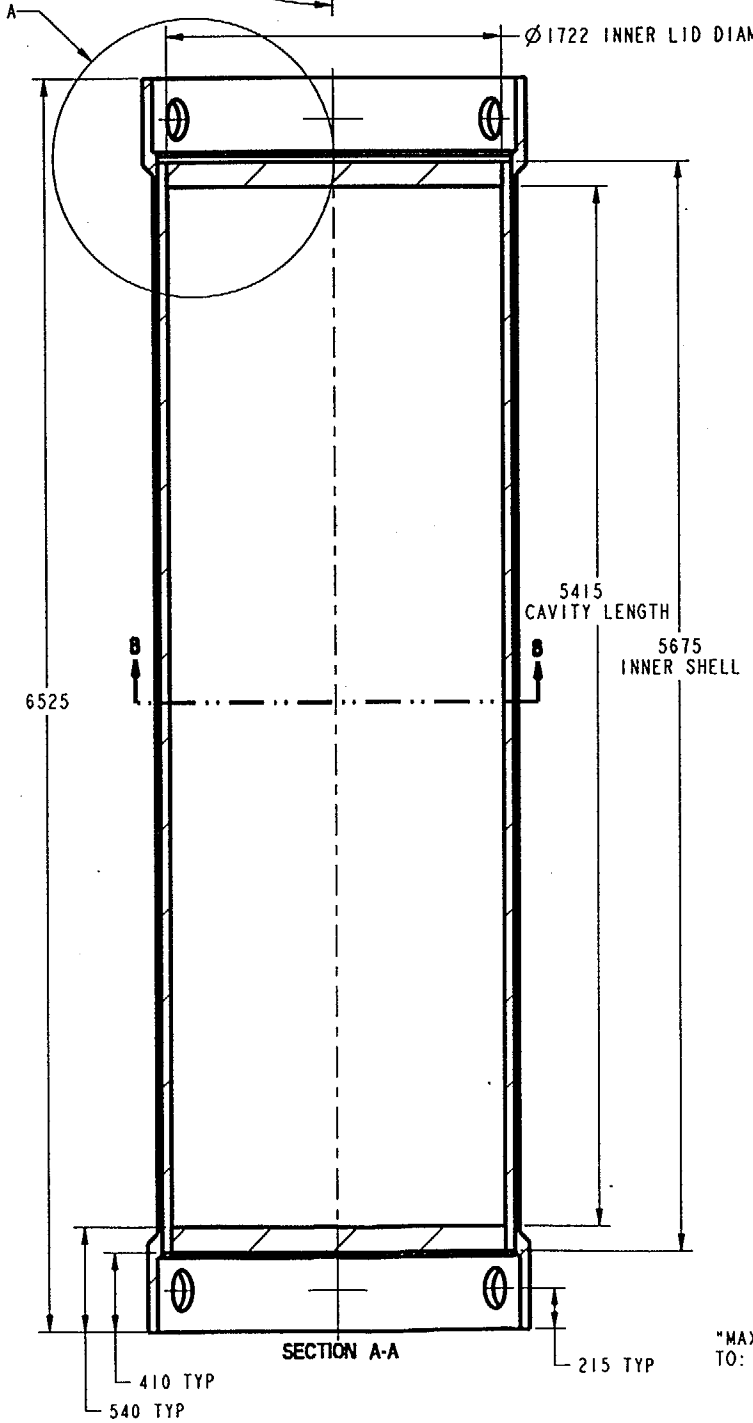
UNITS: mm

DO NOT SCALE FROM SKETCH

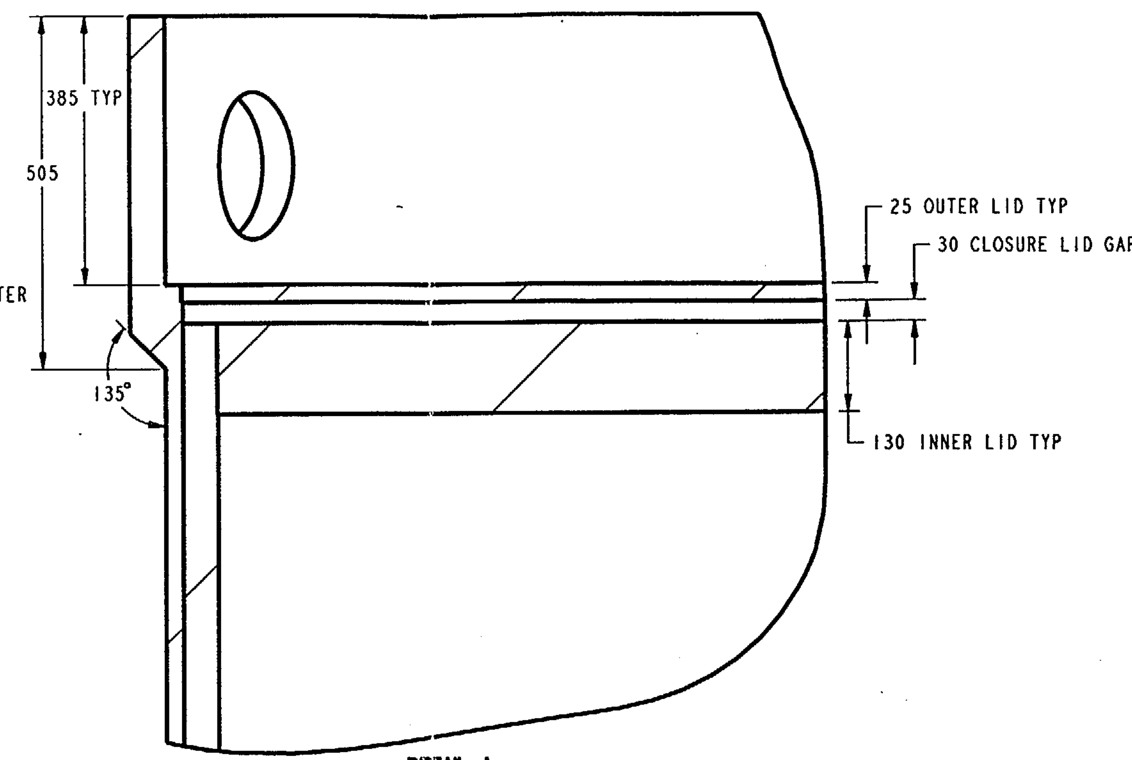
EMPLACEMENT PALLET

SKETCH NUMBER:	SK-0144 REV 01
SKETCHED BY:	ANDREW AILES AA SMB TWD
DATE:	08-12-99 8-13-99 08/16/99 8.18.99
FILE:	/home/ailes/proe/0144/0144rev01.dwg

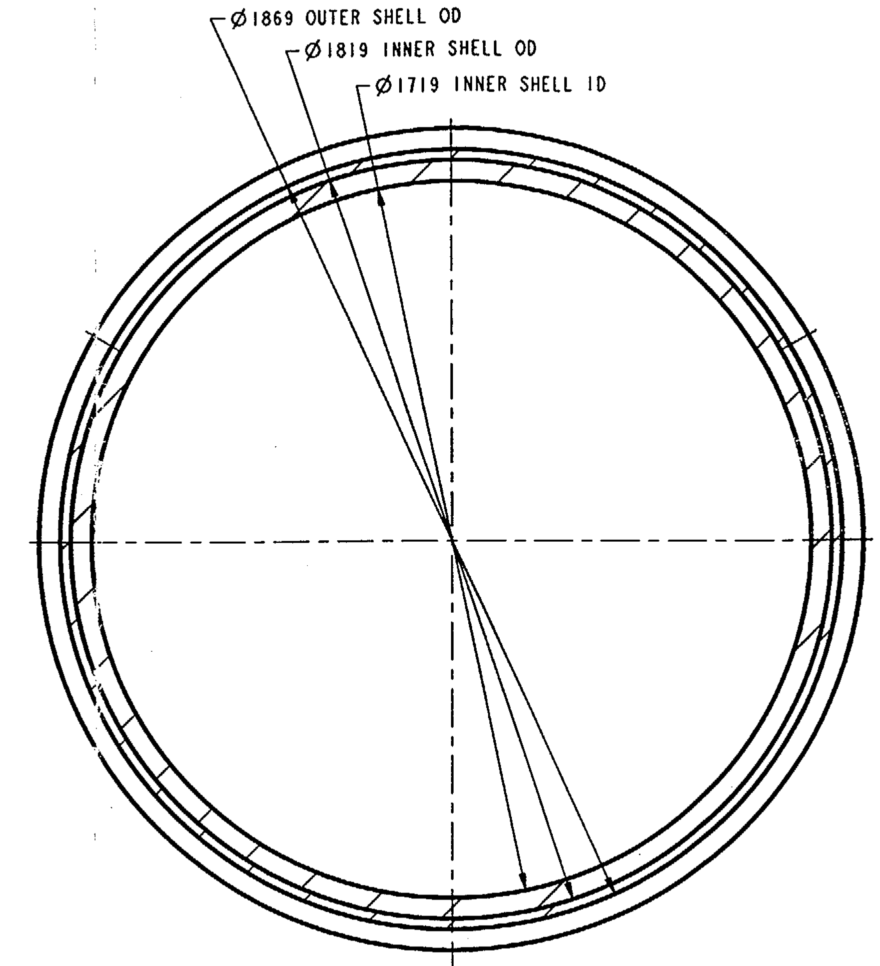




SECTION A-A



DETAIL A



SECTION B-B

COMPONENT NAME	MATERIAL	THICKNESS	MASS (kg)	QTY REQ
INNER SHELL	SA-240 316 NG	50	12567	1
INNER LID	SA-240 316 NG	130	2416	2
OUTER SHELL	SB-575 N06022	25	9659	1
OUTER LID	SB-575 N06022	25	566	2
EMPTY WASTE PACKAGE ASSEMBLY	--	--	28191	1
NAVAL CANISTER	--	--	44452*	1
LOADED WASTE PACKAGE ASSEMBLY	--	--	72643	1

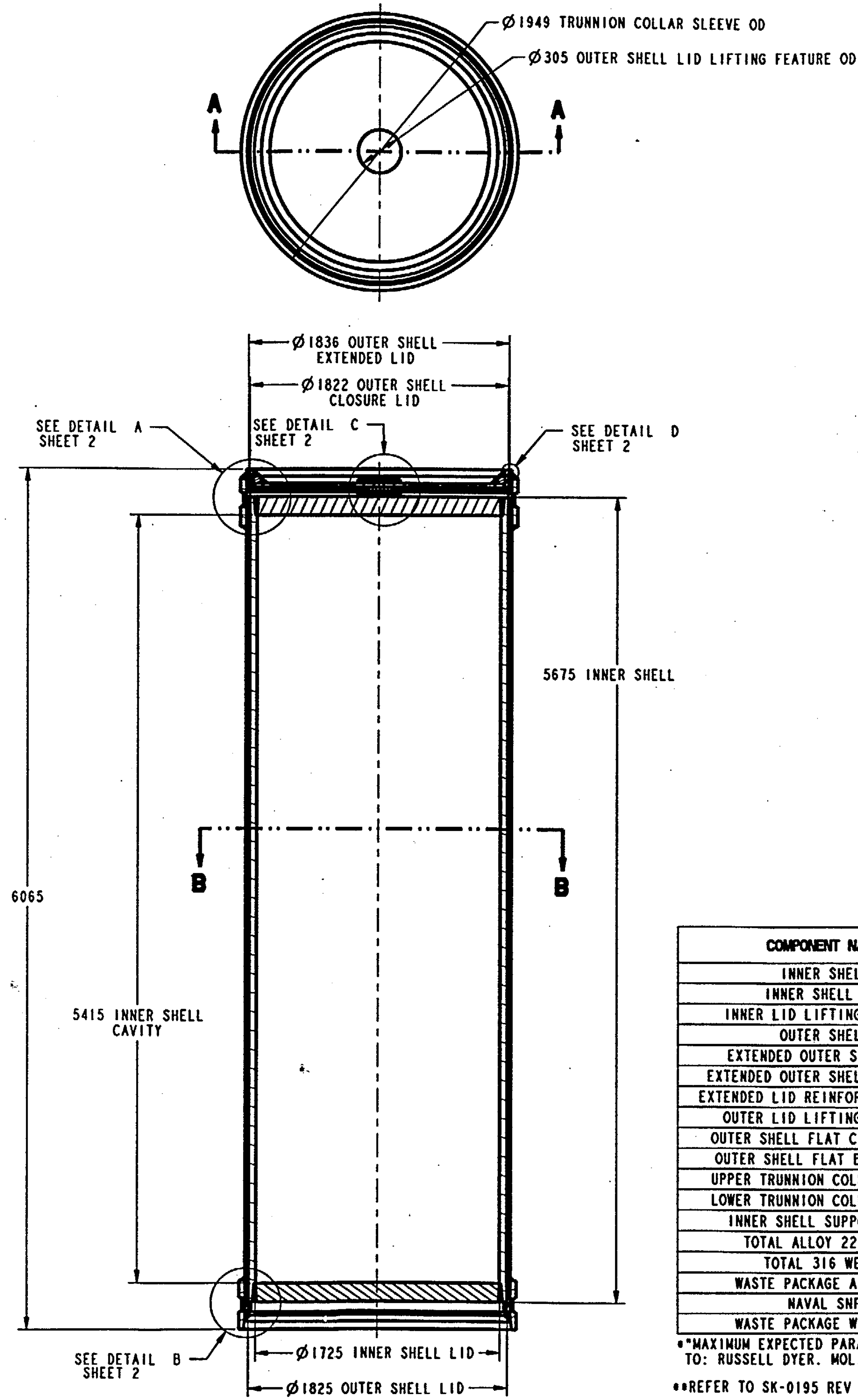
*MAXIMUM EXPECTED PARAMETERS FOR NAVAL REACTORS CANISTERS" 10/29/97 FROM: RICHARD GUIDA
TO: RUSSELL DYER. MOL.19980121.0011

"FOR INFORMATION ONLY"

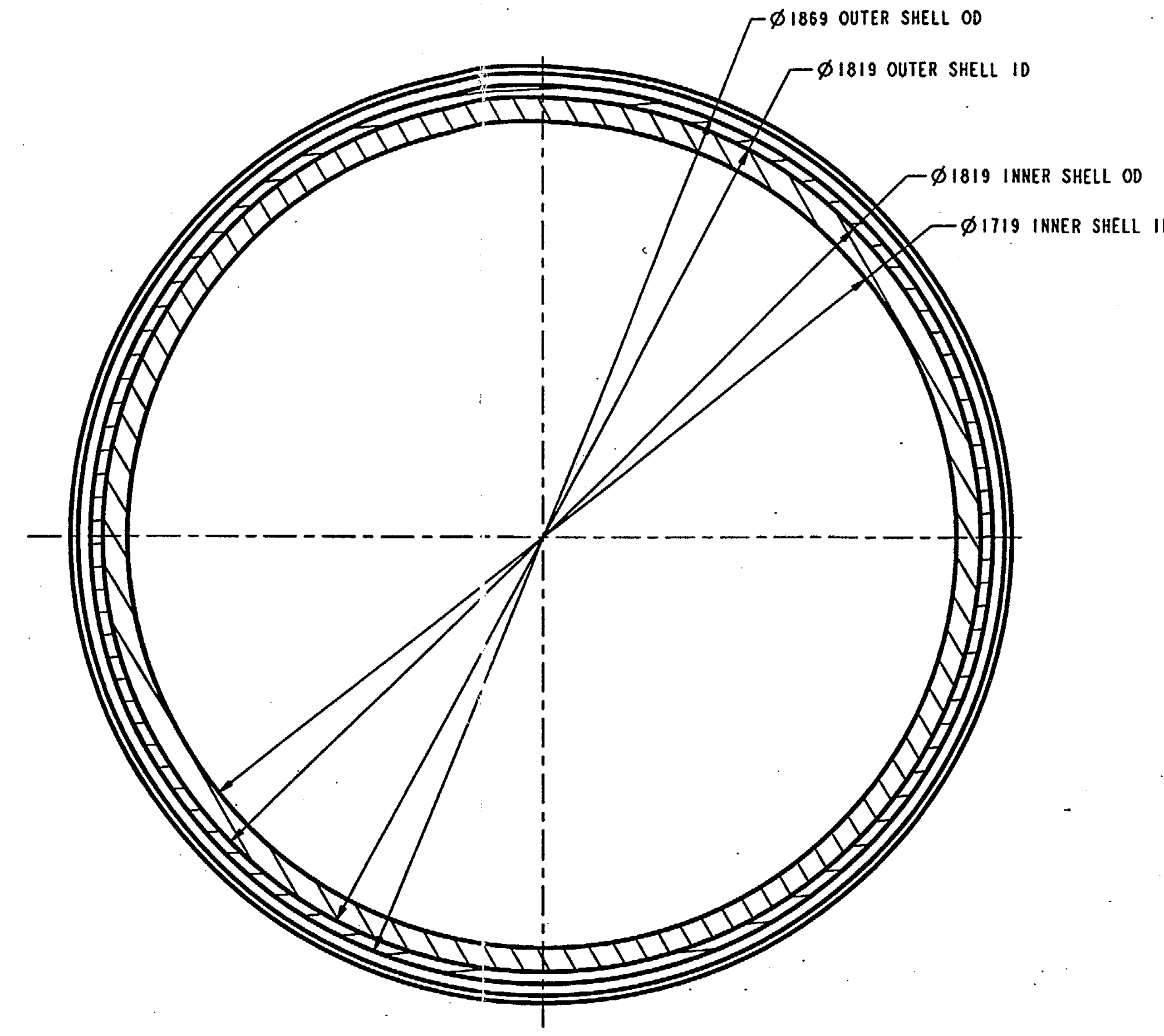
SINGLE CRM NAVAL SNF LONG WASTE PACKAGE ASSEMBLY

SKETCH NUMBER:	SK-0146 REV 00
SKETCHED BY:	ANDREW AILES AA SMB TWD
DATE:	08-10-99 08-19-99 08/19/99 8.19.99
FILE:	home/ailes/proe/0146/0146rev00.dwg

DO NOT SCALE FROM SKETCH UNITS: mm



SECTION A-A



SECTION B-B

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY RQD
INNER SHELL	SA-240 S31600	50	12372	1
INNER SHELL LID	SA-240 S31600	130	2390	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	25	7430	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	158	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	528	1
EXTENDED LID REINFORCEMENT RING	SB-575 N06022	50	118	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	227	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	564	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	604	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	592	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	49	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	298	**
TOTAL 316 WELDS	SFA-5.9 S31680	-	243	**
WASTE PACKAGE ASSEMBLY	-	-	28005	1
NAVAL SNF	-	-	44452*	1
WASTE PACKAGE WITH SNF	-	-	72457	1

*"MAXIMUM EXPECTED PARAMETERS FOR NAVAL REACTORS CANISTERS" 10/29/97 FROM: RICHARD GUIDA TO: RUSSELL DYER. MOL.19980121.0011

**REFER TO SK-0195 REV 00 "NAVAL SNF LONG WASTE PACKAGE WELD CONFIGURATION"

UNITS: mm

DO NOT SCALE FROM SKETCH

"FOR INFORMATION ONLY"

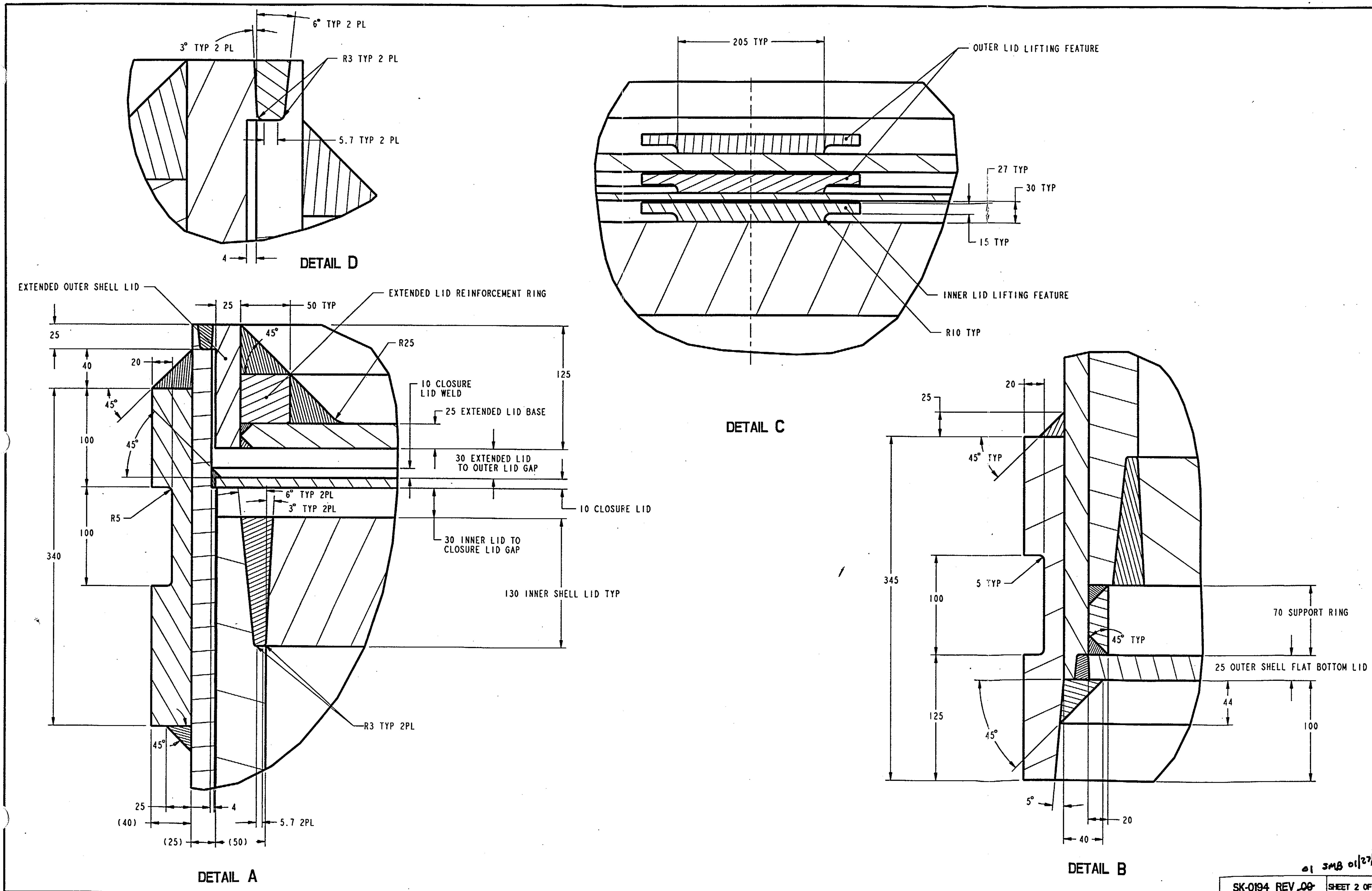
NAVAL SNF LONG WASTE PACKAGE CONFIGURATION FOR SITE RECOMMENDATION

SKETCH NUMBER: SK-0194 REV 01 — SHEET 1 OF 2

SKETCHED BY: GENE CONNELL *29C 01/26/00* *SMB 01/26/00* *JAC 1/26/00*

DATE: 01/11/00 *TOP 1/26/00*

FILE: /home/pro_library/checkout/sketches/naval/naval snf long/SK-0194.dwg


6° TYP 2 PL
3° TYP 2 PL
R3 TYP 2 PL
5.7 TYP 2 PL
4
DETAIL D
205 TYP
OUTER LID LIFTING FEATURE
27 TYP
30 TYP
15 TYP
INNER LID LIFTING FEATURE
R10 TYP
DETAIL C
EXTENDED OUTER SHELL LID
25
50 TYP
EXTENDED LID REINFORCEMENT RING
45°
R25
125
40
20
10 CLOSURE LID WELD
25 EXTENDED LID BASE
30 EXTENDED LID TO OUTER LID GAP
6° TYP 2PL
3° TYP 2PL
10 CLOSURE LID
30 INNER LID TO CLOSURE LID GAP
130 INNER SHELL LID TYP
100
R5
340
R3 TYP 2PL
25
(40)
(25)
(50)
5.7 2PL
DETAIL A
45° TYP
5 TYP
345
70 SUPPORT RING
45° TYP
25 OUTER SHELL FLAT BOTTOM LID
44
125
5°
40
DETAIL B
01 SMB 01/27/00
SK-0194 REV 00
SHEET 2 OF 2

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
                    MASS PROPERTIES OF THE PART INNER_LID

                       VOLUME =  3.0276072e+08 MM^3
                 SURFACE AREA =  5.3611341e+06 MM^2
                      DENSITY =  7.9800000e-06 KILOGRAM / MM^3
                         MASS =  2.4160305e+03 KILOGRAM

         CENTER OF GRAVITY with respect to _INNER_LID coordinate frame:
X   Y   Z           0.0000000e+00  0.0000000e+00  6.5000000e+01  MM

     INERTIA with respect to _INNER_LID coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz         4.6145517e+08 -2.5028263e+05  0.0000000e+00
Iyx Iyy Iyz        -2.5028263e+05  4.6129253e+08  0.0000000e+00
Izx Izy Izz         0.0000000e+00  0.0000000e+00  8.9552709e+08

    INERTIA at CENTER OF GRAVITY with respect to _INNER_LID coordinate frame:
                                                          (KILOGRAM * MM^2)
INERTIA TENSOR:
Ixx Ixy Ixz         4.5124744e+08 -2.5028263e+05  0.0000000e+00
Iyx Iyy Iyz        -2.5028263e+05  4.5108480e+08  0.0000000e+00
Izx Izy Izz         0.0000000e+00  0.0000000e+00  8.9552709e+08

                PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3          4.5090296e+08  4.5142928e+08  8.9552709e+08

         ROTATION MATRIX from _INNER_LID orientation to PRINCIPAL AXES:
                       0.58779       -0.80902        0.00000
                       0.80902        0.58779        0.00000
                       0.00000        0.00000        1.00000

    ROTATION ANGLES from _INNER_LID orientation to PRINCIPAL AXES (degrees):
angles about x  y  z    0.000          0.000          54.000

                RADII OF GYRATION with respect to PRINCIPAL AXES:
R1  R2  R3          4.3200655e+02  4.3225861e+02  6.0881894e+02  MM
```

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
                    MASS PROPERTIES OF THE PART INNER_SHELL

                          VOLUME =  1.5748262e+09 MM^3
                    SURFACE AREA =  6.3635567e+07 MM^2
                         DENSITY =  7.9800000e-06 KILOGRAM / MM^3
                            MASS =  1.2567113e+04 KILOGRAM

        CENTER OF GRAVITY with respect to _INNER_SHELL coordinate frame:
X   Y   Z              0.0000000e+00  0.0000000e+00  0.0000000e+00  MM

    INERTIA with respect to _INNER_SHELL coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz            3.8564524e+10 -3.2507501e+06  0.0000000e+00
Iyx Iyy Iyz           -3.2507501e+06  3.8562736e+10  0.0000000e+00
Izx Izy Izz            0.0000000e+00  0.0000000e+00  9.8403352e+09

   INERTIA at CENTER OF GRAVITY with respect to _INNER_SHELL coordinate frame:
                                                               (KILOGRAM * MM^2)
INERTIA TENSOR:
Ixx Ixy Ixz            3.8564524e+10 -3.2507501e+06  0.0000000e+00
Iyx Iyy Iyz           -3.2507501e+06  3.8562736e+10  0.0000000e+00
Izx Izy Izz            0.0000000e+00  0.0000000e+00  9.8403352e+09

                PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3             9.8403352e+09  3.8560259e+10  3.8567001e+10

        ROTATION MATRIX from _INNER_SHELL orientation to PRINCIPAL AXES:
                          0.00000        0.60620        -0.79532
                          0.00000        0.79532         0.60620
                          1.00000        0.00000         0.00000

   ROTATION ANGLES from _INNER_SHELL orientation to PRINCIPAL AXES (degrees):
angles about x  y  z  -90.000         -52.685         -90.000

                RADII OF GYRATION with respect to PRINCIPAL AXES:
R1  R2  R3             8.8488571e+02  1.7516696e+03  1.7518228e+03  MM
```

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
                    MASS PROPERTIES OF THE ASSEMBLY NAVAL_LONG

                          VOLUME =  3.4221767e+09 MM^3
                    SURFACE AREA =  1.6202106e+08 MM^2
                 AVERAGE DENSITY =  8.2376426e-06 KILOGRAM / MM^3
                            MASS =  2.8190669e+04 KILOGRAM

          CENTER OF GRAVITY with respect to _NAVAL_LONG coordinate frame:
X   Y   Z            0.0000000e+00  0.0000000e+00  5.7420570e+00  MM

    INERTIA with respect to _NAVAL_LONG coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz          1.3243569e+11 -4.6462571e+06  0.0000000e+00
Iyx Iyy Iyz         -4.6462571e+06  1.3243451e+11  0.0000000e+00
Izx Izy Izz          0.0000000e+00  0.0000000e+00  2.0483839e+10

   INERTIA at CENTER OF GRAVITY with respect to _NAVAL_LONG coordinate frame:
                                                              (KILOGRAM * MM^2)
INERTIA TENSOR:
Ixx Ixy Ixz          1.3243476e+11 -4.6462571e+06  0.0000000e+00
Iyx Iyy Iyz         -4.6462571e+06  1.3243358e+11  0.0000000e+00
Izx Izy Izz          0.0000000e+00  0.0000000e+00  2.0483839e+10

                PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3           2.0483839e+10  1.3242949e+11  1.3243885e+11

          ROTATION MATRIX from _NAVAL_LONG orientation to PRINCIPAL AXES:
                        0.00000         0.66075        -0.75061
                        0.00000         0.75061         0.66075
                        1.00000         0.00000         0.00000

    ROTATION ANGLES from _NAVAL_LONG orientation to PRINCIPAL AXES (degrees):
angles about x  y  z  -90.000          -48.643          -90.000

                RADII OF GYRATION with respect to PRINCIPAL AXES:
R1  R2  R3           8.5241873e+02  2.1674029e+03  2.1674796e+03  MM


                 MASS PROPERTIES OF COMPONENTS OF THE ASSEMBLY
             (in assembly units and the _NAVAL_LONG coordinate frame)

                                            MATERIAL
          DENSITY          MASS             C.G.:  X          Y          Z

    INNER_SHELL                             UNKNOWN
        7.98000e-06   1.25671e+04   3.10054e-13  3.11056e-13 -1.08519e-12
    INNER_LID                               UNKNOWN
        7.98000e-06   2.41603e+03   2.51994e-14 -7.69656e-14  2.77250e+03
    INNER_LID                               UNKNOWN
        7.98000e-06   2.41603e+03  -2.51994e-14 -7.69656e-14 -2.77250e+03
    OUTER_SHELL                             UNKNOWN
```

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
        8.69000e-06  9.65863e+03  6.75243e-06  6.85904e-05  1.50000e+01
OUTER_LID                           UNKNOWN
        8.69000e-06  5.66430e+02  0.00000e+00 -8.23591e-14 -2.85000e+03
OUTER_LID                           UNKNOWN
        8.69000e-06  5.66430e+02  0.00000e+00 -8.23591e-14  2.88000e+03
```

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
                    MASS PROPERTIES OF THE PART OUTER_LID

                         VOLUME =  6.5181843e+07 MM^3
                   SURFACE AREA =  5.3576470e+06 MM^2
                        DENSITY =  8.6900000e-06 KILOGRAM / MM^3
                           MASS =  5.6643021e+02 KILOGRAM

          CENTER OF GRAVITY with respect to _OUTER_LID coordinate frame:
X   Y   Z            0.0000000e+00  0.0000000e+00  1.2500000e+01  MM

     INERTIA with respect to _OUTER_LID coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz          1.1764096e+08  3.8227103e+02  0.0000000e+00
Iyx Iyy Iyz          3.8227103e+02  1.1764121e+08  0.0000000e+00
Izx Izy Izz          0.0000000e+00  0.0000000e+00  2.3504617e+08

    INERTIA at CENTER OF GRAVITY with respect to _OUTER_LID coordinate frame:
                                                           (KILOGRAM * MM^2)
INERTIA TENSOR:
Ixx Ixy Ixz          1.1755246e+08  3.8227103e+02  0.0000000e+00
Iyx Iyy Iyz          3.8227103e+02  1.1755271e+08  0.0000000e+00
Izx Izy Izz          0.0000000e+00  0.0000000e+00  2.3504617e+08

                PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3           1.1755218e+08  1.1755299e+08  2.3504617e+08

          ROTATION MATRIX from _OUTER_LID orientation to PRINCIPAL AXES:
                        1.00000        0.00000        0.00000
                        0.00000        1.00000        0.00000
                        0.00000        0.00000        1.00000

    ROTATION ANGLES from _OUTER_LID orientation to PRINCIPAL AXES (degrees):
angles about x  y  z    0.000          0.000          0.000

                RADII OF GYRATION with respect to PRINCIPAL AXES:
R1  R2  R3           4.5555639e+02  4.5555795e+02  6.4417428e+02  MM
```

Mass Properties of Single-CRM Naval SNF Long Waste Package

```
                    MASS PROPERTIES OF THE PART OUTER_SHELL

                        VOLUME = 1.1114654e+09 MM^3
                  SURFACE AREA = 7.6947936e+07 MM^2
                       DENSITY = 8.6900000e-06 KILOGRAM / MM^3
                          MASS = 9.6586344e+03 KILOGRAM

        CENTER OF GRAVITY with respect to _OUTER_SHELL coordinate frame:
X   Y   Z            0.0000000e+00  0.0000000e+00  0.0000000e+00  MM

    INERTIA with respect to _OUTER_SHELL coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz          8.3823571e+09  0.0000000e+00 -7.8337586e+04
Iyx Iyy Iyz          0.0000000e+00  4.6289494e+10  1.3955071e+06
Izx Izy Izz         -7.8337586e+04  1.3955071e+06  4.6290418e+10

   INERTIA at CENTER OF GRAVITY with respect to _OUTER_SHELL coordinate frame:
                                                        (KILOGRAM * MM^2)
INERTIA TENSOR:
Ixx Ixy Ixz          8.3823571e+09  0.0000000e+00 -7.8337586e+04
Iyx Iyy Iyz          0.0000000e+00  4.6289494e+10  1.3955071e+06
Izx Izy Izz         -7.8337586e+04  1.3955071e+06  4.6290418e+10

                PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3           8.3823571e+09  4.6288486e+10  4.6291426e+10

        ROTATION MATRIX from _OUTER_SHELL orientation to PRINCIPAL AXES:
                          1.00000        0.00000        0.00000
                          0.00000        0.81063        0.58556
                          0.00000       -0.58556        0.81063

   ROTATION ANGLES from _OUTER_SHELL orientation to PRINCIPAL AXES (degrees):
angles about x  y  z  -35.843          0.000          0.000

                RADII OF GYRATION with respect to PRINCIPAL AXES:
R1  R2  R3           9.3159086e+02  2.1891656e+03  2.1892352e+03  MM
```

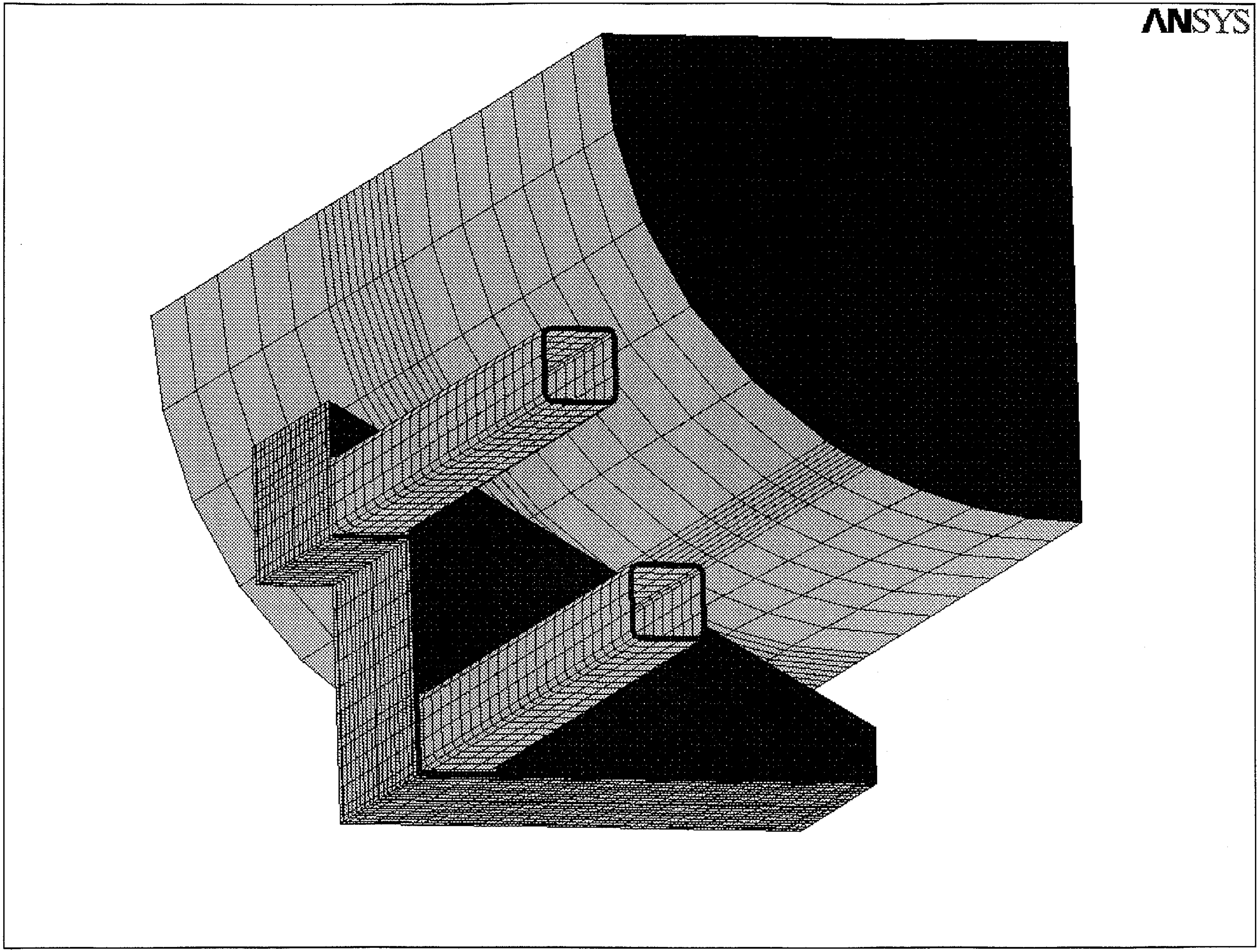


Figure III-1. Finite Element Representation of the Loaded Emplacement Pallet

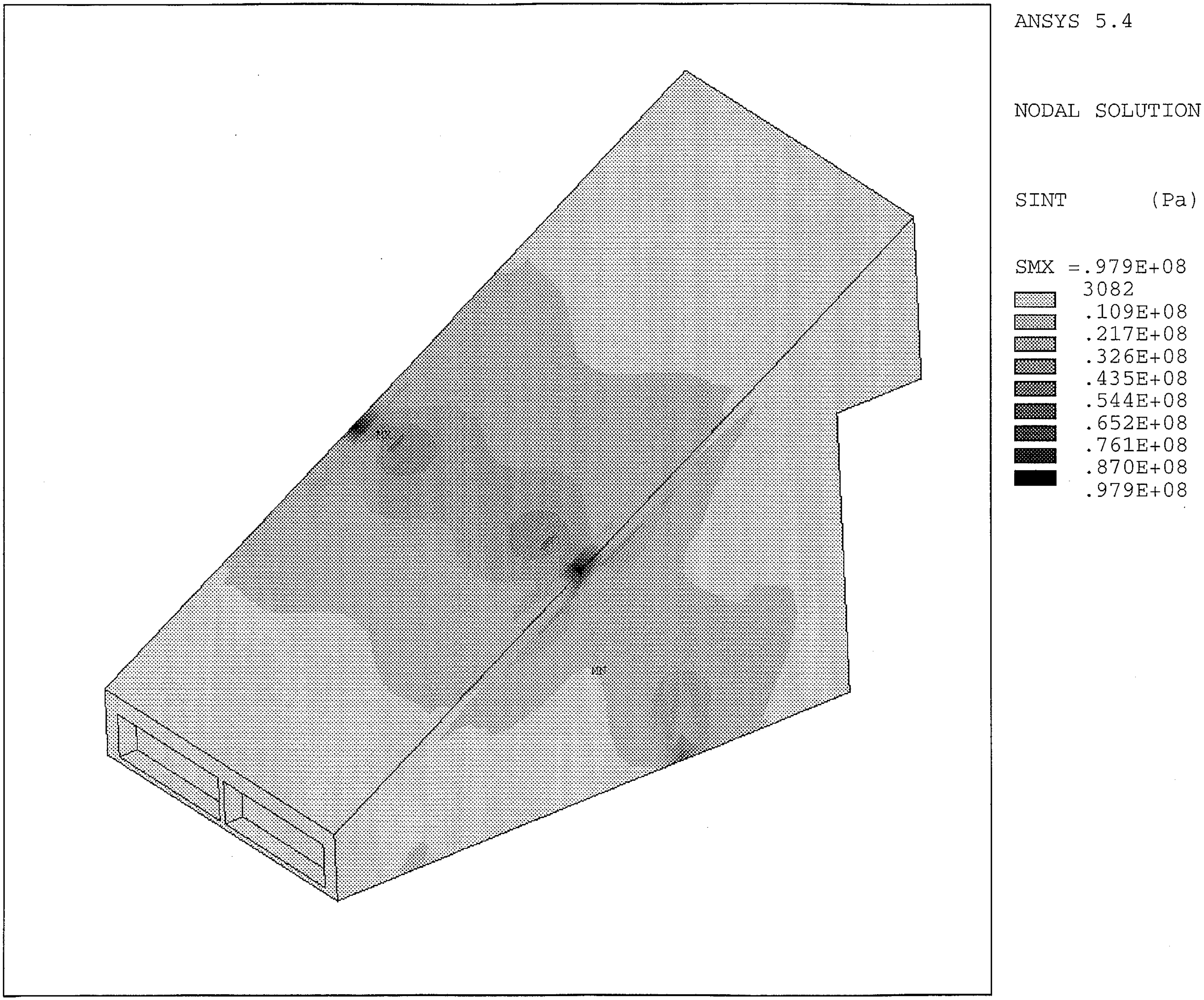


Figure III-2. Stress Intensity Plot for the Alloy 22 Components of the Emplacement Pallet

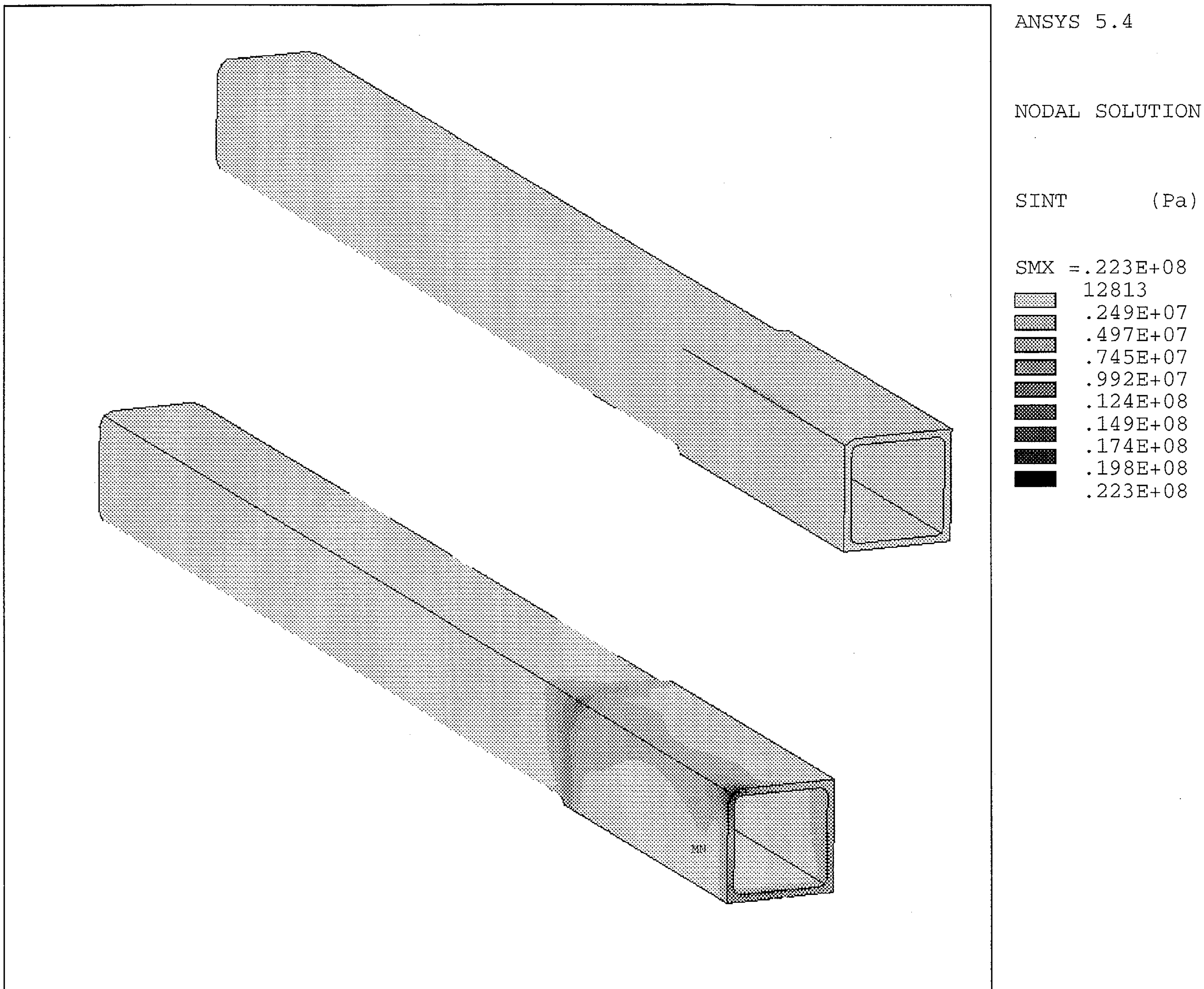


Figure III-3. Stress Intensity Plot for the 316L SS Components of the Emplacement Pallet