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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: QA

2. Calculation Title
Rock Fall on Drip Shield

3. Document Identifier (including Revision Number)
CAL-EDS-ME-000001 REV 00

4. Total Attachments	5. Attachment Numbers - Number of pages in each
3	I-4, II-2, III-19

	Print Name	Signature	Date
6. Originator	Zekai Ceylan	Zekai Ceylan	4/24/00
7. Checker	Sreten Mastilovic	[signature]	04/24/2000
8. Lead	Scott M. Bennett	Scott M. Bennett	04/27/00

9. Remarks

FOR INFORMATION ONLY

Revision History

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

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CONTENTS

1. PURPOSE

The objective of this activity is to determine the structural performance of the drip shield under a rock fall design basis event. The scope of this activity is limited to determining whether or not the drip shield fails when subjected to rock fall events for the following rock masses: 2 Metric Tons (MT), 4 MT, 6 MT, 8 MT, and 52 MT. The stress concentration effects due to rock edge contacting the drip shield is outside the scope of this calculation. When the rock mechanical/physical properties become available and the rock failure is implemented into the rock fall simulation, the stress concentration effects of the rock with different rock orientations can be addressed. The failure of the drip shield is defined as the condition when the strain in the drip shield exceeds the failure strain (ductility), which results in rupturing of the material. This activity will also determine the number of potential cracks and crack sizes due to stress corrosion cracking. This activity is associated with the drip shield design. AP-3.12Q, Revision 0, ICN 0, *Calculations*, is used to develop and document the calculation.

Referencing in this calculation refers to the input document numbers appearing in column 2a of the Document Input Reference System sheet, Attachment I hereto.

2. METHOD

Finite element solution was performed by making use of the commercially available ANSYS version (V) 5.4 and LS-DYNA finite element codes. The results of this calculation were reported by determining failure of drip shield structural components based on their specific failure strains. The result of maximum displacement for a bounding rock size is also reported in this calculation.

3. ASSUMPTIONS

In the course of developing this document, assumptions were made regarding the drip shield structural calculations. These are identified below.

3.1 Drip shield bottom surface is assumed to be fixed to the ground. The finite element representation (FER) of the drip shield is developed so that the drip shield side wall bottom surfaces do not translate in any direction. The basis for this assumption is that the stress on the drip shield will be larger compared to the case of no constraints at the bottom surface. This assumption provides bounding results in terms of stresses in the drip shield due to rock fall. This assumption is used in Section 5.2.

3.2 No failure condition is assumed for the rock. The FER does not include any failure strain value for the rock, which would have been used to simulate the breaking of the rock under impact loads. The basis for this assumption is to obtain bounding stress results for the drip shield subjected to the rock fall design basis event. This assumption is used in Section 5.2.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE (QA) WORK

One of the two finite element analysis computer codes used for this calculation is ANSYS V5.4, which 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 for the drip shield. The calculations using the ANSYS V5.4 software were executed on Hewlett-Packard (HP) workstations. The software qualification of the ANSYS V5.4 software, including problems of the type analyzed in this report, is summarized in the Software Qualification Report for ANSYS V5.4 (Ref. 1). Qualification of ANSYS V5.4 on the Waste Package Operations HP UNIX workstations is documented in References 2, 3, and 4. The ANSYS V5.4 evaluations performed in this document are fully within the range of the validation performed for the ANSYS V5.4 code.

The second finite element analysis computer code used for this calculation is Livermore Software Technology Corporation (LSTC) LS-DYNA version 940, which is an unqualified software (see Ref. 16). The interim use of LS-DYNA version 940 (SAN: LV-2000-095, STN: 10291-940-00) in support of the site recommendation is delineated in *Software Management*, AP-SI.1Q, Revision 2, ICN 4, Section 5.11. LS-DYNA version 940 qualification is being performed as part of the qualification of ANSYS V5.6 since LS-DYNA version 940 is available both as a component (module) of ANSYS and as a separate finite element code. Currently, Waste Package Department licensed LS-DYNA version 940 directly from LSTC. Software Activity Plan (SAP) for ANSYS V5.6, SDN: 10145-SAP-5.6-00, SAN: LV-1999-124, identifies the intended use of LS-DYNA version 940 prior to qualification. LS-DYNA version 940 was obtained from the Configuration Management. LS-DYNA version 940 is appropriate for its intended use. LS-DYNA version 940 validation will be performed in accordance with AP-SI.1Q, Revision 2, ICN 4, Section 5.11. The calculations were executed on a Hewlett-Packard (HP) 9000 series workstation (CRWMS M&O tag #115288).

4.2 SOFTWARE ROUTINES

None used.

4.3 MODELS

None used.

5. CALCULATION

5.1 CALCULATION DATA

Ti-7 (Titanium Grade 7) (SB-265 R52400, drip shield plate material, see Attachment II):

- Modulus of elasticity = 107 GPa (15.5 * 10^6 psi at 20 °C [Ref. 5])
- Density = 4512 kg/m^3 (0.163 lb/in^3 [Ref. 5])
- Poisson's ratio = 0.34 at 20 °C (Ref. 6)
- Yield strength = 276 MPa (40 ksi at 20 °C [Ref. 5])
- Ultimate tensile strength = 345 MPa (50 ksi at 20 °C [Ref. 5])
- Elongation = 0.2 at 20 °C (Ref. 7)

Ti-24 (SB-265 R56405, drip shield stiffener [bulkhead] material, see Attachment II) (note that the first three material properties of Ti-24 given below are specified using the nominal composition, 6Al-4V, in Ref. 6):

- Modulus of elasticity = 113.8 GPa at 20 °C (Ref. 6)
- Density = 4430 kg/m^3 (Ref. 6)
- Poisson's ratio = 0.342 at 20 °C (Ref. 6)
- Yield strength = 828 MPa at 20 °C (Ref. 7)
- Ultimate tensile strength = 895 MPa at 20 °C (Ref. 7)
- Elongation = 0.1 at 20 °C (Ref. 7)

Rock block (Topopah Spring Welded-Lithophysal Poor [TSw2]):

- Modulus of elasticity = 36.8 GPa at 20 °C (Ref. 8)
- Density = 2370 kg/m^3 (Ref. 8)
- Poisson's ratio = 0.21 at 20 °C (Ref. 8)

Emplacement drift diameter = 5.5 m (Ref. 9)

Drift invert allowance = 1.115 m (Ref. 10)

Crane rail height = 0.146 m (Ref. 11)

W shape depth = 0.229 m (9 in., Ref. 11 and Ref. 14)

Plate thickness = 0.019 m (3/4 in., Ref. 11)

5.2 TECHNICAL APPROACH

Three different drip shield rock fall FERs are developed using ANSYS V5.4. These FERs are, then, used in LS-DYNA version 940, in order to perform a transient dynamic analysis of rock fall onto drip shield. The geometries of the first group FERs (2 MT, 4 MT, 6 MT, 8 MT, and 52 MT) are based on the rock shape and dimensions obtained from the Subsurface Facilities Department (SFD) (Ref. 12) and the drip shield design illustrated in Attachment II. All rock sizes and geometries described in the input transmittal from SFD depict the rock center-of-gravity location at an angle of 45 degrees from vertical. However, the FER for the first group is developed to include a conservative orientation for the rock by repositioning the rock directly above the drip shield, thereby allowing the maximum linear momentum and energy transfer from the rock onto the drip shield (see Figures III-1, III-4, and III-6). A second conservatism was implemented by specifying no failure for the rock during impact simulation (Assumption 3.2). This conservatism will be re-evaluated in future studies as more information and test data become available for the physical/mechanical properties of the rock.

If the rock edge causes localized bending of the drip shield, the pointed edge of the rock is anticipated to fail before the drip shield since the drip shield material strength is significantly higher than that of the rock. Therefore, any stress concentration due to rock edge contacting the drip shield would result in partial failure of the rock. This evaluation, which includes a rock with no failure criterion impacting a drip shield, would have resulted in overly conservative, unrealistic solution for the rock edge effects. When the rock failure is implemented into the rock fall simulation in future studies, the stress concentration effects of the rock with different rock orientations will be addressed.

A second type of evaluation is also performed to determine the drip shield response to rock fall on one side of the drip shield. Figure III-14 shows the FER developed for this purpose. The rock is released from its initial position subject to gravitational acceleration. A rigid shell is used for simulating the emplacement drift wall. The rock first impacts the drift wall, then tips over to the drip shield. The simulation is continued until the rock bounces off the drip shield and the maximum stresses are obtained (see Figure III-15).

The third type of evaluation investigates the effect of change in the drip shield side wall height. This height is increased by 200 mm and the resulting maximum displacement is obtained. The maximum

displacement result (see Figure III-16) can be used to modify the drip shield design to prevent the drip shield from contacting the waste package in case of excessive deformation due to rock fall.

Drip shield bottom surface is assumed to be fixed to the ground (Assumption 3.1). The effect of no constraint at the drip shield bottom surface will be evaluated in future studies.

In the first FER type mentioned above, having positioned the rock block just above the drip shield with an initial velocity obtained from the relation between the kinetic energy and the potential energy, dynamic impact simulation is continued until the rock begins to rebound, at which time the stress peaks and the maximum displacements are obtained. During the simulation, the initial contact between the rock and the drip shield is a line, which evolves into an area as the simulation is continued, and eventually, the contact vanishes as the rock rebounds. Therefore, the area and location of contact are intrinsically determined by LS-DYNA during impact.

LS-DYNA finite element solutions were performed over a 3-m length of drip shield instead of the 6 m full-length for the purpose of reducing computer processing unit time and increasing the total number of finite elements used in the solution for improved accuracy. Since the 3-m partial-length of drip shield evaluated is the length where the rock partial-volume is the largest, total number of cracks in drip shield full-length is conservatively obtained by multiplication of the number of cracks in 3-m partial-length by 2; the results of the number of potential cracks are reported for both 3 m partial-length and 6 m full-length of drip shield (see Table 6-1).

As illustrated in the SFD input transmittal, Reference 12, the rock geometry is, essentially, a pyramid with exception of the radius of curvature at the bottom surface, which is the same as the emplacement drift radius. For sizes of rock up to 4 MT, entire rock volume is located above the 3 m partial-length of drip shield. Figures on pages 13 and 48 in the SFD input transmittal (Ref. 12), show that the increase in rock mass is by increase in length of the rock geometry along the emplacement drift rather than any increase in the rock block apex height. For approximately the same apex height (1.3 m), page 13 in Reference 12 shows a 4-MT rock with a total length of 4 m along the emplacement drift whereas page 48 in the same reference includes a 52-MT rock mass with a length of 40 m. The change in effective rock mass with respect to the actual rock mass can be observed in Table 6-1. Using the concept of effective rock mass over a 3-m partial-length of drip shield, maximum rock mass is determined to be 10 MT per 3-m partial-length of drip shield. In other words, an estimated maximum rock of 52 MT will load a 3-m partial-length of drip shield the same as a 10-MT rock, and for any rock mass over 52 MT a 3-m partial-length of drip shield will experience the same load as 10 MT.

LS-DYNA stress results include high frequency response. These results are filtered using an eighth-order Butterworth low-pass filter with a cutoff frequency of 20 Hz. The purpose of the filtering is to obtain a steady-state residual stress value on the drip shield by removing the high frequency response. Since the stress results after the filtering produced steady-state values anticipated by visual inspection of unfiltered stress graphs, this type of filtering was deemed acceptable. The resulting filtered stress graphs are given in Attachment III.

5.3 TANGENT MODULUS AND ROCK VELOCITY CALCULATIONS

The results of the computer simulation are required to include elastic and plastic deformations for all materials. When the materials are driven into the plastic range, the slope of the stress-strain curve continuously changes. Thus, a simplification for this curve is needed to incorporate plasticity into the finite element solution. A standard approximation is commonly used in engineering by using a straight line that connects the yield point to the ultimate tensile strength point of the material. The following parameters will be used in subsequent calculations:

S_y = Yield strength of the material
S_u = Ultimate tensile strength
e_1, e_2, e_3 = Strain magnitudes
E = Elastic modulus (slope of the line in the elastic region)
E_t = Tangent modulus (slope of the line in the plastic region)
v = Poisson's ratio

The slope, E_t is determined by:

$e_1 = S_y / E$ and $e_2 = e_3 - e_1$ where e_3 = elongation specified for material.

Hence, for Ti-7:

$E_t = (S_u - S_y) / e_2 = (0.345 - 0.276) / (0.20 - (0.276 / 107)) = 0.35$ GPa (see Section 5.1)

Ti-24:

$E_t = (0.895 - 0.828) / (0.10 - (0.828 / 113.8)) = 0.723$ GPa (see Section 5.1)

The maximum distance between the drip shield and emplacement drift ceiling (d_{max}) is calculated below:

d_{max} = emplacement drift diameter – (drift invert allowance – (crane rail height + plate thickness + w shape depth)) – drip shield height

$= 5.5 - (1.115 - (0.146 + 0.019 + 0.229)) - 2.521 = 2.258$ m (see Section 5.1 and Attachment II)

A distance of 2.3 m is conservatively used in calculations.

For a height of 2.3 m, rock impact velocity is calculated by conservation of energy:

Kinetic Energy = Potential Energy

mass * $(\text{velocity})^2$ / 2 = mass * gravitational acceleration * height

velocity = $(2 * 9.81 * 2.3)^{1/2} = 6.72$ m/s

Similarly, for a height of 2.1 m:

velocity = $(2 * 9.81 * 2.1)^{1/2} = 6.42$ m/s

6. RESULTS

This document may be affected by technical product input information that requires confirmation. Any changes to the document 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.

The results of the finite element solutions indicate that no crack develops in the drip shield due to the dynamic impact of a rock on the drip shield for any of the rock sizes listed in Table 6-1. This is based on the steady-state drip shield configuration after the impact. The failure of drip shield structural components were specified by failure strain values equal to the material elongation values given in Section 5.1. When the failure strain value is reached during the simulation, the corresponding elements are automatically removed from the FER. Since none of the elements were removed throughout the simulation, the failure strain is not exceeded in any of the components, and the drip shield is deemed to remain intact after the rock fall event. However, further investigation of drip shield performance considering the potential for the initiation of stress corrosion cracking due to the residual stresses caused by the rock fall shows that the drip shield may be susceptible to stress corrosion cracking depending on the size of the rock. Therefore, the results of crack length and total number of cracks due to stress corrosion cracking are summarized in Table 6-1.

In case of a 6-MT rock fall on drip shield, a localized residual stress pattern is observed on the symmetry plane in the vicinity of one of the stiffeners, which are uniformly placed under the drip shield top plate (see sketch in Attachment II and Figures III-7 and III-8). The locations of residual stresses developed as a result of rock sizes other than 6 MT are also observed to be in the vicinity of stiffeners. The reason for such a pattern is that most of the dynamic load is taken by the stiffeners; therefore, the drip shield top plate sections close to these stiffeners also experience high stress and strains caused by the rock fall. The form of residual stresses in drip shield wall thickness are hoop stresses (circumferential stresses). Since the potential crack growth due to stress corrosion cracking will take place perpendicular to this component of stress, the failure on the drip shield top plate will be in the form of "crack" in the vicinity of stiffeners rather than a "large cavity" type of failure.

The region of maximum residual stress for a 2-MT rock fall onto drip shield is depicted in Figure III-2. Elements numbered as 1945 and 285 have similar stress states due to their proximity to each other; the time-history for the element #1945 is given in Figure III-3. This figure shows that residual stresses in all three layers of the shell are less than 20% of the material (Ti-7) yield strength (276 * 0.20 = 55 MPa, see Section 5.1). Therefore, no potential crack is anticipated to develop as a result of the 2-MT rock fall event (see Ref. 13 for 20% limit). However, for each of the rock masses 4 MT and 6 MT, one location is identified for potential crack growth since the 20% limit is exceeded (see Figures III-5, III-8, and III-9). The number of possible crack locations are determined to be 2 and 6 for the rock masses of 8 MT and 52 MT, respectively. The two stress plots for the 8-MT rock mass are shown in Figures III-11 and III-12. For the 52-MT rock mass, one stress plot (element # 4002) out of 6 possible crack growth locations (element numbers 4002, 4030, 4343, 538, 339, and 311) is depicted in Figure III-13. These

results are summarized in Table 6-1. The length of the cracks is determined from the FER stress distribution plots for each different rock size; one of these stress distribution plots is provided in Figure III-8.

Table 6-1. Crack Size and Number of Potential Crack Initiation Points due to Stress Corrosion Cracking

Actual Rock Mass (MT)	Effective Rock Mass Over a 3-m Length of Drip Shield (MT)	Crack Length (cm)	Number of potential Cracks per 3-m Partial-Length of Drip Shield	Number of potential Cracks per 6-m Full-Length of Drip Shield
2	2	None	None	None
4	4	13	1	2
6	5.7	13	1	2
8	6.7	13	2	4
52	10	13	6	12

The results of the rock fall on the drip shield side wall indicate that there is no failure. LS-DYNA output file shows that none of the finite elements is removed from the FER since the maximum failure strain (% elongation) of the material is not exceeded (see Figure III-15).

An additional rock fall simulation is performed to obtain the maximum displacement in a drip shield design with an overall height that was increased by 200 mm. The results show that the maximum displacement is at the bottom of the stiffener supporting the top plates, and the value of displacement is less than 170 mm (see Figure III-16). Depending on the waste package size, the drip shield height can be modified to prevent the contact of the drip shield with the waste package in case of excessive deformation due to rock fall.

7. ATTACHMENTS

Attachment I (4 pages): Document Input Reference System sheets

Attachment II (2 pages): Design sketches

Attachment III (19 pages): Figures and displacement result lists

Attachment IV has been moved to Reference 15. Table 7-1 includes the name, size, date, and time for each electronic file in Reference 15. Note that these electronic files are no longer an attachment to this document; the file information is provided for information only. File sizes may slightly vary depending on the operating system.

Table 7-1. File Names, Sizes, Dates, and Times in Reference 15

File Name	Size	Date	Time
r2mt.old1.out	417 KB	3/27/00	1:37 pm
r2mt.k	1 KB	3/27/00	1:37 pm
bcnodes.inc.2out	2 KB	3/27/00	1:38 pm
elements.inc.2out	465 KB	3/27/00	1:38 pm
nodes.inc.2out	366 KB	3/27/00	1:38 pm
d3hsp.2out	2510 KB	3/27/00	1:39 pm
r4mt.old1.out	422 KB	3/27/00	1:40 pm
r4mt.k	1 KB	3/27/00	1:40 pm
r4mtd.inc	2 KB	3/27/00	1:41 pm
r4mte.inc	465 KB	3/27/00	1:41 pm
r4mtn.inc	366 KB	3/27/00	1:41 pm
d3hsp.4out	2716 KB	3/27/00	1:53 pm
r6mt.old1.out	430 KB	3/27/00	1:42 pm
r6mt.k	1 KB	3/27/00	1:42 pm
r6mtd.inc	2 KB	3/27/00	1:42 pm
r6mte.inc	505 KB	3/27/00	1:42 pm
r6mtn.inc	402 KB	3/27/00	1:43 pm
d3hsp.6out	2865 KB	3/27/00	1:53 pm
r8mt.old1.out	429 KB	3/27/00	1:44 pm
r8mt.k	1 KB	3/27/00	1:44 pm
r8mtd.inc	2 KB	3/27/00	1:44 pm
r8mte.inc	505 KB	3/27/00	1:44 pm
r8mtn.inc	402 KB	3/27/00	1:45 pm
d3hsp.8out	2865 KB	3/27/00	1:53 pm
maxmt.old1.out	428 KB	3/27/00	1:46 pm
maxmt.k	1 KB	3/27/00	1:46 pm
maxmtd.inc	2 KB	3/27/00	1:46 pm
maxmte.inc	505 KB	3/27/00	1:46 pm
maxmtn.inc	402 KB	3/27/00	1:47 pm
d3hsp.mout	2865 KB	3/27/00	1:54 pm
rot1.old1.out	436 KB	3/27/00	1:47 pm
rot1.k	2 KB	3/27/00	1:48 pm
rot1d1.inc	2 KB	3/27/00	1:48 pm
rot1d2.inc	2 KB	3/27/00	1:48 pm

rot1d3.inc	2 KB	3/27/00	1:48 pm
rot1e.inc	457 KB	3/27/00	1:48 pm
rot1n.inc	362 KB	3/27/00	1:49 pm
d3hsp.rout	18700 KB	3/27/00	1:56 pm
tall.old1.out	424 KB	3/27/00	1:50 pm
tall.k	1 KB	3/27/00	1:50 pm
talld.inc	2 KB	3/27/00	1:51 pm
talle.inc	505 KB	3/27/00	1:51 pm
talln.inc	402 KB	3/27/00	1:51 pm
d3hsp.tout	2863 KB	3/27/00	1:52 pm

Note that some of the computer simulations were terminated after the necessary number of load steps had been obtained for a steady-state solution. This has no effect on the results since the steady-state solutions in terms of displacements, strains, and stresses were essentially obtained during the time of computer simulations.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SHEET

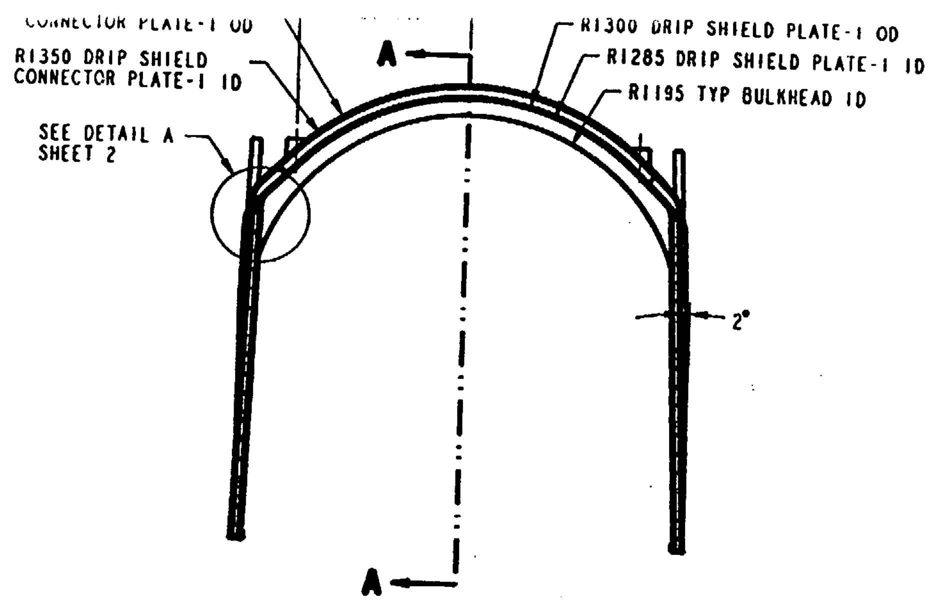
1. Document Identifier No./Rev.:	Change:	Title:
CAL-EDS-ME-000001 Rev. 00 (as of 24-apr-2000 15:46:13)	N/A	ROCK FALL ON DRIP SHIELD

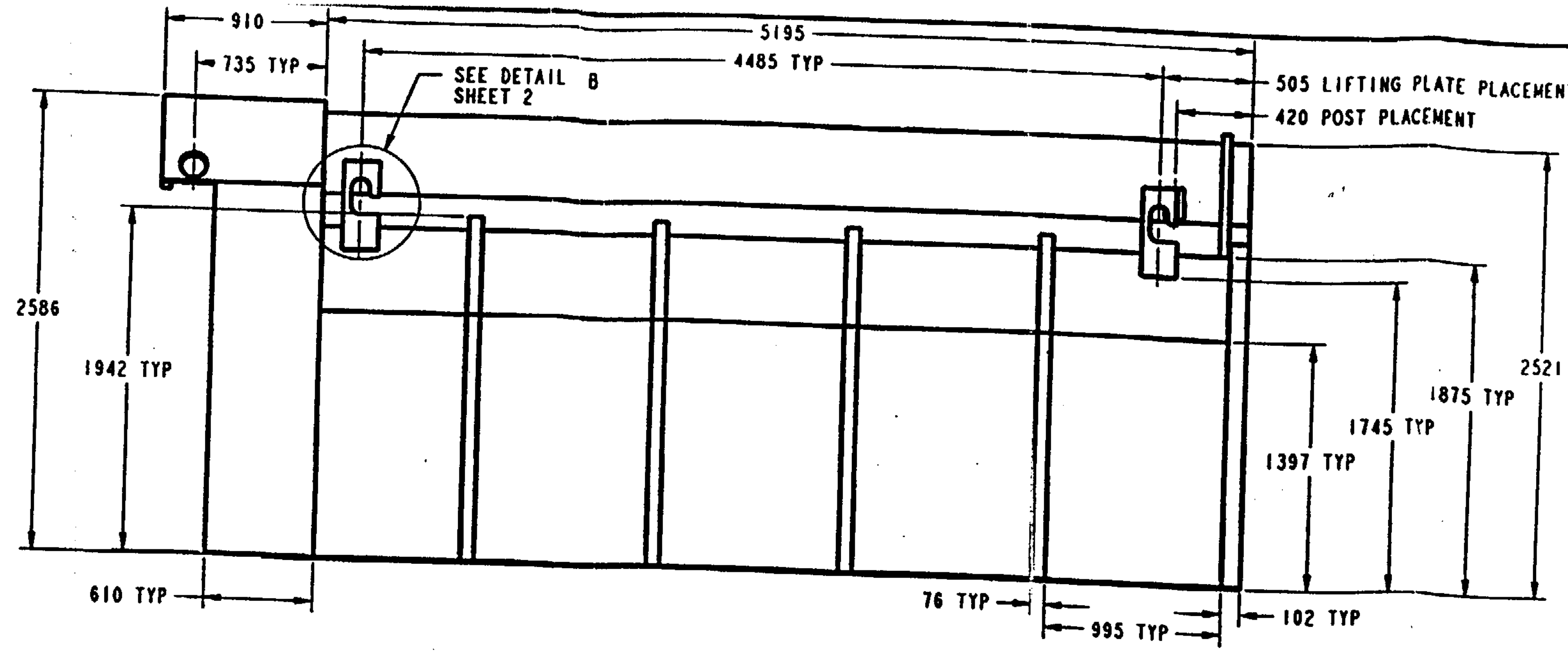
Input Document							8. TBVDue To		
2a.	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-Confirmed
1	CRWMS M&O 1998. *Software Qualification Report for ANSYS 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 document	N/A - Reference Only	4.1	Qualification report for ANSYS V5.4	N/A	N/A	N/A	N/A
2	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 document	N/A - Reference Only	4.1	Applicable UNIX workstations	N/A	N/A	N/A	N/A
3	Doering, T.W. 1998. "Qualification of ANSYS V5.4 on New WPO HP UNIX Workstation." Interoffice correspondence from T.W. Doering (CRWMS M&O) to G. Carlisle, November 11, 1998, LV.WP.MML.11/98-220. ACC: MOL.19981217.0106.	Entire document	N/A - Reference Only	4.1	Applicable UNIX workstations	N/A	N/A	N/A	N/A
4	Doering, T.W. 1999. "Qualification of ANSYS V5.4 on Three New WPO HP UNIX Workstations." Interoffice correspondence from T.W. Doering (CRWMS M&O) to G.P. Carlisle, May 3, 1999, LV.WP.SMB.05/99-071 ACC: MOL.19990518.0322.	Entire document	N/A - Reference Only	4.1	Applicable UNIX workstations	N/A	N/A	N/A	N/A
5	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-5	N/A - Accepted Data (Fact)	5.1	Titanium Grade 7 modulus of elasticity	N/A	N/A	N/A	N/A
		Table NF-2	N/A - Accepted Data (Fact)	5.1	Titanium Grade 7 density	N/A	N/A	N/A	N/A
		Table Y-	N/A -	5.1	Titanium Grade 7 yield and	N/A	N/A	N/A	N/A

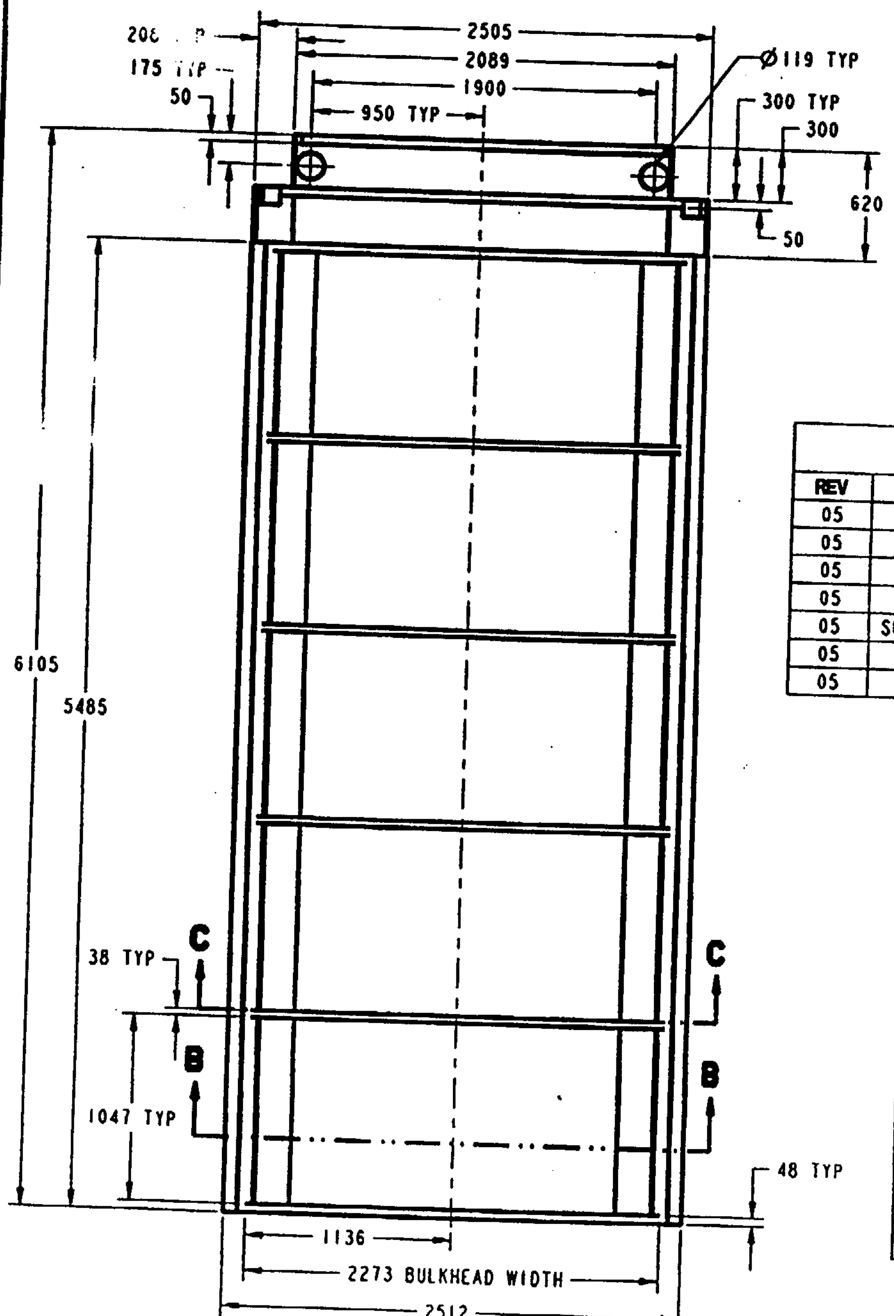
		1	Accepted Data (Fact)	5.1	tensile strengths at 20 degrees C	N/A	N/A	N/A	N'A
6	ASM International 1990. *Properties and Selection: Nonferrous Alloys and Special-Purpose Materials.* Volume 2 of *ASM Metals Handbook.* Materials Park, Ohio: American Society for Metals. TIC: 241059.	Page 621	N/A - Accepted Data (Fact)	5.1	Titanium Grade 7 Poisson's ratio	N/A	N/A	N/A	N/A
		Page 621	N/A - Accepted Data (Fact)	5.1	Titanium Grade 5 modulus of elasticity	N/A	N/A	N/A	N/A
		Page 620	N/A - Accepted Data (Fact)	5.1	Titanium Grade 5 density	N/A	N/A	N/A	N/A
		Page 621	N/A - Accepted Data (Fact)	5.1	Titanuim Grade 5 Poisson's ratio	N/A	N/A	N/A	N/A
7	ASTM B 265-99. 1999. *Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246708.	Table 1	N/A - Accepted Data (Fact)	5.1	Titanium Grade 7 elongation in 2 in.	N/A	N/A	N/A	N/A
		Table 1	N/A - Accepted Data (Fact)	5.1	Tensile requirements of Titanium Grade 5 and Titanium Grade 24	N/A	N/A	N/A	N/A
		Table 1	N/A - Accepted Data (Fact)	5.1	Titanium Grade 5 yield strength at 20 degrees C	N/A	N/A	N/A	N/A
		Table 1	N/A - Accepted Data (Fact)	5.1	Titanium Grade 5 tensile strength at 20 degrees C	N/A	N/A	N/A	N/A
		Table 1	N/A - Accepted Data (Fact)	5.1	Titanium Grade 5 elongation in 2 in.	N/A	N/A	N/A	N/A
8	MO9808RIB00041.000. Reference Information Base Data Item: Rock Geomechanical Properties. Submittal date: 08/05/1998.	Young's Modulus and Poisson's Ratio, and Table 2	TBV-3143	5.1	ROCK GEOMECHANICAL PROPERTIES FOR THERMAL /MECHANICAL UNITS	1	X	N/A	N/A
9	CRWMS M&O 2000. *Emplacement Drift System Description Document.* SDD-EDS-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000121.0119.	Volume I, page 16	N/A - Management Edict or TDL	5.1	Nominal emplacement drift diameter	N/A	N/A	N/A	N/A

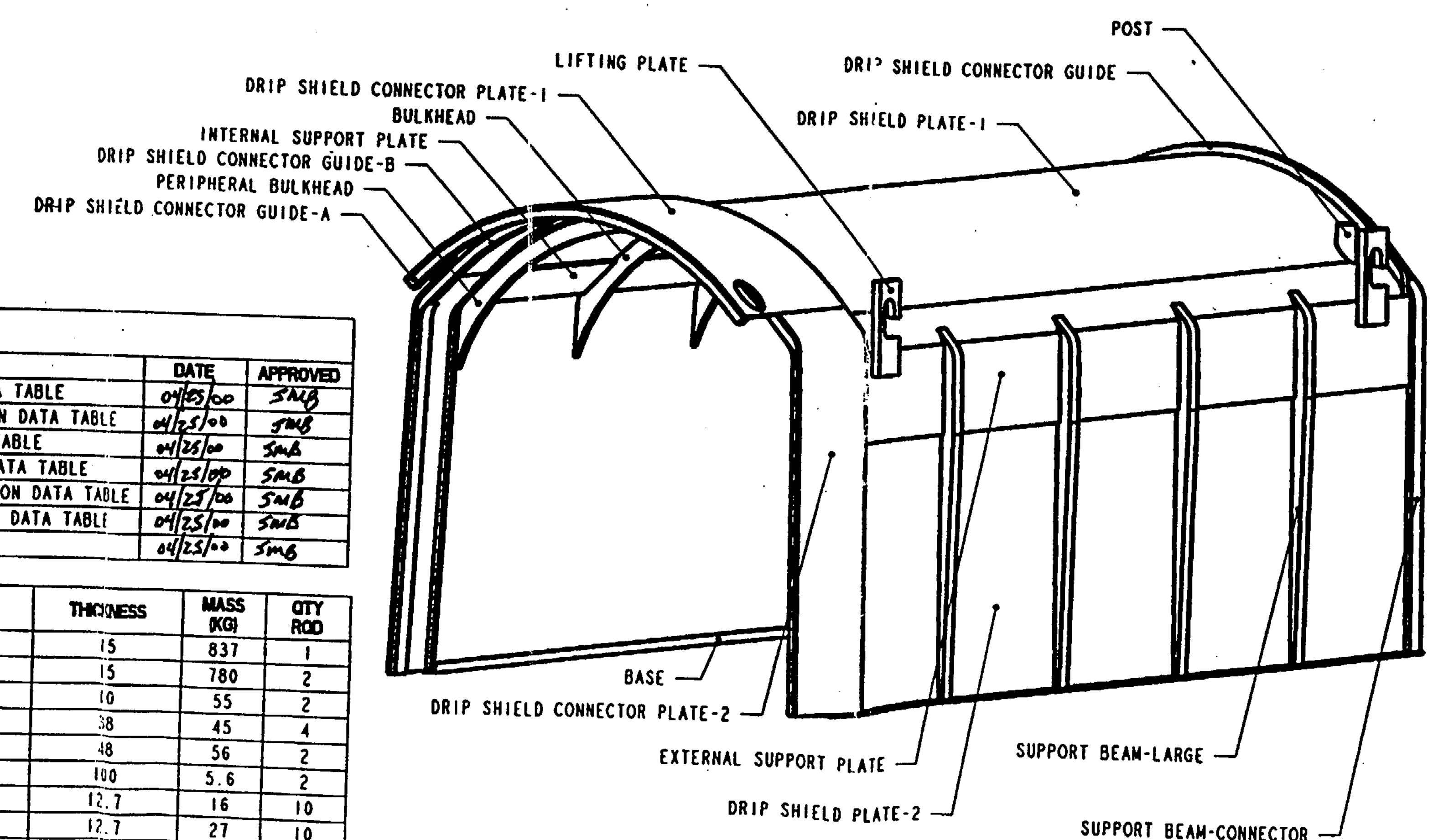
10	CRWMS M&O 1999. *Emplacement Drift Invert Design.* Input Transmittal WP-SSR-99250.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990930.0116.	Item No. 1	TBV-4390	5.1	DRIFT INVERT ALLOWANCE	1	X	N/A	N/A
11	CRWMS M&O 1998. *Emplacement Drift Invert Structural Design Analysis.* BBDC00000-01717-0200-00001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980625.0366.	Page I-54 and page V-2	TBV-4391	5.1	CRANE RAIL, PLATE, AND W SHAPE DIMENSIONS	1	X	N/A	N/A
12	CRWMS M&O 2000. *Possible Rock Block Geometry, Dimension, Orientation, Probability, and Masses.* Input Transmittal WP-SSR-00027.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000208.0344.	Pages 2 through 51	TBV-4392	5.2	PRELIMINARY ROCK BLOCK INFORMATION	1	X	N/A	N/A
13	CRWMS M&O 2000. *Threshold Stress Level for Initiation of Stress Corrosion Cracking (SCC) in Alloy 22, Ti Gr7 and Ti Gr24.* Input Transmittal WP-WP-00031.T. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000207.0123.	Item No. 1	TBV-4281	6	THRESHOLD STRESS LEVEL FOR INITIATION OF STRESS CORROSION CRACKING IN ALLOY 22, TI GR7 AND TI GR24	1	X	N/A	N/A
14	American Institute of Steel Construction 1986. *Manual of Steel Construction, Load and Resistance Factor Design.* 1st Edition. Chicago, Illinois: American Institute of Steel Construction. TIC: 205771.	Page 1-36	N/A - Accepted Data (Fact)	5.1	W shape depth	N/A	N/A	N/A	N/A
15	CRWMS M&O 2000. *Electronic Files for Rock Fall on Drip Shield.* CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0076.	Entire record	N/A - Reference Only	7	Electronic files for rock fall on drip shield	N/A	N/A	N/A	N/A
16	CRWMS M&O. 2000. *Software Code: LSTC LS-DYNA V940.* V940. HP 9000. 10291-940-00.	Entire	TBV-4532	4.1	INTERIM USE OF AN UNQUALIFIED SOFTWARE, LSTC LS-DYNA VERSION 940, IN ACCORDANCE WITH AP-SI.1Q, SUBSECTION 5.11. SAN: LV-2000-095. SDN: 10145-SAP-5.6-00 IDENTIFIES INTENDED	1	X	N/A	N/A

					USE PRIOR TO QUALIFICATION						









REVISION HISTORY

REV	DESCRIPTION	DATE	APPROVED
05	BULKHEAD MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	PERIPHERAL BULKHEAD MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	POST MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	LIFTING PLATE MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	SUPPORT BEAM-CONNECTOR MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	SUPPORT BEAM-LARGE MATERIAL UNS NUMBER CHANGED ON DATA TABLE	04/25/00	SMB
05	REVISION HISTORY TABLE ADDED	04/25/00	SMB

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY RQD
DRIP SHIELD PLATE-1	SB-265 R52400	15	837	1
DRIP SHIELD PLATE-2	SB-265 R52400	15	780	2
BASE	SB-575 N06022	10	55	2
BULKHEAD	SB-265 R56405	38	45	4
PERIPHERAL BULKHEAD	SB-265 R56405	48	56	2
POST	SB-265 R56405	100	5.6	2
INTERNAL SUPPORT PLATE	SB-265 R52400	12.7	16	10
EXTERNAL SUPPORT PLATE	SB-265 R52400	12.7	27	10
LIFTING PLATE	SB-265 R56405	50	17	4
SUPPORT BEAM-CONNECTOR	SB-265 R56405	102	27	6
SUPPORT BEAM-LARGE	SB-265 R56405	76	37	8
DRIP SHIELD CONNECTOR GUIDE	SB-265 R52400	50	30	2
DRIP SHIELD CONNECTOR PLATE-1	SB-265 R52400	15	142	1
DRIP SHIELD CONNECTOR PLATE-2	SB-265 R52400	15	89	2
DRIP SHIELD CONNECTOR GUIDE-A	SB-265 R52400	50	26	1
DRIP SHIELD CONNECTOR GUIDE-B	SB-265 R52400	50	31	1
DRIP SHIELD ASSEMBLY	-	-	4203	1

UNITS: mm

DO NOT SCALE FROM SKETCH

"FOR INFORMATION ONLY"

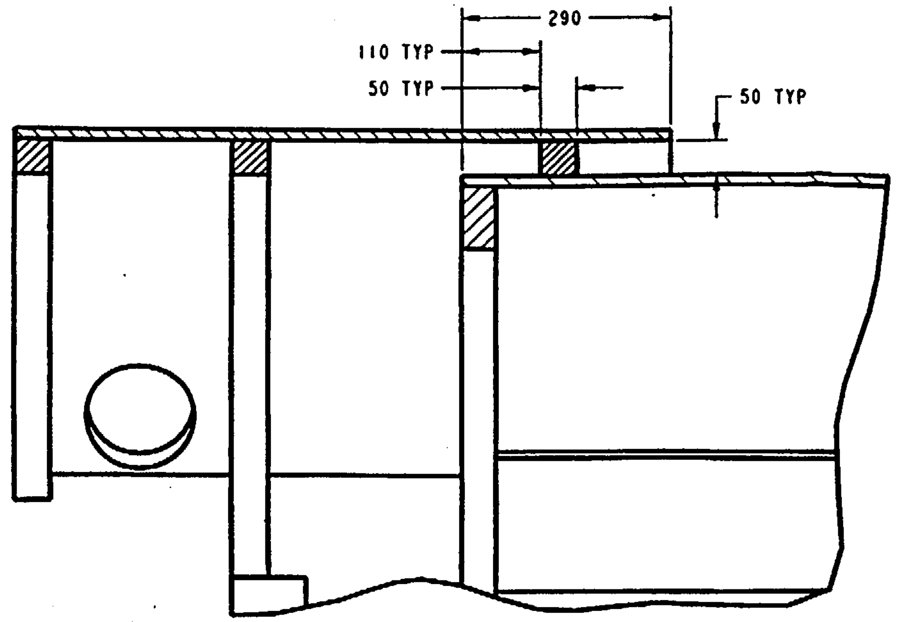
SR DRIP SHIELD

SKETCH NUMBER: SK-0148 REV 05 — SHEET 1 OF 2

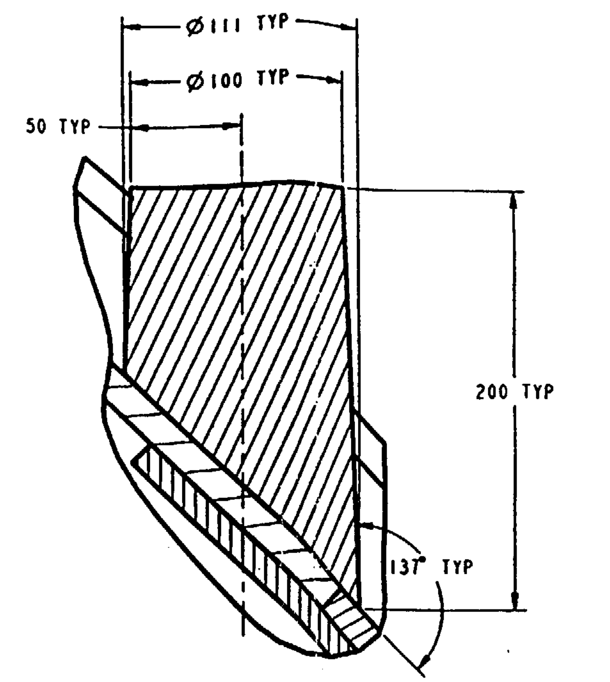
SKETCHED BY: BRYAN HARKINS BH 21April00 SMB 04/25/00 [signature] 4/25/00

DATE: 04/21/00

FILE: /home/harkins/proe/drip_shield/sk-0148_rev05.dwg



SECTION A-A



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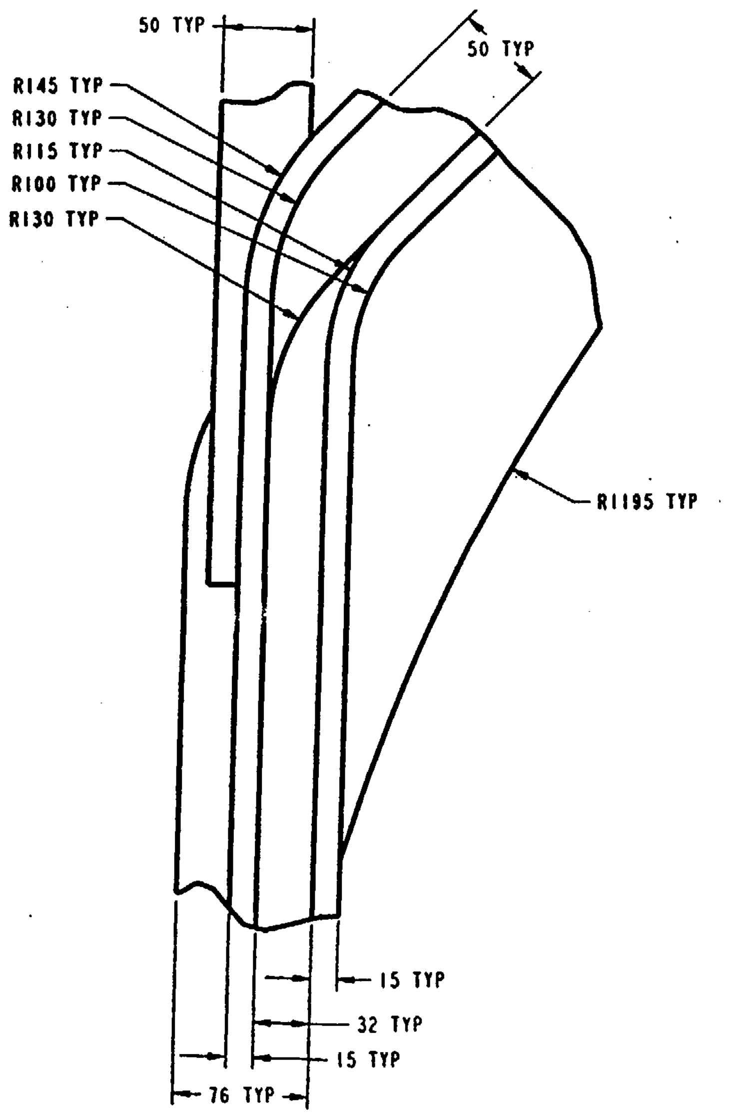
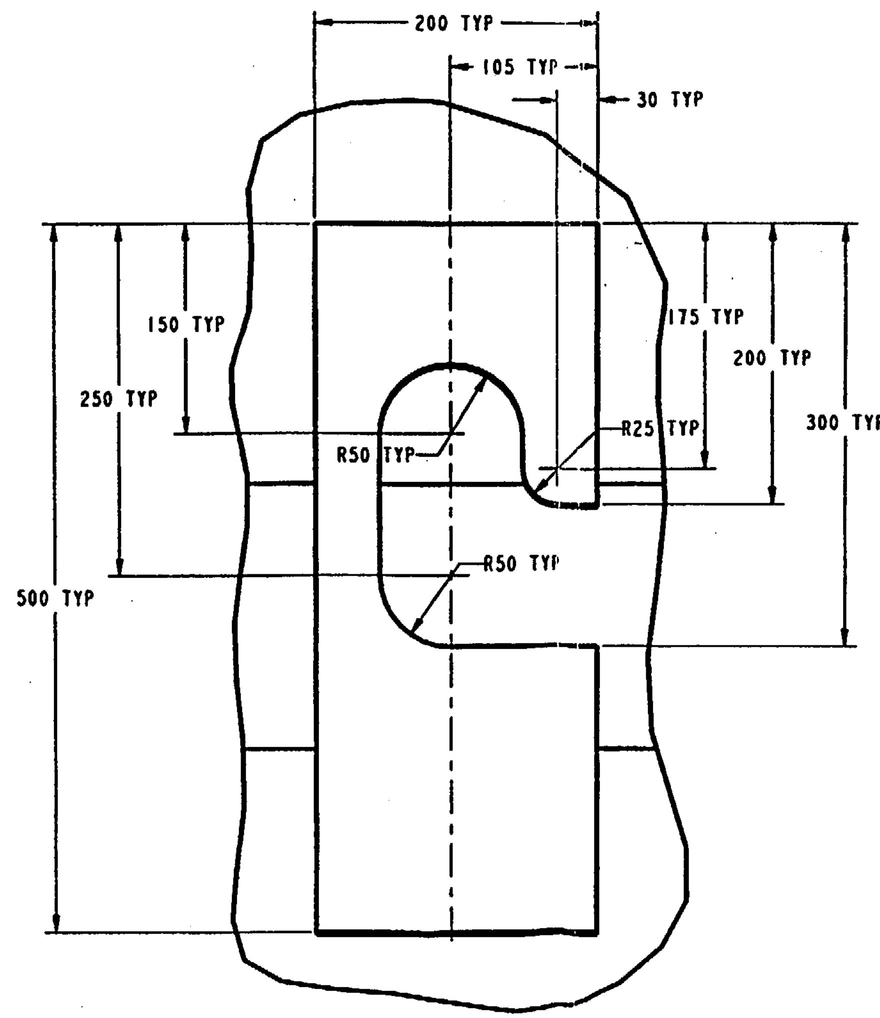
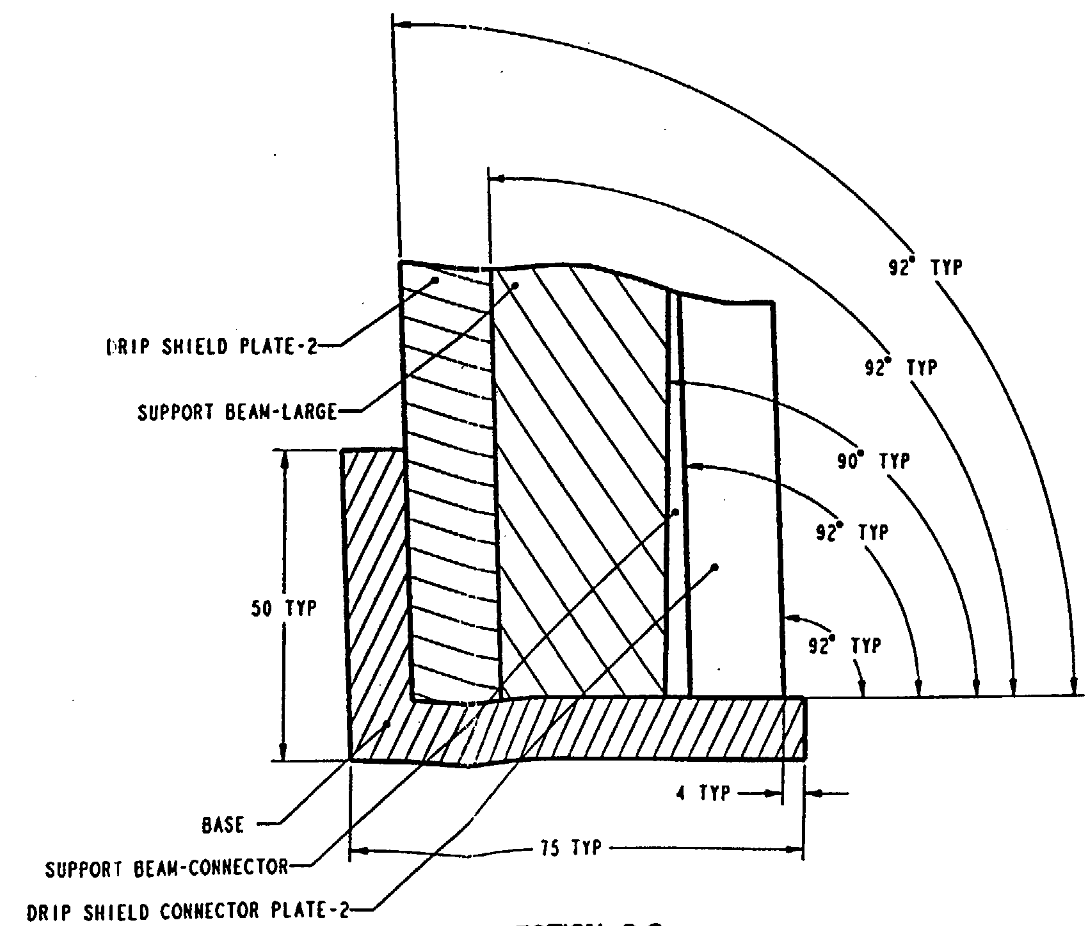


DETAIL A



DETAIL B



SECTION C-C

SK-0148 REV 05	SHEET 2 OF 2

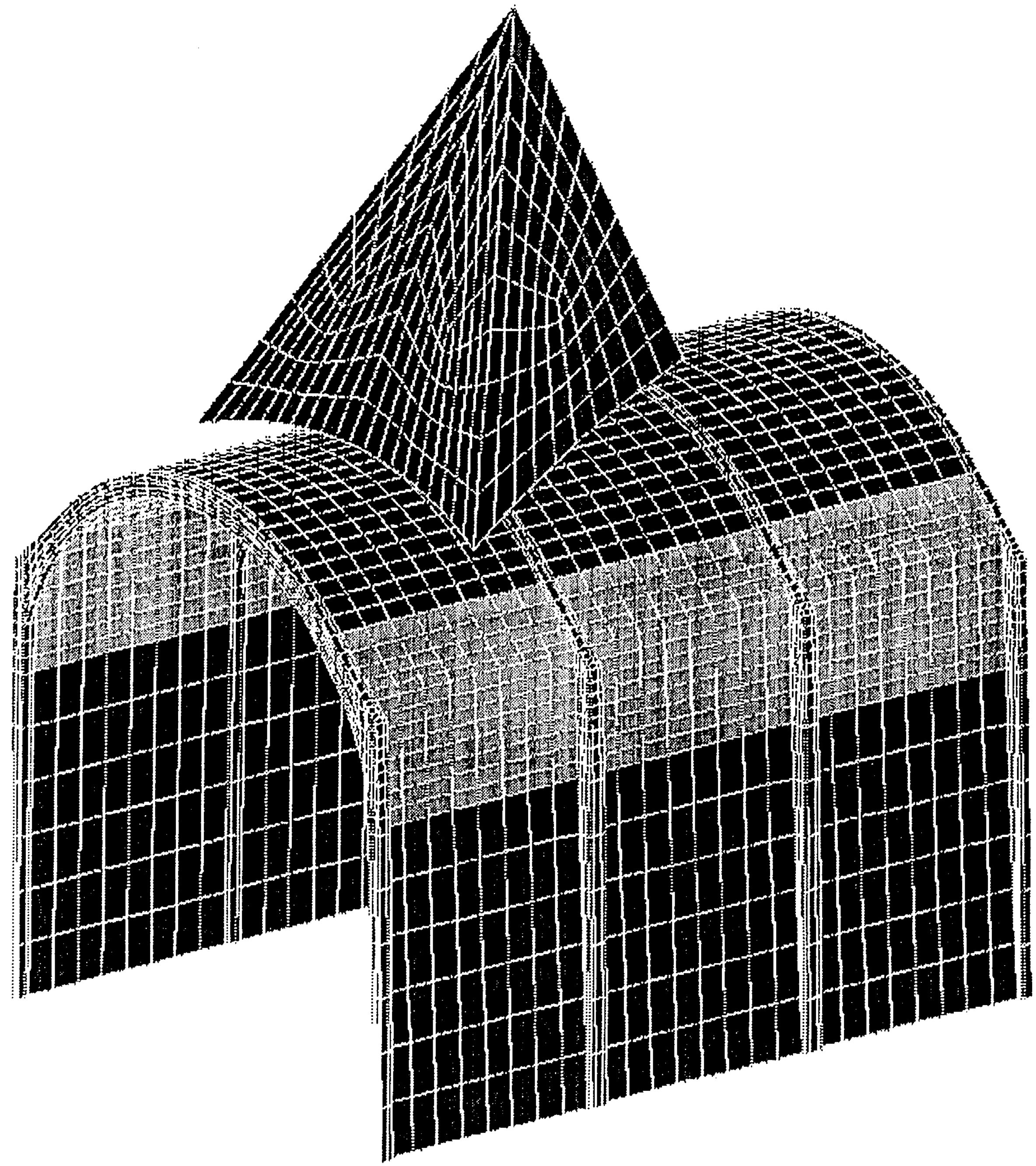


Figure III-1. Finite Element Representation of 2-MT Rock Fall on Drip Shield

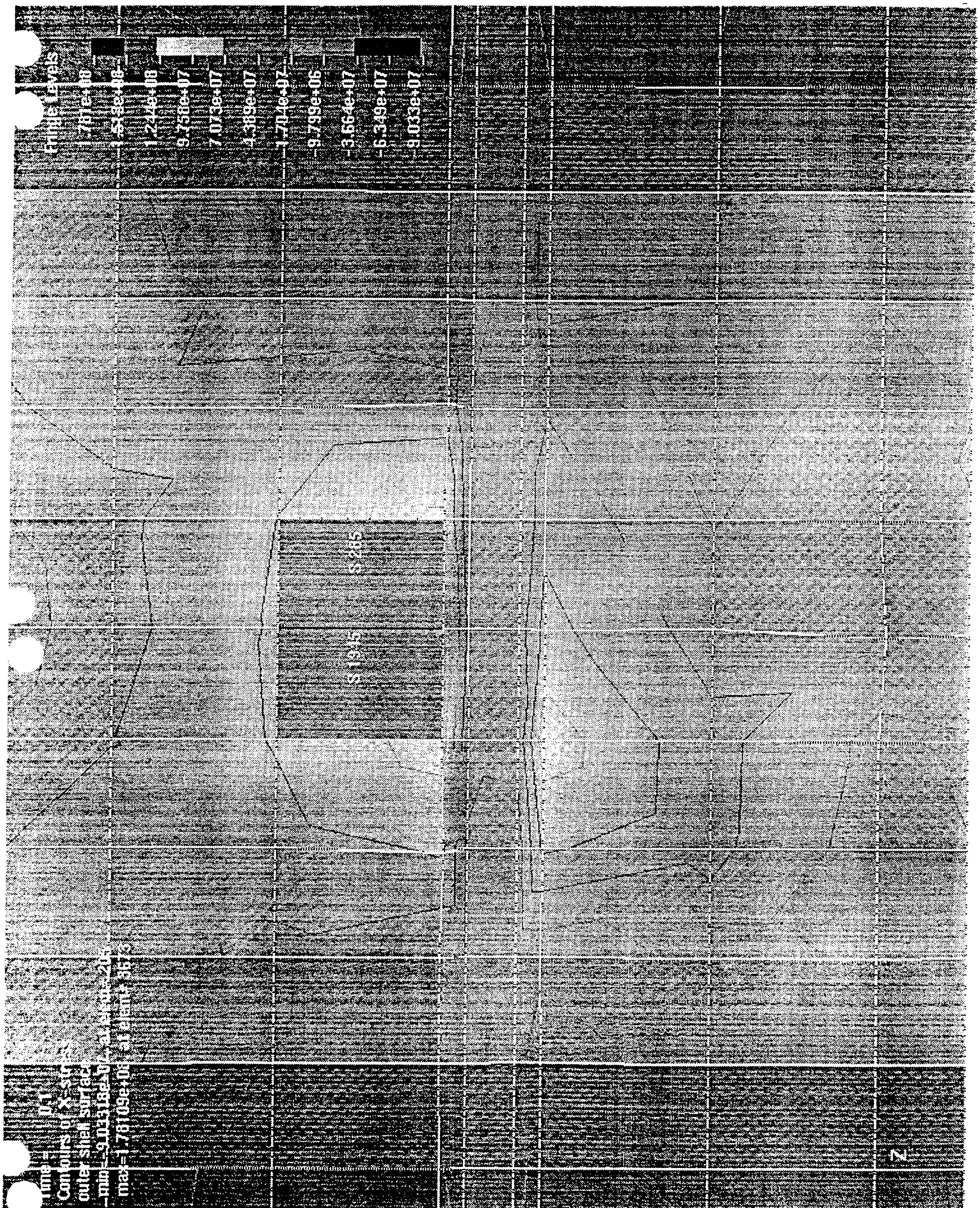


Figure III-2. Elements of Maximum Residual Stress (2-MT rock fall)

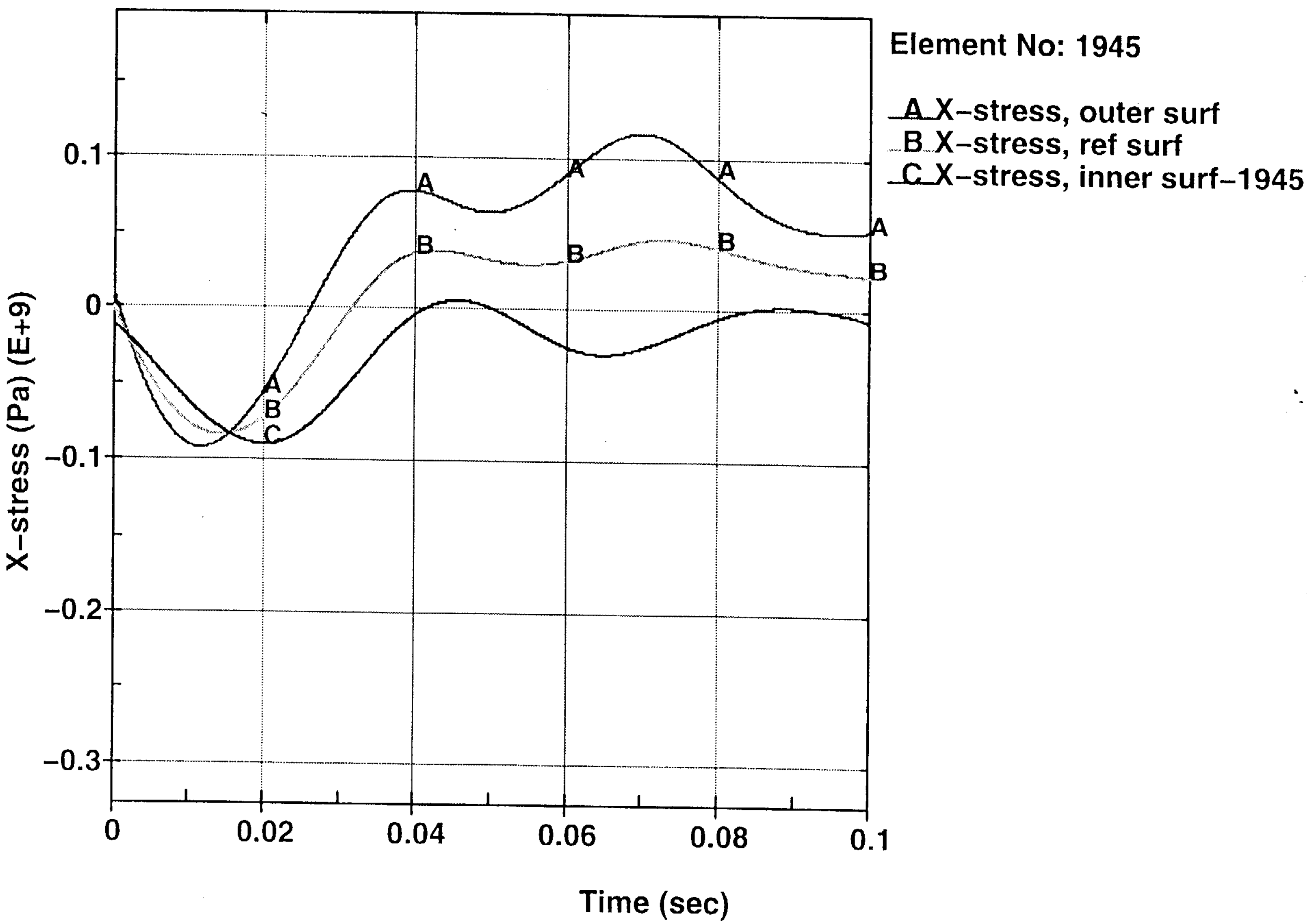


Figure III-3. Time-History for the Maximum Residual Stress (2-MT rock fall)

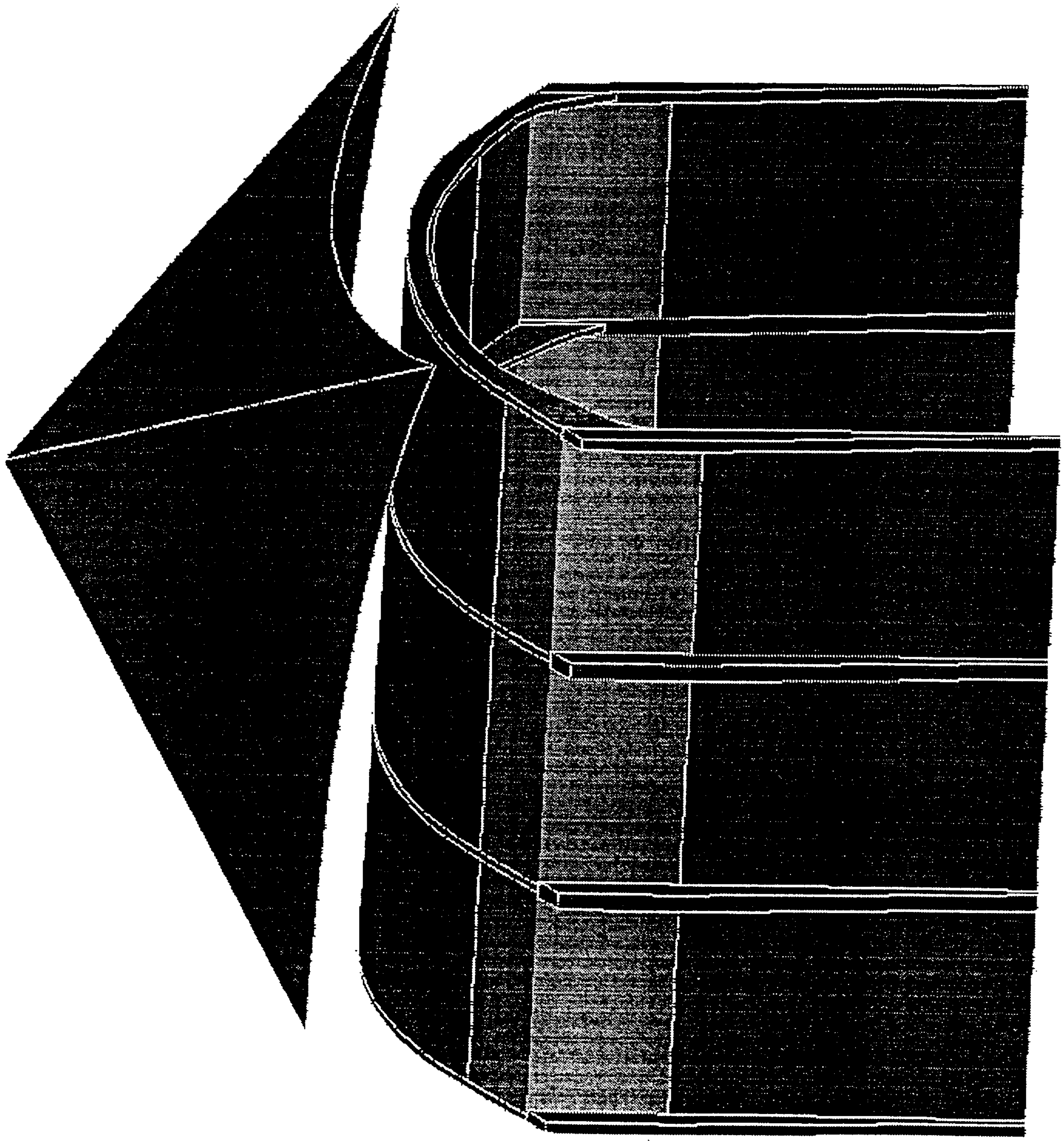


Figure III-4. Displacement Plot After the Impact (4-MT rock fall)

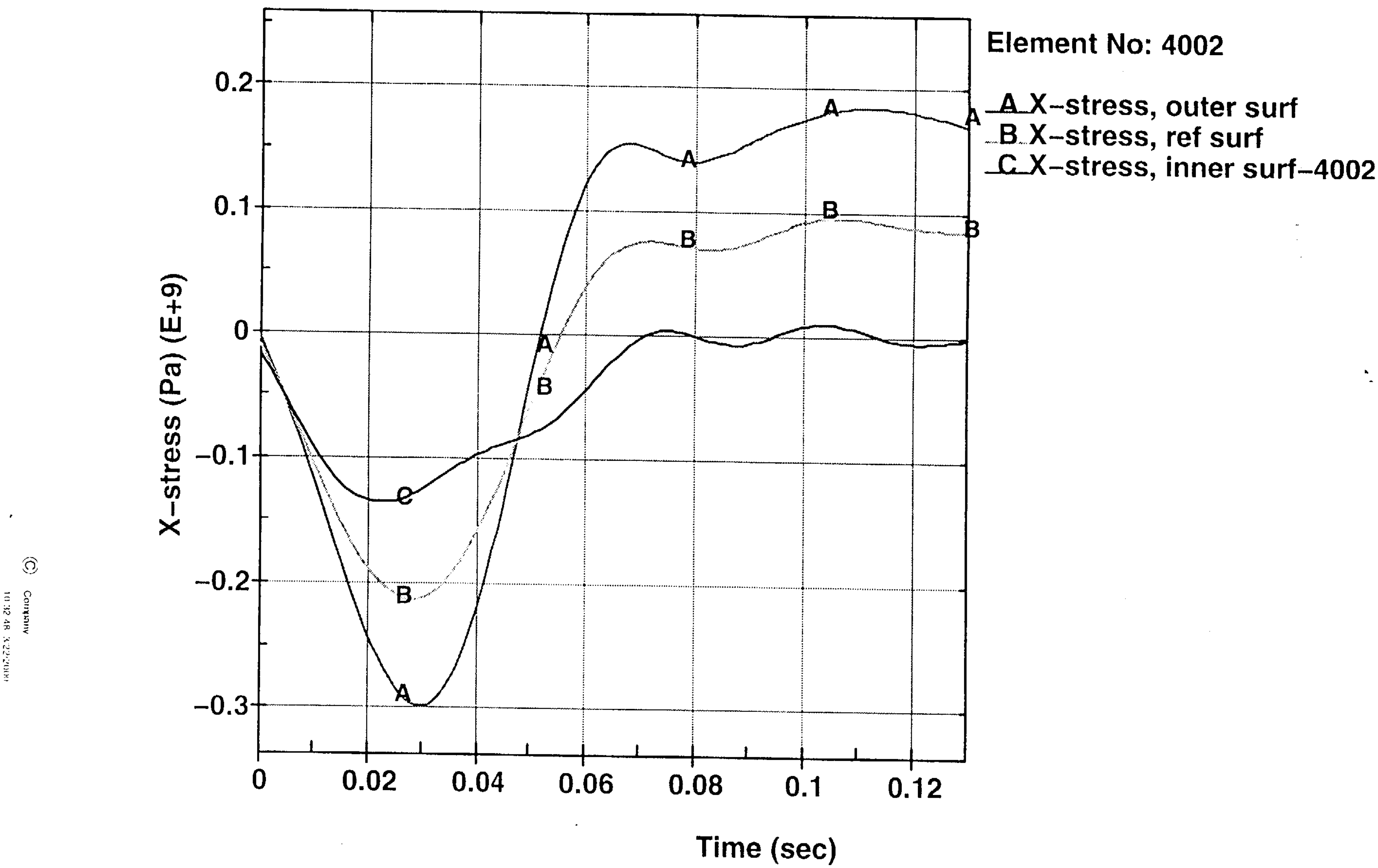


Figure III-5. Time-History for the Maximum Residual Stress (4-MT rock fall)

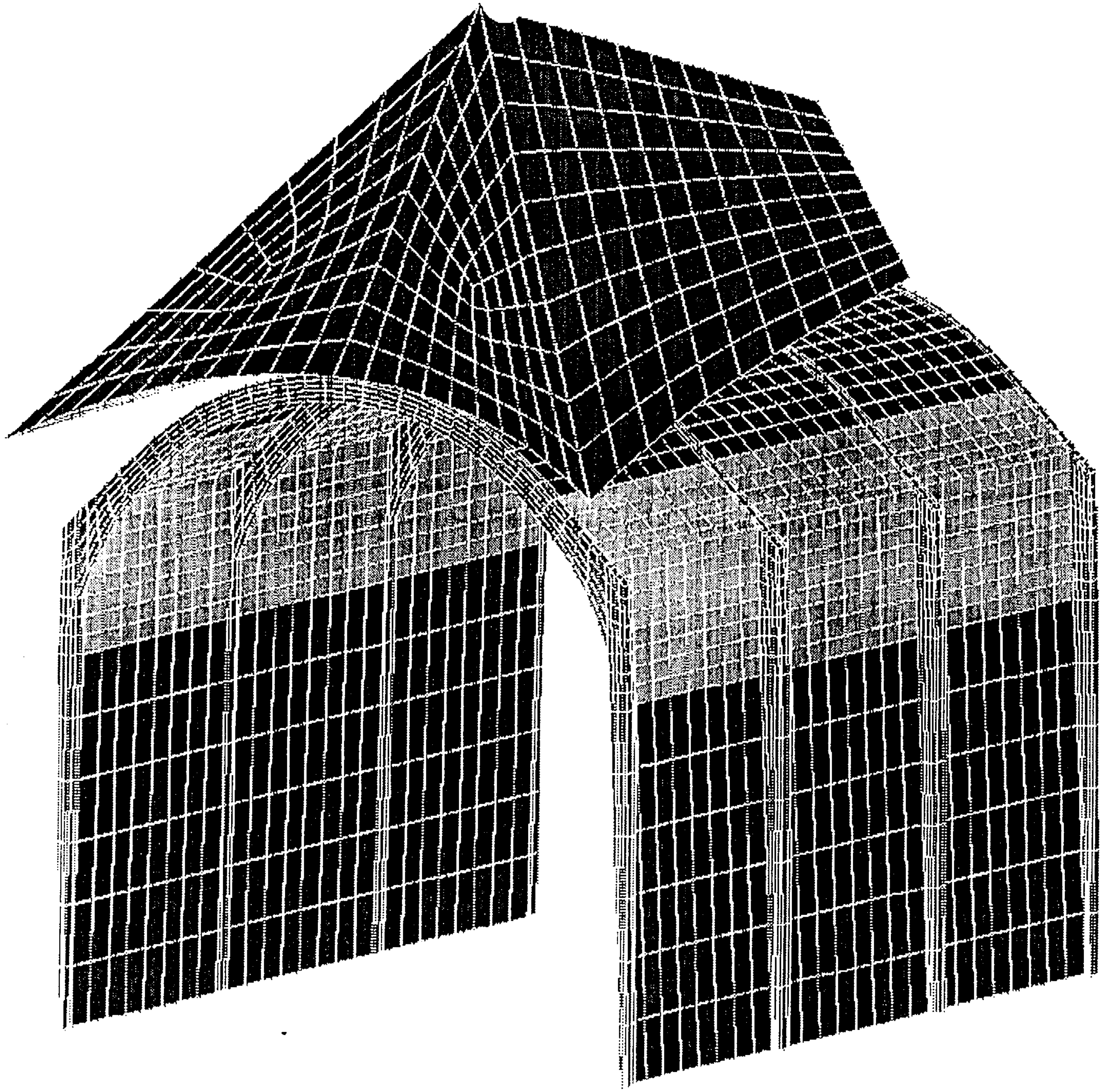


Figure III-6. Finite Element Representation of 6-MT Rock Fall on Drip Shield

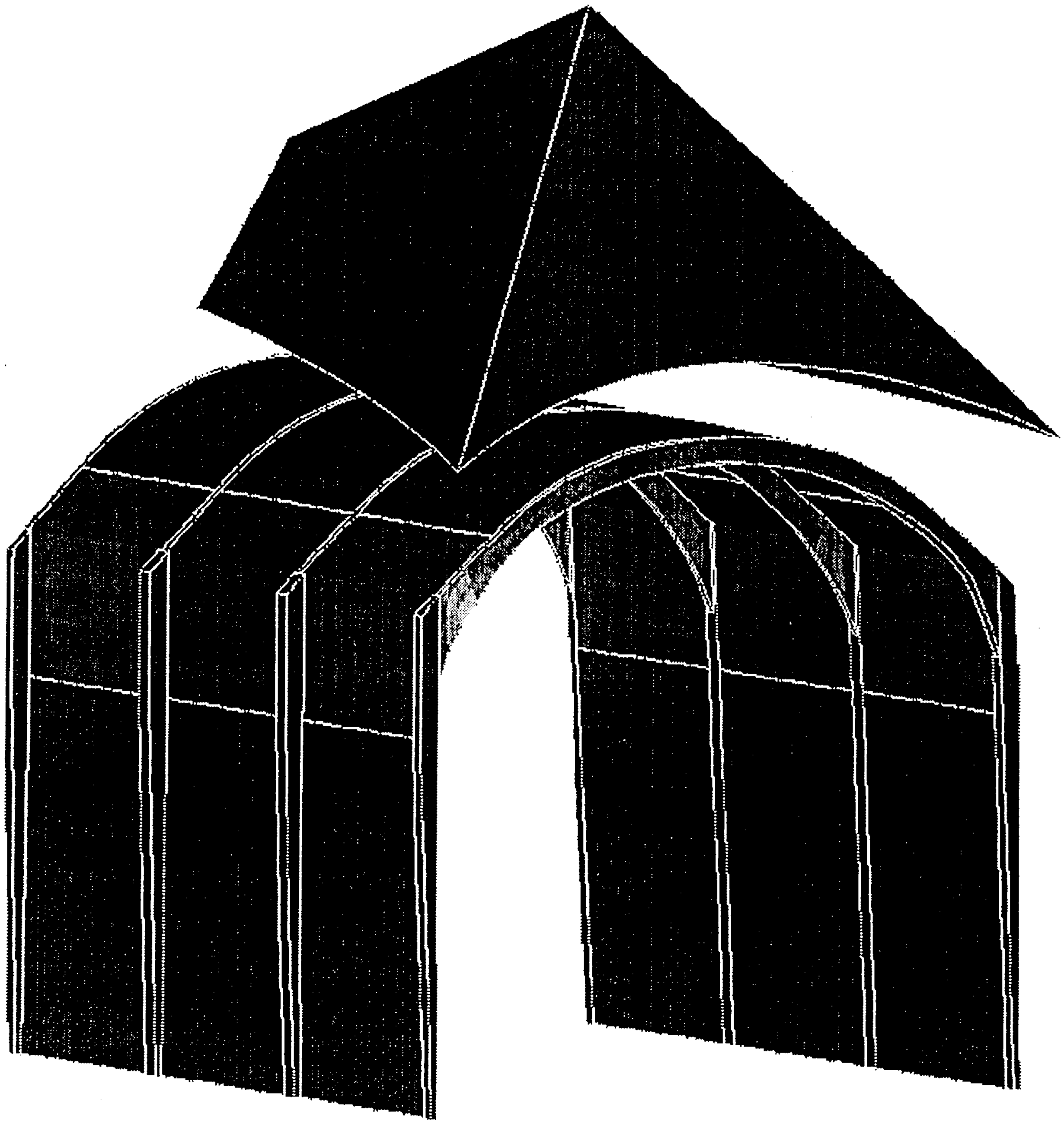


Figure III-7. Displacement Plot After the Impact (6-MT rock fall)

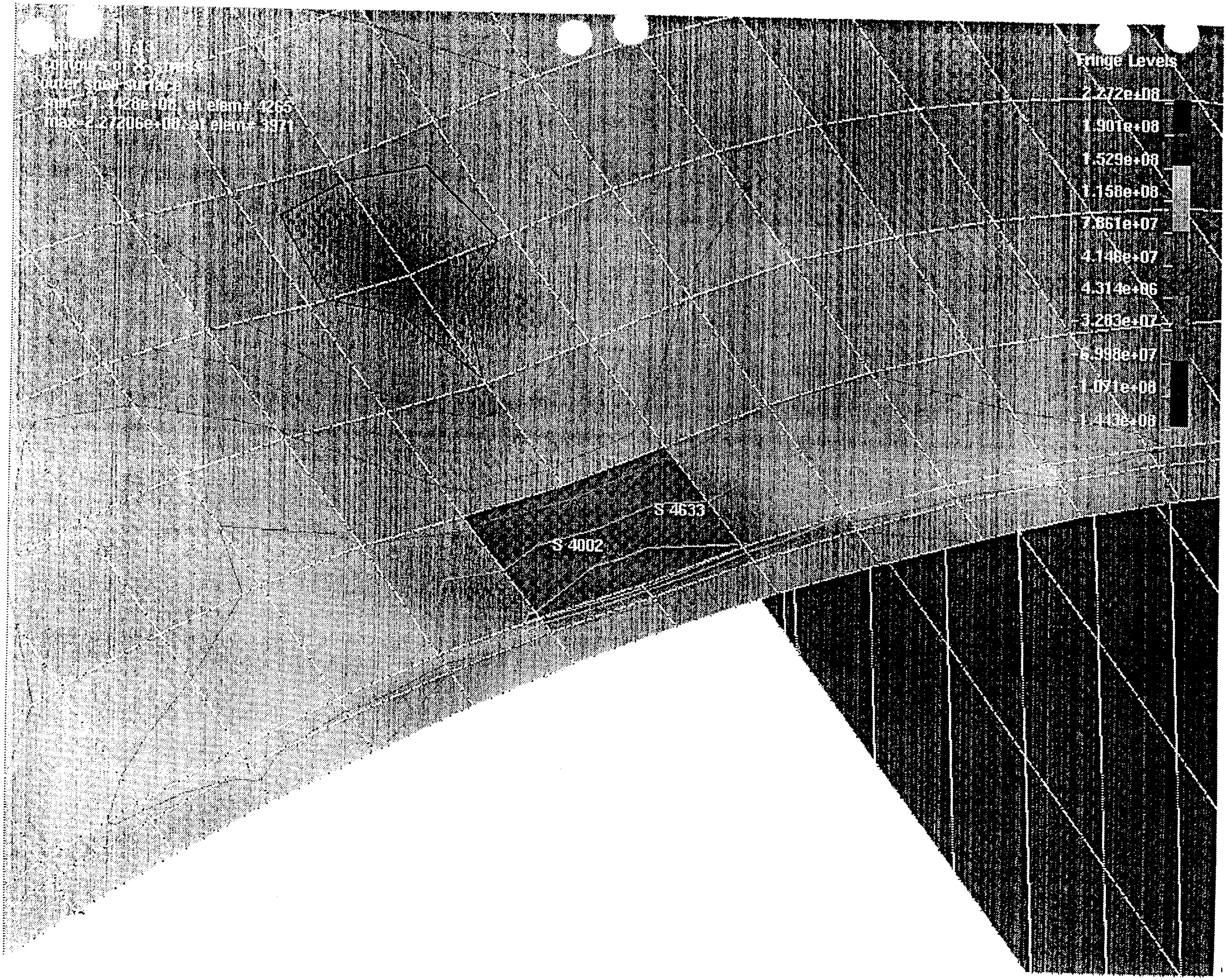


Figure III-8. Elements of Maximum Residual Stress (6-MT rock fall)

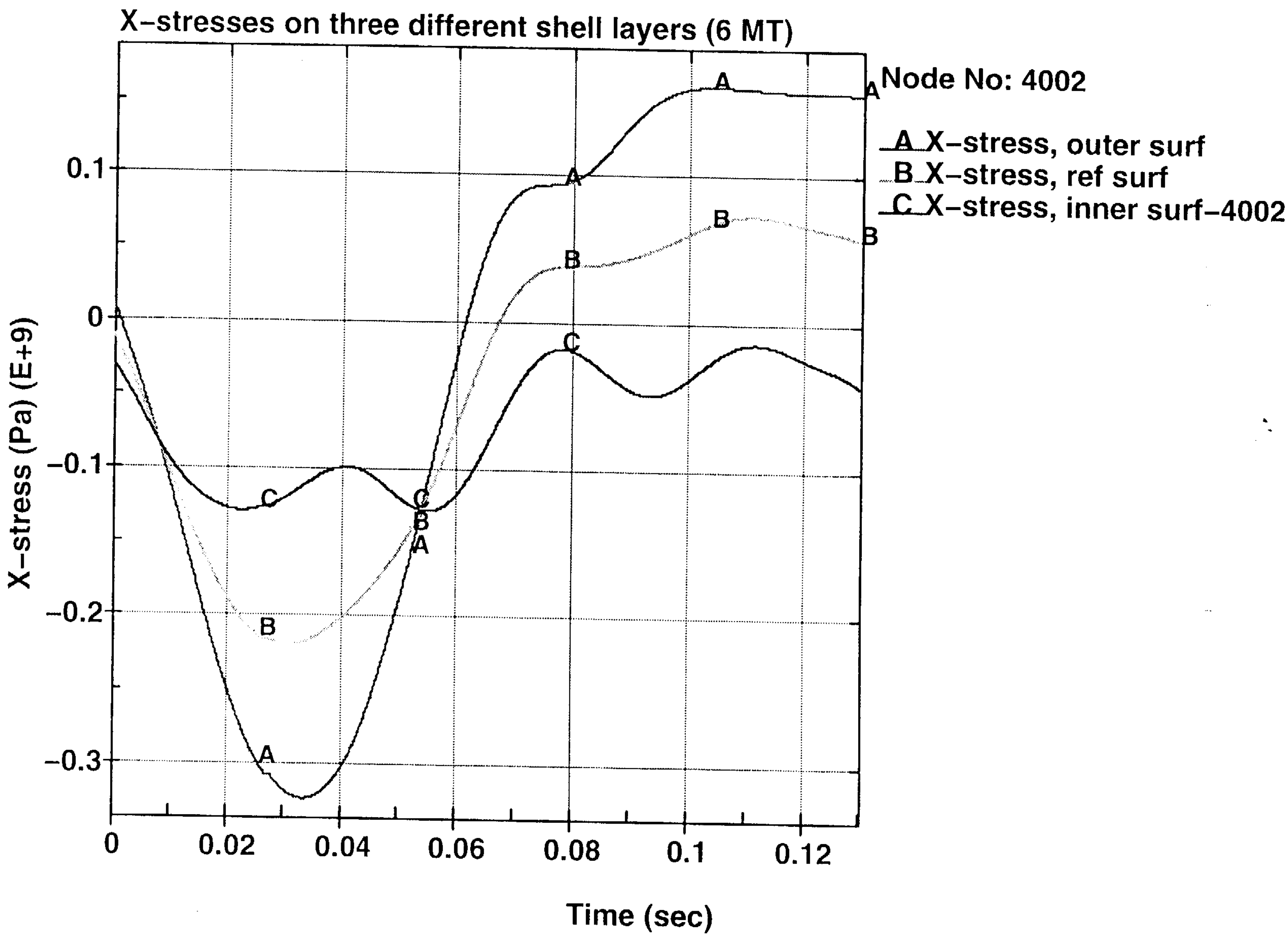


Figure III-9. Time-History for the Maximum Residual Stress (6-MT rock fall)

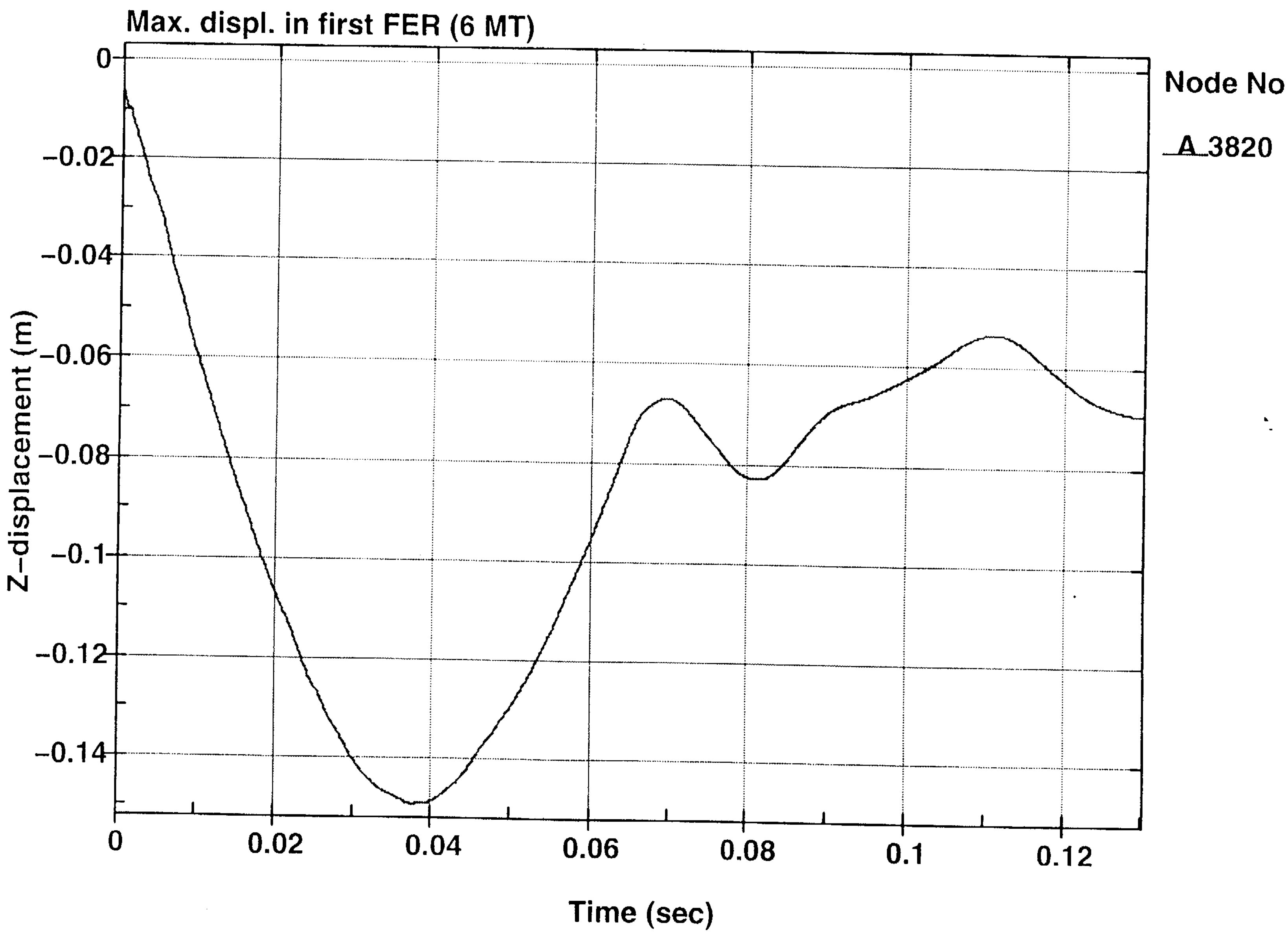


Figure III-10. Maximum Displacement Time-History (6-MT rock fall)

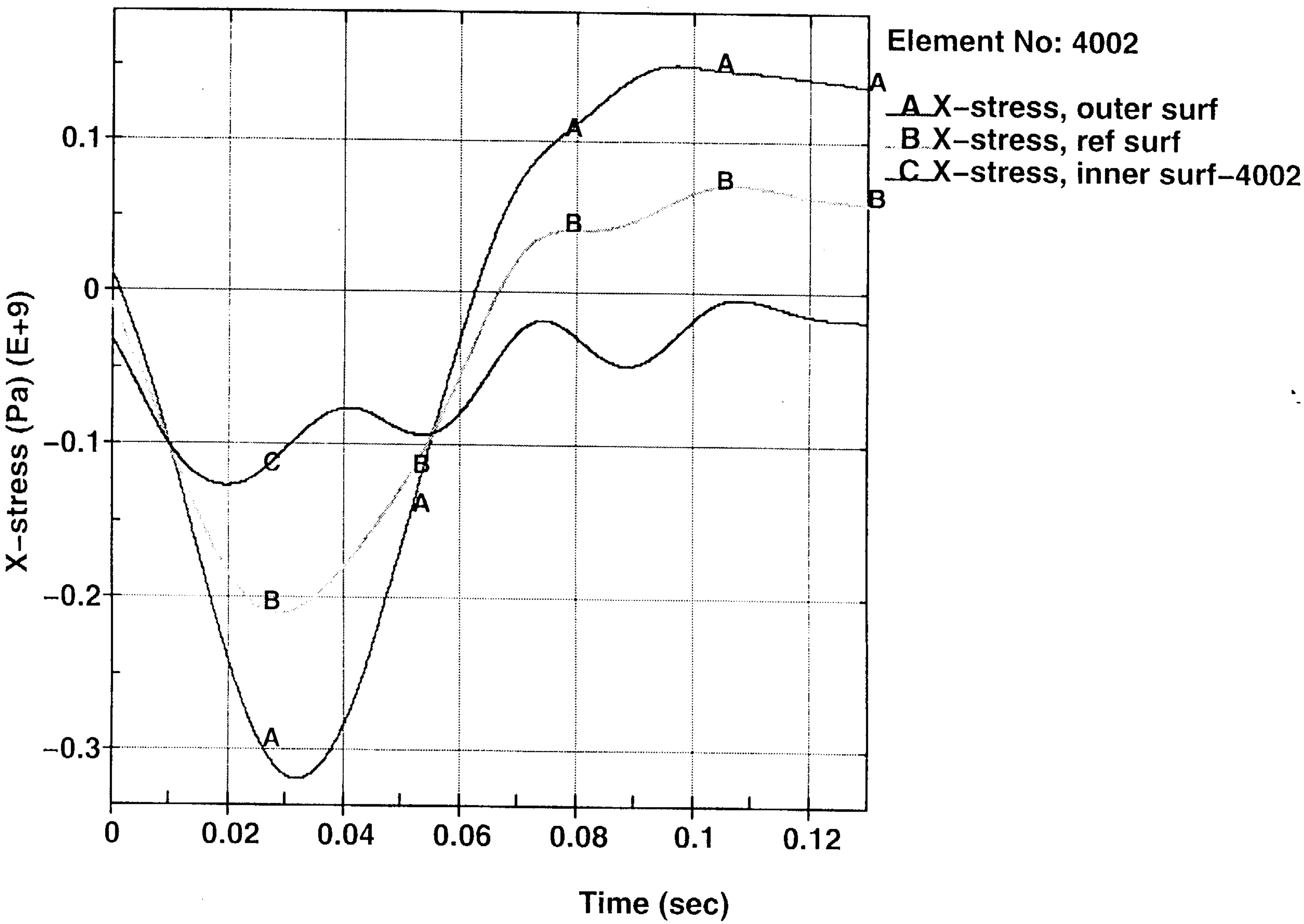


Figure III-11. Time-History for the Maximum Residual Stress (8-MT rock fall, failure location #1)

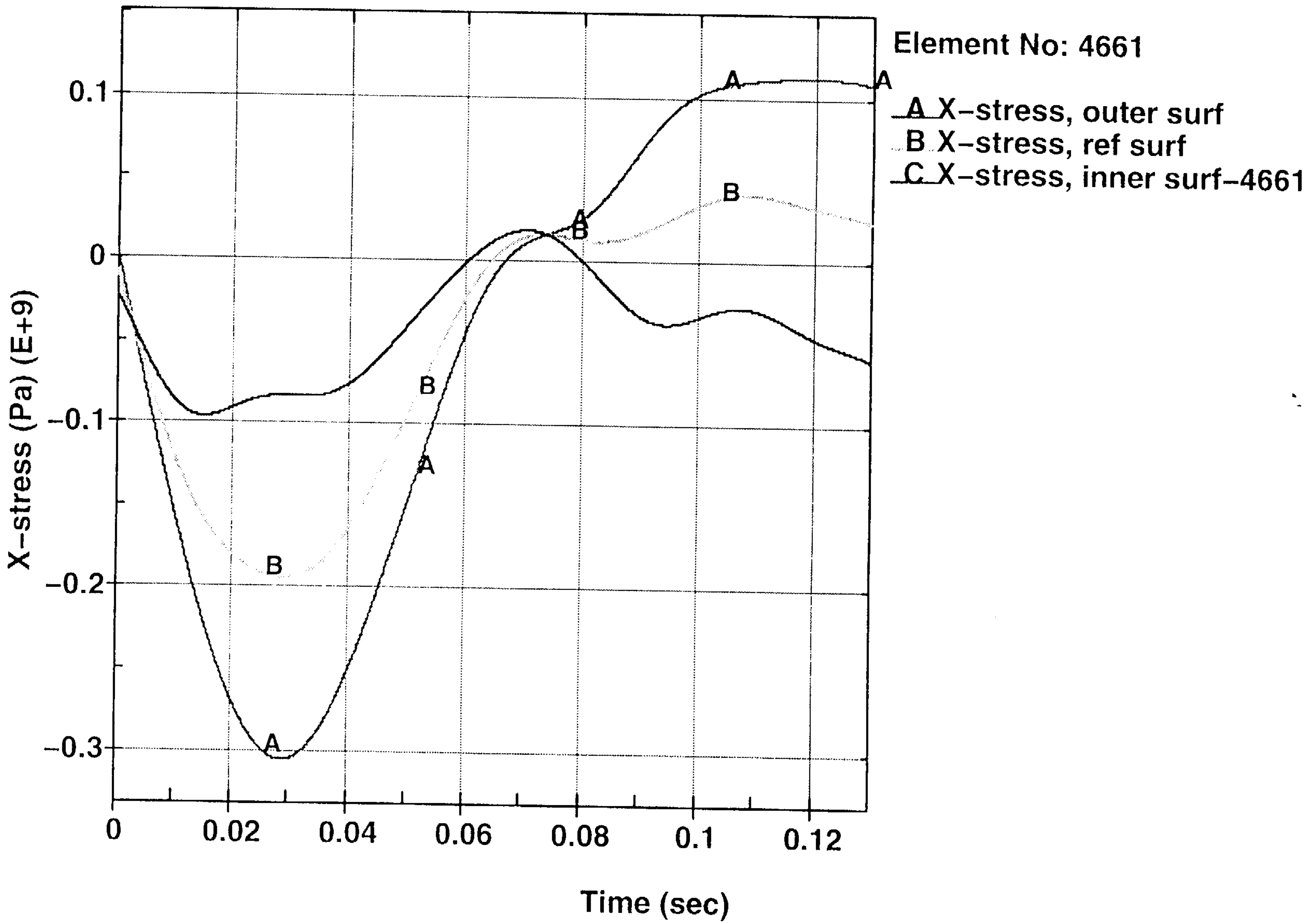


Figure III-12. Time-History for the Maximum Residual Stress (8-MT rock fall, failure location #2)

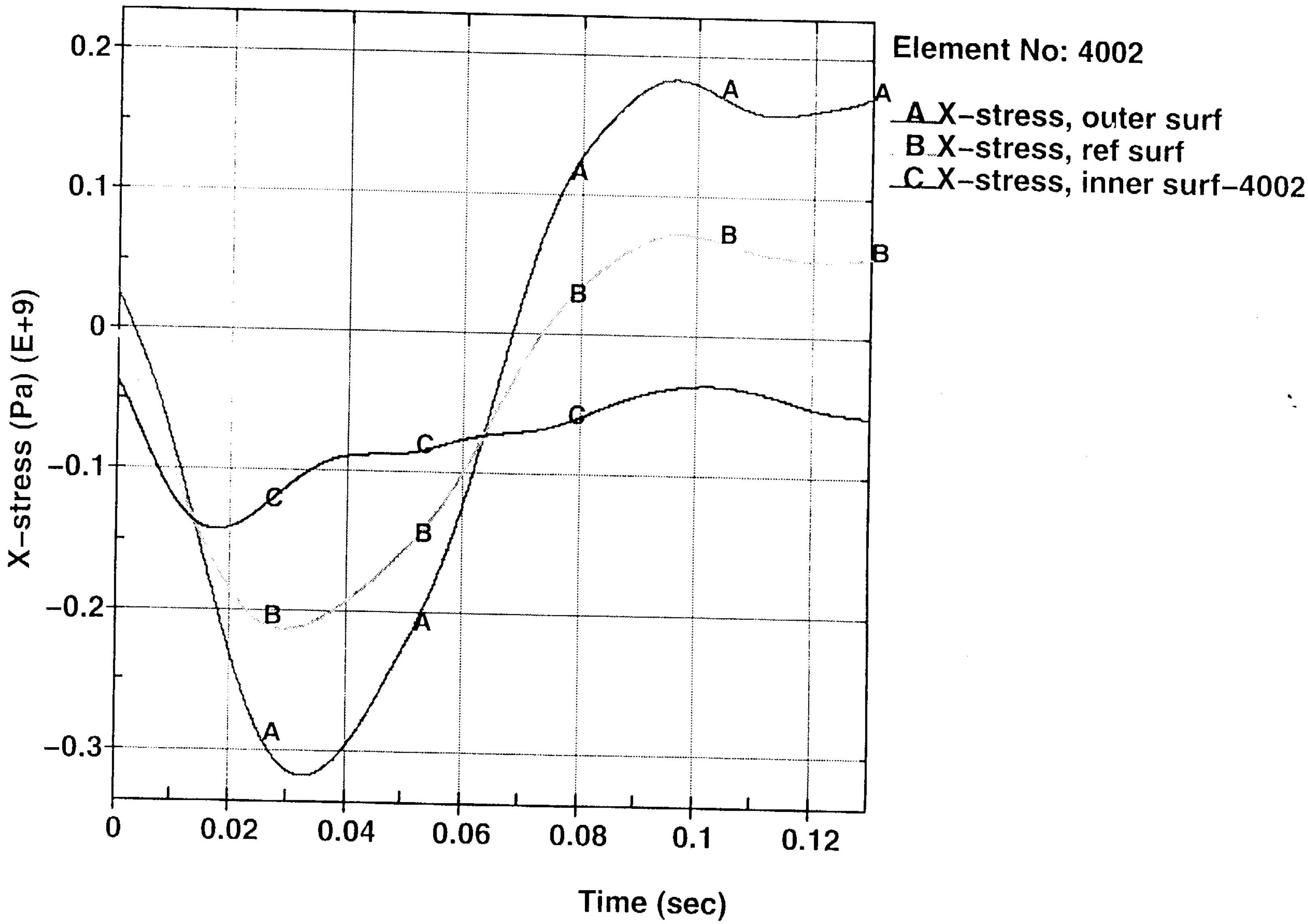


Figure III-13. Time-History for the Maximum Residual Stress (52-MT rock fall)

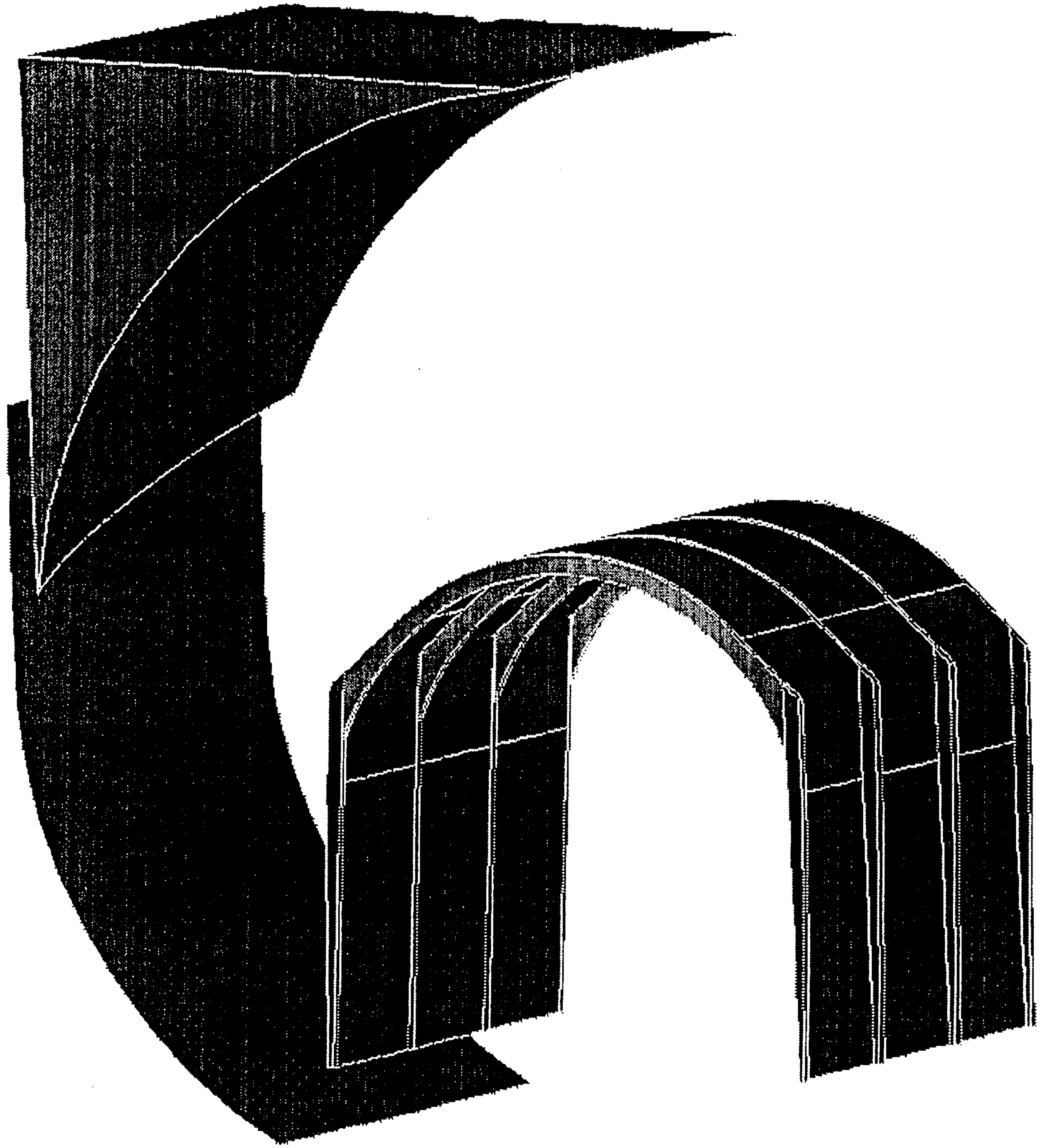


Figure III-14. Off-center Rock Fall on Drip Shield - Finite Element Representation

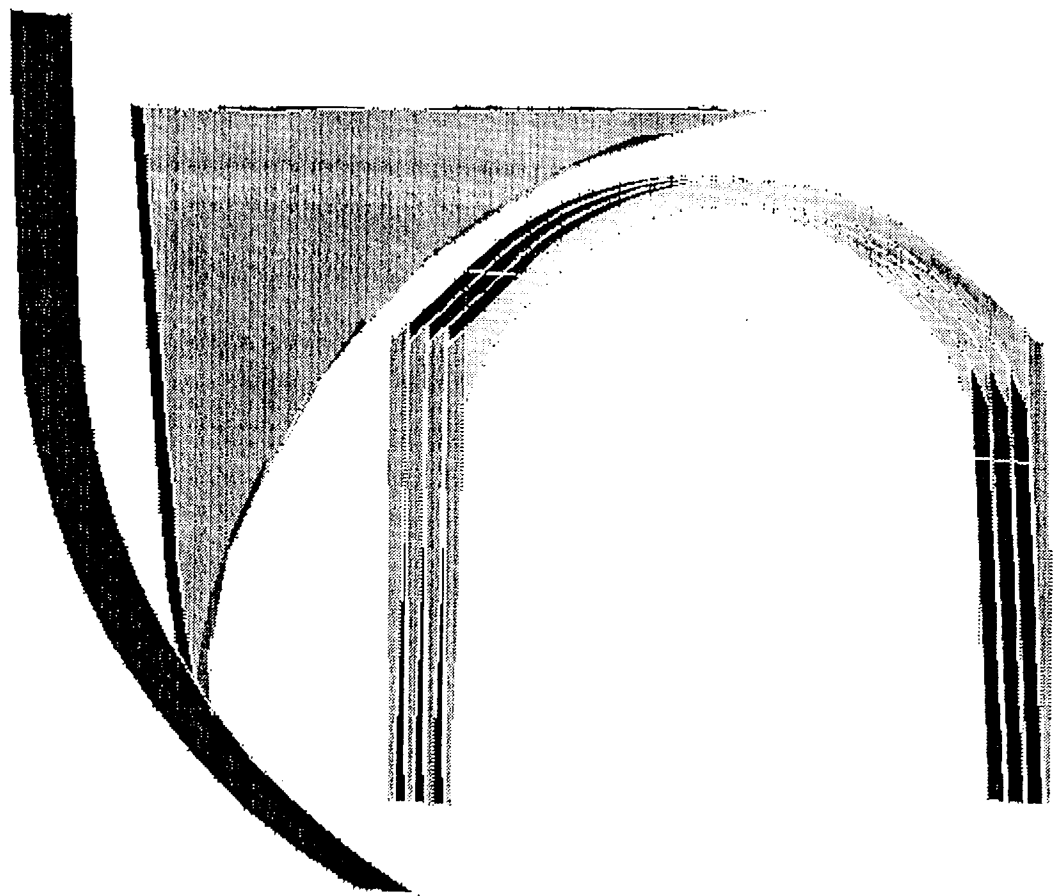


Figure III-15. Displacement Plot after Off-center Rock Fall on Drip Shield

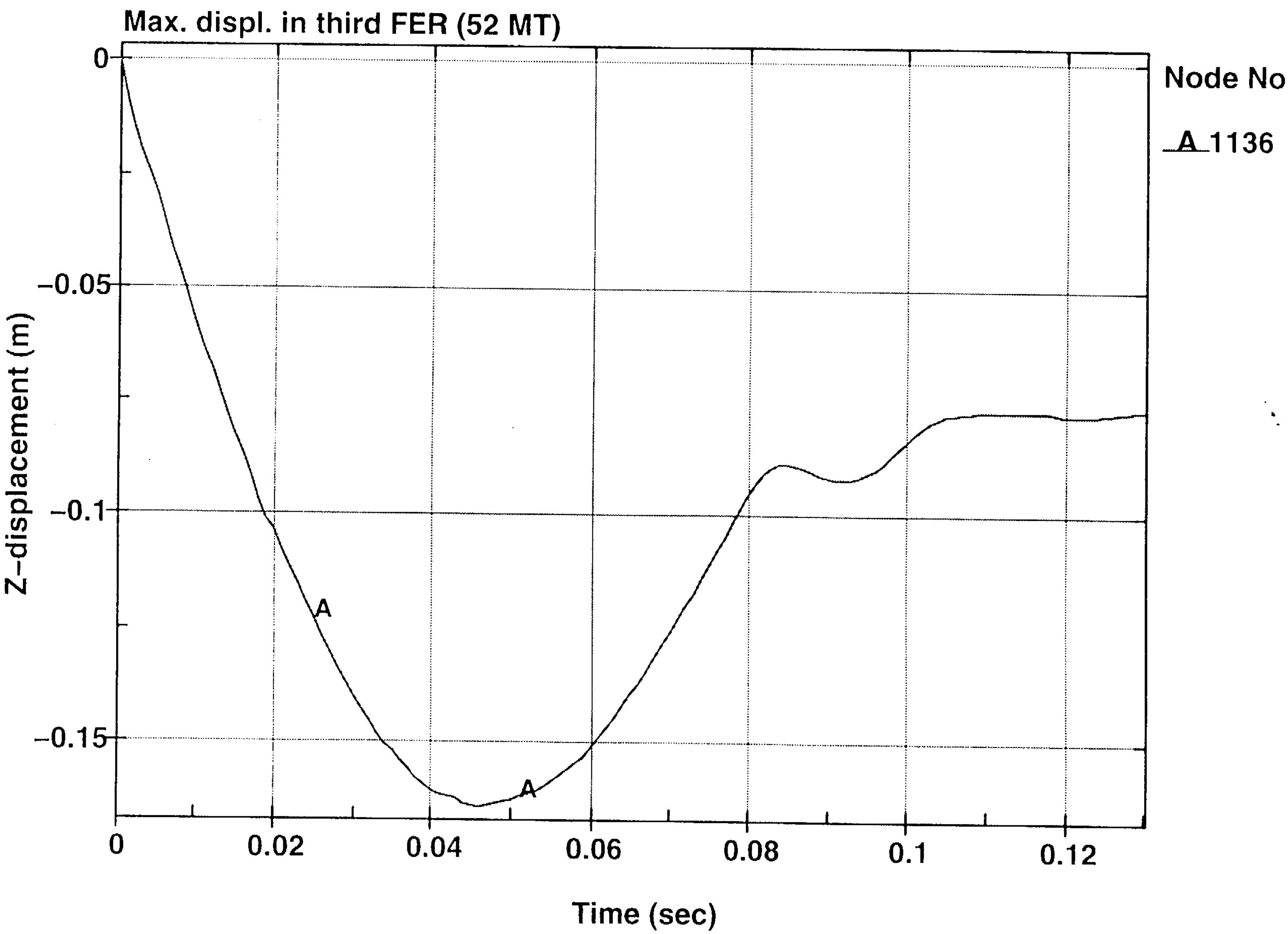


Figure III-16. Maximum Displacement Time-History (52-MT rock fall on drip shield with 200-mm increased side-wall height)

dynaplot
Max. displ. in third FER (52 MT)
Time (sec)
Z-displacement (m)
Node No
1 132
1136

0.0000000000e+00	0.0000000000e+00
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1.9989961293e-03	-1.4155387878e-02
2.9997411184e-03	-1.9801378250e-02
3.9996150881e-03	-2.4864673615e-02
4.9991868436e-03	-2.9292583466e-02
5.9993937612e-03	-3.5038232803e-02
6.9993450306e-03	-4.1092872620e-02
7.9996548593e-03	-4.6679973602e-02
8.9998096228e-03	-5.2273035049e-02
9.9993031472e-03	-5.7443380356e-02
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1.1999260634e-02	-6.7590475082e-02
1.2999928556e-02	-7.2500705719e-02
1.3999371789e-02	-7.7116012573e-02
1.4999853447e-02	-8.1644773483e-02
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4.2999908328e-02	-1.6222357750e-01
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7.4999473989e-02	-1.1065626144e-01
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7.7999792993e-02	-1.0113644600e-01
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7.9998955131e-02	-9.5221996307e-02
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8.1999167800e-02	-9.0359687805e-02
8.2999274135e-02	-8.9067459106e-02
8.3999380469e-02	-8.8393211365e-02
8.4999486804e-02	-8.8197469711e-02
8.5999593139e-02	-8.8412046432e-02
8.6999699473e-02	-8.8932275772e-02
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8.9998967946e-02	-9.1224670410e-02
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    1.1599987000e-01    -7.6610565186e-02
    1.1699997634e-01    -7.6620578766e-02
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    1.1999924481e-01    -7.7219486237e-02
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    1.2199945748e-01    -7.7409982681e-02
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