GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

May 26, 1993

Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Review Schedule - **Sample Pipe Break Analysis Report and Appendix 3L Modification (Replacement)**

Dear Chet:

Enclosed are replacements to SSAR markups of new Appendix 3L and to the report GE-NE-123-E070-0493 "Sample Analysis for the Effect of Postulated Pipe Break ABWR Main Steam Piping" provided in my May 18, 1993 letter.

Please provide a copy of this transmittal to Shou Hou.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Maryann Herzog (GE)
Norman Fletcher (DOE)

JF93-160

020016

D050 1/1

3X.4 PIPE RUPTURE EVALUATION

3X.4.1 GENERAL APPROACH

There are several analytical approaches that may be used in analyzing the pipe/pipe whip restraint system for the effects of pipe rupture. This procedures defines two acceptable approaches.

(1) **Dynamic Time-History Analysis With Simplified Model:** A dynamic time history analysis of a portion of a piping system may be performed in lieu of a complete system analysis when it can be shown to be conservative by test data or by comparison with a more complete system analysis. For example, in those cases where pipe stresses in the containment penetration region need not be calculated, it is acceptable to model only a portion of the piping system as a simple cantilever with fixed or pinned end or as a beam with fixed ends.

When a circumferential break is postulated, the pipe system is modeled as a simple cantilever, the thrust load is applied opposite the fixed (or pinned) end and the pipe whip restraint acts between the fixed end and thrust load. It is then assumed that all deflection of the pipe is in one plane. As the pipe moves a resisting bending moment in the pipe is created and later a restraining force at the pipe whip restraint. Pipe movement stops when the resisting moments about the fixed (or pinned) end exceed the applied thrust moment.

When a longitudinal break is postulated, the pipe system has both ends supported. To analyze this case, two simplifications are made to allow the use of the cantilever model described above. First, an equivalent point mass is assumed to exist at D (See Fig 5-4) instead of pipe length DE. The inertia characteristics of this mass, as it rotates about point B, are calculated to be identical to those of pipe length DE, as it rotates about point E. Second, an equivalent resisting force is calculated (from the bending moment-angular deflection relationships for end DE) for any deflection for the case of a built-in end. This equivalent force is subtracted from the applied thrust force when calculating the net energy.

See Figures 5-2, 5-3 and 5-4 for the models described above.

(2) **Dynamic Time-History Analysis with Detailed Piping Model.** In many cases it is necessary to calculate stresses in the ruptured pipe at locations remote from the pipe whip restraint location. For example, the pipe in the containment penetration area must meet the limits of SRP 3.6.2. In these cases it is required the ruptured piping, the pipe supports, and the pipe whip restraints be modeled in sufficient detail to reflect its dynamic characteristics. A time-history analysis using the fluid forcing functions at the point of rupture and the fluid forcing functions of each pipe segment is performed to determine deflections, strains, loads to structure and equipment and pipe stresses.

3X.4.2 PROCEDURE FOR DYNAMIC TIME-HISTORY ANALYSIS WITH SIMPLIFIED MODEL.

3X.4.2.1 Modeling of Piping System:

INSERT 3L.4.2.1 a

~~For most piping systems, all required information on their response to a postulated pipe rupture can be determined by modeling a portion of the piping system as a cantilever with either a fixed or pinned end, as shown in Figures 5-2, 5-3 and 5-4, based on the piping configuration.~~ The pipe whip restraint is modeled as two components acting in series; the restraint itself and the structure to which the restraint is attached. The restraint and piping behave as determined by an experimentally or analytically determined force-deflection relationship. The structure deflects as a simple linear spring of representative spring constant.

INSERT 3L.4.2.1 a

For many piping systems, all required information on their response to a postulated pipe rupture can be determined by modeling a portion of the piping system as a cantilever with either a fixed or pinned end. The fixed end model, as shown in Figure 5-2, is used for piping systems where the stiffness of the piping segment located between A and B is such that the slope of the pipe length, BD, at B, will be approximately zero. The pinned end model, as shown in Figure 5-3, is used for piping systems where the slope of the pipe length, BD, at B, is much greater than zero. The pinned end model is also used whenever it is not clear that the pipe end is fixed.

A simplified cantilever model may also be used for a postulated longitudinal break in a pipe supported at both ends, as shown in Figure 5-4. The pipe can have both ends fixed or have a pinned end at B and a fixed end at E, as shown in Figure 5-4. Section 3L.4.1(l) discusses the simplification techniques used to allow the use of a cantilever model. A fixed end is used when the rotational stiffness of the piping at that location is such that the slope of the pipe at that end is approximately zero. A pinned end is used when the pipe slope at that end is much greater than zero. If it is not clear whether an end is fixed or pinned, the end condition giving more conservative results should be assumed.

SIMPLIFIED PIPING MODELS

Replace with the following two pages

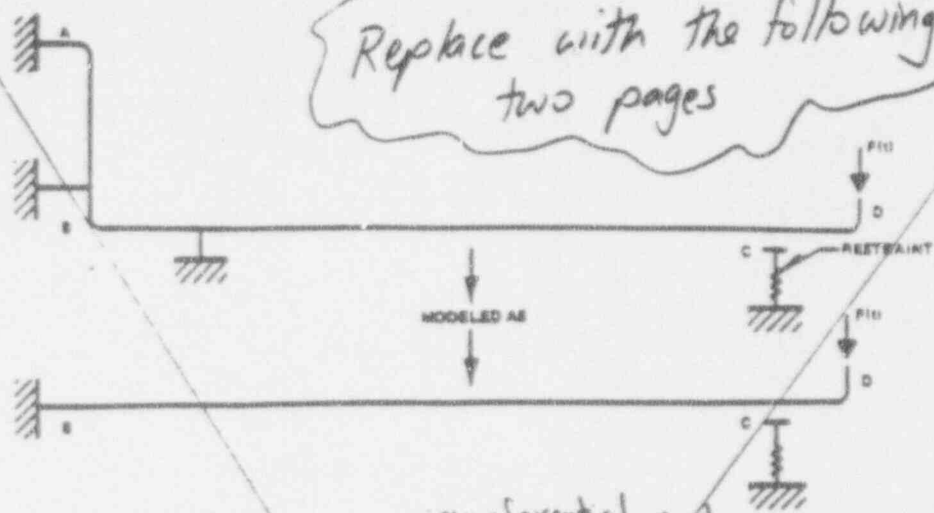


Figure 6-2. Representation of circumferential rupture using Built-in Pipe

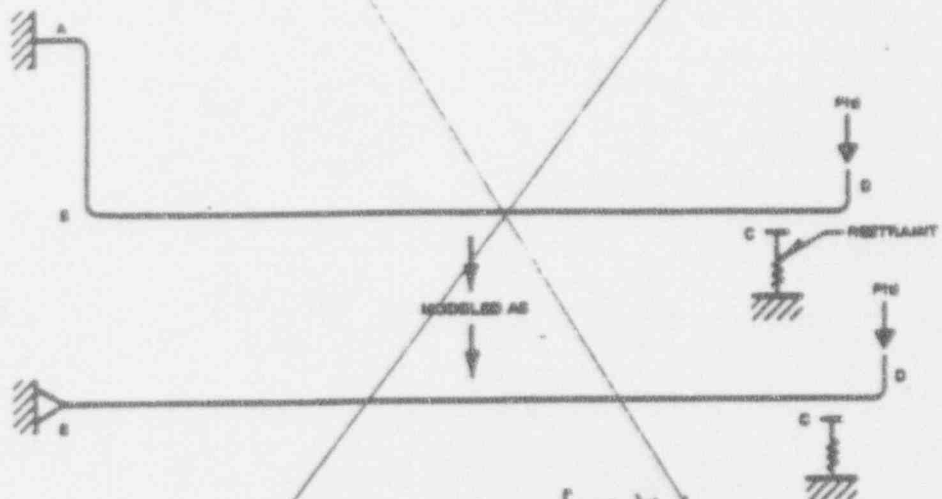


Figure 6-3. Representation of circumferential rupture using Pinned-End Pipe

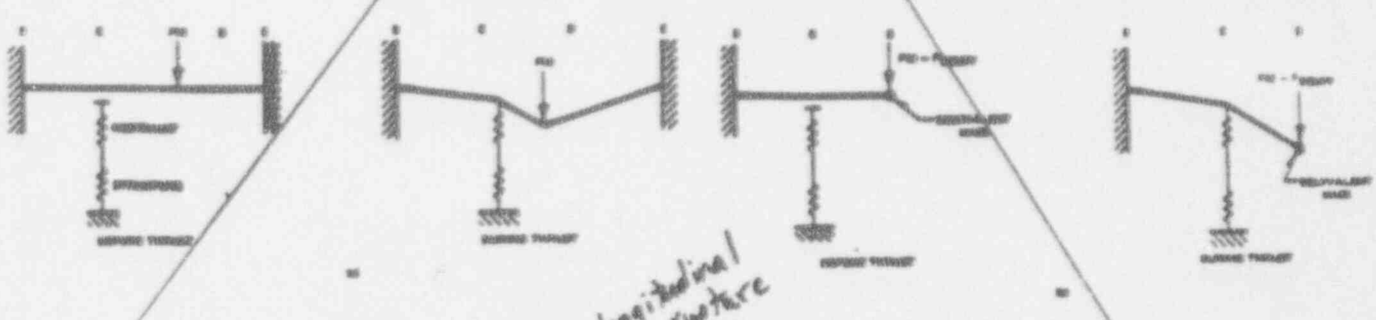


Figure 6-4. Representation of longitudinal rupture Pipe With Both Ends Built In

Simplified Piping Models

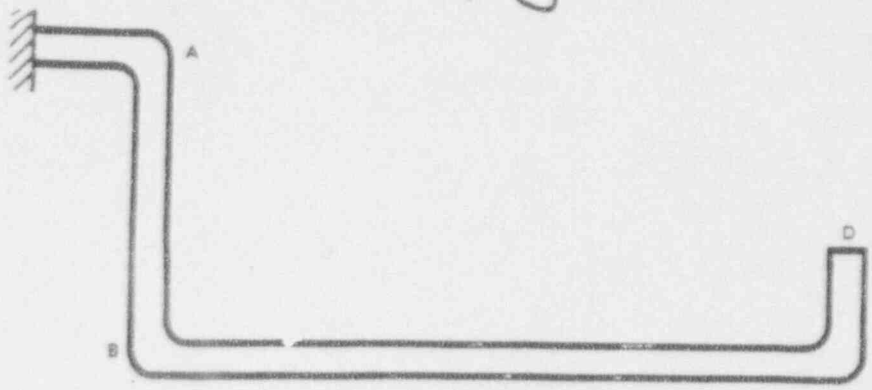


Figure 5-1. Generic Representation of Pipe

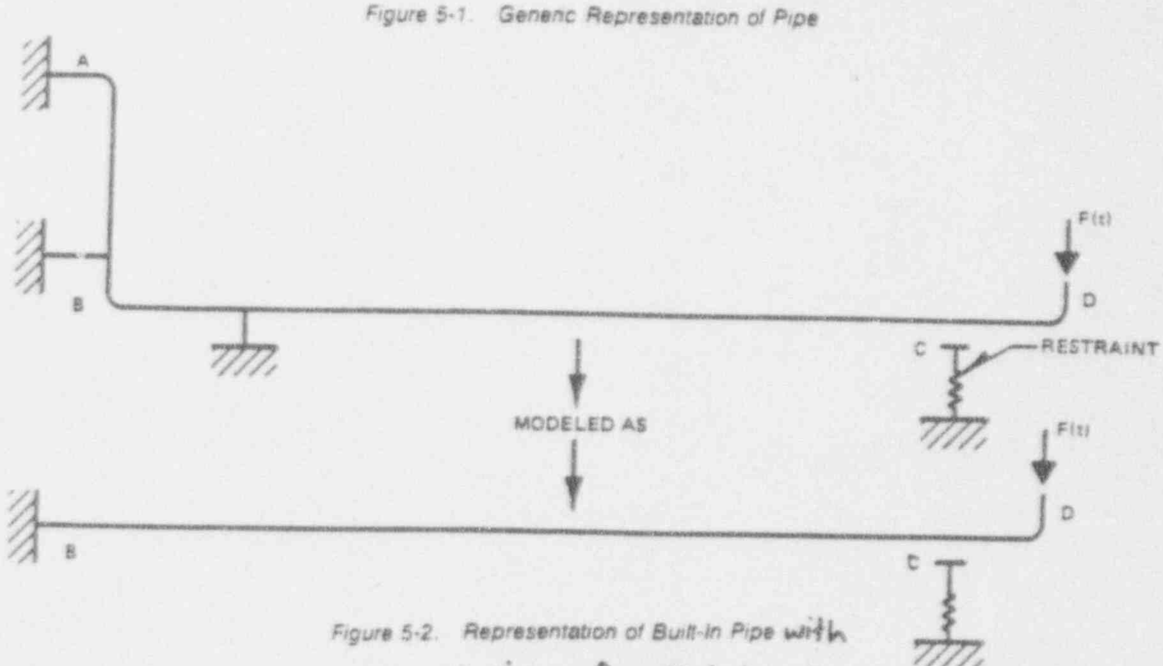


Figure 5-2. Representation of Built-In Pipe with a circumferential break

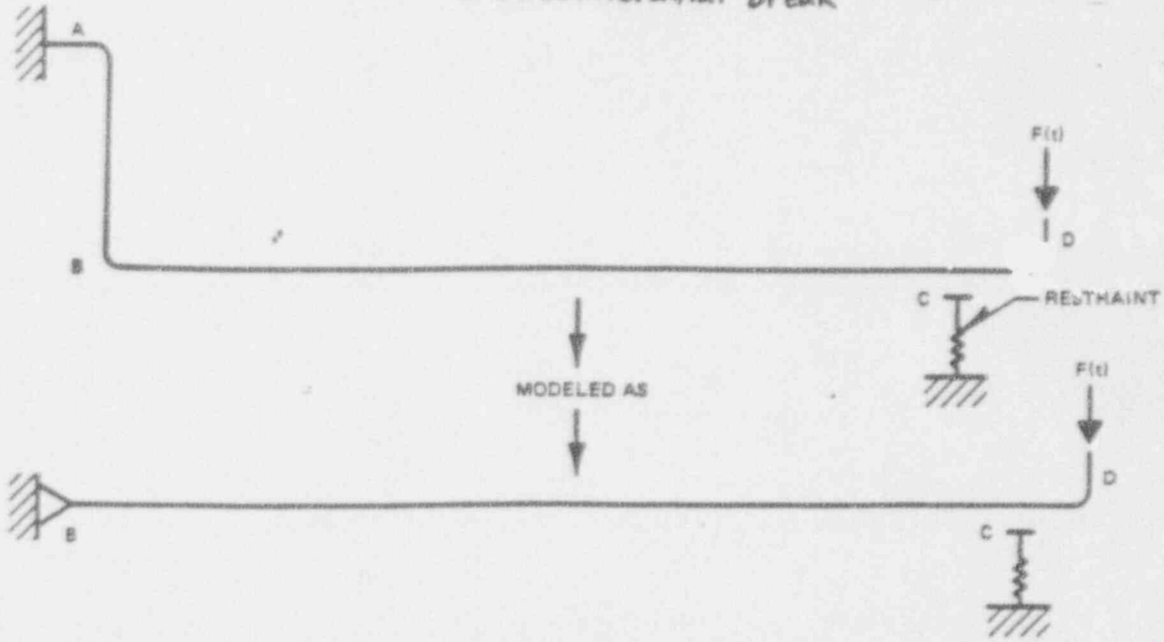
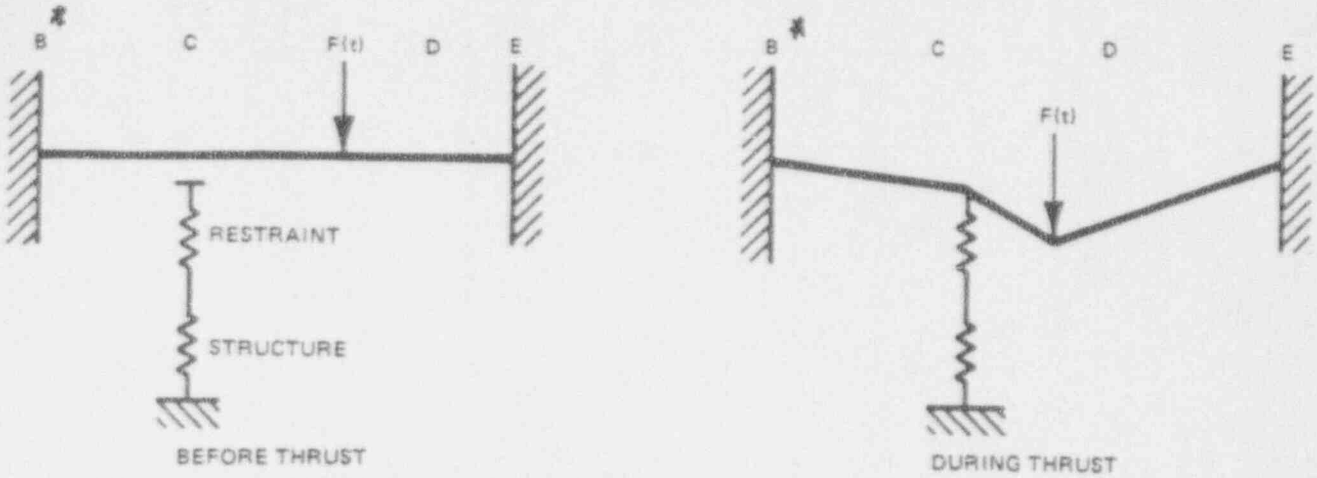


Figure 5-3. Representation of Pinned-End Pipe with a circumferential break

SIMPLIFIED PIPING MODELS



* The end at B can be fixed or pinned.

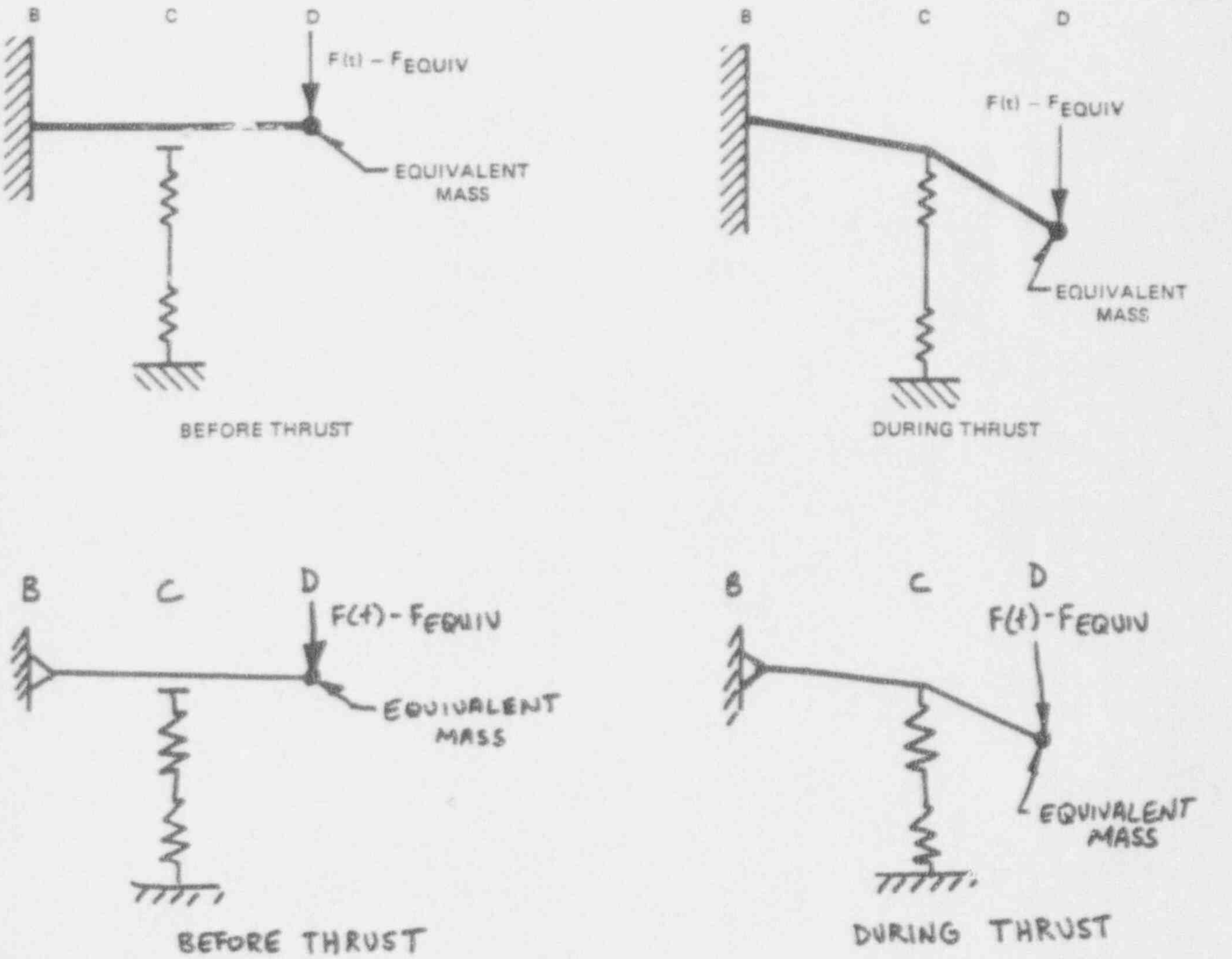


Figure 5-4 Representation of Pipe with both ends supported with a longitudinal break

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SAMPLE ANALYSIS FOR THE EFFECT OF POSTULATED PIPE BREAK ABWR MAIN STEAM PIPING

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9305210255 55pp.

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ABSTRACT

This report documents the results of a pipe break analysis performed at the request of the NRC for a GE Advanced Boiling Water Reactor (ABWR) main steam line following a postulated circumferential break in the main steam line where it connects to the reactor pressure vessel nozzle. This report supports the ABWR Standard Safety Analysis Report (SSAR) and supplements Appendix "3L" of the SSAR, "Procedure for Evaluation of Postulated Ruptures in High Energy Pipes."

This pipe break analysis illustrates GE's pipe break analysis methods. It also addresses the specific NRC questions regarding the GE methodology raised during the NRC audit of the SSAR. These NRC concerns are listed below:

(1) Document GE procedure for calculating the forcing functions for line segments of a ruptured pipe and for the thrust force at break location.

(2) Document GE procedure for performing the nonlinear time-history analysis of the ruptured pipe using the ANSYS computer program.

(3) Show compliance with ASME III, Equation (9) stress limit set by SRP 3.6.2 (MEB 3-1) for the piping between the containment isolation valves following a postulated pipe rupture.

(4) Provide justification for the 0.001 time step used by GE in the ANSYS time-history analysis.

(5) Show that GE methodology based on the simplifying assumption of no rotation of the thrust force at the pipe break is valid for predicting stresses in the containment piping.

(6) Show the use of the GE program, PDA, provides a satisfactory basis for selecting the size of the pipe whip restraint.

This report documents the following results of the sample analyses:

(1) The postulated pipe break location that results in the highest stresses inside the containment is at the connection of the main steam pipe to RPV nozzle.

(2) The ASME III, Equation (9) stresses in the containment area of the main steam pipe following a pipe rupture at the RPV nozzle are below the SRP 3.6.2 limit of 2.25 Sm, even with the following conservative assumptions: (a) the restraining effects of snubbers on main steam line are not considered; (b) the restraining effects of SRV branch lines are not considered; (c) the lower pressure in main steam pipe immediately following a pipe rupture is not considered.

(3) Decreasing the time step from 0.001 seconds to 0.0005 seconds has insignificant effect on results, proving convergence of the ANSYS solution with the GE analytical assumption of 0.001 seconds.

(4) The maximum pipe stress in the containment area does not increase due to rotation of the thrust force at the pipe rupture location. This confirms that the GE nonlinear analysis based on no rotation of the thrust force provides accurate results.

(5) The GE computer program, PDA, provides a satisfactory basis for selecting the size of the pipe whip restraints.

1.0 INTRODUCTION

This report presents the results of an analysis performed to evaluate the effects of a postulated circumferential pipe break at the connection of the ABWR main steam pipe to the Reactor Pressure Vessel (RPV) nozzle on the pipe stresses between the inboard and the outboard Main Steam Isolation Valves (MSIV). This postulated break was chosen for analysis because this break will create the maximum stress in the pipe between the containment isolation valves, since the M.S. pipe has the largest diameter (i.e. 28") compared with SRVDL's 10" and Feedwater's 12" size.

The analysis for the postulated main steam pipe break analysis presented in this report includes forcing function calculations and the nonlinear dynamic analysis.

The result of the analysis show that the stresses in the pipe between the containment isolation valves meet SRP 3.6.2 stress limit (2.25Sm).

2.0 PIPE BREAK FORCING FUNCTION ANALYSIS

2.1 Description

The steam flows in the main steam line from the RPV to the turbine during normal operation. When a postulated pipe break occurs at the RPV nozzle safe end or at the first elbow down stream of the RPV nozzle, the steam flow in the main steam line suddenly reverses and flows back to the break location. A decompression wave starts at the break location and propagates toward the turbine, creating force time histories on each main steam pipe segment.

In order to calculate the force time histories on each pipe segment, a modification in the Turbine Stop Valve Closure Force (TSFOR) calculation method is used. TSFOR is an Engineering Computer Program (ECP) used to calculate the pipe segment force time histories due to turbine stop valve closure event. The program is described in NEDE-23789. The boundary condition of this program is modified to calculate the pipe segment force time histories due to the postulated pipe break of the main steam pipe at the RPV nozzle.

Modifications to TSFOR and the procedures to calculate the force time histories are described in the following sections.

2.2 Generation of Main Steam Pipe Break Input Data

The back flow of steam through the main steam piping can be computed by applying the break boundary condition at the main steam RPV nozzle as shown below (Reference 1).

p/p0 = (2/(K+1))**(2K/K-1) = 0.30

<j>/C0 = (2/(K+1)) = 0.87

<rho>/(rho 0) = (2/(K+1))**(2/(K-1)) = 0.40

where,

p = steam pressure at the break exit, psia

p0 = stagnation pressure, psia

<j> = discharge velocity at the break exit, ft/sec

C0 = sonic velocity at the stagnation condition

rho = steam density at the exit, lbm/ft^3

rho 0 = stagnation density, lbm/ft^3

K = gas constant, 1.3 for saturated steam.

An executable program file, called MS-BRK, has been set up to calculate the pipe segment forces due to the postulated break. The method of analysis is the same as described in the ANS-58.2, Appendix A.

The MS-BRK program input is setup exactly the same as the TSFOR input which is described in NEDE-23789, Reference 4. The pipe break boundary condition computer input is calculated as described above. The input includes pipe inside diameter, flow rate, pressure, specific volume, segment length, the friction factor and the gas constant.

The procedure defined in this paragraph for a main steam pipe break is not applicable for a break in the feedwater pipe. For piping systems containing water, force time histories due to a postulated pipe break are calculated using the methodologies provided in Section 6.2 and Appendix B of ANS 58.2 (Reference 2).

2.3 Calculation of Input Force Time Histories at the Break Location

Let the length of the first pipe segment with the break be L ft. The time for the pressure wave to travel through the first pipe segment is

t_1 = L/C, where C = sonic velocity in steam.
t_1 = 0.0038 seconds

For $t < t_1$ $F = PA = 533,671$ lbs.
For $t \geq t_1$ $F = C_T PA = 373,570$ lbs.

Where $P = 1,070$ psi
$A = 498.4\ in^2$
$C_T = 0.7$

The blowdown force time history shown in Figure A-1 is input at the pipe break location.

The determination of the steady state thrust coefficient, C_T, is dependent on the fluid and the friction loss terms.

$fL/D = 2.5$ (Based on representative values for previous BWR's

$C_T = 0.7$ (From Figure B-3 ANS 58.2, Appendix B, Reference 2)

The fL/D value includes the friction from the pipe break to the turbine, plus the friction through MSIV's and through the other three pipes from RPV. The overall fL/D is > 2.5.

2.4 Analysis Steps

The following steps can be used to generate the pipe segment force time histories due to main steam pipe break at the nozzle safe-end.

1) Prepare the TSFOR01 input deck.
   Create a PERM file to save force time histories.

2) Select the following file to run instead of TSFOR01 :

   $$ SELECT FS0027/HLH/MS-BRK-R

3) Down load the time histories to PC (ASCII).

4) Run MS-BRK-R to convert the force time histories to ANSYS input format.

5) Prepare the ANSYS input model.

6) RUN ANSYS.

Details of Steps 3 through 6 are included in ANSYS Analysis Procedures.

2.5 Forcing Function Calculation Results

The nodes to which the forces for each pipe segment are applied are defined in the table below. Bend radius of elbows is not considered in segment definition when calculating segment forces. Where elbows exist, the segment extends to the tangent intersection point. This approximation has proved valid when calculating segment forces due to other thermo-hydraulic loads such as turbine stop valve closure and safety relief valve discharge.

Segment No.	Nodes
1st	5
2nd	12
3rd	16
4th	39
5th	43
6th	Outside Containment
7th	Outside Containment
8th	Outside Containment

Examples of the output plots are shown in the following figures:

Figure A-1 : Force time history for broken pipe segment
Figure A-2 : Force time history for 2nd pipe segment
Figure A-3 : Force time history for 3rd pipe segment
Figure A-4 : Force time history for 4th pipe segment
Figure A-5 : Force time history for 5th pipe segment
Figure A-6 : Force time history for 6th pipe segment
Figure A-7 : Force time history for 7th pipe segment
Figure A-8 : Force time history for 8th pipe segment

3.0 ANSYS NON-LINEAR ANALYSIS

3.1 Analysis Model

The pipe break non-linear time history analysis can be performed by ANSYS program. The piping model is shown in Figure 1.

The selection of elements and nodes is the same as for the seismic and dynamic analysis of the pipe. The main steam guide located inside the drywell, which provides only lateral restraint, in the horizontal direction and in the vertical direction, is included in the model and is modeled as two spring elements. Snubbers, seismic restraints and branch piping are excluded from the model. This model simplification is generally conservative when estimating displacements of the piping system since they would act as restraints to displacements.

In some cases a seismic support could be oriented such that following a pipe break, the restraint provided by the seismic support could result in higher piping stresses. Therefore, the engineer should first review the seismic support design to determine whether seismic supports should be included in the ANSYS analysis model.

The selection of the input are described as follows:

Analysis : KAN=4
Plastic pipe : use STIF 20
Plastic elbow: use STIF 60
Pipe whip restraint : use STIF 39

3.2 Analysis Time Step

When performing the non-linear analysis, it is necessary to show the analysis time step is adequate to result in convergence. In order to show that the analysis time step of 0.001 seconds is adequate, an analysis with time step of 0.0005 seconds has been performed. The results of the analysis are plotted in the figures listed below. Comparisons of the results between 0.001 seconds and 0.0005 seconds time step show that the differences are less than 3%. Therefore, time step of 0.001 seconds can be used in the analysis.

3.3 Analysis Results

Plots of the calculated loads and displacements are provided in the figures listed below.

Figure 2: Impact force at the pipe whip restraint. DT=0.001 sec
(max impact=670,000 lb)

Figure 3: Bending moment time histories. DT=0.001 sec. at Elm. 2I, at elbow near break

Figure 4: Displacement time histories. DT=0.001 sec at the break location

Figure 5: Moment time histories at headfitting, (Elm 42J) DT=0.001 sec.

Figure 6: Force time histories at headfitting. (Elm 42J) DT=0.001 sec

Figure 7: Bending moment time histories. DT=0.001 sec at Elm 22J,
before main steam guide

Figure 8: Bending moment time histories. DT=0.001 sec at Elm 42I, near headfitting

Figure 9: Bending moment time histories. DT=0.001 sec. at Elm 38I, 1st elm after MSIV.

Figure 2A: Impact force at the pipe whip restraint. DT=0.0005 sec
(0.7PA=373,600 lb, max impact=670,000 lb)

Figure 3A: Bending moment time histories. DT=0.0005 sec.
at Elm. 2I, at elbow near break

Figure 4A: Displacement time histories. DT=0.0005 sec
at the break location

Figure 5A: Moment time histories at headfitting, (Elm 42J)
DT=0.0005 sec.

Figure 6A: Force time histories at headfitting. (Elm 42J)
DT=0.0005 sec

Figure 7A: Bending moment time histories. DT=0.0005 sec
at Elm 22J, before main steam guide

Figure 8A: Bending moment time histories. DT=0.0005 sec
at Elm 42I, near headfitting

3.4 Discussion of Large Displacement Analyses

Since the analysis was based on the ANSYS option that assumes small displacements of the piping model, it is necessary to confirm the validity of the analysis if large displacements occur. The displacements from the terminal end Main Steam Break Structure (MSBS) analysis (using ANSYS) results show that the largest displacements and rotations occur at the break. These rotations and displacements of the pipe at the break cause a change in the direction of the thrust force at the break. To determine if the effects of this thrust direction change the stresses in the pipe between the isolation valves, GE has performed time history analyses for both the original and displaced positions to confirm the validity of the small displacement assumption in the non-linear time history analysis results.

Two cases of displaced analysis have been performed. In Case 1, the element at the break and the thrust force are rotated. In Case 2, the thrust force and the section of piping between the break location and the first pipe whip restraint are rotated.

The results of the Case 1 analysis are shown in the following figures:

Figure 2B: Impact force at the pipe whip restraint. DT=0.001 sec
(Included rotated blowdown angle)

Figure 4B: Displacement time histories. DT=0.001 sec at the break location
(Included rotated blowdown angle)

Figure 5B: Moment time histories at 42J (headfitting)
(Included rotated blowdown angle)

Figure 6B: Force time histories at 42J (headfitting)
(Included rotated blowdown angle)

Figure 7B: Bending moment time histories. DT=0.001 sec at Elm 22J,
before main steam guide
(Included rotated blowdown angle)

Figure 9B: Bending Moment time histories. DT=.001 sec at Elm 38I, 1st elm after MSIV
(Included rotated blowdown angle).

The results of the Case 2 analysis are shown in the following figures:

Figure 2C: Impact force at the pipe whip restraint. DT=0.001 sec
(Included displaced elbow and broken pipe orientation)

Figure 5C: Moment time histories at 42J (headfitting)
(Included displaced elbow and broken pipe orientation)

Figure 6C: Force time histories at 42J (headfitting)
(Included displaced elbow and broken pipe orientation)

Figure 9C: Bending moment time histories. DT=0.001 sec. at Elm 38I, 1st elm after MSIV.
(Included displaced elbow and broken pipe orientation)

The maximum stresses between the MSIV's do not increase due to the force direction change as result of the large displacements at the break location. This shows that the nonlinear analysis based on design location is acceptable. If the results from Case 1 and Case 2 did not closely agree with the design location, an acceptable alternative would be to use the large displacement option of the ANSYS program.

4.0 STRESS ANALYSIS

4.1 Pipe Data

Pipe = 28" OD x 1.423" t

I = (28^4 - 25.154^4) x 3.1416/64
= 10520 in^4
Z = 751 in^3

Assume break occurs at normal operation. T = 552° F.
Sm = 18,570 psi for SA-350-LF2 (Carbon steel)

Allowable limit = 2.25 Sm
=41780 psi

The maximum bending moment between the MSIV's will be developed about 0.075 second after the break. The decompressing wave travels at 1600 ft/sec. It has traveled a distance of 1600x0.075=120 ft when the maximum moment occurs. Therefore, the pressure between the MSIV at the time when the maximum bending moment is developed will be much less than normal operating pressure of 1050 psi. It is conservative to use 1050 psi to calculate the pressure stress.

Sp = PD/4t
< 1050 x 28/(4x1.423)
= 5165 psi

Weight stress, **Swt** = 1074 psi
Sp + Swt = 6239 psi

4.2 Moment and Stress Comparisons

Comparisons of the bending moments and bending stresses at the head fitting are as follows.

Results 1 = Using normal procedure with time step 0.001 sec.

Results 2 = Study case with time step 0.0005 sec.

Results 3 = Study case with time step 0.001 sec.
Include rotated force angle

Results 4 = Study case with time step 0.001 sec.
(Included displaced elbow and broken pipe orientation)

Moments and stresses at the headfitting:

	Ma (E6)	Mb (E6)	Mc (E6)	Mr (E6)	B2 M/Z psi
Result 1	15.3	15.0	13.3	25.2	33600
Result 2	15.0	15.0	13.3	25.1	33500
Result 3	20.5	4.5	9.0	22.8	30400
Result 4	19.9	13.0	8.0	25.0	33390

The B2 index for a taper transition, B2 = 1.0, is used at the head fitting. This index is from NB-3600. The table above shows the value calculated from the Result 1 is slightly conservative.

From Figure 9, moment time history plots at element 381, the first element after MSIV, the maximum bending are as follows:

Ele 381	Ma (E6)	Mb (E6)	Mc (E6)	Mr (E6)	B2 M/Z psi
Result 1	15.0	13.0	11.5	23.0	30600
Result 4	19.5	8.5	13.0	24.9	33200

This shows that the maximum stress between the isolation valves is at the headfitting for the analysis with the design configuration. The combined stress is as follows:

$$Sp + Sw + S\ break = 5165 + 1074 + 33600$$
$$= 39{,}839\ psi$$

Allowable stress = 41,780 psi

Stress ratio = 39839/41780 = 0.954

All the stresses are within the allowable limit of 2.25 Sm.

4.3 Pipe Whip Restraint Loads as Comparison With PDA Results

The maximum pipe whip restraint loads calculated are as follows:

		Figure No.
ANSYS Result 1	670,000 lb	2
ANSYS Result 2	670,000 lb	2A
ANSYS Result 3	650,000 lb	2B
ANSYS Result 4	640,000 lb	2C
PDA Result	666,727 lb	

The above results show that the PDA calculated consistent result with ANSYS output. The PDA analysis is shown in Appendix A.

5.0 CONCLUSIONS

1) The maximum combined stress in the pipe between the containment isolation valves is 39839 psi. This is below 2.25 Sm allowable limit (i.e. 41780 psi) as specified in SRP 3.6.2.

2) The maximum pipe stresses between the MSIV's do not increase due to the force direction change as result of the displacements at the break location. This shows that the nonlinear analysis based on design location is acceptable.

3) Calculated pipe whip restraint load by ANSYS is 670,000 lb. The PDA calculated peak restraint load is 666,727 lb. Both results are comparable.

Either PDA or ANSYS program is acceptable to be used for sizing pipe whip restraints.

5.1 Conservatism in the Analysis

Summary of conservative assumptions are as follows:

a) The main steam pipe snubbers are not considered. This is conservative because the supports reduce pipe stresses between MSIV's. The support can absorb energy before failure if load is exceeded.

The branch pipes are not included in the model, which is conservative because the branch pipes act like restraints for the main steam pipe.

b) Pressure stress at the normal operating condition is used in the load combination. This is conservative because the pressure in the pipe will be reduced due to pipe break.

6.0 REFERENCES

1) Lahey, R.T. and Moody, F.J., "Thermal-Hydraulics of a Boiling Water Nuclear Reactor," American Nuclear Society, 1977.

2) ANSI/ANS-58.2-1988, "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture."

3) GE Document NEDE-10813, PDA, "Pipe Dynamic Analysis User's Manual."

4) GE Document NEDE-23789, "TSFOR01 User's Manual."

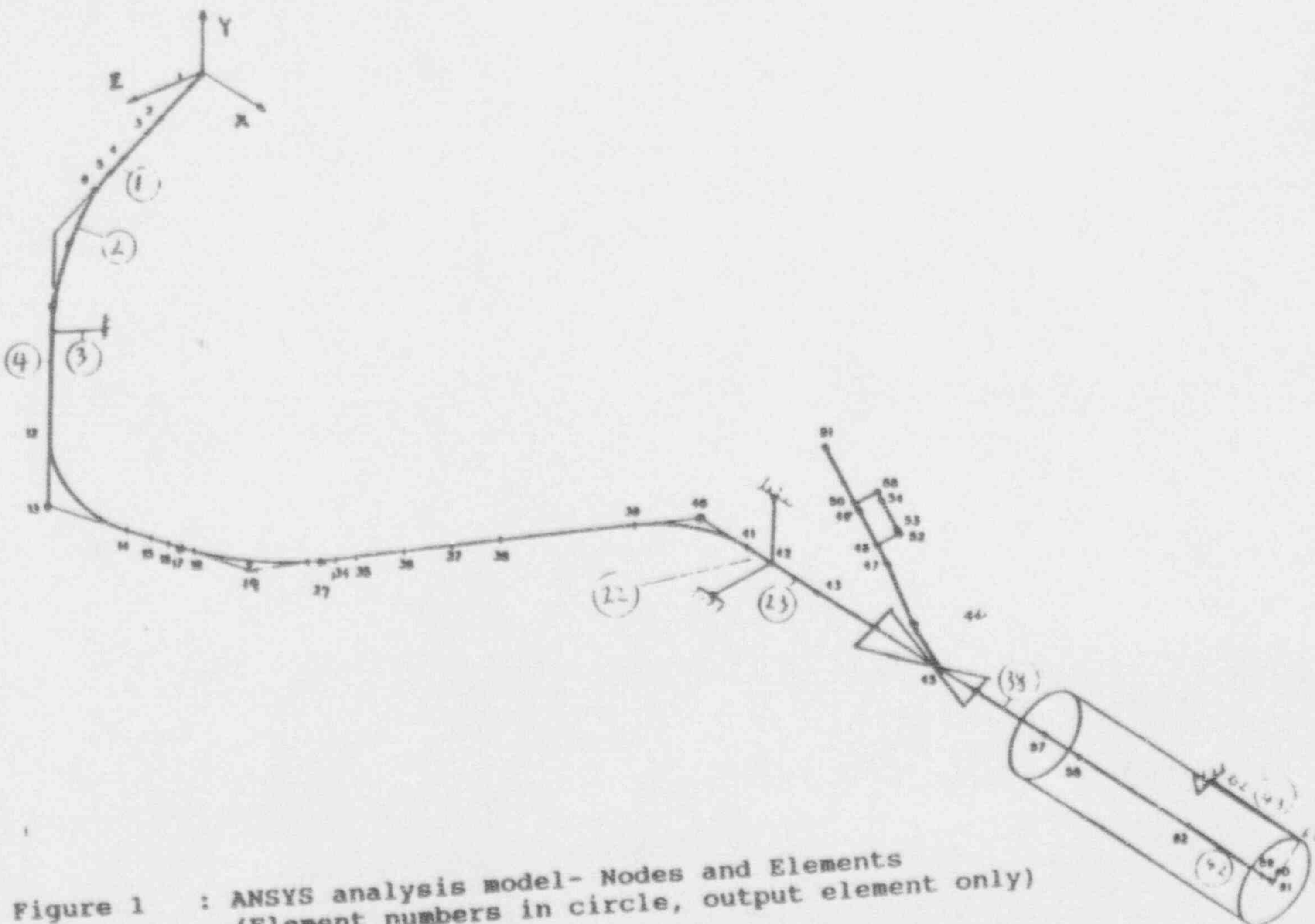


Figure 1 : ANSYS analysis model- Nodes and Elements
(Element numbers in circle, output element only)

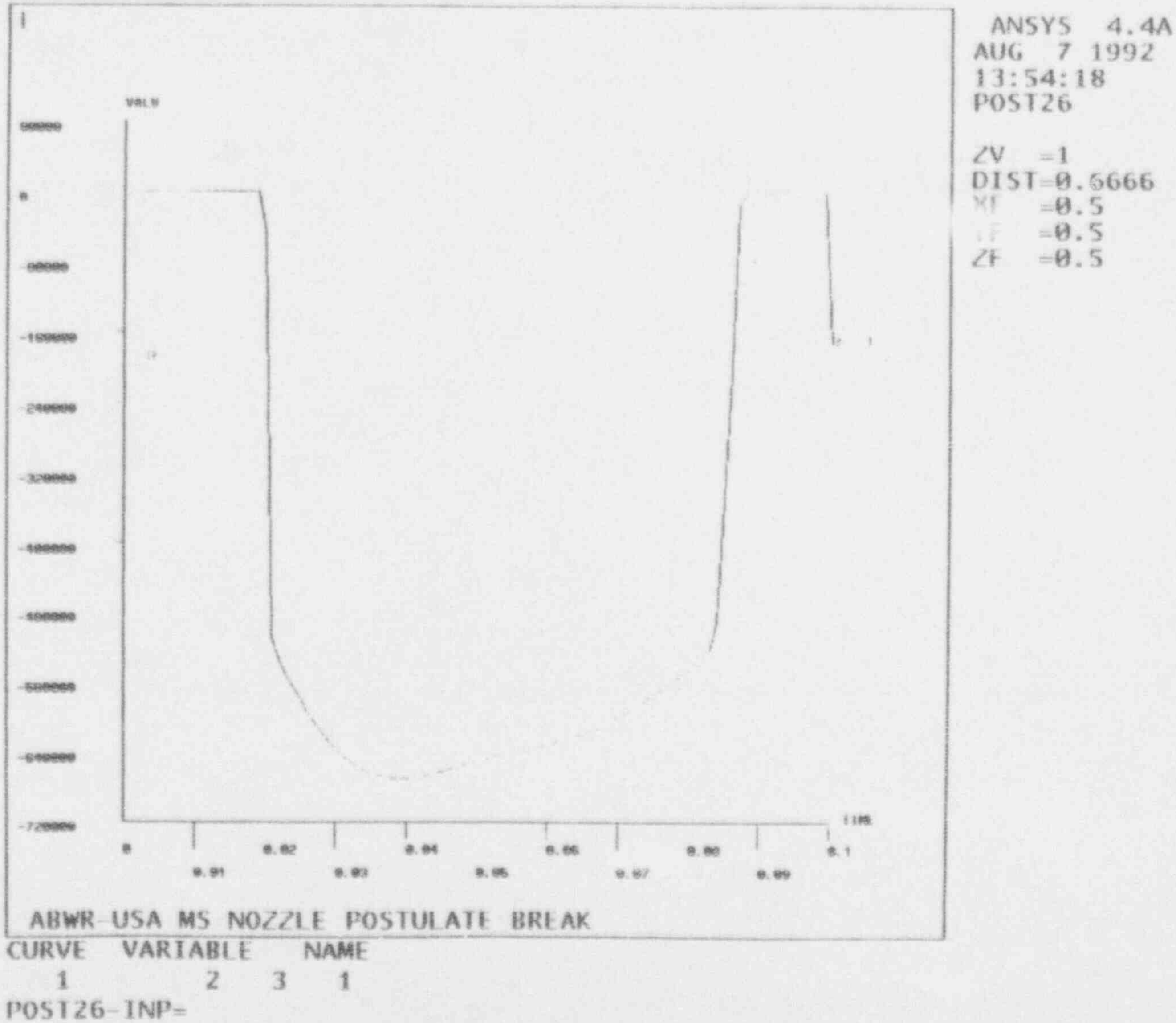
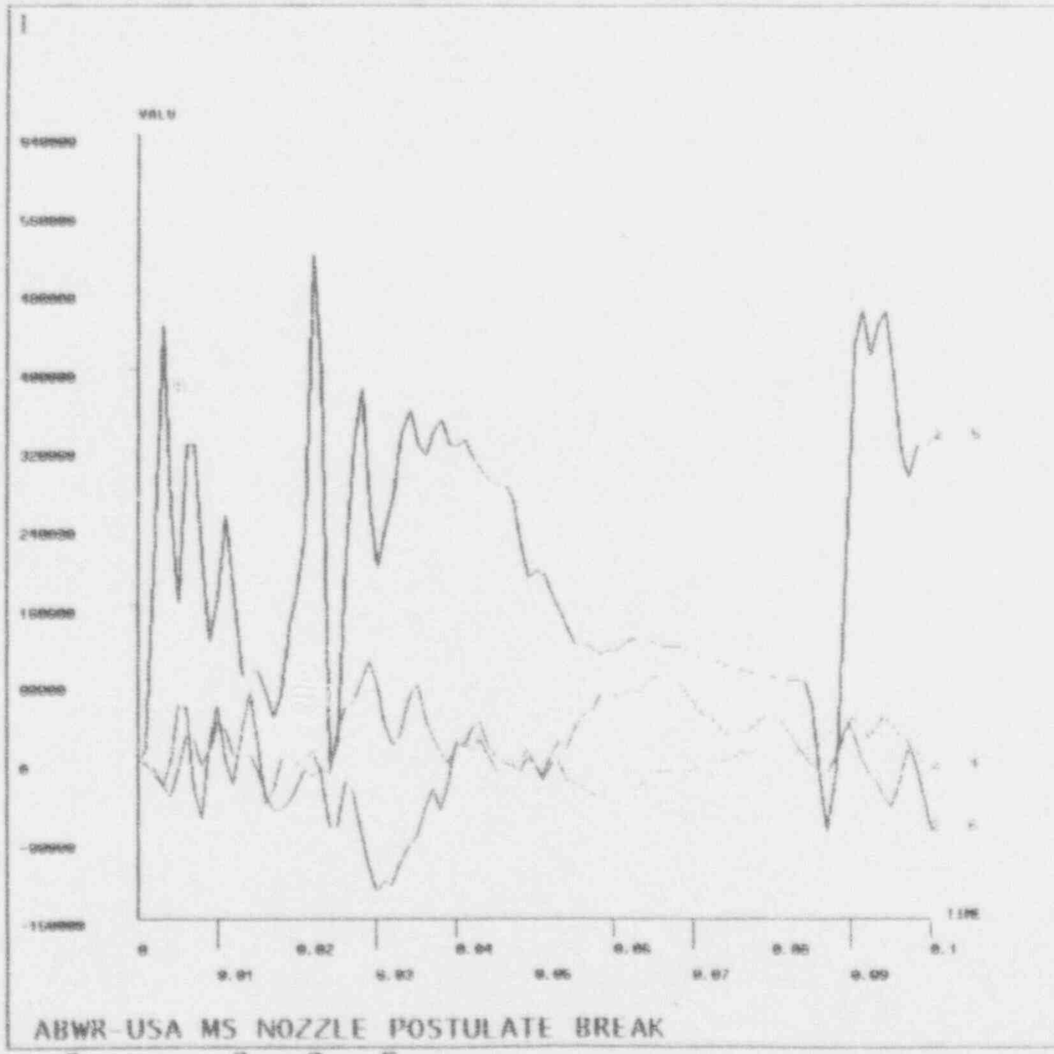


Figure 2 : Impact force at the pipe whip restraint. DT=0.001 sec (pa=373,600 lb, max impact=670,000 lb)

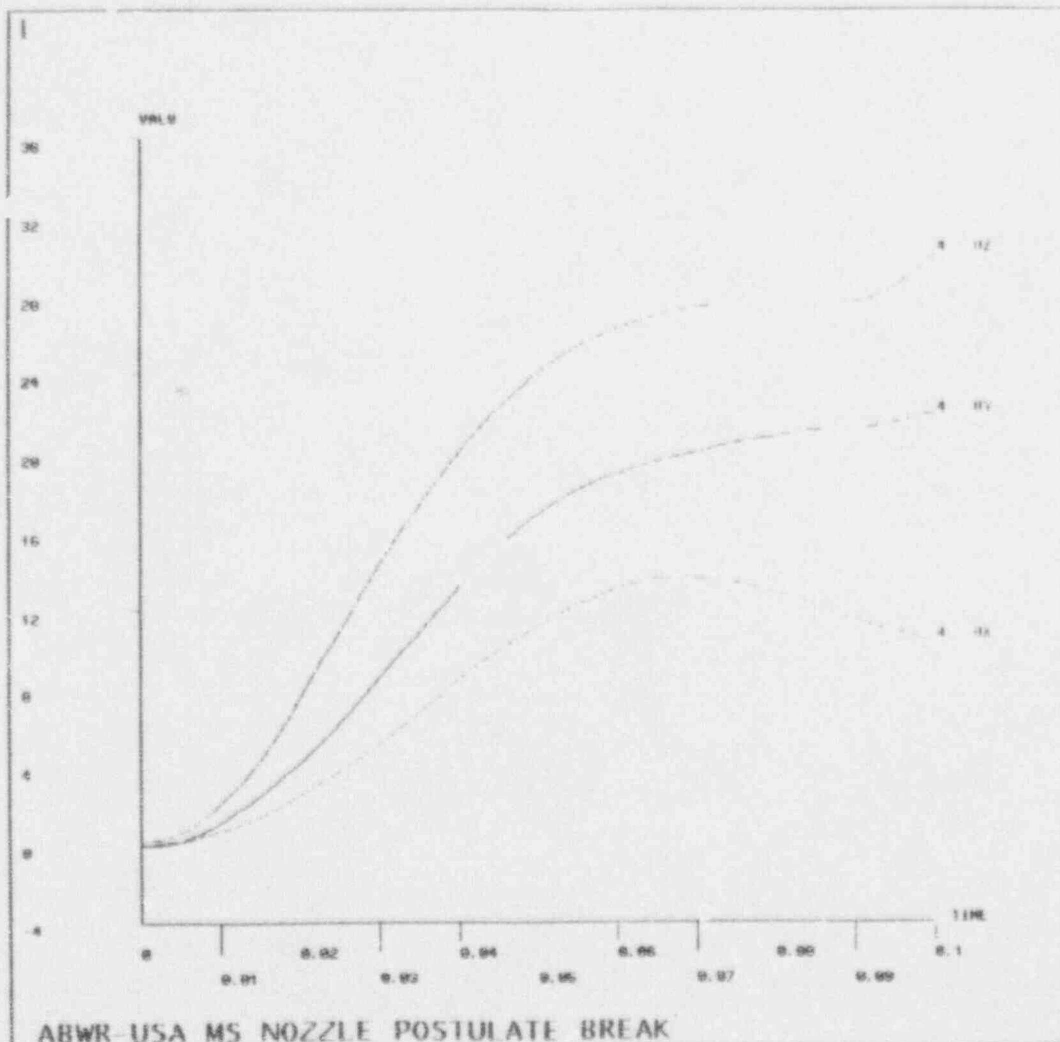


ANSYS 4.4A
AUG 7 1992
14:00:09
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

```
 2        3  2  5
 3        4  2  6
POST26-INP=
```

Figure 3 : Bending moment time histories. DT=0.001 sec. at elm. 2I ,at elbow near break



ANSYS 4.4A
AUG 7 1992
14:03:25
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

2	3	4	UY
3	4	4	UZ

POST26-INP=

Figure 4 : Displacement time histories. DT=0.001 sec at the break location

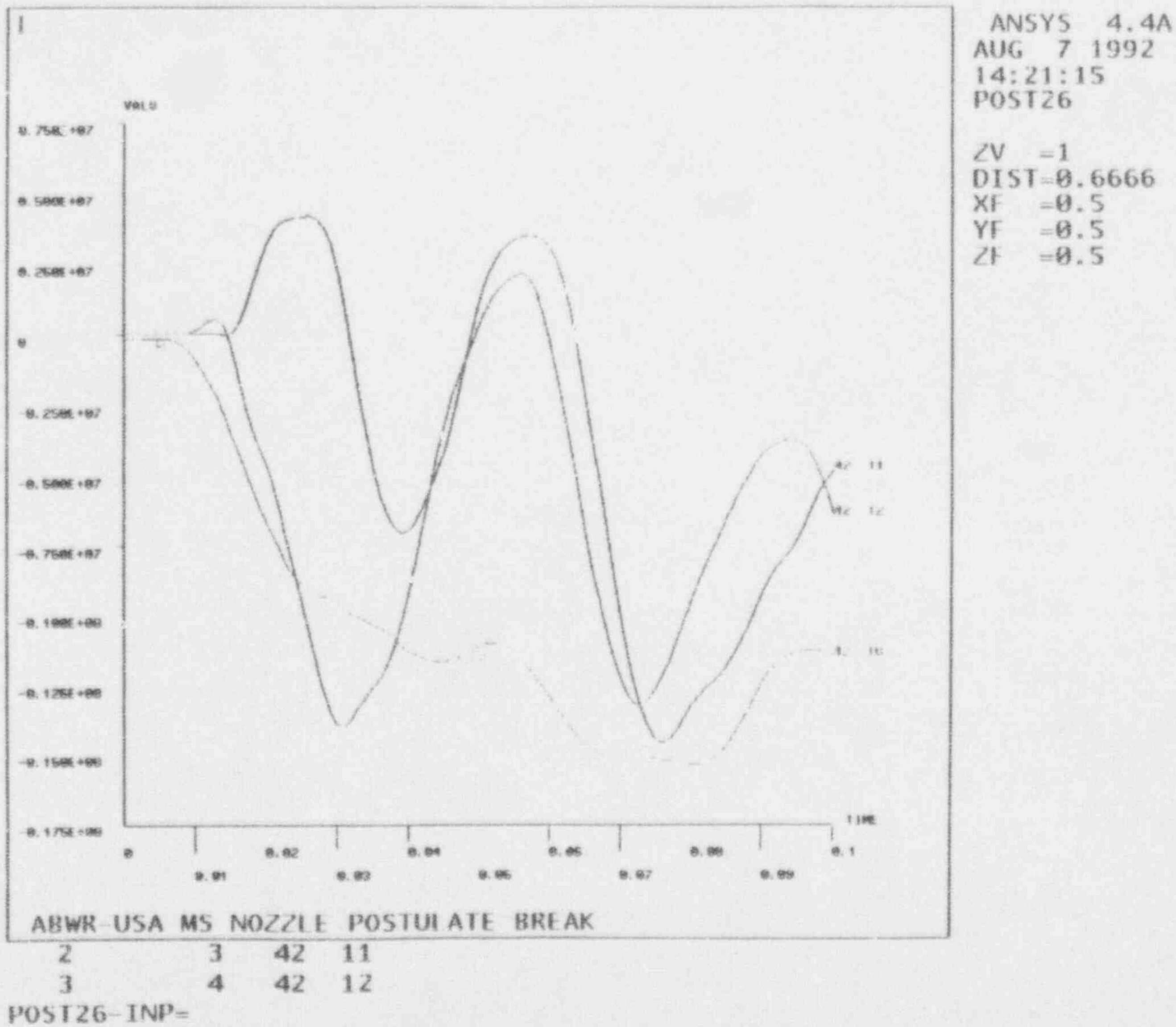
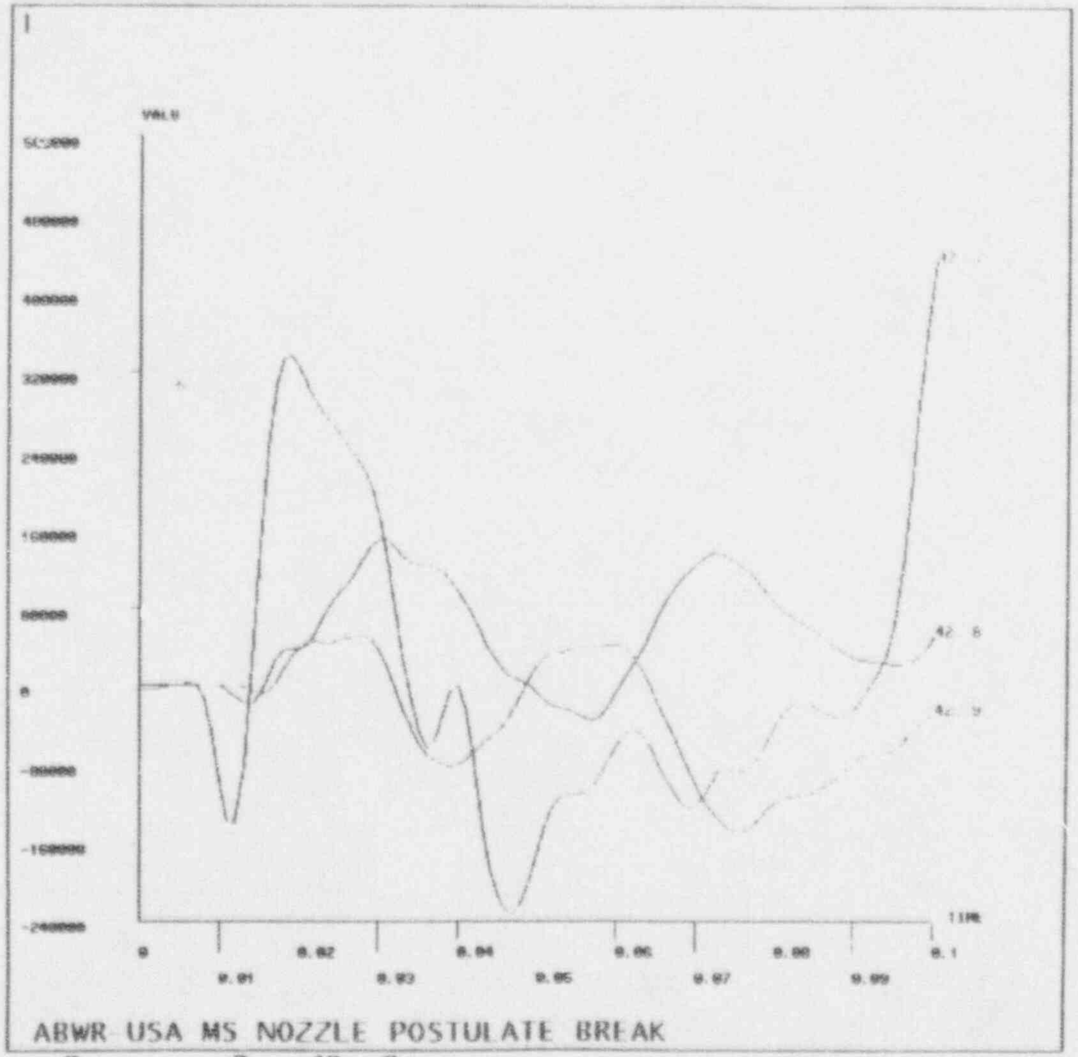


Figure 5 : Moment time history at headfitting, (Elm 42J)
DT=0.001 sec.



ANSYS 4.4A
AUG 7 1992
14:27:03
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

```
   2          3   42  8
   3          4   42  9
POST26-INP=
```

Figure 6 : Force time histories at headfitting. (Elm 42J)
DT=0.001 sec

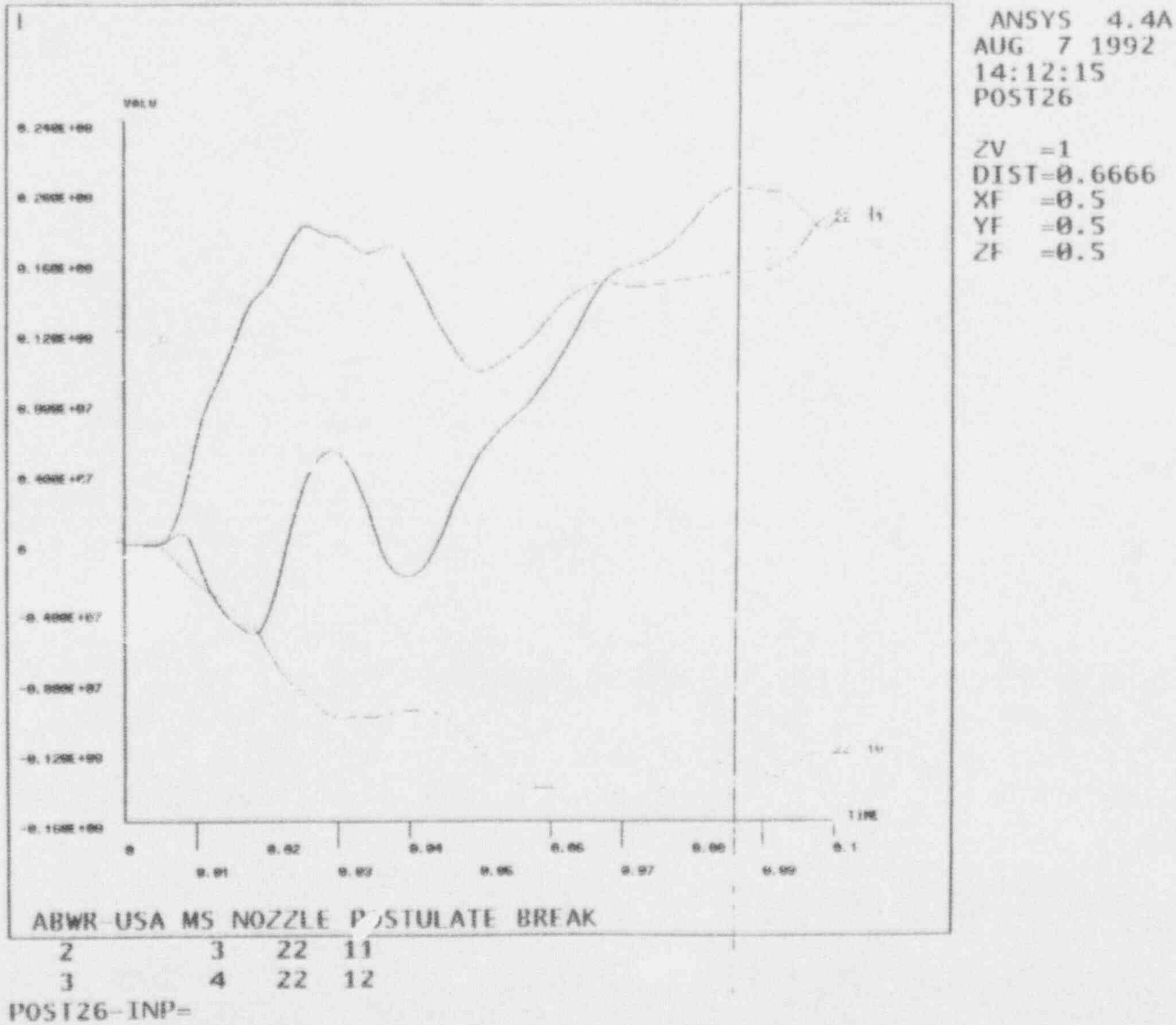
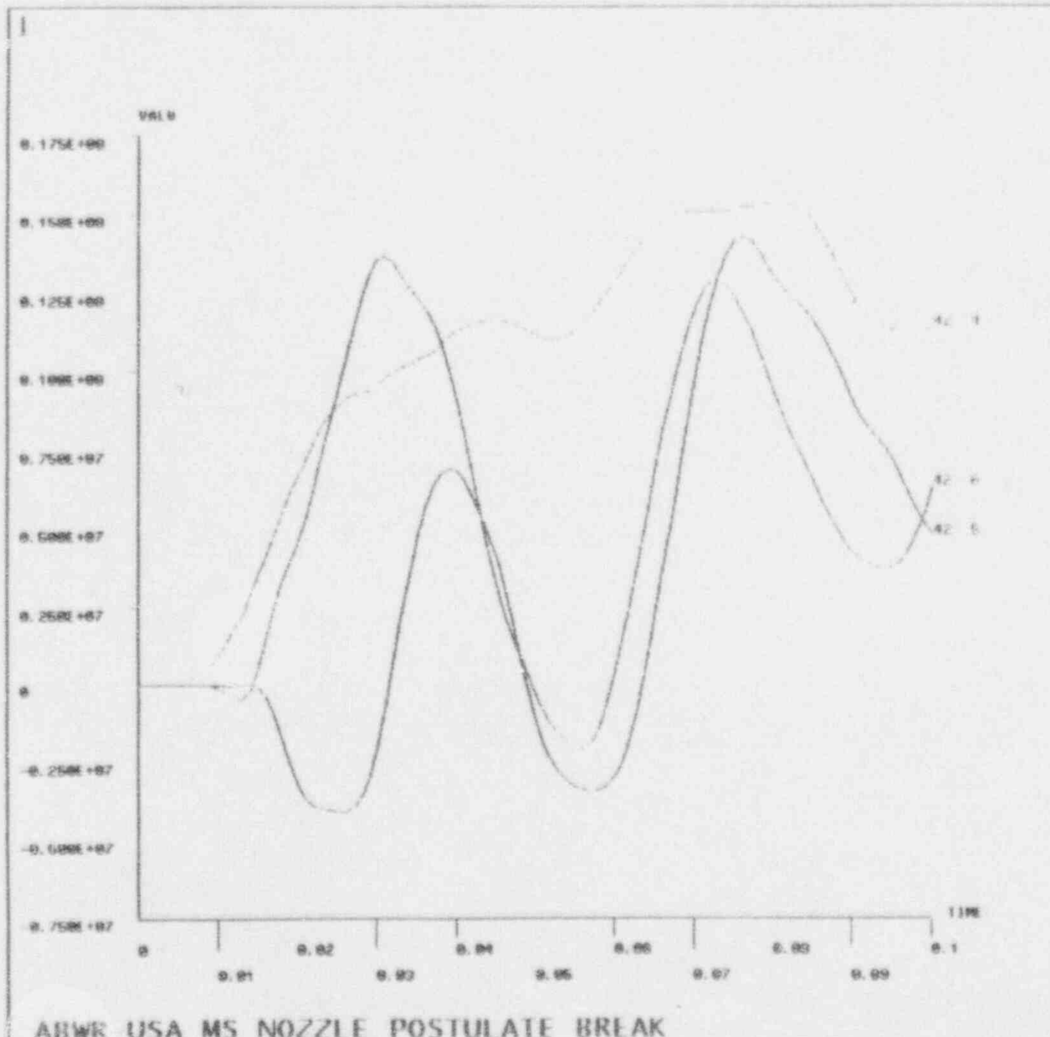


Figure 7 : Bending mom... time histories. DT=0.001 sec at elm 22J ,before main steam guide



ANSYS 4.4A
AUG 7 1992
14:16:59
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

2 3 42 5
3 4 42 6
POST26-INF=

Figure 8 : Bending moment time histories. DT=0.001 sec at elm 42I ,near headfitting

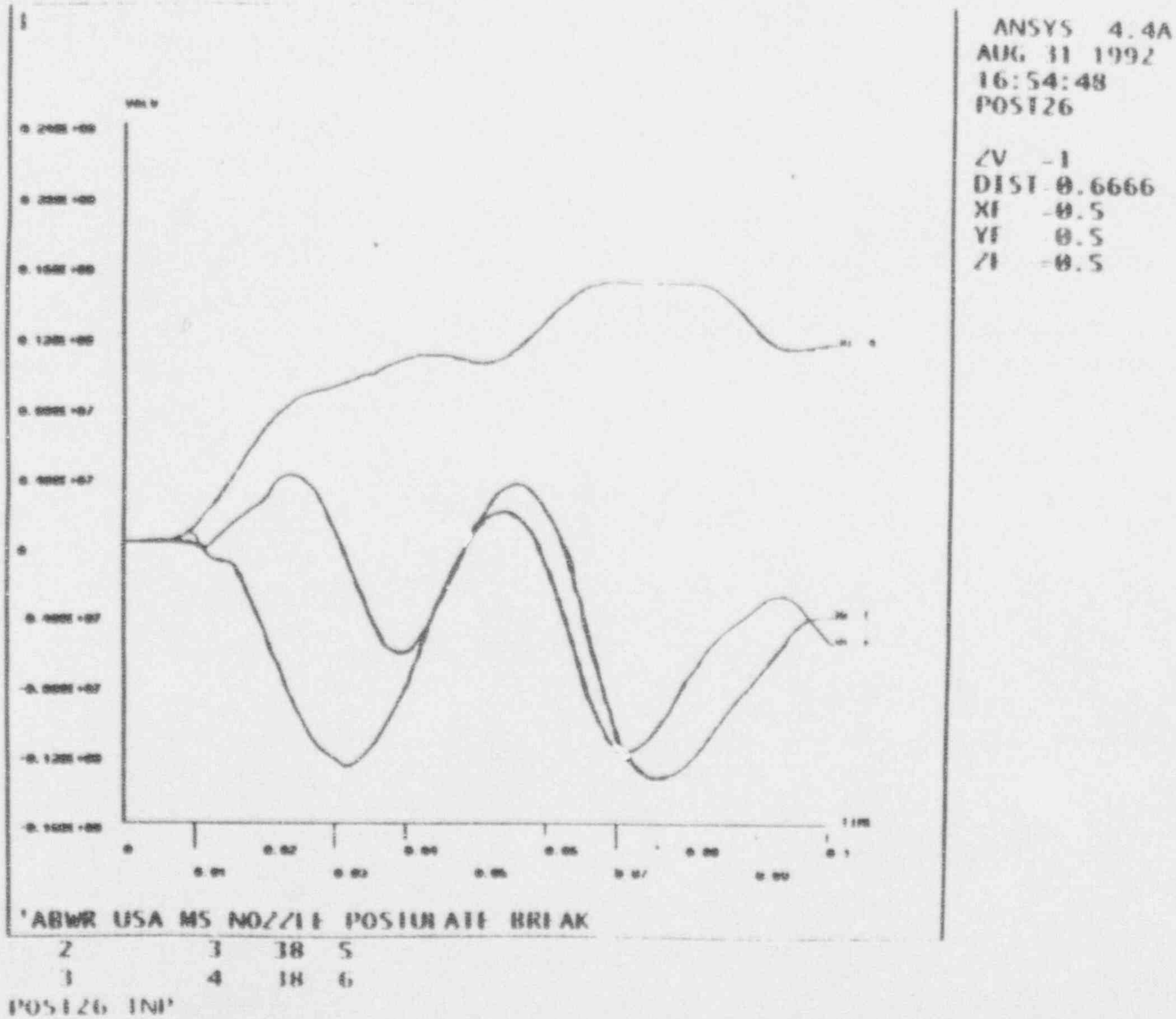


Figure 9 : Bending moment time histories. DT=0.001 sec. at Elm 38I, 1st elm after MSIV.

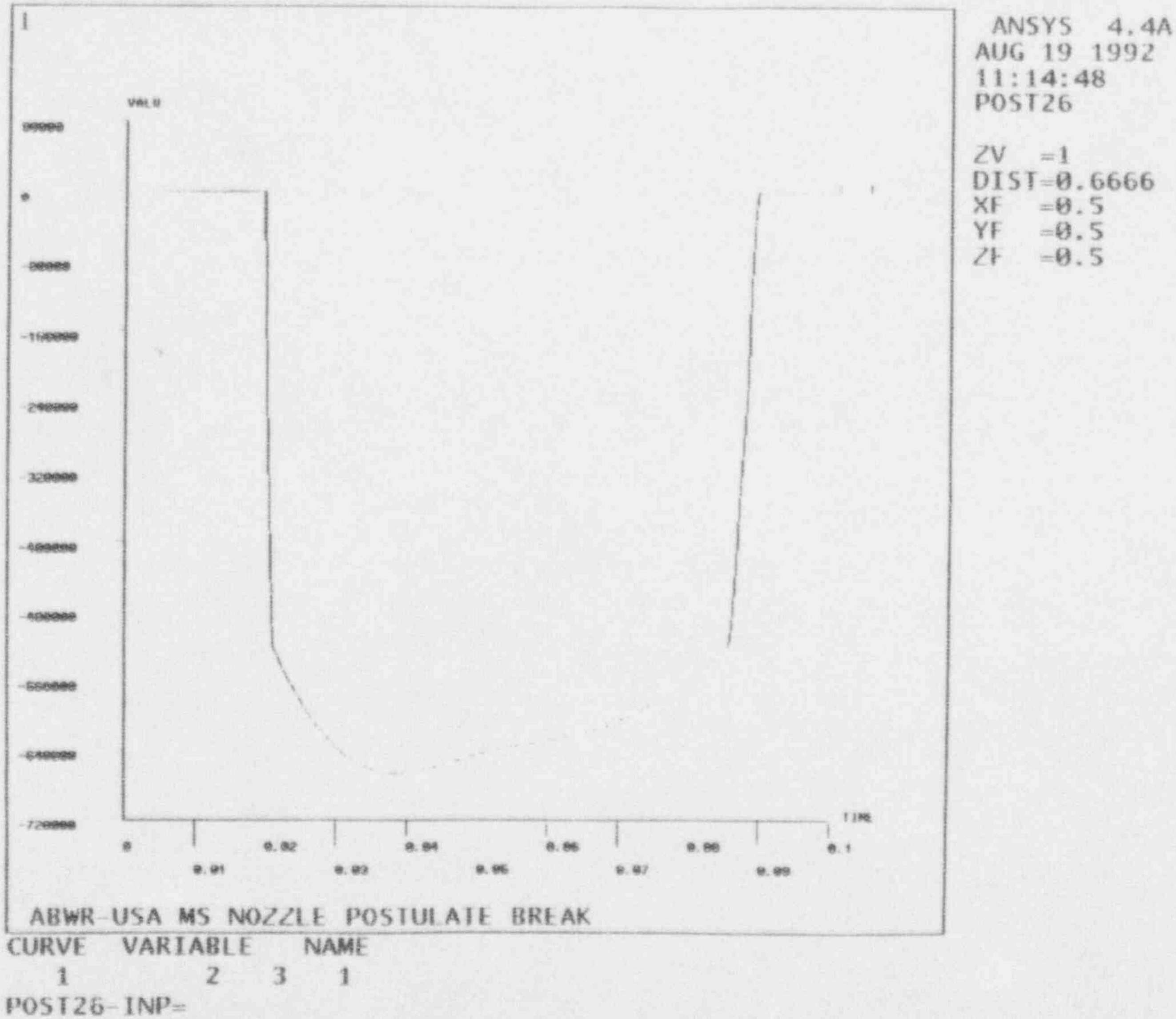


Figure 2A: Impact force at the pipe whip restraint. DT=0.0005 sec (pa=373,600 lb, max impact=670,000 lb)

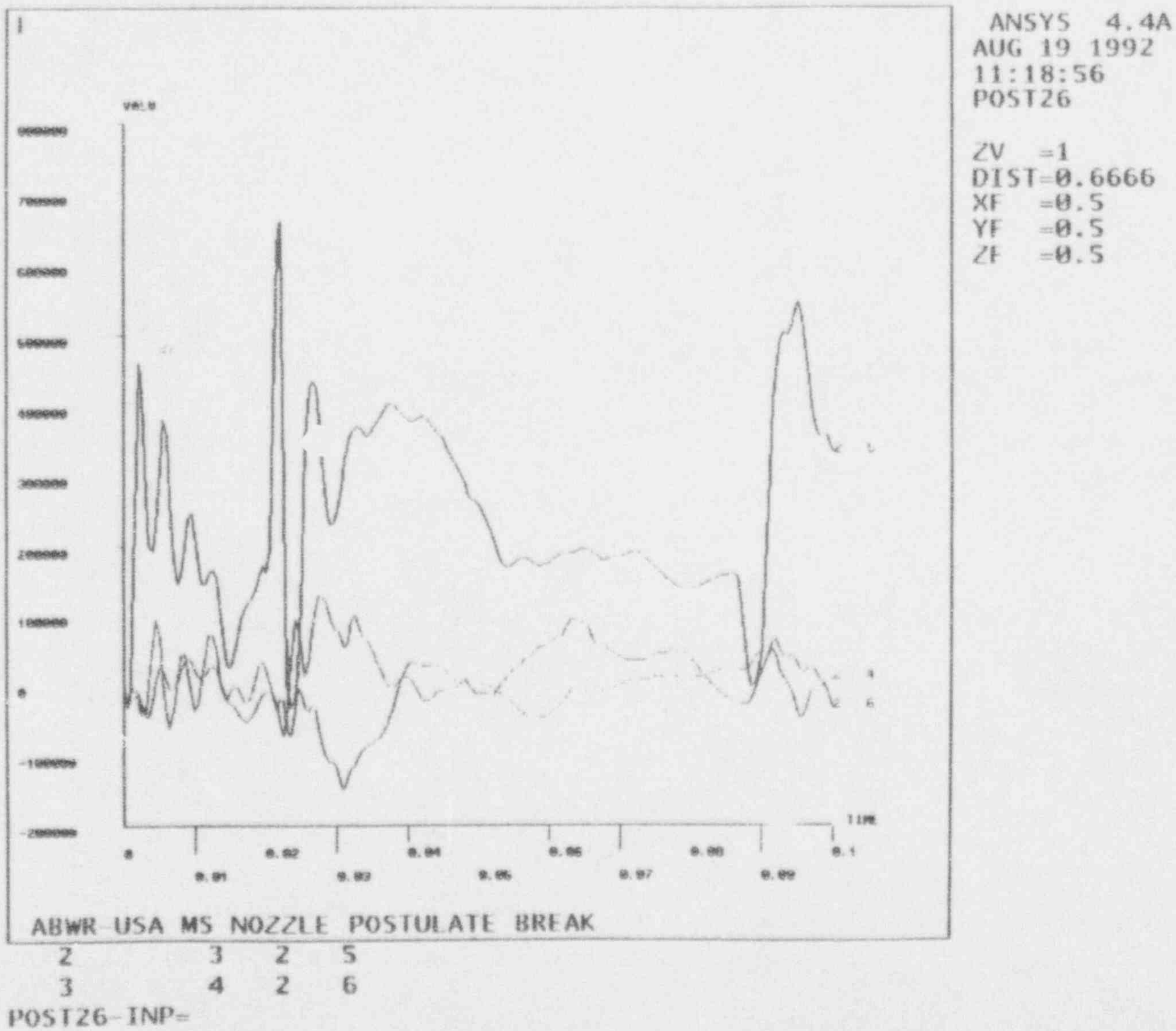
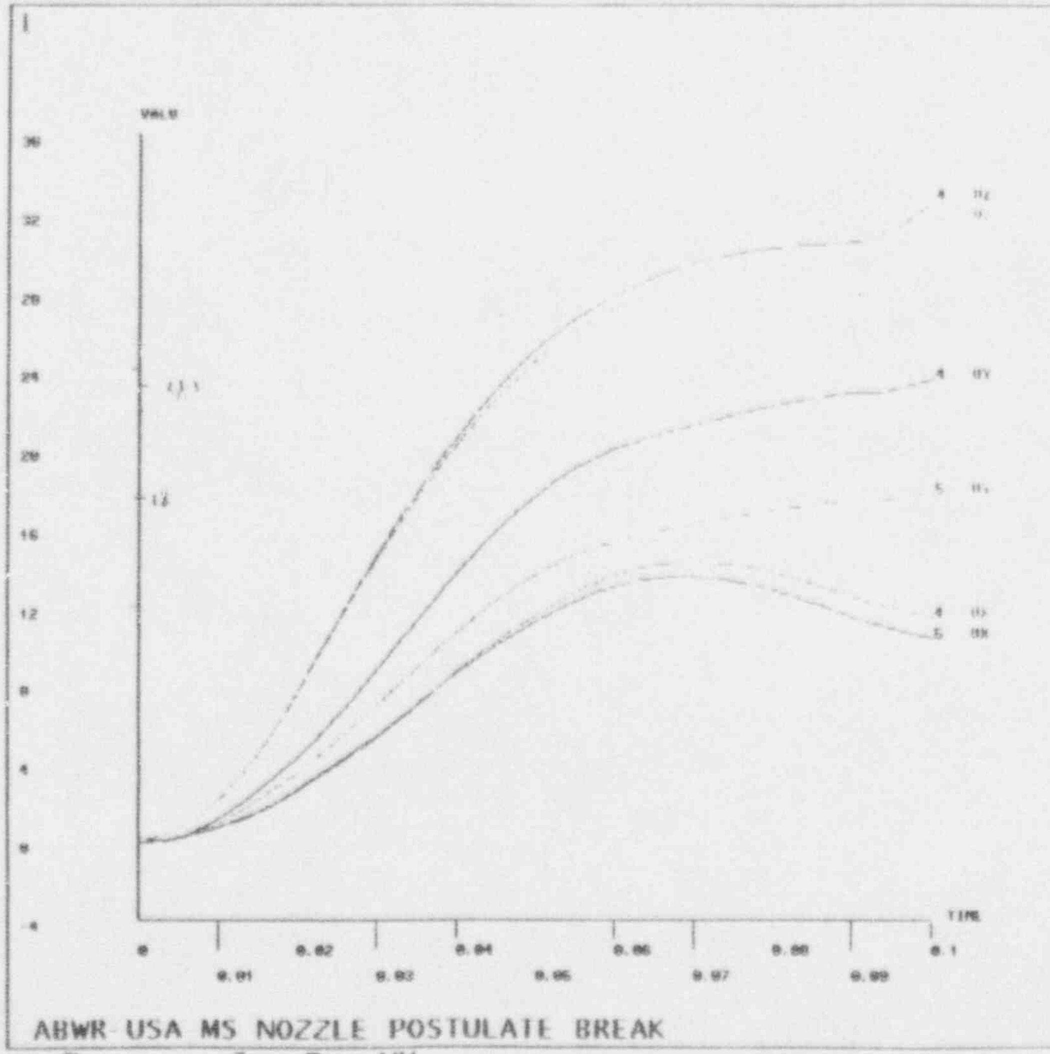


Figure 3A: Bending moment time histories. DT=0.0005 sec. at elm. 2I ,at elbow near break

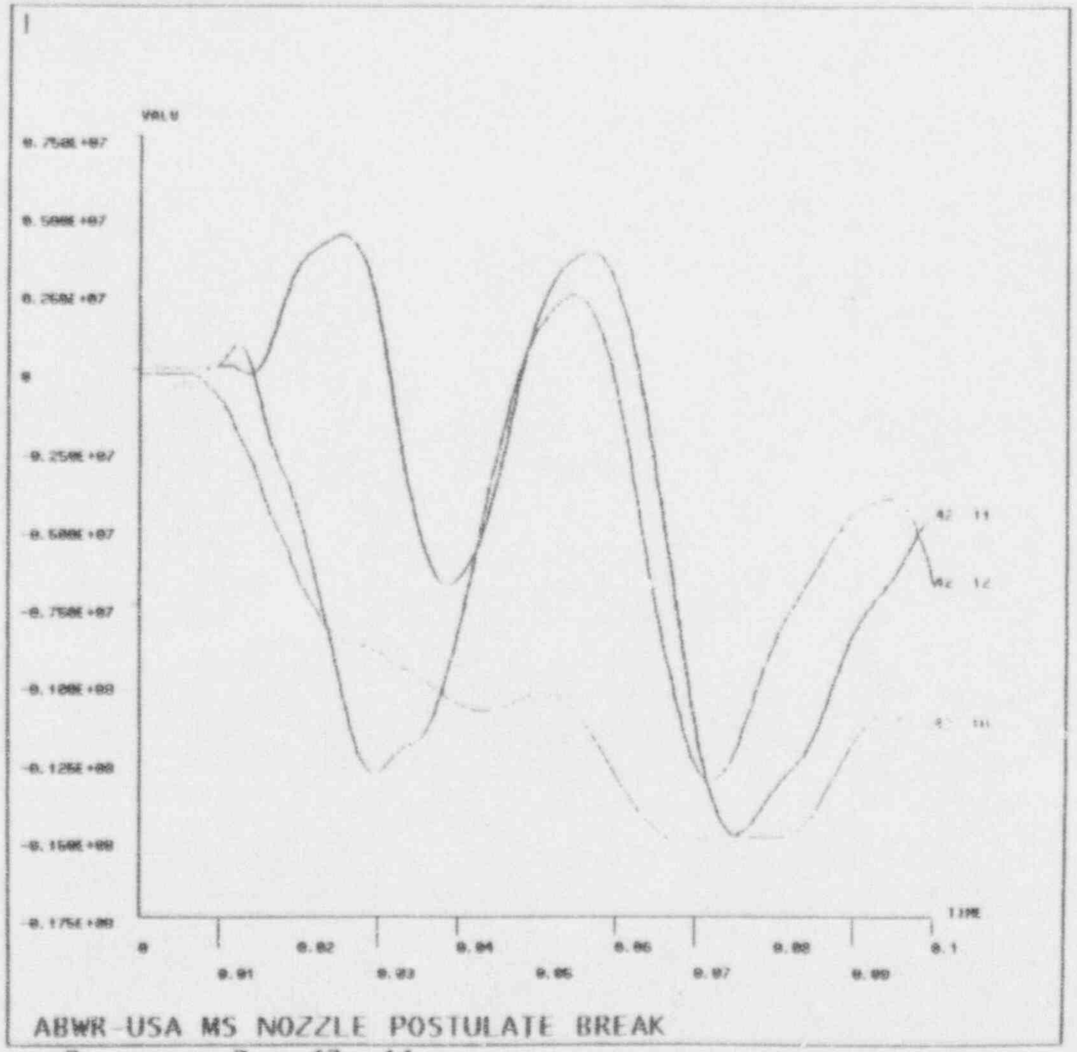


ANSYS 4.4A
AUG 28 1992
10:28:36
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

```
   5        6   5   UY
   6        7   5   UZ
POST26-INP=
```

Figure 4A: Displacement time histories. DT=0.0005 sec at the break location

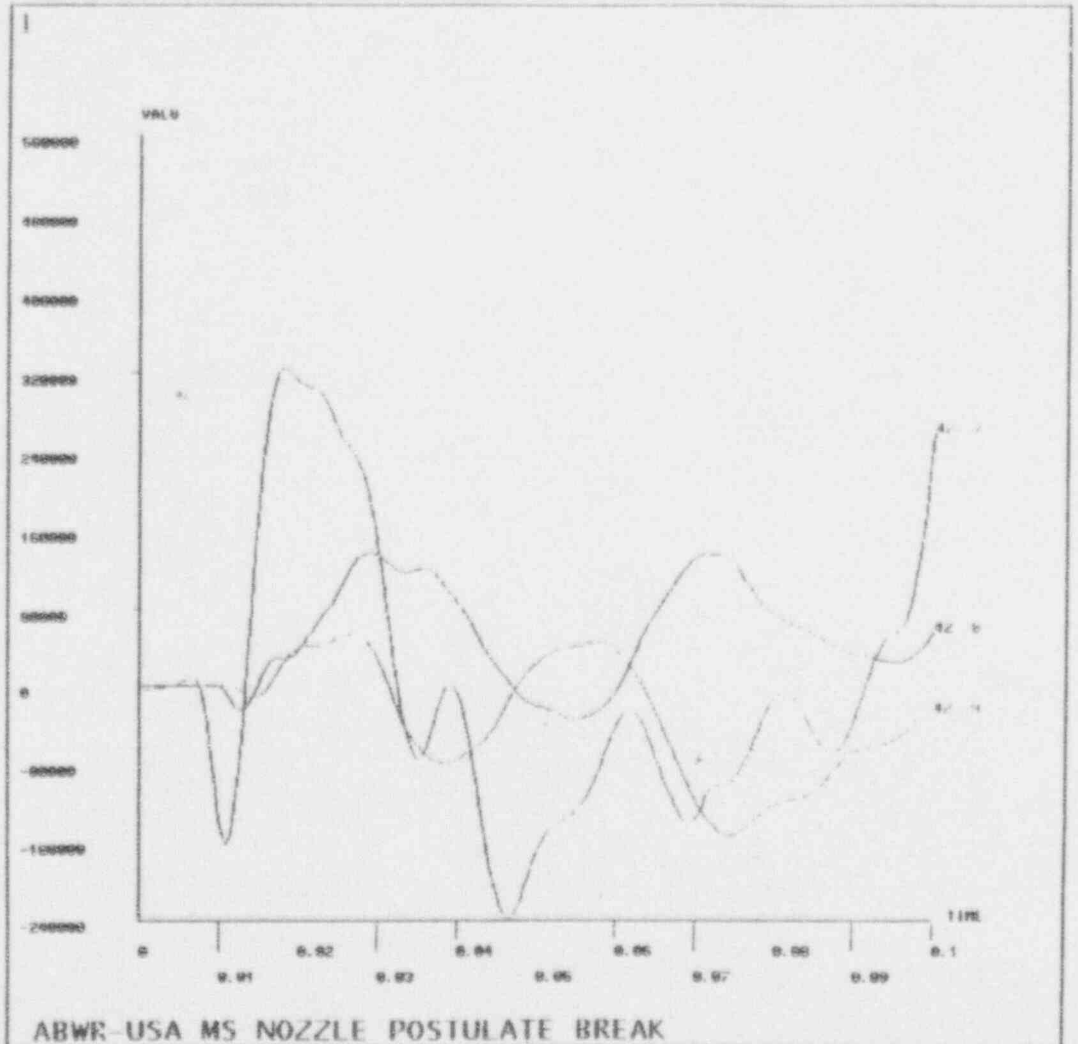


ANSYS 4.4A
AUG 19 1992
11:30:56
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

```
   2          3   42  11
   3          4   42  12
POST26-INP=
```

Figure 5A: Moment time history at headfitting, (Elm 42J)
DT=0.0005 sec.



ANSYS 4.4A
AUG 19 1992
11:33:41
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

2	3	42	8
3	4	42	9

POST26-INP=

Figure 6A: Force time histories at headfitting. (Elm 42J)
DT=0.0005 sec

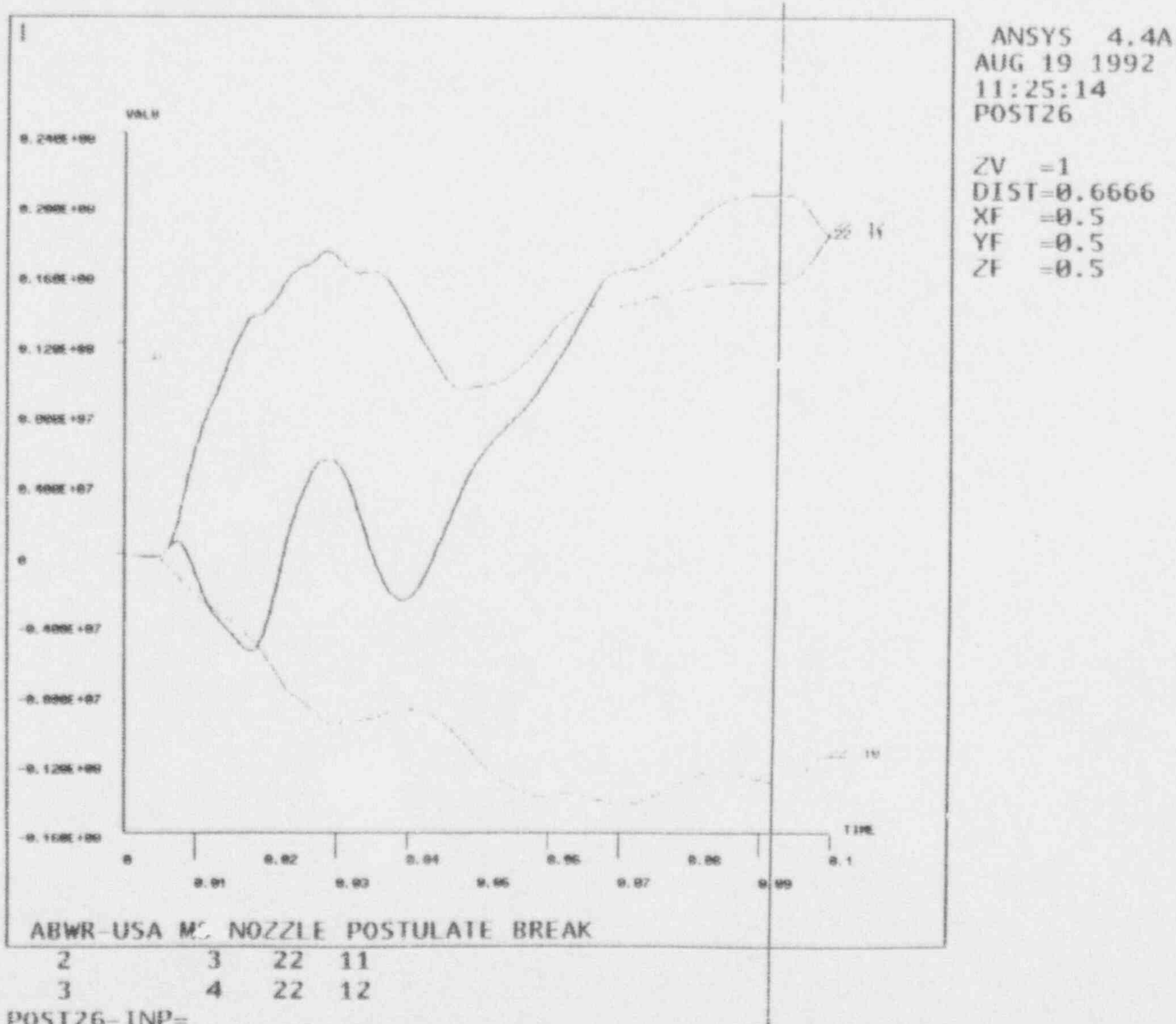


Figure 7A: Bending moment time histories. DT=0.0005 sec at elm 22J ,before main steam guide

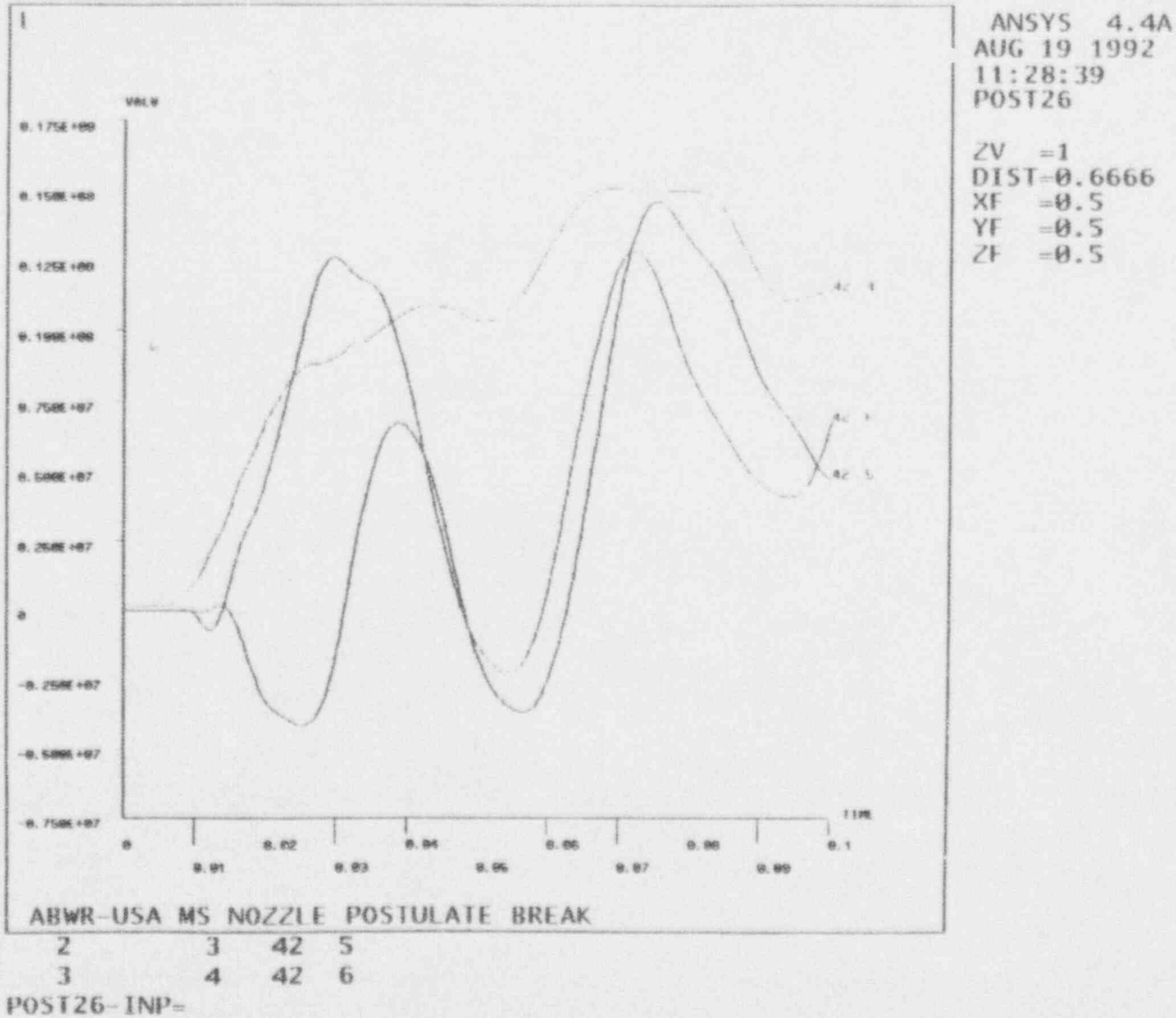
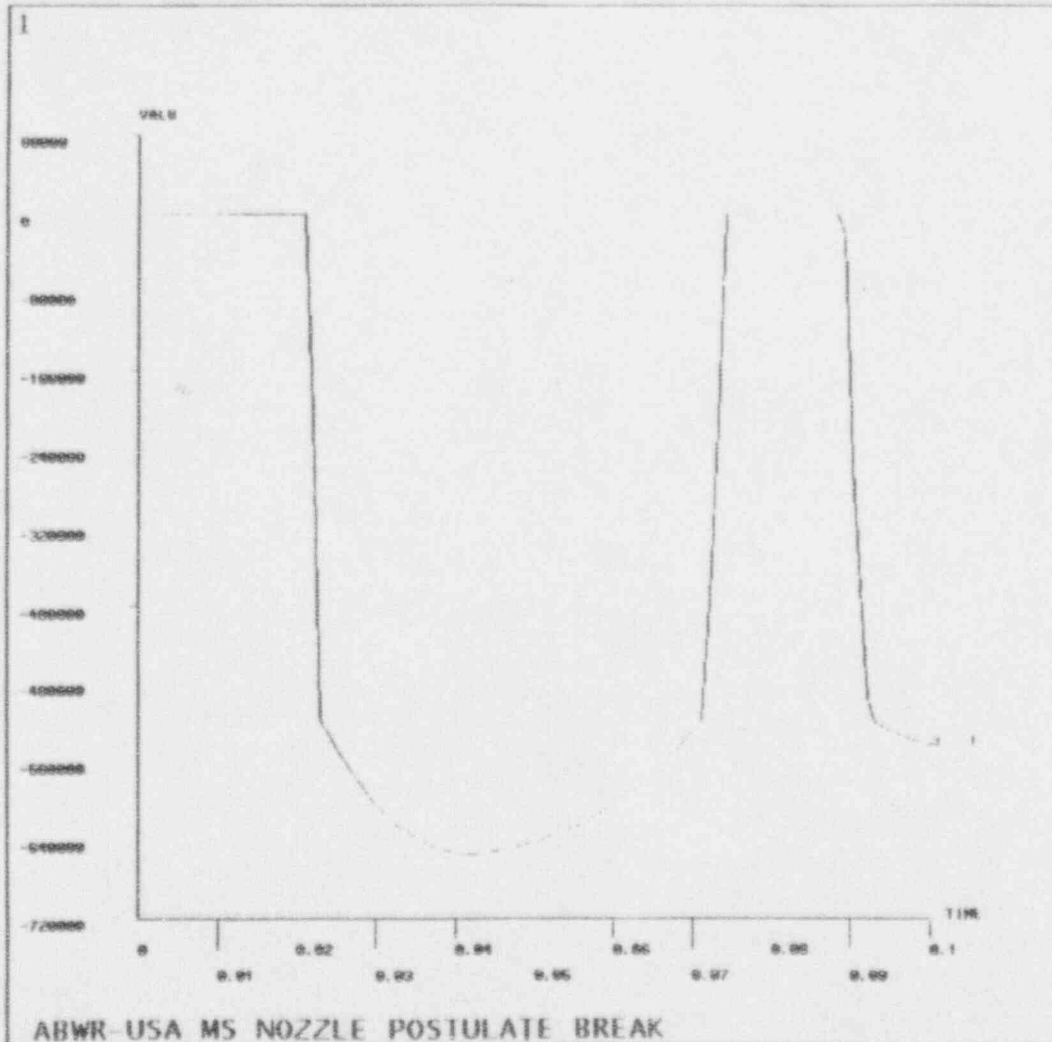


Figure 8A: Bending moment time histories. DT=0.0005 sec at elm 42I ,near headfitting

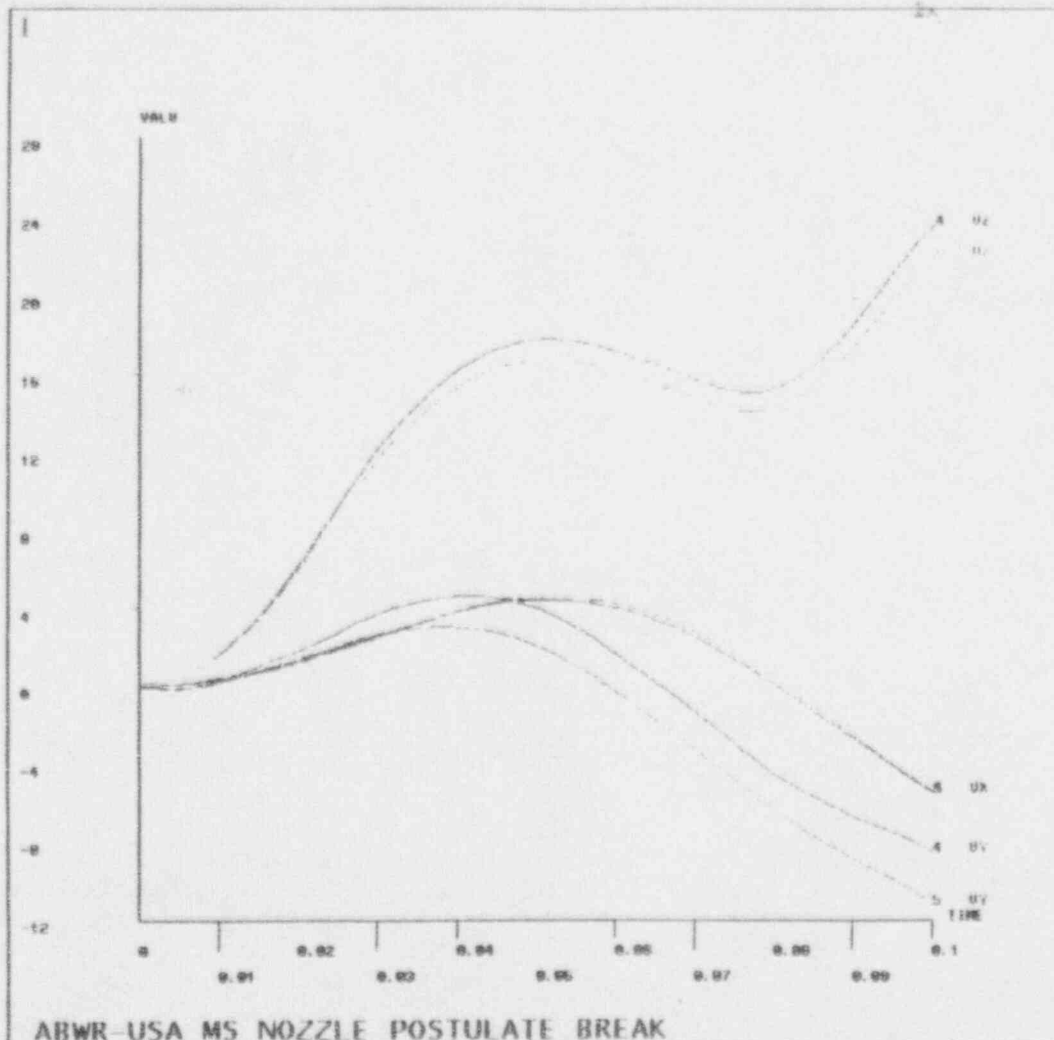


ANSYS 4.4A
AUG 28 1992
13:54:08
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

CURVE VARIABLE NAME
1 2 3 1
POST26-INP=

Figure 2B: Impact force at the pipe whip restraint.
(pa=373,600 lb, max impact=670,000 lb)
(Included rotated blowdown angle)

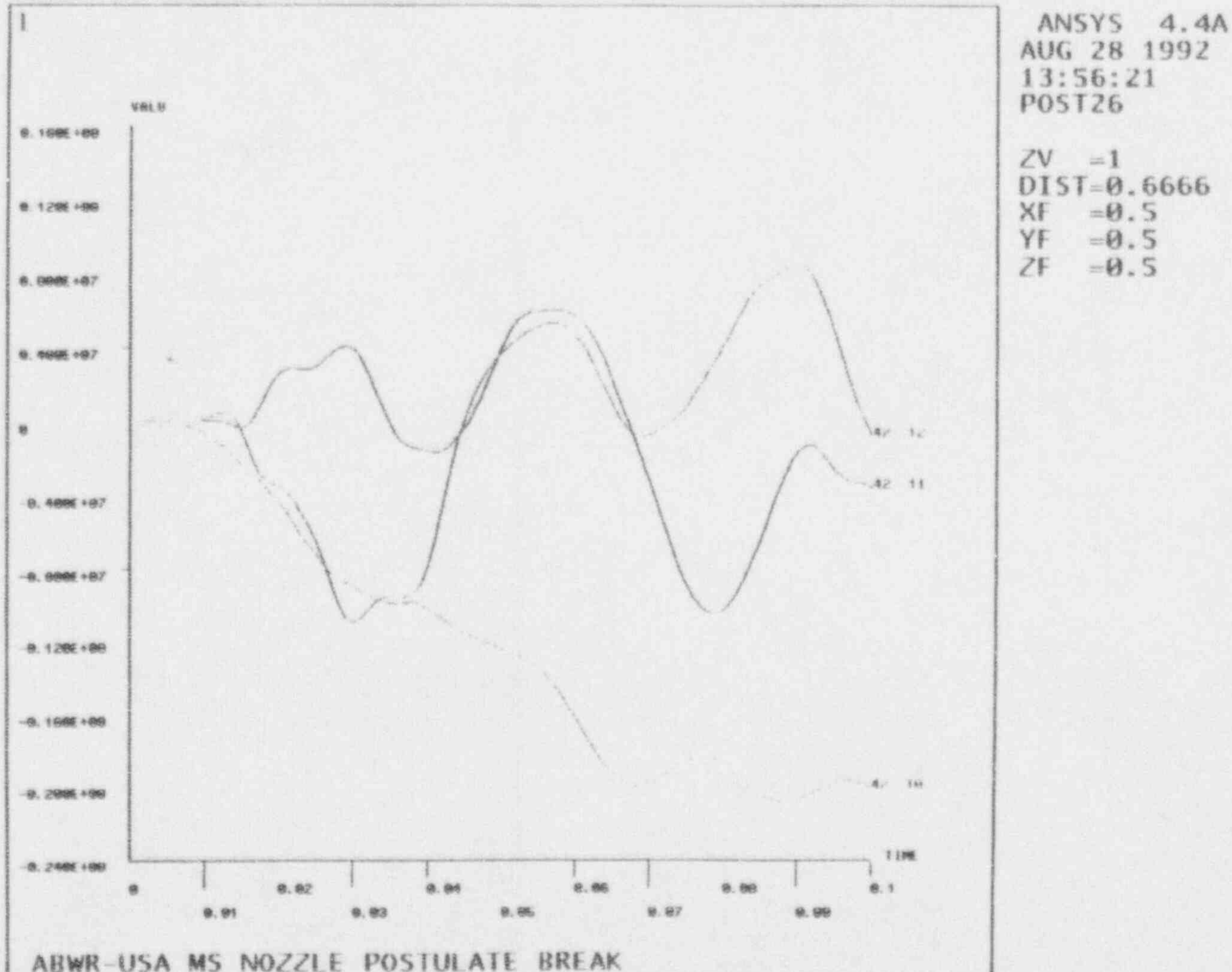


ANSYS 4.4A
AUG 28 1992
13:59:17
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

```
   5          6   5   UY
   6          7   5   UZ
POST26-INP=
```

**Figure 4B: Displacement time histories.
at the break location
(Included rotated blowdown angle)**




```
    2          3    42  11
    3          4    42  12
POST26-INP=
```

Figure 5B: Moment time history at headfitting, (Elm 42J)

(Included rotated blowdown angle)

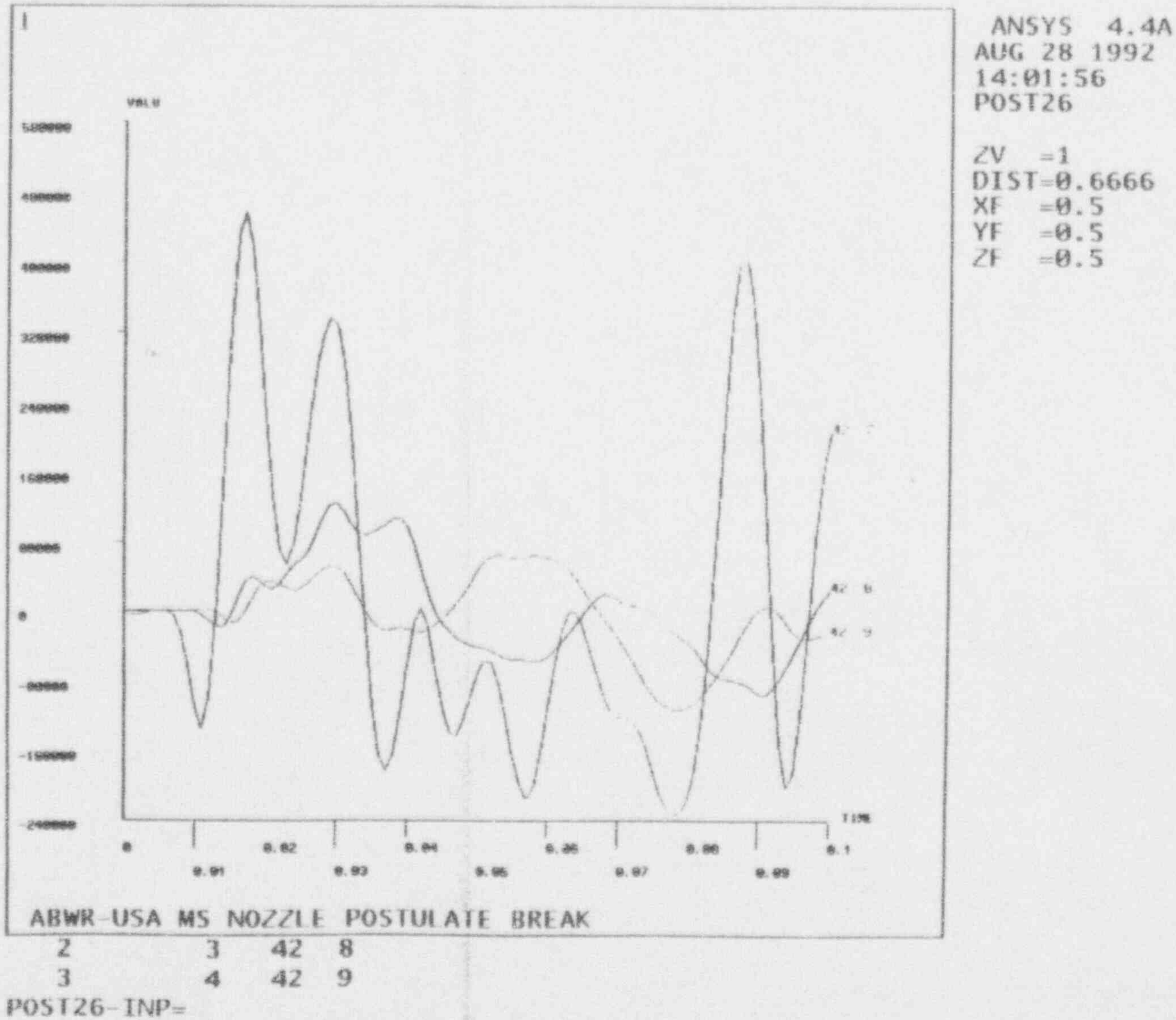


Figure 6B: Force time histories at headfitting. (Elm 42J)

(Included rotated blowdown angle)

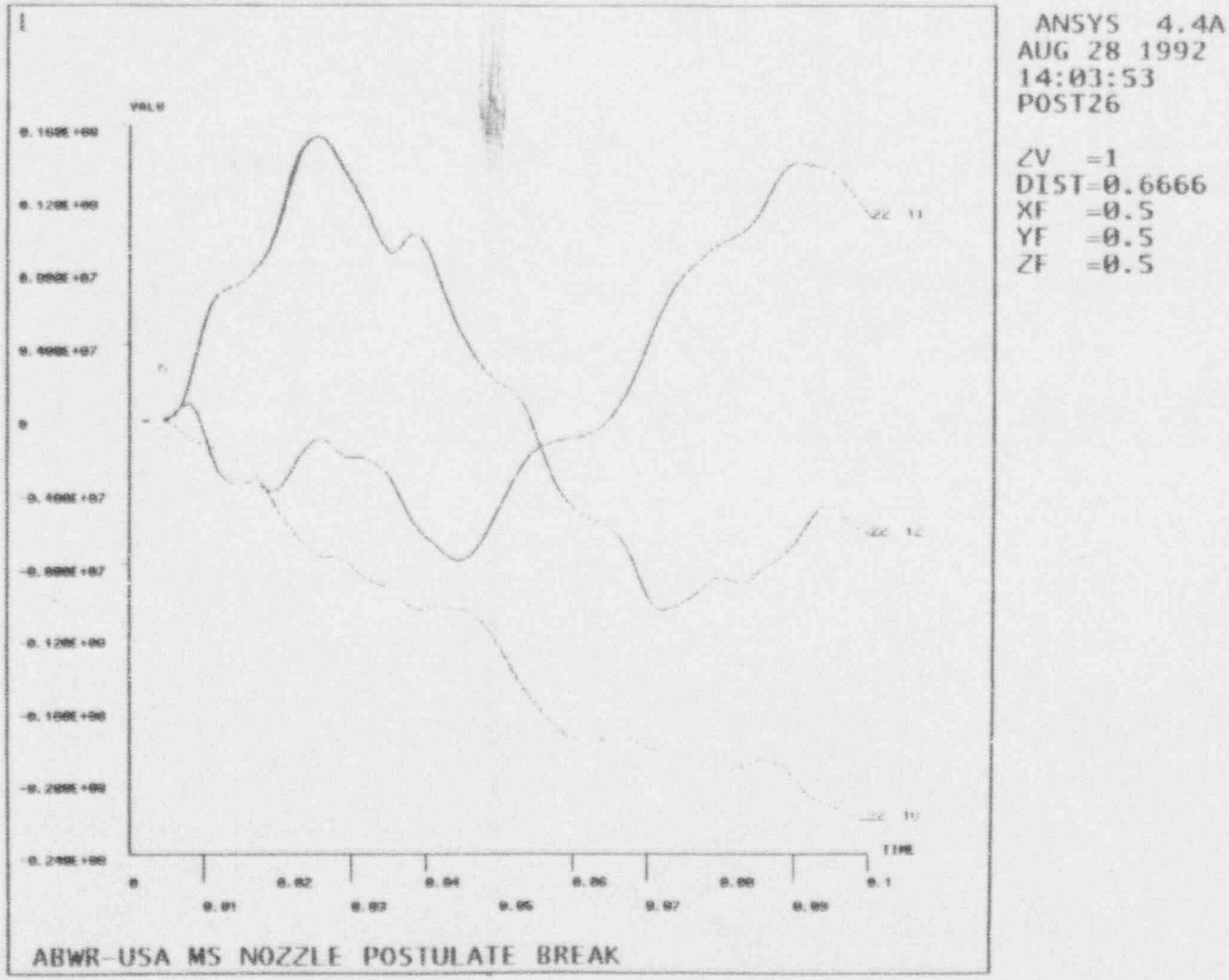
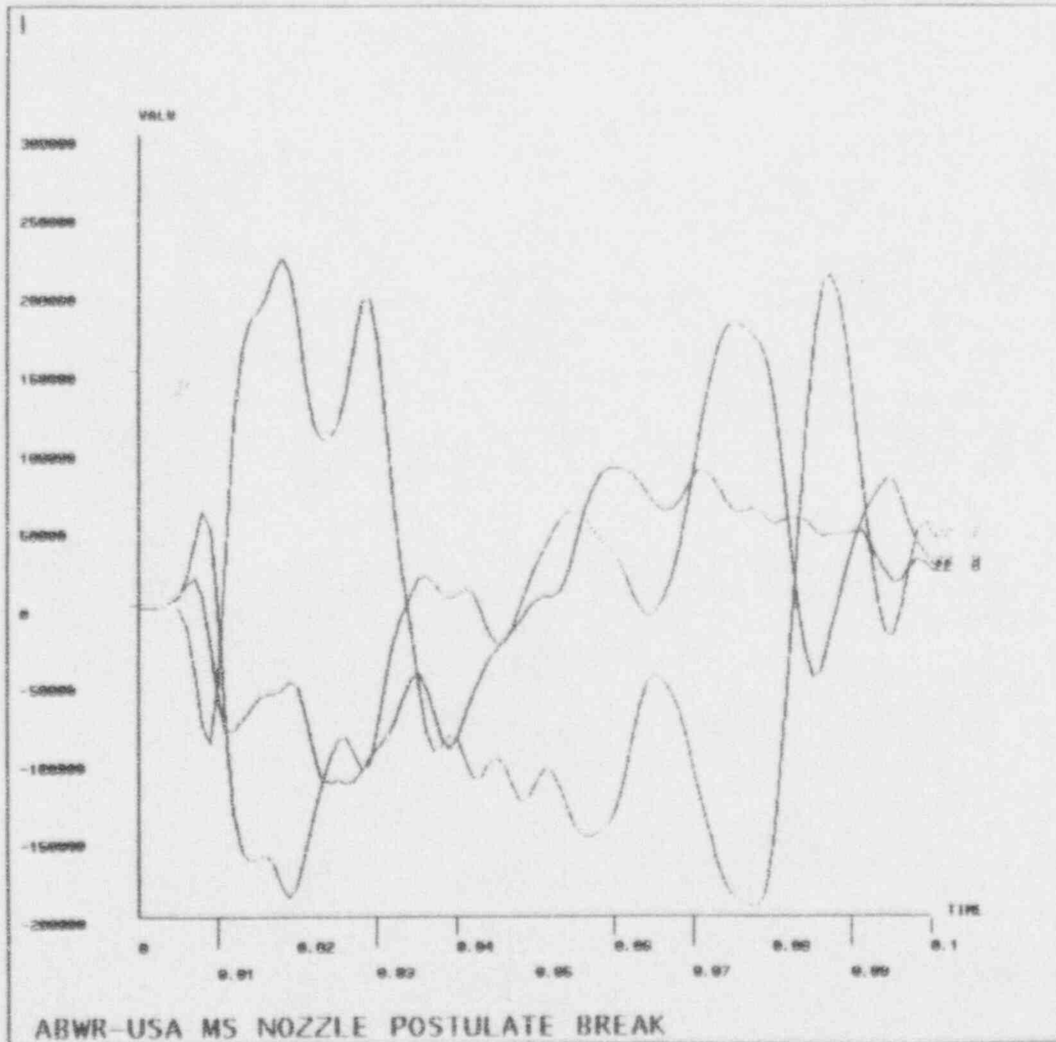


Figure 7B: Bending moment time histories. DT=0.001 sec at elm 22J ,before main steam guide (Included rotated blowdown angle)



ANSYS 4.4A
AUG 28 1992
14:06:58
POST26

ZV =1
DIST=0.6666
XF =0.5
YF =0.5
ZF =0.5

2 3 22 8
3 4 22 9
POST26-INP=

Figure 9B: Force time histories.
at elm 22J ,before main steam guide
(Included rotated blowdown angle)

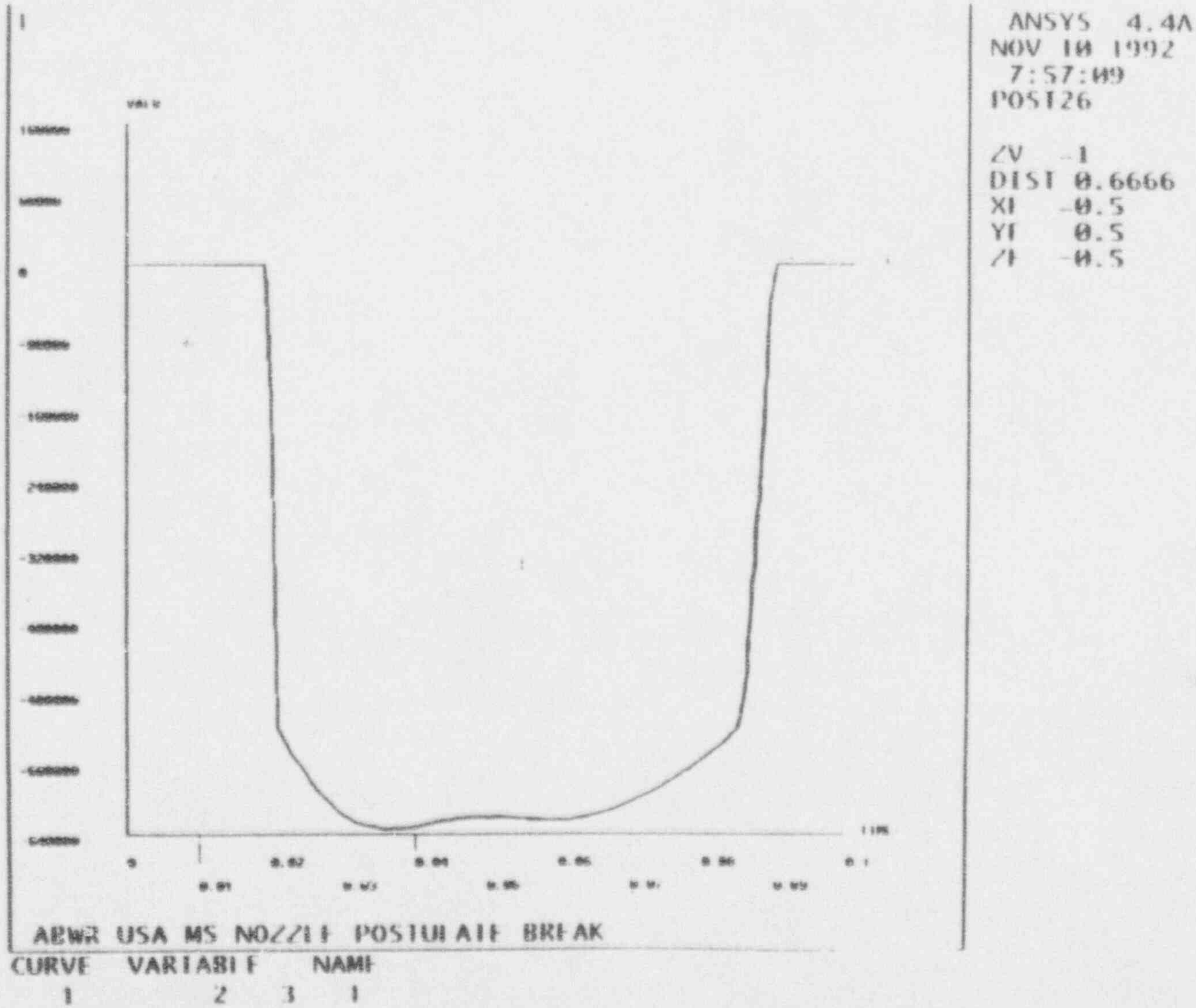


Figure 2C: Impact force at the pipe whip restraint. DT=0.001 sec

(Included displaced elbow and break pipe orientation)

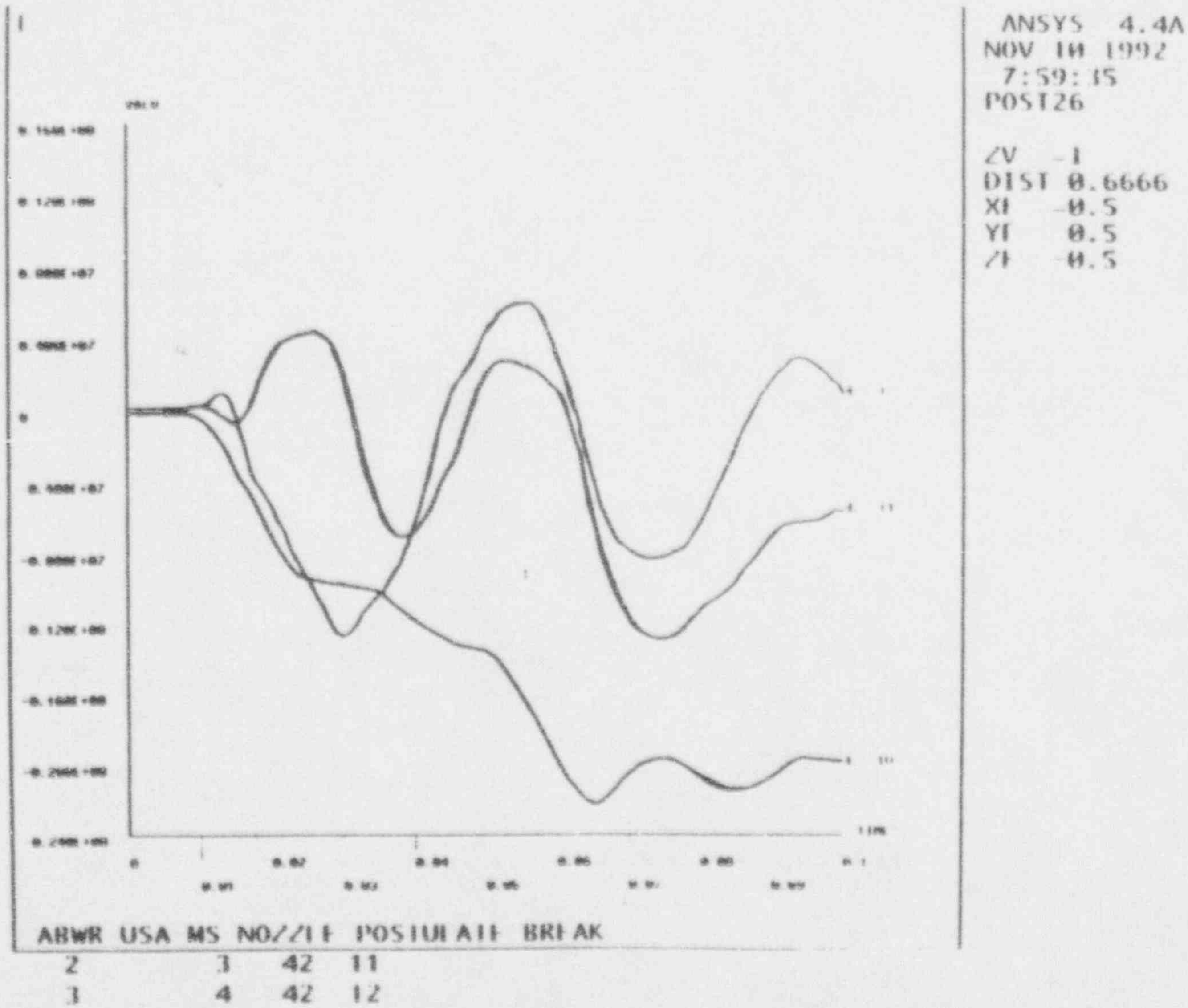


Figure 5C: Moment time histories at 42J (headfitting)
(Included displaced elbow and break pipe orientation)

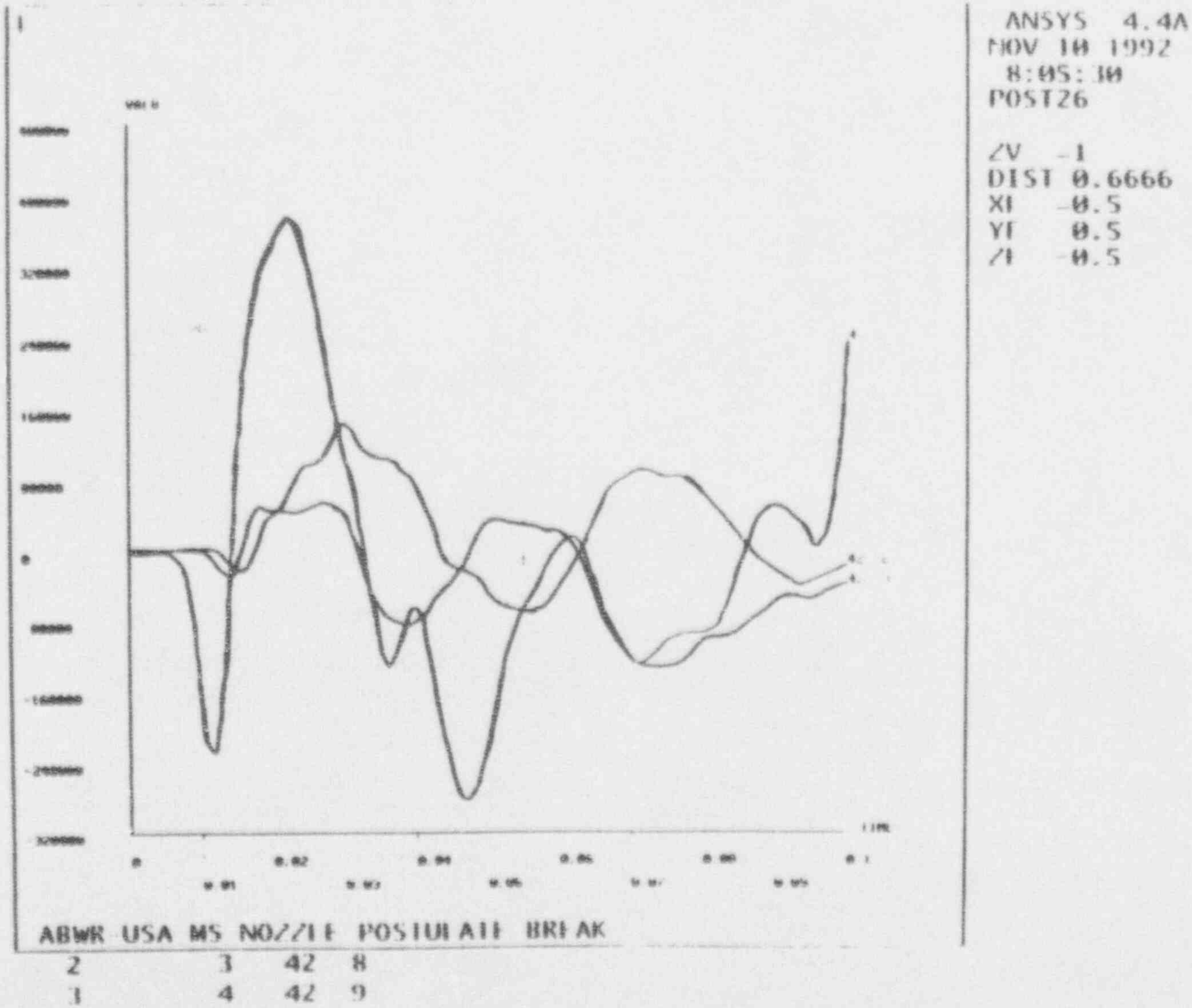


Figure 6C: Force time histories at 42J (headfitting)
(Included displaced elbow and break pipe orientation)

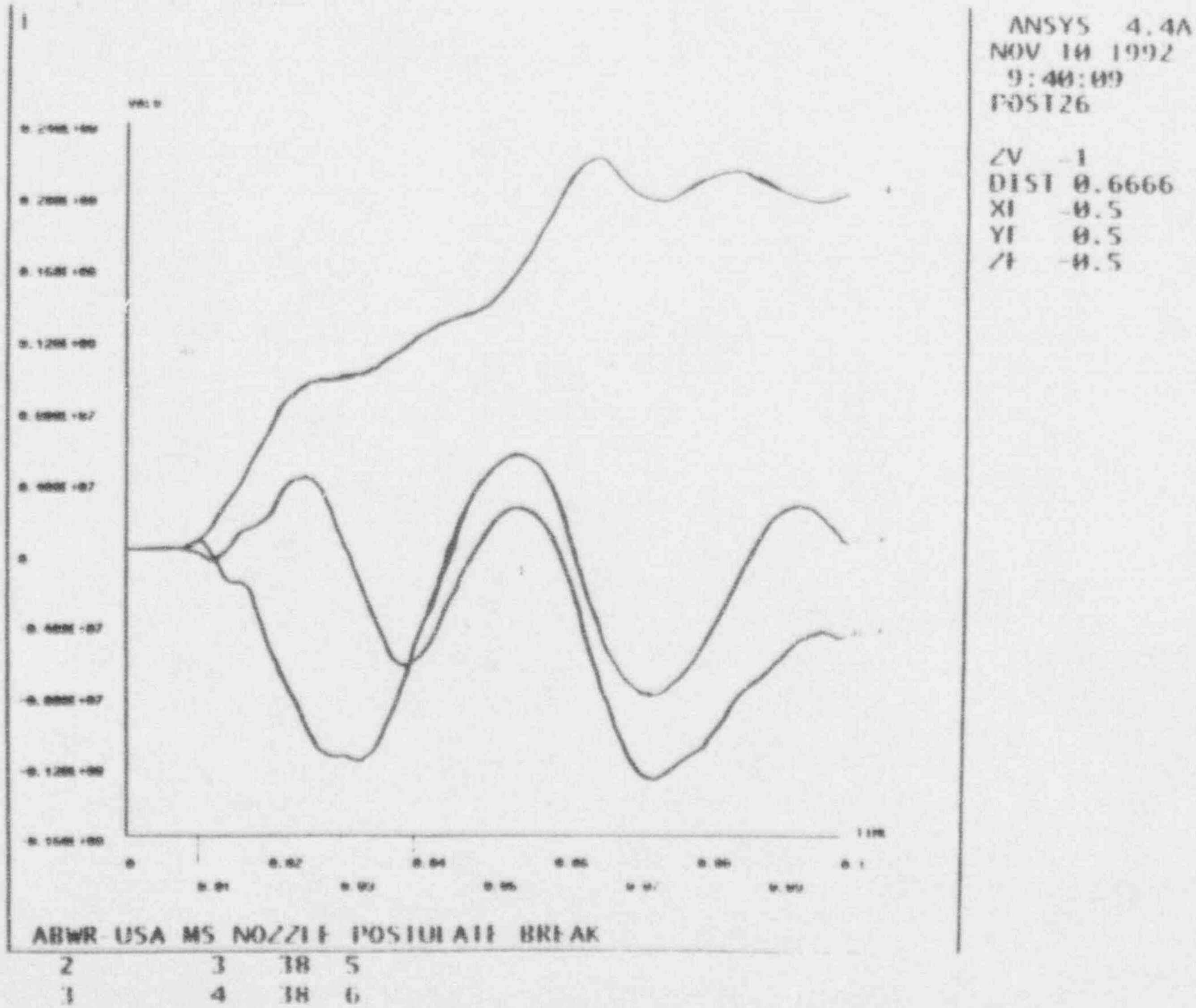


Figure 9C: Bending moment time histories. DT=0.001 sec.
at Elm 38I, 1st elm after MSIV.
(Included displaced elbow and break pipe orientation)

```
523240.0   0.7      0.7        .00386    .01271   13.27     9.1
28.        25.189   .19        110000.   402.89   2311.65   1000000.
4.543      .0268    1579602.   104924.   .235     8.480     36.
0606010101
```

G E N E R A L   E L E C T R I C   C O M P A N Y

N U C L E A R   E N E R G Y   S Y S T E M S   D I V I S I O N

APPENDIX A

```
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXX                                          XXX
XXX                                          XXX
XXX      PPPPP       DDDDD        AAAA       XXX
XXX      P    P      D    D      A    A      XXX
XXX      P    P      D    D      A    A      XXX
XXX      P    P      D    D      A    A      XXX
XXX      PPPPP       D    D      AAAAAA      XXX
XXX      P           D    D      A    A      XXX
XXX      P           D    D      A    A      XXX
XXX      P           DDDDD       A    A      XXX
XXX                                          XXX
XXX                                          XXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

P I P E   D Y N A M I C   A N A L Y S I S   P R O G R A M

R E V I S I O N   2   2 / 1 2 / 1 9 7 6

PROGRAM DEVELOPED BY: LD STEINERT MARCH 1973
ADMINISTERED BY:
STANDARD PLANT PIPING
DESIGN COMP. NO. 123

EFFECTIVE CLEARANCE (INCHES)	LENGTH FROM RESTRAINT TO BREAK(FT)	RESTRAINT LOADING DIRECTION	
4.543	4.170	0 DEGREES	
PIPE BENDING STRAIN LIMIT(IN/IN)	PIPE ROTATION STABILITY LIMIT(DEGR.)	MAX. ALLOWABLE BENDING MOMENT (FT-LBS)	
1.004E-01	8.6281		4647695.

IMPACT VELOCITY= 21.70 FT/SEC   IMPACT TIME= .0240 SECONDS

NO. OF EARS COMPOSING THE REST.	DEFL. OF STUC. IN DIR. OF THRUST (IN.)	DEFL OF REST. IN DIR. OF THRUST (IN.)	REL.DEFL. OF PIPE END IN DIR. OF THRUST (IN.)	TOTAL DEFL. OF PIPE END
6	.6543	1.1784	.0134	9.1103

FORCE ON REST IN DIR. OF THRUST (LBS.)	FORCE ON STR. IN DIR. OF THRUST (LBS.)	TIME AT PEAK DYNAMIC LOAD (SEC)	DEFL. TIME FOR PIPE END SEC AF.IMPC.	TOTAL TIME OF MOVEMENT
654310.	654310.	.0427	.0009	.0427

TOTAL ENERGY ABSO. BY THE REST. (FT-LBS)	ENERGY ABSO. BY THE STRUCTURE (FT-LBS)	ENERGY ABSOB. BY THE BOTTOM HINGE (FT-LBS)	ENERGY ABSO. BY THE REST. HINGE (FT-LBS)	TOTAL ABSO. ENERGY (FT-LBS)
51826.	17838.	217245.	460.	287373.

ENERGY ABSO. BY THE TOP HINGE (FT-LBS)	REST. LOAD (PEAK) COMP. (LBS) PD1	PD2	REST. LOAD (STATIC) COMP. (LBS) PS1	PS2	PIPE DEFL. AT REST. COMP. (IN.) XR1	XR2	PIPE DEFL. AT THE BREA COMP. (IN. XP1	XP
0.	654310.	0.	534107.	0.	6.38	.00	9.31	.0

$654^{Kip} \times \frac{533}{523} = 666{,}927$

*** EXCEPT FOR THE RESTRAINT LOAD COMPONENTS PD1 AND PD2, ALL VARIABLES BELOW ARE IN A DIRECTION PARALLEL TO THE BLOWDOWN FORCE. ***

TIME SEC	P DIS. AT RES. IN.	P VEL. AT R. FT/SEC	P ACC AT R. FT/SEC2	REL DIS. OF END IN.	TTL DIS. OF END (IN.)	RES.LOAD COMP.PD1 (LBS.)	RES.LOAD COMP.PD2 (LBS.)	BLWDWN FORCE (LBS.)
.0088	1.14	14.83	661.9	.00	1.66	0.	0.	366268.
.0145	2.27	18.05	485.0	.00	3.31	0.	0.	366268.
.0195	3.41	20.16	380.9	.00	4.97	0.	0.	366268.
.0240	4.54	21.70	309.2	.00	6.62	0.	0.	366268.
.0256	4.95	20.96	******	.00	7.21	328499.	0.	366268.
.0267	5.22	19.50	******	.00	7.61	442092.	0.	366268.
.0279	5.49	17.48	******	.00	8.01	514300.	0.	366268.
.0293	5.76	14.84	******	.00	8.41	567456.	0.	366268.
.0311	6.04	11.23	******	.00	8.80	609844.	0.	366268.
.0339	6.31	5.02	******	.00	9.20	645311.	0.	366268.

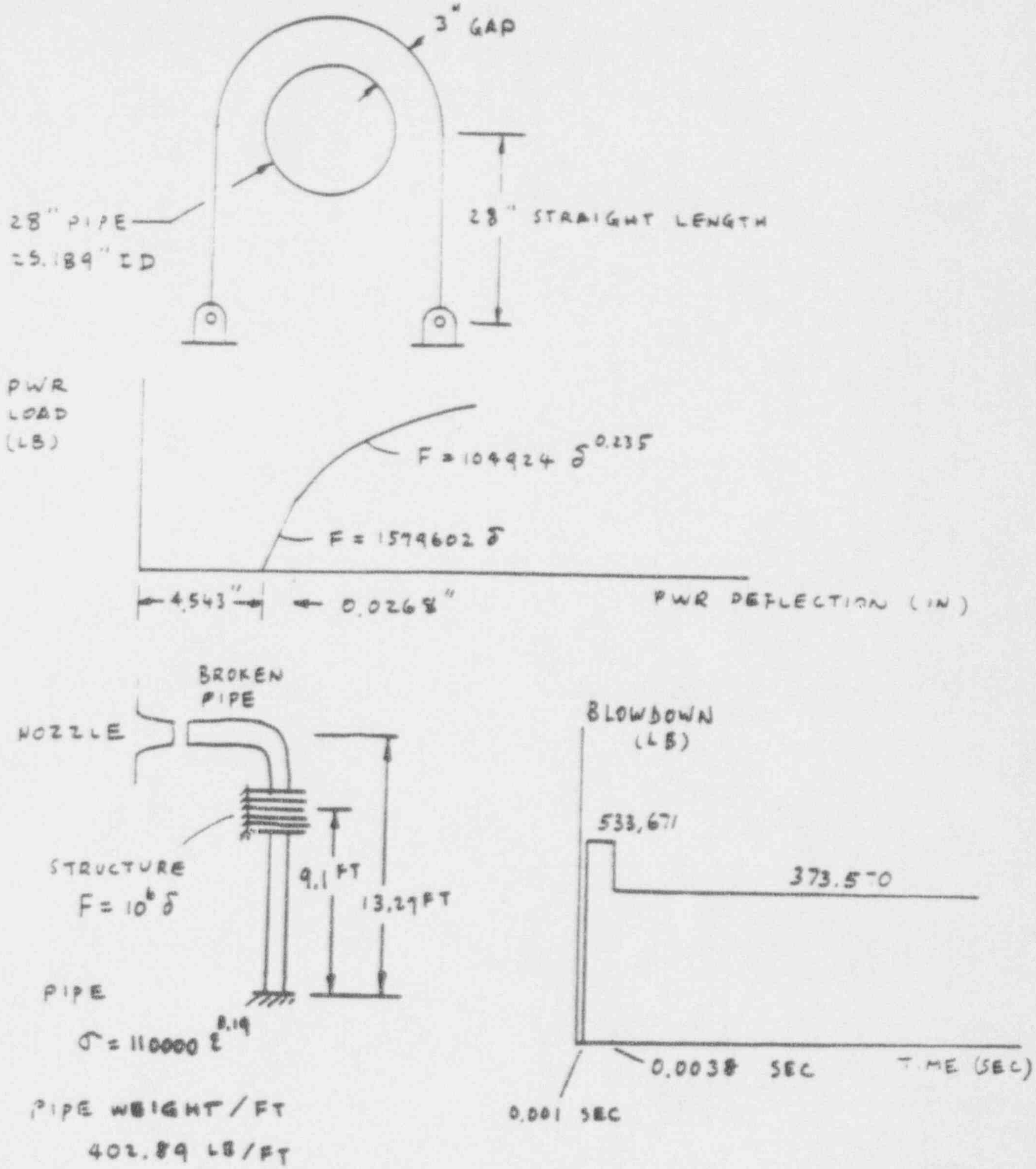


Figure A-1 : Force time history for broken pipe segment

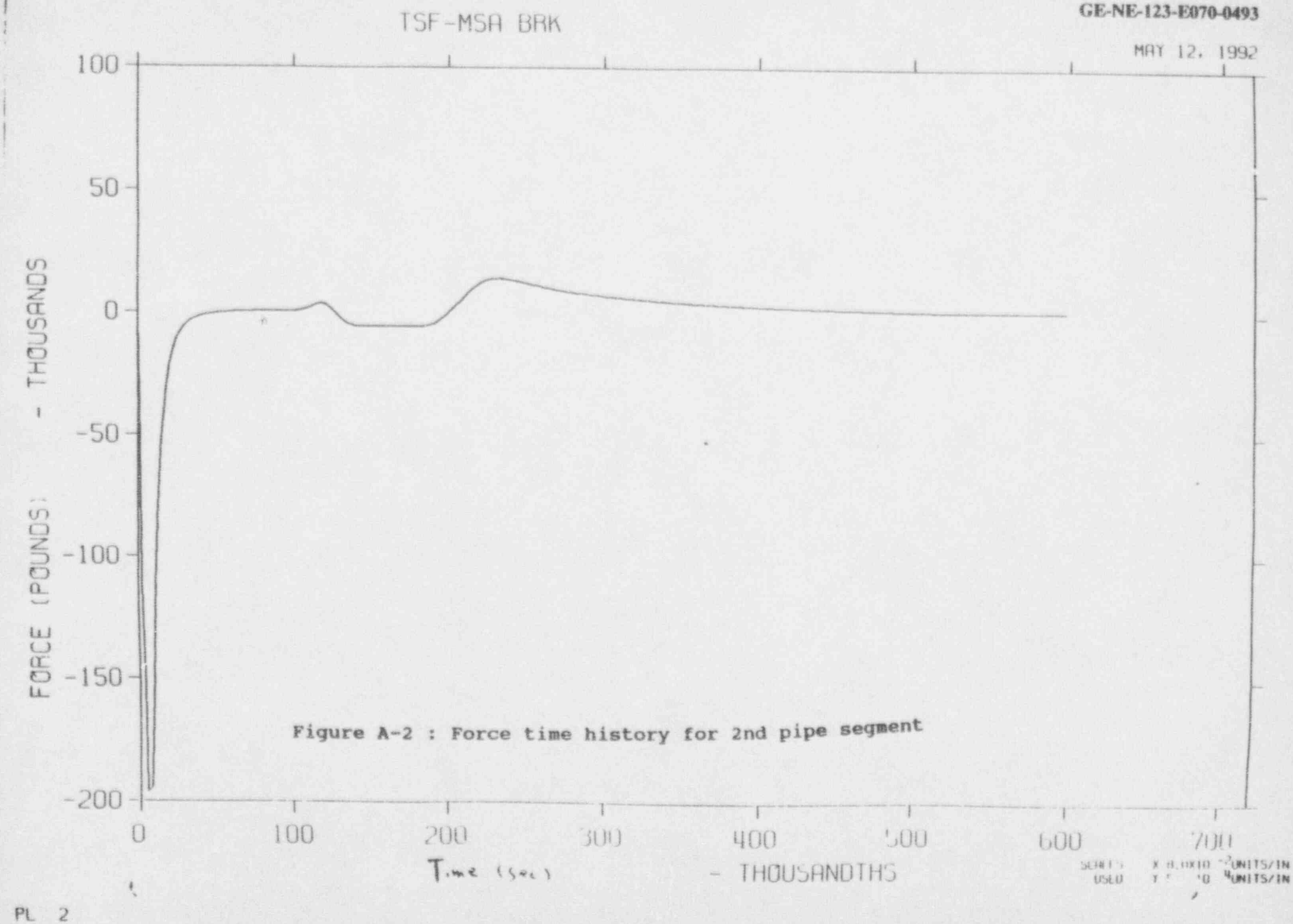


Figure A-2 : Force time history for 2nd pipe segment

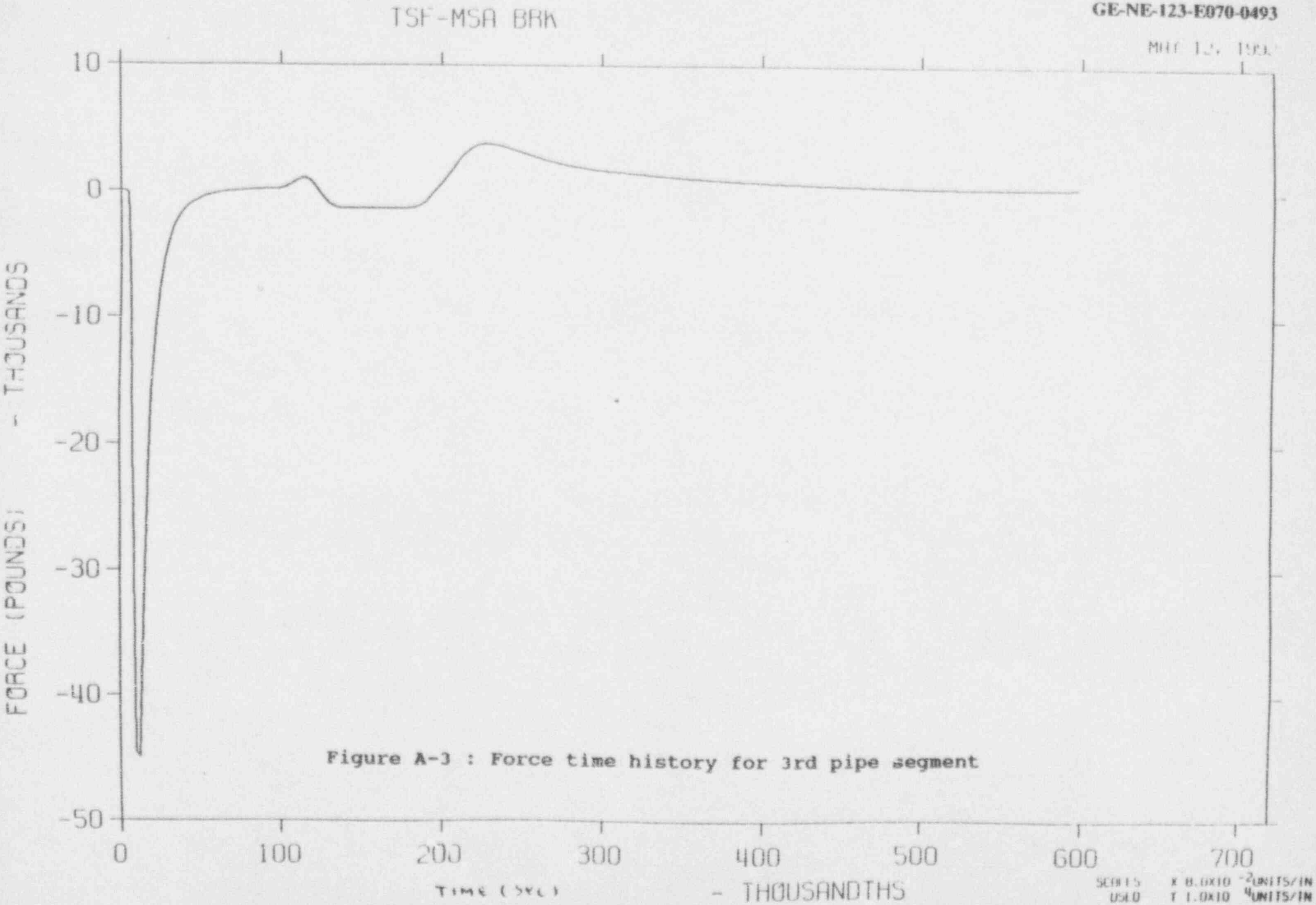


Figure A-3 : Force time history for 3rd pipe segment

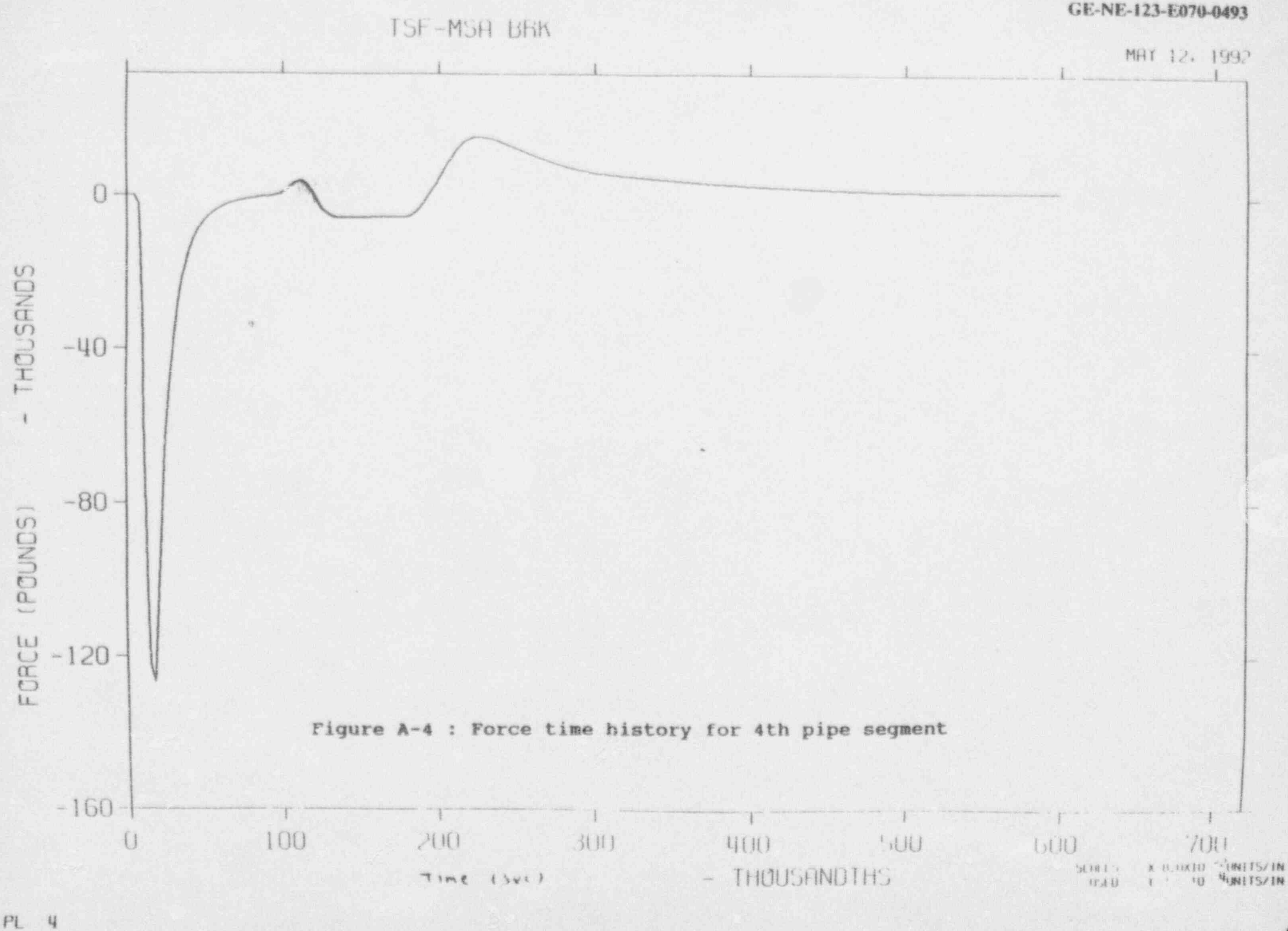


Figure A-4 : Force time history for 4th pipe segment

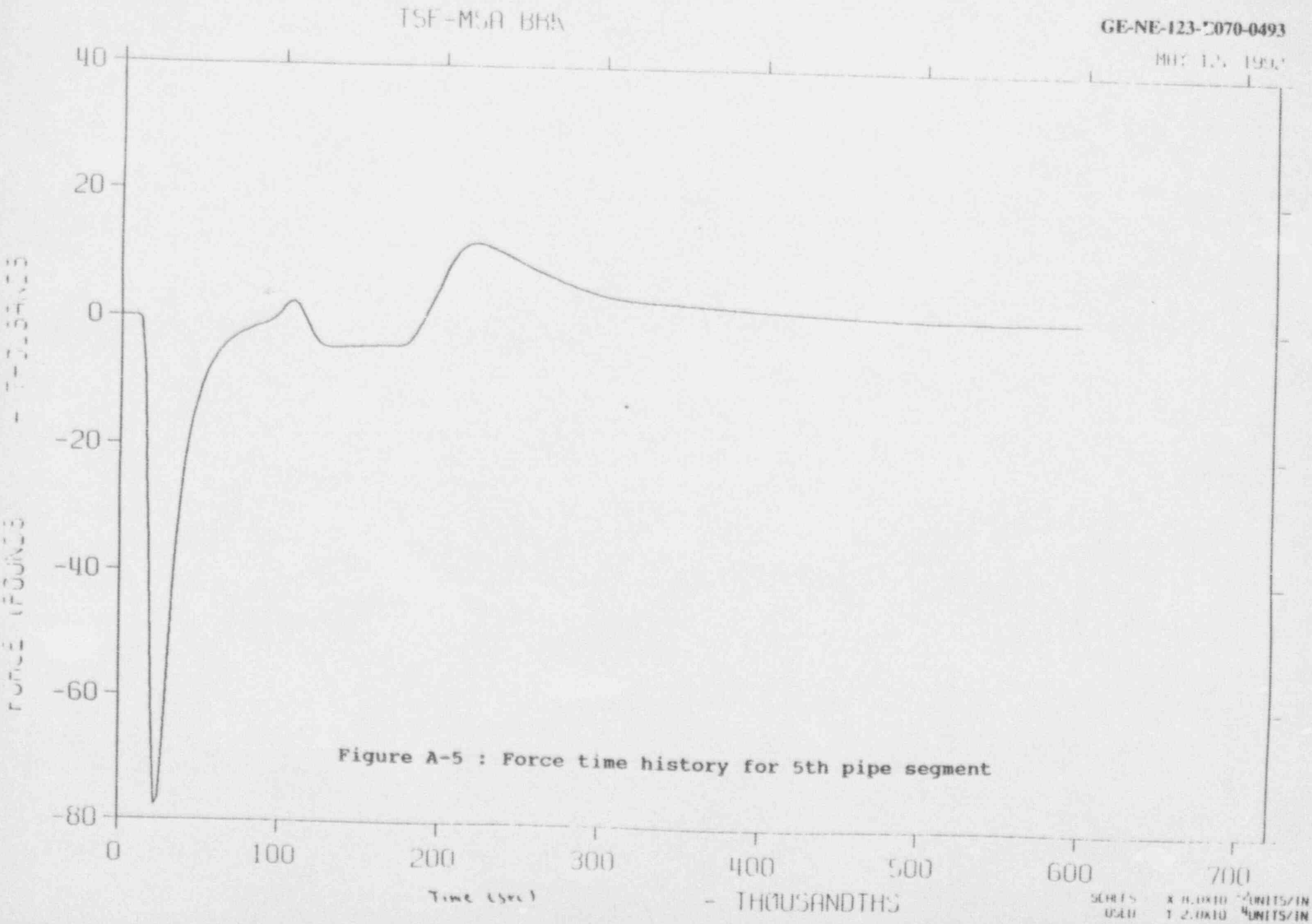


Figure A-5 : Force time history for 5th pipe segment

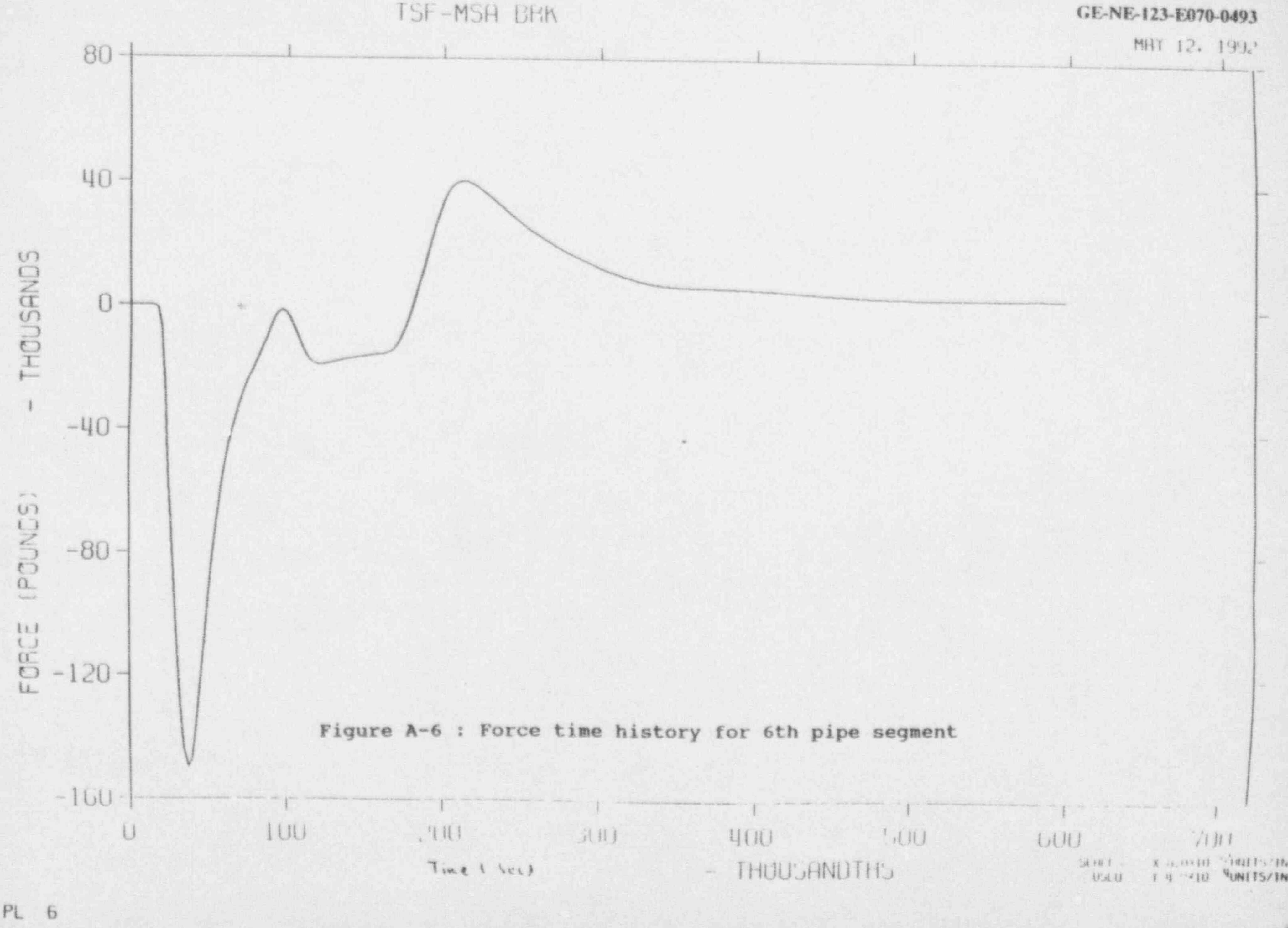


Figure A-6 : Force time history for 6th pipe segment

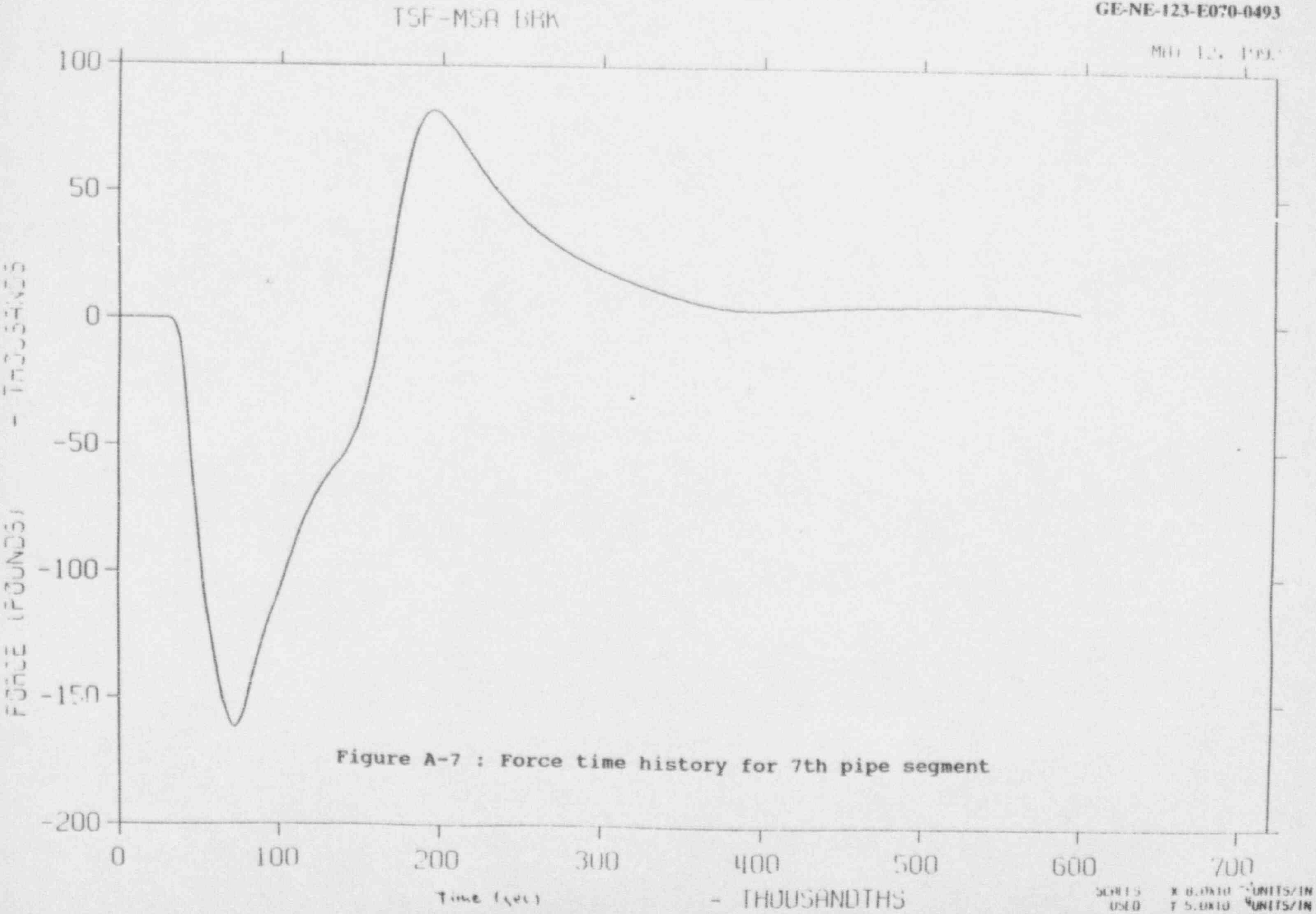


Figure A-7 : Force time history for 7th pipe segment

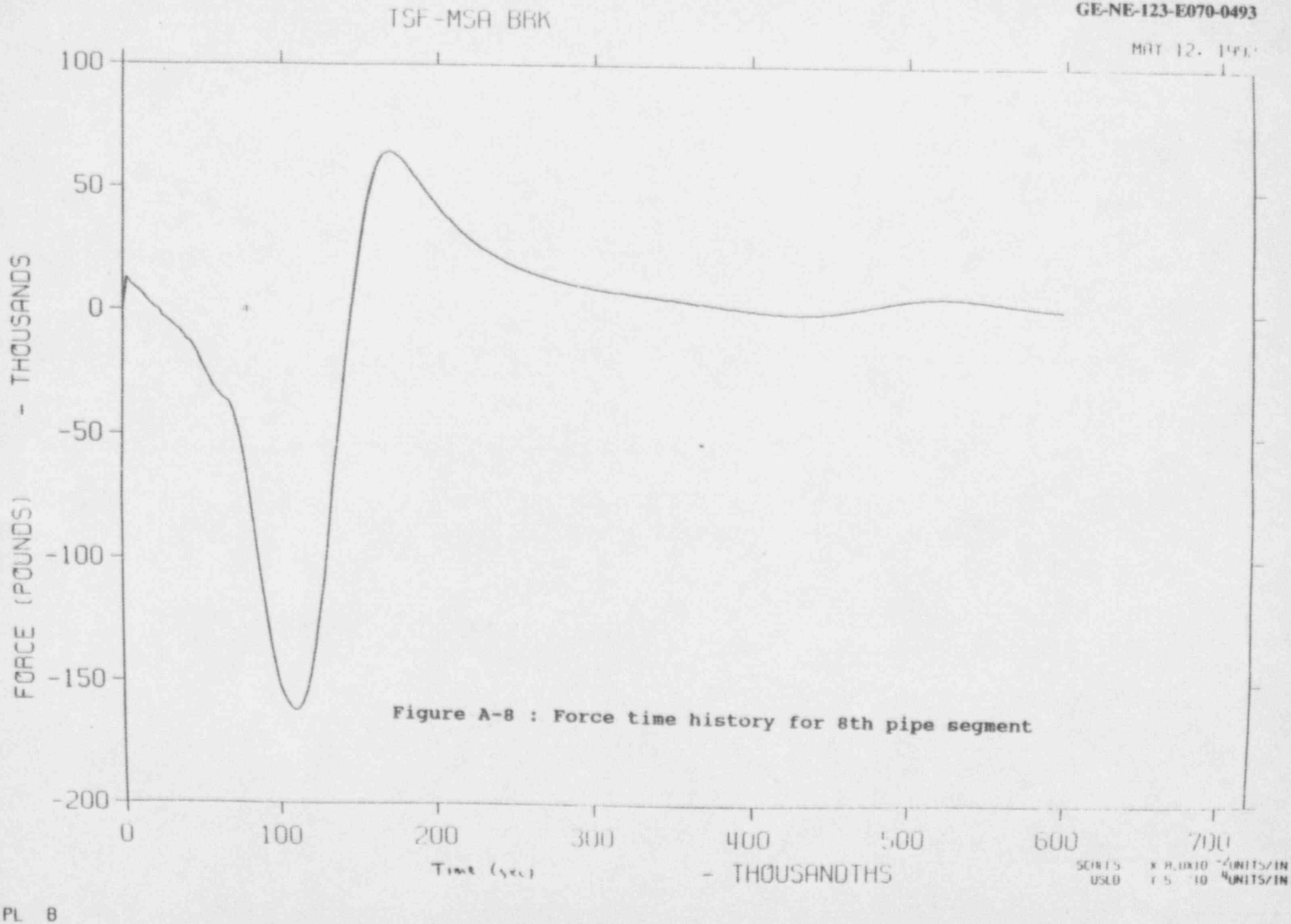


Figure A-8 : Force time history for 8th pipe segment

GE Nuclear Energy

26
May ~~18~~, 1993

Docket No. STN 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Review Schedule - **Sample Pipe Break Analysis Report and Appendix 3L Modification** (replacement)

Dear Chet:

Enclosed are replacements to SSAR markups of new Appendix 3L and to the report GE-NE-123-E070-0493 "Sample Analysis for the Effect of Postulated Pipe Break ABWR Main Steam Piping". ~~The Appendix 3L markups address NRC comments.~~

provided in my May 18, 1993 letter.

Please provide a copy of this transmittal to Shou Hou.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Maryann Herzog (GE)
Norman Fletcher (DOE)

JF93-160