52-001

November 16, 1992

Shou-Nien Hou 7F21
U.S Nuclear Regulatory Commission
1155 Rockville Pike
Rockville, MD 20852

Dear Shou:

Attached is a copy of our report "Sample Analysis for the Effect of Postulated Pipe Break - ABWR Main Steam Piping" by H.L. Hwang. This report provides a sample pipe break analysis and addresses all remaining SSAR issues raised during your audit of the ABWR SSAR regarding postulated pipe ruptures. Although we consider the technical content of this report to be firm and complete, the internal GE review has not yet been completed and the final format of the report is still under discussion. For these reasons the report is marked "Preliminary". It will be issued in final form following the incorporation of GE and NRC comments.

If you have any questions, please call me (408-925-4824) or Henry Hwang (408-925-1984).

Sincerely,

Jack Fox

Jack N. Fox
Advanced Reactor Programs

cc: Chet Poslusny (NRC)
Paul Chen (ETEC)
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D050 /1

PRELIMINARY

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

PREPARED BY :

H L Hwang

VERIFIED BY :

S J Lin

APPROVED BY :

R Patel

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ABSTRACT

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

This special pipe break analysis provides a sample of a GE pipe break analysis. It also addresses the following specific issues and questions regarding the GE methodology that have been raised by the NRC during their audit of the SSAR. These issues and questions are as follows:

(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 containment piping 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.

The report documents the results of the sample analyses performed and contains the following conclusions:

(1) The pipe break location that results in the highest stresses in the containment pipe is the postulated break 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 limit even though several very conservative assumptions were made in the calculations to the minimize cost and time of performing nonlinear time-history analysis. Examples of conservatism are that no credit is taken for: (a) the restraining effects of snubbers on main steam line; (b) the restraining effects of SRV branch lines; (c) the lower pressure in main steam pipe immediately following a pipe rupture.

(3) Decreasing the time step from 0.001 seconds to 0.005 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 pipe does not increase due to rotation of the thrust force at the pipe rupture location. This shows that the GE nonlinear analysis based no rotation of the thrust force is valid.

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

1.0 INTRODUCTION

This analysis report is to present the sample analysis to evaluate the effects of the postulated pipe break at the ABWR main steam pipe nozzle at the Reactor Pressure Vessel (RPV) to the pipe stresses between the inboard and the outboard Main Steam Isolation Valves (MSIV). The reason to choose this break for analysis is because this break is likely to create the maximum stress for the pipe between the containment isolation valves.

When pipe break is postulated at the Safety Relief Discharge pipe branch connections to the main steam pipes, the break area is only about 1/10 of the main steam pipe break area at the RPV nozzle. The thrust force is much smaller at the branch connection than the force at the main steam nozzle.

When the break is postulated at the feedwater nozzle, the break is 12" pipe and the feedwater header to the isolation valve is 22". The break area is less than 1/3 of the head pipe area. Therefore, the pipe stresses between the isolation valves due to the feedwater water nozzle break is less severe than the main steam nozzle break.

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

The result of the analysis show that the stresses between the MSIV's meet SRP 3.6.2 stress limit (2.25Sm).

2.0 : DESCRIPTION OF PIPE BREAK FORCING FUNCTION ANALYSIS

2.1 Description

The steam flows from RPV to turbine during normal operation. When the postulated pipe break occurs at the RPV nozzle safe end or at the first elbow, the steam flows back to the break. A decompression wave starts at the break location and propagates through the whole main steam pipe to create force time histories on each pipe segment.

In order to calculate the force time histories, Turbine Stop Valve Closure Force (TSFOR) program is modified to perform the calculation. TSFOR is an Engineering Computer Program (ECP) program to calculate the pipe segment force time histories due to turbine stop valve closure. 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. This report describes the modifications and the procedures to calculate the force time histories.

2.2 Program Modifications

The back flow can be computed by applying the break boundary condition to the vessel side of the main steam pipe as shown below (Reference 1).

```
p/p0      = (2/(K+1))**(2K/K-1) = 0.28
<j>/C0    = (2/(K+1)) = 0.86
<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

An executable program file, called MS-BRK, have been set up to calculate the pipe segment forces due to the postulated break. The program calculate the force for a closed system only. The method of the analysis is the same as described in the ANS-58.2. The thrust f']time history for he discharge pipe, which is an open pipe, e calculated in accordance with ANS-58.2.

.3 Application of MS-BRK Program

2.3.1 Pipe Segment Time Histories (Excluding the Break Pipe Segment)

Set up the input exactly the same as the TSFOR input which is described in NEDE-23789. The MS-BRK used the pipe break boundary condition for the analysis. No user input boundary condition is needed.

2.3.2 Pipe Segment Time Histories for the Break Pipe Segment

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 t1, is

t1 = L/C

For t < t1 F = PA
For t $\geq$ t1 F = 0.70 PA
0.7 PA = 373,570 lb

Usually t1, a very short period, is only abo').003 sec. To the analysis of the stresses between MSIV's it is equate using 0.70 PA for the first pipe segment. However, the sample problem analysis includes the force equal to PA for 0.003 seconds.

The determination of the 0.70 is based on the friction effect of the steady blowdown force, (Ref. 2):

FL/D = 0.0   Force = 1.26 PA
FL/D = 2.5   Force = 0.70 PA

The FL/D includes the friction from pipe break to the turbine, plus the friction through MSIV's and steam supply 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) Append the output from MS-BRK-A to 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

Example 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 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

The main steam guide is important to reduce the pipe stresses between the MSIV's. The guide is modeled as two spring elements.

3.2 Analysis Time Step

In order to show that the analysis time step 0.001 second is adequate, an analysis with time step of 0.0005 second has been performed. The results of the analysis are plotted in the following figures. Comparisons of the results between 0.001 sec and 0.0005 sec time step showed that the differences are less than 3%. Therefore, time step of 0.001 sec can be used in the future analysis.

Figure 1-1 : ANSYS analysis model- element plot.

Figure 1-2 : ANSYS analysis model- nodal plot.

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 history 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.

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(0.7PA=373,600 lb, max impact=670,000 lb)

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3.3 Discussion of Large Displacement Analyses

The displacements from the terminal end Main Steam Break Structure (MSBS) analysis (using ANSYS) results show large displacements and rotation at the break. The thrust direction changes during the event which could affect the stress in the "Holy Pipe" area. Therefore, GE has performed time history analyses for the original and displaced position to confirm the validity of the small displacement assumption in the non-linear time history analysis results.

Two displaced analysis have been performed. The first displaced analysis is to rotate the element at the break to the displaced angle and change the thrust force to the displaced angle. Another analysis is to rotate the pipe element from the break to the pipe whip restraint to be the same as the displaced orientations.

The results of the analysis are shown in the figures below for the first case, which rotate the pipe break element only.

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

The results of the analysis are shown in the figures below for the second case, which rotate the pipe from the break element and the elbow to the pipe whip restraint element. The results 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)

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 deg. 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(a)	22.0	7.2	5.0	23.7	31560
Result 4(b)	19.9	13.0	8.0	25.0	33390

This can be seen that the values calculated from the result 1 is slightly conservative.

From Figure 9, moment time history plots at element 38I, the first element after MSIV, the maximum bending are as follows:

Elem 38I	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 isolation valve is at the headfitting for the analysis with the design configuration. The combined stress is as follows:

$$S_p + S_w + S_{break} = 5165 + 1074 + 33600 = 39{,}839 \text{ psi}$$

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 load calculated are listed below.

Result 1	670,000 lb
Result 2	670,000 lb
Result 3	650,000 lb
Result 4	640,000 lb
PDA	666,727 lb

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

5.0 CONCLUSIONS

1) The maximum combined stress between the MSIV's is 39265 psi. This is below 2.25 Sm allowable limit as specified in SRP 3.6.2.

The analysis did not include the snubbers on the main steam piping. Therefore, the analysis is very conservative.

2) The maximum 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 of 666,727 lb. Both results are close.

PDA program is acceptable to be used for sizing the pipe whip restraints.

5.1 Discussions of Conservatisms 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.

c) The stresses due to the displacement of the pipe whip restraint are also included as required by SRP 3.6.2.

6.0 REFERENCES

1) "Thermal-Hydraulics of a Boiling Water Nuclear Reactor" by F J Moody and Lahey.

2) ANSI/ANS-58.2-1988 Figure B-3.

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

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(1) Document GE procedure for calculating the forcing functions for line segments of a ruptured pipe [illegible] 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 containment piping following a postulated pipe rupture.

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

The report documents the results of the sample analyses performed and contains the following conclusions:

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

(2) The ASME III, Equat'on (9) stresses in the containment area of the main steam pip following a pipe rupture at the RPV nozzle are below the SRP 6.2 limit of 2.25 Sm limit even though several very conservative assumptions were made in the calculations to the minimize cost and time of performing nonlinear time-history analysis. Examples of conservatism are that no credit is taken for: (a) the restraining effects of snubbers on main steam line; (b) the restraining effects of SRV branch lines; (c) the lower pressure in main steam pipe immediately following a pipe rupture.

(3) Decreasing the time step from 0.001 seconds to 0.005 seconds has insignificant effect on results, proving convergence of the ANSYS solution with the GE analytical assumption of 0.001 seconds.

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1.0 INTRODUCTION

This analysis report is to present the sample analysis to evaluate the effects of the postulated pipe break at the ABWR main steam pipe nozzle at the Reactor Pressure Vessel (RPV) to the pipe stresses between the inboard and the outboard Main Steam Isolation Valves (MSIV). The reason to choose this break for analysis is because this break is likely to create the maximum stress for the pipe between the containment isolation valves.

When pipe break is postulated at the Safety Relief Discharge pipe branch connections to the main steam pipes, the break area is only about 1/10 of the main steam pipe break area at the RPV nozzle. The thrust force is much smaller at the branch connection than the force at the main steam nozzle.

When the break is postulated at the feedwater nozzle, the break is 12" pipe and the feedwater header to the isolation valve is 22". The break area is less than 1/3 of the head pipe area. Therefore, the pipe stresses between the isolation valves due to the feedwater water nozzle break is less severe than the main steam nozzle break.

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

The result of the analysis show that the stresses between the MSIV's meet SRP 3.6.2 stress limit (2.25Sm).

2.0 : DESCRIPTION OF PIPE BREAK FORCING FUNCTION ANALYSIS

2.1 Description

The steam flows from RPV to turbine during normal operation. When the postulated pipe break occurs at the RPV nozzle safe end or at the first elbow, the steam flows back to the break. A decompression wave starts at the break location and propagates through the whole main steam pipe to create force time histories on each pipe segment.

In order to calculate the force time histories, Turbine Stop Valve Closure Force (TSFOR) program is modified to perform the calculation. TSFOR is an Engineering Computer Program (ECP) program to calculate the pipe segment force time histories due to turbine stop valve closure. 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. This report describes the modifications and the procedures to calculate the force time histories.

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The back flow can be computed by applying the break boundary condition to the vessel side of the main steam pipe as shown below (Reference 1).

$$p/p0 = (2/(K+1))^{**}(2K/K-1) = 0.28$$

$$\langle j \rangle/C0 = (2/(K+1)) = 0.86$$

$$\langle rho \rangle/(rho\ 0) = (2/(K+1))^{**}(2/(K-1)) = 0.40$$

where,

- p = steam pressure at the break exit, psia
- p0 = stagnation pressure, psia
- $\langle j \rangle$ = 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

An executable program file, called MS-BRK, have been set up to calculate the pipe segment forces due to the postulated break. The program calculate the force for a closed system only. The method of the analysis is the same as described in the ANS-58.2. The thrust force ltime history for he discharge pipe, which is an open pipe, should be calculated in accordance with ANS-58.2.

2.3 Application of MS-BRK Program

2.3.1 Pipe Segment Time Histories (Excluding the Break Pipe Segment)

Set up the input exactly the same as the TSFOR input which is described in NEDE-23789. The MS-BRK used the pipe break boundary condition for the analysis. No user input boundary condition is needed.

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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 t1, is

$$t1 = L/C$$

For $t < t1$ $\quad F = PA$

For $t \geq t1$ $\quad F = 0.70\ PA$

$0.7\ PA = 373{,}570$ lb

Usually t1, a very short period, is only about 0.003 sec. To the analysis of the stresses between MSIV's it is adequate using 0.70 PA for the first pipe segment. However, the sample problem analysis includes the force equal to PA for 0.003 seconds.

The determination of the 0.70 is based on the friction effect of the steady blowdown force, (Ref. 2):

FL/D = 0.0 Force = 1.26 PA
FL/D = 2.5 Force = 0.70 PA

The FL/D includes the friction from pipe break to the turbine, plus the friction through MSIV's and steam supply 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.

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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) Append the output from MS-BRK-A to 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

Example 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

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3.0 ANSYS NON-LINEAR ANALYSIS

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The pipe break non-linear time history analysis can be performed by ANSYS program. The selection of the input are described as follows:

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In order to show that the analysis time step 0.001 second is adequate, an analysis with time step of 0.0005 second has been performed. The results of the analysis are plotted in the following figures. Comparisons of the results between 0.001 sec and 0.0005 sec time step showed that the differences are less than 3%. Therefore, time step of 0.001 sec can be used in the future analysis.

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(max impact=670,000 lb)

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

The results of the analysis are shown in the figures below for the second case, which rotate the pipe from the break element and the elbow to the pipe whip restraint element. The results 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)

4.0 STRESS ANALYSIS

4.1 Pipe Data

Pipe = 2?" 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 deg. 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. ... 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(a)	22.0	7.2	5.0	2[illegible].7	31560
Result 4(b)	19.9	13.0	8.0	25.0	33390

This can be seen that the values calculated from the result 1 is slightly conservative.

From Figure 9, moment time history plots at element 38I, the first element after MSIV, the maximum bending are as follows:

Elem 38I	Ma (E6)	Mb (E6)	Mc (E6)	Mr (E6)	B2 M/Z psi
Result 1	15.0	13.0	11.5	23.0	30600
Result [illegible]	19.5	8.5	13.0	24.9	33200

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

Sp + Sw + S break = 5165 + 107[illegible] [illegible]3600
= 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 load calculated are listed below.

Result 1	670,000 lb
Result 2	670,000 lb
Result 3	65[illegible],000 lb
Result 4	64[illegible],000 lb
PDA	666,727 lb

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

5.0 CONCLUSIONS

1) The maximum combined stress between the MSIV's is 39265 psi. This is below 2.25 Sm allowable limit as specified in SRP 3.6.2.

The analysis did not include the snubbers on the main steam piping. Therefore, the analysis is very conservative.

2) The maximum 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 of 666,727 lb. Both results are close.

PDA program is acceptable to be used for sizing the pipe whip restraints.

5.1 Discussions of Conservatisms 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.

c) The stresses due to the displacement of the pipe whip restraint are also included as required by SRP 3.6.2.

6.0 REFERENCES

1) "Thermal-Hydraulics of a Boiling Water Nuclear Reactor" by F J Moody and Lahey.

2) ANSI/ANS-58.2-1988 Figure B-3.

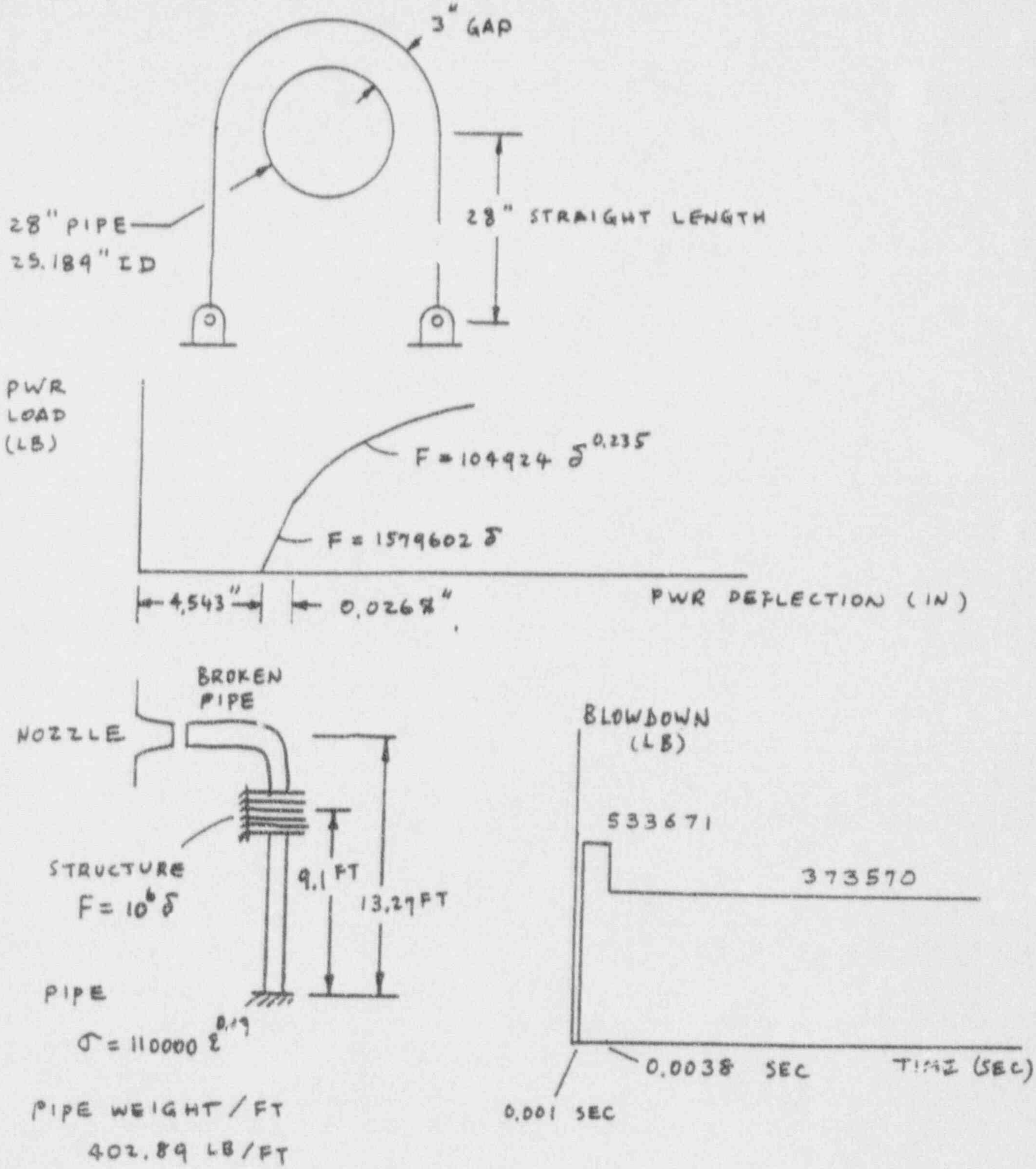


Figure A-1 : Force time history for broken pipe segment

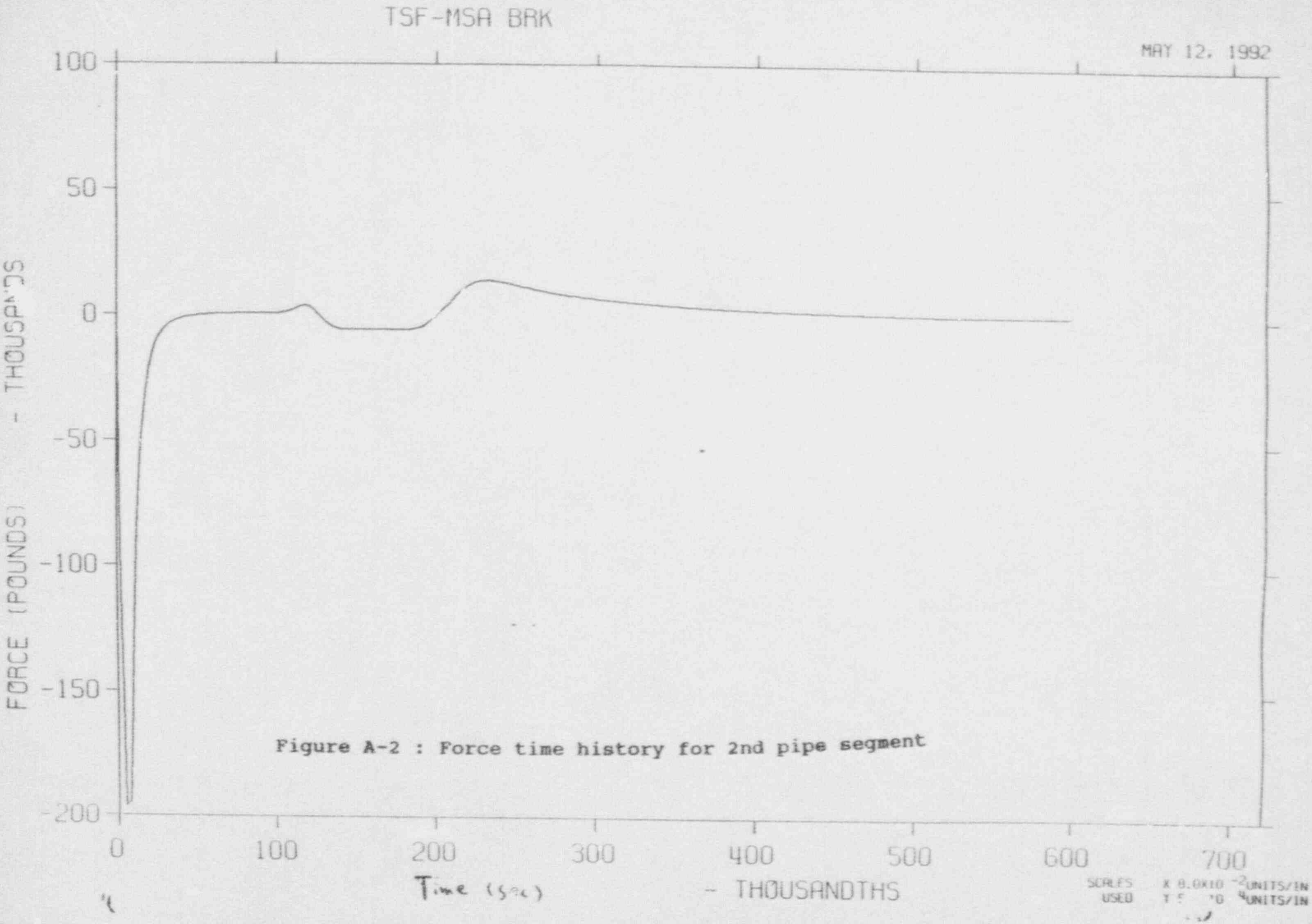


Figure A-2 : Force time history for 2nd pipe segment

PL 2

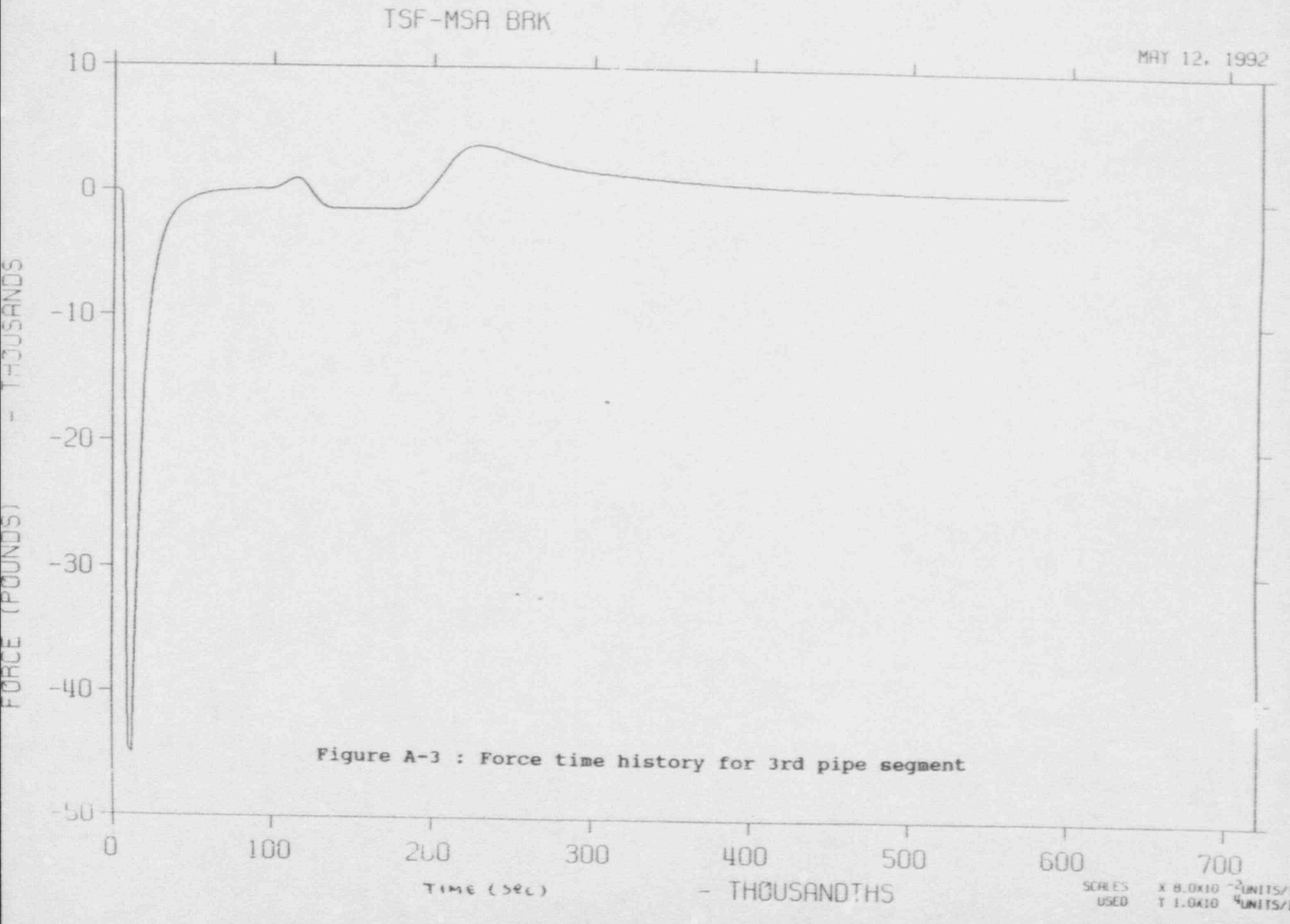


Figure A-3 : Force time history for 3rd pipe segment

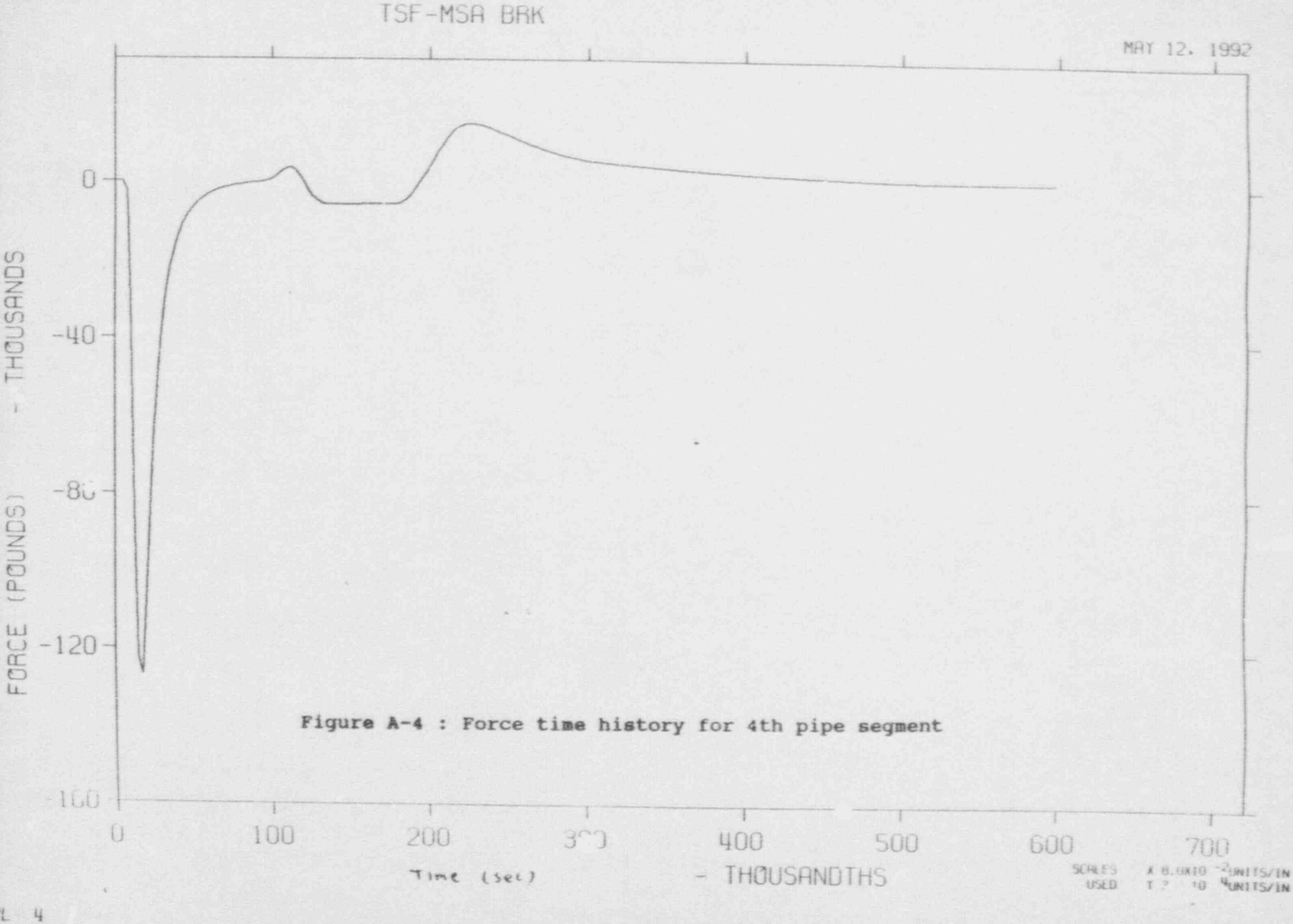


Figure A-4 : Force time history for 4th pipe segment

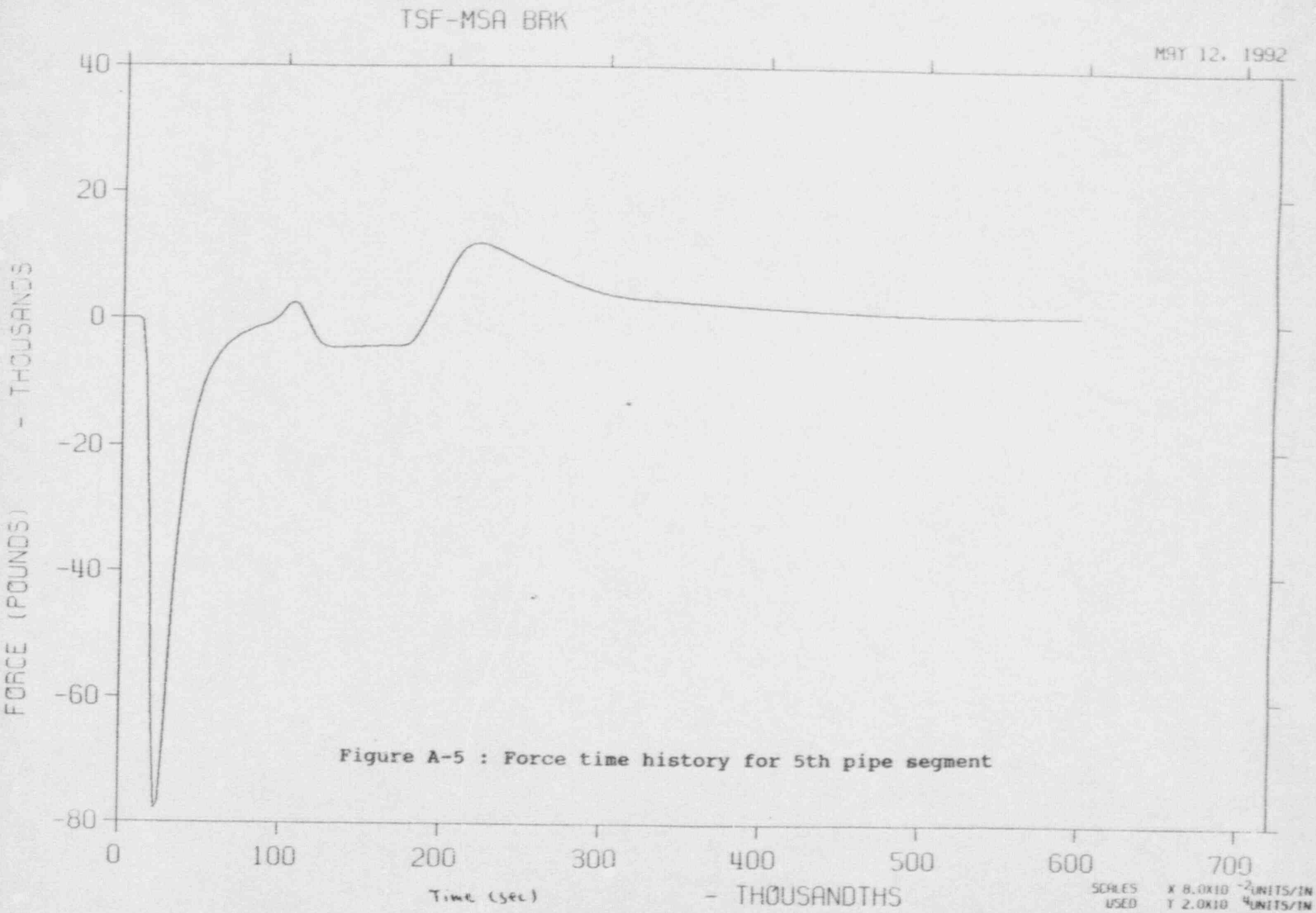


Figure A-5 : Force time history for 5th pipe segment

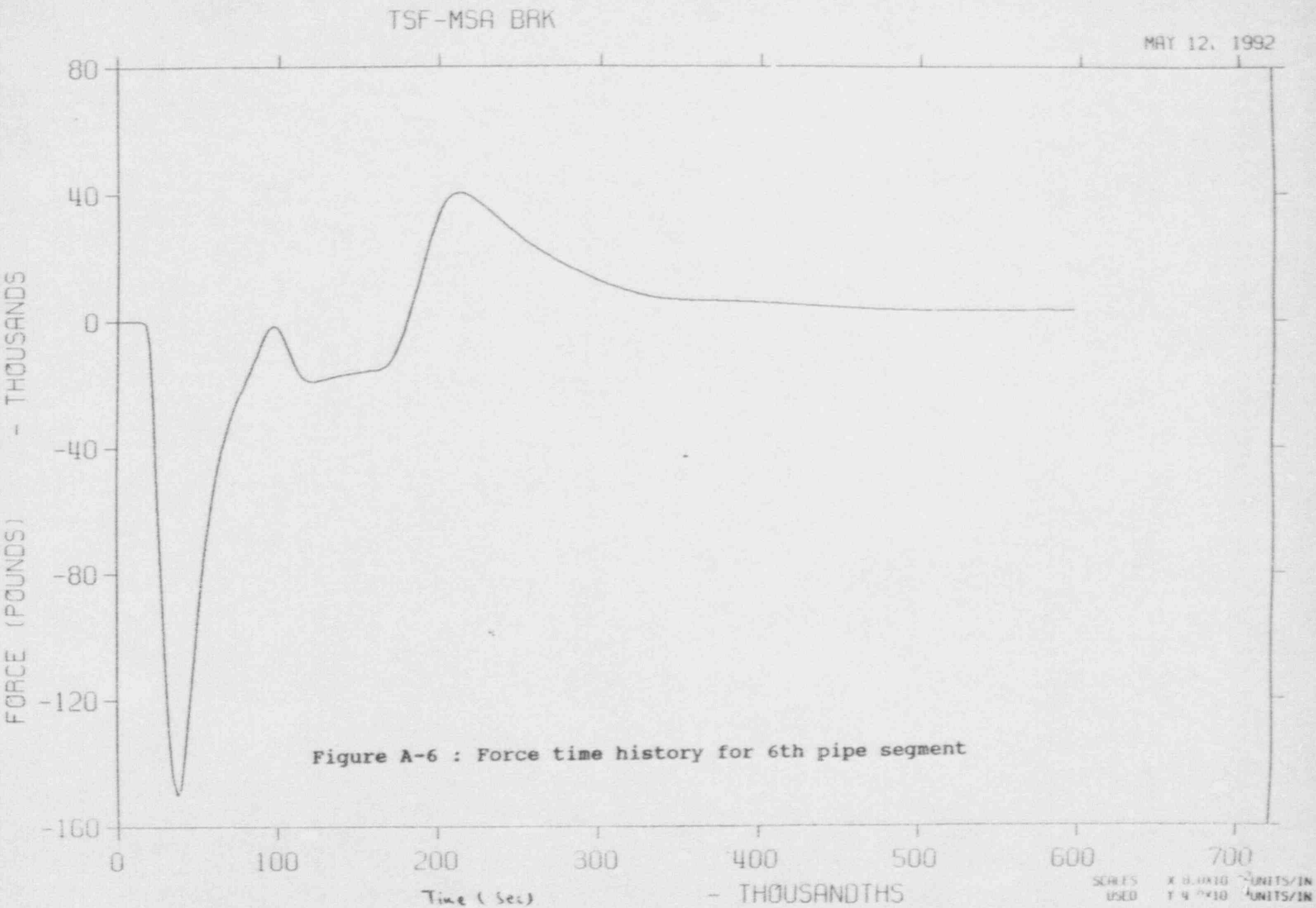


Figure A-6 : Force time history for 6th pipe segment

PL 6

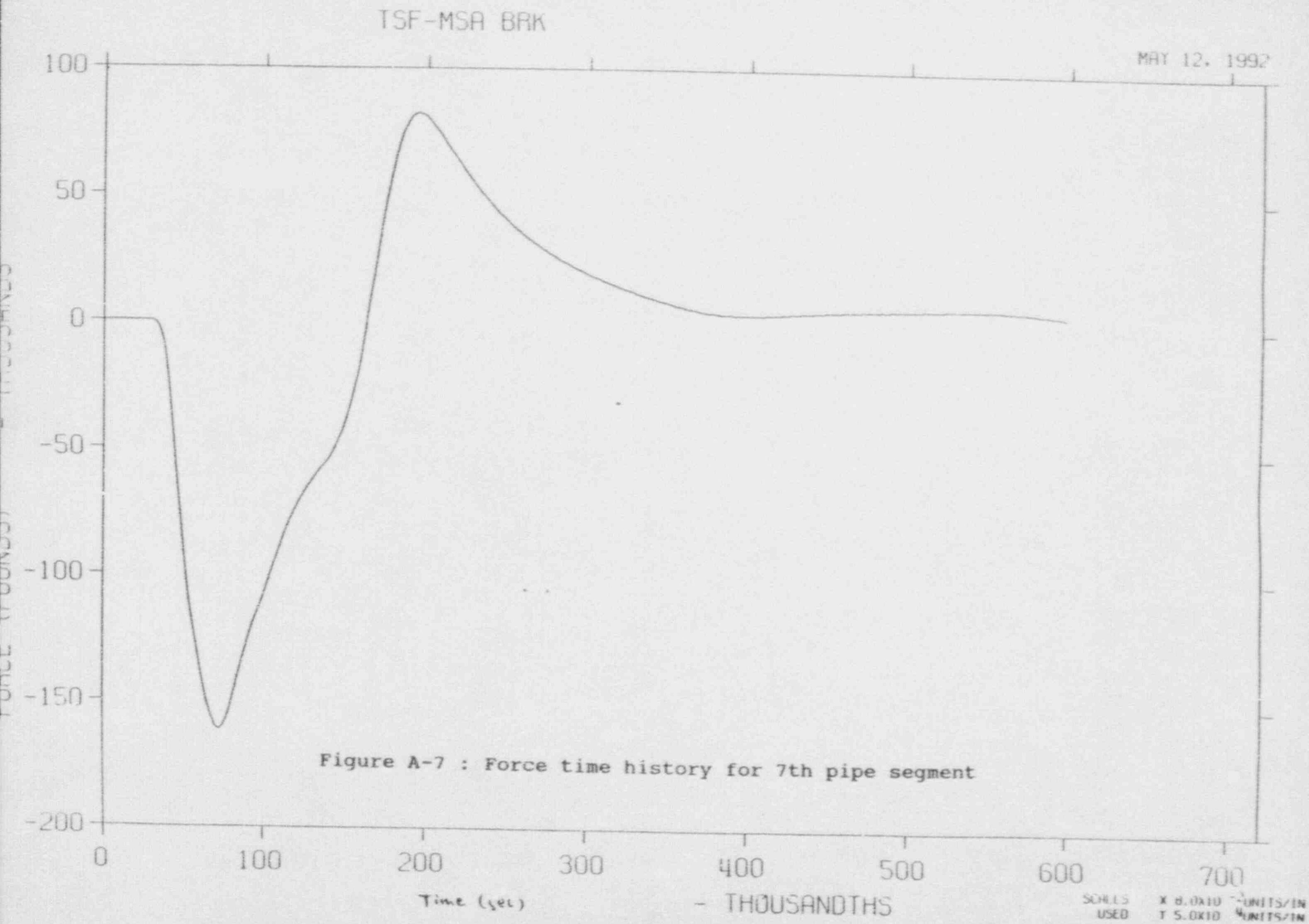


Figure A-7 : Force time history for 7th pipe segment

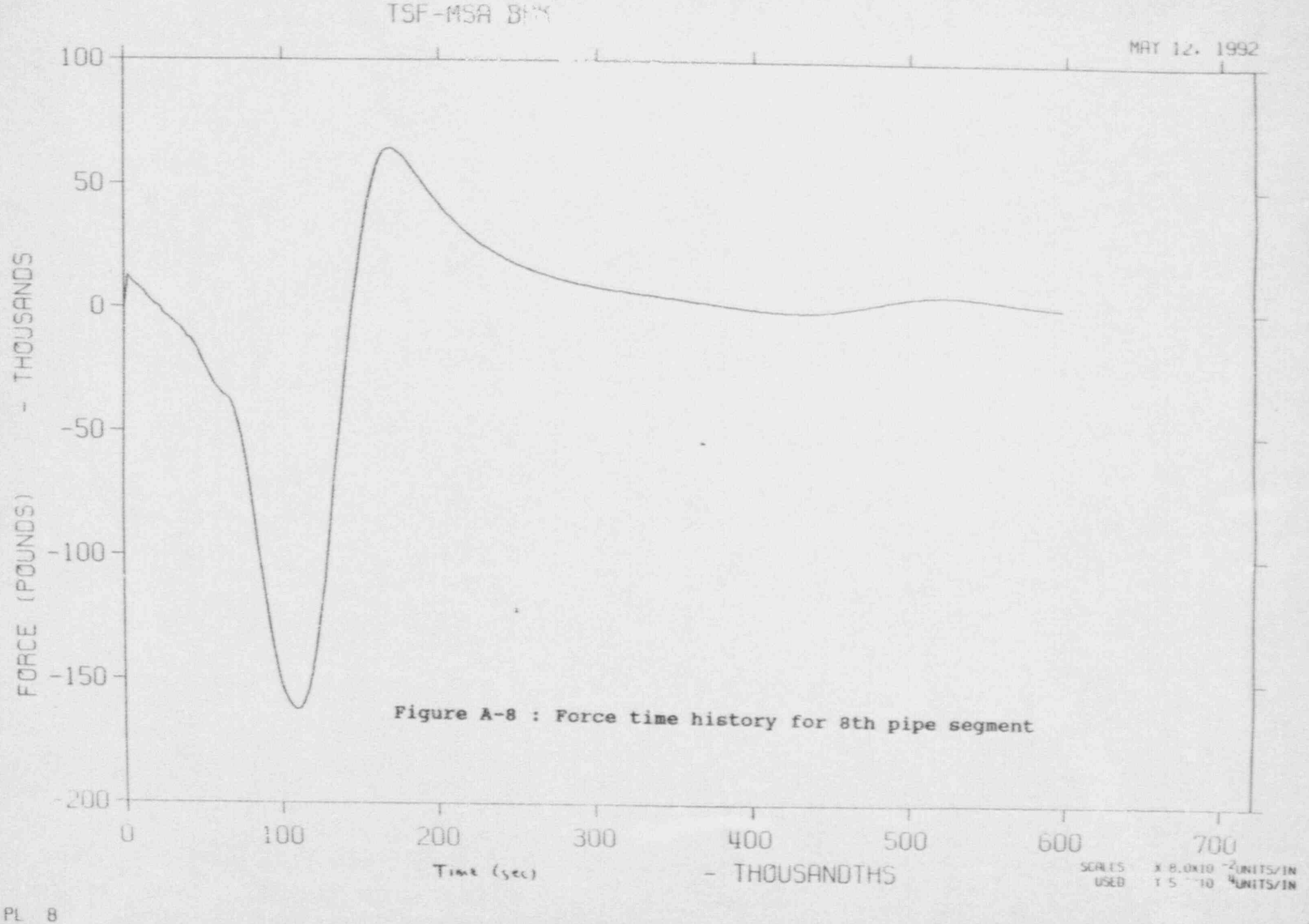


Figure A-8 : Force time history for 8th pipe segment

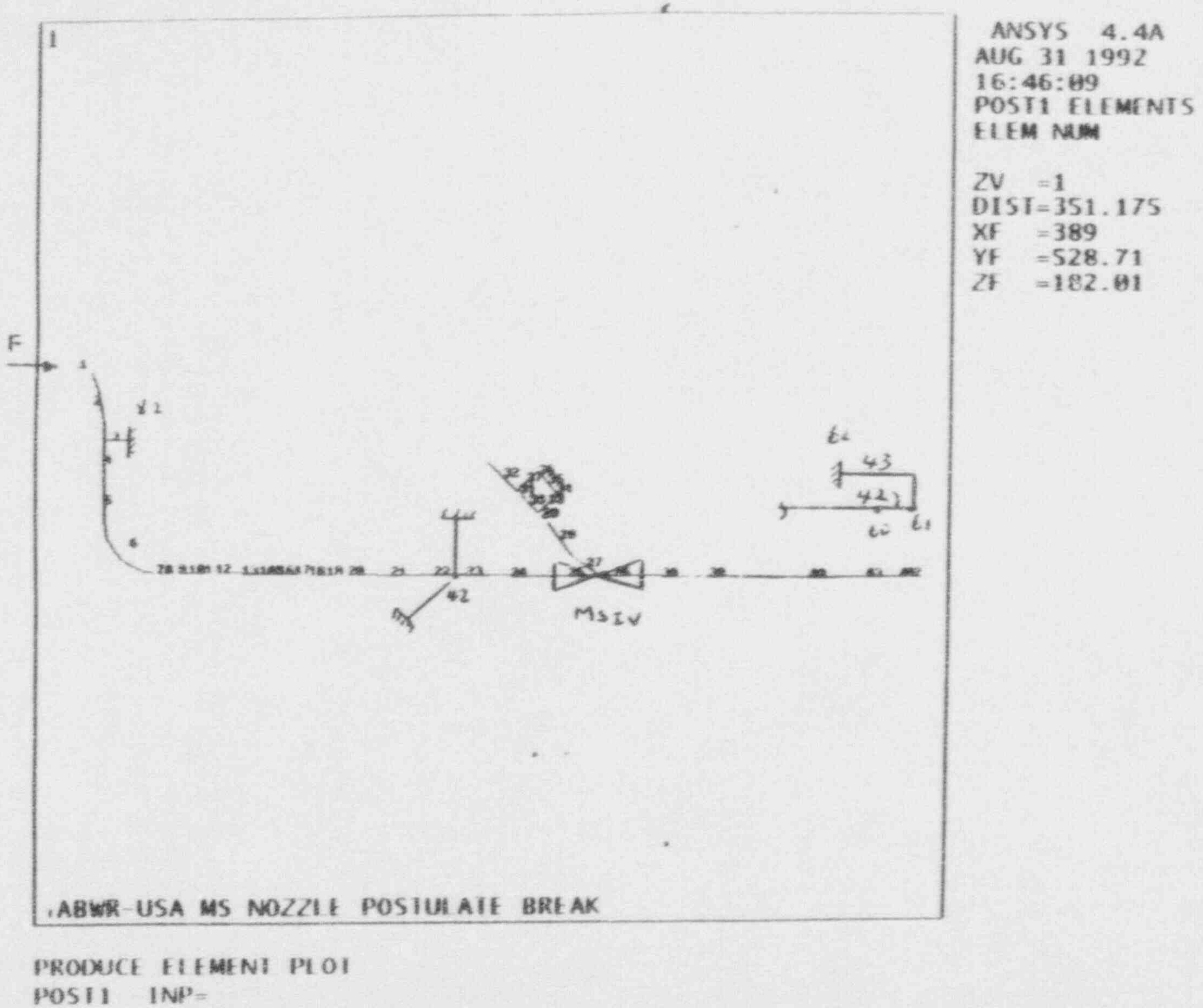


Figure 1-1 : ANSYS analysis model- element plot.

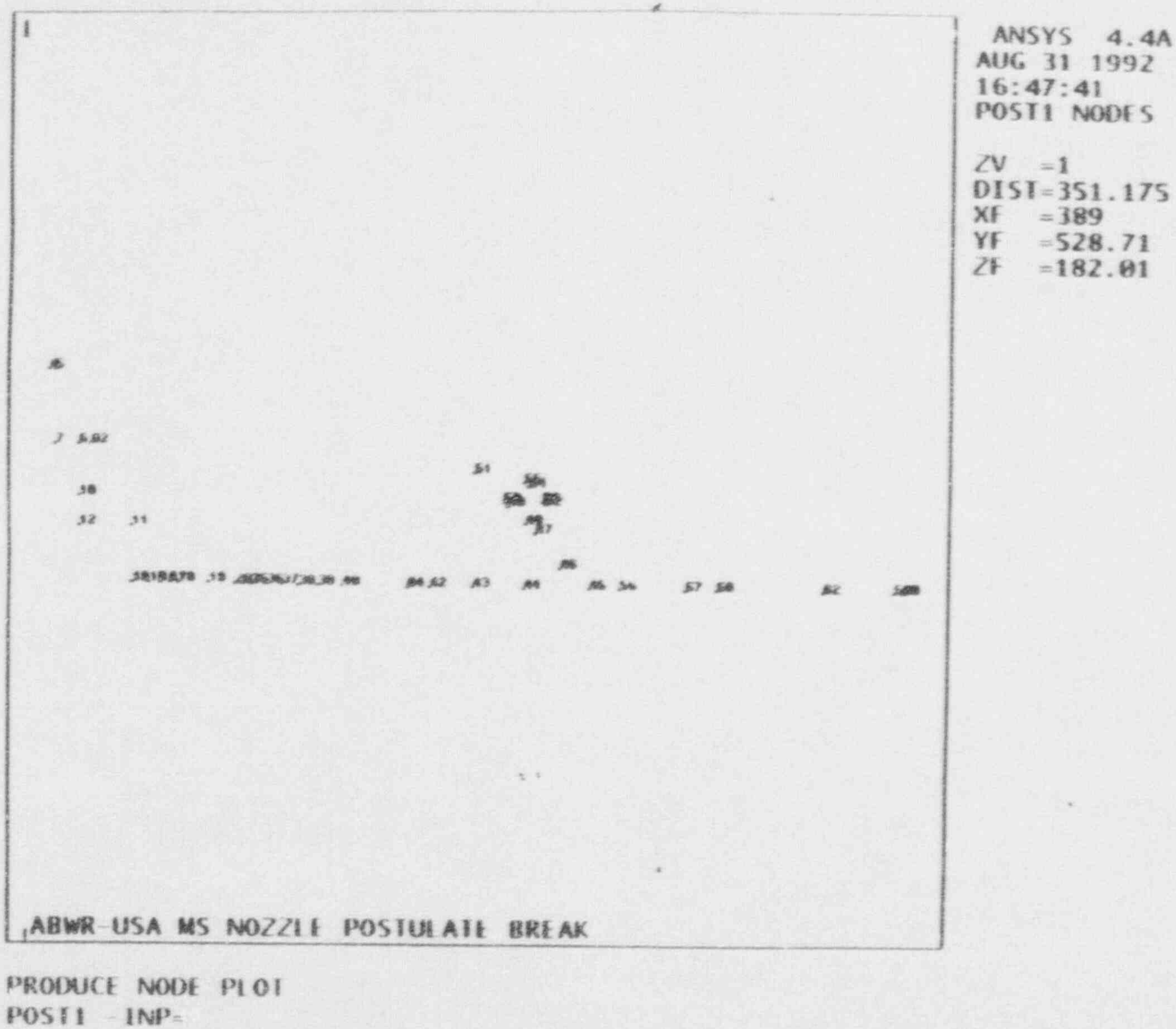
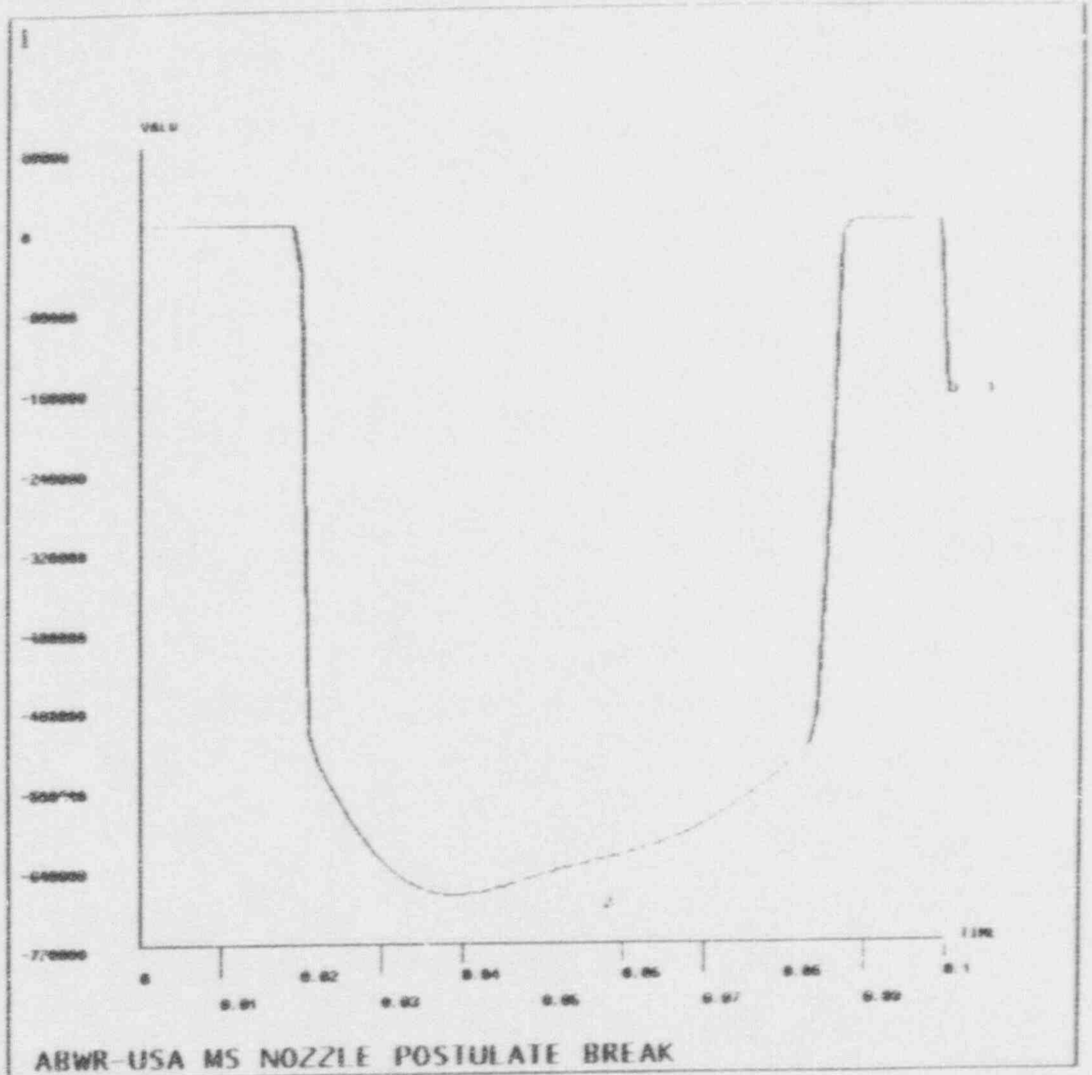


Figure 1-2 : ANSYS analysis model- nodal plot.



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AUG 7 1992
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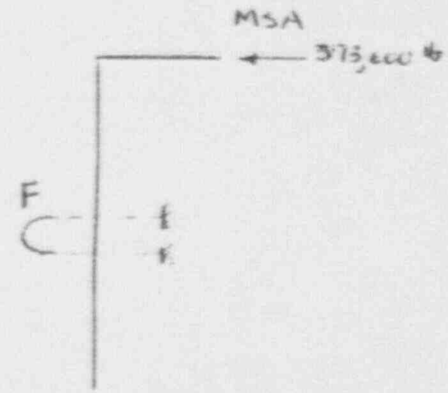

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POST26 INP=

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

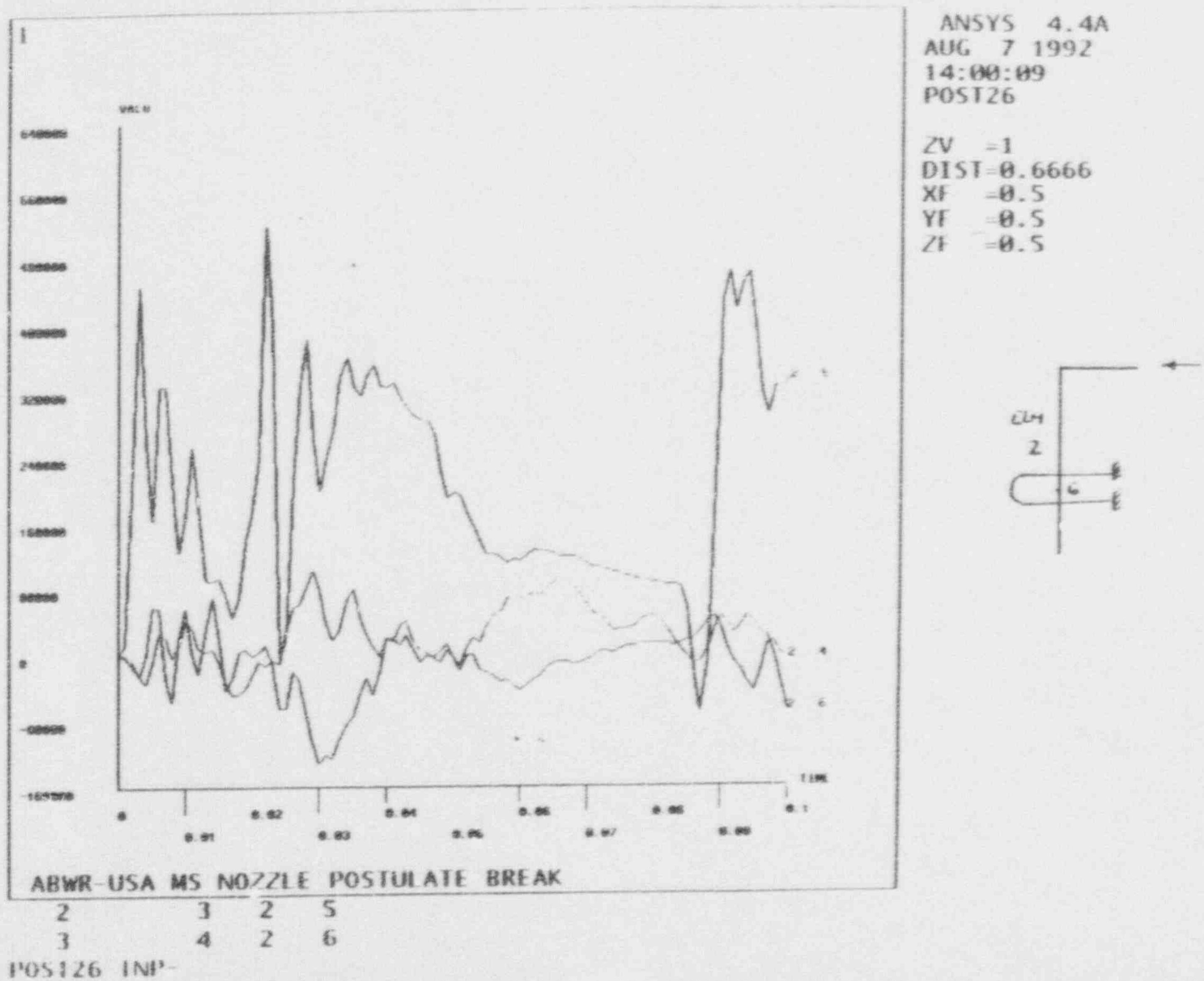


Figure 3 : Bending moment time histories. DT=0.001 sec. at elm. 2I ,at elbow near break

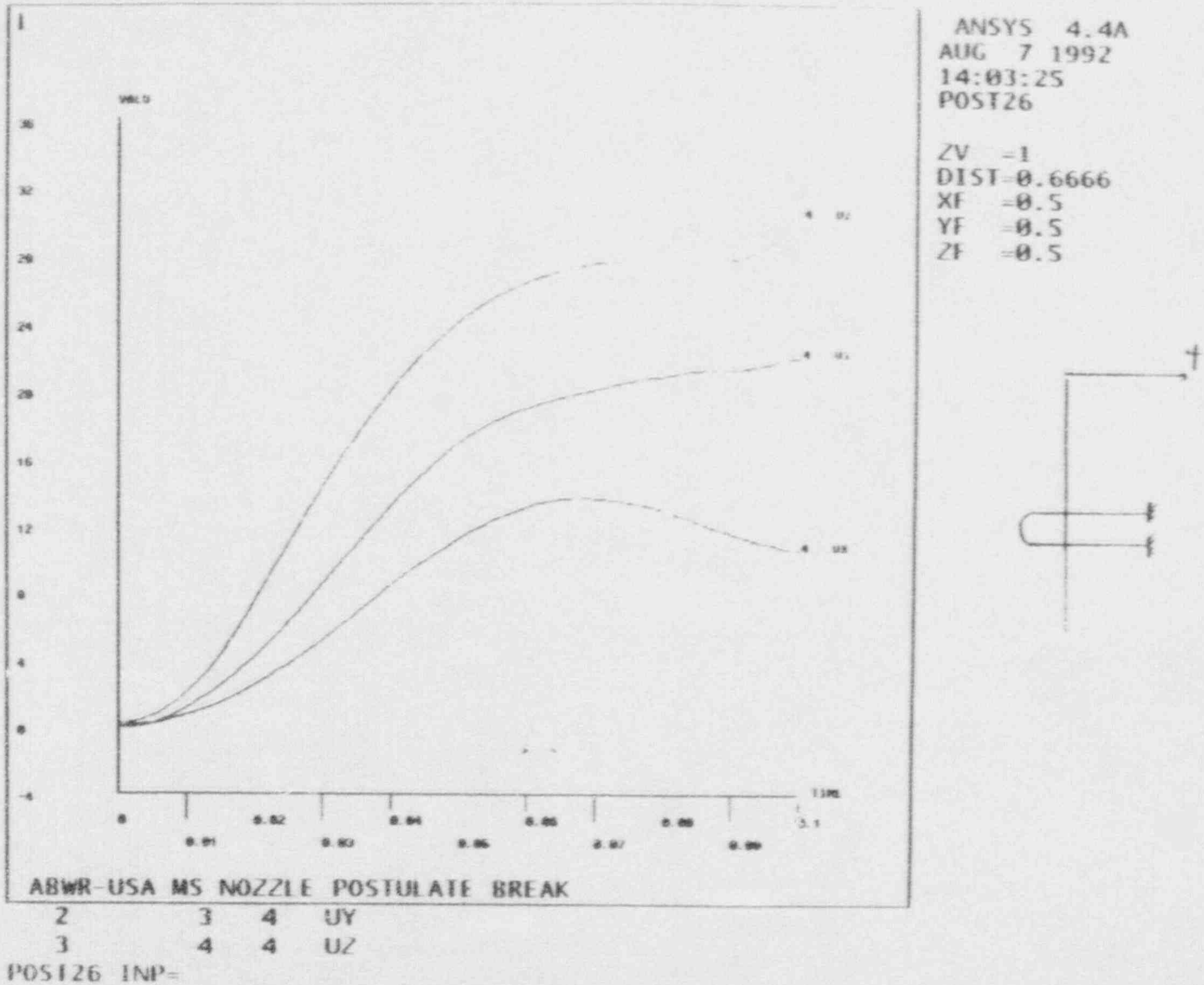
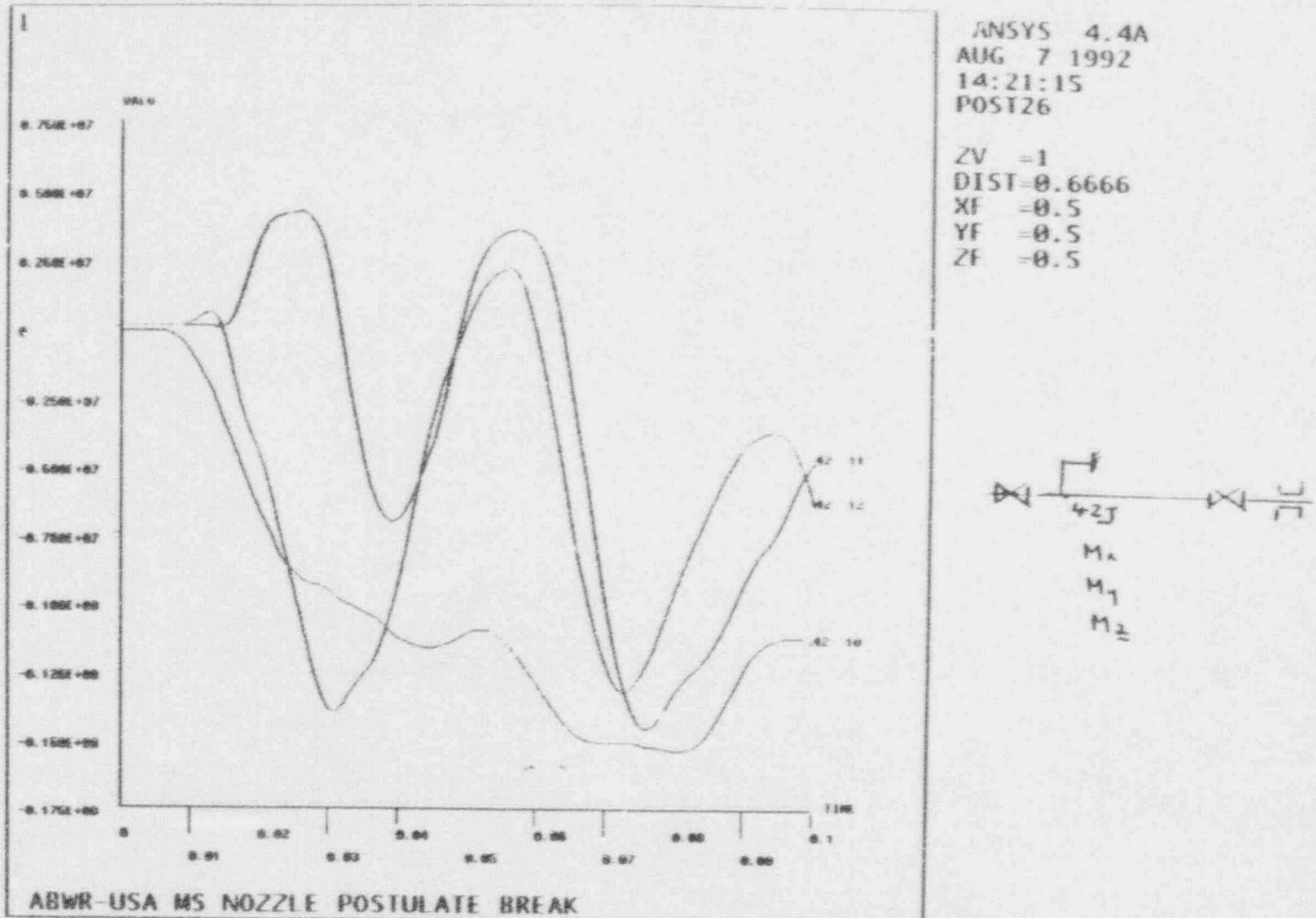
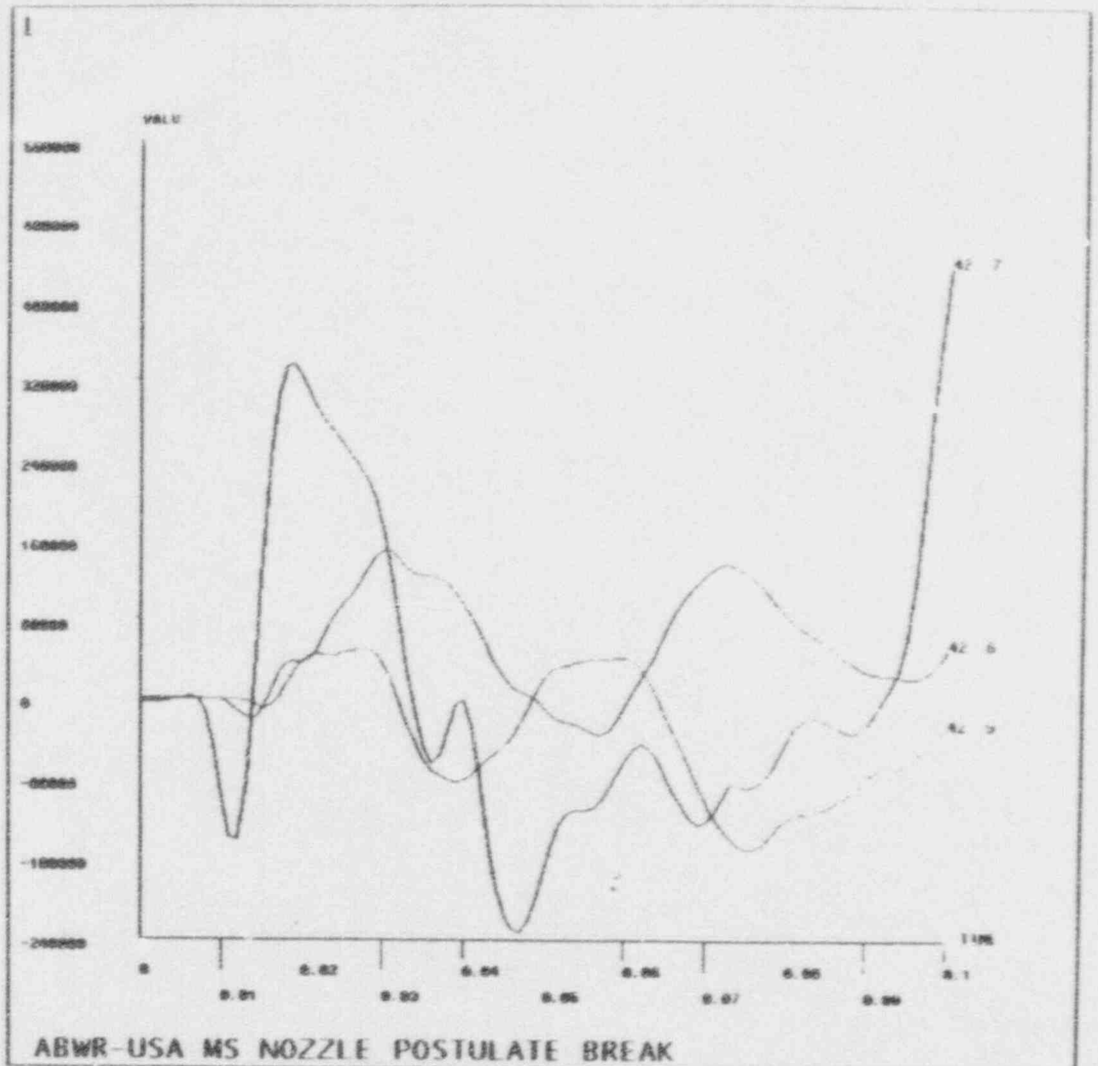


Figure 4 : Displacement time histories. DT=0.001 sec at the break location



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

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



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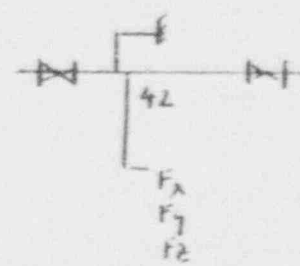
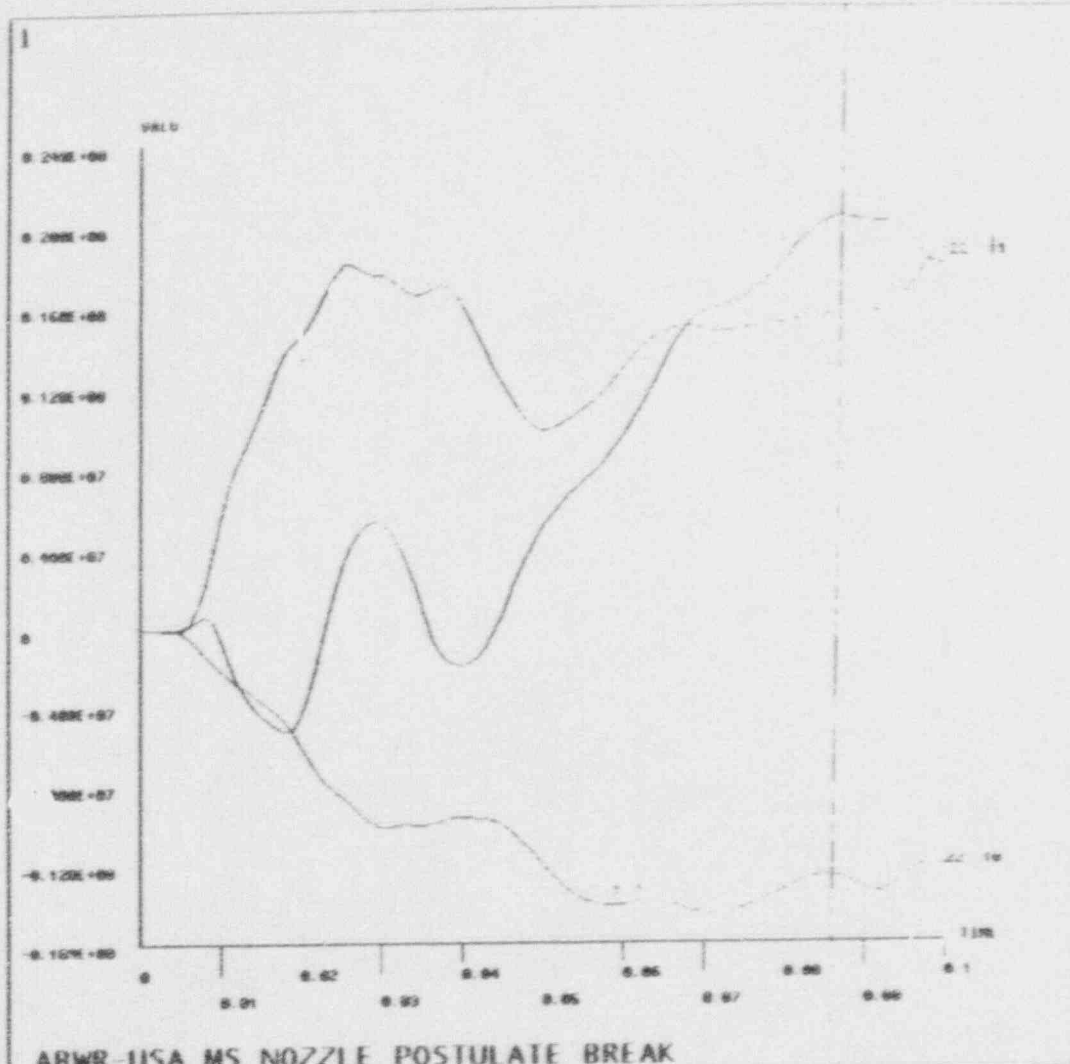


2	3	42	8
3	4	42	9

POST26-INP=

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



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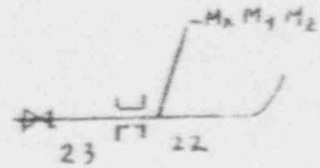


2	3	22	11
3	4	22	12

POST26 INP=

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

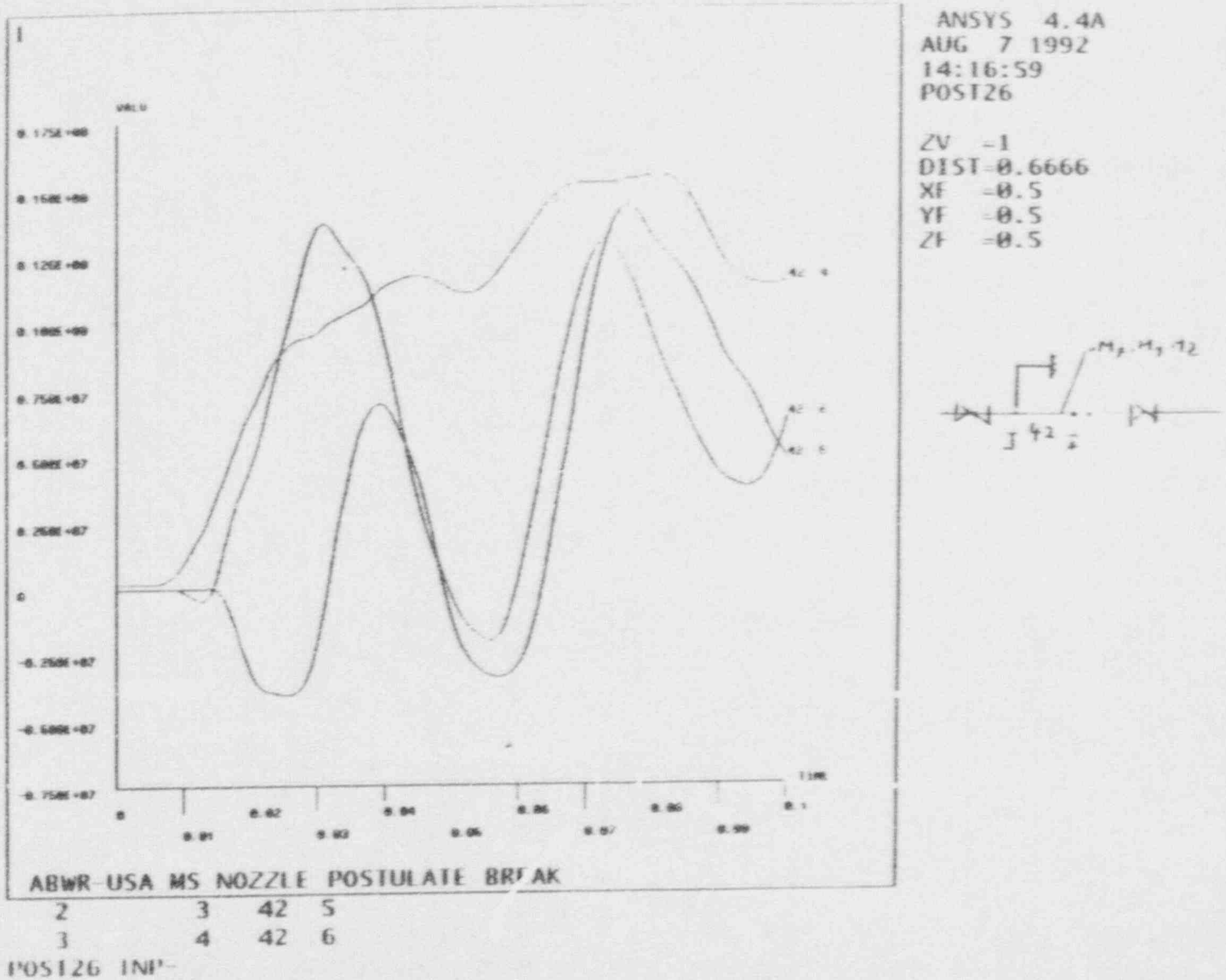
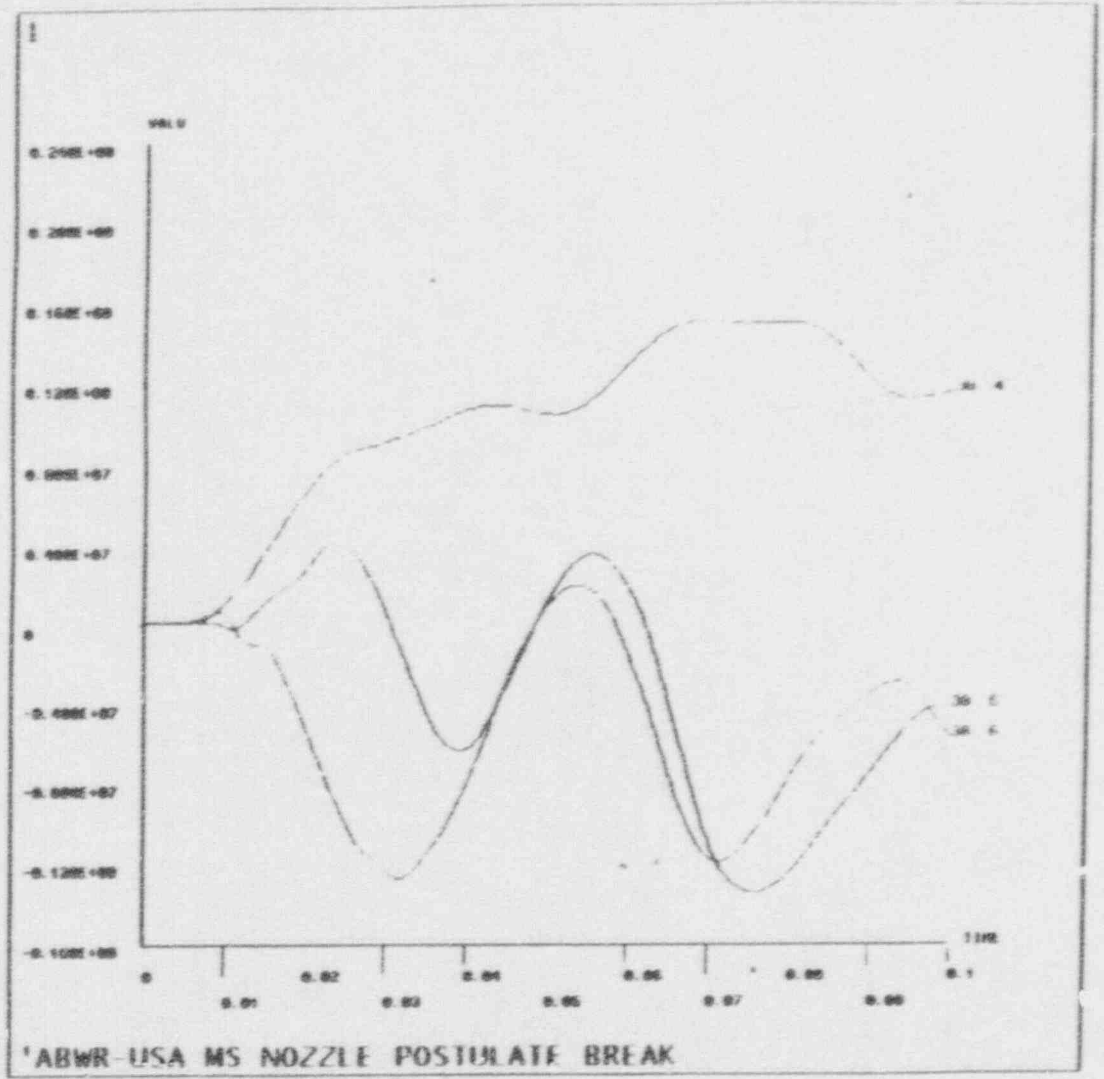


Figure 8 : Bending moment time histories. DT=0.001 sec at elm 42I ,near headfitting

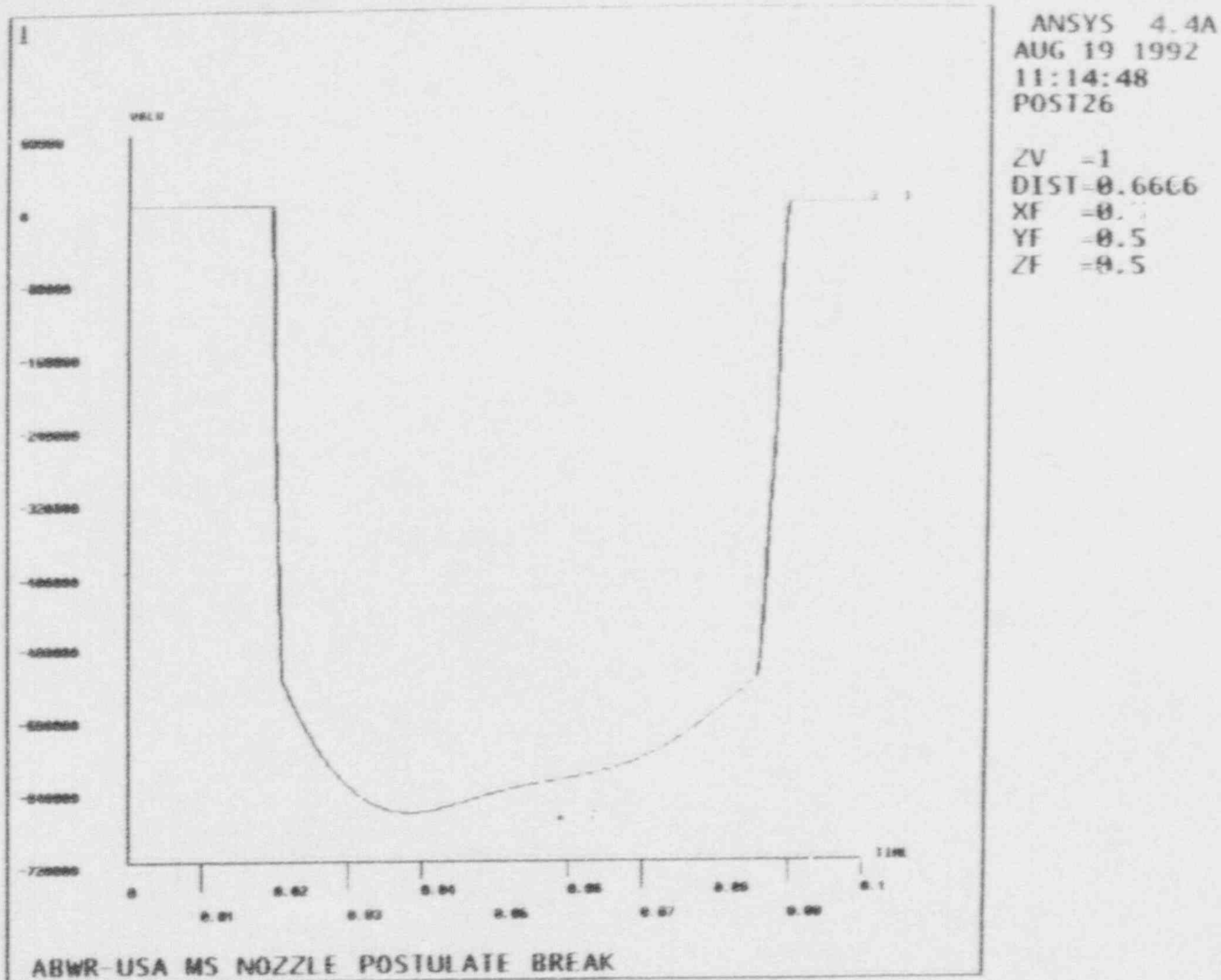


ANSYS 4.4A
AUG 31 1992
16:54:48
POST26

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

2 3 38 5
3 4 38 6
POST26 INP-

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



CURVE VARIA·LE NAME
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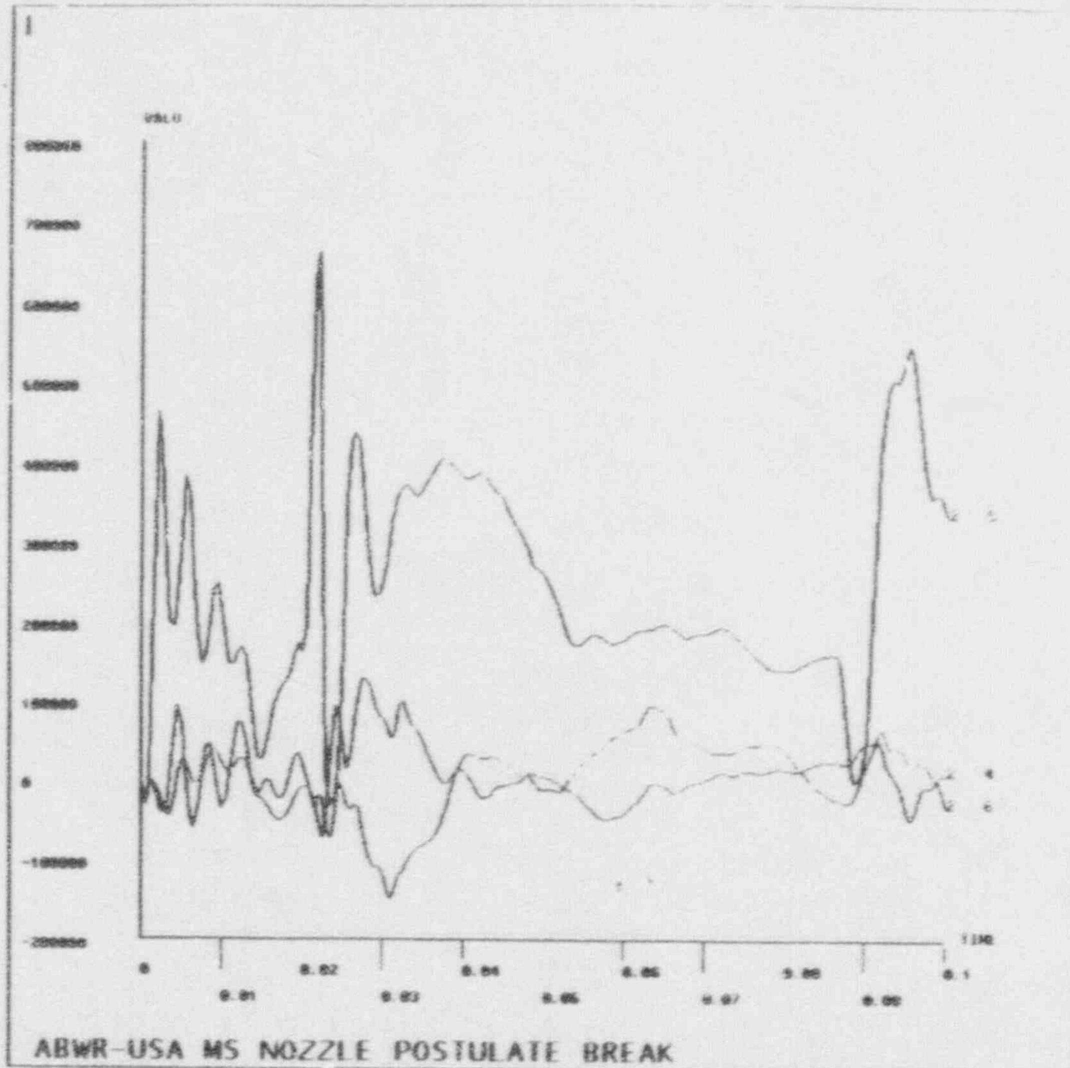
POST26-INP=

Figure 2A: Impact force at the pipe whip restraint. DT=0.0005 sec

Δt - 0.0005 sec



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11:18:56
POST26

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YF =0.5
ZF =0.5

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

Figure 3A: Bending moment time histories. DT=0.0005 sec. at elm. 21 ,at elbow near break

Δt = 0.0005 sec

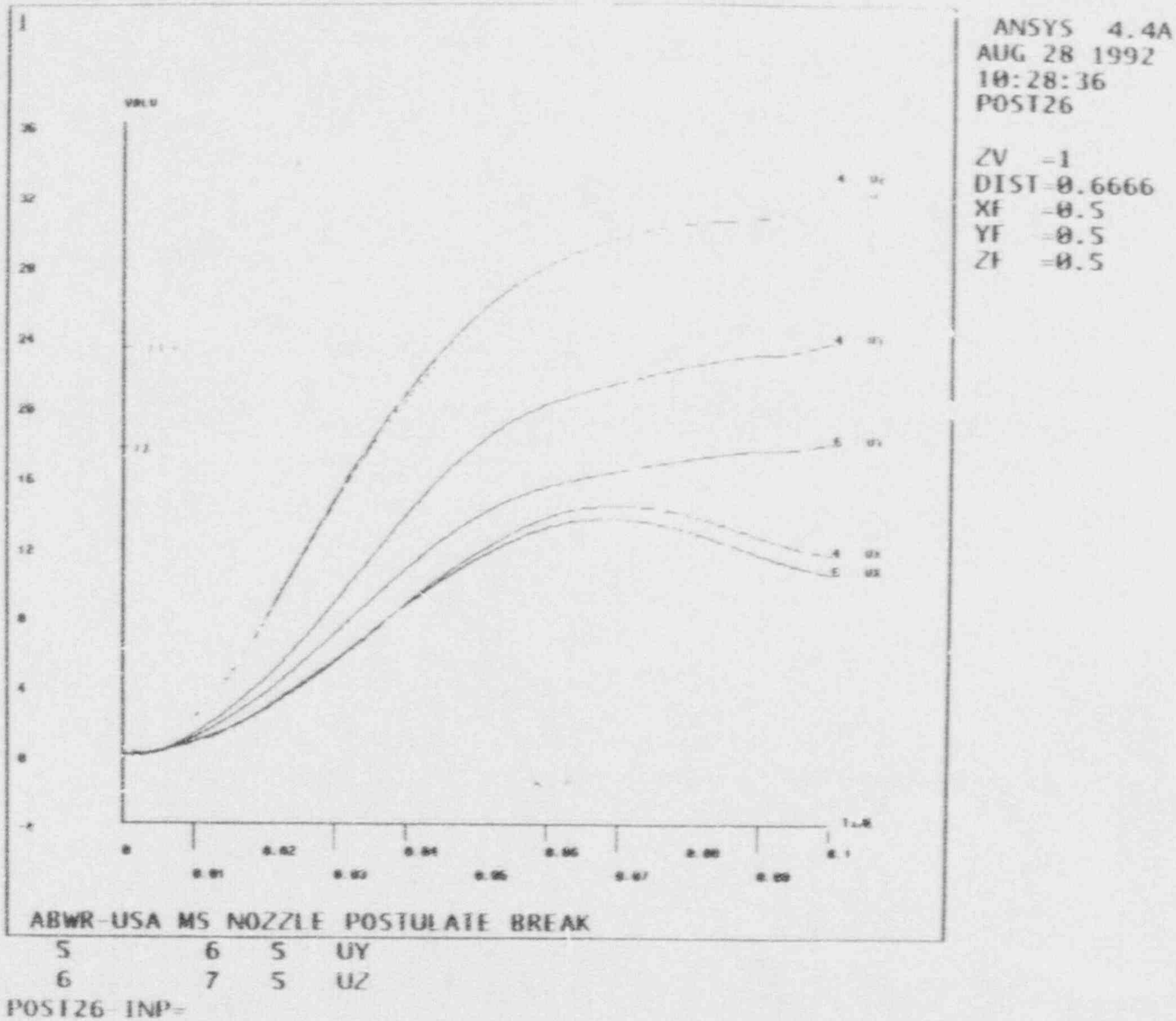
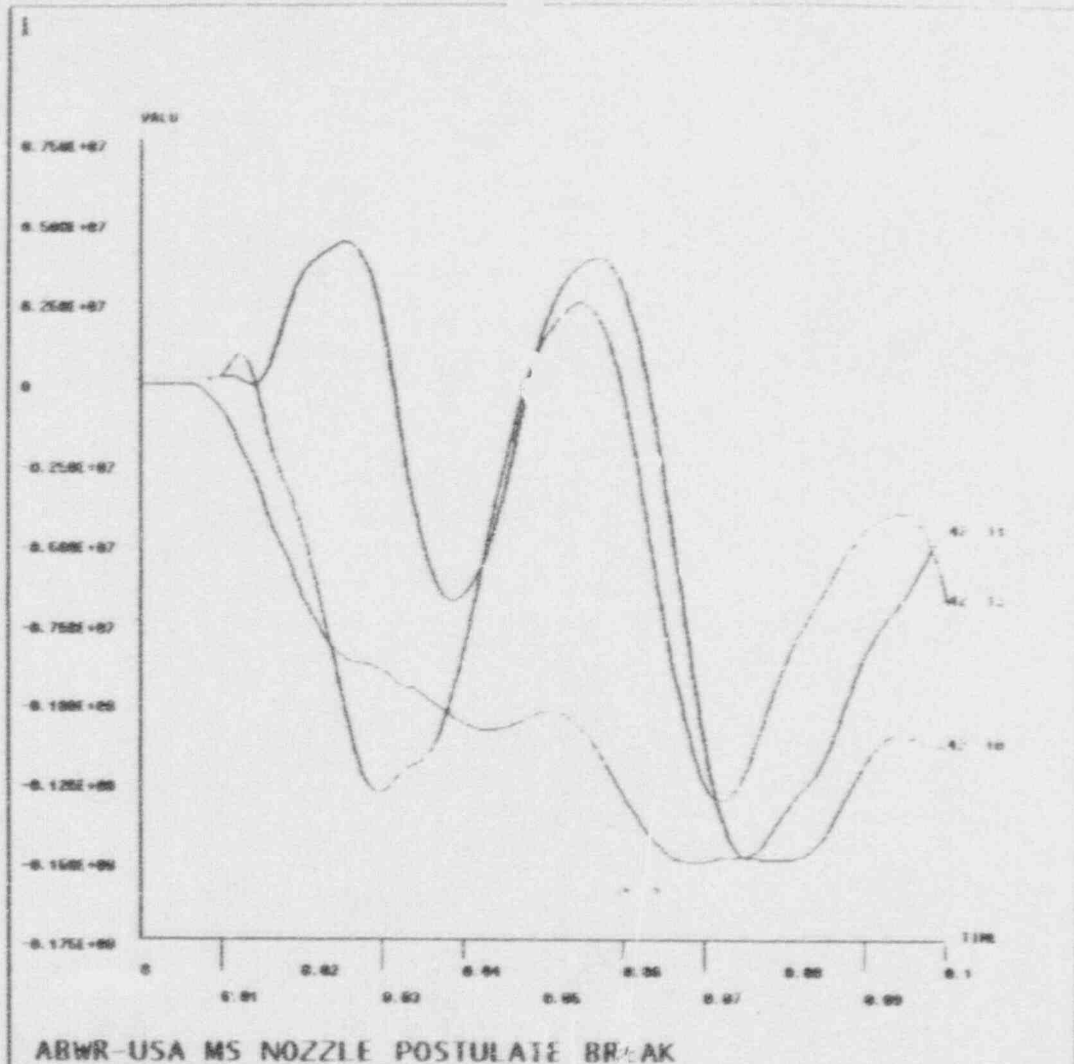


Figure 4A: Displacement time histories. DT=0.0005 sec at the break location



ANSYS 4.4A
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POST26

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YF =0.5
ZF =0.5

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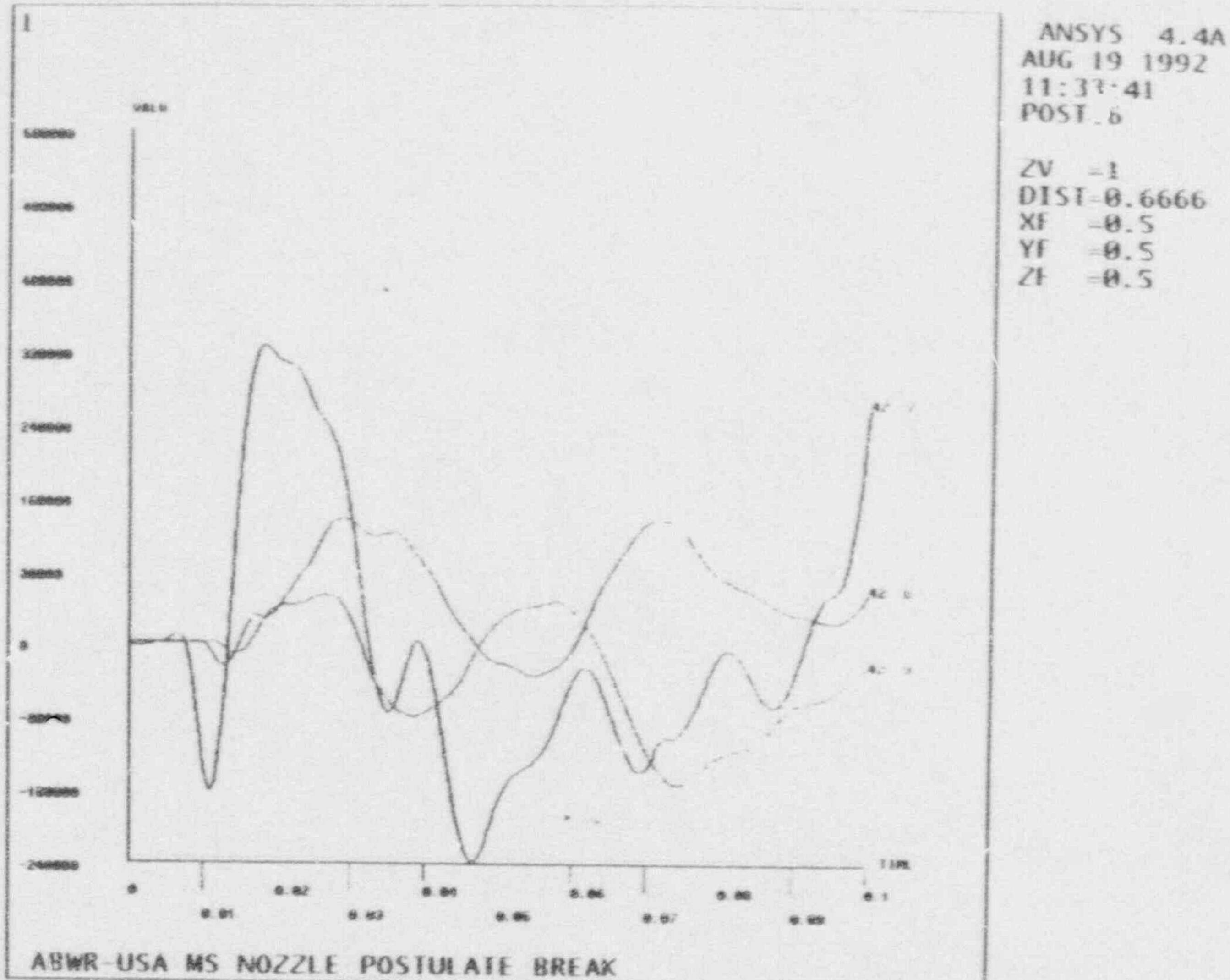
3	4	42	12

POST26 INP

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

Δt = 0.0005 sec

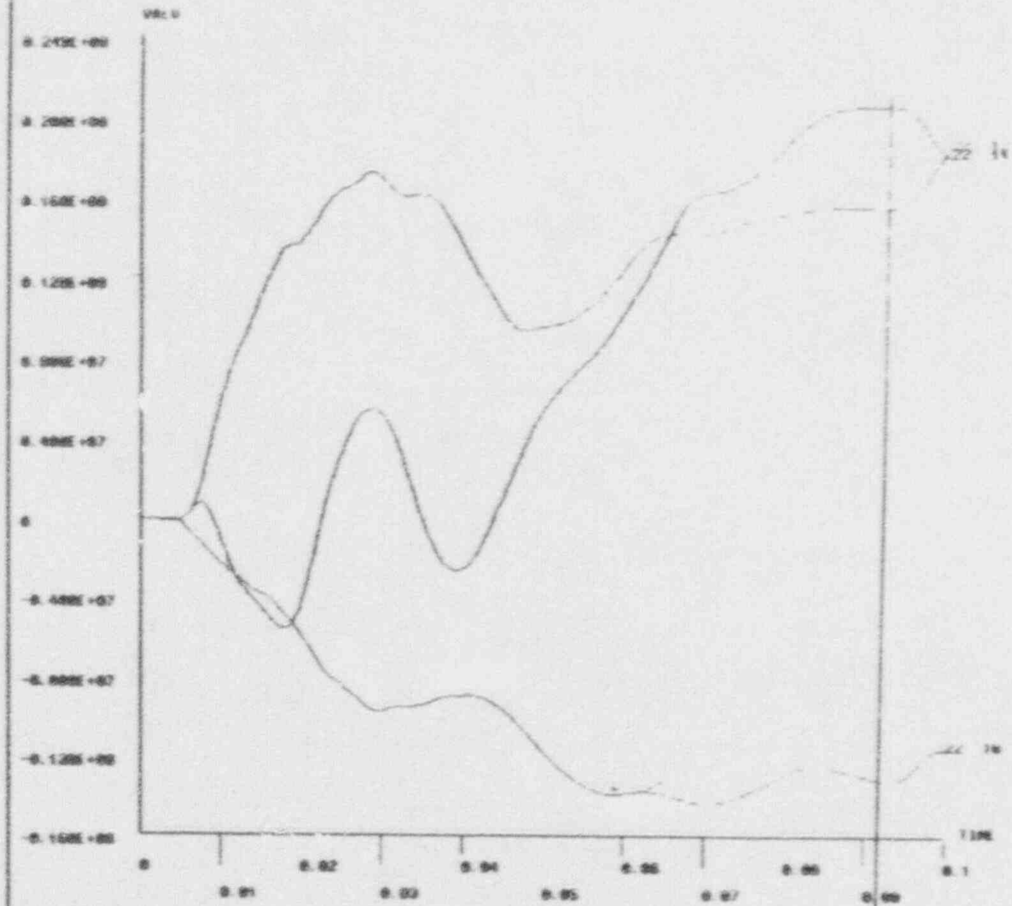


2	3	42	8
3	4	42	9

POST26-INP=

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

1



ANSYS 4.4A
AUG 19 1992
11:25:14
POST26

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YF =0.5
ZF =0.5

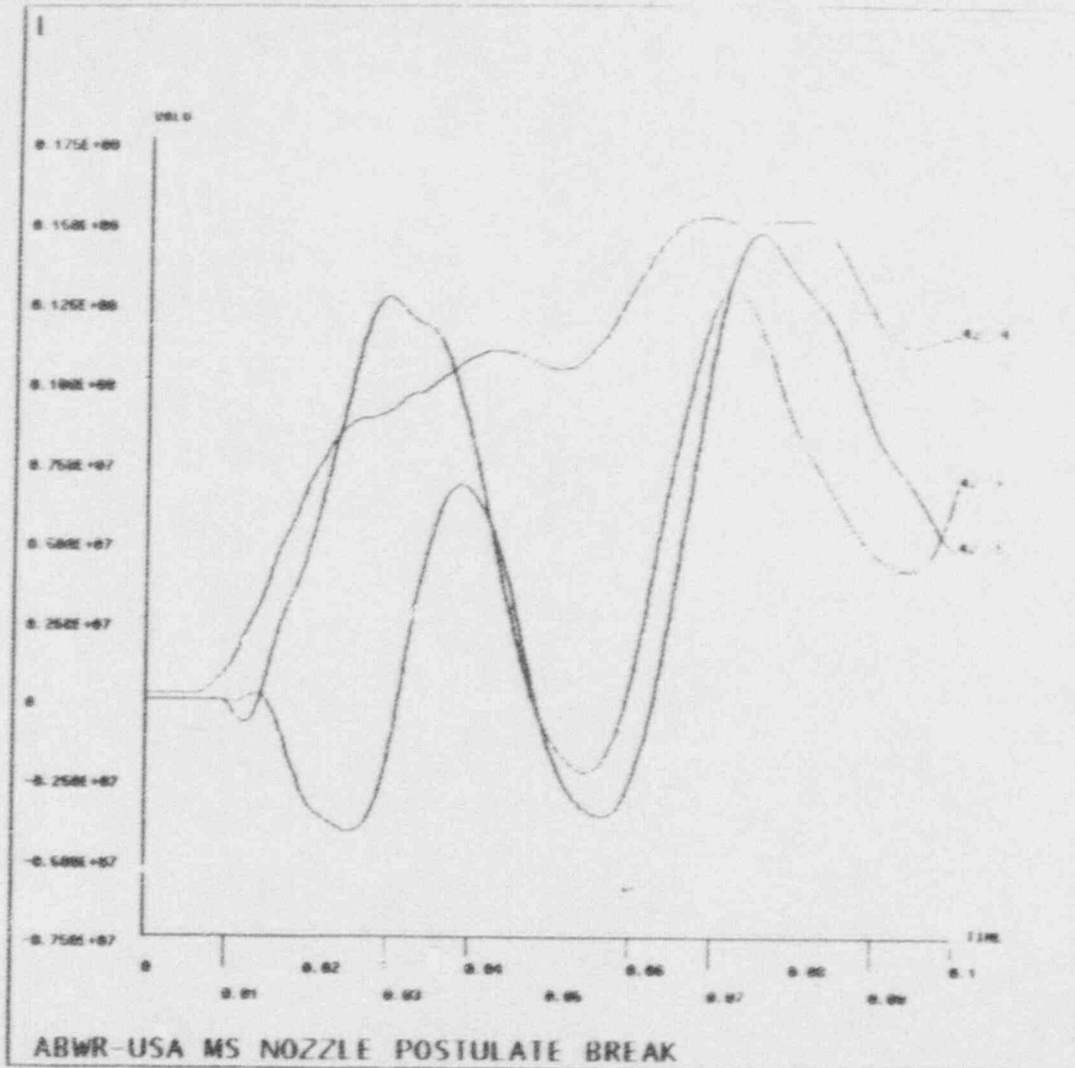
ABWR-USA MS NOZZLE POSTULATE BREAK

2	3	22	11
3	4	22	12

POST26 INP=

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

Δt = 0.0005 sec



ANSYS 4.4A
AUG 19 1992
11:28:39
POST26

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YF =0.5
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3	4	42	6

POST26-INP=

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

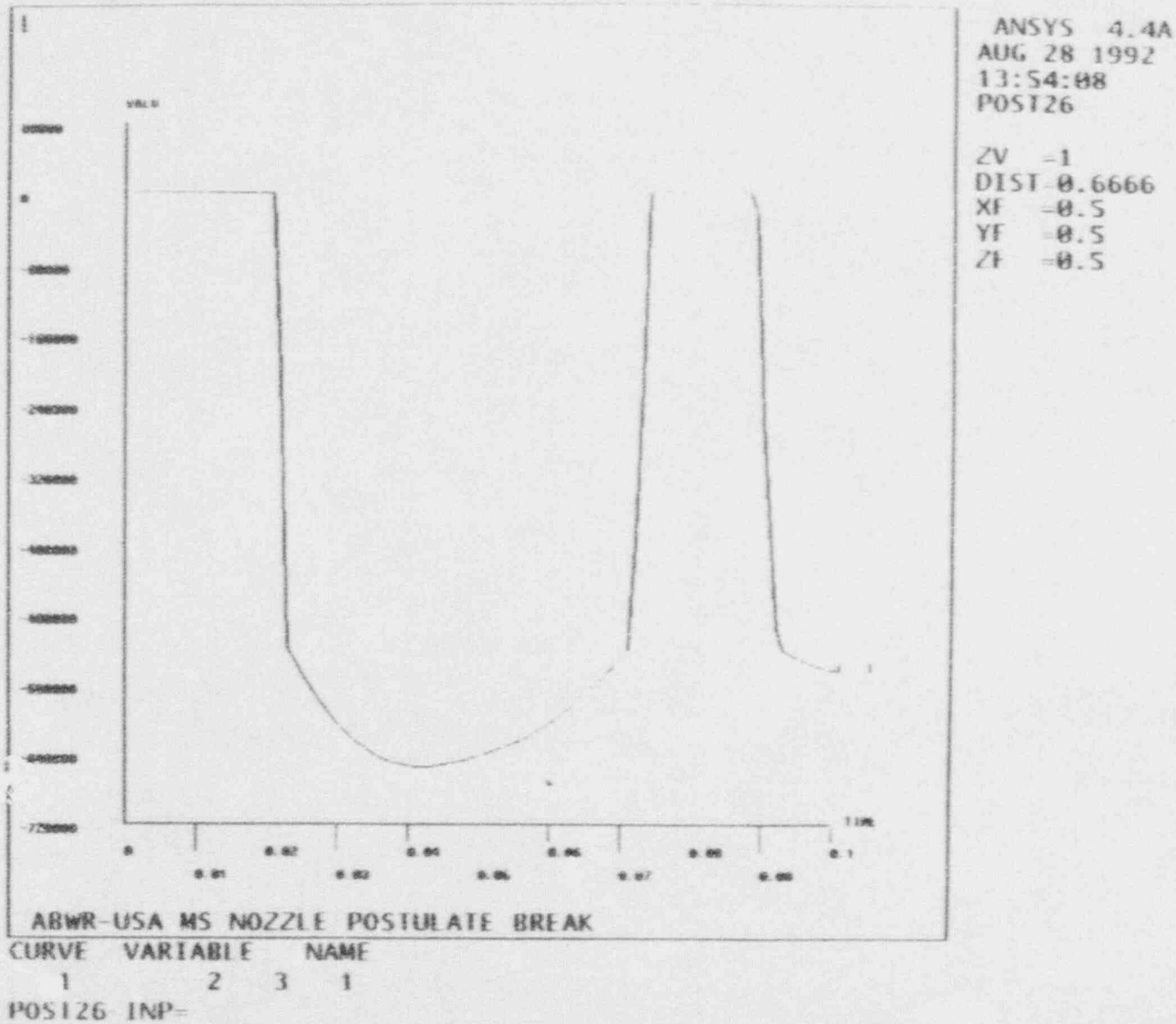


Figure 2B: Impact force at the pipe whip restraint.

(Included rotated blowdown angle)

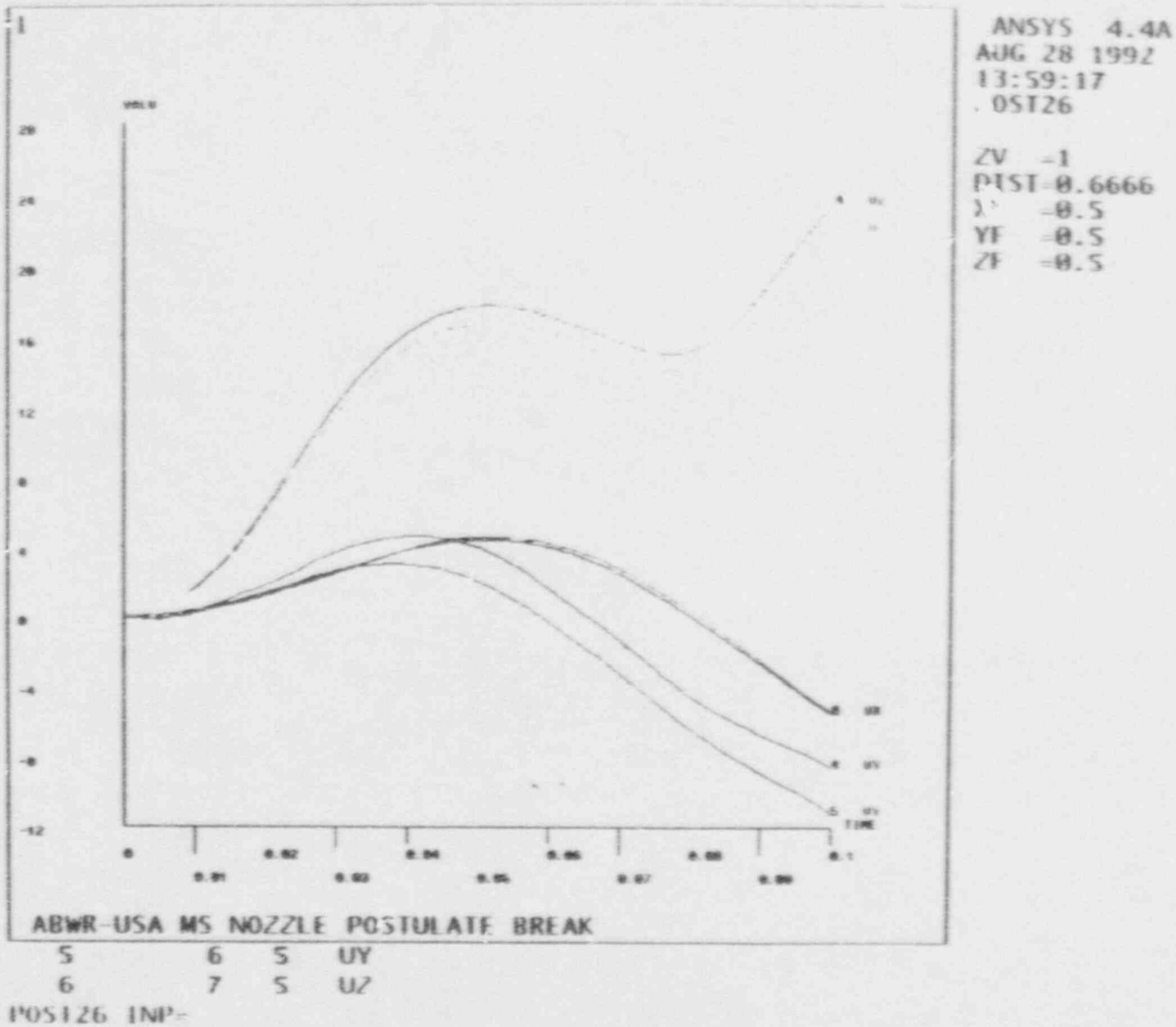
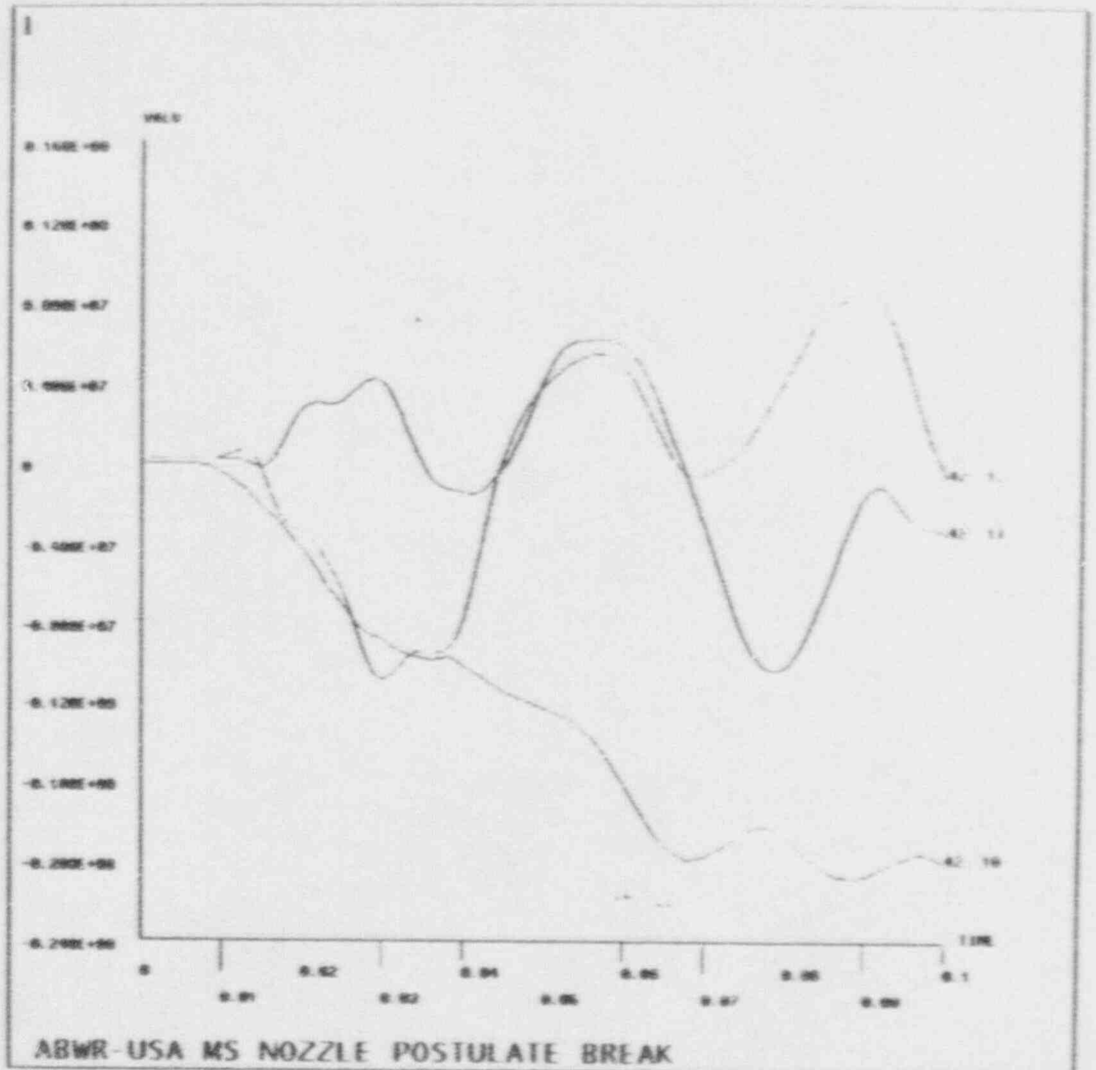


Figure 4B: Displacement time histories. at the break location (Included rotated blowdown angle)



2 3 42 11
3 4 42 12
POST26 INP=

ANSYS 4.4A
AUG 28 1992
13:56:21
POST26

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YF =0.5
ZF =0.5

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

(Included rotated blowdown angle)

ANSYS 4.4A
AUG 28 1992
14:01:56
POST26

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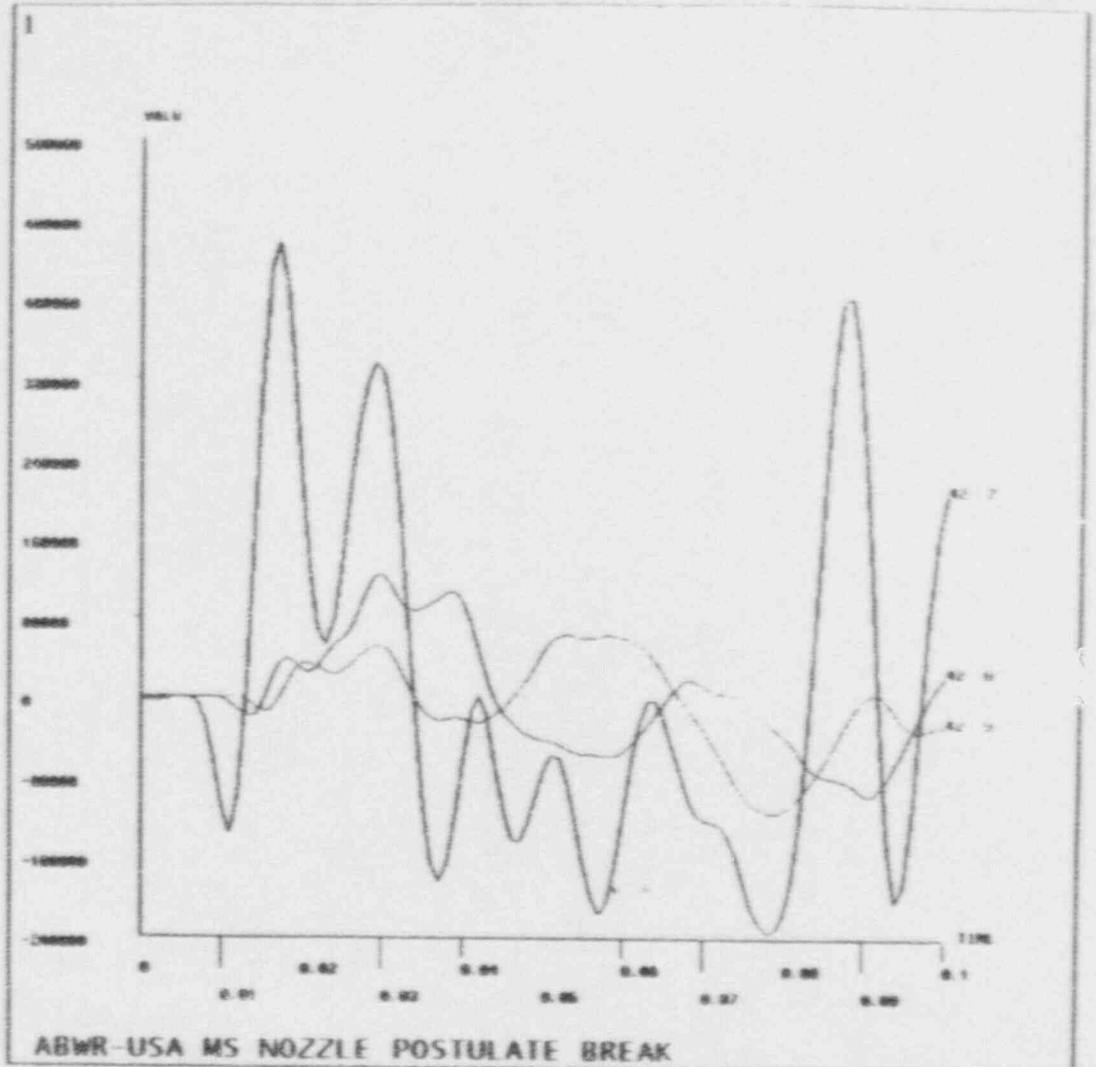
ZF =0.5



2	3	42	8
3	4	42	9

POST26 INP=

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

(Included rotated blowdown angle)

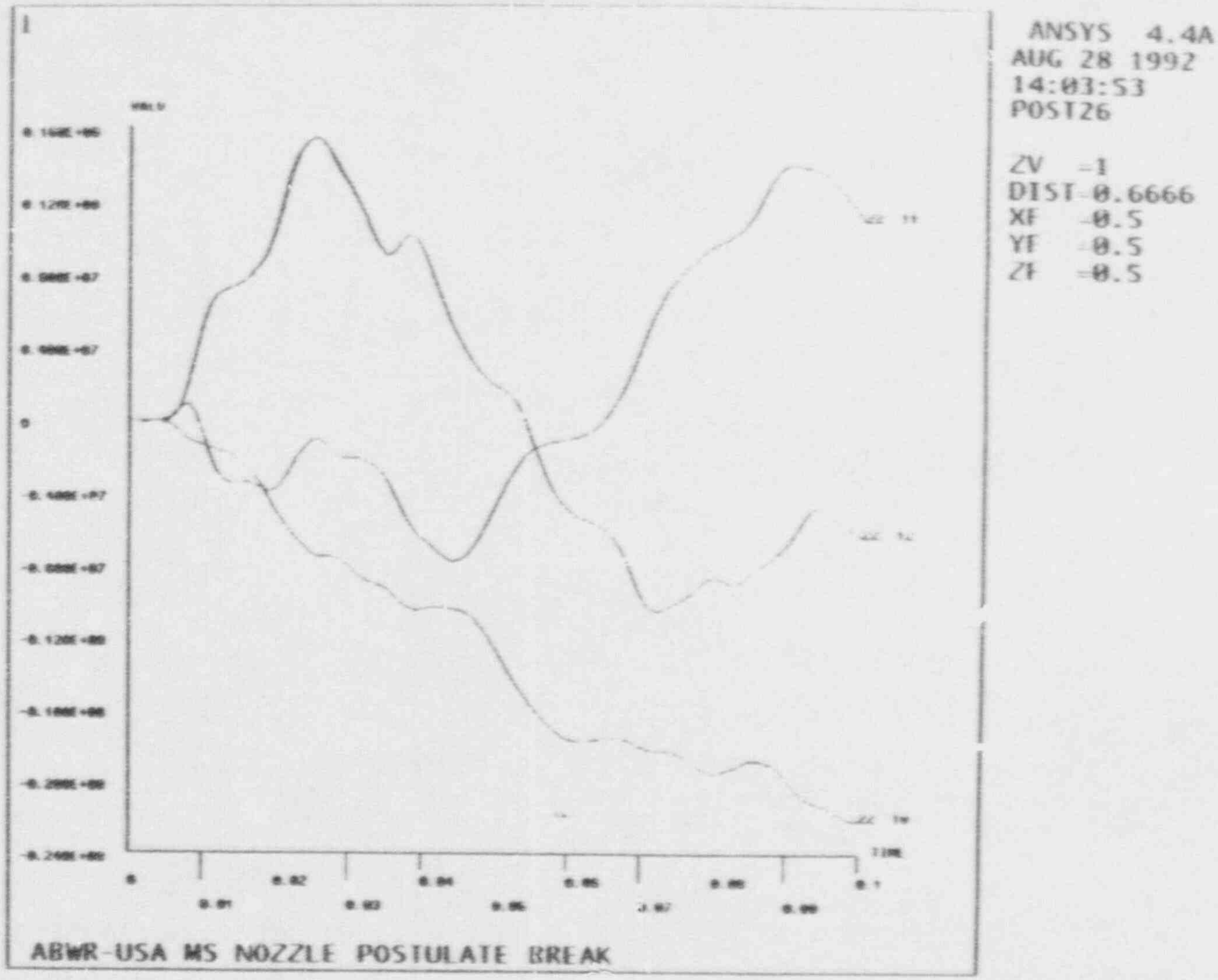
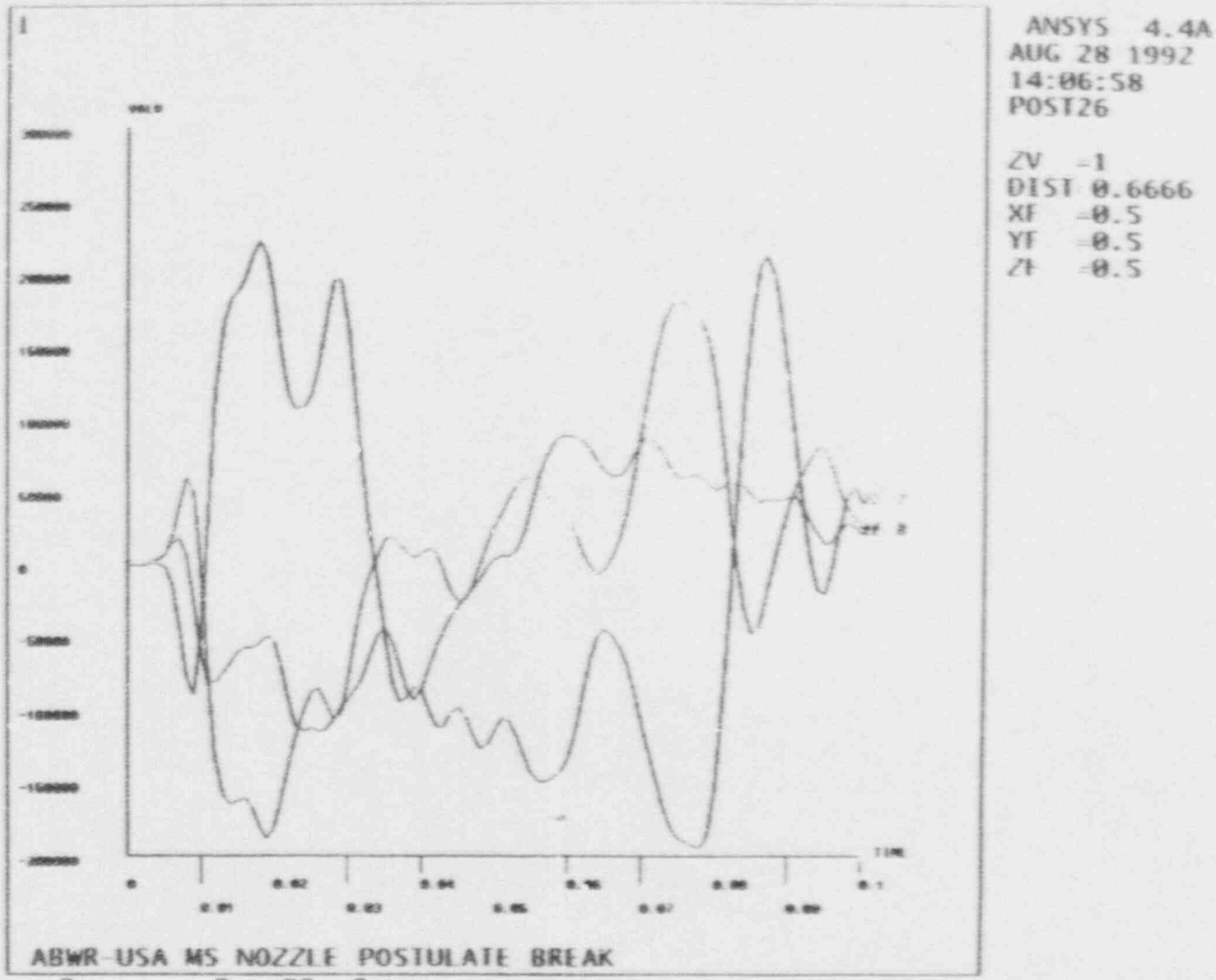


Figure 7B: Bending moment time histories. DT=0.001 sec at elm 22J ,before main steam guide (Included rotated blowdown angle)



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)

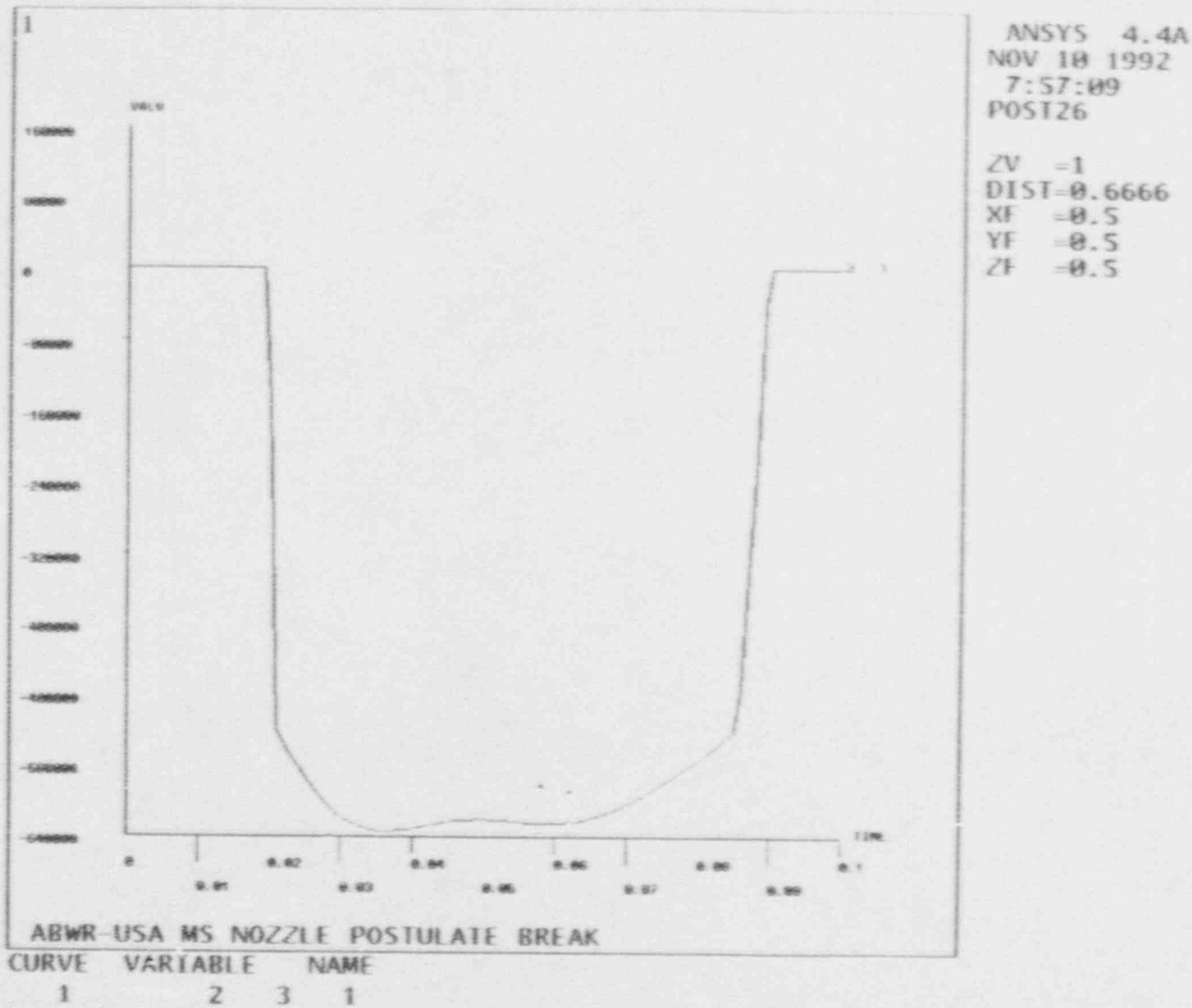


Figure 2C: Impact force at the pipe whip restraint. DT=0.001 sec

(Included displaced elbow and break pipe orientation)

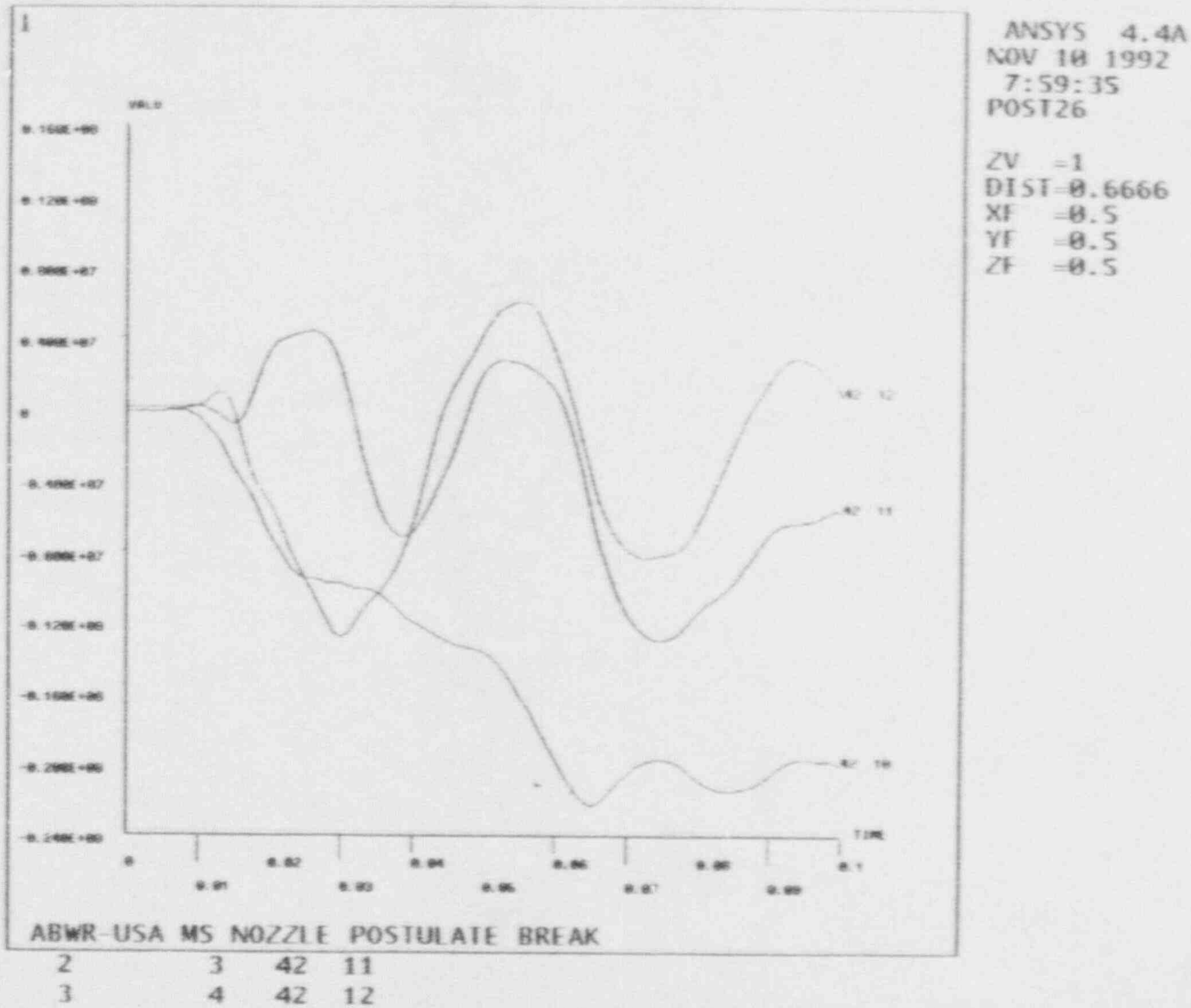


Figure 5C: Moment time histories at 42J (headfitting)
(Included displaced elbow and break pipe orientation)

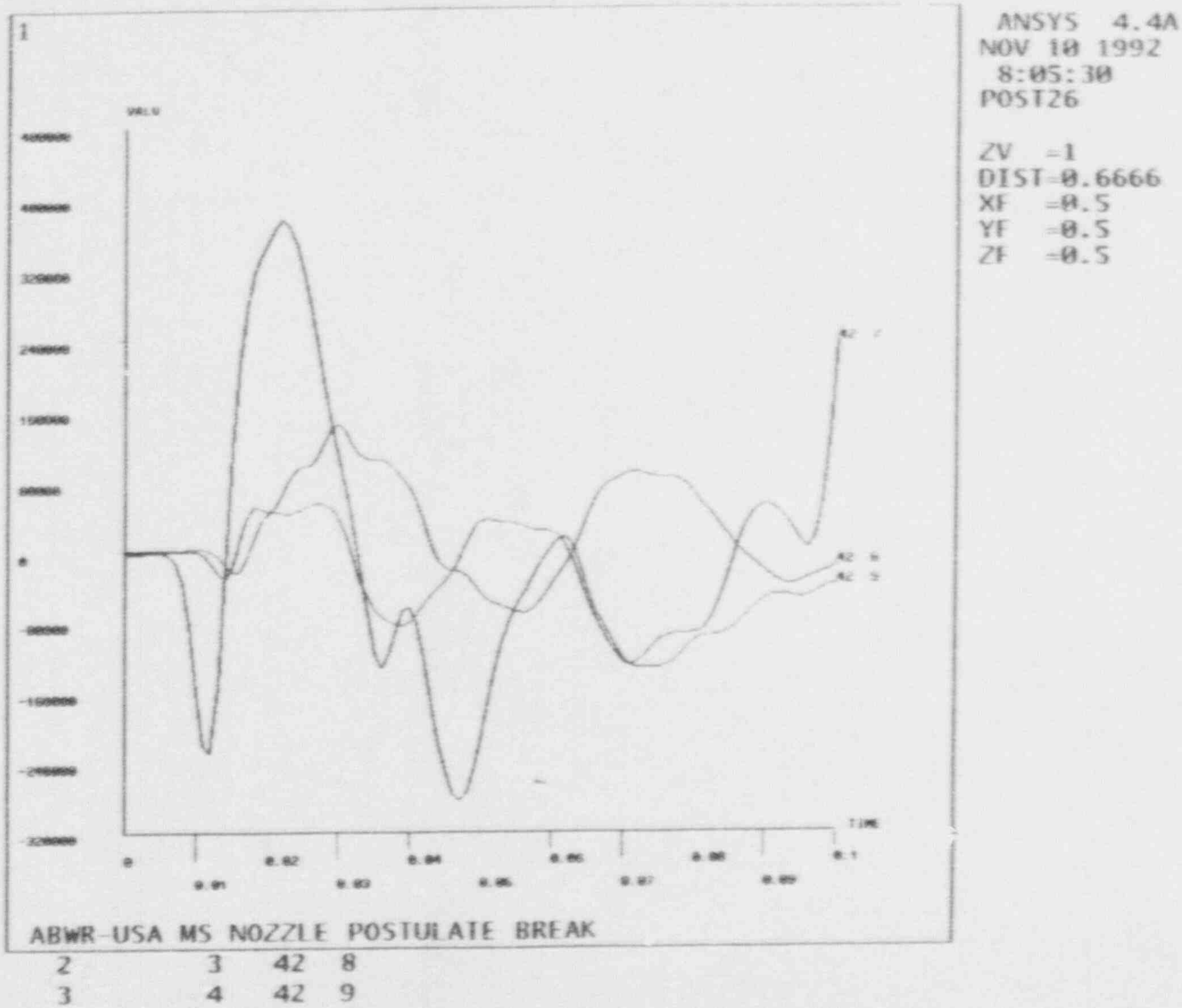


Figure 6C: Force time histories at 42J (headfitting)
(Included displaced elbow and break pipe orientation)

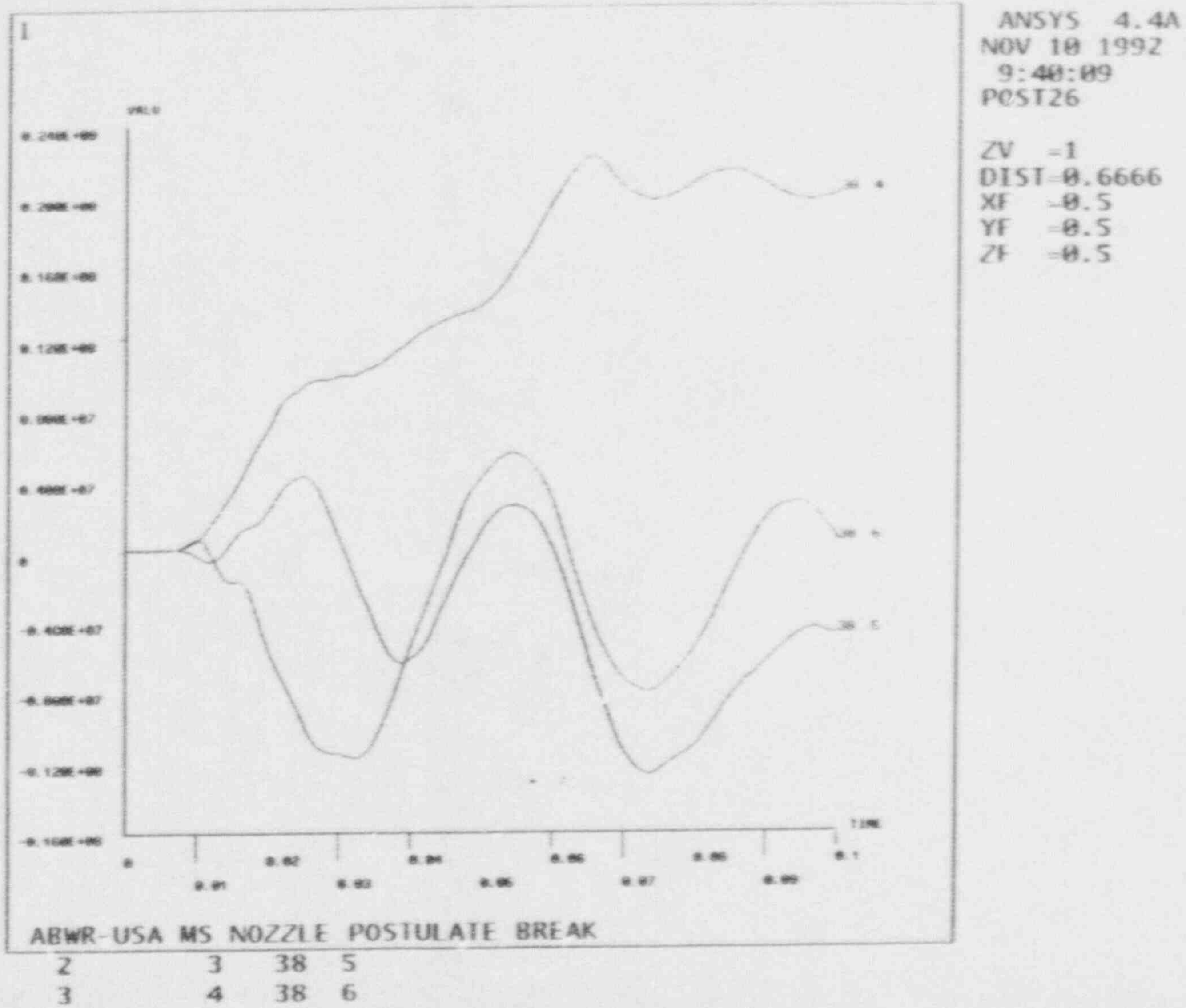


Figure 9C: Bending moment time histories. DT=0.001 sec.
at Elm 38I, 1st elm after MSIV.
(Included displaced elbow and break pipe orientation)

533671.0	0.7	0.7	.0038	.0127	13.27	9.1
28.	25.189	.19	110000.	402.89	2311.65	1000000.
4.543	.0268	1579602.	104924.	.235	[illegible].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

ATTACHMENT A

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XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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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= 22.40 FT/SEC   IMPACT TIME= .0235 SECONDS

NO. OF BARS 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 IN DIR. OF THRUST (IN.)
6	.6667	1.2766	.0140	9.4726

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
666727.	666727.	.0353	.0010	.0353

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)
57229.	18522.	221601.	485.	297837.

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 BREAK COMP. (IN.) XP1	XP
0.	666727	0.	544755.	0.	6.49	.00	9.47	.00

*** 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.)
.0087	1.14	15.12	701.6	.00	1.66	0.	0.	373570.
.0143	2.27	18.48	524.6	.00	3.31	0.	0.	373570.
.0191	3.41	20.73	420.4	.00	4.97	0.	0.	373570.
.0235	4.54	22.40	348.6	.00	6.62	0.	0.	373570.
.0251	4.97	21.73	******	.00	7.25	340937.	0.	373570.
.0262	5.24	20.32	******	.00	7.64	449348.	0.	373570.
.0273	5.51	18.42	******	.00	8.04	519390.	0.	373570.
.0287	5.79	15.96	******	.00	8.44	571403.	0.	373570.
.0303	6.06	12.72	******	.00	8.84	613089.	0.	373570.
.0325	6.33	7.88	******	.00	9.24	648080.	0.	373570.