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WIPS—Computer Code for Whip and Impact Analysis of Piping Systems

Part D—Verification Manual

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Part D – Verification Manual

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WIPS: COMPUTER CODE FOR WHIP and IMPACT ANALYSIS OF PIPING SYSTEMS

PART D

VERIFICATION MANUAL

ABSTRACT

This report presents details of a number of examples which have been chosen to verify the WIPS code. The examples have been selected to verify most (but not all) features of WIPS. For each example the following information is provided:

(1) A description of the example.

(2) Complete WIPSLOG file listings, detailing the steps followed in setting up the example. These listings will enable a user to reproduce each example.

(3) DATA file listings.

(4) Results, including comparisons with previously reported experiments and/or analyses if available.

The conclusions which can be reached from the verification study are as follows.

(1) WIPS is an effective tool for the analysis of restrained pipes. Nevertheless, it is recommended that additional verification examples be analyzed before WIPS is used for production analysis.

(2) WIPS is an effective tool for the analysis of unrestrained pipes (with large displacements) up to impact with adjacent objects. Again, however, it is recommended that additional verification examples be analyzed before WIPS is used for production analysis.

(3) WIPS appears to work well for analyses which make use of the impact analysis option but has not been tested thoroughly. These analyses are extremely complex and very expensive computationally. Considerable additional verification is recommended before production analyses are attempted.

<u>TABLE OF CONTENTS</u>

D1. INTRODUCTION

WIPS (Whip and Impact of Piping Systems) is a special purpose computer code for the analysis of pipe whip following postulated pipe rupture. The scope and purpose of the code have been described in the WIPS Summary Report. User instructions, theoretical data and programmer instructions have been presented in WIPS Reports A, B, and C, respectively. In this report, the results of a number of examples are presented.

The purpose of the examples is to provide verification of the WIPS code, using, where possible, comparisons with previously reported experimental and analytical results. The examples also serve as illustrations on the use of WIPS. Details of the example analyses are presented in Sections D2.1 through D2.7.

D2. EXAMPLES

THE FOLLOWING SECTIONS PRESENT DETAILS OF THE EXAMPLE ANALYSES. EACH EXAMPLE IS PRESENTED AS A SEPARATE CHAPTER TO ALLOW ADDITIONAL EXAMPLES TO BE ADDED IF DESIRED.

D2.1 STATIC BEHAVIOR OF ELBOWS

D2.1.1 PURPOSE

This series of examples tests the curved PIPE element, by comparison with previously reported test results. The influence of large ovalling on the computed behavior is explored. Large displacement effects and strain rate effects are not considered.

D2.1.2 DESCRIPTION

A series of tests on pipe elbows has been reported by Bolt and Greenstreet [2.1.1]. The test configuration is shown in Fig. 2.1.1. All 15 of the test specimens considered in [2.1.1] have been analyzed using WIPS. The properties of the test specimens are summarized in Table 2.1.1.

The pipes were made of ASTM A-106 Grade B carbon steel and ASTM A-312 Type 304L stainless steel. Nominal yield stresses (0.2% offset) were given for the test specimens in [2.1.1]. However, detailed stress-strain curves for the steels were not given, and hence, there is some uncertainty in the specification of the material properties. The trilinear stress-strain curves shown in Tables 2.1.2 through 2.1.5 have been assumed for the WIPS analyses. For the A-312 stainless steel and the A-106 steel with 50 ksi yield, curves similar to those used by Scheller and Mallett [2.1.3] have been assumed. For the weaker A-106 steels, curves similar to the 50 ksi curve have been assumed, but with lower strengths.

There is also uncertainty about the actual dimensions of the elbows. For a supplementary series of tests described in [2.1.2], variations from the nominal dimensions are reported. For the first 15 tests, however, this information was not reported. For the WIPS analyses, nominal dimensions have been assumed as follows:

6-in. Schedule 40 Pipe: 6.625 in. O.D. x 0.280 in. wall thickness.

6-in. Schedule 80 Pipe: 6.625 in. x 0.432 in.

Long Radius (LR) Elbow: 9-in. radius to pipe centerline.

Short Radius (SR) Elbow: 6-in. radius.

D2.1.3 WIPS ANALYSIS MODEL

D2.1.3.1 Geometry and Loading

The WIPS analysis model consisted of three straight PIPE elements and two curved PIPE elements, as shown in Fig. 2.1.2. Loads were applied at node 6 (upwards, downwards, or out-of-plane). The response is static, whereas WIPS performs only dynamic analyses. Static behavior was obtained by specifying negligibly small mass and damping values. In addition, the displacements were controlled by adding a very stiff UBAR (10000 k/in. stiffness) at node 6. A force time history increasing linearly from zero was specified (ramp loading) and the UBAR stiffness, load magnitude, and time step were chosen to extend the UBAR element by 0.05 inches in each time step. Because the UBAR was much stiffer than the PIPE elements, node 6 displaced almost exactly 0.05 inches per step. The displacement increments at node 5 also increased essentially equal amounts in each step. The shear force in PIPE element 5-6 gave the load carried by the pipe specimen.

D2.1.3.2 Ovalling Parameters

The ovalling theory for the PIPE element is only semi-rational and requires that certain ovalling stiffness and strength parameters be specified. An initial ovalling stiffness is determined automatically (the value is consistent with the flexibility factor commonly used in piping analyses), and a nominal ovalling yield strength is also determined automatically. The following parameters must then be specified in order to define a trilinear relationship between ovalling deformation and a corresponding ovalling "force":

(1) Ovalling strength at first yield, as a multiple of the nominal yield strength. In WIPS, the default value his multiple is 1.3.

(2) Ovalling stiffness after first yield, as a multiple of the initial ovalling stiffness. The default value is 0.35.

(3) Ovalling stiffness after second yield, as a multiple of the initial ovalling stiffness. The default value is 0.08.

It is not required to specify the ovalling strength at second yield. Second yield is automatically assumed to occur at a deformation of twice the first yield deformation. For the analyses, the default values were used.

In addition, the analyst may specify "small" or "large" ovalling. For small ovalling changes in shape of the pipe cross section are assumed to be small, and cross section properties are computed assuming a circular section. For large ovalling the changes in pipe diameter are assumed to be significant, and cross section properties are progressively recomputed for the ovalled section. All cases were analyzed with large ovalling, one case being re-analyzed with small ovalling for comparison. In addition, one case was analyzed substituting straight elements for the two curved elements. The major effect of this substitution is that ovalling is completely ignored.

D2.1.3.3 Analysis Control Parameters

The analysis control parameters were chosen to ensure a constant time step during the analysis. The Newmark step-by-step option was used, with essentially zero mass and a very small damping factor to eliminate dynamic effects.

D2.1.3.4 WIPS Input

Tables 2.1.6 through 2.1.8 contain WIPSLOG listings up to the WIPS-DATA phase for a typical case (Test PE1). Table 2.1.9 is a listing of the DATA file for the same case. All other DATA files were similar.

D2.1.4 RESULTS

D2.1.4.1 Tests PE1 through PE6

The WIPS and experimental results are compared for Tests PE1 through PE3 in Figs. 2.1.3 through 2.1.5. For Tests PE1 and PE2 (up and down loading, respectively), the agreement is close. For Test PE3 (out-of-plane loading), the computed strength is significantly larger than the measured strength. An analysis of Test PE3 has been reported in [2.1.3] using two other elbow elements, with comparable differences between analysis and experiment.

The computed results for Tests PE1 and PE2 are compared in Fig. 2.1.6. The computed results assuming small ovalling are also shown. The difference in strength for upwards and downwards load is not large and is not likely to have a significant effect for pipe whip analysis. For most applications, therefore, it is recommended that small ovalling be assumed.

Figure 2.1.7 shows the effect of ovalling on strength and stiffness, by comparing analyses of Test PE1 with (a) the elbow modelled with two curved elements (as in Fig. 2.1.2) and (b) the elbow modelled with two straight elements. The main difference in the two analyses is that in the case with straight elements ovalling is ignored. It is clear that ovalling greatly reduces the strength and should not be ignored.

The results for Tests PE4 through PE6 (with internal pressure of 1500 psi) are shown in Figs. 2.1.8 through 2.1.10. For Test PE4 (up loading), the agreement is close. For Test PE5 (down loading), the computed strength is significantly below the measured strength. Note, however, that the test results indicate that specimen PE5 was stiffer than specimen PE4 up to a load of over 8 kips. This is the opposite of what would be expected and suggests significant variability in the test specimens. For the out-of-plane loading (Test PE6), the computed strength again exceeds the measured strength.

D2.1.4.2 Tests PE7 through PE9

The results for Tests PE7 through PE9 (up, down, and out-of-plane loading, respectively, with zero pressure) are shown in Figs. 2.1.11 through 2.1.13. The computed strengths for Tests PE7 and PE8 are significantly below the measured strengths, whereas the results for Test PE9 are in close agreement.

D2.1.4.3 Tests PE10 through PE14

The results for Tests PE10 through PE12 (up, down, and out-of-plane loading, respectively, with zero pressure) are shown in Figs. 2.1.14 through 2.1.16. The tests for these cases were terminated at rather small displacements, and hence, a comparison of strength cannot be obtained. It appears, however, that the computed strengths for the in-plane Tests PE10 and PE11 are below the measured values, whereas the results for Test PE12 could be in close agreement.

The results for Tests PE13 and PE14 (up and out-of-plane loading, respectively, with 1500 psi pressure) are shown in Figs. 2.1.17 and 2.1.18. The computed strength for Test PE13 is far below the measured value. The computed strength for Test PE14 is also low.

D2.1.4.4 Test PE15

The results for Test PE15 (down loading with zero pressure) are shown in Fig. 2.1.19. The agreement is quite close. Close agreement has also been reported in [2.1.3] for a test on a similar elbow (Test PE16).

D2.1.5 CONCLUSION

The computed and measured results agree within about 10% for the in-plane loadings for Tests PE1, PE2, PE4, PE5, and PE15. For these tests the material properties were selected with guidance from [2.1.3], and it appears likely that the assumed properties agree with the actual properties. For the out-of-plane tests PE3 and PE6, the computed strength exceeds the measured strength by about 20%.

For the remaining cases with in-plane loading, the computed strengths are substantially below the measured strengths, whereas for the remaining cases with out-of-plane loading the results agree quite closely. For all of these cases, it is less certain that the material properties have been approximated correctly. More detailed investigation is needed to determine the reasons for the differences.

A detailed study of the differences between the measured and computed strengths would require a major research effort and has not been possible within the present study. Overall, the agreement between analysis and experiment is believed to be sufficiently close for pipe whip applications. It should be noted that pipe elbows are extremely complex structures. The WIPS curved pipe element appears to model the essential features of elbow behavior, while still being reasonably simple theoretically and quite efficient computationally.

D2.1.6 REFERENCES

2.1.1 Bolt, S. E. and Greenstreet, W. L., "Experimental Determinations of Plastic Collapse Loads of Elbows," ASME Paper 71-PVP-37, 1971.

2.1.2 Greenstreet, W. L., "Experimental Study of Plastic Responses of Pipe Elbows," ORNL/NUREG-24, February 1978.

2.1.3 Scheller, J. D. and Mallett, R. H., "Numerical Evaluation of an Inelastic Piping Elbow Element," ASME Paper 79-PVP-41, 1979.

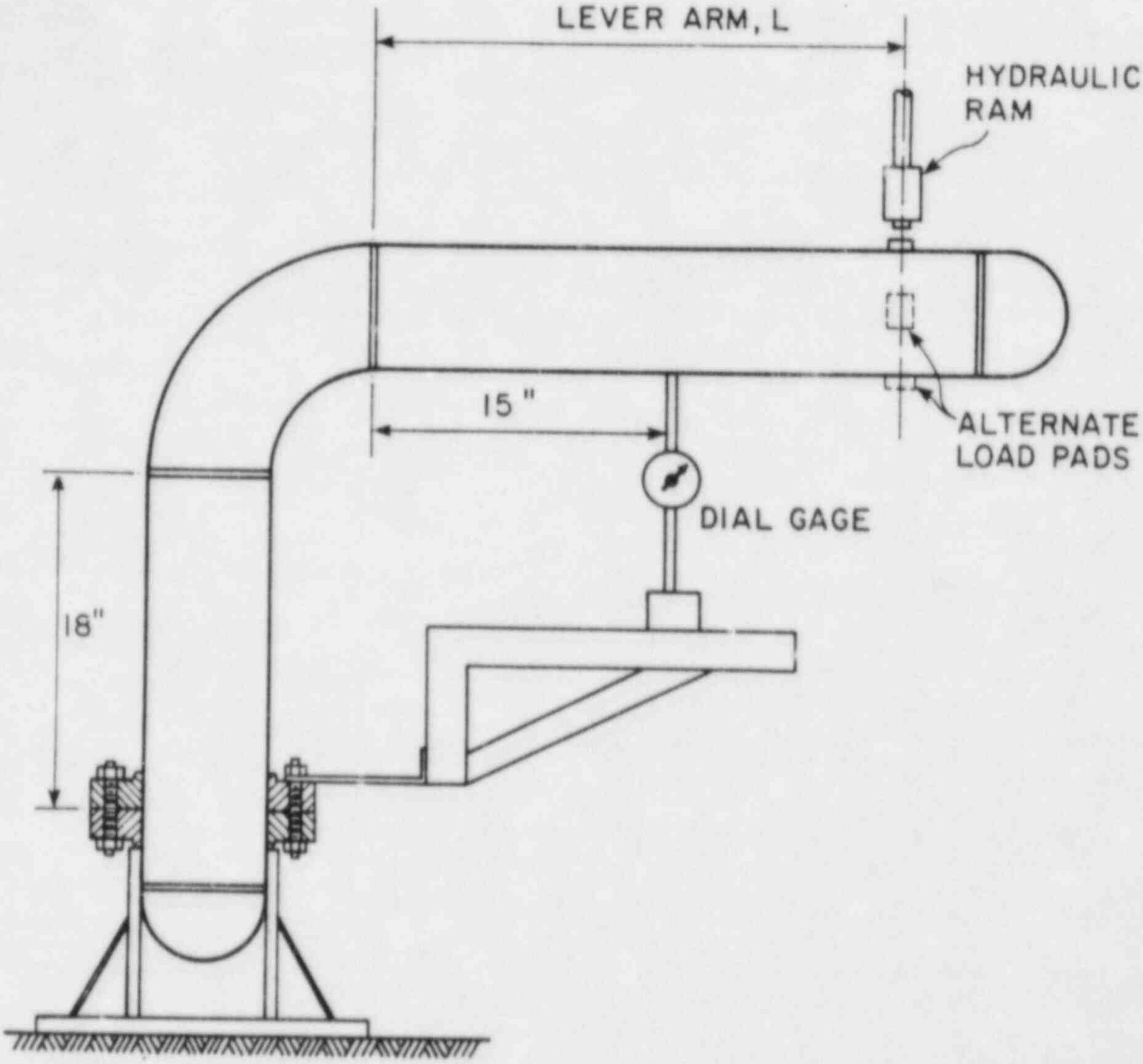

FIG. 2.1.1 TEST CONFIGURATION

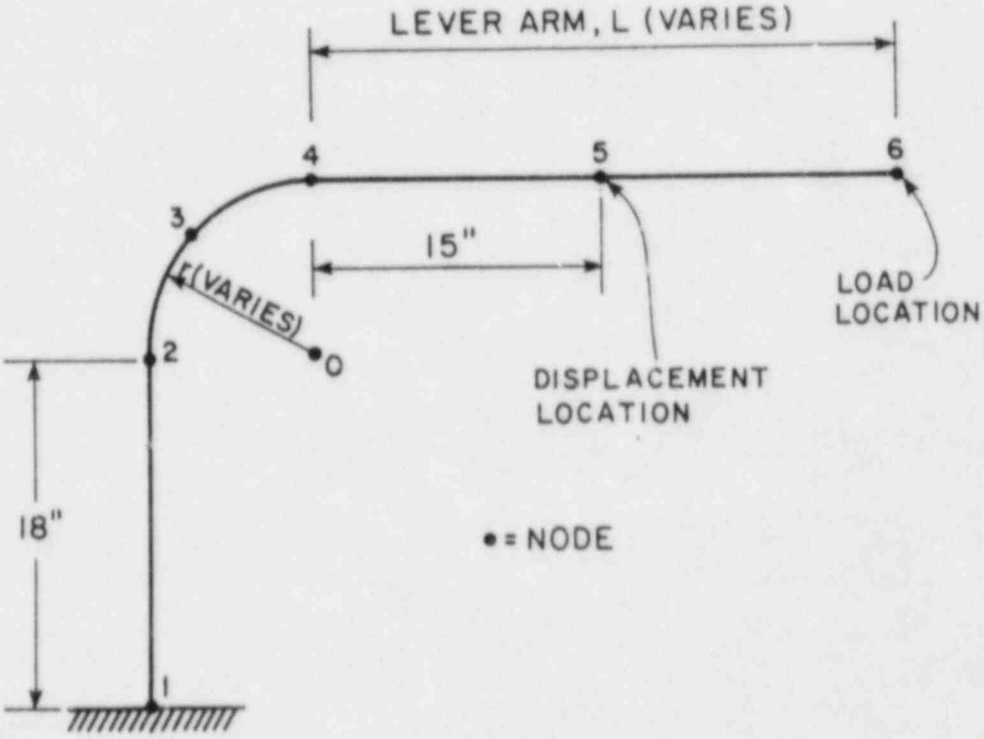

FIG. 2.1.2 ELEMENT SUBDIVISION

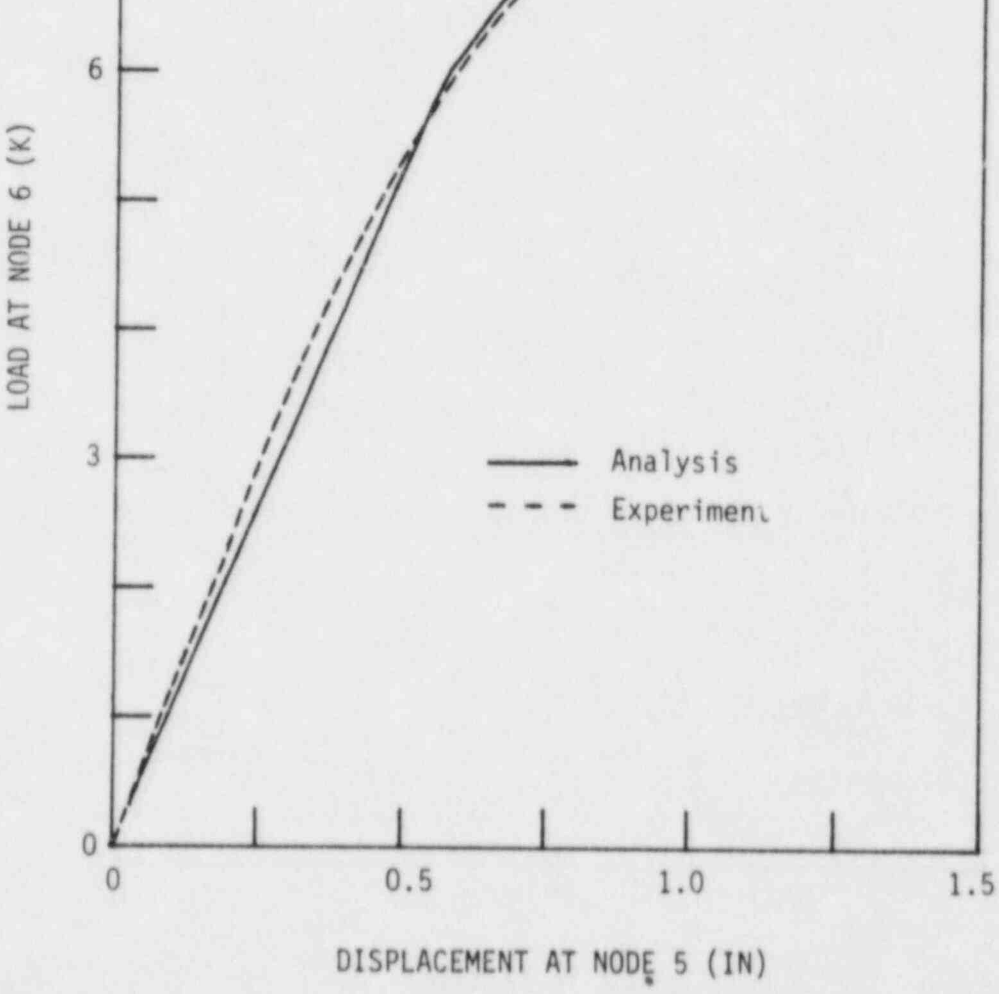

FIG. 2.1.3 TEST PE1.
UPWARDS LOAD, PRESSURE = 0.

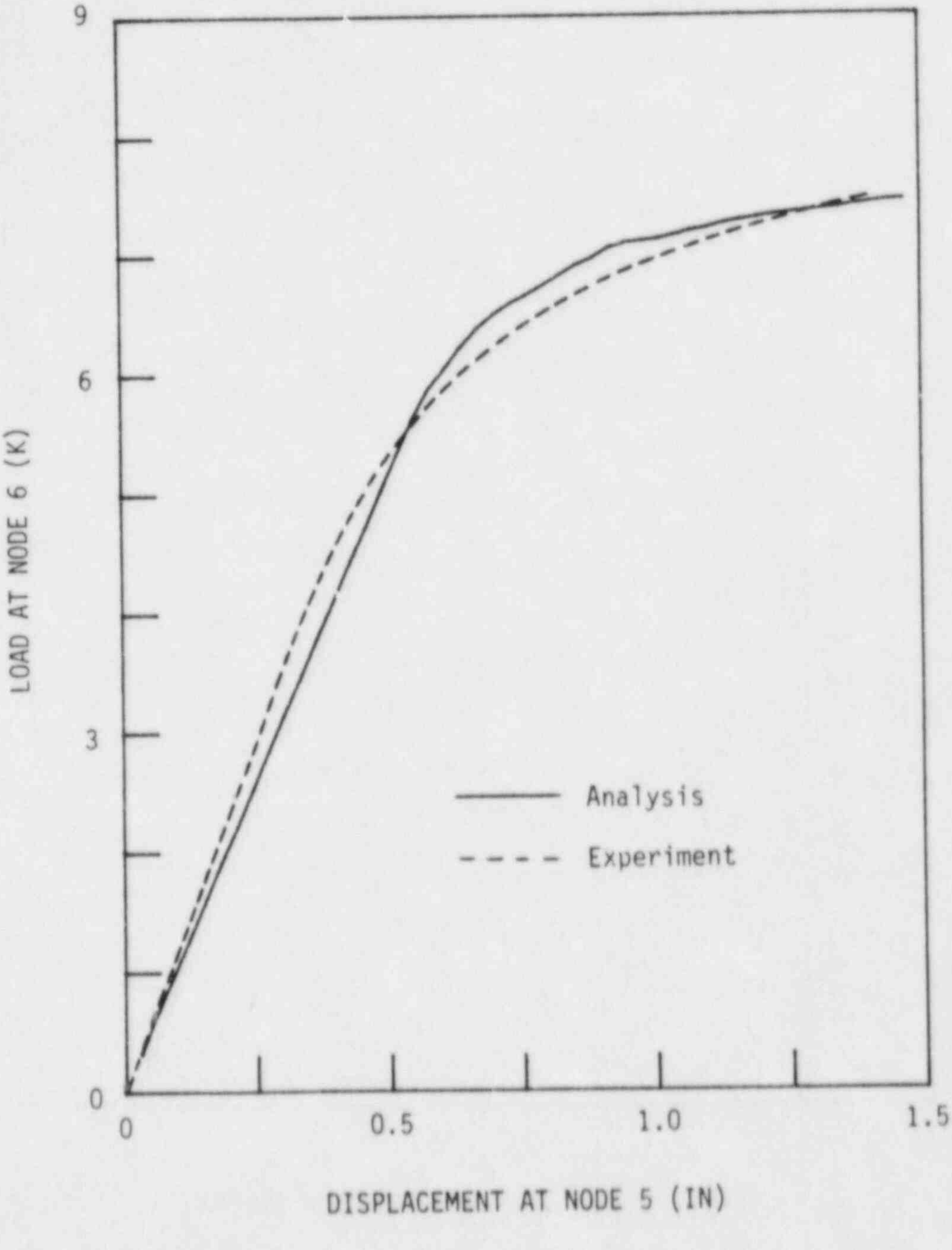

FIG. 2.1.4 TEST PE2.
DOWNWARDS LOAD, PRESSURE = 0.

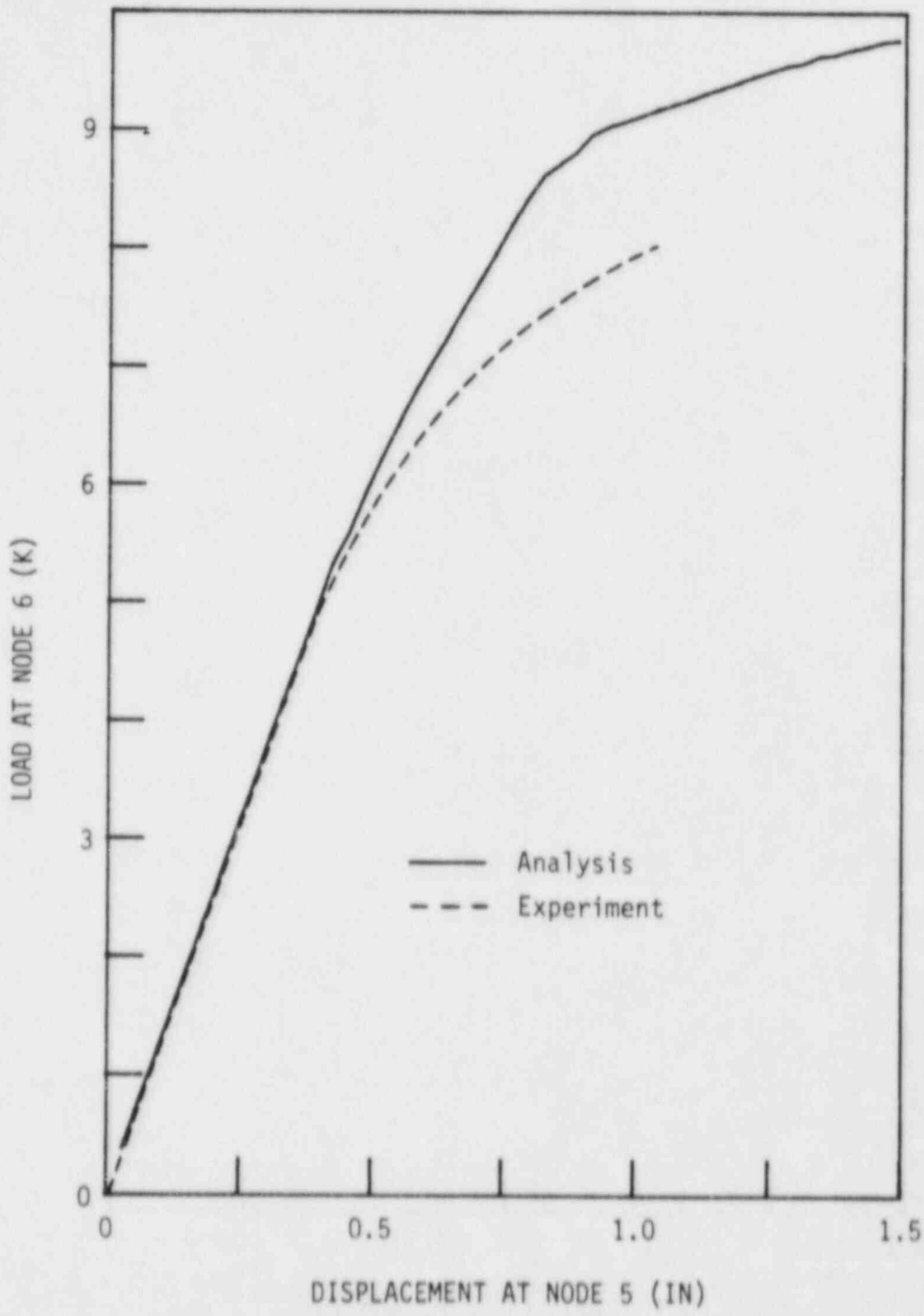

FIG. 2.1.5 TEST PE3.
OUT-OF-PLANE LOAD, PRESSURE = 0.

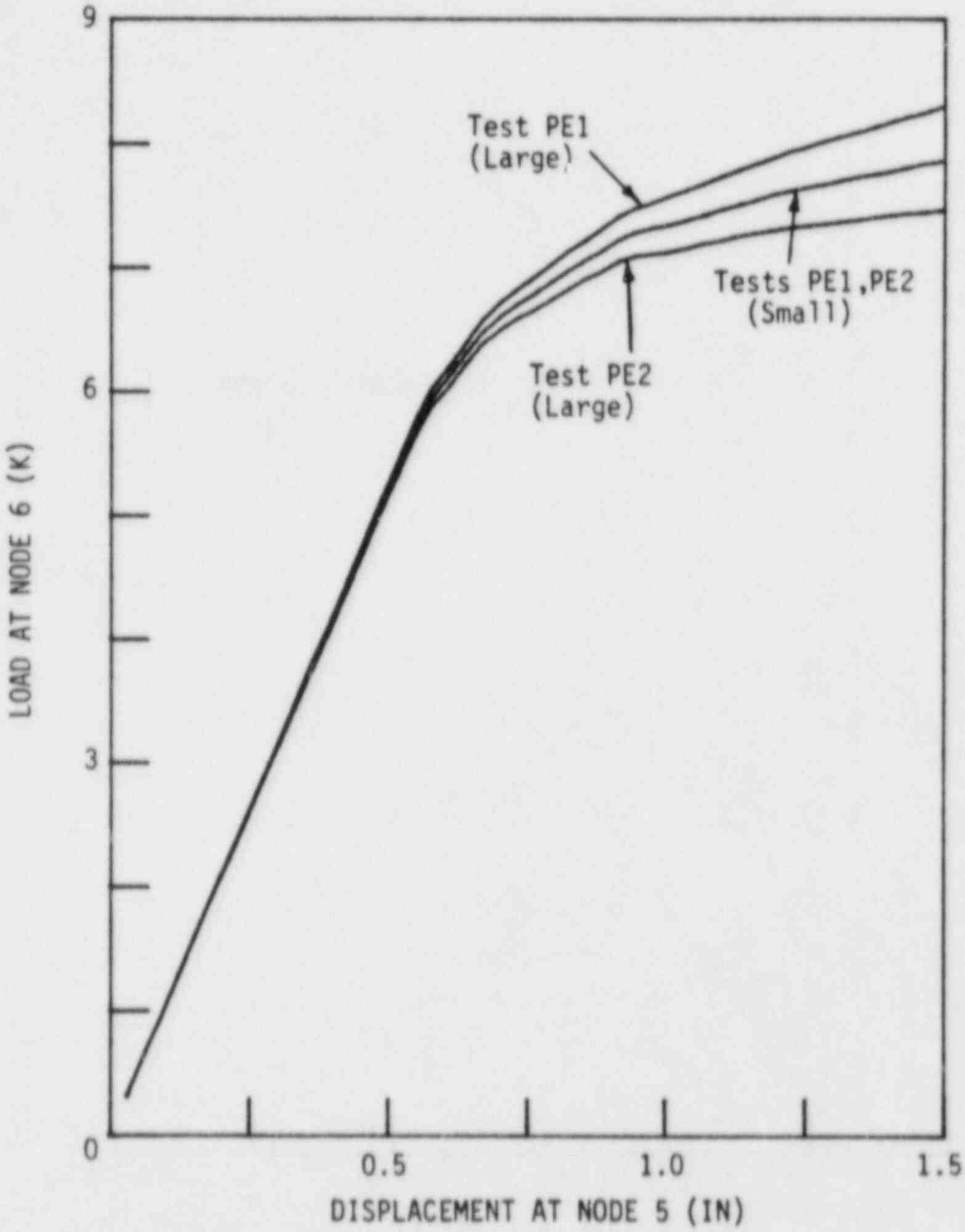

FIG. 2.1.6 COMPARISON OF ANALYSES WITH SMALL AND LARGE OVALLING

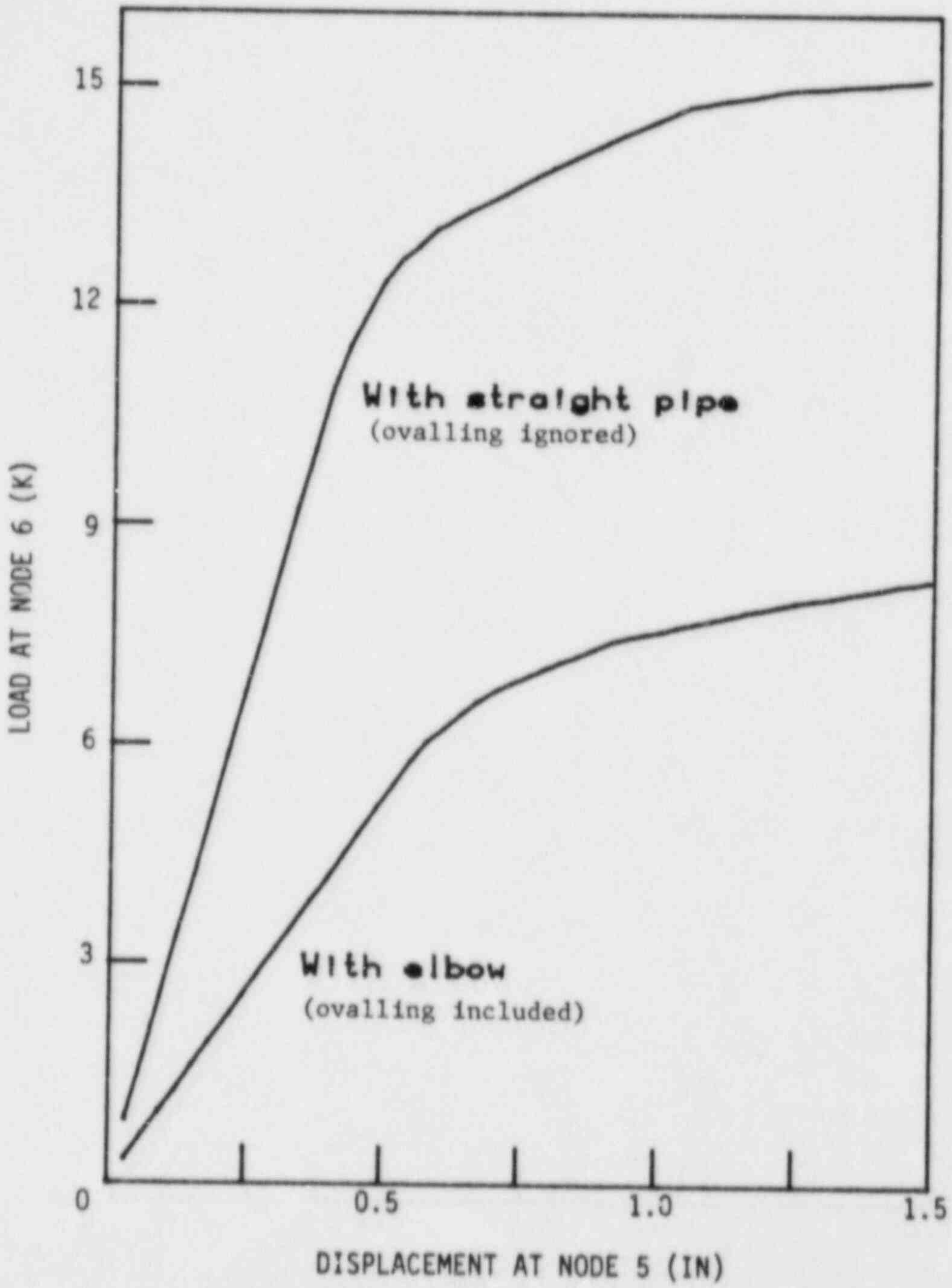

FIG. 2.1.7 EFFECT OF IGNORING OVALLING ON ANALYSIS RESULTS (TEST PE1)

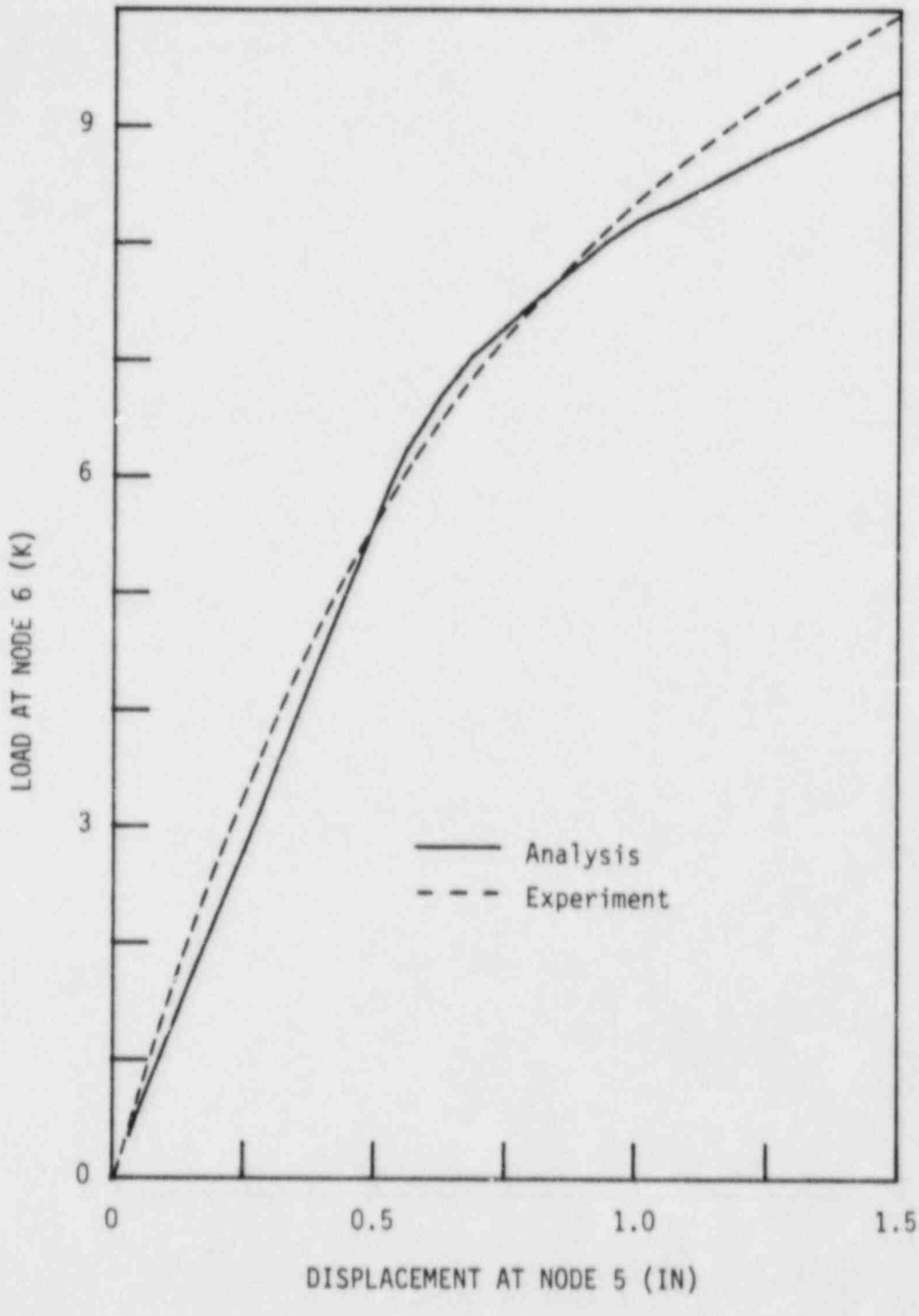

FIG. 2.1.8 TEST PE4.
UPWARDS LOAD, PRESSURE = 1500 PSI.

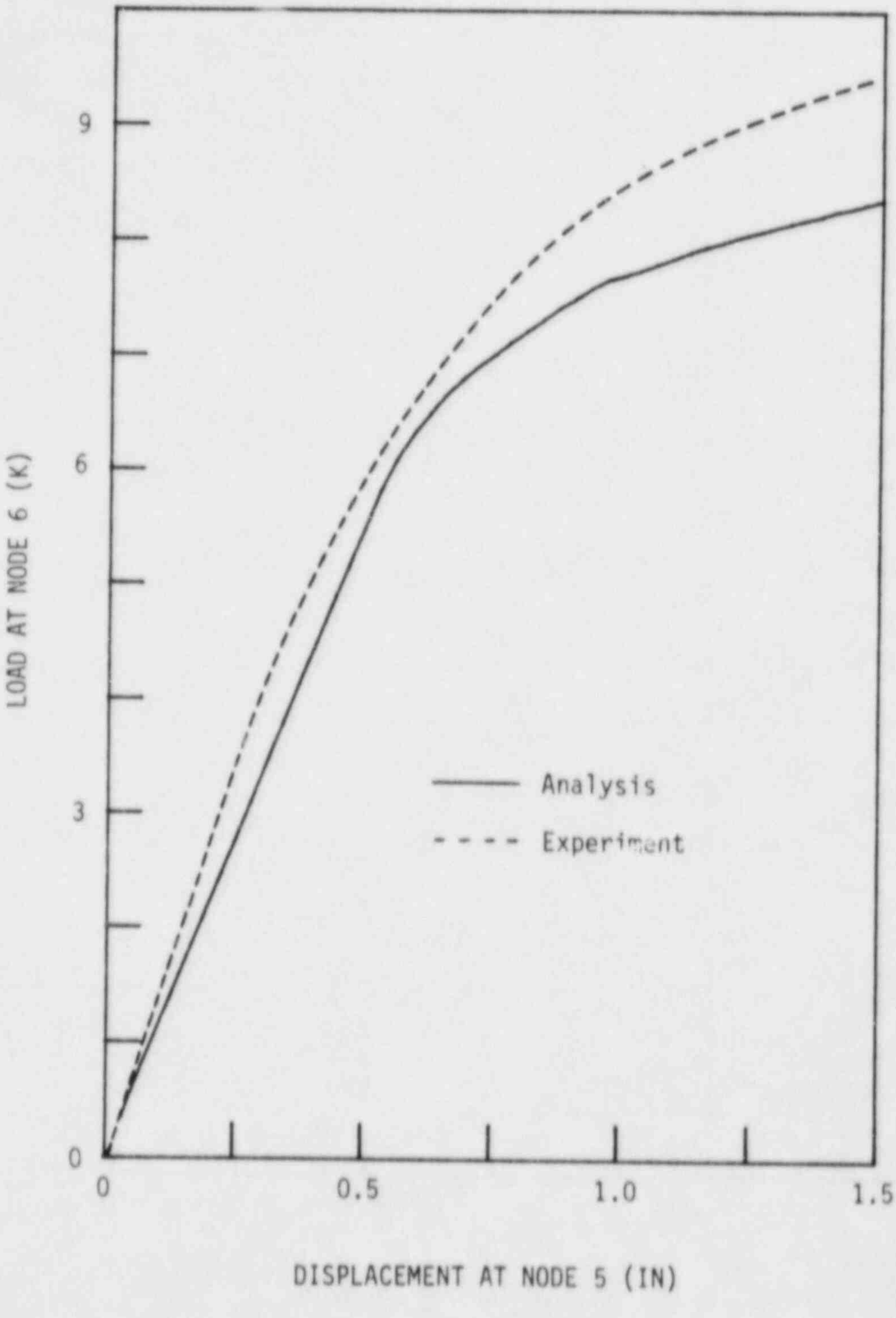

FIG. 2.1.9 TEST PE5.
DOWNWARDS LOAD, PRESSURE = 1500 PSI.

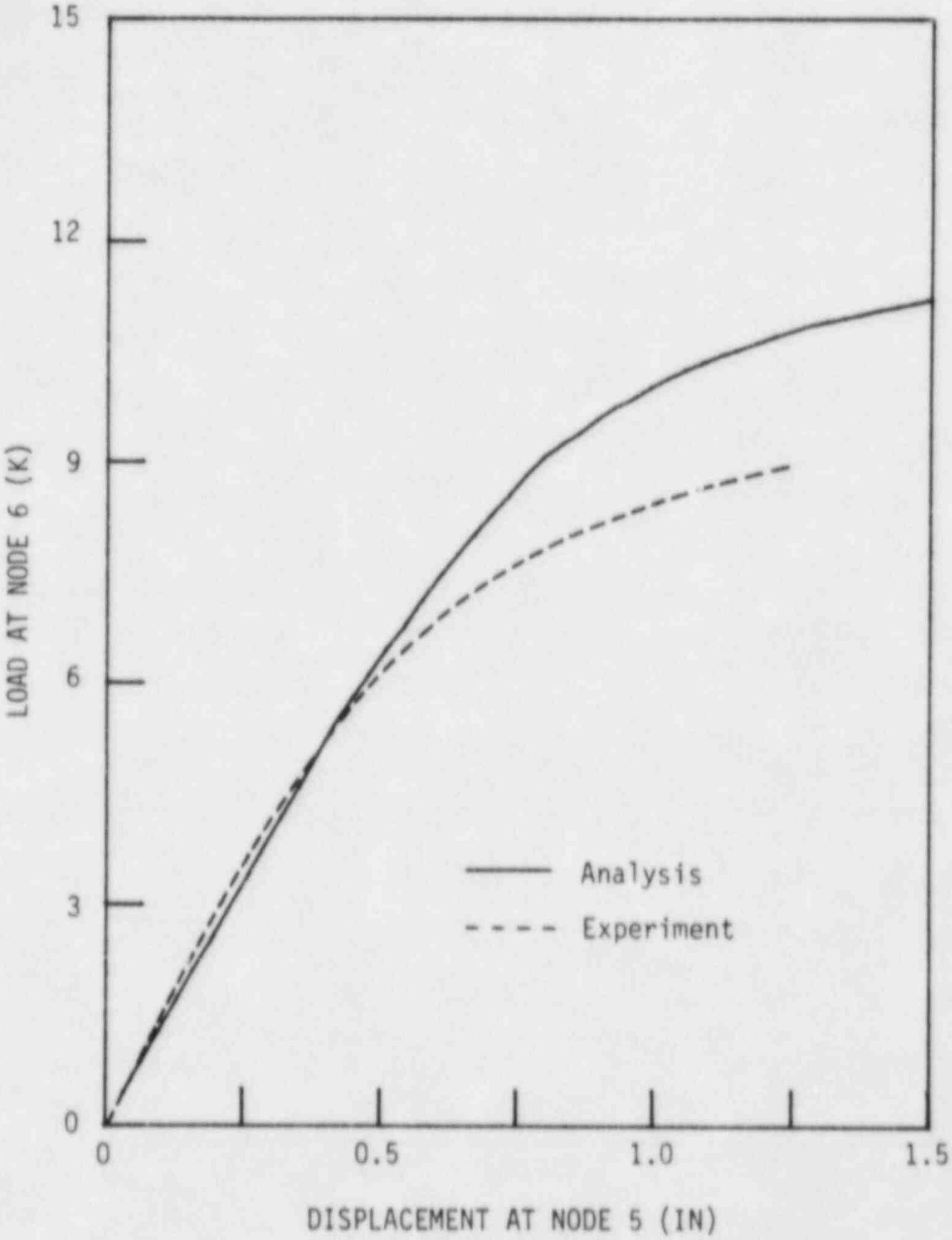

FIG. 2.1.10 TEST PE6.
OUT-OF-PLANE LOAD, PRESSURE = 1500 PSI

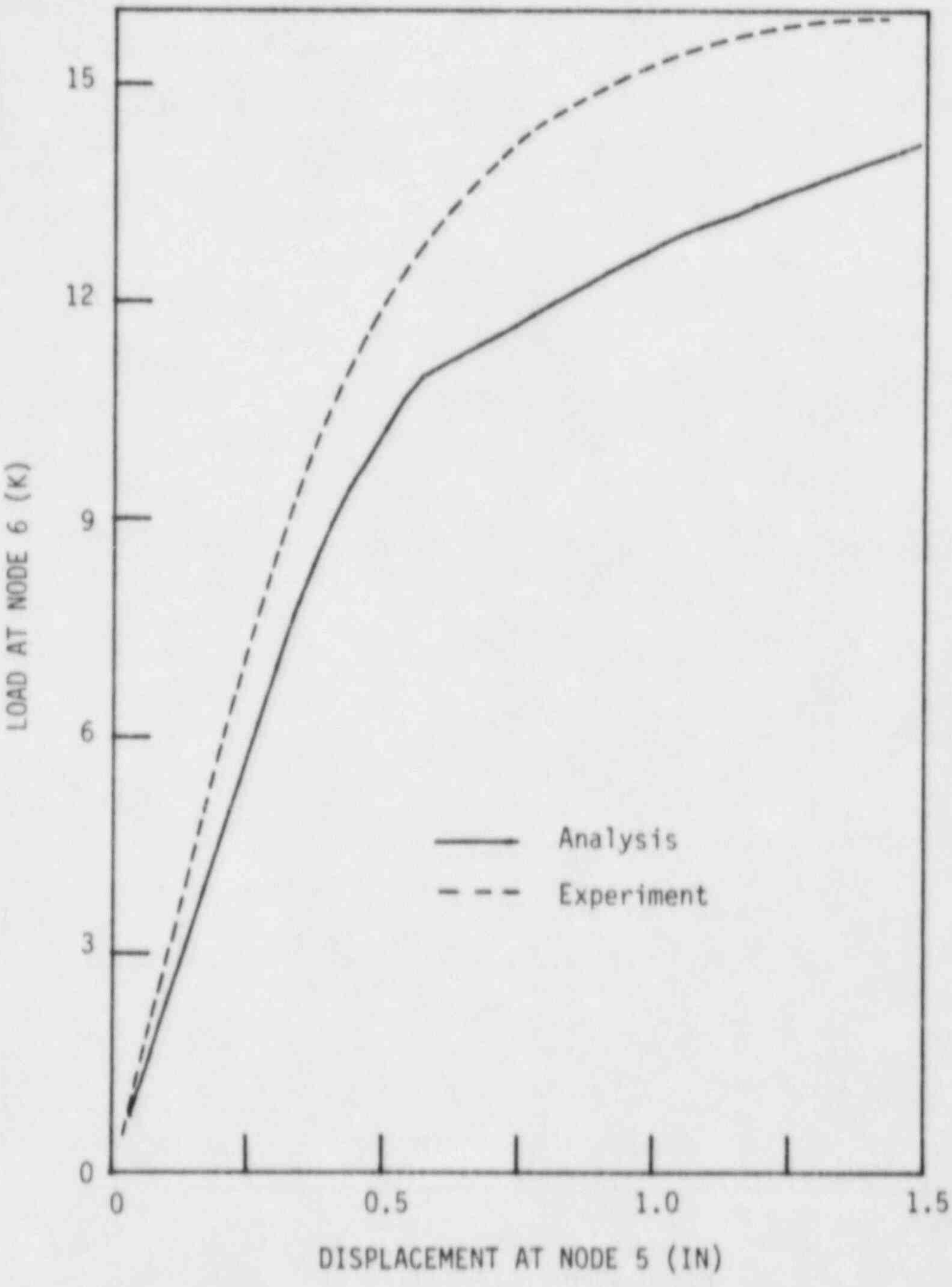

FIG. 2.1.11 TEST PE7.
UPWARDS LOAD, PRESSURE = 0.

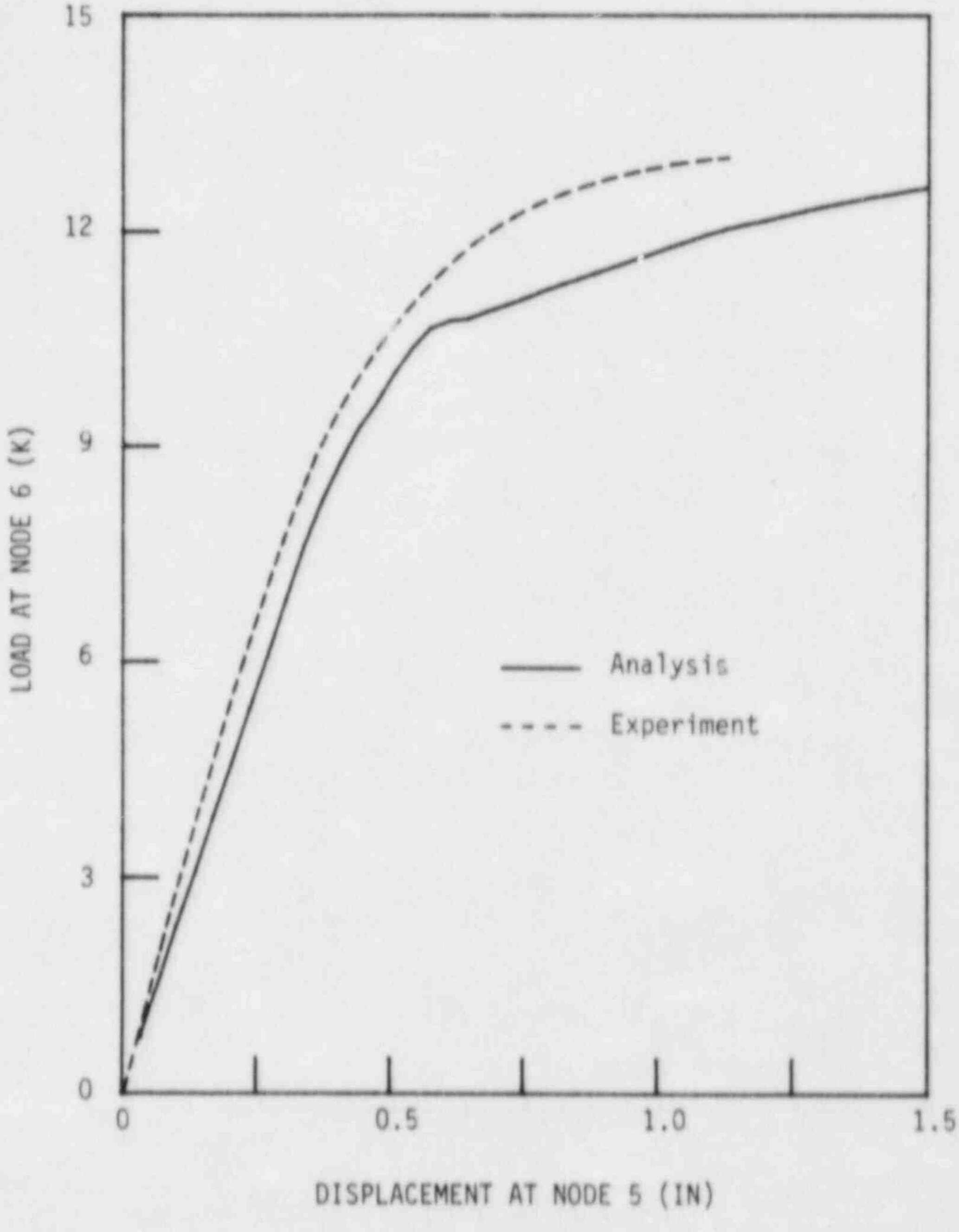

FIG. 2.1.12 TEST PE8.
DOWNWARDS LOAD, PRESSURE = 0.

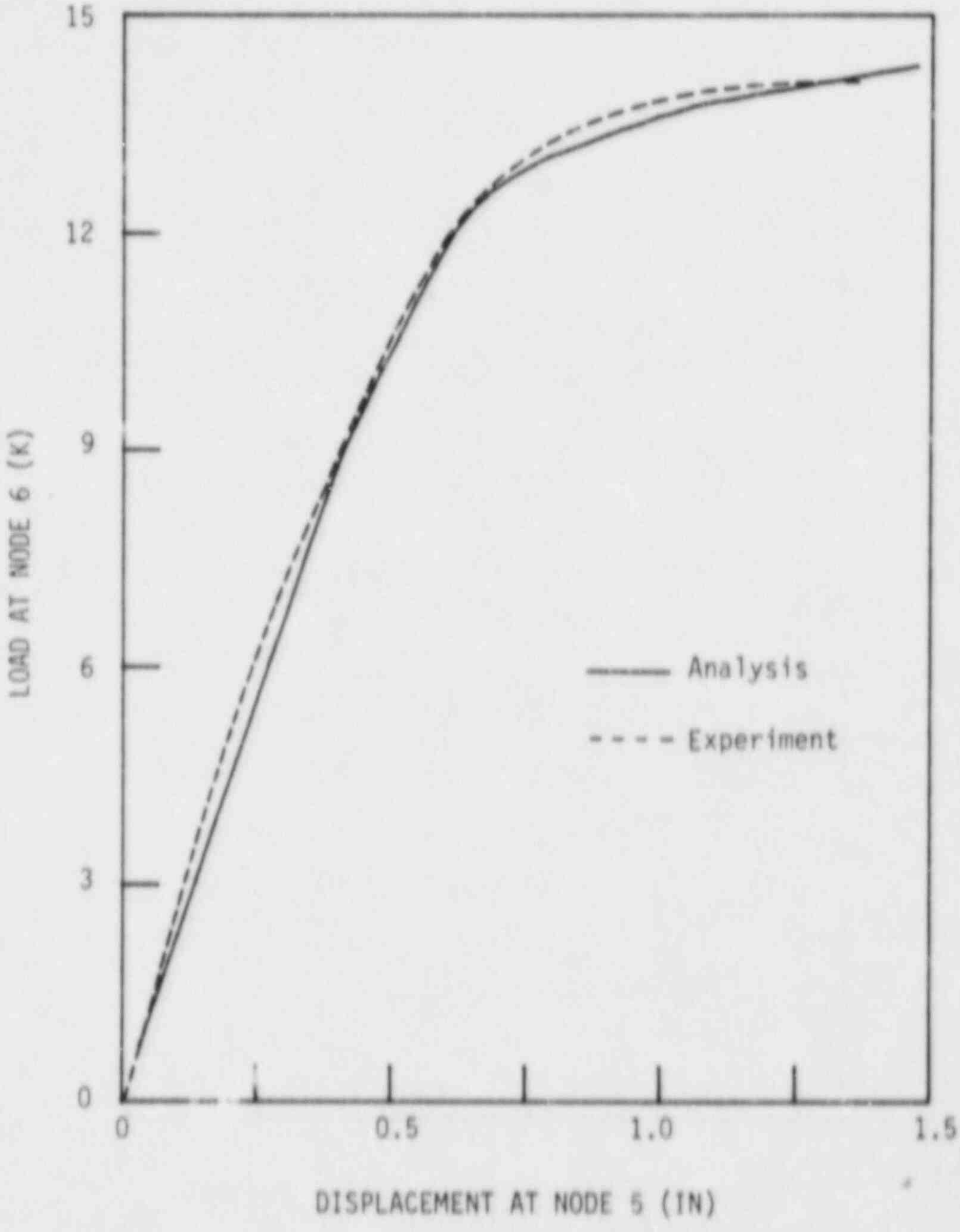

FIG. 2.1.13 TEST PE9.
OUT-OF-PLANE LOAD, PRESSURE = 0.

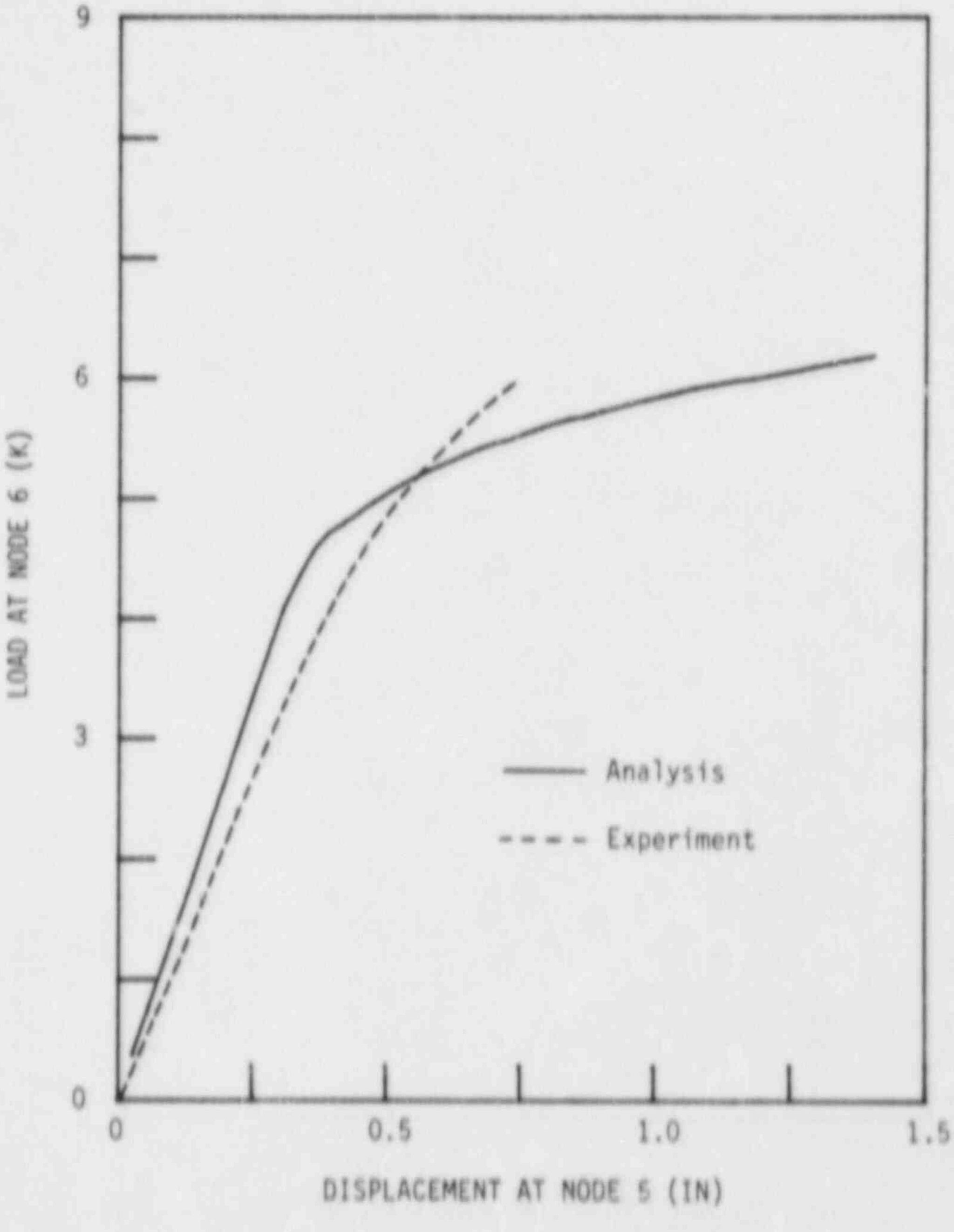

FIG. 2.1.14 TEST PE10.
UPWARDS LOAD, PRESSURE = 0.

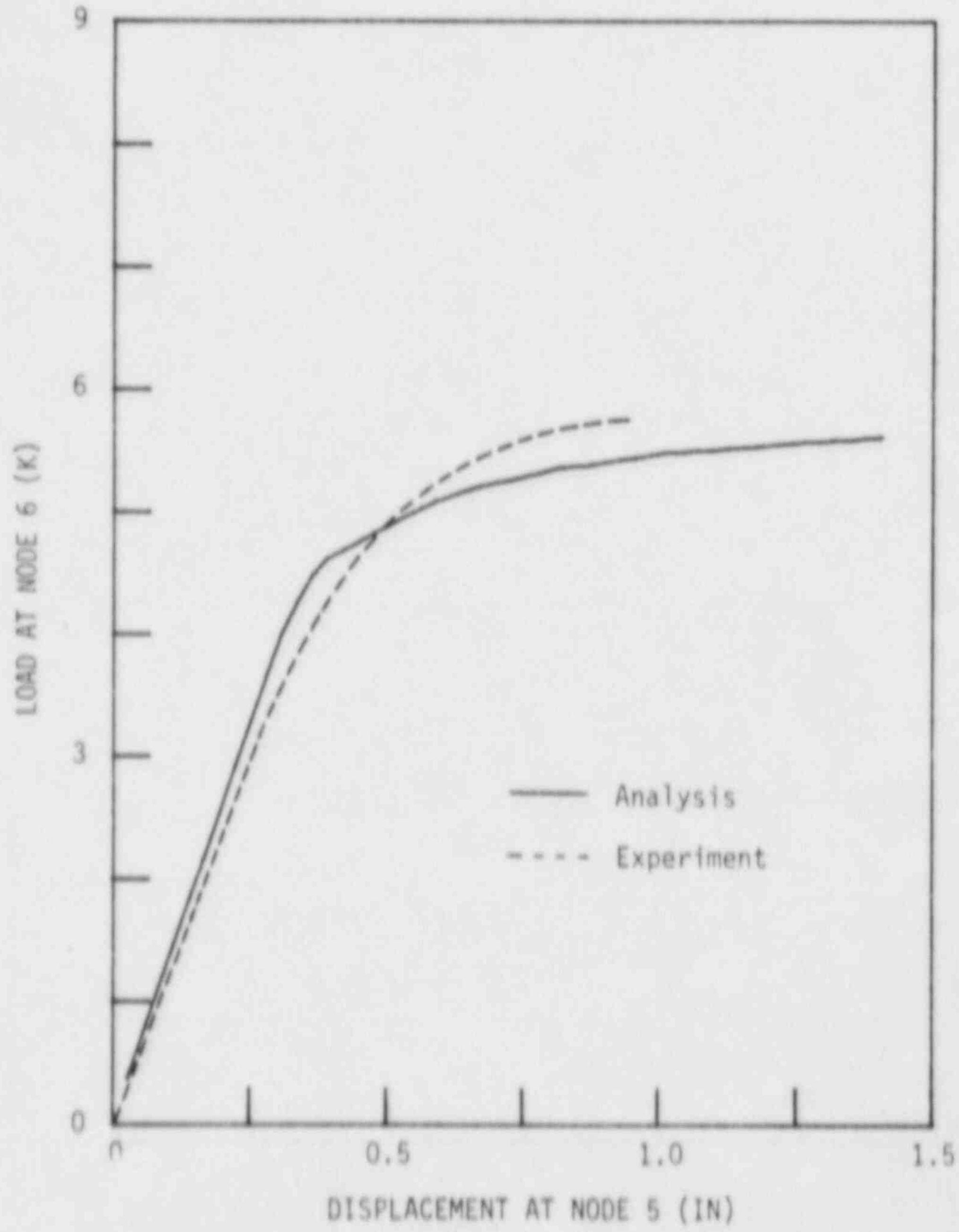

FIG. 2.1.15 TEST PEI1.
DOWNWARDS LOAD, PRESSURE = 0.

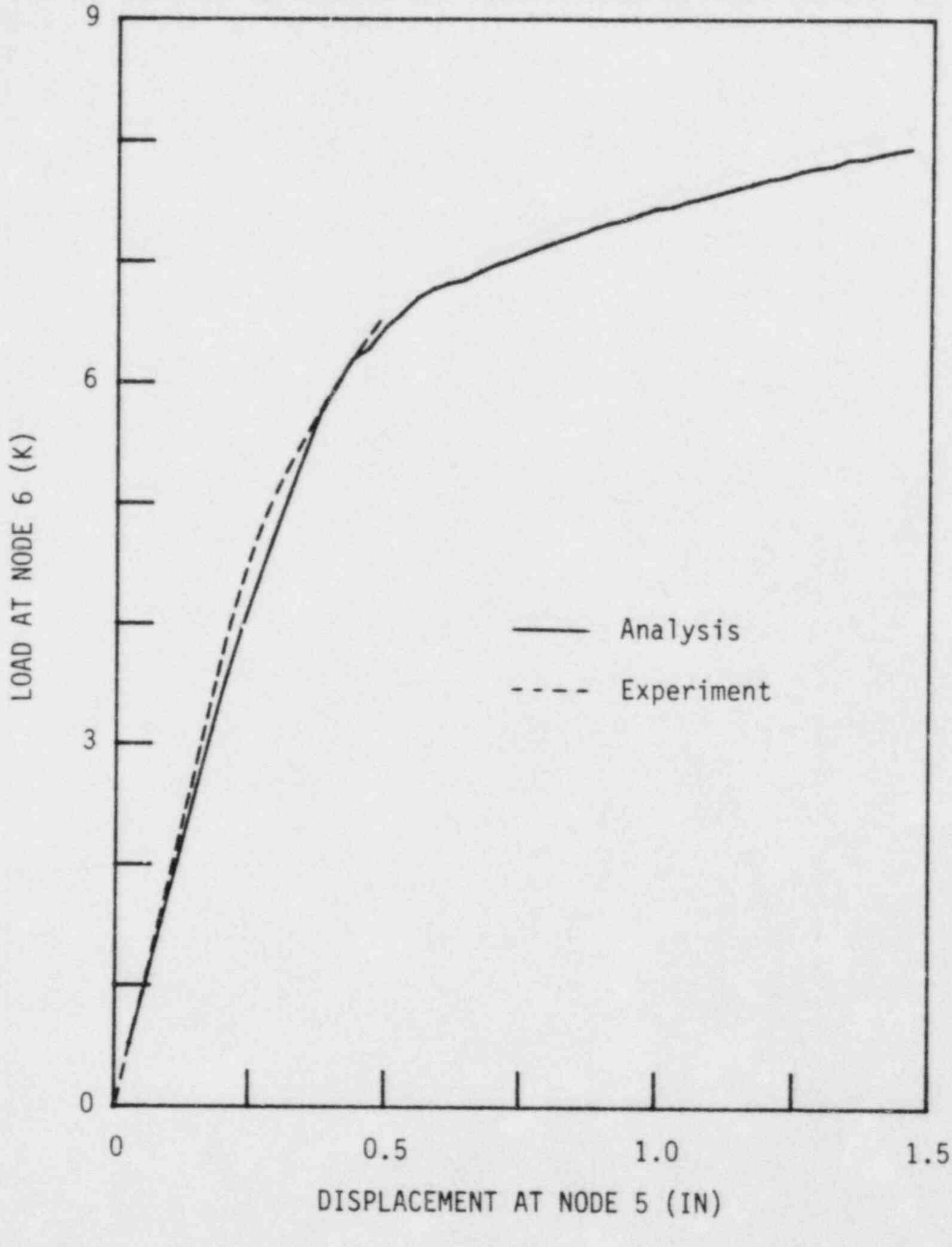

FIG. 2.1.16 TEST PE12.
OUT-OF-PLANE LOAD, PRESSURE = 0.

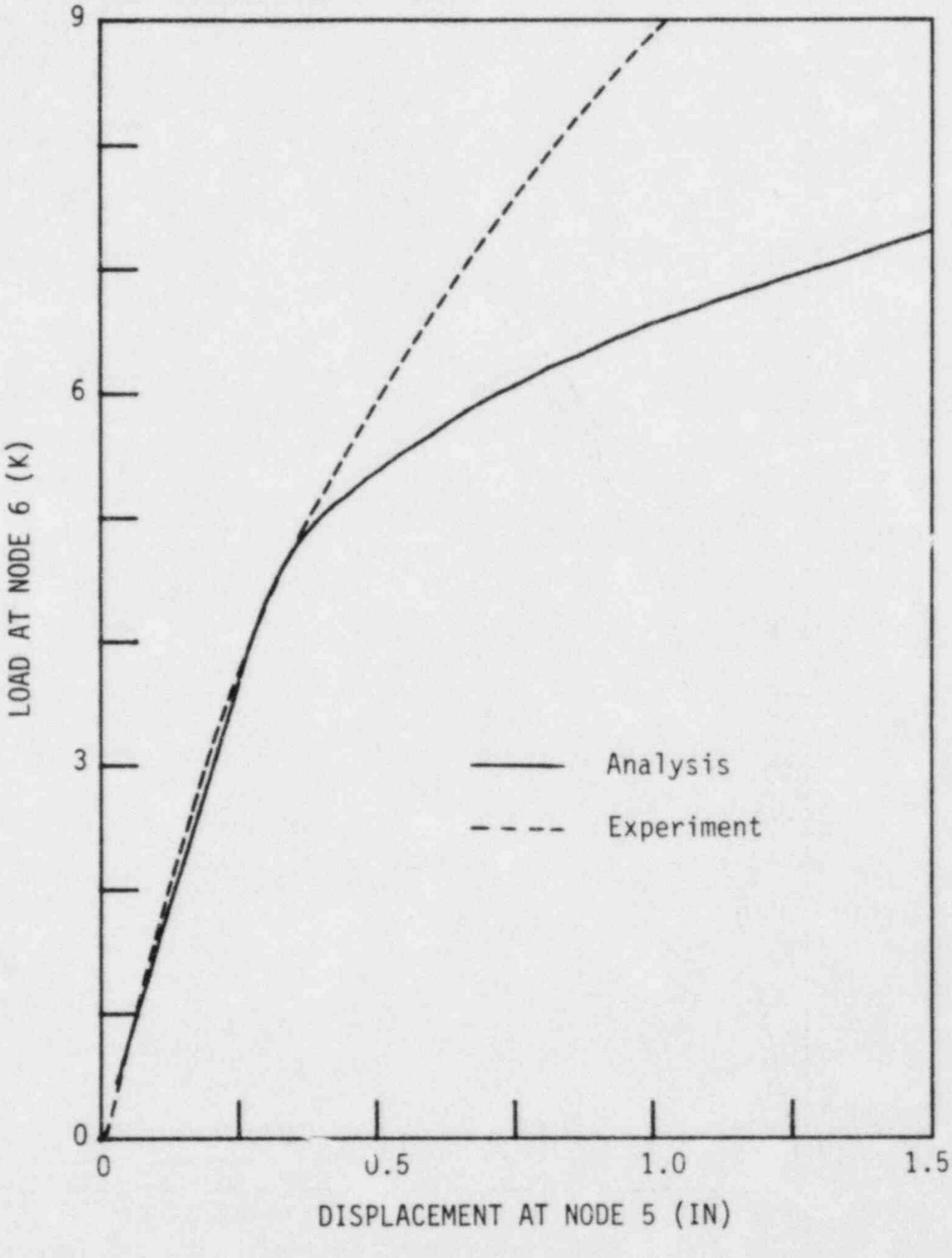

FIG. 2.1.17 TEST PE13.
UPWARDS LOAD, PRESSURE = 1500 PSI.

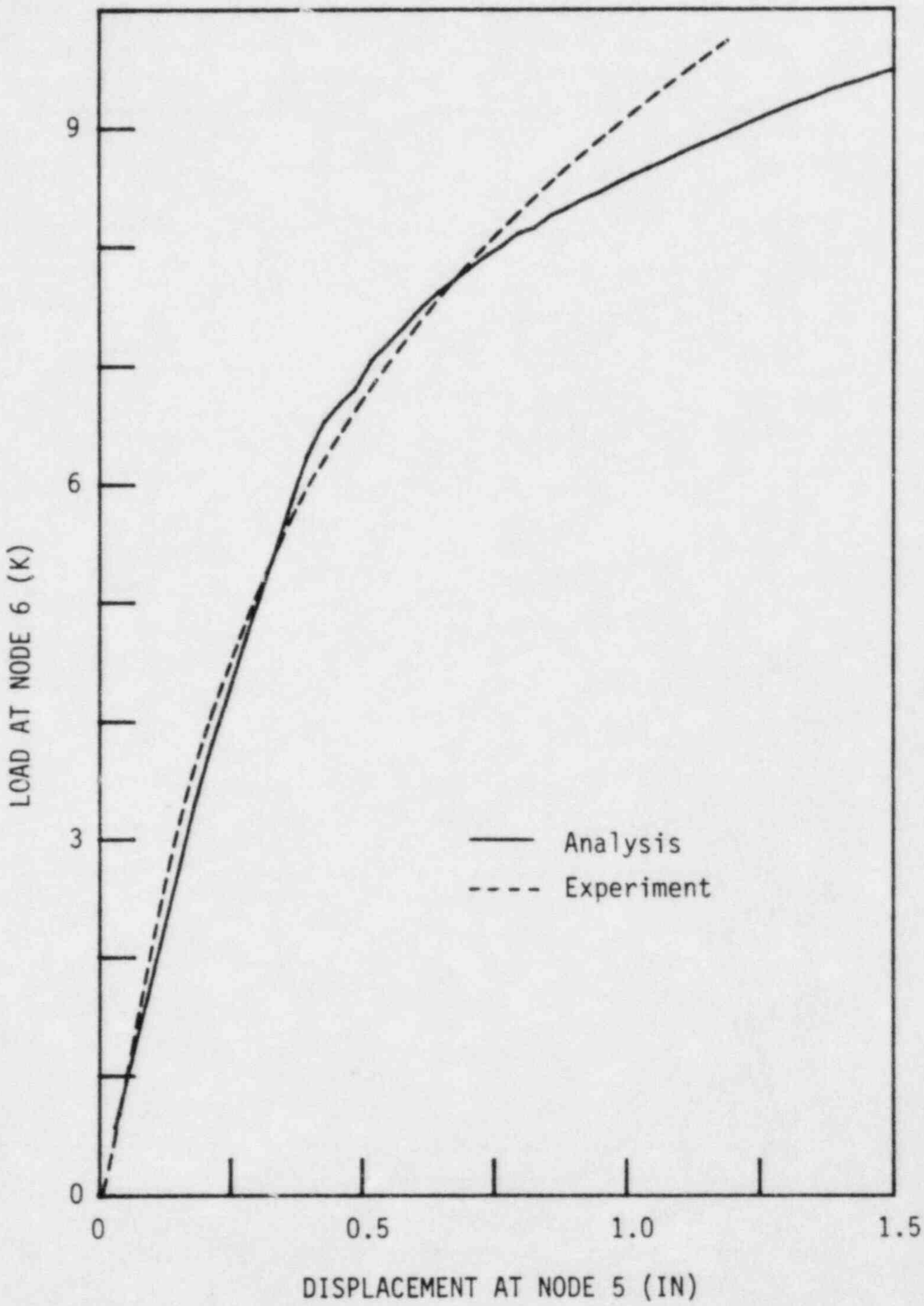

FIG. 2.1.18 TEST PE14.
OUT-OF-PLANE LOAD, PRESSURE = 1500 PSI.

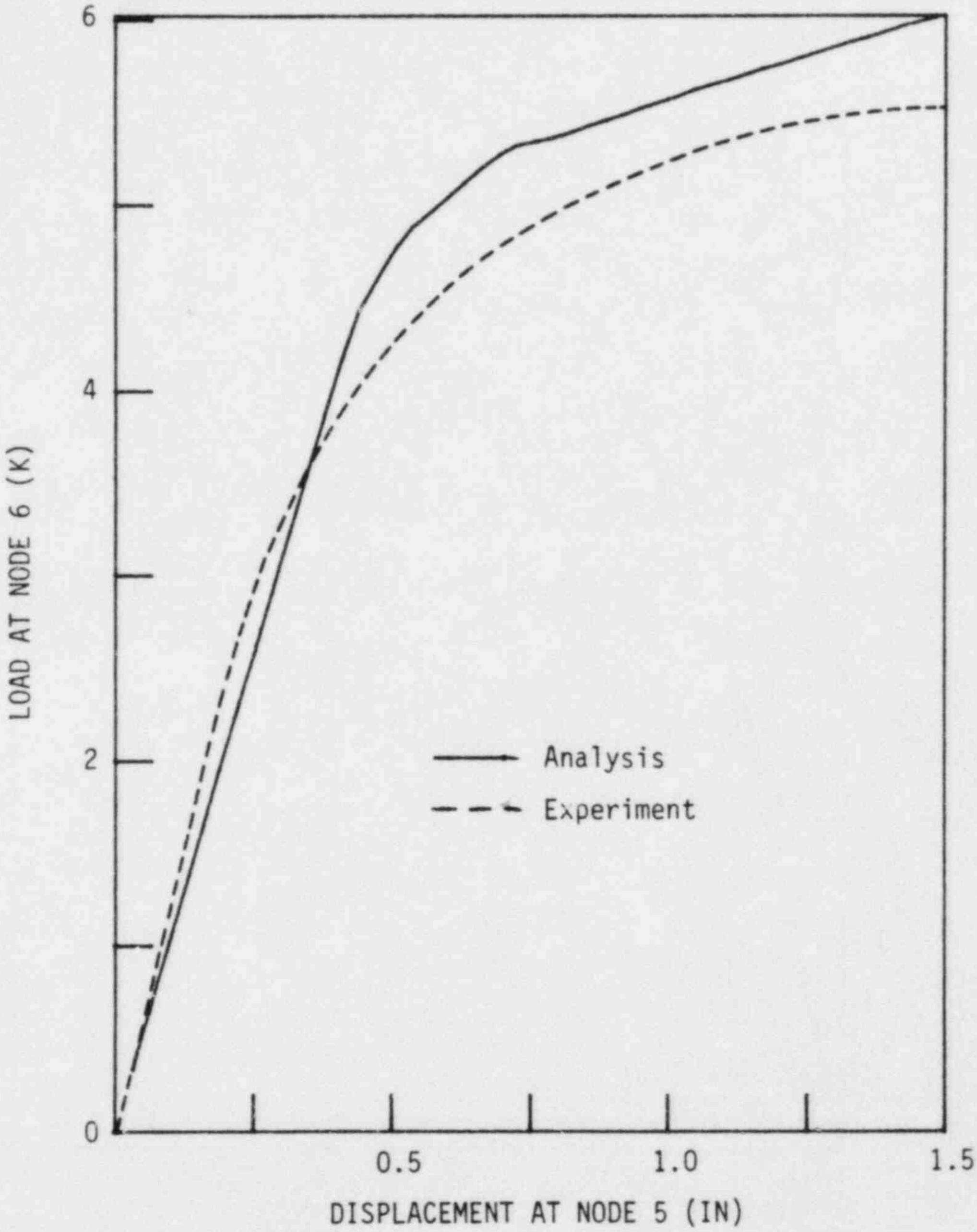

FIG. 2.1.19 TEST PE15.
DOWNWARDS LOAD, PRESSURE = 0.

TABLE 2.1.1 - PROPERTIES OF TEST SPECIMENS						
Test No.	Pipe Size	Material	Yield Stress(ksi)	Loading	Lever Arm (in)	Pressure (psi)
PE1	6Sch40LR	A106B	50	Up	28.50	0
PE2				Down	28.25	0
PE3				Side	28.75	0
PE4				Up	27.56	1500
PE5				Down	27.50	1500
PE6				Side	27.75	1500
PE7	6Sch80LR	A106B	37.8	Up	25.00	0
PE8				Down	25.00	0
PE9				Side	25.88	0
PE10	6Sch40SR	A106B	39.6	Up	29.75	0
PE11				Down	30.00	0
PE12				Side	28.00	0
PE13				Up	27.50	1500
PE14				Side	27.00	1500
PE15	6Sch40LR	A312	37.7	Down	26.75	0

TABLE 2.1.2 - TRILINEAR APPROXIMATION - A-106B STEEL, 50 KSI		
Stress (ksi)	Strain	Modulus (ksi)
0	0	30000
45.5	.00152	1700
51.0	.00475	120

TABLE 2.1.3 - TRILINEAR APPROXIMATION - A-106B STEEL, 39.6 KSI		
Stress (ksi)	Strain	Modulus (ksi)
0	0	30000
36	.00120	1415
41.5	.00500	170

TABLE 2.1.4 - TRILINEAR APPROXIMATION - A-106B STEEL, 37.8 KSI		
Stress (ksi)	Strain	Modulus (ksi)
0	0	30000
34	.00113	1500
39.5	.00500	120

TABLE 2.1.5 - TRILINEAR APPROXIMATION - A312-304L STEEL, 37.7 KSI		
Stress (ksi)	Strain	Modulus (ksi)
0	0	29000
33	.00114	1630
45	.00850	210

TABLE 2.1.6 - WIPSLOG LISTING. GEOM PHASE.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Bolt-Greenstreet Cases PE1,2,3

NEXT WIPS-EXEC COMMAND : geom

GEOM - SPECIFICATION OF SYSTEM GEOMETRY

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Specify new GEOM data

START RUN NO.  1
Enter c.p. data in sequence along run

  c.p. name and type : 1
  coord option : di
  x,y,z :
  Any changes? :

  c.p. name and type : 2 tn
  no. of extra nodes :
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : ti ti
  bend radius : 9
  coord option :
  c.p., dx,dy,dz : 1,,27
  Any changes? :

  c.p. name and type : 4 tn
  no. of extra nodes : 1
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : 5
  no. of extra nodes :
  coord option :
  c.p., dx,dy,dz : ,15
  offset point defaults to preceding c.p.
  Any changes? :

  c.p. name and type : 6
  no. of extra nodes :
  coord option :
  c.p., dx,dy,dz : ti 37.5
  Any changes? :

  c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this run? : y
```

Table 2.1.6 (cont'd)

GEOM DATA FOR RUN

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. i	c.p.? j ?	coordinate data x,dx,p	y,dy	z,dz
1										
	1			0	di			0.	0.	0.
	2	tn		0	tn			0.	0.	0.
	ti	ti	9.000	0	of	1		0.	27.000	0.
	4	tn		1	tn			0.	0.	0.
	5			0	of	4		15.000	0.	0.
	6			0	of	ti		37.500	0.	0.

END OF DATA

START RUN NO. 2
Enter c.p. data in sequence along run

c.p. name and type :
Last run? : y

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOMC101

Produce COOR data? : y

Display COOR data? : y

COOR DATA

run no.	c.p. name	c.p. type	bend radius	node no.	x coord	y ? coord?	z coord
1							
	1			1	0.	0.	0.
	2	tn		2	0.	18.000	0.
	ti	ti	9.000		0.	27.000	0.
			center		9.000	18.000	0.
				3	2.636	24.364	0.
	4	tn		4	9.000	27.000	0.
	5			5	24.000	27.000	0.
	6			6	37.500	27.000	0.

END OF DATA

Plot geometry? :

Modify GEOM data? :

DATA COMPLETE FOR THIS SESSION

Save final GEOM data? : y
Comment for file catalog : Test PE1 (37.5)
GEOM DATA SAVED. FILE NAME = GEOM0101
Save COOR data? : y
Comment for file catalog : Test PE1 (37.5)
COOR DATA SAVED. FILE NAME = COOR0101

End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

TABLE 2.1.7 - WIPSLOG LISTING FOR MATL, PIPE, UBAR AND FREC PHASES.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl


MATL - SPECIFICATION OF MATERIAL PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new MATL file

Specify a new property set? : y

SET NO. =  1
Property set description : ASTM A106B 50ksi Trilinear.
  Static moduli (min=2,max=5)
   : 30000 1700 120
  Yield strengths (no. of moduli minus 1)
   : 45.5 51
  Strain rate stiffnesses (min=0,max=3)
   :
  No strain rate effect
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? :

No. of property sets in MATL file =  1

Display property set descriptions? :
Write in session log? :

Display new property set data? :
Write in session log? :

Display all property set data? : y

MATL PROPERTY DATA

SET NO.  1.  ASTM A106B 50ksi Trilinear.

        Matl     Data    Segm     Modulus  or     Stress/Strain
        Type     Type     No.     Coefficient        Limit
        mroz
                static     1      0.3000e+05       0.4550e+02
                           2      0.1700e+04       0.5100e+02
                           3      0.1200e+03
                yld.tol.          0.2000e-01
                stif tol          0.5000e-01
```

Table 2.1.7 (cont'd)

```
                 rate tol            0.5000e-01
                 poisson             0.3000e+00
                 density             0.2840e-03
   Hit RETURN for next set
   END OF DATA

   New MATL file created
   Comment for file catalog : 1 set

   End this MATL session? : y

   EXEC - WIPS EXECUTIVE

   NEXT WIPS-EXEC COMMAND : pipe


   PIPE - SPECIFICATION OF PIPE PROPERTIES

   Define units
     Length (ft,in,m,mm) : in
     Force (k,lb,kgf,kN) : k

   No. of MATL property sets available =  1
   Display material descriptions? :
   Write in session log? :

   Start new PIPE file

   Specify a new property set? : y

   SET NO. =  1
   Property set description : 6sch40, A106B 50ksi.
     Outside diameter : 6.625
     Wall thickness : .28
     Weight/unit length (dflt=pipe weight) :
     No. of X-section elements (dflt=12) :
     Material number : 1
     Large ovalling (yes or no)? (dflt=no) : y
   Use default ovalling properties? :
     No. of hardening ratios for ovalling (dflt=2) :
     Hardening ratios for ovalling : .35 .08
     Stiffness modification factor : 1
     Strength modification factor : 1

   Any errors? :

   This set added to PIPE file

   Specify a new property set? : y

   SET NO. =  2
   Property set description : As for Set 1 but small ovalling.
     Outside diameter : 6.625
     Wall thickness : .28
     Weight/unit length (dflt=pipe weight) :
     No. of X-section elements (dflt=12) :
```

Table 2.1.7 (cont'd)

```
  Material number : 1
  Large ovalling (yes or no)? (dflt=no) :
Use default ovalling properties? :
  No. of hardening ratios for ovalling (dflt=2) :
  Hardening ratios for ovalling : .35 .08
  Stiffness modification factor : 1
  Strength modification factor : 1

Any errors? :

This set added to PIPE file

Specify a new property set? :

No. of property sets in PIPE file =  2

Display property set descriptions? : y

PIPE PROPERTY DESCRIPTIONS
  Set No.   Description
     1      6sch40, A106B 50ksi.
     2      As for Set 1 but small ovalling.

Display new property set data? :
Write in session log? :

Display all property set data? : y

 PIPE PROPERTY DATA

SET NO.  1.  6sch40, A106B 50ksi.

        Data                  Segm    Modulus or    Stress/Strain
        Type                   No.    Data Value        Limit

        Outside diameter              0.6625e+01
        Wall thickness                0.2800e+00
        Unit weight                   0.1585e-02
        No. of elements                  12
        No. of slices                     2
        Stress v strain         1     0.3000e+05    0.4550e+02
                                2     0.1700e+04    0.5100e+02
                                3     0.1200e+03
        Poisson ratio                 0.3000e+00
        Large ovalling                   yes
        Ovalling ratios         1     0.3500e+00
                                2     0.8000e-01
Hit RETURN for next set

SET NO.  2.  As for Set 1 but small ovalling.

        Data                  Segm    Modulus or    Stress/Strain
        Type                   No.    Data Value        Limit

        Outside diameter              0.6625e+01
        Wall thickness                0.2800e+00
```

Table 2.1.7 (cont'd)

```
        Unit weight                     0.1585e-02
        No. of elements                   12
        No. of slices                      2
        Stress v strain          1      0.3000e+05     0.4550e+02
                                 2      0.1700e+04     0.5100e+02
                                 3      0.1200e+03
        Poisson ratio                   0.3000e+00
        Large ovalling                     no
        Ovalling ratios          1      0.3500e+00
                                 2      0.8000e-01
Hit RETURN for next set
END OF DATA

New PIPE file created
Comment for file catalog : 2 sets

End this PIPE session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : ubar

UBAR - SPECIFICATION OF U-BAR PROPERTIES

Define units
  Length (ft;in;m;mm) : in
  Force (k,lb,kgf,kN) : k

Start new UBAR file

Specify a new property set? : y

SET NO. =  1
Property set description : Stiff bar to control displs.
Static stiffnesses (min=2,max=6)
 : 2000 200
Static strengths (no. of stiffnesses minus 1)
 : 1e6
Extension rate Stiffnesses (min=0,max=3)
 :
No extension rate effect
Default gap clearance : .001
Use default tolerances? : y

Any errors? :

This set added to UBAR file

Specify a new property set? :

No. of property sets in UBAR file =  1

Display property set descriptions? :
Write in session log? :

Display new property set data? :
```

Table 2.1.7 (cont'd)

```
Write in session log? :

Display all property set data? : y

UBAR PROPERTY DATA

SET NO. 1.  Stiff bar to control displs.

        Data                 Segm  Stiffness or    Force
        Type                  No.   Coefficient    Limit

        Static properties     1      0.2000e+04  0.1000e+07
                              2      0.2000e+03
        Default gap                  0.1000e-02
        Stiffness tol.               0.5000e-01
        Overshoot tol.               0.2000e+00
        Unloading tol.               0.2000e+00
Hit RETURN for next set
END OF DATA

New UBAR file created
Comment for file catalog : 1 set

End this UBAR session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

FREC - SPECIFY DYNAMIC FORCE RECORDS

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new FREC file

Specify a new record ? : y

RECORD NO.  1

Record name (4 characters) : rec1
Description (max. 40 char.) : Ramp to 10000k in 10 sec.

Enter Time-Force pairs
First pair automatically set to 0,0
  Pair no.  2 : 10 10000
  Pair no.  3 :
Last pair? : y
Any errors ? :

Specify a new record ? :

Display any records ? :

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog : 1 record

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
----------------------------------------------------------------------
```

TABLE 2.1.8 - WIPSLOG LISTING. MODL AND DATA PHASES.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl

MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type     No. of Sets
  pipe          2
  ubar          1
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.    1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 6 pipe pr=1 wf=1e-10
 2: 6 ubar pr=1 dy=-1 gap=.001
 3:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. = 1
  c.p.  elem    optn     data          optn      data          optn      data
  1
                bcon    111111
  6     pipe
                prop         1
                locl         +          ldis      no           this      yes
                wfac    0.1000e-09
  6     ubar
                prop         1
                ldis        no          this      yes
                dyij    -1.0000         gap     0.1000e-02
Any changes? :

SEGMENT NO.   2
```

Table 2.1.8 (cont'd)

```
Pipe run no. :
Last segment? : y

Any externa. substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : PE-1, large ovalling.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Sequence no. of MODL file : 1

Problem description (4 lines)
 Line 1 : Bolt-Greenstreet Test PE1.                        GHP 7/82
 Line 2 :
 Line 3 : Large ovalling. ASTM A106B material. To 2.5in displ. at 6.
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed

Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 6
  Force direction (x,y,z or follower) : y
  Scale factor (+,- controls direction) : 1
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : .05 .051 .049
 Max steps + max total time : 50 10
Error tolerances : upper + lower : 1e10 1e-10

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) : .0001
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : PE1. Large ovalling.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

-----------------------------------------------------------------------
```

TABLE 2.1.9 - LISTING OF DATA FILE FOR A TYPICAL CASE (TEST PE1)

```
  ECHO0101  SLDG0101  RSLT0101
star,
gbui
new,main,nonl,cart,0
 substructure name = main
refn,7
    1  0.          e+00  0.          e+00  0.         e+00
    2  0.          e+00  0.1800000e+02  0.         e+00
    3  0.2636039e+01  0.2436396e+02  0.         e+00
    4  0.9000000e+01  0.2700000e+02  0.         e+00
    5  0.2400000e+02  0.2700000e+02  0.         e+00
    6  0.3750000e+02  0.2700000e+02  0.         e+00
 9999
boun,7
    1                           111111
    2                             1110
    3                             1110
    4                             1110
    5                             1110
    6                             1110
 9999                           111111
enod,0
matl,3,64
0.200000000e+010.299999982e+000.300000000e+050.170000000e+040.120000000e+03
0.455000000e+020.510000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.100000000e+010.200000000e+010.100000000e+01
0.100000000e+010.662500000e+010.280000001e+000.158510788e-020.          e+0C
0.349999994e+000.799999982e-010.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.499999970e-01
0.639999986e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+00
0.200000000e+010.299999982e+000.300000000e+050.170000000e+040.120000000e+03
0.455000000e+020.510000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.          e+000.200000000e+010.100000000e+01
0.100000000e+010.662500000e+010.280000001e+000.158510788e-020.          e+0C
0.349999994e+000.799999982e-010.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.499999970e-01
0.639999986e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+00
0.200000000e+010.          e+000.100000005e-020.499999970e-010.200000000e+04
0.200000000e+030.100000000e+070.999999932e+200.199999988e+000.199999988e+0C
0.199999988e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
0.          e+000.          e+000.          e+000.          e+000.          e+0C
```

Table 2.1.9 (cont'd)

```
0.         e+000.         e+000.         e+000.         e+000.         e+00
0.         e+000.         e+000.         e+000.         e+000.         e+00
0.         e+000.         e+000.         e+000.         e+000.         e+00
0.         e+000.         e+000.         e+000.         e+000.         e+00
0.         e+000.         e+000.         e+000.         e+000.         e+00
0.         e+000.         e+000.         e+000.         e+00
elem,2
    2    1    1                                    0.
    1    0    0    0    6    3    0    1    0    1
0.375000000e+020.260000000e+020.         e+000.         e+000.         e+00
0.         e+000.100000005e-02

    3    5    1                                    1.00
    1    0    0    0    1    2    1    0    1    1    0    1
-.100000000e+010.         e+000.         e+000.         e+00
    2    0    0    0    2    3    1    0    1    0    1    1
0.900000095e+010.180000000e+020.         e+000.         e+00
    3    0    0    0    3    4    1    0    1    0    1    1
0.900000095e+010.180000000e+020.         e+000.         e+00
    4    0    0    0    4    5    1    0    1    1    0    1
0.900000000e+010.280000000e+020.         e+000.         e+00
    5    0    0    0    5    6    1    0    1    1    0    1
0.240000000e+020.280000000e+020.         e+000.         e+00

nord,opto
prof
end
fini
mode
tree,main
fini
mbui
new,main
pmas,7
    10 0.18575e-14 0.18575e-14 0.18575e-14 0.      e+00 0.      e+00 0.      e+0000
    20 0.25684e-14 0.25684e-14 0.25684e-14 0.      e+00 0.      e+00 0.      e+0000
    30 0.14217e-14 0.14217e-14 0.14217e-14 0.      e+00 0.      e+00 0.      e+0000
    40 0.22588e-14 0.22588e-14 0.22588e-14 0.      e+00 0.      e+00 0.      e+0000
    50 0.29411e-14 0.29411e-14 0.29411e-14 0.      e+00 0.      e+00 0.      e+0000
    60 0.13932e-14 0.13932e-14 0.13932e-14 0.      e+00 0.      e+00 0.      e+0000
    60 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+0000
end
fini
ptre
newr,recl,pair,2,100
(2e15.7)
  0.       e+00  0.       e+00
  0.1000000e+05  0.1000000e+02
fini
thou,217
         2          65    3    1    0    0
ndyn
mass
dylo,1,1
recl     2    0.     1.000        1
    6
```

Table 2.1.9 (cont'd)

```
timo,rslt,1,0.1000e+01
auto,defi
inte,newm,0.5000e-01,0.e+00,0.e+00,0.1000e-03
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,50
zero,ltme
step
unba
auto,init
loop,20
stif
auto,load
load
disp
kinr,10
elmr,9,10
auto,merr,0.1000e-09,0.1000e+11
if,3,3,1,1
entr,1
auto,fact
kinr,1
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.4900e-01,0.5100e-01,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e-03
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,8
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,lrsb
unba
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.1000e+02
if,5,8,8,0
entr,8
cont
fini
stop
DATA0101
```

D2.2 PIPE WITH U-BAR RESTRAINT

D2.2.1 PURPOSE

This example tests the PIPE and UBAR elements, by comparison with test results and previously reported analysis results. Analyses are carried out both with and without strain rate effects.

D2.2.2 DESCRIPTION

Analyses and tests of simple pipe whip configurations have been reported by Esswein et al [2.2.1]. An analysis of one of the two configurations has been reported by Hibbitt and Karlsson [2.2.2]. The dimensions are shown in Fig. 2.2.1.

The following static material properties were reported in [2.2.1] for the pipe steel.

$$\sigma = 30000\,\epsilon \text{ for } \sigma < 18.6 \qquad (2.2.1a)$$

$$\sigma = 81.8\,\epsilon^{0.2} \text{ for } \sigma > 18.6 \qquad (2.2.1b)$$

where σ = stress (ksi) and ϵ = strain. For the analyses in both [2.2.1] and [2.2.2], the strength was increased by 50% to account for strain rate effects. The equations given in [2.2.1] are inconsistent in this respect. For the analysis in [2.2.2], the following consistent equations were used:

$$\sigma = 30000\,\epsilon \text{ for } \sigma < 31.02 \qquad (2.2.2a)$$

$$\sigma = (1.5 \times 81.8)\,\epsilon^{0.2} \text{ for } \sigma > 31.02 \qquad (2.2.2b)$$

The following static force-extension relationship was reported in [2.2.1] for the U-bar restraint:

$$F = 681.4\,\Delta \text{ for } \Delta < 0.005 \qquad (2.2.3a)$$

$$F = 11.79\,\Delta^{0.235} \text{ for } \Delta > 0.005 \qquad (2.2.3b)$$

where F = restraint force (k) and Δ = extension (in.). For the analyses in [2.2.1] and [2.2.2], the strength was increased by 10% to account for strain rate effects. The following relationships were used:

$$F = 1.1 \times 681.4\,\Delta \text{ for } \Delta < 0.005 \qquad (2.2.4a)$$

$$F = (1.1 \times 11.79)\,\Delta^{0.235} \text{ for } \Delta > 0.005 \qquad (2.2.4b)$$

For the analyses in [2.2.1] and [2.2.2], the inertia of the vertical leg was lumped at the elbow. This was not done for the WIPS analysis. Note that the rupture disc assembly weighted 210 lbs. This is a large proportion of the total weight and exerts a substantial influence on the response. The element subdivision for the WIPS analysis is shown in Fig. 2.2.2. The blowdown forcing function is shown in Table 2.2.1.

D2.2.3 PROPERTIES FOR WIPS ANALYSIS

The PIPE element with 12 subelements in the cross section was used to model the pipe, and a UBAR element to model the U-bar. Small displacements were assumed. The internal pressure in the pipe was assumed to be zero (i.e. internal pressure effects on pipe strength were ignored).

Analyses with the following material properties were carried out.

Case 1: Multilinear representations of the pipe steel and U-bar properties as shown in Tables 2.2.2 and 2.2.4. These correspond to the properties defined by Eqns. 2.2.1 and 2.2.3, with no allowance for strain rate effects.

Case 2: Pipe steel and U-bar properties as shown in Tables 2.2.3 and 2.2.5. These correspond to the properties defined by Eqns. 2.2.2 and 2.2.4.

Case 3: Pipe and U-bar properties as for Case 1, plus trilinear representations of strain rate effects as shown in Table 2.2.6. This strain rate data was used directly for the pipe steel. The data was converted to force-extension data for the U-bar, assuming a bar area of 0.22 in^2 (0.375 in. dia. bars) and an effective bar length of 9.7 in. The resulting effect is shown in Table 2.2.7. Note that these are assumptions for analysis purposes and do not necessarily represent the true strain rate behavior of the pipe and U-bar materials. The data in Table 2.2.6 is based on data for low carbon steel reported by Manjoine [2.2.3].

D2.2.4 WIPS INPUT DATA

Table 2.2.8 is the WIPSLOG listing for specification of the system geometry. Table 2.2.9 is the WIPSLOG listing for specification of the pipe and U-bar properties and the blowdown force record. Tables 2.2.10 and 2.2.11 are the WIPSLOG listings for the MODL and DATA phases for all three cases. Table 2.2.12 is the DATA file listing for Case 3. The DATA files for Cases 1 and 2 were the same as for Case 3, except for Columns 31-35 of the element cards.

D2.2.5 RESULTS

D2.2.5.1 General

Key results are summarized in Table 2.2.13. Time histories of computed restraint forces are shown in Figs. 2.2.3 through 2.2.5 for each of Cases 1, 2, and 3. The experimental values reported in [2.2.1] are also shown. In Fig. 2.2.4 the analysis results reported in [2.2.2] are shown. The results for all three cases are superimposed in Fig. 2.2.6 for comparison.

The analyses for Figs. 2.2.3 through 2.2.5 were carried out using the Newmark step-by-step option, with $\beta/\Delta t_0 = 0.1$ and $\Delta t_0 = 0.0002$ sec. An analysis was also carried out for Case 2 using the HHT option, with $\alpha = -0.05$. The results are shown in Fig. 2.2.7. These results are very close to those in Fig. 2.2.4.

D2.2.5.2 Discussion

The computed results for Cases 1, 2, and 3 differ significantly. The restraint force for Case 3 (with strain rate effects) is larger than the experimental value, and the corresponding restraint extension is smaller. This indicates that the assumed relationship between extension rate and strength increase is not correct. The agreement with experiment is closest for Case 2. This is not surprising since the 1.1 factor used in this analysis was probably chosen to match the experimental results.

The time to gap closure is virtually the same for all analyses. This suggests that the motion before gap closure is governed mainly by the inertia of the pipe and that the pipe strength has little effect.

The results for Case 2 using the Newmark and HHT step-by-step schemes were virtually identical. These results were very close to those reported in [2.2.2] up to unloading of the restraint, but the computed rebound behavior was significantly different.

For interest, the number of time steps required for each analysis is shown in Table 2.2.13. The upper midstep error tolerance in all cases was 14% of the initial jet force (7.2 k). The lower tolerance was one-fifth of the upper tolerance.

D2.2.6 CONCLUSION

This example shows that close agreement with experiment can be obtained, provided appropriate assumptions are made for the stiffness and strength properties of the pipe and restraint.

D2.2.7 REFERENCES

2.2.1 Esswein, G., Levy, S., Triplett, M., Chan, G., and Varadarajan, N., "Pipe Whip Dynamics," Conference on Dynamic Analysis of Pressure Vessels and Piping, ASME PVP-PB-022, 1978.

2.2.2 Hibbitt and Karlsson, "Analysis of Pipe Whip," EPRI NP-1208, Electric Power Research Institute, 1979.

2.2.3 Manjoine, M. J., "Influence of Rate of Strain and Temperature on Yield Stresses of Mild Steel," J. Appl. Mech., Vol. II, A-211, 1944.

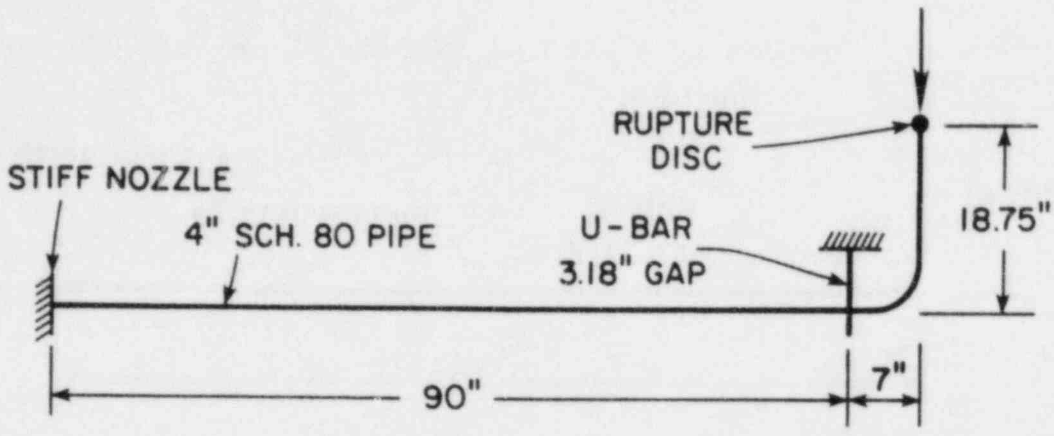

FIG. 2.2.1 SYSTEM DIMENSIONS

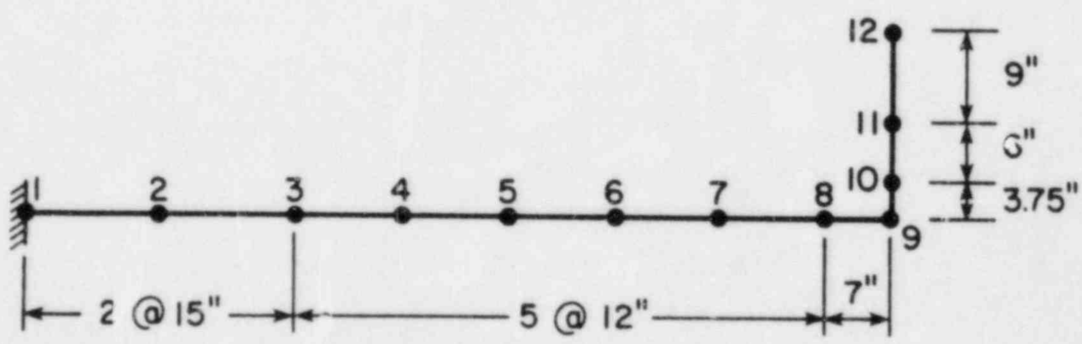

FIG. 2.2.2 ELEMENT SUBDIVISION

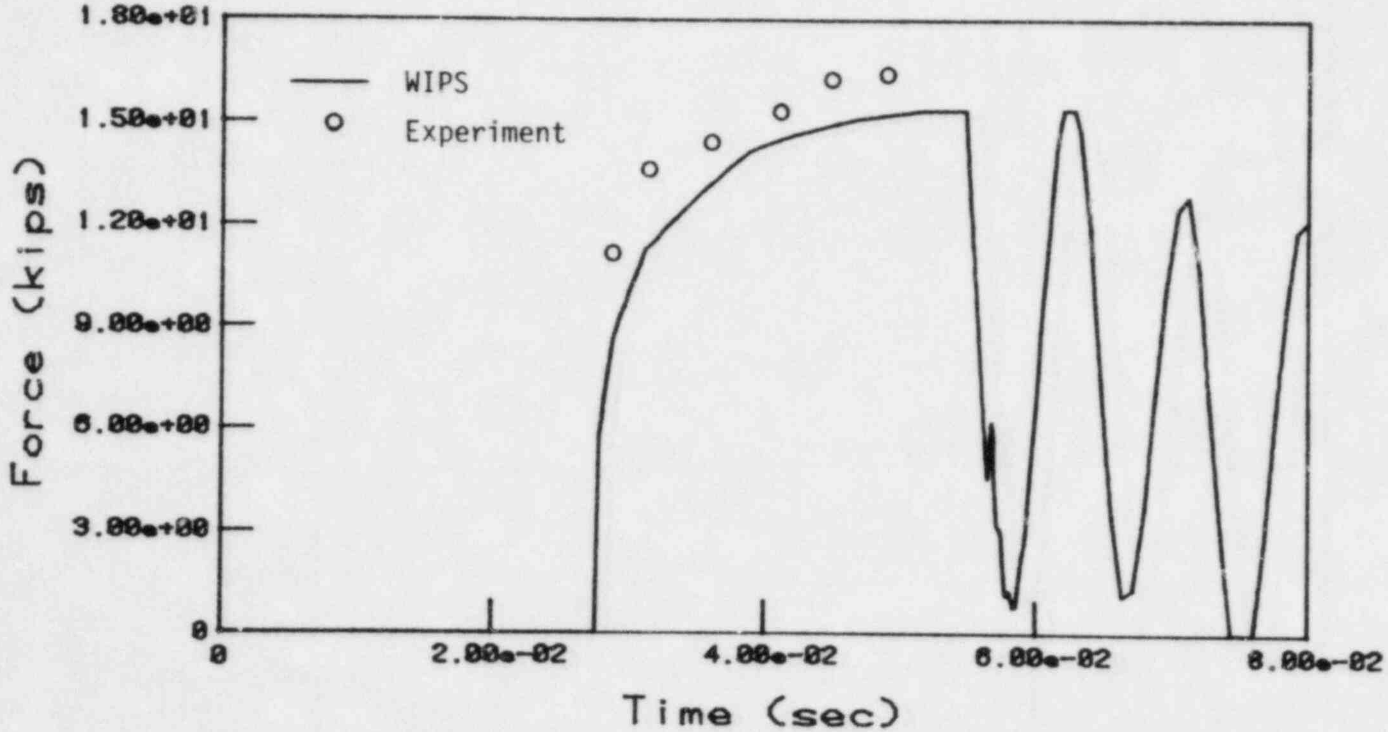

FIG. 2.2.3 RESTRAINT FORCE VS. TIME - CASE 1.

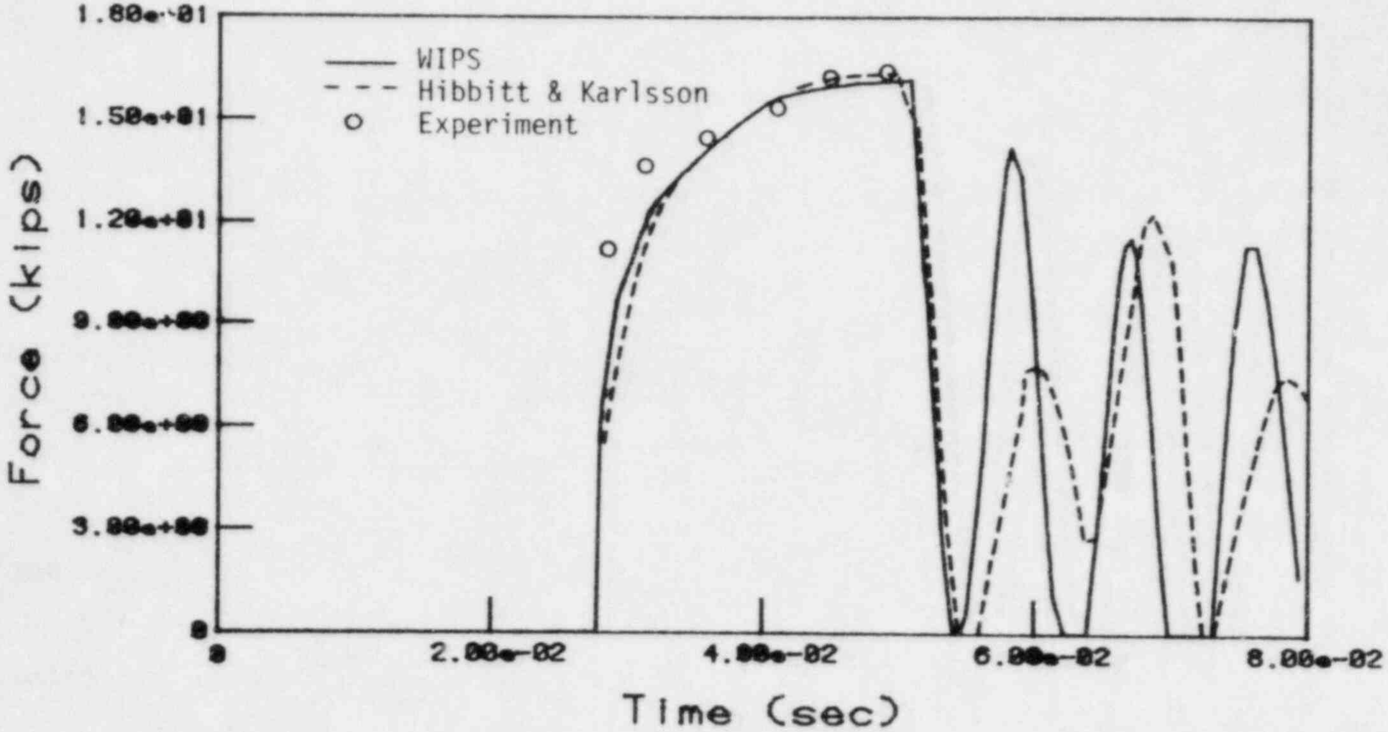

FIG. 2.2.4 RESTRAINT FORCE VS. TIME - CASE 2.

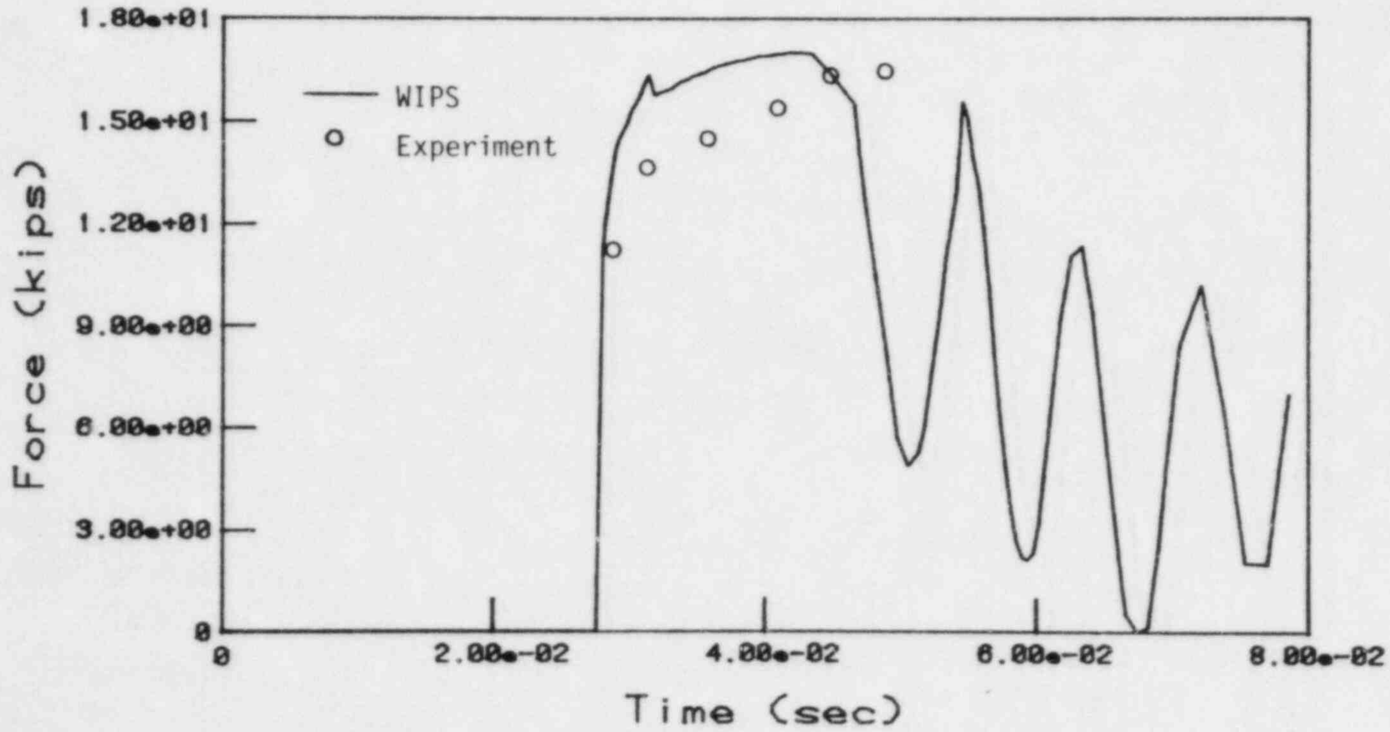

FIG. 2.2.5 RESTRAINT FORCE VS. TIME - CASE 3.

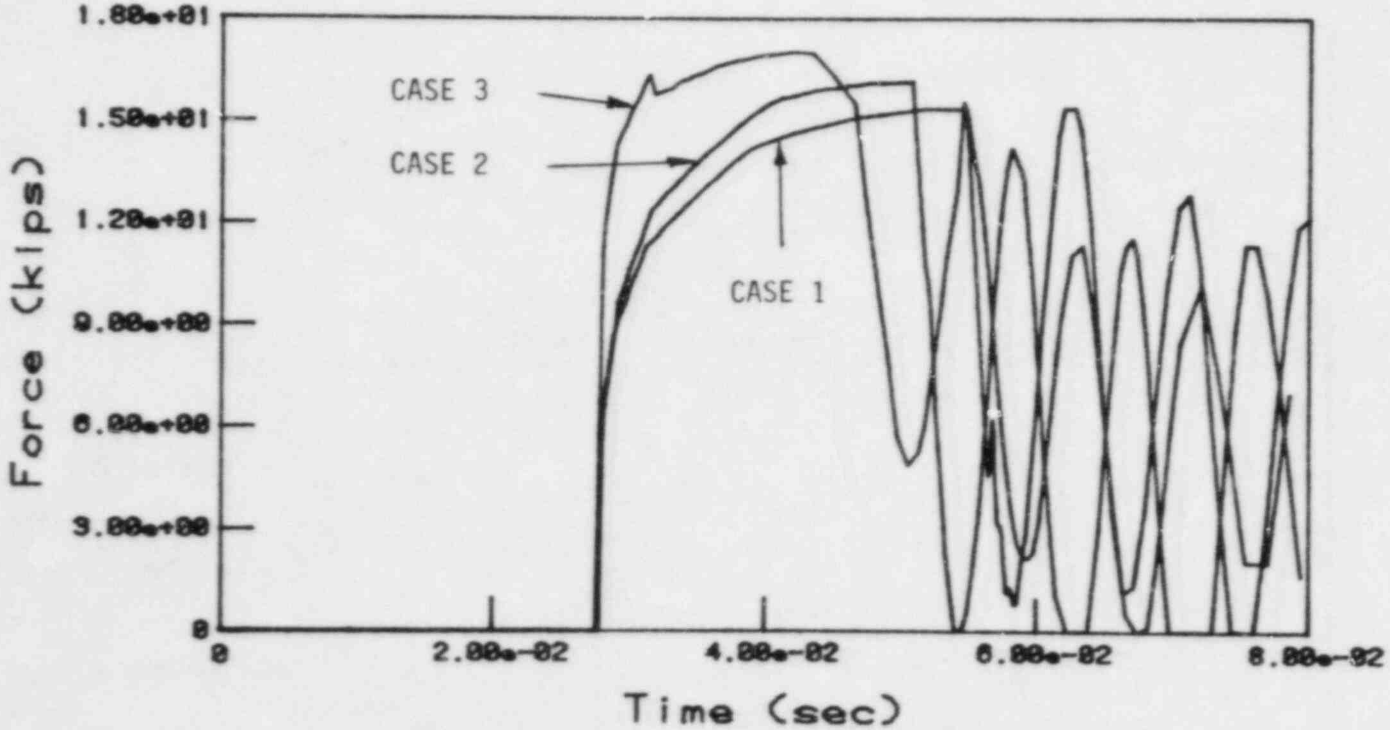

FIG. 2.2.6 RESTRAINT FORCE VS. TIME.
COMPARISON OF CASES 1, 2, AND 3.

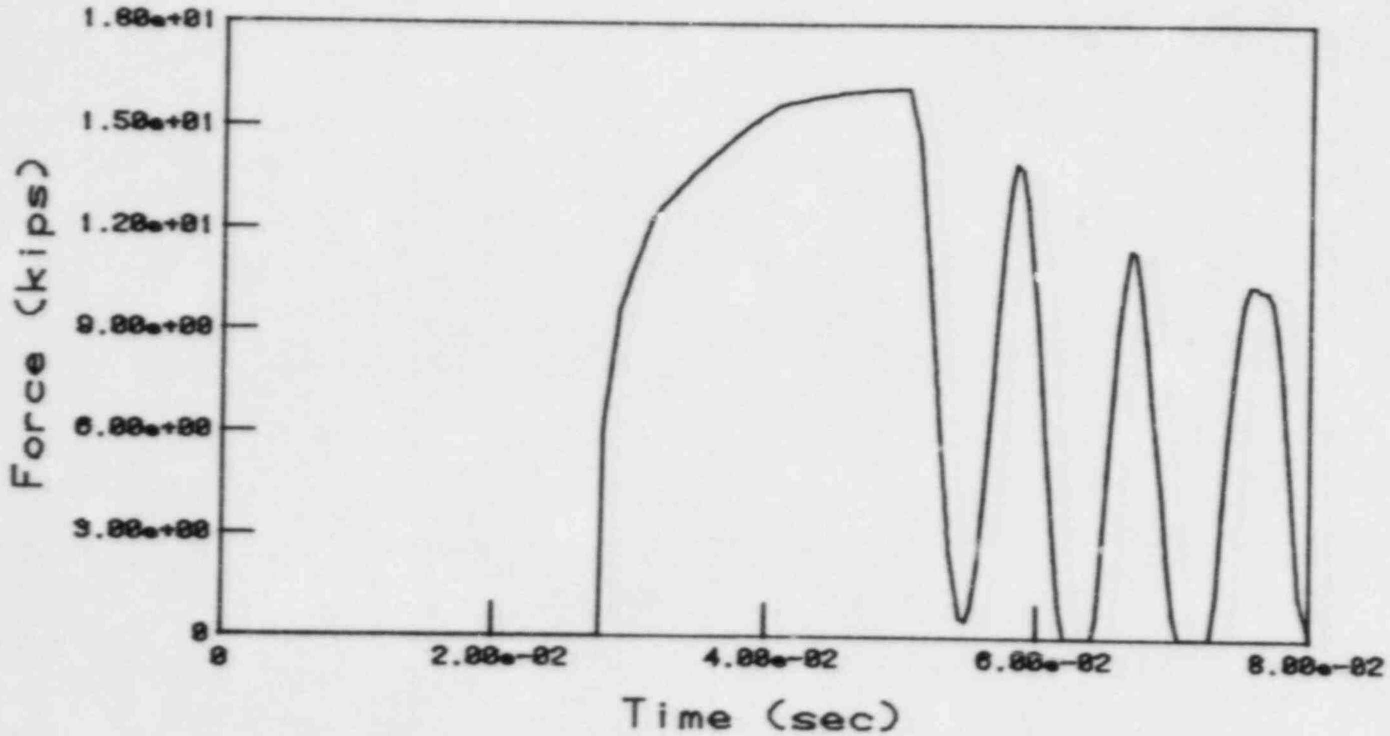

FIG. 2.2.7 RESTRAINT FORCE VS. TIME.
CASE 2 WITH HHT SOLUTION SCHEME.

TABLE 2.2.1 - BLOWDOWN FORCING FUNCTION	
Time (sec)	Force (k)
0.00001	7.200
0.00045	7.200
0.00046	7.272
0.02910	7.272
0.02920	7.920
0.10000	7.920

TABLE 2.2.2 - TRILINEAR REPRESENTATION OF PIPE STEEL PROPERTIES FROM EQN. 2.2.1		
Stress (ksi)	Strain	Modulus (ksi)
0	0	30000
19.0	.00063	2406
28.0	.00437	421

TABLE 2.2.3 - TRILINEAR REPRESENTATION OF PIPE STEEL PROPERTIES FROM EQN. 2.2.2		
Stress (ksi)	Strain	Modulus (ksi)
0	0	30000
31.0	.00103	2607
45.0	.00640	533

TABLE 2.2.4 - MULTILINEAR REPRESENTATION OF U-BAR PROPERTIES FROM EQN. 2.2.3		
Force (k)	Extension (in)	Stiffness (k/in)
0	0	681.39
5.50	0.0081	13.43
8.75	0.2500	5.00
11.25	0.7500	2.10
14.20	2.1500	1.00

TABLE 2.2.5 - MULTILINEAR REPRESENTATION OF U-BAR PROPERTIES FROM EQN. 2.2.4		
Force (k)	Extension (in)	Stiffness (k/in)
0	0	750.0
6.05	0.0081	14.80
9.63	0.2500	5.50
12.38	0.7500	2.31
15.62	2.1500	1.00

TABLE 2.2.6 - ASSUMED STRAIN RATE EFFECT FOR PIPE STEEL TRILINEAR REPRESENTATION		
Stress Increase (ksi)	Strain Rate $\left(sec^{-1}\right)$	Stiffness (ksi.sec)
0	0	25.00
9.00	0.36	2.20
18.00	4.44	0.44

TABLE 2.2.7 - ASSUMED STRAIN RATE EFFECT FOR U-BAR TRILINEAR REPRESENTATION		
Force Increase (k)	Extension Rate (in/sec)	Stiffness (k.sec/in)
0	0	0.566
1.98	3.50	0.050
3.96	43.07	0.010

TABLE 2.2.8 - WIPSLOG LISTING. GEOM PHASE.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: DECC-Esswein

NEXT WIPS-EXEC COMMAND : geom

GEOM - SPECIFICATION OF SYSTEM GEOMETRY

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Specify new GEOM data

START RUN NO. 1
Enter c.p. data in sequence along run

   c.p. name and type : 1
   coord option : di
   x,y,z :
   Any changes? :

   c.p. name and type : 3
   no. of extra nodes : 1
   coord option :
   c.p., dx,dy,dz : ,30
   offset point defaults to preceding c.p.
   Any changes? :

   c.p. name and type : 8
   no. of extra nodes : 4
   coord option :
   c.p., dx,dy,dz : ,60
   offset point defaults to preceding c.p.
   Any changes? :

   c.p. name and type : 9
   no. of extra nodes :
   coord option :
   c.p., dx,dy,dz : ,7
   offset point defaults to preceding c.p.
   Any changes? :

   c.p. name and type : 10
   no. of extra nodes :
   coord option :
   c.p., dx,dy,dz : ,,3.75
   offset point defaults to preceding c.p.
   Any changes? :

   c.p. name and type : 11
   no. of extra nodes :
   coord option :
   c.p., dx,dy,dz : ,,6
   offset point defaults to preceding c.p.
   Any changes? :
```

Table 2.2.8 (cont'd)

```
  c.p. name and type : 12
  no. of extra nodes :
  coord option :
  c.p., dx,dy,dz : ,,9
  offset point defaults tc preceding c.p.
  Any changes? :

  c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this rur? : y

GEOM DATA FOR RUN

run  c.p.  c.p.   bend   xtra  coord  c.p.  c.p.?        coordinate  data
no.  name  type  radius  nods   opt    i     j  ?    x,dx,p      y,dy       z,dz

 1
     1                    0     dl                    0.         0.        0.
     3                    1     of    1              30.000      0.        0.
     8                    4     of    3              60.000      0.        0.
     9                    0     of    8               7.000      0.        0.
     10                   0     of    9               0.         3.750     0.
     11                   0     of    10              0.         6.000     0.
     12                   0     of    11              0.         9.000     0.
END CF DATA

START RUN NC. 2
Enter c.p. data in sequence along run

  c.p. name and type :
Last run? : y

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOM0101

Produce COOR data? : y

Display COOR data? : y


COOR DATA

 run    c.p.  c.p.    bend   node       x          y ?        z
 no.    name  type   radius   no.     coord      coord?     coord

  1
        1                      1      0.         0.         0.
                               2     15.000      0.         0.
        3                      3     30.000      0.         0.
```

Table 2.2.8 (cont'd)

```
                             4      42.000      0.          0.
                             5      54.000      0.          0.
                             6      66.000      0.          0.
                             7      78.000      0.          0.
        8                    8      90.000      0.          0.
        9                    9      97.000      0.          0.
       10                   10      97.000      3.750       0.
Hit RETURN for more
       11                   11      97.000      9.750       0.
       12                   12      97.000     18.750       0.
END OF DATA

Plot geometry? :

Modify GEOM data? :

DATA COMPLETE FOR THIS SESSION
Save final GEOM data? : y
Comment for file catalog : Esswein discretization.
GEOM DATA SAVED. FILE NAME = GEOM0101
Save COOR data? : y
Comment for file catalog : Esswein discretization.
COOR DATA SAVED. FILE NAME = COOR0101

End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

---------------------------------------------------------------------
```

TABLE 2.2.9 - WIPSLOG LISTING. MATL, PIPE, UBAR AND FREC PHASES.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl


MATL - SPECIFICATION OF MATERIAL PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new MATL file

Specify a new property set? : y

SET NO. =  1
Property set description : Trilinear, no strain rate.
  Static moduli (min=2,max=5)
   : 30000 2406 421
  Yield strengths (no. of moduli minus 1)
   : 19 28
  Strain rate stiffnesses (min=0,max=3)
   :
  No strain rate effect
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? : y

SET NO. =  2
Property set description : Trilinear, with strain rate.
  Static moduli (min=2,max=5)
   : 30000 2406 421
  Yield strengths (no. of moduli minus 1)
   : 19 28
  Strain rate stiffnesses (min=0,max=3)
   : 25 2.2 .44
  Strain rate limits (no. of stiffnesses minus 1)
   : .36 4.44
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? : y

SET NO. =  3
Property set description : Trilinear, 50% increase.
```

Table 2.2.9 (cont'd)

```
    Static moduli (min=2,max=5)
     : 30000 2607 533
    Yield strengths (no. of moduli minus 1)
     : 31 45
    Strain rate stiffnesses (min=0,max=3)
     :
    No strain rate effect
    Use default tolerances? : y
    Poisson ratio (dflt = .3) :
    Weight density (dflt=steel) :

  Any errors? :

  This set added to MATL file

  Specify a new property set? :

  No. of property sets in MATL file =  3

  Display property set descriptions? :
  Write in session log? :

  Display new property set data? :
  Write in session log? :

  Display all property set data? : y

  MATL PROPERTY DATA

  SET NO.  1.  Trilinear, no strain rate.

          Matl     Data     Segm     Modulus  or      Stress/Strain
          Type     Type     No.      Coefficient         Limit
          mroz
                   static     1      0.3000e+05        0.1900e+02
                              2      0.2406e+04        0.2800e+02
                              3      0.4210e+03
                   yld.tol.          0.2000e-01
                   stif tol          0.5000e-01
                   rate tol          0.5000e-01
                   poisson           0.3000e+00
                   density           0.2840e-03
  Hit RETURN for next set

  SET NO.  2.  Trilinear, with strain rate.

          Matl     Data     Segm     Modulus  or      Stress/Strain
          Type     Type     No.      Coefficient         Limit
          mroz
                   static     1      0.3000e+05        0.1900e+02
                              2      0.2406e+04        0.2800e+02
                              3      0.4210e+03
                   str.rate   1      0.2500e+02        0.3600e+00
                              2      0.2200e+01        0.4440e+01
                              3      0.4400e+00
                   yld.tol.          0.2000e-01
```

Table 2.2.9 (cont'd)

```
               stif tol          0.5000e-01
               rate tol          0.5000e-01
               poisson           0.3000e+00
               density           0.2840e-03
Hit RETURN for next set

SET NO.  3.  Trilinear, 50% increase.

          Matl    Data    Segm    Modulus  or     Stress/Strain
          Type    Type    No.     Coefficient        Limit
          mroz
               static      1      0.3000e+05       0.3100e+02
                           2      0.2607e+04       0.4500e+02
                           3      0.5330e+03
               yld.tol.           0.2000e-01
               stif tol           0.5000e-01
               rate tol           0.5000e-01
               poisson            0.3000e+00
               density            0.2840e-03
Hit RETURN for next set
END OF DATA

New MATL file created
Comment for file catalog : 3 materials

End this MATL session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : pipe


PIPE - SPECIFICATION OF PIPE PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

No. of MATL property sets available =  3
Display material descriptions? : y

MATL PROPERTY DESCRIPTIONS
  Set No.  Type  Description
     1     mroz  Trilinear, no strain rate.
     2     mroz  Trilinear, with strain rate.
     3     mroz  Trilinear, 50% increase.

Start new PIPE file

Specify a new property set? : y

SET NO. =  1
Property set description : 4sch80, no strain rate.
  Outside diameter : 4.5
  Wall thickness : .337
  Weight/unit length (dflt=pipe weight) :
```

Table 2.2.9 (cont'd)

```
    No. of X-section elements (dflt=12) :
    Material number : 1
    Large ovalling (yes or no)? (dflt=no) :
  Use default ovalling properties? : y

  Any errors? :

  This set added to PIPE file

  Specify a new property set? : y

  SET NO. =  2
  Property set description : 4sch80, with strain rate
    Outside diameter : 4.5
    Wall thickness : .337
    Weight/unit length (dflt=pipe weight) :
    No. of X-section elements (dflt=12) :
    Material number : 2
    Large ovalling (yes or no)? (dflt=no) :
  Use default ovalling properties? : y

  Any errors? :

  This set added to PIPE file

  Specify a new property set? : y

  SET NO. =  3
  Property set description : 4sch80, 50% strength increase.
    Outside diameter : 4.5
    Wall thickness : .337
    Weight/unit length (dflt=pipe weight) :
    No. of X-section elements (dflt=12) :
    Material number : 3
    Large ovalling (yes or no)? (dflt=no) :
  Use default ovalling properties? : y

  Any errors? :

  This set added to PIPE file

  Specify a new property set? :

  No. of property sets in PIPE file =  3

  Display property set descriptions? : y

  PIPE PROPERTY DESCRIPTIONS
    Set No.   Description
        1     4sch80, no strain rate.
        2     4sch80, with strain rate
        3     4sch80, 50% strength increase.

  Display new property set data? :
  Write in session log? :
```

Table 2.2.9 (cont'd)

Display all property set data? : y

PIPE PROPERTY DATA

SET NO. 1. 4sch80, no strain rate.

Data Type	Segm No.	Modulus or Data Value	Stress/Strain Limit
Outside diameter		0.4500e+01	
Wall thickness		0.3370e+00	
Unit weight		0.1252e-02	
No. of elements		12	
No. of slices		2	
Stress v strain	1	0.3000e+05	0.1900e+02
	2	0.2406e+04	0.2800e+02
	3	0.4210e+03	
Poisson ratio		0.3000e+00	
Large ovalling		no	
Ovalling ratios	1	0.4000e+00	
	2	0.5000e-01	

Hit RETURN for next set

SET NO. 2. 4sch80, with strain rate

Data Type	Segm No.	Modulus or Data Value	Stress/Strain Limit
Outside diameter		0.4500e+01	
Wall thickness		0.3370e+00	
Unit weight		0.1252e-02	
No. of elements		12	
No. of slices		2	
Stress v strain	1	0.3000e+05	0.1900e+02
	2	0.2406e+04	0.2800e+02
	3	0.4210e+03	
Stress v strain rate	1	0.2500e+02	0.3600e+00
	2	0.2200e+01	0.4440e+01
	2	0.2200e+01	
Poisson ratio		0.3000e+00	
Large ovalling		no	
Ovalling ratios	1	0.4000e+00	
	2	0.5000e-01	

Hit RETURN for next set

SET NO. 3. 4sch80, 50% strength increase.

Data Type	Segm No.	Modulus or Data Value	Stress/Strain Limit
Outside diameter		0.4500e+01	
Wall thickness		0.3370e+00	
Unit weight		0.1252e-02	
No. of elements		12	
No. of slices		2	
Stress v strain	1	0.3000e+05	0.3100e+02

Table 2.2.9 (cont'd)

```
                                  2       0.2607e+04      0.4500e+02
                                  3       0.5330e+03
      Poisson ratio                       0.3000e+00
      Large ovalling                          no
      Ovalling ratios             1       0.4000e+00
                                  2       0.5000e-01
Hit RETURN for next set
END OF DATA

New PIPE file created
Comment for file catalog : 3 sets.

End this PIPE session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : ubar

UBAR - SPECIFICATION OF U-BAR PROPERTIES

Define units
  Length (ft;in;m;mm) : in
  Force (k,lb,kgf,kN) : k

Start new UBAR file

Specify a new property set? : y

SET NO. =  1
Property set description : 5 segments, no strain rate.
Static stiffnesses (min=2,max=6)
 : 681.39 13.43 5 2.1 1
Static strengths (no. of stiffnesses minus 1)
 : 5.5 8.75 11.25 14.2
Extension rate Stiffnesses (min=0,max=3)
 :
No extension rate effect
Default gap clearance :
*** error - must be positive
Default gap clearance : 3.18
Use default tolerances? : y

Any errors? :

This set added to UBAR file

Specify a new property set? : y

SET NO. =  2
Property set description : 5 segments, with strain rate.
Static stiffnesses (min=2,max=6)
 : 681.39 13.43 5 2.1 1
Static strengths (no. of stiffnesses minus 1)
 : 5.5 8.75 11.25 14.2
Extension rate Stiffnesses (min=0,max=3)
 : .566 .05 .01
```

Table 2.2.9 (cont'd)

```
Strength limits (no. of stiffnesses minus 1)
 : 1.98 3.96
Default gap clearance : 3.18
Use default tolerances? : y

Any errors? :

This set added to UBAR file

Specify a new property set? : y

SET NO. =  3
Property set description : 5 segments, 10% increase.
Static stiffnesses (min=2,max=6)
 : 750 14.8 5.5 2.31 1
Static strengths (no. of stiffnesses minus 1)
 : 6.05 9.63 12.38 15.62
Extension rate Stiffnesses (min=0,max=3)
 :
No extension rate effect
Default gap clearance : 3.18
Use default tolerances? : y

Any errors? :

This set added to UBAR file

Specify a new property set? :

No. of property sets in UBAR file =  3

Display property set descriptions? : y

UBAR PROPERTY DESCRIPTIONS
  Set No.   Description
     1      5 segments, no strain rate.
     2      5 segments, with strain rate.
     3      5 segments, 10% increase.

Display new property set data? :
Write in session log? :

Display all property set data? : y

UBAR PROPERTY DATA

SET NO.  1.  5 segments, no strain rate.
```

Data Type	Segm No.	Stiffness or Coefficient	Force Limit
Static properties	1	0.6814e+03	0.5500e+01
	2	0.1343e+02	0.8750e+01
	3	0.5000e+01	0.1125e+02
	4	0.2100e+01	0.1420e+02
	5	0.1000e+01	

Table 2.2.9 (cont'd)

```
        Default gap                     0.3180e+01
        Stiffness tol.                  0.5000e-01
        Overshoot tol.                  0.2000e+00
        Unloading tol.                  0.2000e+00
Hit RETURN for next set

SET NO.  2.  5 segments, with strain rate.

        Data                 Segm  Stiffness or     Force
        Type                 No.   Coefficient      Limit

        Static properties     1     0.6814e+03   0.5500e+01
                              2     0.1343e+02   0.8750e+01
                              3     0.5000e+01   0.1125e+02
                              4     0.2100e+01   0.1420e+02
                              5     0.1000e+01
        Rate effect           1     0.5660e+00   0.1980e+01
                              2     0.5000e-01   0.3960e+01
                              3     0.1000e-01
        Default gap                 0.3180e+01
        Stiffness tol.              0.5000e-01
        Overshoot tol.              0.2000e+00
        Unloading tol.              0.2000e+00
Hit RETURN for next set

SET NO.  3.  5 segments, 10% increase.

        Data                 Segm  Stiffness or     Force
        Type                 No.   Coefficient      Limit

        Static properties     1     0.7500e+03   0.6050e+01
                              2     0.1480e+02   0.9630e+01
                              3     0.5500e+01   0.1238e+02
                              4     0.2310e+01   0.1562e+02
                              5     0.1000e+01
        Default gap                 0.3180e+01
        Stiffness tol.              0.5000e-01
        Overshoot tol.              0.2000e+00
        Unloading tol.              0.2000e+00
Hit RETURN for next set
END OF DATA

New UBAR file created
Comment for file catalog : 3 sets.

End this UBAR session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

FREC - SPECIFY DYNAMIC FORCE RECORDS

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k
```

Table 2.2.9 (cont'd)

```
Start new FREC file

Specify a new record ? : y

RECORD NO.  1

Record name (4 characters) : rec1
Description (max. 40 char.) : DECO/Esswein

Enter Time-Force pairs
First pair automatically set to 0,0
  Pair no.  2 : .00001 7.2
  Pair no.  3 : .00045 7.2
  Pair no.  4 : .00046 7.272
  Pair no.  5 : .02910 7.272
  Pair no.  6 : .02920 7.920
  Pair no.  7 : .10000 7.920
  Pair no.  8 :
Last pair? : y
Any errors ? :

Specify a new record ? :

Display any records ? :

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog : 1 record

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
----------------------------------------------------------------------
```

TABLE 2.2.10 - WIPSLOG LISTING. MODL PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl

MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type     No. of Sets
  pipe          3
  ubar          3
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.    1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 8 pipe pr=1 th=no
 2: 8 ubar pr=1 dy=1
 3: 12 pipe
 4: 12,,lumw=.21
 5:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem    optn      data       optn      data       optn      data
  1
                bcon    111111
  8     pipe
                prop         1
                locl         +       ldis       no        this       no
                wfac    1.0000
  8     ubar
                prop         1
                ldis        no       this       yes
                dyij    1.0000
  12    pipe
                prop         1
```

Table 2.2.10 (cont'd)

```
                 locl      *         ldis      no        this      yes
                 wfac   1.0000
Hit RETURN for more
  12
                 lumw   0.2100
Any changes? :

SEGMENT NO.   2

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : Case 1. No strain rate.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl


MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type    No. of Sets
  pipe        3
  ubar        3
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.   1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111
```

Table 2.2.10 (cont'd)

```
Specify c.p.name + elem type + optional data
 1: 8 pipe pr=3 th=no
 2: 8 ubar pr=3
*** error - direction nct defined - use 'jnod' or 'd*ij'
 2: 8 ubar pr=3 dy=1
 3: 12 pipe
 4: 12,,lu=.21
 5:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem    optn     data        optn     data        optn     data
  1
                bcon   111111
  8     pipe
                prop        3
                locl        +        ldis     no          this     no
                wfac   1.0000
  8     ubar
                prop        3
                ldis       no        this     yes
                dyij   1.0000
  12    pipe
                prop        3
                locl        +        ldis     no          this     yes
                wfac   1.0000
 Hit RETURN for more
  12
                lumw   0.2100
Any changes? :

SEGMENT NO.   2

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : Case 2. 50%/10% Increases.

MODL file saved. File name = MODL0102
End of this MODL session

EXEC - WIPS EXECUTIVE
```

Table 2.2.10 (cont'd)

```
NEXT WIPS-EXEC COMMAND : modl

MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type     No. of Sets
  pipe          3
  ubar          3
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.   1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 8 pipe pr=2 th=no
 2: 8 ubar pr=2 dy=1
 3: 12 pipe
 4: 12,,lu=.21
 5:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.   1.  Run No. =  1
  c.p.  elem    optn     data        optn     data       optn     data
  1
                bcon   111111
  8     pipe
                prop        2
                locl        +         ldis     no         this     no
                wfac   1.0000
  8     ubar
                prop        2
                ldis       no         this     yes
                dylj   1.0000
  12    pipe
                prop        2
                locl        +         ldis     no         this     yes
                wfac   1.0000
```

Table 2.2.10 (cont'd)

```
Hit RETURN for more
  12
                Tumw    0.2100
Any changes? :

SEGMENT NO.    2

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MCDL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : Case 3. With strain rate.

MODL file saved. File name = MODL0103
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
------------------------------------------------------------------------
```

TABLE 2.2.11 - WIPSLOG LISTING. DATA PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Sequence no. of MODL file : 1

Problem description (4 lines)
 Line 1 : DECO/Esswein Case 1.            GHP 7/82
 Line 2 :
 Line 3 :
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processec

Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 12
  Force direction (x,y,z or follower) : y
  Scale factor (+,- controls direction) : -0.5
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : .0002 .004 .00004
 Max steps + max total time : 400 .08
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : Case 1.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Sequence no. of MODL file : 2
```

Table 2.2.11 (cont'd)

```
Problem description (4 lines)
 Line 1 : DECO/Esswein Case 2.                                 GHP 7/82
 Line 2 :
 Line 3 :
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processec

Specify data for each loaded point
LOAD NO.  1
  Force record name : recl
  Name of loaded c.p. : 12
  Force direction (x,y,z or fcllower) : y
  Scale factor (+,- contrcls directicn) : -.5
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : .0002 .004 .00004
 Max steps + max total time : 300 .08
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalcg : Case 2.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0102

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Sequence no. of MODL file : 3

Problem description (4 lines)
 Line 1 : DECO/Esswein Case 3.                                 GHP 7/82
 Line 2 :
 Line 3 :
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed
```

Table 2.2.11 (cont'd)

```
Specify data for each loaced point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 12
  Force direction (x,y,z cr fcllower) : y
  Scale factor (+,- controls cirection) : -0.5
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : .0002 .004 .00004
 Max steps + max total time : 300 .08
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm cr hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=C.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : Case 3.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0103

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

------------------------------------------------------------------------
```

TABLE 2.2.12 - LISTING OF DATA FILE FOR CASE 3

```
 ECHO0103  SLOG0103  RSLT0103
star,
gbui
new,main,nonl,cart,0
 substructure name = main
refn,13
    1  0.         e+00  0.          e+00  0.          e+00
    2  0.1500000e+02  0.          e+00  0.          e+00
    3  0.3000000e+02  0.          e+00  0.          e+00
    4  0.4200000e+02  0.          e+00  0.          e+00
    5  0.5400000e+02  0.          e+00  0.          e+00
    6  0.6600000e+02  0.          e+00  0.          e+00
    7  0.7800000e+02  0.          e+00  0.          e+00
    8  0.9000000e+02  0.          e+00  0.          e+00
    9  0.9700000e+02  0.          e+00  0.          e+00
   10  0.9700000e+02  0.3750000e+01  0.          e+00
   11  0.9700000e+02  0.9750000e+01  0.          e+00
   12  0.9700000e+02  0.1875000e+02  0.          e+00
 9999
boun,13
    1                        111111
    2                          1110
    3                          1110
    4                          1110
    5                          1110
    6                          1110
    7                          1110
    8                          1110
    9                          1110
   10                          1110
   11                          1110
   12                          1110
 9999                        111111
enod,0
matl,6,64
0.200000000e+010.299999982e+000.300000000e+050.240600000e+040.421000000e+03
0.190000000e+020.280000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.           e+000.200000000e+010.100000000e+01
0.100000000e+010.450000000e+010.337000012e+000.125171524e-020.           e+00
0.399999976e+000.499999970e-010.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.499999970e-01
0.199995988e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+00
0.200000000e+010.299999982e+000.300000000e+050.240600000e+040.421000000e+03
0.190000000e+020.280000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.           e+000.200000000e+010.100000000e+01
0.100000000e+010.450000000e+010.337000012e+000.125171524e-020.           e+00
0.399999976e+000.499999970e-010.300000000e+010.250000000e+020.220000005e+01
0.439999998e+000.360000014e+000.444000006e+010.999999932e+200.499999970e-01
0.199999988e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
```

Table 2.2.12 (cont'd)

```
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
0.200000000e+010.299999982e+000.300000000e+050.260700000e+040.533000000e+03
0.310000000e+020.450000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.            e+000.200000000e+010.100000000e+01
0.100000000e+010.450000000e+010.337000012e+000.125171524e-020.            e+00
0.399999976e+000.499999970e-010.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.499999970e-01
0.199999988e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
0.500000000e+010.            e+000.318000007e+010.499999970e-010.681390015e+03
0.134300003e+020.500000000e+010.209999990e+010.100000000e+010.550000000e+01
0.875000000e+010.112500000e+020.141999998e+020.999999932e+200.199999988e+00
0.199999988e+000.199999988e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
0.500000000e+010.300000000e+010.318000007e+010.499999970e-010.681390015e+03
0.134300003e+020.500000000e+010.209999990e+010.100000000e+010.550000000e+01
0.875000000e+010.112500000e+020.141999998e+020.999999932e+200.565999985e+00
0.500000007e-010.999999975e-020.198000002e+010.396000004e+010.999999932e+20
0.199999988e+000.199999988e+000.199999988e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
0.500000000e+010.            e+000.318000007e+010.499999970e-010.750000000e+03
0.148000002e+020.550000000e+010.230999994e+010.100000000e+010.605000019e+01
0.963000011e+010.123800001e+020.156199999e+020.999999932e+200.199999988e+00
0.199999988e+000.199999988e+000.198000002e+010.396000004e+010.999999932e+20
0.199999988e+000.199999988e+000.199999988e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
```

Table 2.2.12 (cont'd)

```
0.          e+000.          e+000.          e+000.          e+00
elem,2
    2    1    1                                    0.
    1    0    0    0    8    5    0    1    0    1
0.900000000e+020.100000000e+010.          e+000.          e+000.          e+00
0.          e+000.          e+00

    3   11    1                                    1.00
    1    0    0    0    1    2    2    0    0    1    0    1
0.          e+000.100000000e+010.          e+000.          e+00
    2    0    0    0    2    3    2    0    0    1    0    1
0.150000000e+020.100000000e+010.          e+000.          e+00
    3    0    0    0    3    4    2    0    0    1    0    1
0.300000000e+020.100000000e+010.          e+000.          e+00
    4    0    0    0    4    5    2    0    0    1    0    1
0.420000000e+020.100000000e+010.          e+000.          e+00
    5    0    0    0    5    6    2    0    0    1    0    1
0.540000000e+020.100000000e+010.          e+000.          e+00
    6    0    0    0    6    7    2    0    0    1    0    1
0.660000000e+020.100000000e+010.          e+000.          e+00
    7    0    0    0    7    8    2    0    0    1    0    1
0.780000000e+020.100000000e+010.          e+000.          e+00
    8    0    0    0    8    9    2    0    1    1    0    1
0.900000000e+020.100000000e+010.          e+000.          e+00
    9    0    0    0    9   10    2    0    1    1    0    1
0.960000000e+020.          e+000.          e+000.          e+00
   10    0    0    0   10   11    2    0    1    1    0    1
0.960000000e+020.375000000e+010.          e+000.          e+00
   11    0    0    0   11   12    2    0    1    1    0    1
0.960000000e+020.975000000e+010.          e+000.          e+00

nord,opto
prof
end
fini
mode
trec,main
fini
mbul
new,main
pmas,14
     10 0.12224e-04 0.12224e-04 0.12224e-04 0.      e+00 0.      e+00 0.      e+0000
     20 0.24448e-04 0.24448e-04 0.24448e-04 0.      e+00 0.      e+00 0.      e+0000
     30 0.22003e-04 0.22003e-04 0.22003e-04 0.      e+00 0.      e+00 0.      e+0000
     40 0.19558e-04 0.19559e-04 0.19558e-04 0.      e+00 0.      e+00 0.      e+0000
     50 0.19559e-04 0.19558e-04 0.19558e-04 0.      e+00 0.      e+00 0.      e+0000
     60 0.19558e-04 0.19558e-04 0.19558e-04 0.      e+00 0.      e+00 0.      e+0000
     70 0.19558e-04 0.19558e-04 0.19558e-04 0.      e+00 0.      e+00 0.      e+0000
     80 0.97790e-05 0.97790e-05 0.97790e-05 0.      e+00 0.      e+00 0.      e+0000
     80 0.57044e-05 0.57044e-05 0.57044e-05 0.      e+00 0.      e+00 0.      e+0000
     90 0.87604e-05 0.87604e-05 0.87604e-05 0.      e+00 0.      e+00 0.      e+0000
    100 0.79455e-05 0.79455e-05 0.79455e-05 0.      e+00 0.      e+00 0.      e+0000
    110 0.12224e-04 0.12224e-04 0.12224e-04 0.      e+00 0.      e+00 0.      e+0000
    120 0.73343e-05 0.73343e-05 0.73343e-05 0.      e+00 0.      e+00 0.      e+0000
    120 0.27344e-03 0.27344e-03 0.27344e-03 0.      e+00 0.      e+00 0.      e+0000
end
```

Table 2.2.12 (cont'd)

```
fini
ptre
newr,recl,pair,7,100
(2e15.7)
  0.        e+00  0.        e+00
  0.7200000e+01  0.1000000e-04
  0.7200000e+01  0.4500000e-03
  0.7272000e+01  0.4600000e-03
  0.7272000e+01  0.2910000e-01
  0.7920000e+01  0.2920000e-01
  0.7920000e+01  0.1000000e+00
fini
thou,241
         2       119    3    1    0    0
ndyn
mass
dylo,1,1
recl      2    0.     -0.500        1
   12
timo,rslt,1,0.1000e+01
auto,defl
inte,newm,0.2000e-03,0.e+00,0.e+00,0.1000e+00
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,300
zero,ltme
step
unba
auto,init
loop,20
stif
auto,load
load
disp
kinr,10
elmr,9,10
auto,merr,0.1000e+00,0.5000e+00
if,3,3,1,1
entr,1
auto,fact
kinr,1
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.4000e-04,0.4000e-02,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
```

Table 2.2.12 (cont'd)

```
entr,6
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,8
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,1rsb
unba
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.8000e-01
if,5,8,8,0
entr,8
cont
fini
stop
```

TABLE 2.2.13 - SUMMARY OF RESULTS						
	Expt. [2.2.1]	Case 1	Case 2 (Newmark)	Case 2 (HHT)	Case 2 [2.2.2]	Case 3
(1) Time to Gap Closure (msec)	27	27.7	27.8	27.9	28	27.7
(2) Max. Restraint Extension (in)	2.94	3.34	2.69	2.69	2.7	2.08
(3) Max. Restraint Force (k)	16.3	15.3	16.2	16.2	16.4	17.0
(4) Number of time steps (to 0.08 secs)		126	124	166		111

D2.3 PIPE WHIP ANALYSIS WITH LARGE DISPLACEMENT

D2.3.1 PURPOSE

This example tests the PIPE and GAPF elements, in part by comparison with previously reported analysis results. No test results are available. Large displacements and strain rate effects are considered for the PIPE elements, and the follower force option is exercised. The GAPF element is tested with and without friction. The analysis is only two-dimensional, so that full three-dimensional behavior is not checked.

D2.3.2 DESCRIPTION

Analyses of a cantilevered pipe with large displacements and impact have been reported by Hibbitt and Karlsson [2.3.1]. The dimensions of the pipe are shown in Fig. 2.3.1. The trilinear stress-strain relationship used for the pipe steel is shown in Table 2.3.1 and the blowdown force record in Table 2.3.2.

Gap-friction (GAPF) elements are located at nodes 16 through 19, with initial gaps specified to represent a flat surface. Each GAPF element is arbitrarily assigned a stiffness of 10^4 k/in, which allows a small amount of flexibility after gap closure. In the analysis reported in [2.3.1], the flat surface was assigned a very large mass, rather than an elastic stiffness. Because impact of an actual pipe would involve substantial local deformation of the pipe, and probably significant deformation of the impacted wall, the assumption of an essentially rigid surface is not realistic, and the computed impact forces are likely to be much larger than those which would occur in actual practice.

The analysis reported in [2.3.1] did not consider strain rate effects. Strain rate effects for the WIPS analysis were assumed to be shown in Table 2.3.3, based on data for low carbon steel reported by Manjoine [2.3.2].

The following WIPS analyses were performed:

(1) No strain rate effect, zero friction.

(2) With strain rate effect, friction coefficient = 0.4.

D2.3.3 WIPS ANALYSIS MODEL

D2.3.3.1 Geometry, Loading, and Pipe Properties

The PIPE element subdivision is shown in Fig. 2.3.1. This is similar to the subdivision used in [2.3.1]. It may be noted that only a single element is used in the vertical leg between nodes 19 and 20. This introduces a significant error in the rotational inertia of this leg, and for practical analysis a larger number of nodes is probably desirable. It should also be noted that the initial gap clearance used in the analysis is different from that shown in Fig. 4-12 of Reference 2.3.1. The value used for the current analysis is consistent with that reported in [2.3.3] and is believed to be correct. Motion was permitted in the XY plane only. The default ovalling strengths and stiffnesses were assumed for the curved PIPE elements, with small ovalling assumed. Twelve subelements (the default value) were used in each PIPE element cross section.

The jet force was applied at node 20, directed towards node 19 (i.e. the follower option). To allow for the symmetry, the jet forces shown in Table 2.3.2 were multiplied by 0.5 (because only half of the element strengths and stiffnesses are used in symmetrical segments of the analysis model).

D2.3.3.2 Analysis Control Parameters

The Newmark step-by-step option was used, with the following parameters.

Initial time step = 5×10^{-4} sec.

Minimum time step = 10^{-5} sec.

Maximum time step = 10^{-3} sec.

Initial $\beta/\Delta t$ = 0.1

Lower midstep tolerance = 50 k

Upper midstep tolerance = 250 k

D2.3.3.3 WIPS Input

Tables 2.3.4 through 2.3.8 contain the WIPSLOG listings for the GEOM, MATL, PIPE, GAPF, and FREC phases. Tables 2.3.9 and 2.3.10 contain the WIPSLOG listings for the MODL and DATA phases for Case 1 (no strain rate effect, negligible friction). Table 2.3.11 is a listing of the DATA file for Case 1. The MODL and DATA phases for Case 2 were similar.

D2.3.4 RESULTS

D2.3.4.1 Pipe Motion

The computed pipe locations at four different times are shown in Fig. 2.3.2 for the no-friction case and in Fig. 2.3.3 for the case with friction.

For the no-friction case, the time to initial contact (0.107 sec.) is very close to that reported in [2.3.1], and the deformed shapes are also very similar. For the case with friction, the computed pipe motion after impact is much different, with only a small amount of slip taking place.

The case with friction also included strain rate effects in the PIPE elements. The computed time to impact and the deformed shape at impact were essentially identical to those for the case without strain rate effects. This indicates that the pipe motion up to gap closure is governed mainly by the inertia of the pipe, and (in this example) does not depend greatly on the pipe strength.

D2.3.4.2 Impact Force

For the case with friction, the computed impact force (sum of all gap-friction elements) varied as shown in Fig. 2.3.4. The peak value is 17300 k, reached shortly after initial impact. The analysis then indicated several cycles of separation and new contact, with much lower impact forces. For this analysis, results output was requested every time step, and hence the detailed results shown in Fig. 2.3.4 could be plotted. For the case with no friction, results output was requested only every 20 steps. As a result, no detailed response could be plotted, and the peak impact force was not recorded.

It is important to note that the computed impact forces are strongly dependent on the assumed gap stiffnesses and are not realistic values. In this example each gap element was assumed to have a stiffness of 10^4 k/in., which is much larger than the crush stiffness of an actual elbow. As a result, the computed peak impact force is probably a gross overestimate.

The computed impact force in an analysis of this type may also depend on the method of analysis. In the analysis of [2.3.1], the impacted surface was modelled as a rigid body with very large mass, and a peak impact force of approximately 8500 k was reported.

D2.3.5 CONCLUSION

For the case with no friction, the computed motion of the pipe was very similar to that previously reported in [2.3.1]. This indicates that large displacements behavior of the PIPE elements is computed correctly in two dimensions and that the impacted surface was adequately represented by stiff GAPF elements.

For the case with friction, the WIPS analysis predicted only a small amount of slip on the impacted surface. No previously reported analysis is available for comparison.

The computed impact force depends on the modelling assumptions and is unlikely to be close to the true impact force. Because the friction force developed in GAPF elements depends on the normal (impact) force, it follows that the computed pipe motion after impact may not be the same as that which would be observed in an actual test.

It can be concluded that the PIPE element can be used to compute the motions of unrestrained pipes up to impact. However, the problem of post-impact behavior is complex, and further study is needed to determine whether impact forces and post-impact motions can be determined with simple models of the type used in this example.

D2.3.6 REFERENCES

2.3.1 Hibbitt and Karlsson, "Analysis of Pipe Whip," Report No. EPRI NP-1208, Electric Power Research Institute, 1979.

2.3.2 Manjoine, M. J., "Influence of Strain Rate and Temperature on Yield Stresses of Mild Steel," J. Appl. Mech., Vol. II, A-211, 1944.

2.3.3 Vijay, D. K. and Kozluk, M. J., "Pipe Whip Analysis of Unrestrained Piping Systems," ASME Paper 80-C27-PVP-149, 1980.

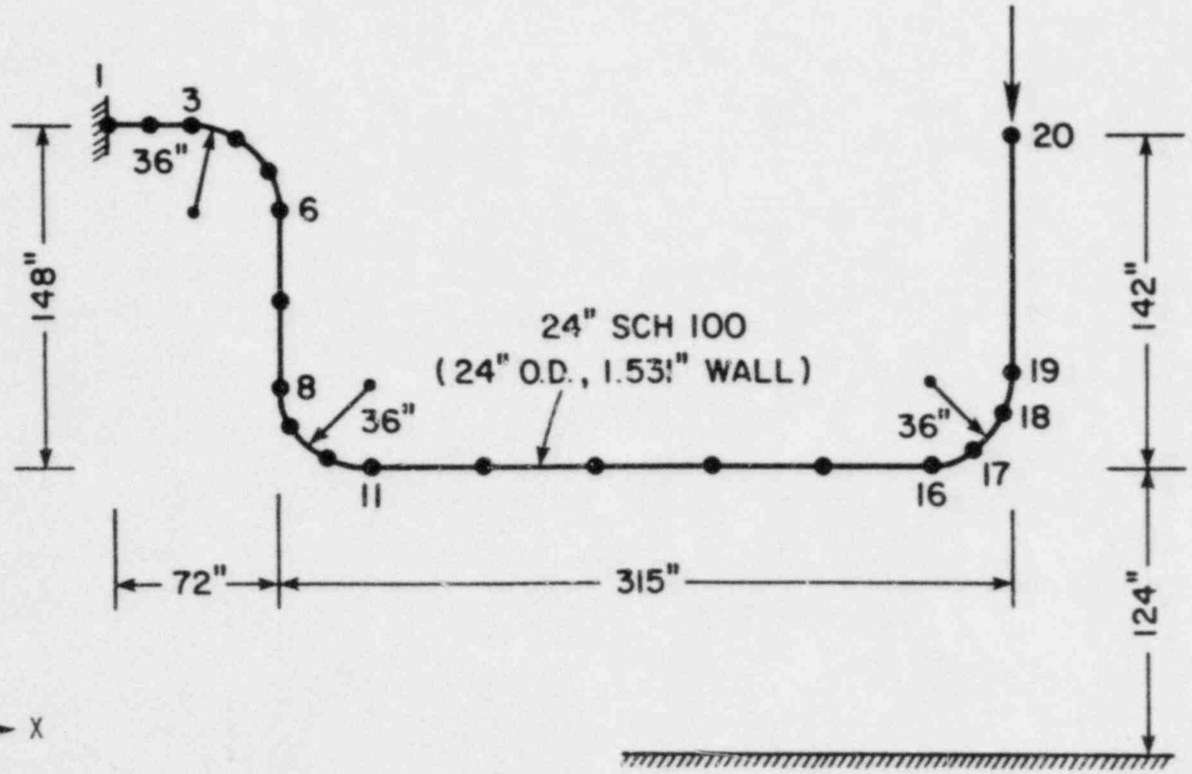

FIG. 2.3.1 PIPE WHIP WITH LARGE DISPLACEMENTS

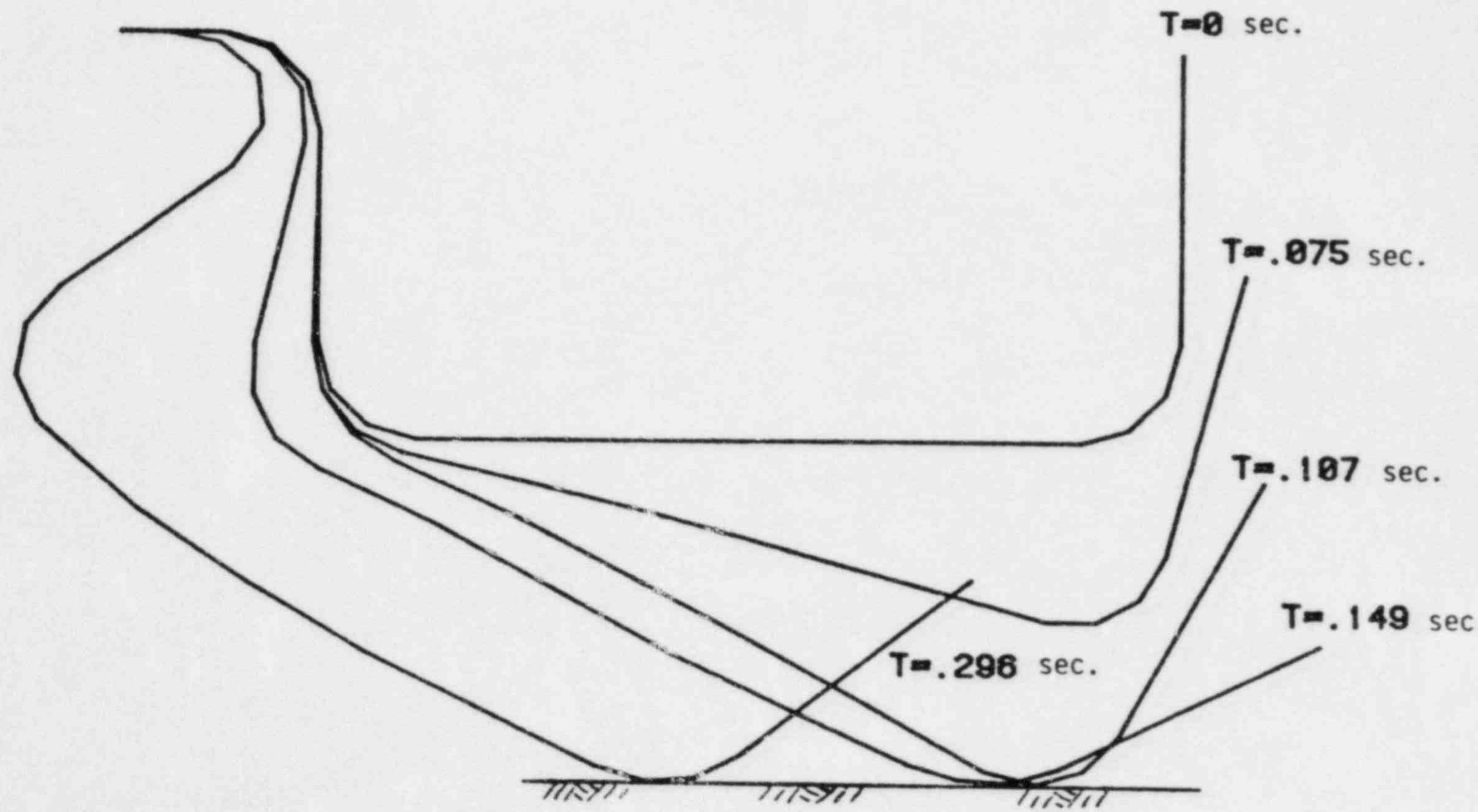

FIG. 2.3.2 DEFORMED SHAPES. CASE WITH NO FRICTION.

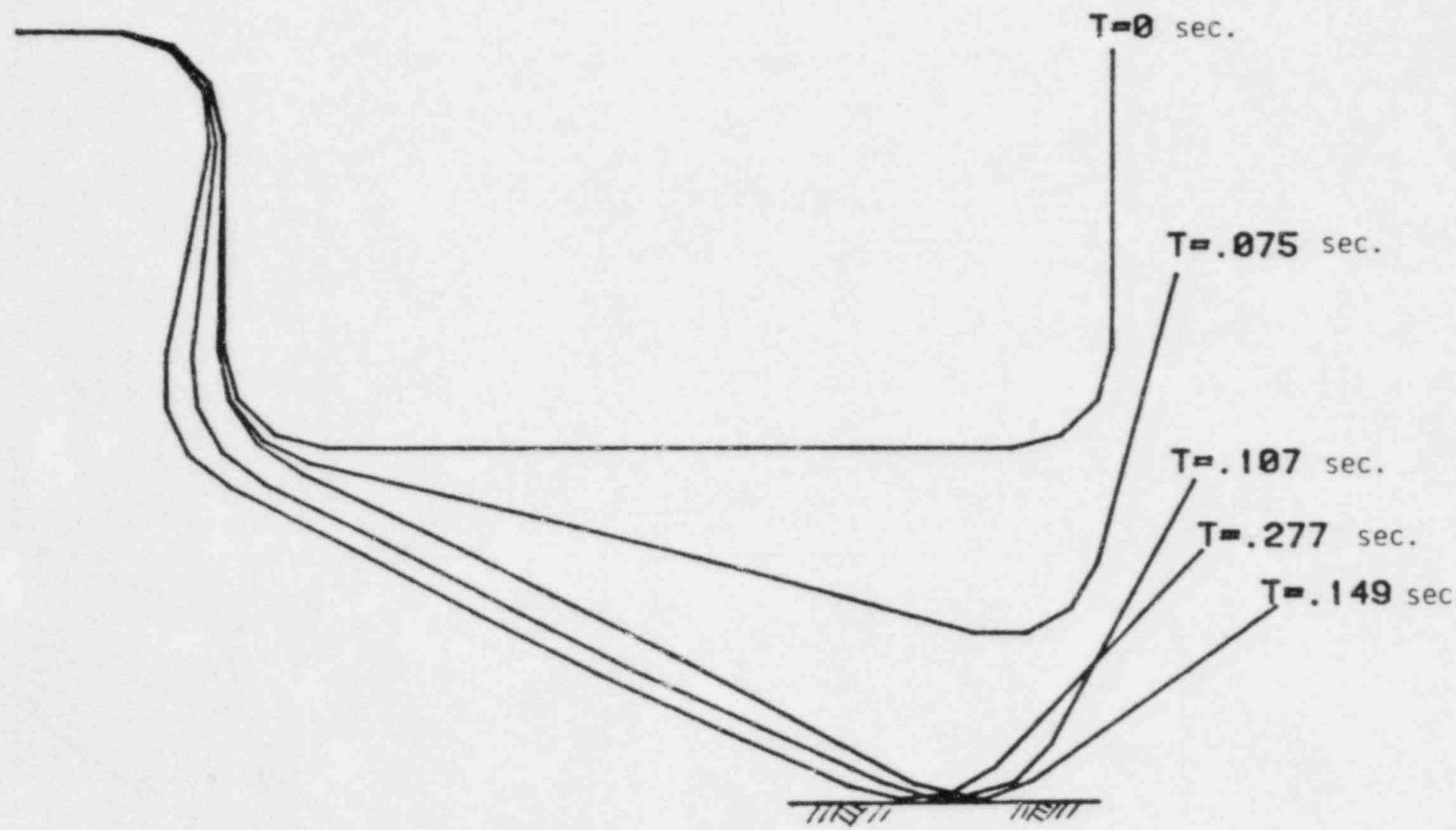

FIG. 2.3.3 DEFORMED SHAPES. CASE WITH FRICTION.

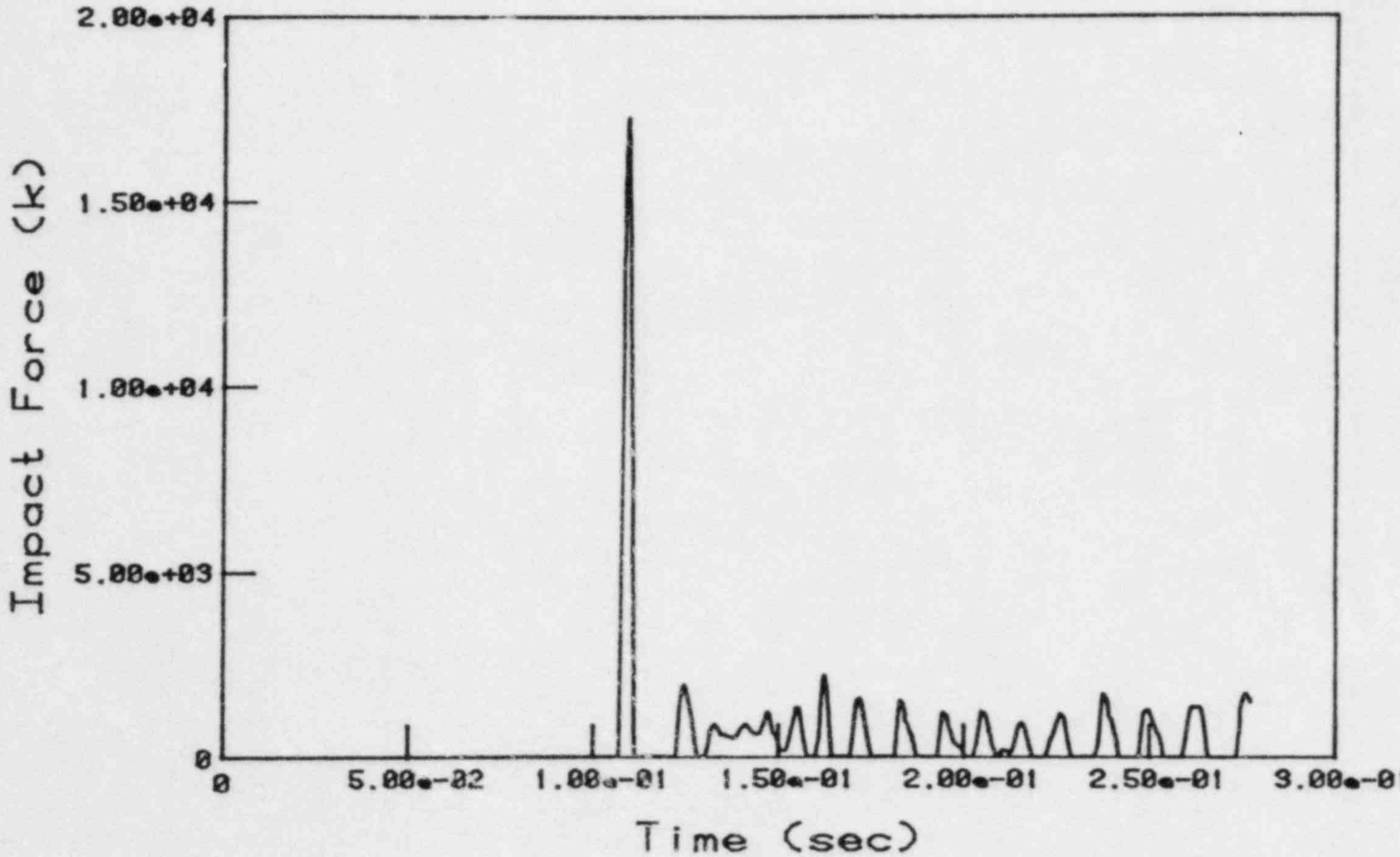

FIG. 2.3.4 COMPUTED IMPACT FORCE. CASE WITH FRICTION.

TABLE 2.3.1 - STATIC STRESS-STRAIN RELATIONSHIP FOR PIPE STEEL		
Stress (ksi)	Strain	Modulus (ksi)
0	0	26700
26.7	0.001	219
44.0	0.080	2

TABLE 2.3.2 - BLOWDOWN FORCE RECORD	
Time (sec)	Force (k)
0	0
0.0001	650
0.0010	880
0.0020	1000
0.0030	880
0.0050	780
0.0200	430
10.0	430

TABLE 2.3.3 - ASSUMED STRAIN RATE EFFECT		
Stress Increase (ksi)	Strain Rate (sec^{-1})	Dashpot Stiffness ($ksec/in^2$)
0	0	25.00
9	0.36	2.20
18	4.44	0.44

TABLE 2.3.4 - WIPSLOG LISTING FOR GEOM PHASE.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Hibbitt Fig.4.12 with gapf

NEXT WIPS-EXEC COMMAND : geom

GEOM - SPECIFICATION OF SYSTEM GEOMETRY

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Specify new GEOM data

START RUN NO. 1
Enter c.p. data in sequence along run

  c.p. name and type : 1
  coord option : d!
  x,y,z :
  Any changes? :

  c.p. name and type : 3 tn
  no. of extra nodes : 1
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : ti1 ti
  bend radius : 36
  coord option :
  c.p., dx,dy,dz : 1 72
  Any changes? :

  c.p. name and type : 6 tn
  no. of extra nodes : 2
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : 8 tn
  no. of extra nodes : 1
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : ti2 ti
  bend radius : 36
  coord option :
  c.p., dx,dy,dz : ti1 0 -148
  Any changes? :

  c.p. name and type : 11 tn
  no. of extra nodes : 2
  coord option :
  tn generated automatically
```

Table 2.3.4 (cont'd)

```
  Any changes? :

  c.p. name and type : 16 tn
  no. of extra nodes : 4
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : ti3 ti
  bend radius : 36
  coord option :
  c.p., dx,dy,dz : ti2 315
  Any changes? :

  c.p. name and type : 19 tn
  no. of extra nodes : 2
  coord option :
  tn generated automatically
  Any changes? :

  c.p. name and type : 20
  no. of extra nodes :
  coord option :
  c.p., dx,dy,dz : ti3 0 142
  Any changes? :

  c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this run? : y

GEOM DATA FOR RUN
```

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. I	c.p.? J ?	coordinate data x,dx,p	y,dy	z,dz
1										
	1			0	di			0.	0.	0.
	3	tn		1	tn			0.	0.	0.
	ti1	ti	36.000	0	of	1		72.000	0.	0.
	6	tn		2	tn			0.	0.	0.
	8	tn		1	tn			0.	0.	0.
	ti2	ti	36.000	0	of	ti1		0.	-148.000	0.
	11	tn		2	tn			0.	0.	0.
	16	tn		4	tn			0.	0.	0.
	ti3	ti	36.000	0	of	ti2		315.000	0.	0.
	19	tn		2	tn			0.	0.	0.
Hit RETURN for more										
	20			0	of	ti3		0.	142.000	0.

```
END OF DATA

START RUN NO.  2
Enter c.p. data in sequence along run

  c.p. name and type :
Last run? : y
```

Table 2.3.4 (cont'd)

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEUM0101

Produce COOR data? : y

Display COOR data? : y

COOR DATA

run no.	c.p. name	c.p. type	bend radius	node no.	x coord	y ? coord?	z coord
1							
	1			1	0.	0.	0.
				2	18.000	0.	0.
	3	tn		3	36.000	0.	0.
	ti1	ti	36.000		72.000	0.	0.
			center		36.000	-36.000	0.
				4	54.000	-4.823	0.
				5	67.177	-18.000	0.
	6	tn		6	72.000	-36.000	0.
				7	72.000	-74.000	0.
	8	tn		8	72.000	-112.000	0.
Hit RETURN for more							
	ti2	ti	36.000		72.000	-148.000	0.
			center		108.000	-112.000	0.
				9	76.823	-130.000	0.
				10	90.000	-143.177	0.
	11	tn		11	108.000	-148.000	0.
				12	156.600	-148.000	0.
				13	205.200	-148.000	0.
				14	253.800	-148.000	0.
				15	302.400	-148.000	0.
	16	tn		16	351.000	-148.000	0.
Hit RETURN for more							
	ti3	ti	36.000		387.000	-148.000	0.
			center		351.000	-112.000	0.
				17	369.000	-143.177	0.
				18	382.177	-130.000	0.
	19	tn		19	387.000	-112.000	0.
	20			20	387.000	-6.000	0.

END OF DATA

Plot geometry? :

Modify GEOM data? :

DATA COMPLETE FOR THIS SESSION
Save final GEOM data? : y

Table 2.3.4 (cont'd)

```
Comment for file catalog : Hibbitt Fig.4.12 Example
GEOM DATA SAVED. FILE NAME = GEOM0101
Save COOR data? : y
Comment for file catalog : Hibbitt Fig.4.12. From GEOM0101
COOR DATA SAVED. FILE NAME = COOR0101

End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

--------------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : geom

GEOM - SPECIFICATION OF SYSTEM GEOMETRY

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Modify existing GEOM file? : y
Sequence no. : 1

Display existing GEOM data? :
Write in session log? :

Modify GEOM data? : y
Specify modifications
Change data for a c.p.? : y
  c.p. name : 19
  enter revised data
  c.p. type : tn
  no. of extra nodes :
  coord option :
  tn generated automatically
  Any changes? :

More changes? : y
Change data for a c.p.? :
Insert new c.p's? : y
  name of preceding c.p. : 16
  enter data for new c.p's

  c.p. name and type : 17
  no. of extra nodes :
  coord option : cu
  c.p.i, c.p.j, proportion : 16 19 .33333
  Any changes? :

  c.p. name and type : 18
  no. of extra nodes :
  coord option : cu
```

Table 2.3.4 (cont'd)

```
c.p.i, c.p.j, proportion : 16 19 .66667
Any changes? :

c.p. name and type :

More changes? :

Display modified GEOM data? :
Write in session log? : y

MODIFIED GEOM DATA
```

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. i	c.p.? j ?	coordinate data x,dx,p	y,dy	z,dz
1										
	1			0	dl			0.	0.	0.
	3	tn		1	tn			0.	0.	0.
	ti1	ti	36.000	0	of	1		72.000	0.	0.
	6	tn		2	tn			0.	0.	0.
	8	tn		1	tn			0.	0.	0.
	ti2	ti	36.000	0	of	ti1		0.	-148.000	0.
	11	tn		2	tn			0.	0.	0.
	16	tn		4	tn			0.	0.	0.
	17			0	cu	16	19	0.333	0.	0.
	18			0	cu	16	19	0.667	0.	0.
	ti3	ti	36.000	0	of	ti2		315.000	0.	0.
	19	tn		0	tn			0.	0.	0.
	20			0	of	ti3		0.	142.000	0.

```
Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOM0102

Produce COOR data? : y

Display COOR data? : y


COOR DATA
```

run no.	c.p. name	c.p. type	bend radius	node no.	x coord	y ? coord?	z coord
1							
	1			1	0.	0.	0.
				2	18.000	0.	0.
	3	tn		3	36.000	0.	0.
	ti1	ti	36.000		72.000	0.	0.
			center		36.000	-36.000	0.
				4	54.000	-4.823	0.
				5	67.177	-18.000	0.
	6	tn		6	72.000	-36.000	0.
				7	72.000	-74.000	0.
	8	tn		8	72.000	-112.000	0.

```
Hit RETURN for more
```

Table 2.3.4 (cont'd)

```
        ti2     ti     36.000                 72.000   -148.000        0.
                       center                108.000   -112.000        0.
                                      9       76.823   -130.000        0.
                                     10       90.000   -143.177        0.
        11      tn                   11      108.000   -148.000        0.
                                     12      156.600   -148.000        0.
                                     13      205.200   -148.000        0.
                                     14      253.800   -148.000        0.
                                     15      302.400   -148.000        0.
        16      tn                   16      351.000   -148.000        0.
Hit RETURN for more
        17                           17      369.000   -143.177        0.
        18                           18      382.177   -130.000        0.
        ti3     ti     36.000                387.000   -148.000        0.
                       center                351.000   -112.000        0.
        19      tn                   19      387.000   -112.000        0.
        20                           20      387.000     -6.000        0.
END OF DATA

Plot geometry? :

Modify GEOM data? :

DATA COMPLETE FOR THIS SESSION
Save final GEOM data? : y
Comment for file catalog : Hibbitt Fig.4.12, 17,18 added.
GEOM DATA SAVED. FILE NAME = GEOM0102
Save COOR data? : y
Comment for file catalog : Hibbitt Fig.4.12, 17,18 added.
COOR DATA SAVED. FILE NAME = COOR0102

End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
```

TABLE 2.3.5 - WIPSLOG LISTING FOR MATL PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl


MATL - SPECIFICATION OF MATERIAL PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new MATL file

Specify a new property set? : y

SET NO. =  1
Property set description : Hibbitt material, no strain rate.
  Static moduli (min=2,max=5)
   : 26700 219 2
  Yield strengths (no. of moduli minus 1)
   : 26.7 44
  Strain rate stiffnesses (min=0,max=3)
   :
  No strain rate effect
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? : y

SET NO. =  2
Property set description : Hibbitt material, with strain rate.
  Static moduli (min=2,max=5)
   : 26700 219 2
  Yield strengths (no. of moduli minus 1)
   : 26.7 44
  Strain rate stiffnesses (min=0,max=3)
   : 25 2.2 .44
  Strain rate limits (no. of stiffnesses minus 1)
   : .36 4.44
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? :

No. of property sets in MATL file =  2
```

Table 2.3.5 (cont'd)

```
Display property set descriptions? : y

MATL PROPERTY DESCRIPTIONS

  Set No.  Type  Description
      1    mroz  Hibbitt material, no strain rate.
      2    mroz  Hibbitt material, with strain rate.

Display new property set data? : y

MATL PROPERTY DATA

SET NO.  1.  Hibbitt material, no strain rate.

        Matl     Data     Segm     Modulus  or       Stress/Strain
        Type     Type     No.      Coefficient           Limit
        mroz
                 static    1       0.2670e+05        0.2670e+02
                           2       0.2190e+03        0.4400e+02
                           3       0.2000e+01
                 yld.tol.          0.2000e-01
                 stif tol          0.5000e-01
                 rate tol          0.5000e-01
                 poisson           0.3000e+00
                 density           0.2840e-03
Hit RETURN for next set

SET NO.  2.  Hibbitt material, with strain rate.

        Matl     Data     Segm     Modulus  or       Stress/Strain
        Type     Type     No.      Coefficient           Limit
        mroz
                 static    1       0.2670e+05        0.2670e+02
                           2       0.2190e+03        0.4400e+02
                           3       0.2000e+01
                 str.rate  1       0.2500e+02        0.3600e+00
                           2       0.2200e+01        0.4440e+01
                           3       0.4400e+00
                 yld.tol.          0.2000e-01
                 stif tol          0.5000e-01
                 rate tol          0.5000e-01
                 poisson           0.3000e+00
                 density           0.2840e-03
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :

New MATL file created
Comment for file catalog :

End this MATL session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
-----------------------------------------------------------------------
```

TABLE 2.3.6 - WIPSLOG LISTING FOR PIPE PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : pipe


PIPE - SPECIFICATION OF PIPE PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

No. of MATL property sets available =  2
Display material descriptions? :
Write in session log? :

Start new PIPE file

Specify a new property set? : y

SET NO. =  1
Property set description : 24sch100, no strain rate, small oval.
  Outside diameter : 24
  Wall thickness : 1.531
  Weight/unit length (dflt=pipe weight) :
  No. of X-section elements (dflt=12) :
  Material number : 1
  Large ovalling (yes or no)? (dflt=no) :
Use default ovalling properties? : y

Any errors? :

This set added to PIPE file

Specify a new property set? : y

SET NO. =  2
Property set description : 24sch100, with strain rate, small oval.
  Outside diameter : 24
  Wall thickness : 1.531
  Weight/unit length (dflt=pipe weight) :
  No. of X-section elements (dflt=12) :
  Material number : 2
  Large ovalling (yes or no)? (dflt=no) :
Use default ovalling properties? : y

Any errors? :

This set added to PIPE file

Specify a new property set? :

No. of property sets in PIPE file =  2

Display property set descriptions? : y

PIPE PROPERTY DESCRIPTIONS
```

Table 2.3.6 (cont'd)

```
  Set No.   Description
     1      24sch100, no strain rate, small oval.
     2      24sch100, with strain rate, small oval.

Display new property set data? : y

 PIPE PROPERTY DATA

SET NO.  1.  24sch100, no strain rate, small oval.

        Data                     Segm    Modulus or     Stress/Strain
        Type                     No.     Data Value        Limit

        Outside diameter                 0.2400e+02
        Wall thickness                   0.1531e+01
        Unit weight                      0.3069e-01
        No. of elements                     12
        No. of slices                        2
        Stress v strain           1      0.2670e+05     0.2670e+02
                                  2      0.2190e+03     0.4400e+02
                                  3      0.2000e+01
        Poisson ratio                    0.3000e+00
        Large ovalling                      no
        Ovalling ratios           1      0.3500e+00
                                  2      0.8000e-01
Hit RETURN for next set

SET NO.  2.  24sch100, with strain rate, small oval.

        Data                     Segm    Modulus or     Stress/Strain
        Type                     No.     Data Value        Limit

        Outside diameter                 0.2400e+02
        Wall thickness                   0.1531e+01
        Unit weight                      0.3069e-01
        No. of elements                     12
        No. of slices                        2
        Stress v strain           1      0.2670e+05     0.2670e+02
                                  2      0.2190e+03     0.4400e+02
                                  3      0.2000e+01
        Stress v strain rate      1      0.7500e+02     0.2000e+00
                                  2      0.5250e+01     0.1353e+02
                                  2      0.5250e+01
        Poisson ratio                    0.3000e+00
        Large ovalling                      no
        Ovalling ratios           1      0.3500e+00
                                  2      0.8000e-01
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :

New PIPE file created
Comment for file catalog :

End this PIPE session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
```

TABLE 2.3.7 - WIPSLOG LISTING FOR GAPF PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : gapf

GAPF - SPECIFICATION OF GAP FRICTION PROPERTIES

Define units
  Length (ft;in;m;mm) : in
  Force (k,lb,kgf,kN) : k

Start new GAPF file

Specify a new property set? : y

SET NO.  1
Property set description : 10000k/in, fric. coeff.=1.e-6
Normal stiffness : 10000
Tangent stiffness : 10000
Friction coefficient : le-o
Use default tolerances?
Stiffness tolerance (dflt=.05) :
Overshoot tolerance (dflt=200lb) :
Any errors? :

This set added to GAPF file

Specify a new property set? : y

SET NO.  2
Property set description : 10000k/in, fric. coeff.=0.4
Normal stiffness : 10000
Tangent stiffness : 10000
Friction coefficient : .4
Use default tolerances? y
Any errors? :

This set added to GAPF file

Specify a new property set? :

No. of property sets in GAPF file =  2

Display property set descriptions? : y

GAPF PROPERTY DESCRIPTIONS
  Set No.   Description
     1      10000k/in, fric. coeff.=1.e-6
     2      10000k/in, fric. coeff.=0.4

Display new property set data? : y

 GAPF PROPERTY DATA

Set   Data                         Data
No.   Type                         Value
 1
```

Table 2.3.7 (cont'd)

```
          Normal stiffness       0.1000e+05
          Tangent stiffness      0.1000e+05
          Friction coefficient   0.1000e-05
          Stiffness tolerance    0.5000e-01
          Overshoot tolerance    0.2000e+00
Hit RETURN for next set
   2
          Normal stiffness       0.1000e+05
          Tangent stiffness      0.1000e+05
          Friction coefficient   0.4000e+00
          Stiffness tolerance    0.5000e-01
          Overshoot tolerance    0.2000e+00
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :

New GAPF file created
Comment for file catalog :

End this GAPF session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

----------------------------------------------------------------------
```

TABLE 2.3.8 - WIPSLOG LISTING FOR FREC PHASE.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

FREC - SPECIFY DYNAMIC FORCE RECORDS

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new FREC file

Specify a new record ? : y

RECORD NO.  1

Record name (4 characters) : rec1
Description (max. 40 char.) : Hibbitt record, max. 1000k.

Enter Time-Force pairs
First pair automatically set to 0,0
  Pair no.  2 : .0001 650
  Pair no.  3 : .001 880
  Pair no.  4 : .002 1000
  Pair no.  5 : .003 880
  Pair no.  6 : .005 780
  Pair no.  7 : .02 430
  Pair no.  8 : 10 430
  Pair no.  9 :
Last pair? : y
Any errors ? :

Specify a new record ? :

Display any records ? : y
Record number (dflt=all) :

RECORD NO.  1.  Name = rec1
      Time          Force
   0.          0.     e+00
   0.00010     0.6500e+03
   0.00100     0.8800e+03
   0.00200     0.1000e+04
   0.00300     0.8800e+03
   0.00500     0.7800e+03
   0.02000     0.4300e+03
  10.00000     0.4300e+03
END OF RECORD

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog :

EXEC - WIPS EXECUTIVE


NEXT WIPS-EXEC COMMAND : quit

-----------------------------------------------------------
```

TABLE 2.3.9 - WIPSLOG LISTING FOR MODL PHASE. CASE 1.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl

MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 2

Available element property sets
  Type    No. of Sets
  pipe         2
  gapf         2
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.   1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 16 pipe pr=1 ld=y
 2: 16 gapf pr=1 dy=-1 gap=124
 3: 17 pipe
 4: 17 gapf gap=128.82
 5: 18 pipe
 6: 18 gapf gap=142
 7: 19 pipe
 8: 19 gapf gap=160
 9: 20 pipe
10:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem    optn     data        optn     data        optn     data
  1
                bcon   111111
  16    pipe
                prop        1
                locl        +        ldis      yes        this      yes
                wfac   1.0000
  16    gapf
```

Table 2.3.9 (cont'd)

```
                    prop         1
                    this       yes
                    dyij   -1.0000          gap      124.0
  17     pipe
                    prop         1
                    locl         +          ldis       yes        this       yes
                    wfac    1.0000
Hit RETURN for more
  17     gapf
                    prop         1
                    this       yes
                    dyij   -1.0000          gap      128.8
  18     pipe
                    prop         1
                    locl         +          ldis       yes        this       yes
                    wfac    1.0000
  18     gapf
                    prop         1
                    this       yes
                    dyij   -1.0000          gap      142.0
Hit RETURN for more
  19     pipe
                    prop         1
                    locl         +          ldis       yes        this       yes
                    wfac    1.0000
  19     gapf
                    prop         1
                    this       yes
                    dyij   -1.0000          gap      160.0
  20     pipe
                    prop         1
                    locl         +          ldis       yes        this       yes
                    wfac    1.0000
Hit RETURN for more
Any changes? :

SEGMENT NO.   2

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : No friction, no strain rate.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE


NEXT WIPS-EXEC COMMAND : quit

-----------------------------------------------------------------------
```

TABLE 2.3.10 - WIPSLOG LISTING FOR DATA PHASE. CASE 1.

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of MODL file : 1

Problem description (4 lines)
 Line 1 : Example as in Fig.4.12 of Hibbitt-Karlsson Report.
 Line 2 :
 Line 3 : PIPE with no strain rate. GAPF with negligible friction.
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed

Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 20
  Force direction (x,y,z or follower) : foll
  Follower c.p. name : 19
  Scale factor (+,- controls direction) : .5
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : .0005 .001 .00001
Max steps + max total time : 1500 .3
Error tolerances : upper + lower : 50 10

Results output intervals
  Max. no. of steps : 20
  Max. time (secs.) : .02
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : No s.r., no friction.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
```

TABLE 2.3.11 - DATA FILE LISTING. CASE 1.

```
  ECHO0102  SLOG0102  RSLT0102
star,
gbui
new,main,nonl,cart,0
 substructure name = main
refn,21
     1  0.          e+00  0.          e+00  0.          e+00
     2  0.1800000e+02  0.          e+00  0.          e+00
     3  0.3600000e+02  0.          e+00  0.          e+00
     4  0.5400000e+02 -0.4823090e+01  0.          e+00
     5  0.6717691e+02 -0.1800000e+02  0.          e+00
     6  0.7200000e+02 -0.3600000e+02  0.          e+00
     7  0.7200000e+02 -0.7400000e+02  0.          e+00
     8  0.7200000e+02 -0.1120000e+03  0.          e+00
     9  0.7682310e+02 -0.1300000e+03  0.          e+00
    10  0.9000001e+02 -0.1431769e+03  0.          e+00
    11  0.1080000e+03 -0.1480000e+03  0.          e+00
    12  0.1566000e+03 -0.1480000e+03  0.          e+00
    13  0.2052000e+03 -0.1480000e+03  0.          e+00
    14  0.2538000e+03 -0.1480000e+03  0.          e+00
    15  0.3024000e+03 -0.1480000e+03  0.          e+00
    16  0.3510000e+03 -0.1480000e+03  0.          e+00
    17  0.3689998e+03 -0.1431770e+03  0.          e+00
    18  0.3821770e+03 -0.1299998e+03  0.          e+00
    19  0.3870000e+03 -0.1120000e+03  0.          e+00
    20  0.3870000e+03 -0.6000000e+01  0.          e+00
 9999
boun,21
     1                           111111
     2                             1110
     3                             1110
     4                             1110
     5                             1110
     6                             1110
     7                             1110
     8                             1110
     9                             1110
    10                             1110
    11                             1110
    12                             1110
    13                             1110
    14                             1110
    15                             1110
    16                             1110
    17                             1110
    18                             1110
    19                             1110
    20                             1110
 9999                            111111
enod,0
matl,4,64
0.200000000e+010.299999982e+000.267000000e+050.219000000e+030.200000000e+01
0.267000008e+020.440000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200030000e+010.          e+000.200000000e+010.100000000e+01
0.100000000e+010.240030000e+020.153100002e+010.306922067e-010.          e+00
0.349999976e+000.799999970e-010.          e+000.          e+000.          e+00
```

Table 2.3.11 (cont'd)

```
0.          e+000.          e+000.          e+000.          e+000.499999970e-01
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+00
0.200000000e+010.299999982e+000.267000000e+050.219000000e+030.200000000e+01
0.267000008e+020.440000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.          e+000.200000000e+010.100000000e+01
0.100000000e+010.240000000e+020.153100002e+010.306922067e-010.          e+00
0.349999976e+000.799999970e-010.300000000e+010.250000000e+020.220000000e+01
0.440000000e+000.360000003e+000.444000000e+010.999999932e+200.499999970e-01
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+00
0.999999997e-060.100000000e+050.          e+000.999999932e+200.199999986e+21
0.100000000e+050.999999939e+030.999999847e+020.499999970e-010.199999988e+00
0.199999988e+000.199999988e+000.199999988e+000.199999988e+000.199999988e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+00
0.400000006e+000.100000000e+050.          e+000.999999932e+200.199999986e+21
0.100000000e+050.999999939e+030.999999847e+020.499999970e-010.199999988e+00
0.199999988e+000.199999988e+000.199999988e+000.199999988e+000.199999988e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+00
elem,2
    3   19    1                                     1.00
    1    0    0    0    1    2    1    1    1    1    0    1
0.          e+000.100000000e+010.          e+000.          e+00
    2    0    0    0    2    3    1    1    1    1    0    1
0.180000000e+020.100000000e+010.          e+000.          e+00
    3    0    0    0    3    4    1    1    1    0    1    1
0.359999962e+02-.360000038e+020.          e+000.          e+00
    4    0    0    0    4    5    1    1    1    0    1    1
```

<u>Table 2.3.11</u> (cont'd)

```
0.359999962e+02-.360000038e+020.             e+000.         e+00
    5     0     0     0     5     6     1     1     1     0     1     1
0.359999962e+02-.360000038e+020.             e+000.         e+00
    6     0     0     0     6     7     1     1     1     1     0     1
0.730000000e+02-.360000000e+020.             e+000.         e+00
    7     0     0     0     7     8     1     1     1     1     0     1
0.730000000e+02-.740000000e+020.             e+000.         e+00
    8     0     0     0     8     9     1     1     1     0     1     1
0.108000008e+03-.112000000e+030.             e+000.         e+00
    9     0     0     0     9    10     1     1     1     0     1     1
0.108000008e+03-.112000000e+030.             e+000.         e+00
   10     0     0     0    10    11     1     1     1     0     1     1
0.108000008e+03-.112000000e+030.             e+000.         e+00
   11     0     0     0    11    12     1     1     1     1     0     1
0.108000000e+03-.147000000e+030.             e+000.         e+00
   12     0     0     0    12    13     1     1     1     1     0     1
0.156600006e+03-.147000000e+030.             e+000.         e+00
   13     0     0     0    13    14     1     1     1     1     0     1
0.205200012e+03-.147000000e+030.             e+000.         e+00
   14     0     0     0    14    15     1     1     1     1     0     1
0.253800003e+03-.147000000e+030.             e+000.         e+00
   15     0     0     0    15    16     1     1     1     1     0     1
0.302400024e+03-.147000000e+030.             e+000.         e+00
   16     0     0     0    16    17     1     1     1     0     1     1
0.351000000e+03-.112000000e+030.             e+000.         e+00
   17     0     0     0    17    18     1     1     1     0     1     1
0.351000000e+03-.112000000e+030.             e+000.         e+00
   18     0     0     0    18    19     1     1     1     0     1     1
0.351000000e+03-.112000000e+030.             e+000.         e+00
   19     0     0     0    19    20     1     1     1     1     0     1
0.386000000e+03-.112000000e+030.             e+000.         e+00

    4     4     1                                  0.
    1     0     0     0    16     0     3     1     1
0.          e+000.100000000e+010.            e+000.100000000e+010.          e+00
0.          e+000.124000000e+03
    2     0     0     0    17     0     3     1     1
0.          e+000.100000000e+010.            e+000.100000000e+010.          e+00
0.          e+000.128820007e+03
    3     0     0     0    18     0     3     1     1
0.          e+000.100000000e+010.            e+000.100000000e+010.          e+00
0.          e+000.142000000e+03
    4     0     0     0    19     0     3     1     1
0.          e+000.100000000e+010.            e+000.100000000e+010.          e+00
0.          e+000.160000000e+03

nord,opto
prof
end
fini
mode
tree,main
fini
mbui
new,main
pmas,24
```

Table 2.3.11 (cont'd)

```
      10 0.35967e-03 0.35967e-03 0.35967e-03 0.       e+00 0.       e+00 0.       e+0000
      20 0.71935e-03 0.71935e-03 0.71935e-03 0.       e+00 0.       e+00 0.       e+0000
      30 0.73204e-03 0.73204e-03 0.73204e-03 0.       e+00 0.       e+00 0.       e+0000
      40 0.74472e-03 0.74472e-03 0.74472e-03 0.       e+00 0.       e+00 0.       e+0000
      50 0.74472e-03 0.74472e-03 0.74472e-03 0.       e+00 0.       e+00 0.       e+0000
      60 0.11317e-02 0.11317e-02 0.11317e-02 0.       e+00 0.       e+00 0.       e+0000
      70 0.15186e-02 0.15186e-02 0.15186e-02 0.       e+00 0.       e+00 0.       e+0000
      80 0.11317e-02 0.11317e-02 0.11317e-02 0.       e+00 0.       e+00 0.       e+0000
      90 0.74472e-03 0.74472e-03 0.74472e-03 0.       e+00 0.       e+00 0.       e+0000
     100 0.74472e-03 0.74472e-03 0.74472e-03 0.       e+00 0.       e+00 0.       e+0000
     110 0.13435e-02 0.13435e-02 0.13435e-02 0.       e+00 0.       e+00 0.       e+0000
     120 0.19422e-02 0.19422e-02 0.19422e-02 0.       e+00 0.       e+00 0.       e+0000
     130 0.19422e-02 0.19422e-02 0.19422e-02 0.       e+00 0.       e+00 0.       e+0000
     140 0.19422e-02 0.19422e-02 0.19422e-02 0.       e+00 0.       e+00 0.       e+0000
     150 0.19422e-02 0.19422e-02 0.19422e-02 0.       e+00 0.       e+00 0.       e+0000
     160 0.97112e-03 0.97112e-03 0.97112e-03 0.       e+00 0.       e+00 0.       e+0000
     160 0.37236e-03 0.37236e-03 0.37236e-03 0.       e+00 0.       e+00 0.       e+0000
     170 0.37236e-03 0.37236e-03 0.37236e-03 0.       e+00 0.       e+00 0.       e+0000
     170 0.37237e-03 0.37237e-03 0.37237e-03 0.       e+00 0.       e+00 0.       e+0000
     180 0.37237e-03 0.37237e-03 0.37237e-03 0.       e+00 0.       e+00 0.       e+0000
     180 0.37236e-03 0.37236e-03 0.37236e-03 0.       e+00 0.       e+00 0.       e+0000
     190 0.37236e-03 0.37236e-03 0.37236e-03 0.       e+00 0.       e+00 0.       e+0000
     190 0.21181e-02 0.21181e-02 0.21181e-02 0.       e+00 0.       e+00 0.       e+0000
     200 0.21181e-02 0.21181e-02 0.21181e-02 0.       e+00 0.       e+00 0.       e+0000
end
fini
ptre
newr,recl,pair,8,100
(2e15.7)
  0.        e+00  0.        e+00
  0.6500000e+03  0.1000000e-03
  0.8800000e+03  0.1000000e-02
  0.1000000e+04  0.2000000e-02
  0.8800000e+03  0.3000000e-02
  0.7800000e+03  0.5000000e-02
  0.4300000e+03  0.2000000e-01
  0.4300000e+03  0.1000000e+02
fini
thou,792
         2        191     3     1     0     0
ndyn
mass
dylo,1,1
recl      0     0.       0.500          2
   20   19
timo,rslt,20,0.2000e-01
auto,defi
inte,newm,0.5000e-03,0.e+00,0.e+00,0.1000e+00
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,1500
zero,ltme
step
```

Table 2.3.11 (cont'd)

```
unba
auto,init
loop,20
stif
auto,load
load
disp
kinr,10
elmr,9,10
auto,merr,0.1000e+02,0.5000e+02
if,3,3,1,1
entr,1
auto,fact
kinr,1
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.1000e-04,0.1000e-02,0.5000e+00,0.[illegible]000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,8
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,lrsb
unba
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.3000e+00
if,5,8,8,0
entr,8
cont
fini
stop
```

D2.4 CLAMPED BEAM WITH IMPULSIVE LOADING

D2.4.1 PURPOSE

This example tests the BEAM element, by comparison with test results and previously reported analysis results. Large displacement and strain rate effects are considered, and the initial velocity loading option is tested.

D2.4.2 DESCRIPTION

Tests and analyses of a clamped-end beam under impulse (explosive) loading have been reported by Witmer et al [2.4.1]. Analyses of the same beam have been reported by Hibbitt and Karlsson [2.4.2].

The dimensions of the beam are shown in Fig. 2.4.1. Initial velocities as shown were produced by an explosive charge.

The beam was made of 6061-T6 aluminum alloy. The static Young's modulus reported in [2.4.1] was 10400 ksi ($7.171 \times 10^{10}\ N/m^2$). For analysis, bilinear stress-strain relationships were assumed in both [2.4.1] and [2.4.2]. Very similar results were reported in [2.4.1] for (a) elastic-perfectly-plastic material with an extensional yield stress of 41.4 ksi ($2.854 \times 10^8\ N/m^2$) and (b) elastic-strain-hardening material with a yield stress of 40.5 ksi ($2.792 \times 10^8\ N/m^2$) and a strain hardening modulus of 76.1 ksi ($5.247 \times 10^8\ N/m^2$). The elastic-strain-hardening material was assumed for the WIPS analyses.

For the analyses in both [2.4.1] and [2.4.2], high strain rates were assumed to increase the yield stress according to the equation:

$$\sigma_y - \sigma_o = \sigma_o \left(|\dot{\epsilon}|/6500\right)^{0.25} \qquad (2.4.1)$$

in which $\dot{\epsilon}$ = extensional strain rate; σ_o = static yield stress; and σ_y = dynamic yield stress. For the WIPS analyses a trilinear approximation as shown in Table 2.4.1 was assumed.

The following WIPS analyses were performed:

(1) Ten BEAM elements in half span, no strain rate effect, Newmark solution scheme.

(2) Ten BEAM elements in half span, no strain rate effect, Hilber-Hughes-Taylor (HHT) solution scheme.

(3) Ten BEAM elements in half span, with strain rate effect, Newmark solution scheme.

In addition, an analysis with twenty BEAM elements in the half span and no strain rate effect was carried out to explore the effect of discretization. The results were not significantly different from those for Case 1 and are not reported here.

D2.4.3 WIPS ANALYSIS MODEL

D2.4.3.1 Geometry and Loading

The element subdivision and initial velocities for the 10-element analysis are shown in Fig. 2.4.2. The initial kinetic energy is the same as for the beam shown in Fig. 2.4.1. Only motion in the XY plane was permitted (i.e. no beam twist or lateral bending).

D2.4.3.2 BEAM Element Properties

For the assumed elastic-strain-hardening material, force-extension and moment-curvature relationships were calculated for the BEAM element cross section. The force-extension relationship has the same shape as the stress-strain curve, whereas the moment-curvature relationship is curvilinear. The two relationships were approximated using four linear segments each, as shown in Tables 2.4.2 and 2.4.3.

The procedure for determining strain rate properties for BEAM elements is described in the Theory Manual, Section B4.4.2. With this procedure and the dashpot stiffnesses shown in Table 2.4.1, the dimensionless properties shown in Table 2.4.4 were calculated.

D2.4.3.3 Analysis Control Parameters

For analysis with the Newmark scheme, the following parameters were specified:

Initial time step = 2×10^{-6} sec.

Minimum time step = 1×10^{-6} sec.

Maximum time step = 1×10^{-4} sec.

Initial $\beta/\Delta t$ = 0.1

Lower midstep tolerance = 0.5 k

Upper midstep tolerance = 2.5 k

The same parameters were used with the HHT scheme, except that the damping parameter was $\alpha = -0.1$.

D2.4.3.4 WIPS Input

Table 2.4.5 contains the WIPSLOG listing through the WIPS-DATA phase for Case 3. The procedures for the other cases were similar. Table 2.4.6 is a listing of the DATA file for Case 3.

D2.4.4 RESULTS

D2.4.4.1 No Strain Rate: Newmark Scheme

For the Newmark scheme and no strain rate, Fig. 2.4.3 compares the WIPS results for midspan deflection with the test results from [2.4.1] and the analysis results from [2.4.1] and [2.4.2]. The analysis in [2.4.1] used a finite difference scheme with 30 nodes in the half span. The analysis in [2.4.2] used a finite element model with 10 elements in the half span. It should be noted that during the test the beam twisted significantly because the explosion wavefront traveled laterally across the beam. Hence, there is some doubt whether the test and analysis results are directly comparable.

The three analyses differ significantly, that from [2.4.2] predicting the largest displacement and the WIPS analysis predicting the smallest displacement. None of the analyses agrees closely with the test results.

Because the displacements computed using WIPS were smaller than those reported in [2.4.1] and [2.4.2], an analysis was also carried out using very small numerical damping ($\beta/\Delta t_o$ = 0.002 rather than the default value of 0.1). The results differed only very slightly from those shown in Fig. 2.4.3. However, the number of time steps required for the solution increased dramatically (from 70 to 202 steps).

D2.4.4.2 No Strain Rate: HHT Scheme

Figure 2.4.4 compares the results for analyses with the Newmark and HHT schemes. The results are closely similar up to 0.5 milliseconds. The HHT analysis required 63 time steps for the solution.

D2.4.4.3 With Strain Rate

For the Newmark scheme with strain rate effects, Fig. 2.4.5 shows comparisons with experiment and the analyses reported in [2.4.1] and [2.4.2]. The WIPS analysis agrees quite closely with the analysis from [2.4.1]. Note, however, that the WIPS strain rate theory is not identical to that used in [2.4.1]. In particular, the strength increase in WIPS is based on plastic strain rate rather than total strain rate. This will tend to make the WIPS model somewhat more flexible. The analysis required 63 time steps. The results of the WIPS analyses with and without strain rate effects are compared in Fig. 2.4.6.

D2.4.5 CONCLUSION

Compared with the two other reported analyses, the BEAM element in WIPS is slightly stiff. This is not due to the numerical damping scheme. For the case with no strain rate, the WIPS analyses and the two other reported analyses all differ from each other significantly. For the case with strain rate the WIPS analysis agrees quite closely with the analysis from [2.4.1] but differs significantly from the analysis in [2.4.2]. None of the analyses agrees closely with experiment. However, the experimental results are not necessarily reliable because of twisting of the beam.

Without further study it is not possible to say which of the analyses is the most accurate.

D2.4.6 REFERENCES

2.4.1 Witmer, E. A., Balmer, H. A., Leech, J. W., and Pian, T.H.H., "Large Dynamic Deformations of Beams, Rings, Plates, and Shells," *AIAA Journal*, Vol. 1, No. 8, pp. 1848-1857, 1963.

2.4.2 Hibbitt and Karlsson, "Analysis of Pipe Whip," Report No. EPRI NP-1208, Electric Power Research Institute, 1979.

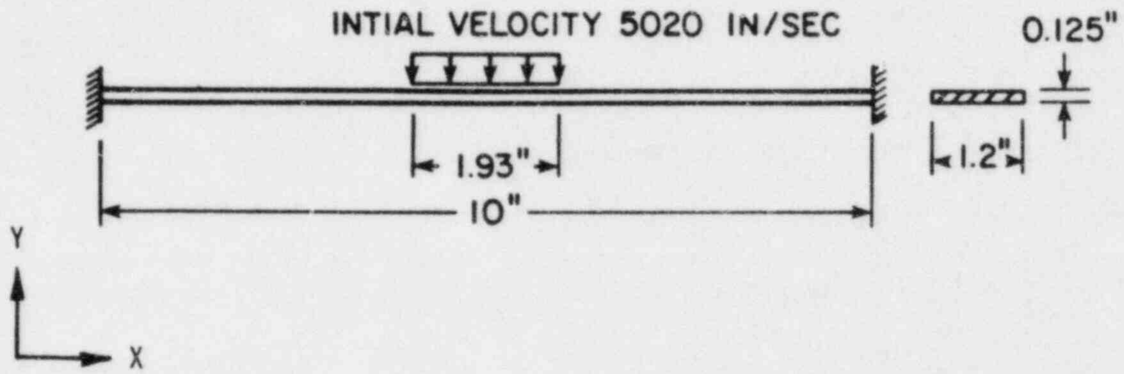

FIG. 2.4.1 IMPULSIVELY LOADED BEAM

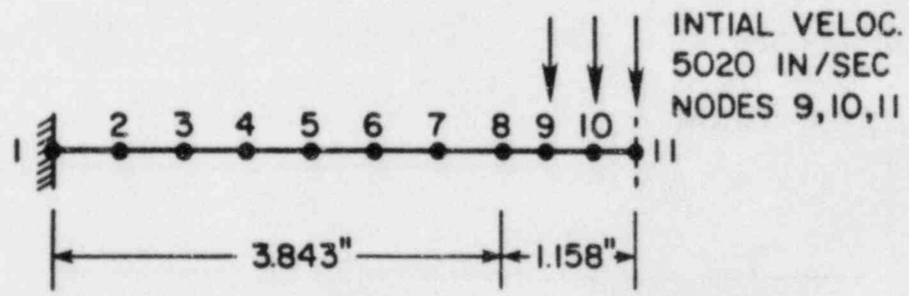

FIG. 2.4.2 ELEMENT SUBDIVISION

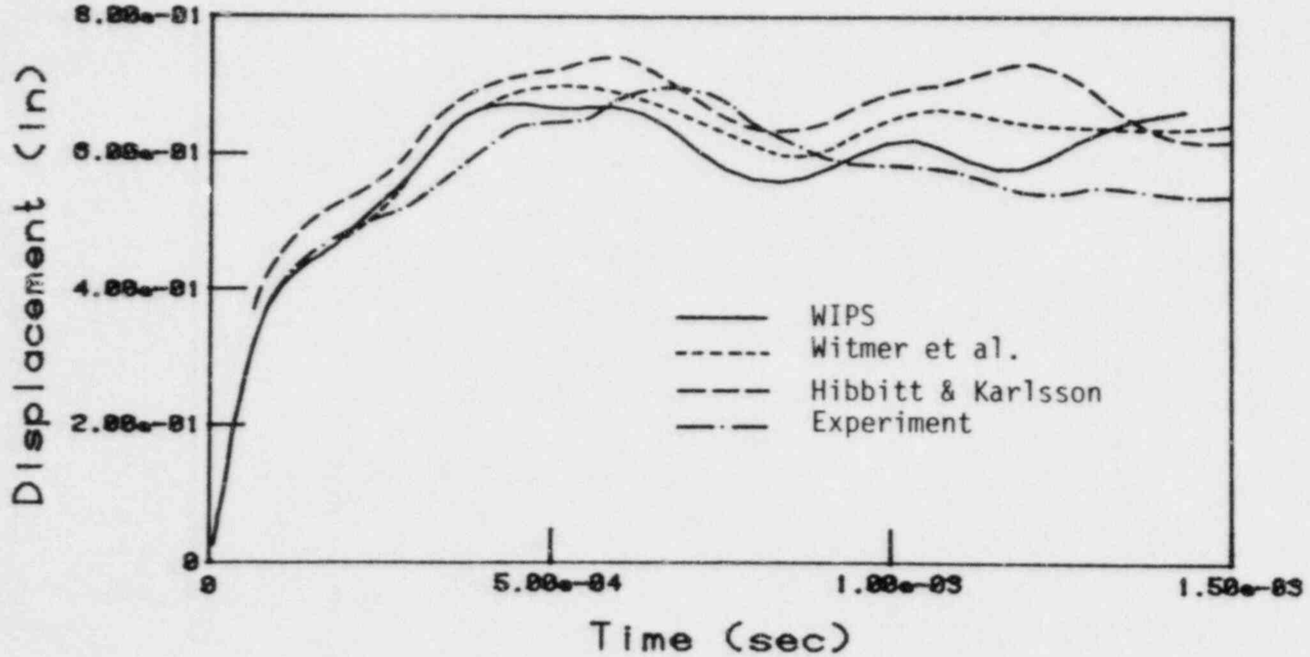

FIG. 2.4.3 DISPLACEMENT AT BEAM CENTER, WITHOUT STRAIN RATE EFFECT.

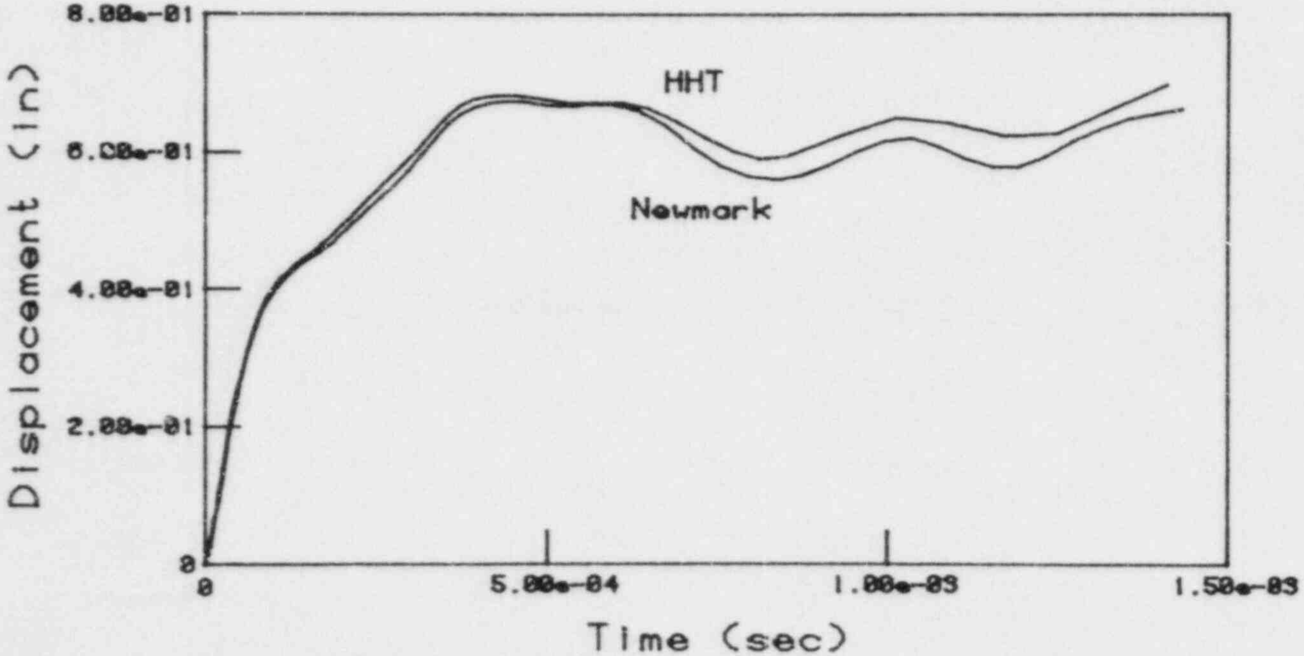

FIG. 2.4.4 DISPLACEMENT AT BEAM CENTER.
COMPARISON OF NEWMARK AND HHT SCHEMES.

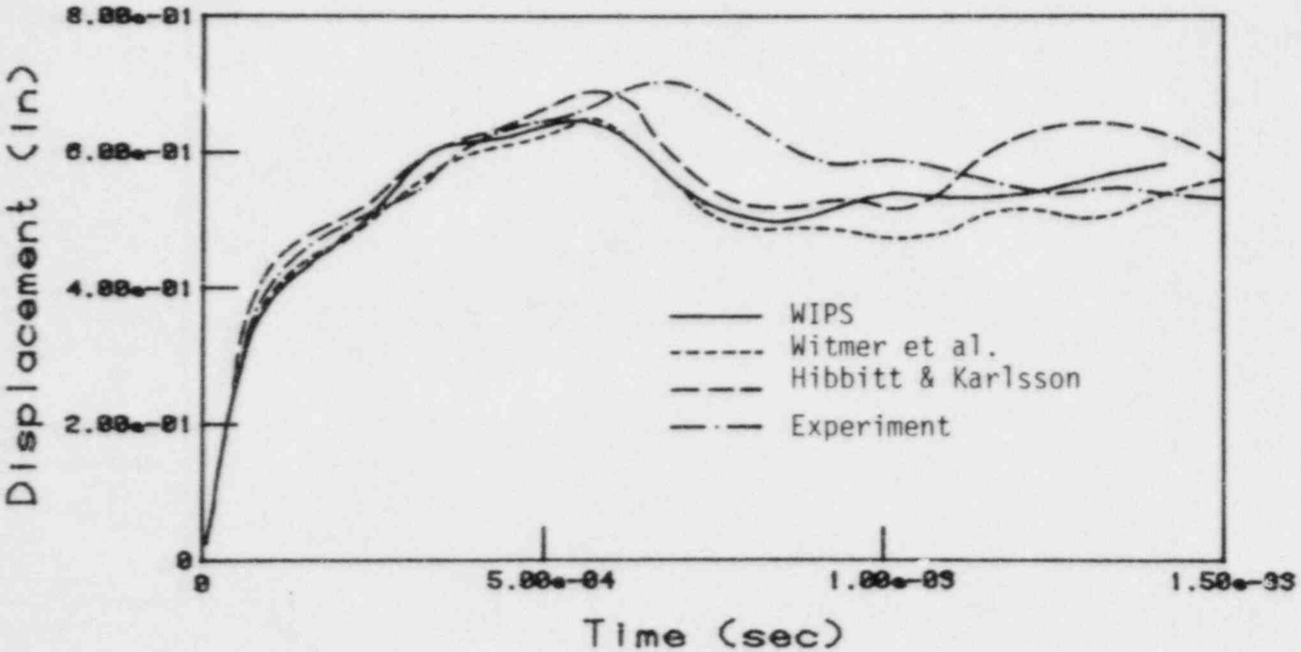

FIG. 2.4.5 DISPLACEMENT AT BEAM CENTER, WITH STRAIN RATE EFFECT.

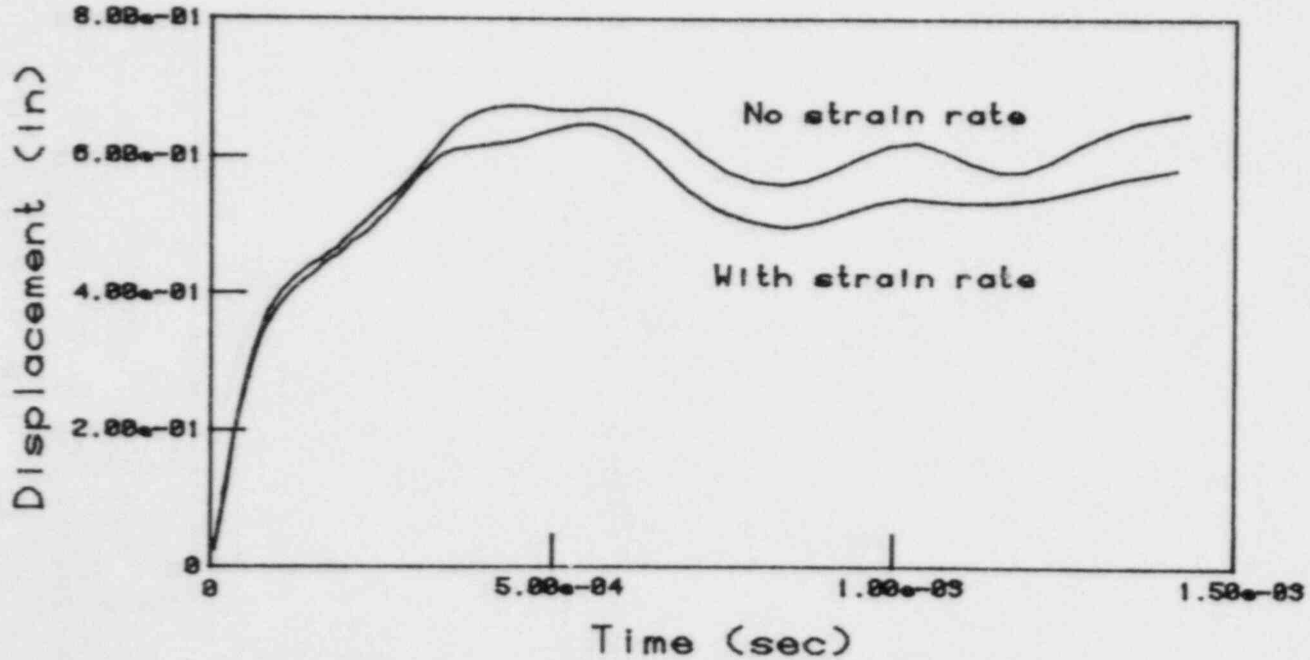

FIG. 2.4.6 DISPLACEMENT AT BEAM CENTER.
INFLUENCE OF STRAIN RATE ON RESULTS.

TABLE 2.4.1 - TRILINEAR APPROXIMATION FOR STRAIN RATE EFFECT		
Stress Increase (ksi)	Strain Rate (sec^{-1})	Dashpot Stiffness ($k.sec/in^2$)
0	0	2.0
8	4	0.0685
18	150	0.0108

TABLE 2.4.2 - STATIC FORCE-EXTENSION RELATIONSHIP FOR BEAM ELEMENT		
Force (k)	Axial Strain	Stiffness (k)
0	0	1560.00
6.075	0.00389	11.42
6.170	0.01121	11.41
6.634	0.05184	11.40

TABLE 2.4.3 - STATIC MOMENT-CURVATURE RELATIONSHIP FOR BEAM ELEMENT		
Moment (k.in)	Curvature (in^{-1})	Stiffness ($k.in^2$)
0	0	2.0310
0.156	0.0768	0.2290
0.189	0.2212	0.0150
0.201	1.0225	0.0149

TABLE 2.4.4 - DIMENSIONLESS STRAIN RATE RELATIONSHIP FOR BEAM ELEMENT	
Strength Increase Factor	Deformation Rate Factor
0	0
0.1869	1027
0.4206	38520
2.9370	2.607×10^6

TABLE 2.4.5 - WIPSLOG LISTING. GEOM, BEAM, FREC, MODL AND DATA PHASES.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Clamped beam with initial velocity. BEAM model.

NEXT WIPS-EXEC COMMAND : geom

GEOM - SPECIFICATION OF SYSTEM GEOMETRY

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Specify new GEOM data

START RUN NO.  1
Enter c.p. data in sequence along run

  c.p. name and type : 1
  coord option : di
  x,y,z :
  Any changes? :

  c.p. name and type : 8
  no. of extra nodes : 6
  coord option :
  c.p., dx,dy,dz : ,3.843
  offset point defaults to preceding c.p.
  Any changes? :

  c.p. name and type : 9
  no. of extra nodes :
  coord option :
  c.p., dx,dy,dz : ,.386
  offset point defaults to preceding c.p.
  Any changes? :

  c.p. name and type : 11
  no. of extra nodes : 1
  coord option :
  c.p., dx,dy,dz : 1 5
  Any changes? :

  c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this run? : y

GEOM DATA FOR RUN
```

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. I	c.p.? J ?	coordinate data x,dx,p	y,dy	z,dz
1										
	1			0	di			0.	0.	0.
	8			6	of	1		3.843	0.	0.
	9			0	of	8		0.386	0.	0.
	11			1	of	1		5.000	0.	0.

Table 2.4.5 (cont'd)

```
END OF DATA

START RUN NO.  2
Enter c.p. data in sequence along run

  c.p. name and type :
Last run? : y

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOM0101

Produce COOR data? : y

Display COOR data? : y


COOR DATA

 run    c.p.   c.p.    bend    node        x          y  ?       z
 no.    name   type   radius    no.      coord      coord?     coord

  1
        1                        1       0.         0.         0.
                                 2       0.549      0.         0.
                                 3       1.098      0.         0.
                                 4       1.647      0.         0.
                                 5       2.196      0.         0.
                                 6       2.745      0.         0.
                                 7       3.294      0.         0.
        8                        8       3.843      0.         0.
        9                        9       4.229      0.         0.
                                10       4.615      0.         0.
Hit RETURN for more
        11                      11       5.000      0.         0.
END OF DATA

Plot geometry? :

Modify GEOM data? :

DATA COMPLETE FOR THIS SESSION
Save final GEOM data? : y
Comment for file catalog : 10 elements.
GEOM DATA SAVED. FILE NAME = GEOM0101
Save COOR data? : y
Comment for file catalog : 10 elements.
COOR DATA SAVED. FILE NAME = COOR0101

End of this GEOM session
```

Table 2.4.5 (cont'd)

```
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : beam

BEAM - SPECIFICATION OF BEAM PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new BEAM file

Specify a new property set? : y

SET NO. =  1
Property set description : 1.2x0.125, 40.5ksi, no strain rate.

Yield surface type (1-4) (dflt=1) : 2
Weight per unit length : 1.448e-5

Elastic stiffnesses
   EAx,GAy,GAz : 1560 500 500
   GJx,EIy,EIz : 2.031 2.031 2.031
 Strengths at first yield
   Fx,Mxx,Myy,Mzz : 6.075 .156 .156 .156
 Stiffnesses after first yield
   EA,GJx,EIy,EIz : 11.42 .229 .229 .229
 Strengths at second yield
   Fx,Mxx,Myy,Mzz : 6.17 .189 .189 .189
 Stiffnesses after second yield
   EA,GJx,EIy,EIz : 11.41 .015 .015 .015
 Strengths at third yield
   Fx,Mxx,Myy,Mzz : 11.4 .0149 .0149 .0149
 *** error - must exceed previous values
 Strengths at third yield
   Fx,Mxx,Myy,Mzz : 6.634 .201 .201 .201
 Stiffnesses after third yield
   EA,GJx,EIy,EIz : 11.4 .0149 .0149 .0149
 Strain rate factors (0-3, dflt=none) :
 No strain rate effect
 Use default tolerances? : y

 Any errors? :

 This set added to BEAM file

 Specify a new property set? : y

 SET NO. =  2
 Property set description : 1.2x0.125, 40.5ksi, with strain rate.

 Yield surface type (1-4) (dflt=1) : 2
 Weight per unit length : 1.448e-5

 Elastic stiffnesses
```

Table 2.4.5 (cont'd)

```
   EAx,GAy,GAz : 1560 500 500
   GJx,EIy,EIz : 2.031 2.031 2.031
 Strengths at first yield
   Fx,Mxx,Myy,Mzz : 6.075 .156 .156 .156
 Stiffnesses after first yield
   EA,GJx,EIy,EIz : 11.42 .229 .229 .229
 Strengths at second yield
   Fx,Mxx,Myy,Mzz : 6.17 .189 .189 .189
 Stiffnesses after second yield
   EA,GJx,EIy,EIz : 11.41 .015 .015 .015
 Strengths at third yield
   Fx,Mxx,Myy,Mzz : 6.634 .201 .201 .201
 Stiffnesses after third yield
   EA,GJx,EIy,EIz : 11.4 .0149 .0149 .0149
 Strain rate factors (0-3, dflt=none) : 1027 38520 2.607e6
 Corresponding strength factors : .1869 .4206 2.937
 Use default tolerances? : y

 Any errors? :

 This set added to BEAM file

 Specify a new property set? :

 No. of property sets in BEAM file =  2

 Display property set descriptions? : y

 BEAM PROPERTY DESCRIPTIONS
   Set No.   Description
      1      1.2x0.125, 40.5ksi, no strain rate.
      2      1.2x0.125, 40.5ksi, with strain rate.

 Display new property set data? :
 Write in session log? :

 Display all property set data? : y

 BEAM PROPERTY DATA

 SET NO.  1.  1.2x0.125, 40.5ksi, no strain rate.

  Data Type                Data 1      Data 2      Data 3      Data 4

  Unit weight           0.1448e-04
  Elastic EAx,GAy,GAz   0.1560e+04 0.5000e+03 0.5000e+03
          GJx,EIy,EIz   0.2031e+01 0.2031e+01 0.2031e+01
  First yield
       Fx,Mxx,Myy,Mzz   0.6075e+01 0.1560e+00 0.1560e+00 0.1560e+00
       EA,GJx,EIy,EIz   0.1142e+02 0.2290e+00 0.2290e+00 0.2290e+00
  Second yield
       Fx,Mxx,Myy,Mzz   0.6170e+01 0.1890e+00 0.1890e+00 0.1890e+00
       EA,GJx,EIy,EIz   0.1141e+02 0.1500e-01 0.1500e-01 0.1500e-01
  Third yield
       Fx,Mxx,Myy,Mzz   0.6634e+01 0.2010e+00 0.2010e+00 0.2010e+00
       EA,GJx,EIy,EIz   0.1140e+02 0.1490e-01 0.1490e-01 0.1490e-01
```

Table 2.4.5 (cont'd)

```
 Stiffness tolerance   0.5000e-01
 Yield tolerance       0.2000e-01
 Unloading tolerance   0.2000e-01
Hit RETURN for next set

SET NO.  2.  1.2x0.125, 40.5ksi, with strain rate.

 Data Type                  Data 1      Data 2      Data 3      Data 4

 Unit weight               0.1448e-04
 Elastic EAx,GAy,GAz       0.1560e+04 0.5000e+03 0.5000e+03
          GJx,EIy,EIz      0.2031e+01 0.2031e+01 0.2031e+01
 First yield
       Fx,Mxx,Myy,Mzz      0.6075e+01 0.1560e+00 0.1560e+00 0.1560e+00
       EA,GJx,EIy,EIz      0.1142e+02 0.2290e+00 0.2290e+00 0.2290e+00
 Second yield
       Fx,Mxx,Myy,Mzz      0.6170e+01 0.1890e+00 0.1890e+00 0.1890e+00
       EA,GJx,EIy,EIz      0.1141e+02 0.1500e-01 0.1500e-01 0.1500e-01
 Third yield
       Fx,Mxx,Myy,Mzz      0.6634e+01 0.2010e+00 0.2010e+00 0.2010e+00
       EA,GJx,EIy,EIz      0.1140e+02 0.1490e-01 0.1490e-01 0.1490e-01
 Strain rate factors       0.1027e+04 0.3852e+05 0.2607e+07
 Strength factors          0.1869e+00 0.4206e+00 0.2937e+01
 Stiffness tolerance       0.5000e-01
 Yield tolerance           0.2000e-01
 Unloading tolerance       0.2000e-01
 Str. rate tolerance       0.5000e-01
Hit RETURN for next set
END OF DATA

New BEAM file created
Comment for file catalog : 2 sets.

End this BEAM session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

FREC - SPECIFY DYNAMIC FORCE RECORDS

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Start new FREC file

Specify a new record ? : y

RECORD NO.  1

Record name (4 characters) : rec1
Description (max. 40 char.) : Dummy zero record.

Enter Time-Force pairs
First pair automatically set to 0,0
```

Table 2.4.5 (cont'd)

```
  Pair no.  2 : 10 0.
  Pair no.  3 :
Last pair? : y
Any errors ? :

Specify a new record ? :

Display any records ? : y
Record number (dflt=all) :

RECORD NO.  1.  Name = rec1
     Time          Force
  0.          0.    e+00
 10.00000     0.    e+00
END OF RECORD

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog : 1 dummy record.

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl


MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type    No. of Sets
  beam        2
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.   1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 9 beam pr=2 ld=y
 2:
End of segment? : y
```

Table 2.4.5 (cont'd)

```
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem    optn      data        optn     data       optn      data
  1
                bcon   111111
  9     beam
                prop        2
                locl        +         ldis      yes        this       yes
                wfac   1.0000
Any changes? :

SEGMENT NO.   2

Pipe run no. : 1
First c.p. of segment : 9
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. :
Symmetric - boundary code reset to 001110

Specify c.p.name + elem type + optional data
 1: 11 beam
 2:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  2.  Run No. =  1
  c.p.  elem    optn      data        optn     data       optn      data
  9
                bcon     1110
  11    beam
                prop        2
                locl        +         ldis      yes        this       yes
                wfac   1.0000
Any changes? : y
 Re-enter data for this segment

SEGMENT NO.   2

Pipe run no. : 1
First c.p. of segment : 9
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. :
Symmetric - boundary code reset to 001110

Specify c.p.name + elem type + optional data
 1: 11 beam
 2: 11,,bc=101111
```

Table 2.4.5 (cont'd)

```
 3:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  2.  Run No. =  1
  c.p.  elem    optn     data       optn     data       optn     data
  9
                bcon     1110
  11    beam
                prop        2
                locl        +       ldis     yes        this     yes
                wfac   1.0000
  11
                bcon   101111
Any changes? :

SEGMENT NO.   3

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? : y
Specify initial velocities for affected segments
Warning - only partial consistency check is performed on data
  SEGMENT NO. : 2
   Segment has transverse symmetry
  Motion in xy plane only
  Name of pivot point (dflt = no pivot) :
  Specify global x+y velocities : 0 -5020
  SEGMENT NO. :
  Last affected segment ? : y
   Wait while data is processed
Comment for file catalog : 10 elements, with strain rate.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : list

Problem 1: Clamped beam with initial velocity. BEAM model

file    sequence          date                             description
type     number
GEOM       1     Fri Aug 13 14:45:24 1982   10 elements.
```

Table 2.4.5 (cont'd)

```
COOR       1   Fri Aug 13 14:45:24 1982   10 elements.
BEAM           Fri Aug 13 14:53:48 1982   2 sets.
FREC           Fri Aug 13 14:55:28 1982   1 dummy record.
MODL       1   Fri Aug 13 15:01:09 1982   10 elements, with strain rate.

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Sequence no. of MODL file : 1

Problem description (4 lines)
 Line 1 : Clamped Beam with Initial Velocity.          GHP 7/82
 Line 2 :
 Line 3 : 10 elements, with strain rate. 5020 velocity at 9,10,11.
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed
Initial velocities may be scaled if desired
Specify scale factor (dflt=1.0) :

Specify data for each loaded point
LOAD NO.  1
  Force record name : recl
  Name of loaded c.p. : 1
  Force direction (x,y,z or follower) : y
  Scale factor (+,- controls direction) : 1
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : 2e-6 le-4 le-6
 Max steps + max total time : 200 .0015
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) : .5
Max. unbal. to stop analysis (dflt=no limit) : 10

DATA file set complete
Comment for file catalog : 10 elem, strain rate, Newmark 0.1
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : list
```

Table 2.4.5 (cont'd)

```
Problem 1: Clamped beam with initial velocity. BEAM model.

file    sequence          date                              description
type     number
GEOM       1     Fri Aug 13 14:45:24 1982   10 elements.
COOR       1     Fri Aug 13 14:45:24 1982   10 elements.
BEAM             Fri Aug 13 14:53:48 1982   2 sets.
FREC             Fri Aug 13 14:55:28 1982   1 dummy record.
MODL       1     Fri Aug 13 15:01:09 1982   10 elements, with strain rate.
DATA       1     Fri Aug 13 15:01:09 1982   10 elem, strain rate, Newmark 0.1
RSLT       1     Fri Aug 13 15:01:09 1982   10 elem, strain rate, Newmark 0.1
ECHO       1     Fri Aug 13 15:01:09 1982   10 elem, strain rate, Newmark 0.1
SLOG       1     Fri Aug 13 15:01:09 1982   10 elem, strain rate, Newmark 0.1

NEXT WIPS-EXEC COMMAND : quit

---------------------------------------------------------------------------
```

TABLE 2.4.6 - DATA FILE LISTING, CASE 3.

```
  ECHO0101  SLO60101  RSLT0101
star,
gbui
new,main,nonl,cart,0
 substructure name = main
refn,12
    1  0.         e+00  0.         e+00  0.         e+00
    2  0.5490000e+00  0.         e+00  0.         e+00
    3  0.1098000e+01  0.         e+00  0.         e+00
    4  0.1647000e+01  0.         e+00  0.         e+00
    5  0.2196000e+01  0.         e+00  0.         e+00
    6  0.2745000e+01  0.         e+00  0.         e+00
    7  0.3294000e+01  0.         e+00  0.         e+00
    8  0.3843000e+01  0.         e+00  0.         e+00
    9  0.4229000e+01  0.         e+00  0.         e+00
   10  0.4614500e+01  0.         e+00  0.         e+00
   11  0.5000000e+01  0.         e+00  0.         e+00
 9999
boun,12
    1                          111111
    2                            1110
    3                            1110
    4                            1110
    5                            1110
    6                            1110
    7                            1110
    8                            1110
    9                            1110
   10                            1110
   11                          101111
 9999                          111111
enod,0
matl,2,64
0.200000000e+010.499999970e-010.           e+000.           e+000.           e+00
0.           e+000.199999996e-010.199999996e-010.203099990e+010.229000002e+00
0.149999997e-010.148999998e-010.156000003e+000.188999996e+000.201000005e+00
0.500000000e+030.203099990e+010.229000002e+000.149999997e-010.148999998e-01
0.156000003e+000.188999996e+000.201000005e+000.500000000e+030.203099990e+01
0.229000002e+000.149999997e-010.148999998e-010.156000003e+000.188999996e+00
0.201000005e+000.           e+000.156000000e+040.114200001e+020.114099998e+02
0.113999996e+020.607499981e+010.617000008e+010.663399982e+010.499999970e-01
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.144800006e-040.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+000.           e+00
0.           e+000.           e+000.           e+000.           e+00
0.200000000e+010.499999970e-010.           e+000.           e+000.           e+00
0.           e+000.199999996e-010.199999996e-010.203099990e+010.229000002e+00
0.149999997e-010.148999998e-010.156000003e+000.188999996e+000.201000005e+00
0.500000000e+030.203099990e+010.229000002e+000.149999997e-010.148999998e-01
0.156000003e+000.188999996e+000.201000005e+000.500000000e+030.203099990e+01
0.229000002e+000.149999997e-010.148999998e-010.156000003e+000.188999996e+00
0.201000005e+000.           e+000.156000000e+040.114200001e+020.114099998e+02
0.113999996e+020.607499981e+010.617000008e+010.663399982e+010.499999970e-01
0.300000000e+010.102700000e+040.385200000e+050.260700000e+070.186900005e+00
0.420599997e+000.293700004e+010.144800006e-040.           e+000.           e+00
```

Table 2.4.6 (cont'd)

```
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+00
elem,1
    1   10    1                                     1.00
    1    0    0    0    1    2    2    1    1    1    0    1
0.          e+000.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    2    0    0    0    2    3    2    1    1    1    0    1
0.549000025e+000.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    3    0    0    0    3    4    2    1    1    1    0    1
0.109800005e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    4    0    0    0    4    5    2    1    1    1    0    1
0.164699996e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    5    0    0    0    5    6    2    1    1    1    0    1
0.219600010e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    6    0    0    0    6    7    2    1    1    1    0    1
0.274500012e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    7    0    0    0    7    8    2    1    1    1    0    1
0.329399991e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    8    0    0    0    8    9    2    1    1    1    0    1
0.384299994e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
    9    0    0    0    9   10    2    1    1    1    0    1
0.422900009e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00
   10    0    0    0   10   11    2    1    1    1    0    1
0.461450005e+010.100000000e+010.          e+000.          e+000.          e+00
0.          e+00

nord,opto
prof
end
fini
mode
tree,main
fini
mbui
new,main
pmas,13
    10 0.51755e-08 0.51755e-08 0.51755e-08 0.     e+00 0.     e+00 0.     e+0000
    20 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    30 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    40 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    50 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    60 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    70 0.10351e-07 0.10351e-07 0.10351e-07 0.     e+00 0.     e+00 0.     e+0000
    80 0.88143e-08 0.88143e-08 0.88143e-08 0.     e+00 0.     e+00 0.     e+0000
    90 0.36389e-08 0.36389e-08 0.36389e-08 0.     e+00 0.     e+00 0.     e+0000
    90 0.36341e-08 0.36341e-08 0.36341e-08 0.     e+00 0.     e+00 0.     e+0000
```

Table 2.4.6 (cont'd)

```
   100 0.72683e-08 0.72683e-08 0.72683e-08 0.         e+00 0.         e+00 0.         e+0000
   110 0.36341e-08 0.36341e-08 0.36341e-08 0.         e+00 0.         e+00 0.         e+0000
   110 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+0000
end
fini
ptre
newr,recl,pair,2,100
(2e15.7)
   0.         e+00  0.         e+00
   0.         e+00  0.1000000e+02
fini
thou,249
          2         110     3     1     0     0
ndyn
velo,1,1
 main    11
     1  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     2  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     3  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     4  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     5  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     6  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     7  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     8  0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00 0.         e+00
     9  0.         e+00-0.50200e+04 0.         e+00 0.         e+00 0.         e+00 0.         e+00
    10  0.         e+00-0.50200e+04 0.         e+00 0.         e+00 0.         e+00 0.         e+00
    11  0.         e+00-0.50200e+04 0.         e+00 0.         e+00 0.         e+00 0.         e+00
mass
dylo,1,1
recl      2     0.      1.000          1
     1
timo,rslt,1,0.1000e+01
auto,defl
inte,newm,0.2000e-05,0.e+00,0.e+00,0.1000e+00
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,200
zero,ltme
step
unba
auto,init
loop,20
stif
auto,load
load
disp
kinr,10
elmr,9,10
auto,merr,0.1000e+00,0.5000e+00
if,3,3,1,1
entr,1
auto,fact
kinr,1
```

Table 2.4.6 (cont'd)

```
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.1000e-05,0.1000e-03,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,8
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,irsb
unba,chec,stop,0.5000e+00,0.1000e+02
if,3,3,9,9
entr,9
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.1500e-02
if,5,8,8,0
entr,8
cont
fini
stop
```

D2.5 IMPULSIVELY LOADED RING

D2.5.1 PURPOSE

This example tests the BEAM and SHELL elements, by comparison with test results and previously reported analysis results. Large displacement and strain rate effects are considered, and the initial velocity loading option is tested.

D2.5.2 DESCRIPTION

Tests and analyses of a free ring under impulse (explosive) loading have been reported by Witmer et al [2.5.1]. Analyses of the same ring have been reported by Hibbitt and Karlsson [2.5.2].

The dimensions of the ring are shown in Fig. 2.5.1. Initial velocities as shown were produced by an explosive charge.

The beam was made of 6061-T6 aluminum alloy. The static Young's modulus reported in [2.5.2] was 10500 ksi (7.239×10^{10} N/m^2). For analysis, a bilinear stress-strain relationship was assumed in [2.5.2], with a yield stress of 42.8 ksi (2.951×10^8 N/m^2) and a strain hardening modulus of 78.7 ksi (5.426×10^8 N/m^2). These values were used for the WIPS analysis.

For the analyses in both [2.5.1] and [2.5.2], high strain rates were assumed to increase the yield stress according to the equation:

$$\sigma_y - \sigma_o = \sigma_o (|\dot{\epsilon}|/6500)^{0.25} \tag{2.5.1}$$

in which $\dot{\epsilon}$ = extensional strain rate; σ_o = static yield stress; and σ_y = dynamic yield stress. The trilinear approximation used for the WIPS analysis is shown in Table 2.5.1.

WIPS analyses were performed as follows:

(1) Eighteen BEAM elements in half ring, no strain rate effect.

(2) Eighteen BEAM elements in half ring, with strain rate effect.

(3) Eighteen SHELL elements in half ring, no strain rate effect, 5 integration points through thickness.

(4) Eighteen SHELL elements in half ring, with strain rate effect, 5 integration points through thickness.

D2.5.3 WIPS ANALYSIS MODEL

D2.5.3.1 Geometry and Loading

The nodes and initial velocities for the BEAM model are shown in Fig. 2.5.1. The geometry and velocities for the SHELL model were essentially the same, but more nodes are needed to define the shell model (4 nodes, 2 each on the middle and outer surfaces, at each nodal cross section).

Only motion in the XY plane was permitted for the BEAM model, and only one-half of the ring was analyzed. Symmetry was similarly considered for the shell model. The geometry of the BEAM model was generated using the WIPS input modules. However, the geometry for the SHELL model could not be generated in this way, and it was necessary to set up the DATA file by hand.

D2.5.3.2 BEAM Element Properties

For the assumed elastic-strain-hardening material, force-extension and moment-curvature relationships were calculated for the BEAM element cross section. The force-extension relationship has the same shape as the stress-strain curve, whereas the moment-curvature relationship is curvilinear. The two relationships were approximated using four linear segments each, as shown in Tables 2.5.2 and 2.5.3.

The procedure for determining strain rate properties for BEAM elements is described in the Theory Manual, Section B4.4.2. With this procedure and the dashpot stiffnesses shown in Table 2.5.1, the dimensionless properties shown in Table 2.5.4 were calculated.

D2.5.3.3 SHELL Element Properties

The shell material was specified to be bilinear, as indicated in Section D2.5.2, with strain rate effects as in Table 2.5.1. Five Gauss quadrature points were specified through the thickness in each element.

D2.5.3.4 Analysis Control Parameters

The Newmark solution scheme was used, with the following parameters.

Initial time step = 2×10^{-6} sec.

Minimum time step = 1×10^{-6} sec.

Maximum time step = 1×10^{-4} sec.

Initial $\beta/\Delta t$ = 0.1

Lower midstep tolerance = 0.5 k

Lower midstep tolerance = 2.5 k

D2.5.3.5 WIPS Input

Table 2.5.5 contains the WIPSLOG listing up to the WIPS-DATA phase for the BEAM model with strain rate effects. Table 2.5.6 is a listing of the DATA file for the corresponding analysis. Table 2.5.7 is a listing of the DATA file for the SHELL model with strain rate effects. The WIPSLOG and DATA file listings for the cases with no strain rate were similar.

The initial velocities for the BEAM model were not specified in the WIPS-MODL phase but instead were added by editing the DATA file. This was simpler than using the WIPS-MODL velocity option.

D2.5.4 RESULTS

D2.5.4.1 BEAM Model

For the BEAM model, Fig. 2.5.2 shows the variation with time of the computed diameter change for the first 2 milliseconds of response, plus analytical and experimental results as reported in [2.5.2].

Figure 2.5.3 shows the undeformed configuration and the computed deformed shapes at two different times, for the cases with and without strain rate effects (the shapes were drawn using WIPS-RSLT, then cut and pasted together). Analytical and experimental deformed shapes at similar times have been reported in [2.5.2]. Table 2.5.8 shows the value of a key parameter for the deformed shapes, namely the ratio of vertical to horizontal diameter.

Figure 2.5.3 and Table 2.5.8 indicate that when strain rate effects are included, the WIPS analysis and the analysis reported in [2.5.2] agree well with the experimental results up to the time of maximum diameter change at approximately 1.4 milliseconds. Beyond that time the WIPS analysis predicts a slower rate of diameter increase (i.e., a less rapid rebound) than either the experiment or the analysis of [2.5.2].

D2.5.4.2 SHELL Model

For the SHELL model, Fig. 2.5.4 shows the WIPS results for the first 2 milliseconds of response, plus analytical and experimental results as reported in [2.5.2]. The analysis in [2.5.2] used a beam type of model, with monitoring of stress-strain behavior at seven points through the beam depth. This model is closer to the WIPS SHELL model than to the BEAM model. Table 2.5.9 compares the ratio of vertical to horizontal diameter for the analytical and experimental deformed shapes.

Figure 2.5.4 shows that the WIPS analysis including strain rate effects follows the experimental results closely up to approximately 1.1 milliseconds. Beyond that time, however, the WIPS analysis predicts much more rapid rebound than was observed in the experiment.

Figure 2.5.4 and Table 2.5.9 again show that when strain rate effects are ignored the analytical and experimental results differ substantially. In contrast with the BEAM model, however, the WIPS analysis results are in quite close agreement with the analysis results from [2.5.2].

D2.5.5 CONCLUSION

When strain rate effects are considered, the BEAM and SHELL models gave similar results up to a time of 1.1 milliseconds, and predicted maximum diameter changes which were close to those observed in the experiment. Beyond this, however, the results for this example are not encouraging, for the following reasons.

(1) The magnitude of the strain rate effect was much larger for the SHELL model than for the BEAM model.

(2) The SHELL model with strain rate effects showed a much more rapid rebound than was observed in the experiment and computed in the analysis of [2.5.2.].

For the BEAM element, this example involves much higher strain rates and much larger deformations than will be present in typical pipe whip analyses. Because of this, it does not follow that the BEAM element is unsatisfactory for pipe whip analyses. The results do, however, suggest that before it is used for production analysis the BEAM element should be tested on additional examples which are more typical of pipe whip configurations.

For the SHELL element, the strain rates are still higher than would be expected in pipe whip applications, but are not completely unreasonable. This is because the SHELL element is intended primarily for analysis of pipe-to-pipe and pipe-to-wall impact. In such cases the impact velocity could approach the order of magnitude of the initial velocity in this example. The behavior of the SHELL element should thus be investigated in more detail before production impact analyses are performed.

It should be noted that analyses of shells with impact, large displacements, inelastic behavior and strain rate dependence are extremely complex by any standards. Any analytical studies of pipe-to-pipe or pipe-to-wall impact will be very expensive and will require very careful study to ensure that correct results are obtained. A part of such study should involve more detailed checking of the SHELL element.

D2.5.6 REFERENCES

2.5.1 Witmer, E. A., Balmer, H. A., Leech, J. W., and Pian, T.H.H., "Large Dynamic Deformations of Beams, Rings, Plates, and Shells," *AIAA Journal*, Vol. 1, No. 8, pp. 1848-1857, 1963.

2.5.2 Hibbitt and Karlsson, "Analysis of Pipe Whip," Report No. EPRI NP-1208, Electric Power Research Institute, 1979.

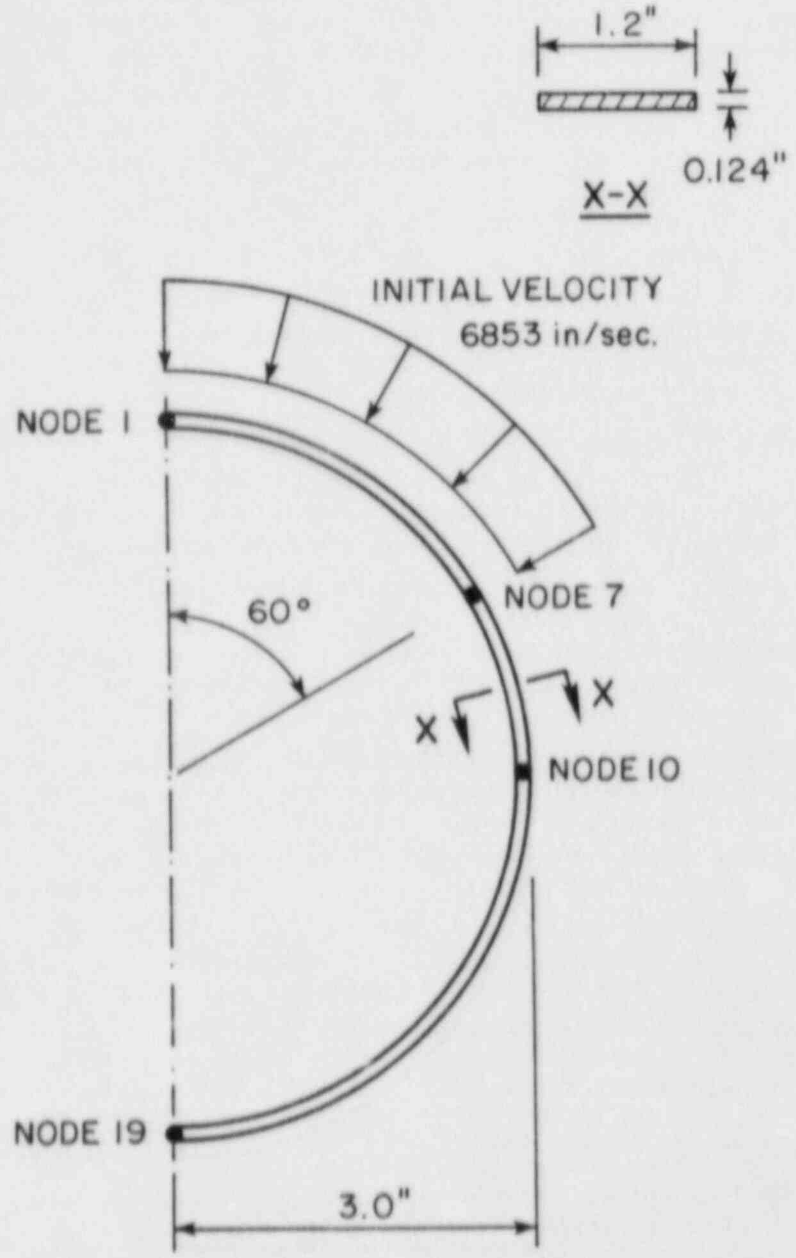

FIG. 2.5.1 RING WITH IMPULSIVE LOADING. DIMENSIONS AND INITIAL VELOCITY.

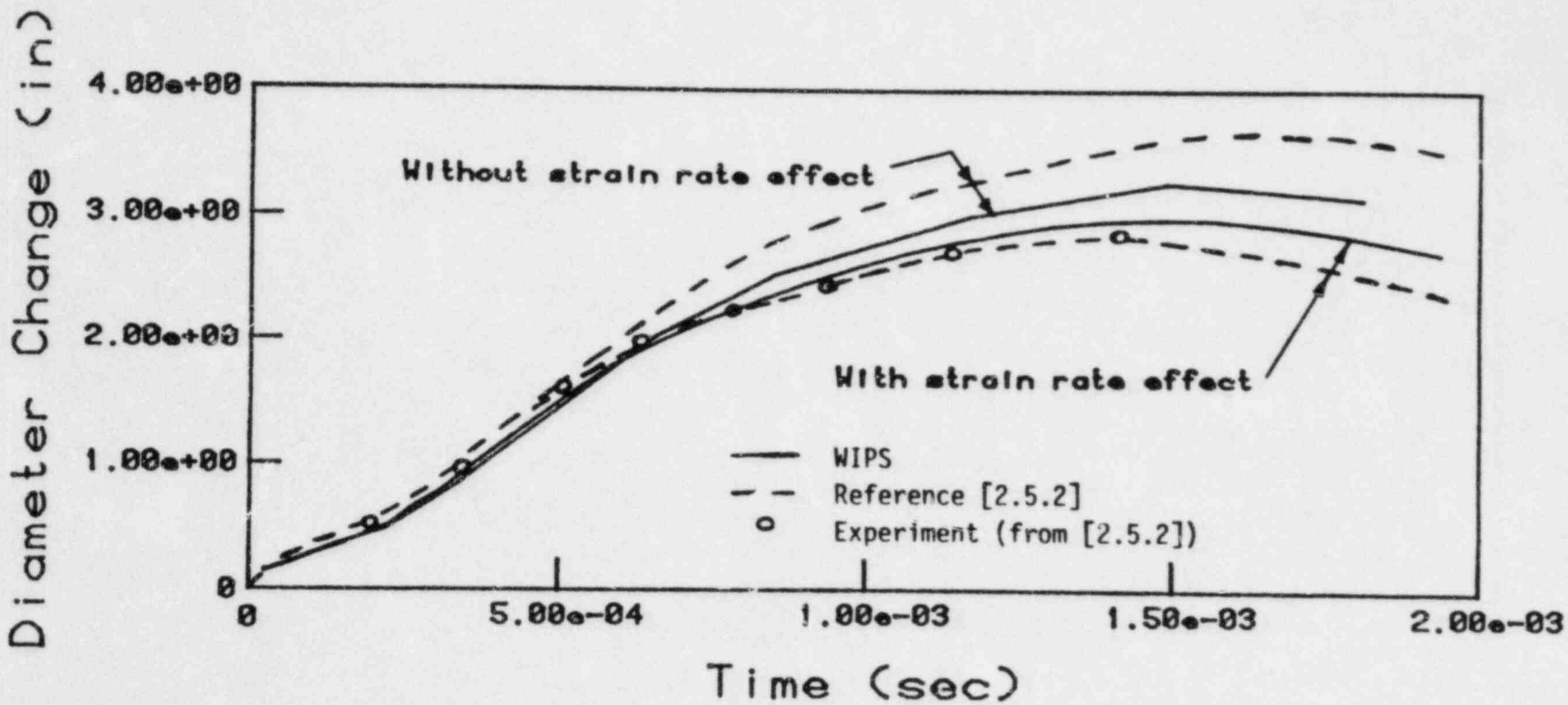

FIG. 2.5.2 CHANGE IN VERTICAL DIAMETER. BEAM MODEL.

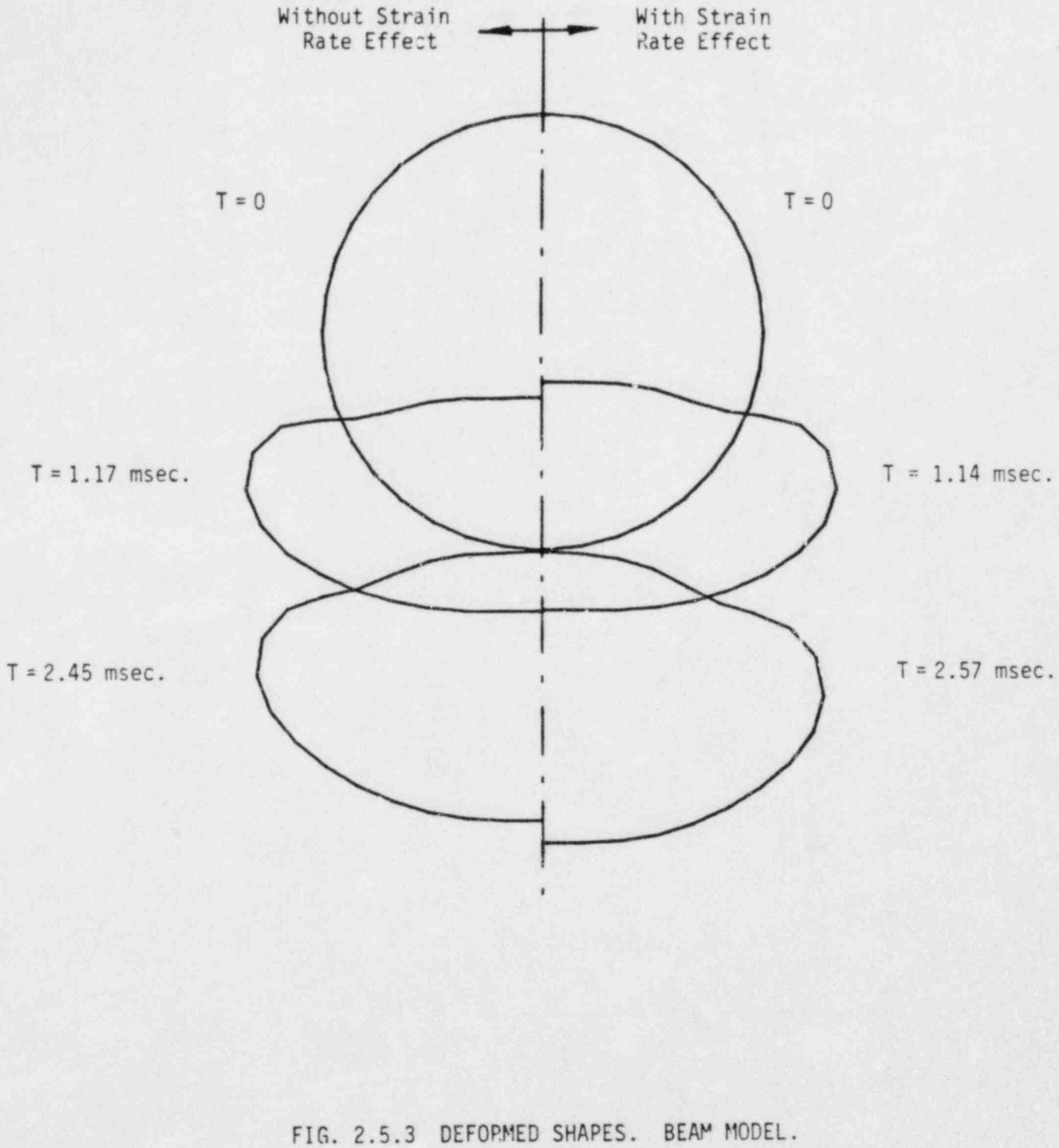

FIG. 2.5.3 DEFORMED SHAPES. BEAM MODEL.

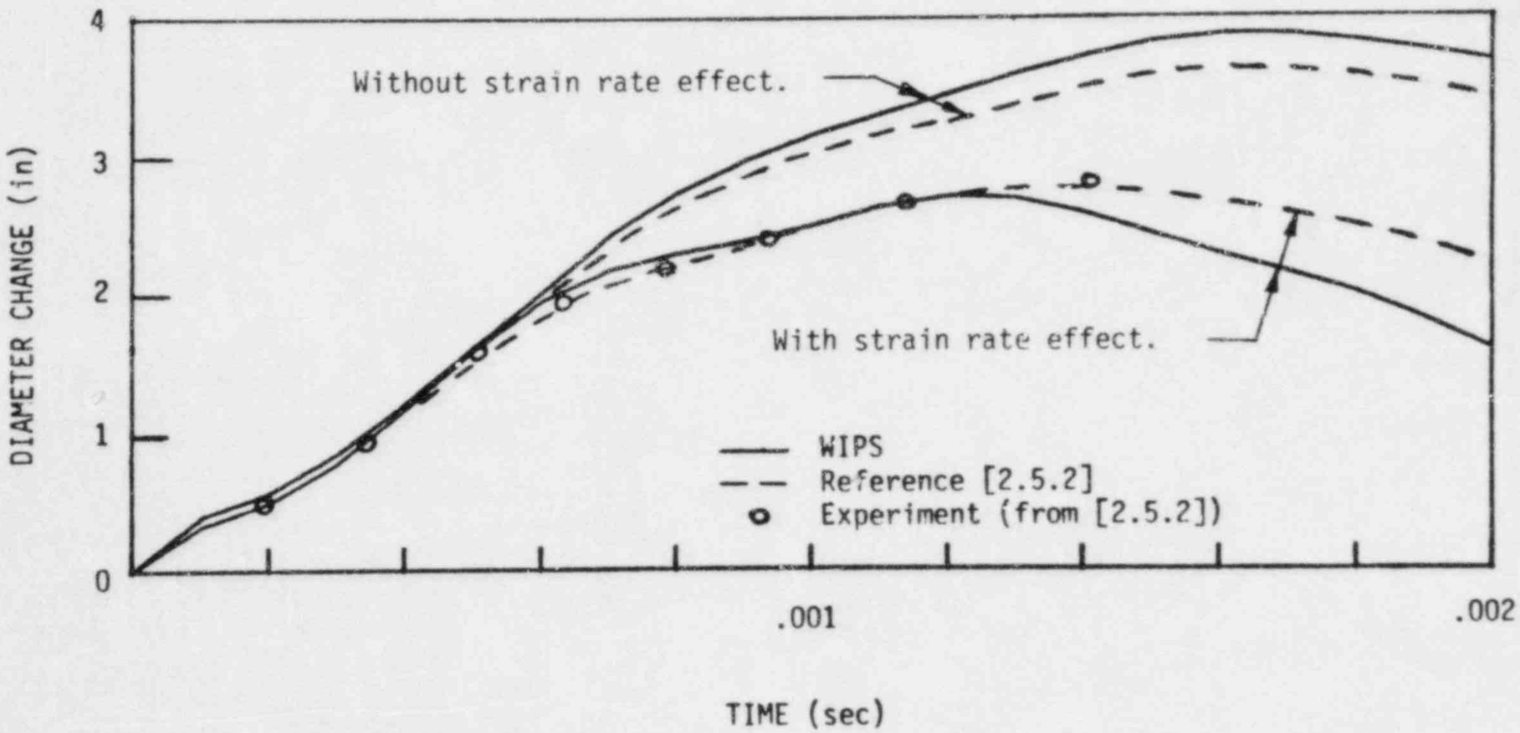

FIG. 2.5.4 CHANGE IN VERTICAL DIAMETER. SHELL MODEL.

TABLE 2.5.1 - TRILINEAR APPROXIMATION FOR STRAIN RATE EFFECT		
Stress Increase (ksi)	Strain Rate (sec^{-1})	Dashpot Stiffness ($k.sec/in^2$)
0	0	2.0
8	4	0.0685
18	150	0.0108

TABLE 2.5.2 - STATIC FORCE-EXTENSION RELATIONSHIP FOR BEAM ELEMENT		
Force (k)	Axial Strain	Stiffness (k)
0	0	1560.00
6.420	0.00412	11.81
6.503	0.01121	11.80
6.987	0.05226	11.79

TABLE 2.5.3 - STATIC MOMENT-CURVATURE RELATIONSHIP FOR BEAM ELEMENT		
Moment (k.in)	Curvature (in^{-1})	Stiffness ($k.in^2$)
0	0	2.0310
0.165	0.0812	0.2500
0.200	0.2212	0.0156
0.2125	1.0225	0.0155

TABLE 2.5.4 - DIMENSIONLESS STRAIN RATE RELATIONSHIP FOR BEAM ELEMENT	
Strength Increase Factor	Deformation Rate Factor
0	0
0.1869	972
0.4206	36450
2.9370	2.466×10^6

TABLE 2.5.5 - WIPSLOG LISTING. ALL PHASES.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Ring with Initial Velocity.

NEXT WIPS-EXEC COMMAND : geom

 GEOM - SPECIFICATION OF SYSTEM GEOMETRY

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Specify new GEOM data

 START RUN NO.  1
 Enter c.p. data in sequence along run

   c.p. name and type : a
   coord option : di
   x,y,z : -1 2.9375
   Any changes? :

   c.p. name and type : 1
   no. of extra nodes :
   coord option : tn
 *** error - this option can be used only with tn points
   coord option :
   c.p., dx,dy,dz :
   offset point defaults to preceding c.p.
   Any changes? : y
   reenter data for this c.p.

   c.p. name and type : 1 tn
   no. of extra nodes :
   coord option : tn
   tn generated automatically
   Any changes? :

   c.p. name and type : ti1 ti
   bend radius : 2.9375
   coord option : di
   x,y,z : 2.9375 2.9375
   Any changes? :

   c.p. name and type : 10 tn
   no. of extra nodes : 9
   coord option : tn
   tn generated automatically
   Any changes? :

   c.p. name and type : ti2 ti
   bend radius : 2.9375
   coord option : di
   x,y,z : 2.9375 -2.9375
   Any changes? :
```

Table 2.5.5 (cont'd)

```
   c.p. name and type : 19 tn
   no. of extra nodes : 8
   coord option : tn
   tn generated automatically
   Any changes? :

   c.p. name and type : b
   no. of extra nodes :
   coord option : di
   x,y,z : -1 -2.9375
   Any changes? :

   c.p. name and type :
 Last c.p. in this run? : y
 Display GEOM data for this run? : y

 GEOM DATA FOR RUN

 run   c.p.   c.p.    bend    xtra   coord   c.p.   c.p.?          coordinate  data
 no.   name   type   radius   nods    opt     i      j  ?     x,dx,p        y,dy         z,dz

   1
       a                        0      di                     -1.000       2.938       0.
       1      tn                0      tn                      0.          0.          0.
       ti1    ti     2.938      0      di                      2.938       2.938       0.
       10     tn                9      tn                      0.          0.          0.
       ti2    ti     2.938      0      di                      2.939      -2.938       0.
       19     tn                9      tn                      0.          0.          0.
       b                        0      di                     -1.000      -2.938       0.
 END OF DATA

 START RUN NO.  2
 Enter c.p. data in sequence along run

   c.p. name and type :
 Last run? : y

 Display new GEOM data? :
 Write in session log? :

 Modify GEOM data? :

 Save current GEOM data? : y
 Comment for file catalog :
 GEOM DATA SAVED. FILE NAME = GEOM0101

 Produce COOR data? : y

 Display COOR data? : y


 COOR DATA

  run     c.p.   c.p.     bend    node          x          y  ?        z
  no.     name   type    radius   no.         coord      coord?      coord
```

Table 2.5.5 (cont'd)

```
 1
        a                              1      -1.000     2.938     0.
        1       tn                     2       0.        2.938     0.
        ti1     ti      2.938                  2.938     2.938     0.
                        center                 0.        0.        0.
                                       3       0.510     2.893     0.
                                       4       1.005     2.760     0.
                                       5       1.469     2.544     0.
                                       6       1.888     2.250     0.
                                       7       2.250     1.888     0.
                                       8       2.544     1.469     0.
   Hit RETURN for more
                                       9       2.760     1.005     0.
                                      10       2.893     0.510     0.
        10      tn                    11       2.938     0.        0.
        ti2     ti      2.938                  2.938    -2.938     0.
                        center                 0.        0.        0.
                                      12       2.893    -0.510     0.
                                      13       2.760    -1.005     0.
                                      14       2.544    -1.469     0.
                                      15       2.250    -1.888     0.
                                      16       1.888    -2.250     0.
   Hit RETURN for more
                                      17       1.469    -2.544     0.
                                      18       1.005    -2.760     0.
                                      19       0.510    -2.893     0.
        19      tn                    20       0.       -2.938     0.
        b                             21      -1.000    -2.938     0.
   END OF DATA

   Plot geometry? :

   Modify GEOM data? :

   DATA COMPLETE FOR THIS SESSION
   Save final GEOM data? : y
   Comment for file catalog : Ring. C.p. a-1-19-b, nodes 1-21.
   GEOM DATA SAVED. FILE NAME = GEOM0101
   Save COOR data? : y
   Comment for file catalog : From GEOM0101
   COOR DATA SAVED. FILE NAME = COOR0101

   End of this GEOM session

  EXEC - WIPS EXECUTIVE

  NEXT WIPS-EXEC COMMAND : beam


   BEAM - SPECIFICATION OF BEAM PROPERTIES

   Define units
     Length (ft,in,m,mm) : in
     Force (k,lb,kgf,kN) : k

   Start new BEAM file
```

Table 2.5.5 (cont'd)

```
Specify a new property set? : y

SET NO. =  1
Property set description : 1.2*0.125, 40.5ksi, no strain rate.

Yield surface type (1-4) (dflt=1) : 2
Weight per unit length : 1.448e-5

Elastic stiffnesses
  EAx,GAy,GAz : 1560 500 500
  GJx,EIy,EIz : 2.031 2.031 2.031
Strengths at first yield
  Fx,Mxx,Myy,Mzz : 6.075 .156 .156 .156
Stiffnesses after first yield
  EA,GJx,EIy,EIz : 11.42 .229 .229 .229
Strengths at second yield
  Fx,Mxx,Myy,Mzz : 6.17 .189 .189 .189
Stiffnesses after second yield
  EA,GJx,EIy,EIz : 11.41 .0149 .0149 .0149
Strengths at third yield
  Fx,Mxx,Myy,Mzz : 6.634 .201 .201 .201
Stiffnesses after third yield
  EA,GJx,EIy,EIz : 11.4 .01485 .01485 .01485
Strain rate factors (0-3, dflt=none) :
No strain rate effect
Use default tolerances? : y

Any errors? :

This set added to BEAM file

Specify a new property set? : y

SET NO. =  2
Property set description : 1.2*0.125, 40.5ksi, with strain rate.

Yield surface type (1-4) (dflt=1) : 2
Weight per unit length : 1.448e-5

Elastic stiffnesses
  EAx,GAy,GAz : 1560 500 500
  GJx,EIy,EIz : 2.031 2.031 2.031
Strengths at first yield
  Fx,Mxx,Myy,Mzz : 6.075 .156 .156 .156
Stiffnesses after first yield
  EA,GJx,EIy,EIz : 11.42 .229 .229 .229
Strengths at second yield
  Fx,Mxx,Myy,Mzz : 6.17 .189 .189 .189
Stiffnesses after second yield
  EA,GJx,EIy,EIz : 11.41 .0149 .0149 .0149
Strengths at third yield
  Fx,Mxx,Myy,Mzz : 6.634 .201 .201 .201
Stiffnesses after third yield
  EA,GJx,EIy,EIz : 11.4 .01485 .01485 .01485
Strain rate factors (0-3, dflt=none) : 1027 38520 2.607e6
```

<u>Table 2.5.5</u> (cont'd)

```
Corresponding strength factors : .1869 .4205 2.937
Use default tolerances? : y

Any errors? :

This set added to BEAM file

Specify a new property set? :

No. of property sets in BEAM file =  2

Display property set descriptions? : y

BEAM PROPERTY DESCRIPTIONS
  Set No.   Description
     1      1.2*0.125, 40.5ksi, no strain rate.
     2      1.2*0.125, 40.5ksi, with strain rate.

Display new property set data? : y

BEAM PROPERTY DATA

SET NO.  1.  1.2*0.125, 40.5ksi, no strain rate.

 Data Type                 Data 1      Data 2      Data 3      Data 4

 Unit weight            0.1448e-04
 Elastic EAx,GAy,GAz    0.1550e+04 0.5000e+03 0.5000e+03
         GJx,EIy,EIz    0.2031e+01 0.2031e+01 0.2031e+01
 First yield
       Fx,Mxx,Myy,Mzz   0.6075e+01 0.1560e+00 0.1560e+00 0.1560e+00
       EA,GJx,EIy,EIz   0.1142e+02 0.2290e+00 0.2290e+00 0.2290e+00
 Second yield
       Fx,Mxx,Myy,Mzz   0.5170e+01 0.1890e+00 0.1890e+00 0.1890e+00
       EA,GJx,EIy,EIz   0.1141e+02 0.1490e-01 0.1490e-01 0.1490e-01
 Third yield
       Fx,Mxx,Myy,Mzz   0.5534e+01 0.2010e+00 0.2010e+00 0.2010e+00
       EA,GJx,EIy,EIz   0.1140e+02 0.1485e-01 0.1485e-01 0.1485e-01
 Stiffness tolerance    0.5000e-01
 Yield tolerance        0.2000e-01
 Unloading tolerance    0.2000e-01
Hit RETURN for next set

SET NO.  2.  1.2*0.125, 40.5ksi, with strain rate.

 Data Type                 Data 1      Data 2      Data 3      Data 4

 Unit weight            0.1448e-04
 Elastic EAx,GAy,GAz    0.1550e+04 0.5000e+03 0.5000e+03
         GJx,EIy,EIz    0.2031e+01 0.2031e+01 0.2031e+01
 First yield
       Fx,Mxx,Myy,Mzz   0.6075e+01 0.1560e+00 0.1560e+00 0.1560e+00
       EA,GJx,EIy,EIz   0.1142e+02 0.2290e+00 0.2290e+00 0.2290e+00
 Second yield
       Fx,Mxx,Myy,Mzz   0.5170e+01 0.1890e+00 0.1890e+00 0.1890e+00
       EA,GJx,EIy,EIz   0.1141e+02 0.1490e-01 0.1490e-01 0.1490e-01
```

Table 2.5.5 (cont'd)

```
 Third yield
        Fx,Mxx,Myy,Mzz  0.6534e+01 0.2010e+00 0.2010e+00 0.2010e+00
        EA,GJx,EIy,EIz  0.1140e+02 0.1485e-01 0.1485e-01 0.1485e-01
  Strain rate factors   0.1027e+04 0.3852e+05 0.2607e+07
  Strength factors      0.1359e+00 0.4206e+00 0.2937e+01
  Stiffness tolerance   0.5000e-01
  Yield tolerance       0.2000e-01
  Unloading tolerance   0.2000e-01
  Str. rate tolerance   0.5000e-01
 Hit RETURN for next set
 END OF DATA

 Display all property set data? :
 Write in session log? :

 New BEAM file created
 Comment for file catalog : 2 sets

 End this BEAM session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

 FREC - SPECIFY DYNAMIC FORCE RECORDS

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Start new FREC file

 Specify a new record ? : y

 RECORD NO.  1

 Record name (4 characters) : rec1
 Description (max. 40 char.) : Dummy zero record

 Enter Time-Force pairs
 First pair automatically set to 0,0
   Pair no.  2 : 10 0.
   Pair no.  3 :
 Last pair? : y
 Any errors ? :

 Specify a new record ? :

 Display any records ? : y
 Record number (dflt=all) :

 RECORD NO.  1.  Name = rec1
       Time          Force
    0.          0.     e+00
   10.00000     0.     e+00
 END OF RECORD
```

Table 2.5.5 (cont'd)

```
Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog : 1 record

NOTE: BOUNDARY CONDITION ERRORS WERE MADE IN THE FIRST MODL
      AND DATA RUNS. THE CORRESPONDING PART OF THE WIPSLOG
      FILE HAS BEEN REMOVED.

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl


MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of COOR file : 1

Available element property sets
  Type     No. of Sets
  beam          2
Available substructure property sets
  None

DEFINE MODEL IN SEGMENTS

SEGMENT NO.   1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? :
Displacement plane (xy,yz or zx) : xy
Any substructures in this segment? :
Boundary condition code for first c.p. : 101111

Specify c.p.name + elem type + optional data
 1: 19 beam pr=1 ld=y th=no
 2: 19 zero bc=101111
 3:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem     optn      data        optn      data        optn      data
  1
                 bcon   101111
  19    beam
                 prop        1
```

Table 2.5.5 (cont'd)

```
                    locl      +          ldis       yes        this       no
                    wfac    1.000
   19    zero
                    bcon   101111
 Any changes? :

 SEGMENT NO.   2

 Pipe run no. :
 Last segment? : y

 Any external substructures? :

 Display commands for all segments? :
 Write in session log? :

 Produce MODL file? : y
 Wait while data is processed

 Specify initial velocities ? :
 Comment for file catalog : No strain rate. Velocities to be added.

 MODL file saved. File name = MODL0102
 End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl


 MODL - SPECIFICATION OF ANALYSIS MODEL

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Sequence no. of COOR file : 1

 Available element property sets
   Type     No. of Sets
   beam          2
 Available substructure property sets
   None

 DEFINE MODEL IN SEGMENTS

 SEGMENT NO.   1

 Pipe run no. : 1
 First c.p. of segment : 1
 Full 3D motion ? :
 Displacement plane (xy,yz or zx) : xy
 Any substructures in this segment? :
 Boundary condition code for first c.p. : 101111

 Specify c.p.name + elem type + optional data
```

Table 2.5.5 (cont'd)

```
 1: 19 beam pr=2 ld=y th=no
 2: 19 zero bc=101111
 3:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem    optn      data       optn     data       optn     data
  1
                bcon    101111
  19    beam
                prop         2
                locl         +        ldis      yes        this      no
                wfac     1.000
  19    zero
                bcon    101111
Any changes? :

SEGMENT NO.   2

Pipe run no. :
Last segment? : y

Any external substructures? :

Display commands for all segments? :
Write in session log? :

Produce MODL file? : y
Wait while data is processed

Specify initial velocities ? :
Comment for file catalog : With strain rate. Velocities to be added.

MODL file saved. File name = MODL0103
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data

DATA - SET UP WIPS-ANAL INPUT DATA

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of MODL file : 2

Problem description (4 lines)
 Line 1 : Ring with Initial Velocity. No strain rate.        GHP 12/82.
 Line 2 :
 Line 3 :
```

Table 2.5.5 (cont'd)

```
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed

Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 1
  Force direction (x,y,z or follower) : y
  Scale factor (+,- controls direction) : 1
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : 2e-6 1e-4 1e-6
Max steps + max total time : 2000 2.9e-3
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 10
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : No strain rate.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0102

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data


DATA - SET UP WIPS-ANAL INPUT DATA

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of MODL file : 3

Problem description (4 lines)
 Line 1 : Ring with Initial Velocity. With Strain Rate.        GHP 12/82
 Line 2 :
 Line 3 :
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed
```

Table 2.5.5 (cont'd)

```
Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 1
  Force direction (x,y,z or follower) : y
  Scale factor (+,- controls direction) : 1
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : y

Time steps : initial + max + min : 2e-6 1e-4 1e-6
Max steps + max total time : 2000 2.9e-3
Error tolerances : upper + lower : .5 .1

Results output intervals
  Max. no. of steps : 10
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : with strain rate.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0103

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
```

NOTE: THE INPUT DATA TO THIS POINT DOES NOT CONTAIN INITIAL VELOCITIES. THESE WERE ADDED "BY HAND" USING THE UNIX EDITOR.

TABLE 2.5.6 - DATA FILE LISTING. BEAM MODEL WITH STRAIN RATE EFFECTS.

```
  ECHJ0103  SLUG0103  RSLT0103
star,
gbui
new,main,nonl,cart,0
 substructure name = main
retn,20
     2  0.         e+00  0.2937500e+01  0.          e+00
     3  0.5100914e+00  0.2892873e+01  0.          e+00
     4  0.1004684e+01  0.2760347e+01  0.          e+00
     5  0.1469750e+01  0.2543950e+01  0.          e+00
     6  0.1888188e+01  0.2250255e+01  0.          e+00
     7  0.2250256e+01  0.1888189e+01  0.          e+00
     8  0.2543950e+01  0.1469750e+01  0.          e+00
     9  0.2760347e+01  0.1004684e+01  0.          e+00
    10  0.2892873e+01  0.5100913e+00  0.          e+00
    11  0.2937500e+01  0.         e+00  0.          e+00
    12  0.2892873e+01 -0.5100914e+00  0.          e+00
    13  0.2760347e+01 -0.1004684e+01  0.          e+00
    14  0.2543950e+01 -0.1469750e+01  0.          e+00
    15  0.2250255e+01 -0.1888188e+01  0.          e+00
    16  0.1888189e+01 -0.2250256e+01  0.          e+00
    17  0.1469750e+01 -0.2543950e+01  0.          e+00
    18  0.1004684e+01 -0.2760347e+01  0.          e+00
    19  0.5100913e+00 -0.2892873e+01  0.          e+00
    20  0.         e+00 -0.2937500e+01  0.          e+00
 9999
boun,20
     2                          101111
     3                            1110
     4                            1110
     5                            1110
     6                            1110
     7                            1110
     8                            1110
     9                            1110
    10                            1110
    11                            1110
    12                            1110
    13                            1110
    14                            1110
    15                            1110
    16                            1110
    17                            1110
    18                            1110
    19                            1110
    20                          101111
 9999                           111111
end,0
matl,2,64
0.200000000e+010.499999970e-010.          e+000.          e+000.          e+00
0.          e+000.199999996e-010.199999996e-010.203099990e+010.229000002e+00
0.148999998e-010.148499999e-010.156000003e+000.188999996e+000.201000005e+00
0.500000000e+030.203099990e+010.229000002e+000.148999998e-010.148499999e-01
0.156000003e+000.188999996e+000.201000005e+000.500000000e+030.203099990e+01
0.229000002e+000.148999998e-010.148499999e-010.156000003e+000.188999996e+00
0.201000005e+000.          e+000.156000000e+040.114200001e+020.114099998e+02
```

Table 2.5.6 (cont'd)

```
0.11399996e+020.60749991e+010.61700008e+010.66339998e+010.49999970e-01
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.14480006e-040.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.20000000e+010.49999970e-010.            e+000.            e+00
0.            e+000.19999996e-010.19999996e-010.20309999e+010.22900002e+00
0.14899999e-010.14849999e-010.15600003e+000.18899999e+000.20100005e+00
0.50000000e+030.20309999e+010.22900002e+000.14899999e-010.14849999e-01
0.15600003e+000.18899996e+000.20100005e+000.50000000e+030.20309990e+01
0.22900002e+000.14899998e-010.14849999e-010.15600003e+000.18899996e+00
0.20100005e+000.            e+000.15600000e+040.11420001e+020.11409998e+02
0.11399996e+020.60749991e+010.61700008e+010.66339998e+010.49999970e-01
0.30000000e+010.10270000e+040.38520000e+050.26070000e+070.18690005e+00
0.42059999e+000.29370004e+010.14480006e-040.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
elem,1
     1    18     1                                           1.00
     1     0     0     0     2     3     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     2     0     0     0     3     4     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     3     0     0     0     4     5     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     4     0     0     0     5     6     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     5     0     0     0     6     7     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     6     0     0     0     7     8     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     7     0     0     0     8     9     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     8     0     0     0     9    10     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
     9     0     0     0    10    11     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
    10     0     0     0    11    12     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
    11     0     0     0    12    13     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+00
    12     0     0     0    13    14     2     1     0     0     1     1
0.            e+000.            e+000.            e+000.            e+000.            e+00
```

Table 2.5.6 (cont'd)

```
0.          e+00
   13    0    0    0   14   15    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00
   14    0    0    0   15   16    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00
   15    0    0    0   15   17    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00
   16    0    0    0   17   18    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00
   17    0    0    0   13   19    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00
   18    0    0    0   19   20    2    1    0    0    1    1
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+00

nord,opto
prof
end
fini
mode
tree,main
fini
mbji
new,main
pmas,20
     20 0.48270e-08 0.48270e-08 0.48270e-08 0.      e+00 0.      e+00 0.      e+0000
     30 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     40 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     50 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     60 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     70 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     80 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
     90 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    100 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    110 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    120 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    130 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    140 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    150 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    160 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    170 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    180 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    190 0.96541e-08 0.96541e-08 0.96541e-08 0.      e+00 0.      e+00 0.      e+0000
    200 0.48270e-08 0.48270e-08 0.48270e-08 0.      e+00 0.      e+00 0.      e+0000
    200 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+0000
end
fini
ptre
newr,recl,pair,2,100
(2e15.7)
  0.        e+00  0.        e+00
```

Table 2.5.6 (cont'd)

```
  0.        e+00  0.1000000e+02
fini
thou,181
        2         182    3    1    0    0
ndyn
velo,1,1
 main    7
    2 0.        e+00-.685300e+040.        e+000.        e+000.        e+000.        e+00
    3 -.119001e+04-.674899e+040.        e+000.        e+000.        e+000.        e+00
    4 -.234336e+04-.643971e+040.        e+000.        e+000.        e+000.        e+00
    5 -.342650e+04-.593487e+040.        e+000.        e+000.        e+000.        e+00
    6 -.440502e+04-.524970e+040.        e+000.        e+000.        e+000.        e+00
    7 -.524970e+04-.440502e+040.        e+000.        e+000.        e+000.        e+00
    8 -.419659e+04-.242290e+040.        e+000.        e+000.        e+000.
mass
dylo,1,1
recl     2    0.       1.00         1
    2
timo,rslt,10,0.1000e+01
auto,defi
inte,newm,0.2000e-05,0.e+00,0.e+00,0.1000e+00
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,2000
zero,ltme
step
unba
auto,init
loop,20
stif
auto,load
load
disp
kinr,10
elmr,9,10
auto,nerr,0.1000e+00,0.5000e+00
if,3,3,1,1
entr,1
auto,fact
kinr,1
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.1000e-05,0.1000e-03,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
entr,6
```

Table 2.5.6 (cont'd)

```
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,3
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zerc,irsb
unpa
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.2400e-02
if,5,3,8,0
entr,3
cont
fini
stop
DATA0103
```

TABLE 2.5.7 - DATA FILE LISTING. SHELL MODEL WITH STRAIN RATE EFFECTS.

```
  ECHOSPOO  SLOGSROO  RSLTSROO  PAUSSROO  PAUZSROO
star,paus
qbui
new,ring,nonl,cart,0,100,100
       shell element example - free ring ... rate dependent matl
refn,76
    10.            e+000.293800000e+010.            e+00
    20.            e+000.293800000e+01-.600000000e+00
    30.            e+000.300000000  01-.600000000e+00
    40.            e+000.300000000e+010.            e+00
    50.510178346e+000.289336518e+010.            e+00
    60.510178346e+000.289336518e+01-.600000000e+00
    70.520944533e+000.295442326e+01-.600000000e+00
    80.520944533e+000.295442326e+010.            e+00
    90.100485518e+010.276081692e+010.            e+00
   100.100485518e+010.276081692e+01-.600000000e+00
   110.102606043e+010.281907786e+01-.600000000e+00
   120.102606043e+010.281907786e+010.            e+00
   130.146900000e+010.254438264e+010.            e+00
   140.146900000e+010.254438264e+01-.600000000e+00
   150.150000000e+010.259807621e+01-.600000000e+00
   160.150000000e+010.259807621e+010.            e+00
   170.188851000e+010.225063857e+010.            e+00
   180.188851000e+010.225063857e+01-.600000000e+00
   190.192836283e+010.229813333e+01-.600000000e+00
   200.192836283e+010.229813333e+010.            e+00
   210.225063857e+010.188851000e+010.            e+00
   220.225063857e+010.188851000e+01-.600000000e+00
   230.229813333e+010.192836283e+01-.600000000e+00
   240.229813333e+010.192836283e+010.            e+00
   250.254438264e+010.146900000e+010.            e+00
   260.254438264e+010.146900000e+01-.600000000e+00
   270.259807621e+010.150000000e+01-.600000000e+00
   280.259807621e+010.150000000e+010.            e+00
   290.276081692e+010.100485518e+010.            e+00
   300.276081692e+010.100485518e+01-.600000000e+00
   310.281907786e+010.102606043e+01-.600000000e+00
   320.281907786e+010.102606043e+010.            e+00
   330.289336518e+010.510178346e+000.            e+00
   340.289336518e+010.510178346e+00-.600000000e+00
   350.295442326e+010.520944533e+00-.600000000e+00
   360.295442326e+010.520944533e+000.            e+00
   370.293800000e+010.640459853d-160.            e+00
   380.293800000e+010.640459853d-16-.600000000e+00
   390.300000000e+010.653975343d-16-.600000000e+00
   400.300000000e+010.653975343d-160.            e+00
   410.289336518e+01-.510178346e+000.            e+00
   420.289336518e+01-.510178346e+00-.600000000e+00
   430.295442326e+01-.520944533e+00-.600000000e+00
   440.295442326e+01-.520944533e+000.            e+00
   450.276081692e+01-.100485518e+010.            e+00
   460.276081692e+01-.100485518e+01-.600000000e+00
   470.281907786e+01-.102606043e+01-.600000000e+00
   480.281907786e+01-.102606043e+010.            e+00
   490.254438264e+01-.146900000e+010.            e+00
   500.254438264e+01-.146900000e+01-.600000000e+00
```

Table 2.5.7 (cont'd)

```
      510.259807621e+01-.150000000e+01-.600000000e+00
      520.259807621e+01-.150000000e+010.           e+00
      530.225063857e+01-.188851000e+010.           e+00
      540.225063857e+01-.188851000e+01-.600000000e+00
      550.229813333e+01-.192836283e+01-.600000000e+00
      560.229813333e+01-.192836283e+010.           e+00
      570.188851000e+01-.225063857e+010.           e+00
      580.188851000e+01-.225063857e+01-.600000000e+00
      590.192836283e+01-.229813333e+01-.600000000e+00
      600.192836283e+01-.229813333e+010.           e+00
      610.146900000e+01-.254438264e+010.           e+00
      620.146900000e+01-.254438264e+01-.600000000e+00
      630.150000000e+01-.259807621e+01-.600000000e+00
      640.150000000e+01-.259807621e+010.           e+00
      650.100485518e+01-.276081692e+010.           e+00
      660.100485518e+01-.276081692e+01-.600000000e+00
      670.102606043e+01-.281907786e+01-.600000000e+00
      680.102606043e+01-.281907786e+010.           e+00
      690.510178346e+00-.289336518e+010.           e+00
      700.510178346e+00-.289336518e+01-.600000000e+00
      710.520944533e+00-.295442326e+01-.600000000e+00
      720.520944533e+00-.295442326e+010.           e+00
      730.128091971d-15-.293800000e+010.           e+00
      740.128091971d-15-.293800000e+01-.600000000e+00
      750.130795069d-15-.300000000e+01-.600000000e+00
      760.130795069d-15-.300000000e+010.           e+00
bcun,10
    5                           000111     4   69
    6                           001111     4   70
    7                           001111     4   71
    8                           000111     4   72
    1                           100111
    2                           101111
    3                           101111     1    4
   73                           100111
   74                           101111
   75                           101111     1   76
enod,1
matl,1,36
1.0, 3.0, 0.1, 0.1, 0.3
9.66e-5, 0.1, 0.0, 0.0, 10.4e+3
79.7, 0.0, 0.0, 0.0, 0.0
42.6, 1.0e+10, 0.0, 0.0, 0.0
0.0, 2.0, 6.849e-2, 1.0769e-2, 8.0
18.0, 1.0e+10, 0.0, 0.0, 1.0
0.0, 0.0, -1.0, 0.0, 0.0
0.0
elem,1
20,18,1,5,2,3,,,1.0
    1    0    0    0    1    5    6    2    4    8    7     31,1,1,5

    2    0    0    0    5    9   10    6    8   12   11     71,1,0,5

    3    0    0    0    9   13   14   10   12   16   15    111,1,0,5

    4    0    0    0   13   17   18   14   16   20   19    151,1,0,5
```

Table 2.5.7 (cont'd)

5	0	0	0	17	21	22	18	20	24	23	191,1,0,5
6	0	0	0	21	25	26	22	24	28	27	231,1,0,5
7	0	0	0	25	29	30	26	28	32	31	271,1,0,5
8	0	0	0	29	33	34	30	32	36	35	311,1,0,5
9	0	0	0	33	37	38	34	36	40	39	351,1,1,5
10	0	0	0	37	41	42	38	40	44	43	391,1,0,5
11	0	0	0	41	45	46	42	44	48	47	431,1,0,5
12	0	0	0	45	49	50	46	48	52	51	471,1,0,5
13	0	0	0	49	53	54	50	52	56	55	511,1,0,5
14	0	0	0	53	57	58	54	56	60	59	551,1,0,5
15	0	0	0	57	61	62	58	60	64	63	591,1,0,5
16	0	0	0	61	65	66	62	64	68	67	631,1,0,5
17	0	0	0	65	69	70	66	68	72	71	671,1,0,5
18	0	0	0	69	73	74	70	72	76	75	711,1,0,5

```
nord
prof
end
fini
mbui
new,ring
pmas,38
    1 2.4032e-9, 2.4032e-9, 2.4032e-9
    2 2.4032e-9, 2.4032e-9, 2.4032e-9
    5 4.8065e-9, 4.8065e-9, 4.8065e-9
    6 4.8065e-9, 4.8065e-9, 4.8065e-9
    9 4.8065e-9, 4.8065e-9, 4.8065e-9
   10 4.8065e-9, 4.8065e-9, 4.8065e-9
   13 4.8065e-9, 4.8065e-9, 4.8065e-9
   14 4.8065e-9, 4.8065e-9, 4.8065e-9
   17 4.8065e-9, 4.8065e-9, 4.8065e-9
   18 4.8065e-9, 4.8065e-9, 4.8065e-9
   21 4.8065e-9, 4.8065e-9, 4.8065e-9
   22 4.8065e-9, 4.8065e-9, 4.8065e-9
   25 4.8065e-9, 4.8065e-9, 4.8065e-9
   26 4.8065e-9, 4.8065e-9, 4.8065e-9
   29 4.8065e-9, 4.8065e-9, 4.8065e-9
   30 4.8065e-9, 4.8065e-9, 4.8065e-9
   33 4.8065e-9, 4.8065e-9, 4.8065e-9
   34 4.8065e-9, 4.8065e-9, 4.8065e-9
   37 4.8065e-9, 4.8065e-9, 4.8065e-9
```

Table 2.5.7 (cont'd)

```
e  38 4.8065e-9, 4.8065e-9, 4.8065e-9
   41 4.8065e-9, 4.8065e-9, 4.8065e-9
   42 4.8065e-9, 4.8065e-9, 4.8065e-9
   45 4.8065e-9, 4.8065e-9, 4.8065e-9
   46 4.8065e-9, 4.8065e-9, 4.8065e-9
   49 4.8065e-9, 4.8065e-9, 4.8065e-9
   50 4.8065e-9, 4.8065e-9, 4.8065e-9
   53 4.8065e-9, 4.8065e-9, 4.8065e-9
   54 4.8065e-9, 4.8065e-9, 4.8065e-9
   57 4.8065e-9, 4.8065e-9, 4.8065e-9
   58 4.8065e-9, 4.8065e-9, 4.8065e-9
   61 4.8065e-9, 4.8065e-9, 4.8065e-9
   62 4.8065e-9, 4.8065e-9, 4.8065e-9
   65 4.8065e-9, 4.8065e-9, 4.8065e-9
   66 4.8065e-9, 4.8065e-9, 4.8065e-9
   69 4.8065e-9, 4.8065e-9, 4.8065e-9
   70 4.8065e-9, 4.8065e-9, 4.8065e-9
   73 2.4032e-9, 2.4032e-9, 2.4032e-9
   74 2.4032e-9, 2.4032e-9, 2.4032e-9
end
fini
mode
tree,rinc
fini
thou,741
0000000002000000068600000300001
ndyn
mass
timo,prir,1000,0.0001
velo,1,0
1,14
     1 0.        e+00-.685300e+040.      e+000.      e+000.      e+000.      e+00
     2 0.        e+00-.685300e+040.      e+000.      e+000.      e+000.      e+00
     5 -.119001e+04-.674889e+040.      e+000.      e+000.      e+000.      e+00
     6 -.119001e+04-.674889e+040.      e+000.      e+000.      e+000.      e+00
     9 -.234386e+04-.643971e+040.      e+000.      e+000.      e+000.      e+00
    10 -.234386e+04-.643971e+040.      e+000.      e+000.      e+000.      e+00
    13 -.342650e+04-.593487e+040.      e+000.      e+000.      e+000.      e+00
    14 -.342650e+04-.593487e+040.      e+000.      e+000.      e+000.      e+00
    17 -.440502e+04-.524970e+040.      e+000.      e+000.      e+000.      e+00
    18 -.440502e+04-.524970e+040.      e+000.      e+000.      e+000.      e+00
    21 -.524970e+04-.440502e+040.      e+000.      e+000.      e+000.      e+00
    22 -.524970e+04-.440502e+040.      e+000.      e+000.      e+000.      e+00
    25 -.419659e+04-.242290e+040.      e+000.      e+000.      e+000.
    26 -.419659e+04-.242290e+040.      e+000.      e+000.      e+000.
auto,defi
inte,rewm,0.2e-5,0.0,0.,0.1
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,2000
zero,ltme
step
unba
```

Table 2.5.7 (cont'd)

```
auto,init
loop,30
stif
auto,load
load
disp
kinr,10
elmr,5,10
auto,merr,0.5,2.5
if,3,3,1,1
entr,1
auto,fact
kinr,1
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,1.0e-6,1.0e-4
if,4,5,5,4
entr,4
inte,newm,,auto,0.0,0.0,0.0,0.1
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
stif,init
goto,8
entr,7
chou
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,lrsb
unba
if,3,3,9,9
entr,9
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.0028
if,5,8,8,0
entr,8
cont
fini
stop
```

TABLE 2.5.8 - BEAM MODEL
RATIO OF VERTICAL DIAMETER TO HORIZONTAL DIAMETER

CASE	RATIO
Experiment [2.5.2] Time = 1.14 msec.	0.393
WIPS with strain rate Time = 1.14 msec.	0.391
Analysis with strain rate [2.5.2] Time = 1.14 msec.	0.406
WIPS without strain rate Time = 1.17 msec.*	0.358
Analysis without strain rate [2.5.2] Time = 1.14 msec.	0.333
Experiment [2.5.2] Time = 2.58 msec.	0.657
WIPS with strain rate Time = 2.57 msec.	0.519
Analysis with strain rate [2.5.2] Time = 2.58 msec.	0.613
WIPS without strain rate Time = 2.45 msec.*	0.466
Analysis without strain rate [2.5.2] Time = 2.58 msec.	0.423

*Results output was requested only every 20 steps. These were the closest available output times.

TABLE 2.5.9 - SHELL MODEL
RATIO OF VERTICAL DIAMETER TO HORIZONTAL DIAMETER

CASE	RATIO
Experiment [2.5.2] Time = 1.14 msec.	0.391
WIPS with strain rate Time = 1.10 msec.	0.431
Analysis with strain rate [2.5.2] Time = 1.14 msec.	0.406
WIPS with strain rate Time = 1.10 msec.	0.325
Analysis without strain rate [2.5.2] Time = 1.14 msec.	0.333
Experiment [2.5.2] Time = 2.58 msec.	0.657
WIPS with strain rate Time = 2.6 msec.	0.849
Analysis with strain rate [2.5.2] Time = 2.58 msec.	0.613
WIPS without strain rate Time = 2.6 msec.	0.395
Analysis without strain rate [2.5.2] Time = 2.58 msec.	0.423

D2.6 PIPE IMPACT ON INCLINED SLAB STRUCTURE

D2.6.1 PURPOSE

The purpose of this example is to test the SLAB substructure option, the impact analysis option, and three-dimensional motion of the PIPE element. Large displacement and contact friction effects are considered, but strain rate effects are ignored. The SLAB substructure is divided into only a small number of elements, to reduce the computation cost, and has been modelled assuming an elastic material.

The example has been chosen to test the computational procedure only. There are no test results or other analytical results available for comparison.

D2.6.2 DESCRIPTION

A pipe with the same geometry and properties as that in Section D2.3 has been assumed, except that full three-dimensional motion is allowed. A flat slab is located beneath the pipe, inclined at 45 degrees to the horizontal so that the pipe moves out-of-plane and slides over the slab after impact. The dimensions are shown in Fig. 2.6.1.

D2.6.3 WIPS ANALYSIS MODEL

D2.6.3.1 Pipe and Slab Properties

The pipe properties and pipe element subdivision were exactly as for the pipe considered in Section D2.3, ignoring strain rate effects. The slab was assumed to be of steel, 3 inches thick, with a very high yield strength. Boundary conditions for the slab were assumed arbitrarily to test the boundary condition specification in the WIPS-SLAB phase. A 3 x 5 finite element mesh was arbitrarily assumed. This mesh would be too coarse for a practical analysis. For sliding after impact, a coefficient of friction of 0.4 was specified.

D2.6.3.2 WIPS Input

Table 2.6.1 contains the WIPSLOG listings through the WIPS-DATA phase. Table 2.6.2 is a listing of the DATA file.

The data for this example was prepared on a VAX 11/780 computer at the University of California. A copy of the DATA file was then transferred by tape to the CRAY computer at Lawrence Livermore National Laboratory, and the analysis was performed on the CRAY. A formatted file containing the results output was produced (in fact, two files because the CRAY analysis was stopped and restarted). The output file was then transferred by tape back to the VAX, and incorporated into the RSLT file using the WIPS-MERG option. Finally, the results were processed on the VAX using WIPS-RSLT.

D2.6.4 RESULTS

D2.6.4.1 General

It is important to note that the purpose of this example is to test the impact analysis features of WIPS, not to obtain realistic results for pipe-to-slab impact. There are two features of the model which would be questionable in a practical impact analysis, namely (1) the coarseness of the finite element mesh and the assumption of elastic behavior for the SLAB substructure and (2) the fact that the pipe was modelled as a series of PIPE elements rather than with an ELBO substructure.

This second feature is particularly important when the calculated impact forces are considered. In an actual pipe-to-slab impact, substantial local deformation of the pipe will occur (and possibly also of the slab). This local deformation will have a major influence on the impact forces. When a model using PIPE elements is used, local deformations of the pipe are ignored; and, as a consequence, the calculated impact forces are likely to be completely unrealistic (almost certainly much too large). Further, the calculated forces for such a model may depend on the integration time step used in the analysis, and possibly on other analysis assumptions. Impact analyses using PIPE or BEAM elements may predict the pipe motion with reasonable accuracy (although even this remains to be proved). They will not, however, predict accurate impact forces.

D2.6.4.2 Pipe Motion

The complete model is shown in Fig. 2.6.2, with the undeformed shape and the deformed shapes at two times after impact. At the second of these times the pipe had moved off the slab. In the following step the analysis stopped because of convergence problems. Fig. 2.6.3 shows a part of the model in more detail at three times during the interaction, beginning with the initial impact at 0.071 seconds. This figure shows that the pipe nodes cross boundaries in the slab mesh (the primary surface for the impact analysis).

The views in Figs. 2.6.2 and 2.6.3 are projections on the X-Y plane. Fig. 2.6.4 shows a part of the model (essentially the same part as in Fig. 2.6.3) but projected on the Y-Z plane. This figure indicates how the pipe translates and twists out of its original plane after it strikes the inclined slab. The lines representing the slab in this figure show the deformed positions of the slab center line at the four times.

D2.6.4.3 Impact Forces

Fig. 2.6.5 shows the variation with time of the calculated normal impact force, up to 0.1 seconds. Immediately after impact the variation is erratic and the calculated forces are very large. The pipe then bounces down the slab, successively separating and re-establishing contact. Further contact occurred at about 0.12 seconds, but is not shown on the graph.

D2.6.5 CONCLUSION

This example indicates that the contact analysis algorithm in WIPS performs as intended, preventing the secondary nodes (in this case the PIPE nodes) from penetrating the primary surface (the SLAB substructure). It must be emphasized, however, that contact analyses are extremely complex. Until more experience is gained, the results of contact analyses should be interpreted cautiously, particularly the calculated impact forces.

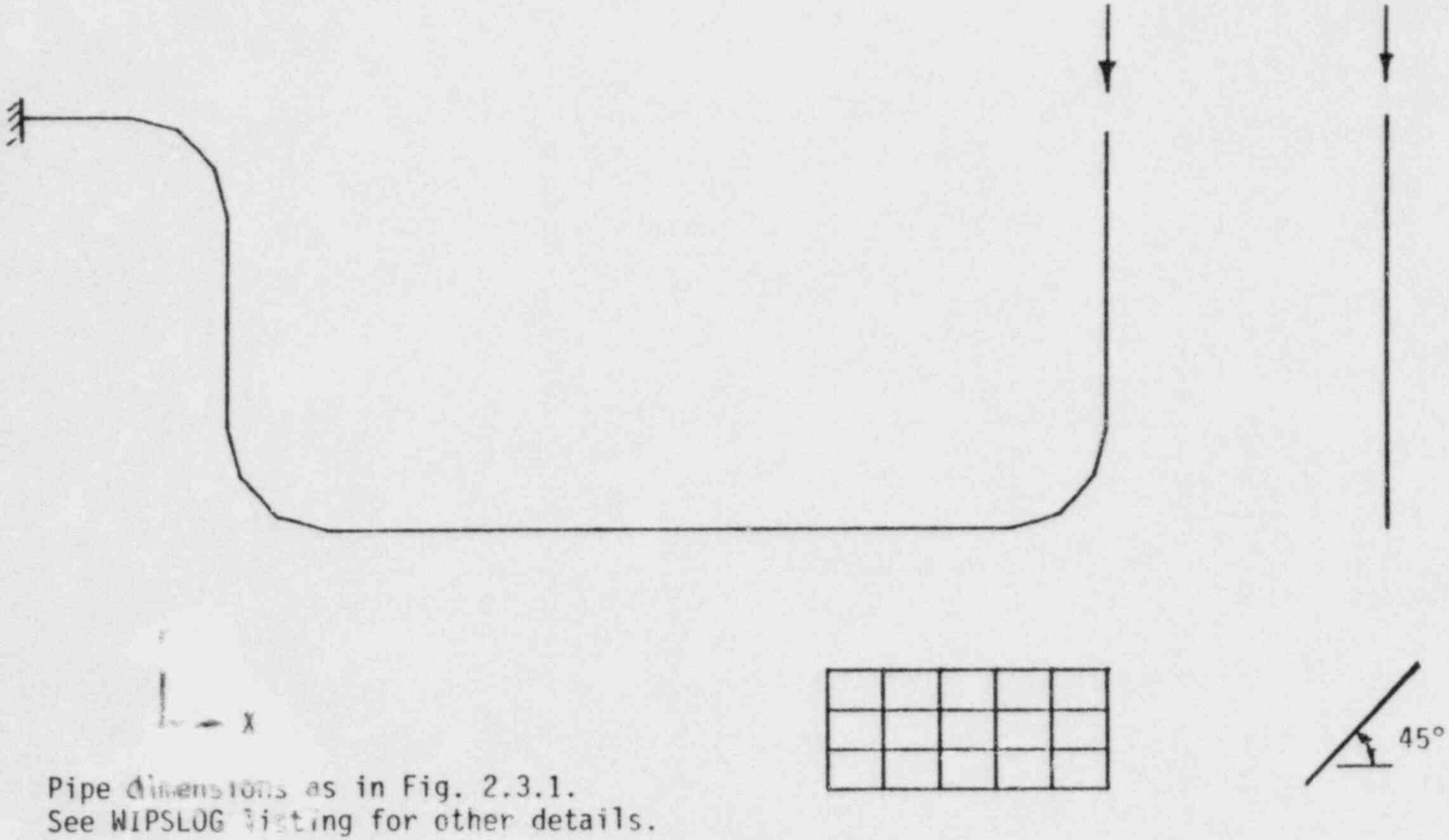

FIG. 2.6.1 PIPE IMPACTING INCLINED SLAB.

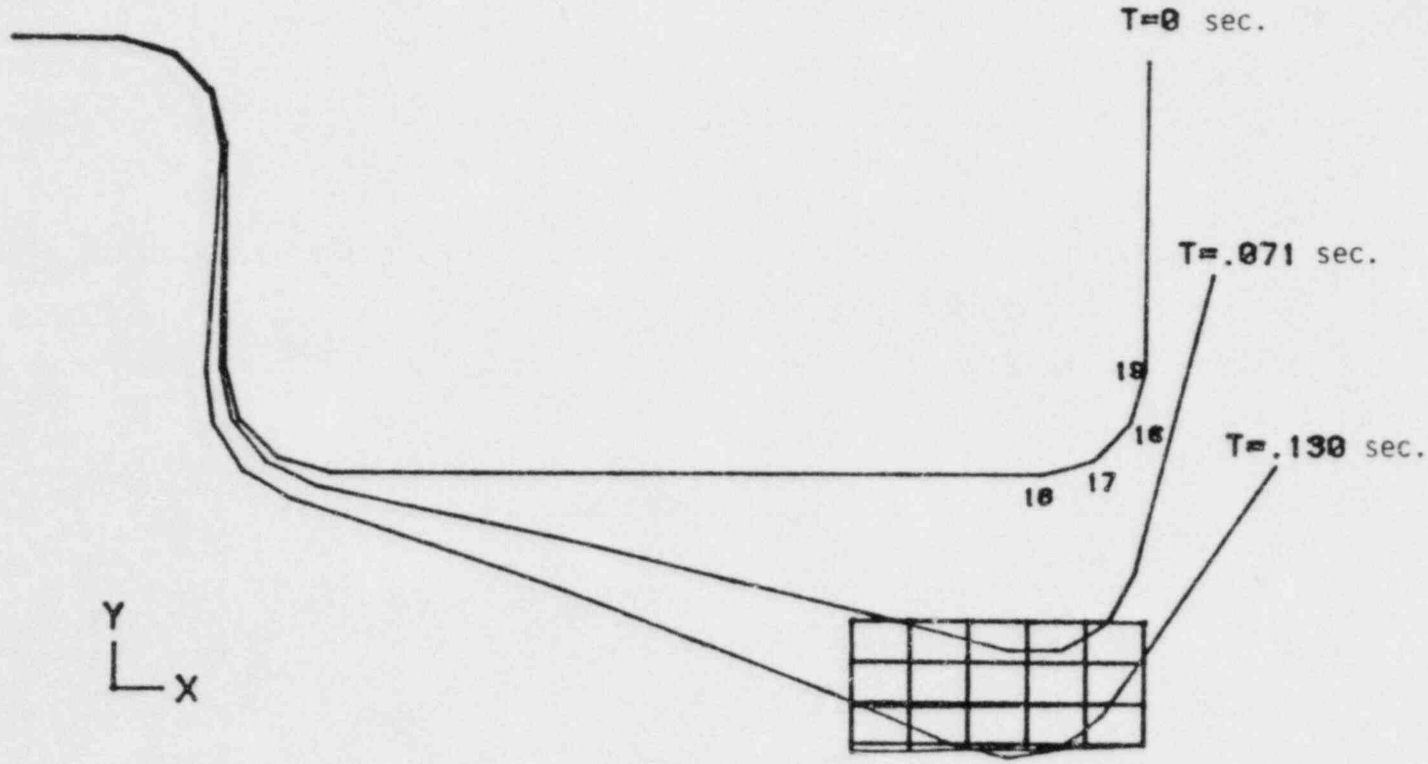

FIG. 2.6.2 DEFORMED PIPE AND SLAB. COMPLETE SYSTEM.

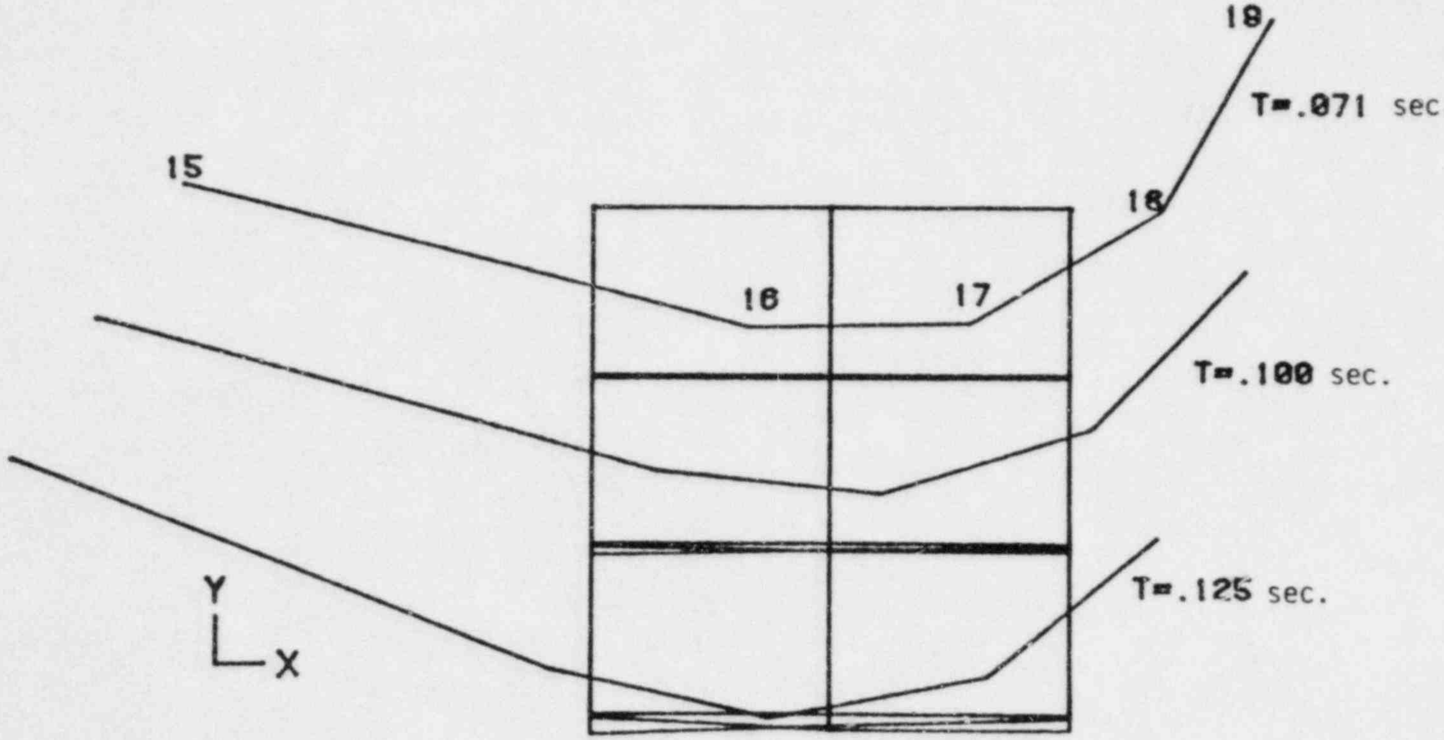

FIG. 2.6.3 DEFORMED PIPE AND SLAB. PART OF SYSTEM.

Only the part of the pipe from nodes 15-19 is shown (see node numbers in Part (b) of the figure).

Only one line of nodes near the slab centerline is shown.

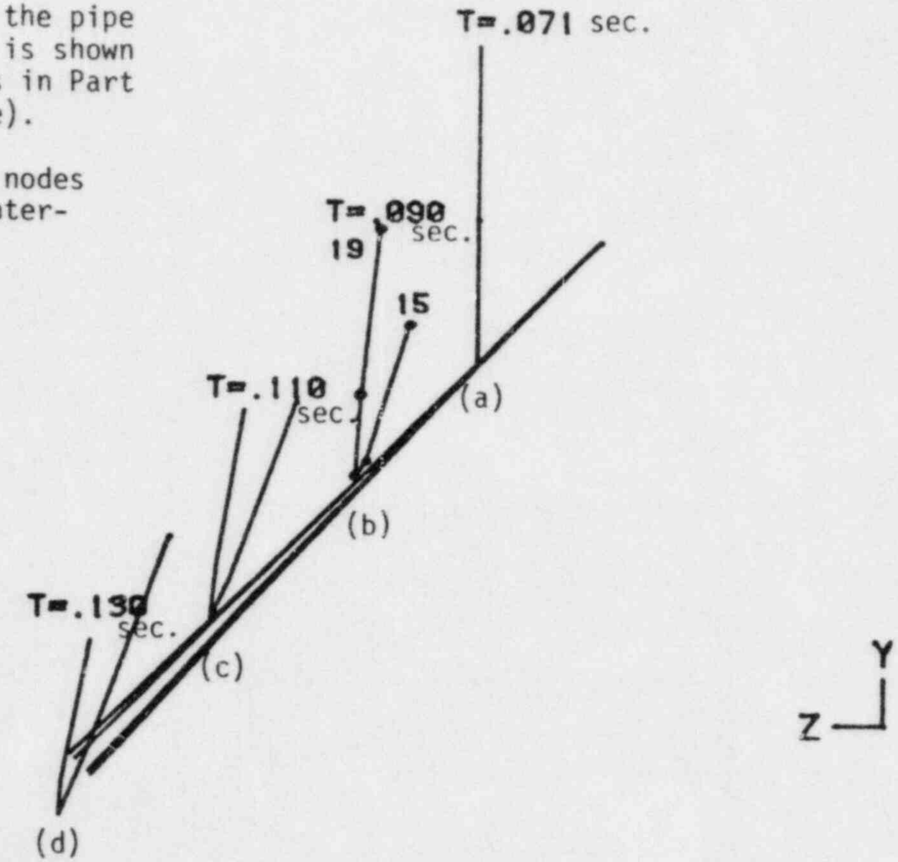

FIG. 2.6.4 DEFORMED PIPE AND SLAB. PART OF SYSTEM. END VIEW.

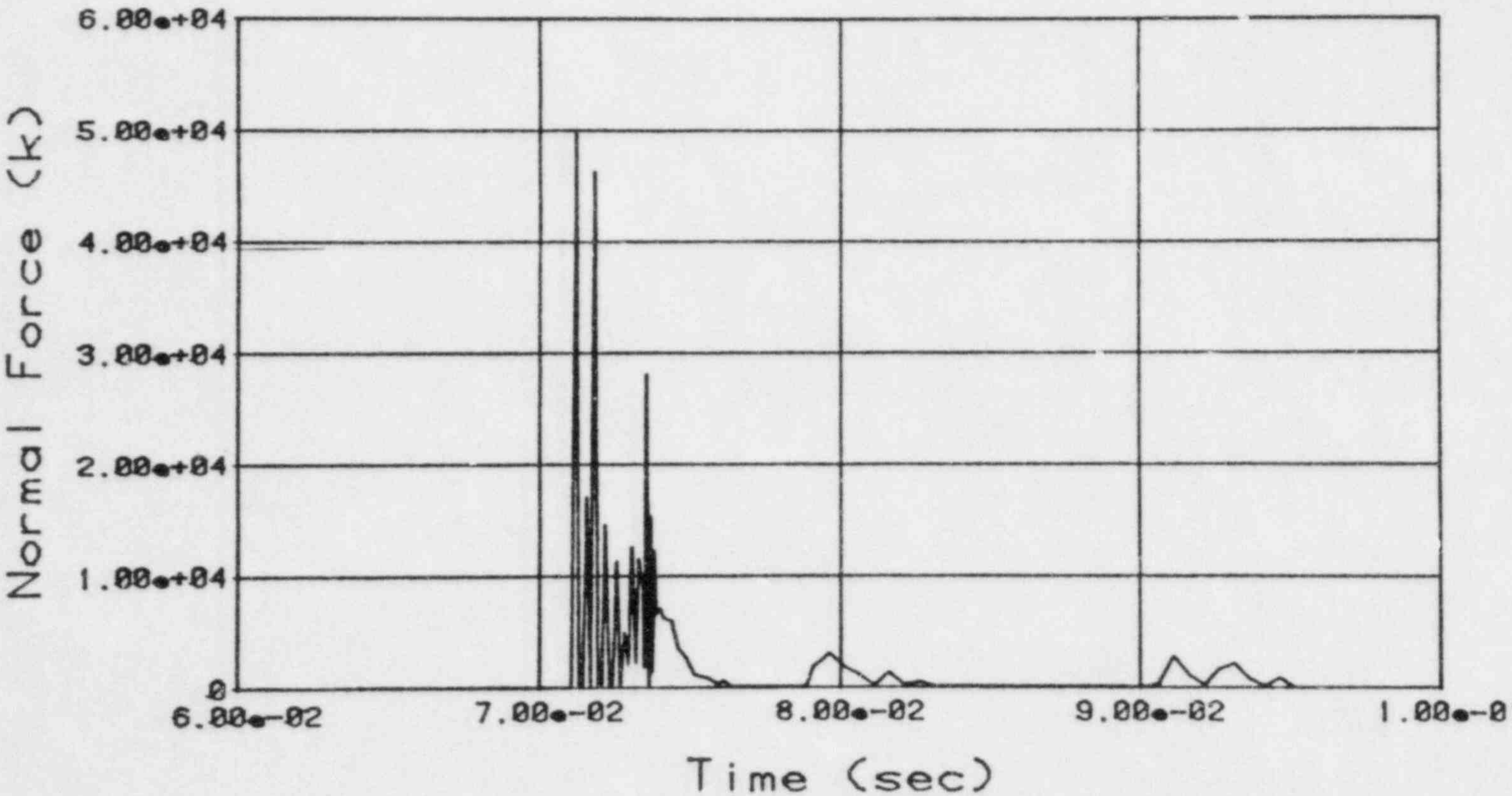

FIG. 2.6.5 IMPACT FORCE TIME HISTORY

TABLE 2.6.1 - WIPSLOG LISTINGS. GEOM, MATL, PIPE, SLAB, FREC, MODL, AND DATA PHASES.

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Pipe impacting inclined slab.

NEXT WIPS-EXEC COMMAND : geom

 GEOM - SPECIFICATION OF SYSTEM GEOMETRY

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Specify new GEOM data

 START RUN NO.  1
 Enter c.p. data in sequence along run

   c.p. name and type : 1
   coord option : di
   x,y,z :
   Any changes? :

   c.p. name and type : 2 tn
   no. of extra nodes : 1
   coord option :
   tn generated automatically
   Any changes? :

   c.p. name and type : ti1 ti
   bend radius : 36
   coord option :
   c.p., dx,dy,dz : 1 72
   Any changes? :

   c.p. name and type : 4 tn
   no. of extra nodes : 2
   coord option :
   tn generated automatically
   Any changes? :

   c.p. name and type : 5 tn
   no. of extra nodes : 1
   coord option :
   tn generated automatically
   Any changes? :

   c.p. name and type : ti2 ti
   bend radius : 36
   coord option :
   c.p., dx,dy,dz : ti1 0 -146
   Any changes? :

   c.p. name and type : 11 tn
   no. of extra nodes : 2
   coord option :
   tn generated automatically
```

Table 2.6.1 (cont'd)

```
Any changes? :

c.p. name and type : 16 tn
no. of extra nodes : 4
coord option :
tn generated automatically
Any changes? :

c.p. name and type : 17
no. of extra nodes :
coord option : cu
c.p.i, c.p.j, proportion : 16 19 .33333
Any changes? :

c.p. name and type : 18
no. of extra nodes :
coord option : cu
c.p.i, c.p.j, proportion : 16 19 .66667
Any changes? :

c.p. name and type : ti3 ti
bend radius : 36
coord option :
c.p., dx,dy,dz : ti2 315
Any changes? :

c.p. name and type : 19 tn
no. of extra nodes :
coord option :
tn generated automatically
Any changes? :

c.p. name and type : 20
no. of extra nodes :
coord option :
c.p., dx,dy,dz : ti3 0 142
Any changes? :

c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this run? : y
```

GEOM DATA FOR RUN

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. i	c.p.? j ?	coordinate data x,dx,p	y,dy	z,dz
1										
	1			2	oi			0.	0.	0.
	3	tn		1	tn			0.	0.	0.
	ti1	ti	36.000	0	of	1		72.000	0.	0.
	6	tn		2	tn			0.	0.	0.
	8	tn		1	tn			0.	0.	0.
	ti2	ti	36.000	0	of	ti1		0.	-144.000	0.
	11	tn		2	tn			0.	0.	0.
	16	tn		4	tn			0.	0.	0.

Table 2.6.1 (cont'd)

```
      17                        0     cu    16    19       0.333      0.          0.
      18                        0     cu    16    19       0.667      0.          0.
Hit RETURN for more
      ti3    ti    36.000       0     cf    ti2            315.000      0.          0.
      19     tn                 0     tn                     0.         0.          0.
      20                        0     cf    ti3              0.       142.000       0.
END OF DATA

START RUN NO.  2
Enter c.p. data in sequence along run

  c.p. name and type :
Last run? : y

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOM0101

Produce COOR data? : y

Display COOR data? : y


COOR DATA

 run    c.p.   c.p.    bend    node        x          y ?        z
 no.    name   type   radius    no.      coord      coord?     coord

  1
        1                         1        0.          0.         0.
                                  2       18.000       0.         0.
        3      tn                 3       36.000       0.         0.
        ti1    ti     36.000              72.000       0.         0.
                      center              36.000     -36.000      0.
                                  4       54.000      -4.823      0.
                                  5       67.177     -18.000      0.
        6      tn                 6       72.000     -36.000      0.
                                  7       72.000     -74.000      0.
        8      tn                 8       72.000    -112.000      0.
Hit RETURN for more
        ti2    ti     36.000              72.000    -148.000      0.
                      center             108.000    -112.000      0.
                                  9       76.823    -130.000      0.
                                 10       90.000    -143.177      0.
        11     tn                11      108.000    -148.000      0.
                                 12      156.600    -148.000      0.
                                 13      205.200    -148.000      0.
                                 14      253.800    -148.000      0.
                                 15      302.400    -148.000      0.
        16     tn                16      351.000    -148.000      0.
Hit RETURN for more
```

Table 2.6.1 (cont'd)

```
          17                         17    369.000  -143.177      0.
          18                         18    382.177  -130.000      0.
          t18    ti     36.000              387.000  -148.000      0.
                        center              351.000  -112.000      0.
          19     tn                  19    387.000  -112.000      0.
          20                         20    387.000    -6.000      0.
 END OF DATA

 Plot geometry? :

 Modify GEOM data? :

 DATA COMPLETE FOR THIS SESSION
 Save final GEOM data? : y
 Comment for file catalog : Pipe as in Hibbitt Fig.4.12.
 GEOM DATA SAVED. FILE NAME = GEOM0101
 Save COOR data? : y
 Comment for file catalog : From GEOM0101.
 COOR DATA SAVED. FILE NAME = COOR0101

 End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

---------------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl


 MATL - SPECIFICATION OF MATERIAL PROPERTIES

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) :

 Start new MATL file

 Specify a new property set? : y

 SET NO. =  1
 Property set description : Hibbitt material, no strain rate.
   Static moduli (min=2,max=5)
    : 26700 219 2
   Yield strengths (no. of moduli minus 1)
    : 26.7 44
   Strain rate stiffnesses (min=0,max=3)
    :
   No strain rate effect
   Use default tolerances? : y
   Poisson ratio (dflt = .3) :
   Weight density (dflt=steel) :
```

Table 2.6.1 (cont'd)

```
Any errors? :

This set added to MATL file

Specify a new property set? :

No. of property sets in MATL file =  1

Display property set descriptions? : y

MATL PROPERTY DESCRIPTIONS

  Set No.  Type  Description
     1     mro2  Hibbitt material, no strain rate.

Display new property set data? : y

MATL PROPERTY DATA

SET NO.  1.  Hibbitt material, no strain rate.

        Matl    Data      Segm     Modulus  or     Stress/Strain
        Type    Type      No.      Coefficient        Limit
        mro2
                static     1       0.2670e+05       0.2670e+02
                           2       0.2190e+03       0.4400e+02
                           3       0.2000e+01
                yld.tol.           0.2000e-01
                stif tol           0.5000e-01
                rate tol           0.5000e-01
                poisson            0.3000e+00
                density            0.2840e-03
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :

New MATL file created
Comment for file catalog :

End this MATL session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl

MATL - SPECIFICATION OF MATERIAL PROPERTIES

Define units
  Length (ft,in,m,cm) : in
  Force (k,lb,kgf,kN) : k

Existing MATL file being extended.
No. of existing property sets =  1
```

Table 2.6.1 (cont'd)

```
Specify a new property set? : y

SET NO. =  2
Property set description : Elastic material for slab.
  Static moduli (min=2,max=5)
   : 30000 300
  Yield strengths (no. of moduli minus 1)
   : 1e20
  Strain rate stiffnesses (min=0,max=3)
   :
  No strain rate effect
  Use default tolerances? :
  Yield tolerance (dflt=.02) : .02
  Stiffness tolerance (dflt=.05) : .05
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? :

No. of property sets in MATL file =  2

Display property set descriptions? : y

MATL PROPERTY DESCRIPTIONS

  Set No.  Type  Description
     1     mroz  Hibbitt material, no strain rate.
     2     mroz  Elastic material for slab.

Display new property set data? : y

MATL PROPERTY DATA

SET NO.  2.  Elastic material for slab.

        Matl    Data     Segm    Modulus  or    Stress/Strain
        Type    Type     No.     Coefficient       Limit
        mroz
               static     1      0.3000e+05       0.1000e+21
                          2      0.3000e+03
               yld.tol.          0.2000e-01
               stif tol          0.5000e-01
               rate tol          0.    e+00
               poisson           0.3000e+00
               density           0.2840e-03
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :
```

Table 2.6.1 (cont'd)

```
 Existing MATL file extended
 Comment for file catalog :

 End this MATL session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
------------------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : pipe


 PIPE - SPECIFICATION OF PIPE PROPERTIES

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 No. of MATL property sets available =  2
 Display material descriptions? : y

 MATL PROPERTY DESCRIPTIONS
   Set No.  Type  Description
       1    mrod  Hibbitt material, no strain rate.
       2    mrod  Elastic material for slab.

 Start new PIPE file

 Specify a new property set? : y

 SET NO. =  1
 Property set description : 24sch100, no strain rate, small oval.
   Outside diameter : 24
   Wall thickness : .531
   Weight/unit length (dflt=pipe weight) :
   No. of X-section elements (dflt=12) :
   Material number : 1
   Large ovalling (yes or no)? (dflt=no) :
 Use default ovalling properties? : y

 Any errors? :

 This set added to PIPE file

 Specify a new property set? :

 No. of property sets in PIPE file =  1

 Display property set descriptions? : y

 PIPE PROPERTY DESCRIPTIONS
   Set No.   Description
```

Table 2.6.1 (cont'd)

```
1      24schl00, no strain rate, small oval.

Display new property set data? : y

 PIPE PROPERTY DATA

SET NO.  1.  24schl00, no strain rate, small oval.

       Data                  Segm    Modulus or    Stress/Strain
       Type                  No.     Data Value        Limit

       Outside diameter              0.2400e+02
       Wall thickness                0.5310e+00
       Unit weight                   0.1112e-01
       No. of elements                  12
       No. of slices                     2
       Stress v strain         1     0.2670e+05    0.2670e+02
                               2     0.2190e+03    0.4400e+02
                               3     0.2000e+01
       Poisson ratio                 0.3000e+00
       Large ovalling                   no
       Ovalling ratios         1     0.3500e+00
                               2     0.8000e-01
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :

New PIPE file created
Comment for file catalog :

End this PIPE session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
------------------------------------------------------------------------
EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : slab

 SLAB - SPECIFICATION OF SLAB PROPERTIES

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 No. of MATL property sets available =  2
 Display material descriptions? : y

 MATL PROPERTY DESCRIPTIONS
   Set No.  Type  Description
```

```
      1     mrcx  hibbitt material, no strain rate.
      2     mrcx  Elastic material for slab.

Start new SLAB file

Specify a new property set? : y

SET NO.  1

Substructure description : Inclined slab
Length of side OA : 60
Length of side OB : 100
Outer strip widths (proportions of OA)
  Left strip  :
  Right strip :
Outer strip widths (proportions of OB)
  Bottom strip : .2
  Top strip    : .2
No. of subdivisions along OA
  Center strip : 3
No. of subdivisions along OB
  First strip  : 1
  Center strip : 3
  Last strip   : 1
Slab thickness : 3
No. of Gauss points thru thickness
  Center region : 2
  Outer regions : 2
Direction cosines of OA,OB
  OA (3 values) : 0 -1 1
  OB (3 values) : 1 0 0
Coords of point O (X,Y,Z values) : 287 -196 -10
Boundary codes (free,hing,clmp,syxy,syyz,or syzx)
  OA : free
  BC : hing
  OB : clmp
  AC : free
Material set number : 2

Any errors? :

This set added to SLAB file

Specify a new property set? :

No. of property sets in SLAB file =  1

Display property set descriptions? : y

SLAB PROPERTY DESCRIPTIONS
  Set No.   Description
     1      Inclined slab

Display new property data? : y

SLAB PROPERTY DATA
```

Table 2.6.1 (cont'd)

```
SET NO.  1.  Inclined slab
                              First        Center         Last
                              Strip         Strip         Strip
  Widths along OA          0.    e+00  0.6000e+02  0.    e+00
  Widths along OB          0.2000e+02  0.6000e+02  0.2000e+02
  Elements along OA             0           3           0
  Elements along OB             1           3           1
  Thicknesses              0.3000e+01  0.3000e+01  0.3000e+01
  No. of Gauss points           2           2           2

                                X           Y             Z
  Direction cosines
     Edge OA               0.    e+00 -0.7071e+00  0.7071e+00
     Edge OB               0.1000e+01  0.    e+00  0.    e+00
  Coordinates of O         0.2070e+03 -0.1960e+03 -0.1000e+02

  Boundary codes OA,BC = free, hing
  Boundary codes OB,AC = clmp, free
 Hit RETURN for next set
 END OF DATA

 Display all property data? :
 Write in session log? :

 New SLAB file created
 Comment for file catalog :

 End this SLAB session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

-----------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : frec

 FREC - SPECIFY DYNAMIC FORCE RECORDS

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Start new FREC file

 Specify a new record ? : y

 RECORD NO.  1

 Record name (4 characters) : rec1
 Description (max. 40 char.) : Nibbitt record, max. 1000k.

 Enter Time-Force pairs
```

Table 2.6.1 (cont'd)

```
First pair automatically set to 0,0
  Pair no.  2 : .0001 650
  Pair no.  3 : .001 880
  Pair no.  4 : .002 1000
  Pair no.  5 : .003 880
  Pair no.  6 : .005 780
  Pair no.  7 : .02 430
  Pair no.  8 : 10 430
  Pair no.  9 :
Last pair? : ,
Any errors ? :

Specify a new record ? :

Display any records ? : y
Record number (dflt=all) :

RECORD NO.  1.  Name = rec1
     Time          Force
   0.            0.    e+00
   0.00010     0.6500e+03
   0.00100     0.8800e+03
   0.00200     0.1000e+04
   0.00300     0.8800e+03
   0.00500     0.7800e+03
   0.02000     0.4300e+03
  10.00000     0.4300e+03
END OF RECORD

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog :

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
------------------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl

MODL - SPECIFICATION OF ANALYSIS MODEL

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

Sequence no. of CLCK file : 1

Available element property sets
  Type     No. of Sets
```

Table 2.6.1 (cont'd)

```
  pipe          1
Available substructure property sets
  Type     No. of Sets
  slab          1

DEFINE MODEL IN SEGMENTS

SEGMENT NO.    1

Pipe run no. : 1
First c.p. of segment : 1
Full 3D motion ? : y
Boundary condition code for first c.p. : 111111

Specify c.p.name + elem type + optional data
 1: 20 pipe pr=1 lo=y th=no
 2:
End of segment? : y
Display commands for this segment? : y

MODL COMMAND TABLE

SEGMENT NO.  1.  Run No. =  1
  c.p.  elem     optn      data        optn       data        optn      data
  1
                 bcon    111111
  20     pipe
                 prop         1
                 locl      auto        ldis       yes         this       no
                 wfac     1.000
Any changes? :

SEGMENT NO.    2

Pipe run no. :
Last segment? : y

Any external substructures? : y
Specify substructure type + optional data
 1 : slab pr=1 ld=y th=no
More external substructures? :
Display commands for external substructures? : y

MODL COMMAND TABLE

EXTERNAL SUBSTRUCTURES
        type     optn      data        optn       data        optn      data
        slab
                 prop         1
                 name      s001        ldis       yes         this       no
                 wfac     1.000
Any changes? :

Display commands for all segments? :
Write in session log? :
```

Table 2.6.1 (cont'd)

```
Produce MODL file? : y
Wait while data is processed

Impact analysis required ? : y
No. of impact surface pairs : 1

SURFACE PAIR NO. 1
Surface pair name : sur1

Define primary surface
  Substructure name : sc01
SLAB substructure, property set no. 1
  Divisions along DA = 3
  Divisions along DB = 5
Allowable grid range along DA = 1 thru 4
Allowable grid range along DB = 1 thru 6
Define grid ranges
  DA : 1 4
  DB : 1 6
Thickness from nodes to surface :

Define secondary nodes
  Substructure name (dflt = main) :
Main structure. Define c.p. ranges
  Run no., c.p.1, c.p.2 : 1 16 19
  Run no., c.p.1, c.p.2 :
Last range ? : y
No. of impact nodes = 4
Thickness from nodes to surface :
Friction coefficient (dflt=zero) : .4
Sliding veloc. for full friction (dflt=50in/sec) : 100
Any errors ? :

Specify initial velocities ? :
Comment for file catalog : with inclined slab.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
-----------------------------------------------------------------------

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : data

 DATA - SET UP WIPS-ANAL INPUT DATA

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k
```

Table 2 5.1 (cont'd)

```
Sequence no. of MODL file : 1

Problem description (4 lines)
 Line 1 : Test of impact feature. Pipe as in Hibbitt Fig.4.12, with slab.
 Line 2 : Slab at 45 degree angle below elbow, approximately 50in clearance.
 Line 3 :
 Line 4 :

Set up PAUSE files at end of analysis ? :
Wait while files are processed

Specify data for each loaded point
LOAD NO.  1
  Force record name : rec1
  Name of loaded c.p. : 20
  Force direction (x,y,z or follower) : foll
  Follower c.p. name : 1,
  Scale factor (+,- controls direction) : 1
  Time delay (sec) (dflt=0) :
LOAD NO.  2
  Force record name :
Last load? : ,

Time steps : initial + max + min : .0005 .001 .00001
Max steps + max total time : 200 .1
Error tolerances : upper + lower : 250 50

Results output intervals
  Max. no. of steps : 1
  Max. time (secs.) : 1
Integration scheme (newm or hilb)(dflt=newm) :
Damping factor (dflt=0.1) :
Factor for time step increase (dflt=2.0) :
Factor for time step decrease (dflt=0.5) :
Max. unbal. to reduce time step (dflt=no limit) :
Max. unbal. to stop analysis (dflt=no limit) :

DATA file set complete
Comment for file catalog : With inclined slab.
WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit

-------------------------------------------------------------------
```

TABLE 2.6.2 - LISTING OF DATA FILE. PIPE IMPACTING INCLINED SLAB.

```
  ECHO0101   SLCO0101   RSLT0101
star,
goui
new,s001,nonl,cart,0,49,15
 slab substructure. name = s001
refn,49
     10.287000000e+03-.198000000e+03-.100000000e+02
     20.287000000e+03-.196939346e+03-.893933964e+01
     30.287000000e+03-.212142136e+030.414213562e+01
     40.287000000e+03-.211081482e+030.520279598e+01
     50.287000000e+03-.226284271e+030.182842712e+02
     60.287000000e+03-.225223618e+030.193449306e+02
     70.287000000e+03-.240426407e+030.324264069e+02
     80.287000000e+03-.239365753e+030.334870662e+02
     90.307000000e+03-.198000000e+03-.100000000e+02
    100.307000000e+03-.196939346e+03-.893933964e+01
    110.307000000e+03-.212142136e+030.414213562e+01
    120.307000000e+03-.211081482e+030.520279598e+01
    130.307000000e+03-.226284271e+030.182842712e+02
    140.307000000e+03-.225223618e+030.193449306e+02
    150.307000000e+03-.240426407e+030.324264069e+02
    160.307000000e+03-.239365753e+030.334870662e+02
    170.327000000e+03-.198000000e+03-.100000000e+02
    180.327000000e+03-.196939346e+03-.893933964e+01
    190.327000000e+03-.212142136e+030.414213562e+01
    200.327000000e+03-.211081482e+030.520279598e+01
    210.327000000e+03-.226284271e+030.182842712e+02
    220.327000000e+03-.225223618e+030.193449306e+02
    230.327000000e+03-.240426407e+030.324264069e+02
    240.327000000e+03-.239365753e+030.334870662e+02
    250.347000000e+03-.198000000e+03-.100000000e+02
    260.347000000e+03-.196939346e+03-.893933964e+01
    270.347000000e+03-.212142136e+030.414213562e+01
    280.347000000e+03-.211081482e+030.520279598e+01
    290.347000000e+03-.226284271e+030.182842712e+02
    300.347000000e+03-.225223618e+030.193449306e+02
    310.347000000e+03-.240426407e+030.324264069e+02
    320.347000000e+03-.239365753e+030.334870662e+02
    330.367000000e+03-.198000000e+03-.100000000e+02
    340.367000000e+03-.196939346e+03-.893933964e+01
    350.367000000e+03-.212142136e+030.414213562e+01
    360.367000000e+03-.211081482e+030.520279598e+01
    370.367000000e+03-.226284271e+030.182842712e+02
    380.367000000e+03-.225223618e+030.193449306e+02
    390.367000000e+03-.240426407e+030.324264069e+02
    400.367000000e+03-.239365753e+030.334870662e+02
    410.387000000e+03-.198000000e+03-.100000000e+02
    420.387000000e+03-.196939346e+03-.893933964e+01
    430.387000000e+03-.212142136e+030.414213562e+01
    440.387000000e+03-.211081482e+030.520279598e+01
    450.387000000e+03-.226284271e+030.182842712e+02
    460.387000000e+03-.225223618e+030.193449306e+02
    470.387000000e+03-.240426407e+030.324264069e+02
    480.387000000e+03-.239365753e+030.334870662e+02
  9999
boun,34
```

Table 2.6.2 (cont'd)

```
      1                                   000111     1    46
      3                                   000111
      4                                   000111
      5                                   000111
      6                                   000111
     43                                   111111
     44                                   000111
     45                                   111111
     46                                   000111
      9                                   111111
     10                                   111111
     17                                   111111
     18                                   111111
     25                                   111111
     26                                   111111
     33                                   111111
     34                                   111111
     15                                   000111
     16                                   000111
     23                                   000111
     24                                   000111
     31                                   000111
     32                                   000111
     39                                   000111
     40                                   000111
      1                                   111111
      2                                   111111
      7                                   000111
      8                                   000111
     41                                   111111
     42                                   111111
     47                                   111111
     48                                   000111
   9999                                   011111
cnod,1
 9999
enod,0
matl,1,36
0.100000000e+010.          e+000.199999996e-010.500000007e-010.299999982e+00
0.283999980e-030.          e+000.          e+000.          e+000.300000000e+05
0.300000000e+030.          e+000.          e+000.          e+000.          e+00
0.100000002e+210.999999932e+200.           e+000.          e+000.          e+00
0.         e+000.          e+000.          e+000.          e+000.          e+00
0.         e+000.          e+000.          e+000.          e+000.100000000e+01
0.         e+000.          e+00-.100000000e+010.           e+000.          e+00
0.         e+00
elem,1
   20   15    1    2    1    0                      1.00
    1    0    0    0    1    3   11    9    2    4   12   10    1    1    0    2
0.         e+000.          e+000.          e+00
    2    0    0    0    3    5   13   11    4    6   14   12    1    1    0    2
0.         e+000.          e+000.          e+00
    3    0    0    0    5    7   15   13    6    8   16   14    1    1    0    2
0.         e+000.          e+000.          e+00
    4    0    0    0    9   11   19   17   10   12   20   18    1    1    0    2
0.         e+000.          e+000.          e+00
```

Table 2.6.2 (cont'd)

```
     5     0     0     0    11    13    21    19    12    14    22    20     1     1     0     2
0.          e+000.            e+000.            e+00
     6     0     0     0    13    15    23    21    14    16    24    22     1     1     0     2
0.          e+000.            e+000.            e+00
     7     0     0     0    17    19    27    25    16    20    28    26     1     1     0     2
0.          e+000.            e+000.            e+00
     8     0     0     0    19    21    29    27    20    22    30    28     1     1     0     2
0.          e+000.            e+000.            e+00
     9     0     0     0    21    23    31    29    22    24    32    30     1     1     0     2
0.          e+000.            e+000.            e+00
    10     0     0     0    25    27    35    33    26    28    36    34     1     1     0     2
0.          e+000.            e+000.            e+00
    11     0     0     0    27    29    37    35    26    30    38    36     1     1     0     2
0.          e+000.            e+000.            e+00
    12     0     0     0    29    31    39    37    30    32    40    38     1     1     0     2
0.          e+000.            e+000.            e+00
    13     0     0     0    33    35    43    41    34    36    44    42     1     1     0     2
0.          e+000.            e+000.            e+00
    14     0     0     0    35    37    45    43    36    38    46    44     1     1     0     2
0.          e+000.            e+000.            e+00
    15     0     0     0    37    39    47    45    38    40    48    46     1     1     0     2
0.          e+000.            e+000.            e+00

nord,
prof
end
new,main,nonl,cart,0,21,21
 main structure
refn,21
    1  0.          e+00  0.          e+00  0.          e+00
    2  0.1600000e+02  0.          e+00  0.          e+00
    3  0.3600000e+02  0.          e+00  0.          e+00
    4  0.5400000e+02 -0.4023090e+01  0.          e+00
    5  0.6717691e+02 -0.1800000e+02  0.          e+00
    6  0.7200000e+02 -0.3600000e+02  0.          e+00
    7  0.7200000e+02 -0.7400000e+02  0.          e+00
    8  0.7200000e+02 -0.1120000e+03  0.          e+00
    9  0.7682310e+02 -0.1300000e+03  0.          e+00
   10  0.9000001e+02 -0.1431769e+03  0.          e+00
   11  0.1080000e+03 -0.1480000e+03  0.          e+00
   12  0.1566000e+03 -0.1480000e+03  0.          e+00
   13  0.2052000e+03 -0.1480000e+03  0.          e+00
   14  0.2538000e+03 -0.1480000e+03  0.          e+00
   15  0.3024000e+03 -0.1480000e+03  0.          e+00
   16  0.3510000e+03 -0.1480000e+03  0.          e+00
   17  0.3689992e+03 -0.1431770e+03  0.          e+00
   18  0.3821770e+03 -0.1299998e+03  0.          e+00
   19  0.3870000e+03 -0.1120000e+03  0.          e+00
   20  0.3870000e+03 -0.6000000e+01  0.          e+00
 9999
cons,1
 s001    1
 9999 9999
boun,2
    1                          111111
 9999                          111111
```

Table 2.6.2 (cont'd)

```
enod,0
matl,1,64
0.200000000e+020.299999982e+000.267000000e+050.219000000e+030.200000000e+01
0.267000006e+020.440000000e+020.999999932e+200.199999996e-010.499999970e-01
0.120000000e+020.200000000e+010.             e+000.200000000e+010.100000000e+01
0.100000000e+010.240000000e+020.531000018e+000.111188097e-010.             e+00
0.349999994e+000.799999982e-010.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.499999970e-01
0.639999986e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+000.             e+00
0.           e+000.             e+000.             e+000.             e+00
elem,1
    3   19    1                                    1.00
    1    0    0    0    1    2    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
    2    0    0    0    2    3    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
    3    0    0    0    3    4    1    1    0    0    1    0
0.359999962e+02-.360000030e+020.             e+000.             e+00
    4    0    0    0    4    5    1    1    0    0    1    0
0.359999962e+02-.360000030e+020.             e+000.             e+00
    5    0    0    0    5    6    1    1    0    0    1    0
0.359999962e+02-.360000030e+020.             e+000.             e+00
    6    0    0    0    6    7    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
    7    0    0    0    7    8    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
    8    0    0    0    8    9    1    1    0    0    1    0
0.108000008e+03-.112000000e+030.             e+000.             e+00
    9    0    0    0    9   10    1    1    0    0    1    0
0.108000008e+03-.112000000e+030.             e+000.             e+00
   10    0    0    0   10   11    1    1    0    0    1    0
0.108000008e+03-.112000000e+030.             e+000.             e+00
   11    0    0    0   11   12    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
   12    0    0    0   12   13    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
   13    0    0    0   13   14    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
   14    0    0    0   14   15    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
   15    0    0    0   15   16    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
   16    0    0    0   16   17    1    1    0    0    1    0
0.351000000e+03-.112000000e+030.             e+000.             e+00
   17    0    0    0   17   18    1    1    0    0    1    0
0.351000000e+03-.112000000e+030.             e+000.             e+00
   18    0    0    0   18   19    1    1    0    0    1    0
0.351000000e+03-.112000000e+030.             e+000.             e+00
   19    0    0    0   19   20    1    1    0    0    0    0
0.           e+000.             e+000.             e+000.             e+00
```

Table 2.6.2 (cont'd)

```
nord,opto
prof
end
fini
mode
tree,main
fini
moui
new,s001
pmas,25
   10 0.22187e-03 0.22187e-03 0.22187e-03 0.        e+00 0.        e+00 0.        e+0000
   30 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
   50 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
   70 0.22187e-03 0.22187e-03 0.22187e-03 0.        e+00 0.        e+00 0.        e+0000
   90 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  110 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  130 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  150 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  170 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  190 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  210 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  230 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  250 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  270 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  290 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  310 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  330 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  350 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  370 0.88750e-03 0.88750e-03 0.88750e-03 0.        e+00 0.        e+00 0.        e+0000
  390 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  410 0.22187e-03 0.22187e-03 0.22187e-03 0.        e+00 0.        e+00 0.        e+0000
  430 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  450 0.44375e-03 0.44375e-03 0.44375e-03 0.        e+00 0.        e+00 0.        e+0000
  470 0.22187e-03 0.22187e-03 0.22187e-03 0.        e+00 0.        e+00 0.        e+0000
99990 0.10000e+01
end
new,main
pmas,20
   10 0.26060e-03 0.26060e-03 0.26060e-03 0.        e+00 0.        e+00 0.        e+0000
   20 0.52119e-03 0.52119e-03 0.52119e-03 0.        e+00 0.        e+00 0.        e+0000
   30 0.53039e-03 0.53039e-03 0.53039e-03 0.        e+00 0.        e+00 0.        e+0000
   40 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
   50 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
   60 0.81994e-03 0.81994e-03 0.81994e-03 0.        e+00 0.        e+00 0.        e+0000
   70 0.11003e-02 0.11003e-02 0.11003e-02 0.        e+00 0.        e+00 0.        e+0000
   80 0.81994e-03 0.81994e-03 0.81994e-03 0.        e+00 0.        e+00 0.        e+0000
   90 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
  100 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
  110 0.97340e-03 0.97340e-03 0.97340e-03 0.        e+00 0.        e+00 0.        e+0000
  120 0.14072e-02 0.14072e-02 0.14072e-02 0.        e+00 0.        e+00 0.        e+0000
  130 0.14072e-02 0.14072e-02 0.14072e-02 0.        e+00 0.        e+00 0.        e+0000
  140 0.14072e-02 0.14072e-02 0.14072e-02 0.        e+00 0.        e+00 0.        e+0000
  150 0.14072e-02 0.14072e-02 0.14072e-02 0.        e+00 0.        e+00 0.        e+0000
  160 0.97340e-03 0.97340e-03 0.97340e-03 0.        e+00 0.        e+00 0.        e+0000
  170 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
  180 0.53958e-03 0.53958e-03 0.53958e-03 0.        e+00 0.        e+00 0.        e+0000
```

Table 2.6.2 (cont'd)

```
   190 0.18044e-02 0.18044e-02 0.18044e-02 0.      e+00 0.      e+00 0.      e+0000
   200 0.15346e-02 0.15346e-02 0.15346e-02 0.      e+00 0.      e+00 0.      e+0000
end
fini
impa,1
 surl     1 0.40000001e+00 0.10000000e+03 0.        e+00 0.        e+00
 s001     5     5
    1     3     5     7
    9    11    13    15
   17    19    21    23
   25    27    29    31
   33    35    37    39
   41    43    45    47
 main     4
   16    17    18    19
fini
ptre
newr,recl,pair,8,100
(2e15.7)
  0.         e+00  0.         e+00
  0.6500000e+02  0.1000000e-03
  0.8800000e+03  0.1000000e-02
  0.1000000e+04  0.2000000e-02
  0.8800000e+03  0.3000000e-02
  0.7800000e+03  0.5000000e-02
  0.4300000e+03  0.2000000e-01
  0.4300000e+03  0.1000000e+02
fini
thou,343
        8         344     3     1     0     0
      197         344     1     1     0     0
        2     1     0     0
ndyn
mass
dylo,1,1
recl      0     0.        1.00          2
   20    19
timo,rslt,1,0.1000e+01
auto,defi
inte,newm,0.5000e-03,0.e+00,0.e+00,0.1000e+00
stif
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,200
zero,ltme
impa,init,,0.e+00,0.e+00
step
unba
auto,init
loop,30
stif
auto,load
load
disp
```

Table 2.6.2 (cont'd)

```
impa,anal
kinr,10
elmr,9,10
auto,merr,0.5000e+02,0.2500e+03
if,3,3,1,1
entr,1
auto,fact
kinr,1
impa,upda,0
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.1000e-04,0.1000e-02,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
impa,upda,1
stif,init
goto,8
entr,7
chou
impa,mome
impa,rslt
elmr,1,2,4,6,11
kinr,4,9,11
wrou
zero,lrsb
unba
summ
elmr,3
kinr,3
stif,upda
auto,exit,0.1000e+00
if,5,8,8,0
entr,8
cont
fini
stop
```

D2.7 ELBOW IMPACT ON RIGID STRUCTURE

D2.7.1 PURPOSE

The main purpose of this example is to test the ELBO substructure, impact analysis, and initial velocity options. A secondary purpose is to obtain an indication of the impact forces likely to be developed when a pipe elbow impacts on a rigid surface, allowing for local deformation of the elbow.

D2.7.2 DESCRIPTION

D2.7.2.1 ELBO and SLAB Substructures

In the example analyzed in Section D2.3, an unrestrained pipe underwent large displacements and then impacted an essentially rigid surface. The surface was modelled using very stiff GAPF elements, and it was noted that the computed impact force was probably not a realistic value.

In order to compute realistic impact forces for this type of problem, it is necessary to allow for local deformations of the pipe (and possibly of the impacted surface) near the point of contact. This can be done accurately only by modelling the pipe as a mesh of shell elements and performing an impact analysis.

With WIPS, it is possible to model the impacting pipe elbow as a substructure composed of SHELL elements. For the analysis described in this section, the elbow and short lengths of adjacent straight pipe were modelled, with 20 elements around the circumference and 16 elements longitudinally (10 in the elbow, 3 each in the adjacent lengths of straight pipe). For the analysis, only in-plane pipe motion was allowed, so that only one-half of the circumference was considered. The resulting mesh was thus 10 x 16. This is probably the coarsest mesh which can be expected to give reasonable results. For an accurate analysis a finer mesh is probably needed. The ELBO substructure is shown in Fig. 2.7.1.

The impacted surface can also be modelled using SHELL elements, as a SLAB substructure. For this analysis, only a 1 x 1 mesh was specified, producing a rigid surface.

D2.7.2.2 Piping Model

For parts of the pipe away from the impacting elbow, PIPE elements may be specified. It is possible to specify the same overall geometry as in Section D2.3. If this were done, however, a large amount of computer time would be required to perform the pre-impact analysis, yet the impacting elbow would undergo negligible deformation before impact.

For this reason, the specified geometry was somewhat different from that in Section D2.3. The geometry used is shown in Fig. 2.7.2. The choice was based on the following observations.

The analyses of Section D2.3 showed that before impact the pipe essentially hinged about the second elbow. These analyses also showed that the impacting pipe was inclined at approximately 24 degrees to the horizontal at impact, with an angular velocity of approximately 6.45 radians/second. The geometry was thus modified to place a hinged support at the approximate location of the plastic hinge; to locate a SLAB substructure just below the elbow, with a 24 degree inclination; and to specify an initial angular velocity of 6.45 radians/second about the hinge support. The geometry thus approximated the geometry of the Section D2.3 model just before impact.

D2.7.3 WIPS ANALYSIS MODEL

Table 2.7.1 shows the WIPSLOG listing for all phases of the data specification. This listing is largely self-explanatory. It may be noted that a time delay of -0.107 seconds (the time to impact calculated in Section D2.3) was specified in the WIPS-DATA phase. With this delay, the jet force applied at time zero in the analysis corresponds to the force at the impact time. Table 2.7.2 shows the DATA file.

As with the example in Section D2.6, the DATA file was prepared on the University of California VAX computer and transferred to the Lawrence Livermore National Laboratory CRAY for execution.

D2.7.4 RESULTS

D2.7.4.1 General

As noted earlier in this section, the finite element mesh for the ELBO substructure was coarser than would probably be needed for an accurate analysis. Also, rate dependence in the pipe steel was not considered. Hence, this example serves primarily to confirm the contact analysis capabilities of WIPS, not to calculate correct impact forces.

Initial impact occurred at 0.0004 seconds, and the analysis was continued to .0048 seconds, for a total of some 30 time steps. Each time step required a number of substeps. In the last step the allowable substep limit was exceeded, and the analysis stopped. To continue the analysis it would be necessary to restart with a smaller time step or a larger substep limit.

D2.7.4.2 Elbow Deformations

Fig. 2.7.3 shows a side view of the elbow at the end of the analysis. Fig. 2.7.4 shows a cross section of the elbow near the center of the impacting region at initial impact and at three times after impact. These figures confirm that the elbow flattens against the rigid slab surface and show that the elbow separates from the surface in the center of the contact area. Qualitatively, this behavior is correct. More extensive studies are needed to determine whether WIPS produces quantitatively correct results.

D2.7.4.3 Impact Forces

Fig. 2.7.5 shows the variation with time of the calculated normal impact force (the sum over all contacting nodes at each time). The variation is rather erratic, suggesting that a shorter time step should have been used. As already noted, however, the calculated contact force is not necessarily realistic. The maximum value is much less than that calculated in Section D2.3.

D2.7.5 CONCLUSION

This example indicates that the contact analysis algorithm in WIPS performs as intended and that the shell element in ELBO substructures is capable of modelling large deformations of a pipe. Until more experience is gained, however, the results of analyses of this type should be interpreted cautiously for practical application.

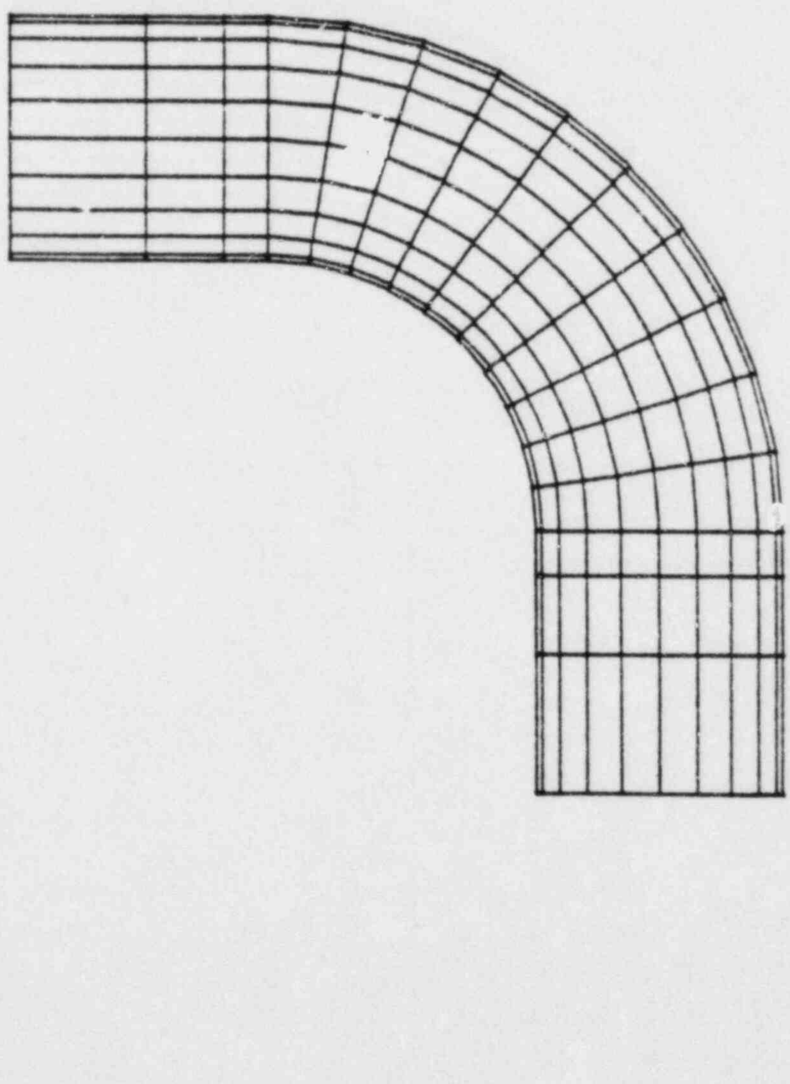

FIG. 2.7.1 ELBOW SUBSTRUCTURE.

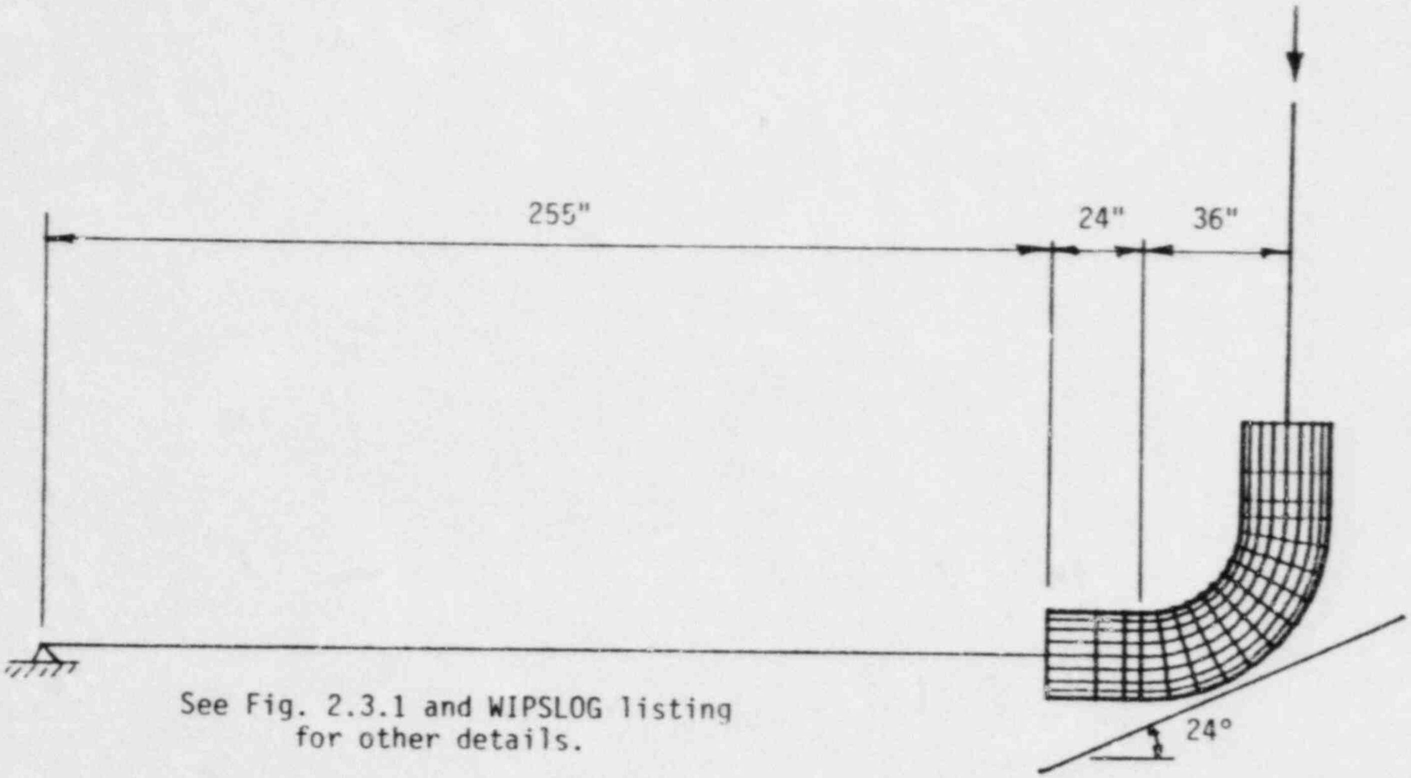

FIG. 2.7.2 PIPE WITH ELBOW AND SLAB SUBSTRUCTURES.

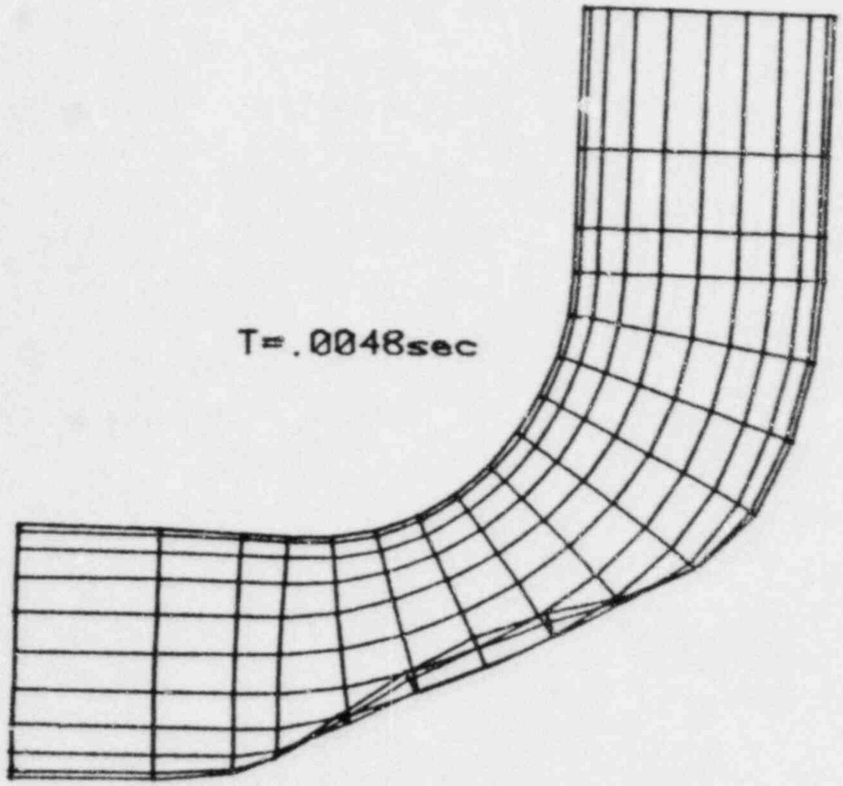

FIG. 2.7.3 DEFORMED ELBOW SUBSTRUCTURE.

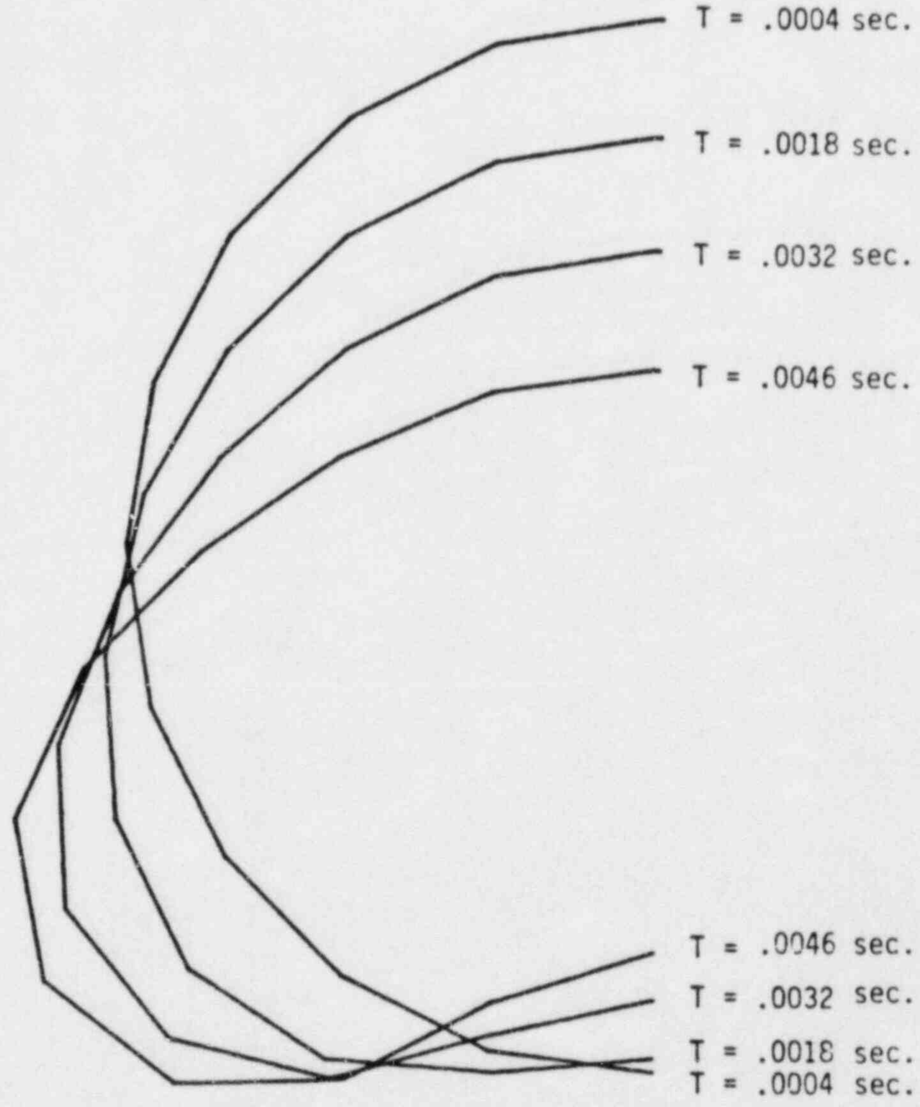

FIG. 2.7.4 CROSS SECTION DEFORMATIONS NEAR CENTER OF CONTACT REGION

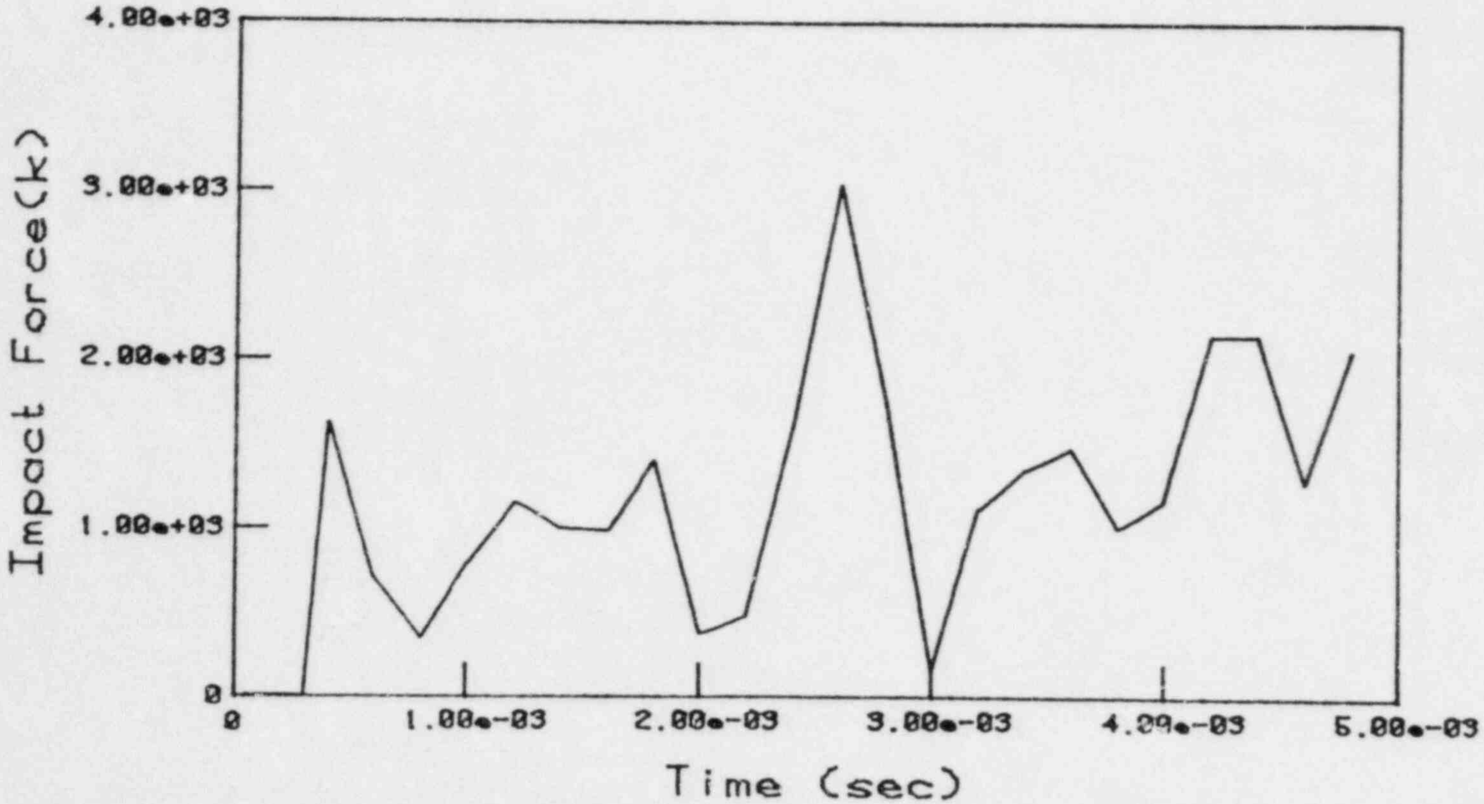

FIG. 2.7.5 IMPACT FORCE TIME HISTORY.

TABLE 2.7.1 - WIPSLOG LISTING - GEOM, MATL, PIPE, SLAB, FREC, MODL, AND DATA PHASES

```
EXEC - WIPS EXECUTIVE
Creating problem no. 1
Problem description: Test case, ELBO substructure impact on rigid surface

NEXT WIPS-EXEC COMMAND : geo.

 GEOM - SPECIFICATION OF SYSTEM GEOMETRY

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Specify new GEOM data

 START RUN NO.  1
 Enter c.p. data in sequence along run

   c.p. name and type : 1
   coord option : di
   x,y,z :
   Any changes? :

   c.p. name and type : 2
   no. of extra nodes : 3
   coord option :
   c.p., dx,dy,dz : ,255
   offset point defaults to preceding c.p.
   Any changes? :

   c.p. name and type : 3 tn
   no. of extra nodes :
   coord option :
   tn generated automatically
   Any changes? :

   c.p. name and type : ti ti
   bend radius : 36
   coord option :
   c.p., dx,dy,dz : 2,60
   Any changes? :

   c.p. name and type : 4 tn
   no. of extra nodes :
   coord option :
   tn generated automatically
   Any changes? :

   c.p. name and type : 5
   no. of extra nodes :
   coord option :
   c.p., dx,dy,dz : ti,,60
   Any changes? :

   c.p. name and type : 6
   no. of extra nodes :
   coord option :
```

c.p., dx,dy,dz : [illegible]
offset point defaults to preceding c.p.
Any changes? :

c.p. name and type :
Last c.p. in this run? : y
Display GEOM data for this run? : y

GEOM DATA FOR RUN

run no.	c.p. name	c.p. type	bend radius	xtra nods	coord opt	c.p. i	c.p.? j ?	coordinate data x,dx,[illegible]	y,dy	z,dz
1										
	1			0	di			0.	0.	0.
	2			3	cf	1		255.000	0.	0.
	3	tn		0	tn			0.	0.	0.
	ti	ti	36.000	0	cf	2		60.000	0.	0.
	4	tn		0	tn			0.	0.	0.
	5			0	cf	ti		0.	60.000	0.
	6			0	cf	5		0.	82.000	0.

END OF DATA

START RUN NO. 2
Enter c.p. data in sequence along run

c.p. name and type :
Last run? : y

Display new GEOM data? :
Write in session log? :

Modify GEOM data? :

Save current GEOM data? : y
Comment for file catalog :
GEOM DATA SAVED. FILE NAME = GEOM0101

Produce COOR data? : y

Display COOR data? : y

COOR DATA

run no.	c.p. name	c.p. type	bend radius	node no.	x coord	y ? coord?	z coord
1							
	1			1	0.	0.	0.
				2	63.750	0.	0.
				3	127.500	0.	0.
				4	191.250	0.	0.
	2			5	255.000	0.	0.
	3	tn		6	279.000	0.	0.
	ti	ti	36.000		315.000	0.	0.

Table ? 7.1 (cont'd)

```
                    center              279.000     36.000       0.
     4        tn                  7     315.000     36.000       0.
     5                            8     315.000     60.000       0.
 Hit RETURN for more
     6                            9     315.000    142.000       0.
 END OF DATA

 Plot geometry? :

 Modify GEOM data? :

 DATA COMPLETE FOR THIS SESSION
 Save final GEOM data? : y
 Comment for file catalog : For LLBD substructure
 GEOM DATA SAVED. FILE NAME = GEOM0101
 Save COOR data? : y
 Comment for file catalog : From GEOM0101
 COOR DATA SAVED. FILE NAME = COOR0101

 End of this GEOM session

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : matl


 MATL - SPECIFICATION OF MATERIAL PROPERTIES

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Start new MATL file

 Specify a new property set? : y

 SET NO. =  1
 Property set description : Trilinear, no strain rate.
   Static moduli (min=2,max=5)
    : 28700 219 20
   Yield strengths (no. of moduli minus 1)
    : 26.7 44
   Strain rate stiffnesses (min=0,max=3)
    :
   No strain rate effect
   Use default tolerances? :
   Yield tolerance (dflt=.02) : .1
   Stiffness tolerance (dflt=.05) : .1
   Poisson ratio (dflt = .3) :
   Weight density (dflt=steel) :

 Any errors? :

 This set added to MATL file

 Specify a new property set? : y
```

Table 2.7.1 (cont'd)

```
SET NO. =  2
Property set description : Elastic
  Static moduli (min=1,max=5)
   : 26700 26600
  Yield strengths (no. of moduli minus 1)
   : 1e8
  Strain rate stiffnesses (min=0,max=3)
   :
  No strain rate effect
  Use default tolerances? : y
  Poisson ratio (dflt = .3) :
  Weight density (dflt=steel) :

Any errors? :

This set added to MATL file

Specify a new property set? :

No. of property sets in MATL file =  2

Display property set descriptions? : y

MATL PROPERTY DESCRIPTIONS

  Set No.  Type  Description
     1     mroz  Trilinear, no strain rate.
     2     mroz  Elastic

Display new property set data? : y

MATL PROPERTY DATA

SET NO.  1.  Trilinear, no strain rate.

        Matl     Data    Segm     Modulus  or    Stress/Strain
        Type     Type    No.      Coefficient        Limit
        mroz
                 static    1      0.2670e+05      0.2670e+02
                           2      0.2190e+05      0.4400e+02
                           3      0.2000e+02
                 yld.tol.         0.1000e+00
                 stif tol         0.1000e+00
                 rate tol         0.    e+00
                 poisson          0.3000e+00
                 density          0.2840e-03
Hit RETURN for next set

SET NO.  2.  Elastic

        Matl     Data    Segm     Modulus  or    Stress/Strain
        Type     Type    No.      Coefficient        Limit
        mroz
                 static    1      0.2670e+05      0.1000e+09
                           2      0.2660e+05
```

Table 2.7.1 (cont'd)

```
                    ,ls.tol.          0.2000e-01
                    stif tol          0.5000e-01
                    rate tol          0.5000e-01
                    poisson           0.3000e+00
                    density           0.2540e-03
   Hit RETURN for next set
   END OF DATA

   Display all property set data? :
   Write in session log? :

   New MATL file created
   Comment for file catalog : 2 materials

   End this MATL session? : y

  EXEC - WIPS EXECUTIVE

  NEXT WIPS-EXEC COMMAND : elbo


   ELBO - SPECIFICATION OF ELBO PROPERTIES

   Define units
     Length (ft,in,m,mm) : in
     Force (k,lb,kgf,kN) : k

   No. of MATL property sets available =  2
   Display material descriptions? : y

   MATL PROPERTY DESCRIPTIONS
     Set No.  Type  Description
        1     mrc.  Trilinear, no strain rate.
        2     mrc.  Elastic

   Start new ELBO file

   Specify a new property set? : y

   SET NO.  1

   Substructure description : 24in OD, 1.531 WT, SR.
   No. of circumf. divisions : 20
   First Tangent
      Length : 24
      No. of divisions : 2
      Mesh factor : 1.75
      Outside diameter : 24
      Wall thickness : 1.531
      No. of integ. pts thru thickness : 5
   Elbow
      Bend radius : 36
      Bend angle (deg) : 90
      No. of divisions : 15
      Outside diameter : 24
      Wall thickness : 1.531
```

Table 2.7.1 (cont'd)

```
      No. of integ. pts thru thickness : 5
   Second Tangent
      Length : 24
      No. of divisions : 3
      Mesh factor : 1.75
      Outside diameter : 24
      Wall thickness : 1.531
      No. of integ. pts thru thickness : 5
   Material numbers (tang.1, elbow, tang.2) : 1 1 1

   Any errors? :

   This set added to ELBO file

   Specify a new property set? :

   No. of property sets in ELBO file =  1

   Display property set descriptions? : y

   ELBO PROPERTY DESCRIPTIONS
     Set No.    Description
         1      24in OD, 1.531 WT, SR.

   Display new property data? : y

   ELBO PROPERTY DATA

   SET NO.  1.  24in OD, 1.531 WT, SR.
     Circumferential divisions = 20

                      Tangent 1        Elbow      Tangent 2
     Length          0.2400e+02                   0.2400e+02
     Divisions                3           10               3
     Mesh factor     0.1750e+01                   0.1750e+01
     Diameter        0.2400e+02   0.2400e+02      0.2400e+02
     Thickness       0.1531e+01   0.1531e+01      0.1531e+01
     Bend radius                  0.3600e+02
     Angle (deg)                  0.9000e+02
     Integ. order             5            5               5
     Material no.             1            1               1
   Hit RETURN for next set
   END OF DATA

   Display all property data? :
   Write in session log? :

   New ELBO file created
   Comment for file catalog : 1 set

   End this ELBO session? : y

  EXEC - WIPS EXECUTIVE

  NEXT WIPS-EXEC COMMAND : ELBO
```

Table 2.7.1 (cont'd)

```
SLAB - SPECIFICATION OF SLAB PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

No. of MATL property sets available =  2
Display material descriptions? : y

MATL PROPERTY DESCRIPTIONS
  Set No.  Type  Description
     1     mrcs  Trilinear, no strain rate.
     2     mrcs  Elastic

Start new SLAB file

Specify a new property set? : y

SET NO.  1

Substructure description : Elastic, rigid because single element
Length of side OA : 100
Length of side OB : 100
Outer strip widths (proportions of OA)
  Left strip  :
  Right strip :
Outer strip widths (proportions of OB)
  Bottom strip :
  Top strip    :
No. of subdivisions along OA
  Center strip : 1
No. of subdivisions along OB
  Center strip : 1
Slab thickness : 2
No. of Gauss points thru thickness
  Center region : 2
  Outer regions : 2
Direction cosines of OA,OB
  OA (3 values) : 0 0 1
  OB (3 values) : .9135 .4067 0
Coords of point O (X,Y,Z values) : 253.45 -29.56 -50
Boundary codes (free,hing,clmp,syxy,syyz,or syzx)
  OA : hing
  BC : hing
  OB : hing
  AC : free
Material set number : 2

Any errors? :

This set added to SLAB file

Specify a new property set? :

No. of property sets in SLAB file =  1
```

```
   Display property set descriptions? : y

   SLAB PROPERTY DESCRIPTIONS
     Set No.    Description
        1       Elastic, rigid because single element

   Display new property data? : y

   SLAB PROPERTY DATA

   SET NO.  1.  Elastic, rigid because single element
                                   First        Center          Last
                                   Strip         Strip          Strip
     Widths along OA          0.     e+00  0.1000e+03  0.     e+00
     Widths along OB          0.     e+00  0.1000e+03  0.     e+00
     Elements along OA             0            1            0
     Elements along OB             0            1            0
     Thicknesses              0.2000e+01  0.2000e+01  0.2000e+01
     No. of Gauss points           2            2            2

                                   X            Y            Z
     Direction cosines
        Edge OA               0.     e+00 0.     e+00  0.1000e+01
        Edge OB               0.9136e+00  0.4067e+00  0.     e+00
     Coordinates of O         0.2534e+03 -0.2950e+02 -0.5000e+02

     Boundary codes OA,BC = hing, hing
     Boundary codes OB,AC = hing, free
  Hit RETURN for next set
  END OF DATA

  Display all property data? :
  Write in session log? :

  New SLAB file created
  Comment for file catalog : 1 set

  End this SLAB session? : y

 EXEC - WIPS EXECUTIVE

 NEXT WIPS-EXEC COMMAND : frec

  FREC - SPECIFY DYNAMIC FORCE RECORDS

  Define units
    Length (ft,in,m,mm) : in
    Force (k,lb,kgf,kN) : k

  Start new FREC file

  Specify a new record ? : y

  RECORD NO.  1
```

Table 2.7.1 (cont'd)

```
Record name (4 characters) : rec1
Description (max. 40 char.) : Hibbitt record, max. 1000k.

Enter Time-Force pairs
First pair automatically set to 0,0
  Pair no.  2 : .0001 650
  Pair no.  3 : .001 880
  Pair no.  4 : .002 1000
  Pair no.  5 : .003 680
  Pair no.  6 : .005 760
  Pair no.  7 : .02 430
  Pair no.  8 : 10 430
  Pair no.  9 :
Last pair? : y
Any errors ? :

Specify a new record ? :

Display any records ? : y
Record number (dflt=all) :

RECORD NO.  1.  Name = rec1
     Time          Force
    0.           0.     e+00
    0.00010     0.6500e+03
    0.00100     0.8800e+03
    0.00200     0.1000e+04
    0.00300     0.6800e+03
    0.00500     0.7600e+03
    0.02000     0.4300e+03
   10.00000     0.4300e+03
END OF RECORD

Write records in session log? :

End this FREC session? : y
New FREC file created
Comment for file catalog : 1 record

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : pipe


PIPE - SPECIFICATION OF PIPE PROPERTIES

Define units
  Length (ft,in,m,mm) : in
  Force (k,lb,kgf,kN) : k

No. of MATL property sets available =  2
Display material descriptions? : y

MATL PROPERTY DESCRIPTIONS
  Set No.  Type  Description
     1     mrec  Trilinear, no strain rate.
```

Table 2.7.1 (cont'd)

```
      2     mf..  Elastic

Start new PIPE file

Specify a new property set? : y

SET NO. =  1
Property set description : 24in OD, 1.531in WT.
  Outside diameter : 24
  Wall thickness : 1.531
  Weight/unit length (dflt=pipe weight) :
  No. of X-section elements (dflt=12) :
  Material number : 1
  Large ovalling (yes or no)? (dflt=no) :
Use default ovalling properties? : y

Any errors? :

This set added to PIPE file

Specify a new property set? :

No. of property sets in PIPE file =  1

Display property set descriptions? : y

PIPE PROPERTY DESCRIPTIONS
  Set No.   Description
     1      24in OD, 1.531in WT.

Display new property set data? : y

 PIPE PROPERTY DATA

SET NO.  1.  24in OD, 1.531in WT.

        Data                    Segm     Modulus or    Stress/Strain
        Type                     No.     Data Value        Limit

        Outside diameter                 0.2400e+02
        Wall thickness                   0.1531e+01
        Unit weight                      0.3069e-01
        No. of elements                     12
        No. of slices                        2
        Stress v strain           1      0.2670e+05    0.2670e+02
                                  2      0.2190e+03    0.4400e+02
                                  3      0.2000e+02
        Poisson ratio                    0.3000e+00
        Large ovalling                      no
        Ovalling ratios           1      0.3500e+00
                                  2      0.3000e-01
Hit RETURN for next set
END OF DATA

Display all property set data? :
Write in session log? :
```

Table 2.7.1 (cont'd)

```
 New PIPE file created
 Comment for file catalog : isc

 End this PIPE session? : y

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : modl


 MODL - SPECIFICATION OF ANALYSIS MODEL

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Sequence no. of COOK file : 1

 Available element property sets
   Type    No. of Sets
   pipe        1
 Available substructure property sets
   Type    No. of Sets
   elbo        1
   slab        1

 DEFINE MODEL IN SEGMENTS

 SEGMENT NO.   1

 Pipe run no. : 1
 First c.p. of segment : 1
 Full 3D motion ? :
 Displacement plane (xy,yz or zx) : xy
 Any substructures in this segment? : y
 They must lie on +z or -z side of plane
 Specify side (+ or -) : +
 Boundary condition code for first c.p. : 11,110

 Specify c.p.name + elem type + optional data
  1: 2 pipe prop=1 ldis
  1: 2 pipe prop
  1: 2 pipe prop=1 ldis=yes this=no
  2: 5 elbo prop=1 name=elbo this=no ldis=yes
  3: 6 pipe
  4:
 End of segment? : y
 Display commands for this segment? : y

 MODL COMMAND TABLE

 SEGMENT NO.  1  Run No. =  1
   c.p.  elem    optn     data        optn     data        optn     data
   1
                 bcon   111110
```

```
  4      pipe
                 prop        1
                 locl        +           ldis       yes         this       no
                 wfac     1.000
  5      elbo
                 prop        1
                 name      elbo          ldis       yes         this       no
                 wfac     1.000
  6      pipe
                 prop        1
                 locl        +           ldis       yes         this       no
                 wfac     1.000
Hit RETURN for more
Any changes? :

SEGMENT NO.   2

Pipe run no. :
Last segment? : y

Any external substructures? : y
Specify substructure type + optional data
 1 : slab prop=1 name=slab this=no
More external substructures? :
Display commands for external substructures? : y

MODL COMMAND TABLE

EXTERNAL SUBSTRUCTURES
        type     optn       data        optn       data        optn       data
        slab
                 prop        1
                 name      slab          ldis       yes         this       no
                 wfac     1.000
Any changes? : y
Redefine all external substructures

Any external substructures? : y
Specify substructure type + optional data
 1 : slab prop=1 name=slab this=no ldis=no
More external substructures? :
Display commands for external substructures? : y

MODL COMMAND TABLE

EXTERNAL SUBSTRUCTURES
        type     optn       data        optn       data        optn       data
        slab
                 prop        1
                 name      slab          ldis       no          this       no
                 wfac     1.000
Any changes? :

Display commands for all segments? :
Write in session log? :
```

Table 2.7.1 (cont'd)

```
Produce MODL file? : y
Wait while data is processed

Impact analysis required ? : y
No. of impact surface pairs : 1

SURFACE PAIR NO.  1
Surface pair name : sur1

Define primary surface
  Substructure name : slab
SLAB substructure, property set no.  1
  Divisions along OA =  1
  Divisions along OB =  1
Allowable grid range along OA = 1 thru  2
Allowable grid range along OB = 1 thru  2
Define grid ranges
  OA : 1 2
  OB : 1 2
Thickness from nodes to surface : 1

Define secondary nodes
  Substructure name (dflt = main) : elbo
ELBO substructure, property set no.  1
  Circumf. divisions = 20
  Longitl. divisions = 16  (  3, 10,  3)
Only first circumferential half of mesh used
Allowable grid range = 1 thru 11
Allowable longitudinal grid range = 1 thru 17
Define grid ranges
  Circumferential : 5 11
  Longitudinal : 4 13
Thickness from nodes to surface : .765
Friction coefficient (dflt=zero) :
Sliding veloc. for full friction (dflt=50in/sec) :
Any errors ? :

Specify initial velocities ? : y
Specify initial velocities for affected segments
Warning - only partial consistency check is performed on data
   SEGMENT NO. : 1
    Segment has transverse symmetry
   Motion in xy plane only
   Name of pivot point (dflt = no pivot) : 1
   Pivot axis = global z
   Angular velocity (rad/sec, r.h. rule) : -6.45
   SEGMENT NO. :
   Last affected segment ? : y
    Wait while data is processed
Comment for file catalog : -6.45 rad/sec, zero friction.

MODL file saved. File name = MODL0101
End of this MODL session

EXEC - WIPS EXECUTIVE
```

Table 2.7.1 (cont'd)

```
NEXT WIPS-EXEC COMMAND : data

 DATA - SET UP WIPS-ANAL INPUT DATA

 Define units
   Length (ft,in,m,mm) : in
   Force (k,lb,kgf,kN) : k

 Sequence no. of MODL file : 1

 Problem description (4 lines)
  Line 1 : Test of elbow substructure impact on rigid slab substructure.
  Line 2 :
  Line 3 : Geometry similar to Hibbitt unrestrained example. Initial geometry
  Line 4 : set to just before impact. 1000in/sec approx. impact velocity.

 Set up PAUSE files at end of analysis ? : y
 Wait while files are processed
 Initial velocities may be scaled if desired
 Specify scale factor (dflt=1.0) :

 Specify data for each loaded point
 LOAD NO.  1
   Force record name : rec1
   Name of loaded c.p. : 6
   Force direction (x,y,z or follower) : foll
   Follower c.p. name : 5
   Scale factor (+,- controls direction) : .5
   Time delay (sec) (dflt=0) : -.107
 LOAD NO.  2
   Force record name :
 Last load? : y

 Time steps : initial + max + min : 2e-4 .001 2e-6
 Max steps + max total time : 200 .02
 Error tolerances : upper + lower : 250 50

 Results output intervals
   Max. no. of steps : 1
   Max. time (secs.) : .1
 Integration scheme (newm or hilb)(dflt=newm) :
 Damping factor (dflt=0.1) :
 Factor for time step increase (dflt=2.0) :
 Factor for time step decrease (dflt=0.5) :
 Max. unbal. to reduce time step (dflt=no limit) :
 Max. unbal. to stop analysis (dflt=no limit) :

 DATA file set complete
 Comment for file catalog : 200 steps, max 20msec.
 WIPS-ANAL DATA FILES SET UP. PARENT FILE NAME = DATA0101

EXEC - WIPS EXECUTIVE

NEXT WIPS-EXEC COMMAND : quit
```

TABLE 2.7.2 - LISTING OF DATA FILE. PIPE WITH ELBO SUBSTRUCTURE IMPACTING RIGID SURFACE.

```
  ECH00101  SEL0C101  FSLT0101  PAU00101  PAU20101
star,paus
goui
new,elbo,nonl,cart,0,376,160
 elbow substructure. name = elbo
retn,376
     10.2550000000e+030.112344999e+020.             e+00
     20.2550000000e+030.1200000000e+020.            e+00
     30.2550000000e+030.106846447e+020.347165106e+01
     40.2550000000e+030.114126787e+020.370820379e+01
     50.2550000000e+030.908890152e+010.660347319e+01
     60.2550000000e+030.970820427e+010.705342293e+01
     70.2550000000e+030.660347414e+010.908890152e+01
     80.2550000000e+030.705342388e+010.970820427e+01
     90.2550000000e+030.347165227e+010.106846457e+02
    100.2550000000e+030.370820475e+010.114126776e+02
    110.2550000000e+030.848181173e-060.112344999e+02
    120.2550000000e+030.905974344e-060.1200000000e+02
    130.2550000000e+03-.347165084e+010.106846447e+02
    140.2550000000e+03-.370820332e+010.114126767e+02
    150.2550000000e+03-.660347271e+010.908890152e+01
    160.2550000000e+03-.705342245e+010.970820427e+01
    170.2550000000e+03-.908890057e+010.660347462e+01
    180.2550000000e+03-.970820238e+010.705342436e+01
    190.2550000000e+03-.106846437e+020.347165442e+01
    200.2550000000e+03-.114126768e+020.370820737e+01
    210.2550000000e+03-.112344999e+020.437487552e-05
    220.2550000000e+03-.1200000000e+020.467297241e-05
    230.267645172e+030.112344999e+020.             e+00
    240.267645172e+030.1200000000e+020.            e+00
    250.267645172e+030.106846447e+020.347165106e+01
    260.267645172e+030.114126787e+020.370820379e+01
    270.267645172e+030.908890152e+010.660347319e+01
    280.267645172e+030.970820427e+010.705342293e+01
    290.267645172e+030.660347414e+010.908890152e+01
    300.267645172e+030.705342388e+010.970820427e+01
    310.267645172e+030.347165227e+010.106846457e+02
    320.267645172e+030.370820475e+010.114126776e+02
    330.267645172e+030.848181173e-060.112344999e+02
    340.267645172e+030.905974344e-060.1200000000e+02
    350.267645172e+03-.347165084e+010.106846447e+02
    360.267645172e+03-.370820332e+010.114126767e+02
    370.267645172e+03-.660347271e+010.908890152e+01
    380.267645172e+03-.705342245e+010.970820427e+01
    390.267645172e+03-.908890057e+010.660347462e+01
    400.267645172e+03-.970820238e+010.705342436e+01
    410.267645172e+03-.106846437e+020.347165442e+01
    420.267645172e+03-.114126768e+020.370820737e+01
    430.267645172e+03-.112344999e+020.437487552e-05
    440.267645172e+03-.1200000000e+020.467297241e-05
    450.274870972e+030.112344999e+020.             e+00
    460.274870972e+030.1200000000e+020.            e+00
    470.274870972e+030.106846447e+020.347165106e+01
    480.274870972e+030.114126787e+020.370820379e+01
    490.274870972e+030.908890152e+010.660347319e+01
    500.274870972e+030.970820427e+010.705342293e+01
```

Table 2.7.2 (cont'd)

```
510.274870972e+030.660347414e+010.908890152e+01
520.274870972e+030.705342386e+010.970820427e+01
530.274870972e+030.347165227e+010.106846457e+02
540.274870972e+030.370020475e+010.114126778e+02
550.274870972e+030.848281173e-060.112344999e+02
560.274870972e+030.905974044e-060.120000000e+02
570.274870972e+03-.347165084e+010.106846447e+02
580.274870972e+03-.370020332e+010.114126767e+02
590.274870972e+03-.660347271e+010.908890152e+01
600.274870972e+03-.705342245e+010.970820427e+01
610.274870972e+03-.908890057e+010.660347462e+01
620.274870972e+03-.970020236e+010.705342436e+01
630.274870972e+03-.106846437e+020.347165442e+01
640.274870972e+03-.114126766e+020.370820757e+01
650.274870972e+03-.112344999e+020.437487552e-05
660.274870972e+03-.120000000e+020.467297241e-05
670.279000000e+030.112344999e+020.          e+00
680.279000000e+030.120000000e+020.          e+00
690.279000000e+030.106846447e+020.347165106e+01
700.279000000e+030.114126787e+020.370820379e+01
710.279000000e+030.908890152e+010.660347319e+01
720.279000000e+030.970020427e+010.705342293e+01
730.279000000e+030.660347414e+010.908890152e+01
740.279000000e+030.705342386e+010.970820427e+01
750.279000000e+030.347165227e+010.106846457e+02
760.279000000e+030.370020475e+010.114126778e+02
770.279000000e+030.848281173e-060.112344999e+02
780.279000000e+030.905974044e-060.120000000e+02
790.279000000e+03-.347165084e+010.106846447e+02
800.279000000e+03-.370020332e+010.114126767e+02
810.279000000e+03-.660347271e+010.908890152e+01
820.279000000e+03-.705342245e+010.970820427e+01
830.279000000e+03-.908890057e+010.660347462e+01
840.279000000e+03-.970020236e+010.705342436e+01
850.279000000e+03-.106846437e+020.347165442e+01
860.279000000e+03-.114126766e+020.370820737e+01
870.279000000e+03-.112344999e+020.437487552e-05
880.279000000e+03-.120000000e+020.467297241e-05
890.282874175e+030.115394039e+020.          e+00
900.282754425e+030.122954796e+020.          e+00
910.282960205e+030.109963186e+020.347165106e+01
920.282846313e+030.117153093e+020.370820379e+01
930.283209829e+030.942022133e+010.660347319e+01
940.283112946e+030.100318995e+020.705342293e+01
950.283599605e+030.696539354e+010.908890152e+01
960.283528229e+030.740980367e+010.970820427e+01
970.284088562e+030.387212944e+010.106846457e+02
980.284051544e+030.410576963e+010.114126778e+02
990.284631655e+030.443219781e+000.112344999e+02
1000.284631655e+030.443219041e+000.120000000e+02
1010.285174715e+03-.298569012e+010.106846447e+02
1020.285211731e+03-.321933031e+010.114126767e+02
1030.285664642e+03-.607095422e+010.908890152e+01
1040.285735046e+03-.652335454e+010.970820427e+01
1050.286053467e+03-.853378201e+010.660347462e+01
1060.286150325e+03-.914545916e+010.705342436e+01
```

Table 2.7.2 (cont'd)

```
1070.286330312e+03-.101098795e+020.347165442e+01
1080.286416992e+03-.108289490e+020.370820737e+01
1090.286369099e+03-.106529655e+020.437487552e-05
1100.286509852e+03-.114090414e+020.467297241e-05
1110.286652954e+030.124466105e+020.          e+00
1120.286416422e+030.131743445e+020.          e+00
1130.286622875e+030.119236607e+020.347165106e+01
1140.285597905e+030.126263086e+020.370820379e+01
1150.287315979e+030.104060249e+020.660347319e+01
1160.287124605e+030.109950171e+020.705342293e+01
1170.288084045e+030.604224396e+010.908890152e+01
1180.287944977e+030.647017097e+010.970820427e+01
1190.289051619e+030.506370401e+010.106846437e+02
1200.288978729e+030.528867912e+010.114126776e+02
1210.290124605e+030.176195754e+010.112344999e+02
1220.290124605e+030.176195754e+010.120000000e+02
1230.291197426e+03-.153970941e+010.106846447e+02
1240.291270505e+03-.176474404e+010.114126767e+02
1250.292165192e+03-.451030364e+010.908890152e+01
1260.292304220e+03-.494623661e+010.970820427e+01
1270.292933225e+03-.668209152e+010.660347462e+01
1280.293124605e+03-.747208175e+010.705342436e+01
1290.293426301e+03-.839973259e+010.347165442e+01
1300.293651337e+03-.909213352e+010.370820737e+01
1310.293596285e+03-.892267704e+010.437487552e-05
1320.293632825e+03-.965071100e+010.467297241e-05
1330.290243317e+030.139337786e+020.          e+00
1340.289895782e+030.146158447e+020.          e+00
1350.290492955e+030.134438543e+020.347165106e+01
1360.290162415e+030.140925379e+020.370820379e+01
1370.291217377e+030.120220375e+020.660347319e+01
1380.290936226e+030.125738401e+020.705342293e+01
1390.292345764e+030.980750561e+010.908890152e+01
1400.292141479e+030.102084141e+020.970820427e+01
1410.293767575e+030.701703167e+010.106846437e+02
1420.293660127e+030.722780180e+010.114126776e+02
1430.295343656e+030.392376762e+010.112344999e+02
1440.295343656e+030.392375762e+010.120000000e+02
1450.295919769e+030.830503702e+000.106846447e+02
1460.297027161e+030.619734049e+000.114126767e+02
1470.298341565e+03-.195997006e+010.908890152e+01
1480.298545827e+03-.236087799e+010.970820427e+01
1490.299469945e+03-.417450237e+010.660347462e+01
1500.299751099e+03-.472630405e+010.705342436e+01
1510.300194397e+03-.559631920e+010.347165442e+01
1520.300524962e+03-.624500179e+010.370820737e+01
1530.300444031e+03-.608624456e+010.437487552e-05
1540.300791565e+03-.676831055e+010.467297241e-05
1550.293556795e+030.159642906e+020.          e+00
1560.293106842e+030.165835734e+020.          e+00
1570.293880005e+030.155194463e+020.347165106e+01
1580.293452057e+030.161064404e+020.370820379e+01
1590.294617905e+030.142284066e+020.660347319e+01
1600.294453926e+030.147294922e+020.705342293e+01
1610.295278839e+030.122177124e+020.908890152e+01
1620.295014374e+030.125017299e+020.970820427e+01
```

Table 2.7.2 (cont'd)

```
1630.295119055e+030.906431527e+010.105846457e+02
1640.297950055e+030.987537101e+010.114126776e+02
1650.300160275e+030.687539055e+010.112344959e+02
1660.300160275e+030.687539101e+010.120000000e+02
1670.302200867e+030.406675379e+010.105846447e+02
1680.302339905e+030.387539077e+010.114126767e+02
1690.304041607e+030.155300866e+010.908890152e+01
1700.304306105e+030.126905165e+010.970820427e+01
1710.305502594e+03-.477684498e+000.660347462e+01
1720.305866602e+03-.978710175e+000.705342436e+01
1730.306440555e+03-.176660817e+010.347165442e+01
1740.305668469e+03-.135765039e+010.370820737e+01
1750.306763733e+03-.221351051e+010.437487552e-05
1760.307213604e+03-.263281322e+010.467297241e-05
1770.295511871e+030.164081490e+020.         e+00
1780.295970501e+030.190294399e+020.         e+00
1790.296900605e+030.160993423e+020.347165100e+01
1800.296385604e+030.156141415e+020.370620379e+01
1810.298029022e+030.169707816e+020.660347319e+01
1820.297591125e+030.174068955e+020.705342293e+01
1830.299786499e+030.152135201e+020.908890152e+01
1840.299468325e+030.155316830e+020.970820427e+01
1850.302001007e+030.129969372e+020.105846457e+02
1860.301833745e+030.131662560e+020.114126776e+02
1870.304455841e+030.105441599e+020.112344999e+02
1880.304455841e+030.105441599e+020.120000000e+02
1890.306910675e+030.808933163e+010.105846447e+02
1900.307077942e+030.792206383e+010.114126767e+02
1910.309125224e+030.567479925e+010.908890152e+01
1920.309443359e+030.555663681e+010.970820427e+01
1930.310882605e+030.411733627e+010.660347462e+01
1940.311320587e+030.307942381e+010.705342436e+01
1950.312011047e+030.298097552e+010.347165442e+01
1960.312525016e+030.247417831e+010.370820737e+01
1970.312399641e+030.260016870e+010.437487552e-05
1980.312941122e+030.205587794e+010.467297241e-05
1990.299035706e+030.214432060e+020.         e+00
2000.298416422e+030.218931561e+020.         e+00
2010.299480506e+030.211200085e+020.347165106e+01
2020.298691571e+030.215479374e+020.370820379e+01
2030.300771545e+030.201820545e+020.660347319e+01
2040.300270506e+030.205460720e+020.705342253e+01
2050.302782225e+030.187211571e+020.908890152e+01
2060.302418274e+030.189056319e+020.970820427e+01
2070.305315979e+030.168003190e+020.105846457e+02
2080.305124605e+030.170193615e+020.114126776e+02
2090.308124605e+030.148397341e+020.112344999e+02
2100.308124605e+030.148397341e+020.120000000e+02
2110.310933225e+030.127991480e+020.105846447e+02
2120.311124605e+030.126601067e+020.114126767e+02
2130.313466949e+030.109583101e+020.908890152e+01
2140.313830905e+030.106935362e+020.970820427e+01
2150.315477692e+030.949741266e+010.660347462e+01
2160.315978719e+030.913337015e+010.705342436e+01
2170.316760677e+030.855945776e+010.347165442e+01
2180.317357666e+030.813155376e+010.370820737e+01
```

Table 2.7.2 (cont'd)

```
2190.317213501e+030.623626041e+010.437487552e-05
2200.317632815e+030.778631357e+010.467297241e-05
2210.301066215e+030.247567005e+020.           e+00
2220.300384115e+030.251042509e+020.           e+00
2230.301556152e+030.245070724e+020.347165106e+01
2240.300907471e+030.248375931e+020.370820379e+01
2250.302977906e+030.237625195e+020.660347319e+01
2260.302426175e+030.240637779e+020.705342293e+01
2270.305192505e+030.226542567e+020.908890152e+01
2280.304791595e+030.228585320e+020.970820427e+01
2290.307982971e+030.212324429e+020.106846457e+02
2300.307772217e+030.213398342e+020.114126776e+02
2310.311076215e+030.196563454e+020.112344999e+02
2320.311076235e+030.196563454e+020.120000000e+02
2330.314169495e+030.160802498e+020.106846447e+02
2340.314380200e+030.179728565e+020.114126767e+02
2350.316959991e+030.166584320e+020.908890152e+01
2360.317360875e+030.164541586e+020.970820427e+01
2370.319174500e+030.155300713e+020.660347462e+01
2380.319726316e+030.152489147e+020.705342436e+01
2390.320596344e+030.148055192e+020.347165442e+01
2400.321245015e+030.144753996e+020.370820737e+01
2410.321086243e+030.145559902e+020.437487552e-05
2420.321768311e+030.142084608e+020.467297241e-05
2430.302553406e+030.263470440e+020.           e+00
2440.301825346e+030.265835972e+020.           e+00
2450.303076324e+030.261771297e+020.347165106e+01
2460.302383942e+030.264021053e+020.370820379e+01
2470.304593994e+030.276840191e+020.660347319e+01
2480.304004974e+030.278753929e+020.705342293e+01
2490.305957764e+030.269159794e+020.908890152e+01
2500.306529645e+030.270550213e+020.970820427e+01
2510.309936315e+030.259481945e+020.106846457e+02
2520.309711324e+030.260212917e+020.114126776e+02
2530.313238037e+030.248753948e+020.112344999e+02
2540.313238037e+030.248753946e+020.120000000e+02
2550.316539764e+030.236025970e+020.106846447e+02
2560.316764740e+030.237294979e+020.114126767e+02
2570.319518311e+030.228348103e+020.908890152e+01
2580.319946259e+030.226957684e+020.970820427e+01
2590.321882111e+030.220667706e+020.660347462e+01
2600.322471100e+030.218753967e+020.705342436e+01
2610.323399750e+030.215730599e+020.347165442e+01
2620.324092115e+030.213486862e+020.370820737e+01
2630.323922659e+030.214037457e+020.437487552e-05
2640.324650715e+030.211671925e+020.467297241e-05
2650.303460602e+030.321253270e+020.           e+00
2660.302704519e+030.322455786e+020.           e+00
2670.304003655e+030.320398140e+020.347165106e+01
2680.303284607e+030.321537010e+020.370820379e+01
2690.305579773e+030.317901840e+020.660347319e+01
2700.304968109e+030.318670640e+020.705342293e+01
2710.308034607e+030.314013786e+020.908890152e+01
2720.307590215e+030.314717655e+020.970820427e+01
2730.311127609e+030.309114532e+020.106846457e+02
2740.310694226e+030.309484577e+020.114126776e+02
```

Table 2.7.2 (cont'd)

```
2750.3145567950e+030.3036830810e+020.112344999e+02
2760.3145557500e+030.3026830810e+020.120000000e+02
2770.3179656270e+030.2982520310e+020.106846447e+02
2780.3182193000e+030.2970627800e+020.114126767e+02
2790.3210789490e+030.2933535900e+020.908890152e+01
2800.3215233700e+030.2920497000e+020.970820427e+01
2810.3235337000e+030.2894655200e+020.660347462e+01
2820.3241454770e+030.2884957200e+020.705342456e+01
2830.3251098940e+030.2869692400e+020.347165442e+01
2840.3258285490e+030.2850303450e+020.370820757e+01
2850.3256529050e+030.2862090850e+020.437487552e-05
2860.3264090550e+030.2849115750e+020.467297241e-05
2870.3037655050e+030.3000000380e+020.         e+00
2880.3030000000e+030.3000000000e+020.         e+00
2890.3043153690e+030.3000000380e+020.347165100e+01
2900.3035873110e+030.3000000380e+020.370820379e+01
2910.3059111020e+030.3000000380e+020.660347319e+01
2920.3052918090e+030.3000000380e+020.705342293e+01
2930.3083965150e+030.3000000380e+020.908890152e+01
2940.3079465040e+030.3000000380e+020.970820427e+01
2950.3115283510e+030.3000000380e+020.106846437e+02
2960.3112918090e+030.3000000380e+020.114126778e+02
2970.3150000000e+030.3000000380e+020.112344999e+02
2980.3150000000e+030.3000000380e+020.120000000e+02
2990.3184716490e+030.3000000380e+020.106846447e+02
3000.3187081910e+030.3000000380e+020.114126767e+02
3010.3216034850e+030.3000000380e+020.908890152e+01
3020.3220534250e+030.3000000380e+020.970820427e+01
3030.3240898550e+030.3000000380e+020.660347462e+01
3040.3247082210e+030.3000000380e+020.705342456e+01
3050.3256846620e+030.3000000380e+020.347165442e+01
3060.3264126090e+030.3000000380e+020.370820757e+01
3070.3262344970e+030.3000000380e+020.437487552e-05
3080.3270000000e+030.3000000760e+020.467297241e-05
3090.3037655050e+030.4012903590e+020.         e+00
3100.3030000000e+030.4012903210e+020.         e+00
3110.3043153690e+030.4012903590e+020.347165100e+01
3120.3035873110e+030.4012903590e+020.370820379e+01
3130.3059111020e+030.4012903590e+020.660347319e+01
3140.3052918090e+030.4012903590e+020.705342293e+01
3150.3083965150e+030.4012903590e+020.908890152e+01
3160.3079465040e+030.4012903590e+020.970820427e+01
3170.3115283510e+030.4012903590e+020.106846437e+02
3180.3112918090e+030.4012903590e+020.114126778e+02
3190.3150000000e+030.4012903590e+020.112344999e+02
3200.3150000000e+030.4012903590e+020.120000000e+02
3210.3184716490e+030.4012903590e+020.106846447e+02
3220.3187081910e+030.4012903590e+020.114126767e+02
3230.3216034850e+030.4012903590e+020.908890152e+01
3240.3220534250e+030.4012903590e+020.970820427e+01
3250.3240898550e+030.4012903590e+020.660347462e+01
3260.3247082210e+030.4012903590e+020.705342456e+01
3270.3256946620e+030.4012903590e+020.347165442e+01
3280.3254126090e+030.4012903590e+020.370820757e+01
3290.3252344970e+030.4012903590e+020.437487552e-05
3300.3270000000e+030.4012903900e+020.467297241e-05
```

Table 2.7.2 (cont'd)

```
 3310.303765500e+030.473548431e+020.            e+00
 3320.303000000e+030.473548392e+020.            e+00
 3330.304315309e+030.473548431e+020.347165100e+01
 3340.303587311e+030.473548431e+020.370820379e+01
 3350.305911102e+030.473548431e+020.660347319e+01
 3360.305291809e+030.473548431e+020.705342293e+01
 3370.308395552e+030.473548431e+020.908890152e+01
 3380.307946504e+030.473548431e+020.970820427e+01
 3390.311528351e+030.473548431e+020.106846457e+02
 3400.311291809e+030.473548431e+020.114126770e+02
 3410.315000000e+030.473548431e+020.112344999e+02
 3420.315000000e+030.473548431e+020.120000000e+02
 3430.318471649e+030.473548431e+020.106846447e+02
 3440.318708191e+030.473548431e+020.114126767e+02
 3450.321603425e+030.473548431e+020.908890152e+01
 3460.322053416e+030.473548431e+020.970820427e+01
 3470.324088855e+030.473548431e+020.660347462e+01
 3480.324708211e+030.473548431e+020.705342430e+01
 3490.325684661e+030.473548431e+020.347165442e+01
 3500.326412609e+030.473548431e+020.370820737e+01
 3510.326234497e+030.473548431e+020.437487552e-05
 3520.327000000e+030.473548470e+020.467297241e-05
 3530.303765503e+030.600000030e+020.            e+00
 3540.303000000e+030.600000000e+020.            e+00
 3550.304315309e+030.600000030e+020.347165100e+01
 3560.303587311e+030.600000030e+020.370820379e+01
 3570.305911102e+030.600000030e+020.660347319e+01
 3580.305291809e+030.600000030e+020.705342293e+01
 3590.308396552e+030.600000030e+020.908890152e+01
 3600.307946504e+030.600000030e+020.970820427e+01
 3610.311528351e+030.600000030e+020.106846457e+02
 3620.311291779e+030.600000030e+020.114126776e+02
 3630.315000000e+030.600000030e+020.112344999e+02
 3640.315000000e+030.600000030e+020.120000000e+02
 3650.318471649e+030.600000030e+020.106846447e+02
 3660.318708191e+030.600000030e+020.114126767e+02
 3670.321603425e+030.600000030e+020.908890152e+01
 3680.322053426e+030.600000030e+020.970820427e+01
 3690.324068855e+030.600000030e+020.660347462e+01
 3700.324708191e+030.600000030e+020.705342430e+01
 3710.325684611e+030.600000030e+020.347165442e+01
 3720.325412609e+030.600000030e+020.370820737e+01
 3730.325234497e+030.600000030e+020.437487552e-05
 3740.327000000e+030.600000076e+020.467297241e-05
99980.255000000e+030.            e+000.            e+00
99990.315000000e+030.600000030e+020.            e+00
boun,68
    1                              000111    1  100
  101                              000111    1  200
  201                              000111    1  300
  301                              000111    1  374
    2                              001111
   22                              001111
   23                              001111
   24                              001111
   43                              001111
```

Table 2.7.2 (cont'd)

44	0C1111
45	0C1111
46	0C1111
65	0C1111
66	0C1111
67	0C1111
68	0C1111
87	0C1111
88	0C1111
89	0C1111
90	0C1111
109	0C1111
110	0C1111
111	0C1111
112	0C1111
131	0C1111
132	0C1111
133	0C1111
134	0C1111
153	0C1111
154	0C1111
155	0C1111
156	0C1111
175	0C1111
176	0C1111
177	0C1111
178	0C1111
197	0C1111
198	0C1111
199	0C1111
200	0C1111
219	0C1111
220	0C1111
221	0C1111
222	0C1111
241	0C1111
242	0C1111
243	0C1111
244	0C1111
263	0C1111
264	0C1111
265	0C1111
266	0C1111
265	0C1111
286	0C1111
287	0C1111
288	0C1111
307	0C1111
308	0C1111
309	0C1111
310	0C1111
329	0C1111
330	0C1111
331	0C1111
332	0C1111
351	0C1111

```
  352                          001111
  354                          001111
  374                          001111
slav,22
    1 9998                     111000
    3 9998                     111000
    5 9998                     111000
    7 9998                     111000
    9 9998                     111000
   11 9998                     111000
   13 9998                     111000
   15 9998                     111000
   17 9998                     111000
   19 9998                     111000
   21 9998                     111000
  353 9999                     111000
  355 9999                     111000
  357 9999                     111000
  359 9999                     111000
  361 9999                     111000
  363 9999                     111000
  365 9999                     111000
  367 9999                     111000
  369 9999                     111000
  371 9999                     111000
  373 9999                     111000
cnod,2
 9998
 9999
enod,0
matl,3,36
0.20000000e+030.          e+000.10000001e+000.10000001e+000.29999998e+00
0.28399998e-020.          e+000.          e+000.          e+000.25700000e+05
0.21900000e+030.20000000e+020.            e+000.          e+000.          e+00
0.26700000e+030.44000000e+020.99999993e+200.              e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.10000000e+01
0.          e+000.        e+00-.10000000e+010.            e+000.          e+00
0.          e+00
0.20000000e+030.          e+000.10000001e+000.10000001e+000.29999998e+00
0.28399998e-020.          e+000.          e+000.          e+000.26700000e+05
0.21900000e+030.20000000e+020.            e+000.          e+000.          e+00
0.26700000e+030.44000000e+020.99999993e+200.              e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.10000000e+01
0.          e+000.        e+00-.10000000e+010.            e+000.          e+00
0.          e+00
0.20000000e+030.          e+000.10000001e+000.10000001e+000.29999998e+00
0.28399998e-020.          e+000.          e+000.          e+000.26700000e+05
0.21900000e+030.20000000e+020.            e+000.          e+000.          e+00
0.26700000e+030.44000000e+020.99999993e+200.              e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.          e+00
0.          e+000.        e+000.          e+000.          e+000.10000000e+01
0.          e+000.        e+00-.10000000e+010.            e+000.          e+00
0.          e+00
elem,1
```

Table 2.7.2 (cont'd)

20	165	[illegible]	[illegible]	[illegible]	[illegible]				1.00						
1	0	0	0	3	25	23	1	4	26	24	2	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
2	0	0	0	5	27	25	3	6	28	26	4	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
3	0	0	0	7	29	27	5	8	30	28	6	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
4	0	0	0	9	31	29	7	10	32	30	8	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
5	0	0	0	11	33	31	9	12	34	32	10	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
6	0	0	0	13	35	33	11	14	36	34	12	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
7	0	0	0	15	37	35	13	16	38	36	14	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
8	0	0	0	17	39	37	15	18	40	38	16	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
9	0	0	0	19	41	39	17	20	42	40	18	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
10	0	0	0	21	43	41	19	22	44	42	20	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
11	0	0	0	25	47	45	23	26	48	46	24	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
12	0	0	0	27	49	47	25	28	50	48	26	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
13	0	0	0	29	51	49	27	30	52	50	28	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
14	0	0	0	31	53	51	29	32	54	52	30	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
15	0	0	0	33	55	53	31	34	56	54	32	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
16	0	0	0	35	57	55	33	36	58	56	34	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
17	0	0	0	37	59	57	35	38	60	58	36	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
18	0	0	0	39	61	59	37	40	62	60	38	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
19	0	0	0	41	63	61	39	42	64	62	40	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
20	0	0	0	43	65	63	41	44	66	64	42	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
21	0	0	0	47	69	67	45	48	70	68	46	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
22	0	0	0	49	71	69	47	50	72	70	48	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
23	0	0	0	51	73	71	49	52	74	72	50	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
24	0	0	0	53	75	73	51	54	76	74	52	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
25	0	0	0	55	77	75	53	56	78	76	54	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
26	0	0	0	57	79	77	55	58	80	78	56	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
27	0	0	0	59	81	79	57	60	82	80	58	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
28	0	0	0	61	83	81	59	62	84	82	60	1	1	0	5

Table 2.7.2 (cont'd)

0.		e+00	0.		e+00	0.		e+00							
29	0	0	0	63	85	83	61	64	86	84	62	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
30	0	0	0	65	87	85	63	66	88	86	64	1	1	0	5
0.		e+00	0.		e+00	0.		e+00							
31	0	0	0	69	91	89	67	70	92	90	68	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
32	0	0	0	71	93	91	69	72	94	92	70	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
33	0	0	0	73	95	93	71	74	96	94	72	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
34	0	0	0	75	97	95	73	76	98	96	74	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
35	0	0	0	77	99	97	75	78	100	98	76	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
36	0	0	0	79	101	99	77	80	102	100	78	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
37	0	0	0	81	103	101	79	82	104	102	80	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
38	0	0	0	83	105	103	81	84	106	104	82	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
39	0	0	0	85	107	105	83	86	108	106	84	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
40	0	0	0	87	109	107	85	88	110	108	86	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
41	0	0	0	91	113	111	89	92	114	112	90	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
42	0	0	0	93	115	113	91	94	116	114	92	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
43	0	0	0	95	117	115	93	96	118	116	94	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
44	0	0	0	97	119	117	95	98	120	118	96	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
45	0	0	0	99	121	119	97	100	122	120	98	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
46	0	0	0	101	123	121	99	102	124	122	100	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
47	0	0	0	103	125	123	101	104	126	124	102	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
48	0	0	0	105	127	125	103	106	128	126	104	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
49	0	0	0	107	129	127	105	108	130	128	106	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
50	0	0	0	109	131	129	107	110	132	130	108	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
51	0	0	0	113	135	133	111	114	136	134	112	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
52	0	0	0	115	137	135	113	116	138	136	114	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
53	0	0	0	117	139	137	115	118	140	138	116	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
54	0	0	0	119	141	139	117	120	142	140	118	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
55	0	0	0	121	143	141	119	122	144	142	120	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
56	0	0	0	123	145	143	121	124	146	144	122	2	1	0	5

Table 2.7.2 (cont'd)

0.	e+00	0.		e+00	0.		e+00								
57	0	0	0	125	147	145	123	126	148	146	124	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
58	0	0	0	127	149	147	125	128	150	148	126	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
59	0	0	0	129	151	149	127	130	152	150	128	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
60	0	0	0	131	153	151	129	132	154	152	130	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
61	0	0	0	135	157	155	133	136	158	156	134	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
62	0	0	0	137	159	157	135	138	160	158	136	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
63	0	0	0	139	161	159	137	140	162	160	138	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
64	0	0	0	141	163	161	139	142	164	162	140	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
65	0	0	0	143	165	163	141	144	166	164	142	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
66	0	0	0	145	167	165	143	146	168	166	144	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
67	0	0	0	147	169	167	145	148	170	168	146	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
68	0	0	0	149	171	169	147	150	172	170	148	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
69	0	0	0	151	173	171	149	152	174	172	150	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
70	0	0	0	153	175	173	151	154	176	174	152	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
71	0	0	0	157	179	177	155	158	180	178	156	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
72	0	0	0	159	181	179	157	160	182	180	158	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
73	0	0	0	161	183	181	159	162	184	182	160	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
74	0	0	0	163	185	183	161	164	186	184	162	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
75	0	0	0	165	187	185	163	166	188	186	164	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
76	0	0	0	167	189	187	165	168	190	188	166	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
77	0	0	0	169	191	189	167	170	192	190	168	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
78	0	0	0	171	193	191	169	172	194	192	170	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
79	0	0	0	173	195	193	171	174	196	194	172	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
80	0	0	0	175	197	195	173	176	198	196	174	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
81	0	0	0	179	201	199	177	180	202	200	178	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
82	0	0	0	181	203	201	179	182	204	202	180	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
83	0	0	0	183	205	203	181	184	206	204	182	2	1	0	5
0.	e+00	0.		e+00	0.		e+00								
84	0	0	0	185	207	205	183	186	208	206	184	2	1	0	5

Table 2.7.2 (cont'd)

0.		e+00	0.		e+00	0.		e+00							
85	0	0	0	187	209	207	185	188	210	208	186	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
86	0	0	0	189	211	209	187	190	212	210	188	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
87	0	0	0	191	213	211	189	192	214	212	190	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
88	0	0	0	193	215	213	191	194	216	214	192	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
89	0	0	0	195	217	215	193	196	218	216	194	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
90	0	0	0	197	219	217	195	198	220	218	196	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
91	0	0	0	201	223	221	199	202	224	222	200	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
92	0	0	0	203	225	223	201	204	226	224	202	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
93	0	0	0	205	227	225	203	206	228	226	204	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
94	0	0	0	207	229	227	205	208	230	228	206	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
95	0	0	0	209	231	229	207	210	232	230	208	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
96	0	0	0	211	233	231	209	212	234	232	210	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
97	0	0	0	213	235	233	211	214	236	234	212	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
98	0	0	0	215	237	235	213	216	238	236	214	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
99	0	0	0	217	239	237	215	218	240	238	216	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
100	0	0	0	219	241	239	217	220	242	240	218	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
101	0	0	0	223	245	243	221	224	246	244	222	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
102	0	0	0	225	247	245	223	226	248	246	224	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
103	0	0	0	227	249	247	225	228	250	248	226	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
104	0	0	0	229	251	249	227	230	252	250	228	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
105	0	0	0	231	253	251	229	232	254	252	230	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
106	0	0	0	233	255	253	231	234	256	254	232	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
107	0	0	0	235	257	255	233	236	258	256	234	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
108	0	0	0	237	259	257	235	238	260	258	236	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
109	0	0	0	239	261	259	237	240	262	260	238	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
110	0	0	0	241	263	261	239	242	264	262	240	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
111	0	0	0	245	267	265	243	246	268	266	244	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
112	0	0	0	247	269	267	245	248	270	268	246	2	1	0	5

Table 2.7.2 (cont'd)

0.		e+00	0.		e+00	0.		e+00							
113	0	0	0	249	271	269	247	250	272	270	248	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
114	0	0	0	251	273	271	249	252	274	272	250	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
115	0	0	0	253	275	273	251	254	276	274	252	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
116	0	0	0	255	277	275	253	256	278	276	254	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
117	0	0	0	257	279	277	255	258	280	278	256	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
118	0	0	0	259	281	279	257	260	282	280	258	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
119	0	0	0	261	283	281	259	262	284	282	260	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
120	0	0	0	263	285	283	261	264	286	284	262	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
121	0	0	0	267	289	287	265	268	290	288	266	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
122	0	0	0	269	291	289	267	270	292	290	268	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
123	0	0	0	271	293	291	269	272	294	292	270	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
124	0	0	0	273	295	293	271	274	296	294	272	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
125	0	0	0	275	297	295	273	276	298	296	274	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
126	0	0	0	277	299	297	275	278	300	298	276	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
127	0	0	0	279	301	299	277	280	302	300	278	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
128	0	0	0	281	303	301	279	282	304	302	280	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
129	0	0	0	283	305	303	281	284	306	304	282	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
130	0	0	0	285	307	305	283	286	308	306	284	2	1	0	5
0.		e+00	0.		e+00	0.		e+00							
131	0	0	0	289	311	309	287	290	312	310	288	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
132	0	0	0	291	313	311	289	292	314	312	290	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
133	0	0	0	293	315	313	291	294	316	314	292	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
134	0	0	0	295	317	315	293	296	318	316	294	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
135	0	0	0	297	319	317	295	298	320	318	296	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
136	0	0	0	299	321	319	297	300	322	320	298	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
137	0	0	0	301	323	321	299	302	324	322	300	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
138	0	0	0	303	325	323	301	304	326	324	302	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
139	0	0	0	305	327	325	303	306	328	326	304	3	1	0	5
0.		e+00	0.		e+00	0.		e+00							
140	0	0	0	307	329	327	305	308	330	328	306	3	1	0	5

```
   0.      e+00   0.      e+00   0.      e+00
  141    0    0    0  311  333  331  309  312  334  332  310    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  142    0    0    0  313  335  333  311  314  336  334  312    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  143    0    0    0  315  337  335  313  316  338  336  314    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  144    0    0    0  317  339  337  315  318  340  338  316    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  145    0    0    0  319  341  339  317  320  342  340  318    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  146    0    0    0  321  343  341  319  322  344  342  320    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  147    0    0    0  323  345  343  321  324  346  344  322    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  148    0    0    0  325  347  345  323  326  348  346  324    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  149    0    0    0  327  349  347  325  328  350  348  326    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  150    0    0    0  329  351  349  327  330  352  350  328    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  151    0    0    0  333  355  353  331  334  356  354  332    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  152    0    0    0  335  357  355  333  336  358  356  334    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  153    0    0    0  337  359  357  335  338  360  358  336    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  154    0    0    0  339  361  359  337  340  362  360  338    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  155    0    0    0  341  363  361  339  342  364  362  340    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  156    0    0    0  343  365  363  341  344  366  364  342    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  157    0    0    0  345  367  365  343  346  368  366  344    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  158    0    0    0  347  369  367  345  348  370  368  346    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  159    0    0    0  349  371  369  347  350  372  370  348    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00
  160    0    0    0  351  373  371  349  352  374  372  350    3    1    0    5
   0.      e+00   0.      e+00   0.      e+00

nord.
prof
end
new,slab,nonl,curt,0,9,1
 slab substructure. name = slab
retn,9
     10.2534499597e+03-.1955999995e+02-.5000000000e+02
     20.2530432749e+03-.1064644610e+02-.5000000000e+02
     30.2534499597e+03-.1955999995e+020.5000000000e+02
     40.2530432749e+03-.1064644810e+020.5000000000e+02
     50.3448051455e+030.1111229521e+02-.5000000000e+02
     60.3443998425e+030.1202553465e+02-.5000000000e+02
     70.3448051455e+03-.1111229521e+020.5000000000e+02
     80.3443998425e+030.1202553465e+020.5000000000e+02
```

Table 2.7.2 (cont'd)

```
 9999
boun,10
    1                          000111     1    6
    1                          111111
    2                          000111
    3                          111111
    4                          000111
    5                          111111
    6                          000111
    7                          111111
    8                          000111
 9999                          0.1111
cnod,1
 9999
enod,0
matl,1,36
0.100000000e+010.          e+000.199999990e-010.499999970e-010.299999982e+00
0.283999940e-010.499999970e-010.          e+000.          e+000.257000000e+05
0.265000000e+010.          e+000.          e+000.          e+000.          e+00
0.100000000e+010.999999932e+200.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.          e+00
0.          e+000.          e+000.          e+000.          e+000.100000000e+01
0.          e+000.          e+00-.100000000e+010.          e+000.          e+00
0.          e+00
elem,1
   20    1    1    2    1    0                   1.00
    1    0    0    0    1    3    7    5    2    4    8    6    1    0    0    2
0.          e+000.          e+000.          e+00

nora,
prof
end
new,main,nonl,cart,0,10,10
 main structure
rafn,8
    1  0.          e+00  0.          e+00  0.          e+00
    2  0.63750000e+02  0.          e+00  0.          e+00
    3  0.12750000e+03  0.          e+00  0.          e+00
    4  0.19125000e+03  0.          e+00  0.          e+00
    5  0.25500000e+03  0.          e+00  0.          e+00
    8  0.31500000e+03  0.60000000e+02  0.          e+00
    9  0.31500000e+03  0.14200000e+03  0.          e+00
 9999
cons,1
 elbo    2
 9998    5
 9999    8
cons,1
 slab    1
 9999 9999
boun,8
    1                         111110
    2                           1110
    3                           1110
    4                           1110
    5                           1110
```

Table 2.7.2 (cont'd)

```
    6                                  1110
    9                                  1110
 9999                                 1.1111
enod,0
matl,1,64
0.200000000e+010.299999982e+000.267000000e+050.219000000e+030.200000000e+02
0.267000000e+020.440000000e+020.999999932e+200.100000001e+000.100000001e+00
0.120000000e+020.200000000e+010.            e+000.200000000e+010.100000000e+01
0.100000000e+020.240000000e+020.153100002e+010.306922067e-010.            e+00
0.349999994e+000.799999982e-010.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.639999986e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+000.            e+00
0.            e+000.            e+000.            e+000.            e+00
elem,1
    3    5    -                                      1.00
    1    0    0    0    1    2    1    1    0    1    0    1
0.            e+000.100000000e+010.            e+000.            e+00
    2    0    0    0    2    3    1    1    0    1    0    1
0.637500000e+010.100000000e+010.            e+000.            e+00
    3    0    0    0    3    4    1    1    0    1    0    1
0.127500000e+020.100000000e+010.            e+000.            e+00
    4    0    0    0    4    5    1    1    0    1    0    1
0.191250000e+020.100000000e+010.            e+000.            e+00
    5    0    0    0    8    9    1    1    0    1    0    1
0.314000000e+020.600000000e+020.            e+000.            e+00

nord,opto
prof
end
fini
mode
tree,main
fini
moui
new,eloo
pmas,187
    10 0.12634e-04 0.12634e-04 0.12634e-04 0.        e+00 0.        e+00 0.        e+0000
    30 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
    50 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
    70 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
    90 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   110 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   130 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   150 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   170 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   190 0.25267e-04 0.25267e-04 0.25267e-04 0.        e+00 0.        e+00 0.        e+0000
   210 0.12634e-04 0.12634e-04 0.12634e-04 0.        e+00 0.        e+00 0.        e+0000
   230 0.19853e-04 0.19853e-04 0.19853e-04 0.        e+00 0.        e+00 0.        e+0000
   250 0.39706e-04 0.39706e-04 0.39706e-04 0.        e+00 0.        e+00 0.        e+0000
   270 0.39706e-04 0.39706e-04 0.39706e-04 0.        e+00 0.        e+00 0.        e+0000
   290 0.39706e-04 0.39706e-04 0.39706e-04 0.        e+00 0.        e+00 0.        e+0000
```

Table 2.7.2 (cont'd)

310	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
330	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
350	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
370	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
390	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
410	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
430	0.19853e-04	0.19853e-04	0.19853e-04	0.	e+00 0.	e+00 0.	e+0000
450	0.11345e-04	0.11345e-04	0.11345e-04	0.	e+00 0.	e+00 0.	e+0000
470	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
490	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
510	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
530	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
550	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
570	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
590	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
610	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
630	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
650	0.11345e-04	0.11345e-04	0.11345e-04	0.	e+00 0.	e+00 0.	e+0000
670	0.80079e-05	0.80079e-05	0.80079e-05	0.	e+00 0.	e+00 0.	e+0000
690	0.16188e-04	0.16188e-04	0.16188e-04	0.	e+00 0.	e+00 0.	e+0000
710	0.16689e-04	0.16689e-04	0.16689e-04	0.	e+00 0.	e+00 0.	e+0000
730	0.17468e-04	0.17468e-04	0.17468e-04	0.	e+00 0.	e+00 0.	e+0000
750	0.18450e-04	0.18450e-04	0.18450e-04	0.	e+00 0.	e+00 0.	e+0000
770	0.19538e-04	0.19538e-04	0.19538e-04	0.	e+00 0.	e+00 0.	e+0000
790	0.20627e-04	0.20627e-04	0.20627e-04	0.	e+00 0.	e+00 0.	e+0000
810	0.21609e-04	0.21609e-04	0.21609e-04	0.	e+00 0.	e+00 0.	e+0000
830	0.22388e-04	0.22388e-04	0.22388e-04	0.	e+00 0.	e+00 0.	e+0000
850	0.22889e-04	0.22889e-04	0.22889e-04	0.	e+00 0.	e+00 0.	e+0000
870	0.11531e-04	0.11531e-04	0.11531e-04	0.	e+00 0.	e+00 0.	e+0000
890	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
910	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
930	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
950	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
970	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
990	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
1010	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
1030	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
1050	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
1070	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
1090	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
1110	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
1130	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
1150	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
1170	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
1190	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
1210	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
1230	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
1250	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
1270	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
1290	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
1310	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
1330	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
1350	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
1370	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
1390	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
1410	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000

Table 2.7.2 (cont'd)

1430	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
1450	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
1470	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
1490	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
1510	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
1530	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
1550	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
1570	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
1590	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
1610	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
1630	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
1650	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
1670	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
1690	0.[illegible]717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
1710	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
1730	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
1750	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
1770	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
1790	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
1810	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
1830	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
1850	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
1870	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
1890	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
1910	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
1930	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
1950	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
1970	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
1990	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
2010	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
2030	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
2050	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
2070	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
2090	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
2110	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
2130	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
2150	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
2170	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
2190	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
2210	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
2230	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
2250	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
2270	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
2290	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
2310	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
2330	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
2350	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
2370	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
2390	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
2410	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
2430	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
2450	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
2470	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
2490	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
2510	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
2530	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000

Table 2.7.2 (cont'd)

2550	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
2570	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
2590	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
2610	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
2630	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
2650	0.77653e-05	0.77653e-05	0.77653e-05	0.	e+00 0.	e+00 0.	e+0000
2670	0.15875e-04	0.15875e-04	0.15875e-04	0.	e+00 0.	e+00 0.	e+0000
2690	0.16876e-04	0.16876e-04	0.16876e-04	0.	e+00 0.	e+00 0.	e+0000
2710	0.18435e-04	0.18435e-04	0.18435e-04	0.	e+00 0.	e+00 0.	e+0000
2730	0.20399e-04	0.20399e-04	0.20399e-04	0.	e+00 0.	e+00 0.	e+0000
2750	0.22576e-04	0.22576e-04	0.22576e-04	0.	e+00 0.	e+00 0.	e+0000
2770	0.24753e-04	0.24753e-04	0.24753e-04	0.	e+00 0.	e+00 0.	e+0000
2790	0.26717e-04	0.26717e-04	0.26717e-04	0.	e+00 0.	e+00 0.	e+0000
2810	0.28275e-04	0.28275e-04	0.28275e-04	0.	e+00 0.	e+00 0.	e+0000
2830	0.29276e-04	0.29276e-04	0.29276e-04	0.	e+00 0.	e+00 0.	e+0000
2850	0.14810e-04	0.14810e-04	0.14810e-04	0.	e+00 0.	e+00 0.	e+0000
2870	0.80079e-05	0.80079e-05	0.80079e-05	0.	e+00 0.	e+00 0.	e+0000
2890	0.16188e-04	0.16188e-04	0.16188e-04	0.	e+00 0.	e+00 0.	e+0000
2910	0.16689e-04	0.16689e-04	0.16689e-04	0.	e+00 0.	e+00 0.	e+0000
2930	0.17466e-04	0.17466e-04	0.17466e-04	0.	e+00 0.	e+00 0.	e+0000
2950	0.18450e-04	0.18450e-04	0.18450e-04	0.	e+00 0.	e+00 0.	e+0000
2970	0.19538e-04	0.19538e-04	0.19538e-04	0.	e+00 0.	e+00 0.	e+0000
2990	0.20627e-04	0.20627e-04	0.20627e-04	0.	e+00 0.	e+00 0.	e+0000
3010	0.21609e-04	0.21609e-04	0.21609e-04	0.	e+00 0.	e+00 0.	e+0000
3030	0.22388e-04	0.22388e-04	0.22388e-04	0.	e+00 0.	e+00 0.	e+0000
3050	0.22889e-04	0.22889e-04	0.22889e-04	0.	e+00 0.	e+00 0.	e+0000
3070	0.11531e-04	0.11531e-04	0.11531e-04	0.	e+00 0.	e+00 0.	e+0000
3090	0.11345e-04	0.11345e-04	0.11345e-04	0.	e+00 0.	e+00 0.	e+0000
3110	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3130	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3150	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3170	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3190	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3210	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3230	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3250	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3270	0.22689e-04	0.22689e-04	0.22689e-04	0.	e+00 0.	e+00 0.	e+0000
3290	0.11345e-04	0.11345e-04	0.11345e-04	0.	e+00 0.	e+00 0.	e+0000
3310	0.19853e-04	0.19853e-04	0.19853e-04	0.	e+00 0.	e+00 0.	e+0000
3330	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3350	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3370	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3390	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3410	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3430	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3450	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3470	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3490	0.39706e-04	0.39706e-04	0.39706e-04	0.	e+00 0.	e+00 0.	e+0000
3510	0.19853e-04	0.19853e-04	0.19853e-04	0.	e+00 0.	e+00 0.	e+0000
3530	0.12634e-04	0.12634e-04	0.12634e-04	0.	e+00 0.	e+00 0.	e+0000
3550	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000
3570	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000
3590	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000
3610	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000
3630	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000
3650	0.25267e-04	0.25267e-04	0.25267e-04	0.	e+00 0.	e+00 0.	e+0000

<u>Table 2.7.2</u> (cont'd)

```
  3670 0.25267e-04 0.25267e-04 0.25267e-04 0.      e+00 0.      e+00 0.      e+0000
  3690 0.25267e-04 0.25267e-04 0.25267e-04 0.      e+00 0.      e+00 0.      e+0000
  3710 0.25267e-04 0.25267e-04 0.25267e-04 0.      e+00 0.      e+00 0.      e+0000
  3730 0.12634e-04 0.12634e-04 0.12634e-04 0.      e+00 0.      e+00 0.      e+0000
end
new,slab
pmas,5
    10 0.36979e-02 0.36979e-02 0.36979e-02 0.      e+00 0.      e+00 0.      e+0000
    30 0.36979e-02 0.36979e-02 0.36979e-02 0.      e+00 0.      e+00 0.      e+0000
    50 0.36979e-02 0.36979e-02 0.36979e-02 0.      e+00 0.      e+00 0.      e+0000
    70 0.36979e-02 0.36979e-02 0.36979e-02 0.      e+00 0.      e+00 0.      e+0000
 99990 0.10000e+01
end
new,main
pmas,7
    10 0.12736e-02 0.12736e-02 0.12736e-02 0.      e+00 0.      e+00 0.      e+0000
    20 0.25477e-02 0.25477e-02 0.25477e-02 0.      e+00 0.      e+00 0.      e+0000
    30 0.25477e-02 0.25477e-02 0.25477e-02 0.      e+00 0.      e+00 0.      e+0000
    40 0.25477e-02 0.25477e-02 0.25477e-02 0.      e+00 0.      e+00 0.      e+0000
    50 0.12736e-02 0.12736e-02 0.12736e-02 0.      e+00 0.      e+00 0.      e+0000
    80 0.16385e-02 0.16385e-02 0.16385e-02 0.      e+00 0.      e+00 0.      e+0000
    90 0.16385e-02 0.16385e-02 0.16385e-02 0.      e+00 0.      e+00 0.      e+0000
end
fini
impa,1
 surl     1 0.         e+00 0.5000000e+02 0.1000000e+01 0.7649999e+00
 slab     1     -
    1     3
    5     7
 elbo    70
   75    77    79    81    83    85    87    97    99   101   103   105   107   109   119   121
  123   125   127   129   131   141   143   145   147   149   151   153   163   165   167   169
  171   173   175   185   187   189   191   193   195   197   207   209   211   213   215   217
  219   229   231   233   235   237   239   241   251   253   255   257   259   261   263   273
  275   277   279   281   283   285
fini
ptre
newr,recl,pair,5,100
(2e15.7)
  0.        e+00  0.        e+00
  0.6500000e+02  0.1000000e-03
  0.6800000e+02  0.1000000e-02
  0.1000000e+04  0.2000000e-02
  0.8800000e+03  0.3000000e-02
  0.7800000e+03  0.5000000e-02
  0.4300000e+03  0.2000000e-01
  0.4300000e+03  0.1000000e+02
fini
thou,1234
         8       1235     1     1     0     0
        60       1235     1     1     0     0
      1203       1235     1     1     0     0
         2    -     0     0
ndyn
velo,2,1
 elbo  376
```

Table 2.7.2 (cont'd)

1	0.72463e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
2	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
3	0.68916e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
4	0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
5	0.58623e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
6	0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
7	0.42592e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
8	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
9	0.22392e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
10	0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
11	0.54708e-05	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
12	0.37277e-06	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
13	-0.22392e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
14	-0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
15	-0.42592e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
16	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
17	-0.58623e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
18	-0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
19	-0.68916e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
20	-0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
21	-0.72463e+02	-0.16440e+04	0. e+00	0. e+00	0. e+00	0. e+00
22	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
23	0.72463e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
24	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
25	0.68916e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
26	0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
27	0.58623e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
28	0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
29	0.42592e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
30	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
31	0.22392e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
32	0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
33	0.54708e-05	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
34	0.37277e-06	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
35	-0.22392e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
36	-0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
37	-0.42592e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
38	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
39	-0.58623e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
40	-0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
41	-0.68916e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
42	-0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
43	-0.72463e+02	-0.17263e+04	0. e+00	0. e+00	0. e+00	0. e+00
44	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
45	0.72463e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
46	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
47	0.68916e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
48	0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
49	0.58623e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
50	0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
51	0.42592e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
52	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
53	0.22392e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
54	0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
55	0.54708e-05	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00
56	0.37277e-06	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

57	-0.22392e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
58	-0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
59	-0.42592e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
60	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
61	-0.58623e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
62	-0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
63	-0.58916e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
64	-0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
65	-0.72463e+02	-0.17729e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
66	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
67	0.72463e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
68	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
69	0.58916e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
70	0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
71	0.58623e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
72	0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
73	0.42592e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
74	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
75	0.22392e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
76	0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
77	0.54708e-05	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
78	0.37277e-06	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
79	-0.22392e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
80	-0.15258e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
81	-0.42592e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
82	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
83	-0.58623e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
84	-0.39945e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
85	-0.68916e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
86	-0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
87	-0.72463e+02	-0.17995e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
88	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
89	0.74429e+02	-0.18245e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
90	0.48767e+01	0.77239e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
91	0.70926e+02	-0.16251e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
92	0.46380e+01	0.73460e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
93	0.60760e+02	-0.18267e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
94	0.39453e+01	0.62496e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
95	0.44927e+02	-0.18292e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
96	0.28564e+01	0.45411e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
97	0.24975e+02	-0.18324e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
98	0.15070e+01	0.23676e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
99	0.26588e+01	-0.18359e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
100	0.38445e-06	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
101	-0.19258e+02	-0.18394e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
102	-0.15070e+01	-0.23676e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
103	-0.39209e+02	-0.18425e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
104	-0.26664e+01	-0.45411e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
105	-0.55043e+02	-0.18450e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
106	-0.39453e+01	-0.62476e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
107	-0.65209e+02	-0.18467e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
108	-0.46380e+01	-0.73460e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
109	-0.68712e+02	-0.18472e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
110	-0.48767e+01	-0.77239e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
111	0.80281e+02	-0.18469e+04	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
112	0.46958e+01	0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

113	0.76906e+02	-0.16560e+04	0. e+00	0. e+00	0. e+00	0. e+00
114	0.44650e+01	0.14511e+01	0. e+00	0. e+00	0. e+00	0. e+00
115	0.57119e+02	-0.16532e+04	0. e+00	0. e+00	0. e+00	0. e+00
116	0.37990e+01	0.22344e+01	0. e+00	0. e+00	0. e+00	0. e+00
117	0.51872e+02	-0.16562e+04	0. e+00	0. e+00	0. e+00	0. e+00
118	0.27601e+01	0.89699e+00	0. e+00	0. e+00	0. e+00	0. e+00
119	0.32661e+02	-0.16044e+04	0. e+00	0. e+00	0. e+00	0. e+00
120	0.14511e+01	0.47143e+00	0. e+00	0. e+00	0. e+00	0. e+00
121	0.11365e+02	-0.16713e+04	0. e+00	0. e+00	0. e+00	0. e+00
122	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
123	-0.99315e+01	-0.18782e+04	0. e+00	0. e+00	0. e+00	0. e+00
124	-0.14511e+01	-0.47143e+00	0. e+00	0. e+00	0. e+00	0. e+00
125	-0.29143e+02	-0.16045e+04	0. e+00	0. e+00	0. e+00	0. e+00
126	-0.27601e+01	-0.89686e+00	0. e+00	0. e+00	0. e+00	0. e+00
127	-0.44309e+02	-0.16044e+04	0. e+00	0. e+00	0. e+00	0. e+00
128	-0.37990e+01	-0.22344e+01	0. e+00	0. e+00	0. e+00	0. e+00
129	-0.54176e+02	-0.16920e+04	0. e+00	0. e+00	0. e+00	0. e+00
130	-0.44650e+01	-0.14511e+01	0. e+00	0. e+00	0. e+00	0. e+00
131	-0.57551e+02	-0.16937e+04	0. e+00	0. e+00	0. e+00	0. e+00
132	-0.46958e+01	-0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00
133	0.89873e+02	-0.16721e+04	0. e+00	0. e+00	0. e+00	0. e+00
134	0.43993e+01	0.22416e+01	0. e+00	0. e+00	0. e+00	0. e+00
135	0.86713e+02	-0.16737e+04	0. e+00	0. e+00	0. e+00	0. e+00
136	0.41840e+01	0.21320e+01	0. e+00	0. e+00	0. e+00	0. e+00
137	0.77542e+02	-0.16784e+04	0. e+00	0. e+00	0. e+00	0. e+00
138	0.35591e+01	0.18135e+01	0. e+00	0. e+00	0. e+00	0. e+00
139	0.63258e+02	-0.18850e+04	0. e+00	0. e+00	0. e+00	0. e+00
140	0.25859e+01	0.13176e+01	0. e+00	0. e+00	0. e+00	0. e+00
141	0.45260e+02	-0.18940e+04	0. e+00	0. e+00	0. e+00	0. e+00
142	0.13595e+01	0.69267e+00	0. e+00	0. e+00	0. e+00	0. e+00
143	0.25308e+02	-0.19050e+04	0. e+00	0. e+00	0. e+00	0. e+00
144	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
145	0.53567e+01	-0.19151e+04	0. e+00	0. e+00	0. e+00	0. e+00
146	-0.13595e+01	-0.69267e+00	0. e+00	0. e+00	0. e+00	0. e+00
147	-0.12642e+02	-0.19243e+04	0. e+00	0. e+00	0. e+00	0. e+00
148	-0.25859e+01	-0.13174e+01	0. e+00	0. e+00	0. e+00	0. e+00
149	-0.26926e+02	-0.19316e+04	0. e+00	0. e+00	0. e+00	0. e+00
150	-0.35591e+01	-0.18135e+01	0. e+00	0. e+00	0. e+00	0. e+00
151	-0.36096e+02	-0.19363e+04	0. e+00	0. e+00	0. e+00	0. e+00
152	-0.41840e+01	-0.21316e+01	0. e+00	0. e+00	0. e+00	0. e+00
153	-0.39256e+02	-0.19379e+04	0. e+00	0. e+00	0. e+00	0. e+00
154	-0.43993e+01	-0.22416e+01	0. e+00	0. e+00	0. e+00	0. e+00
155	0.10297e+03	-0.16934e+04	0. e+00	0. e+00	0. e+00	0. e+00
156	0.39945e+01	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
157	0.10010e+03	-0.18955e+04	0. e+00	0. e+00	0. e+00	0. e+00
158	0.37990e+01	0.27603e+01	0. e+00	0. e+00	0. e+00	0. e+00
159	0.91774e+02	-0.19016e+04	0. e+00	0. e+00	0. e+00	0. e+00
160	0.32316e+01	0.23482e+01	0. e+00	0. e+00	0. e+00	0. e+00
161	0.78804e+02	-0.19110e+04	0. e+00	0. e+00	0. e+00	0. e+00
162	0.23479e+01	0.17058e+01	0. e+00	0. e+00	0. e+00	0. e+00
163	0.62462e+02	-0.19229e+04	0. e+00	0. e+00	0. e+00	0. e+00
164	0.12344e+01	0.89686e+00	0. e+00	0. e+00	0. e+00	0. e+00
165	0.44346e+02	-0.19360e+04	0. e+00	0. e+00	0. e+00	0. e+00
166	0.30756e-05	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
167	0.26231e+02	-0.19492e+04	0. e+00	0. e+00	0. e+00	0. e+00
168	-0.12344e+01	-0.89686e+00	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

169	0.98883e+01	-0.19611e+04	0. e+00	0. e+00	0. e+00	0. e+00
170	-0.23479e+01	-0.17060e+01	0. e+00	0. e+00	0. e+00	0. e+00
171	-0.30511e+01	-0.19705e+04	0. e+00	0. e+00	0. e+00	0. e+00
172	-0.32316e+01	-0.23479e+01	0. e+00	0. e+00	0. e+00	0. e+00
173	-0.11408e+02	-0.19765e+04	0. e+00	0. e+00	0. e+00	0. e+00
174	-0.37990e+01	-0.27601e+01	0. e+00	0. e+00	0. e+00	0. e+00
175	-0.14277e+02	-0.19786e+04	0. e+00	0. e+00	0. e+00	0. e+00
176	-0.39945e+01	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
177	0.11925e+03	-0.19125e+04	0. e+00	0. e+00	0. e+00	0. e+00
178	0.34913e+01	0.34913e+01	0. e+00	0. e+00	0. e+00	0. e+00
179	0.11674e+03	-0.19150e+04	0. e+00	0. e+00	0. e+00	0. e+00
180	0.33205e+01	0.33205e+01	0. e+00	0. e+00	0. e+00	0. e+00
181	0.10946e+03	-0.19223e+04	0. e+00	0. e+00	0. e+00	0. e+00
182	0.28245e+01	0.28244e+01	0. e+00	0. e+00	0. e+00	0. e+00
183	0.96127e+02	-0.19326e+04	0. e+00	0. e+00	0. e+00	0. e+00
184	0.20522e+01	0.20522e+01	0. e+00	0. e+00	0. e+00	0. e+00
185	0.83843e+02	-0.19479e+04	0. e+00	0. e+00	0. e+00	0. e+00
186	0.10789e+01	0.10789e+01	0. e+00	0. e+00	0. e+00	0. e+00
187	0.68010e+02	-0.19637e+04	0. e+00	0. e+00	0. e+00	0. e+00
188	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
189	0.52176e+02	-0.19790e+04	0. e+00	0. e+00	0. e+00	0. e+00
190	-0.10789e+01	-0.10789e+01	0. e+00	0. e+00	0. e+00	0. e+00
191	0.37892e+02	-0.19939e+04	0. e+00	0. e+00	0. e+00	0. e+00
192	-0.20521e+01	-0.20520e+01	0. e+00	0. e+00	0. e+00	0. e+00
193	0.26557e+02	-0.20052e+04	0. e+00	0. e+00	0. e+00	0. e+00
194	-0.28245e+01	-0.28246e+01	0. e+00	0. e+00	0. e+00	0. e+00
195	0.19279e+02	-0.20125e+04	0. e+00	0. e+00	0. e+00	0. e+00
196	-0.33204e+01	-0.33203e+01	0. e+00	0. e+00	0. e+00	0. e+00
197	0.16771e+02	-0.20150e+04	0. e+00	0. e+00	0. e+00	0. e+00
198	-0.34913e+01	-0.34913e+01	0. e+00	0. e+00	0. e+00	0. e+00
199	0.13831e+03	-0.19280e+04	0. e+00	0. e+00	0. e+00	0. e+00
200	0.29022e+01	0.39944e+01	0. e+00	0. e+00	0. e+00	0. e+00
201	0.13622e+03	-0.19316e+04	0. e+00	0. e+00	0. e+00	0. e+00
202	0.27601e+01	0.37990e+01	0. e+00	0. e+00	0. e+00	0. e+00
203	0.13017e+03	-0.19400e+04	0. e+00	0. e+00	0. e+00	0. e+00
204	0.23479e+01	0.32317e+01	0. e+00	0. e+00	0. e+00	0. e+00
205	0.12075e+03	-0.19529e+04	0. e+00	0. e+00	0. e+00	0. e+00
206	0.17059e+01	0.23479e+01	0. e+00	0. e+00	0. e+00	0. e+00
207	0.10888e+03	-0.19693e+04	0. e+00	0. e+00	0. e+00	0. e+00
208	0.89682e+00	0.12344e+01	0. e+00	0. e+00	0. e+00	0. e+00
209	0.95716e+02	-0.19874e+04	0. e+00	0. e+00	0. e+00	0. e+00
210	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
211	0.82555e+02	-0.20055e+04	0. e+00	0. e+00	0. e+00	0. e+00
212	-0.89682e+00	-0.12344e+01	0. e+00	0. e+00	0. e+00	0. e+00
213	0.70681e+02	-0.20219e+04	0. e+00	0. e+00	0. e+00	0. e+00
214	-0.17059e+01	-0.23479e+01	0. e+00	0. e+00	0. e+00	0. e+00
215	0.61258e+02	-0.20340e+04	0. e+00	0. e+00	0. e+00	0. e+00
216	-0.23479e+01	-0.32317e+01	0. e+00	0. e+00	0. e+00	0. e+00
217	0.55206e+02	-0.20432e+04	0. e+00	0. e+00	0. e+00	0. e+00
218	-0.27601e+01	-0.37990e+01	0. e+00	0. e+00	0. e+00	0. e+00
219	0.53124e+02	-0.20466e+04	0. e+00	0. e+00	0. e+00	0. e+00
220	-0.29022e+01	-0.39944e+01	0. e+00	0. e+00	0. e+00	0. e+00
221	0.15958e+03	-0.15417e+04	0. e+00	0. e+00	0. e+00	0. e+00
222	0.22416e+01	0.43993e+01	0. e+00	0. e+00	0. e+00	0. e+00
223	0.15807e+03	-0.19470e+04	0. e+00	0. e+00	0. e+00	0. e+00
224	0.21319e+01	0.41040e+01	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

225	0.15340e+03	-0.19942e+04	0. e+00	0. e+00	0. e+00	0. e+00
226	0.15135e+01	0.25590e+01	0. e+00	0. e+00	0. e+00	0. e+00
227	0.14612e+03	-0.19865e+04	0. e+00	0. e+00	0. e+00	0. e+00
228	0.13176e+01	0.25859e+01	0. e+00	0. e+00	0. e+00	0. e+00
229	0.13695e+03	-0.19865e+04	0. e+00	0. e+00	0. e+00	0. e+00
230	0.59257e+00	0.13594e+01	0. e+00	0. e+00	0. e+00	0. e+00
231	0.12578e+03	-0.20064e+04	0. e+00	0. e+00	0. e+00	0. e+00
232	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
233	0.11662e+03	-0.20264e+04	0. e+00	0. e+00	0. e+00	0. e+00
234	-0.59264e+00	-0.13590e+01	0. e+00	0. e+00	0. e+00	0. e+00
235	0.10745e+03	-0.20444e+04	0. e+00	0. e+00	0. e+00	0. e+00
236	-0.13176e+01	-0.25857e+01	0. e+00	0. e+00	0. e+00	0. e+00
237	0.10017e+03	-0.20587e+04	0. e+00	0. e+00	0. e+00	0. e+00
238	-0.18135e+01	-0.35594e+01	0. e+00	0. e+00	0. e+00	0. e+00
239	0.95496e+02	-0.20670e+04	0. e+00	0. e+00	0. e+00	0. e+00
240	-0.21319e+01	-0.41840e+01	0. e+00	0. e+00	0. e+00	0. e+00
241	0.93896e+02	-0.20710e+04	0. e+00	0. e+00	0. e+00	0. e+00
242	-0.22416e+01	-0.43993e+01	0. e+00	0. e+00	0. e+00	0. e+00
243	0.18284e+03	-0.19515e+04	0. e+00	0. e+00	0. e+00	0. e+00
244	0.15258e+01	0.46960e+01	0. e+00	0. e+00	0. e+00	0. e+00
245	0.18174e+03	-0.19546e+04	0. e+00	0. e+00	0. e+00	0. e+00
246	0.14511e+01	0.44659e+01	0. e+00	0. e+00	0. e+00	0. e+00
247	0.17856e+03	-0.19640e+04	0. e+00	0. e+00	0. e+00	0. e+00
248	0.12344e+01	0.37992e+01	0. e+00	0. e+00	0. e+00	0. e+00
249	0.17361e+03	-0.19799e+04	0. e+00	0. e+00	0. e+00	0. e+00
250	0.89682e+00	0.27602e+01	0. e+00	0. e+00	0. e+00	0. e+00
251	0.16737e+03	-0.19991e+04	0. e+00	0. e+00	0. e+00	0. e+00
252	0.47148e+00	0.14511e+01	0. e+00	0. e+00	0. e+00	0. e+00
253	0.16045e+03	-0.20204e+04	0. e+00	0. e+00	0. e+00	0. e+00
254	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
255	0.15353e+03	-0.20417e+04	0. e+00	0. e+00	0. e+00	0. e+00
256	-0.47149e+00	-0.14511e+01	0. e+00	0. e+00	0. e+00	0. e+00
257	0.14726e+03	-0.20609e+04	0. e+00	0. e+00	0. e+00	0. e+00
258	-0.89682e+00	-0.27603e+01	0. e+00	0. e+00	0. e+00	0. e+00
259	0.14233e+03	-0.20762e+04	0. e+00	0. e+00	0. e+00	0. e+00
260	-0.12344e+01	-0.37990e+01	0. e+00	0. e+00	0. e+00	0. e+00
261	0.13915e+03	-0.20859e+04	0. e+00	0. e+00	0. e+00	0. e+00
262	-0.14511e+01	-0.44659e+01	0. e+00	0. e+00	0. e+00	0. e+00
263	0.13805e+03	-0.20893e+04	0. e+00	0. e+00	0. e+00	0. e+00
264	-0.15258e+01	-0.46958e+01	0. e+00	0. e+00	0. e+00	0. e+00
265	0.20721e+03	-0.19573e+04	0. e+00	0. e+00	0. e+00	0. e+00
266	0.77239e+00	0.48767e+01	0. e+00	0. e+00	0. e+00	0. e+00
267	0.20666e+03	-0.19606e+04	0. e+00	0. e+00	0. e+00	0. e+00
268	0.73458e+00	0.46381e+01	0. e+00	0. e+00	0. e+00	0. e+00
269	0.20505e+03	-0.19710e+04	0. e+00	0. e+00	0. e+00	0. e+00
270	0.62488e+00	0.39452e+01	0. e+00	0. e+00	0. e+00	0. e+00
271	0.20254e+03	-0.19866e+04	0. e+00	0. e+00	0. e+00	0. e+00
272	0.45400e+00	0.28664e+01	0. e+00	0. e+00	0. e+00	0. e+00
273	0.19936e+03	-0.20060e+04	0. e+00	0. e+00	0. e+00	0. e+00
274	0.23868e+00	0.15070e+01	0. e+00	0. e+00	0. e+00	0. e+00
275	0.19588e+03	-0.20289e+04	0. e+00	0. e+00	0. e+00	0. e+00
276	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
277	0.19237e+03	-0.20510e+04	0. e+00	0. e+00	0. e+00	0. e+00
278	-0.23866e+00	-0.15070e+01	0. e+00	0. e+00	0. e+00	0. e+00
279	0.16921e+03	-0.20716e+04	0. e+00	0. e+00	0. e+00	0. e+00
280	-0.45401e+00	-0.28666e+01	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

281	0.16671e+03	-0.20066e+04	0. e+00	0. e+00	0. e+00	0. e+00
282	-0.52496e+00	-0.39454e+01	0. e+00	0. e+00	0. e+00	0. e+00
283	0.16510e+03	-0.20970e+04	0. e+00	0. e+00	0. e+00	0. e+00
284	-0.73459e+00	-0.46579e+01	0. e+00	0. e+00	0. e+00	0. e+00
285	0.16454e+03	-0.21005e+04	0. e+00	0. e+00	0. e+00	0. e+00
286	-0.77239e+00	-0.46767e+01	0. e+00	0. e+00	0. e+00	0. e+00
287	0.23220e+03	-0.19593e+04	0. e+00	0. e+00	0. e+00	0. e+00
288	-0.24605e-04	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00
289	0.23220e+03	-0.19620e+04	0. e+00	0. e+00	0. e+00	0. e+00
290	0. e+00	0.46960e+01	0. e+00	0. e+00	0. e+00	0. e+00
291	0.23220e+03	-0.19731e+04	0. e+00	0. e+00	0. e+00	0. e+00
292	0. e+00	0.39944e+01	0. e+00	0. e+00	0. e+00	0. e+00
293	0.23220e+03	-0.19892e+04	0. e+00	0. e+00	0. e+00	0. e+00
294	0. e+00	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
295	0.23220e+03	-0.20094e+04	0. e+00	0. e+00	0. e+00	0. e+00
296	0. e+00	0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00
297	0.23220e+03	-0.20310e+04	0. e+00	0. e+00	0. e+00	0. e+00
298	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
299	0.23220e+03	-0.20541e+04	0. e+00	0. e+00	0. e+00	0. e+00
300	0. e+00	-0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00
301	0.23220e+03	-0.20743e+04	0. e+00	0. e+00	0. e+00	0. e+00
302	0. e+00	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
303	0.23220e+03	-0.20904e+04	0. e+00	0. e+00	0. e+00	0. e+00
304	0. e+00	-0.39946e+01	0. e+00	0. e+00	0. e+00	0. e+00
305	0.23220e+03	-0.21007e+04	0. e+00	0. e+00	0. e+00	0. e+00
306	0. e+00	-0.46950e+01	0. e+00	0. e+00	0. e+00	0. e+00
307	0.23220e+03	-0.21042e+04	0. e+00	0. e+00	0. e+00	0. e+00
308	0.24605e-04	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00
309	0.25883e+03	-0.19593e+04	0. e+00	0. e+00	0. e+00	0. e+00
310	-0.24605e-04	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00
311	0.25883e+03	-0.19620e+04	0. e+00	0. e+00	0. e+00	0. e+00
312	0. e+00	0.46960e+01	0. e+00	0. e+00	0. e+00	0. e+00
313	0.25883e+03	-0.19731e+04	0. e+00	0. e+00	0. e+00	0. e+00
314	0. e+00	0.39944e+01	0. e+00	0. e+00	0. e+00	0. e+00
315	0.25883e+03	-0.19892e+04	0. e+00	0. e+00	0. e+00	0. e+00
316	0. e+00	0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
317	0.25883e+03	-0.20094e+04	0. e+00	0. e+00	0. e+00	0. e+00
318	0. e+00	0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00
319	0.25883e+03	-0.20310e+04	0. e+00	0. e+00	0. e+00	0. e+00
320	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00	0. e+00
321	0.25883e+03	-0.20541e+04	0. e+00	0. e+00	0. e+00	0. e+00
322	0. e+00	-0.15257e+01	0. e+00	0. e+00	0. e+00	0. e+00
323	0.25883e+03	-0.20743e+04	0. e+00	0. e+00	0. e+00	0. e+00
324	0. e+00	-0.29022e+01	0. e+00	0. e+00	0. e+00	0. e+00
325	0.25883e+03	-0.20904e+04	0. e+00	0. e+00	0. e+00	0. e+00
326	0. e+00	-0.39946e+01	0. e+00	0. e+00	0. e+00	0. e+00
327	0.25883e+03	-0.21007e+04	0. e+00	0. e+00	0. e+00	0. e+00
328	0. e+00	-0.46950e+01	0. e+00	0. e+00	0. e+00	0. e+00
329	0.25883e+03	-0.21042e+04	0. e+00	0. e+00	0. e+00	0. e+00
330	0.24605e-04	-0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00
331	0.30544e+03	-0.19593e+04	0. e+00	0. e+00	0. e+00	0. e+00
332	-0.24605e-04	0.49375e+01	0. e+00	0. e+00	0. e+00	0. e+00
333	0.30544e+03	-0.19620e+04	0. e+00	0. e+00	0. e+00	0. e+00
334	0. e+00	0.46960e+01	0. e+00	0. e+00	0. e+00	0. e+00
335	0.30544e+03	-0.19731e+04	0. e+00	0. e+00	0. e+00	0. e+00
336	0. e+00	0.39944e+01	0. e+00	0. e+00	0. e+00	0. e+00

Table 2.7.2 (cont'd)

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 337  0.30544e+03-0.19892e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 338  0.      e+00 0.29022e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 339  0.30544e+03-0.20094e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 340  0.      e+00 0.15257e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 341  0.30544e+03-0.20316e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 342  0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 343  0.30544e+03-0.20541e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 344  0.      e+00-0.15257e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 345  0.30544e+03-0.20743e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 346  0.      e+00-0.29022e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 347  0.30544e+03-0.20904e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 348  0.      e+00-0.39944e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 349  0.30544e+03-0.21007e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 350  0.      e+00-0.46950e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 351  0.30544e+03-0.21042e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 352  0.24605e-04-0.49375e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 353  0.38700e+03-0.19593e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 354 -0.24605e-04 0.49375e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 355  0.38700e+03-0.19620e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 356  0.      e+00 0.46960e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 357  0.38700e+03-0.19731e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 358  0.      e+00 0.39944e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 359  0.38700e+03-0.19892e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 360  0.      e+00 0.29022e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 361  0.38700e+03-0.20094e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 362  0.      e+00 0.15259e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 363  0.38700e+03-0.20316e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 364  0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 365  0.38700e+03-0.20541e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 366  0.      e+00-0.15257e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 367  0.38700e+03-0.20743e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 368  0.      e+00-0.29022e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 369  0.38700e+03-0.20904e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 370  0.      e+00-0.39944e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 371  0.38700e+03-0.21007e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 372  0.      e+00-0.46960e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 373  0.38700e+03-0.21042e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
 374  0.24605e-04-0.49375e+01 0.      e+00 0.      e+00 0.      e+00 0.      e+00
9998  0.      e+00-0.16440e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
9999  0.38700e+03-0.20316e+04 0.      e+00 0.      e+00 0.      e+00 0.      e+00
main     7
   1  0.      e+00 0.      e+00 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   2  0.      e+00-0.41119e+03 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   3  0.      e+00-0.82230e+03 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   4  0.      e+00-0.12330e+04 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   5  0.      e+00-0.16440e+04 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   8  0.38700e+03-0.20316e+04 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
   9  0.91590e+03-0.20316e+04 0.      e+00 0.      e+00 0.      e+00-0.64500e+01
mass
dylo,1,1
recl      0-0.167      0.500         2
    9     9
[illegible],rslt,1,0.[illegible]00e+00
auto,defi
inte,newm,0.2000e-03,0.e+00,0.e+00,0.1000e+00
stif
```

Table 2.7.2 (cont'd)

```
stif,upda
kinr,12
elmr,1,2,6,3
kinr,5
loop,200
zero,ltme
impa,init,,0.e+00,0.e+00
step
unba
auto,init
loop,30
stif
auto,load
load
disp
impa,anal
kinr,10
elmr,9,10
auto,merr,0.5000e+02,0.2500e+03
if,3,3,1,1
entr,1
auto,fact
kinr,1
impa,upda,0
if,3,2,2,3
entr,2
elmr,1
cont
goto,0
entr,3
auto,step,0.2000e-05,0.1000e-02,0.5000e+00,0.2000e+01
if,4,5,5,4
entr,4
inte,newm,,auto,0.e+00,0.e+00,0.e+00,0.1000e+00
entr,5
if,3,6,6,7
entr,6
kinr,12
elmr,5,2,6
kinr,5
impa,upda,1
stif,init
goto,8
entr,7
chou
impa,mone
impa,rslt
elmr,1,2,4,5,1
kinr,4,9,11
wrou
zero,lrsb
unta
samn
elmr,3
kinr,3
stif,upda

auto,exit,0.2000e-01
if,5,8,8,0
entr,8
cont
fini
paus
```

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16. ABSTRACT (200 words or less)

WIPS (Whip and Impact of Piping Systems) is a special purpose computer code for the structural analysis of pipe whip dynamic effects following a postulated pipe rupture. WIPS has been developed primarily to provide support for the pipe whip analysis procedures described in Section 3.6.2 of the U.S. Nuclear Regulatory Commission Standard Review Plan.

This report summarizes the purpose and scope of the WIPS development effort, identifying those clauses in the standard Review Plan which refer to pipe whip analysis, and indicating how the WIPS code can be used to provide supporting data. Detailed information on use of the code is contained in accompanying reports which cover (1) use instructions, (2) theory, (3) programming procedures, and (4) verification examples.

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