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SUBJECT: Forwards addl info on reanalysis of seven safety-related piping sys,in response to IE Bulletin 79-07.Includes Teledyne Engineering Svc technical rept, "Verification & Qualification of TMRPIPE Computer Program" & printouts & other supporting info. See Rpts

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b) TELEDYNE Engineering Services Technical Rpts is entitled: "Verification and Qualification of TMRPIPE Computer Program." dtd 2-21-79 ANO 7906150412 See Rpts

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NIAGARA MOHAWK POWER CORPORATION/300 ERIE BOULEVARD WEST, SYRACUSE, N.Y. 13202/TELEPHONE (315) 474-1511

June 12, 1979

Director of Nuclear Reactor Regulation
Attn: Mr. Thomas A. Ippolito, Chief
Operating Reactors/Branch #3
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Gentlemen:

Re: Nine Mile Point Unit 1
Docket No. 50-220

Enclosed please find the information requested by members of your staff regarding our response to I. E. Bulletin 79-07 for the seven piping systems which were re-analyzed.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

D. P. Dise

D. P. Dise
Vice President-Engineering

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A001 S 1/1

VERIFICATION AND QUALIFICATION
OF
TMRPIPE COMPUTER PROGRAM

Prepared by:

P. P. Raju
A. G. Beardsley
P. T. Rahme
J. H. Baker

FEBRUARY 21, 1979

TELEDYNE ENGINEERING SERVICES

303 BEAR HILL ROAD
WALTHAM, MASSACHUSETTS 02154
617-890-3350

ABSTRACT

This report briefly describes the general analysis features of the TMRPIPE code to perform a complete analysis of a nuclear piping system. This report presents benchmark problem solutions employed to verify correct execution of the TMRPIPE Code. The solutions of benchmark problems have been compared with closed-form solutions available in the literature or with solutions obtained using other similar codes.

This report satisfies the Teledyne Engineering Services (TES) procedure on computer code Verification which is responsive to and implements criterion number 1 in "General Design Criteria" of Appendix A, and the Design Control Measures in "Quality Assurance for Nuclear Power Plants" of Appendix B in 10CFR50 of the NRC Rules and Regulations.

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INTRODUCTION

TMRPIPE is a system of computer programs intended primarily to perform a complete analysis of nuclear piping systems. The integrated package consists of the following individual programs:

LION 4.	for generation of thermal models and for determination of the temperature distributions
TMRSAP	for the static and dynamic structural analysis of the piping system.
PASS	for tabulating the support reactions and displacements from TMRSAP, calculating the support design loads, performing a stress evaluation at selected data points and printing the information in technical report format.
NUCPIPE	for evaluating the stress results in accordance with the ASME Code, Subarticle NB-3600.

This report presents a detailed description of each of the above programs and benchmark solutions employed to verify the use of TMRPIPE for the solution of thermal, static and dynamic analysis of piping systems such as a reactor coolant loop subjected to forcing functions, including ground accelerations due to seismic events. Benchmark problem solutions employed to verify the use of TMRPIPE for the solution of steady state and transient heat conduction analyses are also included. TMRPIPE has been used by Teledyne Engineering Services to perform many piping analyses. This report, however, presents only the benchmark problem solutions for verification of the basic capabilities of the code.

The following chapter presents details of the verification procedure adopted in this report. General description, application, capabilities, theory, qualification and benchmark problems are included in this report for each one of the programs described above.

VERIFICATION PROCEDURE

The verification procedure has been carried out by comparing solutions obtained using the TMRPIPE Code either to closed-form solutions when available, or to solutions obtained from other computer codes with completely different techniques and methods of analysis. Hand computations have also been used occasionally to compare the results of TMRPIPE. As a result of the numerous problems solved, several of the code features are verified many times in this report. Such Verification is naturally an additional assurance of the high level of confidence of the code.

A set of problems was designed to check the ability of the TMRPIPE program to carry out stiffness matrix, flexibility matrix and dynamic matrix generation, to calculate free thermal growth of piping systems, to perform load, deflection, and support reaction calculations, to assess individual and cumulative modal response and to perform frequency and mode shape calculations. An ASME benchmark verification problem was also set up for evaluating the stress results in accordance with the ASME Code, Subarticle NB-3600.

The problems were modeled and analyzed by engineers reporting to a technical leader then checked by another engineer. Discrepancies have been clarified by discussions between the parties involved.

LION 4

A computer program to determine temperature distribution for arbitrary shapes and complicated boundary conditions.

1.0 GENERAL DESCRIPTION

LION 4 is a digital computer program which is used to solve the steady-state or transient temperature distribution in any three-dimensional configuration. The heat source may be externally conducted or internally generated.

In addition to the solving of heat conduction in structural elements, LION 4 may also be used in such cases as forced convection, free convection, or radiation where the output will yield temperatures and heat fluxes for points representing the surface of the structure.

Input to the program consists of structural geometry, physical properties, boundary conditions, internal heat generation rates and coolant flow properties and rates.

2.0 APPLICATION

The program solves the transient heat conduction equations for a three-dimensional field using a first forward difference method. Since the method of solution is based on a nodal representation of the geometry, any type of configuration can be handled through the evaluation of the "equivalent resistances" of the nodal connectors. In addition, the program solves the energy equation (at constant pressure) for the coolant nodes and also allow sub-cooled nucleate boiling to be considered.

3.0 CAPABILITIES

The LION 4 digital computer program can solve three-dimensional transient and steady-state temperature distribution problems. The input consists of geometry, physical properties, boundary conditions, internal heat generation rates, and coolant problems of heat conduction in a structure. LION 4 can handle forced convection, free convection, and radiation or a combination of these at the surface of the structure. The output consists of complete nodal temperature distributions along with surface fluxes and surface heat transfer coefficients. An option is included in the program for determining the mean temperature in any specified section of the structure.

4.0 THEORY

Nodal Equations

LION 4 employs the first forward difference method in obtaining a solution. The basic equations (whose mathematical development is available in the original program report, Reference [1]) in matrix form for the internal nodes are as follows:

$$(\Delta T)_{t_1} = \tau \left\{ (Q)_{t_1} + (Y)(T)_{t_1} \right\} (C)^{-1} \quad (1)$$

$$(T)_{t_1+\tau} = (T)_{t_1} + (\Delta T)_{t_1} \quad (2)$$

t = time
τ = time increment
(C) = capacitance matrix
(Q) = internal heat generation matrix
(Y) = internal admittance matrix
(T) = temperature matrix
(ΔT) = temperature change matrix for time step

Equations (1) and (2) as shown above are used to determine the temperature change in the time interval and the temperature at the end of that time interval for all internal nodes.

The temperature change for a surface node is calculated by applying the Ohm's law analogy for heat flow to a node with no capacitance. This technique is as follows for the i^{th} surface node. Let the i^{th} surface node have n heat flow paths to it and let these heat flow paths be indexed on α.

Thus,

T_α = temperature of node at end of heat flow path

Y_α = admittance of heat flow path α between the temparature potentials T_i and $T\alpha$

Q_α = heat flow in path α

it follows that,

$$Q_\alpha = Y_\alpha (T_\alpha - T_i)$$

Since a surface node has no capacitance, the application of the analogy yields

$$\sum_{\alpha=1}^{n} Q_\alpha = 0$$

or

$$\sum_{\alpha=1}^{n} Y_\alpha T_\alpha - T_i \sum_{\alpha=1}^{n} Y_\alpha = 0$$

Rewriting the above

$$T_i = \frac{\sum_{\alpha=1}^{n} Y_\alpha T_\alpha}{\sum_{\alpha=1}^{n} Y_\alpha}$$

or in the time increment form

$$(T_i)_{t+\tau} = \left(\frac{\sum_{\alpha=1}^{n} Y_\alpha T_\alpha}{\sum_{\alpha=1}^{n} Y_\alpha} \right)_t \qquad (3)$$

Equation (3) as shown above is the expression used in the program to determine the surface node temperatures at each time interval.

For the coolant nodes two heat flow paths must be specified. The first being heat flow from the surfaces, and the second being heat flow (or energy transport) due to the coolant flow. The equivalent heat flows are calculated as follows:

let A be the coolant node index.
let B be the index of the surface node connected to coolant node A.
let C be the index of the coolant or boundary node upstream and connected to node A.

The heat flow from the surface to node A is

$$A_{B-A} = Y_{BA}\,(T_B - T_A)$$

where Y_{BA} is the admittance between nodes B and A. The equivalent heat flow from the upstream node C is

$$Q_{C-A} = (T_C - T_A)(C_p)(\text{Flow rate})$$

where C_p = specific heat of coolant

Flow rate = mass/time

It easily follows by using the electrical analogy* that for the time t

$$(\Delta T_A)t = \left(\frac{(Q_{B-A} + Q_{C-A})\tau}{C_A}\right)_t \qquad (4)$$

where C_A = total thermal capacitance of node A = C_p x (Volume of node A) x (Density of node A).

---

*Using electrical terminology and the basic physical law

$q = CE$,

differentiating and assuming C is independent of time

$\frac{dq}{dt} = C\,\frac{dE}{dt}$, and

using definition of current and writing in differential form,

$\Delta E = \frac{i\Delta t}{C}$. This expression is analogous to expression (4).

Then

$$(T_A)_{t+\tau} = (\Delta T_A)_t + (T_A)_t \qquad (5)$$

Equations (4) and (5) are used as shown in the code to determine the coolant node temperatures at each time step.

Stability Criterion

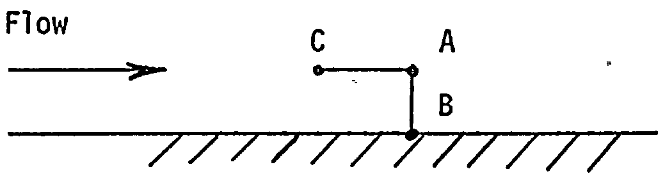
If the LION 4 user specifies the time increment too large, the program will automatically choose a time increment which meets the stability criterion. The original TIGER report [1] develops the stability criterion based on the internal nodes which is as follows:

$$\tau < \frac{C_i}{-Y_{ii}}$$

where C_i = total thermal capacitance of internal node i.

Y_{ii} = the negative sum of all the individual admittances connected to the internal node i.

Since an averaging technique, independent of the time increment, is used to determine the temperature changes for the surface nodes, the surface nodes do not require a stability criterion. However, the addition of coolant nodes to TIGER created an additional stability criterion. By a similar analysis to that done in Reference [1], the stability criterion can be derived for the coolant nodes. Consider, for analysis purposes, only one surface connected to the coolant node.



Node A - coolant node
Node B - surface node
Node C - coolant or boundary

C_p = specific heat of coolant
Y_{BA} = total admittance between nodes A and B
τ = time increment
C_A = total thermal capacitance of node A
F = coolant mass flow rate

Considering the heat flow to node A and applying the electrical analogy (refer to the section entitled Computational Equations of this report) yields

$$\Delta T_A = \frac{\tau}{C_A} [Y_{BA}(T_B - T_A) + C_p F (T_C - T_A)]$$

in the numerical method form

$$(T_A)_{t+\tau} = (T_A)_t + (\Delta T_A)_t$$

or

$$(T_A)_{t+\tau} = (T_A)_t + \left\{ \frac{\tau}{C_A} [Y_{BA}(T_B - T_A) + C_p F(T_C - T_A)] \right\}_t \qquad (6)$$

If an error is introduced in evaluating T_A at time t', then at any time t, after t', the resulting temperature T_A will differ from that obtained if the error were not present. Let this difference be

$$(\delta_A)_t = (\hat{T}_A)_t - (T_A)_t$$

Since the temperature after the error is introduced must obey equation (6), it follows

$$(\hat{T}_A)_{t+\tau} = (\hat{T}_A)_t + \left\{ \frac{\tau}{C_A} \left[Y_{B-A}(\hat{T}_B - \hat{T}_A) + C_p F(\hat{T}_C - \hat{T}_A) \right] \right\}_t \qquad (7)$$

Subtracting (6) from (7) and using the definitions

$$\delta_A = \hat{T}_A - T_A$$
$$\delta_B = \hat{T}_B - T_B$$
$$\delta_C = \hat{T}_C - T_C$$

yields

$$(\delta_A)_{t+\tau} \; (\delta_A)_t + \left\{ \frac{\tau}{C_A} \left[Y_{BA}(\delta_B - \delta_A) + C_p F(\delta_C - \delta_A) \right] \right\}_t$$

which can be written as

$$(\delta_A)_{t+\tau} = (\delta_A)_t \left[1 - \frac{\tau}{C_A} (Y_{BA})_t - \frac{\tau C_p (F)_t}{C_A} \right]$$

$$+ \frac{\tau}{C_A} \left[(Y_{BA})_t (\delta_B)_t + C_p (F)_t (\delta_C)_t \right]$$

with the following definition

$$\left| (\bar{\delta})_t \right| \geq \left| (\delta_i)_t \right|$$

where i is indexed on all surface, boundary, and coolant nodes.

Dividing equation (8) by $(\bar{\delta})_t$ and using the properties of the absolute value

$$\left| \frac{(\delta_A)_{t+\tau}}{(\bar{\delta})_t} \right| \leq \left| \frac{(\delta_A)_t}{(\bar{\delta})_t} \right| \left| 1 - \frac{\tau}{C_A} (Y_{BA})_t - \frac{\tau C_p (F)_t}{C_A} \right|$$

$$+ \frac{\tau}{C_A} (Y_{BA})_t \left| \frac{(\delta_B)_t}{(\bar{\delta})_t} \right| + \frac{\tau C_p (F)_t}{C_A} \left| \frac{(\delta_C)_t}{(\bar{\delta})_t} \right| \quad (9)$$

where τ, C_A, C_p and F are always positive.

From the definition of $\left| (\bar{\delta})_t \right|$, it follows that

$$\left| \frac{(\delta_A)_t}{(\bar{\delta})_t} \right| \leq 1, \left| \frac{(\delta_B)_t}{(\bar{\delta})_t} \right| \leq 1, \quad \left| \frac{(\delta_C)_t}{(\bar{\delta})_t} \right| \leq 1$$

equation (4) becomes

$$\left| \frac{(\delta_A)_{t+\tau}}{(\bar{\delta})_t} \right| \leq \left| 1 - \frac{\tau}{C_A} (Y_{BA})_t - \frac{\tau C_p (F)_t}{C_A} \right| + \frac{\tau}{C_A} (Y_{BA})_t + \frac{\tau C_p (F)_t}{C_A} \quad (10)$$

For the error in the coolant temperature to decrease with time (i.e. for stability)

$$\frac{(\delta_A)_{t+\tau}}{(\overline{\delta})_t} \leq 1$$

From this criterion and equation (10), it follows that

$$1 - \frac{\tau}{C_A} (Y_{BA})_t + \frac{\tau C_p (F)_t}{C_A} + \frac{\tau}{C_A} (Y_{BA})_t + \frac{\tau C_p (F)_t}{C_A} \leq 1 \qquad (10)$$

This inequality requires that

$$\frac{\tau}{C_A} (Y_{BA})_t + \frac{\tau C_p (F)_t}{C_A} \leq 1$$

Solving for

$$\tau \leq \frac{C_A}{(Y_{BA})_t + C_p (F)_t} \qquad (11)$$

Due to the relative magnitudes and the conservatism of the present expression, it is assumed that (11) can be approximated by*

$$\tau \leq \frac{C_A}{C_p (F)_t}.$$

Noting that

$C_A = C_p$ x (Volume of coolant node A) x (Coolant density)

where

(Volume of coolant node A) = (Surface area of attached surface node) x (Flow path width)

yields

$$\tau \leq \frac{\text{(Volume of coolant node A) (Coolant Density)}}{(F)_t}$$

since the maximum flow represents the most limiting case

$$\tau \leq \frac{\text{(Volume of coolant node A) (Coolant Density)}}{F_{max}}$$

*It is possible that this criterion may not be stringent enough in some extreme cases. However, to avoid use of a very small time increment in the general problem, this assumption is made.

This expression is used in LION 4 to determine the maximum allowable time increment for coolant node temperature calculation stability.

The smallest time increment, from both the internal node and coolant node criteria is used as the maximum allowable time increment for stability of the solution.

PROGRAM DESCRIPTION

Nodes

1. Internal Nodes - The internal nodes must be numbered consecutively starting with one through the total number being used. The node material, dimensions, initial temperature and base internal heat generation rate must be specified in the input. The internal generation rate may be varied with time by use of the internal generation rate fraction library.

2. Surface Nodes - The surface nodes must be numbered consecutively starting with the integer one above the total number of internal nodes being used. Surface node dimensions, initial temperatures, and types of heat transfer coefficients must be specified as input.

3. Boundary Nodes - The boundary nodes must be numbered consecutively starting with the integer one above the total number of surface nodes being used. The boundary node has no dimensions. Thus, the only input required is the initial temperature* library.

4. Coolant Nodes - The coolant nodes must be numbered consecutively starting with the integer one above the total number of all other nodes being used. The initial temperature** must be specified.

---

*Only for boundary nodes that supply coolant channels, enter enthalpy instead of temperature if the boundary node fluid is in quality initially. Library entries must be consistent with initial condition and either all enthalpy or all temperature throughout any one library.

** If enthalpy is being considered, enter enthalpies instead of temperatures.

Node Connections

1. Internal Connection - An internal connection is defined as a heat flow path either between an internal node and another internal node or between an internal node and a surface node. An internal connection may be specified as one material or as two materials in series.

2. Surface Connection - A surface connection is defined as a heat flow path between either a surface node and a coolant node or between a surface node and a boundary node. The mechanism of heat transfer for a surface connection may be of any one of six types described in detail in the section entitled Subrountine Descriptions.

An internal node may have only internal connections (maximum of seven). No restriction is made as to whether these internal connections are to surface nodes or to other internal nodes.

A surface node may have only one internal connection (i.e. may be connected to only one internal node) but may have a maximum of six surface connections. Only one of these surface connections may be to a coolant node, but none of the six need be to a coolant node. It follows that all of the surface connections may be to boundary nodes. Note that multi-mechanism heat transfer from a surface node is possible.

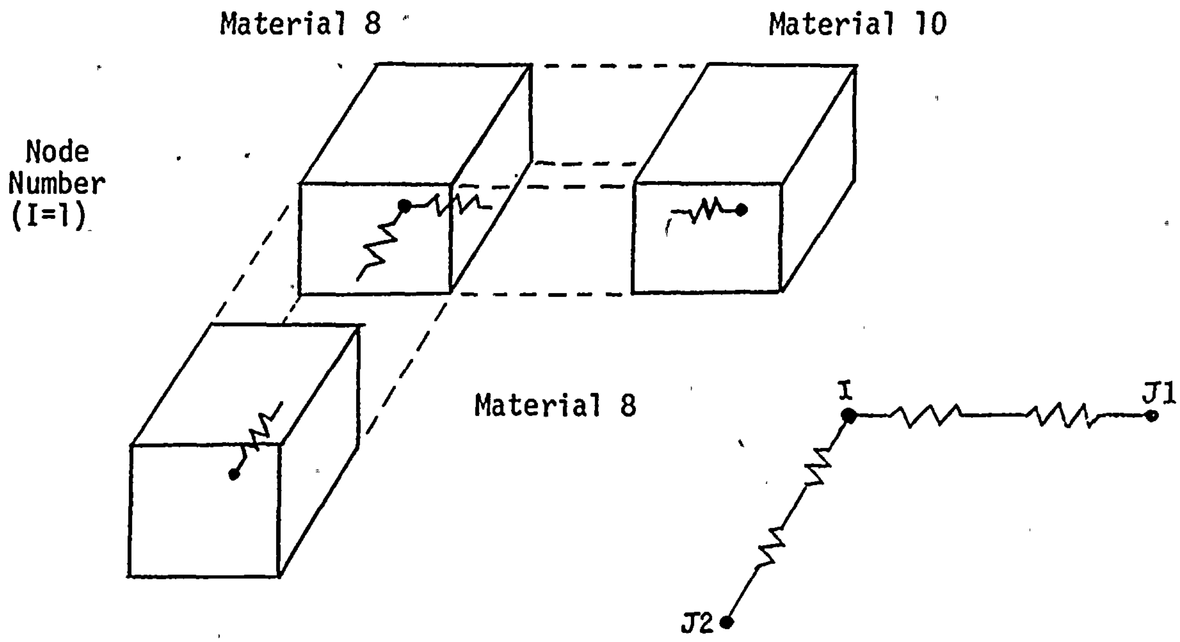
Each coolant node must be connected to at least one and not more than four surface nodes and must be connected to one upstream node (either coolant or boundary node). The upstream node for the first node (inlet node) in a channel must be a boundary node. The upstream nodes for all other coolant nodes in the channel are all coolant nodes.

A boundary node may be connected to an unlimited (within the total number of connections in the program) number of surface nodes and/or coolant nodes. A boundary node may not be connected to an internal node.

Calculation of the Thermal Conductances (YMAT)

One of the main functions of the LION 4 program is to calculate the conductances between nodes. This is done in the subroutine called YMAT by means of admittance matrix techniques and is described here in some detail. This subroutine reads in the connector information for all the internal nodes including the connections between the internal and surface nodes.

For example, if one has the following configuration



The input necessary for the NODE I is the designation of the node it is connected to, the appropriate resistance lengths, the type of material for each node, and the appropriate surface area.

5.0 QUALIFICATION

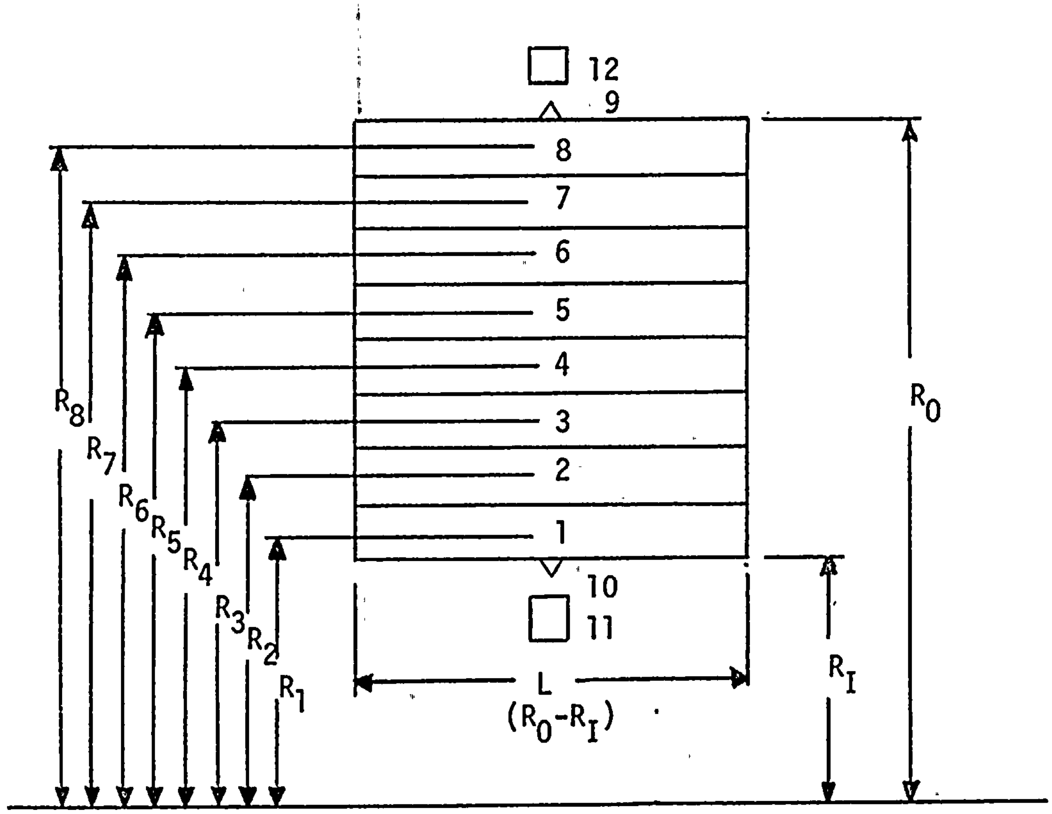
The LION 4 program may be used for the solution of steady-state or transient temperature distributions in any three-dimensional configuration. The heat source may be externally conducted or internally generated. Thermal networks involving radiation, conduction, forced convection and free convection can be solved. Since the method of solution is based on a nodal representation of the geometry, any type of configuration can be handled through the evaluation of the "equivalent resistances" of the nodal connectors. In addition the program can solve the energy equation (at constant pressure) for the coolant nodes and also allows sub-cooled nucleate boiling to be considered.

6.0 BENCHMARK VERIFICATION PROBLEMS

6.1 Sample Problem 1

In this benchmark verification problem, LION 4 results are compared to TMRTEMP [3] results in an analysis for the transient response of a one-dimensional model to a step change in temperature. The model as pictured in Figure 6.1-1 is a one-dimensional idealization of the wall of a 14 in. Sch. 140 pipe. The forcing function is a 100°F step change in fluid temperature from an initial uniform system temperature of 0°F. A comparison of the transient responses can be seen in Figures 6.1-2, 3 and 4 for Node 1 (INSIDE Surface), Node 5 (NEAR CENTER of Pipe Wall) and Node 8 (OUTSIDE Surface) respectively. As can be seen, the agreement between the LION 4 and TMRTEMP response is reasonable.

An example of a one-dimensional model appears in the following figure.



Node Number	Description
1 thru 8	Internal (pipe wall) Nodes
9 and 10	Surface Nodes
11 and 12	Boundary Nodes

Figure 6.1-1 One-Dimensional Thermal Model

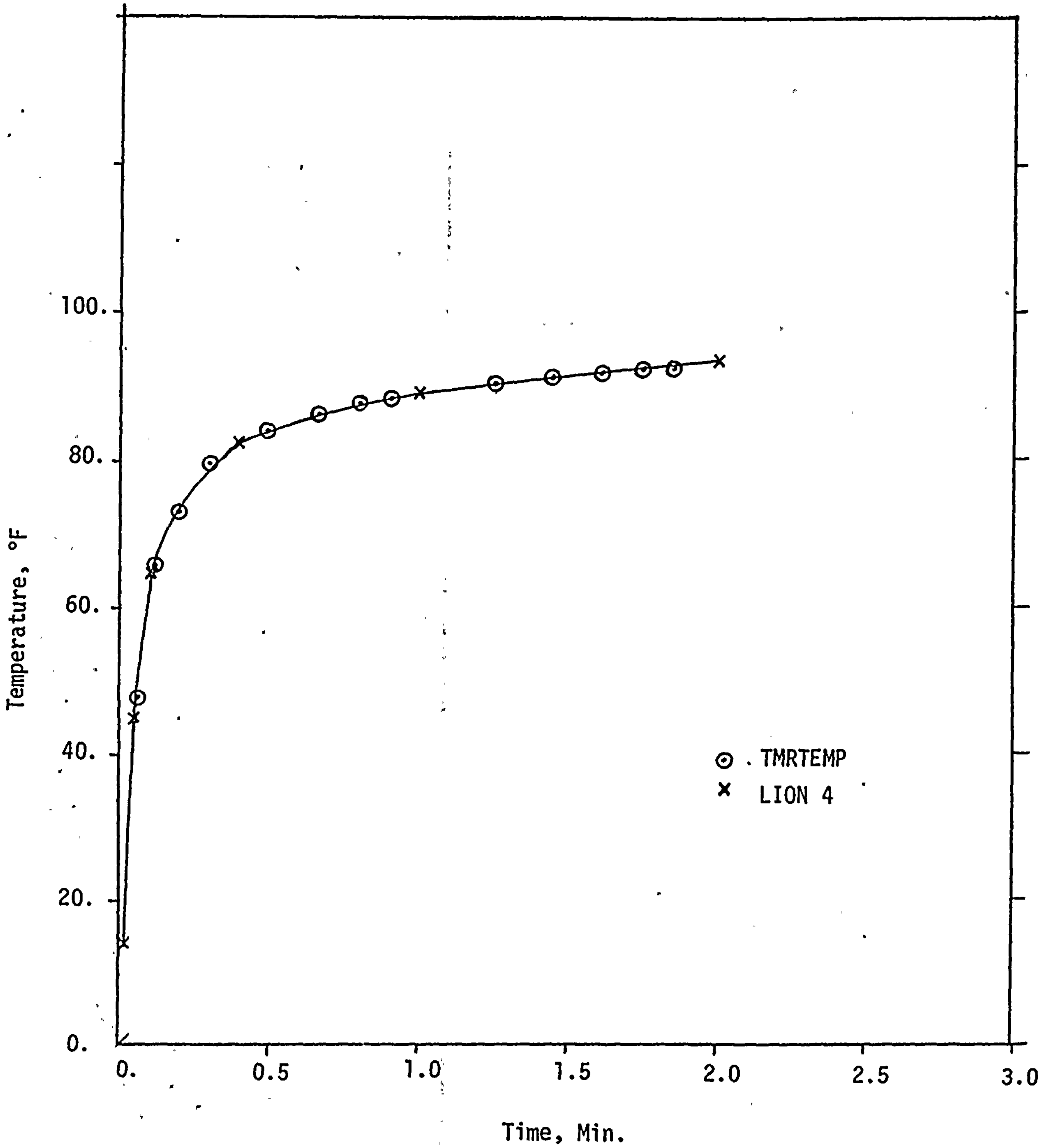


Figure 6.1-2 Temperature Response of Node 1

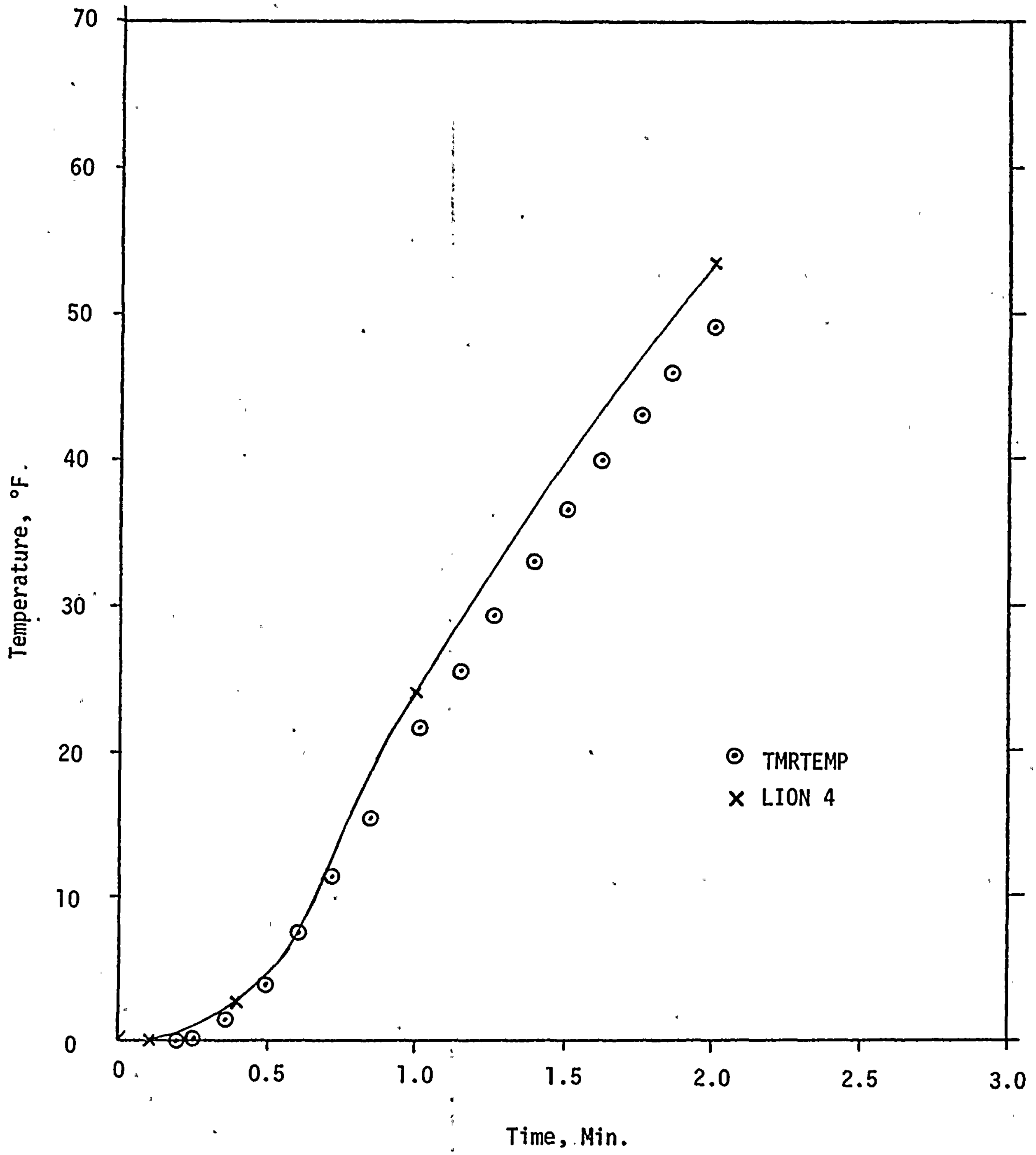


Figure 6.1-3 Temperature Response of Node 5

NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/300 ERIE BOULEVARD WEST, SYRACUSE, N.Y. 13202/TELEPHONE (315) 474-1511

Mark,
This is one of a kind which should be returned to the docket room

June 12, 1979

Director of Nuclear Reactor Regulation
Attn: Mr. Thomas A. Ippolito, Chief
Operating Reactors/Branch #3
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Phil Polk
X27872

Gentlemen:

Re: Nine Mile Point Unit 1
Docket No. 50-220

Enclosed please find the information requested by members of your staff regarding our response to I. E. Bulletin 79-07 for the seven piping systems which were re-analyzed.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

D. P. Dise

D. P. Dise
Vice President-Engineering

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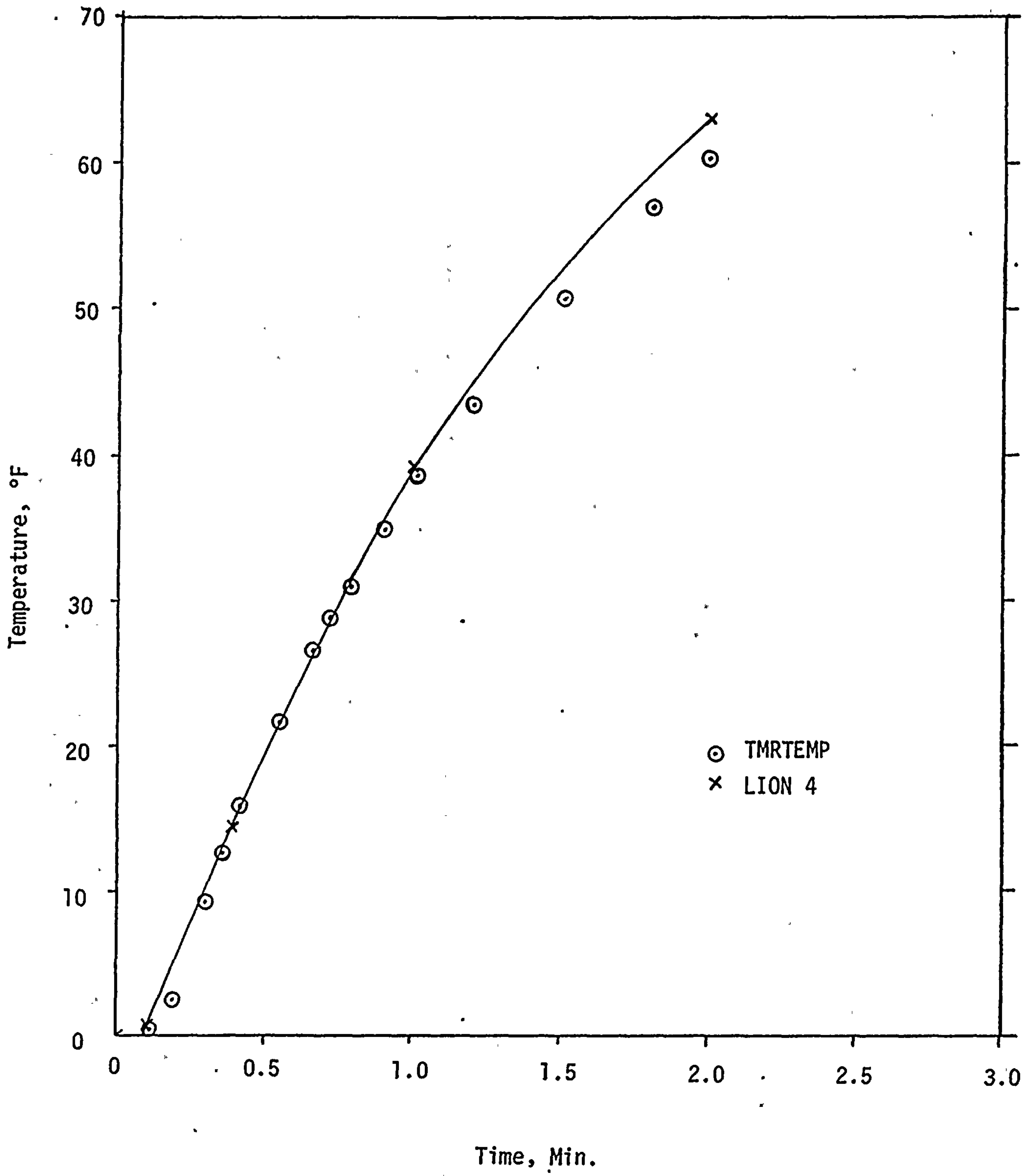
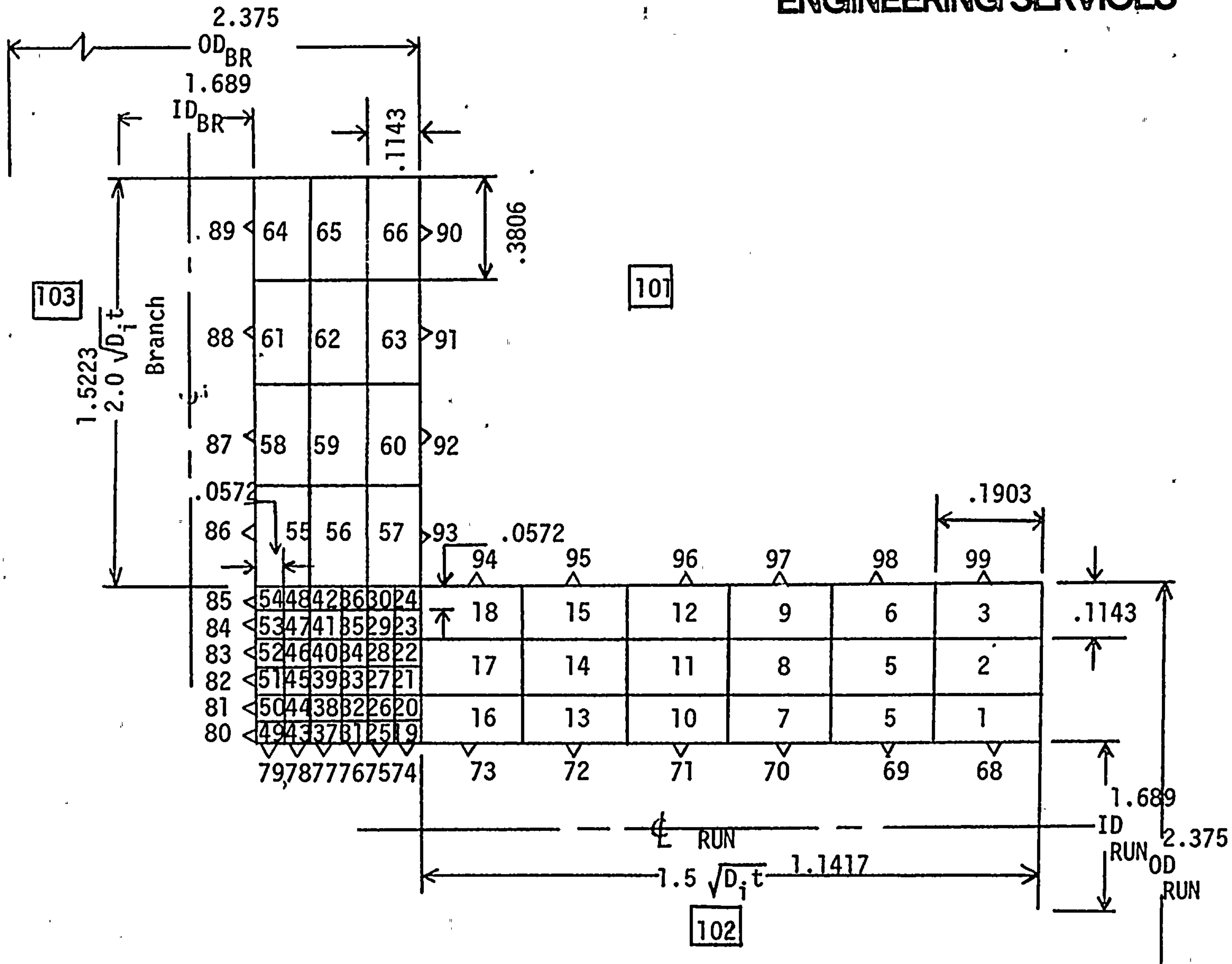


Figure 6.1-4 Temperature Response of Node 8

6.2 Sample Problem 2

Here, a two-dimensional idealization is used to model a full size 2 In. Sch. 160 Carbon Steel Tee. A comparison is made of the transient responses derived by LION 4 and TMRTEMP for a 552°F to 350°F step transient. The output is displayed on plots Figure 6.2-2 and 6.2-3 for Node 34 (Located internally at the junction) and Node 49 (inside corner of the junction) respectively. The agreement in both cases is excellent.



NOTE: Node Depth Measured from ℄ of Branch

Node Number	Description
1 thru 66	Internal (pipe material) Nodes
68 thru 99	Surface Nodes
101,102,103	Boundary Nodes

Figure 6.2-1 - Idealized Model of a Full Size Tee

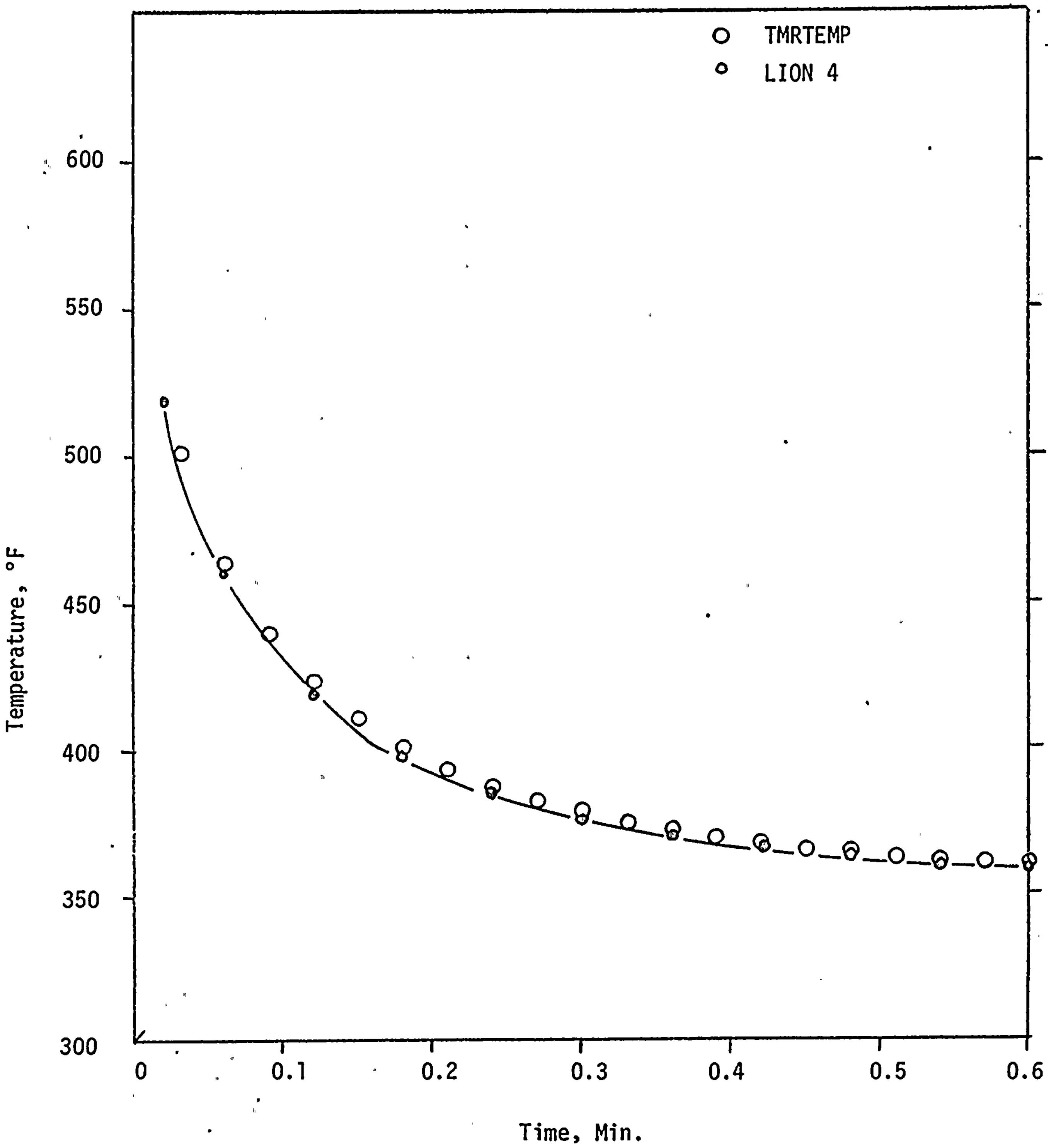


Figure 6.2-2 Temperature Response for Node 34, 2 Inch Schedule 160 Carbon Steel Tee.

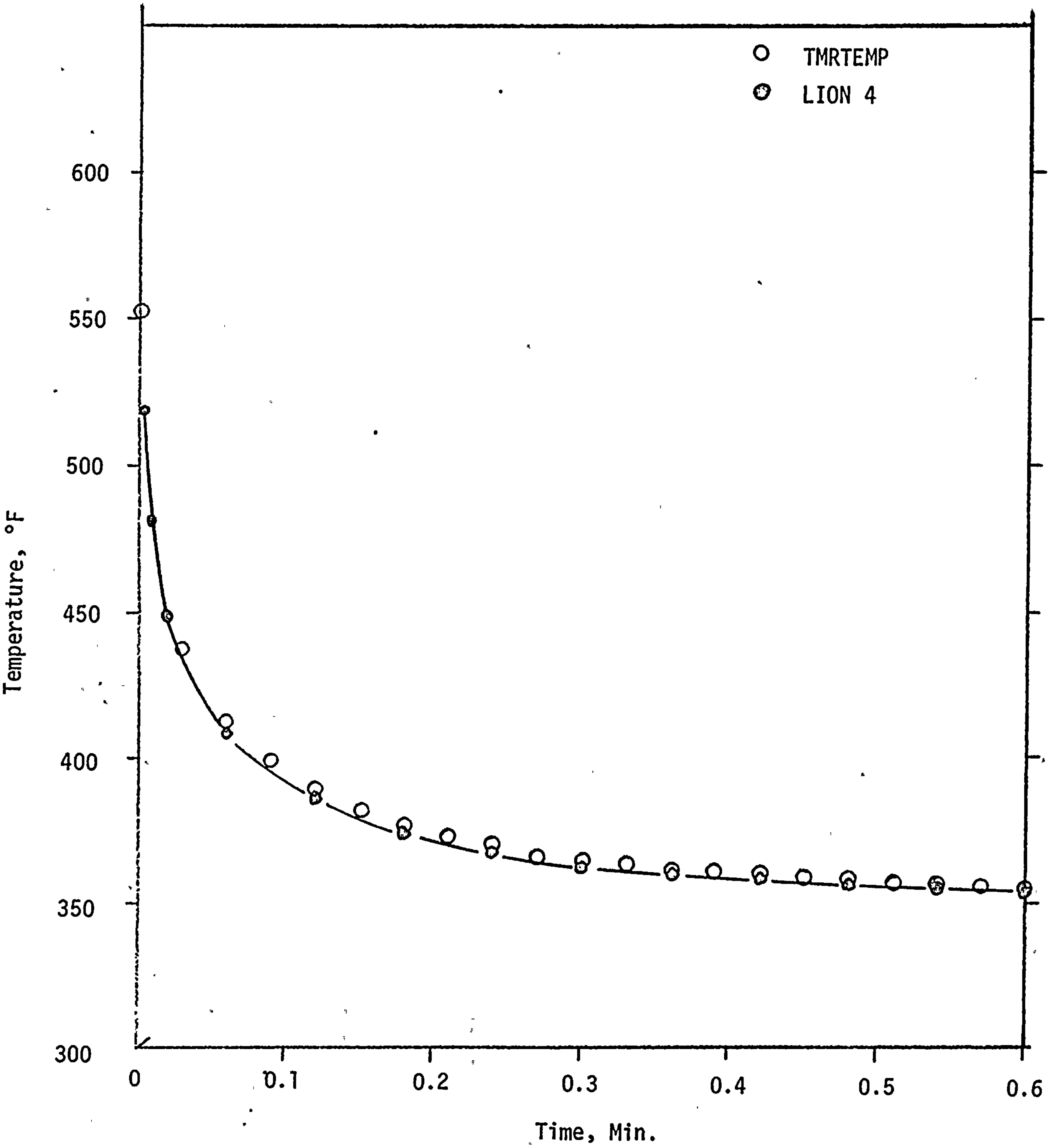


Figure 6.2-3 Temperature Response for Node 49,
2 Inch Schedule 160 Carbon Steel Tee.

6.3 Sample Problem 3

As a further comparison, a 2-dimensional idealization of a 8.25' high x 1" thick x 14' radius vessel support skirt was used. The skirt was divided into 33, 3" long nodes with the lower 14 and the upper 17 surface nodes having film coefficients of h=1.25 and 0.077 (BTU/Hr. Ft.^{2}°F) respectively. The base node was assumed to be adiabatic and the ambient boundary nodes assumed the 120°F temperature that was initially uniform throughout the system. At time zero the skirt and surface (h=10,000 BTU/Hr. Ft.^{2}°F) was subjected to a step change from the initial temperature of 120°F to 940°F.

The thermal response for the three end nodes was plotted for the initial five minutes.

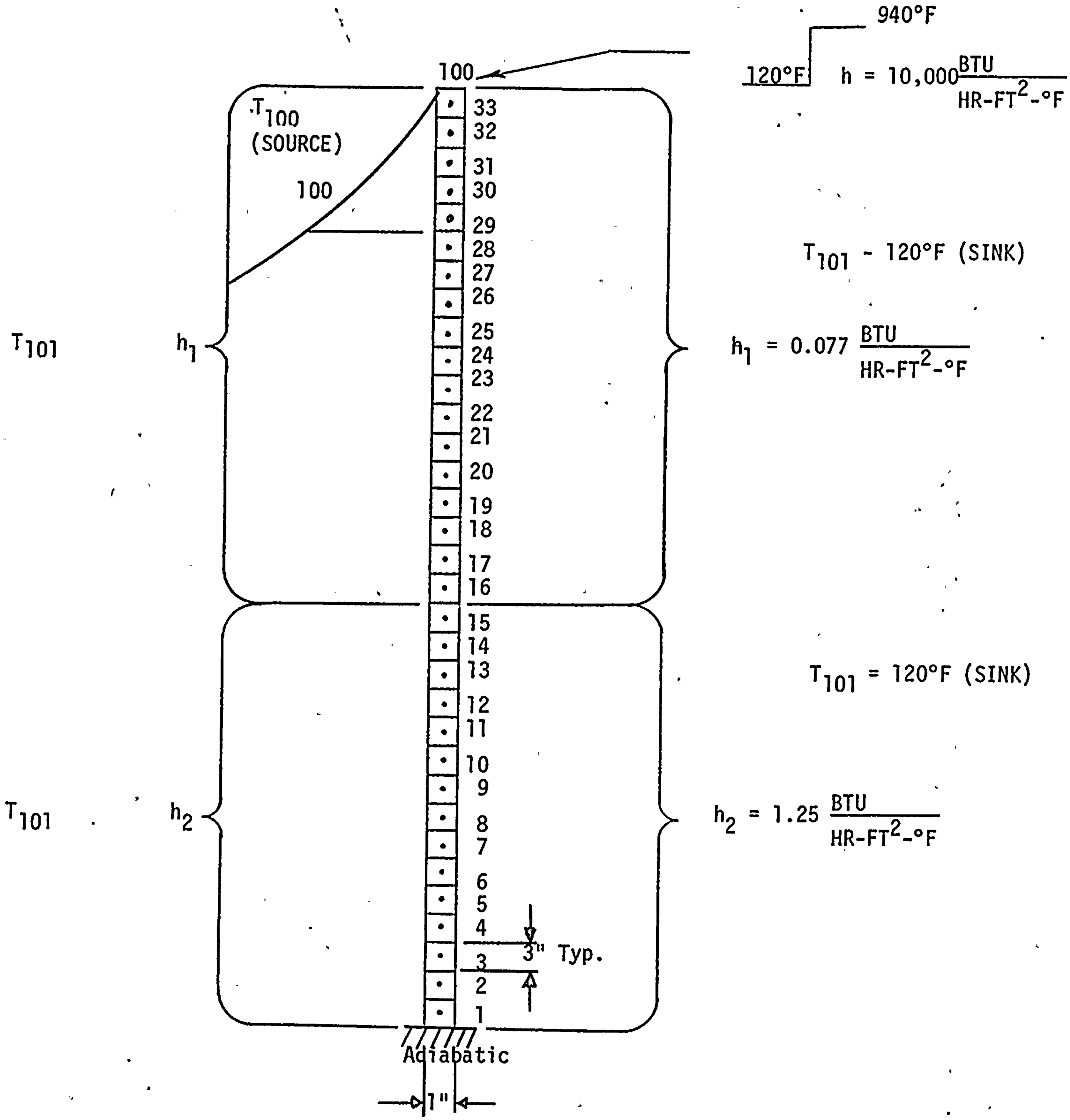


Figure 6.3-1 TMRTEMP Thermal Model for Skirt Temperature Distribution

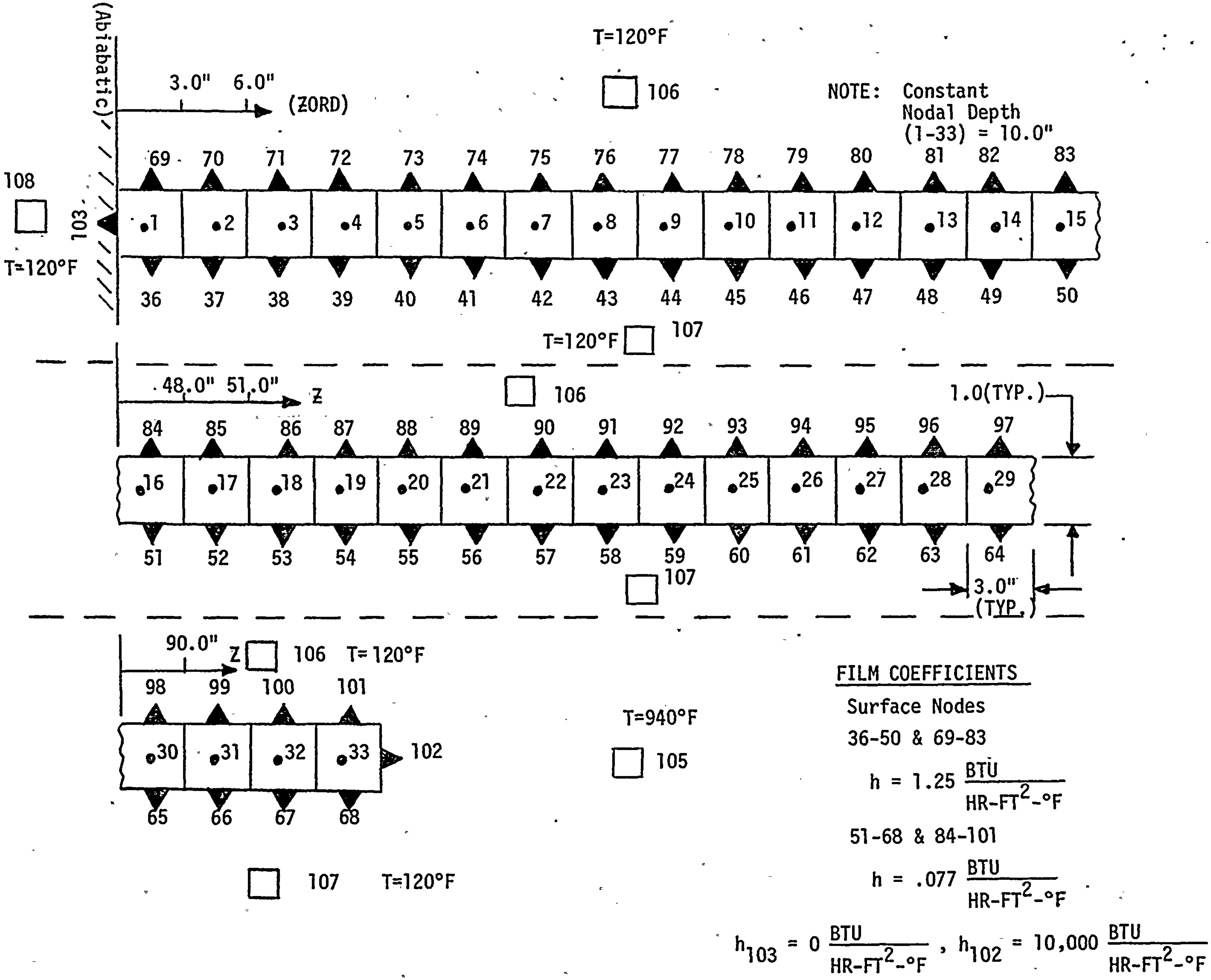


Figure 6.3-2 LION 4 Thermal Model for Skirt Temperature Distribution

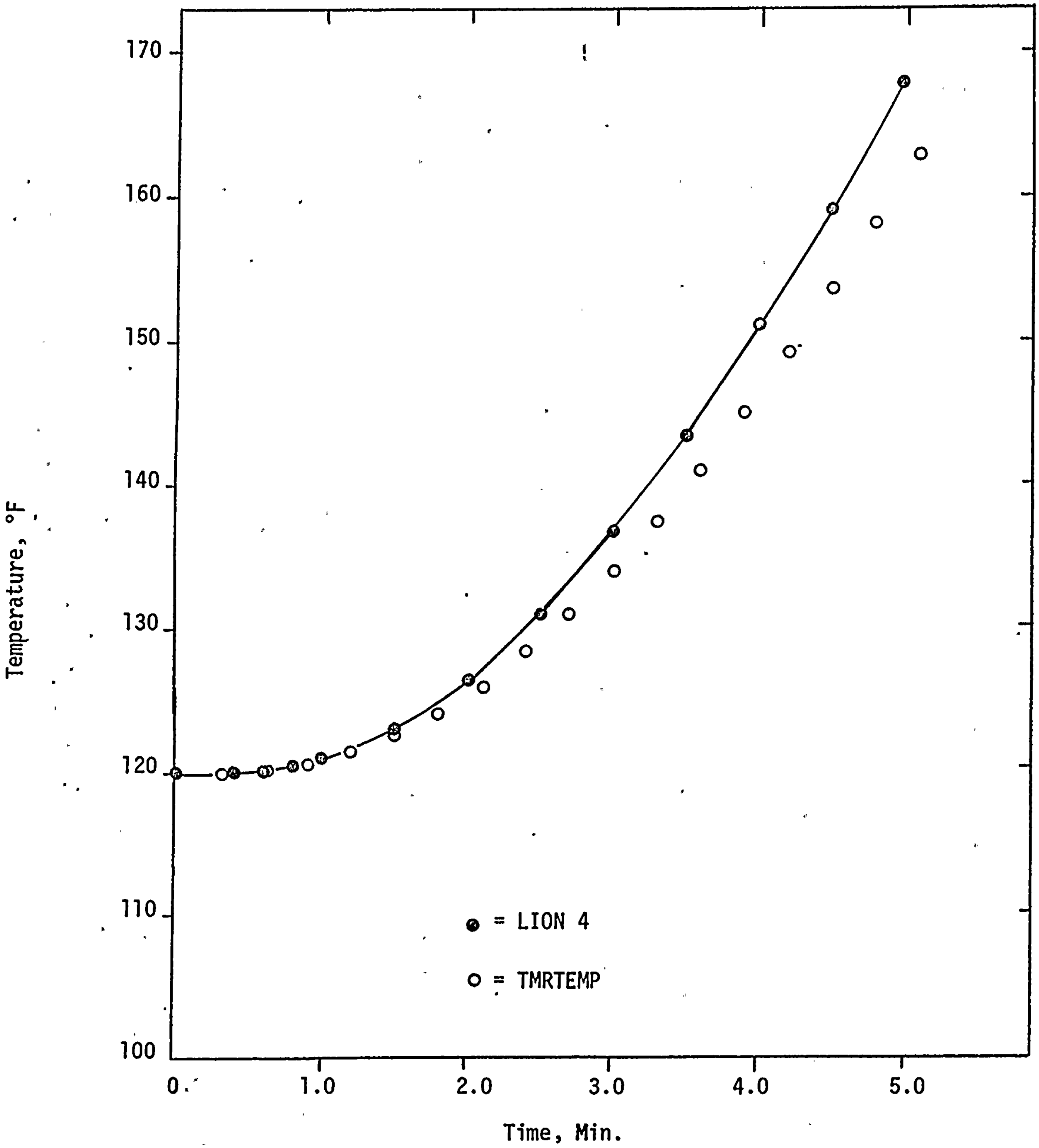


Figure 6.3-3 Temperature Response for Node 31.

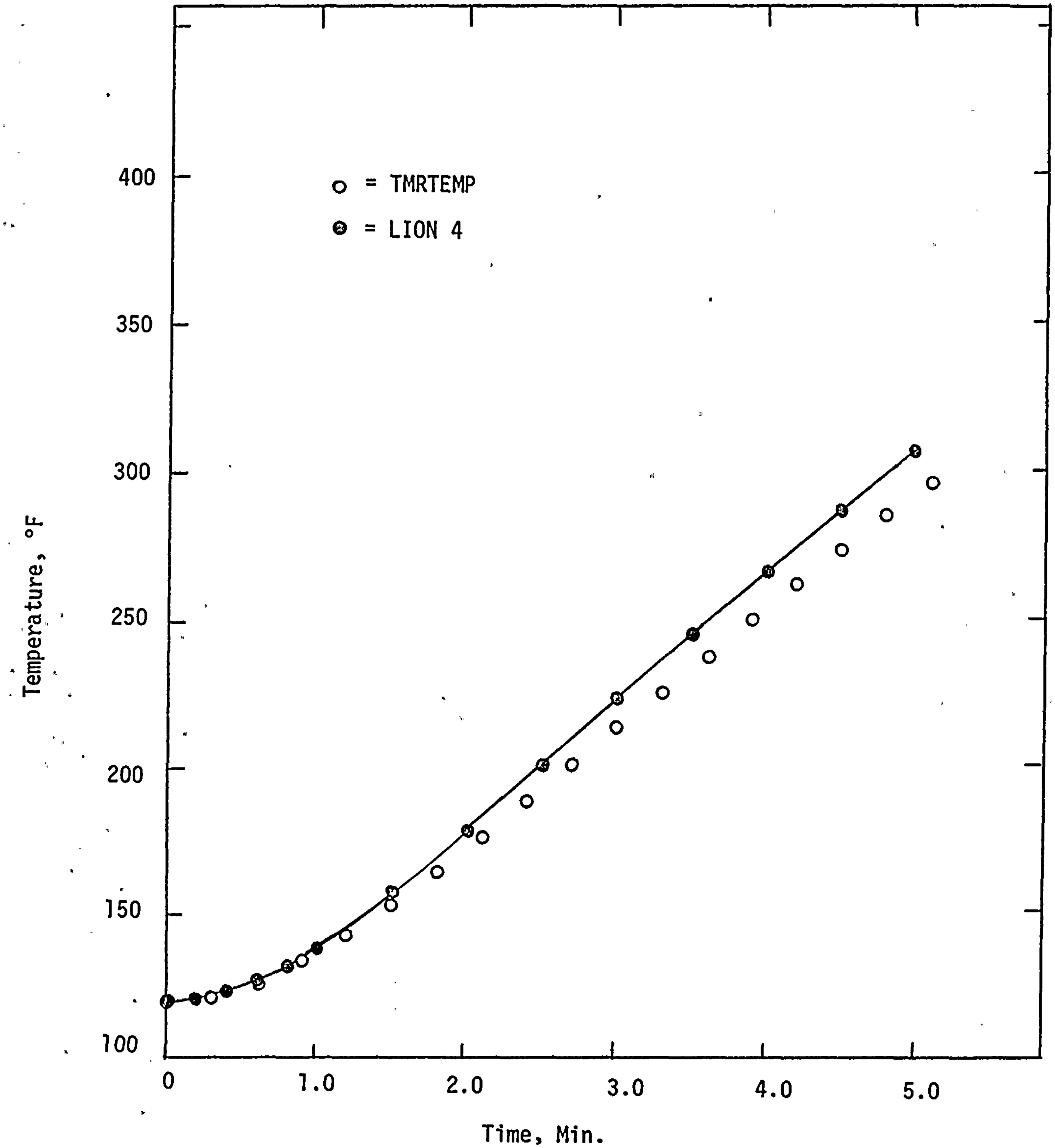


Figure 6.3-4 Temperature Response for Node 32.

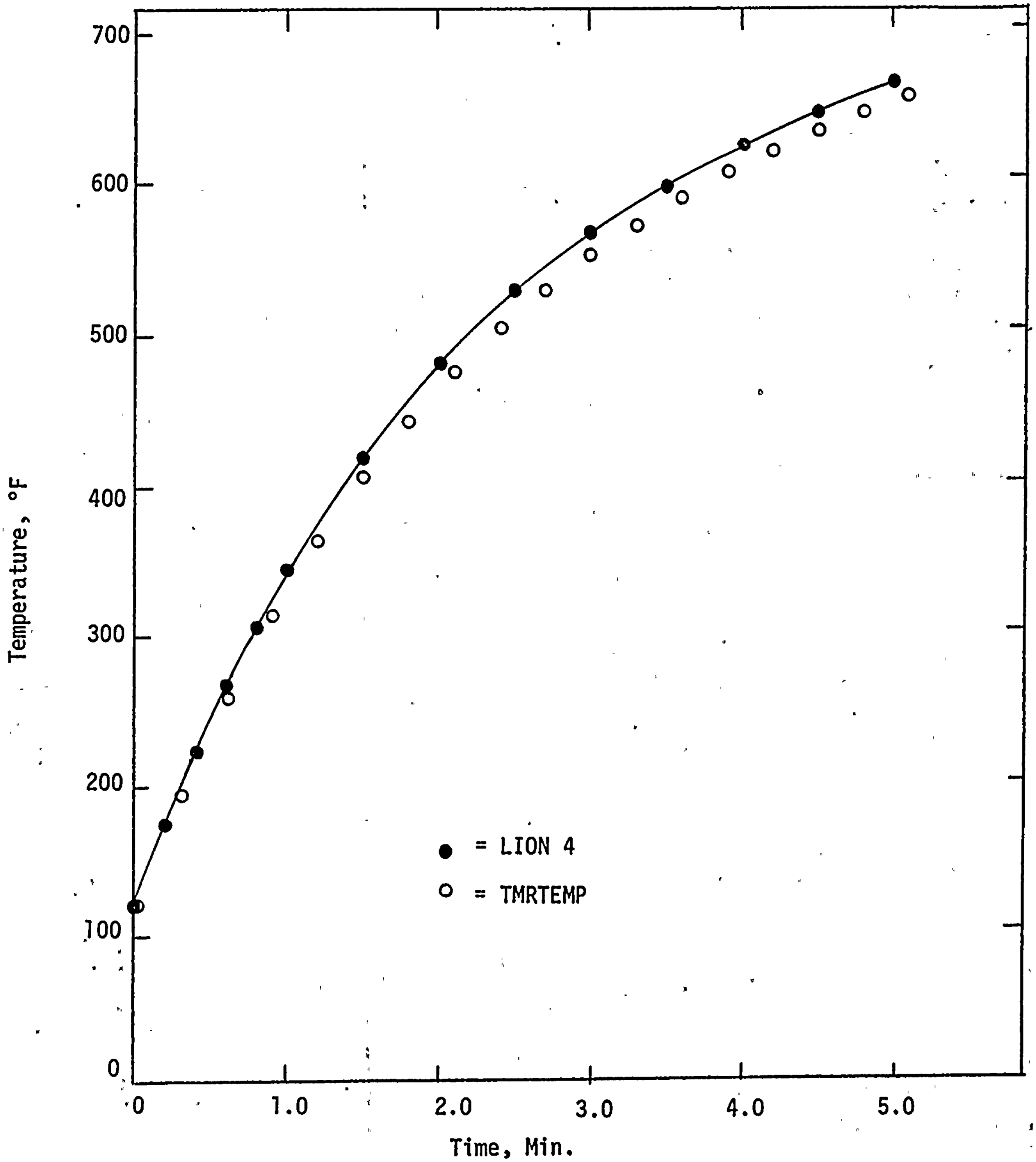


Figure 6.3-5 Temperature Response for Node 33

6.4 Sample Problem 4

For a final comparison, the one dimensional model used in Sample Problem 1 was used by LION 4, TMRTEMP and the classical Brock-McNeill [2] solution to plot the responses for the inside surface, mean, and outside surface temperatures. Evidently, LION 4 compares favorably with BROCK and TMRTEMP.

BROCK CALCULATIONS

$h = 3{,}000. \frac{BTU}{Lbs \cdot Ft^2 - °F}$

$a = 1.25" = 0.1042$ Ft.

$K_{s.s} = 8.00 \frac{BTU}{Hr-Ft-°F}$

$\alpha_{s.s.} = 0.15 \frac{Ft^2}{Hr}$

$N_B = \frac{ha}{K} = 39.1$ Biot Number

$\theta = \frac{\alpha t}{a^2} = \frac{\alpha t(min)}{a^2 60.} = 0.2303\ t(min)$

$Log_{10}(\theta) = Log_{10}(0.2303\ t(min))$

t(min)	$Log_{10}(\theta)$	H	T_H(°F)	A	T_A(°F)	I	T_I(°F)
0.0	---						
0.2	-1.337	0.93	93.	0.27	27.	0.00	0.
0.4	-1.036	0.95	95.	0.32	32.	0.03	3.
0.6	-0.860	0.96	96.	0.38	38.	0.11	11.
0.8	-0.735	0.97	97.	0.45	45.	0.19	19.
1.0	-0.638	0.97	97.	0.52	52.	0.28	28.
1.2	-0.559	0.98	98.	0.57	57.	0.35	35.
1.4	-0.492	0.98	98.	0.61	61.	0.41	41.
1.6	-0.434	0.98	98.	0.64	64.	0.49	49.
1.8	-0.383	0.98	98.	0.68	68.	0.55	55.
2.0	-0.337	0.98	98.	0.72	72.	0.60	60.

Using N_B and the time dependent $Log_{10}(\theta)$ the coefficients H, A, and I for the inside surface temp. average temp., and outside surface temp. respectively, were interpolated from the curves in Brock Figure 1, 2, and 3.

where: $T_H = T_o = (T_F - T_o)\ H$ (Inside Surface Temp.)

$T_A = T_A + (T_F - T_o)\ A$ (Average Temp.)

$T_I = T_o + (T_F - T_o)\ I$ (Outside Surface Temp.)

H = Coefficient for Inside Surface Temperature

A = Coefficient for Average Temperature

I = Coefficient for Outside Surface Temperature

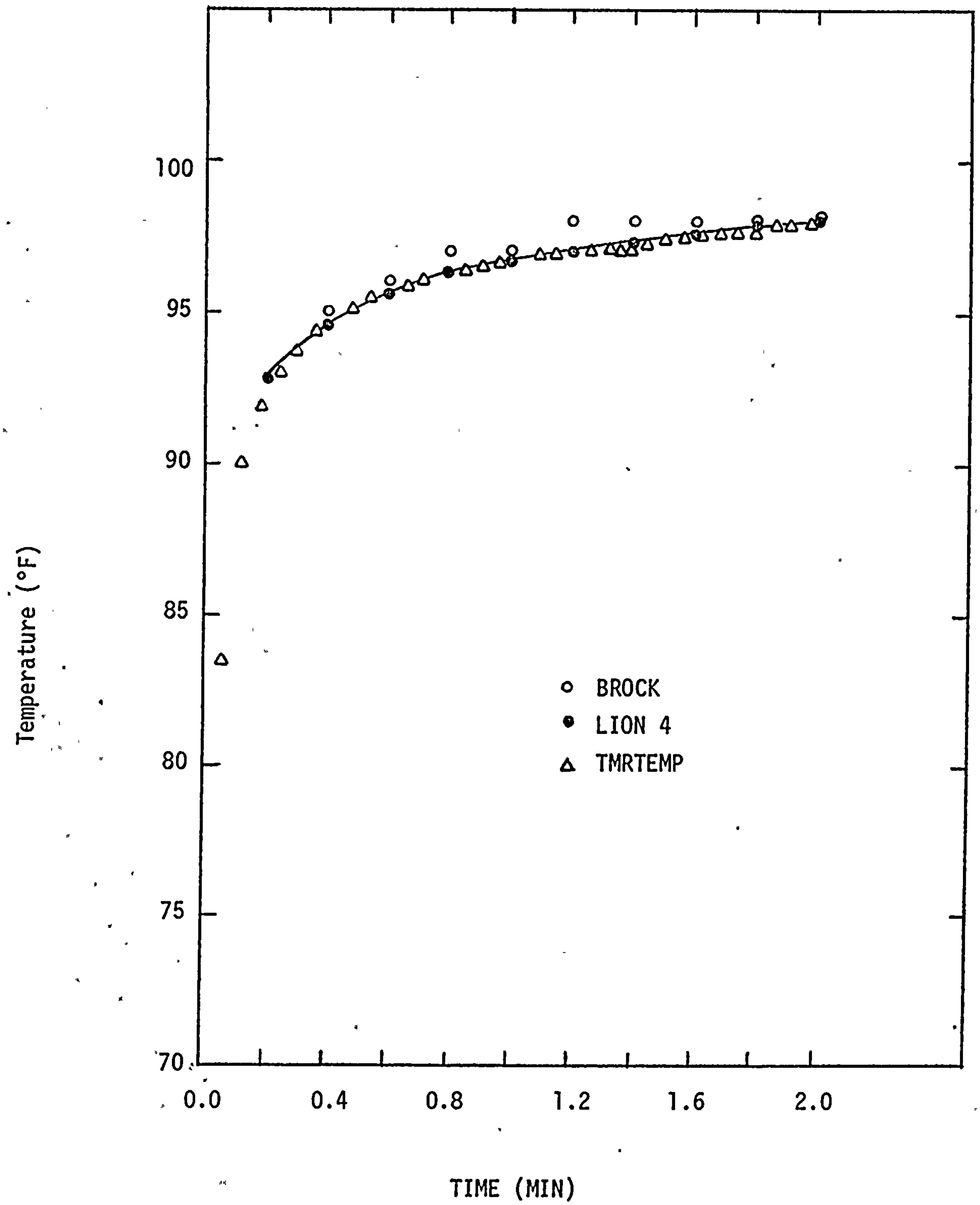


Figure 6.4-1 Inside Surface Temperature

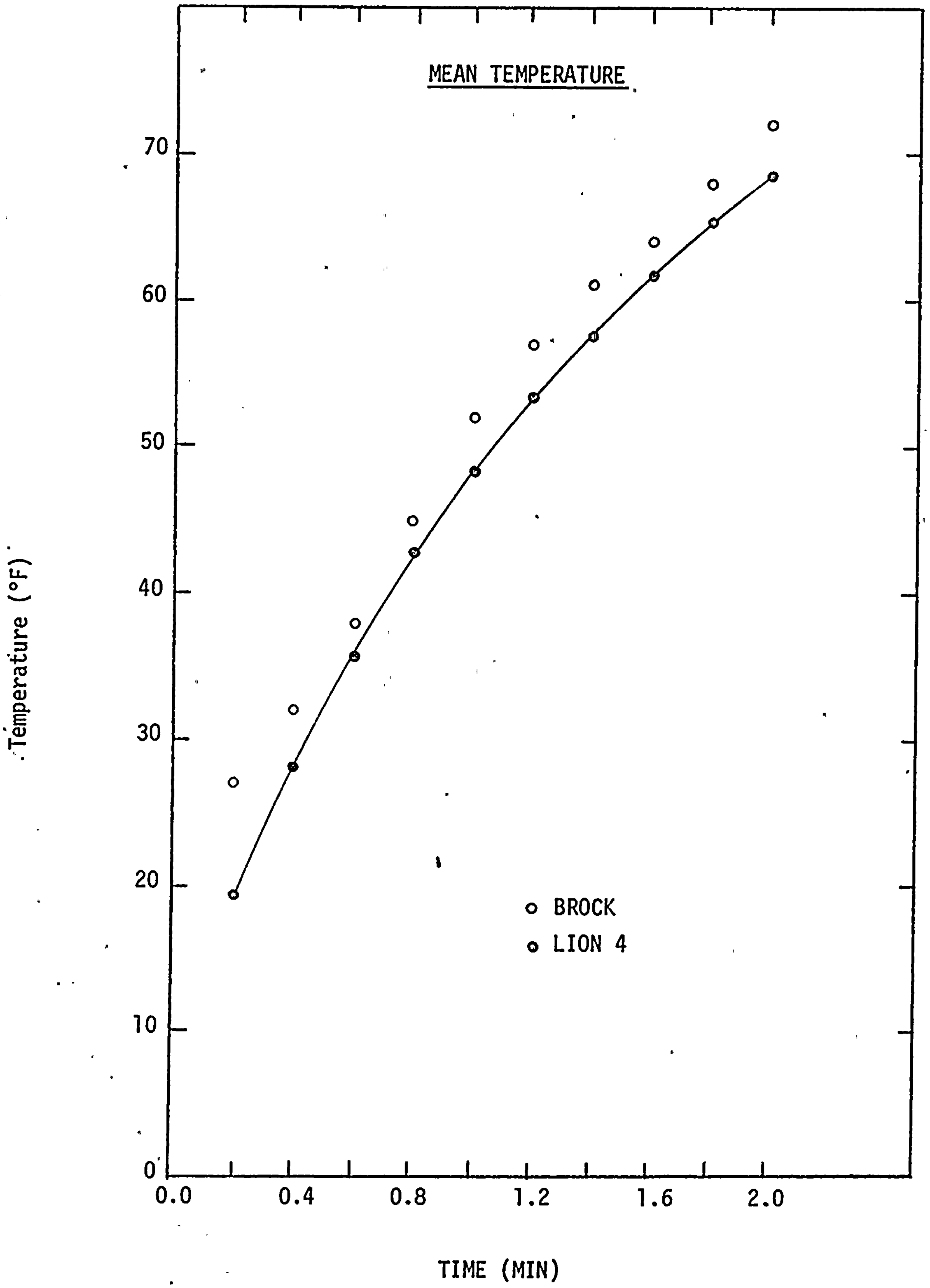


Figure 6.4-2 Mean Temperature

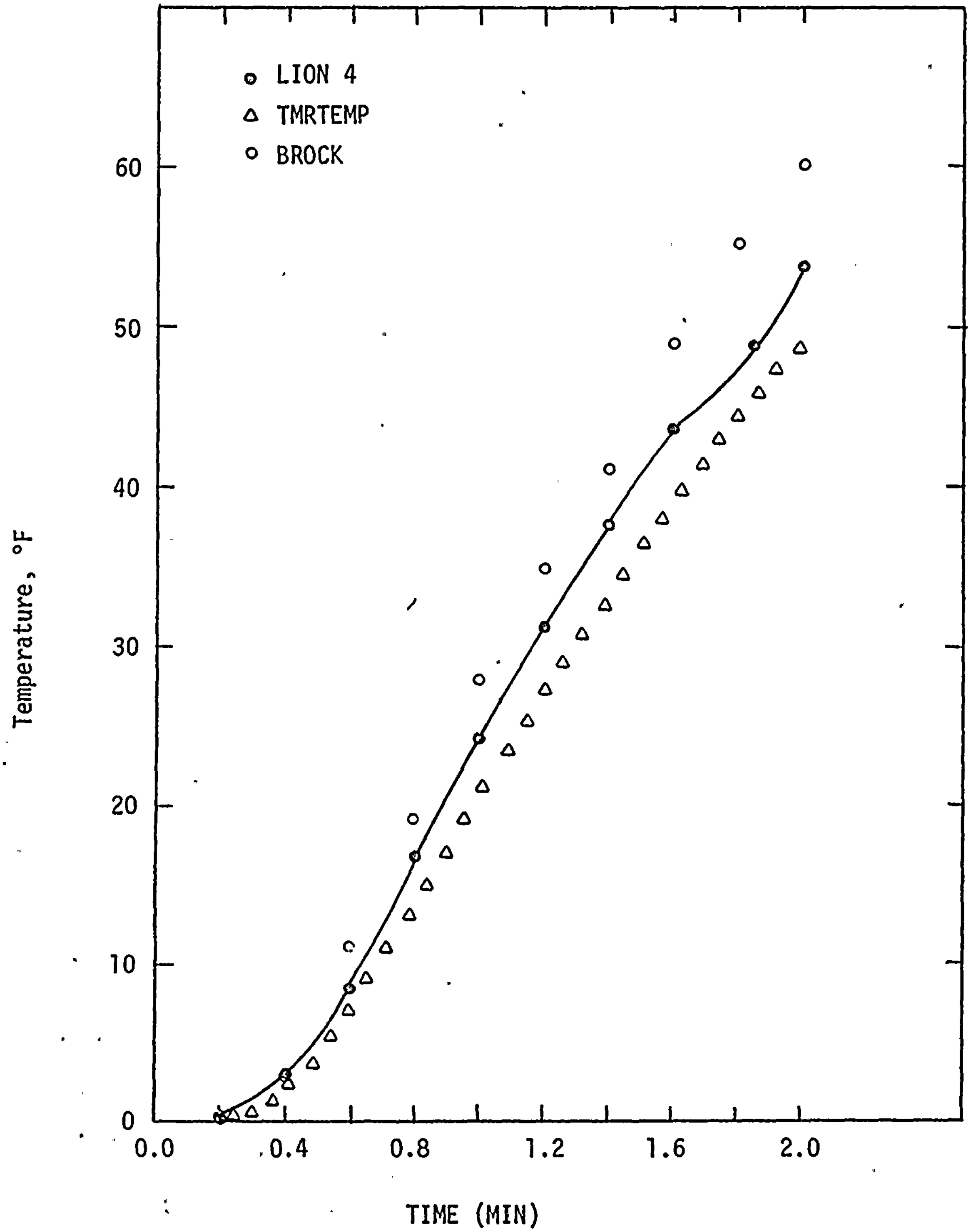
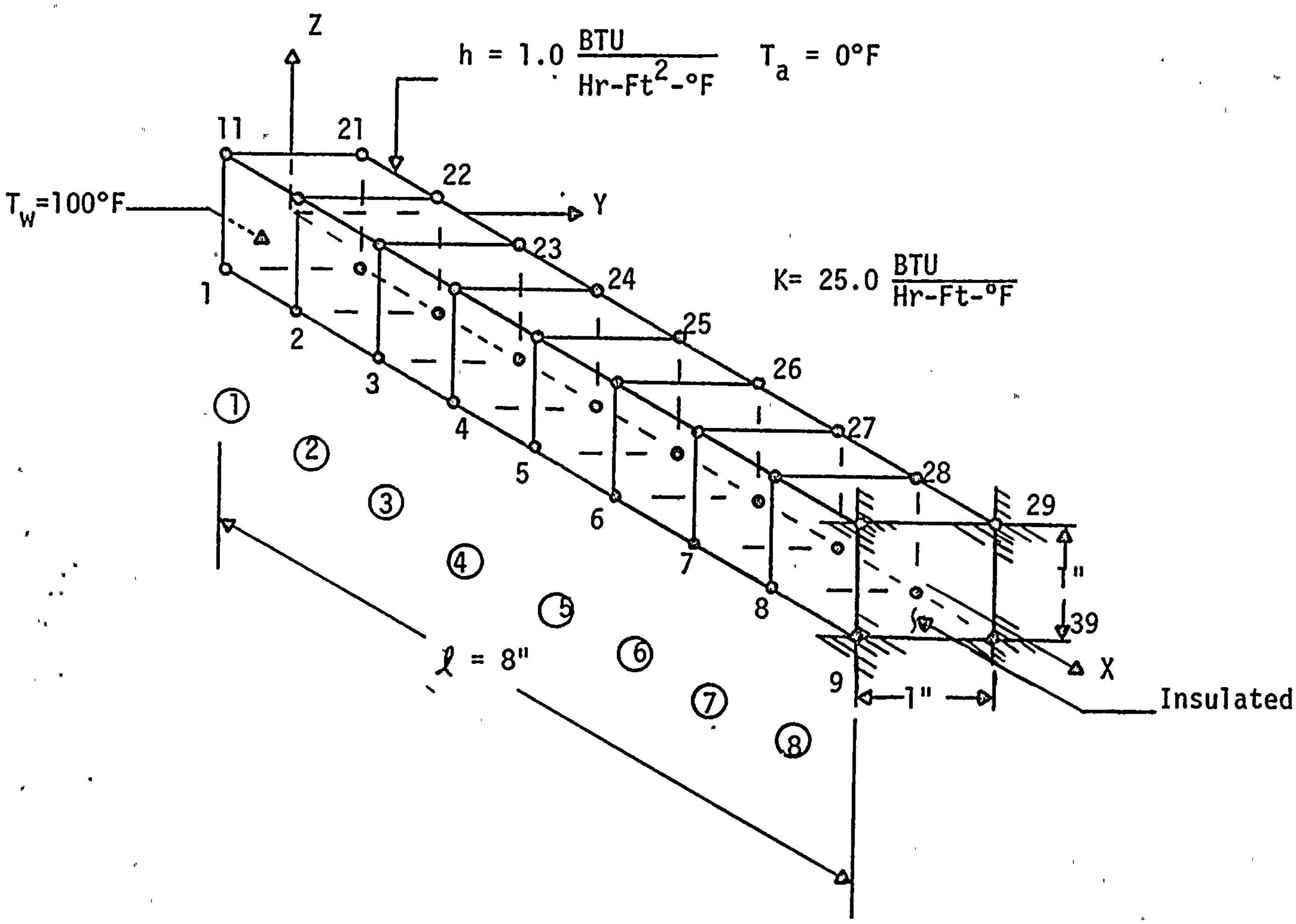


Figure 6.4-3 Outside Surface Temperature

6.5 Sample Problem No. 5

A cooling fin of square cross-sectional area A, length ℓ, and conductivity K extends from a wall maintained at temperature T_w. The surface convection coefficient between the fin and the surrounding air is h, the air temperature is T_a, and the tip of the fin is insulated. Determine the heat conducted by the fin q and the temperature of the tip T_ℓ.



Finite Element Model

MODELING HINTS: Coupled nodal temperatures are used to insure symmetry.

Figure 6.5-1 Heat Transfer From a Cooling Fin

TABULATED RESULTS

ANSYS OUTPUT — LION 4 OUTPUT

NODES	TEMPERATURE	ELEMENT	ELEM.MEAN TEMP.	ELEM. TEMP.
1, 11, 21, 31	(100.0)°F (BASE)	1	96.127°F	(100.00) 95.65°F
2, 12, 22, 32	92.253	2	88.995	88.24
3, 13, 23, 33	85.736	3	83.049	82.03
4, 14, 24, 34	80.362	4	78.211	76.95
5, 15, 25, 35	76.060	5	74.416	72.95
6, 16, 26, 36	72.772	6	71.613	69.98
7, 17, 27, 37	70.454	7	69.762	68.02
8, 18, 28, 38	69.076	8	68.847	67.53
9, 19, 29, 39	(68.618) (END)			(67.53)

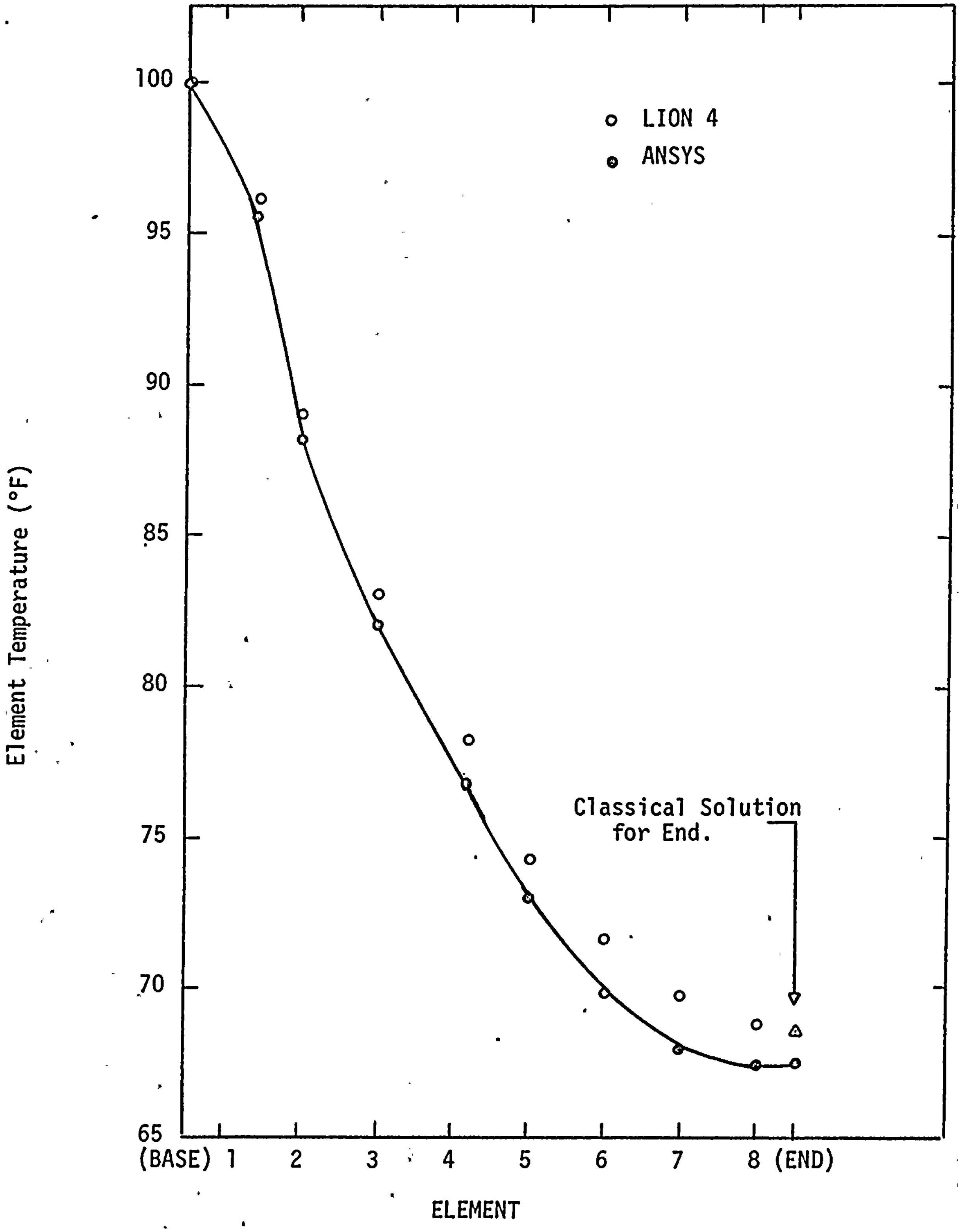
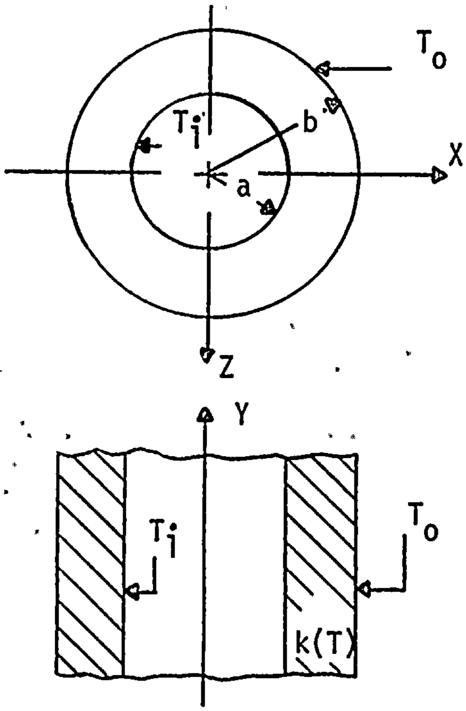


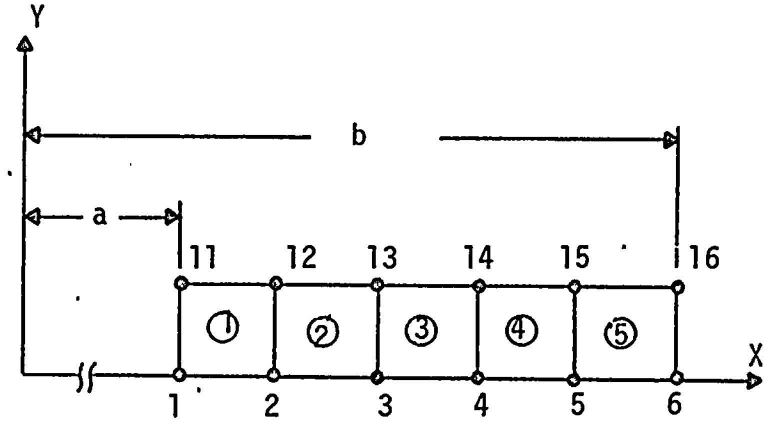
Figure 6.5-2 Steady State Temperature Distribution

6.6 Sample Problem No. 6

A long hollow cylinder is maintained at temperature T_i along its inner surface and T_0 along its outer surface. The thermal conductivity of the cylinder material is known to vary with temperature according to the linear function $K(T) = C_0 + C_1T$. Determine the temperature distribution in the cylinder for 1) k = constant, i.e. $C_1 = 0$, and 2) k = k (T).



Problem Sketch



Finite Element Model

<u>GIVEN</u>: C_1 = 50 BTU/hr-ft^2-°F, C_2 = 0.5 BTU/hr-ft^2-°F^2, r_i = 1/2 in = 0.041666 ft.
r_o = 1 in. = 0.083333 ft, T_i = 100°F, T_o = 0°F.

<u>MODELING HINTS</u>: The axial length of the model is arbitrarily chosen to be 0.01 ft. Nodal coupling is used to insure axial symmetry. The steady-state convergence procedures are used.

Figure 6.6-1 Cylinder with Temperature Dependent Conductivity

TABULATED RESULTS

ELEMENT	CASE 1 K=50.0 BTU. / Hr-Ft -°F		CASE 2 K=50.0+0.5T BTU / Hr-Ft-°F	
	ANSYS	LION 4	ANSYS	LION 4
(INSIDE)	100.0°F	100.0°F	100.0°F	100.0°F
1	86.8	85.6	89.6	88.9
2	62.6	61.7	69.4	68.9
3	41.8	41.1	49.9	49.5
4	23.7	23.2	30.5	30.2
5	7.6	7.2	10.4	10.3
(OUTSIDE)	0.0	0.0	0.0	0.0

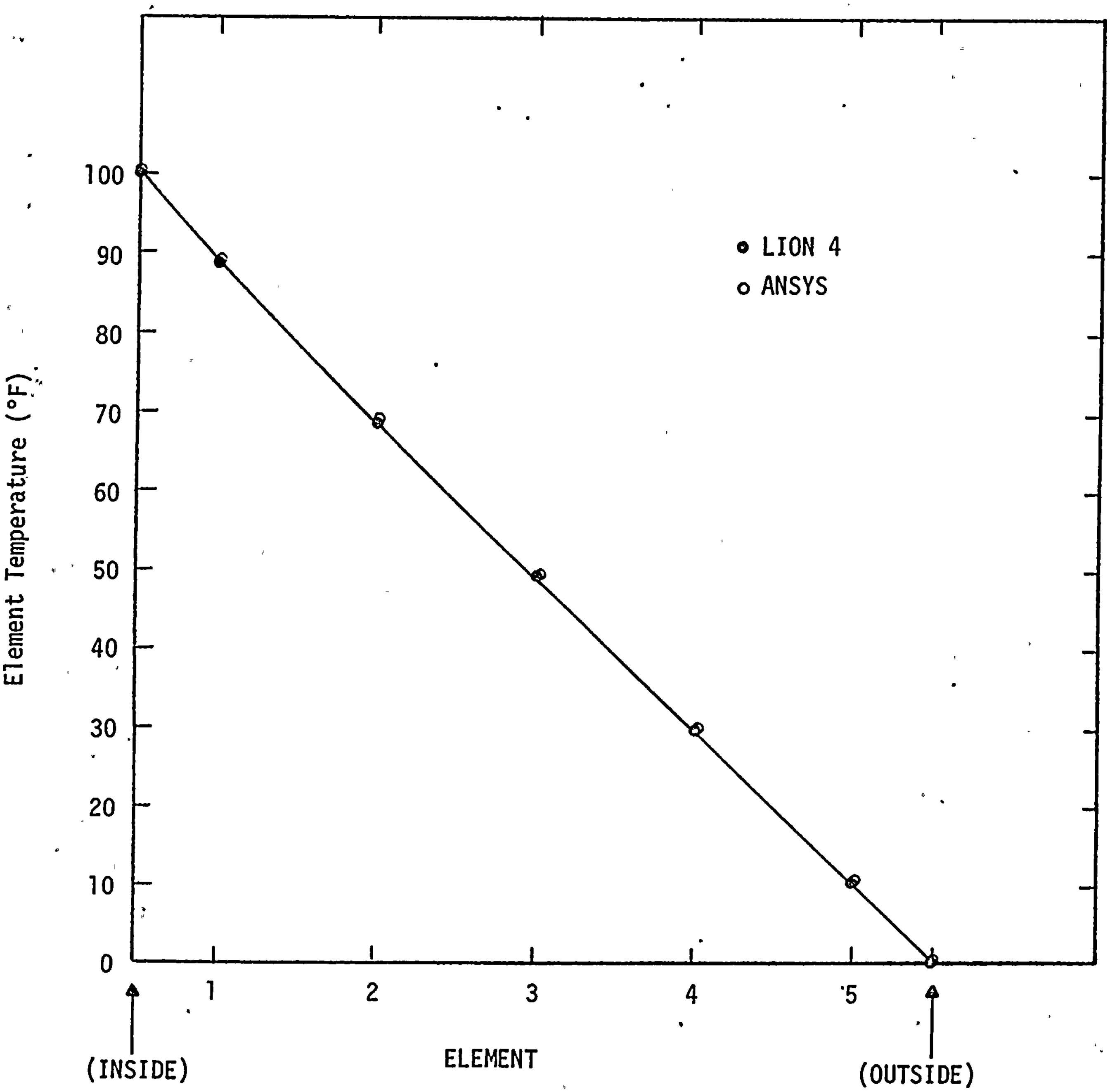


Figure 6.6-2 Steady State Temperature Distribution for Case 1, Constant Conductivity

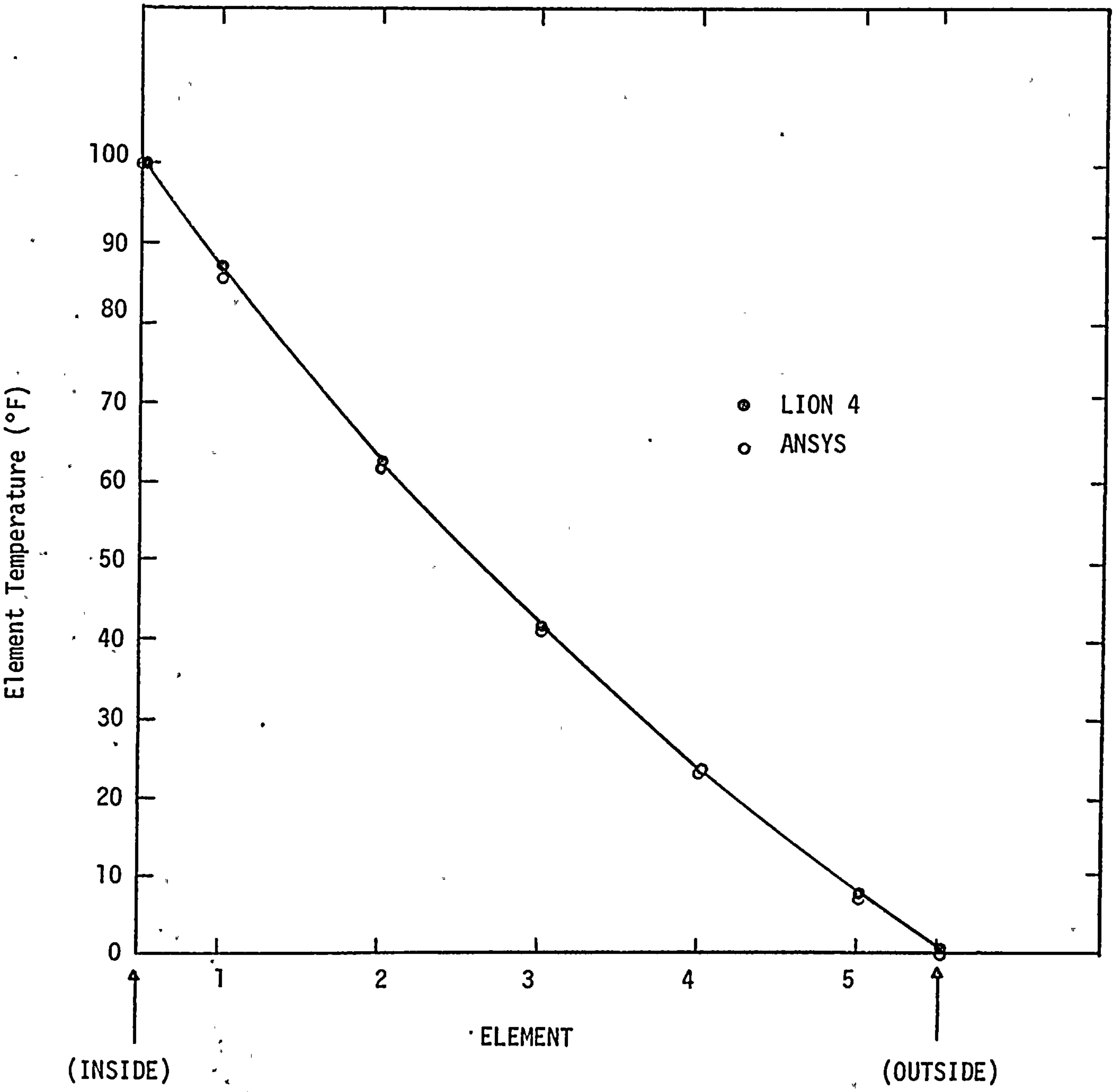


Figure 6.6-3 Steady State Temperature Distribution for Case 2, Temperature Dependent Conductivity

7.0 CONCLUSIONS

Comparisons of LION 4 Thermal Analysis with BROCK, TMRTEMP, and ANSYS thermal analysis techniques shows favorable agreement of results. One can assume that LION 4 can be used with confidence for thermal analysis of transient and steady state responses to be used for conservative engineering design evaluation.

8.0 REFERENCES

[1] A.P.; Bray "TIGER - Temperatures from Internal Generation Rates".

[2] D.R., McNeill, J.E. Brock, "Calculating Transient Temperature in Pipes".

[3] TMRTEMP - A General Thermal Analyzer Program, January, 1979, by Teledyne Engineering Services.

[4] ANSYS - Engineering Analysis System, by Swanson Analysis Systems, Inc.

TMRSAP

A digital computer program for the structural analysis of piping systems.

1.0 GENERAL DESCRIPTION

The TMRSAP computer program provides an elastic analysis of complex piping systems subjected to thermal, static and dynamic loads. TMRSAP is a modified version of the SAP IV computer program. A preprocessor has been added to provide a more user-oriented input format. Point-to-Point coordinate input and arbitrary node numbering are included for ease of modeling and for implementing geometry changes into existing models without having to re-do the entire input data for a given model. The pre-processor reads the card input defining the model in a user-oriented format, transforms the input data to a SAP IV compatible format and creates an intermediate file in BCD mode (coded file). SAP IV subsequently reads the input data from the intermediate file and proceeds with the execution.

The piping systems to be analyzed are composed of two element types: (1) pipe elements (tangent and bend), and (2) boundary elements. The pipe element can be represented by a straight segment (tangent) or a circularly curved segment (bend). The boundary element is used to constrain nodal displacements to specified values, to compute support reactions and to provide linear elastic supports to nodes.

Four (4) types of dynamic analysis can be performed by the program.

1. Determination of system mode shapes and frequencies only.
2. Dynamic Response Analysis for arbitrary time dependent loads using mode superposition.
3. Response Spectrum Analysis.
4. Dynamic Response Analysis for arbitrary time dependent loads using step-by-step direct integration.

Program printout consists of forces and moments acting on the pipe element at the ends of each member and at the midpoints of the arcs in bend elements. Stresses within the piping system due to effects of internal pressure and bending are computed in accordance with ANSI B31.1, "Power Piping."

2.0 APPLICATION

The TMRSAP program provides a solution for the static and dynamic structural analysis of nuclear piping systems. The program analyzes elastic piping systems subjected to thermal, static, and dynamic loads.

The piping systems are modeled using either of two element types, namely, boundary element or pipe element (tangent and bend). These elements may be used in a static or dynamic analysis. The pipe element is represented by a straight segment (tangent) or a circularly curved segment (bend); both elements require a uniform section and uniform material properties. Elements can be directed arbitrarily in space. The member stiffness matrices account for bending, torsion, axial and shear deformations. In addition, the effect of internal pressure on the stiffness of curved pipe elements is considered.

The loads contributed by the pipe elements include gravity in the global directions, and loads due to thermal distortions and deformations induced by internal pressure. Forces and moments acting at the member ends and at the center of each bend are calculated in coordinate systems aligned with the member's cross-section.

Four types of dynamic analysis can be performed by the program:

1. Determination of system mode shapes and frequencies.
2. Dynamic response analysis for arbitrary time-dependent loads using mode superposition.
3. Response spectrum analysis.
4. Dynamic response analysis for arbitrary time-dependent loads using step-by-step direct integration.

3.0 CAPABILITIES

The capabilities of the TMRSAP program are as follows:

a. Static Analysis - deadweight
   thermal
   deadweight + thermal

b. Dynamic Analysis - response spectrum (seismic)
   forced response (time history)
   1. mode superposition
   2. direct integration

c. Plotting - On request, the program generates a geometry file which becomes the input file to a SAP IV plotting program "SAPLOT"* and may be executed in the same job stream following the analysis or a geometry input data check (no analysis). If desired, the geometry plot file may be saved on magnetic tape, disk, or copied to a punch file and plotted in a separate computer run.

d. Bandwidth Minimization - The program has an optional bandwidth minimization capability which is a separate overlay. It employs a Cuthill-McKee nodal renumbering algorithm to ensure that the stiffness matrix will have a narrow bandwidth resulting in a more efficient solution of the system of equations and considerably less execution time. The bandwidth minimization overlay reads the SAP IV model from an intermediate mass storage file created in the TMRSAP preprocessor overlay in BCD mode, then performs the resequencing strategy and writes the modified model back onto tape in BCD mode where it is ready for execution by SAP IV for either a problem solution or an input data check.

e. Closely Spaced Modes - The program has been modified to include a closely spaced frequency criteria in accordance with the "ten percent method" defined in NRC Regulatory Guide 1.92, C.1.2.2 for combining the modal response in a response spectrum dynamic analysis. The closely spaced

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frequency criteria may be overridden at the input level by defining a criteria $<< 0.1$ causing the program to encounter no "closely" spaced modes whereby the closely spaced mode term in the equation goes to zero resulting in a square root sum of the squares modal summation.

$$R = \left[\sum_{k=1}^{N} R_k^2 + 2 \Sigma |R_i \cdot R_j| \right]^{1/2} \qquad i \neq j \qquad (1)$$

f. Output Features - The program generates an output file of pipe element forces, moments, deflections on tape which may be copied to a punch file, magnetic tape or cataloged on a disk file for each load condition. These files may then be manipulated and merged to become a single input file to postprocessing programs.

The TMRSAP piping system model is written on tape in BCD mode as it is transformed to a SAP IV model. If it is desired, the transformed SAP IV model may then be copied to a punch file to provide a SAP IV data deck. This deck may then be modified to meet the needs of special analyses or modeling techniques using the standard version of SAP IV: i.e., for requirements which are beyond the current capabilities of TMRSAP.

4.0 THEORY

The calculation of the structure stiffness matrix and mass matrix is accomplished in three distinct phases:

1. The nodal point input data is read and generated by the program. In this phase the equation numbers for the active degrees of freedom at each nodal point are established.

2. The element stiffness and mass matrices are calculated together with their connection arrays; the arrays are stored in sequence on tape (or other low-speed storage).
3. The structure stiffness matrix and mass matrix are formed by addition of the element matrices and stored in block form on tape.

The formation of the structure matrices is carried out in the same way in a static or dynamic analysis. The static analysis is continued by solving the equations of equilibrium followed by the computation of element stresses. In a dynamic analysis the choice is between

1. frequency calculations only,
2. frequency calculations followed by response history analysis,
3. frequency calculations followed by response spectrum analysis,
4. response history analysis by direct integration.

To obtain the frequencies and vibration mode shapes solution routines are used which calculate the required eigenvalues and eigenvectors directly without a transformation of the structure stiffness matrix and mass matrix to a reduced form. In the direct integration an unconditionally stable integration scheme is used, which also operates on the original structure stiffness matrix and mass matrix. This way the program operation and necessary input data for a dynamic analysis is a simple addition to what is needed for a static analysis.

STATIC ANALYSIS

A static analysis involves the solution of the equilibrium equations

$$K\ u = R \tag{2}$$

where

R = Load Vector
u = Displacement Vector
K = Stiffness Matrix

followed by the calculation of element stresses.

Solution of Equilibrium Equations

The load vectors R have been assembled at the same time as the structure stiffness matrix and mass matrix were formed. The solution of the equations is obtained using the large capacity linear equation solver SESOL [7]. This subroutine uses Gauss elimination on the positive-definite symmetrical system of equations. The algorithm performs a minimum number of operations; i.e. there are no operations with zero elements. In the program, the L^TDL decomposition of K is used, hence Eq. (2) can be written as

$$L^T v = R \tag{3}$$

and

$$v = DLu \tag{4}$$

where the solution for v in Eq. (3) is obtained by a reduction of the load vectors; the displacement vectors u are then calculated by a back-substitution.

In the solution, the load vectors are reduced at the same time as K is decomposed. In all operations it is necessary to have at any one time the required matrix elements in high-speed storage. In the reduction, two blocks are in high speed storage (as was also the case in the formation of the stiffness matrix and mass matrix), i.e., the "leading" block, which finally stores the elements of L and D, and in succession those blocks which are affected by the decomposition of the "leading" block.

Evaluation of Element Stresses

After the nodal point displacements have been evaluated, sequentially the element stress-displacement matrices are read from low speed storage and the element stresses are calculated.

DYNAMIC ANALYSIS

In dynamic response analysis the solution of the equations

$$M \ddot{u} + C \dot{u} + K u = R(t) \tag{5}$$

where

M = Mass Matrix

C = Damping Matrix

K = Stiffness Matrix

is required, where R(t) can be a vector of arbitrary time varying loads or of effective loads which result from ground motion. Specifically, in the case of ground motion, if it is assumed that the structure is uniformly subjected to the ground acceleration $\ddot{u}_g$, the equilibrium equations considered are:

$$M \ddot{u}_r + C \dot{u}_r + K u_r = - M \ddot{u}_g \tag{6}$$

where u_r is the relative displacement of the structure with respect to the ground, i.e., $u_r = u - u_g$.

The program can carry out a history analysis for solution of Eq. (5) or (6), or a response spectrum analysis for solution of Eq. (6). The history analysis can be carried out using mode superposition or direct integration. The response spectrum analysis necessitates, of course, first the solution of the required eigensystem.

Response History Analysis by Mode Superposition

In the mode superposition analysis, it is assumed that the structural response can be described adequately by the p lowest vibration modes, where $p \ll n$. Using the transformation $u = \Phi X$, where the columns in Φ are the p M-orthonormalized eigenvectors, Eq. (5) can be written as

$$\ddot{X} + \Delta \dot{X} + \Omega^2 X = \Phi^T R \tag{7}$$

where

$$\Delta = \text{diag}\,(2\omega_i\,\xi_i); \qquad \Omega^2 = \text{diag}\,(\omega_i^2) \qquad .(8)$$

In Eq. (8) it is assumed that the damping matrix C satisfies the modal orthogonality condition

$$\Phi_i^T\,C\,\Phi_j = 0 \qquad (i \neq j) \qquad .(9)$$

Equation (7) therefore represents p uncoupled second order differential equations. These are solved in the program using the Wilson θ - method, which is an unconditionally stable step-by-step integration scheme [1]. The same time step is used in the integration of all equations to simplify the calculation of stress components at preselected times.

In the case of prescribed ground motion $u_r = \Phi$ and in Eq. (7) the right hand side is given by $- \Phi^T M\ddot{u}_g$, where the ground acceleration is considered as the sum of the components in the s, y and z directions.

Response History Analysis by Direct Integration

The solution of the equations of motion, Eqs. (5) and (6), can be obtained by direct integration [1]. In the program the Wilson θ-method is used, which is uncondtionally stable. It need be noted that Rayleigh damping is assumed, i.e. $C = \alpha M + \beta K$ [2]. This form of damping is easily taken account of in the analysis, because no storage and no multiplications for a damping matrix are required.

5.0 QUALIFICATION

The TMRSAP computer program is designed to perform an elastic analysis of complex piping systems subjected to thermal, static and dynamic loads.

. Four (4) types of dynamic analysis can be performed by the program.

1. Determination of system mode shapes and frequencies only.
2. Dynamic Response Analysis for arbitrary time dependent loads loads using mode superposition.
3. Response Spectrum Analysis.
4. Dynamic Response Analysis for arbitrary time dependent loads using step-by-step direct integration.

The piping systems to be analyzed may be composed of two element types; (1) pipe elements (tangent and bend), and (2) boundary elements. The pipe element may be represented by a straight segment (tangent) or a circularly curved segment (bend). The boundary element may be used to constrain nodal displacements to specified values, to compute support reactions and to provide linear elastic supports to nodes.

6.0 VERIFICATION

This section contains the solution comparisons between TMRSAP and independent classical, benchmark, and other pipe stress programs whose solutions have been documented. The comparison of static, dynamic, and thermal problems are presented in the Sections indicated below:

6.1	Static Analysis - Continuous Beam
6.2	Deadweight Load Condition - piping system
6.3	Thermal Expansion - piping system
6.4	Thermal Expansion - piping system
6.5	Dynamic Analysis - natural frequency, cantilevered beam
6.6	Dynamic Analysis - three dimensional structure
6.7	Dynamic Analysis - natural frequency, uniform beam
6.8	Dynamic Analysis - forced response, piping system

6.1 Static Analysis

Continuous Beam - Uniformly Loaded - Four Equal Spans

Introduction - The purpose of this problem is to compare the results arrived at by the TMRSAP program with the results as found in the American Institute of Steel Construction Manual of a uniformly loaded beam whose classical solution is given.

Problem Description - Under the Beam Diagram & Formula Section of the American Steel Construction Manual [5], a continuous uniformly loaded beam as shown in Figure 6.1-1 was modeled for input to the TMRSAP computer program. Sixteen equal segments each 30 inches long were grouped to form four equal spans. Each span is ten feet long and is simply supported for gravity in the vertical direction at each end. This mathematical representation is shown in Figure 6.1-2. A static analysis using the Deadweight option of the TMRSAP computer program was then performed.

Property Data

a) Member properties

Pipe Outside Diameter (inches) 10.75
Pipe Wall Thickness (inches) 1.125
Young's Modulus - E (psi) 28.3E6
Weight (#/in.) .... 10.

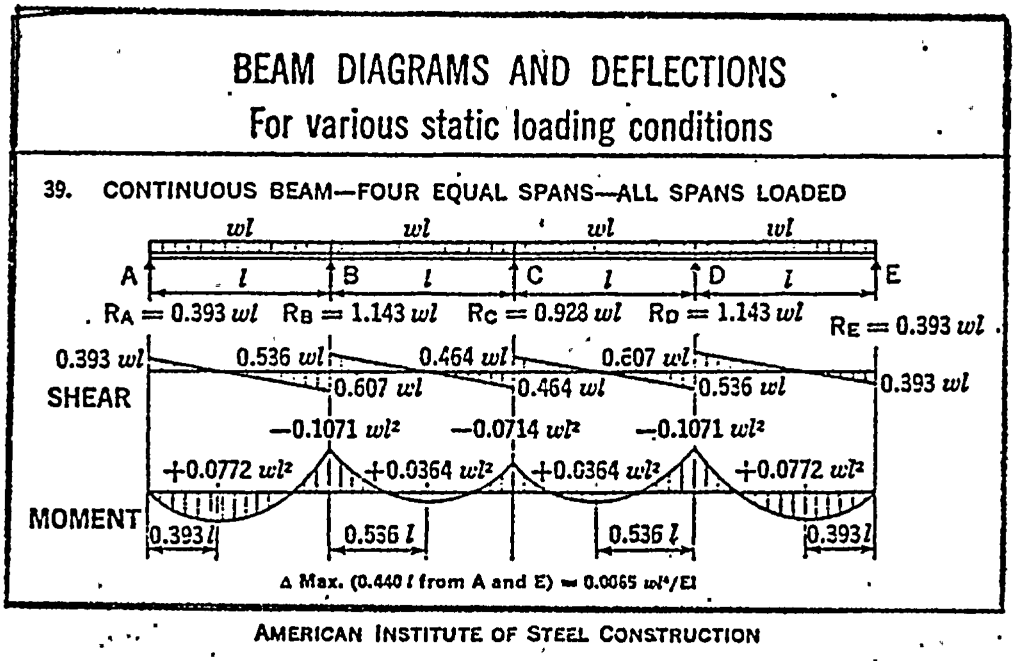


Figure 6.1-1 Geometry

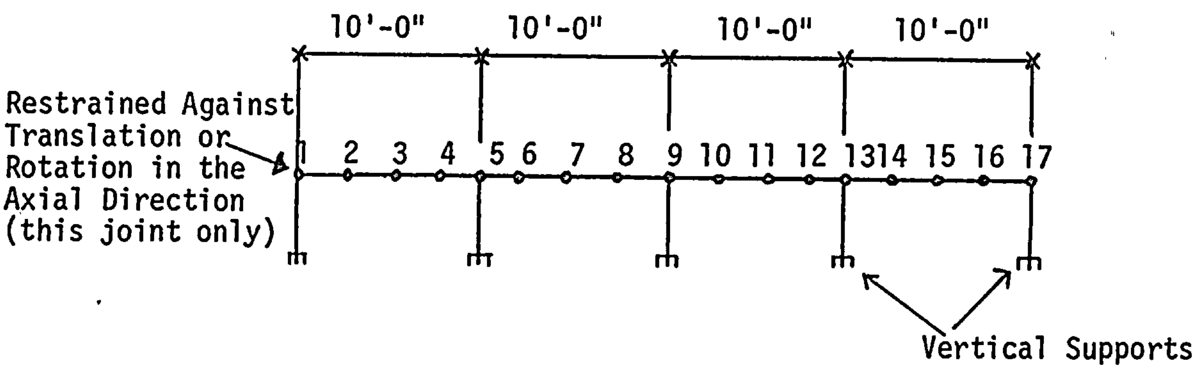


Figure 6.1-2 Structural Model

Point	Support Type	Joint Coordinates (Inches) X	Y	Z
1	* XYZ - Restraint Torsional Restraint	0	0	0
2		30	0	0
3		60	0	0
4		90	0	0
5	Y-Restraint	120	0	0
6		150	0	0
7		180	0	0
8		210	0	0
9	Y-Restraint	240	0	0
10		270	0	0
11		300	0	0
12		330	0	0
13	Y-Restraint	360	0	0
14		390	0	0
15		420	0	0
16		450	0	0
17	Y-Restraint	480	0	0

*Note - Point 1 is supported in the XYZ direction as well as restrained against torsional rotation so as not to create an unstable structure.

Results - listed below are the Reaction Forces for the supported points. The comparative results are shown:

REACTION FORCES (lbs)

Reaction Points	Steel Manual	TMRSAP	Difference (%)
1	0.393 wl = 471.6	473	.3
5	1.145 wl = 1371.6	1367	.3
9	0.928 wl = 1113.6	1120	.6
13	1.193 wl = 1371.6	1367	.3
17	0.393 wl = 471.6	473	.3

Conclusions - TMRSAP prints reaction forces less than 1 percent (.6) difference than results shown in the Steel Manual. This difference is well within acceptable levels.

6.2 Deadweight Analysis

Introduction - The purpose of this problem is to show that the results of static deadweight analysis as performed by the TMRSAP program is in agreement with the results of the Arthur D. Little ADLPIPE program whose results have been verified.

Problem Description - A three dimensional piping system consisting of straight segments, elbows, tees and branch connections is modeled for a deadweight load condition utilizing TMRSAP. In this loading condition, the bending stresses, forces, moments and displacement as a result of the deadweight load of the piping system are determined. The input parameters to the program include pipe geometry, physical properties of the pipe as well as concentrated weights in the system. The program takes into account terminal points, modeled as anchors, and all intermediate pipe support/hanger locations.

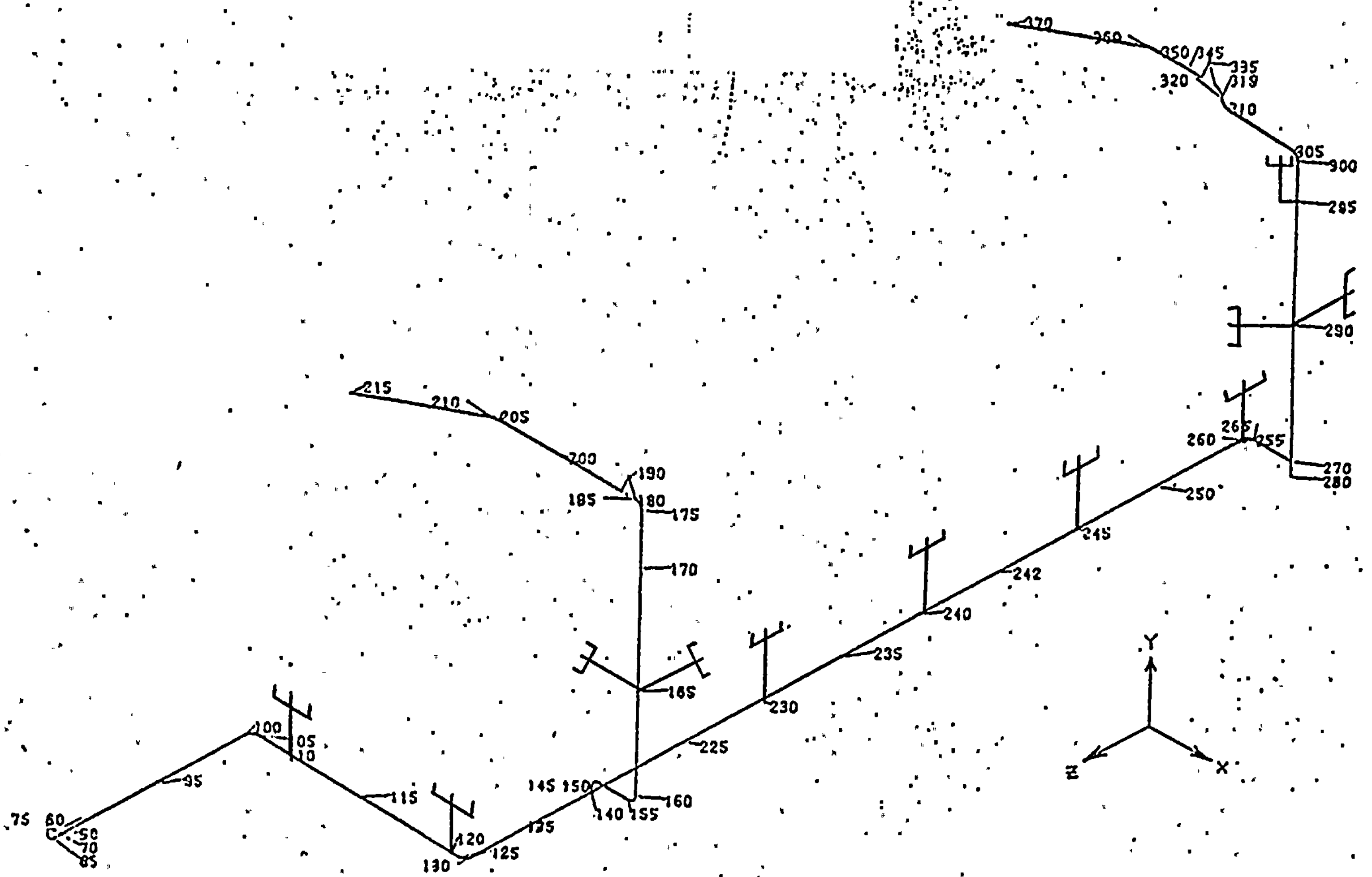
Property Data

a) Member properties

Pipe Outside Diameter (inches)	4.5
Wall thickness (inches)	.337
Young's Modulus (psi)	27.9E6
Weight (lbs/in.)	1.719

b) Geometry

A structural model, showing the piping geometry, support type and location is shown in Figure 6.2-1.



ISOMETRIC VIEW
ONE INCH EQUALS .10563085E+03

Figure 6.2-1

Results

The reaction forces for terminal ends as well as a few intermediate supports are shown below.

Point	Program	Reaction Forces - Moments					
Support Type		Fx(lbs)	Fy(lbs)	Fz(lbs)	Mx(in-lbs)	My(in-lbs)	Mz(in-lbs)
68	TMRSAP	-2.	199.	1.	3243.	189.	-1768.
Anchor	ADLPIPE	-2.	199.	1.	3243.	189.	-1768.
215	TMRSAP	14.	165.	-1.	7670.	-439.	18017.
Anchor	ADLPIPE	14.	165.	0	7670.	-439.	18017.
370	TMRSAP	21.	367.	-1.	17089.	-767.	41989.
Anchor	ADLPIPE	21.	367.	-1.	17088.	-767.	41988.
120	TMRSAP	0.	256.	0.	0.	0.	0.
Y Rest.	ADLPIPE	0.	256.	0.	0.	0.	0.
230	TMRSAP	0.	239.	0.	0.	0.	0.
Y Rest.	ADLPIPE	0.	239.	0.	0.	0.	0.
290	TMRSAP	-21.	0.	-1.	0.	0.	0.
XZ Rest.	ADLPIPE	-21.	0.	-1.	0.	0.	0.

In addition a few points were chosen randomly to compare the displacements at these points.

Program	Point	Displacement (inches)		
		dx	dy	dz
TMRSAP	115	-.0077	-.0387	-.0022
ADLPIPE	115	-.008	-.039	-.002
TMRSAP	160	-.0067	-.0003	-.0048
ADLPIPE	160	-.007	-.000	-.005
TMRSAP	310	-.0019	-.0351	-.0007
ADLPIPE	310	-.002	-.035	-.001

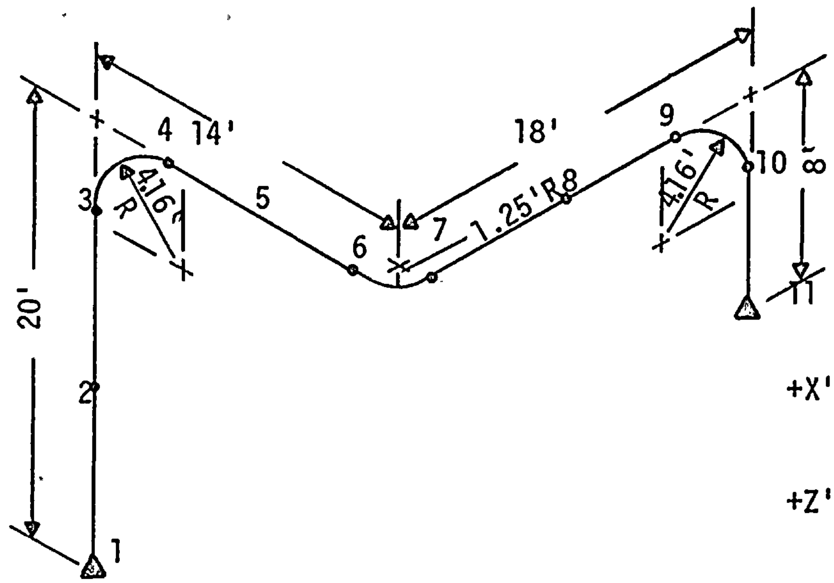
Conclusion - The TMRSAP computer program results are almost identical to the verified Arthur D. Little program. (ADLPIPE).

6.3 Thermal Expansion - Problem 1

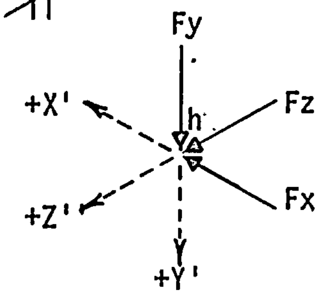
Introduction - The purpose of this problem is to compare the reaction forces and moments derived by TMRSAP at each terminal end of a three dimensional piping problem with results as shown in the Piping Design & Engineering Section of the Grinnell Book. [3].

Problem Description - A three dimensional piping problem anchored at both ends and containing two five diameter bends and a standard long radius elbow as shown in figure 6.3-1 was subjected to a temperature change of 750 degrees F. As a result of the elevated temperature, thermal expansion occurs which induces forces & moments in the anchors.

The piping system was mathematically modeled as an elastic system of uniformly loaded members. These members were divided into straight and curved segments and analyzed as a thermal expansion problem to determine the reactions at both anchors.



Bend R = $5D_n$ = 4.16'
L.R.Ell. R = $1.5D_n$ = 1.25'



△ = Full Anchor

Given: A 10" piping system in accordance with the sketch shown above.

Maximum Operating Pressure P 350 psi
Maximum Operating Temperature 750°F
Piping Specification A.S.T.M. A-106 Grade A

Data:

t = 0.365 inches
schedule 40
d = 10.02 inches

Find: Reaction forces F_x, F_y and F_z at point 11 (at point 1 reaction forces equal and opposite).

Figure 6.3-1 Multiple plane system containing Circular Arcs.

Property Data -

Member properties

Pipe Outside Diameter (inches)	10.75
Wall thickness (inches)	0.365
Young's Modulus (psi)	27.9E6
Temperature Change (°F)	750.0
Coefficient of Thermal Expansion (in/in./°F)	7.54E-6

Results - The reactions (both forces & moments) are shown below:

Reaction Forces and Moments			
Terminal Point #1			
Reaction	TMRSAP	Grinnell	Difference (%)
Fx (lbs)	793	811	2.2
Fy (lbs)	503	514	2.2
Fz (lbs)	909	875	3.9
Mx (ft-lbs)	12452	11170	11.5
My (ft-lbs)	4112	3820	7.6
Mz (ft-lbs)	9371	9550	1.4
Terminal Point #11			
Fx (lbs)	793	811	2.2
Fy (lbs)	503	514	2.2
Fz (lbs)	909	875	3.9
Mx (ft-lbs)	10598	9930	6.7
My (ft-lbs)	5671	6170	8.8
Mz (ft-lbs)	6889	7020	1.9

Conclusions - From the above table, the results show reasonable agreement.

6.4 Thermal Expansion - Problem 2

Introduction - The purpose of this problem is to show that the results of the thermal expansion analysis as performed by the TMRSAP program is in agreement with the results of the Arthur D. Little (ADLPIPE) program whose results have been verified.

Problem Description - A three dimensional piping system consisting of straight segments, elbows, tees, and branch connections is modeled for the thermal expansion load condition utilizing TMRSAP. The mathematical model showing the piping geometry, pipe changes, concentrated weights as well as pipe support locations is shown in Figure 6.4-1. Note that this is the same piping system that has been previously used in the static comparison between the TMRSAP and ADLPIPE program in Section 6.2. As a result of strain flow through the piping system, the temperature change creates thermal expansion and distortion in the pipe. It is this expansion and distortion that induces thermal stress, forces & moments which are to be compared with the verified ADLPIPE program.

Property Data

a) Member properties

Temperature change (°F) 565
Coefficient of Thermal Expansion (in/in./°F).... 7.156E-6

b) Geometry

The mathematical model, as well as all other member properties are the same as those defined in Section 6.2.

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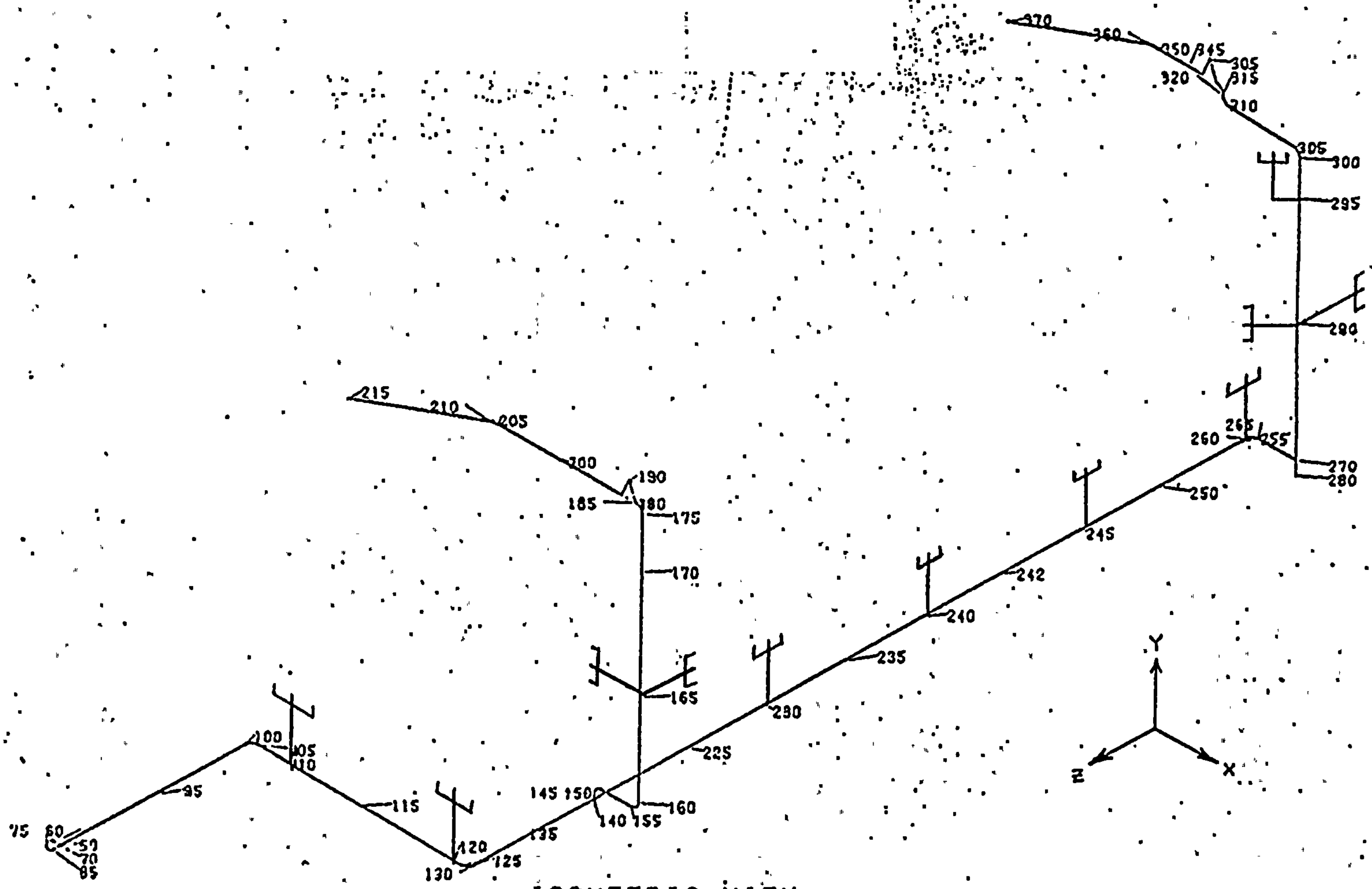

Figure 6.4-1

Results - The reaction forces for terminal ends as well as a few intermediate supports are shown below.

Point	Program	Reactions					
Support Type		Forces (lbs) Fx	Fy	Fz	Moments (in-lbs) Mx	My	Mz
68 Anchor	TMRSAP	319.	-25.	-375.	1337.	-26190.	3008.
	ADLPIPE	320.	-25.	-375.	1337.	-26248.	3010.
215 Anchor	TMRSAP	301.	-528.	14.0	-22941.	-20979.	-80958.
	ADLPIPE	303.	-529.	14.0	-22973.	-21006.	-80981.
370 Anchor	TMRSAP	-57.	-162.	-165.	-9606.	41192.	-22915.
	ADLPIPE	-55.	-165.	-165.	-9736.	41058.	-23267.
120 Y Rest.	TMRSAP	0.	46.	0.	0.	0.	0.
	ADLPIPE	0.	46.	0.	0.	0.	0.
230 Y Rest.	TMRSAP	0.	9.	0.	0.	0.	0.
	ADLPIPE	0.	8.	0.	0.	0.	0.
290 XZ Rest.	TMRSAP	29.	0.	656.	0.	0.	0.
	ADLPIPE	27.	0.	655.	0.	0.	0.

In addition a few points were chosen randomly to compare the displacements at these points.

Program	Point	Displacement (inches)		
		dx	dy	dz
TMRSAP	115	-.5359	.0448	.1302
ADLPIPE		-.539	.045	.130
TMRSAP	160	-.4132	-.2285	.1984
ADLPIPE		-.417	-.230	.198
TMRSAP	310	.5011	.1265	.1149
ADLPIPE		.510	.127	.115

Conclusion - A review of the results shows that the TMRSAP program has values within 1 to 2 percent of the verified ADLPIPE program. These values are well within acceptable limits.

6.5 Dynamics - Beam Problem

Natural Frequency Calculations of a Uniformly Loaded Cantilevered Beam

Introduction - The purpose of this problem is to compare the dynamic property, natural frequency, of a uniformly loaded cantilevered beam as obtained by the TMRSAP program with the value calculated by a standard analytical procedure found in any dynamic handbook.

Problem Description - In the Shock & Vibration Handbook by Harris & Crede [4], the natural frequencies of some commonly used systems are given. In this problem, we calculate the natural frequncy of a uniformly loaded contilevered beam according to the formula presented in the handbook and compare it to the value determined by the Eigenvalue solution in the TMRSAP Program.

In modeling the problem, a 12 inch schedule 40 pipe, nine feet long, anchored at one end and free to vibrate is divided into nine equal segments each twelve inches long with a uniformly distributed weight. This is shown in Figure 6.5-1.

Property Data

Member Properties

Pipe Outside Diameter (inches)	12.75
Pipe Wall Thickness (inches)	0.375
Young's Modulus - E (psi)	27.9E6
Weight (lbs/in.)	4.1333
Moment of Inertia ($inches^4$)	279.3
Length (inches)	108

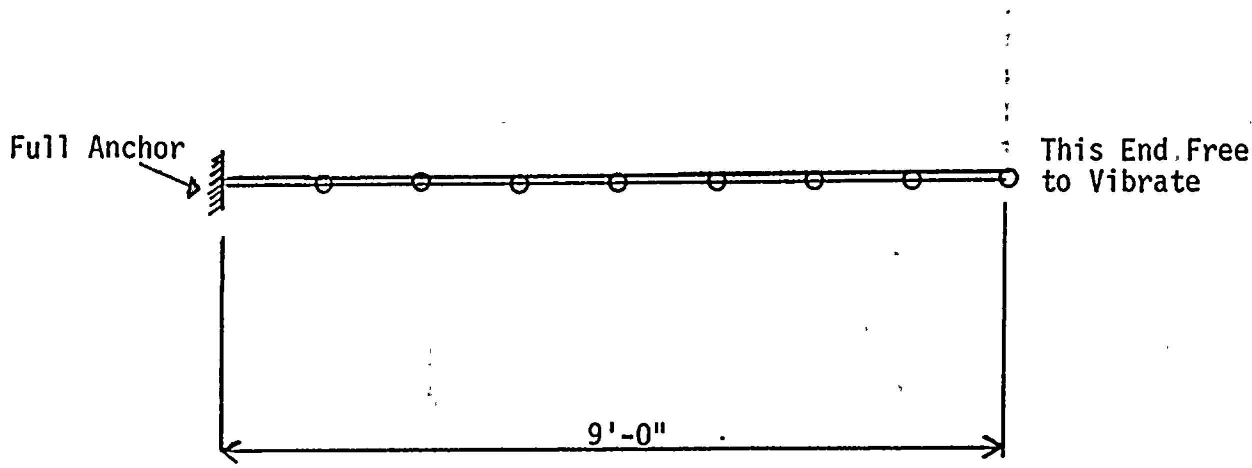

Figure 6.5-1

Hand Calculations

For Beams of Uniform Section and Uniform Distributed Load, the natural frequency calculation is based upon the formula:

$$F = \frac{A}{2\pi} \sqrt{\frac{EIg}{wl^4}}$$

where

F = cycles/sec

A = coefficient based upon type of supported beam

A = 3.52 for cantilevered beam (first mode)

$g = 386.4 \text{ in/sec}^2$

$\pi = 3.1416$

All other terms, same as property data. For the above problem

$$F = \frac{3.52}{2*3.1416}\sqrt{\frac{27.9*10^6 * 279.3 * 386.4}{4.133 * (108)^4}} \approx 41 \text{ cps}$$

The TMRSAP program computes the 1st natural frequency at $\approx$ 40 cps. The difference is 2.64%.

Conclusions - The greater the number of lumped mass points the more accurate the results, since the number of dynamic degrees-of-freedom is based upon the mathematical modeling of the system. The result obtained showing the 2.64% difference is within acceptable limits.

6.6 Dynamic Analysis of Three Dimensional Structure

Introduction - The purpose of this problem is to cross-check the results of TMRSAP with a benchmark previously used in verification and qualification of other computer programs. This problem compares the dynamic characteristics, mode shapes and frequencies, using the lumped mass matrix method against this benchmark. As an additional check, TMRSAP results were also compared with experimental results obtained from a vibration test machine.

Problem Description - A three dimensional structure comprised of two inch steel pipe and steel cubes welded together in the shape of a coffee table as shown in Figure 6.6-1 is subjected to vibration to determine the dynamic characteristics of the structure.

In formulating the mathematical model, the mass of the pipe and cubes are lumped at specified joints connected by massless springs. Each concentrated mass or lumped weight as it is commonly called is assigned three dynamical degrees-of-freedom. The mathematical idealization of this three dimensional structure is shown in Figure 6.6-2.

Property Data

a) Member Properties

Pipe Outside Diameter (inches)	2.375
Pipe Wall Thickness (inches)	0.154
Young's Modulus - E (psi)	27.9E6
Poisson's Ratio - μ	0.3

b) Geometry and Weights

Point	Joint Coordinates (inches) X	Y	Z	Lumped Weights (pounds)
1	0	10	0	3.4517
2	27.25	10	0	3.4517
3	27.25	10	17.25	3.4517

Point	Joint Coordinates (inches) X	Y	Z	Lumped Weights (pounds)
4	0	10	17.25	3.4517
5	0	18.625	17.25	9.7973
6	0	18.625	8.625	3.4517
7	0	18.625	0	9.7973
8	8.625	18.625	0	3.4517
9	18.625	18.625	0	3.4517
10	27.25	18.625	0	9.7973
11	27.25	18.625	8.625	3.4517
12	27.25	18.625	17.25	9.7973
13	18.625	18.625	17.25	3.4517
14	8.625	18.625	17.25	3.4517
15	0	0	0	0
16	27.25	0	0	0
17	27.25	0	17.25	0
18	0	0	17.25	0

(c) System Restraints

(i) 15, 16, 17, and 18 are full anchors. (This is to minimize - 0 unknown influences at the supports)

(ii) The corners are modeled as the junction of three mutually perpendicular pipes -- the block stiffness is not taken into consideration.

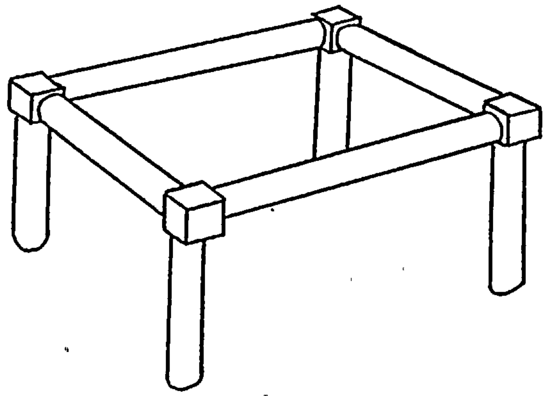

Figure 6.6-1 Three-Dimensional Structure Used in Experiment

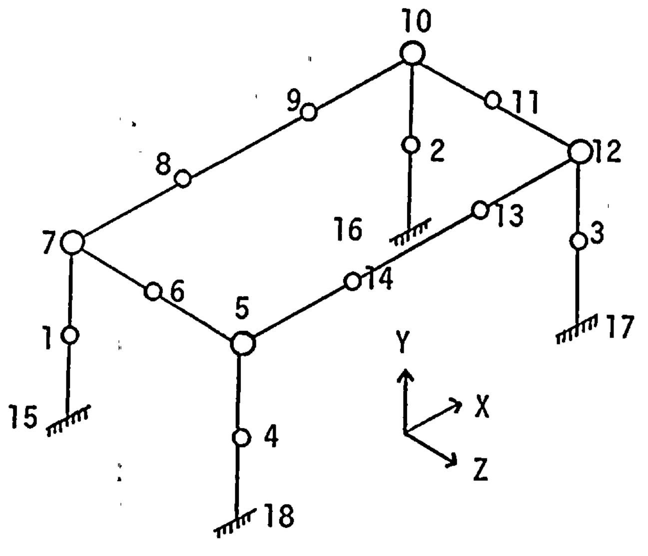

Figure 6.6-2 Mathematical Idealization of Three-Dimensional Structure

Results

TABLE 1

CALCULATED AND MEASURED RESONANT FREQUENCIES
FOR STRUCTURE SHOWN IN FIG. 6.6-2

Resonant Frequency, cps

Experimentally Measured	ANSYS Finite Element	TMRSAP
110	109.0	111.2
117	115.9	115.8
134	135.0	137.1
214	212.5	215.8
359	352.4	409.5
382	394.6	422.9
416	422.2	451.8
553	532.1	549.2
*	655.8	739.0
697	684.9	758.9
*	760.7	851.8
821	822.1	892.7
853	849.3	893.5
885	873.2	911.3
898	903.5	932.7

* - Not observed experimentally.

The results of TMRSAP fall within accpetable limits as shown above.

6.7 Natural Frequency Calculation, Uniform Beam with Two Concentrated Weights

Introduction - The purpose of this problem is to compare the natural frequency calculation as determined by hand book procedure with the results determined by the TMRSAP computer program.

Problem Description - A two dimensional beam problem, free to vibrate in the plane shown, has two concentrated weights W_1 = 500 lbs and W_2 = 100 lbs. This is shown in Figure 6.7-1.

The problem is mathematically modeled as a continuous pipe consisting of two concentrated weights interconnected by weightless members and supported in the manner shown in Figure 6.7-2. In this problem, we calculate the natural frequency by the method given in the Vibration Theory and Applications book [6], and compare it with the results as printed by the Eigenvalue solution of the TMRSAP program.

Property Data

Member Properties

Outside Diameter (inches)	12.75
Wall Thickness (inches)	0.375
Young's Modulus - E (psi)	27.9E6
Moment of Inertia ($inches^4$)	279.6
Length (inches)	240.0

Calculation - As presented in the Vibration Theory and Applications book,[6], (page 224), the fundamental frequency is defined by the following equation.

$$W = 4.57\sqrt{\frac{EI}{l^3}}$$

where W is the first natural frequency expressed as radians per second and all other terms are the same as property data. For the above problem;

$$W = 4.57 \sqrt{\frac{27.9E6 * 279.6}{(240)^3}} = 108.5 \text{ rad/sec} = 17.27 \text{ cps}$$

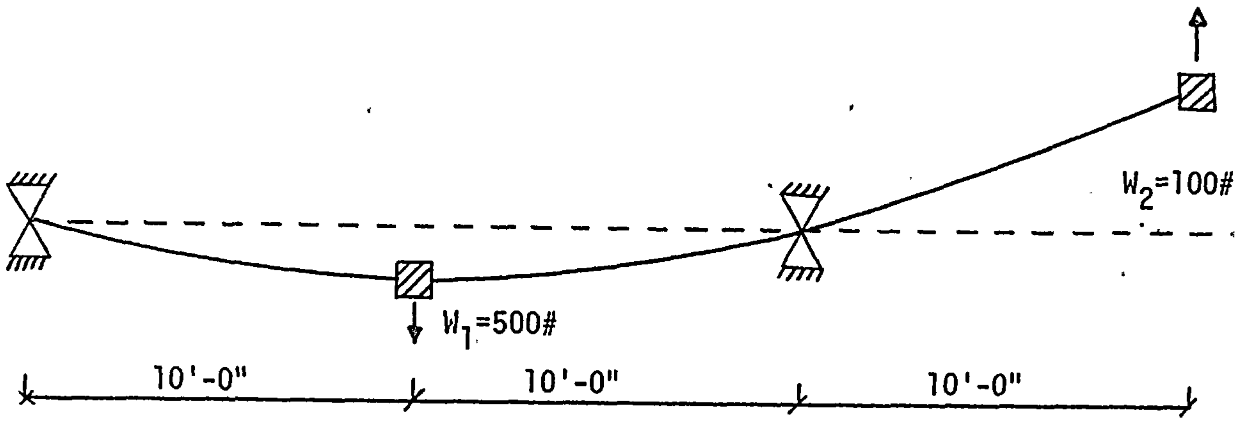

Figure 6.7-1 Mathematical Idealization of Structure

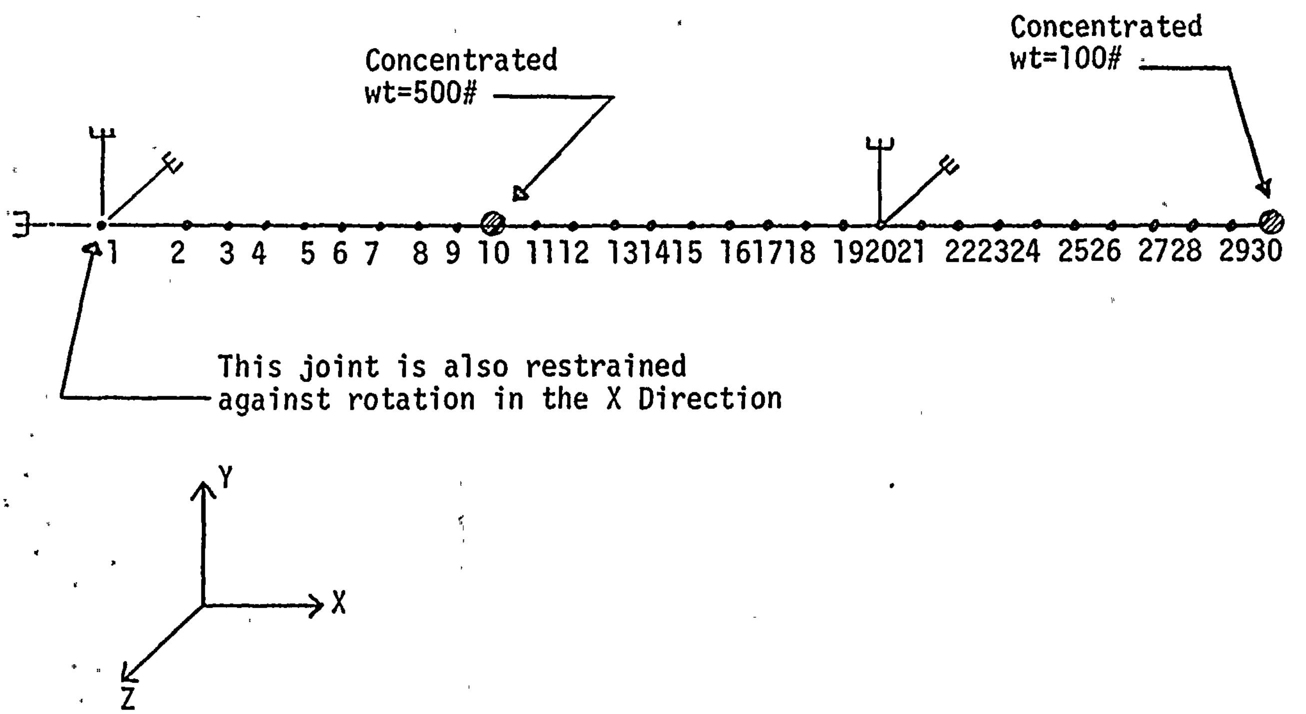

Figure 6.7-2 Two-Dimensional Structure, Concentrated Wts.

Results - The TMRSAP program prints the first fundamental frequency as 108 rad/sec = 17.19 cps.

Also, the amplitude ratio, expressed as $\frac{X_1}{X_2}$, is 2.58 from TMRSAP as compared with Thomson's 2.60.

These results are well within acceptable limits.

6.8 Dynamic Analysis of a Three-Dimensional Piping System Subjected to Time Varying Loads

Introduction - A dynamic analysis is performed with the piping shown in Figure 6.8-1 using the STARDYNE program and the TMRSAP program with analysis types,

NDYN = 2; Dynamic Response Analysis for arbitrary time dependent loads using mode superposition.

NDYN = 4; Dynamic Response Analysis for arbitrary time dependent loads using step-by-step direct integration.

Problem Description - The computer model is shown in Figure 6.8-1 and is composed of sections of straight pipe, curved pipe (elbows) and a valve with a concentrated weight. Nodes 1 and 48 are anchors and therefore are prevented from having any displacement or rotation. The time varying loads applied to the nodal points on the structure are shown in Figure 6.8-2.

Property Data

a) Member Properties

From Node	To Node	O.D. (in.)	t (in.)	Wt. (lb/in)	Comments
1	42	18.0	0.562	8.71	----
42	46	24.0	2.0	39.12	5000 lb. concentrated weight at node 44
46	48	16.0	0.50	6.89	---

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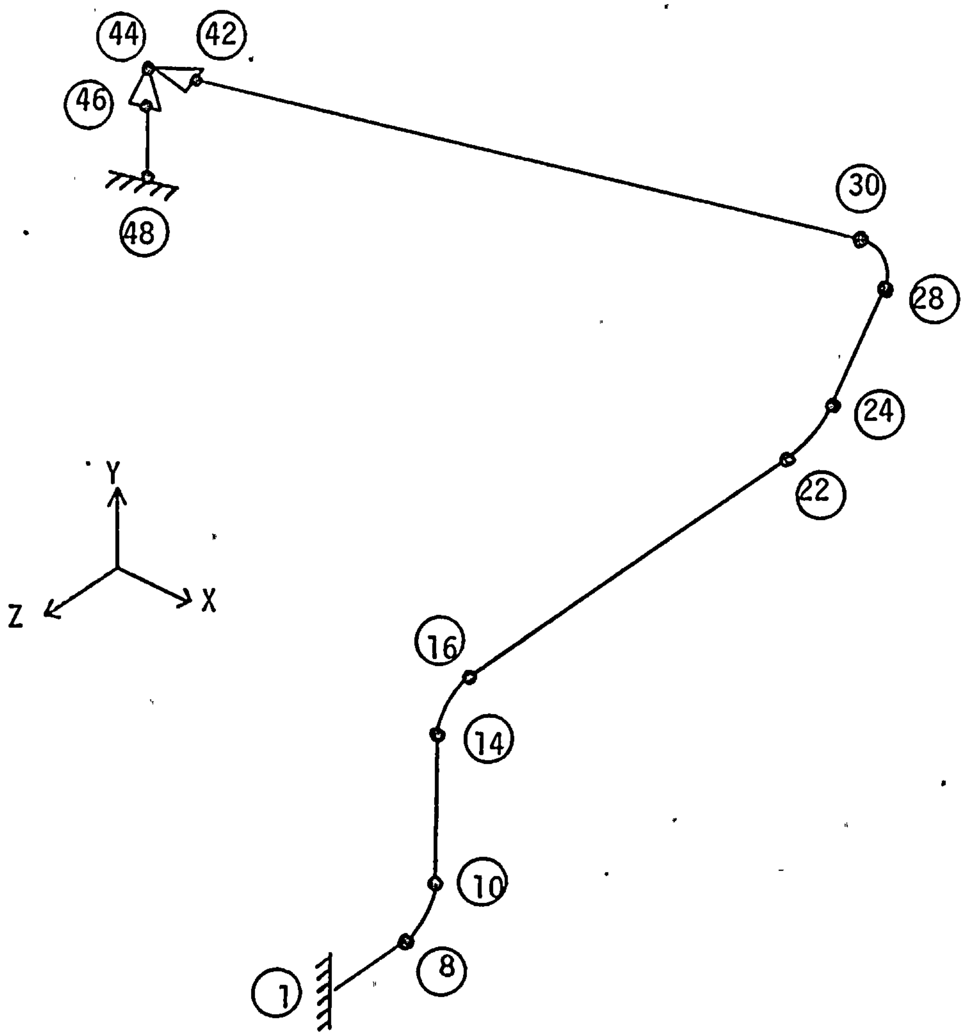

Figure 6.8-1 3-D Piping System

b) Geometry

Node No.	Coordinates X	Y	Z
1	0	0	0
8	0	0	-10.752
10	0	27.000	-37.752
14	0	90.277	-37.752
16	0	117.275	-64.474
22	0	118.639	-196.772
24	0	126.545	-215.585
28	0	136.858	-225.898
30	-26.728	156.138	-244.800
42	-327.240	160.392	-244.800
44	-347.244	160.680	-244.800
46	-347.244	144.672	-244.800
48	-347.244	135.732	-244.800

c) System Restraints

Nodes 1 and 48 are full anchors

Time Varying Load Input

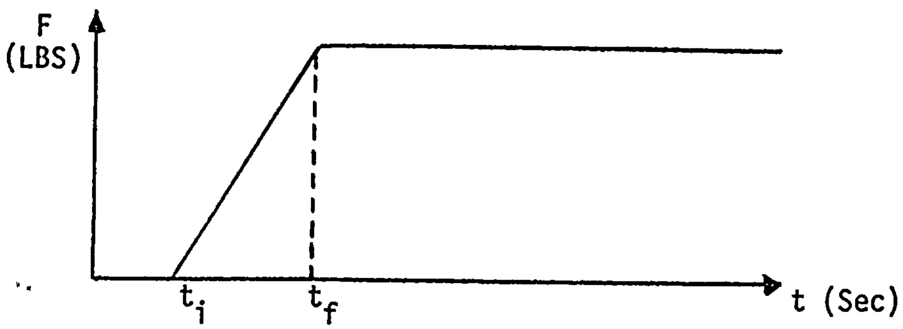

Figure 6.8-2

NODAL LOADS

Node	t_i	t_f	F_x	F_y	F_z
44	0.0	0.05	-34,460.6	--	--
30	.01993	.06993	33,200.7	--	--
28	.01993	.06993	--	23,476.4	-23,476.4
24	.02303	.07303	--	-23,058.9	23,058.9
22	.02303	.07303	--	--	-32,610.2
16	.03310	.08310	--	--	31,664.7
14	.03310	.08310	--	31,664.7	--
10	.04004	.09004	--	-30,543.6	--
8	.04004	.09004	--	--	-30,543.6

Results

The following plots show the moment response acting at node 28, the first bend downstream of the valve and at anchor node 48. A three way correlation of results is shown with excellent agreement.

1) TMRSAP by Mode Superposition
2) TMRSAP by Direct Integration
3) STARDYNE by Mode Superposition

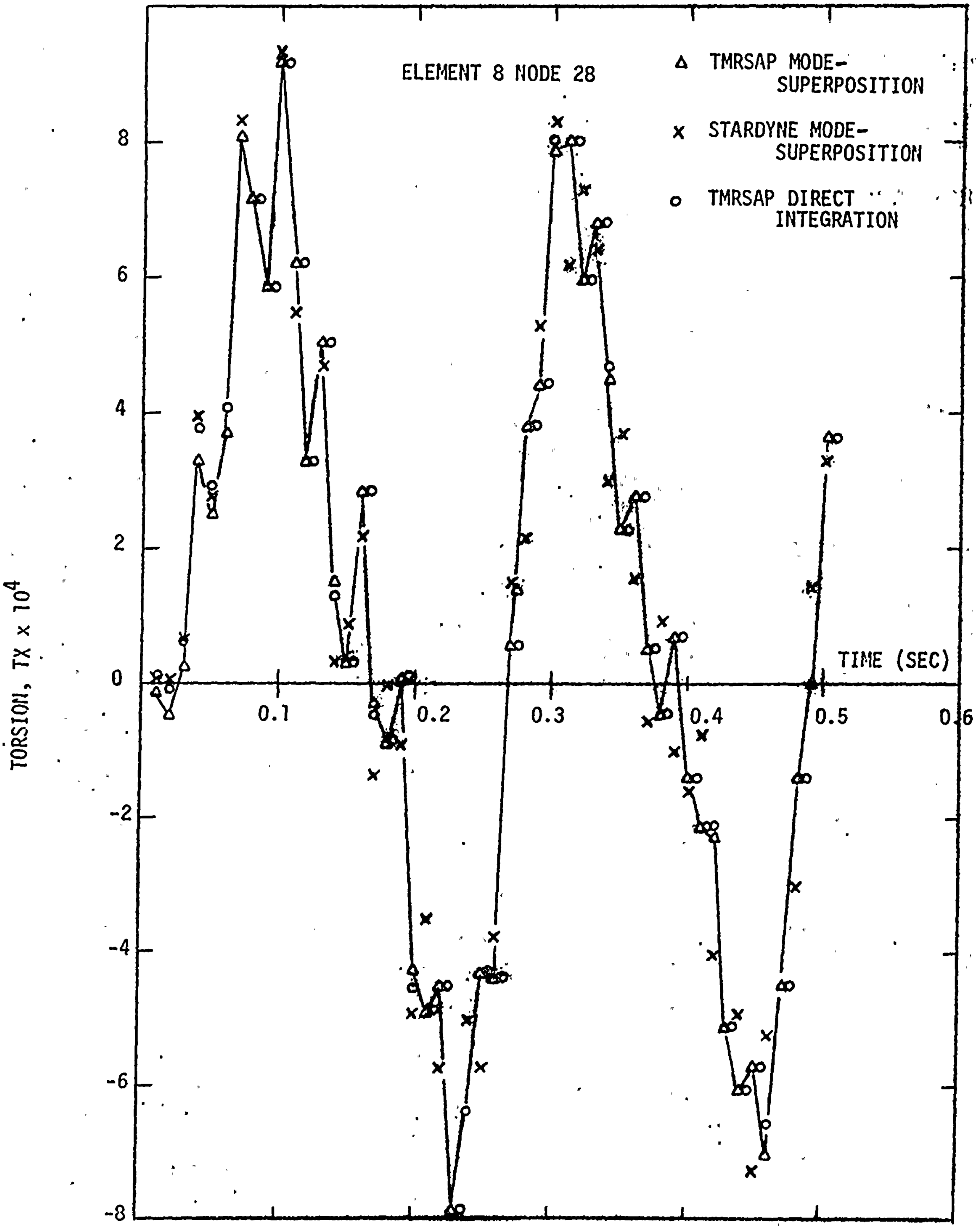

Figure 6.8-3 Time History Response Node 28 - Torsion T_X

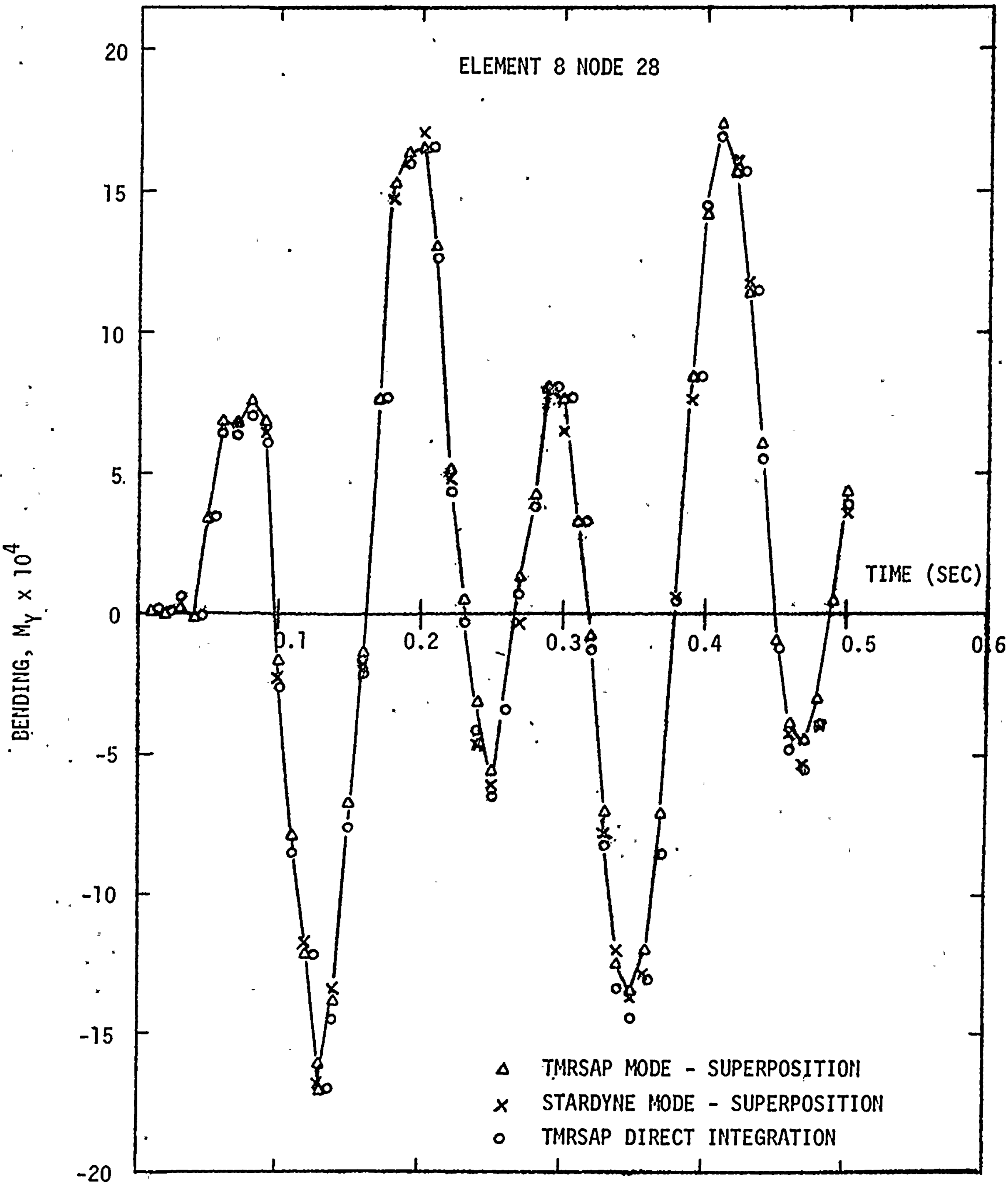

Figure 6.8-4 Time History Response Node 28 - Bending M_y

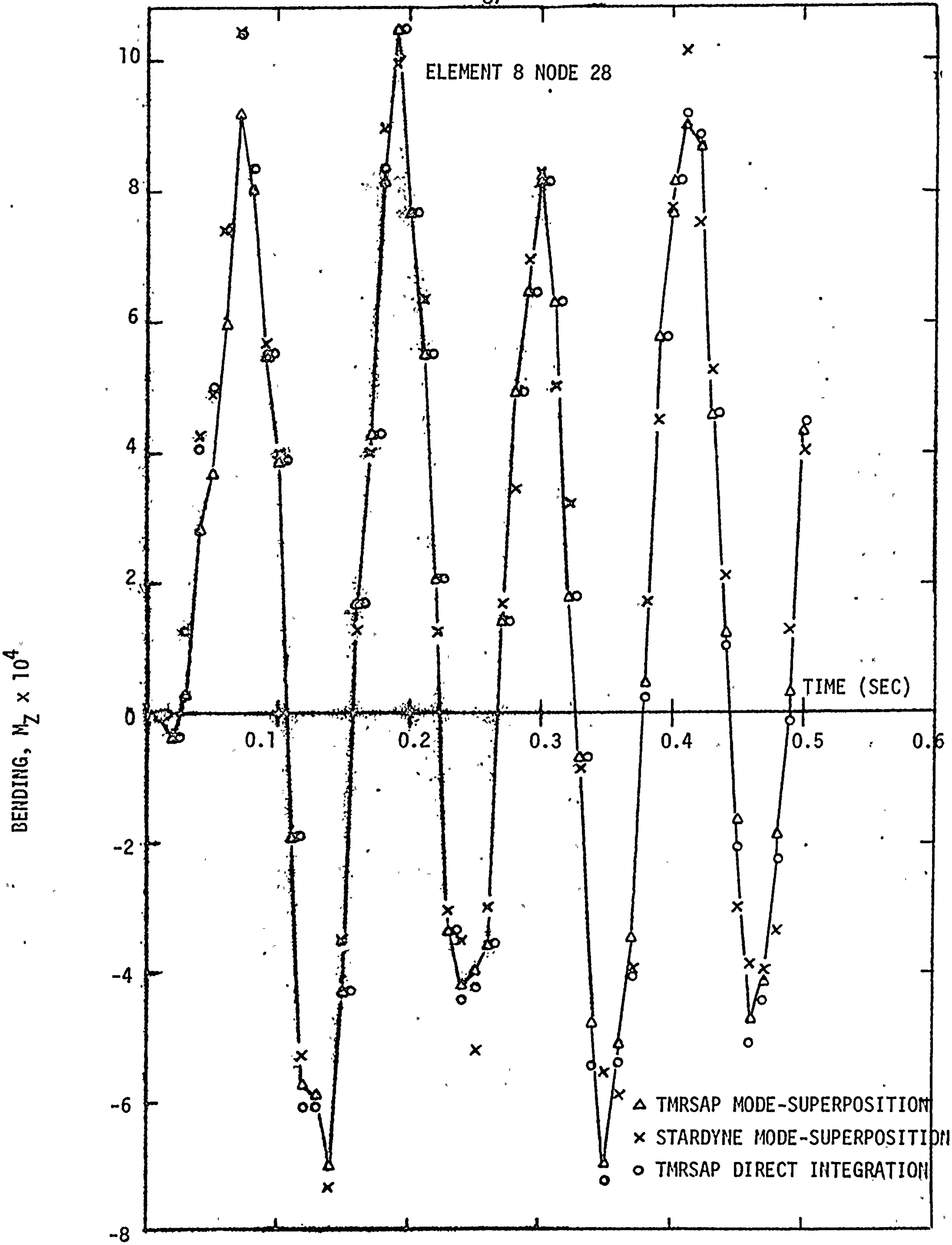

Figure 6.8-5 Time History Response Node 28 - Bending M_Z

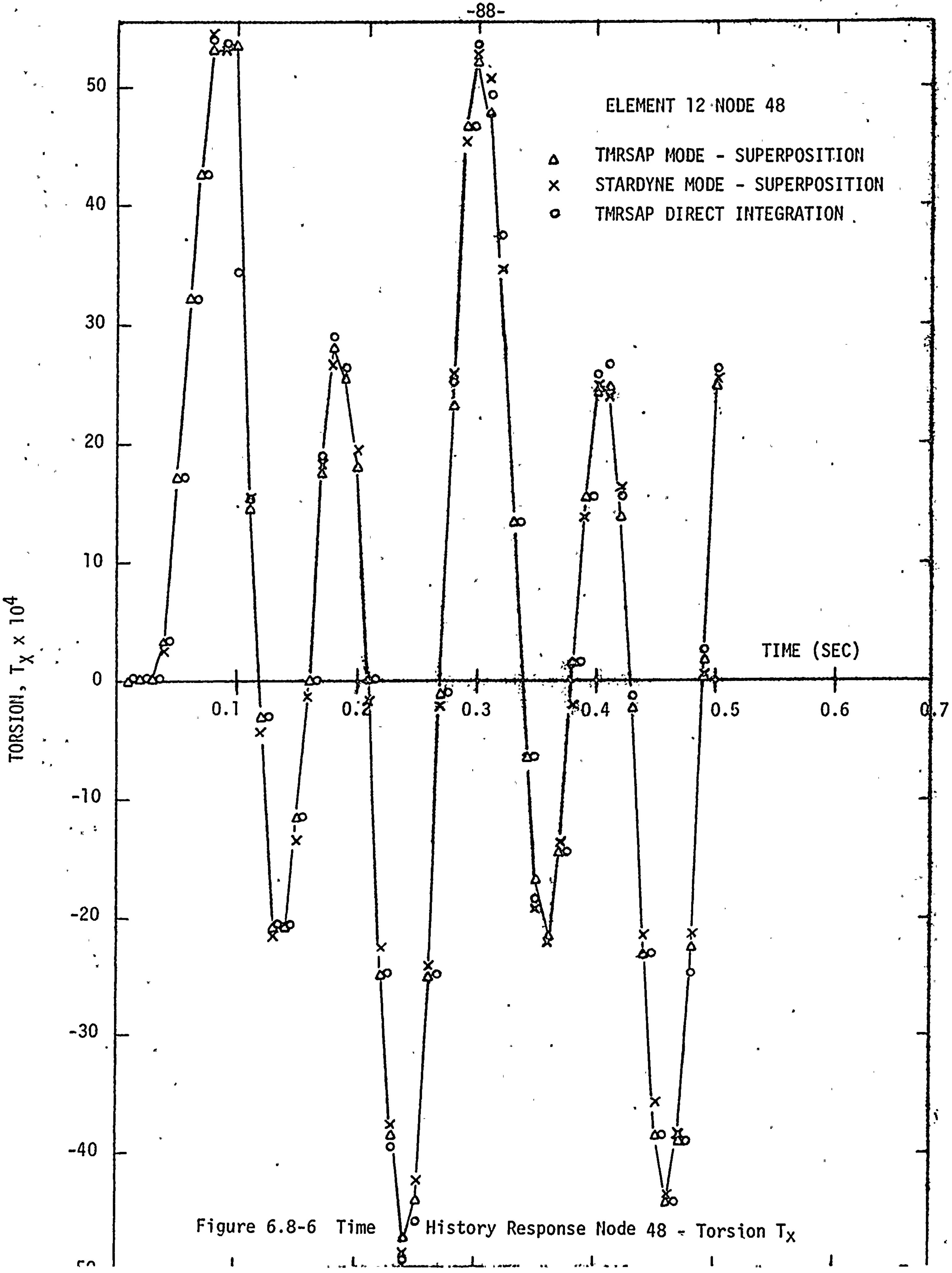

Figure 6.8-6 Time History Response Node 48 - Torsion T_X

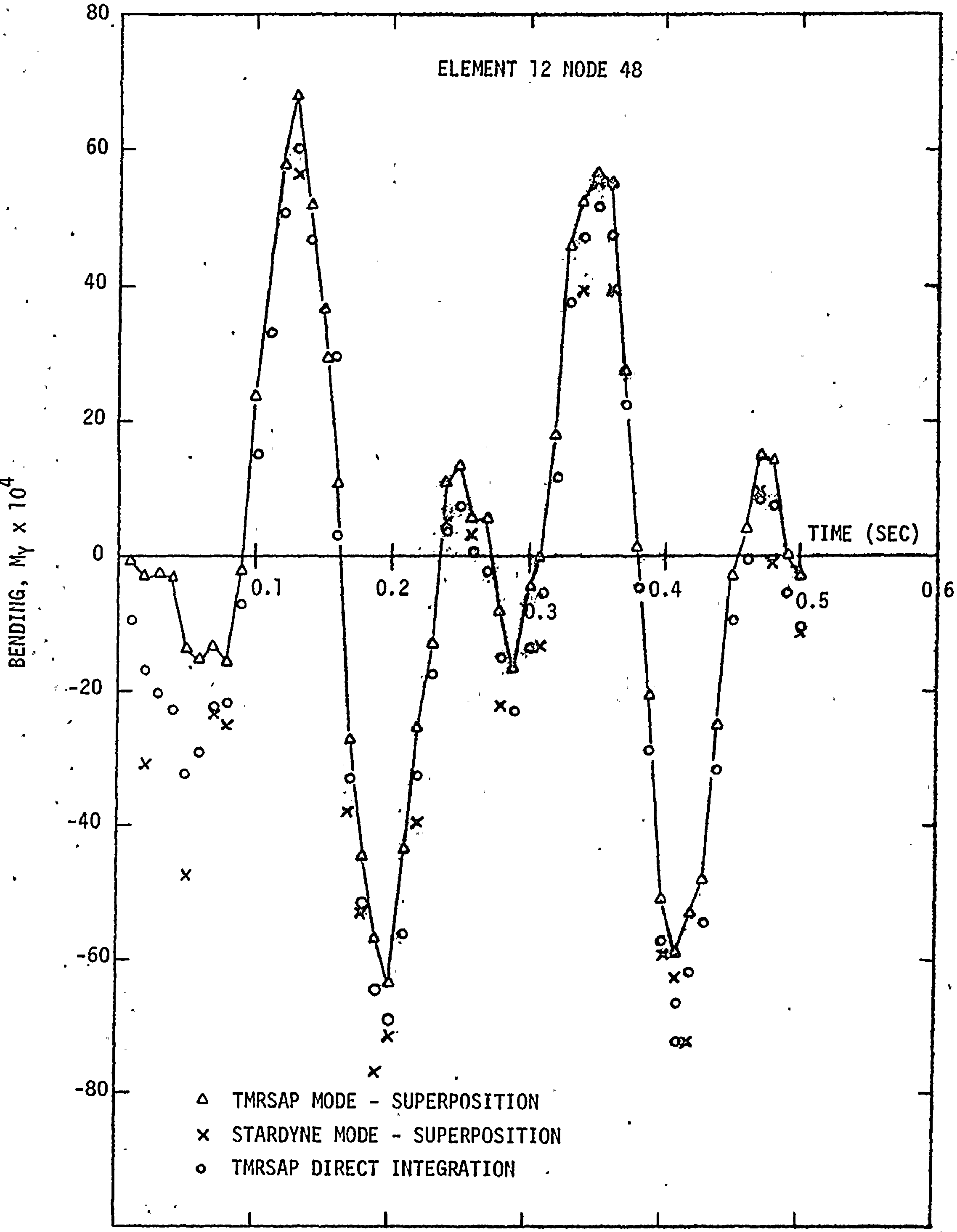

Figure 6.8-7 Time History Response Node 48 - Bending M_y

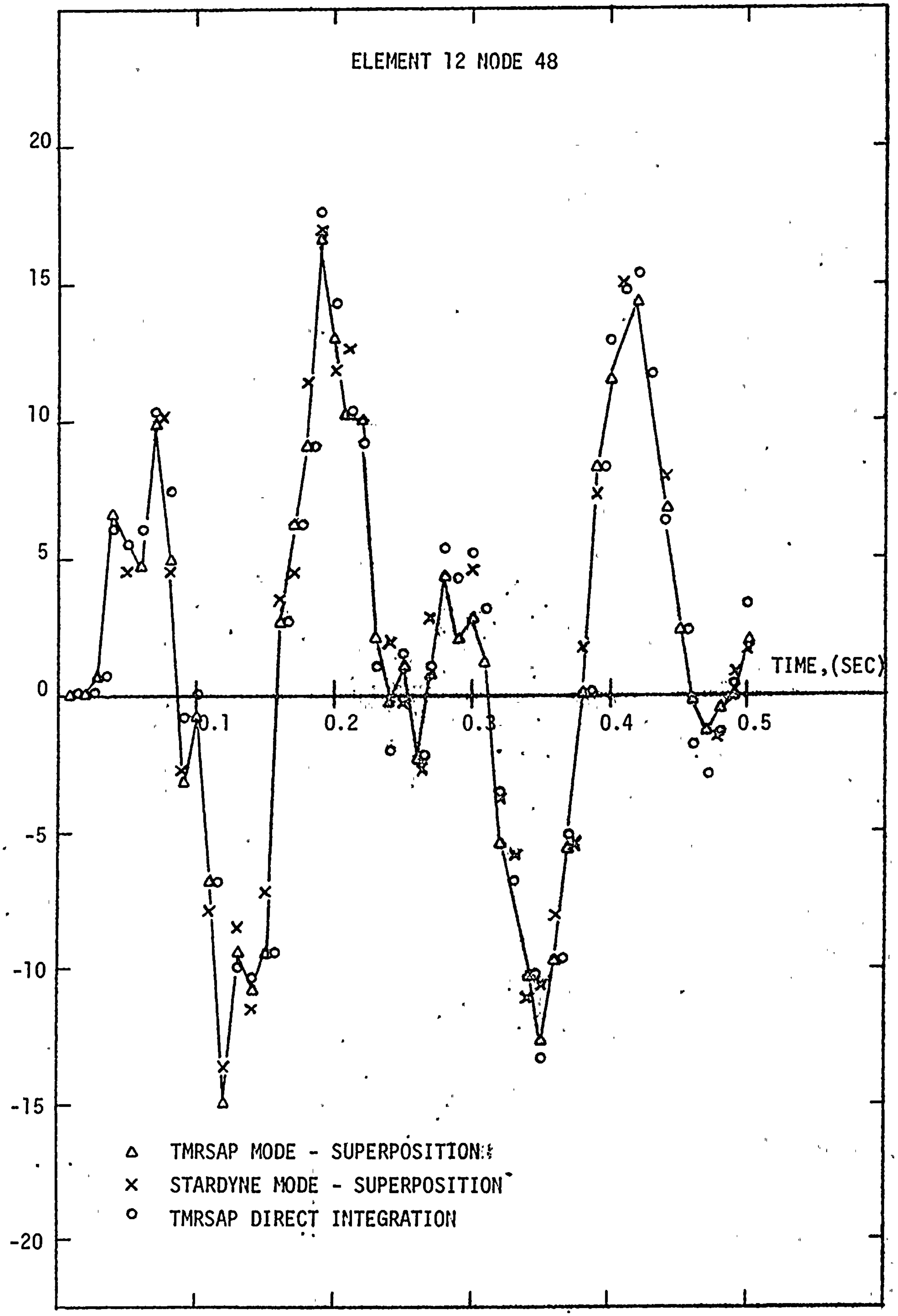

Figure 6.8-8 Time History Response Node 48 - Bending M_Z

7.0 CONCLUSION

Static, dynamic and thermal analysis capabilities of TMRSAP computer program have been verified through a number of benchmark problems ranging from a simple beam analysis to three dimensional analysis of a piping system. A comparison of TMRSAP results with published results, closed form solutions and the results of other computer solutions showed close agreement despite the fact that the computer programs used for comparison employed different methodologies and numerical procedures to solve the same problems. Hence, TMRSAP program is considered verified and suitable to analyze piping systems under different loading conditions mentioned above.

8.0 REFERENCES

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[5] American Institute of Steel Construction", Manual of Steel Construction", Seventh Edition, 1970.

[6] Thomson, William T., "Vibration Theory and Applications", Prentice-Hall, 1965.

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PASS

REPORT GENERATOR PROGRAM FOR

PIPING ANALYSIS SUPPORT SYSTEMS

1.0 GENERAL DESCRIPTION

A computer program has been developed to function as a report generator for the Hanger Selection Summary Reports eliminating the laborious task of manually examining output for maximum loads, displacements, and calculating maximum stresses. The program requires as input the TMRSAP structural Model along with the internal forces, moments, and deflections resulting from the flexibility analyses for various load conditions (static and dynamic). The program prints out a summary of (1) nozzle and anchor loads, (2) hanger and restraint loads, and (3) a stress summary of selected data points.

2.0 APPLICATION

The purpose of this program is to determine the adequacy of the piping support system for a given TMRSAP structural Model by evaluating stresses for sustained loads, occasional loads, and thermal expansion in accordance with the design and analysis philosophy of subsections NB-3652 and NC-3652 in Section III of the ASME Boiler and Pressure Vessel Code (BPVC). The program also provides design load summaries for anchors and restraints and reports the maximum loads for each load condition and the required net design load.

3.0 CAPABILITIES

The PASS Computer Program is a post-processor to the TMRSAP Computer Program which provides an elastic analysis of redundant piping systems subjected to thermal, static and dynamic loads. The program requires as input, the TMRSAP structural Model describing the piping geometry, and the internal forces, moments and deflections resulting from the flexibility analyses for various load conditions (deadweight, hydrotest, thermal, seismic inertia, attachment displacements). The PASS program also functions as a report generator for the hanger selection summary reports. The program computes and summarizes in a tabular report style format: (1) nozzle and anchor loads, (2) hanger and restraint loads, (3) a stress

summary of selected data points in accordance with the rules of Section III, Subsection NC-3652 for; sustained loads - Equation (8); occasional loads - Equation (9); thermal expansion - Equation (10) and Equation (11) for Class 1 and Class 2 components, and (4) a stress summary in accordance with the rules of Section III, Subsection NB-3652 for the primary stress-intensity limit - Equation (9), for Class 1 components only.

4.0 THEORY

The PASS program is designed to read the TMRSAP structural Model and determine all network point restraints from the restraint cards. Those points restrained in the six degrees of freedom are considered anchors; other restraint points are defined by a restraint code in the respective X, Y, Z direction on the network point restraint cards of the TMRSAP structural Model and a restraint summary table of all network point restraints indicating the direction and type of restraint. The outside diameter and thickness for each member and bend radii for all elbows is then determined and a table of member geometries printed.

Points to be analyzed are subsequently read as input data by the program which must include all restraint points as they appear in the TMRSAP structural Model.

The internal forces, moments, and deflections for each load condition are then read as input data by the program and stored for those data points defined on the network point restraint cards and for those points undergoing stress evaluation.

Once the input data have been read in for all load conditions, the net design loads are determined for each anchor point in the following manner:

1. The deadweight loads and hydro-test loads are retrieved for the point of interest.
2. The loads for all thermal conditions are scanned and the maximum positive (+) and maximum negative (-) loads for each direction determined.
3. The load combinations for determining the maximum design loads are defined as follows for both full anchors (those points restrained in six degrees-of-freedom) and restraints, with the exception of springs and snubbers. Only deadweight and hydro-test loads are considered for a spring and seismic loads only for a snubber.

MAXIMUM DESIGN LOAD (+):

DL1 = + SEISMIC (DBE) + E.E. (DBE)

DL2 = + SEISMIC (DBE) + E.E. (DBE) + DYNAMIC (+) + DEADWEIGHT

DL3 = + SEISMIC (DBE) + E.E. (DBE) + DYNAMIC (+) + THERMAL (+) + DEADWEIGHT

DL4 = MAX.(+) OF (DEADWEIGHT OR HYDRO)

(+) DESIGN LOAD = MAX. (+) OF DL1, DL2, DL3, DL4

MINIMUM DESIGN LOAD (-):

DL1 = - SEISMIC (DBE) - E.E. (DBE)

DL2 = - SEISMIC (DBE) - E.E. (DBE) + DYNAMIC (-) + DEADWEIGHT

DL3 = - SEISMIC (DBE) - E.E. (DBE) + DYNAMIC (-) + THERMAL (-) + DEADWEIGHT

DL4 = MAX. (-) OF (DEADWEIGHT OR HYDRO)

(-) DESIGN LOAD = MAX. (-) OF DL1, DL2, DL3, DL4

where, DBE = Design Basis Earthquake
E.E.= End Effects Loads

Thermal and seismic displacements are then determined for all restraint points. The thermal displacements are defined by a maximum and minimum range while the seismic displacements are to be considered plus (+) and minus (-) since for a normal mode analysis the resultant internal forces and moments are computed from the square root sum of the squares (SRSS) of the modal forces and moments. Two options are available for computing the combined seismic response;

Option 1:

$$F_i = \sqrt{(F_i)^2_X + (F_i)^2_Z} + |F_i|_Y$$

$$M_i = \sqrt{(M_i)^2_X + (M_i)^2_Z} + |M_i|_Y$$

$$\delta_i = \sqrt{(\delta_i)^2_X + (\delta_i)^2_Z} + |\delta_i|_Y$$

Option 2:

$$F_i = \sqrt{(F_i)^2_X + (F_i)^2_Y + (F_i)^2_Z}$$

$$M_i = \sqrt{(M_i)^2_X = (M_i)^2_Y + (M_i)^2_Z}$$

$$S_i = \sqrt{(S_i)^2_X + (S_i)^2_Y + (S_i)^2_Z}$$

where, i = x, y, z = Response Directions
X, Y, Z = Shock Directions

The program then evaluates stresses for Class 2 specified data points in accordance with the rules of NC-3652, Section III.

Sustained Loads:
NC-3652.1

$$\frac{PD_o}{4t} + 0.75i\left(\frac{M_A}{Z}\right) \leq 1.0\ S_h \qquad (8)$$

Occasional Loads: NC-3652.2

$$\frac{P_{max}D_o}{4t} + 0.75i\ \frac{(M_A + M_B)}{Z} \leq 1.2\ S_h \quad (9)$$

Thermal Expansion: NC-3652.3

$$i\left(\frac{M_c}{Z}\right) \leq S_A \quad (10)$$

$$\frac{PD_o}{4t} + 0.75i\left(\frac{M_A}{Z}\right) + i\left(\frac{M_c}{Z}\right) \leq (S_h + S_A) \quad (11)$$

The primary stress-intensity limit, Equation (9) of NB-3652, is evaluated for design conditions of all Class 1 data points specified in the node list for stress analysis.

$$B_i\left(\frac{PD_o}{2t}\right) + B_2\left(\frac{D_o}{2I}\right)M_i \leq 1.5\ S_m \quad (9)$$

For a complete definition of the preceding equations, reference subsections NB-3652 and NC-3652 of Section III in the ASME BPVC.

The program currently evaluates Equations (9), (10), and (11) of NC-3652 with and without moments due to secondary end effects (building or equipment movements). The moments produced by such displacements from seismic inertia effects are included with earthquake moments in the evaluation of Equation (9) in NC-3652.1 and Equation (9) in NB-3652.

The stress intensification factor, i, of NC-3652 is determined by the program in accordance with Figure NC-3672.9(a)-1 for Class 2 components and the stress indices B_1 and B_2 of NB-3652 are determined in accordance with Table NB-3683.2-1 for Class 1 Components. If the stress intensification factor, i, or the stress indices B_1 and B_2 are provided with the stress input data, these factors will override those computed by the program.

In addition to printing stress summary tables for all specified stress points, the program determines critical points as those points with the greatest stress to allowable ratio for Equations (8) and (9) of NC-3652 (Class 2) and Equation (9) of NB-3652 (Class 1).

5.0 QUALIFICATION

The program may be used to determine the adequacy of a piping support system subjected to sustained loads, occasional loads, and thermal expansion and compliance with the rules of Subsection NC-3652 of Section III of the ASME BPVC. It may be used to derive support design loads for anchors and restraints (rigid, spring, snubber).

6.0 VERIFICATION

This section contains the solution comparisons between PASS and independent hand calculations for a typical piping system, shown on Figure 6.0-1. The comparison of (1) anchor and nozzle reactions, (2) hanger/restraint reactions and displacement tolerances and (3) the Class 2 stress evaluation are presented in Tables 1 to 4. The results show very close agreement.

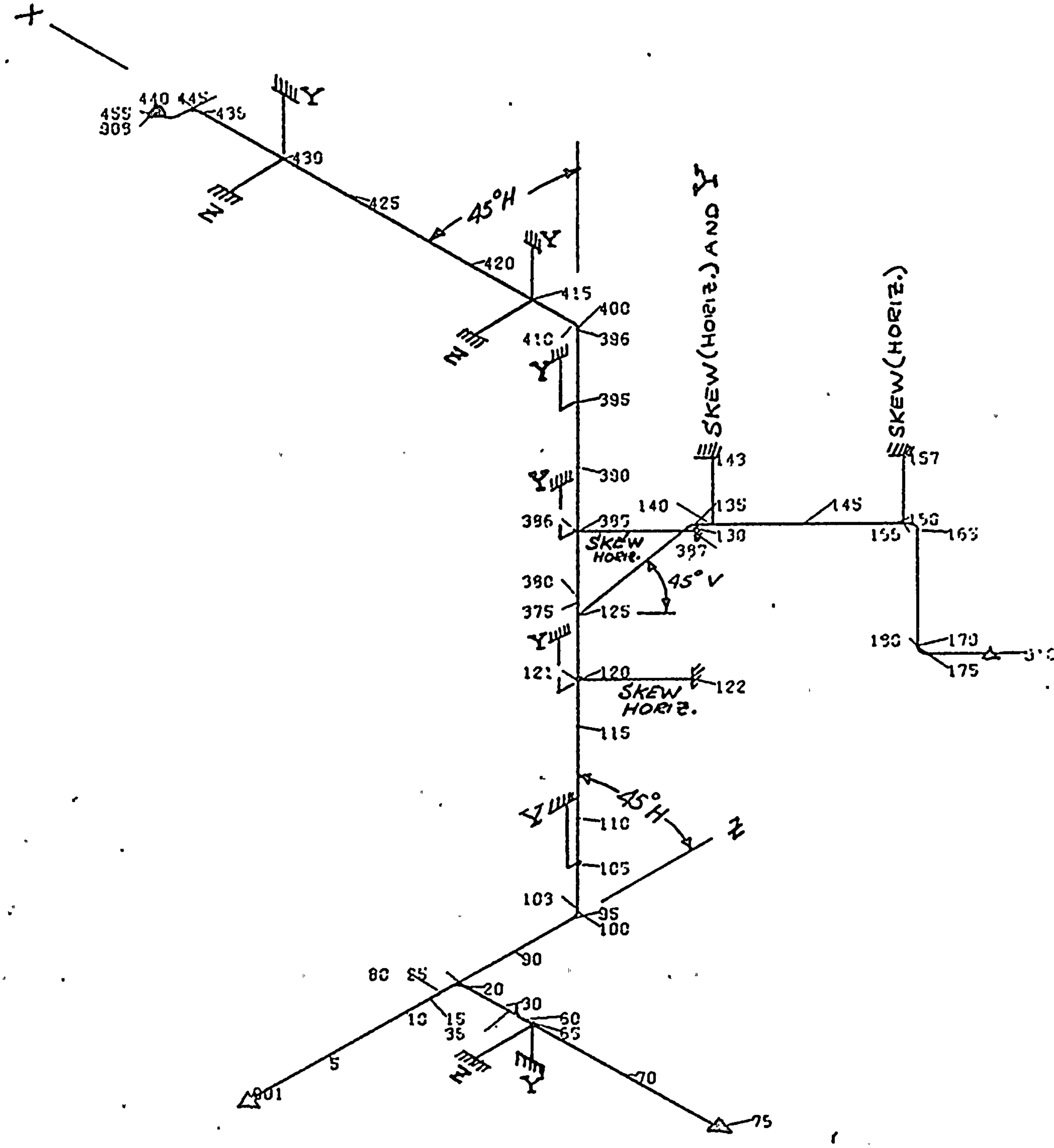

Figure 6.0-1 ISOMETRIC VIEW
ONE INCH EQUALS .98288889E+02
SAMPLE PROBLEM

TABLE 1 — COMPARISON OF NOZZLE AND ANCHOR REACTIONS

NODE 901

	F_x (LB.)		F_y (LB.)		F_z (LB.)	
	PASS	HAND	PASS	HAND	PASS	HAND
DESIGN LOAD (+)	1616	1617	1386	1385	719	719
DESIGN LOAD (-)	-499	-501	-348	-347	-2676	-2676

	M_x (IN.-LB.)		M_y (IN.-LB.)		M_z (IN.-LB.)	
	PASS	HAND	PASS	HAND	PASS	HAND
DESIGN LOAD (+)	87192	87192	24819	24820	17033	17031
DESIGN LOAD (-)	-31632	-31632	-87739	-87740	-35747	-35745

NODE 910

	F_x (LB.)		F_y (LB.)		F_z (LB.)	
	PASS	HAND	PASS	HAND	PASS	HAND
DESIGN LOAD (+)	30	29	329	331	57	57
DESIGN LOAD (-)	-51	-50	-168	-170	-35	-35

	M_x (IN.-LB.)		M_y (IN.-LB.)		M_z (IN.-LB.)	
	PASS	HAND	PASS	HAND	PASS	HAND
DESIGN LOAD (+)	3632	3633	971	971	3510	3508
DESIGN LOAD (-)	-6267	-6268	-964	-963	-6151	-6149

TABLE 2 – COMPARISON OF HANGER AND RESTRAINT LOADS

NODE	RESTRAINT TYPE AND DIRECTION	DESIGN LOAD (+)		DESIGN LOAD (-)	
		PASS	HAND	PASS	HAND
65	Y RIGID	2538	2538	-835	-835
65	Z RIGID	2279	2280	-745	-745
395	Y RIGID	222	222	-104	-104
430	Y RIGID	388	388	-158	-158
430	Z RIGID	341	339	-389	-387

TABLE 3 — COMPARISON OF HANGER AND RESTRAINT DISPLACEMENTS

THERMAL DISPLACEMENTS

NODE	DX (IN.)		DY (IN.)		DZ (IN.)	
	PASS	HAND	PASS	HAND	PASS	HAND
65 (+)	.000	.000	.000	.000	.000	.000
65 (-)	-.034	-.034	-.000	-.000	-.000	-.000
395 (+)	.097	.097	.000	.000	.000	.000
395 (-)	-.000	-.000	-.000	-.000	-.158	-.158
430 (+)	.000	.000	.000	.000	.000	.000
430 (-)	-.004	-.004	-.000	-.000	-.000	-.000

SEISMIC DISPLACEMENTS (±)

NODE	DX (IN.)		DY (IN.)		DZ (IN.)	
	PASS	HAND	PASS	HAND	PASS	HAND
65	.120	.120	.000	.000	.000	.000
395	.213	.212	.000	.000	.388	.386
430	.148	.148	.000	.000	.000	.000

TABLE 4 - CLASS 2 STRESS EVALUATION COMPARISON[1]

NODE	COMPONENT TYPE	EQUATION 8		EQUATION 9 WITH END EFFECTS		EQUATION 10 WITHOUT END EFFECTS	
		PASS	HAND	PASS	HAND	PASS	HAND
15	TEE-RUN	2390	2390	5352	5351	15698	15697
15	TEE-BRANCH	2465	2464	4948	4947	6894	6894
15	TEE-RUN	1645	1645	5969	5968	9485	9484
90	RUN	1653	1653	2684	2685	1323	1323
100	ELBOW	1295	1295	3695	3696	5807	5807
110	RUN	1117	1118	3151	3151	1128	1128
125	TEE-RUN	1897	1897	5509	5509	3781	3781
125	TEE-BRANCH	1281	1280	6969	6967	1991	1991
125	TEE-RUN	1863	1863	6041	6041	3448	3448
155	RUN AT RESTRAINT	745	745	1081	1106	405	406
380	REDUCER	1641	1641	3570	3575	1883	1886
395	RUN AT RESTRAINT	1045	1045	3885	3890	1922	1925
410	ELBOW	1112	1112	4584	4590	6187	6196
910	ANCHOR	2889	2889	4520	4522	24	24

(1) Refer to NC-3652 of Section III of the ASME BPVC, Winter 1972 Addenda

NUCPIPE

A digital computer program for the stress analysis and fatigue evaluation of nuclear power piping systems.

1.0 GENERAL DESCRIPTION

The Nuclear Power Piping Program, NUCPIPE, performs analyses in accordance with the design and analysis philosophy of ASME Section III Nuclear Power Piping Code for two separate protections: (1) protection against membrane or catastrophic failure, and (2) protection against fatigue or leak type failure. Two general types of loadings are considered: (1) self-limiting loads or those loads induced as a result of restraint of deformation of the structure, and (2) non-self-limiting loads, which are applied loads such as internal pressure and weight. Membrane analysis is performed by considering all non-self-limiting loads. Fatigue analysis is performed by considering both self-limiting and and non-self-limiting loads.

2.0 APPLICATION

In order to analyze and validate a piping design in accordance with the rules of Section III, it is necessary to perform several flexibility analyses and to use the moments obtained from these analyses to determine:

a. Satisfaction of primary stress-intensity limit, Eq. (9).
b. Satisfaction of primary plus secondary stress-intensity range, EQ. (10).
c. Satisfaction of peak stress-intensity range, Eq. (11).
d. Simplified elastic-plastic discontinuity analysis: expansion stress, Eq. (12); range of primary-plus-secondary membrane plus bending stress intensity, excluding thermal bending and thermal expansion stresses, Eq. (13); and alternating stress intensity, Eq. (14).

A piping system should be analyzed for the operating and design conditions given in the Design Specification. In general, the calculation of loads will indicate that only a few components require investigation using the Code Rules. For example, specific locations in the piping system will have higher moment loadings and higher temperature loadings (ΔT_1, ΔT_2, T_a, T_b) than others. For those components having essentially the same loadings the stress indices for one component will be controlling.

The compariative analysis given herein follows the general procedure defined in Section III subsection NB-3652 of the ASME Boiler and Pressure Vessel Code. The intent of the analysis given herein is to provide evidence which shows comparison of results between the NUCPIPE program and the ASME publication Sample Analysis of a Piping System Class 1 Nuclear (Ref. 1).

3.0 CAPABILITIES

NUCPIPE performs a stress evaluation using the results of the structural analyses performed with the TMRSAP program. The stress evaluation is in accordance with ASME Section III, Subsection NB-3650 and addresses (1) membrane failure, and (2) fatigue or leak-type failure.

Two general types of loading are considered:

(1) non-self-limiting loads (i.e. applied loads such as internal pressure and weight) and
(2) self-limiting loads (i.e. loads induced as a result of restraint of deformation of the structure).

Membrane stress evaluation considers all non-self-limiting loads. Fatigue evaluation considers both self-limiting and non-self-limiting loads.

An optional capability of NUCPIPE permits the combination of moment loads corresponding to plant operating conditions for different thermal transients. Thermal expansion moments may also be generated by interpolation or extrapolation for additional thermal expansion conditions from a reference set of input data.

NUCPIPE contains an option for simulating an NB-3200 stress analysis for butt-welded components by allowing a direct input of thermal stress derived from the thermal transient analyses .

$$S_n = \frac{1}{2(1-\nu)} E\alpha|\Delta T_1| + C_3 E_{ab} |\alpha_a T_a - \alpha_b T_b|$$

$$S_p = \frac{1}{2(1-\nu)} K_3 E_\alpha |\Delta T_1| + K_3 C_3 E_{ab} |\alpha_a T_a - \alpha_b T_b| + \frac{1}{(1-\nu)} E_\alpha |\Delta T_2|$$

This NB-3200 optional capability may result in a smaller range of thermal stress since the algebraic sign of the thermal gradients is considered in the solution of the stress-time history.

4.0 THEORY

The program utilizes random access files for the storage of input geometry and moments for the various load and operating conditions. As each point is evaluated in accordance with NB-3650, the geometry and moments for that point are retrieved from the random access files and a stress evaluation is performed to satisfy:

1. Primary stress intensity limit (NB-3652, Eq. 9)
2. Primary plus secondary stress intensity range (NB-3653.1,Eq.10)
3. Peak stress intensity range (NB-3653.2, Eq. 11)

If the primary plus secondary stress intensity range, Eq. 10, is not satisfied, a simplified elastic-plastic discontinuity analysis per NB-3653.6 is performed. Following the stress evaluation for design and normal operating conditions, a fatigue evaluation is carried out for all combinations of load sets.

The program sets up matrices of equations during the calculation of stress ranges for all load set combinations. For those load sets where Eq. 10, $S_n > 3S_m$, Equations (12) and (13) must be satisfied, and the value of S_n, Eq. 10, is then used to calculate K_e in Equation (14) for the subsequent fatigue analysis. The fatigue analysis is carried out by computing the usage factor for each load set pair in descending order of magnitude of alternating stress, Eq. 14, eliminating one of the load sets each time the process is carried out. The process is continued until all the load sets have been eliminated or until there is no further contribution of usage factors.

5.0 QUALIFICATION

A piping system contains an infinite number of points in space along the segments of pipe and piping components. During the operation of the system various transient conditions given in the Design Specification, produce an infinite number of time "points". The intent of the ASME Boiler and Pressure Vessel Code for Piping Systems is that a sufficient number of these points in space and time be analyzed so that it is reasonably obvious that all components of the piping system conform to the Code requirements for design and analysis.

A piping system should be analyzed for the design and operating conditions given in the Design Specification. Generally, the calculation of loads may indicate that only a few components require analysis using the Code Rules. Specific locations in the piping system will have higher moment loads and higher thermal loads (ΔT_1, ΔT_2, $T_a - T_b$) than others. For those components having essentially the same loadings, the stress indices for one component will be controlling.

The sample stress anlaysis contained herein follows the general procedure defined in Section III, subsection NB-3652 of the ASME Boiler and Pressure Vessel Code.

The procedure used by the NUCPIPE program employs the logic and rules of the Code. The procedure of the Code should be understood before applying the program to any piping components. Utilization of the program which employs the Code does not negate the need for competent engineering.

6.0 VERIFICATION

Comparison of Analytical and Published ASME Results

Analytical results obtained with the computer program discussed herein were compared with the results published in the ASME document, Sample Analysis of a Piping System Class 1 Nuclear.

The analytical results given herein were derived by the NUCPIPE computer program which is in accordance with the general procedure defined in Section III, subsection NB-3650 of the ASME Boiler and Pressure Vessel Code.

Three components in the sample piping system described herein were used for comparison;

1) GIRTH BUTT WELD, Location 14B
2) BUTT WELDING ELBOW, Location 27
3) BUTT WELDING TEE, Center at Location 10

The analytical results for the three components compare favorably with the ASME published results and are summarized herein for Eq. (9) and Cumulative Usage Factor as defined in subsection NB-3652, Section III of the ASME BPVC.

Node Location	Equation (9)		Cumulative Usage Factor	
	ASME	NUCPIPE	ASME	NUCPIPE
14B	7195	7234	--	$< 10^{-6}$
27	16050	16041	--	$< 10^{-6}$
10	20825	21198	.3699	.35256

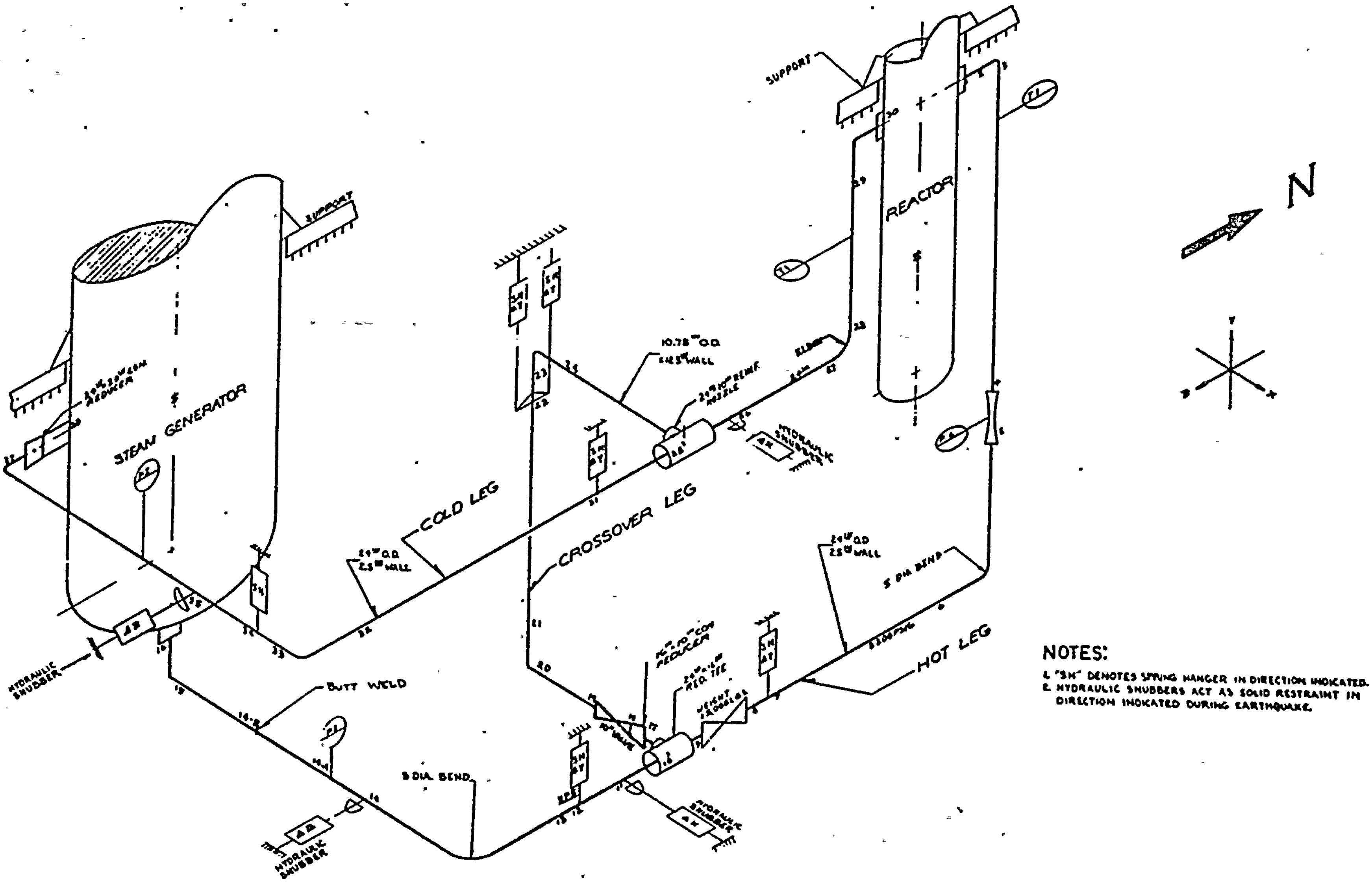

Figure 6.0-1 Sample Piping System

6.1 Benchmark Verification Problems

6.1.1 NUCPIPE Analytical Results

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,148,19,27

POINT 14 CARD 14

****

DIAMETER (IN)	WALL THICK. (IN)	BEND RADIUS (IN)	SM EQ.9 (PSI)	RUN1	RUN2	DMAX (IN)	DMIN (IN)	DESIGN PRESSURE (PSI)
24.000	2.500	0.0	15600.	0	0	0.000	0.000	2485.
(3- 0- 0- 0- 0-)				(0- 0- 0- 0-)				

MATERIAL PROPERTIES: E = 28.3X10+6 (PSI)
ALPHA = 9.11X10-6 (IN/IN/DEG F)

****

STRESS INDICES

B1	B2 (RUN)	B2 (BR)	C1	C2 (RUN)	C2 (BR)	C3	K1	K2 (RUN)	K2 (BR)	K3	C3*
.50	1.00		1.10	1.00		1.00	1.20	1.80		1.70	.50

****

COND	SM (PSI)	PRESSURE (PSI)	EXPECTED CYCLES	E (PSI) X10+6	ALPHA IN/IN X10-6	DELTA T1	DELTA T2	DELTA T3
0	0.	0.	5	0.0	0.00	0.	0.	0.
1	15600.	3590.	5	28.3	9.11	0.	0.	0.
2	15600.	2200.	40	28.3	9.11	14.	3.	0.
3	15600.	0.	40	28.3	9.11	-14.	-3.	0.
4	15600.	2200.	100	28.3	9.11	14.	3.	0.
5	15600.	0.	100	28.3	9.11	-14.	-3.	0.
6	15600.	2200.	18300	28.3	9.11	28.	5.	0.
7	15600.	2200.	18300	28.3	9.11	-28.	-5.	0.
8	15600.	2515.	80	28.3	9.11	19.	8.	0.
9	15600.	1500.	80	28.3	9.11	-19.	-8.	0.
10	15600.	2200.	50	28.3	9.11	0.	0.	0.
11	15600.	2200.	50	28.3	9.11	0.	0.	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********.

ASME SAMPLE ANAL. LOCATIONS 10,148,19,27

POINT 14 CARD 14

	M O M E N T S				
	WEIGHT	EARTHQUAKE (EQ. 9) (COND. 1)			EARTHQUAKE (EQ. 9 EMER. COND.)
M1	59700.	29000.	0.	M1	58000.
M2	-281200.	58900.	0.	M2	117800.
M3	527800.	458600.	0.	M3	917200.

EXPANSION AND ANCHOR

COND	M1	M2	M3
0	0	0	0
1	0.	0.	0.
2	766100.	2565500.	-3064900.
3	0.	0.	0.
4	869900.	3326100.	-3844500.
5	0.	0.	0.
6	1014200.	4104500.	-5025000.
7	869900.	3326100.	-3844500.
8	1065600.	4087400.	-5022100.
9	931500.	3552300.	-4313200.
10	906200.	3399700.	-3271300.
11	833600.	3252500.	-4417700.

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 14 STRESS EVALUATION

EQN. 9 = 7234. EQN. 9 (EMER. COND.) = 7788.
1.5(SM) = 23400. 2.25(SM) = 35100.

****

POSTULATED PIPE BREAK EVALUATION
PRIMARY PLUS SECONDARY STRESS INTENSITY
ALLOWABLE= 2.40(SM)

COND	STRESS INTENSITY	ALLOWABLE STRESS

(ALL CONDITIONS MEET ALLOWABLE)

****

SET	EQN. 10 (SN)	3(SM)
3 6	27317.	46800.

****

POINT 14 FATIGUE EVALUATION

SET	3(SM)	SN	SP	KE	SALT	USAGE FACTOR
3 8	46800.	27225.	44491.	1.000	22245.	0.00000
					CUMULATIVE USAGE FACTOR	0.00000

****

SET	SP	SALT	NUMCYL	ALLOWED	USEFACTOR
3 8	44491.	22245.	40	99999999.	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 27 CARD 27

DIAMETER (IN)	WALL THICK. (IN)	BEND RADIUS (IN)	SM EQ.9 (PSI)	RUN1	RUN2	DMAX (IN)	DMIN (IN)	DESIGN PRESSURE (PSI)
24.000	2.500	36.0	15600.	0	0	0.000	0.000	2485.

(9- 0- 0- 0- 0-) (0- 0- 0- 0-)

MATERIAL PROPERTIES: E = 28.3X10+6 (PSI)
ALPHA = 9.11X10-6 (IN/IN/DEG.F)

STRESS INDICES

B1	B2 (RUN	BR)	C1	C2 (RUN	BR)	C3	K1	K2 (RUN	BR)	K3	C3*
1.00	1.73		1.21	2.30		1.00	1.00	1.00		1.00	.50

COND	SM (PSI)	PRESSURE (PSI)	EXPECTED CYCLES	E (PSI) X10+6	ALPHA IN/IN X10-6	DELTA T1	DELTA T2	DELTA T3
0	0.	0.	5	0.0	0.00	0.	0.	0.
1	15600.	3590.	5	28.3	9.11	0.	0.	0.
2	15600.	2200.	40	28.3	9.11	14.	3.	0.
3	15600.	0.	40	28.3	9.11	-14.	-3.	0.
4	15600.	2200.	100	28.3	9.11	14.	3.	0.
5	15600.	0.	100	28.3	9.11	-14.	-3.	0.
6	15600.	2200.	18300	28.3	9.11	0.	0.	0.
7	15600.	2200.	18300	28.3	9.11	0.	0.	0.
8	15600.	2515.	80	28.3	9.11	11.	8.	0.
9	15600.	1500.	80	28.3	9.11	-11.	-8.	0.
10	15600.	2200.	50	28.3	9.11	0.	0.	0.
11	15600.	2200.	50	28.3	9.11	0.	0.	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 27 CARD 27

M O M E N T S

	WEIGHT	EARTHQUAKE (EQ. 9) (COND. 1)			EARTHQUAKE (EQ. 9 EMER. COND.)
M1	-366400.	-1581600.	0.	M1	-3163200.
M2	4000.	-146700.	0.	M2	-293400.
M3	104800.	78300.	0.	M3	156600.

EXPANSION AND ANCHOR

COND	M1	M2	M3
0	0	0	0
1	0.	0.	0.
2	3197400.	-1384800.	839800.
3	0.	0.	0.
4	4329700.	-1817300.	992500.
5	0.	0.	0.
6	4672100.	-1924000.	1071800.
7	4329700.	-1817300.	992500.
8	4673900.	-1922600.	1065500.
9	4300600.	-1787600.	983100.
10	2352700.	-2000700.	1090300.
11	6306700.	-1633900.	894700.

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 27 STRESS EVALUATION

EQN. 9 = 16041. EQN. 9 (EMER. COND.) = 19373.
1.5(SM) = 23400. 2.25(SM) = 35100.

****

POSTULATED PIPE BREAK EVALUATION
PRIMARY PLUS SECONDARY STRESS INTENSITY
ALLOWABLE= 2.40(SM)

COND	STRESS INTENSITY	ALLOWABLE STRESS

(ALL CONDITIONS MEET ALLOWABLE)

****

SET	EQN. 10 (SN)	3(SM)
3 11	33764.	46800.

****

POINT 27 FATIGUE EVALUATION

SET	3(SM)	SN	SP	KE	SALT	USAGE FACTOR
3 8	46800.	33588.	37455.	1.000	18728.	0.00000

CUMULATIVE USAGE FACTOR 0.00000

****

SET	SP	SALT	NUMCYL	ALLOWED	USEFACTOR
3 8	37455.	18728.	40	99999999.	0.

17

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 9 CARD 9

****

DIAMETER (IN)	WALL THICK. (IN)	BEND RADIUS (IN)	SM EQ.9 (PSI)	RUN1	RUN2	DMAX (IN)	DMIN (IN)	DESIGN PRESSURE (PSI)
24.000	2.500	0.0	15600.	0	0	0.000	0.000	2485.
(3- 0- 0- 0- 0-)				(0- 0- 0- 0-)				

MATERIAL PROPERTIES: E = 28.3X10+6 (PSI)
ALPHA = 9.11X10-6 (IN/IN/DEG F)

****

STRESS INDICES

B1	B2 (RUN	BR)	C1	C2 (RUN	BR)	C3	K1	K2 (RUN	BR)	K3	C3*
.50	1.00		1.10	1.00		1.00	1.20	1.80		1.70	.50

****

COND	SM (PSI)	PRESSURE (PSI)	EXPECTED CYCLES	E (PSI) X10+6	ALPHA IN/IN X10-6	DELTA T1	DELTA T2	DELTA T3
0	0.	0.	5	0.0	0.00	0.	0.	0.
1	15600.	3590.	5	28.3	9.11	0.	0.	0.
2	15600.	2200.	40	28.3	9.11	0.	0.	0.
3	15600.	0.	40	28.3	9.11	0.	0.	0.
4	15600.	2200.	100	28.3	9.11	0.	0.	0.
5	15600.	0.	100	28.3	9.11	0.	0.	0.
6	15600.	2200.	18300	28.3	9.11	0.	0.	0.
7	15600.	2200.	18300	28.3	9.11	0.	0.	0.
8	15600.	2515.	80	28.3	9.11	0.	0.	0.
9	15600.	1500.	80	28.3	9.11	0.	0.	0.
10	15600.	2200.	50	28.3	9.11	0.	0.	0.
11	15600.	2200.	50	28.3	9.11	0.	0.	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 9 CARD 9

M O M E N T S

	WEIGHT	EARTHQUAKE (EQ. 9) (COND. 1)			EARTHQUAKE (EQ. 9 EMER. COND.)
M1	1025200.	836500.	0.	M1	1673000.
M2	-218700.	-276200.	0.	M2	-552400.
M3	20400.	34800.	0.	M3	69600.

EXPANSION AND ANCHOR

COND	M1	M2	M3
0	0	0	0
1	0.	0.	0.
2	-3295700.	2841400.	92600.
3	0.	0.	0.
4	-5689700.	4000800.	738000.
5	0.	0.	0.
6	-7071700.	4916900.	859300.
7	-5689700.	4000800.	738000.
8	-7038500.	4941600.	936900.
9	-6091100.	4285900.	804000.
10	-4644100.	3655500.	781500.
11	-6735300.	4346100.	694500.

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 9 STRESS EVALUATION

EQN. 9 = 8302. EQN. 9 (EMER. COND.) = 9370.
1.5(SM) = 23400. 2.25(SM) = 35100.

****

POSTULATED PIPE BREAK EVALUATION
PRIMARY PLUS SECONDARY STRESS INTENSITY
ALLOWABLE= 2.40(SM)

COND	STRESS INTENSITY	ALLOWABLE STRESS

(ALL CONDITIONS MEET ALLOWABLE)

****

SET	EQN. 10 (SN)	3(SM)
0 8	23774.	46800.

****

POINT 9 FATIGUE EVALUATION

SET	3(SM)	SN	SP	KE	SALT	USAGE FACTOR
0 8	46800.	23774.	34826.	1.000	17413.	0.00000

CUMULATIVE USAGE FACTOR 0.00000

****

SET	SP	SALT	NUMCYL	ALLOWED	USEFACTOR
0 8	34826.	17413.	5	99999999	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 10 CARD 10

****

DIAMETER (IN)	WALL THICK. (IN)	BEND RADIUS (IN)	SM EQ.9 (PSI)	RUN1	RUN2	DMAX (IN)	DMIN (IN)	DESIGN PRESSURE (PSI)
16.000	1.687	0.0	15600.	9	11	0.000	0.000	2485.
(10- 0- 0- 0- 0-)				(0- 0- 0- 0-)				

MATERIAL PROPERTIES: E = 28.3X10+6 (PSI)
ALPHA = 9.11X10-6 (IN/IN/DEG F)

****

STRESS INDICES

B1	B2 (RUN	B2 BR)	C1	C2 (RUN	C2 BR)	C3	K1	K2 (RUN	K2 BR)	K3	C3*
1.00	1.50	1.50	1.50	2.00	2.00	1.00	4.00	1.00	1.00	1.00	.50

****

COND	SM (PSI)	PRESSURE (PSI)	EXPECTED CYCLES	E (PSI) X10+6	ALPHA IN/IN X10-6	DELTA T1	DELTA T2	DELTA T3
0	0.	0.	5	0.0	0.00	0.	0.	0.
1	15600.	3590.	5	28.3	9.11	0.	0.	0.
2	15600.	2200.	40	28.3	9.11	16.	6.	516.
3	15600.	0.	40	28.3	9.11	-16.	-6.	-516.
4	15600.	2200.	100	28.3	9.11	16.	6.	516.
5	15600.	0.	100	28.3	9.11	-16.	-6.	-516.
6	15600.	2200.	18300	28.3	9.11	31.	12.	1032.
7	15600.	2200.	18300	28.3	9.11	-31.	-12.	-1032.
8	15600.	2515.	80	28.3	9.11	20.	19.	774.
9	15600.	1500.	80	28.3	9.11	-20.	-19.	-774.
10	15600.	2200.	50	28.3	9.11	0.	0.	0.
11	15600.	2200.	50	28.3	9.11	0.	0.	0.

********** ASME SECTION III. NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,148,19,27

POINT 10 CARD 10

M O M E N T S

	WEIGHT	EARTHQUAKE (EQ. 9)	(COND. 1)		EARTHQUAKE (EQ. 9 EMER. COND.)
M1	-17500.	57100.	0.	M1	114200.
M2	-26000.	1011300.	0.	M2	2022600.
M3	287000.	74600.	0.	M3	149200.

EXPANSION AND ANCHOR

COND	M1	M2	M3
0	0	0	0
1	0.	0.	0.
2	251700.	245200.	-111200.
3	0.	0.	0.
4	337200.	323600.	-2233200.
5	0.	0.	0.
6	381600.	357800.	-2799000.
7	337200.	323600.	-2233200.
8	348200.	358700.	-2838800.
9	345700.	326700.	-2422000.
10	408600.	1587700.	-2139900.
11	265800.	-940500.	-2326500.

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 10 STRESS EVALUATION

EQN. 9 = 21198. EQN. 9 (EMER. COND.) = 28166.
1.5(SM) = 23400. 2.25(SM) = 35100.

****

SET	EQN. 10 (SN)	3(SM)	EQN. 12 (SE)	EQN. 13 (SC)
3 8	65530.	46800.	39503.	31112.
5 8	65530.	46800.	39503.	31112.
3 6	65319.	46800.	39276.	28973.
5 6	65319.	46800.	39276.	28973.
0 8	62068.	46800.	39503.	30854.
0 6	61857.	46800.	39276.	28715.
1 6	56025.	46800.	39276.	22883.
3 4	54301.	46800.	31536.	28715.
4 5	54301.	46800.	31536.	28715.
0 7	54117.	46800.	31536.	28715.
3 11	54006.	46800.	34704.	28457.
5 11	54006.	46800.	34704.	28457.
1 9	53487.	46800.	33982.	27794.
1 8	51700.	46800.	39503.	20486.
3 10	51494.	46800.	32191.	28457.
5 10	51494.	46800.	32191.	28457.
0 4	50839.	46800.	31536.	28457.
3 7	50655.	46800.	31536.	28457.
5 7	50655.	46800.	31536.	28457.
0 11	50544.	46800.	34704.	23199.
0 9	49239.	46800.	33982.	23546.
1 7	48285.	46800.	31536.	22883.
0 10	48031.	46800.	32191.	23199.
3 9	45776.	46800.		

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 10 FATIGUE EVALUATION

SET		3(SM)	SN	SE	KE	SALT	USAGE FACTOR
3	8	46800.	65530.	128878.	2.334	150405.	.10899 *
5	8	46800.	65530.	128878.	2.334	150405.	.10899 *
5	6	46800.	65319.	119469.	2.319	138526.	.12658 *
0	6	46800.	61857.	113796.	2.072	117917.	.00627 *
1	9	46800.	53487.	105444.	1.476	77831.	.00155 *
2	9	46800.	36761.	60904.	1.000	30452.	.00011
9	11	46800.	35903.	57836.	1.000	28918.	.00007
6	11	46800.	35302.	39722.	1.000	19861.	0.00000

CUMULATIVE USAGE FACTOR .35256

****

SET		SP	SALT	NUMCYL	ALLOWED	USEFACTOR
3	8	128878.	150405.	40	367	.108992E+00
5	8	128878.	150405.	40	367	.108992E+00
5	6	119469.	138526.	60	474	.126582E+00
0	6	113796.	117917.	5	797	.627353E-02
1	9	105444.	77831.	5	3225	.155039E-02
2	9	60904.	30452.	40	376486	.106246E-03
9	11	57836.	28918.	35	508188	.688721E-04
6	11	39722.	19861.	15	99999999	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL., LOCATIONS 10,148,19,27

POINT 11 CARD. 11

****

DIAMETER (IN)	WALL THICK. (IN)	BEND RADIUS (IN)	SM EQ.9 (PSI)	RUN1	RUN2	DMAX (IN)	DMIN (IN)	DESIGN PRESSURE (PSI)
24.000	2.500	0.0	15600.	0	0	0.000	0.000	2485.
(3- 0- 0- 0- 0-)				(0- 0- 0- 0-)				

MATERIAL PROPERTIES: E = 28.3X10+6 (PSI)
ALPHA = 9.11X10-6 (IN/IN/DEG F)

****

STRESS INDICES

B1	B2 (RUN BR)	C1	C2 (RUN BR)	C3	K1	K2 (RUN BR)	K3	C3*
.50	1.00	1.10	1.00	1.00	1.20	1.80	1.70	.50

****

COND	SM (PSI)	PRESSURE (PSI)	EXPECTED CYCLES	E (PSI) X10+6	ALPHA IN/IN X10-6	DELTA T1	DELTA T2	DELTA T3
0	0.	0.	5	0.0	0.00	0.	0.	0.
1	15600.	3590.	5	28.3	9.11	0.	0.	0.
2	15600.	2200.	40	28.3	9.11	0.	0.	0.
3	15600.	0.	40	28.3	9.11	0.	0.	0.
4	15600.	2200.	100	28.3	9.11	0.	0.	0.
5	15600.	0.	100	28.3	9.11	0.	0.	0.
6	15600.	2200.	18300	28.3	9.11	0.	0.	0.
7	15600.	2200.	18300	28.3	9.11	0.	0.	0.
8	15600.	2515.	80	28.3	9.11	0.	0.	0.
9	15600.	1500.	80	28.3	9.11	0.	0.	0.
10	15600.	2200.	50	28.3	9.11	0.	0.	0.
11	15600.	2200.	50	28.3	9.11	0.	0.	0.

********** ASME SECTION III NUCLEAR POWER PIPING PROGRAM**********

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 11 CARD 11

M O M E N T S

	WEIGHT	EARTHQUAKE (EQ. 9) (COND. 1)			EARTHQUAKE (EQ. 9 EMER. COND.)
M1	-1007700.	-893600.	0.	M1	-1787200.
M2	244700.	-735000.	0.	M2	-1470000.
M3	-307300.	-109400.	0.	M3	-218800.

EXPANSION AND ANCHOR

COND	M1	M2	M3
0	0	0	0
1	0.	0.	0.
2	3044000.	-3086600.	18700.
3	0.	0.	0.
4	5352500.	-4324400.	1495200.
5	0.	0.	0.
6	6690100.	-5274700.	1939700.
7	5352500.	-4324400.	1495200.
8	6654300.	-5300200.	1901600.
9	5745400.	-4612600.	1617900.
10	4235500.	-5243200.	1358400.
11	6469500.	-3405600.	1632000.

ASME SAMPLE ANAL. LOCATIONS 10,14B,19,27

POINT 11 STRESS EVALUATION

EQN. 9 = 8608. EQN. 9 (EMER. COND.) = 9993.
1.5(SM) = 23400. 2.25(SM) = 35100.

****

SET	EQN. 10 (SN)	3(SM)
0 8	23855.	46800.

****

POINT 11 FATIGUE EVALUATION

SET	3(SM)	SN	SP	KE	SALT	USAGE FACTOR
0 8	46800.	23855.	34971.	1.000	17485.	0.00000

CUMULATIVE USAGE FACTOR 0.00000

****

SET	SP	SALT	NUMCYL	ALLOWED	USEFACTOR
0 8	34971.	17485.	5	99999999	0.

7.0 CONCLUSION

It is not the intent of this document to provide verification of the NUCPIPE program in an absolute sense but rather to provide evidence that the logic and numerical procedure used in the program is in accordance with the design and analysis rules defined in SECTION III, subsection NB-3652, of the ASME Boiler and Pressure Vessel Code.

One basic difference exists in the procedure used by the NUCPIPE program and the ASME published analysis. In the fatigue evaluation for the calculation of cumulative usage factor, the NUCPIPE program keys on alternating stress, S_a, in descending order of magnitude in determining the usage factors for each load set pair. The ASME published procedure (Ref. 1, page 25-26, Table 624.3) keys on peak stress intensity range, S_p, in calculating the usage factors.

8.0 REFERENCES

1. ASME, "Sample Analysis of a Piping System Class 1 Nuclear", 1972.

2. Teledyne Engineering Services, "TMRPIPE - A System of Computer Programs for the Complete Analysis of Nuclear Piping", April 1976.

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Request 1

Please provide a tabulation of the re-analysis run comparing the original stresses with the new calculated stresses for the high stress points, anchor points and points where the stresses increased.

Response

Table 1, attached, compares the original and new stresses for the high stress areas, anchor points and points where the stress has increased for the seven piping systems which were re-analyzed.

Request 2

Verify that the modeling of the seven re-analyzed piping systems accurately reflect the as-built conditions.

Response

Niagara Mohawk has verified that the modeling accurately depicted the as-built condition of the plant including the location of the restraints in the systems.

Request 3

Indicate if there will be an effect on the testing and inspection performed under I. E. Bulletin 79-02, as a result of the recalculation of seismic stresses.

Response to Request 3

The re-analysis has resulted in stress increases at ten restraints. These restraints have been re-analyzed with the increased loads and found to be within original code allowable design limits. The primary piping and supports were originally designed to the ASA B31.1 Code for Pressure Piping 1955, as indicated on Pages V-3 through V-5 of Table V-1 and Page V-17 in Section V.C of the Nine Mile Point Unit 1 Final Safety Analysis Report. Since the restraints where loads have increased are not supported by concrete anchor bolts, the re-analysis has no effect on the testing and inspection performed under I. E. Bulletin 79-02.

Request 4

What effect does our response to I. E. Bulletin 79-04 dealing with Velan valves have on our pipe stress re-analysis. Were valves nozzles and equipment interfaces modeled as rigid or flexible components.

Response

Our response to I. E. Bulletin 79-04 was that there are none of the valves in question installed in seismic Category I piping systems at Nine Mile Point Unit 1. Therefore, we do not have the problem described in the Bulletin of using incorrect valve weights in our pipe stress analyses.

Valves were modeled as lumped concentrated weights, stiffer than the pipe they are in, but not as an infinitely rigid piece of pipe. Nozzles and equipment are modeled as infinitely rigid components, which is standard practice.

Request 5

What affect does the increased stress levels have on our pipe break analysis.

Response

The relatively minor increased stress levels at certain points in the re-analyzed lines has no affect on our pipe break analysis. Our analysis (see the Response to Question 10 of Amendment No. 1 to the Technical Supplement to Petition for Conversion from Provisional Operating License to Full-Term Operating License) assumed that any of the high energy lines can break anywhere inside the primary containment. If a line break did occur, because of redundancy and separation, the engineered safeguard systems would still perform their intended functions.

Request 6

Provide information concerning the verification of the TMRSAP code used for the analysis of the reroute of the cleanup system piping.

Response

Enclosed please find the code verification information for TMRSAP. This information includes a listing of the portion of TMRSAP which performs the response spectrum analysis sample problem and a sample output.

Your sample problems can be run on TMRSAP within two to three weeks of receipt of the problem from members of your staff.

TMRSAP code analyzes each of three orthogonal earthquake components (two horizontal and one vertical) independently. For each mode the co-directional forces resulting from each orthogonal earthquake component are combined by absolute summation after which the modal values are combined by the Square Root of the sum of the squares method.

Request 7

Was a standard version of ADLPIPE used to do the re-analyses or was it a version modified in any way? Also, how does the code combine the earthquake components?

Response

The most recent re-analysis of piping systems used the standard version of ADLPIPE dated July 1975. ADLPIPE is a proprietary code which was used on the CDC Cybernet computer system and is not available for the user to modify.

ADLPIPE analyzes each of three orthogonal earthquake components (two horizontal and one vertical) independently. The modal responses are combined by the Square Root of the sum of the squares mothod to obtain the representative maximum value of forces in the x, y and z direction for each orthogonal earthquake component. The independent spatial components for each of the earthquake motions are then combined by the Square Root of the sum of the squares method to produce the resultant forces used for stress analysis calculations.

TABLE 1

NODE	SYSTEM NAME	ISO NO.	LINE SIZE	ORIGINAL TOTAL (PSI)	ORIGINAL SEISMIC (PSI)	NEW TOTAL (PSI)	NEW SEISMIC (PSI)	ALLOWABLE
				MODEL 1-SHUTDOWN COOLING SUCTION				
20(Branch)	Reactor Recirculation System	C-26874-C Sheet 2	14"	12433	7674	13628	9267	19080
160	Shutdown Cooling Suction	↓	14"	13043	6419	12652	6028	↓
200	↓	↓	14"	9220	4063	9424	4335	↓
255(Anchor)	↓	↓	14"	7499	0	7499	0	↓
				MODEL 2-SHUTDOWN COOLING DISCHARGE				
50(Branch)	Reactor Recirculation System	C-19711-C Sheet 3	14"	13920	4775	13822	4644	16200
58	Shutdown Cooling Discharge	↓	14"	19354	7957	18716	7319	19080

TABLE 1 (CONTINUED)

NODE	SYSTEM NAME	ISO NO.	LINE SIZE	ORIGINAL TOTAL (PSI)	ORIGINAL SEISMIC (PSI)	NEW TOTAL (PSI)	NEW SEISMIC (PSI)	ALLOWABLE
			MODEL 2-SHUTDOWN COOLING DISCHARGE (CONTINUED)					
60	Shutdown Cooling Discharge	C-19711-C Sheet 3	14"	19573	7698	18939	7064	19080
61	↓	↓	14"	16088	5906	15489	5307	↓
62	↓	↓	14"	15709	5249	15135	4675	↓
64	↓	↓	14"	13470	4623	12934	4087	↓
80	↓	↓	14"	11545	4400	11544	4399	↓
			MODEL 2-EMERGENCY CONDENSER RETURN					
7(Branch)	Reactor Recirculation System	C-19710-C Sheet 3	10"	15124	5709	15520	6105	17280
106	Emergency Cooling Return	↓	10"	15894	7590	16375	8231	↓
108	↓	↓	10"	16370	7640	16280	7520	↓
118	↓	↓	10"	12484	5143	13252	6167	↓
142	↓	↓	10"	12371	5266	12308	5182	↓

TABLE 1 (CONTINUED)

MODEL 3-EMERGENCY CONDENSER RETURN, REACTOR WATER CLEAN UP SUCTION AND REACTOR DRAIN

NODE	SYSTEM NAME	ISO NO.	LINE SIZE	ORIGINAL TOTAL (PSI)	ORIGINAL SEISMIC (PSI)	NEW TOTAL (PSI)	NEW SEISMIC (PSI)	ALLOWABLE
1(Anchor)	Reactor Recirc. System	C-26843-C Sheet 3	28"	8829	628	9374	1355	19080
27	↓	↓	28"	11452	3130	10244	1520	↓
47	↓	↓	28"	8215	560	8220	565	↓
53	↓	↓	28"	7313	114	7321	122	↓
59(Anchor)	↓	↓	28"	9055	431	9371	853	↓
87	Emergency Condenser	↓	10"	6769	1192	7080	1503	↓
91	↓	↓	10"	8948	3289	8517	2715	↓
93	↓	↓	10"	7115	1050	7383	1318	↓
95	↓	↓	10"	7643	1322	7683	1362	↓
135	Reactor Clean Up System	↓	6"	5672	1006	5746	1080	↓
139	↓	↓	6"	13165	7717	10462	4113	↓
146	↓	↓	6"	5809	1069	5900	1160	↓
154(Anchor)	↓	↓	6"	10764	629	10773	641	↓
173	Reactor Drain	↓	2"	18259	11969	12172	5882	↓
178	↓	↓	2"	6589	3091	7370	3872	↓
180	↓	↓	2"	5903	2539	6776	3412	↓

TABLE 1 (CONTINUED)

NODE	SYSTEM NAME	ISO NO.	LINE SIZE	ORIGINAL TOTAL (PSI)	ORIGINAL SEISMIC (PSI)	NEW TOTAL (PSI)	NEW SEISMIC (PSI)	ALLOWABLE
MODEL 3-EMERGENCY CONDENSER RETURN, REACTOR WATER CLEAN UP SUCTION AND REACTOR DRAIN (CONTINUED)								
182	Reactor Drain	C-26843-C Sheet 3	2"	4512	1229	5099	1816	19080
184	↓	↓	2"	4705	1378	4813	1486	↓
MODEL 5-REACTOR FEEDWATER SYSTEM								
5(Anchor)	Reactor Feedwater System	C-18117-C C-18118-C C-18119-C	18"	9339	1295	9862	1818	18000
10			18"	9544	1857	10328	2903	
45			18"	9819	1335	10545	2061	
100			18"	13963	1028	13943	1008	
105			18"	6359	963	6652	1256	
170(Anchor)			18"	10984	1302	11171	1489	
200			18"	11637	923	12773	2059	
230			18"	10334	1100	11121	2150	
240(Anchor)	↓	↓	18"	10629	1128	11063	1562	↓

TABLE 1 (CONTINUED)

NODE	SYSTEM NAME	ISO NO.	LINE SIZE	ORIGINAL TOTAL (PSI)	ORIGINAL SEISMIC (PSI)	NEW TOTAL (PSI)	NEW SEISMIC (PSI)	ALLOWABLE
MODEL 6-CONTROL ROD DRIVE SYSTEM								
1(Anchor)	Control Rod Drive	C-26849-C	3"	5700	1643	5637	1559	21840
20	↓	↓	3"	12674	4000	11858	3184	↓
85	↓	↓	3"	7671	4286	7442	3981	↓
100	↓	↓	3"	12134	2215	11757	1712	↓
105	↓	↓	3"	18134	4949	17436	4251	↓
120(Anchor)	↓	↓	3"	9502	2657	9130	2285	↓

TMRSAP: RESPONSE SPECTRUM ANALYSES

SUBROUTINE SPECTR

1. FORM MODAL PARTICIPATION FACTORS, PX(I,IDRN)
   IDRN = 1, 2, 3 FOR X, Y, Z DIRECTION EARTHQUAKE.

2. COMPUTE MODAL AMPLITUDES FROM SPECTRUM & PARTICIPATION FACTORS, PX.

$$W_i = \left[\sum_{j=1}^{3} |Px_j| \times DIRN_j \right]_i$$

DIRN = X, Y, Z DIRECTION FACTORS

i = 1 to NF (NO. OF MODES)

3. COMPUTE MODAL DISPLACEMENTS, F, & RMS.

$$F_j = \sum_{j=1}^{NF} F_j \times W_j$$

DATE: 6/5/79

A.M.B.

thin shell elements along the thirty-nine degree meridian. The curves drawn in Fig. 10 are plots of meridian (ϕ) and circumferential (θ) direction surface stresses predicted by the SAP program at the element centroids.

The solution of this problem is given in the text by Timoshenko [27], where the stress distribution of Fig. 10 may be found for comparison. It should be noted that program SAP calculates membrane stresses (force per unit area) and bending resultants (moment per unit length) from which the surface stresses in the figure have been evaluated.

3. Frequency and Mode Shape Analysis of Plane Frame

The lowest three frequencies and corresponding mode shapes of the plane frame shown in Fig. 11 are calculated. The results can be compared with the solutions published in references [4] [5]. Note that depending on the high speed storage available either a determinant search or a subspace iteration solution may be performed. The three lowest vibration periods of the frame are given in Table 6.

4. Response Spectrum Analysis of Pipe Network

A response spectrum analysis of the pipe assemblage shown in Fig. 12 is carried out. This is example 1 in the User's Manual for the "PIPDYN" computer program [36]. Good correspondence between the SAP and PIPDYN solutions is obtained. Table 7 compares local z-direction member end moments calculated by the two programs. In the analysis the lowest five modes are considered. Both, horizontal and vertical (proportional) spectra are simultaneously specified.

TABLE 7 COMPARISON OF MOMENT PREDICTIONS

(SAP ANALYSIS OF PIPDYN EXAMPLE 1)

ELEMENT NUMBER	MOMENT MZ (Kip in) IN ELEMENT LOCAL COORDINATES (at element ends 1, see Ref. 29 pp. 54)	
	SAP	PIPDYN
1	376.9	377.0
2	30.67	30.68
3	152.9	152.9
4	100.6	100.6
5	83.27	83.27
6	46.17	46.19
7	1.081	1.082
8	21.59	21.81
9	7.052	7.038
10	7.537	7.571
11	160.3	160.4
12	78.07	78.09
13	26.08	25.80

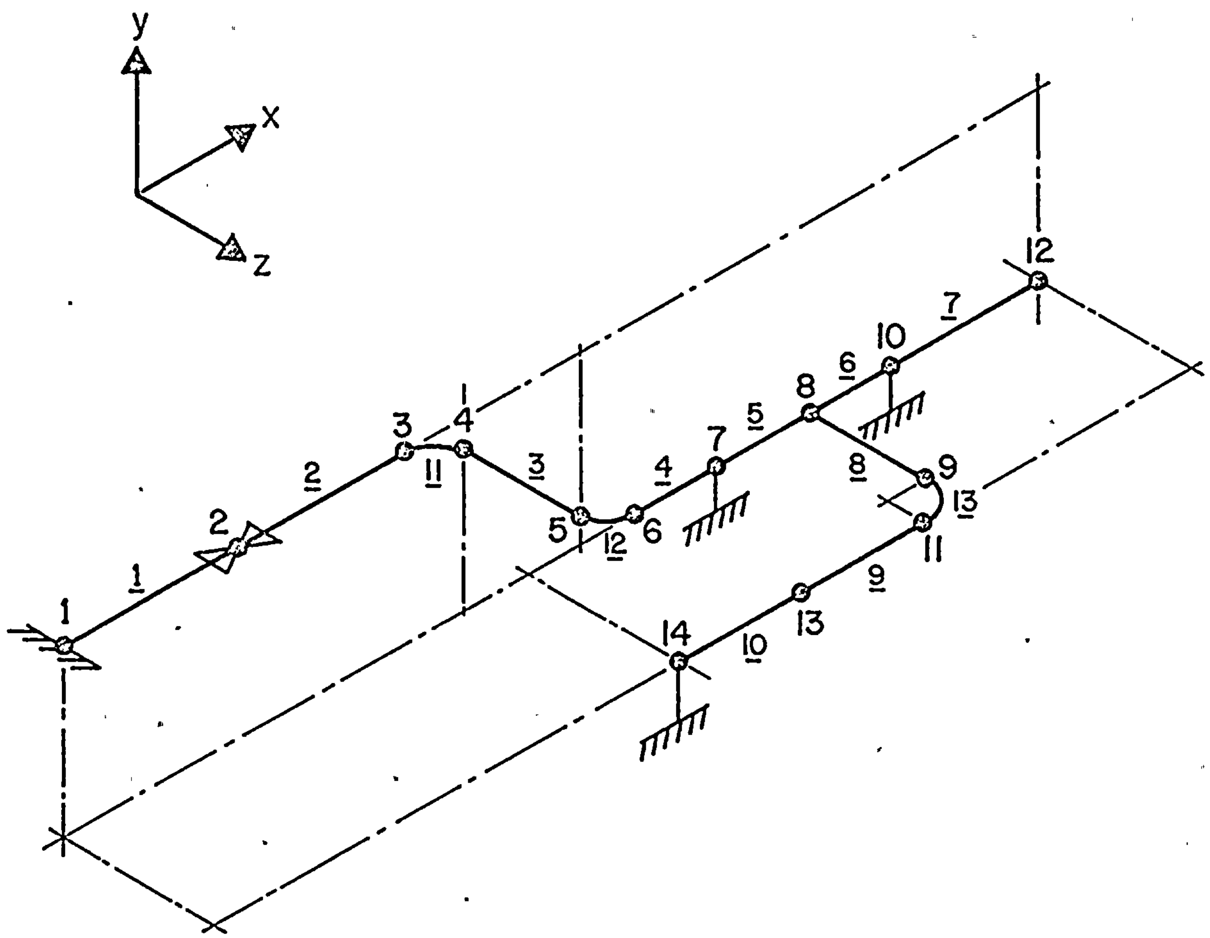
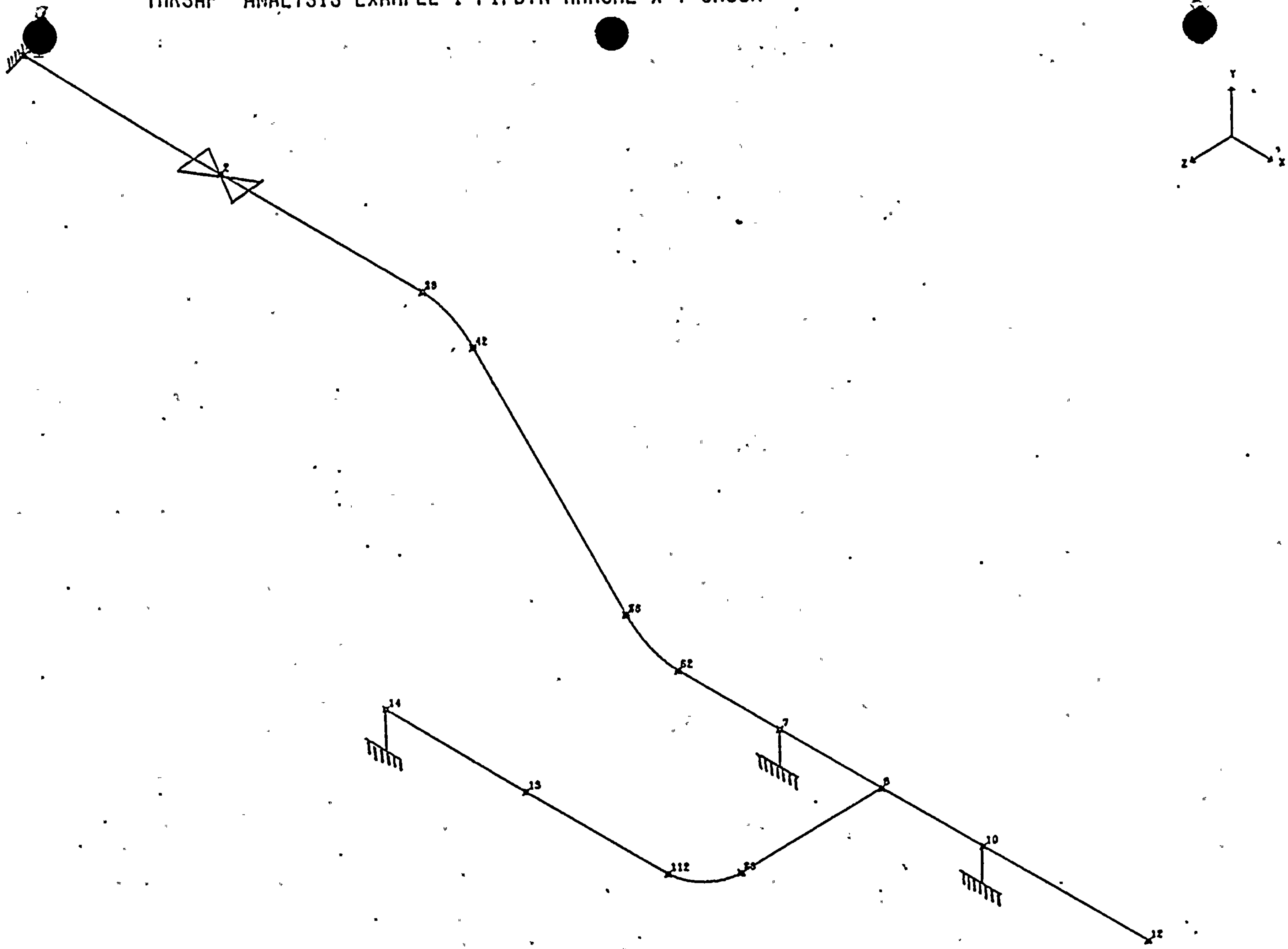


FIGURE 12: SAP MODEL OF PIPDYN EXAMPLE 1,
RESPONSE SPECTRUM ANALYSIS

TMRSAP ANALYSIS EXAMPLE 1 PIPDYN MANUAL X-Y SHOCK



```
****************************************************************
*                                                              *
*        TMRPIPE SYSTEM - APRIL 1976 VERSION                   *
*          PIPING ANALYSIS, DEVELOPED BY                       *
*          TELEDYNE ENGINEERING SERVICES                       *
*                 WALTHAM, MASS.                               *
*     COPYRIGHT 1976 TELEDYNE ENGINEERING SERVICES             *
*               WORLD RIGHTS RESERVED                          *
*                                                              *
****************************************************************
```

```
**************************************************************************************************
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*                                                                                                *
*                          THE USER MUST VERIFY HIS OWN RESULTS                                  *
*                          ------------------------------------                                  *
*                                                                                                *
**************************************************************************************************
```

BATCH UPDATED 06/04/79 TODAY IS 06/05/79
TWIN CITIES CYBERNET CENTER CYBER 76 TCA/TCZ

```
   $$      $$$$$$   $$$$$$$    $$$$$$    $$$$$$    $$$$$$    $$$$$$
  $$$$    $$    $$  $$    $$  $$    $$  $$    $$  $$    $$  $$    $$
 $$  $$   $$        $$    $$        $$        $$  $$        $$    $$
$$    $$  $$        $$$$$$$        $$$$      $$$$   $$$$$$$   $$    $$
$$    $$  $$        $$    $$        $$    $$        $$    $$  $$    $$
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$$    $$  $$    $$  $$    $$  $$    $$  $$          $$    $$  $$    $$
$$    $$   $$$$$$   $$$$$$$    $$$$$$   $$$$$$$$     $$$$$$    $$$$$$
```

```
    $$      $$$$$$   $$$$$$$   $$$$$$   $$$$$$   $$$$$$   $$$$$$
   $$$$    $$    $$  $$    $$ $$    $$ $$    $$ $$    $$ $$    $$
  $$  $$   $$        $$    $$       $$       $$ $$       $$    $$
 $$    $$  $$        $$$$$$$     $$$$     $$$$  $$$$$$$  $$    $$
 $$    $$  $$        $$    $$       $$  $$      $$    $$ $$    $$
 $$$$$$$$  $$  $$$$  $$    $$       $$ $$       $$    $$ $$    $$
 $$    $$  $$    $$  $$    $$       $$ $$       $$    $$ $$    $$
 $$    $$  $$    $$  $$    $$ $$    $$ $$       $$    $$ $$    $$
 $$    $$   $$$$$$   $$$$$$$   $$$$$$  $$$$$$$$  $$$$$$   $$$$$$
```

TMRSAP : RESPONSE SPECTRUM ANALYSIS X-Y MULTIPLE SHOCK SPECTRA

SAMPLE PROBLEM FROM SAP IV & PIPDYN PROGRAMS

DATE: 6/5/79

AMB.

THRPIPE ANALYSIS EX. 1 PIPDYNE MANUAL EIGENVALUE EXTRACTION

OP	0	0	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
BA	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SH	0	5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ANCHOR	0	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RESTRAINT	0	1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
INERTIA	0	2	7000.0000	7000.0000	7000.0000	0.0000	0.0000	0.0000
ANCHOR	0	7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RESTRAINT	0	7	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
JUNCTION	0	8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ANCHOR	0	10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RESTRAINT	0	10	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
ANCHOR	0	14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RESTRAINT	0	14	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
SECTION	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PIPE	1	2	24.0000	.6870	29.0000	0.0000	0.0000	28.7500
RUN	1	2	8.3333	0.0000	0.0000	0.0000	0.0000	0.0000
SECTION	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PIPE	2	28	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUN	2	28	8.3333	0.0000	0.0000	0.0000	0.0000	0.0000
SECTION	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PIPE	28	42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUN	28	3	1.2427	0.0000	0.0000	0.0000	0.0000	0.0000
ELBOW	3	4	0.0000	0.0000	0.0000	36.0000	0.0000	0.0000
RUN	4	42	.8787	-.8787	0.0000	0.0000	0.0000	0.0000
SECTION	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PIPE	42	48	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUN	42	48	6.2499	-6.2499	0.0000	0.0000	0.0000	0.0000
SECTION	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

```
      OVERLAY (SSAP,17,0)                                               OVL15       2
      PROGRAM DYNSPE                                                    DYNSPE      2
C                                                                       DYNSPE      3
C     DYNAMIC SPECTRUM ANALYSIS                                         DYNSPE      4
C                                                                       DYNSPE      5
      CALL RESPEC                                                       DYNSPE      6
C                                                                       DYNSPE      7
      RETURN                                                            DYNSPE      8
      END                                                               DYNSPE      9
      SUBROUTINE RESPEC                                                 RESPEC      2
C                                                                       RESPEC      3
C                                                                       RESPEC      4
      COMMON /SOL/ NBLOCK,NEQB,LL,NF                                    RESPEC      5
      COMMON /JUNK/ XXX(4),NDYN,JUK(200)                                RESPEC      6
      COMMON /ELPAR/ NPAR(14),NUMNP,MBAND,NELTYP,N1,N2,N3,N4,N5,MTOT,NEQ RESPEC      7
      COMMON /EXTRA/ MODEX,NT8                                          RESPEC      8
      DIMENSION T(4)                                                    RESPEC      9
      COMMON A(1)                                                       RESPEC     10
      LEVEL 2,A                                                         RESPEC     11
C                                                                       RESPEC     12
C                                                                       RESPEC     13
      WRITE (6,1010)                                                    RESPEC     14
```

```
      XXX(4)=0.
      CALL SECOND (T(1))
      IF (MODEX.EQ.1) GO TO 100
      N2=N1 + 6*NUMNP
      CALL EMIDR (A(N1),A(N2),NUMNP,NEQB)
C
C
  100 N2=N1+NEQB*NF
      N3=N2+NF*3
      N4=N3+NEQB
      N5=N4+NF
      N6=N5+NEQB
      N7=N6+NF
      MM=N7-MTOT
      IF (MM.GT.0) CALL ERROR (MM)
      CALL SPECTR  (A(N1), A(N2),A(N3),A(N4),A(N5),NEQB,NF,NBLOCK,A(N6))
C
C     MODE SHAPE NG IS R.M.S. DISPLACEMENT
C
      CALL SECOND (T(2))
      IF (MODEX.EQ.1) GO TO 200
      N2=N1+6*NUMNP
      NG=NF+1
      N3=N2+6*NG
      N4=N3+NEQB*NG
      MM=N4-MTOT
      IF (MM.GT.0) CALL ERROR (MM)
      NT=2
      CALL PRINTD(A(N1),A(N2),A(N3),NEQB,NUMNP,NG,NBLOCK,NEQ,NT,3)
C
C     COMPUTE STRESSES
C
  200 CALL SECOND(T(3))
      NSB=NBLOCK*NEQB
      N2=N1+12*NF
      N3=N2+NSB*NF
      N4=N3+12
      MM=N4-MTOT
      IF (MM.GT.0) CALL ERROR(MM)
C
      CALL STRESR (A(N1),A(N2),A(N3),NF,NSB,NEQB,NBLOCK)
      CALL SECOND (T(4))
C
      TT=0.
      DO 10 I=1,3
      T(I)=T(I+1)-T(I)
   10 TT=TT+T(I)
      T(4)=TT
      WRITE (6,1000) (T(I),I=1,4)
      RETURN
C
 1000 FORMAT (27H1R. M. S.   T I M E   L O G, /
     1 5X,37HCOMPUTE MAXIMUM NODAL DISPLACEMENTS =, F8.2 /
     2 5X,37HOUTPUT  MAXIMUM NODAL DISPLACEMENTS =, F8.2 /
     3 5X,37HCOMPUTE ELEMENT STRESSES            =, F8.2 //
     4 5X,37HTOTAL FOR SPECTRUM ANALYSIS         =, F8.2 )
 1010 FORMAT (1H1,//34H R E S P O N S E   S P E C T R U M, 3X,
     1              15HA N A L Y S I S, // 1X)
      END
      SUBROUTINE EMIDR (ID,MASS,NUMNP,NEQB)
      DIMENSION ID(NUMNP,6),MASS(NEQB)
      LEVEL 2,ID,MASS
C
      REWIND 3
      REWIND 8
      READ (8) ID
```

SOURCE LISTING FROM TMRSAP FOR RESPONSE SPECTRUM ANALYSIS.

DATE: 6/5/79

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```
      L=1
      DO 200 N=1,NUMNP
      DO 100 I=1,6
      IF(ID(N,I).LE.0) GO TO 100
      IF(L.LE.NEQB) GO TO 75
      WRITE (3) MASS
      L=1
   75 MASS(L)=0
      IF (I.GT.3) GO TO 90
      MASS(L)=I
   90 L=L+1
  100 CONTINUE
  200 CONTINUE
      IF (L.GT.NEQB) GO TO 310
      DO 300 I=L,NEQB
  300 MASS(I)=0
  310 WRITE (3) MASS
C
      RETURN
      END
      SUBROUTINE SPECTR  (F,PX,XM,W,MASS,NEQB,NF,NBLOCK,TM)
      COMMON /EXTRA/ MODEX,NT8
      DIMENSION PX(NF,3),F(NEQB,NF),XM(NEQB),W(NF),MASS(NEQB)
      LEVEL 2,F,PX,XM, W,MASS,TM
      DIMENSION DIRN(3)
C
C     COMPUTES MODAL AND R.M.S. DISPL RESPONSE TO EARTHQUAKE
C
      KI=12
      IF (MODEX.EQ.1) GO TO 270
      TPI=6.2831853
      DO 100 I=1,NF
      DO 100 J=1,3
  100 PX(I,J)=0.
C
C     FORM MODAL PARTICIPATION FACTORS PX(I,IDRN)
C            IDRN=1,2,3 .... FOR X,Y,Z, DIRN EARTHQUAKE
C
      REWIND 9
      REWIND 3
      DO 200 N=1,NBLOCK
      BACKSPACE 7
      READ (7) F
      BACKSPACE 7
      READ (3) MASS
      READ (9) XM
C
      DO 250 I=1,NEQB          deg. of freedom/node
      J=MASS(I)
      IF (J.LE.0) GO TO 250
      DO 240 L=1,NF            no. of modes
  240 PX(L,J)=PX(L,J)+F(I,L)*XM(I)
  250 CONTINUE
  200 CONTINUE
C
C     READ FREQUENCIES W OFF TAPE 7
C
      BACKSPACE 7
      READ (7) W
      REWIND 2
      WRITE (2) W
C
C     COMPUTE MODAL AMPLITUDES (IN W) FROM SPECTRUM AND PX
C
  270 READ(KI,1000) DIRN,IND
      WRITE (6,2000) DIRN
```

```
      WRITE (6,2010) IND
      IF (MODEX.EQ.1) W(1)=SD(1)
      IF (MODEX.EQ.1) RETURN
      WRITE (6,2020)
      DO 280 I=1,NF
  280 WRITE (6,2040) I,(PX(I,J),J=1,3)
      DO 300 I=1,NF
      WW=TPI/W(I)
      WR=0.
      DO 290 K=1,3
  290 WR=WR + ABS(PX(I,K))*DIRN(K)
      WR=WR*SD(WW)
      IF (IND.EQ.1) WR=WR/(W(I)*W(I))
  300 W(I)=WR
C
C     WRITE MODAL DISPLS F AND R.M.S. ON TAPE 2
C
      REWIND 7
      READ (7)
      DO 350 N=1,NBLOCK
      READ (7) F
      DO 310 J=1,NF
      AMP=W(J)
      DO 310 I=1,NEQB
  310 F(I,J)=F(I,J)*AMP
C
      DO 320 I=1,NEQB
      WW=0.
      DO 330 J=1,NF
  330 WW=WW+F(I,J)**2
  320 XM(I)=SQRT(WW)
  350 WRITE (2) F,XM
C
      RETURN
 1000 FORMAT (3F10.0,I5)
 2000 FORMAT (20H DIRECTION FACTORS   / /
     1        10X,3HX = F10.4,4X,3HY = F10.4,4X,3HZ = F10.4   //)
 2010 FORMAT (56H0INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM =
     1 I5  //
     2        20H EQ.0  DISPLACEMENT     /
     3        20H EQ.1  ACCELERATION     ///)
 2020 FORMAT (28H MODAL PARTICIPATION FACTORS, // 5H MODE,3X,
     1 11HX-DIRECTION,3X,11HY-DIRECTION,3X,11HZ-DIRECTION, / 1X)
 2040 FORMAT (1H ,I4,3E14.4 / 1X)
      END
      FUNCTION   SD(TT)
C
      COMMON / JUNK / MM,L,K,NTAG,NDYN,T(90),S(90),HED(12),I,W,SS,SI,TI
      COMMON /EXTRA/ MODEX,NT8
      KI=12
      IF (NTAG.EQ.1) GO TO 500
      NTAG=1
C
C     READ SPECTRUM (MAX DISPL AS FUNCTION OF PERIOD)
C
      READ(KI,1000) HED
      WRITE (6,2000) HED
      READ(KI,1010) NPTS,SFTR
      IF (ABS(SFTR).LT.1.E-12) SFTR=1.
      WRITE (6,2010) NPTS,SFTR
      READ(KI,1020) (T(I),S(I),I=1,NPTS)
      WRITE (6,2020) (I,T(I),S(I),I=1,NPTS)
      IF (MODEX.EQ.1) RETURN
  500 CONTINUE
C
      K=0
```

```
      DO 600 I=1,NPTS                                                   SD        23
      K=K+1                                                             SD        24
      IF (TT.LT.T(I)) GO TO 700                                         SD        25
  600 CONTINUE                                                          SD        26
  700 TK=T(K)-T(K-1)                                                    SD        27
      SK=S(K)-S(K-1)                                                    SD        28
      SS=S(K-1) + SK*(TT-T(K-1))/TK                                     SD        29
      SD=SFTR*SS                                                        SD        30
C                                                                       SD        31
 1000 FORMAT (12A6)                                                     SD        32
 1010 FORMAT (I5,F10.0)                                                 SD        33
 1020 FORMAT (2F10.0)                                                   SD        34
C                                                                       SD        35
 2000 FORMAT (//17H SPECTRUM TABLE (,12A6,1H),/ 1X)                     SD        36
 2010 FORMAT (5X,18HNUMBER OF POINTS =, I4/                             SD        37
     1           5X,18HSCALE FACTOR     = E14.5 / 1X )                  SD        38
 2020 FORMAT (6H INPUT,20X,8HSPECTRUM, / 6H POINT,8X,6HPERIOD,9X,       SD        39
     1 5HVALUE, / (I6,2E14.4) )                                         SD        40
C                                                                       SD        41
      RETURN                                                            SD        42
      END                                                               SD        43
      SUBROUTINE STRESR (SF,FI,SRM,NF,NSB,NEQB,NBLOCK)                  STRESR     2
C                                                                       STRESR     3
C     COMPUTE AND PRINT RMS STRESSES                                    STRESR     4
C                                                                       STRESR     5
      DIMENSION SF(12,NF),FI(NSB,NF),SRM(12),SFG(18,100),SRMCS(12),     STRESR     6
     1 SRMGCS(18),SRMLCS(18),SRSSCS(18),SRSLCS(18),SRMLF(18,100)        STRESR     7
      LEVEL 2,SF,FI,SRM                                                 STRESR     8
      COMMON /EM/ ND,NS,LM(63),SA(42,63),IS(13)                         STRESR     9
      COMMON /ELPAR/ NPAR(14),NUMNP,MBAND,NELTYP,N1,N2,N3,N4,N5,MTOT,NEQ STRESR    10
      COMMON /EXTRA/ MODEX,NT8                                          STRESR    11
      COMMON/NODARY/NODE(999),IANCH(500),NANCH,IJUNC(500),NBRP,         MOD4     326
     1 NAMEL(999),KPLOT,NOPRNT                                          MOD4     327
      COMMON/PTITLE/TITLA(12)                                           STRESR    14
      COMMON/MODFRQ/FREQ(100),PC                                        STRESR    15
      DIMENSION PIP(8),        DISP(6),DC(3,3),SRMG(18),DG(6,2),SRML(18) STRESR    16
      DIMENSION SG(12),SRSS(18),SRMLS(18),SRSL(18)                      STRESR    17
C                                                                       STRESR    18
      DATA            HI/1HI/,HC/1HC/,HJ/1HJ/                           STRESR    19
C                                                                       STRESR    20
C     ASSEMBLE MODESHAPES IN CORE                                       STRESR    21
C                                                                       STRESR    22
      IF(MODEX.EQ.1) RETURN                                             STRESR    23
      REWIND 2                                                          STRESR    24
      READ (2)                                                          STRESR    25
      NE=NSB                                                            STRESR    26
      NS=NE+1-NEQB                                                      STRESR    27
      DO 100 I=1,NBLOCK                                                 STRESR    28
      READ (2) ((FI(J,K),J=NS,NE),K=1,NF)                               STRESR    29
      NS=NS-NEQB                                                        STRESR    30
  100 NE=NE-NEQB                                                        STRESR    31
  110 CONTINUE                                                          STRESR    32
C                                                                       STRESR    33
      IF(NOPRNT.LT.2.OR.NELTYP.GT.1) WRITE(6,2000)                      MOD4     328
      REWIND 1                                                          STRESR    35
      REWIND 14                                                         STRESR    36
      REWIND 15                                                         STRESR    37
      REWIND 17                                                         STRESR    38
      DO 500 N=1,NELTYP                                                 STRESR    39
      READ (1) NPAR                                                     STRESR    40
      NUME=NPAR(2)                                                      STRESR    41
C                                                                       STRESR    42
C     CONSIDER EACH ELEMENT OF THIS TYPE  (NPAR(1))                     STRESR    43
C                                                                       STRESR    44
      IF(NPAR(1).EQ.12) N12=NUME                                        STRESR    45
      DO 400 M=1,NUME                                                   STRESR    46
```

```
      NEL = M
      READ (1) ND,NS,(LM(I),I=1,ND),((SA(I,J),I=1,NS),J=1,ND)
C
C
C     NSET=1 (TANGENT),     NSET=2 (BEND)
C
      DO 133 I=1,18
      DO 133 K=1,100
      SFG(I,K)=0.0
      SRMLF(I,K)=0.0
  133 CONTINUE
      NSET = (NS-1)/12 +1
      DO 390 K3=1,NSET
      K1 = (K3-1)*12 +1
      K2 = K1+11
      IF(K2.GT.NS) K2=NS
      L = 0
      DO 132 K=K1,K2
      L = L+1
  132 IS(L) = K
      IS(L+1) = 0
      L=0
C
C     COMPUTE MODAL STRESSES
C
      DO 300 I=1,12
      IF(IS(I).EQ.0) GO TO 350
      II = IS(I)
      L = L+1
      DO 200 K=1,NF
      SS = 0.0
      DO 150 J=1,ND
      JJ = LM(J)
      IF(JJ.LE.0) GO TO 150
      SS = SS + SA(II,J)*FI(JJ,K)
  150 CONTINUE
  200 SF(L,K) = SS
  300 CONTINUE
  350 DO 330 K=1,NF
      IF(NSET.EQ.2) GO TO 320
      DO 305 I=K1,K2
  305 SFG(I,K)=SF(I,K)
      GO TO 330
  320 DO 325 I=K1,K2
      J=I
      IF(K3.EQ.2) J=I-12
  325 SFG(I,K)=SF(J,K)
  330 CONTINUE
C
      DO 220 I=1,L
      SRM(I)=0.0
      DO 220 K=1,NF
  220 SRM(I)=SRM(I)+SF(I,K)*SF(I,K)
C
C        MODAL SUMMATION FOR CLOSELY SPACED MODES
C        NRC REGULATORY GUIDE 1.92  C.1.2.2.
C
      NF1=NF-1
      DO 222 I=1,L
      SRMCS(I)=0.0
      DO 222 K=1,NF1
      J=K+1
      TENP=(FREQ(J)-FREQ(K))/FREQ(K)
      IF(TENP.GT.PC)  GO TO 222
      SRMCS(I)=SRMCS(I)+ABS(SF(I,K)*SF(I,J))
  222 CONTINUE
```

[illegible]

```
      DO 210 I=1,L                                                      STRESR 113
      SRMCS(I)=SQRT(SRM(I)+2.*SRMCS(I))                                 STRESR 114
  210 SRM(I)=SQRT(SRM(I))                                               STRESR 115
C                                                                       STRESR 116
      IF(NSET.EQ.2.AND.K3.EQ.2) GO TO 267                               STRESR 117
C                                                                       STRESR 118
      IF(NPAR(1).NE.12) GO TO 267                                       STRESR 119
C                                                                       STRESR 120
C     GET DIRECTION COSINES FOR THIS MEMBER                             STRESR 121
C                                                                       STRESR 122
      READ(15) ((DC(I,J),J=1,3),I=1,3)                                  STRESR 123
C                                                                       STRESR 124
C      PIPE ELEMENT - FIND CORRESPONDING SAP/TMR NODES                  STRESR 125
C                                                                       STRESR 126
      READ(17) NAME1,NAME2,NAME3,I1,I2,PIP,NUMMAT,NSECT                 STRESR 127
      IF(EOF(17)) 390,225                                               STRESR 128
  225 CONTINUE                                                          STRESR 129
      J1=I1                                                             STRESR 130
      J2=I2                                                             STRESR 131
      DO 230 L1=1,NUMNP                                                 STRESR 132
      IF(I1.EQ.L1) J1=NODE(L1)                                          STRESR 133
      IF(I2.EQ.L1) J2=NODE(L1)                                          STRESR 134
  230 CONTINUE                                                          STRESR 135
C                                                                       STRESR 136
C     GET NODE DISPLACEMENTS FOR END-I / END-J                          STRESR 137
C                                                                       STRESR 138
      REWIND 13                                                         STRESR 139
      IEND=0                                                            STRESR 140
      JEND=0                                                            STRESR 141
      DO 260 L1=1,NUMNP                                                 STRESR 142
      IF(IEND.EQ.1.AND.JEND.EQ.1) GO TO 265                             STRESR 143
      READ(13) NN,L2,(DISP(I),I=1,6)                                    STRESR 144
      IF(NN.EQ.I1) GO TO 240                                            STRESR 145
      IF(NN.EQ.I2) GO TO 250                                            STRESR 146
      GO TO 260                                                         STRESR 147
  240 DO 241 I=1,6                                                      STRESR 148
  241 DG(I,1)=DISP(I)                                                   STRESR 149
      IEND=1                                                            STRESR 150
      GO TO 260                                                         STRESR 151
  250 DO 251 I=1,6                                                      STRESR 152
  251 DG(I,2)=DISP(I)                                                   STRESR 153
      JEND=1                                                            STRESR 154
  260 CONTINUE                                                          STRESR 155
  265 CONTINUE                                                          STRESR 156
  267 CONTINUE                                                          STRESR 157
C                                                                       STRESR 158
C                                                                       STRESR 159
      IF(NOPRNT.LT.2) GO TO 268                                         MOD4   329
      IF(NELTYP.GT.1.AND.N.EQ.1) GO TO 268                              MOD4   330
      GO TO 269                                                         MOD4   331
  268 CALL ELOUTR (NEL,IS,L,NPAR(1),NS)                                 MOD4   332
  269 CONTINUE                                                          MOD4   333
      IF(NPAR(1).NE.12) GO TO 217                                       STRESR 161
C                                                                       STRESR 162
C                                                                       STRESR 163
C     DO TRANSFORMATION FROM LOCAL TO GLOBAL OF FORCES AND MOMENTS      STRESR 164
C     AT EACH MODE AND DO MODAL SUMMATION                               STRESR 165
C                                                                       STRESR 166
C                                                                       STRESR 167
      DO 212 I=1,18                                                     STRESR 168
      SRSS(I)=0.0                                                       STRESR 169
      SRSL(I)=0.0                                                       STRESR 170
  212 CONTINUE                                                          STRESR 171
C                                                                       STRESR 172
      DO 612 JF=1,NF                                                    STRESR 173
      IF(NSET.EQ.2.AND.K3.EQ.1) GO TO 281                               STRESR 174
```

```
      DO 280 IR=1,16,3
      IRS=IR-1
      DO 275 M1=1,3
      J=IRS+M1
      SRML(J)=0.0
      DO 274 I=1,3
      KN=IR+I-1
  274 SRML(J)=SRML(J) + DC(M1,I)*SFG(KN,JF)
      SRMLF(J,JF)=SRML(J)
C
C       GET SUM OF SQUARES
C
      SRSS(J)=SRSS(J) + SRML(J)*SRML(J)
      SRSL(J)=SRSL(J) + SFG(J,JF)*SFG(J,JF)
  275 CONTINUE
  280 CONTINUE
  281 CONTINUE
C
C     PRINT MODAL STRESS COMPONENTS IF REQUESTED
C
      IF(NOPRNT.GE.1) GO TO 613
      DO 611 I=1,L
  611 SG(I)=SF(I,JF)
      WRITE(6,2030) (SG(I),I=1,L)
  613 CONTINUE
  612 CONTINUE
C
C          MODAL SUMMATION FOR CLOSELY SPACED MODES
C          NRC REGULATORY GUIDE 1.92  C.1.2.2
C
      DO 620 I=1,18
      SRSSCS(I)=0.0
      SRSLCS(I)=0.0
      DO 620 K=1,NF1
      J=K+1
      TENP=(FREQ(J)-FREQ(K))/FREQ(K)
      IF(TENP.GT.PC)  GO TO 620
      SRSSCS(I)=SRSSCS(I)+ABS(SRMLF(I,K)*SRMLF(I,J))
      SRSLCS(I)=SRSLCS(I)+ABS(SFG(I,K)*SFG(I,J))
  620 CONTINUE
      WRITE(6,2035)
C
C     TAKE SQ. ROOT SUM OF SQUARES
C
      DO 216 I=1,18
      SRMG(I)=SQRT(SRSS(I))
      SRML(I)=SQRT(SRSL(I))
      SRMGCS(I)=SQRT(SRSS(I)+2.*SRSSCS(I))
      SRMLCS(I)=SQRT(SRSL(I)+2.*SRSLCS(I))
  216 CONTINUE
C
      IF(NSET.EQ.2.AND.K3.EQ.1) GO TO 610
C
C     SAVE GLOBAL FORCES/MOMENTS/DISPLACEMENTS ON FILE 14
C
      WRITE(14) NS
      IF(NS.EQ.18) GO TO 600
C
C               TANGENT ELEMENT
C
      WRITE(14) M,L,I1,J1,(SRMLCS(I),I=1,6),(SRMGCS(I),I=1,6),
     1(DG(I,1),I=1,3), I2,J2,(SRMLCS(I), I=7,12),
     2(SRMGCS(I), I=7,12),(DG(I,2), I=1,3)
      GO TO 610
C
C               BEND ELEMENT
```

```
C
  600 WRITE(14) M,L,I1,J1,(SRMLCS(I), I=1,12),(SRMGCS(I), I=1,12),
     1(DG(I,1), I=1,3), I2,J2,(SRMLCS(I), I=13,18),
     2(SRMGCS(I), I=13,18),(DG(I,2), I=1,3)
C
  610 CONTINUE
  217 CONTINUE
      IF(NOPRNT.LT.2) GO TO 219
      IF(NELTYP.GT.1.AND.N.EQ.1) GO TO 219
      GO TO 218
  219 CONTINUE
      WRITE(6,2040)
      WRITE (6,2030)(SRM(I),I=1,L)
      WRITE(6,2050)
      WRITE(6,2030) (SRMCS(I),I=1,L)
      WRITE (6,2035)
  218 CONTINUE
C
C     IF REQUESTED, PUNCH PIPE ELEMENT (NPAR(1).EQ.12) MEMBER END FORCES
C     AND MOMENTS AT POINTS (I,J) FOR A TANGENT AND (C,J) FOR A BEND
C     A VALUE OF ONE (1) FOR NPAR(13) ACTIVATES THE PUNCH OPTION
C     NPAR(14) IS A 5 DIGIT IDENTIFIER PUNCHED IN CC 76-80 OF ALL CARDS
C
      IF(NPAR(1).NE.12) GO TO 333
      IF(NPAR(13).NE.1) GO TO 333
      IF(M.EQ.1) WRITE(11,6300) TITLA
      IF(NS.EQ.18) GO TO 328
C
C         TANGENT ELEMENT
C
C
C       CONVERT FORCES/MOMENTS FROM LBS TO KIPS
C
      DO 615 I=1,12
  615 SRMGCS(I)=SRMGCS(I)/1000.
C
C     MERGE NODE DISPLACEMENTS WITH ELEMENT FORCES/MOMENTS
C
      WRITE(11,5000) M,HI,J1,(SRMGCS(I),I=1,6),(DG(I,1),I=1,3)
      WRITE(11,5000) M,HJ,J2,(SRMGCS(I),I=7,12),(DG(I,2),I=1,3)
      GO TO 333
C
C          BEND ELEMENT
C
  328 IF(K3.EQ.1) GO TO 333
C
C        CONVERT FORCES/MOMENTS FROM LBS TO KIPS
C
      DO 616 I=1,18
  616 SRMGCS(I)=SRMGCS(I)/1000.
      WRITE(11,5000) M,HI,J1,(SRMGCS(I),I=1,6),(DG(I,1),I=1,3)
      WRITE(11,5100) M,HC,(SRMGCS(I),I=7,12)
  329 IF(K3.EQ.2)
     1WRITE(11,5000)M,HJ,J2,(SRMGCS(I),I=13,18),(DG(I,2),I=1,3)
  333 CONTINUE
C
  390 CONTINUE
  400 CONTINUE
C
  500 CONTINUE
      WRITE(11,6400)
C
C     PRINT FORCES/MOMENTS/DISPLACEMENTS IN GLOBAL
C
      REWIND 14
      WRITE(6,6000)
```

[illegible]

```
      IF(PCT.EQ.0.1) WRITE(6,5800)                                      STRESR
      WRITE(6,5900)                                                     STRESR
      LINE=5                                                            STRESR
      DO 700,M=1,N12                                                    STRESR
      READ(14) NS                                                       STRESR
      IF(NS.EQ.18) GO TO 650                                            STRESR
C                                                                       STRESR
C        TANGENT ELEMENT                                                STRESR
C                                                                       STRESR
      READ(14) M,L,I1,J1,(SRML(I),I=1,6),(SRMG(I),I=1,6),               STRESR
     $ (DG(I,1),I=1,3),I2,J2,(SRML(I),I=7,12),(SRMG(I),I=7,12),         STRESR
     $ (DG(I,2),I=1,3)                                                  STRESR
      WRITE(6,6100) M,I1,J1,(SRMG(I),I=1,6),(DG(I,1),I=1,3),I2,J2,      STRESR
     $ (SRMG(I),I=7,12),(DG(I,2),I=1,3)                                 STRESR
      LINE=LINE + 3                                                     STRESR
      GO TO 700                                                         STRESR
C                                                                       STRESR
C        BEND ELEMENT                                                   STRESR
C                                                                       STRESR
  650 READ(14) M,L,I1,J1,(SRML(I),I=1,12),(SRMG(I),I=1,12),             STRESR
     $ (DG(I,1),I=1,3),I2,J2,(SRML(I),I=13,18),(SRMG(I),I=13,18),       STRESR
     $ (DG(I,2),I=1,3)                                                  STRESR
      WRITE(6,6200) M,I1,J1,(SRMG(I),I=1,6),(DG(I,1),I=1,3),            STRESR
     $ (SRMG(I),I=7,12),I2,J2,(SRMG(I),I=13,18),(DG(I,2),I=1,3)         STRESR
      LINE=LINE + 4                                                     STRESR
  700 CONTINUE                                                          STRESR
C                                                                       STRESR
C        COMPUTE MEMBER STRESSES                                        STRESR
C                                                                       STRESR
      CALL STRESS(0.0,0.0,0.0,1,1,1,1,0,N12,14)                         STRESR
C                                                                       STRESR
C                                                                       STRESR
 2000 FORMAT (1H1,47HR E S P O N S E   S P E C T R U M   S T R E S S,   STRESR
     1          3X,19HC O M P O N E N T S, // 23H SQUARE ROOT OF THE SUM, STRESR
     2              37H OF THE SQUARES OF THE MODAL STRESSES, /         STRESR
     3              19H (FOR ALL ELEMENTS), /// 1X)                     STRESR
 2030 FORMAT (12E11.4)                                                  STRESR
 2035 FORMAT (1H0)                                                      STRESR
 2040 FORMAT(1X,30HSQUARE ROOT SUM OF THE SQUARES)                      STRESR
 2050 FORMAT(1X36HCLOSELY SPACED MODE SUMMATION METHOD)                 STRESR
C                                                                       STRESR
 5000 FORMAT(I3,A1,I4,3F8.2,3F9.2,3F7.3)                                STRESR
 5100 FORMAT(I3,A1,4X,3F8.2,3F9.2,3F7.3)                                STRESR
 6000 FORMAT(1H1,40X,60HPIPE  FORCES/MOMENTS/DISPLACEMENTS  MEMBER GLOBA STRESR
     $L DIRECTIONS)                                                     STRESR
 5800 FORMAT(43X,55HCLOSELY SPACED MODE SUMMATION USED IS 10 PERCENT MET STRESR
     $HOD)                                                              STRESR
 5900 FORMAT(//,1X12HELEM.  ELEM.,13X4HNODE,/,2X,3HNO.,4X4HTYPE,        STRESR
     $ 2X7HSTATION,                                                     STRESR
     $2X3HSAP,2X3HTMR,9X2HFX,9X2HFY,9X2HFZ,9X2HMX,9X2HMY,9X2HMZ,        STRESR
     $4X2HDX,7X2HDY,7X2HDZ,/)                                           STRESR
 6100 FORMAT(1X,I4,1X7HTANGENT,4X5HEND-I,2I5,6F11.1,3F9.4,/,            STRESR
     $ 17X5HEND-J,2I5,6F11.1,3F9.4,/)                                   STRESR
 6200 FORMAT(1X,I4,4X4HBEND,4X5HEND-I,2I5,6F11.1,3F9.4,/,               STRESR
     $ 16X6HCENTER,10X,6F11.1,/,17X5HEND-J,2I5,6F11.1,3F9.4,/)          STRESR
 6300 FORMAT(12A6)                                                      STRESR
 6400 FORMAT(3H -1)                                                     STRESR
C                                                                       STRESR
      RETURN                                                            STRESR
      END                                                               STRESR
      SUBROUTINE ELOUTR (NEL,IS,L,IELT,NS)                              ELOUTR
C                                                                       ELOUTR
C     NEL       =     ELEMENT NUMBER                                    ELOUTR
C     IS        =     ELEMENT COMPONENT NUMBERS                         ELOUTR
C     L         =     NUMBER OF ELEMENT COMPONENT NUMBERS PER LINE OF   ELOUTR
C                     OUTPUT (12 MAXIMUM)                               ELOUTR
```

THRPIPE ANALYSIS EX. 1 PIPDYNE MANUAL EIGENVALUE EXTRACTION

PIPE	10	12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RUN	10	12	6.8333	0.0000	0.0000	0.0000	0.0000	0.0000
RUN								

TMRPIPE ANALYSIS EX, 1 PIPDYNE MANUAL EIGENVALUE EXTRACTION

PIPE	48	62	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	48	5	,8787	-,8787	0,0000	0,0000	0,0000	0,0000
ELBOW	5	6	0,0000	0,0000	0,0000	36,0000	0,0000	0,0000
RUN	6	62	1,2427	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	62	7	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	62	7	4,1666	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	7	8	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	7	8	4,1667	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	8	88	12,7500	,4060	0,0000	0,0000	0,0000	8,5000
RUN	8	88	0,0000	0,0000	5,8320	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	88	112	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	88	9	0,0000	0,0000	1,5010	0,0000	0,0000	0,0000
ELBOW	9	11	0,0000	0,0000	0,0000	18,0000	0,0000	0,0000
RUN	11	112	-1,5010	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	112	13	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	112	13	-5,8320	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	13	14	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
RUN	13	14	-5,8333	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
PIPE	8	10	24,0000	,6870	0,0000	0,0000	0,0000	28,7500
RUN	8	10	4,1667	0,0000	0,0000	0,0000	0,0000	0,0000
SECTION	0	0	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

GENERATED NODAL DATA

NODE NUMBER	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES X	Y	Z	T
1	1	1	1	1	1	1	0.000	0.000	0.000	0.000
2	0	0	0	0	0	0	99.996	0.000	0.000	0.000
3	0	0	0	0	0	0	199.992	0.000	0.000	0.000
4	0	0	0	0	0	0	199.996	0.000	0.000	0.000
5	0	0	0	0	0	0	225.452	-10.544	0.000	0.000
6	0	0	0	0	0	0	225.452	-10.544	0.000	0.000
7	0	0	0	0	0	0	300.452	-85.544	0.000	0.000
8	0	0	0	0	0	0	300.453	-85.545	0.000	0.000
9	0	0	0	0	0	0	325.909	-96.089	0.000	0.000
10	0	0	0	0	0	0	325.913	-96.089	0.000	0.000
11	0	1	0	0	0	0	375.917	-96.089	0.000	0.000
12	0	0	0	0	0	0	425.921	-96.089	0.000	0.000
13	0	0	0	0	0	0	425.921	-96.089	69.984	0.000
14	0	0	0	0	0	0	425.921	-96.089	69.996	0.000
15	0	0	0	0	0	0	407.921	-96.089	87.996	0.000
16	0	0	0	0	0	0	407.909	-96.089	87.996	0.000
17	0	0	0	0	0	0	337.925	-96.089	87.996	0.000
18	0	1	0	0	0	0	267.929	-96.089	87.996	0.000
19	0	1	0	0	0	0	475.925	-96.089	0.000	0.000
20	0	0	0	0	0	0	557.921	-96.089	0.000	0.000

ORIGINAL LABELING = BANDWIDTH 7 PROFILE 25
** FINAL LABELING = BANDWIDTH 2 PROFILE 22

TMRPIPE ANALYSIS EX. 1 PIPDYNE MANUAL EIGENVALUE EXTRACTION

C O N T R O L   I N F O R M A T I O N

```
NUMBER OF NODAL POINTS     =   20
NUMBER OF ELEMENT TYPES    =    1
NUMBER OF LOAD CASES       =    0
NUMBER OF FREQUENCIES      =    5
ANALYSIS CODE (NDYN)       =    1
  EQ.0,  STATIC
  EQ.1,  MODAL EXTRACTION
  EQ.2,  FORCED RESPONSE
  EQ.3,  RESPONSE SPECTRUM
  EQ.4,  DIRECT INTEGRATION
SOLUTION MODE (MODEX)      =    0
  EQ.0,  EXECUTION
  EQ.1,  DATA CHECK
NUMBER OF SUBSPACE
ITERATION VECTORS (NAD)    =    0
EQUATIONS PER BLOCK        =    0
TAPE10 SAVE FLAG (N10SV)   =    0
```

NODAL POINT INPUT DATA

NODES SAP	TMR	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES X	Y	Z		T
1	14	0	1	0	0	0	0	267.929	-96.089	87.996	0	0.000
2	13	0	0	0	0	0	0	337.925	-96.089	87.996	0	0.000
3	112	0	0	0	0	0	0	407.909	-96.089	87.996	0	0.000
4	11	0	0	0	0	0	0	407.921	-96.089	87.996	0	0.000
5	12	0	0	0	0	0	0	557.921	-96.089	0.000	0	0.000
6	9	0	0	0	0	0	0	425.921	-96.089	69.996	0	0.000
7	10	0	1	0	0	0	0	475.925	-96.089	0.000	0	0.000
8	88	0	0	0	0	0	0	425.921	-96.089	69.984	0	0.000
9	8	0	0	0	0	0	0	425.921	-96.089	0.000	0	0.000
10	7	0	1	0	0	0	0	375.917	-96.089	0.000	0	0.000
11	62	0	0	0	0	0	0	325.913	-96.089	0.000	0	0.000
12	6	0	0	0	0	0	0	325.909	-96.089	0.000	0	0.000
13	5	0	0	0	0	0	0	300.453	-85.545	0.000	0	0.000
14	48	0	0	0	0	0	0	300.452	-85.544	0.000	0	0.000
15	42	0	0	0	0	0	0	225.452	-10.544	0.000	0	0.000
16	4	0	0	0	0	0	0	225.452	-10.544	0.000	0	0.000
17	3	0	0	0	0	0	0	199.996	0.000	0.000	0	0.000
18	28	0	0	0	0	0	0	199.992	0.000	0.000	0	0.000
19	2	0	0	0	0	0	0	99.996	0.000	0.000	0	0.000
20	1	1	1	1	1	1	1	0.000	0.000	0.000	0	0.000

GENERATED NODAL DATA

NODES SAP	TMR	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES X	Y	Z	T
1	14	0	1	0	0	0	0	267.929	-96.089	87.996	0.000
2	13	0	0	0	0	0	0	337.925	-96.089	87.996	0.000
3	112	0	0	0	0	0	0	407.909	-96.089	87.996	0.000
4	11	0	0	0	0	0	0	407.921	-96.089	87.996	0.000
5	12	0	0	0	0	0	0	557.921	-96.089	0.000	0.000
6	9	0	0	0	0	0	0	425.921	-96.089	69.996	0.000
7	10	0	1	0	0	0	0	475.925	-96.089	0.000	0.000
8	88	0	0	0	0	0	0	425.921	-96.089	69.984	0.000
9	8	0	0	0	0	0	0	425.921	-96.089	0.000	0.000

BANDWIDTH MINIMIZATION PHASE

NODAL POINT INPUT DATA

NODE	BOUNDARY CONDITION CODES						NODAL POINT COORDINATES				
NUMBER	X	Y	Z	XX	YY	ZZ	X	Y	Z		T
1	1	1	1	1	1	1	0.000	0.000	0.000	0	0.000
2	0	0	0	0	0	0	99.996	0.000	0.000	0	0.000
3	0	0	0	0	0	0	199.992	0.000	0.000	0	0.000
4	0	0	0	0	0	0	199.996	0.000	0.000	0	0.000
5	0	0	0	0	0	0	225.452	-10.544	0.000	0	0.000
6	0	0	0	0	0	0	225.452	-10.544	0.000	0	0.000
7	0	0	0	0	0	0	300.452	-85.544	0.000	0	0.000
8	0	0	0	0	0	0	300.453	-85.545	0.000	0	0.000
9	0	0	0	0	0	0	325.909	-96.089	0.000	0	0.000
10	0	0	0	0	0	0	325.913	-96.089	0.000	0	0.000
11	0	1	0	0	0	0	375.917	-96.089	0.000	0	0.000
12	0	0	0	0	0	0	425.921	-96.089	0.000	0	0.000
13	0	0	0	0	0	0	425.921	-96.089	69.984	0	0.000
14	0	0	0	0	0	0	425.921	-96.089	69.996	0	0.000
15	0	0	0	0	0	0	407.921	-96.089	87.996	0	0.000
16	0	0	0	0	0	0	407.909	-96.089	87.996	0	0.000
17	0	0	0	0	0	0	337.925	-96.089	87.996	0	0.000
18	0	1	0	0	0	0	267.929	-96.089	87.996	0	0.000
19	0	1	0	0	0	0	475.925	-96.089	0.000	0	0.000
20	0	0	0	0	0	0	557.921	-96.089	0.000	0	0.000

RESULTS OF NODE RENUMBERING:

OLD NODE	NEW NODE	NEW NODE	OLD NODE
1	20	1	18
2	19	2	17
3	18	3	16
4	17	4	15
5	16	5	20
6	15	6	14
7	14	7	19
8	13	8	13
9	12	9	12
10	11	10	11
11	10	11	10
12	9	12	9
13	8	13	8
14	6	14	7
15	4	15	6
16	3	16	5
17	2	17	4
18	1	18	3
19	7	19	2
20	5	20	1

10	7	0	1	0	0	0	0	375.917	-96.089	0.000	0.000
11	62	0	0	0	0	0	0	325.913	-96.089	0.000	0.000
12	6	0	0	0	0	0	0	325.909	-96.089	0.000	0.000
13	5	0	0	0	0	0	0	300.453	-85.545	0.000	0.000
14	48	0	0	0	0	0	0	300.452	-85.544	0.000	0.000
15	42	0	0	0	0	0	0	225.452	-10.544	0.000	0.000
16	4	0	0	0	0	0	0	225.452	-10.544	0.000	0.000
17	3	0	0	0	0	0	0	199.996	0.000	0.000	0.000
18	28	0	0	0	0	0	0	199.992	0.000	0.000	0.000
19	2	0	0	0	0	0	0	99.996	0.000	0.000	0.000
20	1	1	1	1	1	1	1	0.000	0.000	0.000	0.000

EQUATION NUMBERS

N	X	Y	Z	XX	YY	ZZ
1	1	0	2	3	4	5
2	6	7	8	9	10	11
3	12	13	14	15	16	17
4	18	19	20	21	22	23
5	24	25	26	27	28	29
6	30	31	32	33	34	35
7	36	0	37	38	39	40
8	41	42	43	44	45	46
9	47	48	49	50	51	52
10	53	0	54	55	56	57
11	58	59	60	61	62	63
12	64	65	66	67	68	69
13	70	71	72	73	74	75
14	76	77	78	79	80	81
15	82	83	84	85	86	87
16	88	89	90	91	92	93
17	94	95	96	97	98	99
18	100	101	102	103	104	105
19	106	107	108	109	110	111
20	0	0	0	0	0	0

P I P E   E L E M E N T   I N P U T   D A T A

C O N T R O L   I N F O R M A T I O N

NUMBER OF PIPE ELEMENTS = 19

NUMBER OF MATERIAL SETS = 1

MAXIMUM NUMBER OF MATERIAL
TEMPERATURE INPUT POINTS = 1

NUMBER OF SECTION PROPERTY SETS = 3

NUMBER OF BRANCH POINT NODES = 0

MAXIMUM NUMBER OF TANGENTS
COMMON TO A BRANCH POINT = 4

FLAG FOR NEGLECTING AXIAL
DEFORMATIONS IN BEND ELEMENTS = 0
(EQ.1, NEGLECT)

M A T E R I A L   P R O P E R T Y   T A B L E S

MATERIAL NUMBER = (1)
NUMBER OF
TEMPERATURE POINTS = (1)
IDENTIFICATION = ( )

POINT NUMBER	TEMPERATURE	YOUNG*S MODULUS	POISSON*S RATIO	THERMAL EXPANSION
1	0.00	29000000.0	.300	0.

[illegible]

SECTION PROPERTY TABLE

SECTION NUMBER	OUTSIDE DIAMETER	WALL THICKNESS	SHAPE FACTOR FOR SHEAR	WEIGHT/ UNIT LENGTH	MASS/ UNIT LENGTH	DESCRIPTION
1	24.000	.6870	0.0000	.2875E+02	.7440E-01	
2	12.750	.4060	0.0000	.8500E+01	.2200E-01	
3	24.000	.6870	0.0000	.2875E+02	.7440E-01	

ELEMENT LOAD CASE MULTIPLIERS

	CASE A	CASE B	CASE C	CASE D
X-DIRECTION GRAVITY	0.000	0.000	0.000	0.000
Y-DIRECTION GRAVITY	0.000	0.000	0.000	0.000
Z-DIRECTION GRAVITY	0.000	0.000	0.000	0.000
THERMAL DISTORTION	0.000	0.000	0.000	0.000
PRESSURE DISTORTION	0.000	0.000	0.000	0.000

[illegible]

[illegible]

[illegible]

[illegible]

P I P E   E L E M E N T   I N P U T   D A T A

ELEMENT NUMBER	ELEMENT TYPE	NODE -I	NODE -J	MATL. NUMBER	SECTION NUMBER	REFERENCE TEMPERATURE (BEND RADIUS)	INTERNAL PRESSURE (THIRD POINT)	DIRECTION COSINES A(YX) (X3-ORDINATE)	A(YY) (Y3-ORDINATE)	A(YZ) (Z3-ORDINATE)	NODE INCREMENT (WALL FRACTION)	INPUT TAG
1	TANGENT	1	2	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
2	TANGENT	2	28	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
3	TANGENT	28	3	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
4	BEND	3	4	1	1	0.00	0.00					IC
						(36.000)	(TI)	(214.908)	(0.000)	(0.000)	(.1000)	
5	TANGENT	4	42	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
6	TANGENT	42	48	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
7	TANGENT	48	5	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
8	BEND	5	6	1	1	0.00	0.00					IC
						(36.000)	(TI)	(310.997)	(-96.089)	(0.000)	(.1000)	
9	TANGENT	6	62	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
10	TANGENT	62	7	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
11	TANGENT	7	8	1	1	0.00	0.00	0.0000	0.0000	0.0000	1	II
12	TANGENT	8	88	1	2	0.00	0.00	0.0000	0.0000	0.0000	1	II
13	TANGENT	88	9	1	2	0.00	0.00	0.0000	0.0000	0.0000	1	II
14	BEND	9	11	1	2	0.00	0.00					IC
						(18.000)	(TI)	(425.921)	(-96.089)	(87.996)	(.1000)	
15	TANGENT	11	112	1	2	0.00	0.00	0.0000	0.0000	0.0000	1	II
16	TANGENT	112	13	1	2	0.00	0.00	0.0000	0.0000	0.0000	1	II
17	TANGENT	13	14	1	2	0.00	0.00	0.0000	0.0000	0.0000	1	II
18	TANGENT	8	10	1	3	0.00	0.00	0.0000	0.0000	0.0000	1	II
19	TANGENT	10	12	1	3	0.00	0.00	0.0000	0.0000	0.0000	1	II

NUMBER OF EQUATIONS PER BLOCK= 111 FOR 5 MODES, MTOT= 130999

NO. OF MODES FOR THIS DYNAMIC ANALYSIS IS 5 MODES

E Q U A T I O N   P A R A M E T E R S

TOTAL NUMBER OF EQUATIONS	=	111
BANDWIDTH	=	18
NUMBER OF EQUATIONS IN A BLOCK	=	111
NUMBER OF BLOCKS	=	1

NODAL LOADS (STATIC) OR MASSES (DYNAMIC)

NODE SAP	NODE THR	LOAD CASE	X-AXIS FORCE	Y-AXIS FORCE	Z-AXIS FORCE	X-AXIS MOMENT	Y-AXIS MOMENT	Z-AXIS MOMENT
19	2	0	.18100E+02	.18100E+02	.18100E+02	0.	0.	0.

STRUCTURE LOAD CASE	ELEMENT LOAD MULTIPLIERS A	B	C	D
1	0.000	0.000	0.000	0.000

E I G E N V A L U E   A N A L Y S I S

DETERMINANT SEARCH SOLUTION IS CARRIED OUT

CONTROL INFORMATION

```
    FLAG FOR ADDITIONAL PRINTING  =     0
      EQ.0, SUPPRESS
      EQ.1, PRINT

    STURM SEQUENCE CHECK FLAG (*) =     0
      EQ.0, PERFORM CHECK
      EQ.1, PASS

    MAXIMUM ITERATION CYCLES (*)  =    16

    CONVERGENCE TOLERANCE (*)     =      .1000E-04

    CUT-OFF FREQUENCY (CPS)       =      .1000E+09

    NUMBER OF STARTING ITERATION
    VECTORS TO BE READ FROM
    TAPE10 (*)                    =     0

    (*)  APPLICABLE TO SUBSPACE
         ITERATION SOLUTIONS ONLY
```

SOLUTION IS SOUGHT FOR FOLLOWING EIGENPROBLEM

```
NUMBER OF EQUATIONS                 =  111

HALF BANDWIDTH OF STIFFNESS MATRIX =   18

NUMBER OF EQUATION BLOCKS           =    1

NUMBER OF EQUATIONS PER BLOCK       =  111

NUMBER OF EIGENVALUES REQUIRED      =    5
```

WE SOLVED FOR THE FOLLOWING EIGENVALUES

```
   .834105423892E+02   .767888060010E+03   .252450034657E+04   .421925653169E+04   .554695158029E+04
```

THE FOLLOWING ARE PHYSICAL ERROR BOUNDS ON THE EIGENPAIRS

```
   .298024442345E-04   .171296069216E-05   .135749892439E-05   .232579210383E-05   .188696861270E-05
```

PRINT OF FREQUENCIES

MODE NUMBER	CIRCULAR FREQUENCY (RAD/SEC)	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	.9133E+01	.1454E+01	.6880E+00
2	.2771E+02	.4410E+01	.2267E+00
3	.5024E+02	.7997E+01	.1251E+00
4	.6496E+02	.1034E+02	.9673E-01
5	.7448E+02	.1185E+02	.8436E-01

PRINT OF EIGENVECTORS

N O D E   D I S P L A C E M E N T S / R O T A T I O N S

NODE NUMBER SAP	TMR	EIGEN-VECTOR	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
20	1	1	0.	0.	0.	0.	0.	0.
		2	0.	0.	0.	0.	0.	0.
		3	0.	0.	0.	0.	0.	0.
		4	0.	0.	0.	0.	0.	0.
		5	0.	0.	0.	0.	0.	0.
19	2	1	.15676E-05	-.50471E-04	-.88623E-02	.49131E-04	.16615E-03	-.78154E-06
		2	-.34476E-04	.11464E-02	-.60632E-02	.98884E-04	.96243E-04	.17457E-04
		3	-.18361E-03	.77666E-02	-.50461E-01	.27663E-03	.79187E-03	.11442E-03
		4	.11782E-02	-.66914E-01	-.22693E-01	-.82236E-04	.34333E-03	-.95373E-03
		5	.21342E-03	-.14943E-01	.57926E-01	.10319E-02	-.87229E-03	-.20665E-03
18	28	1	.31349E-05	-.13122E-03	-.32025E-01	.98262E-04	.28646E-03	-.60826E-06
		2	-.68907E-04	.29154E-02	-.16636E-01	.19777E-03	.93035E-04	.12989E-04
		3	-.36641E-03	.19018E-01	-.13862E+00	.55326E-03	.83178E-03	.81669E-04
		4	.23477E-02	-.15772E+00	-.59665E-01	-.16447E-03	.34407E-03	-.65035E-03
		5	.42476E-03	-.33924E-01	.15363E+00	.20638E-02	-.95193E-03	-.13142E-03
17	3	1	.31350E-05	-.13123E-03	-.32026E-01	.98264E-04	.28647E-03	-.60823E-06
		2	-.68908E-04	.29154E-02	-.16636E-01	.19777E-03	.93033E-04	.12988E-04
		3	-.36642E-03	.19018E-01	-.13862E+00	.55327E-03	.83177E-03	.81665E-04
		4	.23477E-02	-.15772E+00	-.59666E-01	-.16448E-03	.34406E-03	-.65032E-03
		5	.42477E-03	-.33925E-01	.15364E+00	.20639E-02	-.95193E-03	-.13141E-03
16	4	1	.96442E-05	-.12558E-03	-.43812E-01	.18880E-03	.51158E-03	.11657E-05
		2	-.22546E-03	.27645E-02	-.20057E-01	.20748E-03	.11830E-04	-.27241E-04
		3	-.13184E-02	.18094E-01	-.15865E+00	.47298E-03	.30423E-03	-.16789E-03
		4	.96849E-02	-.15053E+00	-.62304E-01	-.30451E-03	.34503E-04	.13124E-02
		5	.20603E-02	-.32175E-01	.14453E+00	.27443E-02	-.16855E-03	.28659E-03
15	42	1	.96445E-05	-.12558E-03	-.43812E-01	.18880E-03	.51158E-03	.11657E-05
		2	-.22546E-03	.27644E-02	-.20057E-01	.20748E-03	.11830E-04	-.27241E-04
		3	-.13184E-02	.18094E-01	-.15865E+00	.47298E-03	.30422E-03	-.16789E-03
		4	.96852E-02	-.15053E+00	-.62304E-01	-.30451E-03	.34502E-04	.13124E-02
		5	.20604E-02	-.32175E-01	.14453E+00	.27443E-02	-.16855E-03	.28659E-03
14	48	1	.11289E-03	-.24680E-04	-.10044E+00	.19887E-03	.59553E-03	.13070E-05
		2	-.26149E-02	.42489E-03	-.35010E-01	.26887E-03	-.11849E-03	-.29992E-04
		3	-.16096E-01	.35637E-02	-.20577E+00	.64929E-03	-.24959E-03	-.18804E-03
		4	.12565E+00	-.35974E-01	-.34347E-01	-.35942E-03	-.10362E-03	.14982E-02
		5	.27203E-01	-.72474E-02	-.77147E-01	.35195E-02	-.34265E-03	.32457E-03
13	5	1	.11289E-03	-.24680E-04	-.10044E+00	.19887E-03	.59553E-03	.13070E-05
		2	-.26149E-02	.42489E-03	-.35010E-01	.26887E-03	-.11849E-03	-.29992E-04
		3	-.16096E-01	.35636E-02	-.20577E+00	.64929E-03	-.24959E-03	-.18804E-03
		4	.12565E+00	-.35974E-01	-.34347E-01	-.35942E-03	-.10362E-03	.14982E-02
		5	.27203E-01	-.72473E-02	-.77147E-01	.35195E-02	-.34265E-03	.32457E-03
12	6	1	.12334E-03	-.62716E-05	-.11931E+00	.23524E-03	.70472E-03	.21513E-06
		2	-.28479E-02	.26014E-04	-.30829E-01	.17551E-03	-.42017E-03	-.28725E-05
		3	-.17604E-01	.83601E-03	-.19065E+00	.29111E-03	-.13669E-02	-.31369E-04
		4	.13807E+00	-.12292E-01	-.24140E-01	-.46105E-03	-.33703E-03	.36243E-03
		5	.29872E-01	-.21445E-02	-.10560E+00	.36969E-02	-.57327E-03	.70730E-04
11	62	1	.12334E-03	-.62708E-05	-.11931E+00	.23524E-03	.70472E-03	.21511E-06
		2	-.28479E-02	.26005E-04	-.30827E-01	.17551E-03	-.42018E-03	-.28721E-05
		3	-.17604E-01	.83589E-03	-.19065E+00	.29111E-03	-.13670E-02	-.31367E-04

		4	.13807E+00	-.12290E-01	-.24139E-01	-.46105E-03	-.33704E-03	.56241E-03
		5	.29872E-01	-.21442E-02	-.10560E+00	.36969E-02	-.57328E-03	.70725E-04
10	7	1	.12412E-03	0.	-.15512E+00	.23389E-03	.72334E-03	.14105E-06
		2	-.28645E-02	0.	-.79394E-02	.17566E-03	-.50190E-03	-.24391E-06
		3	-.17683E-01	0.	-.11594E+00	.29739E-03	-.16005E-02	-.10008E-04
		4	.13850E+00	0.	-.63153E-02	-.48493E-03	-.36046E-03	.14739E-03
		5	.29933E-01	0.	-.73424E-01	.39839E-02	-.71897E-03	.11785E-04
9	8	1	.12490E-03	.63932E-05	-.19163E+00	.23253E-03	.73392E-03	-.50221E-06
		2	-.28808E-02	-.53845E-05	.19403E-01	.17581E-03	-.59810E-03	-.37670E-06
		3	-.17757E-01	-.19506E-03	-.30736E-01	.30367E-03	-.17741E-02	-.50630E-06
		4	.13885E+00	.26176E-02	.11820E-01	-.50881E-03	-.34836E-03	-.12602E-05
		5	.29972E-01	-.87153E-03	-.33716E-01	.42710E-02	-.85734E-03	-.10023E-04
8	88	1	.51132E-01	-.15820E-01	-.19164E+00	.22245E-03	.72113E-03	-.44427E-04
		2	-.88414E-01	-.12345E-01	.19242E-01	.17630E-03	-.17939E-02	-.33639E-04
		3	-.13594E+00	-.23440E-01	-.30609E-01	.34640E-03	-.14181E-02	-.58476E-04
		4	.15471E+00	.45843E-01	.11781E-01	-.67323E-03	.45280E-03	.10142E-03
		5	-.31722E-01	-.39152E+00	-.33718E-01	.62570E-02	-.79956E-03	-.81520E-03
7	10	1	.12490E-03	0.	-.22851E+00	.23253E-03	.73906E-03	-.10791E-06
		2	-.28814E-02	0.	.49807E-01	.17581E-03	-.61317E-03	.13405E-06
		3	-.17769E-01	0.	.61175E-01	.30367E-03	-.18744E-02	.41889E-05
		4	.13901E+00	0.	.31005E-01	-.50881E-03	-.40212E-03	-.56270E-04
		5	.30018E-01	0.	.11912E-01	.42710E-02	-.94616E-03	.19442E-04
6	9	1	.51141E-01	-.15823E-01	-.19164E+00	.22245E-03	.72113E-03	-.44435E-04
		2	-.88435E-01	-.12347E-01	.19242E-01	.17630E-03	-.17941E-02	-.33645E-04
		3	-.13595E+00	-.23444E-01	-.30609E-01	.34640E-03	-.14179E-02	-.58486E-04
		4	.15471E+00	.45851E-01	.11781E-01	-.67324E-03	.45279E-03	.10144E-03
		5	-.31732E-01	-.39160E+00	-.33718E-01	.62571E-02	-.79951E-03	-.81534E-03
5	12	1	.12490E-03	-.88532E-05	-.28927E+00	.23253E-03	.74156E-03	-.10799E-06
		2	-.28818E-02	.11047E-04	.10059E+00	.17581E-03	-.62115E-03	.13492E-06
		3	-.17777E-01	.34924E-03	.21848E+00	.30367E-03	-.19314E-02	.42800E-05
		4	.13911E+00	-.47449E-02	.65793E-01	-.50881E-03	-.43081E-03	-.58339E-04
		5	.30046E-01	.16542E-02	.92862E-01	.42710E-02	-.99940E-03	.20391E-04
4	11	1	.63680E-01	-.18207E-01	-.17943E+00	.18814E-03	.65598E-03	-.10942E-03
		2	-.14430E+00	-.14318E-01	-.53466E-01	.15168E-03	-.51945E-02	-.84235E-04
		3	-.14225E+00	-.27712E-01	-.21694E-01	.31065E-03	.15960E-02	-.15377E-03
		4	.15965E+00	.54789E-01	.12234E-01	-.62514E-03	-.36421E-03	.28547E-03
		5	-.38291E-01	-.48108E+00	-.33782E-01	.60027E-02	.48769E-03	-.23812E-02
3	112	1	.63680E-01	-.18206E-01	-.17943E+00	.18814E-03	.65598E-03	-.10943E-03
		2	-.14430E+00	-.14317E-01	-.53529E-01	.15168E-03	-.51946E-02	-.84240E-04
		3	-.14225E+00	-.27710E-01	-.21675E-01	.31065E-03	.15961E-02	-.15378E-03
		4	.15965E+00	.54786E-01	.12230E-01	-.62514E-03	-.36426E-03	.28549E-03
		5	-.38291E-01	-.48106E+00	-.33776E-01	.60027E-02	.48776E-03	-.23814E-02
2	13	1	.63682E-01	-.96414E-02	-.13395E+00	.18814E-03	.64633E-03	-.13227E-03
		2	-.14434E+00	-.76558E-02	-.44126E+00	.15168E-03	-.57664E-02	-.10409E-03
		3	-.14237E+00	-.15195E-01	.11405E+00	.31065E-03	.21691E-02	-.20183E-03
		4	.15989E+00	.30798E-01	-.22604E-01	-.62514E-03	-.58881E-03	.39979E-03
		5	-.38367E-01	-.27566E+00	.11732E-01	.60027E-02	.76649E-03	-.35149E-02
1	14	1	.63683E-01	0.	-.88788E-01	.18814E-03	.64472E-03	-.14001E-03
		2	-.14435E+00	0.	-.85190E+00	.15168E-03	-.59081E-02	-.11156E-03
		3	-.14242E+00	0.	.27327E+00	.31065E-03	.23185E-02	-.22339E-03
		4	.15997E+00	0.	-.66842E-01	-.62514E-03	-.64990E-03	.45666E-03
		5	-.38392E-01	0.	.69517E-01	.60027E-02	.85002E-03	-.41135E-02

E I G E N S O L U T I O N   T I M E   L O G

```
EIGENSOLUTION =     .35
PRINTING      =     .04
```

O V E R A L L   T I M E   L O G

NODAL POINT INPUT	=	.37
ELEMENT STIFFNESS FORMATION	=	.19
NODAL LOAD INPUT	=	.01
TOTAL STIFFNESS FORMATION	=	.03
STATIC ANALYSIS	=	0.00
EIGENVALUE EXTRACTION	=	.40
FORCED RESPONSE ANALYSIS	=	0.00
RESPONSE SPECTRUM ANALYSIS	=	0.00
STEP-BY-STEP INTEGRATION	=	0.00
TOTAL SOLUTION TIME	=	.99

[illegible]

THRPIPE ANALYSIS EXAMPLE 1 PIPDYN MANUAL X-Y SHOCK

SAVE		0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DIRECTION		0	4	1.0000	.6667	0.0000	0.0000	0.0000	0.0000
FREQUENCY		1	6	.3333	.5000	.5555	.7143	.8333	1.1110
FREQUENCY		7	12	1.4290	1.7860	3.3330	3.8460	4.5450	5.0000
FREQUENCY		13	15	5.5550	10.0000	50.0000	0.0000	0.0000	0.0000
G	X	1	6	.0560	.0919	.1029	.1369	.1629	.2228
G	X	7	12	.2857	.3478	.5274	.5445	.5505	.5476
G	X	13	15	.5375	.3856	.1199	0.0000	0.0000	0.0000
ENDJOB									

THRPIPE ANALYSIS EXAMPLE 1 PIPDYN MANUAL X-Y SHOCK

C O N T R O L   I N F O R M A T I O N

```
     NUMBER OF NODAL POINTS    =   20
     NUMBER OF ELEMENT TYPES   =    1
     NUMBER OF LOAD CASES      =    0
     NUMBER OF FREQUENCIES     =    5
     ANALYSIS CODE (NDYN)      =   -3
       EQ.0,  STATIC
       EQ.1,  MODAL EXTRACTION
       EQ.2,  FORCED RESPONSE
       EQ.3,  RESPONSE SPECTRUM
       EQ.4,  DIRECT INTEGRATION
     SOLUTION MODE (MODEX)     =    0
       EQ.0,  EXECUTION
       EQ.1,  DATA CHECK
     NUMBER OF SUBSPACE
     ITERATION VECTORS (NAD)   =    0
     EQUATIONS PER BLOCK       =    0
     TAPE10 SAVE FLAG (N10SV)  =    0
```

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

DIRECTION FACTORS

X = 1.0000   Y = .6670   Z = 0.0000

INDICATOR FOR DISPLACEMENT OR ACCELERATION SPECTRUM = 1

EQ.0 DISPLACEMENT
EQ.1 ACCELERATION

MODAL PARTICIPATION FACTORS

MODE	X-DIRECTION	Y-DIRECTION	Z-DIRECTION
1	.2742E+00	-.5431E-01	-.5565E+01
2	-.6552E+00	.1861E-01	-.1363E+01
3	-.1061E+01	.3213E+00	-.3600E+01
4	.4075E+01	-.3276E+01	-.1095E+01
5	.5614E+00	-.2113E+01	.2158E+01

SPECTRUM TABLE (TMRPIPE ANALYSIS EXAMPLE 1 PIPDYN MANUAL X-Y SHOCK)

NUMBER OF POINTS = 15
SCALE FACTOR = .10000E+01

INPUT POINT	PERIOD	SPECTRUM VALUE
1	.2000E-01	.4633E+02
2	.1000E+00	.1490E+03
3	.1800E+00	.2077E+03
4	.2000E+00	.2116E+03
5	.2200E+00	.2127E+03
6	.2600E+00	.2104E+03
7	.3000E+00	.2038E+03
8	.5600E+00	.1344E+03
9	.7000E+00	.1104E+03
10	.9000E+00	.8609E+02
11	.1200E+01	.6295E+02
12	.1400E+01	.5290E+02
13	.1800E+01	.3976E+02
14	.2000E+01	.3551E+02
15	.3000E+01	.2164E+02

NODE DISPLACEMENTS/ROTATIONS

NODE NUMBER SAP	NODE NUMBER TMR	MODE NUMBER	X-TRANSLATION	Y-TRANSLATION	Z-TRANSLATION	X-ROTATION	Y-ROTATION	Z-ROTATION
20	1	1	0.	0.	0.	0.	0.	0.
		2	0.	0.	0.	0.	0.	0.
		3	0.	0.	0.	0.	0.	0.
		4	0.	0.	0.	0.	0.	0.
		5	0.	0.	0.	0.	0.	0.
MAXIMUM VALUE			0.	0.	0.	0.	0.	0.
ABSOLUTE SUM			0.	0.	0.	0.	0.	0.
SQRT,SUM OF SQ			0.	0.	0.	0.	0.	0.
CLSLY SP MODES			0.	0.	0.	0.	0.	0.
19	2	1	.65613E-06	-.21125E-04	-.37095E-02	.20565E-04	.69545E-04	-.32713E-06
		2	-.63638E-05	.21161E-03	-.11192E-02	.18252E-04	.17765E-04	.32222E-05
		3	-.15529E-04	.65686E-03	-.42677E-02	.23396E-04	.66972E-04	.96769E-05
		4	.25312E-03	-.14375E-01	-.48753E-02	-.17667E-04	.73758E-04	-.20489E-03
		5	.97774E-05	-.68457E-03	.26538E-02	.47275E-04	-.39962E-04	-.94671E-05
MAXIMUM VALUE			.25312E-03	.14375E-01	.48753E-02	.47275E-04	.73758E-04	.20489E-03
ABSOLUTE SUM			.28544E-03	.15950E-01	.16625E-01	.12716E-03	.26800E-03	.22759E-03
SQRT,SUM OF SQ			.25386E-03	.14408E-01	.80023E-02	.62052E-04	.12913E-03	.20536E-03
CLSLY SP MODES			.25386E-03	.14408E-01	.80023E-02	.62052E-04	.12913E-03	.20536E-03
18	28	1	.13122E-05	-.54926E-04	-.13405E-01	.41129E-04	.11990E-03	-.25460E-06
		2	-.12719E-04	.53812E-03	-.30707E-02	.36505E-04	.17173E-04	.23975E-05
		3	-.30989E-04	.16084E-02	-.11724E-01	.46792E-04	.70348E-04	.69071E-05
		4	.50436E-03	-.33884E-01	-.12818E-01	-.35334E-04	.73917E-04	-.13972E-03
		5	.19460E-04	-.15542E-02	.70384E-02	.94551E-04	-.43611E-04	-.60209E-05
MAXIMUM VALUE			.50436E-03	.33884E-01	.13405E-01	.94551E-04	.11990E-03	.13972E-03
ABSOLUTE SUM			.56884E-03	.37639E-01	.48055E-01	.25431E-03	.32495E-03	.15530E-03
SQRT,SUM OF SQ			.50585E-03	.33962E-01	.23246E-01	.12410E-03	.16428E-03	.14004E-03
CLSLY SP MODES			.50585E-03	.33962E-01	.23246E-01	.12410E-03	.16428E-03	.14004E-03
17	3	1	.13122E-05	-.54928E-04	-.13405E-01	.41130E-04	.11991E-03	-.25459E-06
		2	-.12719E-04	.53814E-03	-.30708E-02	.36505E-04	.17172E-04	.23974E-05
		3	-.30990E-04	.16084E-02	-.11724E-01	.46793E-04	.70347E-04	.69068E-05
		4	.50437E-03	-.33884E-01	-.12818E-01	-.35335E-04	.73916E-04	-.13971E-03
		5	.19460E-04	-.15542E-02	.70386E-02	.94553E-04	-.43611E-04	-.60206E-05
MAXIMUM VALUE			.50437E-03	.33884E-01	.13405E-01	.94553E-04	.11991E-03	.13971E-03
ABSOLUTE SUM			.56885E-03	.37640E-01	.48057E-01	.25432E-03	.32495E-03	.15529E-03
SQRT,SUM OF SQ			.50586E-03	.33962E-01	.23247E-01	.12411E-03	.16428E-03	.14003E-03
CLSLY SP MODES			.50586E-03	.33962E-01	.23247E-01	.12411E-03	.16428E-03	.14003E-03
16	4	1	.40368E-05	-.52565E-04	-.18338E-01	.79024E-04	.21413E-03	.48791E-06
		2	-.41615E-04	.51027E-03	-.37022E-02	.38298E-04	.21837E-05	-.50283E-05
		3	-.11150E-03	.15303E-02	-.13418E-01	.40002E-04	.25730E-04	-.14199E-04
		4	.20806E-02	-.32339E-01	-.13385E-01	-.65419E-04	.74123E-05	.28195E-03
		5	.94390E-04	-.14740E-02	.66212E-02	.12573E-03	-.77218E-05	.13130E-04
MAXIMUM VALUE			.20806E-02	.32339E-01	.18338E-01	.12573E-03	.21413E-03	.28195E-03
ABSOLUTE SUM			.23322E-02	.35907E-01	.55464E-01	.34847E-03	.25718E-03	.31479E-03
SQRT,SUM OF SQ			.20862E-02	.32413E-01	.27441E-01	.17146E-03	.21595E-03	.28265E-03
CLSLY SP MODES			.20862E-02	.32413E-01	.27441E-01	.17146E-03	.21595E-03	.28265E-03
15	42	1	.40369E-05	-.52565E-04	-.18338E-01	.79024E-04	.21413E-03	.48791E-06
		2	-.41616E-04	.51027E-03	-.37022E-02	.38298E-04	.21837E-05	-.50283E-05

		3	-.11151E-03	.15303E-02	-.13416E-01	.40002E-04	.25730E-04	-.14199E-04
		4	.20807E-02	-.32339E-01	-.13385E-01	-.65419E-04	.74123E-05	.28195E-03
		5	.94393E-04	-.14740E-02	.66212E-02	.12573E-03	-.77218E-05	.13130E-04
MAXIMUM VALUE			.20807E-02	.32339E-01	.18338E-01	.12573E-03	.21413E-03	.28195E-03
ABSOLUTE SUM			.23323E-02	.35907E-01	.55464E-01	.34847E-03	.25718E-03	.31479E-03
SQRT,SUM OF SQ			.20862E-02	.32413E-01	.27441E-01	.17146E-03	.21595E-03	.28265E-03
CLSLY SP MODES			.20862E-02	.32413E-01	.27441E-01	.17146E-03	.21595E-03	.28265E-03
14	48	1	.47251E-04	-.10330E-04	-.42040E-01	.83241E-04	.24927E-03	.54707E-06
		2	-.48267E-03	.78428E-04	-.64623E-02	.49629E-04	-.21870E-04	-.55361E-05
		3	-.13613E-02	.30140E-03	-.17403E-01	.54913E-04	-.21109E-04	-.15904E-04
		4	.26994E-01	-.77284E-02	-.73789E-02	-.77216E-04	-.22260E-04	.32186E-03
		5	.12463E-02	-.33203E-03	-.35344E-02	.16124E-03	-.15698E-04	.14870E-04
MAXIMUM VALUE			.26994E-01	.77284E-02	.42040E-01	.16124E-03	.24927E-03	.32186E-03
ABSOLUTE SUM			.30131E-01	.84506E-02	.76819E-01	.42624E-03	.33021E-03	.35872E-03
SQRT,SUM OF SQ			.27061E-01	.77418E-02	.46679E-01	.21064E-03	.25259E-03	.32264E-03
CLSLY SP MODES			.27061E-01	.77418E-02	.46679E-01	.21064E-03	.25259E-03	.32264E-03
13	5	1	.47251E-04	-.10330E-04	-.42040E-01	.83241E-04	.24927E-03	.54707E-06
		2	-.48267E-03	.78427E-04	-.64623E-02	.49629E-04	-.21871E-04	-.55361E-05
		3	-.13613E-02	.30139E-03	-.17403E-01	.54914E-04	-.21109E-04	-.15904E-04
		4	.26994E-01	-.77284E-02	-.73789E-02	-.77216E-04	-.22260E-04	.32186E-03
		5	.12463E-02	-.33202E-03	-.35344E-02	.16124E-03	-.15698E-04	.14870E-04
MAXIMUM VALUE			.26994E-01	.77284E-02	.42040E-01	.16124E-03	.24927E-03	.32186E-03
ABSOLUTE SUM			.30131E-01	.84505E-02	.76819E-01	.42624E-03	.33021E-03	.35872E-03
SQRT,SUM OF SQ			.27061E-01	.77418E-02	.46679E-01	.21064E-03	.25259E-03	.32264E-03
CLSLY SP MODES			.27061E-01	.77418E-02	.46679E-01	.21064E-03	.25259E-03	.32264E-03
12	6	1	.51625E-04	-.26251E-05	-.49940E-01	.98464E-04	.29497E-03	.90047E-07
		2	-.52567E-03	.48018E-05	-.56905E-02	.32397E-04	-.77556E-04	-.53021E-06
		3	-.14888E-02	.70706E-04	-.16125E-01	.24620E-04	-.11561E-03	-.26530E-05
		4	.29663E-01	-.26407E-02	-.51862E-02	-.99049E-04	-.72406E-04	.77861E-04
		5	.13685E-02	-.98249E-04	-.48380E-02	.16937E-03	-.26263E-04	.32404E-05
MAXIMUM VALUE			.29663E-01	.26407E-02	.49940E-01	.16937E-03	.29497E-03	.77861E-04
ABSOLUTE SUM			.33097E-01	.28171E-02	.81779E-01	.42390E-03	.58681E-03	.84375E-04
SQRT,SUM OF SQ			.29736E-01	.26435E-02	.53260E-01	.22326E-03	.33514E-03	.77976E-04
CLSLY SP MODES			.29736E-01	.26435E-02	.53260E-01	.22326E-03	.33514E-03	.77976E-04
11	62	1	.51625E-04	-.26248E-05	-.49941E-01	.98464E-04	.29497E-03	.90040E-07
		2	-.52567E-03	.48000E-05	-.56902E-02	.32397E-04	-.77558E-04	-.53013E-06
		3	-.14888E-02	.70695E-04	-.16124E-01	.24620E-04	-.11561E-03	-.26528E-05
		4	.29663E-01	-.26404E-02	-.51858E-02	-.99049E-04	-.72407E-04	.77857E-04
		5	.13685E-02	-.98235E-04	-.48379E-02	.16937E-03	-.26264E-04	.32402E-05
MAXIMUM VALUE			.29663E-01	.26404E-02	.49941E-01	.16937E-03	.29497E-03	.77857E-04
ABSOLUTE SUM			.33097E-01	.28168E-02	.81779E-01	.42390E-03	.58681E-03	.84370E-04
SQRT,SUM OF SQ			.29736E-01	.26432E-02	.53261E-01	.22326E-03	.33515E-03	.77971E-04
CLSLY SP MODES			.29736E-01	.26432E-02	.53261E-01	.22326E-03	.33515E-03	.77971E-04
10	7	1	.51952E-04	0.	-.64926E-01	.97897E-04	.30277E-03	.59040E-07
		2	-.52874E-03	0.	-.14655E-02	.32424E-04	-.92641E-04	-.45021E-07
		3	-.14955E-02	0.	-.98053E-02	.25152E-04	-.13536E-03	-.84645E-06
		4	.29754E-01	0.	-.13567E-02	-.10418E-03	-.77438E-04	.31664E-04
		5	.13713E-02	0.	-.33638E-02	.18252E-03	-.32939E-04	.53991E-06
MAXIMUM VALUE			.29754E-01	0.	.64926E-01	.18252E-03	.30277E-03	.31664E-04
ABSOLUTE SUM			.33202E-01	0.	.80918E-01	.44217E-03	.64115E-03	.33154E-04
SQRT,SUM OF SQ			.29828E-01	0.	.65779E-01	.23544E-03	.35448E-03	.31680E-04
CLSLY SP MODES			.29828E-01	0.	.65779E-01	.23544E-03	.35448E-03	.31680E-04
9	8	1	.52278E-04	.26760E-05	-.80212E-01	.97331E-04	.30719E-03	-.21021E-06
		2	-.53175E-03	-.99388E-06	.35815E-02	.32451E-04	-.11040E-03	-.69533E-07

	3	-.15018E-02	-.16498E-04	-.25995E-02	.25683E-04	-.15005E-03	-.42820E-07
	4	.29830E-01	.56235E-03	.25392E-02	-.10931E-03	-.74840E-04	-.27072E-06
	5	.13731E-02	-.39928E-04	-.15447E-02	.19567E-03	-.39278E-04	-.45920E-06
MAXIMUM VALUE		.29830E-01	.56235E-03	.80212E-01	.19567E-03	.30719E-03	.45920E-06
ABSOLUTE SUM		.33289E-01	.62245E-03	.90477E-01	.46044E-03	.68176E-03	.10525E-05
SQRT,SUM OF SQ		.29904E-01	.56402E-03	.80389E-01	.24783E-03	.36907E-03	.57880E-06
CLSLY SP MODES		.29904E-01	.56402E-03	.80389E-01	.24783E-03	.36907E-03	.57880E-06
8 88	1	.21402E-01	-.66217E-02	-.80215E-01	.93112E-04	.30184E-03	-.18596E-04
	2	-.16320E-01	-.22787E-02	.35517E-02	.32542E-04	-.33113E-03	-.62093E-05
	3	-.11497E-01	-.19824E-02	-.25887E-02	.29297E-04	-.11993E-03	-.49456E-05
	4	.33236E-01	.98485E-02	.25308E-02	-.14463E-03	.97277E-04	.21789E-04
	5	-.14533E-02	-.17937E-01	-.15447E-02	.28665E-03	-.36631E-04	-.37347E-04
MAXIMUM VALUE		.33236E-01	.17937E-01	.80215E-01	.28665E-03	.33113E-03	.37347E-04
ABSOLUTE SUM		.83908E-01	.38668E-01	.90431E-01	.58624E-03	.88681E-03	.88887E-04
SQRT,SUM OF SQ		.44309E-01	.21719E-01	.80390E-01	.33716E-03	.47533E-03	.47732E-04
CLSLY SP MODES		.44309E-01	.21719E-01	.80390E-01	.33716E-03	.47533E-03	.47732E-04
7 10	1	.52279E-04	0.	-.95646E-01	.97331E-04	.30935E-03	-.45169E-07
	2	-.53187E-03	0.	.91936E-02	.32451E-04	-.11318E-03	.24743E-07
	3	-.15028E-02	0.	.51739E-02	.25683E-04	-.15853E-03	.35427E-06
	4	.29865E-01	0.	.66608E-02	-.10931E-03	-.86389E-04	-.12089E-04
	5	.13752E-02	0.	.54571E-03	.19567E-03	-.43347E-04	.89072E-06
MAXIMUM VALUE		.29865E-01	0.	.95646E-01	.19567E-03	.30935E-03	.12089E-04
ABSOLUTE SUM		.33327E-01	0.	.11722E+00	.46044E-03	.71079E-03	.13404E-04
SQRT,SUM OF SQ		.29939E-01	0.	.96458E-01	.24783E-03	.37813E-03	.12127E-04
CLSLY SP MODES		.29939E-01	0.	.96458E-01	.24783E-03	.37813E-03	.12127E-04
6 9	1	.21406E-01	-.66229E-02	-.80215E-01	.93111E-04	.30184E-03	-.18599E-04
	2	-.16324E-01	-.22791E-02	.35517E-02	.32542E-04	-.33116E-03	-.62103E-05
	3	-.11498E-01	-.19828E-02	-.25887E-02	.29297E-04	-.11992E-03	-.49464E-05
	4	.33238E-01	.98503E-02	.25308E-02	-.14463E-03	.97275E-04	.21793E-04
	5	-.14538E-02	-.17940E-01	-.15447E-02	.28666E-03	-.36628E-04	-.37353E-04
MAXIMUM VALUE		.33238E-01	.17940E-01	.80215E-01	.28666E-03	.33116E-03	.37353E-04
ABSOLUTE SUM		.83919E-01	.38675E-01	.90431E-01	.58624E-03	.88683E-03	.88902E-04
SQRT,SUM OF SQ		.44314E-01	.21723E-01	.80390E-01	.33716E-03	.47535E-03	.47741E-04
CLSLY SP MODES		.44314E-01	.21723E-01	.80390E-01	.33716E-03	.47535E-03	.47741E-04
5 12	1	.52280E-04	-.37057E-05	-.12108E+00	.97331E-04	.31039E-03	-.45201E-07
	2	-.53194E-03	.20390E-05	.18567E-01	.32451E-04	-.11465E-03	.24904E-07
	3	-.15035E-02	.29537E-04	.18478E-01	.25683E-04	-.16335E-03	.36198E-06
	4	.29886E-01	-.10194E-02	.14134E-01	-.10931E-03	-.92553E-04	-.12533E-04
	5	.13765E-02	.75785E-04	.42543E-02	.19567E-03	-.45786E-04	.93417E-06
MAXIMUM VALUE		.29886E-01	.10194E-02	.12108E+00	.19567E-03	.31039E-03	.12533E-04
ABSOLUTE SUM		.33350E-01	.11304E-02	.17651E+00	.46044E-03	.72673E-03	.13899E-04
SQRT,SUM OF SQ		.29960E-01	.10226E-02	.12476E+00	.24783E-03	.38319E-03	.12573E-04
CLSLY SP MODES		.29960E-01	.10226E-02	.12476E+00	.24783E-03	.38319E-03	.12573E-04
4 11	1	.26654E-01	-.76210E-02	-.75105E-01	.78750E-04	.27457E-03	-.45801E-04
	2	-.26635E-01	-.26429E-02	-.98690E-02	.27998E-04	-.95882E-03	-.15548E-04
	3	-.12030E-01	-.23437E-02	-.18348E-02	.26273E-04	.13498E-03	-.13005E-04
	4	.34298E-01	.11771E-01	.26283E-02	-.13430E-03	-.78243E-04	.61329E-04
	5	-.17543E-02	-.22040E-01	-.15477E-02	.27501E-03	.22343E-04	-.10909E-03
MAXIMUM VALUE		.34298E-01	.22040E-01	.75105E-01	.27501E-03	.95882E-03	.10909E-03
ABSOLUTE SUM		.10137E+00	.46418E-01	.90985E-01	.54233E-03	.14690E-02	.24478E-03
SQRT,SUM OF SQ		.52384E-01	.26360E-01	.75835E-01	.31834E-03	.10097E-02	.13480E-03
CLSLY SP MODES		.52384E-01	.26360E-01	.75835E-01	.31834E-03	.10097E-02	.13480E-03
3 112	1	.26654E-01	-.76205E-02	-.75102E-01	.78750E-04	.27457E-03	-.45804E-04
	2	-.26635E-01	-.26427E-02	-.98805E-02	.27998E-04	-.95884E-03	-.15549E-04

		3	-.12030E-01	-.23435E-02	-.18331E-02	.26273E-04	.13499E-03	-.13006E-04
		4	.34298E-01	.11770E-01	.26274E-02	-.13430E-03	-.78255E-04	.61334E-04
		5	-.17543E-02	-.22039E-01	-.15474E-02	.27501E-03	.22346E-04	-.10910E-03
MAXIMUM VALUE			.34298E-01	.22039E-01	.75102E-01	.27501E-03	.95884E-03	.10910E-03
ABSOLUTE SUM			.10137E+00	.46415E-01	.90990E-01	.54233E-03	.14690E-02	.24479E-03
SQRT,SUM OF SQ			.52384E-01	.26359E-01	.75833E-01	.31834E-03	.10098E-02	.13481E-03
CLSLY SP MODES			.52384E-01	.26359E-01	.75833E-01	.31834E-03	.10098E-02	.13481E-03
2	13	1	.26655E-01	-.40356E-02	-.56067E-01	.78750E-04	.27053E-03	-.55366E-04
		2	-.26642E-01	-.14131E-02	-.81449E-01	.27998E-04	-.10644E-02	-.19214E-04
		3	-.12041E-01	-.12851E-02	.96457E-02	.26273E-04	.18345E-03	-.17070E-04
		4	.34349E-01	.66165E-02	-.48561E-02	-.13430E-03	-.12650E-03	.85887E-04
		5	-.17577E-02	-.12629E-01	.53747E-03	.27501E-03	.35115E-04	-.16103E-03
MAXIMUM VALUE			.34349E-01	.12629E-01	.81449E-01	.27501E-03	.10644E-02	.16103E-03
ABSOLUTE SUM			.10145E+00	.25979E-01	.15256E+00	.54233E-03	.16800E-02	.33856E-03
SQRT,SUM OF SQ			.52424E-01	.14940E-01	.99470E-01	.31834E-03	.11212E-02	.19244E-03
CLSLY SP MODES			.52424E-01	.14940E-01	.99470E-01	.31834E-03	.11212E-02	.19244E-03
1	14	1	.26656E-01	0.	-.37164E-01	.78750E-04	.26986E-03	-.58602E-04
		2	-.26644E-01	0.	-.15725E+00	.27998E-04	-.10905E-02	-.20593E-04
		3	-.12045E-01	0.	.23112E-01	.26273E-04	.19609E-03	-.18893E-04
		4	.34367E-01	0.	-.14360E-01	-.13430E-03	-.13962E-03	.98105E-04
		5	-.17589E-02	0.	.31848E-02	.27501E-03	.38942E-04	-.18846E-03
MAXIMUM VALUE			.34367E-01	0.	.15725E+00	.27501E-03	.10905E-02	.18846E-03
ABSOLUTE SUM			.10147E+00	0.	.23507E+00	.54233E-03	.17351E-02	.38465E-03
SQRT,SUM OF SQ			.52437E-01	0.	.16388E+00	.31834E-03	.11496E-02	.22216E-03
CLSLY SP MODES			.52437E-01	0.	.16388E+00	.31834E-03	.11496E-02	.22216E-03

R E S P O N S E   S P E C T R U M   S T R E S S   C O M P O N E N T S

SQUARE ROOT OF THE SUM OF THE SQUARES OF THE MODAL STRESSES
(FOR ALL ELEMENTS)

ELEMENT TYPE (3/D   P I P E   ) / / / ELEMENT NUMBER (1)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9574E+01	-.3988E+01	-.1943E+03	.1570E+05	.7872E+05	-.5240E+03	.9574E+01	-.3988E+01	-.1943E+03	.1570E+05	.5929E+05	-.1252E+03
-.9286E+02	.4223E+02	-.1931E+03	.1393E+05	.2728E+05	.5309E+04	-.9286E+02	.4223E+02	-.1931E+03	.1393E+05	.7971E+04	.1086E+04
-.2266E+03	.1447E+03	-.7686E+03	.1786E+05	.1049E+06	.1684E+05	-.2266E+03	.1447E+03	-.7686E+03	.1786E+05	.2802E+05	.2368E+04
.3694E+04	-.3454E+04	-.9930E+03	-.1348E+05	.1228E+06	-.3760E+06	.3694E+04	-.3454E+04	-.9930E+03	-.1348E+05	.2354E+05	-.3059E+05
.1427E+03	-.1766E+03	.5483E+03	.3608E+05	-.6707E+05	-.1822E+05	.1427E+03	-.1766E+03	.5483E+03	.3608E+05	-.1224E+05	-.5625E+03

SQUARE ROOT SUM OF THE SQUARES

.3704E+04	.3462E+04	.1397E+04	.4736E+05	.1937E+06	.3769E+06	.3704E+04	.3462E+04	.1397E+04	.4736E+05	.7119E+05	.3070E+05

CLOSELY SPACED MODE SUMMATION METHOD

.3704E+04	.3462E+04	.1397E+04	.4736E+05	.1937E+06	.3769E+06	.3704E+04	.3462E+04	.1397E+04	.4736E+05	.7119E+05	.3070E+05

ELEMENT TYPE (3/D   P I P E   ) / / / ELEMENT NUMBER (2)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9573E+01	-.3943E+01	-.1864E+03	.1570E+05	.5929E+05	-.1252E+03	.9573E+01	-.3943E+01	-.1864E+03	.1570E+05	.4065E+05	.2691E+03
-.9274E+02	.3808E+02	-.1712E+03	.1393E+05	.7971E+04	.1086E+04	-.9274E+02	.3808E+02	-.1712E+03	.1393E+05	-.9146E+04	-.2722E+04
-.2256E+03	.1023E+03	-.4935E+03	.1786E+05	.2802E+05	.2368E+04	-.2256E+03	.1023E+03	-.4935E+03	.1786E+05	-.2132E+05	-.7864E+04
.3666E+04	-.1905E+04	-.4676E+03	-.1348E+05	.2354E+05	-.3059E+05	.3666E+04	-.1905E+04	-.4676E+03	-.1348E+05	-.2322E+05	.1599E+06
.1413E+03	-.7964E+02	.1723E+03	.3608E+05	-.1224E+05	-.5625E+03	.1413E+03	-.7964E+02	.1723E+03	.3608E+05	.4996E+04	.7401E+04

SQUARE ROOT SUM OF THE SQUARES

.3677E+04	.1910E+04	.7456E+03	.4736E+05	.7119E+05	.3070E+05	.3677E+04	.1910E+04	.7456E+03	.4736E+05	.5249E+05	.1603E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3677E+04	.1910E+04	.7456E+03	.4736E+05	.7119E+05	.3070E+05	.3677E+04	.1910E+04	.7456E+03	.4736E+05	.5249E+05	.1603E+06

ELEMENT TYPE (3/D   P I P E   ) / / / ELEMENT NUMBER (3)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9573E+01	-.3926E+01	-.1822E+03	.1570E+05	.4065E+05	.2691E+03	.9573E+01	-.3926E+01	-.1822E+03	.1570E+05	.4065E+05	.2691E+03
-.9270E+02	.3654E+02	-.1624E+03	.1393E+05	-.9146E+04	-.2722E+04	-.9270E+02	.3654E+02	-.1624E+03	.1393E+05	-.9146E+04	-.2722E+04
-.2253E+03	.8722E+02	-.3833E+03	.1786E+05	-.2132E+05	-.7864E+04	-.2253E+03	.8722E+02	-.3833E+03	.1786E+05	-.2132E+05	-.7865E+04
.3658E+04	-.1373E+04	-.2664E+03	-.1348E+05	-.2322E+05	.1599E+06	.3658E+04	-.1373E+04	-.2664E+03	-.1348E+05	-.2322E+05	.1599E+06
.1409E+03	-.4757E+02	.2710E+02	.3608E+05	.4996E+04	.7401E+04	.1409E+03	-.4757E+02	.2710E+02	.3608E+05	.4997E+04	.7402E+04

SQUARE ROOT SUM OF THE SQUARES

.3669E+04	.1377E+04	.5275E+03	.4736E+05	.5249E+05	.1603E+06	.3669E+04	.1377E+04	.5275E+03	.4736E+05	.5249E+05	.1603E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3669E+04	.1377E+04	.5275E+03	.4736E+05	.5249E+05	.1603E+06	.3669E+04	.1377E+04	.5275E+03	.4736E+05	.5249E+05	.1603E+06

ELEMENT TYPE (3/D   P I P E   ) / / / ELEMENT NUMBER (4)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.9572E+01	.3921E+01	.1811E+03	.1570E+05	-.4065E+05	-.2691E+03	.1034E+02	-.4044E-01	.1811E+03	-.5579E+03	-.4107E+05	-.2969E+03
-.9269E+02	-.3611E+02	.1599E+03	.1393E+05	.9146E+04	.2722E+04	-.9945E+02	.2111E+01	.1599E+03	.1681E+05	.5322E+04	.2966E+04

-.2252E+03	-.8295E+02	.3522E+03	.1786E+05	.2132E+05	.7865E+04	-.2398E+03	.9555E+01	.3522E+03	.2562E+05	.1772E+05	.8390E+04
.3656E+04	.1223E+04	.2095E+03	-.1348E+05	.2322E+05	-.1599E+06	.3846E+04	-.2693E+03	.2095E+03	-.2997E+04	.2950E+05	-.1668E+06
.1408E+03	.3850E+02	.1398E+02	.3608E+05	-.4997E+04	-.7402E+04	.1448E+03	-.1830E+02	.1398E+02	.3146E+05	-.1823E+05	-.7546E+04

SQUARE ROOT SUM OF THE SQUARES

.3667E+04	.1227E+04	.4759E+03	.4736E+05	.5249E+05	.1603E+06	.3857E+04	.2701E+03	.4759E+03	.4403E+05	.5684E+05	.1672E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3667E+04	.1227E+04	.4759E+03	.4736E+05	.5249E+05	.1603E+06	.3857E+04	.2701E+03	.4759E+03	.4403E+05	.5684E+05	.1672E+06

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (4)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9541E+01	-.3996E+01	.1811E+03	-.1573E+05	-.3523E+05	-.2680E+03
-.9107E+02	.4001E+02	.1599E+03	.1800E+05	.6878E+03	.2664E+04
-.2179E+03	.1006E+03	.3522E+03	.3142E+05	.1142E+05	.7602E+04
.3450E+04	-.1721E+04	.2095E+03	.9095E+04	.3129E+05	-.1525E+06
.1268E+03	-.7232E+02	.1398E+02	.2213E+05	-.2869E+05	-.6897E+04

SQUARE ROOT SUM OF THE SQUARES

.3460E+04	.1725E+04	.4759E+03	.4617E+05	.5634E+05	.1529E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3460E+04	.1725E+04	.4759E+03	.4617E+05	.5634E+05	.1529E+06

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (5)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9538E+01	.3999E+01	-.1795E+03	-.1573E+05	.3523E+05	.2680E+03	.9538E+01	.3999E+01	-.1795E+03	-.1573E+05	.3523E+05	.2680E+03
-.9076E+02	-.4028E+02	-.1569E+03	.1800E+05	-.6878E+03	-.2664E+04	-.9076E+02	-.4028E+02	-.1569E+03	.1800E+05	-.6879E+03	-.2664E+04
-.2148E+03	-.1033E+03	-.3166E+03	.3142E+05	-.1142E+05	-.7602E+04	-.2148E+03	-.1033E+03	-.3166E+03	.3142E+05	-.1142E+05	-.7601E+04
.3342E+04	.1815E+04	-.1501E+03	.9095E+04	-.3129E+05	.1525E+06	.3342E+04	.1815E+04	-.1501E+03	.9095E+04	-.3129E+05	.1525E+06
.1203E+03	.7801E+02	-.5261E+02	.2213E+05	.2869E+05	.6897E+04	.1203E+03	.7801E+02	-.5261E+02	.2213E+05	.2869E+05	.6897E+04

SQUARE ROOT SUM OF THE SQUARES

.3352E+04	.1821E+04	.4270E+03	.4617E+05	.5634E+05	.1529E+06	.3352E+04	.1821E+04	.4270E+03	.4617E+05	.5634E+05	.1529E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3352E+04	.1821E+04	.4270E+03	.4617E+05	.5634E+05	.1529E+06	.3352E+04	.1821E+04	.4270E+03	.4617E+05	.5634E+05	.1529E+06

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (6)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9525E+01	.4010E+01	-.1734E+03	-.1573E+05	.3523E+05	.2680E+03	.9525E+01	.4010E+01	-.1734E+03	-.1573E+05	.1684E+05	-.1573E+03
-.8958E+02	-.4128E+02	-.1457E+03	.1800E+05	-.6879E+03	-.2664E+04	-.8958E+02	-.4128E+02	-.1457E+03	.1800E+05	-.1614E+05	.1714E+04
-.2033E+03	-.1133E+03	-.1829E+03	.3142E+05	-.1142E+05	-.7601E+04	-.2033E+03	-.1133E+03	-.1829E+03	.3142E+05	-.3082E+05	.4412E+04
.2937E+04	.2172E+04	.7275E+02	.9095E+04	-.3129E+05	.1525E+06	.2937E+04	.2172E+04	.7275E+02	.9095E+04	-.2357E+05	-.7783E+05
.9602E+02	.9936E+02	-.1975E+03	.2213E+05	.2869E+05	.6897E+04	.9602E+02	.9936E+02	-.1975E+03	.2213E+05	.7740E+04	-.3642E+04

SQUARE ROOT SUM OF THE SQUARES

.2947E+04	.2177E+04	.3593E+03	.4617E+05	.5634E+05	.1529E+06	.2947E+04	.2177E+04	.3593E+03	.4617E+05	.4593E+05	.7806E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2947E+04	.2177E+04	.3593E+03	.4617E+05	.5634E+05	.1529E+06	.2947E+04	.2177E+04	.3593E+03	.4617E+05	.4593E+05	.7806E+05

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (7)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)

.9511E+01	.4002E+01	-.1596E+03	-.1573E+05	.1684E+05	-.1573E+03	.9511E+01	.4002E+01	-.1596E+03	-.1573E+05	.1684E+05	-.1573E+03
-.8837E+02	-.4041E+02	-.1261E+03	.1800E+05	-.1614E+05	.1714E+04	-.8837E+02	-.4041E+02	-.1261E+03	.1800E+05	-.1614E+05	.1714E+04
-.1916E+03	-.1058E+03	-.9557E+01	.3142E+05	-.3082E+05	.4412E+04	-.1916E+03	-.1058E+03	-.9557E+01	.3142E+05	-.3082E+05	.4412E+04
.2528E+04	.1945E+04	.1956E+03	.9095E+04	-.2357E+05	-.7783E+05	.2528E+04	.1945E+04	.1956E+03	.9095E+04	-.2357E+05	-.7783E+05
.7159E+02	.8521E+02	-.1202E+03	.2213E+05	.7740E+04	-.3642E+04	.7159E+02	.8521E+02	-.1202E+03	.2213E+05	.7739E+04	-.3642E+04

SQUARE ROOT SUM OF THE SQUARES

.2538E+04	.1950E+04	.3069E+03	.4617E+05	.4593E+05	.7806E+05	.2538E+04	.1950E+04	.3069E+03	.4617E+05	.4593E+05	.7806E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2538E+04	.1950E+04	.3069E+03	.4617E+05	.4593E+05	.7806E+05	.2538E+04	.1950E+04	.3069E+03	.4617E+05	.4593E+05	.7806E+05

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (8)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
.9508E+01	.3999E+01	-.1559E+03	-.1573E+05	.1684E+05	-.1573E+03	.1031E+02	.5639E-01	-.1559E+03	-.8520E+04	.1943E+05	-.1864E+03
-.8805E+02	-.4018E+02	-.1209E+03	.1800E+05	-.1614E+05	.1714E+04	-.9673E+02	-.3428E+01	-.1209E+03	.1012E+05	-.2347E+05	.2027E+04
-.1884E+03	-.1038E+03	.3666E+02	.3142E+05	-.3082E+05	.4412E+04	-.2138E+03	-.2379E+02	.3666E+02	.1733E+05	-.3999E+05	.5326E+04
.2419E+04	.1884E+04	.2283E+03	.9095E+04	-.2357E+05	-.7783E+05	.2956E+04	.8152E+03	.2283E+03	.7286E+01	-.2211E+05	-.9717E+05
.6508E+02	.8144E+02	-.9955E+02	.2213E+05	.7739E+04	-.3642E+04	.9129E+02	.5034E+02	-.9955E+02	.2313E+05	-.2690E+04	-.4586E+04

SQUARE ROOT SUM OF THE SQUARES

.2429E+04	.1889E+04	.3199E+03	.4617E+05	.4593E+05	.7806E+05	.2967E+04	.8171E+03	.3199E+03	.3179E+05	.5499E+05	.9744E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2429E+04	.1889E+04	.3199E+03	.4617E+05	.4593E+05	.7806E+05	.2967E+04	.8171E+03	.3199E+03	.3179E+05	.5499E+05	.9744E+05

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (8)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9551E+01	-.3895E+01	-.1559E+03	-.8640E+03	.1906E+05	-.1589E+03
-.9068E+02	.3385E+02	-.1209E+03	.4088E+02	-.2722E+05	.1809E+04
-.2066E+03	.5984E+02	.3666E+02	.8100E+03	-.4308E+05	.5068E+04
.3043E+04	-.3781E+03	.2283E+03	-.7830E+04	-.1729E+05	-.1003E+06
.1036E+03	.1157E+02	-.9955E+02	.2007E+05	-.1271E+05	-.5029E+04

SQUARE ROOT SUM OF THE SQUARES

.3053E+04	.3845E+03	.3199E+03	.2158E+05	.5848E+05	.1006E+06

CLOSELY SPACED MODE SUMMATION METHOD

.3053E+04	.3845E+03	.3199E+03	.2158E+05	.5848E+05	.1006E+06

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (9)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9547E+01	-.3895E+01	-.1515E+03	-.8643E+03	.1906E+05	-.1589E+03	.9547E+01	-.3895E+01	-.1515E+03	-.8643E+03	.1906E+05	-.1589E+03
-.9025E+02	.3385E+02	-.1163E+03	.4133E+02	-.2722E+05	.1809E+04	-.9025E+02	.3385E+02	-.1163E+03	.4133E+02	-.2722E+05	.1809E+04
-.2027E+03	.5965E+02	.7948E+02	.8107E+03	-.4308E+05	.5068E+04	-.2027E+03	.5965E+02	.7948E+02	.8107E+03	-.4307E+05	.5067E+04
.2911E+04	-.3663E+03	.2514E+03	-.7829E+04	-.1729E+05	-.1003E+06	.2911E+04	-.3663E+03	.2514E+03	-.7829E+04	-.1728E+05	-.1003E+06
.9562E+02	.1214E+02	-.7132E+02	.2007E+05	-.1271E+05	-.5029E+04	.9562E+02	.1214E+02	-.7132E+02	.2007E+05	-.1271E+05	-.5029E+04

SQUARE ROOT SUM OF THE SQUARES

.2921E+04	.3729E+03	.3333E+03	.2158E+05	.5848E+05	.1006E+06	.2921E+04	.3729E+03	.3333E+03	.2158E+05	.5848E+05	.1006E+06

CLOSELY SPACED MODE SUMMATION METHOD

.2921E+04	.3729E+03	.3333E+03	.2158E+05	.5848E+05	.1006E+06	.2921E+04	.3729E+03	.3333E+03	.2158E+05	.5848E+05	.1006E+06

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (10)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9539E+01	-.3894E+01	-.1438E+03	-.8643E+03	.1906E+05	-.1589E+03	.9539E+01	-.3894E+01	-.1438E+03	-.8643E+03	.1187E+05	.3586E+02
-.8950E+02	.3384E+02	-.1082E+03	.4133E+02	-.2722E+05	.1809E+04	-.8950E+02	.3384E+02	-.1082E+03	.4133E+02	-.3263E+05	.1165E+03
-.1957E+03	.5932E+02	.1552E+03	.8107E+03	-.4307E+05	.5067E+04	-.1957E+03	.5932E+02	.1552E+03	.8107E+03	-.3531E+05	.2101E+04
.2678E+04	-.3456E+03	.2921E+03	-.7829E+04	-.1728E+05	-.1003E+06	.2678E+04	-.3456E+03	.2921E+03	-.7829E+04	-.2680E+04	-.8302E+05
.8150E+02	.1316E+02	-.2139E+02	.2007E+05	-.1271E+05	-.5029E+04	.8150E+02	.1316E+02	-.2139E+02	.2007E+05	-.1378E+05	-.5687E+04

SQUARE ROOT SUM OF THE SQUARES

.2688E+04	.3525E+03	.3771E+03	.2158E+05	.5848E+05	.1006E+06	.2688E+04	.3525E+03	.3771E+03	.2158E+05	.5148E+05	.8324E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2688E+04	.3525E+03	.3771E+03	.2158E+05	.5848E+05	.1006E+06	.2688E+04	.3525E+03	.3771E+03	.2158E+05	.5148E+05	.8324E+05

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (11)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.9522E+01	.2280E+02	-.1236E+03	-.8643E+03	.1187E+05	.3586E+02	.9522E+01	.2280E+02	-.1236E+03	-.8643E+03	.5691E+04	-.1104E+04
-.8799E+02	.6606E+01	-.1040E+03	.4133E+02	-.3263E+05	.1165E+03	-.8799E+02	.6606E+01	-.1040E+03	.4133E+02	-.3783E+05	-.2138E+03
-.1817E+03	.2026E+02	.2473E+03	.8107E+03	-.3531E+05	.2101E+04	-.1817E+03	.2026E+02	.2473E+03	.8107E+03	-.2295E+05	.1088E+04
.2211E+04	-.7860E+03	.3134E+03	-.7829E+04	-.2680E+04	-.8302E+05	.2211E+04	-.7860E+03	.3134E+03	-.7829E+04	.1299E+05	-.4371E+05
.5320E+02	-.1482E+03	.4803E+02	.2007E+05	-.1378E+05	-.5687E+04	.5320E+02	-.1482E+03	.4803E+02	.2007E+05	-.1138E+05	.1722E+04

SQUARE ROOT SUM OF THE SQUARES

.2221E+04	.8005E+03	.4333E+03	.2158E+05	.5148E+05	.8324E+05	.2221E+04	.8005E+03	.4333E+03	.2158E+05	.4784E+05	.4377E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2221E+04	.8005E+03	.4333E+03	.2158E+05	.5148E+05	.8324E+05	.2221E+04	.8005E+03	.4333E+03	.2158E+05	.4784E+05	.4377E+05

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (12)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.2359E+02	.9700E+01	-.9468E+01	-.1759E+04	-.3342E+03	.8643E+03	-.2359E+02	.9700E+01	-.9468E+01	-.1759E+04	-.9968E+03	.1855E+03
-.1945E+03	-.8568E+00	.8291E+02	-.5875E+03	-.3036E+05	-.4133E+02	-.1945E+03	-.8568E+00	.8291E+02	-.5875E+03	-.2456E+05	.1863E+02
.7034E+02	-.1032E+02	.1344E+03	-.4692E+03	-.9574E+03	-.8107E+03	.7034E+02	-.1032E+02	.1344E+03	-.4692E+03	.8450E+04	-.8846E+02
-.5466E+02	.9817E+02	-.6428E+03	.2111E+04	.4390E+05	.7829E+04	-.5466E+02	.9817E+02	-.6428E+03	.2111E+04	-.1081E+04	.9592E+03
-.3507E+00	-.2501E+03	.4176E+02	-.3530E+04	-.1132E+04	-.2007E+05	-.3507E+00	-.2501E+03	.4176E+02	-.3530E+04	.1790E+04	-.2568E+04

SQUARE ROOT SUM OF THE SQUARES

.2152E+03	.2690E+03	.6633E+03	.4536E+04	.5340E+05	.2158E+05	.2152E+03	.2690E+03	.6633E+03	.4536E+04	.2607E+05	.2749E+04

CLOSELY SPACED MODE SUMMATION METHOD

.2152E+03	.2690E+03	.6633E+03	.4536E+04	.5340E+05	.2158E+05	.2152E+03	.2690E+03	.6633E+03	.4536E+04	.2607E+05	.2749E+04

ELEMENT TYPE (3/D P I P E) / / / ELEMENT NUMBER (13)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.1844E+02	.1013E+02	-.8094E+01	-.1759E+04	-.9968E+03	.1855E+03	-.1844E+02	.1013E+02	-.8094E+01	-.1759E+04	-.9969E+03	.1854E+03
-.1966E+03	.4903E+00	.7326E+02	-.5875E+03	-.2456E+05	.1863E+02	-.1966E+03	.4903E+00	.7326E+02	-.5875E+03	-.2456E+05	.1863E+02
.7537E+02	-.6467E+01	.1121E+03	-.4692E+03	.8450E+04	-.8846E+02	.7537E+02	-.6467E+01	.1121E+03	-.4692E+03	.8451E+04	-.8838E+02
-.6288E+02	.6618E+02	-.5348E+03	.2111E+04	-.1081E+04	.9592E+03	-.6288E+02	.6618E+02	-.5348E+03	.2111E+04	-.1088E+04	.9584E+03
.6246E+01	-.1735E+03	.3555E+02	-.3530E+04	.1790E+04	-.2568E+04	.6246E+01	-.1735E+03	.3555E+02	-.3530E+04	.1791E+04	-.2566E+04

SQUARE ROOT SUM OF THE SQUARES

.2206E+03	.1861E+03	.5525E+03	.4536E+04	.2607E+05	.2749E+04	.2206E+03	.1861E+03	.5525E+03	.4536E+04	.2607E+05	.2747E+04

CLOSELY SPACED MODE SUMMATION METHOD

.2206E+03	.1861E+03	.5525E+03	.4536E+04	.2607E+05	.2749E+04	.2206E+03	.1861E+03	.5525E+03	.4536E+04	.2607E+05	.2747E+04

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (14)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(C)	VY(C)	VZ(C)	TX(C)	MY(C)	MZ(C)
-.1636E+02	-.7538E+01	-.1030E+02	-.1759E+04	.1853E+03	.9969E+03	-.1690E+02	.6237E+01	-.1030E+02	-.1167E+04	.1244E+04	.1007E+04
-.1975E+03	.6936E+02	-.1032E+01	-.5873E+03	.1835E+02	.2456E+05	-.9058E+02	.1887E+03	-.1032E+01	-.4077E+03	.4151E+03	.2263E+05
.7741E+02	.1030E+03	.4910E+01	-.4693E+03	-.8829E+02	-.8451E+04	.1276E+03	.1813E+02	.4910E+01	-.3684E+03	.3319E+03	-.9355E+04
-.6620E+02	-.4912E+03	-.5325E+02	.2111E+04	.9584E+03	.1088E+04	-.3941E+03	-.3005E+03	-.5325E+02	.1890E+04	-.1493E+04	.6991E+04
.8913E+01	.3304E+02	.1425E+03	-.3530E+04	-.2566E+04	-.1791E+04	.2967E+02	.1706E+02	.1425E+03	-.3559E+04	.2496E+04	-.2164E+04

SQUARE ROOT SUM OF THE SQUARES

.2230E+03	.5078E+03	.1526E+03	.4536E+04	.2747E+04	.2607E+05	.4254E+03	.3558E+03	.1526E+03	.4231E+04	.3208E+04	.2558E+05

CLOSELY SPACED MODE SUMMATION METHOD

.2230E+03	.5078E+03	.1526E+03	.4536E+04	.2747E+04	.2607E+05	.4254E+03	.3558E+03	.1526E+03	.4231E+04	.3208E+04	.2558E+05

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (14)

PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.7538E+01	.1636E+02	-.1030E+02	-.2680E-01	.1574E+04	.8382E+03
.6936E+02	.1975E+03	-.1032E+01	-.2258E+00	.5687E+03	.1975E+05
.1030E+03	-.7741E+02	.4910E+01	.9283E-01	.5576E+03	-.8913E+04
-.4912E+03	.6620E+02	-.5325E+02	-.6298E-01	-.3069E+04	.8738E+04
.3304E+02	-.8913E+01	.1425E+03	-.4300E-01	.6095E+04	-.2225E+04

SQUARE ROOT SUM OF THE SQUARES

.5078E+03	.2230E+03	.1526E+03	.2572E+00	.7049E+04	.2349E+05

CLOSELY SPACED MODE SUMMATION METHOD

.5078E+03	.2230E+03	.1526E+03	.2572E+00	.7049E+04	.2349E+05

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (15)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.6846E+01	.1050E+02	.1441E+02	0.	-.8381E+03	.1574E+04	-.6846E+01	.1050E+02	.1441E+02	0.	-.8380E+03	.1574E+04
.6300E+02	.1666E+01	.1951E+03	0.	-.1975E+05	.5689E+03	.6300E+02	.1666E+01	.1951E+03	0.	-.1975E+05	.5689E+03
.9359E+02	-.3069E+01	-.7885E+02	0.	.8913E+04	.5575E+03	.9359E+02	-.3069E+01	-.7885E+02	0.	.8912E+04	.5576E+03
-.4462E+03	.3779E+02	.6966E+02	0.	-.8738E+04	-.3069E+04	-.4462E+03	.3779E+02	.6966E+02	0.	-.8737E+04	-.3070E+04
.3001E+02	-.1045E+03	-.1158E+02	0.	.2225E+04	.6095E+04	.3001E+02	-.1045E+03	-.1158E+02	0.	.2225E+04	.6097E+04

SQUARE ROOT SUM OF THE SQUARES

.4613E+03	.1117E+03	.2224E+03	0.	.2349E+05	.7049E+04	.4613E+03	.1117E+03	.2224E+03	0.	.2348E+05	.7050E+04

CLOSELY SPACED MODE SUMMATION METHOD

.4613E+03	.1117E+03	.2224E+03	0.	.2349E+05	.7049E+04	.4613E+03	.1117E+03	.2224E+03	0.	.2348E+05	.7050E+04

ELEMENT TYPE (3/D P I P E) /// ELEMENT NUMBER (16)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.5135E+01	.1098E+02	.9587E+01	0.	-.8380E+03	.1574E+04	-.5135E+01	.1098E+02	.9587E+01	0.	-.1670E+03	.8051E+03
.4725E+02	.3229E+01	.1893E+03	0.	-.1975E+05	.5689E+03	.4725E+02	.3229E+01	.1893E+03	0.	-.6507E+04	.3429E+03
.7021E+02	.1486E+01	-.8241E+02	0.	.8912E+04	.5576E+03	.7021E+02	.1486E+01	-.8241E+02	0.	.3144E+04	.4536E+03
-.3348E+03	-.4379E+00	.7819E+02	0.	-.8737E+04	-.3070E+04	-.3348E+03	-.4379E+00	.7819E+02	0.	-.3265E+04	-.3039E+04
.2252E+02	-.1038E+02	-.1819E+02	0.	.2225E+04	.6097E+04	.2252E+02	-.1038E+02	-.1819E+02	0.	.9520E+03	.6823E+04

SQUARE ROOT SUM OF THE SQUARES

.3461E+03	.1553E+02	.2217E+03	0.	.2348E+05	.7050E+04	.3461E+03	.1553E+02	.2217E+03	0.	.7989E+04	.7534E+04

CLOSELY SPACED MODE SUMMATION METHOD

.3461E+03	.1553E+02	.2217E+03	0.	.2348E+05	.7050E+04	.3461E+03	.1553E+02	.2217E+03	0.	.7989E+04	.7534E+04

[illegible]

ELEMENT TYPE (3/D PIPE) /// ELEMENT NUMBER (17)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
-.1712E+01	.1150E+02	.2387E+01	0.	-.1670E+03	.8051E+03	-.1712E+01	.1150E+02	.2387E+01	0.	-.4191E-08	-.3492E-09
.1575E+02	.4899E+01	.9296E+02	0.	-.6507E+04	.3429E+03	.1575E+02	.4899E+01	.9296E+02	0.	.9313E-08	-.2328E-09
.2341E+02	.6480E+01	-.4492E+02	0.	.3144E+04	.4536E+03	.2341E+02	.6480E+01	-.4492E+02	0.	.1863E-08	-.1455E-09
-.1116E+03	-.4342E+02	.4665E+02	0.	-.3265E+04	-.3039E+04	-.1116E+03	-.4342E+02	.4665E+02	0.	.4657E-09	.6985E-09
.7511E+01	.9748E+02	-.1360E+02	0.	.9520E+03	.6823E+04	.7511E+01	.9748E+02	-.1360E+02	0.	-.1164E-09	-.9313E-09
SQUARE ROOT SUM OF THE SQUARES											
.1154E+03	.1076E+03	.1141E+03	0.	.7989E+04	.7534E+04	.1154E+03	.1076E+03	.1141E+03	0.	.1039E-07	.1246E-08
CLOSELY SPACED MODE SUMMATION METHOD											
.1154E+03	.1076E+03	.1141E+03	0.	.7989E+04	.7534E+04	.1154E+03	.1076E+03	.1141E+03	0.	.1039E-07	.1246E-08

ELEMENT TYPE (3/D PIPE) /// ELEMENT NUMBER (18)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.3472E-01	.1310E+02	-.6998E+02	.1863E-08	.6026E+04	.6550E+03	.3472E-01	.1310E+02	-.6998E+02	.1863E-08	.2526E+04	-.7731E-01
-.3252E+01	.7466E+01	.7816E+02	.2328E-09	-.7474E+04	.3737E+03	-.3252E+01	.7466E+01	.7816E+02	.2328E-09	-.3566E+04	.3916E+00
-.3021E+02	.3077E+02	.2064E+03	.6985E-09	-.2199E+05	.1557E+04	-.3021E+02	.3077E+02	.2064E+03	.6985E-09	-.1167E+05	.1865E+02
.1003E+04	-.8949E+03	.3199E+03	-.1863E-08	-.3091E+05	-.4582E+05	.1003E+04	-.8949E+03	.3199E+03	-.1863E-08	-.1492E+05	-.1076E+04
.6075E+02	.1029E+03	.8685E+02	.3725E-08	-.1025E+05	.5252E+04	.6075E+02	.1029E+03	.8685E+02	.3725E-08	-.5903E+04	.1051E+03
SQUARE ROOT SUM OF THE SQUARES											
.1006E+04	.9014E+03	.4044E+03	.4622E-08	.4045E+05	.4615E+05	.1006E+04	.9014E+03	.4044E+03	.4622E-08	.2031E+05	.1081E+04
CLOSELY SPACED MODE SUMMATION METHOD											
.1006E+04	.9014E+03	.4044E+03	.4622E-08	.4045E+05	.4615E+05	.1006E+04	.9014E+03	.4044E+03	.4622E-08	.2031E+05	.1081E+04

ELEMENT TYPE (3/D PIPE) /// ELEMENT NUMBER (19)

PX(I)	VY(I)	VZ(I)	TX(I)	MY(I)	MZ(I)	PX(J)	VY(J)	VZ(J)	TX(J)	MY(J)	MZ(J)
.1330E-01	-.9429E-03	-.3081E+02	0.	.2526E+04	-.7731E-01	.1330E-01	-.9429E-03	-.3081E+02	0.	.3725E-07	.1819E-11
-.1246E+01	.4776E-02	.4349E+02	0.	-.3566E+04	.3916E+00	-.1246E+01	.4776E-02	.4349E+02	0.	0.	0.
-.1158E+02	.2275E+00	.1423E+03	0.	-.1167E+05	.1865E+02	-.1158E+02	.2275E+00	.1423E+03	0.	.3725E-08	-.7276E-11
.3847E+03	-.1312E+02	.1819E+03	0.	-.1492E+05	-.1076E+04	.3847E+03	-.1312E+02	.1819E+03	0.	.1863E-08	.2328E-09
.2329E+02	.1282E+01	.7199E+02	0.	-.5903E+04	.1051E+03	.2329E+02	.1282E+01	.7199E+02	0.	0.	0.
SQUARE ROOT SUM OF THE SQUARES											
.3855E+03	.1318E+02	.2477E+03	0.	.2031E+05	.1081E+04	.3855E+03	.1318E+02	.2477E+03	0.	.3749E-07	.2330E-09
CLOSELY SPACED MODE SUMMATION METHOD											
.3855E+03	.1318E+02	.2477E+03	0.	.2031E+05	.1081E+04	.3855E+03	.1318E+02	.2477E+03	0.	.3749E-07	.2330E-09

PIPE FORCES/MOMENTS/DISPLACEMENTS MEMBER GLOBAL DIRECTIONS
CLOSELY SPACED MODE SUMMATION USED IS 10 PERCENT METHOD

ELEM. NO.	ELEM. TYPE	STATION	NODE SAP	NODE TMR	FX	FY	FZ	MX	MY	MZ	DX	DY	DZ
1	TANGENT	END-I	20	1	3704.4	3462.1	1397.3	47360.8	193714.6	376858.2	0.0000	0.0000	0.0000
		END-J	19	2	3704.4	3462.1	1397.3	47360.8	71186.4	30704.5	.0003	.0144	.0080
2	TANGENT	END-I	19	2	3677.1	1910.0	745.6	47360.8	71186.4	30704.5	.0003	.0144	.0080
		END-J	18	28	3677.1	1910.0	745.6	47360.8	52485.3	160310.1	.0005	.0340	.0232
3	TANGENT	END-I	18	28	3669.1	1377.4	527.5	47360.8	52485.3	160310.1	.0005	.0340	.0232
		END-J	17	3	3669.1	1377.4	527.5	47360.8	52486.0	160316.1	.0005	.0340	.0232
4	BEND	END-I	17	3	3666.9	1226.9	475.9	47360.8	52486.0	160316.1	.0005	.0340	.0232
		CENTER			3857.3	270.1	475.9	44025.3	56844.8	167165.2			
		END-J	16	4	3460.4	1725.4	475.9	46165.3	56340.1	152877.1	.0021	.0324	.0274
5	TANGENT	END-I	16	4	3657.6	1083.3	427.0	45580.9	56813.8	152877.1	.0021	.0324	.0274
		END-J	15	42	3657.6	1083.3	427.0	45580.9	56813.9	152876.6	.0021	.0324	.0274
6	TANGENT	END-I	15	42	3623.0	545.8	359.3	45580.9	56813.9	152876.6	.0021	.0324	.0274
		END-J	14	48	3623.0	545.8	359.3	23523.7	60722.9	78062.4	.0271	.0077	.0467
7	TANGENT	END-I	14	48	3173.0	418.3	306.9	23523.7	60722.9	78062.4	.0271	.0077	.0467
		END-J	13	5	3173.0	418.3	306.9	23523.7	60722.9	78063.0	.0271	.0077	.0467
8	BEND	END-I	13	5	3053.1	384.4	319.9	23523.7	60722.9	78063.0	.0271	.0077	.0467
		CENTER			2674.8	1521.4	319.9	29300.3	56355.7	97441.4			
		END-J	12	6	1889.4	2428.9	319.9	42079.7	45990.4	100567.2	.0297	.0026	.0533
9	TANGENT	END-I	12	6	2921.3	372.9	333.3	21575.8	58483.4	100567.2	.0297	.0026	.0533
		END-J	11	62	2921.3	372.9	333.3	21575.8	58482.9	100565.6	.0297	.0026	.0533
10	TANGENT	END-I	11	62	2688.4	352.5	377.1	21575.8	58482.9	100565.6	.0297	.0026	.0533
		END-J	10	7	2688.4	352.5	377.1	21575.8	51478.5	83237.3	.0298	0.0000	.0658
11	TANGENT	END-I	10	7	2221.2	800.5	433.3	21575.8	51478.5	83237.3	.0298	0.0000	.0658
		END-J	9	8	2221.2	800.5	433.3	21575.8	47839.1	43773.1	.0299	.0006	.0804
12	TANGENT	END-I	9	8	663.3	269.0	215.2	21575.8	53400.5	4536.2	.0299	.0006	.0804
		END-J	8	88	663.3	269.0	215.2	2748.7	26073.8	4536.2	.0443	.0217	.0804
13	TANGENT	END-I	8	88	552.5	186.1	220.6	2748.7	26073.8	4536.2	.0443	.0217	.0804
		END-J	6	9	552.5	186.1	220.6	2746.5	26073.7	4536.2	.0443	.0217	.0804
14	BEND	END-I	6	9	507.8	152.6	223.0	2746.5	26073.7	4536.2	.0443	.0217	.0804
		CENTER			355.8	152.6	425.4	3207.5	25579.9	4230.8			
		END-J	4	11	223.0	152.6	507.8	7048.9	23487.6	.5	.0524	.0264	.0758
15	TANGENT	END-I	4	11	461.3	111.7	222.4	0.0	23487.6	7048.9	.0524	.0264	.0758
		END-J	3	112	461.3	111.7	222.4	0.0	23484.9	7050.2	.0524	.0264	.0758
16	TANGENT	END-I	3	112	346.1	15.5	221.7	0.0	23484.9	7050.2	.0524	.0264	.0758
		END-J	2	13	346.1	15.5	221.7	0.0	7988.8	7534.0	.0524	.0149	.0995
17	TANGENT	END-I	2	13	115.4	107.6	114.1	0.0	7988.8	7534.0	.0524	.0149	.0995
		END-J	1	14	115.4	107.6	114.1	0.0	.0	.0	.0524	0.0000	.1639
18	TANGENT	END-I	9	8	1005.7	901.4	404.4	.0	40452.4	46154.6	.0299	.0006	.0804
		END-J	7	10	1005.7	901.4	404.4	.0	20311.9	1081.1	.0299	0.0000	.0965

[illegible]

19	TANGENT	END-I	7	10	385.5	13.2	247.7	0.0	20311.9	1081.1	.0299	0.0000	.0965
		END-J	5	12	385.5	13.2	247.7	0.0	.0	.0	.0300	.0010	.1248

S T R E S S   S U M M A R Y

ELEM. NO.	ELEM. TYPE	STATION	NODE SAP	NODE TMR	TORSION	***** BENDING ***** IN-PLANE OUT-PLANE	COMBINED	PRESSURE	INTENSIFICATION FACTOR	
1	TANGENT	END-I	20	1	83.1	1486.2	1495.5	0.0	1.000	RU
		END-J	19	2	83.1	271.9	318.6	0.0	1.000	RU
2	TANGENT	END-I	19	2	83.1	271.9	318.6	0.0	1.000	RU
		END-J	18	28	83.1	591.7	614.5	0.0	1.000	RU
3	TANGENT	END-I	18	28	83.1	591.7	614.5	0.0	1.000	RU
		END-J	17	3	83.1	591.7	614.5	0.0	1.000	RU
4	BEND	END-I	17	3	83.1	1658.0	1722.1	0.0	2.802	EL
		CENTER			77.2	1735.4	1788.5	0.0	2.802	EL
		END-J	16	4	81.0	1601.3	1664.4	0.0	2.802	EL
5	TANGENT	END-I	16	4	81.0	571.5	594.0	0.0	1.000	RU
		END-J	15	42	81.0	571.5	594.0	0.0	1.000	RU
6	TANGENT	END-I	15	42	81.0	571.5	594.0	0.0	1.000	RU
		END-J	14	48	81.0	317.7	356.6	0.0	1.000	RU
7	TANGENT	END-I	14	48	81.0	317.7	356.6	0.0	1.000	RU
		END-J	13	5	81.0	317.7	356.6	0.0	1.000	RU
8	BEND	END-I	13	5	81.0	890.2	999.2	0.0	2.802	EL
		CENTER			55.8	1099.7	1143.2	0.0	2.802	EL
		END-J	12	6	37.8	1143.4	1162.9	0.0	2.802	EL
9	TANGENT	END-I	12	6	37.8	408.0	415.0	0.0	1.000	RU
		END-J	11	62	37.8	408.0	415.0	0.0	1.000	RU
10	TANGENT	END-I	11	62	37.8	408.0	415.0	0.0	1.000	RU
		END-J	10	7	37.8	343.3	351.5	0.0	1.000	RU
11	TANGENT	END-I	10	7	37.8	343.3	351.5	0.0	1.000	RU
		END-J	9	8	37.8	227.4	239.7	0.0	1.000	RU
12	TANGENT	END-I	9	8	48.2	1223.0	1226.8	0.0	1.000	RU
		END-J	8	88	48.2	556.8	565.0	0.0	1.000	RU
13	TANGENT	END-I	8	88	48.2	556.8	565.0	0.0	1.000	RU
		END-J	6	9	48.2	556.7	565.0	0.0	1.000	RU
14	BEND	END-I	6	9	48.2	1506.4	1528.8	0.0	2.706	EL
		CENTER			44.9	1481.2	1501.0	0.0	2.706	EL
		END-J	4	11	.0	1409.0	1409.0	0.0	2.706	EL
15	TANGENT	END-I	4	11	0.0	520.7	520.7	0.0	1.000	RU
		END-J	3	112	0.0	520.7	520.7	0.0	1.000	RU
16	TANGENT	END-I	3	112	0.0	520.7	520.7	0.0	1.000	RU
		END-J	2	13	0.0	233.2	233.2	0.0	1.000	RU
17	TANGENT	END-I	2	13	0.0	233.2	233.2	0.0	1.000	RU
		END-J	1	14	0.0	.0	.0	0.0	1.000	RU

STRESS SUMMARY

ELEM. NO.	ELEM. TYPE	STATION	NODE SAP	NODE TMR	TORSION	***** BENDING ***** IN-PLANE OUT-PLANE	COMBINED	PRESSURE	INTENSIFICATION FACTOR	
18	TANGENT	END-I	9	8	.0	215.3	215.3	0.0	1.000	RU
		END-J	7	10	.0	71.3	71.3	0.0	1.000	RU
19	TANGENT	END-I	7	10	0.0	71.3	71.3	0.0	1.000	RU
		END-J	5	12	0.0	.0	.0	0.0	1.000	RU

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R. M. S.   T I M E   L O G
     COMPUTE MAXIMUM NODAL DISPLACEMENTS =       .02
     OUTPUT  MAXIMUM NODAL DISPLACEMENTS =       .07
     COMPUTE ELEMENT STRESSES            =       .29

     TOTAL FOR SPECTRUM ANALYSIS         =       .39
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O V E R A L L   T I M E   L O G

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    NODAL POINT INPUT              =     0.00
    ELEMENT STIFFNESS FORMATION    =     0.00
    NODAL LOAD INPUT               =     0.00
    TOTAL STIFFNESS FORMATION      =     0.00
    STATIC ANALYSIS                =     0.00
    EIGENVALUE EXTRACTION          =     0.00
    FORCED RESPONSE ANALYSIS       =     0.00
    RESPONSE SPECTRUM ANALYSIS     =      .44
    STEP-BY-STEP INTEGRATION       =     0.00

    TOTAL SOLUTION TIME            =      .44
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