SMA-CT 30001.02R01

SEISMIC AND STRESS ANALYSIS OF HIGH PRESSURE CORE SPRAY DISCHARGE LINE PIPING SYSTEM FOR LACROSSE BOILING WATER REACTOR (LACBWR)

Prepared for

DAIRYLAND POWER COOPERATIVE

February 1985

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This work has been performed in accordance with SMA-CT Quality Assurance Manual which meets the requirements set forth in 10 CFR part 50 Appendix B and ANSI N45.2.

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CERTIFICATION OF

SEISMIC AND STRESS ANALYSIS OF

HIGH PRESSURE CORE SPRAY

DISCHARGE LINE PIPING SYSTEM

DAIRYLAND POWER COOPERATIVE

I, the undersigned, being a registered Professional Engineer in the States of Connecticut and California, competent in the ASME Code stress analysis of piping systems, have performed the stress analysis of LACBWR High Pressure Core Spray Discharge Line Piping System and certify that to the best of my Knowledge, the stress report presented herein is in compliance with the criteria set forth in this report.

Certified by Iqbal Husain
I. Husain

Date August 19 1984

STATE OF CONNECTICUT
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REGISTERED
PROFESSIONAL ENGINEER

Revision: 1

Certified by: Iqbal Husain Date: 2-15-198

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Rev. No.	Date	Item	Reason for Revision
1.	2/14/85	Add Addendum 1	Discrepancies between As-analyzed and as-built Configurations

Approval Iqbal Husain

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1. INTRODUCTION

Seismic and stress analysis of the High Pressure Core Spray (HPCS) discharge piping and support system of the La Crosse Boiling Water Reactor (LACBWR) have been performed to verify the adequacy of the "as-built" HPCS piping system to withstand a seismic event. The High Pressure Core Spray System of the LACBWR plant is the principal emergency core cooling system. It is designed to provide emergency coolant spray to the reactor core in the event that reactor water level drops accidentally.

Seismic and stress analyses of the LACBWR HPCS piping system were performed and design of the additional seismic supports were prepared by Nuclear Energy Services, Inc. (Reference 1 and 2) using the seismic criteria and spectra developed by Gulf United Nuclear Fuels Corporation (Reference 3). However, under Systematic Evaluation Program (SEP), the seismic hazard at the LACBWR site has been reevaluated, using current methodology and site specific response spectra. The applicable response spectra developed by EG&G under the SEP program (Reference 4) exceed the original design spectra as indicated in Figures 1-1 through 1-2. In order to assure adequacy of the LACBWR HPCS piping system to withstand the higher postulated seismic excitation, Structural Mechanics Associate of Connecticut Inc. (SMA-CT) has analyzed the HPCS piping system using the current ASME Code and licensing criteria. The revised analysis is based on the "as-built" configuration of the piping and support systems and include the stiffness characteristic of the piping supports. This report presents the results of the seismic and stress analysis conducted to verify the adequacy of the HPCS Suction Discharge piping and support systems. The HPCS Suction piping analysis is presented in separate report.

The HPCS piping and their support systems have been evaluated in accordance with the applicable requirements for Class 1 piping and component supports stipulated in the ASME Boiler and Presuure Vessel Code, Section III, Division 1, "Nuclear Power Plant Components", 1983 (Reference 5) and USNRC Standard Review Plan 3.9.3 "ASME Code Class 1,2, and 3 Components, Component Supports, and Core Support and Structures;" 1981 (Reference 6).

The seismic and stress analyses for the HPCS piping systems have been performed using the NUPIPE computer code (Reference 7), which is widely used code in the nuclear industry. The piping geometry input data (coordinates, diameter, wall thickness and weights), and the pressure and thermal loads have been taken from the piping isometric drawings (Reference 8), specifications (Reference 9), Nuclear Energy Services, Inc. reports (Reference 1,10, and 11) and the "as-built" field verification data (Reference 12). The seismic analysis has been performed using the response spectrum modal superposition method of dynamic analysis including a correction to account for the effects of non-participating mass. The seismic responses have been calculated using the applicable spectra associated with the damping values given in NRC Regulatory Guide 1.61.(Reference 13). The combination of modes and spatial earthquake components are based on requirments of NRC Regulatory Guide 1.92 (Reference 14). The stress analysis and acceptance criteria are in accordance with the design requirement of ASME Code and NRC Standard Review Plan 3.9.3.

Fatigue evaluation have been performed for the critically stressed region of reactor vessel nozzle connection in accordance with the ASME Code methods for Class 1 Components. Peak thermal stress intensity resulting from the thermal transient (initiation of HPCS flow) have been taken from the

original ANSYS thermal element model analysis (Reference 2). The original ANSYS thermal transient analysis represented a significant effort and are not affected by the non-conformances. Initial NES stress calculations, using the conservative stress intensification factors of the ASME Code for the socket weld coupling/reactor vessel nozzle region, resulted in an excessive peak stress value and therefore very low number of permissible HPCS operating cycles. The socket weld coupling/reactor nozzle region was analyzed by means of a detailed finite element model the ANSYS computer Code. The transient thermal loadings produced by the HPCS initiation were determind using the same model developed for stress analysis and using the LION computer program.

Section 2.0 of this report describes the description of the piping systems. Applicable Codes, standards and specification, are given in Section 3.0, while Section 4.0 describes the loading criteria. The acceptance criteria given in the Section 5.0 are consistent with licensing criteria as specified in ASME Code, and current NRC Regulatory Guides and the Standard Review Plan. The analytical methods for the static, dynamic and stress analysis are given in Section 6.0. Section 7.0 summarizes the results and conclusions of the analysis.

The results of the analysis indicate that the HPCS discharge piping systems and their supports meet the acceptance criteria. ASME Code Fatigue evaluation indicate 3×10^5 permissible normal start-up and shutdown cycles, 5,700 permissible HPCS operating cycles, 4000 permissible cycles for the combination of Operating Basis Earthquake (OBE) and maximum credible thermal transient events and 3,300 permissible cycles for the combination of Safe-Shutdown Earthquake (SSE) and maximum credible thermal transient events. Therefore , it has been concluded that the HPCS discharge piping and support system meet the intent of current licensing criteria.

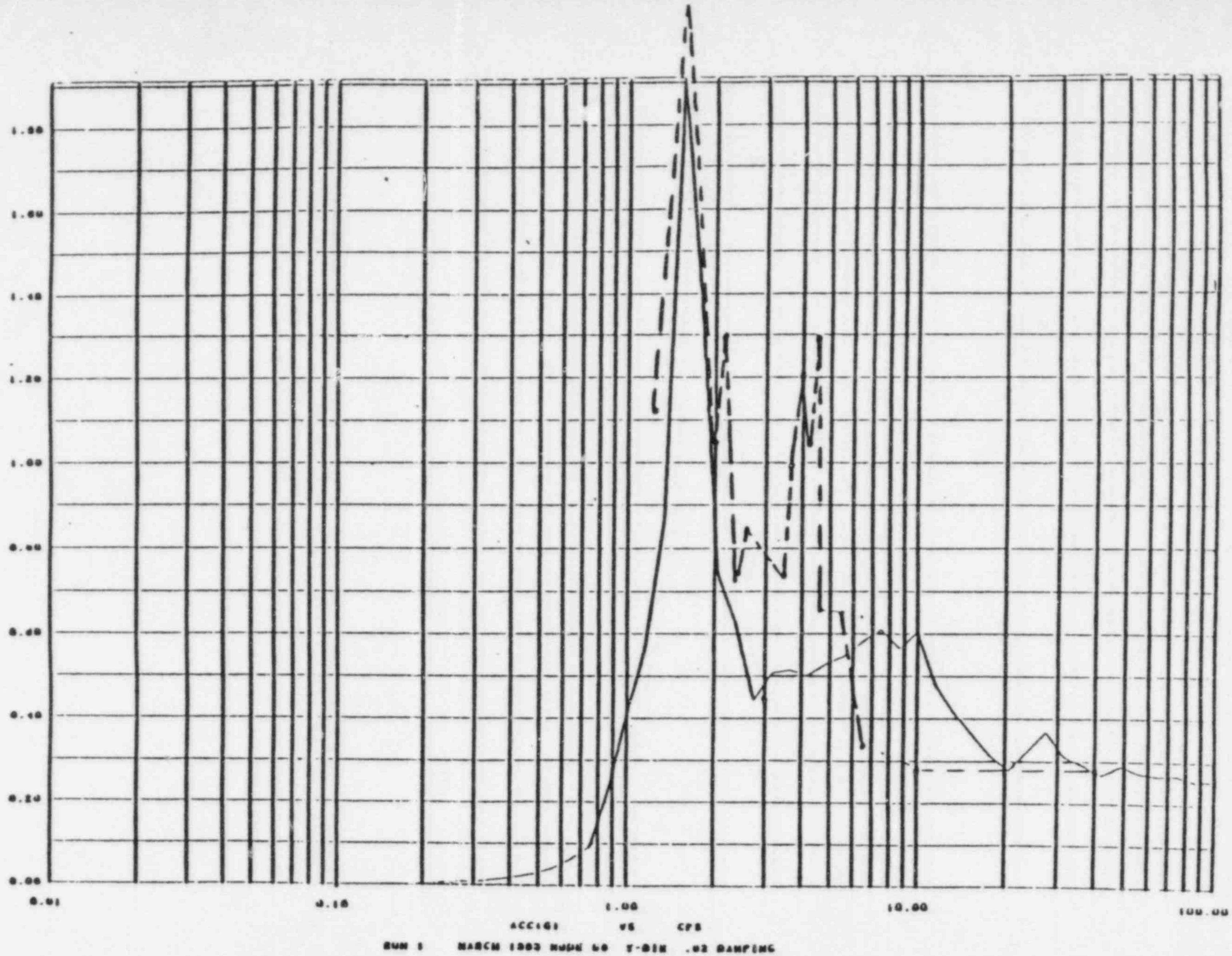


FIGURE B-15. HPCS DISCHARGE HORIZONTAL SPECTRA
(FIGURE 1-1)

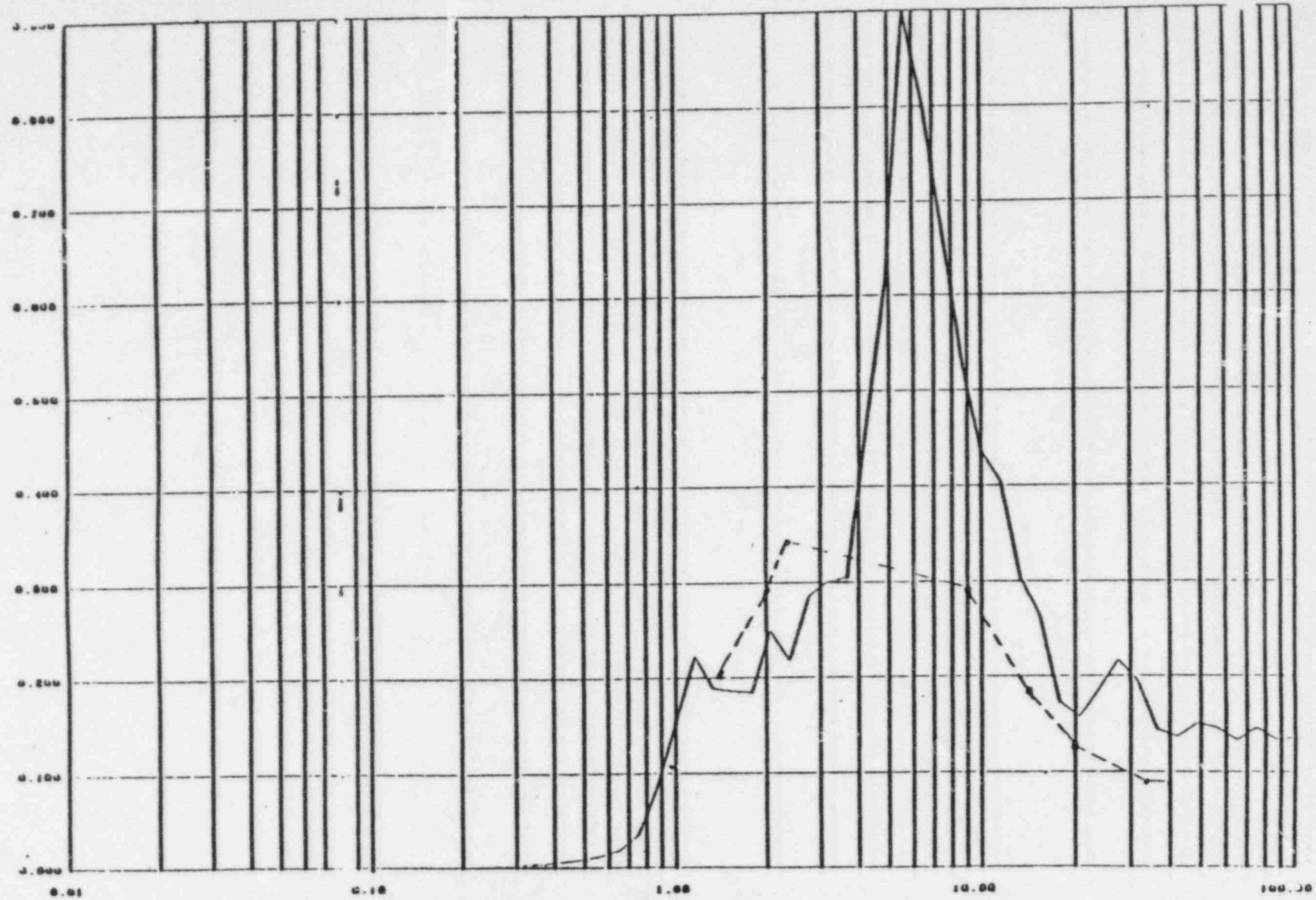


FIGURE B-16. HPCS DISCHARGE VERTICAL SPECTRA
(FIGURE 1-2)

2. DESCRIPTION OF PIPING SYSTEM

The High Pressure Core Spray (HPCS) system of the LACBWR power plant is the principal emergency core cooling system. It is designed to provide an emergency coolant spray to the reactor core in the event that reactor water level drops accidentally. This is done either by means of high pressure water injection under high reactor pressure conditions or by direct gravity feed of water from the overhead storage tank to the core spray header under low reactor pressure conditions.

In order to simplify the seismic and stress analyses of the long and complex HPCS piping system, the HPCS piping system has been divided into two sections. The first consisting generally of the suction piping which runs from the over head storage tank to the HPCS pumps and the second consisting of the discharge piping which runs from the HPCS pumps to the core spray header inlet. The HPCS suction piping analysis is presented in a separate report. The subject analysis of this report is, therefore, the HPCS discharge line.

The HPCS discharge line consists of stainless steel pipe line leading from the two high pressure core spray pumps to the core spray header inside the reactor vessel. The pumps are used for core spray when the reactor remains pressurized, as in the case of a small leak below the core. When the reactor and containment building pressures are equalized, as after a major system leak or rupture, a low pressure supply line bypassing the emergency core spray pumps allows water to flow directly from the overhead storage tank (or service water line) to the core spray header. The high pressure core spray pumps are also used in the boron injection system. Redundant control valves are provided for this purpose in the core spray pumps suction and discharge lines.

Rigid anchors located at points of expected large seismic deflections serve the purpose of isolating the discharge

lines from the interconnecting piping systems. Figure 2-1 shows the routing of the discharge line and the extent of suction line and sodium penaborate lines considered in the subject analysis.

The schematic of the piping systems shown in Figure 2-1 includes major pipe dimensions, elevations, anchor points and support locations. The piping arrangement, has been taken from drawings of reference 8. Piping properties are based on information given in the piping specification (Reference 9) and are summarized in Appendix A. The location of pipe support systems and their structural stiffness charecteristics are based on informations given in Reference 1, 10, & 11, and those obtained/verified by Dairyland Power Cooperative engineers from a field inspection dated February1 through 4, 1983 (Reference 12). The support structural characteristic are shown in Figures 2-2 through 2-4. The support stiffnesses are summarized in Appendix A.

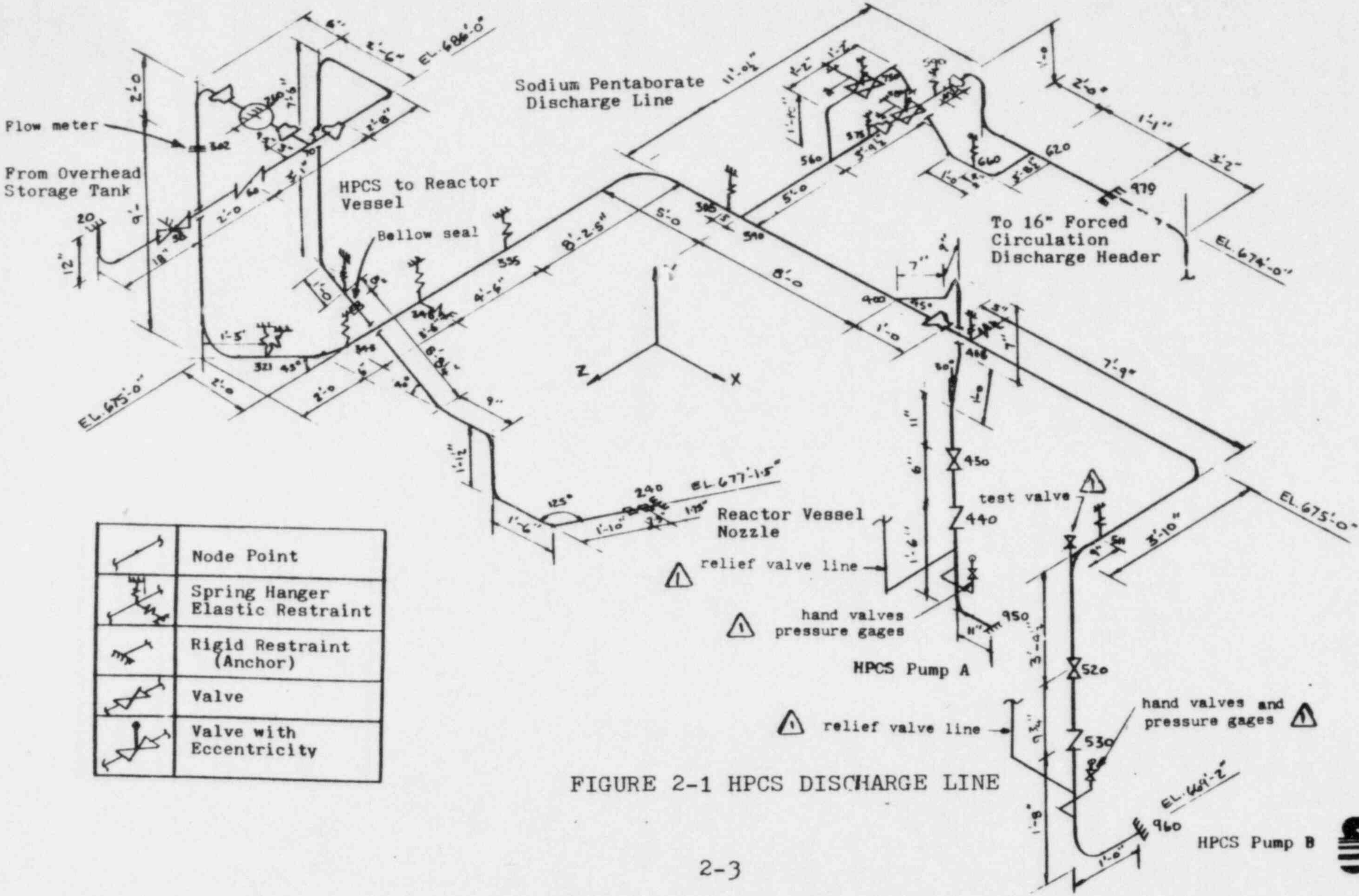


FIGURE 2-1 HPCS DISCHARGE LINE

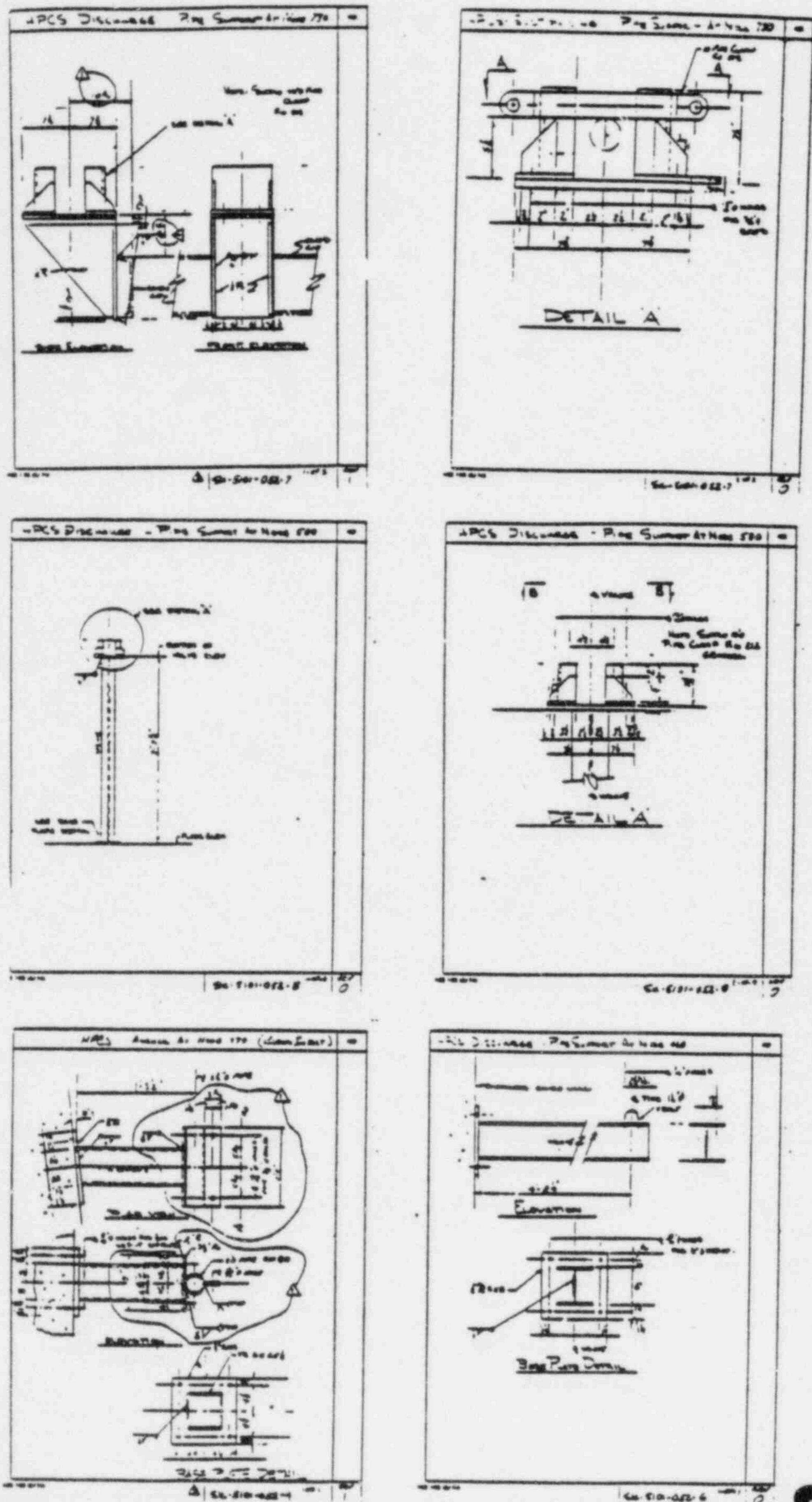


FIGURE 2-2 HPCS DISCHARGE LINE SUPPORTS

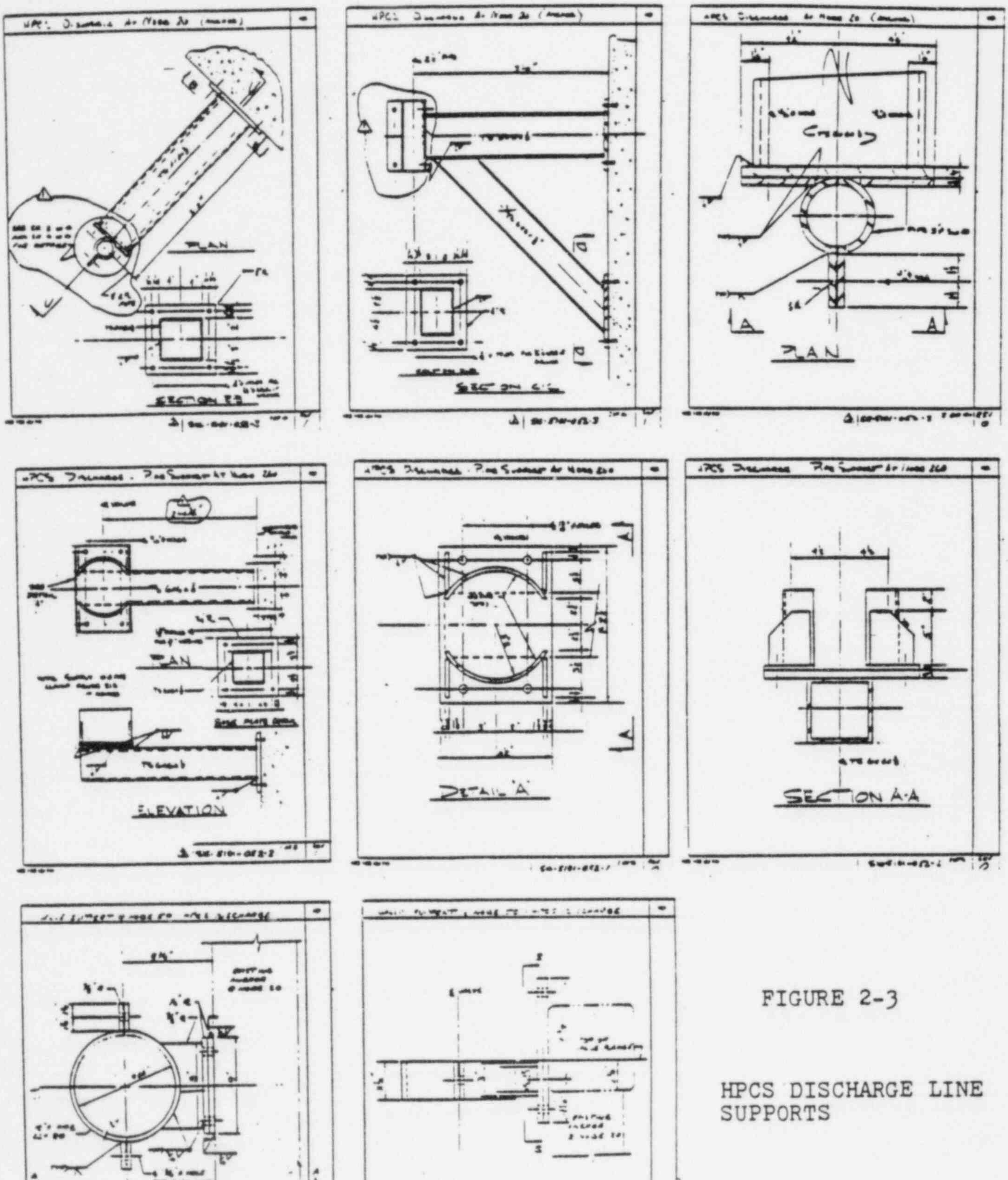
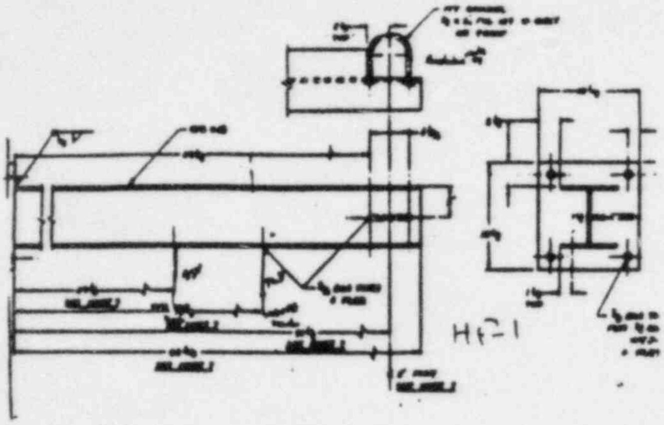
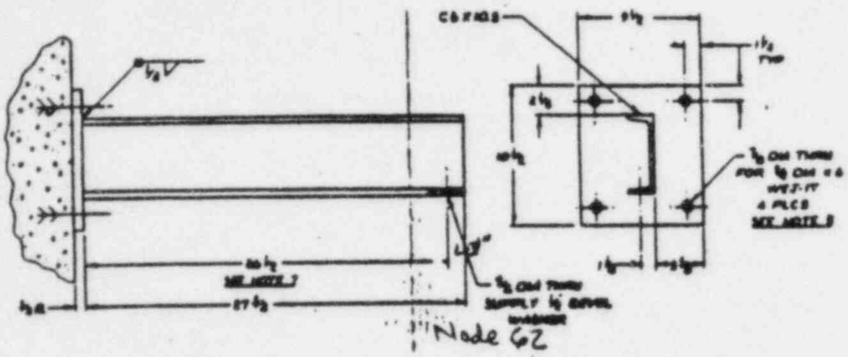


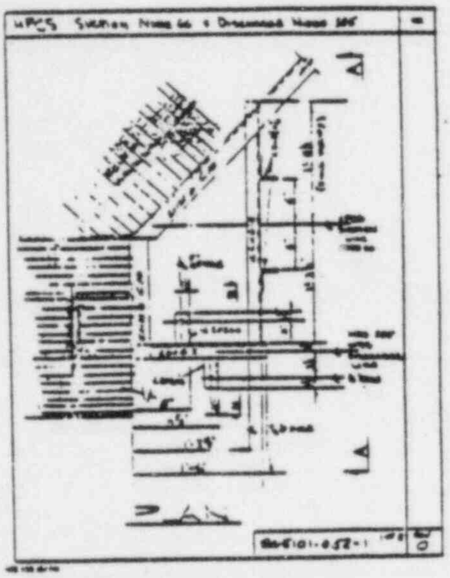
FIGURE 2-3

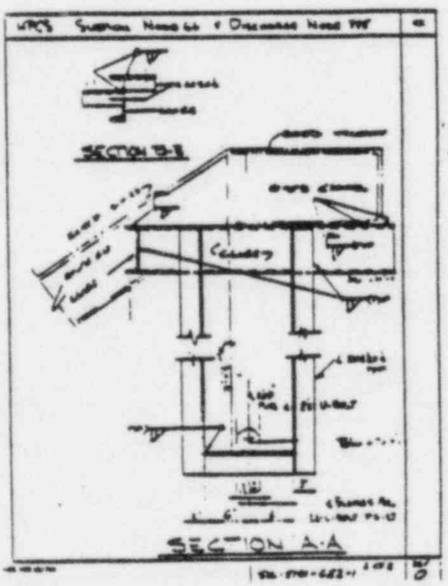
HPCS DISCHARGE LINE SUPPORTS

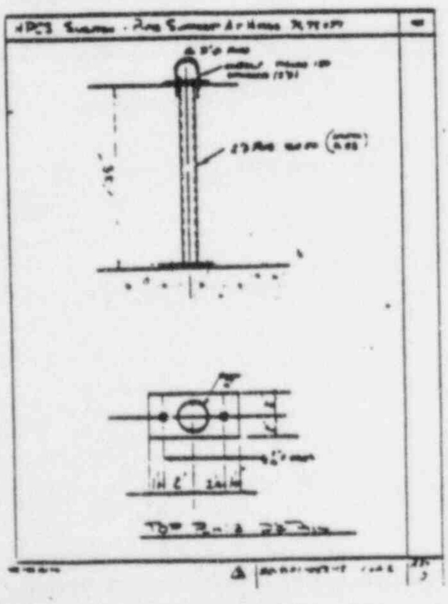




HP-2







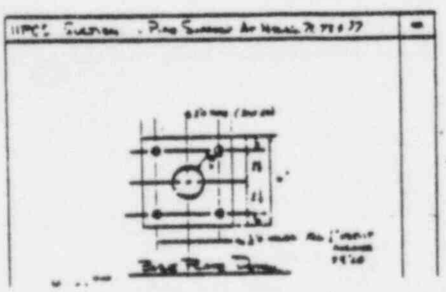


FIGURE 2-4 HPCS DISCHARGE LINE SUPPORTS

3. APPLICABLE CODES, STANDARDS AND SPECIFICATIONS

The HPCS piping and support systems have been analyzed using applicable methodology and acceptance criteria consistent with current ASME Code and Regulatory requirements.

The following design Codes, Regulatory Guides, Standard Review Plan criteria and specifications have been used in the seismic and stress analysis of Class I piping and support systems.

1. ASME Boiler and Pressure Vessel Code Section III, Subsection NB Class I Components, 1983 Edition.

2. Standard Review Plan 3.9.3 "ASME Code Class 1 2 and 3 Components, Component Supports and Core Support Structure".

3. USNRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants", October, 1973.

4. USNRC Regulatory Guide 1.92 "Combination of Modes and Spatial Components in Seismic Response Analysis", Revision 1, February, 1976.

5. Sargent and Lundy Engineers, "Specification for Piping System La Crosse Boiling Water Reactor", LACBWR #256.

6. Allis-Chalmers, "La Crosse Boiling Water Reactor Safeguards Report Volume I and II, LACBWR #283, dated August, 1967.

4. LOADING CONDITION

Appendix A to the Standard Review Plan 3.9.3 and ASME Code Subsection NB provide guidance in the selection of acceptable design and service stress limits associated with various loadings and combinations there of, resulting from plant and system operating conditions and design basis events, and natural phenomenon. Based upon these guidance, the following applicable loading conditions have been considered in the analysis.

Design and Operating Pressures.

Piping design pressures are taken from the LACBWR piping specification (Reference 9) and are 100 psig for piping between node points 20 and 50 and 1400 psig elsewhere in the system. Operating pressures for the HPCS discharge lines are based on the LACBWR Safeguards Report (Reference 15). These are 100 psig upto node points 50, 1340 psig from node 50 to the reactor vessel nozzle and 1400 psig for the remainder of the system.

Dead Weight and Sustained Mechanical Loads.

The dead weight of the piping system is calculated considering the piping to be insulated and filled with water. Sustained mechanical loads considered in the analysis includes the weight of the valves and valve operators. The uniformly distributed piping weights and the concentrated weight are given in Appendix A.

Thermal Loads

Thermal Anchor Movements

Thermal expansion or contraction of the reactor vessel during start-up and shutdown results in maximum displacements of the piping system anchor at the reactor vessel nozzle (node point 240). Thermal anchor movements at node point 240 are summarized in Appendix A.

Thermal: Normal Start-up and Shutdown

During normal start-up and shutdown a temperature change of 344°F is assumed in the piping in the region of the reactor vessel HPCS discharge nozzle.

Thermal: Maximum Credible Accident

The sudden introduction of cold water from the HPCS system piping into the hot pressure vessel nozzle, due to a LOCA or other low water level condition results in a transient thermal condition in the nozzle region. This temperature transient generates stresses in the pipe due to the large temperature gradients across the pipe wall and due to any material discontinuities present. These thermal loads which are applied at node points 230 and 240 have been calculated by means of a transient thermal analysis with the LION Computer Code (Appendix E) and are presented in Appendix B. These loads are considered in conjuction with the upset plant condition.

Seismic Loadings

The piping anchors and supports are subjected to seismic accelerations as defined by the appropriate response spectrum for each of the two horizontal and vertical directions. The 2% damped, peak-broadened Safe Shutdown Earthquake (SSE) Spectra associated with the Containment Building at an elevation of 694.25 feet (Reference 4) are used for the HPCS Discharge line. These spectra shown in Figure 4-1 through 4-3 are conservative for all elevations of the HPCS Discharge line. The digitized seismic spectra are presented in Appendix A.

The relative seismic anchor movements between the various pipe support and anchor points are calculated from the low frequency displacement response obtained from the Containment Building response spectra. The relative seismic anchor movements used in the analysis are presented in Appendix A.

For load combinations including Operating Basis Earthquake (OBE), the SSE response results are conservatively multiplied by a factor of 0.5.

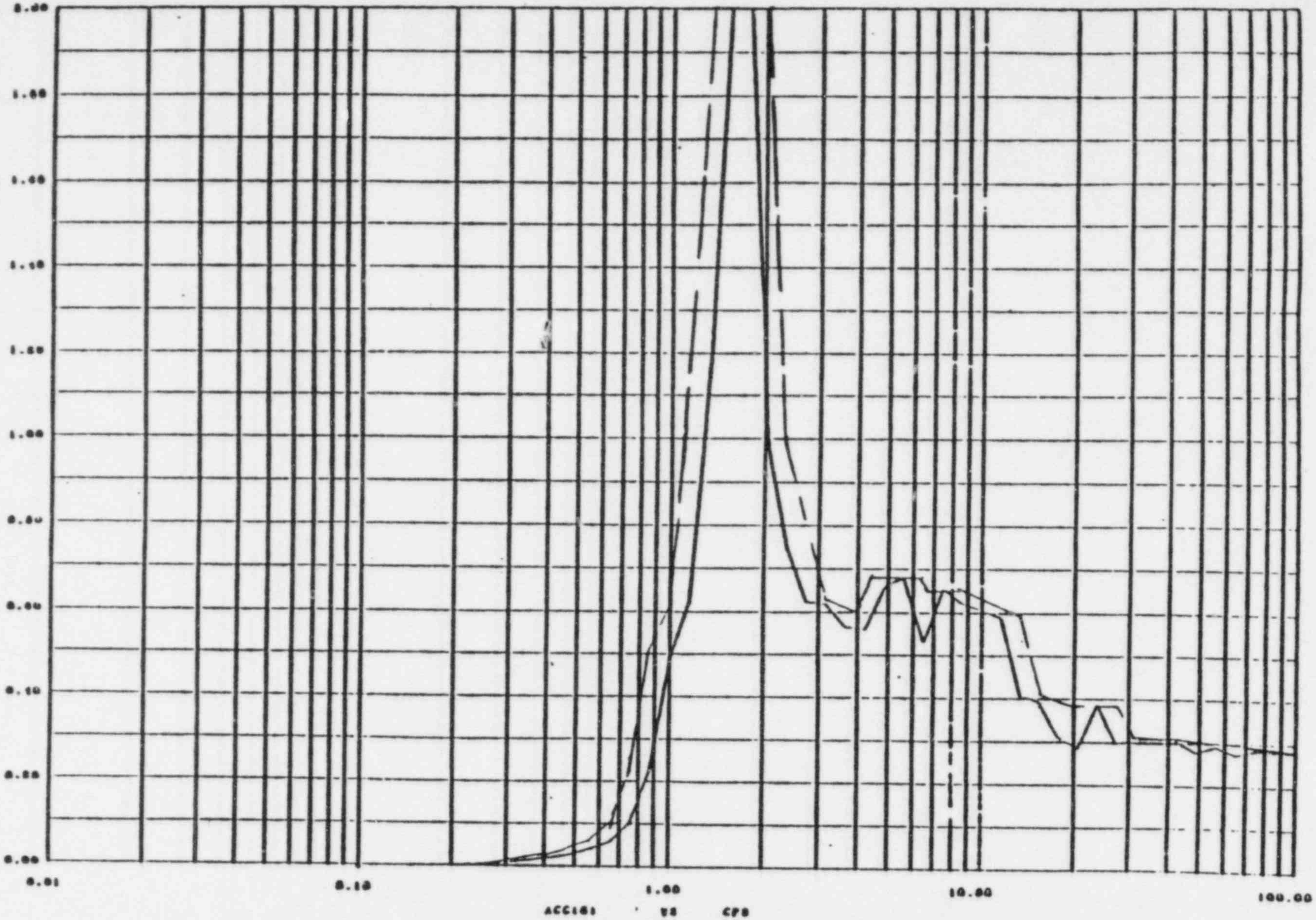


Figure 41. Node 56 (elev. 694.25 ft.) X-Dir. Spectra .02 Damping

(FIGURE 4-1) For Discharge Line

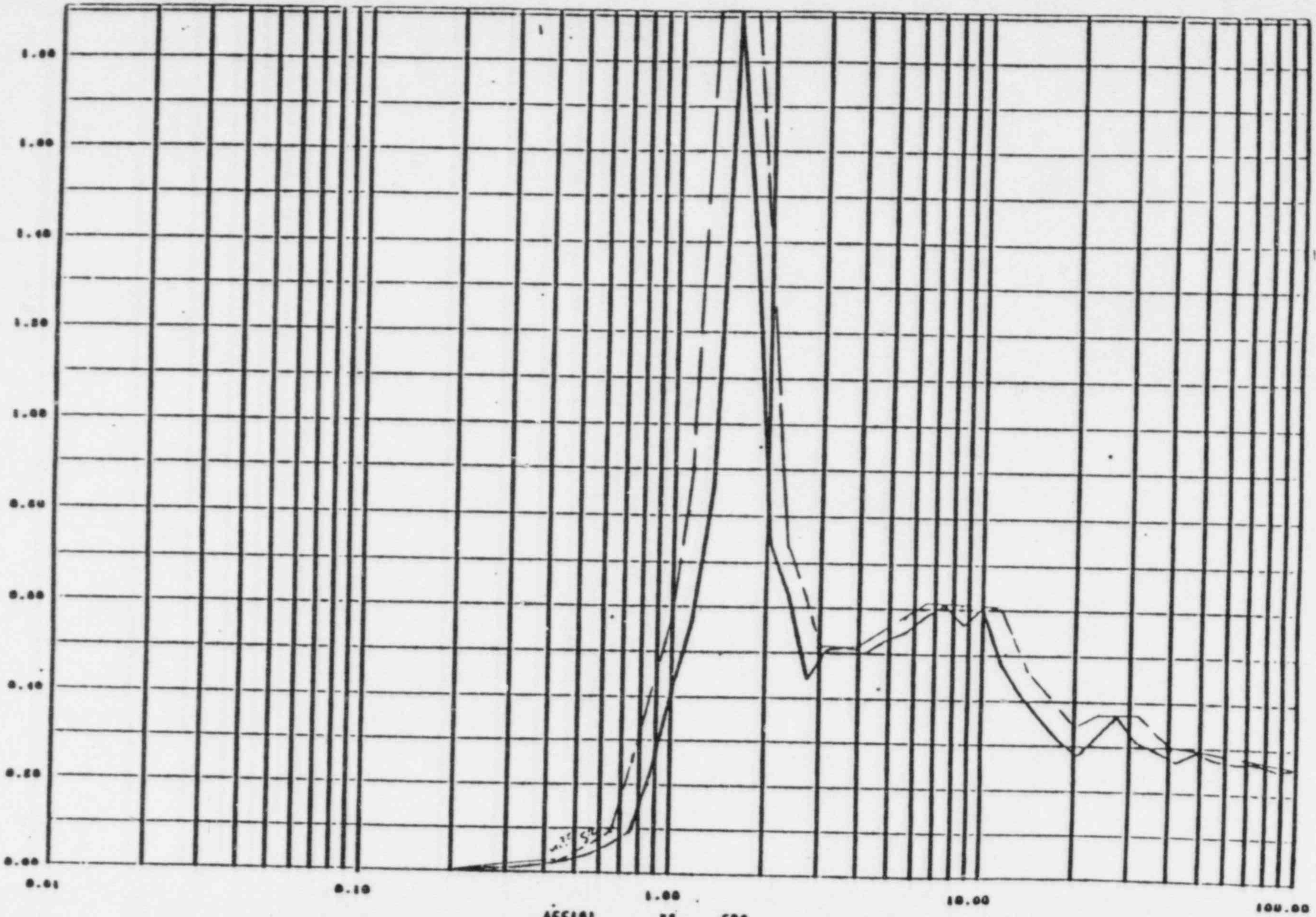


Figure 42. Node 56 (elev. 694.25 ft.) Y-Dir. Spectra .02 Damping

(FIGURE 4-2) For Discharge Line

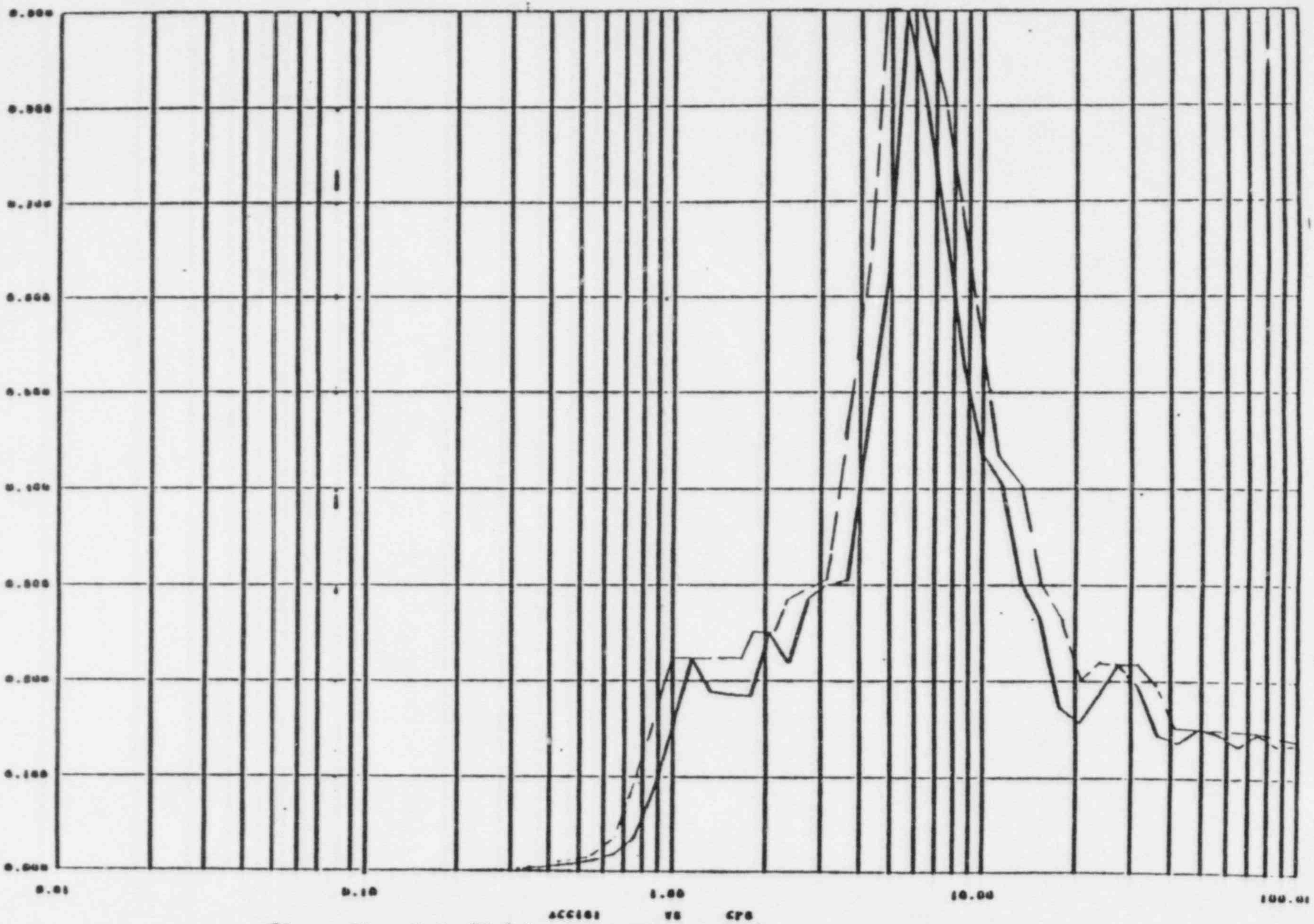


Figure 43. Node 56 (elev. 694.25 ft.) Z-Dir. Spectra .02 Damping
(FIGURE 4-3) For Discharge Line

5. LOAD. COMBINATIONS AND ACCEPTANCE CRITERIA

The requirements for load combinations and stress acceptance criteria for a Class I piping system are giver in NRC Standard Review Plan 3.9.3 (Reference 6) and Subsection NB3600 of Section III of the ASME Code. These requirements are summarized below.

5.1 Design Considerations and Design Loadings.

The primary stress intensity, resulting from design pressure shall satisfy the requirement of equation 1 of the ASME Code.

5.2 Service Loading Combinations.

Service Level A Stress Limit

The piping system shall meet a service limit not greater than Level A when subjected to sustained loads resulting from normal plant/system operation. This requirement is satisfied by limiting the primary stress intensity due to pressure and sustained loads calculated using equation 9 of the ASME Code to 1.5 times the allowable design stress intensity, S_m , at design temperature.

Service Level B Stress Limit

The piping system shall meet a service limit not greater than Level B when subjected to the appropriate combination of loadings resulting from (1) sustained loads, (2) specified plant/system operating transients (SOT) and (3) the Operating Basis Earthquake (OBE) The requirement for Service level B is satisfied by limiting the primary stress due to applicable service level B loadings as calculated by equation 9 of the ASME Code to 1.8 S_m or 1.5 S_y which ever is smaller. In addition the primary plus secondary stress intensity range resulting from the combined effects of linear thermal expansion linear thermal gradient and discontinuity, operating pressure

thermal anchor movement calculated in accordance with equation 10 of the ASME Code must be less than 3 Sm. In the event equation 10 is not satisfied, the piping component may still be acceptable provided the requirement of a simplified elastic-plastic discontinuity analysis (NB-3653.6) are met.

Service Level C Stress Limit

The piping system shall meet a service limit not greater than Level C when subjected to the appropriate loadings resulting from (1) sustained loads and (2) the design basis pipe break event (not specified in this analysis)

Service Level D Stress Limit

The piping system shall meet a service limit not greater than Level D when subjected to the appropriate combination of loadings resulting from (1) sustained load (2) LOCA; and (3) The Safe Shutdown Earthquake (SSE). The requirement for Service level D is satisfied by limiting the primary stress due to applicable service level D loadings as calculated by equation 9 of the ASME Code to $2.4S_m$ or $0.7S_u$ which ever is smaller.

6. PIPING ANALYSIS

6.1 NUPIPE ANALYTICAL PROCEDURES

The basic method of anlysis used in NUPIPE is the finite element stiffness method. In accordance with this method, the continiuous piping is mathematically idealized as an assembly of elastic structural members connecting discrete nodal points. Nodal points are placed in such a manner as to isolate particular types of piping elements, such as straight runs of pipe, elbows, valves, etc., for which force-deformation characteristics can be categorized. Nodal points are also placed at all discontinuities, such as piping supports, concentrated weights, branch lines, and changes in cross-section. System loads such as weights, equivaent thermal forces, and earthquake inertia forces are applied at the nodal points. Stiffness charateristics of the interconnecting members are related to the effective shear area and moment of inertia of the pipe. The stiffness of piping elbows and certain branch connectors is modified to account for local deformation effects by the flexibility factors suggested in the ASME Section III Code. Figures 6-1 and 6-2 show the NUPIPE mathematical model and computer plot of the HPCS discharge piping system.

6.1.1 Static Analysis

The static equation of equilibrium for the idealized system may be written in matrix form, as follows:

$$KU = P - Q \qquad (6\text{-}1)$$

where:

K = stiffness matrix for assembled system
U = nodal displacement vector
P = external forces, weights, etc.
Q = equivalent thermal forces = $\int AE\alpha\, T dL$

The nodal unknown displacements are obtained in NUPIPE by solving these simultaneous using the Gauss method. The nodal displacements are then applied to the individual members, and member stiffness used to find internal forces. The nodal displacements at support locations is used along with the support stiffness to determine support reactions.

6.1.2 Dynamic Analysis

6.1.2.1 Mathematical Model

For dynamic analysis, the mathematical model is described as a lumped mass, multi-degree of freedom model. The distributed piping mass is lumped at the system nodal points. The equation of equilibrium for the system is:

$$M\ddot{U} + C\dot{U} + KU = F \qquad (6\text{-}2)$$

where:

- M = mass matrix for assembled system.
- C = damping matrix for assembled system
- $\ddot{U}$ = nodal acceleration vector = $\ddot{U}(t)$
- $\dot{U}$ = nodal velocity vector = $\dot{U}(t)$
- U = nodal displacement vector
- F = applied dynamic force = $F(t)$ = $M\ddot{U}_g$ for earthquake
- $\ddot{U}_g$ = support acceleration = $\ddot{U}_g(t)$

This equation is solved for the system dynamic response as follows. First, the frequencies and mode shapes are obtained by removing the forcing and damping terms from Equation 6-2 and solving. Next, the natural mode shapes are used to affect an orthogonal transformation of Equation 6-2, yielding a series of indepdndent equation of motion uncoupled in the system modes. Then, the uncoupled equations are solved by the response spectrum method to obtain system response in each mode, and the individual modal results

are then combined in accordance with Regulatory Guide 1.92 (Reference 5) to determine the total system dynamic response. The mathematical formulation of these steps are as follow:

6.1.2.2 Natural Frequencies and Mode Shapes

The eigenvalues (natural angular frequencies ω_n) and the eigenvectors (mode shapes ϕ_n) for each of the natural modes are calculated by solving the frequency equation.

$$\left[K - \omega_n^2 M\right]\left\{\phi_n\right\} = \left\{0\right\} \qquad (6\text{-}3)$$

where:

ω_n = natural frequency in n^{th} mode
K = stiffness matrix
M = mass matrix
ϕ_n = mode shape vector in n^{th} mode
O = null vector

The eigenvalues and eigenvectors are obtained in NUPIPE using the Householder- QR algorithm (NUPIPE -11M) or subspace iteration (NUPIPE-11L).

6.1.2.3 Dynamic Response

Pre and post-multiplication of Equation 6-2 by $[\phi]$, the square matrix of mode shape vectors, constitutes an orthogonal transformation, from which the uncoupled equations of motion shown below are obtained.

$$\ddot{Y}_n + 2\omega_n\lambda_n\dot{Y}_n + \omega_n^2 Y_n = P_n \qquad (6\text{-}4)$$

where:

Y_n = generalized (modal) displacement coordinate for the n^{th} mode ($U_n = \phi_n Y_n$)

λ_n = damping ratio for the n^{th} mode expressed as percent of critical damping

P_n = generalized force for the n^{th} mode = $\phi_n^T F$

Solution to these differential equations is obtained by the method of response spectrum superposition.

6.1.2.4 Response Spectrum Superposition

Based on this method, the maximum generalized acceleration for each mode is given by:

$$\ddot{Y}_{n_{max}} = \left(\sum_{j=x,y,z} \left(R_{nj} \; Sa_{nj} \right)^2 \right)^{1/2} \Big/ M_n \qquad (6\text{-}5)$$

where:

$\ddot{Y}_{n\,max}$ = maximum generalized coordinate acceleration response

Sa_{nj} = spectral acceleration for n^{th} mode in in J-direction (from response spectrum data input)

R_{nj} = Mode participation factor for n^{th} mode in J-direction

M_n = modal mass for the n^{th} mode = $\left(\phi_n^T M \phi \right)$

The maximum internal inertia forces are given by:

$F_{in\,max} = M_i \ddot{Y}_{n\,max} \phi_{in}$ = maximum inertia force at nodal mass point i in the n^{th} mode

These inertia forces are calculated for each of the system natural modes, and applied as static forces in the same manner as the weight or equivalent thermal forces, to find internal forces in each mode. Total system response is then obtained by combining the individual modal response values in accordance with regulatory guide 1.92. The effects of higher modes (Frequency >33 Hz) is automatically considered by applying static loads in proportion to the non-participating mass times the zero period acceleration. The combined seismic response of the three spatial component of the earthquake is obtained by taking the square-root-of-the-sum-of-the-squares of the corresponding maximum response value due to the three components calculated independently (Regulatory Guide 1.92).

6.1.3 Piping Stress Analysis

The modeling of the various piping problems using the NUPIPE computer code was conducted in a manner consistent with the data available from the piping isometric drawings, the support detail drawings, and the NES design analyses. Care was taken to accurately model the mass and stiffness characteristics of the various systems. Particular care was taken to properly model the mass eccentricities associated with the operators of motor operated, air operated, and hand operated valves as well as smaller eccentricities associated with other non- axisymmetric valves.

The formula used to evaluate the primary secondary stress intensity levels and fatigue analysis for Class 1 piping systems is taken from Subsection NB-3600, Section III, ASME Boiler and pressure Vessel Code. These formulas are given below.

Pressure Design Check

The minimum rquired pipe wall thickness (t_m) is computed from

$$t_m = \frac{PD_o}{2(S_m + yP)} \text{ ---------------------(Eqn.1)}$$

where:

P = Internal design pressure

D_o = Outside diameter of pipe

S_m = Maximum allowable stress in material at the design temperature

y = 0.4

Primary Stress Intensity Check

The primary stress intensity is computed from and limited by the following:

$$B_1 \frac{PD_o}{2t} + B_2 \frac{D_o}{2I} M_i = 1.5S_m \text{ ----------------(Eqn.9)}$$

where:

B_1, B_2 = Primary stress indices for the specific piping component being investigated.

t = Nominal wall thickness of piping component

I = Moment of inertia

M_i = Resultant moment loading from loads caused by (1) weight, (2) earthquake, and (3) other mechanical loads (one-half the range, excluding anchor movement effects).

P, D_o, S_m = as in Eqn.1

Primary Plus Secondary Stress Intensity Range Check

The primary plus secondary stress intensity range is computed from and limited by the following:

$$S_n = C_1\left(\frac{P_o D_c}{2t}\right) + C_2\left(\frac{D_o}{2I}\right) M_i + \left[\frac{1}{2(1-v)} \quad E\alpha \; \Delta T_1\right]^{*} + C_3 E_{ab} \left|\alpha_a \bar{T} - \alpha_b \bar{T}_b\right| \leq 3S_m \text{ - (Eqn. 10)}$$

where:

C_1, C_2, C_3	= Secondary stress indices for the specific piping component being investigated.
P_o	= Range of operating pressure
M_i	= Range of moment loading resulting from thermal expansion, anchor movements from any cause, seismic effects, and other mechanical loads.
V	= Poison ratio = 0.3
*	= This term is omitted in the summer, 1979 revision of the ASME Code. Version 1.5 of NUPIPE reflects this change.
$E\alpha$	= Modules of elasticity (E) times the mean coefficient of thermal expansion (α)
ΔT_1	= Range of absolute value (without regard to sign) of the temperature difference between the temperature of the outside surface (T_o) and the temperature of the inside surface (T_i) of the piping component, assuming moment-generating equivalent linear temperatur distribution.
E_{ab}	= Average modulus of elasticity of the two parts of the gross discontinuity.
α_a	= Mean coefficient of expansion on side "a" of a gross discontinuity such as a branch-to-run, flange-to-pipe, or socket-fitting-to-pipe gross discontinuity.
T_a	= Range of average temperature minus the room temperature on side "a" of a gross discontinuity.
α_b	= Mean coefficient of expansion on side "b" of a gross discontinuity.
T_b	= Range of average temperature minus the room temperature on side "b" of a gross discontinuity.

D_o, t, I = As above.

Peak Stress Intensity Range

In peak stress intensity range is calculated, for later use in the fatigue evaluation, as follows:

$$S_p = K_1C_1\left(\frac{P_oD_o}{2t}\right) + K_2C_2\left(\frac{D_o}{2I}\right)M_i + \frac{1}{2(1-v)}\,K_3E\alpha\left|\Delta T_1\right|$$

$$+ K_3C_3E_{ab}\left|\alpha_a\bar{T}_a-\alpha_b\bar{T}_b\right| + \frac{1}{1-v}\,E\alpha\left|\Delta T_2\right| \text{--(Eqn. 11)}$$

where:

K_1, K_2, K_3, = Local stress indices for the specific piping component being investigated.

ΔT_2 = Range of absolute value (without regard to sign) for that portion of the nonlinear thermal gradient through the wall thickness not included in ΔT_1 of (Eqn.10)

Elastic-Plastic Discontinuity Analysis

Where the primary plus secondary stress intensity range, calculated by equation (10), does not fall within the elastic range (3Sm), the following formula (simplified elastic-plastic discontinuity analysis) are evaluated.

$$S_e = C_2\left(\frac{D_o}{2I}\right)M_i \leq 3S_m \text{------------------------(Eqn. 12)}$$

where:

S_e = Expansion stress

C_2 = Secondary stress index for specific piping component being investigated.

M_i = Range of moment loading resulting from thermal expansion and anchor movements.

Limit of primary plus secondary membrane, plus bending stress

intensity, excluding thermal expansion stresses:

$$C_1\left(\frac{P_oD_o}{2t}\right) + C_2\left(\frac{D_oM_i}{2I}\right) + C_3^1E_{ab}\left|\alpha_aT_a - \alpha_bT_b\right| \leq 3S_m \text{------(Eqn. 13)}$$

where:

C_1, C_2 = Secondary stress indices for the specific component under investigation.

C_3^1 = Stress index value for the specific component under investigation.

Both equation (12) and equation (13) must be satisfied before equation (14) is used.

<u>Fatigue Evaluation</u>

Fatigue criteria are satisfied by limiting the usage factor. The uasage factor is defined as the ratio of the number of system cycles between two load conditions to the number of cycles allowable for the alternating stress range between these conditions. This ratio is identified as $U = n_n/N_n$ in subaricle NB3222.4 of the ASME , section III code. The number of cycles allowable is taken from a curve provided in appendix I of the ASME Code and which is contained in NUPIPE. The alternating stress is calculated from:

$$S_{alt} = \tfrac{1}{2}K_eS_p \text{ ------------------(Eqn.14)}$$

where:

S_{alt} = Alternating stress intensity

K_e = Factor used to compensate for reduction in cycle life in plastic cycling.

= 1.0 for $S_n \leq 3S_m$

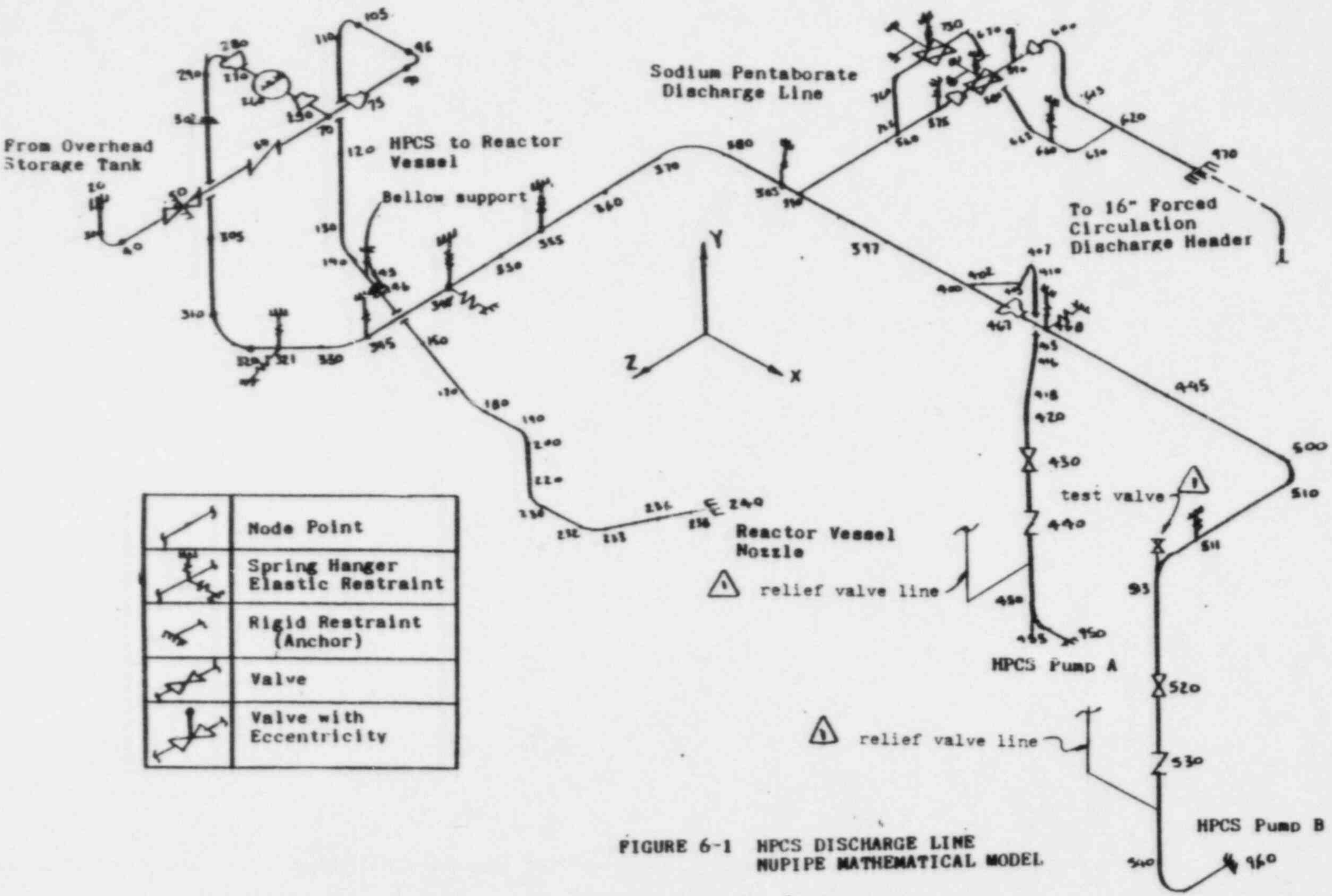


FIGURE 6-1 HPCS DISCHARGE LINE NUPIPE MATHEMATICAL MODEL

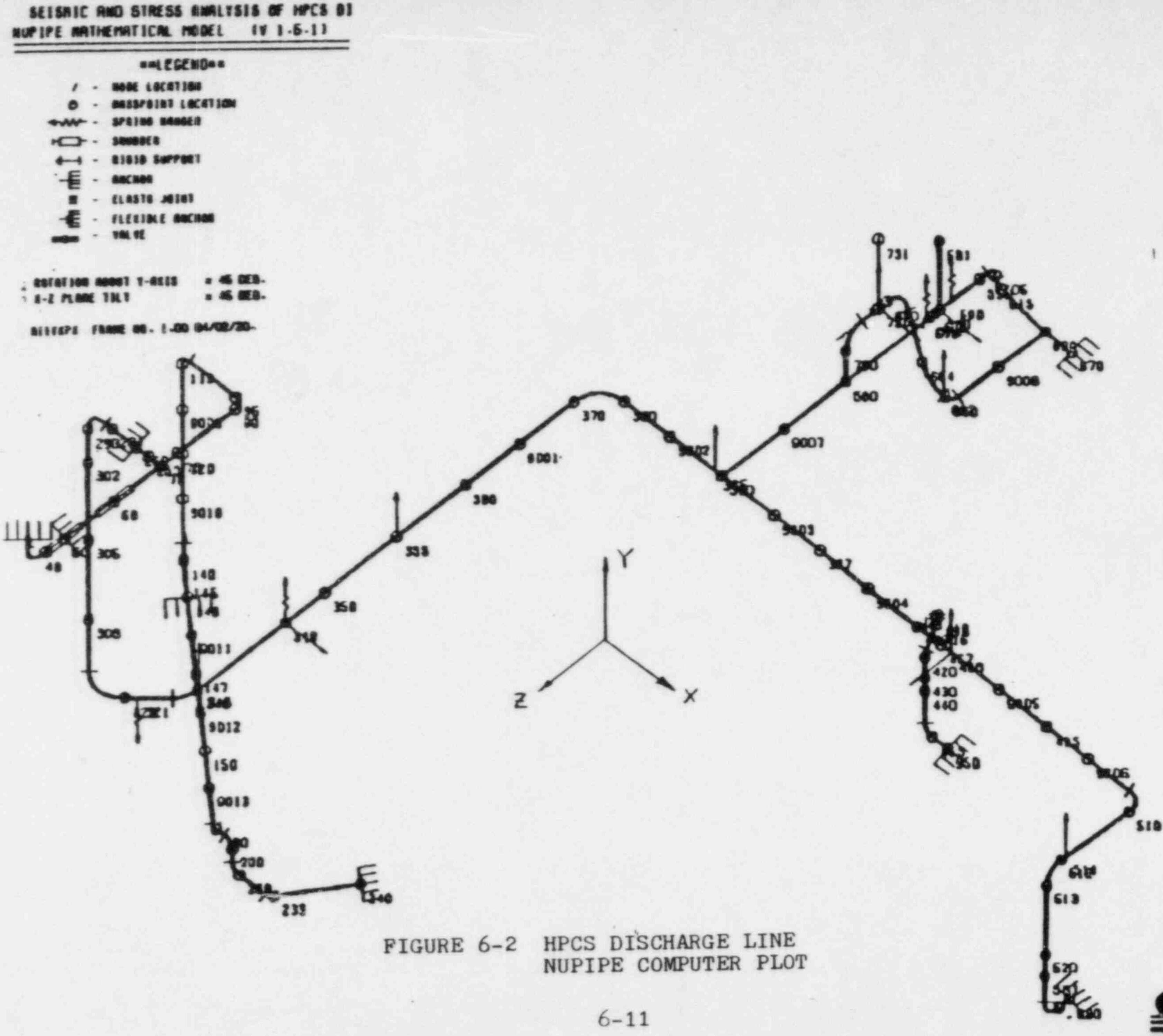


FIGURE 6-2 HPCS DISCHARGE LINE
NUPIPE COMPUTER PLOT

7. RESULTS OF ANALYSIS

The detail results of seismic and stress analysis of LACBWR High Pressure Core Spray Discharge piping systems are contained in Reference 16.

Appendix A contain the NUPIPE input data such as pipe mass and section properties pipe supports stiffnesses, concentrated weights, digitized seismic spectra and seismic anchor movements. Appendix B contain the support reaction loads due to various load cases and acceleration due to seismic load. The input data and results of the ANSYS thermal transient stress analysis taken from Reference 2 are given in Appendix C. The HPCS Discharge nozzle thermal transient analysis with the LION computer code taken from Reference 2 are given in Appendix E. Appendix D provide detail ASME Code calculations for the stress and fatigue evaluations of the critically stressed region of HPCS Discharge line reactor vessel nozzle connection.

7.2 HPCS DISCHARGE LINE

The pertinent natural frequencies of the lower 20 modes of vibration of the HPCS Discharge piping system together with the modal paticipating mass fractions for each mode are given in Table 7-1. The fundamental frequency of 4.54 Hz represents the X-direction horizontal displacement at Nodes360,370. The most important mode in terms of mass participation is mode 15 (15.34 Hz) which represents the z-direction horizontal displacement at Node 581. The effects of higher modes ($>$ 20.1 Hz) is adequately accounted for in the NUPIPE program by applying static loads in proportion to the non-participating mass times the zero period acceleration. The maximum deflection due to the SSE seismic inertia loading is 0.26 inches in horizontal X-direction at Node 512. For a flexible piping system this deflection is acceptable. The

maximum combined SSE seismic acceleration is 1.46 G at Node 500. Therefore valves in the HPCS Discharge piping system should be seismically qualified at 1.46 G acceleration level.

Figures 7-1 and 7-2 represents Class 1 piping stress analysis results. The maximum primary stress intensity of 19.58 ksi, resulting from Service Level D load combination which included SSE seismic event occurs at Node 960 and is considerably smaller than the Code allowable stress intensity of 39.36 ksi. The maximum primary plus secondary stress intensity of 58.15 ksi at Node 238 due to Service Level D load combination which conservatively included simultaneous occurrence of SSE seismic event and maximum credible thermal transient event is smaller than the Code allowable stress intensity of 60.0 ksi.

The peak stress intensity at the pressure vessel HPCS Discharge nozzle, resulting from the thermal transient and material and structural discontinuities are taken from Reference 2 and are presented in Appendices C and E. The peak stress intensities were calculated by means of the detailed ANSYS finite element analysis and are presented in Appedix C. The transient thermal loading (Appendix E) produced by the HPCS initiations were determined using the same basic model developed for stress analysis and using the LION computer code. The peak thermal stress intensity in various critical regions have been combined with the NUPIPE calculated pressure, dead weight and seismic stresses.

Detailed ASME Code Class 1 stress and fatigue evaluations of the HPCS Discharge nozzle are given in Appendix D and summarized in Table 7-2 and 7-3. From Table 7-2 it can be seen that considerable margin of safety exists between the primary stress intensity and the Code allowable stress intensity for both Service Level B (includes OBE) and Service Level D (includes SSE) load combination. The primary plus secondary stress intensity range S_n, for OBE, SSE, thermal normal startup/shutdown and maximum credible thermal transient (HPCS initiation) events occuring separately are considerably smaller than the Code allowable stress intensity value.

The primary plus secondary stress intensity range have also been calculated by conservatively assuming that the OBE or SSE seismic event and the maximum credible thermal transient accident event (MCA) occur simultaneously. The maximum primary plus secondary stress intensity range even for this conservative load combination is smaller than the code allowable stress intensity.

Table 7-3 presents the allowable number of stress cycles for the OBE, SSE, normal plant start-up/shutdown and MCA events occurring separately as well as the unlikely combinations of seismic and MCA events occuring simultaneously. From Table 7-3 it can be seen that considering MCA thermal loads only, 5,700 HPCS operating cycles are permitted. The number of permissible stress cycles for the conservative combination of SSE seismic plus thermal loads is 3300.

The above analysis indicates that the HPCS Discharge pipe is adequate to sustain the effects of the HPCS initiation and SSE seismic events. The evaluation of the piping support is included in section 7.3

7.2 <u>PIPE SUPPORT EVALUATION</u>

The pipe supports for HPCS Discharge piping system were evaluated for the Service Level D (faulted condition) load combination consisting of:

DW + TE $\pm$ SSE (Inertia) $\pm$ SSE (SAM)

where:

DW = Dead weight
TE = Thermal expansion including thermal anchor displacements
SSE (Inertia) = Safe Shutdown Earthquake Inertia loads
SSE (SAM) = SSE Seismic Anchor Movements

This combination is conservative since it conservatively assumes that the maximum support reaction loads due to thermal expansion, SSE inertia loads and SSE seismic anchor movement occurs simultaneously. The resultant support forces and moments so obtained were then compared with the similar loads used by Nuclear Energy Services (NES) in the pipe support evaluation/design.

Where the above comparison indicated that the NES design/evaluation reaction loads exceeded the SMA faulted condition loads, no further evaluation of the support was conducted noting that safety margin greater than 1.0 must exist by definition. Conversely, for those supports for which the SMA reaction loads exceeded the NES reaction loads, the support design adequacy was verified either by comparing the available margin of safety to the increase in the loads or by detail structural calculations.

The evaluation of the HPCS Discharge pipe supports indicated that the supports are adequate to sustain the effects of the SSE event.

TABLE 7-1

HPCS DISCHARGE LINE
MODAL FREQUENCIES AND MODAL MASS FRACTION

INTERPOLATED SPECTRAL ACCELERATION VALUES FOR SPECTRUM 1

MODE	FREQ.	PERIOD	X(G)	Y(G)	Z(G)
~~1~~	~~4.5419~~	~~0.220196~~	~~0.6400~~	~~0.7463~~	~~0.5317~~
2	5.6609	0.178623	0.6400	0.9000	0.5844
3	6.1804	0.161802	0.6400	0.9000	0.5972
~~4~~	~~7.5017~~	~~0.133303~~	~~0.6500~~	~~0.7990~~	~~0.6000~~
5	8.5453	0.117023	0.6500	0.6418	0.6059
6	8.6386	0.115768	0.6500	0.6702	0.6057
~~7~~	~~9.4855~~	~~0.105424~~	~~0.6413~~	~~0.5752~~	~~0.6040~~
8	10.1779	0.098252	0.6336	0.5150	0.6026
9	10.6055	0.094291	0.6288	0.4667	0.6018
~~10~~	~~11.6490~~	~~0.085839~~	~~0.6172~~	~~0.4371~~	~~0.5914~~
11	11.9592	0.083617	0.6138	0.4313	0.5738
12	12.2645	0.081509	0.6103	0.4254	0.5561
~~13~~	~~12.9147~~	~~0.077431~~	~~0.6032~~	~~0.4131~~	~~0.5172~~
14	15.1894	0.065835	0.4270	0.3205	0.4477
15	15.3431	0.065176	0.4136	0.3128	0.4446
~~16~~	~~16.4753~~	~~0.060697~~	~~0.3933~~	~~0.2910~~	~~0.4210~~
17	16.5628	0.060384	0.3925	0.2899	0.4194
18	18.0416	0.055428	0.3825	0.2749	0.3898
~~19~~	~~18.4334~~	~~0.054249~~	~~0.3800~~	~~0.2700~~	~~0.3810~~
20	20.0910	0.049774	0.3800	0.2294	0.3506

MODAL MASS FRACTION

MODE	x	y	z
1	0.6285E-01	0.4335E-03	0.2506E-01
2	0.6773E-01	0.9350E-03	0.4360E-01
~~3~~	~~0.6512E-03~~	~~0.1920E-02~~	~~0.8820E-02~~
4	0.3693E-01	0.3714E-04	0.1878E-03
5	0.7482E-01	0.1762E-03	0.2946E-02
~~6~~	~~0.3020E-02~~	~~0.1209E-01~~	~~0.1390E-02~~
7	0.7872E-01	0.6129E-04	0.7105E-03
8	0.8152E-03	0.4677E-02	0.3100E-01
~~9~~	~~0.5451E-04~~	~~0.1290E-03~~	~~0.4101E-02~~
10	0.1164E-01	0.9627E-02	0.5948E-01
11	0.1091E-02	0.1320E-01	0.1170E-02
~~12~~	~~0.7723E-02~~	[illegible]	~~0.1980E-01~~
13	0.1864E-02	0.1910E-03	0.4315E-05
14	0.1226E-01	0.1370E-03	0.7546E-02
~~15~~	~~0.8447E-04~~	~~0.4870E-03~~	[illegible]
16	0.1453E-01	0.2065E-02	0.3473E-02
17	0.1846E-02	0.1950E-03	0.1211E-05
~~18~~	~~0.6889E-04~~	~~0.3375E-02~~	~~0.1521E-03~~
19	0.1387E-01	0.1911E-03	0.1477E-02
20	0.3886E-01	0.1245E-03	0.2049E-02
~~TOTAL SUM~~	[illegible]	[illegible]	[illegible]

MAXIMUM RIGID BODY FACTOR = MAX(1-SUM(L(I) * PHI(I)))

X	Y	Z
[illegible]	[illegible]	[illegible]

TABLE 7-2

HPCS DISCHARGE PIPE NOZZLE

SUMMARY OF ASME CODE STRESS ANALYSIS RESULTS

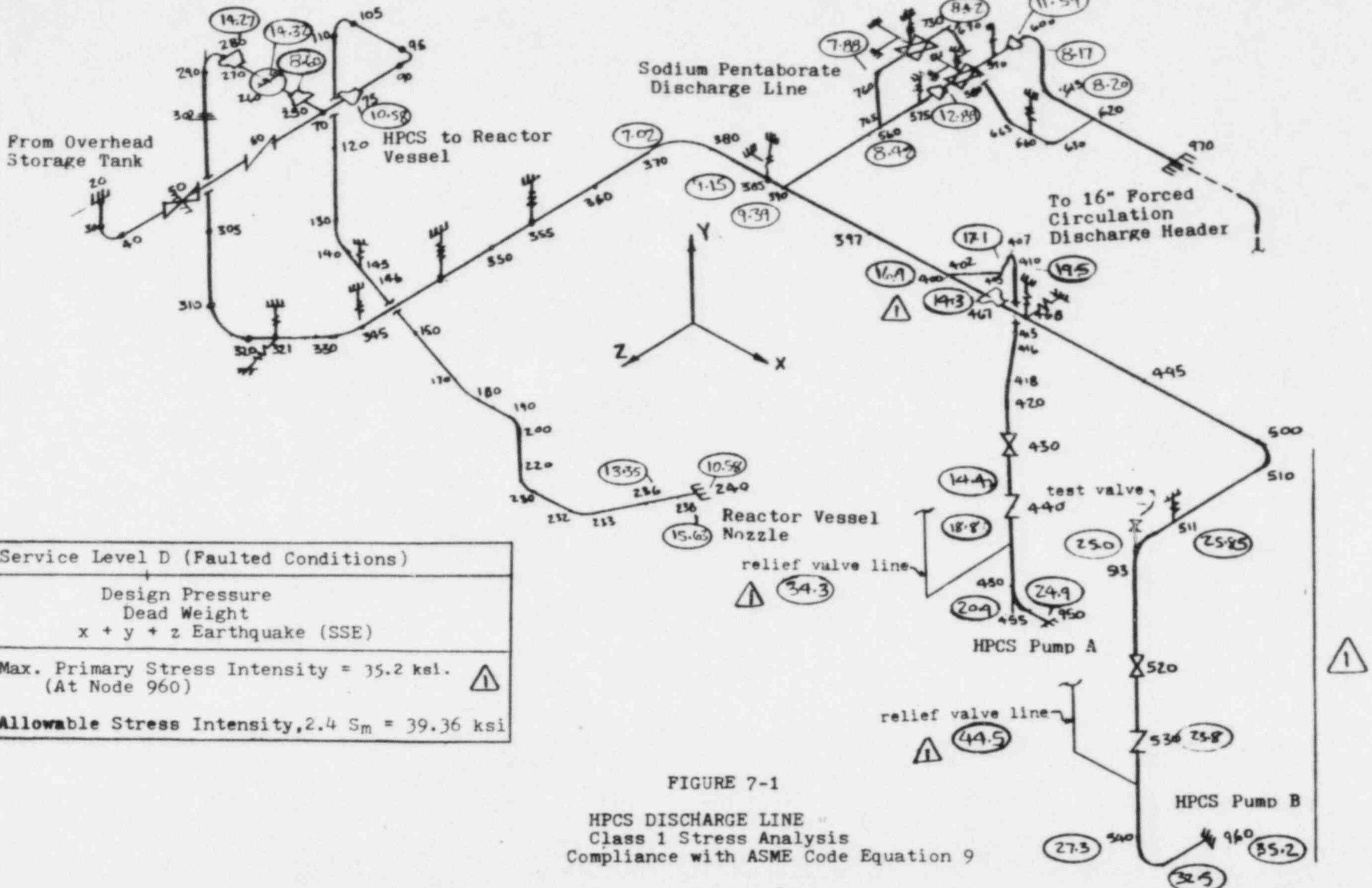
Load Conditions	Components			
	Inconel Safe-End	First Coupling	304L Pipe	Second Coupling
PRIMARY STRESS (psi)				
Service Level B (normal) Condition:				
Dead Weight + OBE Seismic Event	13,469	12,940	12,940	11,540
Allowable stress $1.5S_m$	34,950	37,155	31,200	37,155
Service Level D(Faulted) Condition:				
Dead Weight + SSE Seismic Event	16,036	15,367	15,367	13,594
Allowable stress $2.4S_m$ or $0.7S_u$	56,000	42,630	42,630	42,630
PRIMARY PLUS SECONDARY STRESS INTENSITY RANGE S_n (psi)				
OBE Seismic Event	17,029	16,794	16,794	16,155
SSE Seismic Event	21,330	20,857	20,857	19,584
Thermal Normal Start-up and Shut-down	23,539	23,125	23,125	22,041
Maximum Credible Thermal Transient(MCA)	43,930	41,230	37,030	37,030
OBE Seismic + Maximum Credible Thermal Transient (MCA)	48,229	45,294	41,094	40,455
SSE Seismic + Maximum Credible Thermal Transient (MCA)	52,530	49,357	45,157	43,884
Allowable Stress $3S_m$	69,900	74,310	62,400	74,310

TABLE 7-3

HPCS DISCHARGE PIPE NOZZLE

SUMMARY OF ASME CODE FATIGUE ANALYSIS

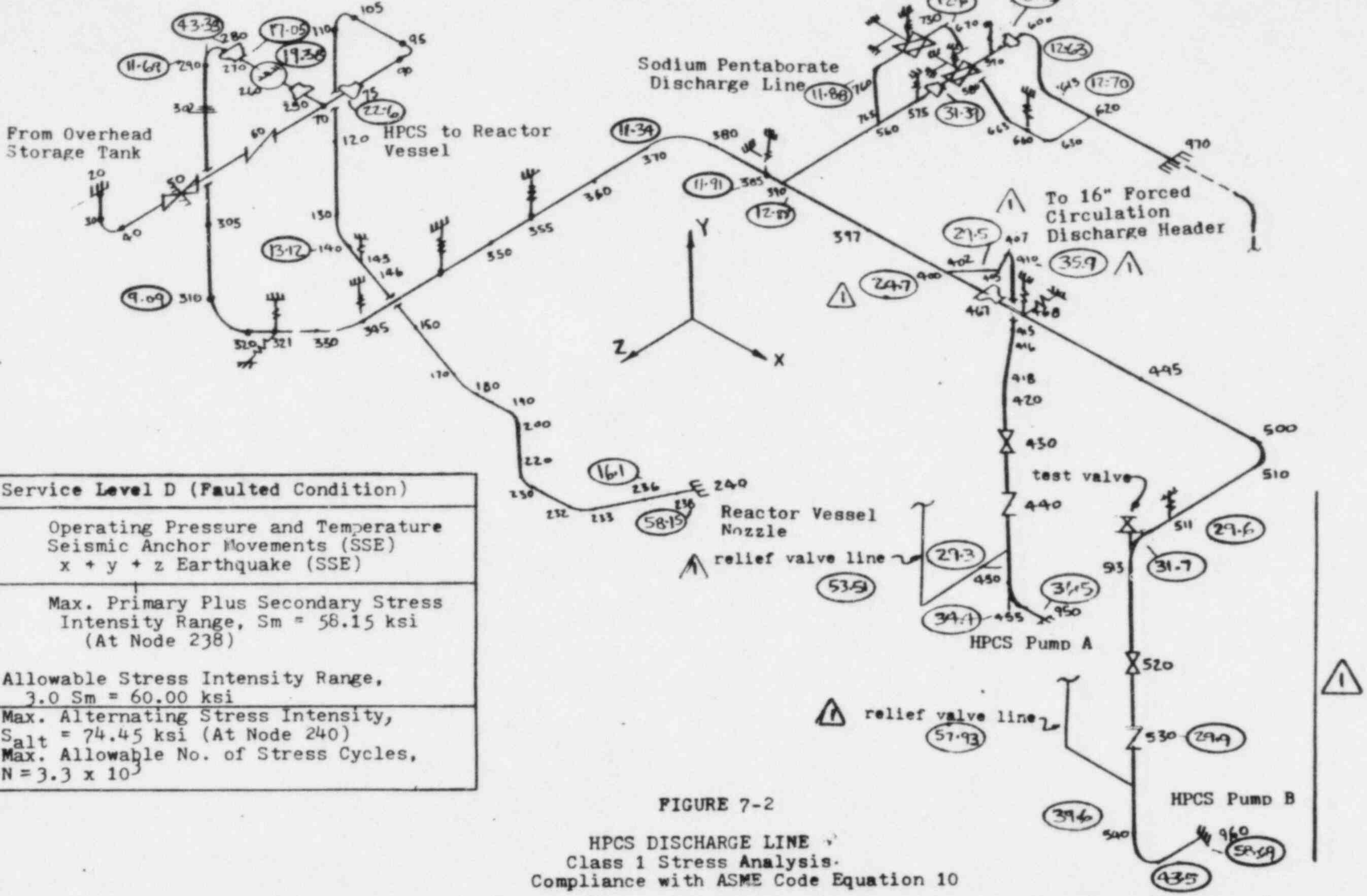
Load Conditions	Allowable Number of Stress Cycles			
	Inconel Safe-End	First Coupling	304 L Pipe	Second Coupling
OBE Seismic Event	10^6	10^6	10^6	10^6
SSE Seismic Event	5×10^5	5.5×10^5	5.5×10^5	6×10^5
Thermal-normal Start-up and Shutdown	3×10^5	3.2×10^5	3.2×10^5	3.6×10^5
Maximum Credible Thermal Transient (MCA)	5,700	7,500	13,000	13,000
OBE Seismic + Maximum Credible Thermal Transient (MCA)	4,000	5,700	9,000	10,000
SSE Seismic + Maximum Credible Thermal Transient (MCA)	3,300	4,500	6,500	7,000



Service Level D (Faulted Conditions)
Design Pressure Dead Weight x + y + z Earthquake (SSE)
Max. Primary Stress Intensity = 35.2 ksi. (At Node 960)
Allowable Stress Intensity, $2.4\ S_m$ = 39.36 ksi

FIGURE 7-1

HPCS DISCHARGE LINE
Class 1 Stress Analysis
Compliance with ASME Code Equation 9



Service Level D (Faulted Condition)
Operating Pressure and Temperature Seismic Anchor Movements (SSE) x + y + z Earthquake (SSE)
Max. Primary Plus Secondary Stress Intensity Range, Sm = 58.15 ksi (At Node 238) Allowable Stress Intensity Range, 3.0 Sm = 60.00 ksi
Max. Alternating Stress Intensity, S_{alt} = 74.45 ksi (At Node 240) Max. Allowable No. of Stress Cycles, N = 3.3×10^3

FIGURE 7-2

HPCS DISCHARGE LINE
Class 1 Stress Analysis
Compliance with ASME Code Equation 10

8. CONCLUSIONS

The results of the seismic and stress analysis of the HPCS Discharge piping and support system indicates the following:

1. Deflections in the piping system due to dead weight, and the specified SSE seismic loads are nominal and acceptable.

2. The fundamental frequency of vibration of the flexible piping system is reasonable.

3. The maximum primary and primary plus secondary stress intensities resulting from appropriate load combinations including the conservative combination of Safe Shutdown Earthquake and the initiation of HPCS system at or near operating temperature are within the ASME Code allowable stress intensity values for Class 1 Components.

4. The total number of HPCS initiations at or near plant operating temperature is limited to 5,700 cycles.

5. The number of permissible stress cycles for the conservative combination of SSE seismic event and the HPCS initiations is 3300.

6. The piping support systems are adequate to withstand the normal and abnormal loads including the effects of SSE.

The acceptance criteria for the HPCS Discharge piping and support system are consistent with licensing criteria as specified in the ASME Code, current NRC Regulatory Guides and the Standard Review Plan. Therefore, it has been concluded that the HPCS Discharge piping and support system meet the intent of current licensing criteria.

9. REFERENCES

1. Nuclear Energy Services Inc., Danbury, Connecticut. Report NES 810090, "Seismic and Stress Analysis of the LACBWR High Pressure Core Spray Suction Line Piping System", July 1976.

2. Nuclear Energy Services Inc., Danbury, Connecticut. Report NES 810091, "Seismic and Stress Analysis of the LACBWR High Pressure Core Spray Discharge Line Piping System," May 1977.

3. Gulf United Services Report No. SS-1162 "Seismic Evaluation of the La Crosse Boiling Water Reactor;" dated January 1, 1974.

4. EG&G "LACBWR Containment Building Independent Seismic Analysis", Attechment to Letter from D.M. Crutchfield (USNRC) to F. Linder (DPC), dated October 18, 1983.

5. ASME Boiler and Pressure Vessel Code Section III, Subsection NB Class I Components, 1983 Edition.

6. USNRC Standard Review Plan 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports and Core Support Structure" 1981.

7. NUPIE II/TRHEAT - Piping Analysis Program, User Information Manual, Control Data Corporation, Revision K. May 25, 1983.

8. Pittsburgh Piping and Equipment Company Drawing Nos. 1087-29,-30,-42 and 35202.

9. Sargent and Lundy Engineers, "Specification for piping system La Crosse Boiling Water Reactor, "LACBWR #256.

10. Nuclear Energy Services Inc. Danbury, Connecticut. Report 81A0042, "High Pressure Core Spray Suction and Discharge Pipe Supports for the La Crosse Boiling Water Reactor", Revision 4 dated March 22, 1983.

11. Nuclear Energy Services Inc. Drawing 80E0040 Rev. 0. "LACBWR Pipe Hanger Base Plates".

12. Dairyland Power Cooperative, "Field verified, as-built" informations and drawings of the HPCS Suction and Discharge System at LACBWR ", P.C. Sampson (DPC) to C. Finnan (NES), dated March 1, 1983.

13. USNRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants", October, 1973.

14. USNRC Regulatory Guide 1.92, "Combination of Modes and Spatial Components in Seismic Response Analysis", Revision 1, February, 1976.

15. Allis-Chalmers, "La Crosse Boiling Water Reactor Safeguard Report Volume I and II; LACBWR #283 dated August 1967.

16. Dairyland Power Cooperative, La-Crosse Boiling Water Reactor (LACBWR), Seismic and Stress Analysis of HPCS Piping System Project SMA-CT 30001.02;SMA-CT/DPC Computer Output Binder #2.

ADDENDUM I

EVALUATION OF DISCREPANCIES

DISCOVERED BY LACBWR RESIDENT INSPECTOR BETWEEN

AS-ANALYZED AND AS-BUILT CONFIGURATIONS

1. SUMMARY

This report, prepared for Dairyland Power Cooperative, is being issued as an addendum to the original report, "Seismic and Stress Analysis of the High Pressure Core Spray Discharge Line Piping System" for LACBWR. SMA-CT Report 30001.0R00 August 1984. The purpose of this addendum is to account for discrepancies discovered by NRC resident inspector between the "as-built" configuration and the analytical model of the HPCS line, and to modify and correct the results previously provided in the original report. On the basis of a combination of both quantitative and qualitative assessments, it has been found that the margin of safety of the as-built HPCS line, although reduced from that previously reported for the original model, is still adequate. The number of permissible stress cycles are unaffected by the discrepancies.

2. DISCREPANCIES *

1. The test valve at the top of the 1 B Pump discharge line was not included in the analysis.

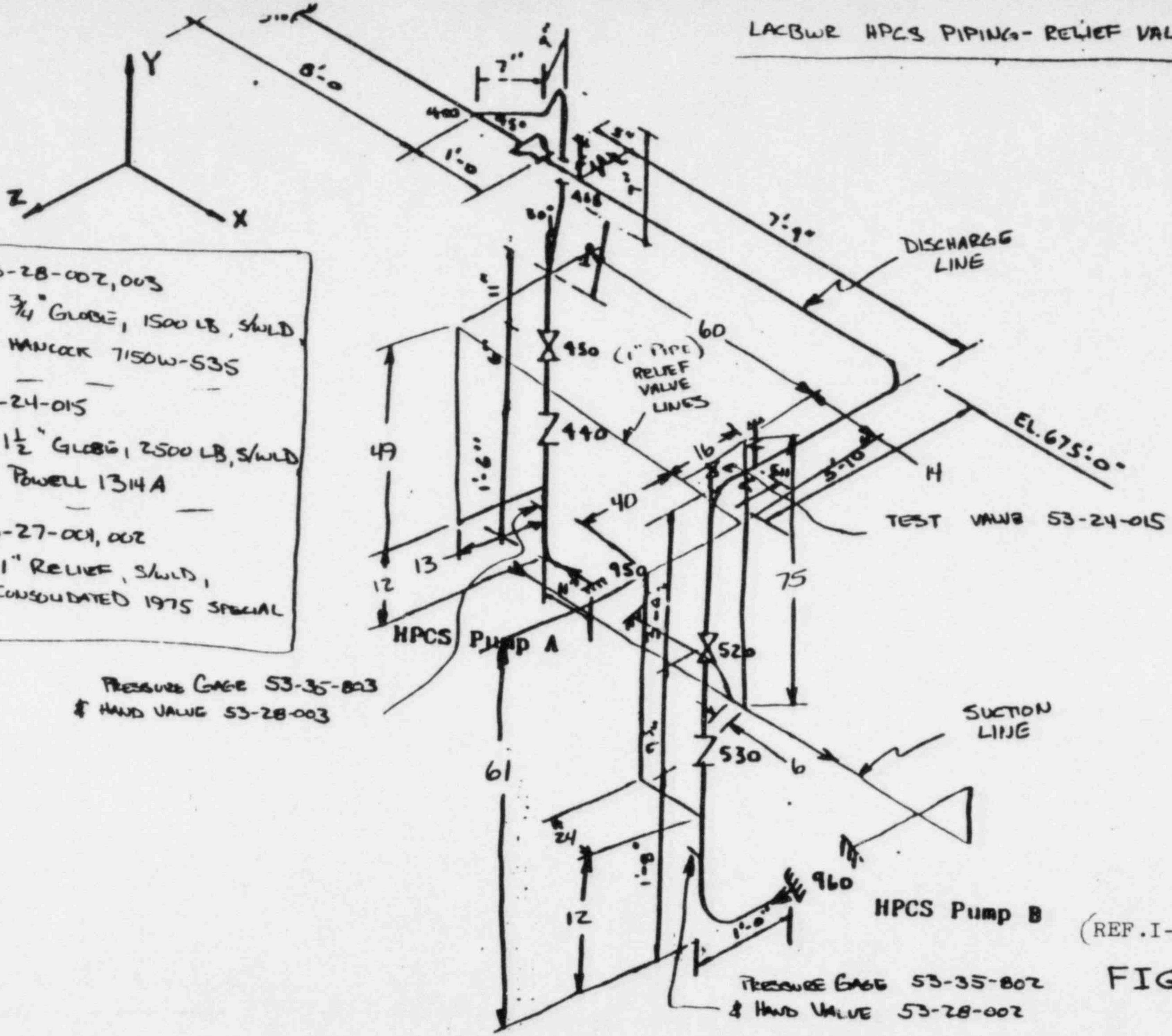
2. The hand valves and pressure gages were not included in the analysis.

3. The relief valve line from the pump discharge to suction line was not included in the analysis. The relief valve line need to be seismically qualified.

Figures 1 and 2 shows the discrepancies. Their effects are discussed in Section 3.

* Reference I-1 : DPC Letters, G. Lange to I. Husain LAC-10278 and 10308 dated October 22, 1984 and November 13, 1984 respectively.

LACBWR HPCS PIPING - RELIEF VALVE LINES



53-28-002, 003
3/4" GLOBE, 1500 LB, S/WLD
HANCOCK 7150W-535

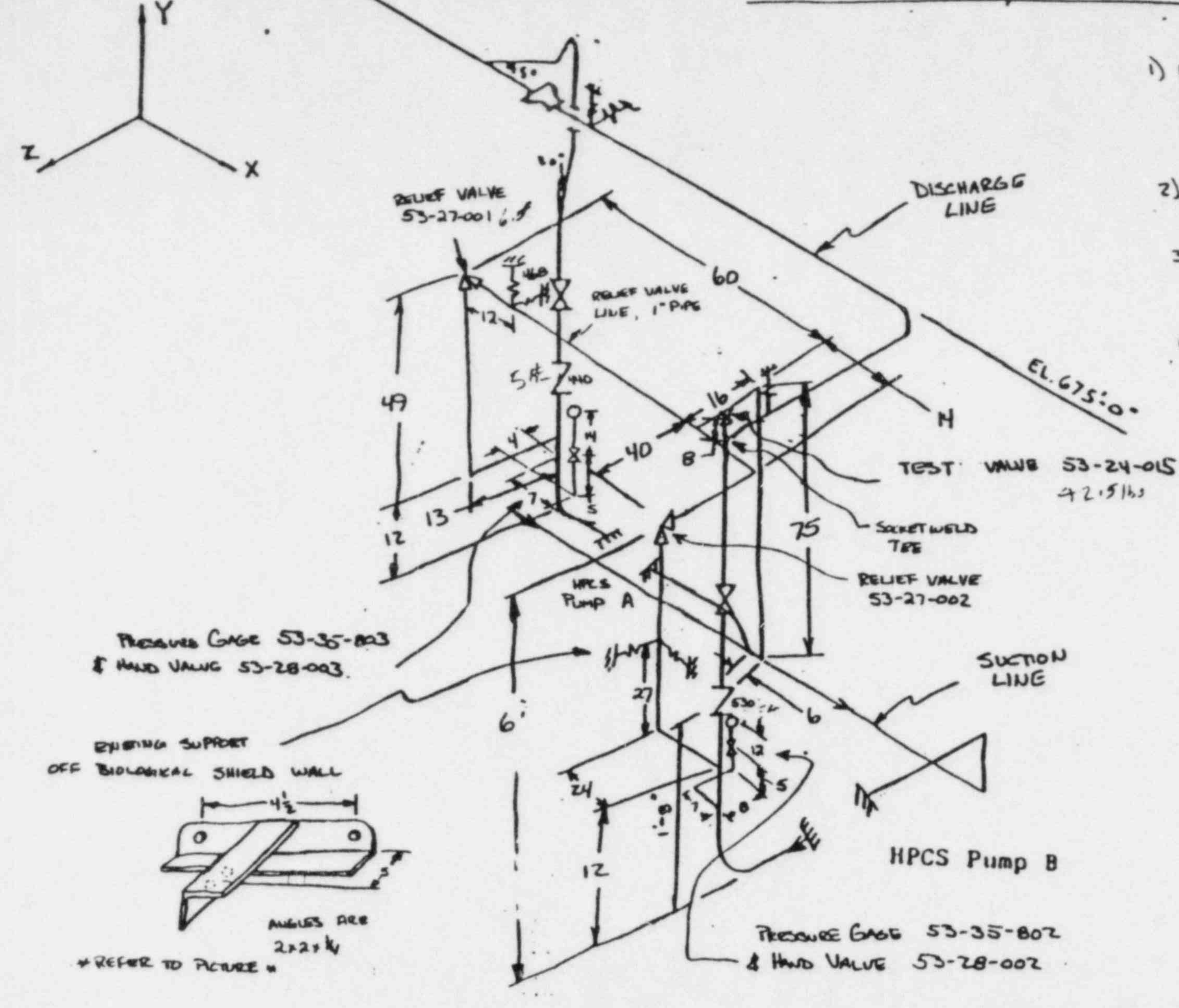
53-24-015
1 1/2" GLOBE, 2500 LB, S/WLD
POWELL 1314A

53-27-001, 002
1" RELIEF, S/WLD,
CONSOLIDATED 1975 SPECIAL

(REF. I-1)

FIGURE 1

LACBWR HPCS PIPING - RELIEF VALVE LINES



1) NODES 440 & 530, MISSING CHECK VALVE 2", FLANGED. FLANGES ARE 1500 LB PER S&L PIPING DESIGN TABLE "CLASS 900 SS-A". ASSUME CHECK VALVE WEIGHT = 5 LBS

2) TEST VALVE 53-24-015, 1½ GLOBE, 1500 LBS S/WELD, POWELL 1314 A, WEIGHT = 42½ LBS

3) RELIEF VALVES, 53-27-001/002, 1" S/WELD, CONSOLIDATED 1975 SPECIAL. APPROX. WEIGHT = 6 LBS

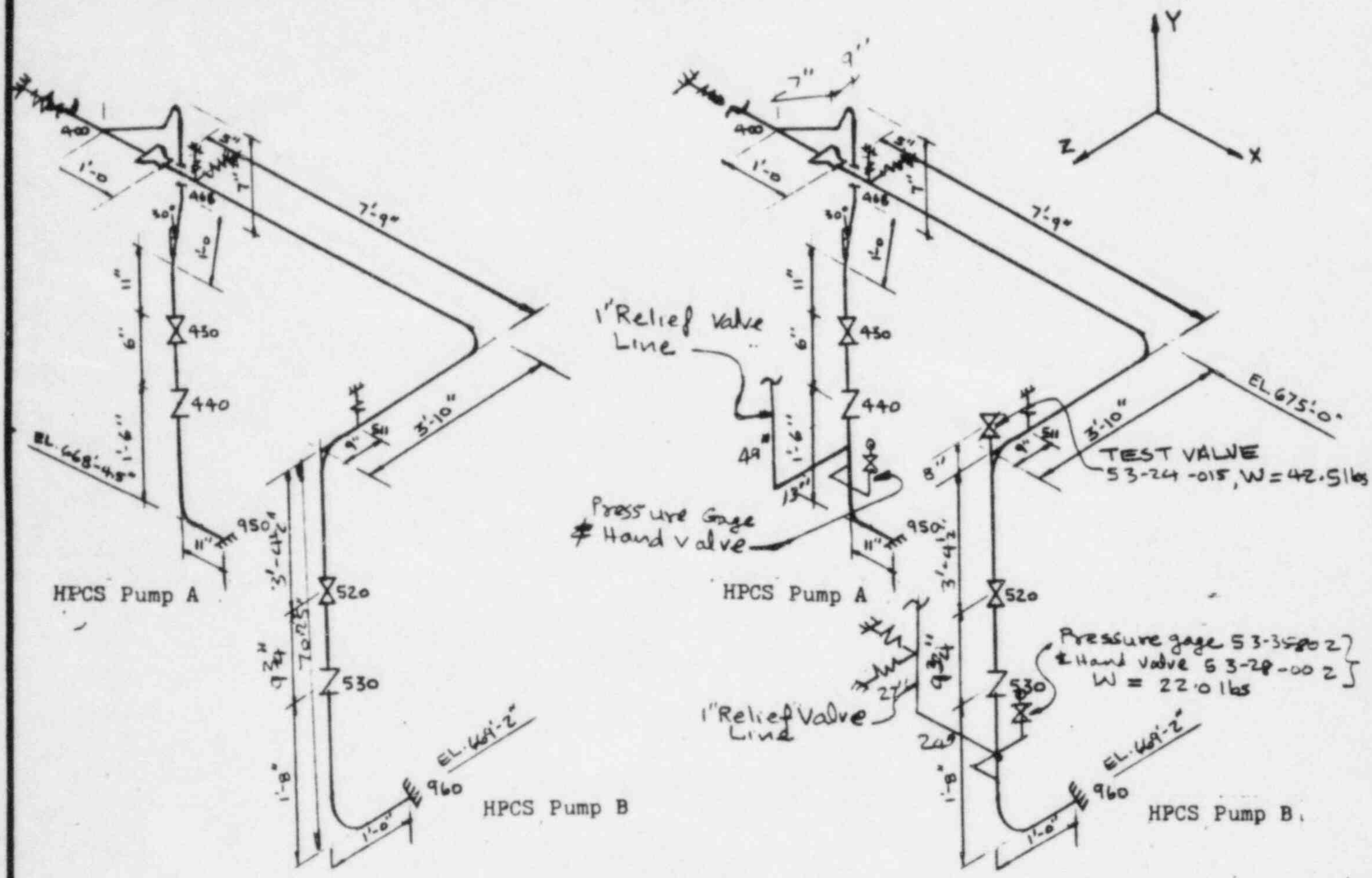
4) HAND VALVE TO PRESSURE GAGE, ¾ GLOBE, 53-28-002, 003, HANCOCK 7150W-535, WEIGHT = 18½ LBS

5) PRESSURE GAGE, 53-35-802, 803, ASHCROFT 4½", WEIGHT = 3½ LBS

(REF. I-1)

FIGURE 2

3.1 EVALUATION OF DISCREPANCIES 1, 2 & 3



HPCS DISCHARGE LINE

AS-ANALYZED CONFIGURATION ACTUAL CONFIGURATION

ANALYSIS DATA

PIPE PROPERTIES -

1½" Sch. 80 Pipe ; $D_o = 1.9''$; $t = 0.2''$

Moment of Inertia $I = 0.391\ in^4$; Section Modulus $S = 0.412\ in^3$

Additional Weight of Test Valve = 42.5 lbs

" " " Pressure Gage & Hand Valve = 22.0 lbs

Tributary Weight of 1" Relief valve line -

At HPCS Pump B $= \frac{2.5}{12}(24+27)\frac{1}{2} = 5.3$ lbs

" " " A $= \frac{2.5}{12}(13+49+12)\frac{1}{2} + \frac{6.0}{2} = 10.7$ lbs.

PEAK SEISMIC ACCELERATIONS (APPENDIX A) FOR SSE

X-EQ.	Y-EQ.	Z-EQ.
2.0 G	0.90G	1.9G

FOR EQUIVALENT STATIC LOAD INCREASE THE ACCELERATION VALUES BY 1.5

METHOD OF APPROACH:

THE MAXIMUM STRESSES IN THE PIPING SYSTEM DUE TO THE ADDITIONAL WEIGHTS WILL BE CONSERVATIVELY COMPUTED USING THE EQUIVALENT STATIC LOAD METHOD (SECTION II.1b of STANDARD REVIEW PLAN 3.7.2).

3.1.1 PIPING NEAR HPCS PUMP B (NODES 960 TO 460)

ADDITIONAL CONCENTRATED LOAD = 42.5 + 22.0 + 5.3
CONSERVATIVELY ASSUME LUMPED P = 69.8"
AT MIDSPAN OF FIXED (CONTINUOUS) BEAM.

MAXIMUM MOMENT DUE TO ADDITIONAL WEIGHT -

VERTICAL (Y) SUPPORTS AT NODES 511 & 960

EQUIVALENT SPAN LENGTH FOR VERTICAL LOADS = PROJECTED PIPE LENGTH ON YZ PLANE = 12+9 = 21" = L_Y

$$\text{MAX. MOMENT} = \frac{PL_Y}{8} = \frac{69.8 \times 21.0}{8} = \underline{183.2} \text{ lbs in}$$

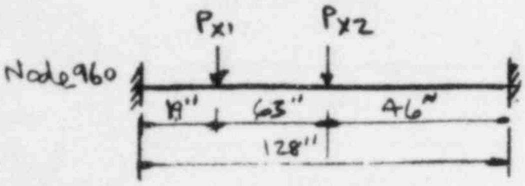
MAX. MOMENTS DUE TO ADDITIONAL SEISMIC INERTIA LOADS:

EARTHQUAKE IN X-DIRECTION;
X-SUPPORTS AT NODES 960, 400/468.

EQUIVALENT SPAN LENGTH = PROJECTED PIPE LENGTH ON Y-Z PLANE = L_X = 12.0 + 20.0 + 9.75 + 40.5 + 46.0 = 128.25"

TITLE Dairvland Power Cooperative		PAGE 3 OF 17	Job No. 30001.01
BY L.H	DATE 2/6/85	STRUCTURAL MECHANICS ASSOCIATES	COMMENTS LACBWR
CHKD. BY J.A	DATE 2/11/85		HPCS Piping Svatem

X - EARTHQUAKE :



$P_{X1} = (22+5.3)\,1.5 \times 2.0 = 81.9$ lbs
$P_{X2} = 42.5 \times 1.5 \times 2.0 = 127.5$ lbs
} Inertia Loads

Max. Moment at Node 960 $= M_x = 81.9(19)\dfrac{(109)^2}{128^2} + 127.5 \times 82 \dfrac{(46)^2}{(128)^2}$

$= 2478.7$ lbs in

EARTHQUAKE IN Y-DIRECTION :

Y-SUPPORTS AT NODES 511 & 960

EQUIVALENT SPAN LENGTH $L_Y = 12 + 9 = 21''$

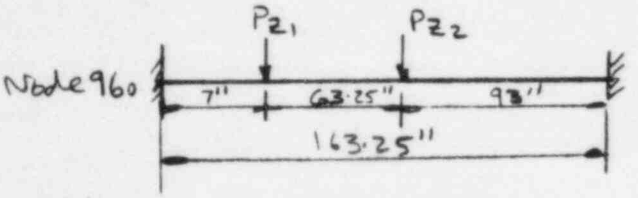
Inertia Loads $P_Y = (22+5.3+42.5)\,1.5 \times 0.9 = 94.23$ lbs.

Seismic Moment $M_Y = \dfrac{94.23 \times 21.0}{8} = 247.4$ lbs in

EARTHQUAKE IN Z - DIRECTION :

Z - Supports at Nodes 960 & 468

Equivalent Span Length $= 12 \times 7.75 + 70.25 = 163.25''$



Inertia Loads $P_{Z1} = (22+5.3)\,1.5 \times 1.9$
$= 77.81$ lbs

" " $P_{Z2} = 42.5 \times 1.5 \times 1.9$
$= 121.13$ lbs

Max. Moment at Node 960 $= M_Z$

$$M_Z = 77.81\,(7)\,\frac{(156.25)^2}{163.25^2} + 121.13\,(70.25)\left(\frac{93}{163.25}\right)^2$$

$= 498.96 + 2761.58 = 3260.54$ lbs in

Max. COMBINED SSE SEISMIC MOMENT $= M_S = \left(M_X^2 + M_Y^2 + M_Z^2\right)^{1/2}$

$$M_S = \left\{ 2478.7^2 + 247.4^2 + 3260.54^2 \right\}^{1/2}$$

$= \underline{4103.2}$ lbs in.

ASME CODE STRESS CALCULATIONS

PRIMARY STRESS INTENSITY (EQUATION 9)

$$\text{STRESS INTENSITY} = B_2 \frac{D_o}{2I} M_i$$

M_i = Moment Due to Dead Weight + SSE
Seismic Loads = 183.2 + 4103.2 = 4286.4 lbs·in

B_2 = Primary Stress Indices
= Socket Fitting = 1.5

D_o = 1.9" ; I = 0.391 in^4

∴ Primary Stress Intensity $= 1.5 \times \frac{1.90}{2 \times 0.391} \times 4286.4$

$= 15{,}621.8$ psi = 15.62 ksi

Corrected Primary Stress Intensity at Nodes

Node 960 = 19.58 + 15.62 = 35.2 ksi
Node 545 = 16.93 + 15.62 = 32.55 ksi
Node 540 = 11.68 + 15.62 = 27.30 ksi
Node 530 = 8.19 + 15.62 = 23.81 ksi
Node 512 = 9.41 + 15.62 = 25.03 ksi
Node 511 = 10.23 + 15.62 = 25.85 ksi

Allowable Stress Intensity $= 2.4 S_m = 2.4 \times 20.0$
At the above Nodes $= 48.0 \text{ ksi} > 35.2 \text{ ksi}$

O.K.

ASME CODE STRESS CALCULATIONS

PRIMARY + SECONDARY STRESS INTENSITY RANGE (S_n)
(EQUATION 10)

$$S_n = C_2 \frac{D_o}{2I} M_i$$

where M_i = Range of Moment Due to Seismic loads = 4103.2 lbs. in.

C_2 = Secondary Stress Indices
= 2.1 For Socket Weld Fittings.

$$\therefore S_n = \frac{2.1 \times 1.9}{2 \times 0.391} \times 4103.2$$

$$= 20{,}935.8 \text{ psi} = 20.94 \text{ Ksi}$$

$\therefore$ Corrected Primary + Secondary Stress Intensity At

Node 960 = 37.75 + 20.94 = 58.69 Ksi
Node 545 = 22.51 + 20.94 = 43.45 Ksi
Node 540 = 18.65 + 20.94 = 39.59 Ksi
Node 530 = 8.92 + 20.94 = 29.86 Ksi
Node 513 = 10.71 + 20.94 = 31.65 Ksi
Node 511 = 8.68 + 20.94 = 29.62 Ksi

Allowable Stress Intensity Range $3 S_m$ = 60.0 Ksi
> 58.69 Ksi
O.K

It should further be noted that the seismic and stress analyses for the additional loads have been performed conservatively.

3.1.2 PIPE NEAR HPCS PUMP A (NODES 950 to 400)

Additional Concentrated Load = Pressure Gage + Hand Valve + 1" Relief Valve Line

$= 22.0 + 10.7 = 32.7 \text{ lbs} = P$

MAX. MOMENT DUE TO ADDITIONAL DEAD WEIGHT -

Vertical (Y) Supports at Nodes 950 & 468

$= 11.0 + \frac{12}{2} + 7 + 9 + 12 + 5 = 50'' = L_Y$

Max. Moment $M_D = \frac{P L_Y}{8} = \frac{32.7 \times 50.0}{8}$

$= \underline{204.4} \text{ lbs in}$

MAX. MOMENT DUE TO ADDITIONAL SEISMIC INERTIA LOADS

EARTHQUAKE IN X-DIRECTION:-

X Supports at Nodes 950 & 400/385.

Equivalent Span = Projected Pipe length on YZ plane

$= 18 + 6 + 11 + 12 + 7 + 9 + 7 = 70.0'' = L_X$

Inertia Load $P_X = 32.7 \times 2.0 \times 1.5$

$= 98.1 \text{ lbs.}$

Max. Moment $M_X = \frac{98.1 \times 70.0}{8} = 858.4 \text{ lbs in}$

EARTHQUAKE IN Y-DIRECTION:

Y Supports at Nodes 950 & 468

$L_Y = 50.0''$

Inertia Load $P_Y = 32.7 \times 0.9 \times 1.5 = 44.15 \text{ lbs}$

Max. Moment $M_Y = \frac{44.15 \times 50}{8} = 275.9 \text{ lbs in}$

EARTHQUAKE IN Z DIRECTION:

Z Supports at Nodes 950, 468 & 385.

Equivalent span Length = Projected Pipe Length on XY Plane

$= 11 + 18 + 6 + 11 + 12 + 7 + 7 + 9 + 12 + 5$

$= 98''$

Inertia Load $P_z = 32.7 \times 1.9 \times 1.5 = 93.2$ lbs

Max. Moment $M_z = \frac{93.2 \times 98.0}{8} = 1141.6$ lbs in

COMBINED SSE SEISMIC MOMENT:

$M_S = \{858.4^2 + 275.9^2 + 1141.6^2\}^{1/2}$

$= \underline{1454.8}$ lbs in

<u>ASME CODE STRESS CALCULATIONS</u>

Primary Stress Intensity Due to Additional Loads $= B_2 \frac{D_o}{2I} M_i$ (Equation 9)

M_i = Moment Due to Dead Weight + Seismic Loads

$= 204.4 + 1454.8 = 1659.2$ lbs in

B_2 = Stress Indices = 1.5

∴ Max. Primary Stress Intensity $= 1.5 \times \frac{1.9}{2 \times 0.391} \times 1659.2$

$= 6047.0$ psi $= 6.05$ Ksi

Corrected Primary stress Intensity At

Node 950 = 18.86 + 6.05 = 24.91 Ksi

" 455 = 14.86 + 6.05 = 20.91 Ksi

" 440 = 12.77 + 6.05 = 18.82 Ksi

" 430 = 8.30 + 6.05 = 14.35 Ksi

" 410 = 13.4 + 6.05 = 19.45 Ksi

" 405 = 11.07 + 6.05 = 17.12 Ksi

" 400 = 10.81 + 6.05 = 16.86 Ksi

" 467 = 8.21 + 6.05 = 14.26 Ksi

Allowable Stress Intensity = 2.4 S_m = 2.4x20.0
At Above Nodes = 48.0 Ksi > 24.91 Ksi
O.K.

PRIMARY + SECONDARY STRESS INTENSITY RANGE (S_n)

$$S_n = C_2 \frac{D_o}{2I} M_i$$ (From Equation 10

where M_i = Range of Moment Due to Seismic Load
= 1454.8 lbs in

C_2 = Secondary Stress Indices
= 2.1

$$\therefore S_n = 2.1 \times \frac{1.9}{2 \times 0.391} \times 1454.8 = 7,422.6 \text{ psi}$$
$$= 7.42 \text{ Ksi}$$

This stress value due to additional seismic loads will be added to those previously calculated values presented in Figure 7-2 of SMA-CT report 30001.02R00.

Corrected Primary + Secondary Stress Intensity -

Node 950 = 29.12 + 7.42 = 36.54 Ksi
Node 455 = 26.62 + 7.42 = 34.04 Ksi
" 450 = 21.88 + 7.42 = 29.30 Ksi
" 410 = 28.51 + 7.42 = 35.93 Ksi
" 405 = 22.10 + 7.42 = 29.52 Ksi
" 400 = 17.32 + 7.42 = 24.74 Ksi.

FIGURES 7-1 & 7-2 OF REPORT SMA-CT 30001.02 R00 SHOULD BE REVISED AS INDICATED BELOW:

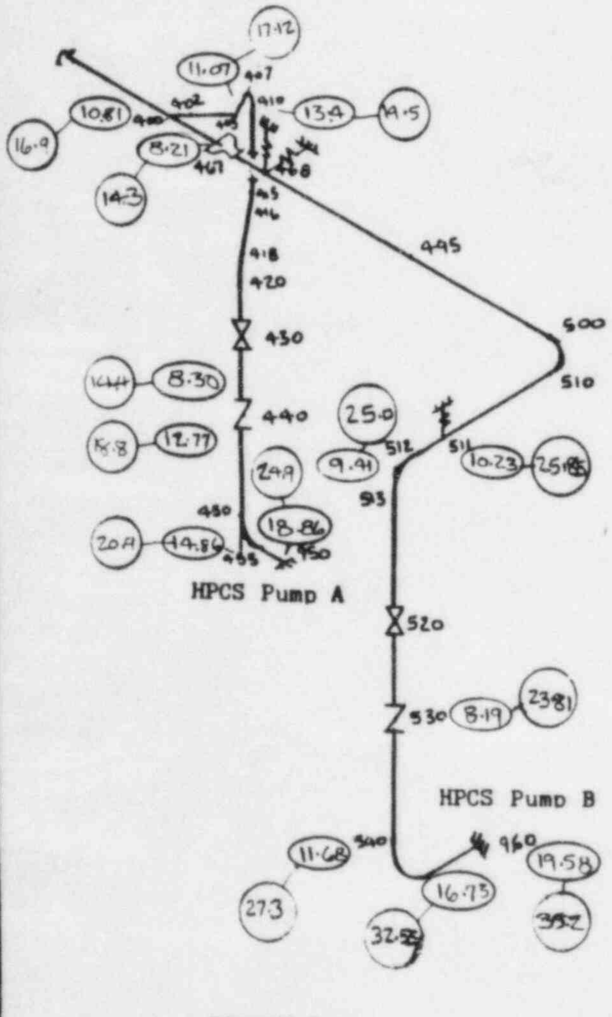


FIGURE 7-1
Compliance with ASME Code Equation 9

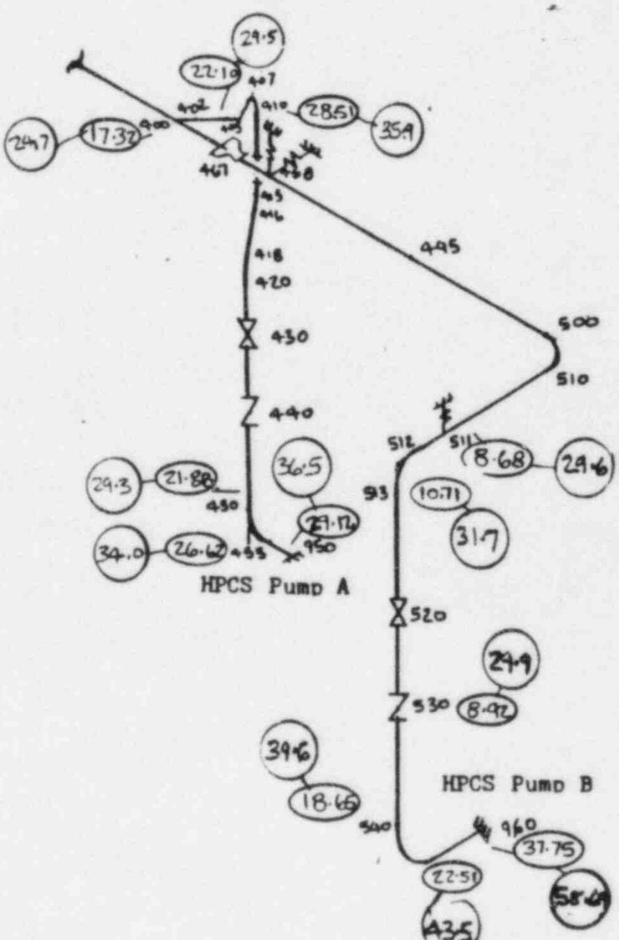
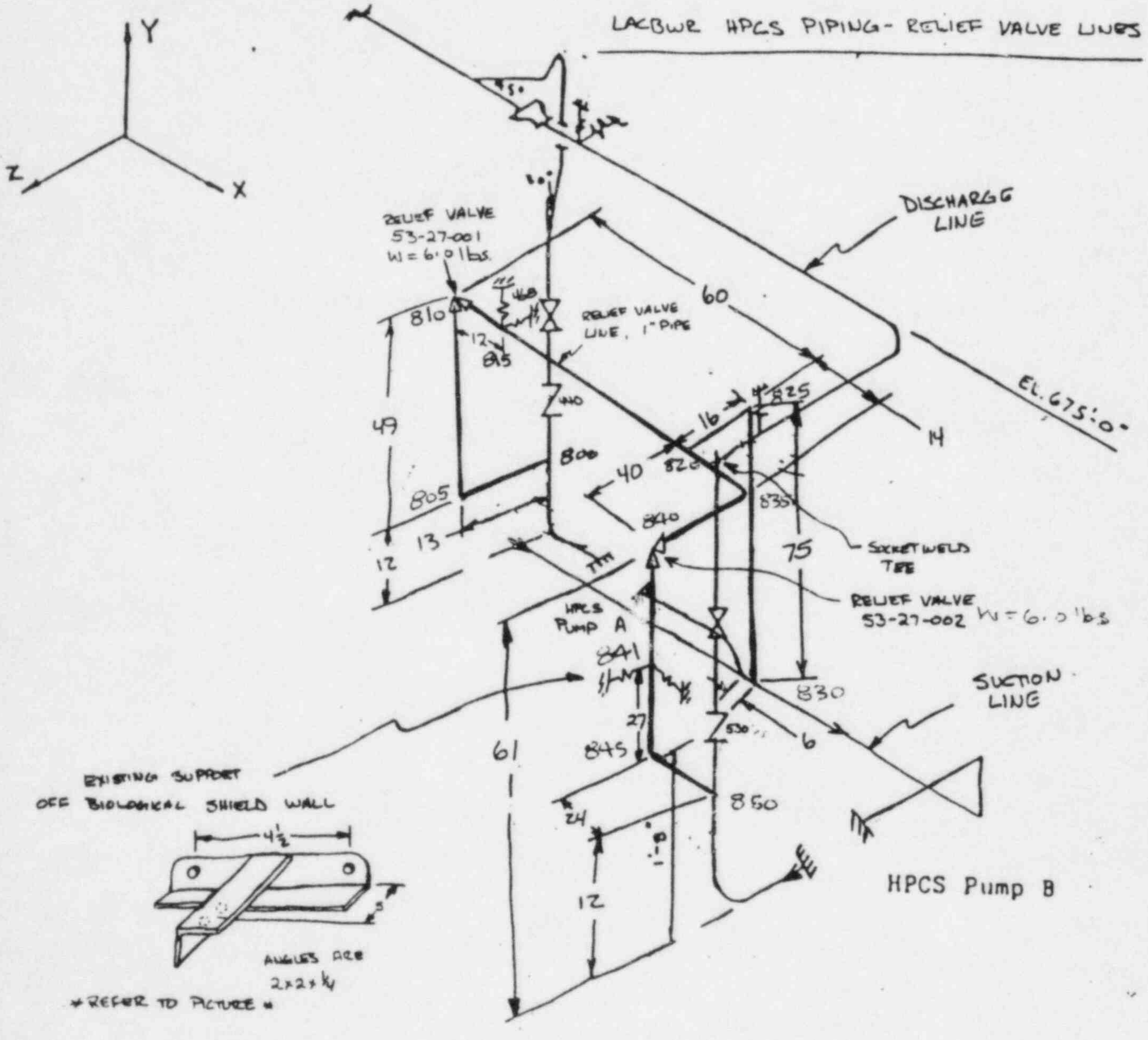


FIGURE 7-2
Compliance with ASME Code Equation 10

⬭ - Original Value
◯ - Corrected (Revised Value)

3.2 SEISMIC/STRESS ANALYSIS OF RELIEF VALVE LINES (DISCREPANCY NO. 3)



PIPE PROPERTIES

1" Φ Sch. 40 Pipe - O.D = 1.315"; $t = 0.133$ in

Moment of Inertia $I = 0.0874\ in^4$; Section Modulus $S = 0.1324\ in^3$

Total Weight/ft = 2.5 lbs/ft.

Weight of Relief Valve = 6.0 lbs

METHOD OF ANALYSIS

THE MAXIMUM STRESSES IN THE PIPING SYSTEM DUE TO SEISMIC INERTIA LOADS WILL BE CALCULATED USING THE EQUIVALENT STATIC LOAD METHOD OF SECTION II.1b of the STANDARD REVIEW PLAN 3.7.2. THE SEISMIC STRESSES WILL BE COMBINED WITH THE PRESSURE & DEAD WEIGHT STRESSESES IN ACCORDANCE WITH ASME CODE RULES.

Peak Seismic Acceleration Values for SSE Are

X-EQ.	Y-EQ	Z-EQ	(APPENIX A)
2.0G	0.9G	1.9G	

For Equivalent Static Load Methods, these values will be increased by 1.5

MOMENTS DUE TO DEAD WEIGHT -

Piping Between Nodes 800 to 815 :

Effective span (l_{y1}) = Projected length on XZ plane

$= 13 + 12 = 25''$

Total Load $= 6.0 + \frac{2.5}{12}(13+49+12) = P = 21.4$ lbs

Maximum Moment $M_{D1} = \frac{21.4 \times 25}{8} = \underline{66.9}$ lbs in

Piping Between Nodes 815, 820, 840 & 850.

Effective Span $l_{y2} = 60 + 14 - 12 + 24 + 40 = 126.0''$

Total Tributary Load $= \frac{2.5}{12}(126.0 + 61 - 12) + 6.0 + \frac{2.5}{12}\left(\frac{16.0}{2}\right)$

$= 44.13$ lbs

Max. Moment $= 44.13 \times \frac{126.0}{8} = \underline{695.0}$ lbs in $= M_{DZ}$

MAX. MOMENTS DUE TO SEISMIC INERTIA LOADS

X - EARTHQUAKE;

Piping Between Nodes 800 to 841/850

Effective Span Length $l_x = (49 + 13 + 40 + 61 - 12 - 27) = 124''$

Seismic Inertia Load $= P_x = 1.5 \times 2.0 \{6.0 \times 2 + \frac{2.5}{12}(124 + 60 + 14)\}$
$= 159.75$ lbs

Max Moment $M_x = 159.75 \times \frac{124}{8}$
$= 2476.1$ lbs in

Y - EARTHQUAKE;

Piping Between 800 to 815

$L_Y = 25''$

Seismic Inertia Load $P_{Y_1} = 1.5 \times 0.9 \{6.0 + \frac{2.5}{12}(13 + 49 + 12)\}$
$= 28.89$ lbs

Max. Moment $M_{Y_1} = 28.89 \times \frac{25}{8} = 90.28$ lbs in

Piping Between Nodes 815 & 850

Effective Span $= 126.0'' = l_{Y2}$

Inertia Load $P_{Y2} = 1.5 \times 0.9 \{\frac{2.5}{12}(126.0 + 61 - 12) + 6.0 + \frac{2.5}{12} \times \frac{16}{2}\}$
$= 59.6$ lbs

Max. Moment $= 59.6 \times \frac{126.0}{8} = M_{Y2}$
$= 938.3$ lbs in

Z - EARTHQUAKE :

Piping Between Nodes 800 to 815

Z supports at Nodes 800 & 815

Span Length $L_{z1} = 49 + 12 = 61.0''$

Inertia Loads $P_{z1} = 1.5 \times 1.9 \{ 6.0 + \frac{2.5}{12}(49+12) \}$

$= 53.3$ lbs.

Max. Moment $M_{z1} = 53.3 \times \frac{61.0}{8}$

$= 406.6$ lbs in

Piping Between Nodes 815 & 841/850

Z supports at Nodes 815 & 841

Span Length $L_{z2} = 60 + 14 \cdot 2 + 61 - 12 - 27$

$= 84''$

Inertia Load $P_{z2} = 1.5 \times 1.9 \{ 6.0 + \frac{2.5}{12}(84 + 40 + \frac{16}{2}) \}$

$= 95.5$ lbs

Max. Moment $= 95.5 \times \frac{84}{8}$

$= 882.0$ lbs in

COMBINED SSE SEISMIC MOMENTS

Piping Between Nodes 800 & 815

$M_{S1} = \{ (2476.1)^2 + (10.28)^2 + (406.6)^2 \}^{1/2}$

$= \underline{2510.9}$ lbs. in

Piping Between Nodes 815 to 841/850

$M_{S2} = \{ (2476.1)^2 + (938.3)^2 + (882.0)^2 \}^{1/2}$

$= \underline{2791.0}$ lbs. in

ASME CODE STRESS CALCULATIONS -

Primary Stress Intensity Check

The primary stress intensity is computed from and limited by the following:

$$S = B_1 \frac{PD_o}{2t} + B_2 \frac{D_o}{2I} M_i = 1.5S_m \text{ ----------------(Eqn.9)}$$

$$= 2.4 S_m \text{ for Faulted (SSE) condition.}$$

where:

B_1, B_2 = Primary stress indices for the specific piping component being investigated (Socket Fitting)
$B_1 = 0.75$; $B_2 = 1.50$

t = Nominal wall thickness of piping component = 0.133"

I = Moment of inertia = 0.0874

M_i = Resultant moment loading from loads caused by (1) weight, (2) earthquake, and (3) other mechanical loads (one-half the range, excluding anchor movement effects).

P = Internal design pressure = 1400.0 psi

D_o = Outside diameter of pipe = 1.315"

S_m = Maximum allowable stress in material at the design temperature = 20.0 ksi

For Piping Run Between Nodes 800 & 815

$$S = 0.75 \times \frac{1400 \times 1.315}{2 \times 0.133} + 1.5 \times \frac{1.315}{2 \times 0.0874} \times (66.9 + 2510.9)$$

$$= 5190.8 + 29{,}088.7 = 34{,}279.5 \text{ psi}$$

$$= \underline{34.28} \text{ Ksi} < 2.4 \times 20.0 = 48.0 \text{ Ksi} \quad \text{O.K.}$$

For Piping Run Between Nodes 815 & 841/850

$$S = 0.75 \times \frac{1400.0 \times 1.315}{2 \times 0.133} + 1.5 \times \frac{1.315}{2 \times 0.0874} (695.0 + 2791.0)$$

$$= 5190.8 + 39{,}337.2 = 44{,}528.0 \text{ psi}$$

$$= \underline{44.53} \text{ Ksi} < 48.0 \text{ Ksi.} \quad \text{O.K}$$

Primary Plus Secondary Stress Intensity Range Check

The primary plus secondary stress intensity range is computed from and limited by the following:

$$S_n = C_1\left(\frac{P_o D_o}{2t}\right) + C_2\left(\frac{D_o}{2I}\right)M_i + \left[\frac{1}{2(\text{[illegible]}}\ E\alpha\ \Delta T_1\right]^{*} + C_3 E_{ab}\left|\alpha_a \bar{T} - \alpha_b \bar{T}_b\right| \leq 3S_m \text{ - (Eqn. 10)}$$

where:

C_1, C_2, C_3 = Sec[illegible]ress indices for the specific pi[illegible]ent being investigated.

$C_1 = 2.0$; $C_2 = 2$ [illegible] t Fittings

P_o = R[illegible]ting pressure = 1400.0 psi

M_i = R[illegible]nt loading resulting from thermal [illegible]anchor movements from any cause, [illegible]fects, and other mechanical loads.

V = Po[illegible]tio = 0.3

* = This [illegible]m is omitted in the summer, 1979 revisi[illegible]n of the ASME Code. Version 1.5 of NUPIPE reflects this change.

$E\alpha$ = Modules of elasticity (E) times the mean coefficient of thermal expansion (α)

ΔT_1 = Range of absolute value (without regard to sign) of the temperature difference between the temperature of the outside surface (T_o) and the temperature of the inside surface (T_i) of the piping component, assuming moment-generating equivalent linear temperatur distribution.

E_{ab} = Average modulus of elasticity of the two parts of the gross discontinuity.

α_a = Mean coefficient of expansion on side "a" of a gross discontinuity such as a branch-to-run, flange-to-pipe, or socket-fitting-to-pipe gross discontinuity.

T_a = Range of average temperature minus the room temperature on side "a" of a gross discontinuity.

α_b = Mean coefficient of expansion on side "b" of a gross discontinuity.

T_b = Range of average temperature minus the room temperature on side "b" of a gross discontinuity.

For the Relief Valve Line there are no unusual thermal expansion or thermal transient events. It is essentially a Cold Line

For Piping Run Between Nodes 800 & 815

$$S_n = 2.0 \times \frac{1400.0 \times 1.315}{2 \times 0.133} + 2.1 \times \frac{1.315}{2 \times 0.0874} (2510.9)$$

$$= 13,842.1 + 39,667.3 = 53,509.4 \text{ psi}$$

$$= \underline{53.51} \text{ Ksi} < 3 \times 20.0 = 60.0 \text{ Ksi} \quad \text{O.K}$$

For Piping Run Between Nodes 815 & 841/850

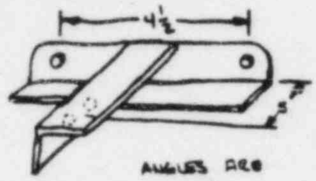
$$S_n = 2.0 \times \frac{1400.0 \times 1.315}{2 \times 0.133} + \frac{2.1 \times 1.315}{2 \times 0.0874} (2791.0)$$

$$= 13,842.1 + 44,092.4 = 57,934.5 \text{ psi}$$

$$= \underline{57.93} \text{ Ksi} < 3S_m = 60.0 \text{ Ksi}$$

It should be noted that the 1" Relief Valve Piping system seismic and stress Analyses have been performed very conservatively still the piping system meets the ASME Code design requirements.

RELIEFE VALVE LINE SUPPORT EVALUATION



Support At Node 841

Area $A = 0.938 \text{ in}^2$

Section Modulus $S = 0.247 \text{ in}^3$

MAX. REACTION LOAD DUE TO SSE SEISMIC EVENT

$$= \frac{1}{2}\left\{P_x^2 + P_y^2 + P_z^2\right\}^{1/2}$$

$$= \frac{1}{2}\left\{(159.75)^2 + (59.6)^2 + (95.5)^2\right\} = 97.7 \text{ lbs.}$$

$\therefore$ Max. Axial Stress $= \dfrac{97.7}{0.938} = 104.2$ psi

Max. Bending Stress $= \dfrac{97.7 \times 5.0}{0.247} = 1978.0$ psi

$\therefore$ Combine Axial + Bending Stress $= 104.2 + 1978.0$

$= 2082.2$ psi

Allowable Stress $= 1.6 \times 0.6 \times 36.0 = 34.56$ Ksi

$\gg 2.08$ Ksi O.K

Max. Pull Out Load For Anchor Bolt $= \dfrac{97.7 \times 5.0}{4.5} + \dfrac{97.7}{2}$

$= 157.4$ lbs

Max. shear Load / Bolt $= \dfrac{97.7}{2} = 48.9$ lbs

These loads are fairly small as compared to the Anchor Bolt shear & Pull out load capacities.

$\therefore$ It can be concluded that the supports are adequate to withstand the SSE seismic loads.

APPENDIX A

LACBWR HPCS DISCHARGE LINE PIPING ANLYSIS

NUPIPE ANALYTICAL INPUT DATA

HPCS DISCHARGE LINE LACBWR

SECTION PROPERTIES

NSECT	OUTSIDE DIAMETER	WALL THICKNESS	WEIGHT	MODULUS COLD * 1.0E-6	DESIGN PRESSURE
	IN	IN	LB/FT	PSI	PSI
1	1.900	.2000	6.44	28.30000	1400.00
2	2.875	.2030	5.86	28.30000	100.00
~~3~~	~~1.900~~	~~.2000~~	~~6.44~~	~~28.30000~~	~~1400.00~~
4	2.875	.2760	12.05	28.30000	1400.00
5	2.375	.2180	[illegible]	28.30000	1400.00
~~6~~	~~2.375~~	~~.2180~~	~~7.18~~	~~28.30000~~	~~1400.00~~
7	2.875	.2760	10.51	28.30000	1400.00
8	1.900	.2000	5.16	28.30000	1400.00
~~9~~	~~5.000~~	~~1.0000~~	~~0.00~~	~~28.00000~~	~~0.00~~

CONCENTRATED WEIGHTS

NODE	WEIGHT	NODE	WEIGHT	NODE	WEIGHT
	LB		LB		LB
~~50~~	~~430.000~~	~~60~~	~~40.000~~	~~260~~	~~340.000~~
520	52.000	530	36.000	580	230.000
731	140.000	302	140.000	146	51.000
~~430~~	~~52.000~~	~~440~~	~~36.000~~		
581	140.000	730	230.000		

HPCS DISCHARGE LINE LACBWR

STATIC RESTRAINT TABLE

NODE	TYPE	STIFFNESS TRANS LB/IN ROT IN-LB/RAD	DIRECTION
20	TRANS	.7824135E+10	X
20	TRANS	.7824135E+10	Y
20	TRANS	.7824135E+10	Z
20	ROT	.7824135E+10	X
20	ROT	.7824135E+10	Y
20	ROT	.7824135E+10	Z
50	TRANS	.3059107E+11	X
50	TRANS	.3059107E+11	Y
50	TRANS	.3059107E+11	Z
50	ROT	.3059107E+11	X
50	ROT	.3059107E+11	Y
50	ROT	.3059107E+11	Z
260	TRANS	.1735842E+11	X
260	TRANS	.1735842E+11	Y
260	TRANS	.1735842E+11	Z
260	ROT	.1735842E+11	X
260	ROT	.1735842E+11	Y
260	ROT	.1735842E+11	Z
960	TRANS	.7824135E+10	X
960	TRANS	.7824135E+10	Y
960	TRANS	.7824135E+10	Z
960	ROT	.7824135E+10	X
960	ROT	.7824135E+10	Y
960	ROT	.7824135E+10	Z
970	TRANS	.3848469E+11	X
970	TRANS	.3848469E+11	Y
970	TRANS	.3848469E+11	Z
970	ROT	.3848469E+11	X
970	ROT	.3848469E+11	Y
970	ROT	.3848469E+11	Z
240	TRANS	.7824135E+10	X
240	TRANS	.7824135E+10	Y
240	TRANS	.7824135E+10	Z
240	ROT	.7824135E+10	X
240	ROT	.7824135E+10	Y
240	ROT	.7824135E+10	Z
950	TRANS	.7824135E+10	X
950	TRANS	.7824135E+10	Y
950	TRANS	.7824135E+10	Z
950	ROT	.7824135E+10	X
950	ROT	.7824135E+10	Y
950	ROT	.7824135E+10	Z
345	TRANS	.4200000E+05	Y
321	TRANS	.9500000E+04	INED
348	TRANS	.1480000E+05	X
348	TRANS	.1550000E+04	Y
355	TRANS	.1320000E+06	Y
385	TRANS	.8600000E+05	Y
468	TRANS	.2080000E+05	Y
468	TRANS	.6690000E+05	Z
511	TRANS	.1144000E+06	Y
575	TRANS	.6900000E+04	Y
590	TRANS	.6900000E+04	Y
662	TRANS	.1707000E+06	Y
580	TRANS	.1120000E+04	X
580	TRANS	.1453000E+07	Y
580	TRANS	.3480000E+04	Z
730	TRANS	.1564700E+07	X
730	TRANS	.8644000E+07	Y
730	TRANS	.2927000E+07	Z
145	TRANS	.3350000E+05	Y
146	TRANS	.5650000E+03	X
146	TRANS	.2036000E+04	Y
146	TRANS	.2036000E+04	Z
146	ROT	.1375090E+09	X
146	ROT	.1695960E+05	Y
146	ROT	.1695960E+05	Z

HPCS DISCHARGE LINE LACBWR

SEISMIC RESPONSE SPECTRA - SET 1 INTERPOLATION OPTION(LL)

X-EARTHQUAKE FREQ. HZ	X-EARTHQUAKE ACCELERATION (G)	Y-EARTHQUAKE FREQ. HZ	Y-EARTHQUAKE ACCELERATION (G)	Z-EARTHQUAKE FREQ. HZ	Z-EARTHQUAKE ACCELERATION (G)
.350	.017	.350	.006	.350	.020
.430	.028	.430	.009	.440	.029
.570	.060	.520	.015	.520	.060
.650	.100	.660	.035	.660	.100
.750	.230	.780	.100	.780	.280
.870	.500	1.000	.225	1.000	.560
1.000	.620	1.650	.225	1.170	.900
1.110	1.000	1.800	.250	1.300	1.910
1.350	2.000	2.100	.250	1.800	1.910
2.070	2.000	2.400	.290	2.000	1.300
2.300	1.000	3.200	.310	2.300	.900
3.160	.630	3.500	.400	2.400	.740
4.000	.600	4.170	.600	2.800	.630
4.300	.680	4.340	.660	3.000	.510
6.300	.680	4.900	.900	4.000	.510
6.500	.650	6.440	.900	6.500	.610
6.700	.650	7.500	.800	11.500	.600
13.200	.600	8.400	.700	13.600	.460
15.500	.400	9.200	.600	20.000	.350
18.400	.380	10.350	.500	24.000	.375
28.000	.380	11.500	.440	32.000	.375
31.700	.310	13.600	.400	40.000	.300
60.000	.300	15.600	.300	60.000	.290
100.000	.280	19.000	.265	100.000	.260
0.000	0.000	21.000	.200	0.000	0.000
0.000	0.000	24.000	.220	0.000	0.000
0.000	0.000	32.000	.220	0.000	0.000
0.000	0.000	36.000	.200	0.000	0.000
0.000	0.000	40.000	.150	0.000	0.000
0.000	0.000	100.000	.140	0.000	0.000

HPCS DISCHARGE LINE LACBWR

EARTHQUAKE ANCHOR DISPLACEMENTS.

SET NO.	NODE	TRANSLATIONAL X	Y	Z
		IN	IN	IN
1	20	.29920	0.00000	0.00000
1	50	.29920	0.00000	0.00000
1	260	.29920	0.00000	0.00000
1	321	.16620	0.00000	0.00000
2	20	0.00000	.02800	0.00000
2	50	0.00000	.02800	0.00000
2	260	0.00000	.02800	0.00000
2	321	0.00000	.01560	0.00000
3	20	0.00000	0.00000	.35650
3	50	0.00000	0.00000	.35650
3	260	0.00000	0.00000	.35650
3	321	0.00000	0.00000	.19920

THERMAL ANCHOR DISPLACEMENTS

MODE	NODE	TRANSLATIONAL X	Y	Z
		IN	IN	IN
2	240	-.11200	1.26000	.15970

APPENDIX B

LACBWR HPCS DISCHARGE LINE
PIPING ANALYSIS NUPIPE ANLYSIS RESULTS

HPCS DISCHARGE LINE LACBLR

SUPPORT REACTIONS FOR LOAD CASE NO. 1

DEAD WEIGHT AND OTHER SUSTAINED MECHANICAL LOADS

NODE	TYPE	REACTION (LBS OR IN-LBS)	DIRECTION
~~20~~	~~FORCE~~	~~-0.~~	~~X COORD~~
20	FORCE	11.	Y COORD
20	FORCE	2.	Z COORD
~~20~~	~~MOMENT~~	~~-8.~~	~~X COORD~~
20	MOMENT	0.	Y COORD
20	MOMENT	-0.	Z COORD
~~50~~	~~FORCE~~	~~2.~~	~~X COORD~~
50	FORCE	489.	Y COORD
50	FORCE	-14.	Z COORD
~~50~~	~~MOMENT~~	~~620.~~	~~X COORD~~
50	MOMENT	-57.	Y COORD
50	MOMENT	179.	Z COORD
~~260~~	~~FORCE~~	~~14.~~	~~X COORD~~
260	FORCE	657.	Y COORD
260	FORCE	11.	Z COORD
~~260~~	~~MOMENT~~	~~58.~~	~~X COORD~~
260	MOMENT	-212.	Y COORD
260	MOMENT	-3343.	Z COORD
~~960~~	~~FORCE~~	~~1.~~	~~X COORD~~
960	FORCE	39.	Y COORD
960	FORCE	1.	Z COORD
~~960~~	~~MOMENT~~	~~-592.~~	~~X COORD~~
960	MOMENT	11.	Y COORD
960	MOMENT	-63.	Z COORD
~~970~~	~~FORCE~~	~~-9.~~	~~X COORD~~
970	FORCE	51.	Y COORD
970	FORCE	23.	Z COORD
~~970~~	~~MOMENT~~	~~32.~~	~~X COORD~~
970	MOMENT	528.	Y COORD
970	MOMENT	-684.	Z COORD
~~240~~	~~FORCE~~	~~-4.~~	~~X COORD~~
240	FORCE	55.	Y COORD
240	FORCE	-2.	Z COORD
~~240~~	~~MOMENT~~	~~-1197.~~	~~X COORD~~
240	MOMENT	-186.	Y COORD
240	MOMENT	-1235.	Z COORD
~~950~~	~~FORCE~~	~~-2.~~	~~X COORD~~
950	FORCE	122.	Y COORD
950	FORCE	-3.	Z COORD
~~950~~	~~MOMENT~~	~~-34.~~	~~X COORD~~
950	MOMENT	-29.	Y COORD
950	MOMENT	-1162.	Z COORD
~~[illegible]~~	~~FORCE~~	~~88.~~	~~Y COORD~~
~~321~~	~~FORCE~~	~~-22.~~	~~INCLINED~~
340	FORCE	-2.	X COORD
340	FORCE	-5.	Y COORD
~~355~~	~~FORCE~~	~~114.~~	~~Y COORD~~
385	FORCE	161.	Y COORD
460	FORCE	68.	Y COORD
~~460~~	~~FORCE~~	~~-3.~~	~~Z COORD~~
511	FORCE	114.	Y COORD
575	FORCE	4.	Y COORD
~~590~~	~~FORCE~~	~~3.~~	~~Y COORD~~
662	FORCE	24.	Y COORD
580	FORCE	1.	X COORD
~~580~~	~~FORCE~~	~~418.~~	~~Y COORD~~
580	FORCE	16.	Z COORD
730	FORCE	7.	X COORD
~~730~~	~~FORCE~~	~~457.~~	~~Y COORD~~
730	FORCE	-16.	Z COORD
145	FORCE	136.	Y COORD
~~140~~	~~FORCE~~	~~8.~~	~~X COORD~~
146	FORCE	26.	Y COORD
146	FORCE	6.	Z COORD
~~146~~	~~MOMENT~~	~~-341.~~	~~X COORD~~
146	MOMENT	3.	Y COORD
146	MOMENT	28.	Z COORD

HPCS DISCHARGE LINE LACB6A

SUPPORT REACTIONS FOR LOAD CASE NO. 2

THERMAL EXPANSION NORMAL OPERATING CONDITION

NODE	TYPE	REACTION (LBS OR IN-LBS)	DIRECTION	NODE	TYPE	REACTION (LBS OR IN-LBS)	DIRECTION
~~20~~	~~FORCE~~	~~0.~~	~~X COORD~~	~~321~~	~~FORCE~~	~~0.~~	~~INCLINED~~
20	FORCE	0.	Y COORD	348	FORCE	0.	X COORD
20	FORCE	0.	Z COORD	348	FORCE	0.	Y COORD
~~20~~	~~MOMENT~~	~~-0.~~	~~X COORD~~	~~355~~	~~FORCE~~	~~0.~~	~~Y COORD~~
20	MOMENT	-0.	Y COORD	385	FORCE	-0.	Y COORD
20	MOMENT	0.	Z COORD	468	FORCE	0.	Y COORD
~~50~~	~~FORCE~~	~~-4.~~	~~X COORD~~	~~468~~	~~FORCE~~	~~0.~~	~~Z COORD~~
50	FORCE	-13.	Y COORD	511	FORCE	-0.	Y COORD
50	FORCE	30.	Z COORD	575	FORCE	-0.	Y COORD
~~50~~	~~MOMENT~~	~~-177.~~	~~X COORD~~	~~598~~	~~FORCE~~	~~0.~~	~~Y COORD~~
50	MOMENT	73.	Y COORD	662	FORCE	0.	Y COORD
50	MOMENT	38.	Z COORD	580	FORCE	0.	X COORD
~~260~~	~~FORCE~~	~~23.~~	~~X COORD~~	~~580~~	~~FORCE~~	~~0.~~	~~Y COORD~~
260	FORCE	32.	Y COORD	580	FORCE	-0.	Z COORD
260	FORCE	-26.	Z COORD	730	FORCE	0.	X COORD
~~260~~	~~MOMENT~~	~~161.~~	~~X COORD~~	~~730~~	~~FORCE~~	~~0.~~	~~Y COORD~~
260	MOMENT	78.	Y COORD	730	FORCE	-0.	Z COORD
260	MOMENT	236.	Z COORD	145	FORCE	10.	Y COORD
~~960~~	~~FORCE~~	~~-0.~~	~~X COORD~~	~~146~~	~~FORCE~~	~~19.~~	~~X COORD~~
960	FORCE	0.	Y COORD	146	FORCE	-62.	Y COORD
960	FORCE	-0.	Z COORD	146	FORCE	16.	Z COORD
~~960~~	~~MOMENT~~	~~-0.~~	~~X COORD~~	~~146~~	~~MOMENT~~	~~928.~~	~~X COORD~~
960	MOMENT	0.	Y COORD	146	MOMENT	67.	Y COORD
960	MOMENT	0.	Z COORD	146	MOMENT	-96.	Z COORD
~~970~~	~~FORCE~~	~~0.~~	~~X COORD~~				
970	FORCE	-0.	Y COORD				
970	FORCE	-0.	Z COORD				
~~970~~	~~MOMENT~~	~~-0.~~	~~X COORD~~				
970	MOMENT	-0.	Y COORD				
970	MOMENT	0.	Z COORD				
~~240~~	~~FORCE~~	~~-38.~~	~~X COORD~~				
240	FORCE	32.	Y COORD				
240	FORCE	-20.	Z COORD				
~~240~~	~~MOMENT~~	~~385.~~	~~X COORD~~				
240	MOMENT	-1124.	Y COORD				
240	MOMENT	-1794.	Z COORD				
~~950~~	~~FORCE~~	~~-0.~~	~~X COORD~~				
950	FORCE	0.	Y COORD				
950	FORCE	0.	Z COORD				
~~950~~	~~MOMENT~~	~~0.~~	~~X COORD~~				
950	MOMENT	0.	Y COORD				

HPCS DISCHARGE LINE LACBWR

SUPPORT REACTIONS FOR LOAD CASE NO. 3

HORIZONTAL X, Y, AND Z SPECTRA (SAFE SHUTDOWN EARTHQUAKE)

COMBINED RESULT FOR MODES 1 THROUGH 20
BY RMS SUMMATION FOR SPECTRUM 1

PLUS RIGID BODY PSEUDO-MODES

NODE	TYPE	REACTIONS (LBS OR IN-LBS)	DIRECTION
20	FORCE	3.	X COORD
20	FORCE	3.	Y COORD
~~20~~	~~FORCE~~	~~2.~~	~~Z COORD~~
20	MOMENT	2.	X COORD
20	MOMENT	1.	Y COORD
~~20~~	~~MOMENT~~	~~6.~~	~~Z COORD~~
50	FORCE	186.	X COORD
50	FORCE	112.	Y COORD
~~50~~	~~FORCE~~	~~217.~~	~~Z COORD~~
50	MOMENT	136.	X COORD
50	MOMENT	311.	Y COORD
~~50~~	~~MOMENT~~	~~68.~~	~~Z COORD~~
260	FORCE	210.	X COORD
260	FORCE	159.	Y COORD
~~260~~	~~FORCE~~	~~195.~~	~~Z COORD~~
260	MOMENT	1643.	X COORD
260	MOMENT	2090.	Y COORD
~~260~~	~~MOMENT~~	~~3154.~~	~~Z COORD~~
960	FORCE	53.	X COORD
960	FORCE	139	Y COORD
~~960~~	~~FORCE~~	~~60.~~	~~Z COORD~~
960	MOMENT	3138.	X COORD
960	MOMENT	792.	Y COORD
~~960~~	~~MOMENT~~	~~1649.~~	~~Z COORD~~
971	FORCE	189.	X COORD
970	FORCE	86.	Y COORD
~~970~~	~~FORCE~~	~~110.~~	~~Z COORD~~
970	MOMENT	536.	X COORD
970	MOMENT	2482.	Y COORD
~~970~~	~~MOMENT~~	~~1859.~~	~~Z COORD~~
240	FORCE	31.	X COORD
240	FORCE	27.	Y COORD
~~240~~	~~FORCE~~	~~24.~~	~~Z COORD~~
240	MOMENT	737.	X COORD
240	MOMENT	964.	Y COORD
~~240~~	~~MOMENT~~	~~772.~~	~~Z COORD~~
950	FORCE	89.	X COORD
950	FORCE	[illegible]	Y COORD
~~950~~	~~FORCE~~	~~[illegible]~~	~~Z COORD~~
950	MOMENT	274.	X COORD
950	MOMENT	341.	Y COORD
~~950~~	~~MOMENT~~	~~2415.~~	~~Z COORD~~
345	FORCE	48.	Y COORD
321	FORCE	62.	INCLINED
340	FORCE	74.	X COORD

NODE	TYPE	REACTIONS (LBS OR IN-LBS)	DIRECTION
340	FORCE	13.	Y COORD
~~355~~	~~FORCE~~	~~38.~~	~~Y COORD~~
385	FORCE	68.	Y COORD
460	FORCE	28.	Y COORD
~~460~~	~~FORCE~~	~~49.~~	~~Z COORD~~
511	FORCE	144.	Y COORD
575	FORCE	31.	Y COORD
~~590~~	~~FORCE~~	~~35.~~	~~Y COORD~~
662	FORCE	152.	Y COORD
580	FORCE	34.	X COORD
~~580~~	~~FORCE~~	~~134.~~	~~Y COORD~~
580	FORCE	69.	Z COORD
730	FORCE	223.	X COORD
~~730~~	~~FORCE~~	~~225.~~	~~Y COORD~~
730	FORCE	252.	Z COORD
14!	FORCE	32.	Y COORD
~~146~~	~~FORCE~~	~~48.~~	~~X COORD~~
146	FORCE	16.	Y COORD
146	FORCE	56.	Z COORD
~~146~~	~~MOMENT~~	~~601.~~	~~X COORD~~
146	MOMENT	47.	Y COORD
146	MOMENT	22.	Z COORD

WPCF DISCHARGE LINE LACBW

SUPPORT REACTIONS FOR LOAD COMBINATION CASE NO. 10

OPERATING BASIS EARTHQUAKE (OBE) X, Y, AND Z SEISMIC ANCHOR MOVEMENT

For SSE Loading Multiply these values by 2.0

NODE	TYPE	REACTIONS (LBS OR IN-LBS)	DIRECTION
~~20~~	~~FORCE~~	~~0.~~	~~X COORD~~
20	FORCE	0.	Y COORD
20	FORCE	0.	Z COORD
~~20~~	~~MOMENT~~	~~0.~~	~~X COORD~~
20	MOMENT	0.	Y COORD
20	MOMENT	0.	Z COORD
~~50~~	~~FORCE~~	~~2.~~	~~X COORD~~
50	FORCE	5.	Y COORD
50	FORCE	13.	Z COORD
~~50~~	~~MOMENT~~	~~67.~~	~~X COORD~~
50	MOMENT	40.	Y COORD
50	MOMENT	60.	Z COORD
~~260~~	~~FORCE~~	~~15.~~	~~X COORD~~
260	ORCE	35.	Y COORD.
260	FORCE	27.	Z COORD
~~260~~	~~MOMENT~~	~~869.~~	~~X COORD~~
260	MOMENT	344.	Y COORD
260	MOMENT	1316.	Z COORD.
~~960~~	~~FORCE~~	~~1.~~	~~X COORD~~
960	FORCE	1.	COORD
960	FORCE	8.	Z COORD
~~960~~	~~MOMENT~~	~~21.~~	~~X COORD~~
960	MOMENT	2.	Y COORD
960	MOMENT	34.	Z COORD
~~970~~	~~FORCE~~	~~2.~~	~~X COORD~~
970	FORCE	2.	Y COORD
970	FORCE	14.	Z COORD
~~970~~	~~MOMENT~~	~~47.~~	~~X COORD~~
970	MOMENT	288.	Y COORD
970	MOMENT	53.	Z COORD
~~240~~	~~FORCE~~	~~3.~~	~~X COORD~~
240	FORCE	2.	Y COORD
240	FORCE	2.	Z COORD
~~240~~	~~MOMENT~~	~~36.~~	~~X COORD~~
240	MOMENT	119.	Y COORD
240	MOMENT	67.	Z COORD
~~950~~	~~FORCE~~	~~3.~~	~~X COORD~~
950	FORCE	1.	Y COORD
950	FORCE	1.	Z COORD
~~950~~	~~MOMENT~~	~~15.~~	~~X COORD~~
950	MOMENT	14.	Y COORD
950	MOMENT	188.	Z COORD
~~345~~	~~FORCE~~	~~33.~~	~~Y COORD~~
321	FORCE	32.	INCLINC
348	FORCE	35.	X COORD
~~348~~	~~FORCE~~	~~3.~~	~~Y COORD~~
355	FORCE	3.	Y COORD
385	FORCE	3.	Y COORD
~~468~~	~~FORCE~~	~~1.~~	~~Y COORD~~
468	FORCE	4.	Z COORD
511	FORCE	1.	Y COORD
~~575~~	~~FORCE~~	~~0.~~	~~Y COORD~~
590	FORCE	1.	Y COORD
662	FORCE	8.	Y COORD
~~580~~	~~FORCE~~	~~1.~~	~~X COORD~~
580	FORCE	1.	Y COORD
580	FORCE	7.	Z COORD
~~730~~	~~FORCE~~	~~10.~~	~~X COORD~~
730	FORCE	5.	Y COORD
730	FORCE	16.	Z COORD
~~145~~	~~FORCE~~	~~21.~~	~~Y COORD~~
146	FORCE	3.	X COORD.
146	FORCE	11.	Y COORD
~~146~~	~~FORCE~~	~~7.~~	~~Z COORD~~
146	MOMENT	419.	X COORD.
146	MOMENT	4.	Y COORD
~~146~~	~~MOMENT~~	~~14.~~	~~Z COORD~~

HPCS DISCHARGE LINE LACBWR

S-STEP ACCELERATION FOR LOAD CASE NO. 3

HORIZONTAL X, Y, AND Z SPECTRA (SAFE SHUTDOWN EARTHQUAKE)
COMBINED RESULT FOR MODES 1 THROUGH 20
BY RMS SUMMATION FOR SPECTRUM 1

PLUS RIGID BODY PSEUDO-MODES

POINT NO.	X-DIRECTION (G)	Y-DIRECTION (G)	Z-DIRECTION (G)
20	0.000	0.000	0.000
21	0.000	0.000	0.000
30	0.000	0.000	0.000
40	0.000	0.000	0.000
41	0.000	0.000	0.000
50	0.000	0.000	0.000
51	0.001	0.000	0.000
52	0.002	0.000	0.000
60	0.003	0.001	0.000
61	0.003	0.001	0.000
101	0.002	0.002	0.001
70	0.000	0.003	0.001
300	0.000	0.002	0.001
250	0.000	0.001	0.001
260	0.000	0.000	0.000
270	0.000	0.017	0.022
280	0.000	0.037	0.045
281	0.000	0.064	0.076
282	0.000	0.096	0.111
290	0.117	0.206	0.328
302	0.311	0.206	0.513
305	0.590	0.206	0.724
306	0.650	0.206	0.633
310	0.680	0.206	0.534
320	0.624	0.163	0.573
321	0.593	0.142	0.601
330	0.511	0.082	0.600
340	0.424	0.025	0.717
345	0.416	0.022	0.717
348	0.060	0.109	0.717
350	0.247	0.107	0.717
355	0.577	0.003	0.717
360	0.662	0.263	0.717
9001	0.593	0.491	0.716
370	0.581	0.666	0.716
380	0.642	0.552	0.573
9002	0.642	0.240	0.333
385	0.642	0.010	0.246

POINT NO.	X-DIRECTION (G)	Y-DIRECTION (G)	Z-DIRECTION (G)
392	0.642	0.046	0.255
9003	0.642	0.160	0.325
397	0.642	0.190	0.354
9004	0.642	0.156	0.294
400	0.642	0.072	0.146
465	0.642	0.030	0.073
467	0.642	0.015	0.048
468	0.642	0.024	0.006
9005	0.642	0.381	0.229
495	0.642	0.795	0.472
9006	0.642	0.990	0.657
500	0.642	1.019	0.824
510	0.641	0.789	0.883
511	0.020	0.015	0.883
512	0.942	0.011	0.883
513	0.931	0.076	0.825
520	0.439	0.075	0.386
530	0.270	0.075	0.235
540	0.092	0.074	0.068
545	0.006	0.016	0.000
960	0.000	0.000	0.000
555	0.630	0.031	0.249
9007	0.549	0.157	0.249
550	0.433	0.184	0.249
560	0.422	0.100	0.249
562	0.411	0.177	0.249
570	0.327	0.099	0.250
575	0.316	0.075	0.250
576	0.311	0.064	0.250
577	0.295	0.027	0.250
580	0.284	0.001	0.250
585	0.271	0.026	0.250
590	0.238	0.077	0.250
581	0.020	0.001	0.718
595	0.205	0.116	0.250
596	0.161	0.176	0.250
598	0.142	0.208	0.250
600	0.129	0.239	0.250
605	0.081	0.268	0.229
606	0.076	0.268	0.226
615	0.039	0.241	0.180
618	0.000	0.072	0.051
620	0.000	0.050	0.035
622	0.000	0.026	0.018
970	0.000	0.000	0.000
625	0.314	0.043	0.035

HPCS DISCHARGE LINE LACBWR

POINT NO.	X-DIRECTION (G)	Y-DIRECTION (G)	Z-DIRECTION (G)
630	0.272	0.027	0.035
660	0.300	0.000	0.050
662	0.300	0.005	0.050
663	0.300	0.006	0.060
664	0.261	0.099	0.130
665	0.206	0.127	0.123
670	0.150	0.153	0.075
680	0.046	0.067	0.001
685	0.035	0.051	0.001
730	0.001	0.000	0.001
731	0.690	0.000	0.552
740	0.037	0.050	0.002
750	0.098	0.110	0.002
760	0.259	0.100	0.006
765	0.382	0.100	0.215
72	0.004	0.005	0.001
75	0.024	0.011	0.001
80	0.184	0.046	0.001
90	0.493	0.110	0.001
95	0.584	0.120	0.094
96	0.584	0.107	0.396
105	0.584	0.105	0.700
110	0.570	0.110	0.803
9009	0.563	0.110	0.760
120	0.572	0.110	0.703
9010	0.610	0.110	0.620
130	0.680	0.110	0.532
140	0.672	0.077	0.470
145	0.605	0.084	0.410
146	0.559	0.079	0.396
9011	0.530	0.275	0.524
147	0.551	0.405	0.690
9012	0.545	0.658	0.770
150	0.474	0.761	0.764
9013	0.363	0.787	0.677
170	0.287	0.750	0.562
180	0.28[illegible]	0.73[illegible]	0.54[illegible]
185	0.285	0.693	0.513
190	0.283	0.683	0.586
200	0.251	0.630	0.434
210	0.220	0.630	0.404
220	0.212	0.630	0.378
230	0.210	0.571	0.308
231	0.210	0.485	0.247
232	0.210	0.373	0.169
233	0.192	0.311	0.135

POINT NO.	X-DIRECTION (G)	Y-DIRECTION (G)	Z-DIRECTION (G)
235	0.030	0.044	0.021
236	0.020	0.029	0.014
237	0.002	0.003	0.002
238	0.000	0.000	0.000
240	0.000	0.000	0.000
402	0.642	0.057	0.135
405	0.641	0.036	0.119
406	0.641	0.026	0.119
407	0.642	0.027	0.132
408	0.643	0.036	0.147
410	0.631	0.043	0.152
412	0.598	0.043	0.151
415	0.590	0.043	0.150
416	0.556	0.043	0.149
418	0.454	0.040	0.147
420	0.412	0.040	0.143
430	0.280	0.040	0.122
440	0.197	0.040	0.099
445	0.110	0.040	0.070
448	0.050	0.040	0.040
450	0.020	0.040	0.029
455	0.000	0.016	0.007
950	0.000	0.000	0.000

APPENDIX C

(From Reference 2)

LACBWR HPCS DISCHARGE NOZZLE WELD ANSYS ANALYSIS INPUT DATA

TABLE C-1

ANSYS MODEL ELEMENT PROPERTIES

HPCS DISCHARGE SOCKET WELD

ELEMENT NUMBERS	MATERIAL	PROPERTY	TEMPERATURE, ^oF 70	100	200	300	400	500
1-31 33-41 43-48 50-55 57-59 64-77 86-88 93-95 100-102 105-110	STAINLESS STEEL SA376, SA312 TP304H	Elastic Modulus E, 10^6 Psi	← 27.0 →					
		Design Stress Intentity S_m, ksi	20.0	20.0	20.0	20.0	18.7	17.4
		Mean Coeff. Of Thermal Expansion, α, 10^{-6} $^oF^{-1}$	9.11	9.16	9.34	9.47	9.59	9.70
		Poisson's Ratio ν	← 0.30 →					
82-84 89-91 96-98 103 111-146	INCONEL 600 SB 166	E, 10^6 Psi	← 30.0 →					
		S_m, ksi	← 23.3 →					
		α, 10^{-6}, $^oF^{-1}$	7.13	7.20	7.40	7.56	7.70	7.8
		ν	← 0.30 →					
42, 49, 56 60-63 78-81 85, 92, 99, 104	DUMMY GAP	E, 10^{-6} Psi	← 0.10 →					
		α, 10^{-6} $^oF^{-1}$	← 0.10 →					
		ν	← 0.30 →					

FIGURE 6.8

HPCS DISCHARGE NOZZLE SOCKET WELD
MATHEMATICAL MODEL GEOMETRY

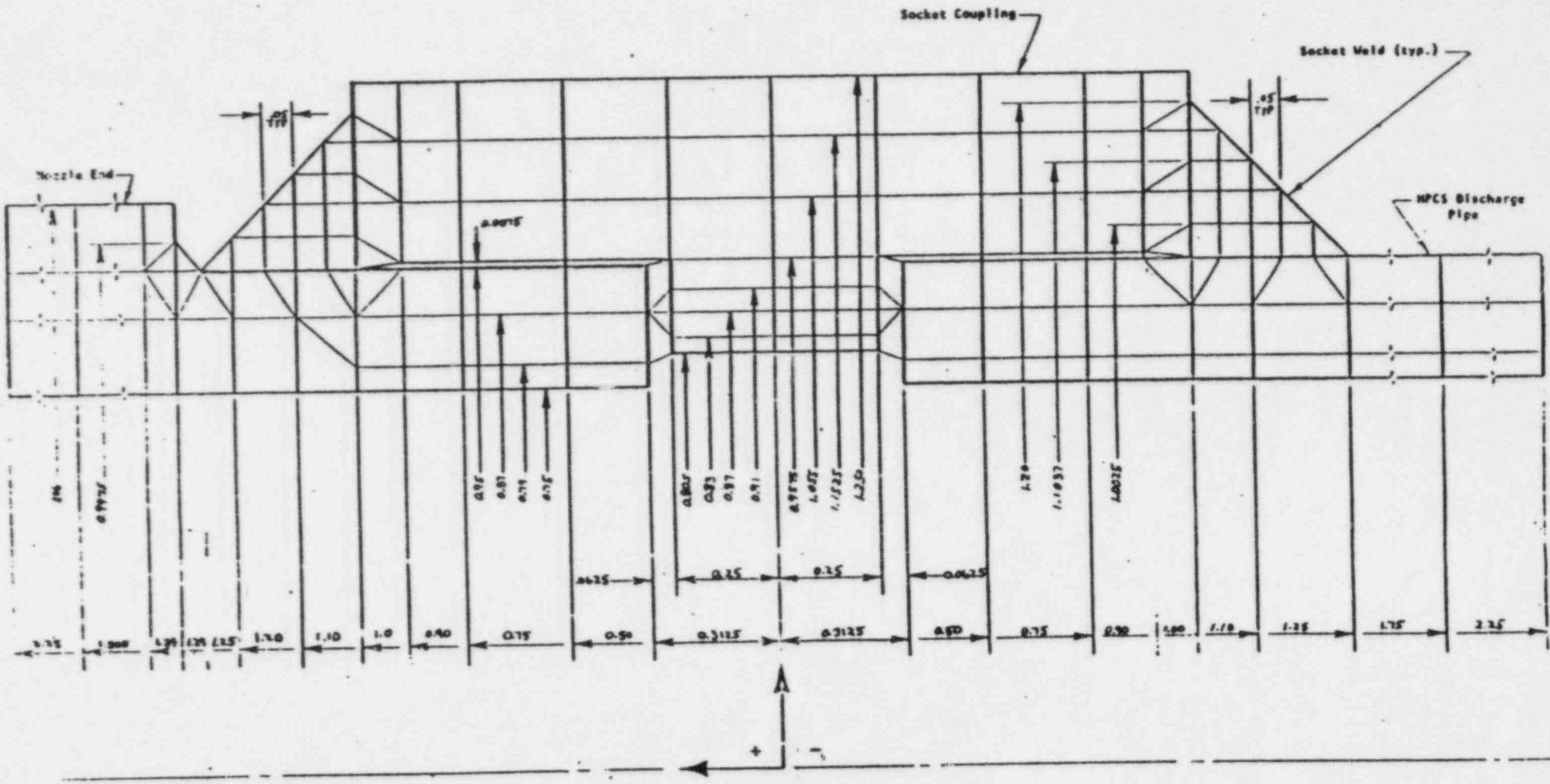
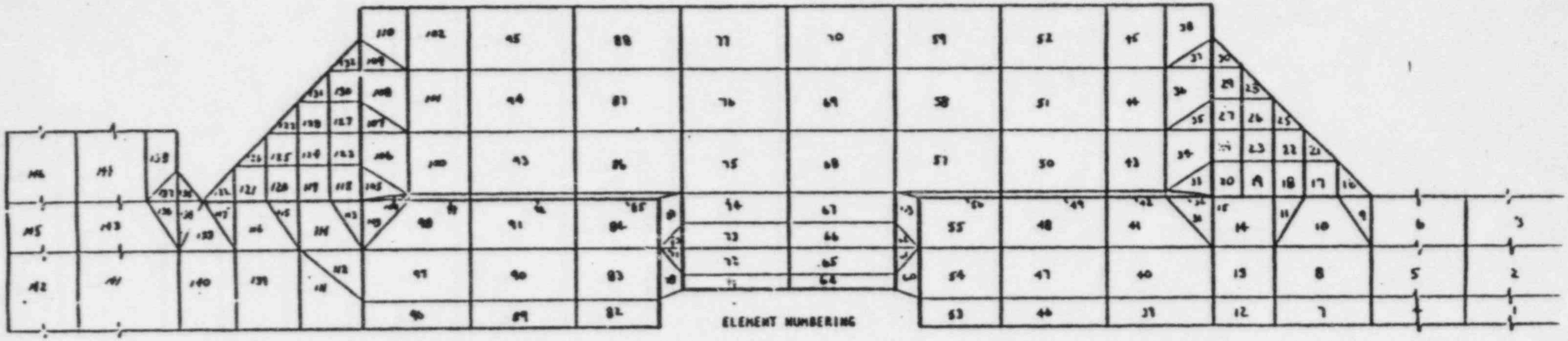
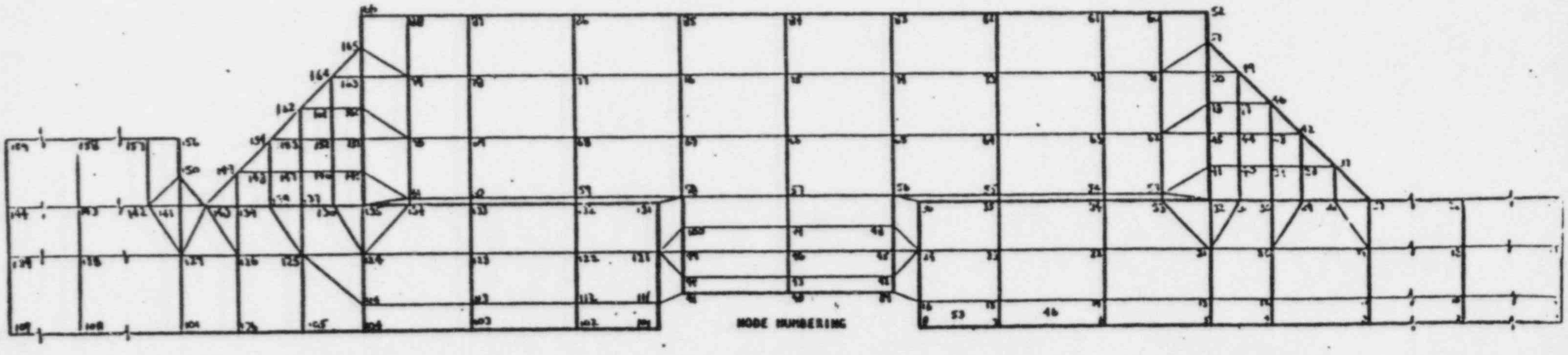


FIGURE 5.2

HPCS DISCHARGE NOZZLE SOCKET WELD
MODEL ELEMENT AND NODE NUMBERING



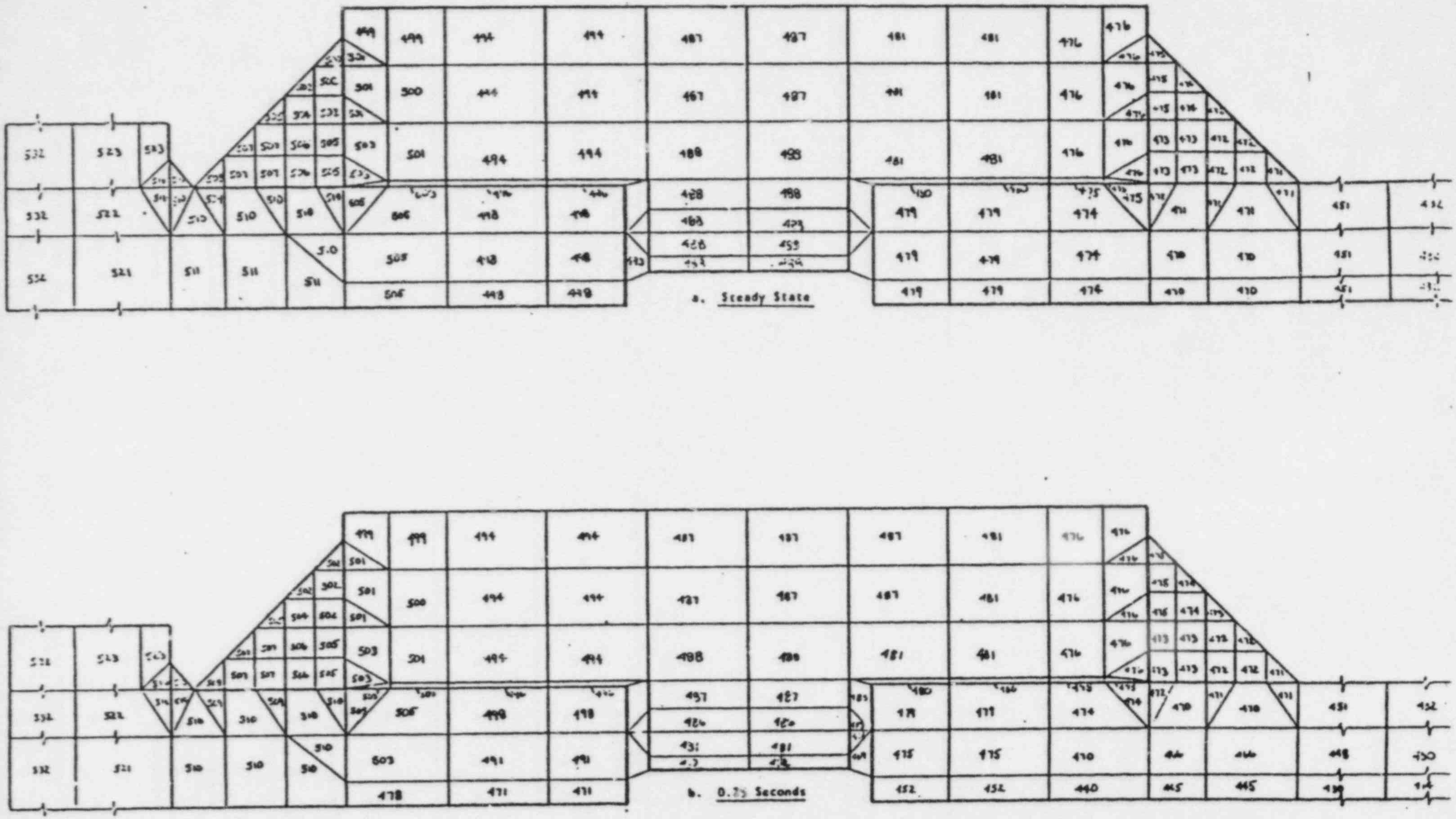
ELEMENT NUMBERING



NODE NUMBERING

FIGURE C-1

ANSYS THERMAL TRANSIENT LOADING

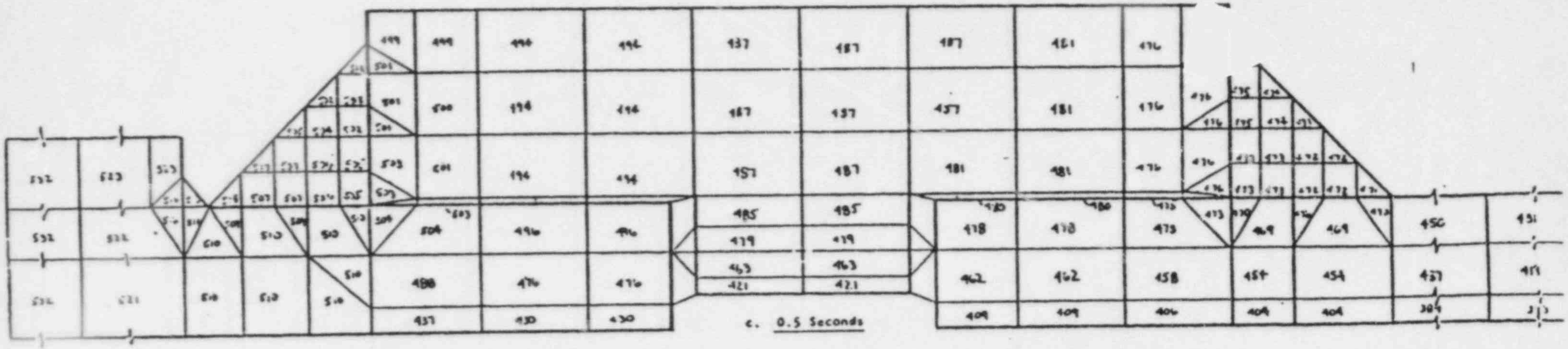


a. Steady State

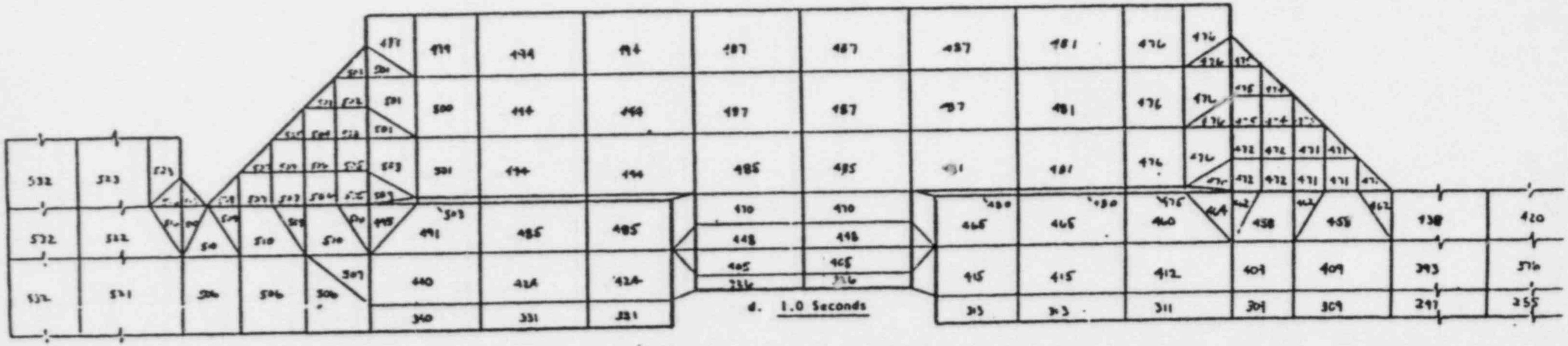
b. 0.25 Seconds

FIGURE C-1 (cont'd)

ANSYS THERMAL TRANSIENT LOADING



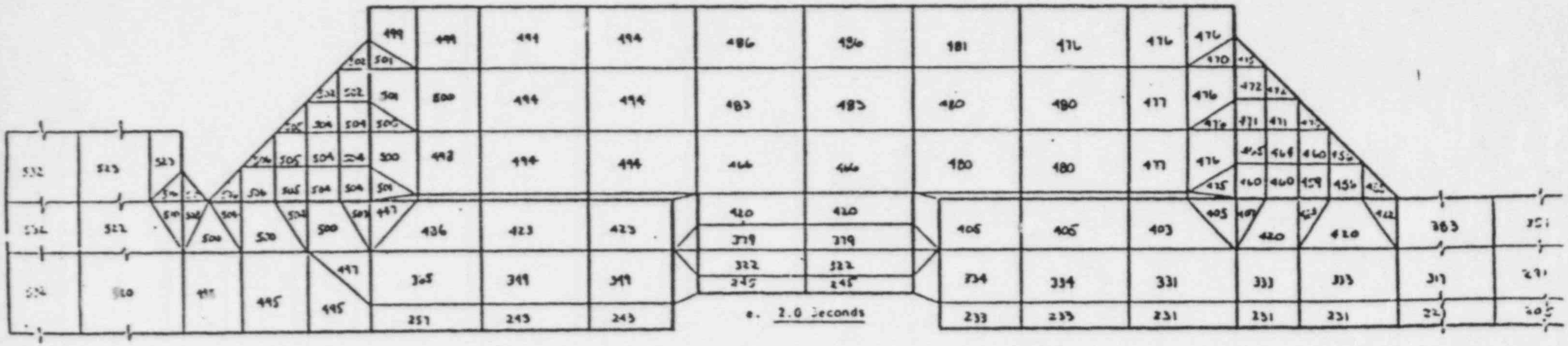
c. 0.5 Seconds



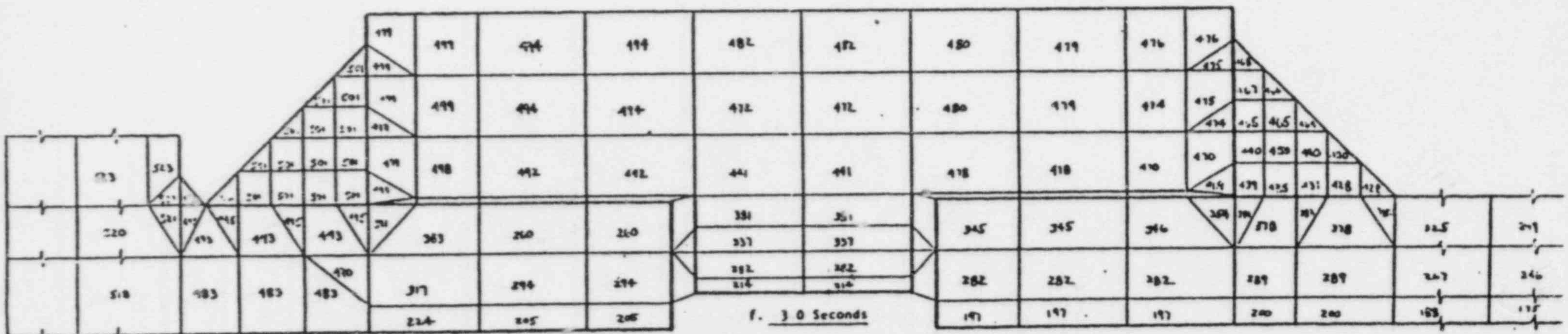
d. 1.0 Seconds

FIGURE C-1 (cont'd)

ANSYS THERMAL TRANSIENT LOADING



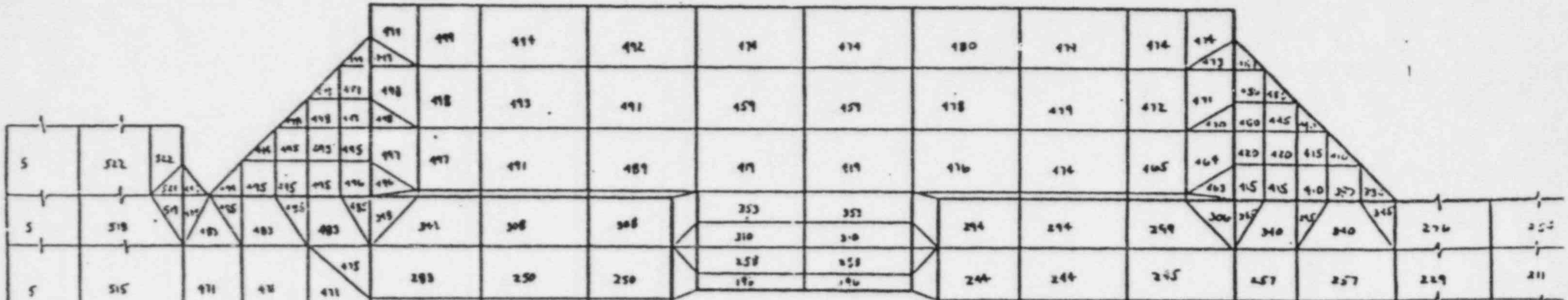
e. 2.0 Seconds



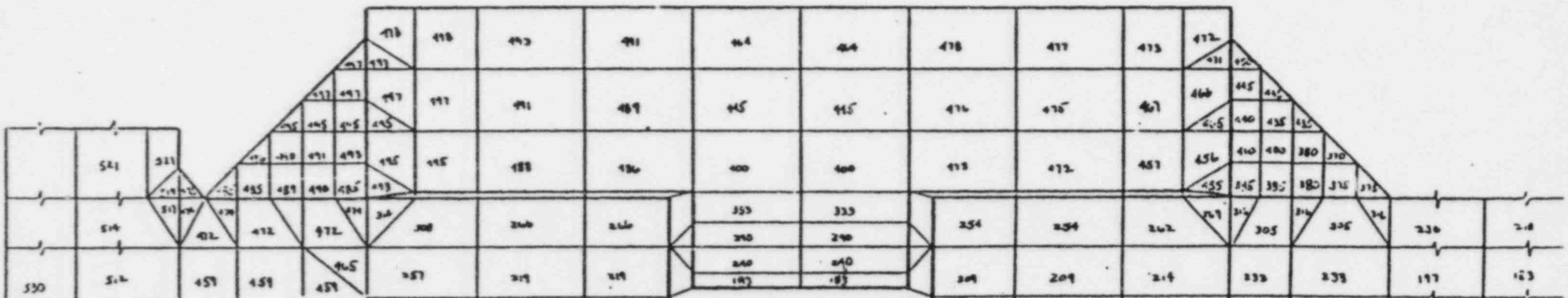
f. 3.0 Seconds

FIGURE C-1 (cont'd)

ANSYS THERMAL TRANSIENT LOADING



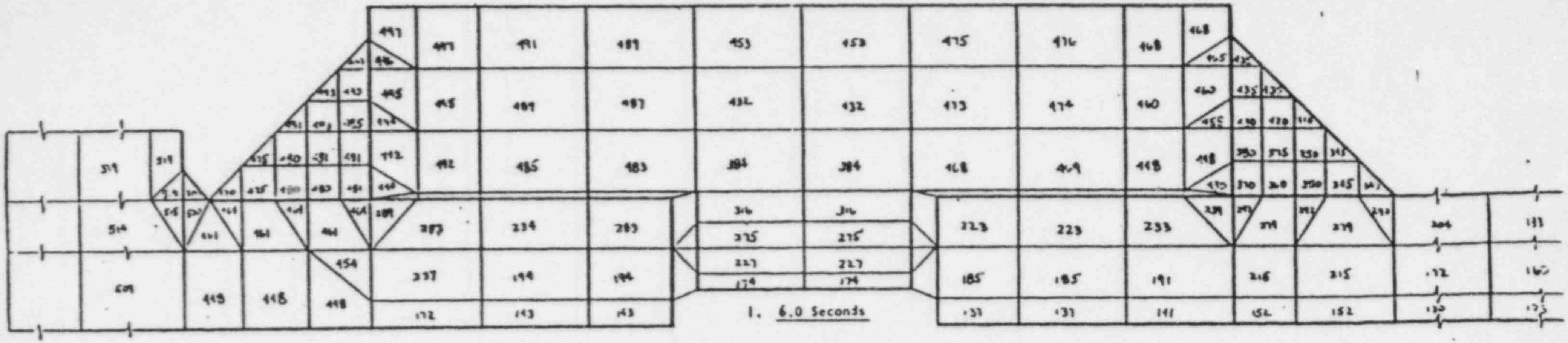
g. 4.0 Seconds



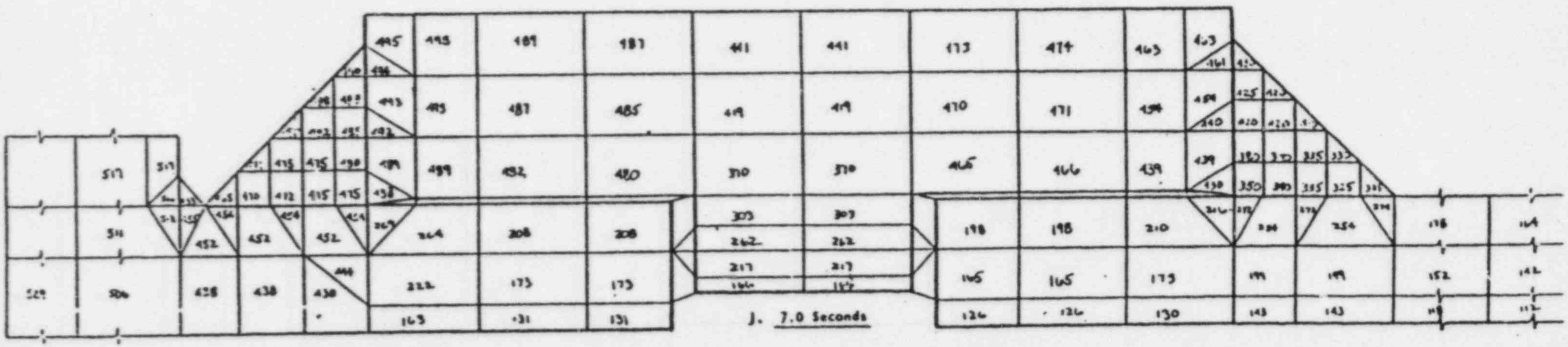
h. 5.0 Seconds

FIGURE . . (cont'd)

ANSYS THERMAL TRANSIENT LOADING



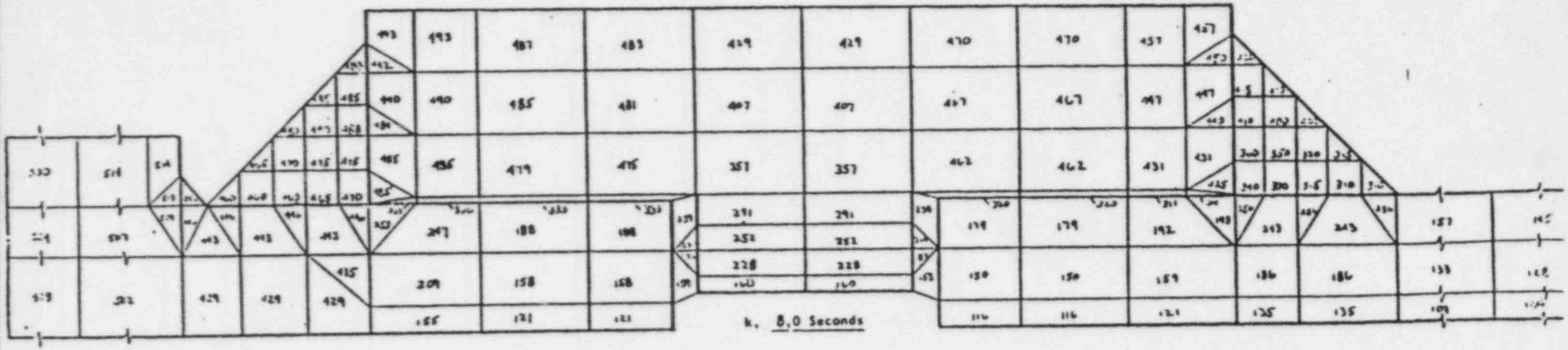
I. 6.0 Seconds



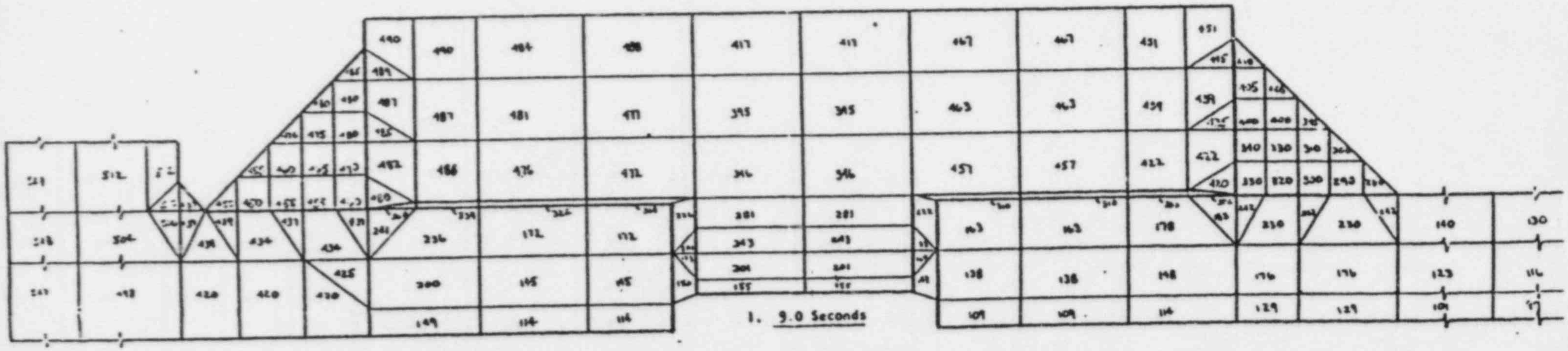
J. 7.0 Seconds

FIGURE (cont'd)

ANSYS THERMAL TRANSIENT LOADING



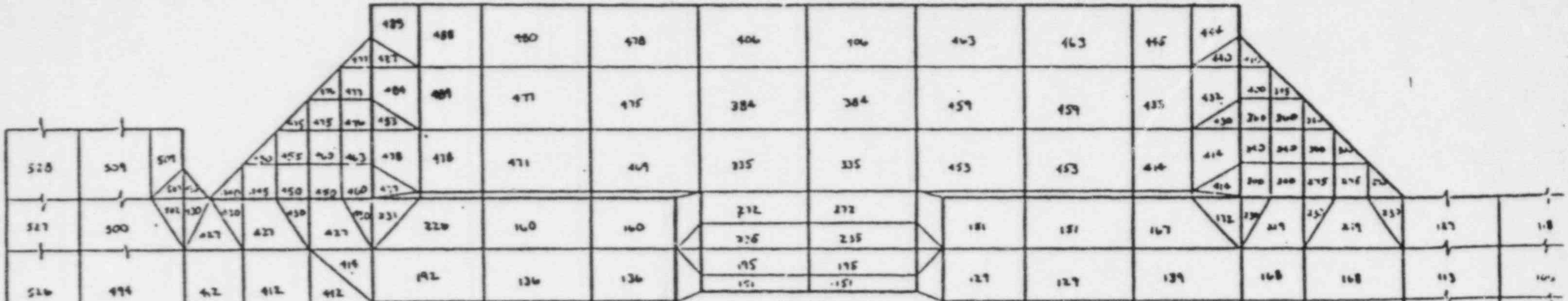
k. 8.0 Seconds



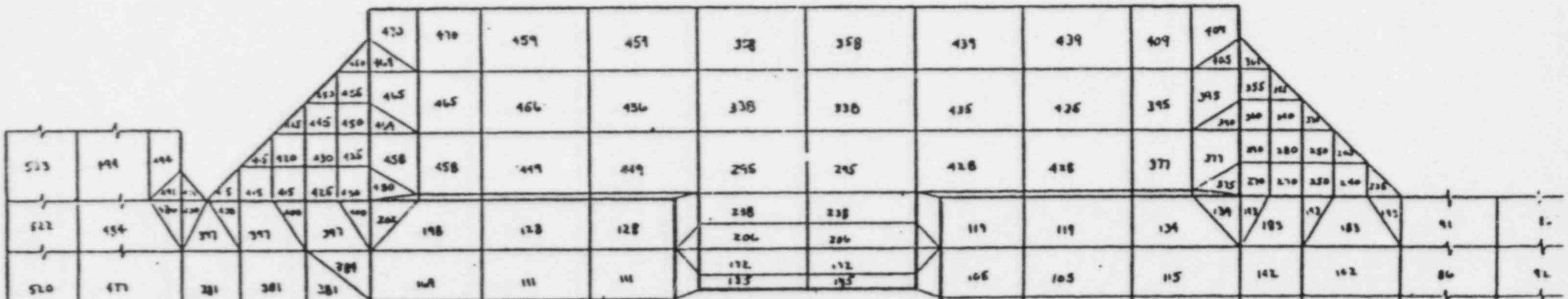
l. 9.0 Seconds

FIG. -1 (cont'd)

ANSYS THERMAL TRANSIENT LOADING



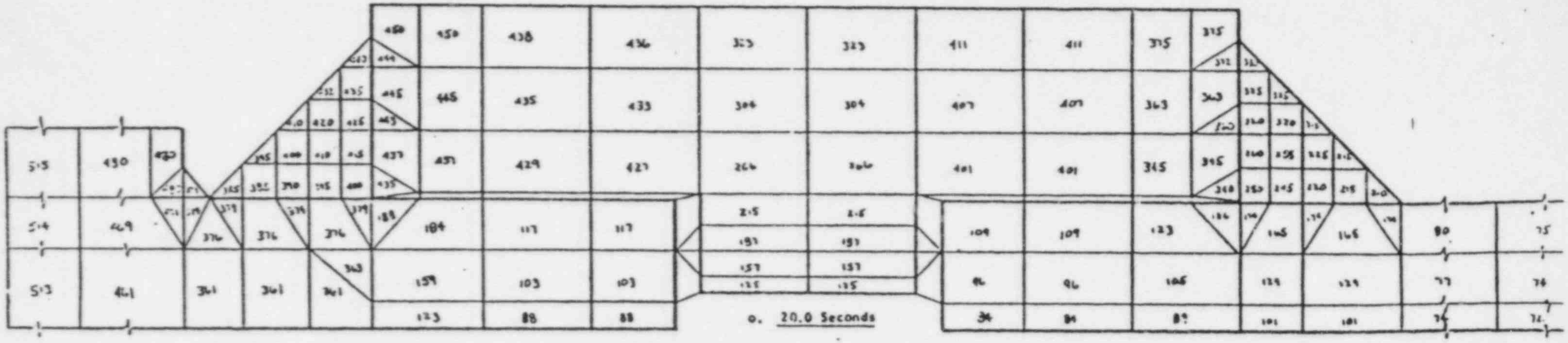
m. 10.0 Seconds



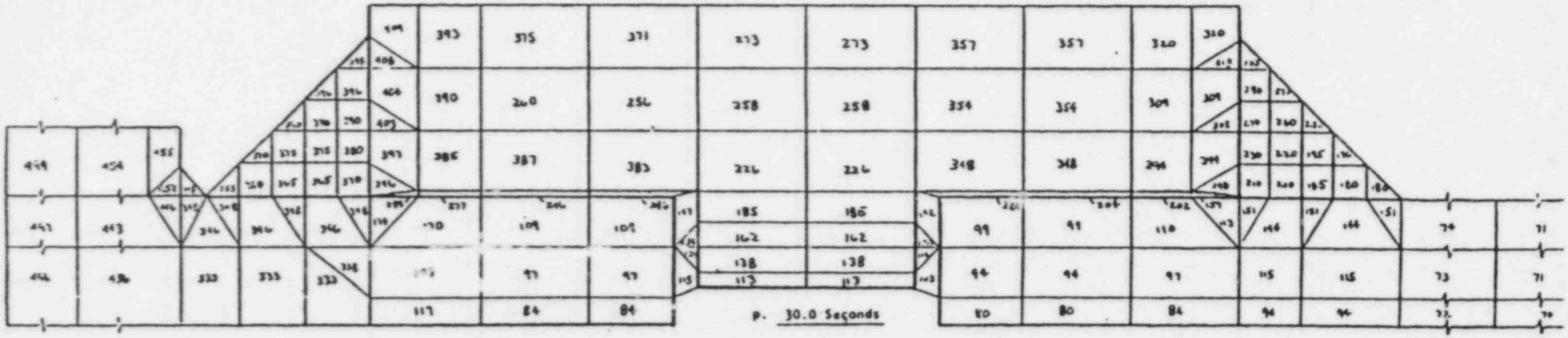
n. 15.0 Seconds

FIGUR (cont'd)

ANSYS THERMAL TRANSIENT LOADING



o. 20.0 Seconds



p. 30.0 Seconds

TABLE 7.2

RESULTS OF ANSYS STPESS ANALYSIS SUMMARY OF PEAK STRESSES VS TIME IN SOCKET WELD REGION

ELEMENT NO.	Stress, ksi — Time, Seconds: 0	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15.0
1	0.2	4.1	12.3	20.9	23.9	26.1	21.2	16.7	13.1	10.2	8.0	6.0	5.5	4.1	2.5
4	0.6	7.0	18.5	31.4	28.6	47.2	43.6	39.4	35.0	32.3	29.8	27.1	25.6	24.0	19.1
7	2.0	8.8	20.1	33.5	40.9	51.7	49.2	47.4	45.4	43.9	41.9	40.3	39.7	38.0	33.2
12	1.2	7.4	19.7	34.8	43.0	58.5	57.6	55.0	52.2	49.6	47.5	45.8	44.1	42.4	37.0
14	1.5	2.5	5.7	10.3	14.6	16.2	15.0	12.3	11.4	10.8	10.4	10.6	10.3	10.3	8.8
16	4.2	4.1	8.1	16.3	38.0	41.8	46.1	46.0	49.6	48.3	49.6	47.4	44.9	44.1	38.9
20	1.0	2.1	5.0	9.6	15.7	28.7	35.4	41.1	42.2	44.5	44.4	47.4	49.6	47.1	47.5
24	1.6	1.9	4.0	7.7	12.7	24.1	29.1	33.0	37.3	36.6	40.2	38.8	36.6	43.9	36.8
31	2.6	1.6	3.6	7.4	12.5	16.1	14.2	19.1	24.2	27.3	30.4	32.3	33.5	34.7	34.9
33	4.2	4.2	5.7	10.1	16.3	32.9	44.6	52.9	56.6	60.8	61.7	64.3	65.7	63.4	61.4
39	0.6	8.7	21.5	36.6	46.3	63.1	65.1	65.0	64.3	63.1	62.2	61.3	60.2	58.7	53.0
46	1.5	10.1	23.0	38.9	49.1	66.5	70.2	72.0	72.8	72.8	72.5	72.2	71.4	70.2	64.5
47	2.0	1.6	3.2	7.5	11.6	28.1	37.0	43.1	48.8	51.9	54.5	55.9	56.8	57.0	54.8
53	3.1	11.0	22.5	36.2	46.2	60.2	63.7	66.3	67.4	67.9	67.8	67.7	67.1	66.2	61.2
54	3.9	3.8	5.6	9.5	13.7	27.2	35.0	41.0	46.5	49.6	52.2	53.6	54.5	54.8	52.7
64	7.7	13.4	22.5	34.6	46.1	63.3	66.3	67.5	67.0	66.0	65.2	63.9	62.7	61.4	56.1
65	6.9	6.8	8.2	11.2	17.4	34.6	40.1	43.5	44.8	45.2	45.0	44.8	44.2	43.7	40.9
71	10.4	15.1	24.5	34.8	45.7	63.2	65.6	67.6	67.3	66.4	65.6	64.4	63.3	62.1	57.1

TABLE 7.2 (continued)

RESULTS OF ANSYS STRESS ANALYSIS SUMMARY OF PEAK STRESSES VS TIME IN SOCKET WELD REGION

	Stress, ksi														
	Time, Seconds														
ELEMENT NO.	0	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15.0
72	8.8	7.3	9.5	12.9	17.5	27.3	40.9	44.3	45.7	46.1	46.0	45.9	45.4	44.9	42.4
82	22.3	28.7	38.7	51.5	60.5	74.7	77.6	79.1	79.9	80.3	80.2	79.8	79.0	78.3	73.2
83	21.2	20.8	23.4	25.0	31.5	41.5	46.1	55.2	58.8	61.5	63.8	64.8	65.6	65.8	63.6
89	19.9	26.0	39.4	54.3	65.5	84.4	86.6	91.3	92.5	93.4	93.5	93.5	92.9	92.4	87.5
90	18.0	17.2	21.5	24.3	32.6	46.4	52.8	63.6	68.1	71.5	74.1	75.1	76.6	77.1	75.3
96	13.4	19.2	31.9	45.6	56.0	73.6	76.4	79.9	81.0	82.1	82.0	82.3	82.0	81.9	78.4
97	11.8	9.8	13.6	16.4	21.1	33.8	40.5	46.4	50.0	52.6	54.5	55.9	56.7	57.6	57.0
100	16.8	17.9	18.2	19.7	22.1	29.2	38.4	40.9	44.3	47.0	48.8	50.3	51.2	51.4	50.8
103	14.3	51.1	13.7	14.3	16.9	25.3	29.2	33.9	36.8	37.9	39.3	40.7	41.5	42.1	42.3
105	19.6	23.8	21.9	24.5	29.9	44.1	59.1	67.5	73.7	78.5	81.3	83.6	84.3	85.4	79.4
111	8.6	11.7	16.2	22.0	28.9	38.9	45.9	47.6	49.0	51.5	51.4	52.3	52.4	52.8	51.1
112	6.6	7.0	9.9	15.1	19.8	35.1	45.2	47.6	50.9	53.3	54.4	55.4	55.4	55.7	54.0
113	17.8	20.8	19.9	22.5	26.4	37.2	50.7	57.2	63.6	67.6	71.9	73.3	74.1	74.7	72.2
117	7.0	7.1	9.1	10.8	7.1	16.9	21.5	23.0	25.8	27.1	28.8	27.7	28.4	29.4	29.8
118	19.6	23.2	21.9	24.2	24.4	34.7	42.6	47.1	50.8	54.1	55.9	56.7	57.5	58.4	58.1
122	17.4	16.7	20.8	23.9	32.7	38.2	47.2	51.6	55.8	60.9	62.7	65.3	66.7	68.9	68.8
123	21.2	25.1	23.1	25.0	27.0	33.8	40.8	44.3	48.1	50.8	51.7	53.4	53.7	53.8	54.0
127	20.5	23.8	21.6	22.7	22.8	28.0	31.4	34.3	35.9	38.2	39.1	40.3	40.8	41.8	42.0

TABLE 7.2 (continued)

RESULTS OF ANSYS STRESS ANALYSIS SUMMARY OF PEAK STRESSES VS TIME IN SOCKET WELD REGION

	Stress, ksi														
	Time, Seconds														
ELEMENT NO.	0	0.25	0.50	0.75	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	15.0
130	15.7	18.8	16.0	16.3	16.5	17.3	18.1	19.4	20.1	21.6	21.6	21.9	21.6	22.2	21.8
132	28.3	35.4	29.0	29.6	30.5	31.6	31.9	33.0	33.5	34.5	35.4	35.6	36.0	36.5	36.6
133	4.6	3.9	6.0	7.3	8.0	12.7	16.1	16.8	17.1	16.5	17.9	20.3	20.5	20.6	20.5
134	12.4	11.6	14.7	16.9	16.9	26.9	35.0	39.1	37.5	46.0	44.7	52.8	54.8	56.6	59.3
135	9.7	10.8	10.9	12.3	12.9	17.6	24.1	27.6	40.0	27.4	44.8	38.7	40.8	43.6	45.1
136	9.2	9.8	10.9	12.6	14.1	20.6	21.9	23.4	28.3	28.3	31.1	28.8	29.4	28.3	30.9
137	6.3	8.1	7.2	8.1	9.2	13.3	16.9	18.1	31.1	23.8	30.6	21.9	22.3	23.3	22.1
138	2.7	3.1	3.9	5.0	6.4	9.9	13.4	14.8	14.5	17.7	11.9	19.3	20.1	22.3	20.8
139	7.8	7.4	9.0	10.6	13.6	18.8	24.2	25.0	26.0	28.9	28.6	30.4	30.9	31.6	31.6
140	6.8	8.4	8.3	9.6	12.3	17.0	21.2	21.1	21.7	21.5	21.5	21.1	20.4	20.7	19.7
141	5.3	3.3	7.0	8.1	10.3	15.5	19.8	21.2	24.5	24.3	26.7	26.0	26.2	26.0	26.0

APPENDIX D

ASME CODE CALCULATIONS AT HPCS DISCHARGE NOZZLE

APPENDIX D

ASME CODE FATIGUE EVALUATION OF HPCS DISCHARGE PIPE NOZZLE

ASME Code fatigue evaluations have been performed for the following four components at the HPCS discharge nozzle. (1) Inconel safe-end, (2) first socket weld coupling, (3) 304L pipe and (4) second socket weld coupling.

The fatigue analysis has been performed by using the results of the SMA-CT analysis for the dead weight, thermal expansion, and seismic loadings and the ANSYS thermal transient analysis performed by NES (Reference) for maximum credible thermal accident event.

From SMA-CT computer output binder SMA-CT/DPC #2 (Reference 16), internal moments and bending stresses due to various load conditions are summarized below:

Load Condition	Node No.*	Internal Moments (lbs.in)				Bending stress (psi)
		M_x	My	M_z	Resultant moment	
Dead Weight	236	839.0	71.0	984.0	1295.0	3143.0
	237	1075.0	94.0	1149.0	1576.3	3826.0
	238	1164.0	102.0	1212.0	1683.5	4086.0
Thermal Expansion	236	171.0	776.0	1645.0	1826.9	4434.0
	237	314.0	1008.0	1745.0	2039.5	4950.0
	238	365.0	1092.0	1781.0	2120.7	5147.0
Safe Shutdown Earthquake (SSE)	236	562.0	731.0	649.0	1127.6	2737.0
	237	678.0	885.0	731.0	1333.0	3236.0
	238	721.0	943.0	761.0	1410.0	3422.0
Seismic Anchor Movement (SSE)	236	41.0	182.0	111.0	217.1	527.0
	237	62.0	222.0	126.0	261.0	634.0
	238	70.0	234.0	131.0	277.2	673.0
Operating Basis Earthquake (OBE)	236	281.0	365.0	324.0	563.8	1368.0
	237	339.0	443.0	365.0	666.5	1618.0
	238	360.0	471.0	380.0	705.0	1711.0
Seismic Anchor Movement (OBE)	236	21.0	91.0	56.0	108.5	263.0
	237	31.0	110.0	63.0	131.0	316.7
	238	35.0	117.0	66.0	138.5	336.0

* Node Nos. 236,237, and 238 represents second socket weld coupling, 304Lpipe/first coupling and Inconel safe-end respectively.

Stress Intensification Factors (SIF) are:

	B_1	C_1	K_1	B_2	C_2	K_2	C_3	C_3	K_3
Pipe	0.5	1.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0
Socket weld	0.75	2.0	3.0	1.5	2.1	2.0	1.8	1.0	3.0
Girth weld	0.5	1.1	1.2	1.0	1.0	1.8	1.0	0.5	1.7

Conservatively use SIF values of Socket weld for each of the four components.

The ANSYS thermal transient analysis performed by NES (Reference 2) are given in Appendix E. The ANSYS thermal transient analysis provided the peak thermal stress intensity which included the combined effects of secondary thermal discontinuity, linear temperature gradient, and non-linear temperature gradient. The peak thermal stress intensity obtained from the NES report for each of the four component is shown in Figure D-1 and summarized below.

Inconel Safe-End	-	93.5	Ksi at Element 89
First Coupling	-	85.4	Ksi at Element 105
304 L pipe	-	72.8	Ksi at Element 46
Second Coupling	-	72.8	Ksi (Conservatively use same as for Element 46)

Since secondary thermal stress components of equation (10) are not evaluated separately in the ANSYS thermal transient analysis, they will be conservatively estimated from the peak thermal stress components which are evaluated by ANSYS and equation (11). The maximum peak thermal stress intensity due to structural and material discontinuity and linear and non-linear temparature gradient from equation 11, NB 3653.2 is :

$$\frac{1}{2(1-\nu)} K_3 E\alpha \left|\Delta T_1\right| + K_3 C_3 E_{ab} \left| \alpha_a T_{aa} - \alpha_b T_b \right| + \frac{1}{1-\nu} E\alpha \left|\Delta T_2\right|$$

For socket weld fitting, stress indices K_1, K_2 and K_3 are

$K_1 = 3.0$; $K_2 = 2.0$; $K_3 = 3.0$

And conservatively:

$$\frac{1}{2(1-\nu)} E\alpha \left|\Delta T_1\right| + C_3 E_{ab} \left| \alpha_a T_a - \alpha_b T_b \right| = 1/3\text{x peak thermal stress intensity}$$

The secondary thermal stress components of equation (10) for each of the four components are summarized below.

Inconel Safe-End - $\frac{93.5}{3}$ = 31.2 Ksi

First Coupling - $\frac{85.4}{3}$ = 28.5 Ksi

304 L pipe - $\frac{72.8}{3}$ = 24.3 Ksi

Second Coupling - $\frac{72.8}{3}$ = 24.3 Ksi

Membrane stress due to design pressure of 1340 psi is

$$\frac{PD_o}{2t} = \frac{1340 \times 1.9}{2 \times 0.2} = 6365 \text{ psi}$$

The allowable design stress intensity value S_m, for the 304 L pipe and the coupling have been determined by prorating the ASME Code S_m values by the ratio of the actual yield strength given in the material certification to the ASME Code yield strength values. Since no material certification for the Inconel Safe-End is available, the value of S_m has been obtained from Appendix I, Table I- 1.2 of the 1980 ASME Appendices, The value of S_m and Su (ultimate tensile stress) are summarized below:

Component	Material	S_m (Ksi) Room Temperature	Design Temperature	S_u (Ksi)
Inconel Safe-End	ASTM SB166-63	23.3	23.3	80.0
304 L Pipe	SA312/304L	$16.7 \times \frac{32.9}{25.0} = 21.97$	$15.8 \times \frac{32.9}{25.0} = 20.8$	60.9
Coupling	304L	$16.7 \times \frac{39.2}{25.0} = 26.19$	$15.8 \times \frac{39.2}{25} = 24.77$	60.9

ASME CLASS I CALCULATIONS

Primary stress intensity is computed from and limited by the following:

$$B_1 \frac{PD_o}{2t} + B_2 \frac{D_o}{2I} M_i = 1.5S_m \quad \text{for Service Level B Condition----(9)}$$

$$\leqslant 2.4S_m \leqslant 0.7S_u \quad \text{for Service Level D Condition}$$

Where:

B_1, B_2 = Primary stress indices for the specific piping component being investigated.

t = Nominal wall thickness of piping component

I = Moment of inertia

M_i = Resultant moment loading from loads caused by (1) weight, (2) earthquake, and (3) other mechanical loads (one-half the range, excluding anchor movement effects).

P =Internal design pressure

D_o =Outside diameter of pipe

S_m =Maximum allowable stress in material at the design temperature

S_u = Ultimate tensile stress in material at the design temperature

<u>Service Level B (Normal) condition (OBE Seismic Event)</u>:

Inconel Safe-End:

Primary Stress = 0.75 x 6365 + 1.5 (4086+1711)
= 13,469 psi $<$ 1.5 S_m = 1.5 x 23,300=34,950psi

First Coupling:

Primary stress = 0.75 x 6365 + 1.5 (3826+1618)
= 12,940 psi $<$ 1.5 x 24770 = 37,155 psi

304 L Pipe:

Primary stress = 0.75 x 6365 + 1.5 (3143 +1368)
= 12,940 psi $<$ 1.5 x 20800 = 31,200 psi

Second Coupling:

Primary stress = 0.75 x 6365 + 1.5(3143 + 1368)
= 11,540 psi $<$ 1.5 x 24770 = 37,155 psi

<u>Service Level D (Faulted) Condition (SSE Seismic event)</u>:

Inconel Safe-End:

Primary stress = 0.75 x 6365 + 1.5 (4086 + 3422)
= 16,036 psi $<$ 2.4S_m = 2.4 x 23300 = 55,920 psi
$<$ 0.7S_u = 0.7 x 80,000 =56,000 psi

First Coupling:

Primary stress $= 0.75 \times 6365 + 1.5\ (3826 + 3236)$
$= 15,367$ psi $< 2.4 \times 24770 = 59,448$ psi
$< 0.7 \times 60,900 = 42,630$ psi

304 L Pipe:

Primary stress $= 0.75 \times 6365 + 1.5\ (3826 + 3236)$
$= 15,367$ psi $< 2.4 \times 20800 = 49,920$ psi
$< 0.7 \times 60900 = 42,630$ psi

Second Coupling:

Primary stress $= 0.75 \times 6365 + 1.5\ (3143 + 2737)$
$= 13,594$ $< 2.4 \times 2477 = 59,448$ psi
$< 0.7 \times 60,900 = 42,630$ psi

Therefore the ASME Code requirements for primary stress intensity (equation 9) are satisfied.

Primary Plus Secondary Stress Intensity Range Check

The primary plus secondary stress intensity range is computed from and limited by the following:

$$S_n = C_1 \frac{P_b D_o}{2t} + C_2 \frac{D_o}{2I} M_i + \qquad (10)$$

$$\frac{1}{2\ (1-\nu)} E\alpha \left|\Delta T_1\right| + C_3 E_{ab} \left|\alpha_a T_a - \alpha_b T_b\right| \leq 3S_m$$

Where:

C_1, C_2, C_3 = Secondary stress indices for the specific piping component being investigated.

P_o = Range of operating pressure conservatively use design pressure.

M_i = Range of moment loading resulting from thermal expansion, anchor movements from any cause, seismic effects, and othes mechanical loads.

OBE Seismic Event:

Inconel Safe-End:

$S_n = 2.0 \times 6365 + 2.1\ (1711 + 336) + 0$
$= 17,029$ psi $< 3S_m = 3 \times 23300 = 69,900$ psi

First Coupling:

$$S_n = 2.0 \times 6365 + 2.1\ (1618 + 317) + 0$$
$$= 16{,}794 \text{ psi} < 3 \times 24770 = 74{,}310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 2.1\ (1618 + 317) + 0$$
$$= 16{,}794 \text{ psi} < 3 \times 20800 = 62{,}400 \text{ psi}$$

Second Coupling:

$$S_n = 2.0 \times 6365 + 2.1\ (1368 + 263) + 0$$
$$= 16{,}155 \text{ psi} < 3 \times 24770 = 74{,}310 \text{ psi}$$

<u>SSE Seismic Event:</u>

Inconel Safe-End:

$$S_n = 2.0 \times 6365 + 2.1\ (3422 + 673) + 0$$
$$= 21{,}330 \text{ psi} < 69{,}900 \text{ psi}$$

First Coupling:

$$S_n = 2 \times 6365 + 2.1\ (3236 + 634) + 0$$
$$= 20{,}857 \text{ psi} < 74{,}310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 2.1\ (3236 + 634) + 0$$
$$= 20{,}857 \text{ psi} < 62{,}400 \text{ psi}$$

Second Coupling:

$$S_n = 2 \times 6365 + 2.1\ (2737 + 527) + 0$$
$$= 19{,}584 \text{ psi} < 74{,}310 \text{ psi}$$

<u>Thermal: Normal Start-up and Shutdown</u>

Inconel Safe-End:

$$S_n = 2 \times 6365 + 2.1\ (5147) + 0$$
$$= 23{,}539 \text{ psi} < 69{,}900 \text{ psi}$$

First Coupling:

$$S_n = 2 \times 6365 + 2.1\ (4950) + 0$$
$$= 23{,}125 \text{ psi} < 74{,}310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 2.1\ (4950) + 0$$
$$= 23{,}125 \text{ psi} < 62{,}400 \text{ psi}$$

Second Coupling:

$$S_n = 2 \times 6365 + 2.1\ (4434) + 0$$
$$= 22,041 \text{ psi} < 74,310 \text{ psi}$$

Maximum Credible Thermal Transient Event (MCA)

Inconel Safe-End

$$S_n = 2 \times 6365 + 31200$$
$$= 43,930 \text{ psi} < 69,900 \text{ psi}$$

First Coupling:

$$S_n = 2 \times 6365 + 28,500$$
$$= 41,230 \text{ psi} < 74,310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 24,300$$
$$= 37,030 \text{ psi} < 62,400 \text{ psi}$$

Second Coupling:

$$S_n = 2 \times 6365 + 24,300$$
$$= 37,030 \text{ psi} < 74,310 \text{ psi}$$

OBE Seismic + Maximum Credible Thermal Transient (MCA) Events

Inconel Safe-End:

$$S_n = 2 \times 6365 + 2.1\ (1711 + 336) + 31200$$
$$= 48,229 \text{ psi} < 69,900 \text{ psi}$$

First Coupling:

$$S_n = 2 \times 6365 + 2.1\ (1618 + 317) + 28,500$$
$$= 45,294 \text{ psi} < 74,310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 2.1\ (1618 + 317) + 24300$$
$$= 41,094 \text{ psi} < 62,400 \text{ psi}$$

Second Coupling:

$$S_n = 2 \times 6365 + 2.1\ (1368 + 263) + 24300$$
$$= 40,455 \text{ psi} < 74,310 \text{ psi}$$

SSE Seismic + Maximum Credible Thermal Transient (MCA) Events

Inconel Safe-End:

$$S_n = 2 \times 6365 + 2.1\ (3422 + 673) + 31,200$$
$$= 52,530 \text{ psi} < 69,900 \text{ psi}$$

First Coupling:

$$S_n = 2 \times 6365 + 2.1\ (3236 + 634) + 28500$$
$$= 49,357 \text{ psi} < 74,310 \text{ psi}$$

304 L Pipe:

$$S_n = 2 \times 6365 + 2.1\ (3236 + 634) + 24300$$
$$= 45,157 \text{ psi} < 62,400 \text{ psi}$$

Second Coupling:

$$S_n = 2 \times 6365 + 2.1\ (2737 + 527) + 24300$$
$$= 43,884 \text{ psi} < 74,310 \text{ psi}$$

Therefore the ASME Code requirements for Primary plus secondary stress intensity range (equation 10) are satisfied for all pairs of load sets even including the unlikely pairs of seismic and maximum credible accident thermal transient events. There is no need to evaluate equations (12) and (13) of ASME Code.

FATIGUE EVALUATION

Peak Stress Intensity Range

Peak stress intensity range is calculated for use in the fatigue evaluation, as follows:

$$S_p = K_1 C_1 \frac{P_o D_o}{2t} + K_2 C_2 \frac{D_o}{2I} M_I +$$

$$\frac{1}{2(1-\nu)} K_3 E\alpha \left|\Delta T_1\right| + K_3 C_3 E_{ab} \left|\alpha_a T_a - \alpha_b T_b\right| + \frac{1}{1-\nu} E\alpha \left|\Delta T_2\right| \qquad (11)$$

Where:

K_1, K_2, K_3, = Local stress indices for the specific piping component being investigated.

The alternating stress is calculated from:

$$S_{alt} = K_e \frac{S_n}{2} \qquad (14)$$

Where:

S_{alt} = Alternating stress intensity

K_e = Factor used to compensate for reduction in cycle life in plastic cycling.
= 1.0 for $S_n \leq 3S_m$

OBE Seismic Event:

Inconel Safe-End:

S_p = 3 x 2 x 6365 + 2 x 2.1 (1711 + 336) + 0
= 38190 + 8597 = 46,787 psi

$S_{alt} = \frac{46787}{2} =$ 23,394 psi

From Figure I - 9.2 Number of stress cycles N = 10^6(Figure D-2)

First Coupling:

S_p = 3 x 2 x 6365 + 2 x 2.1 (1618 + 317) + 0 = 46317 psi

$S_{alt} = \frac{46317}{2}$ = 23,159 psi

From Figure I - 9.2 N = 10^6 cycles

304L Pipe:

S_p = 38190 + 2 x 2.1 (1618 + 317) + 0 = 46317

S_{alt}= 23,159 psi ; N = 10^6cycles

Second Coupling:

S_p = 38190 + 2 x 2.1 (1368 + 263) = 45040 psi

S_{alt} = 22,520 psi ; N = 10^6 cycles

SSE Seismic Event:

Inconel Safe-End:

S_p = 38190 + 2 x 2.1 (3422 + 673) + 0 = 55,389 psi

S_{alt} = 27,695 psi ; N = 5 x 10^5 cycles

First Coupling:

S_p = 38190 + 2 x 2.1 (3236 + 634) + 0 = 54,444 psi

S_{alt} = 27,222 psi ; N = 5.5 x 10^5 cycles

Second Coupling:

$S_p = 38190 + 2 \times 2.1\ (2737 + 527) + 0 = 51,899$ psi

$S_{alt} = 25949$ psi ; $N = 6 \times 10^5$ cycles

Thermal -Normal Start-up and Shut-down

Inconel Safe-End

$S_p = 3819 + 2 \times 2.1\ (5147) = 59,807$ psi

$S_{alt} = 29,904$ psi ; $N = 3 \times 10^5$ cycles

First Coupling:

$S_p = 38190 + 2 \times 2.1\ (4950) = 58,980$ psi

$S_{alt} = 29,490$ psi ; $N = 3.2 \times 10^5$ cycles

304 L Pipe:

$S_p = 38190 + 2 \times 2.1\ (4950) = 58,980$ psi

$S_{alt} = 29,490$ psi ; $N = 3.2 \times 10^5$ cycles

Second Coupling:

$S_p = 38190 + 2 \times 2.1\ (4434) = 56813$ psi

$S_{alt} = 28,406$ psi ; $N = 3.6 \times 10^5$ cycles

Maximum Credible Thermal Transient Event (MCA)

Inconel Safe-End:

$S_p = 38190 + 93500 = 131,690$ psi

$S_{alt} = 65,845$ psi ; $N = 5.7 \times 10^3$ cycles

First Coupling:

$S_p = 38190 + 85400 = 123590$

$S_{alt} = 61,795$ psi ; $N = 7.5 \times 10^3$ cycles

304 L Pipe:

$S_p = 38190 + 72,800 = 110,990$ psi

$S_{alt} = 55,495$ psi ; $N = 1.3 \times 10^4$ cycles

Second Coupling:

S_p = 38190 + 72,800 = 110,990 psi

S_{alt} = 55,495 psi ; N = 1.3 x 10^4 cycles

OBE Seismic + Maximum Credible Thermal Transient (MCA) Events

Inconel Safe-End:

S_p = 38190 + 2 x 2.1 (1711 + 336) + 93500 = 140,287 psi

S_{alt} = 70,144 psi ; N = 4.0 x 10^3 cycles

First Coupling:

S_p = 38190 + 2 x 2.1 (1618 + 317) + 85400 = 131,717 psi

S_{alt} = 65,859 psi ; N = 5.7 x 10^3 cycles

304 L Pipe:

S_p = 38190 + 2 x 2.1 (1618 + 317) + 72,800 = 119,117 psi

S_{alt} = 59,559 psi ; N = 9 x 10^3 cycles

Second Coupling:

S_p = 38190 + 2 x 2.1 (1368 + 263) + 72800 = 117,840 psi

S_{alt} = 58,920 psi ; N = 10^4 cycles

SSE Seismic + Maximum Credible Thermal Transient (MCA) Events.

Inconel Safe-End:

S_p = 38190 + 2 x 2.1 (3422 + 673) + 93500 148,889 psi

S_{alt} = 74,445 psi ; N = 3.3 x 10^3 cycles

First Coupling:

S_p = 38190 + 2 x 2.1 (3236 + 634) + 85400 = 139,844 psi

S_{alt} = 69,922 psi ; N = 4.5 x 10^3 cycles

304 L Pipe:

S_p = 38190 + 2 x 2.1 (3236 + 634) + 72800 = 127,244 psi

S_{alt} = 63,622 psi ; N = 6.5 x 10^3 cycles

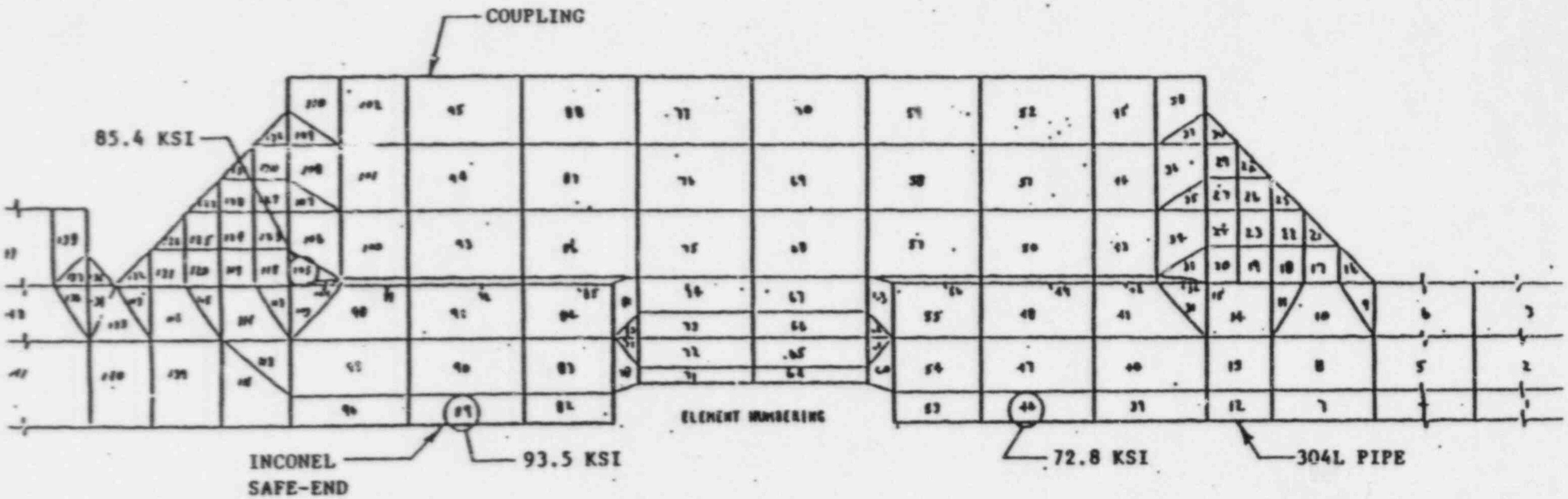


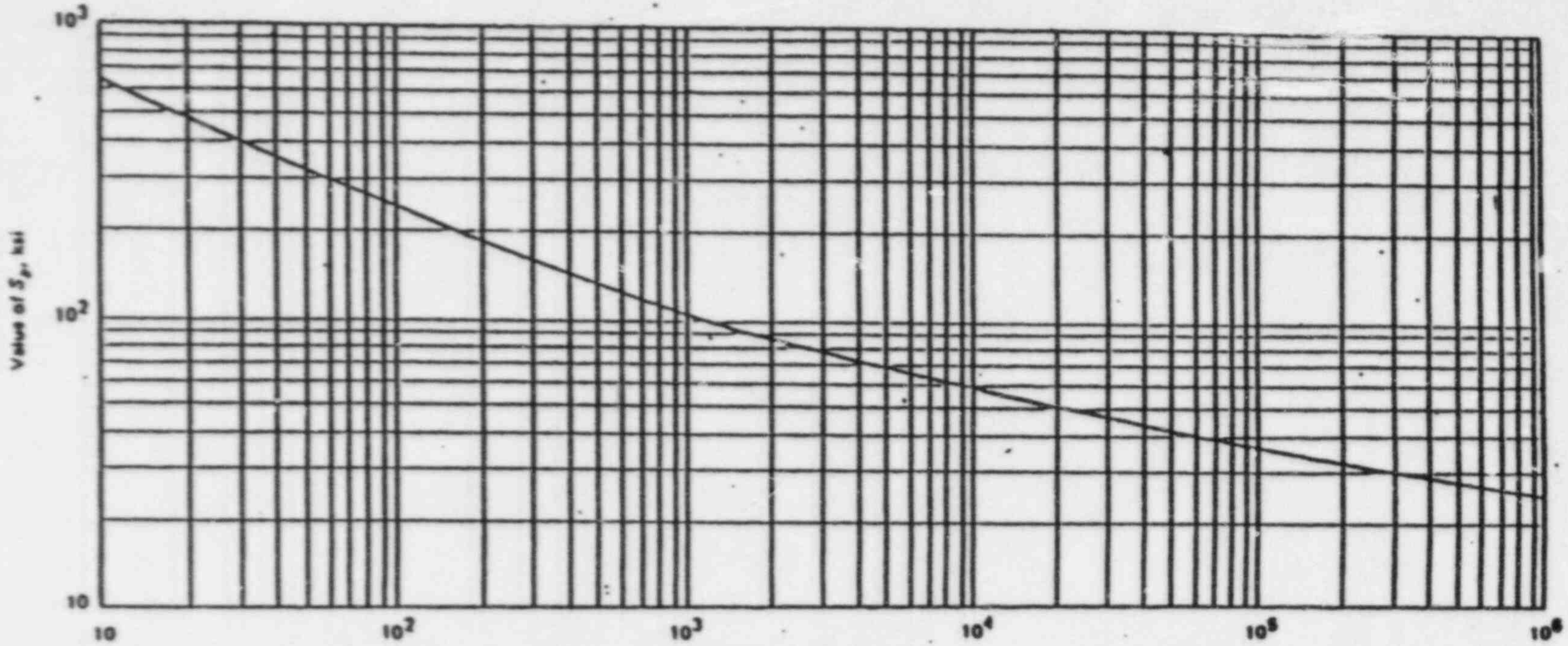
FIGURE D-1
HPCS DISCHARGE NOZZLE SOCKET WELD MODEL

SUMMARY OF RESULTS

Load Conditions	Components			
	Inconel Safe-End	First Coupling	304L Pipe	Second Coupling
PRIMARY STRESS (psi)				
Service Level B (normal) Condition:				
Dead Weight + OBE Seismic Event	13,469	12,940	12,940	11,540
Allowable stress $1.5S_m$	34,950	37,155	31,200	37,155
Service Level D(Faulted) Condition:				
Dead Weight + SSE Seismic Event	16,036	15,367	15,367	13,594
Allowable stress $2.4S_m$ or $0.7S_u$	56,000	42,630	42,630	42,630
PRIMARY PLUS SECONDARY STRESS INTENSITY RANGE S_n (psi)				
OBE Seismic Event	17,029	16,794	16,794	16,155
SSE Seismic Event	21,330	20,857	20,857	19,584
Thermal Normal Start-up and Shut-down	23,539	23,125	23,125	22,041
Maximum Credible Thermal Transient(MCA)	43,930	41,230	37,030	37,030
OBE Seismic + Maximum Credible Thermal Transient (MCA)	48,229	45,294	41,094	40,455
SSE Seismic + Maximum Credible Thermal Transient (MCA)	52,530	49,357	45,157	43,884
Allowable Stress $3S_m$	69,900	74,310	62,400	74,310

SUMMARY OF RESULTS
ALLOWABLE NUMBER OF STRESS CYCLES

Load Conditions	Components			
	Inconel Safe-End	First Coupling	304 L Pipe	Second Coupling
OBE Seismic Event	10^6	10^6	10^6	10^6
SSE Seismic Event	5×10^5	5.5×10^5	5.5×10^5	6×10^5
Thermal-normal Start-up and Shutdown	3×10^5	3.2×10^5	3.2×10^5	3.6×10^5
Maximum Credible Thermal Transient (MCA)	5,700	7,500	13,000	13,000
OBE Seismic + Maximum Credible Thermal Transient (MCA)	4,000	5,700	9,000	10,000
SSE Seismic + Maximum Credible Thermal Transient (MCA)	3,300	4,500	6,500	7,000



NOTE:
E = 26.0 X 10^6 psi

FIGURE D-2

FIG. I-9.2 DESIGN FATIGUE CURVE FOR AUSTENITIC STEELS, NICKEL–CHROMIUM–IRON ALLOY, NICKEL–IRON–CHROMIUM ALLOY, AND NICKEL–COPPER ALLOY FOR TEMPERATURES NOT EXCEEDING 800°F

APPENDIX E

HPCS DISCHARGE NOZZLE THERMAL
TRANSIENT ANALYSIS WITH THE LION 4 CODE
(From Reference 2)

LACBWR HPCS SEISMIC THERMAL STUDY

1. PURPOSE - TO COMPUTE STEADY STATE AND TRANSIENT TEMPERATURES IN LACROSSE BOILING WATER REACTOR VESSEL NOZZLE AND HPCS PIPE, DURING EMERGENCY CORE COOLING.

2. SUMMARY - THE LION 4 (REF 1) THERMAL-HYDRAULICS CODE WAS USED TO COMPUTE THE TEMPERATURES FOR LACROSSE IN THE HPCS PIPE DURING EMERGENCY COOLING.

A THERMAL MODEL WAS DEVELOPED TO FIND THE STEADY STATE TEMPERATURE DISTRIBUTION AND THE RESULTS WERE INPUT AS THE INITIAL TEMPERATURES IN THE TRANSIENT ANALYSIS FOR MAXIMUM CREDIBLE ACCIDENT (HPCS WATER FLOW AT 70°F, AND 577.5°F TO 270°F AT -20°F/SEC IN THE CORE ; REF. 4). THE CRITICAL SECTION OF THE MODEL IS SHOWN IN FIGURES 1 AND 2.

A SERIES OF TEMPERATURE MEANS AND DIFFERENCES WERE OBTAINED TO BE USED IN THERMAL STRESS CALCULATIONS.

3. Analysis - A) Materials - The pipe, coupling, and welds were all assumed to have the properties of stainless steel. The nozzle is a ferritic steel forging with an inconel extension welded to the forging, and clad with stainless steel (Ref 2., and Ref 4. fig A-1B)

B) Steady State - in constructing the steady state model, the coolant was treated as a solid mass, represented by internal nodes, and the steady state temperature distribution obtained was used as input for the transient analysis. The results of the steady state analysis are shown in Figure 3.

C) Transients - In the transient analysis, the internal nodes, representing the coolant, were removed, and replaced by coolant nodes. A boundary node was placed at the entrance to the channel to ensure constant inlet temperature

Flow is assumed to start instantaneously at time = 0.0 min. The transient analysis corresponds to conditions for maximum credible accident as

specified in LACBWR Safeguard Report (Ref. 4), which specifies a 20°F/sec. vessel temperature change. The transient temperatures are shown in Figures 4 thru 30

D) Temperature Means and Differences:

T_A = Mean Temp. thru the Thickness of Material

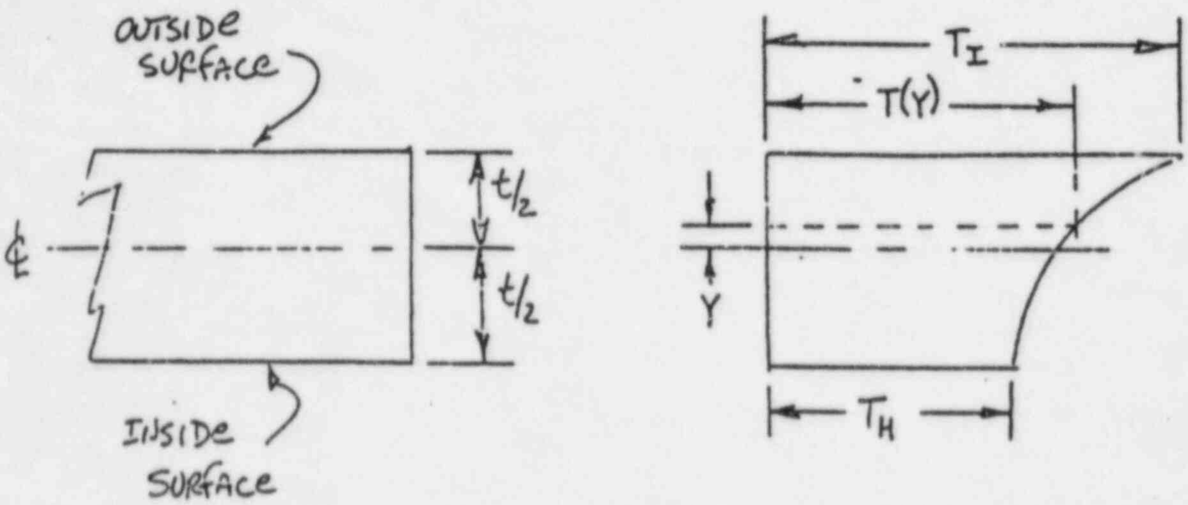
$|\Delta T_1|$ = Range of Absolute Value of the Temp. Difference between the outside surface (T_o) and the inside surface (T_i) of the material, assuming moment-generating equivalent temperature distribution (Ref. 3, pg 31).

$|\Delta T_2|$ = Range of Absolute Value for that portion of the non-linear thermal gradient through the wall, not included in $|\Delta T_1|$ (Ref. 3, pg 64).

Further, ΔT_1 is defined by:

$$\Delta T_1 = \left(\frac{12}{t^2}\right)\int_{-t/2}^{t/2} y\,T(y)\,dy$$

; see Fig A (below) and Ref. 3, pg 57.



T_I = OUTSIDE SURFACE TEMP.

T_{II} = INSIDE SURFACE TEMP.

$T(Y)$ = TEMP. AT POINT (Y)

t = WALL THICKNESS

FIGURE A. WALL MODEL DEFINITIONS.

ΔT_2 is Defined by:

$$\Delta T_2 = \text{MAX}\left[|T_A - T_I| - \left|\frac{\Delta T_1}{2}\right|, |T_H - T_A| - \left|\frac{\Delta T_1}{2}\right|, 0 \right]; (\text{Ref } 3. \text{ pg } 58)$$

where T_H & T_I are inside and outside surface temperatures, respectively, and T_A is:

$$T_A = \frac{1}{t}\int_{-t/2}^{t/2} T(y)\,dy$$

ΔT_1 and ΔT_2 are further illustrated in Fig. B, Below.

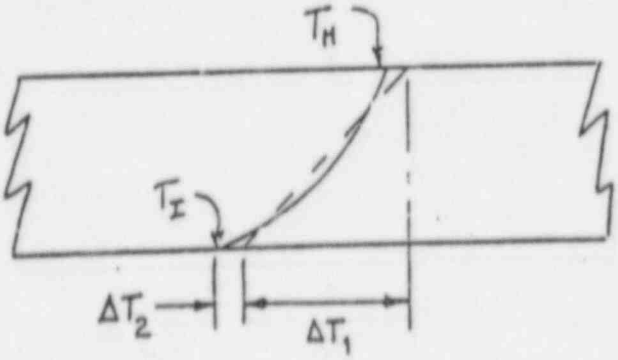


Fig. B. GRAPHIC PRESENTATION of LINEAR AND NON-LINEAR THERMAL GRADIENT THRU WALL THICKNESS (Ref. 3, Pg 36)

4. RESULTS: The steady state mean temperatures obtained from Ref. 5, are shown in Figure 3.

The transient temperature distributions obtained from Ref. 6, are shown in Figures 4 thru 30.

In addition, normal startup and shutdown transients with 150°F/hr rate of temperature changes have been considered in the thermal shock analysis. The steady state temperature distribution of Figure 3 represents the most conservative axial temperature profile during these transients and therefore were considered as such. ΔT_1 and ΔT_2 values are negligible during startup and shutdown transients (less than 2°.

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FIGUREE1 - M EL NODE DESIGNATIONS

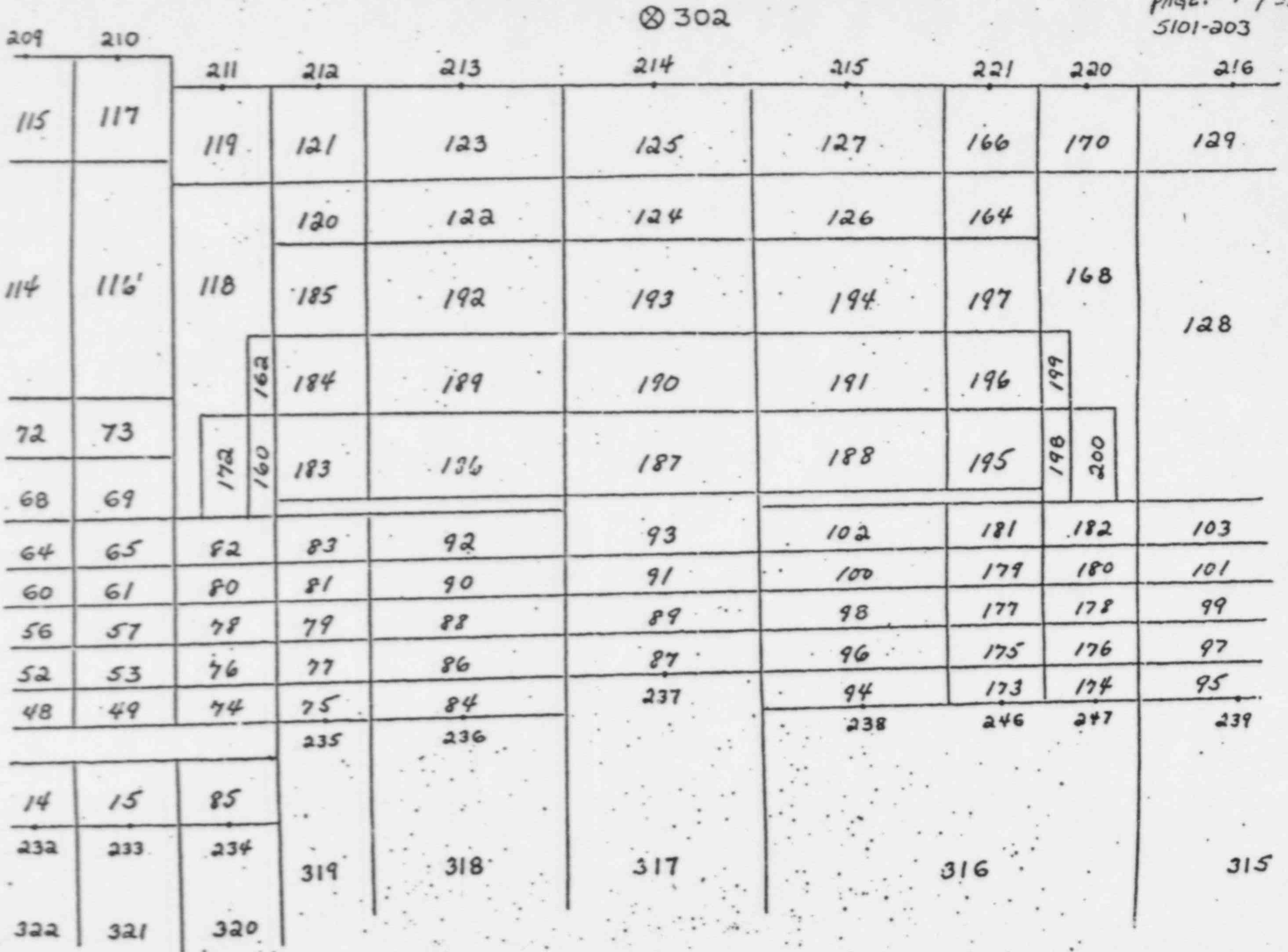

FIGURE 2

MODEL DIMENSIONS AND MATERIALS

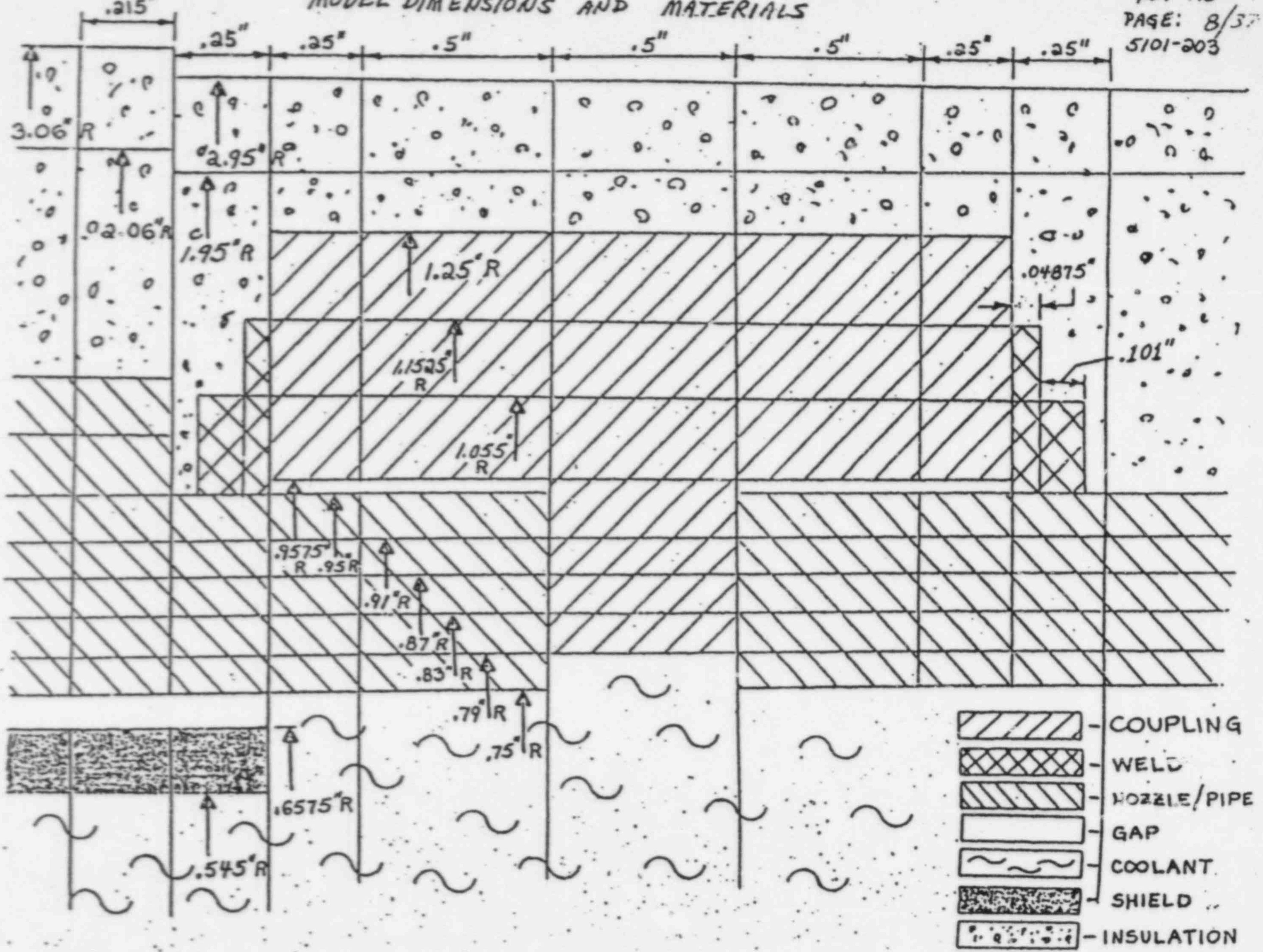

FIGURE 3 - STEADY TATE TEMPERATURE DISTRIBUTION

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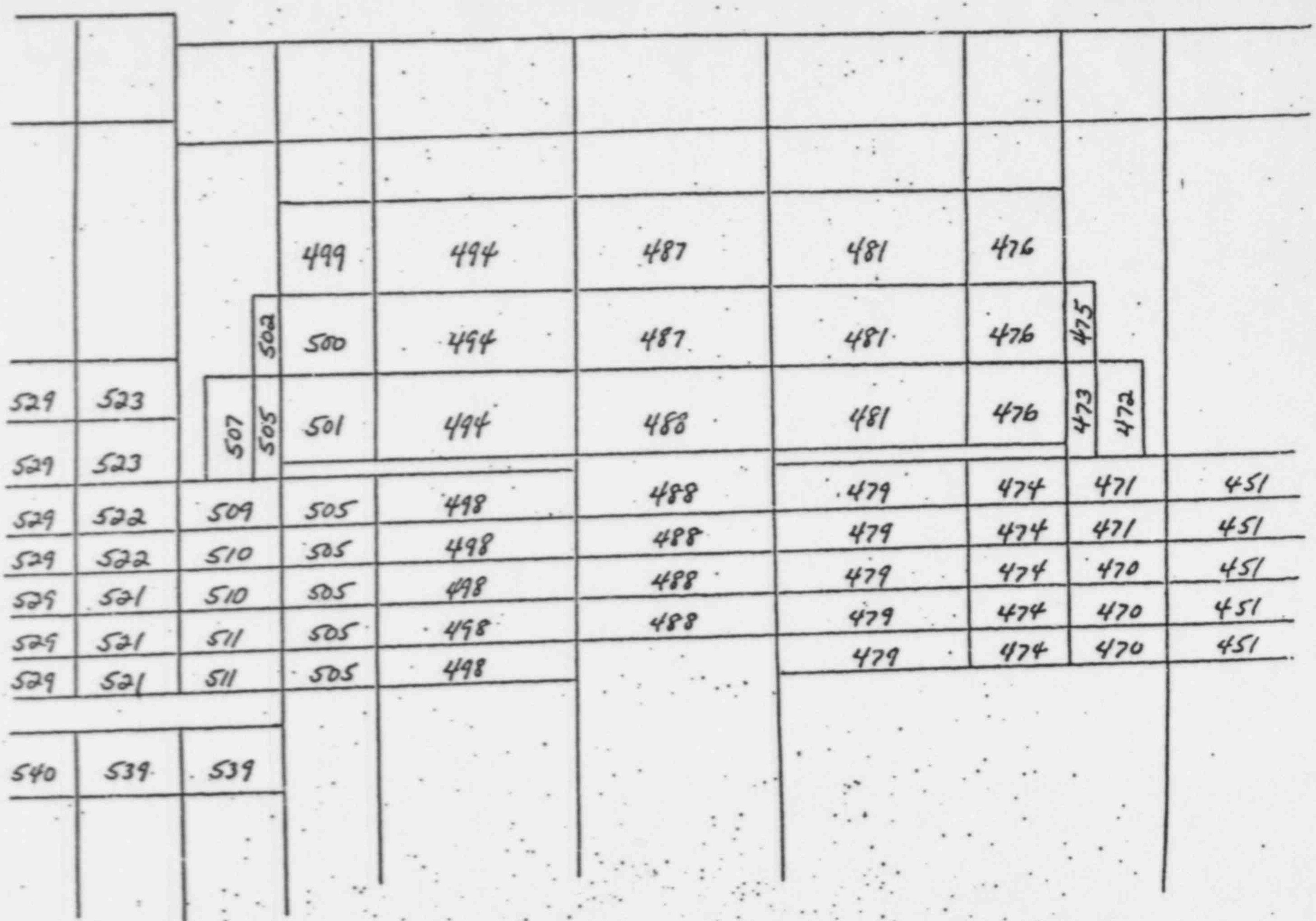

FIGURE 4 -NODE TEMPERATURES AT TIME = .01 sec

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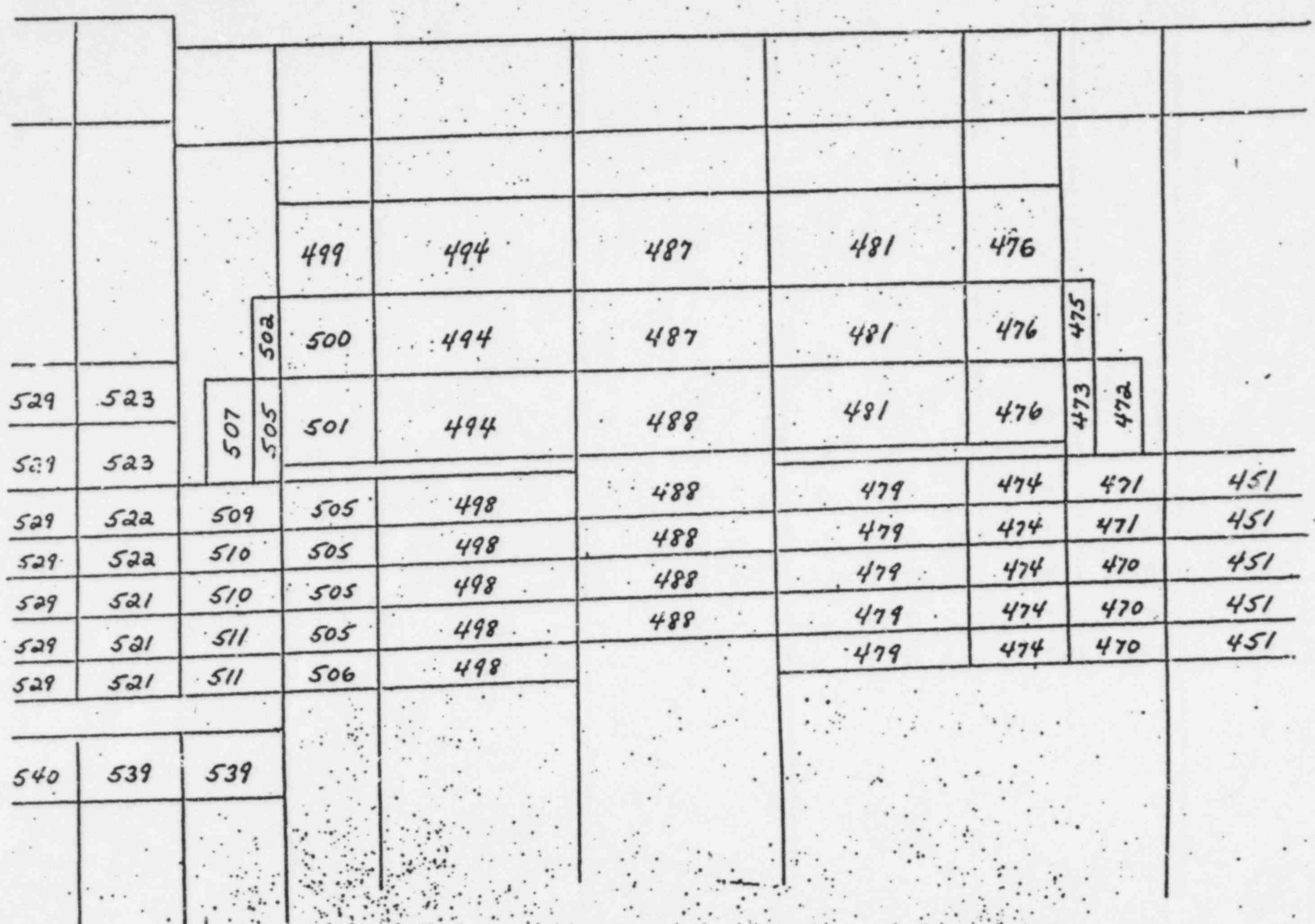

FIGUREE5 - NODE TEMPERATUR 'S AT TIME = .25 sec

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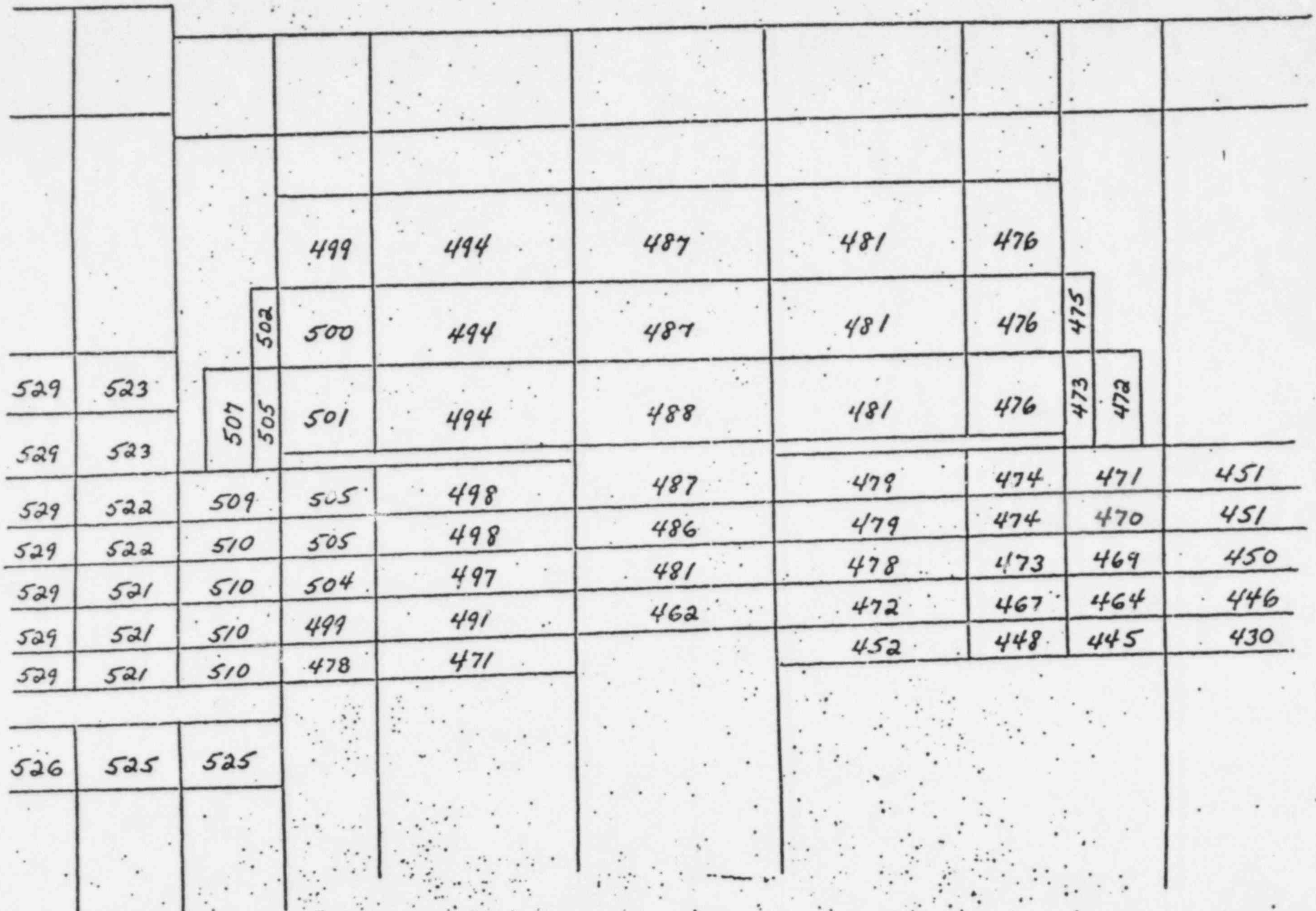

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FIGURE E6 - NODE TEMPERATURES AT TIME = .5 sec

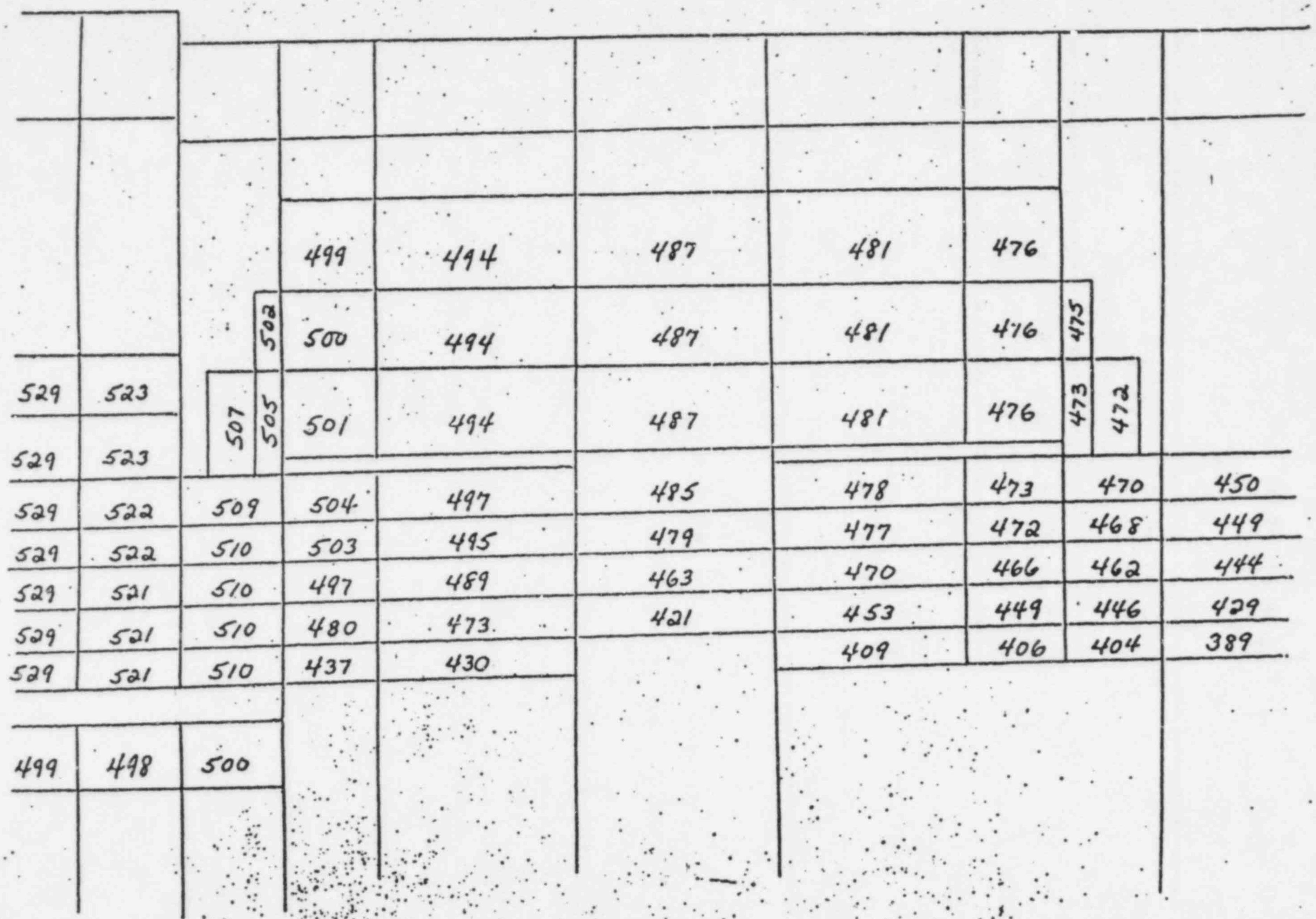

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FIGURE E.7. -NODE TEMPERAT 'ES AT TIME = .75 SEC

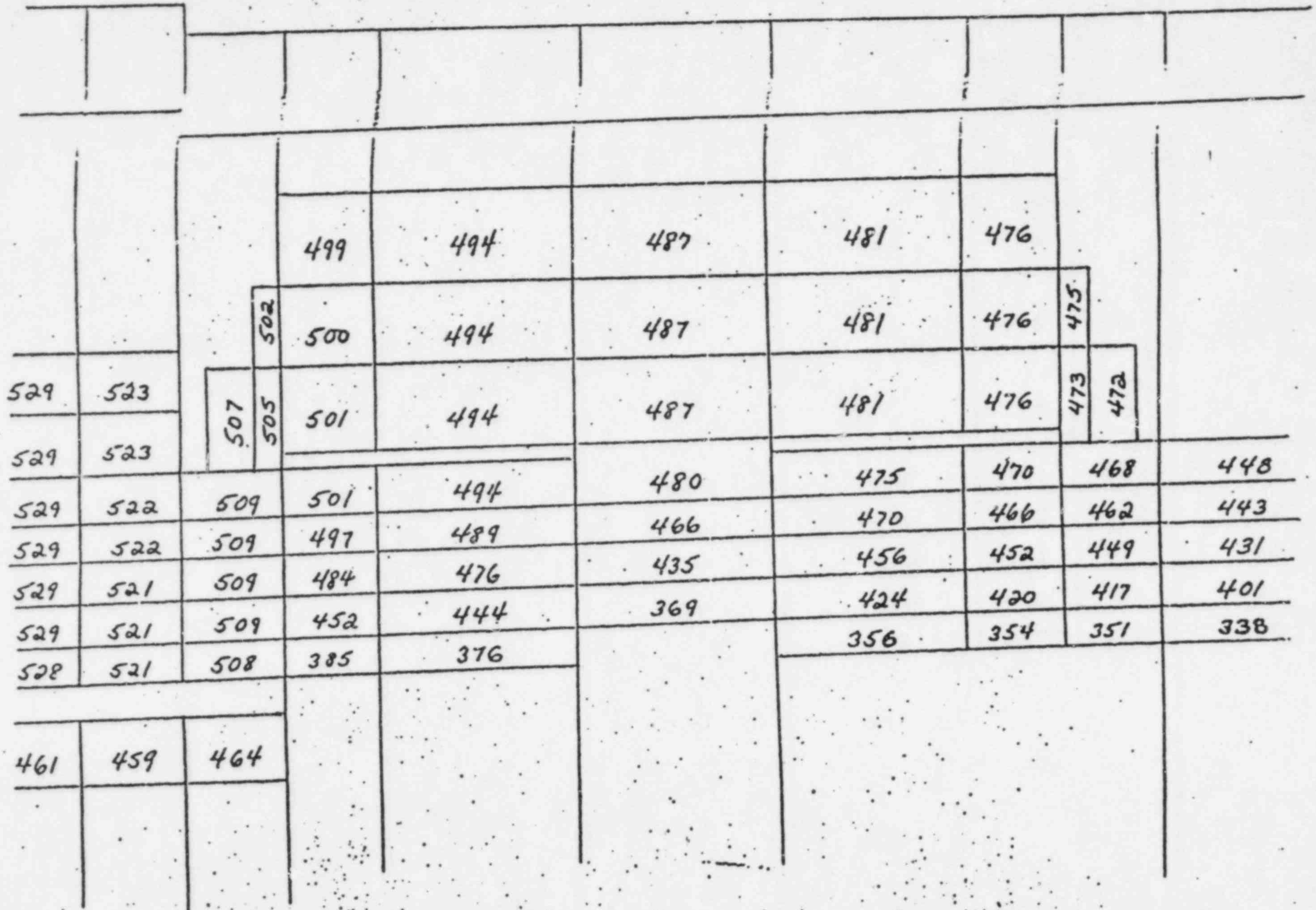

FIGURE 8 - NODE TEMPERATURES AT TIME = 1.0 sec

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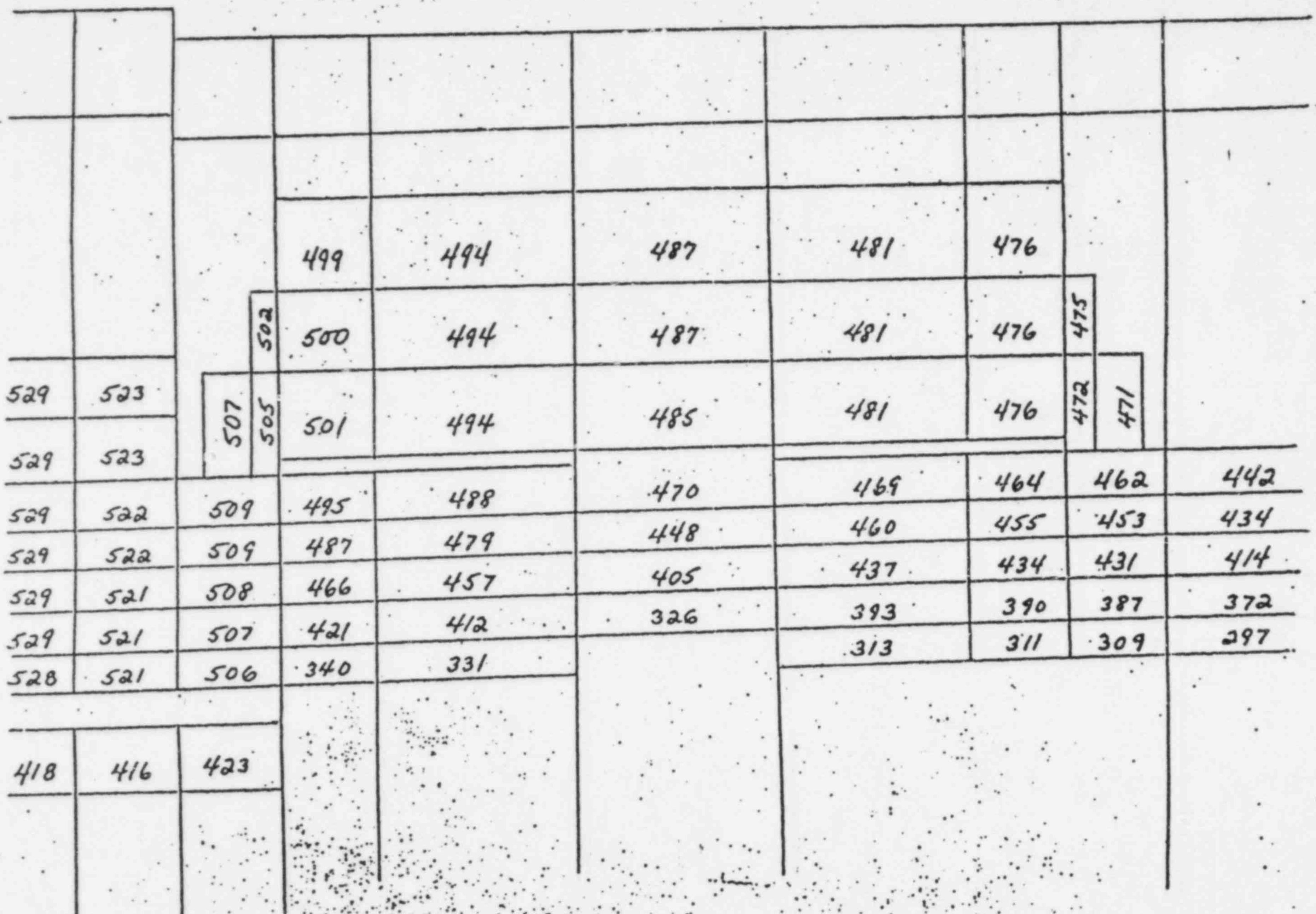

FIGUREE 9... -NODE TEMPERATU ES AT TIME = 1.5 sec

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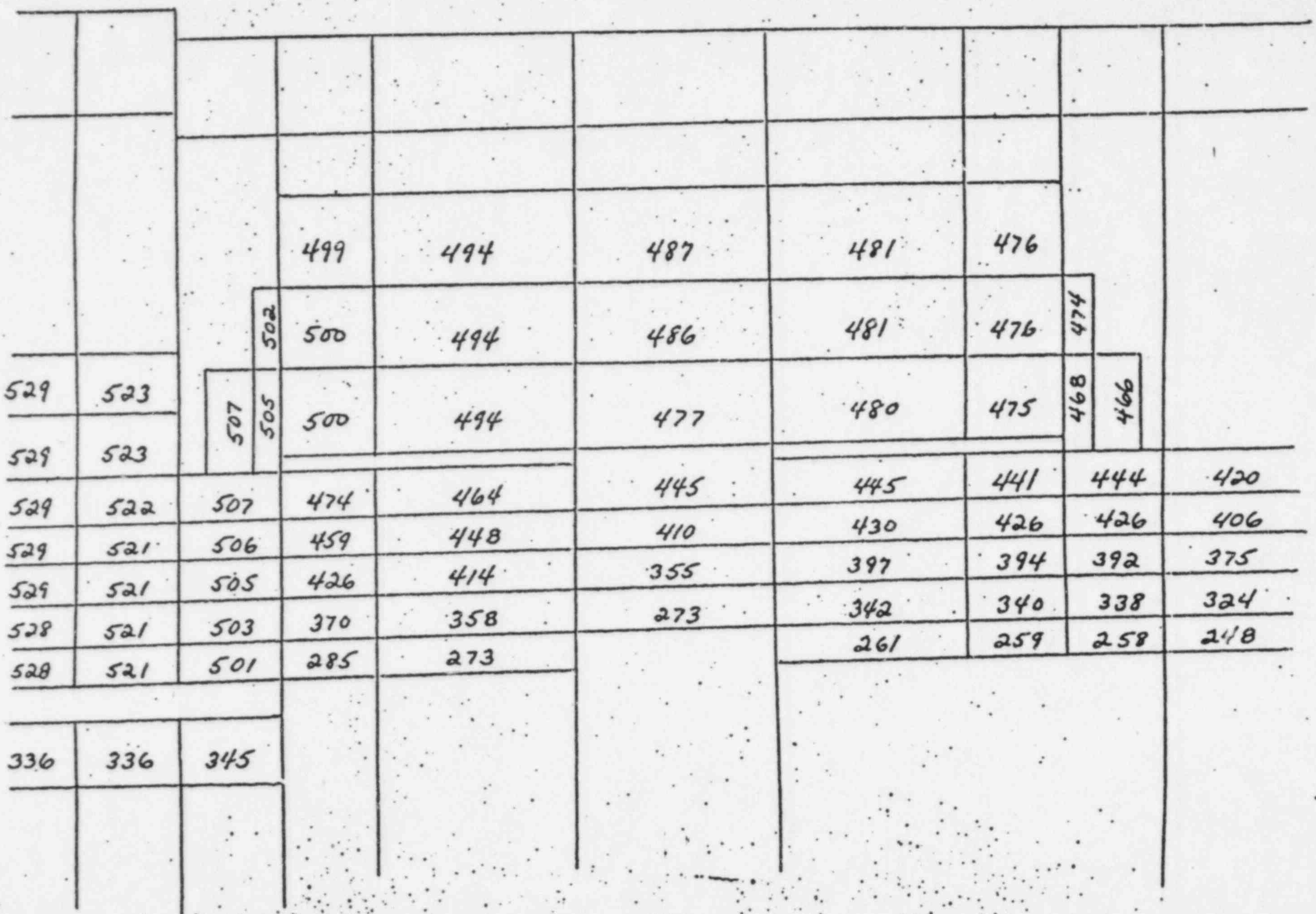

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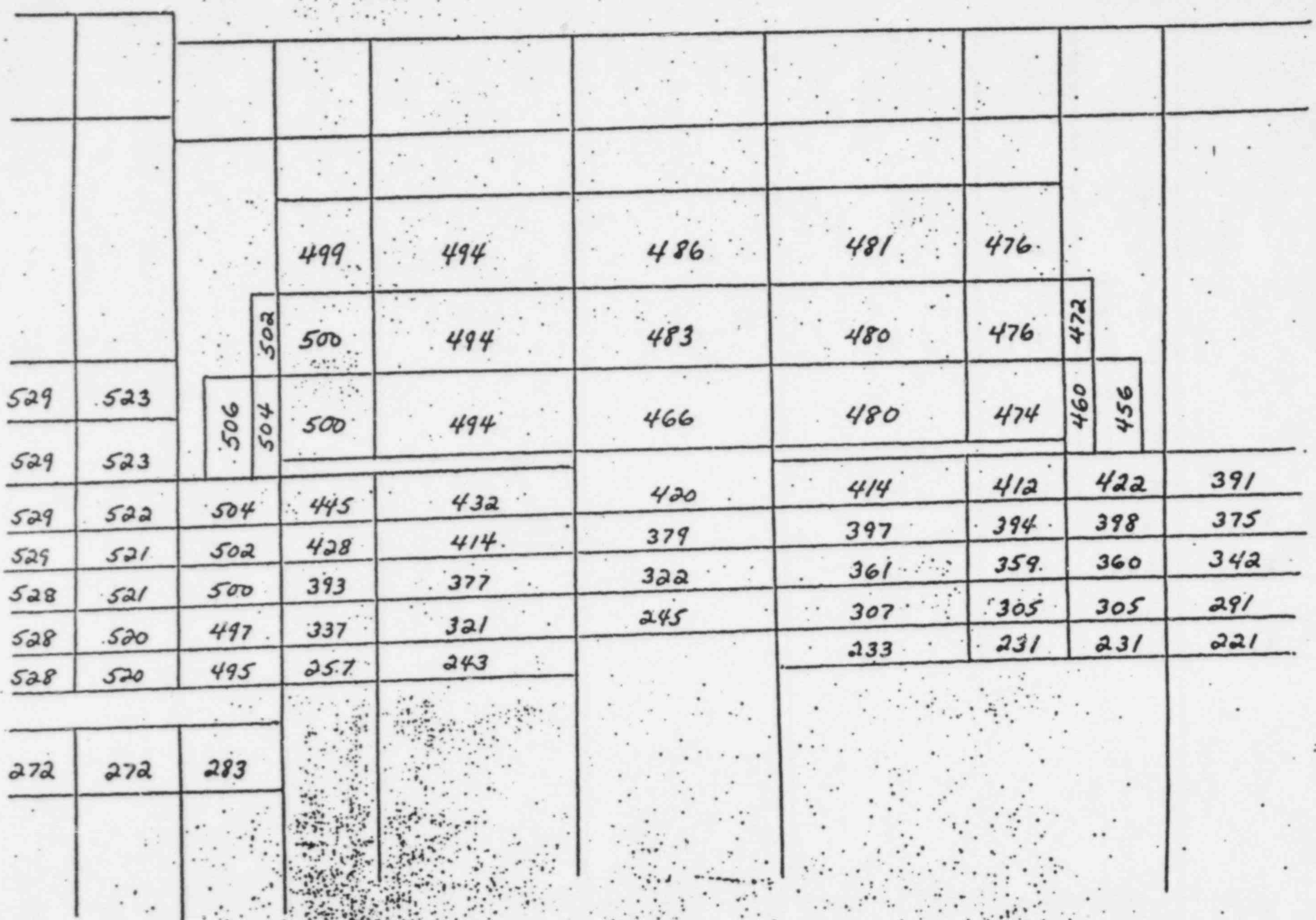
FIGURE 10 - NODE TEMPERATU..ES AT TIME = 2.0 sec



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FIGUREE11 - NODE TEMPERATU..ES AT TIME = 2.5 sec

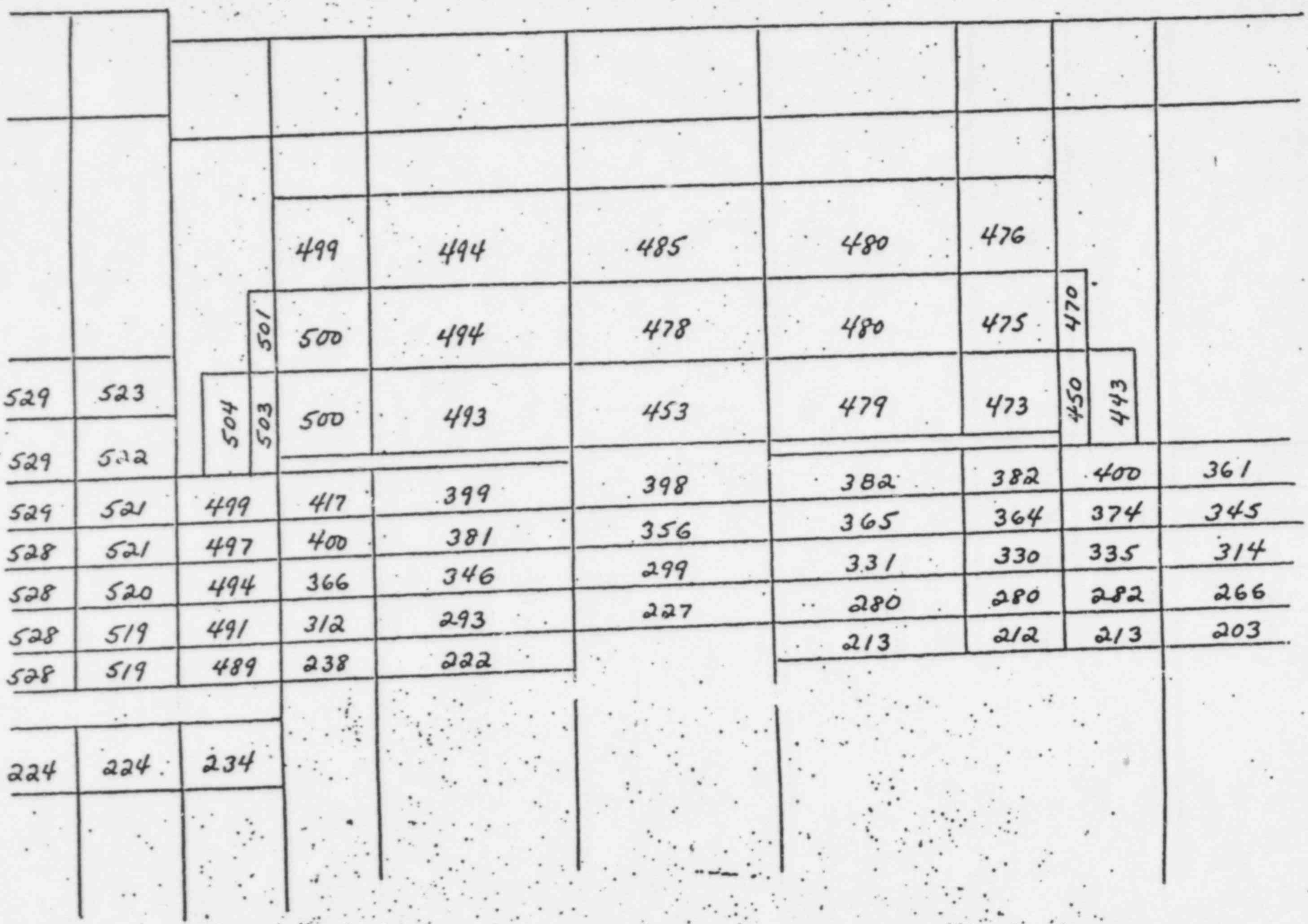

FIGURE E12 - NODE TEMPERATU ES AT TIME = 3.0 sec

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CKD: AV
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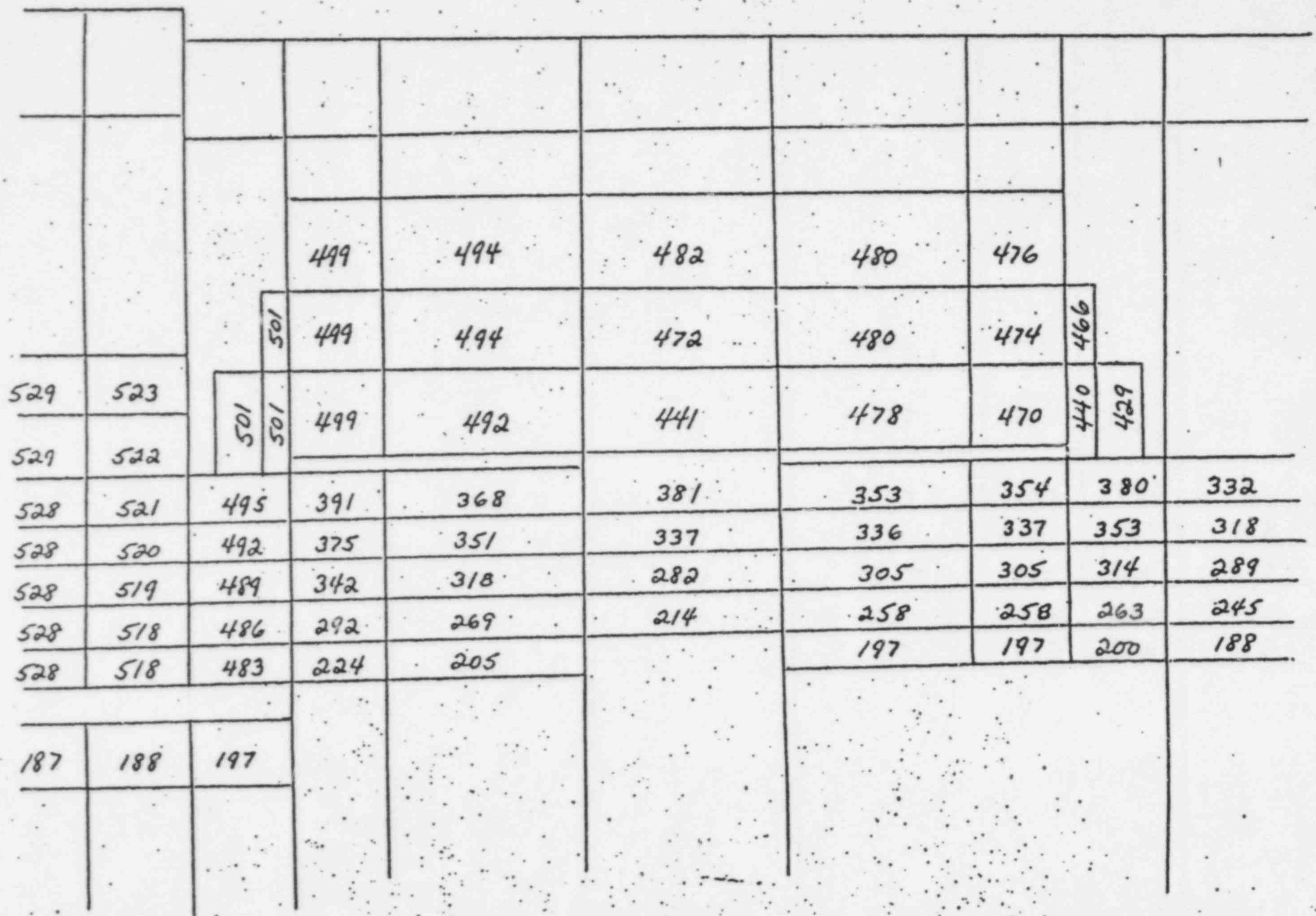

FIGURE E13. - NODE TEMPERATURES AT TIME = 3.5 Sec.

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CKD: AJ
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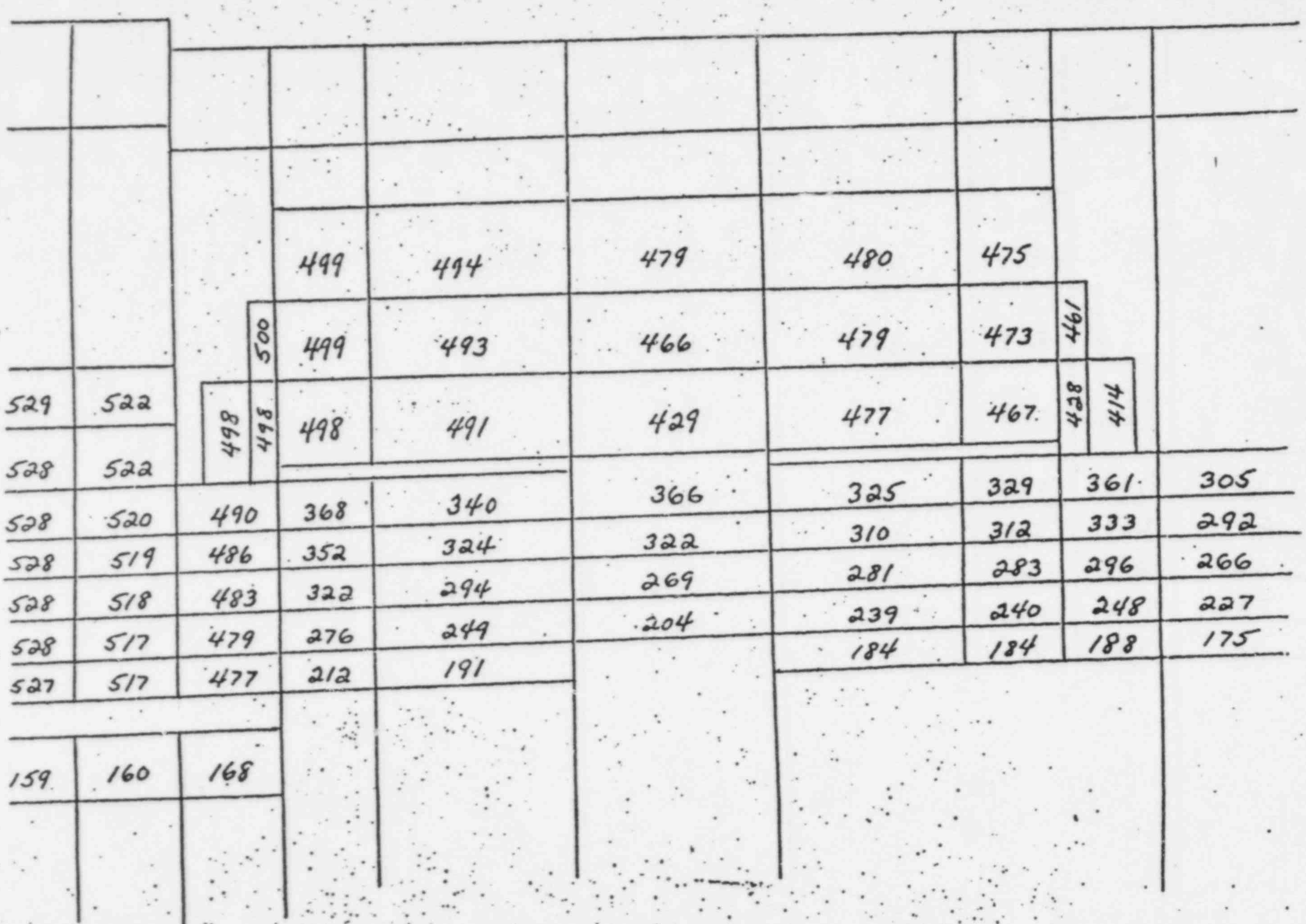

FIGURE 14 - NODE TEMPERATURES AT TIME = 4.0 sec

BY: [illegible]
CKD: RV
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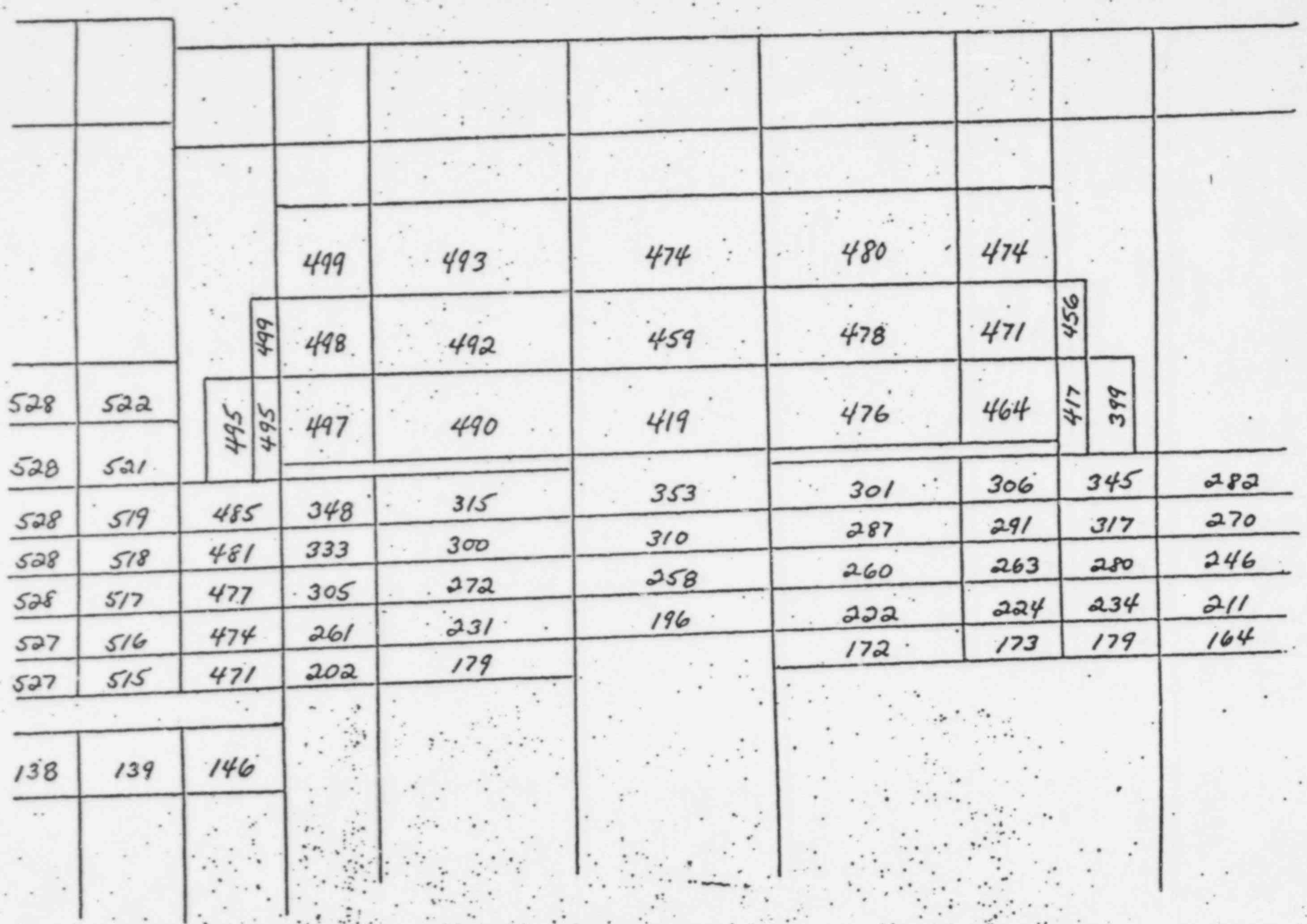

FIGURE E15 -NODE TEMPERATU~S AT TIME = 4.5 sec

BY: [illegible]
CKD: AU
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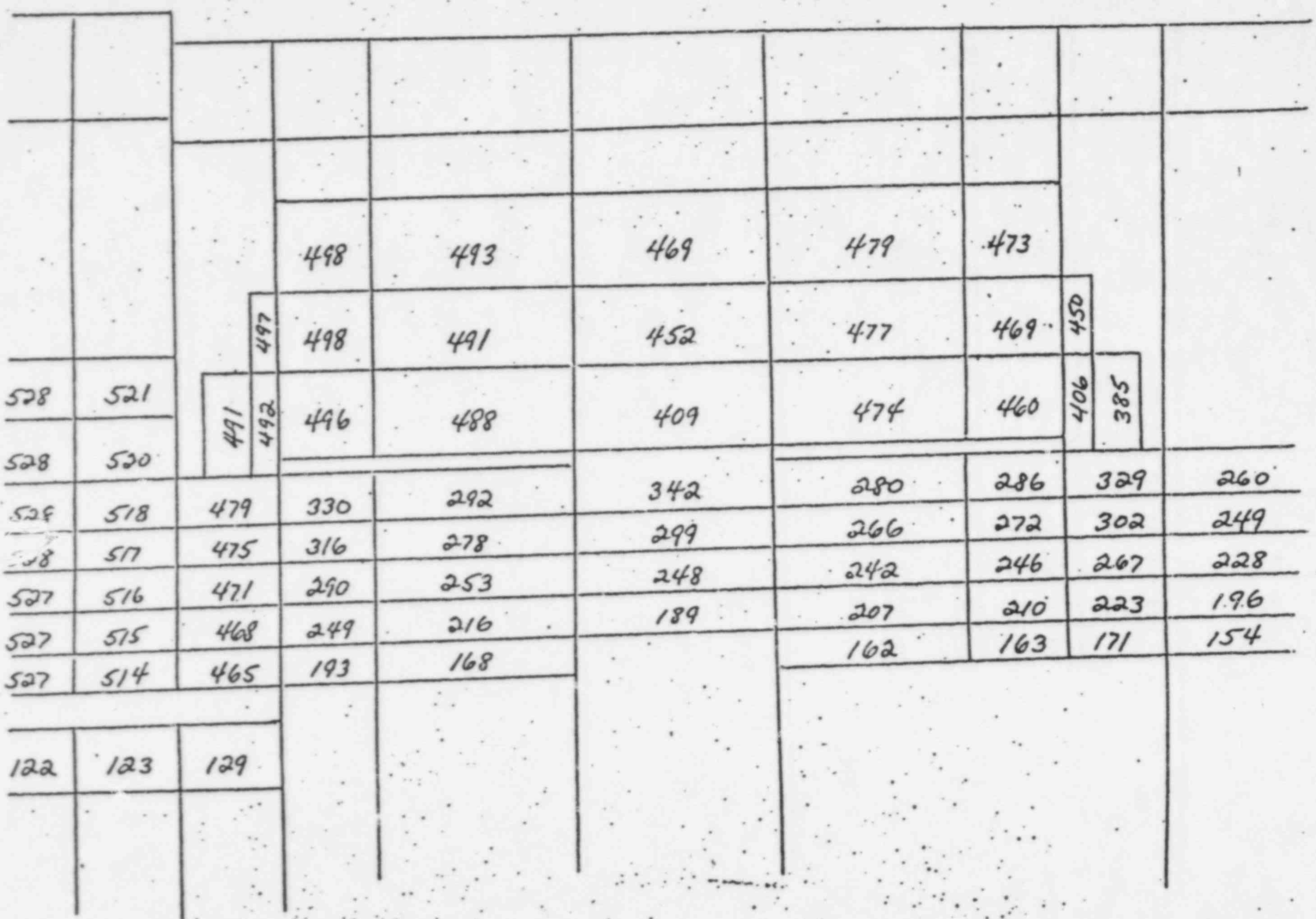

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CKD: AU
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FIGUREE16 - NODE TEMPERATURES AT TIME = 5.0 sec.

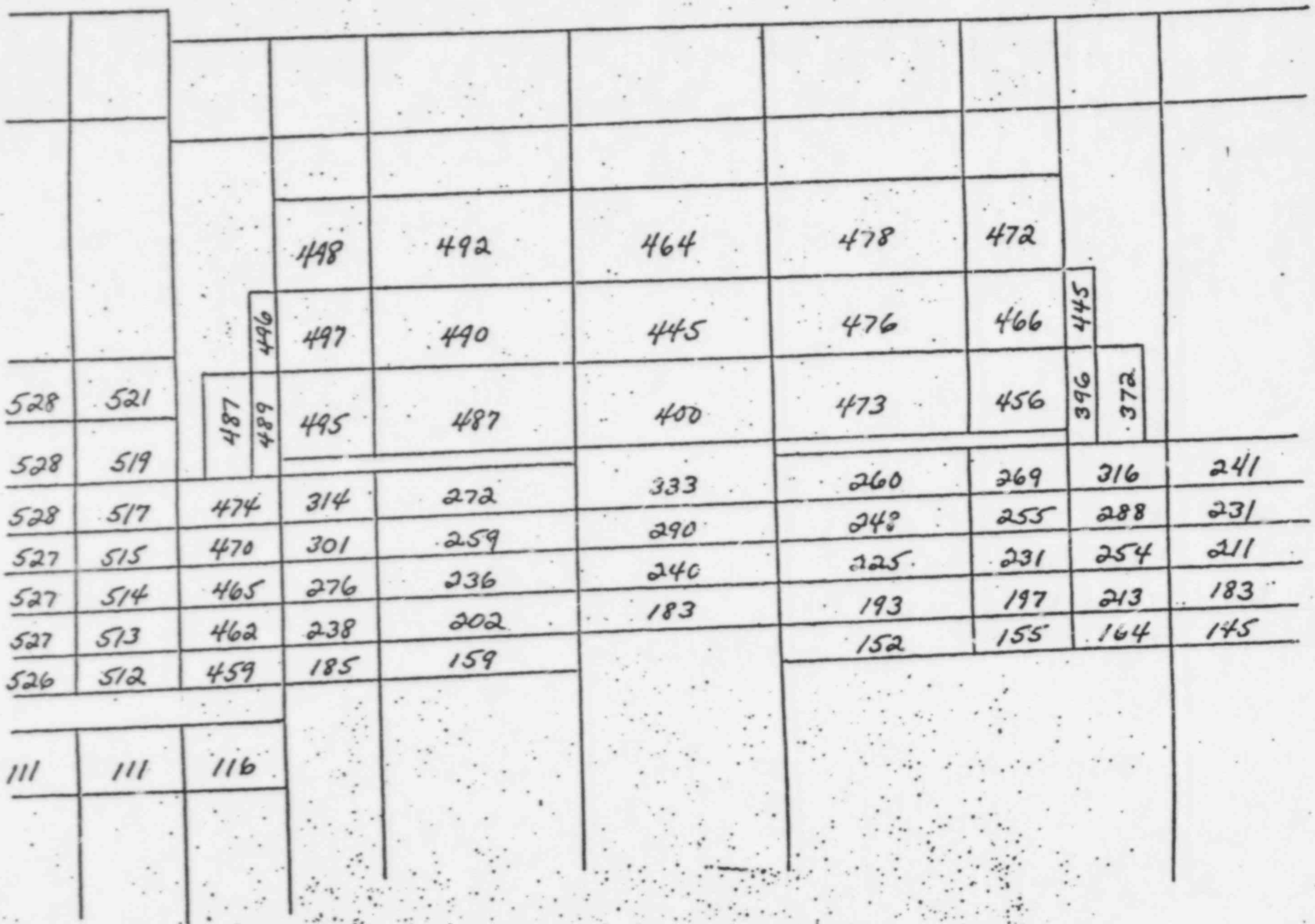

FIGURE E17 - NODE TEMPERATU. ES AT TIME = 5.5 sec

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CKD: [illegible]
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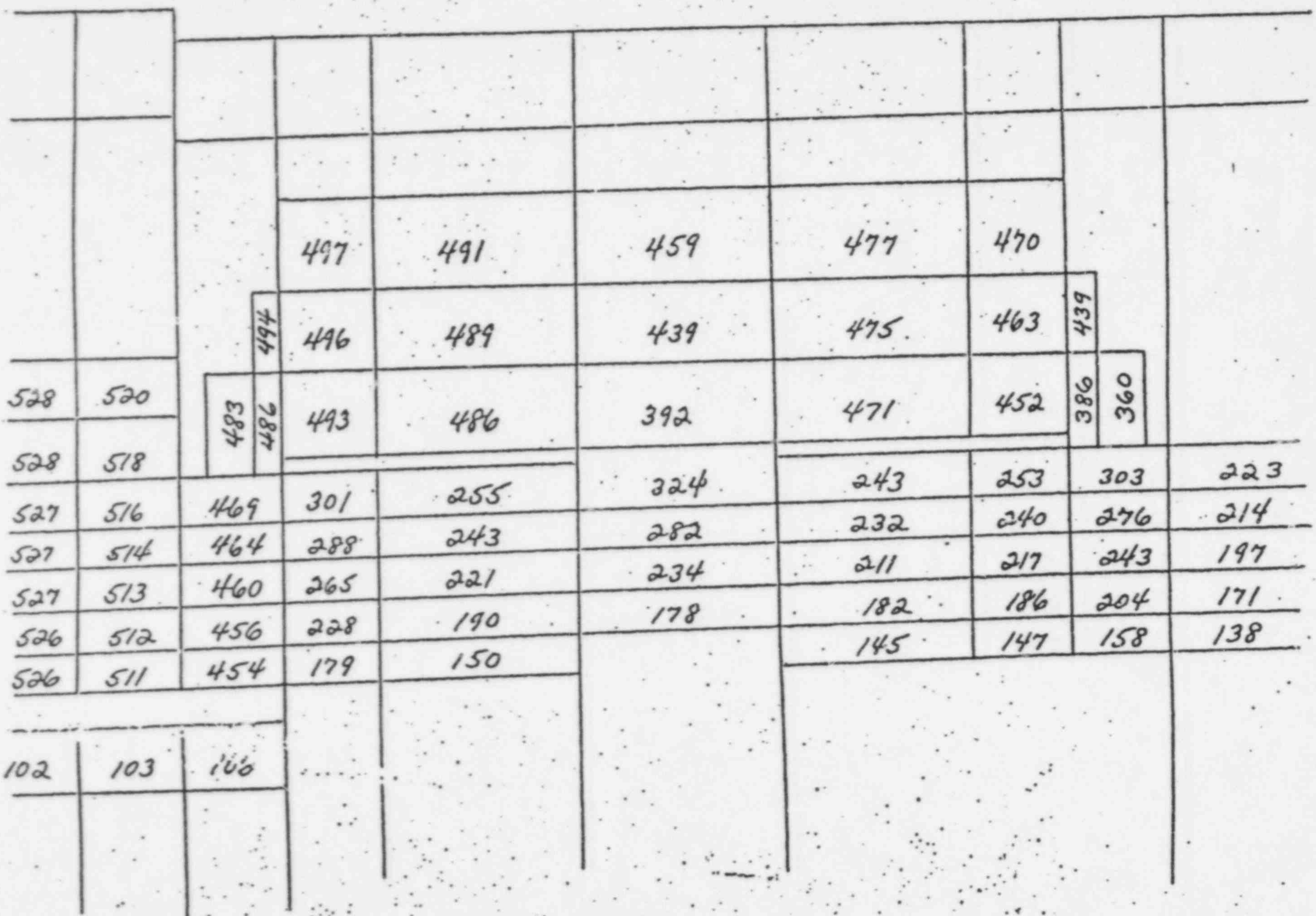

FIGURE E18 - NODE TEMPERATU S AT TIME = 6.0 sec

CKD: RU
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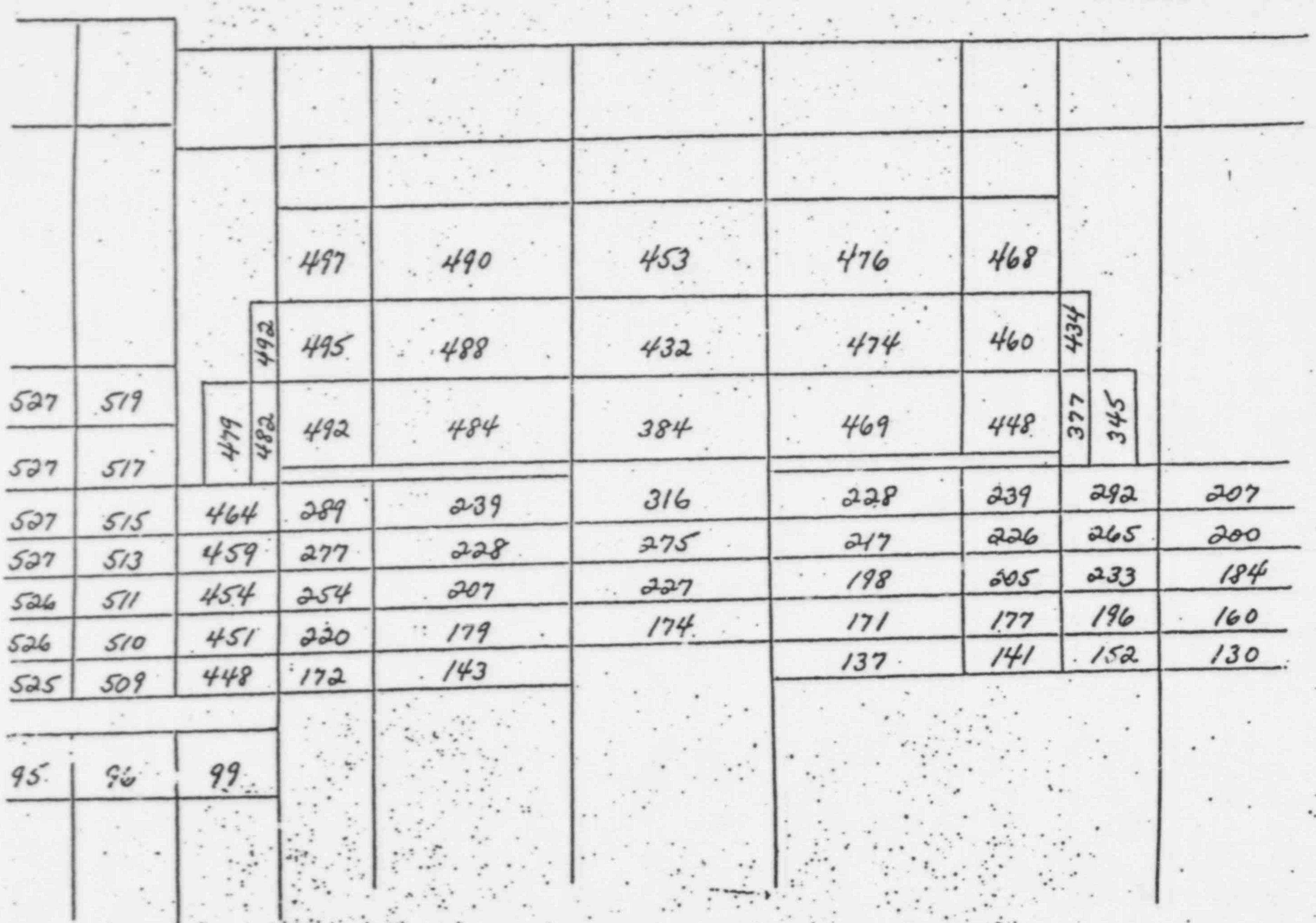

12/[illegible]
BY: GG
CKD: AU
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FIGURE E19 - NODE TEMPERATURES AT TIME = 6.5 sec

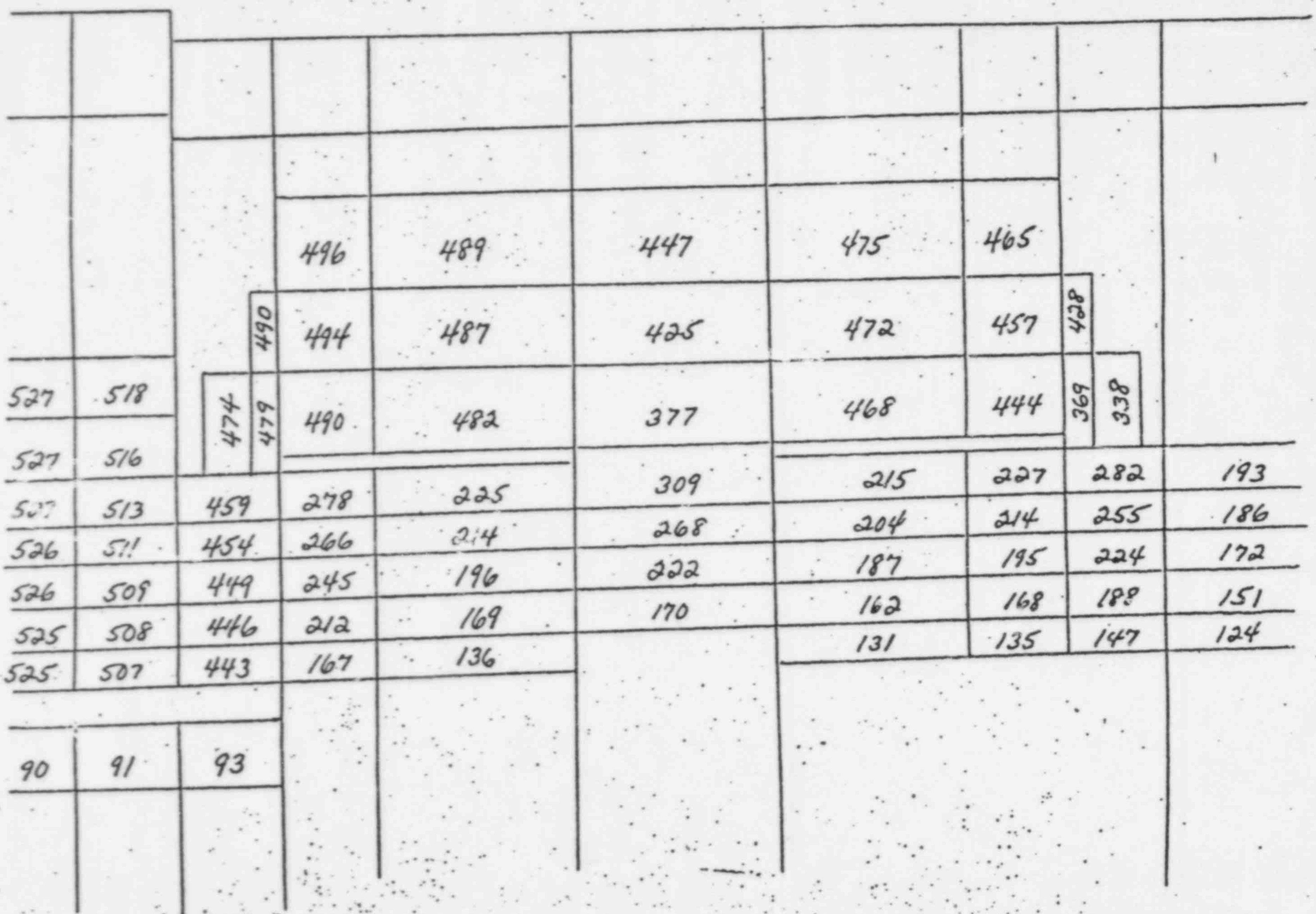

FIGURE E-20 - NODE TEMPERATU..S AT TIME = 7.0 SEC

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CKD: AD
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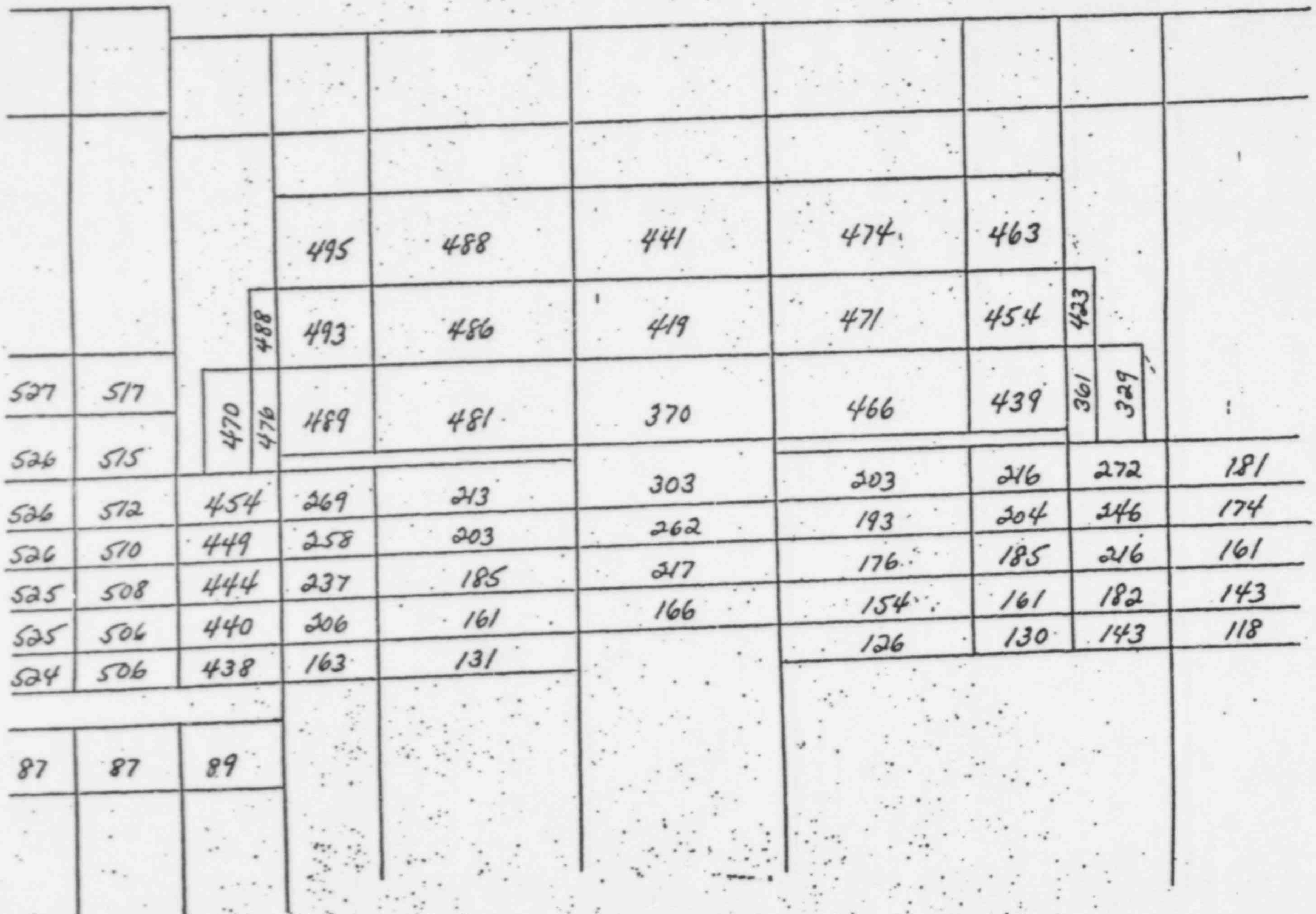

FIGURE 21 - NODE TEMPERATU ES AT TIME = 7.5 sec

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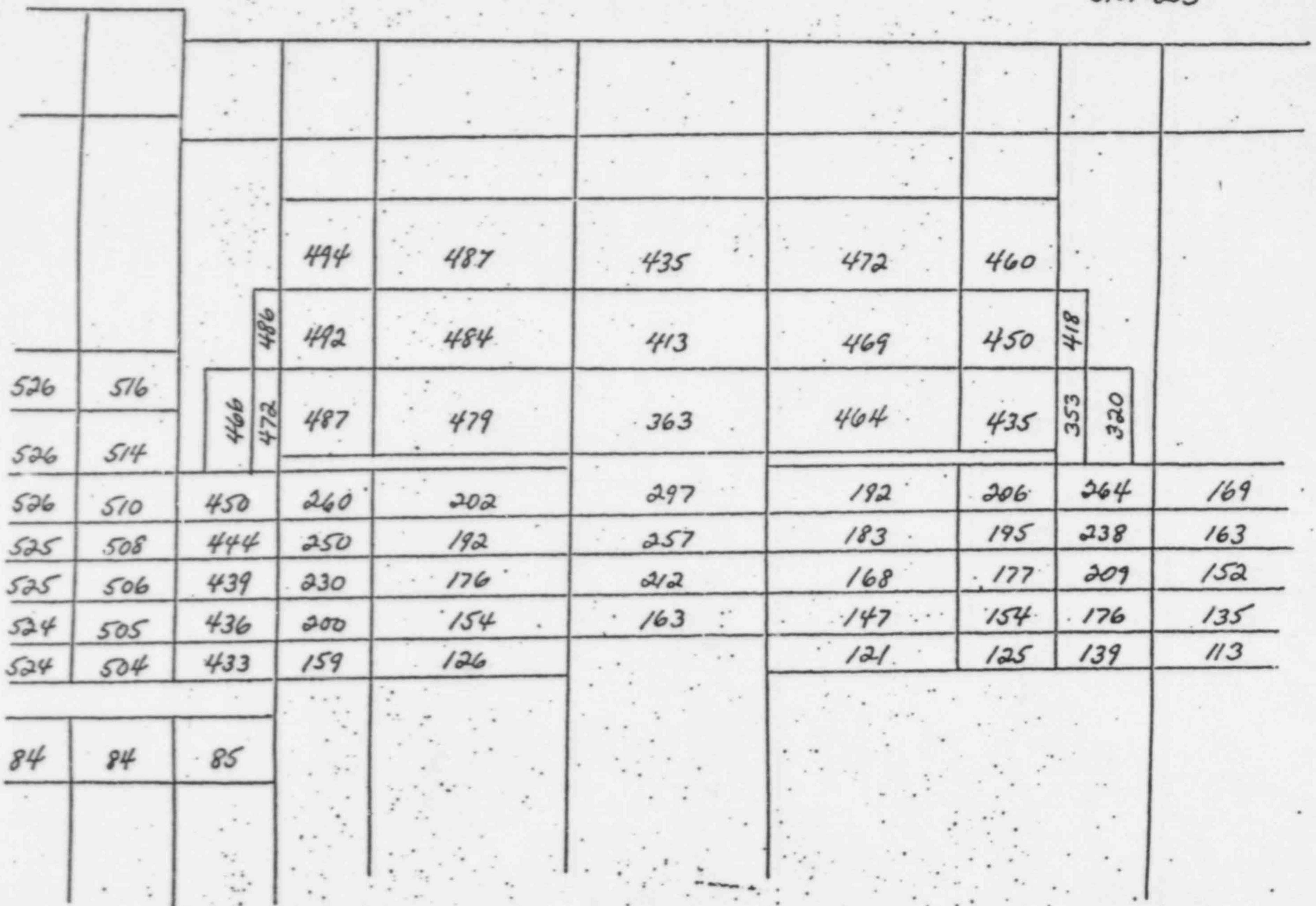

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CKD: [illegible]
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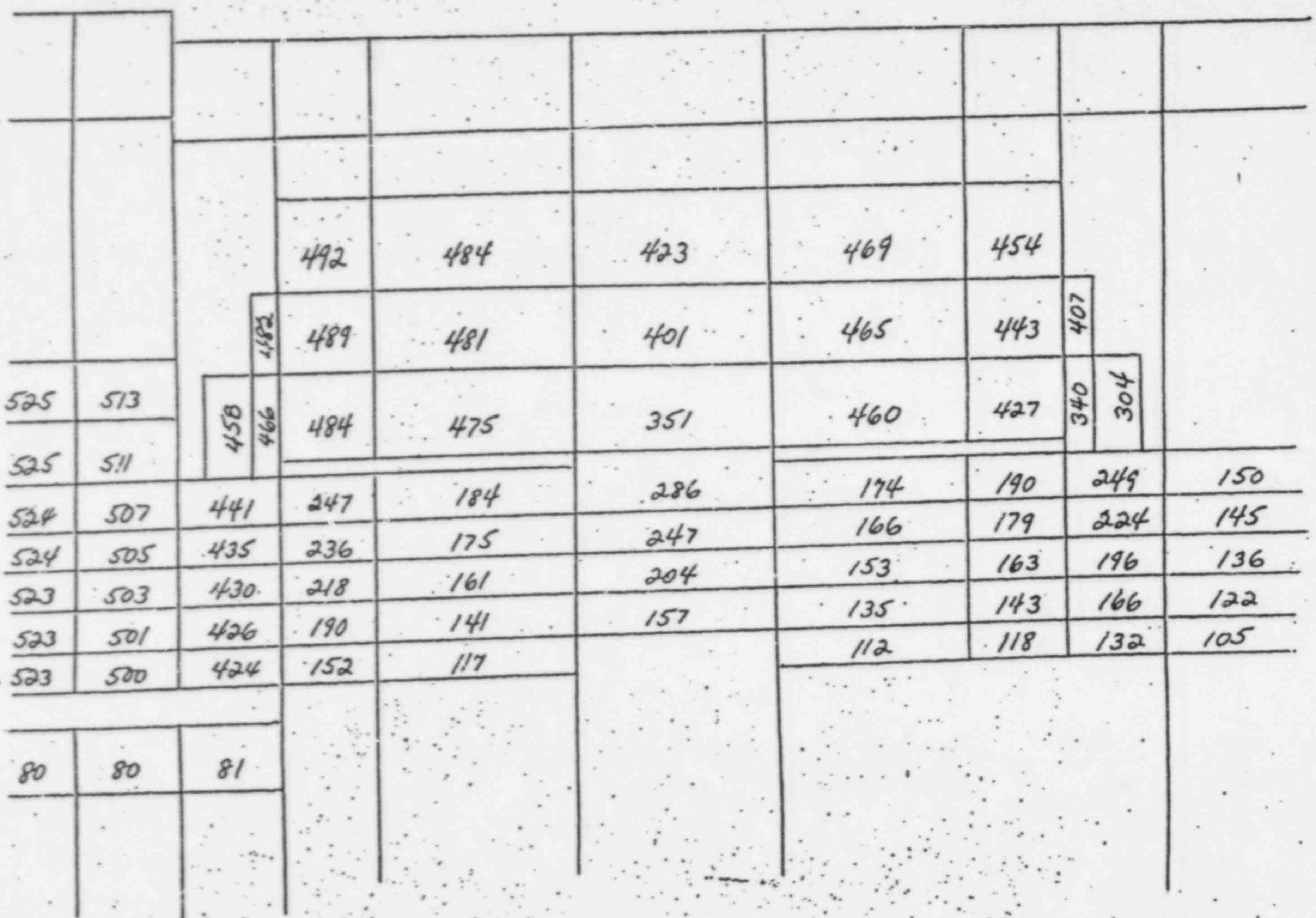
FIGURE E23 - NODE TEMPERATU.ES AT TIME = 8.5 sec



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BY: gg
CKD: RC
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FIGUREE24 - NODE TEMPERATURES AT TIME = 9.0 sec

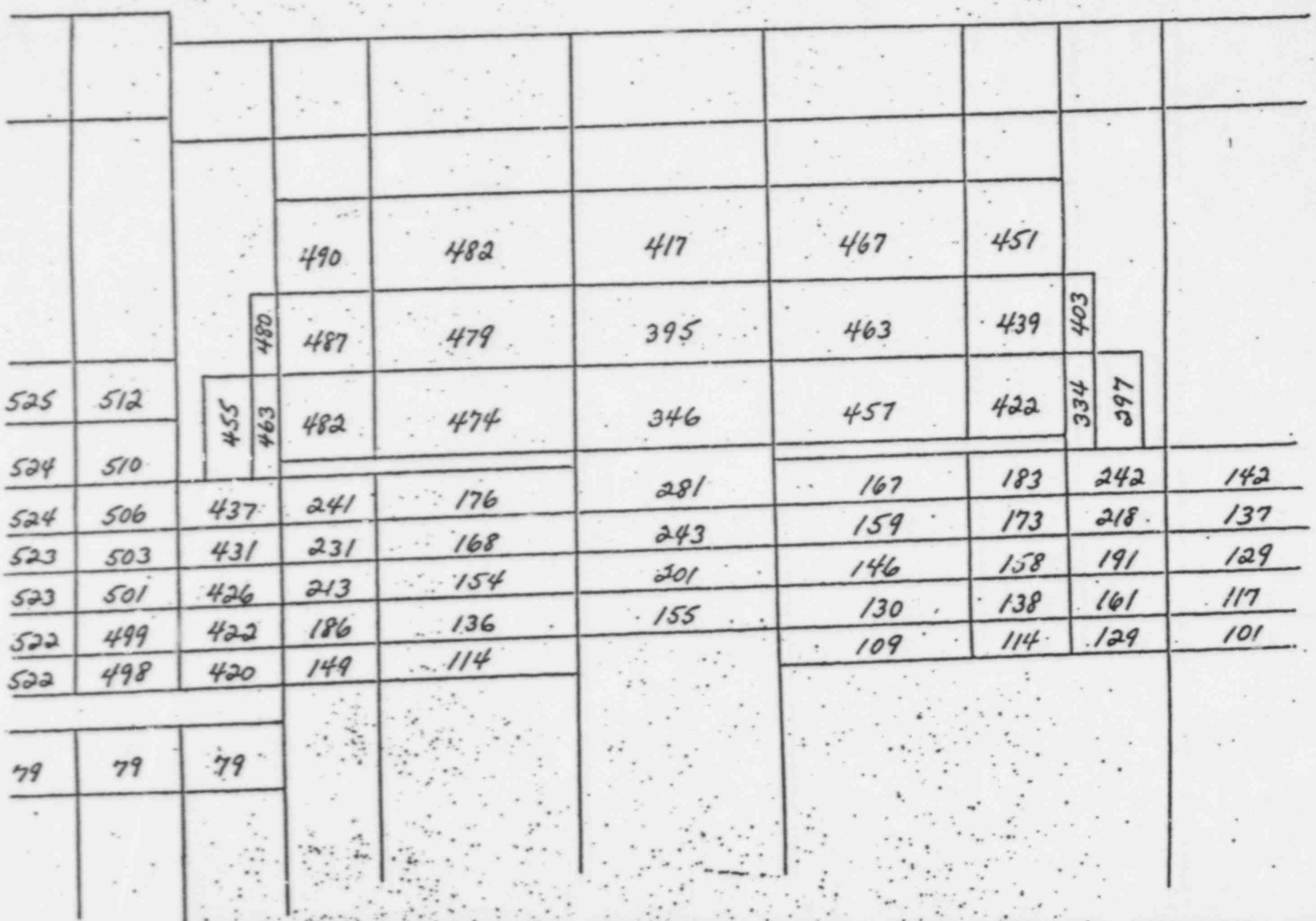

FIGURE E25 - NODE TEMPERATU. .S AT TIME = 9.5 sec

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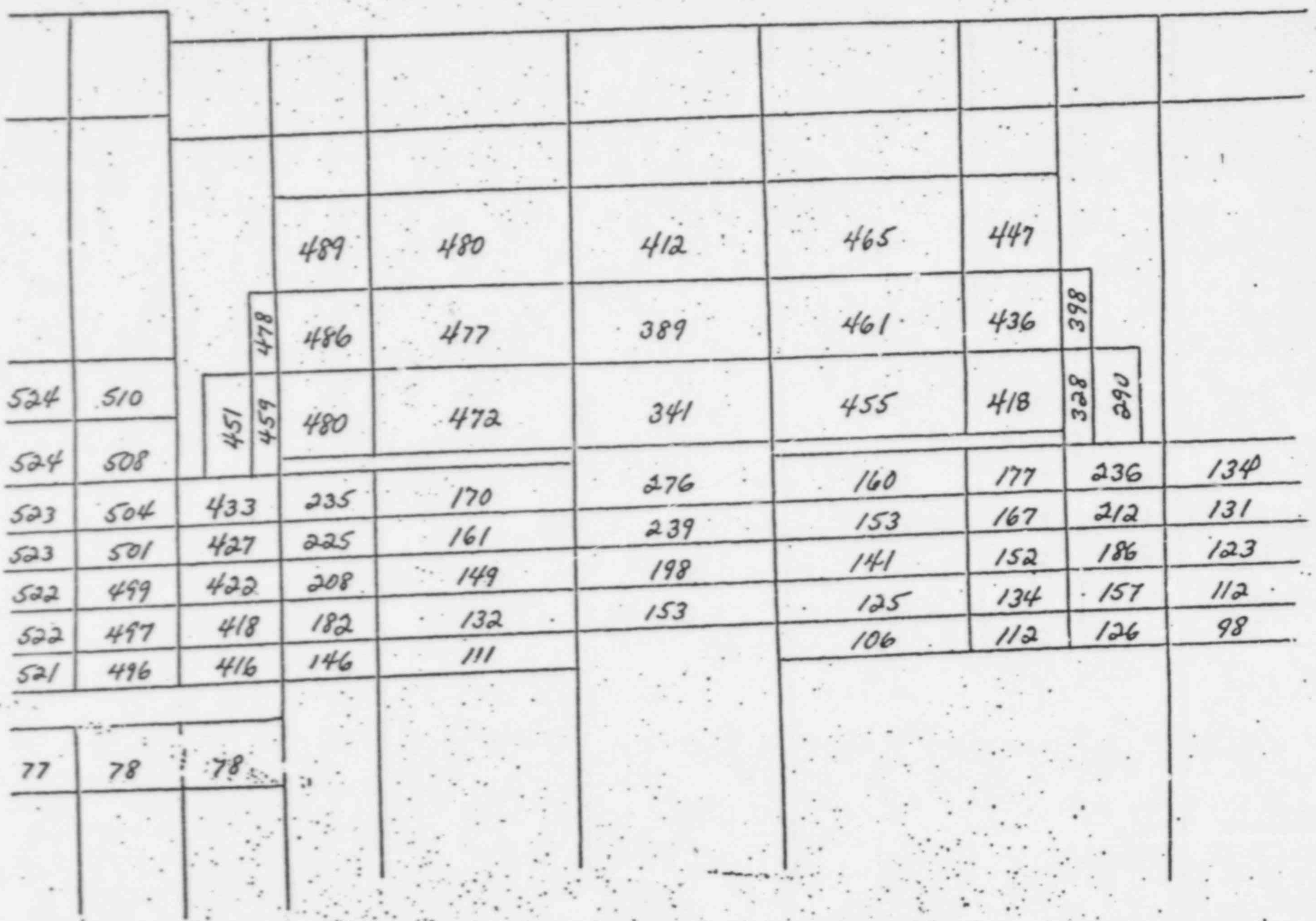
5101-203



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CKD: [illegible]
PAGE: 32/3
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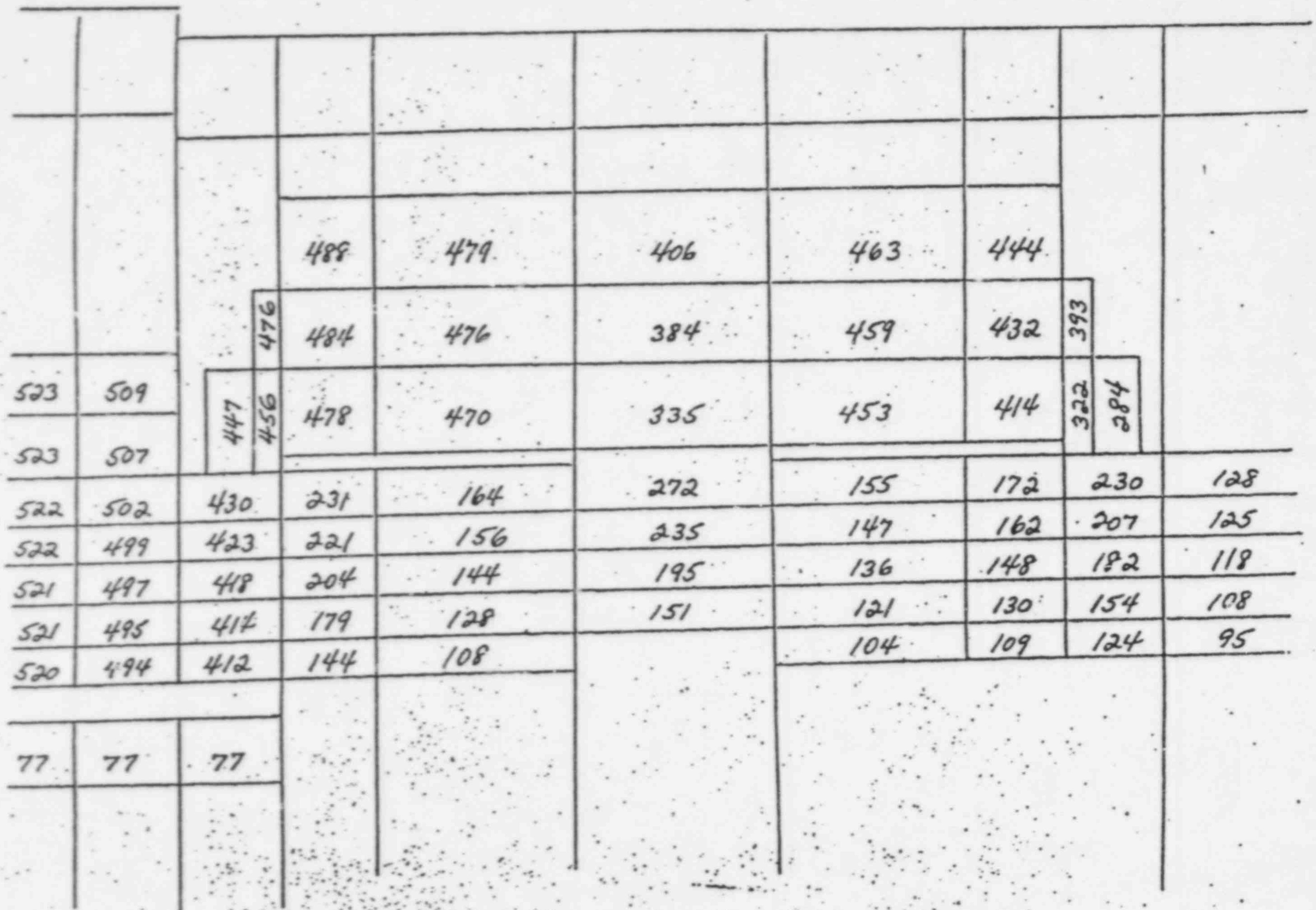
FIGUREE26 - NODE TEMPERATL ES AT TIME = 10.0 sec



FIGUREE27 - NODE TEMPERAT :ES AT TIME = 15.0 sec

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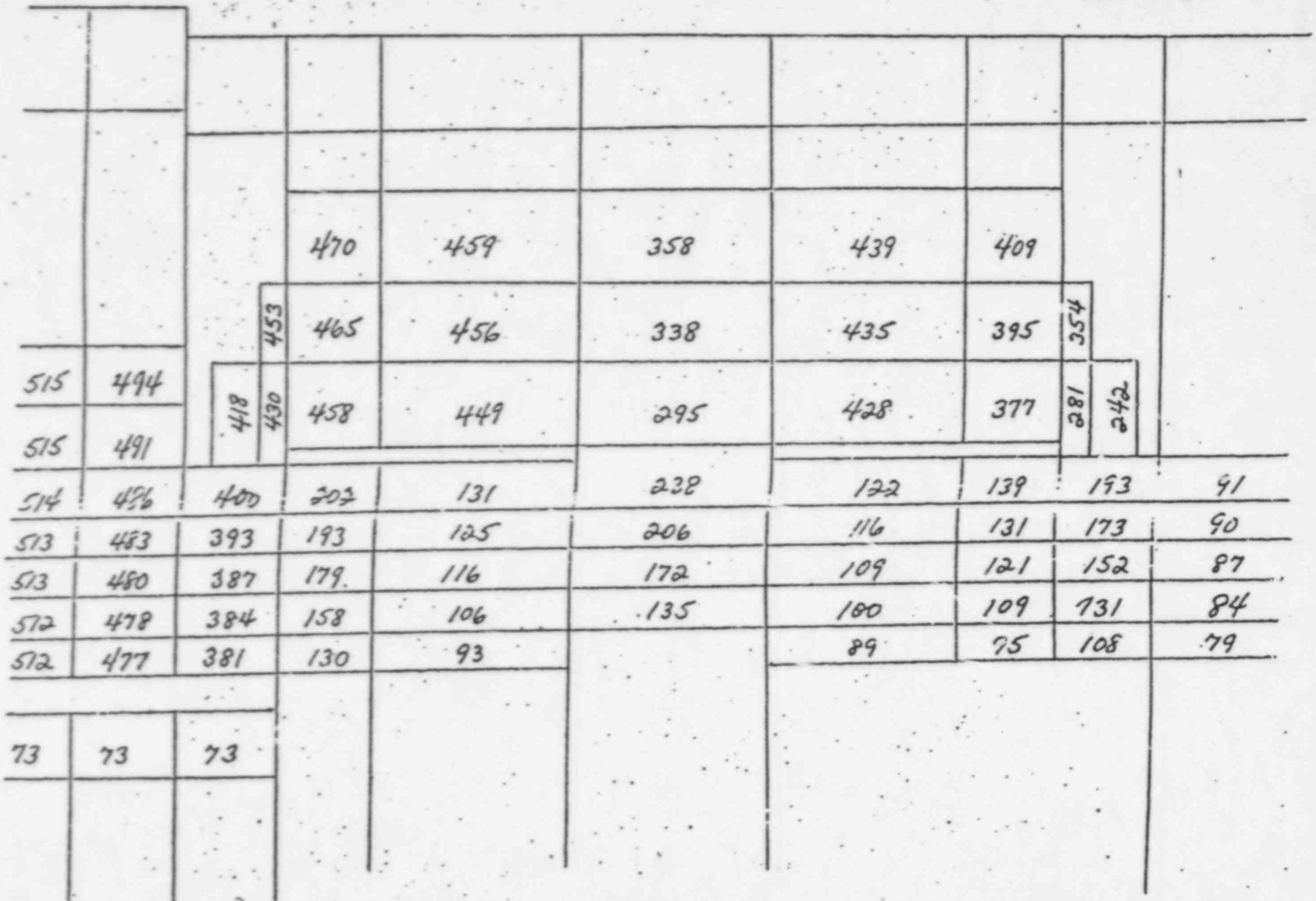
5101-203



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CKD: [illegible]
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FIGURE 28 - NODE TEMPERATURES AT TIME = 20.0 sec

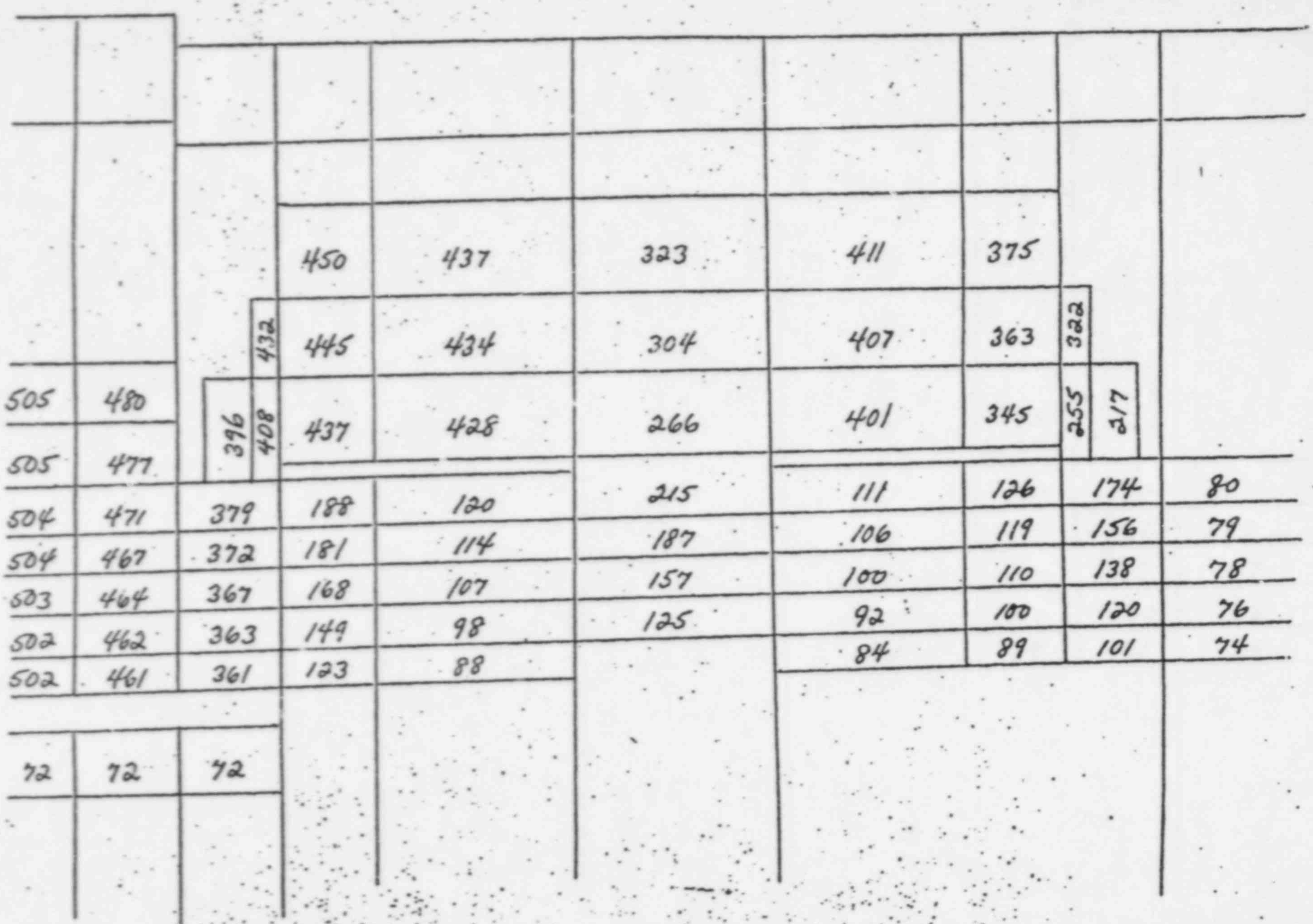

FIGURE 29 - NODE TEMPERATURES AT TIME = 25.0 sec

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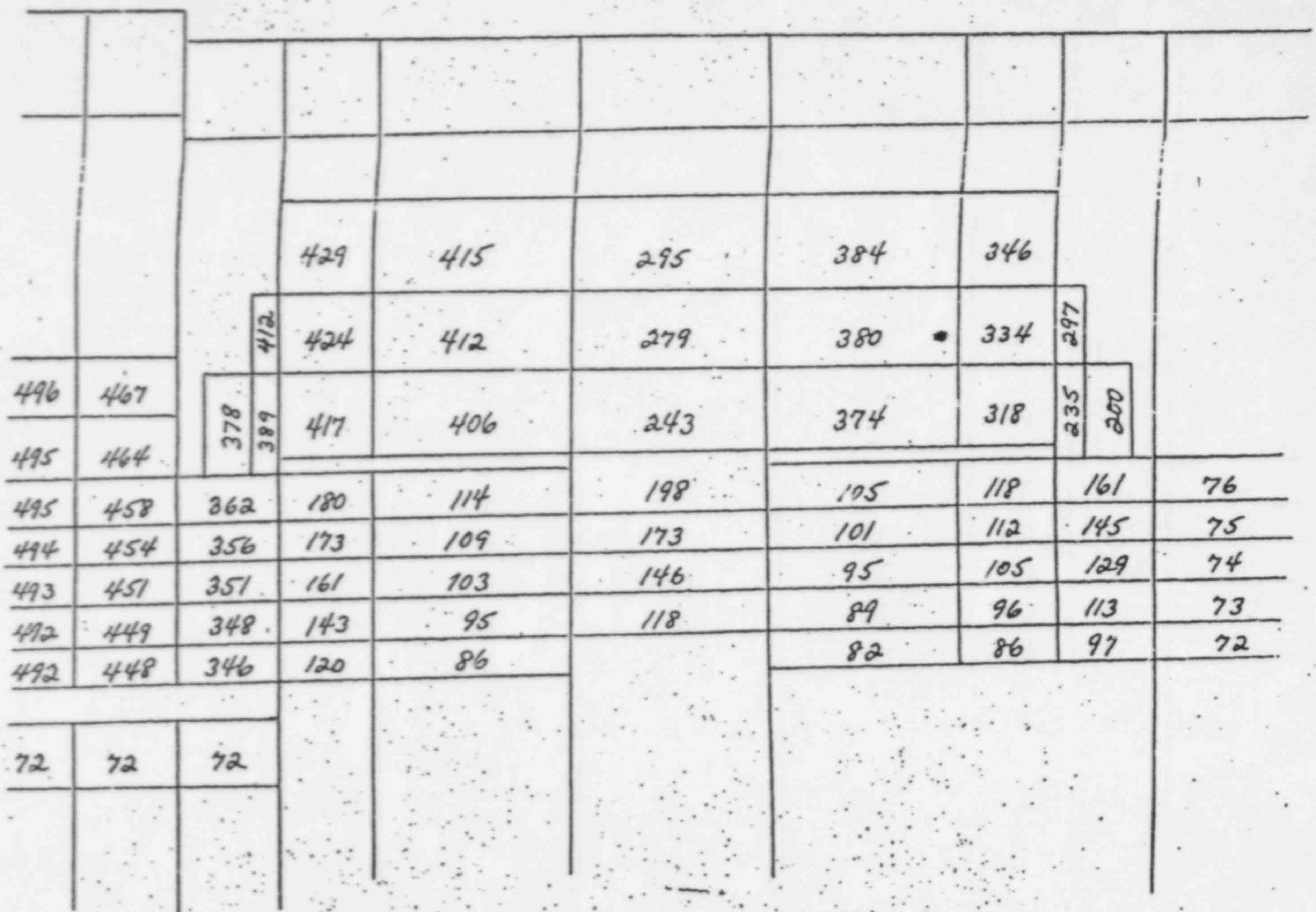

FIGURE 30 - NODE TEMPERATURES AT TIME = 30.0 sec

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CKD: ki
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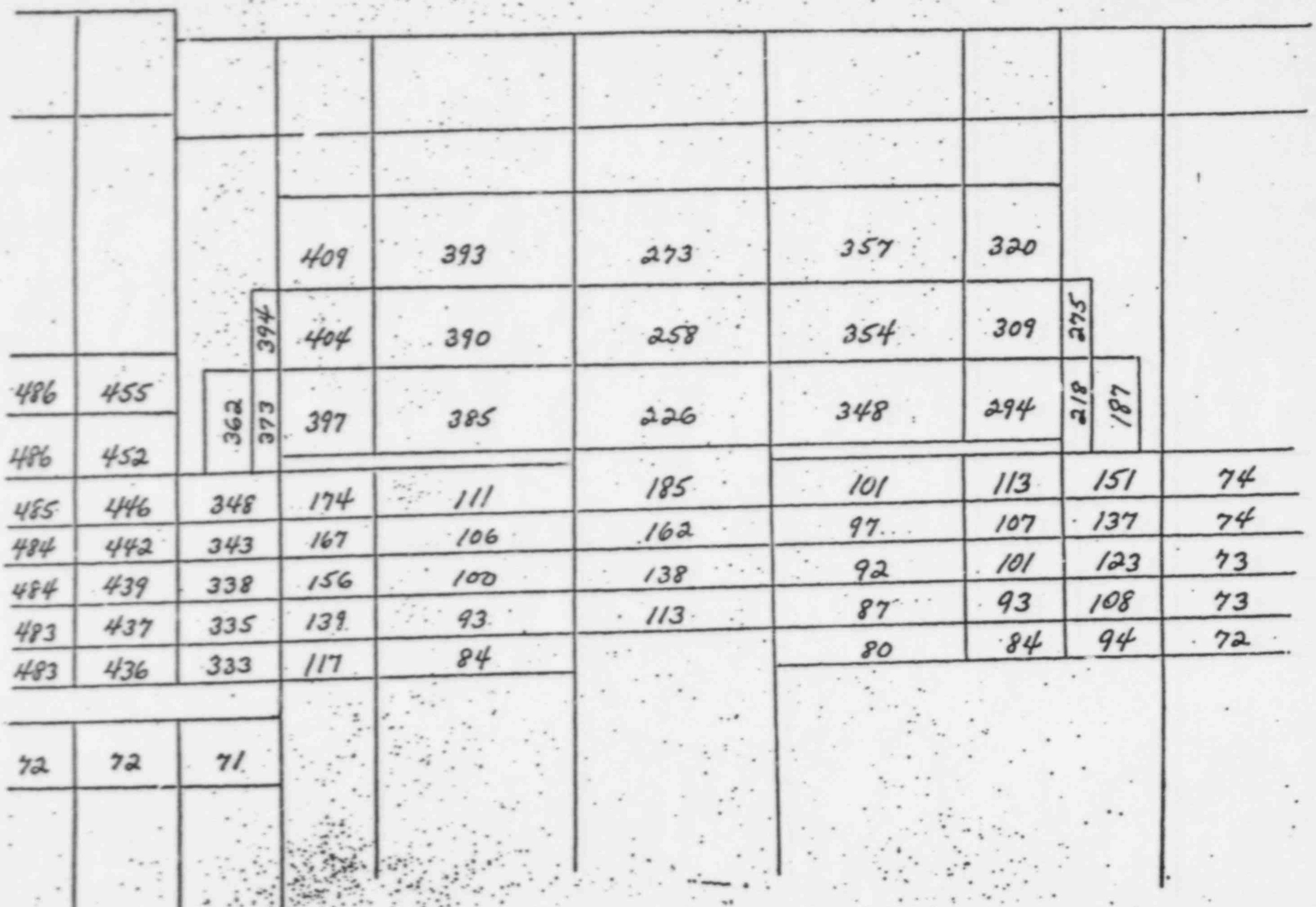

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3) ORNL-TM-3645. "NUCLEAR PIPING DESIGN", OAK RIDGE NATIONAL LABORATORY AND TELEDYNE MATERIALS RESEARCH (UNDER SUBCONTRACT NO. 3059 WITH UNION CARBIDE CORP., NUCLEAR DIVISION), FEB. 1972.

4) LACROSSE BOILING WATER REACTOR - SAFEGUARDS REPORT FOR OPERATING AUTHORIZATION - AEC CONTRACT NO. AT(11-1)-850, REVISED AUG. 1967 VOL. II P. A-4, AND FIG A-18.

5) LION 4 RUN # 1, "LACBWR ECCS SEISMIC THERMAL STEADY STATE - COUPLING INCLUDED," 11-19-75.

6) LION4 RUN # 2, "LACBWR ECCS SEISMIC THERMAL TRANSIENTS - COUPLING INCLUDED," 12-02-75.