G/C REPORT: EA-182 REVISION 0
PERRY NUCLEAR POWER PLANT (TA #92-0002)

TITLE:

N71 PIPE RUPTURE EVALUATION

JANUARY 31, 1992

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I. PURPOSE:

The purpose of this evaluation is to provide additional documentation that the modified 36-inch Fiberglass Reinforced Plastic (FRP) elbow and nearby anchor, both located in the above ground portion of the N71 Circulating Water Auxiliary Condenser inlet piping, are acceptable for continued service. In order to accommodate this requirement, more detailed evaluations of the piping along with a rigorous evaluation of the failed anchor were performed considering both conservative operating conditions and an imposed displacement criteria based on field measured movements.

In addition to the inlet piping, the N71 Circulating Water Auxiliary Condenser outlet piping was also evaluated under system operating conditions to document the piping stress levels and anchor loads presently existing in the outlet piping in the region of the above ground FRP elbow.

II. BACKGROUND:

Initial evaluations of the failed N71 FRP elbow centered on performing a conservative evaluation of the stresses at the critical location of the modified elbow. Because this evaluation was intended to give assurance that the elbow stresses were acceptable, a conservative method was used to maximize stresses by artificially displacing the anchorage to provide a displacement envelope which could be monitored in the field to provide assurance that the FRP elbow stresses were within acceptable values. At this point in time, the emphasis was on the fiberglass piping, not the long-term adequacy of the anchor support (1N71-H0013). In the interim until such a long term evaluation was performed, anchor 1N71-H0013 would be monitored via a baseplate scratch pad to provide indication of possible overload.

III. PROCEDURE:

As a consequence of the required repairs to the 36-inch diameter fiberglass elbow in the inlet line to the auxiliary condenser and the nearby anchor 1N71-H0013, G/C performed several analyses to provide additional assurance that the system is operating long-term within a safe envelope. These evaluations consisted of several phases as described below:

A. INITIAL EVALUATION:

The initial analyses were performed by G/C shortly after the rupture of the fiberglass elbow to provide CEI with a pipe movement criteria which could be monitored at the site. This

criteria was produced using a truncated model of the Auxiliary Condenser Circulating Water (CW) inlet piping with conservative boundary conditions to evaluate maximum stresses in the fiberglass elbow. Three separate values of 30, 50, and 70 lbs/in^3 for the soil modulus of subgrade reaction were utilized in order to conservatively estimate the maximum stresses in the region of the FRP elbow. Initial results produced by this model indicated that concurrent displacements of 0.125 inch in both the vertical and horizontal directions produced a maximum combined stress of 1923 psi in the critical region of the failed elbow which resulted in a factor of safety of 2 when compared to the long term strength of the FRP piping of 3800 psi.

A more detailed description of the original model and the results of this initial evaluation are provided in Appendix I of this report.

B. ADDITIONAL ANALYSES:

Based on this initial criteria, a monitoring system was installed by CEI on the inlet piping to record the movements of the system at the flange connection to the FRP piping. In conjunction with this monitoring system, it was decided to perform additional analyses of the system to more accurately determine the adequacy of the piping and anchor in the vicinity of the FRP elbow. These additional analyses included an expanded piping model of the Auxiliary Condenser Circulating Water (CW) inlet line to include the piping to the condensers and also portions below ground in order to include additional effects which could be influencing the stresses in the FRP elbow. The below ground inlet piping model was extended for approximately 35 feet to the connection to the 144-inch CW line. An expanded model was also utilized to evaluate the loads and stresses existing in the CW outlet piping, and was extended for a similar distance underground.

In addition to the operating case, other load cases were analyzed including a flow transient case in order to assure that no significant dynamic loads occurred in the piping during system operation, and a target criteria case to envelope predicted worst case movements of the piping.

1. INLET MODEL: (Figures 1 and 2)

EXPANDED CONFIGURATION:

The original model of the inlet piping was expanded to include the additional piping going to the auxiliary condensers and additional underground piping to account for displacements

which may be influenced by the buried FRP piping thermal and pressure effects. Because of the importance of determining the nature of the existing anchor loads, a detailed finite element model of the support 1N71-H0013 was constructed to provide detailed spring constants for use in the piping analysis. As described below, this model was also used to evaluate the imposed piping forces and moments resulting from the various loading conditions. The loads on the anchor were evaluated utilizing a STARDYNE finite element model as described in Appendix II. Localized stresses and the weld at the pipe to anchor connection were evaluated separately utilizing the WERCO computer program.

SOIL PROPERTIES:

The initial piping analysis utilized several values of horizontal soil modulus of subgrade reaction. Based on the results of this initial evaluation and a more detailed review of the analytical data, the expanded piping models were evaluated for two different pairs of values for the soil modulus of subgrade reaction in the horizontal and vertical directions. A further review of the resulting analyses determined that the most critical support loads were caused by the stiffer soil properties. Based on this evaluation, all expanded model piping load cases were run with the stiffer soil properties.

OPERATING CONDITION:

The expanded inlet model was run for a design/operating condition with a δT of 65°F (30-95°F) above ground, 40°F below ground, and a pressure of 60 psig. Horizontal and vertical soil springs were included corresponding to the values of soil modulus of subgrade reaction of 135 lb/in^3 vertical and 70 lb/in^3 lateral as previously determined.

2. OUTLET MODEL: (Figures 3 and 4)

OPERATING CONDITION:

A separate model was utilized for the Circulating Water Auxiliary Condenser outlet piping because of differences in configuration both above and below grade. The outlet piping was analyzed at a 12°F higher temperature than the inlet piping and at a pressure of 39 psi. As was done for the inlet piping, concurrent maximum loadings resulting from a flow transient analysis were included in the analysis.

3. INLET/OUTLET MODELS:

FLOW TRANSIENT LOADS:

Because of the concern that the initial rupture may have been caused by an unanalyzed loading due to flow transients in the system, a detailed evaluation of the system operating modes was made. It was determined that the only flow transients that were possible were those resulting from pump switching operations in the CW system. The evaluation of these transients are described in detail in the following section. As may be seen, the magnitudes of the forcing functions obtained from this analysis are relatively small; however, they were included in the piping analysis for completeness. Conservatively, maximum loadings were applied concurrently to the piping system at each change in direction. The resulting loads and stresses were combined absolutely with the loads and stresses obtained in the deadweight and thermal analyses.

4. INLET MODEL:

DISPLACEMENT TARGET CRITERIA:

The expanded inlet model was run with forced displacements at the flange location to better define the original criteria with respect not only to stresses in the FRP elbow but also the resulting loads on the anchor 1N71-H0013. As a means of providing a criteria to monitor operation of the system, displacements were induced in the piping models corresponding to movements of 0.125 inches in the vertical direction and 0.135 inches in the horizontal direction. These displacement values were supplied by CEI as conservative envelopes of monitored displacement data.

The loads on the anchor were evaluated as described above utilizing a STARDYNE finite element model. Localized stresses at the pipe to anchor connection were evaluated separately utilizing the WERCO computer program. Because the target criteria case is considered to only assure that pressure integrity is maintained in the piping system, only primary loads due to deadweight and flow transients are evaluated. The displacement loadings are considered to produce secondary piping stresses which are self-limiting and are therefore not included under primary stress evaluations.

C. PIPE SUPPORT STIFFNESS AND ANCHORAGE EVALUATION FOR PRYING EFFECTS:

See Appendix II of this report for a discussion of the methodology and analyses used to evaluate the pipe support anchors in the Circulating Water Auxiliary Condenser inlet line (Mk No 1N71-H0013) and outlet line (Mk No 1N71-H0021).

D. HYDRODYNAMIC LOADS EVALUATION:

See Appendix III of this report for a discussion of the hydraulic analyses performed to determine potential hydraulic loads (impulse and transient) in the 36-inch diameter Circulating Water Auxiliary Condenser piping.

IV. RESULTS AND CONCLUSIONS:

A detailed analysis of both the inlet and outlet N71 Circulating Water Auxiliary Condenser piping has demonstrated the adequacy of the piping and anchor under operating conditions, including all possible flow transients. The maximum stress occurring in the inlet piping FRP elbow region above ground was determined to be 2014 psi resulting in a factor of safety of 1.9 when compared to the long term strength of 3800 psi. The maximum stress occurring in the outlet piping FRP elbow region above ground was determined to be 2232 psi resulting in a factor of safety of 1.7 when compared to the long term strength of 3800 psi.

As a means of providing a criteria to monitor operation of the system plus to demonstrate added margin, displacements were artificially induced in the piping model corresponding to movements of 0.125 inches in the vertical (upward) direction and 0.135 inches in the horizontal (North) direction. Under this envelope condition, it has been demonstrated that the maximum stress in the above ground FRP is 1948 psi resulting in a factor of safety of 1.9 when compared with the long term strength of 3800 psi for the FRP material.

The anchor evaluation for the target criteria case has shown that the anchor components cannot be shown to be adequate for the full amount of criteria displacement. The maximum allowed displacement that is acceptable based on standard design criteria (Reference 1, Appendix II, Part B) for the anchor has been estimated to be 0.081 inches in the horizontal (North) direction and 0.075 inches in the vertical (upward) direction when measured at the flange location. The displacements at which the anchor components achieve functional limits have been estimated to be 0.115 inches in the horizontal direction and 0.106 inches in the vertical direction, again measured at the flange location.

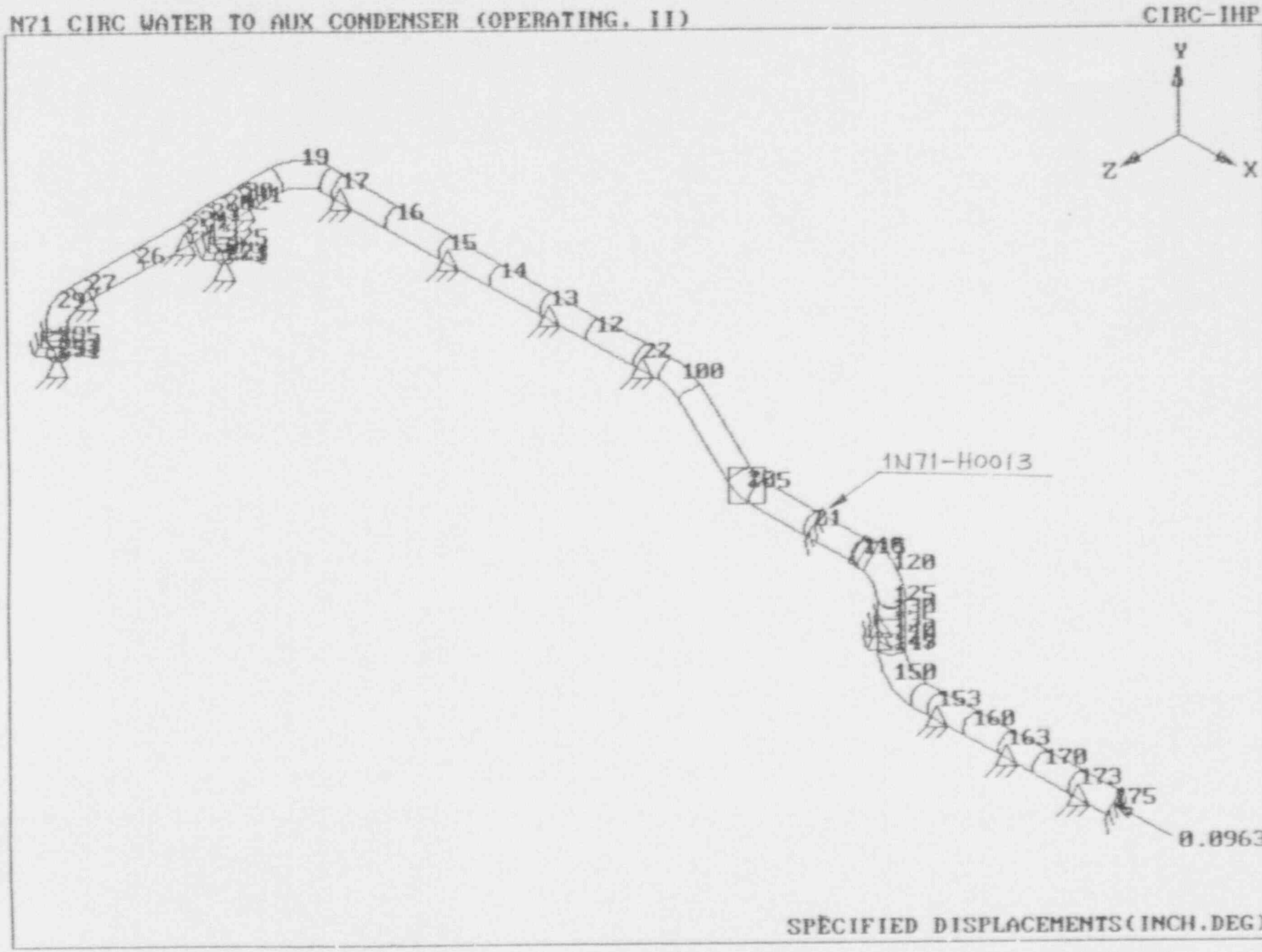

FIGURE 1
PAGE 5A

N71 CIRC WATER TO AUX CONDENSER (OPERATING, II)

CIRC-IHP

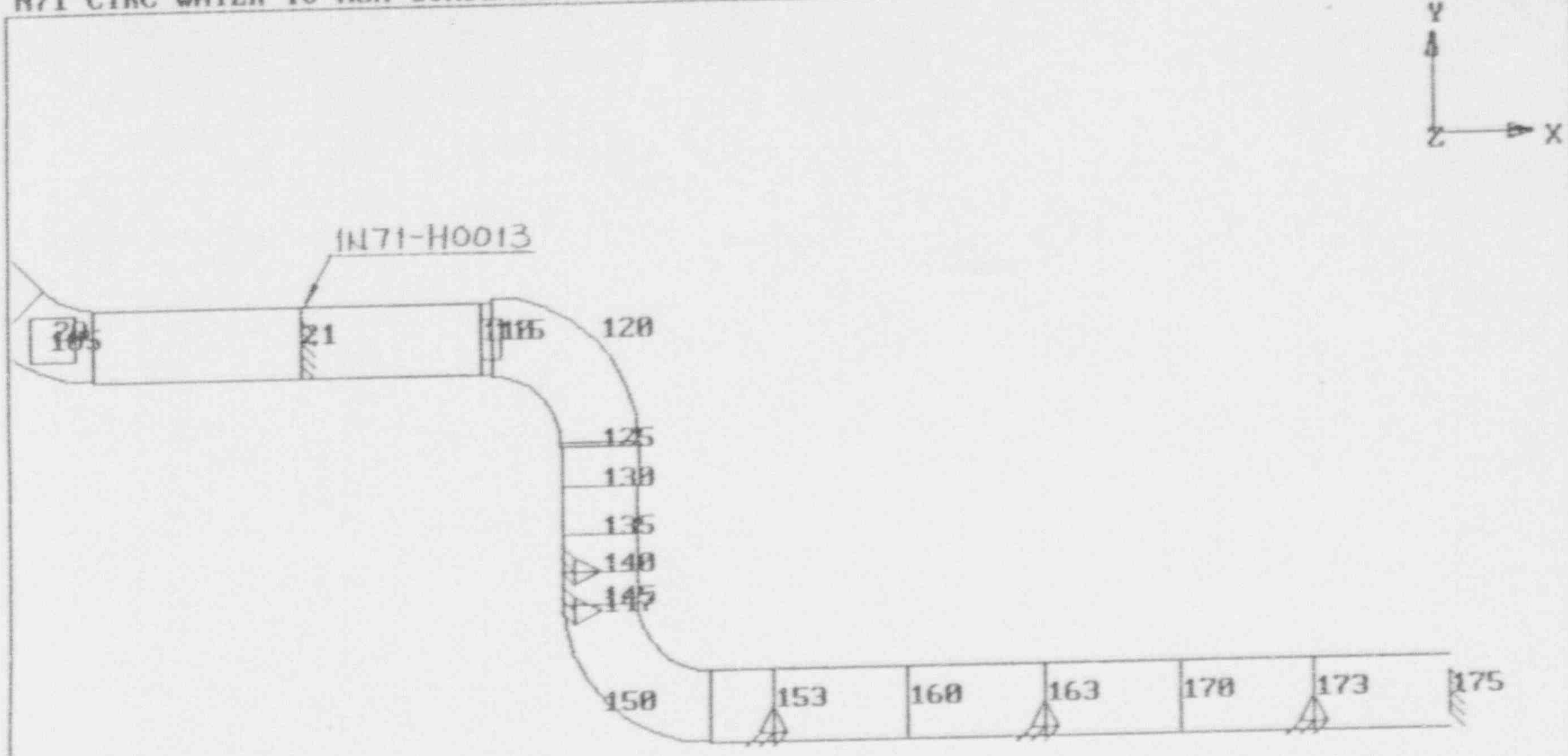

FIGURE 2
PAGE 5B

FW PUMP TURB COND COOL WATER PIPE (4. DESN/OPER) CIRC-OHP

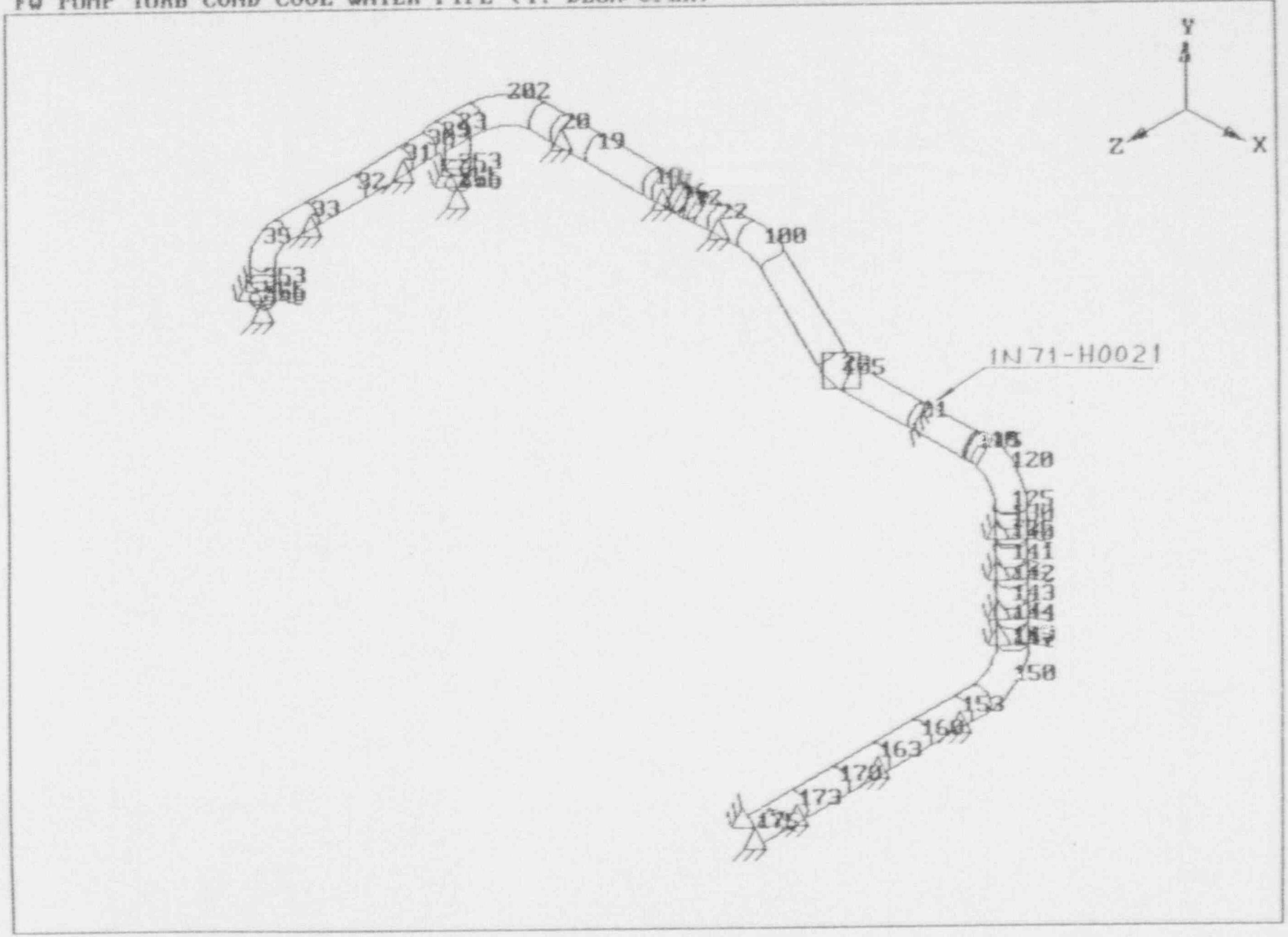

FIGURE 3
PAGE 5C

N71 CIRC WATER TO AUX CONDENSER (OPERATING. II)

CIRC-OHP

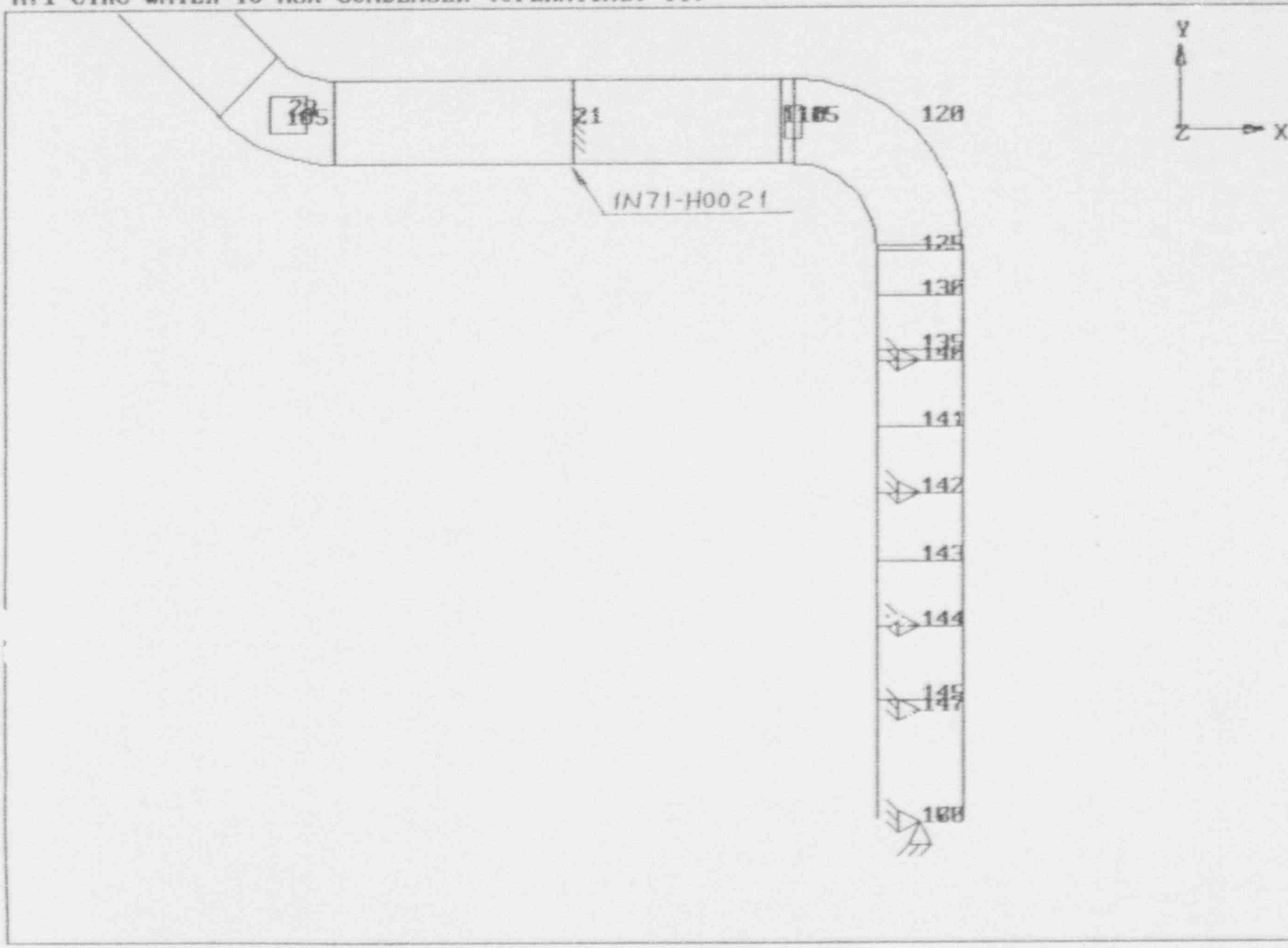

FIGURE 4
PAGE 5D

APPENDIX I

INITIAL G/C ANALYSIS OF FIBERGLASS INLET PIPING 1/3/92

OBJECTIVE

The purpose of this analysis is to evaluate the potential stress levels in the reinforced fiberglass portions of the PNPP FW pump drive turbine condenser cooling water piping for a variety of environmental conditions. The objective is to provide CEI with some pipe movement criteria that can be used in monitoring the system to provide reasonable assurance that the piping is operating within a safe envelope of deflection.

The results of this analysis are to be considered approximate due to the fact that the procedures used are typical of those used to analyze steel pipe and may not be entirely appropriate for reinforced fiberglass piping; however, the results are adequate for the intended purpose of defining an acceptable pipe movement criteria. Further, the results are influenced by the variability of the modulus of elasticity for fiberglass pipe depending upon the orientation of the reinforcing fibers and the possibility that properties of the existing pipe may have changed over time.

ANALYSIS BOUNDARIES

The analysis was performed with the use of the CAEPIPE program, a PC-based general purpose pipe stress program. The model consisted of a truncated section of the pipe running from a rigid hanger 1N71-H0014 at Elevation 634' to the buried fiberglass elbow at Elevation 608'-7". The model includes the new fiberglass elbow at the transition to the carbon steel pipe north of anchor HO13.

INPUT DATA

The following material characteristics and environmental conditions were incorporated into the analysis:

1. Material properties:

   <u>Steel pipe per A-155 Grade KC 60 CL2</u>
   $E=27.9\times10^{6}$ psi
   $\alpha=6.07\times10^{-6}$ in/in/°F

   <u>Fiberglass</u>

Elbow - Flexural modulus $E=1.29x10^6$ psi
Pipe - Flexural modulus $E=1.2x10^6$ psi
Elbow - Expansion coefficient $\alpha=12.0x10^{-6}$ in/in/°F
Pipe - Expansion coefficient $\alpha=11.1x10^{-6}$ in/in/°F

(The tensile or hoop moduli are not considered in the CAEPIPE program.)

2. Environmental conditions:

Temperature range $\delta T=65°F$ above Elevation 615'-1"
Temperature range $\delta T=40°F$ below Elevation 615'-1"
Pressure P=58 psi
Soil modulus of subgrade reaction k = 30-70 lb/in/in²
(Soil springs corresponding to 30, 50, and 70 lb/in/in² were used in order to bracket the range of k.)

3. Imposed movements at Anchor H013:

Movements of 1/8" northward (+x) and 1/8" down (-y) were selected as reasonable boundary limits of motion for the pipe at the anchor nearest the flange connection between the fiberglass elbow. The northward movement corresponds to the diametric clearance in the holes for the anchor bolts in the H013 baseplate, and a vertical movement of similar magnitude was arbitrarily chosen. The directions of these movements (northward and down) were chosen conservatively so that they would be additive to the effects of thermal expansion.

A run with the anchor moving 1/8" up instead of down was made in order to confirm that the assumption of downward movement was more conservative.

ANALYSIS RESULTS

The following results are considered approximate and tentative at this time, pending review and verification of the inputs and calculations.

The highest stresses in the fiberglass piping occur at the top of the vertical section of the 36.8" diameter run where it connects to the tapered transition section on the bottom of the new elbow. This is due to the relatively high bending moment at the critical section combined with the minimum section modulus where the thin wall (0.400") ends. The results of the analysis, which include the combined effects of weight, thermal expansion, and imposed movement at the 1N71-H0013 anchor are as follows (based on soil k=50 lb/in/in²):

1. Movements at points of interest

Point	Vertical movement	North-south movement
Anchor HO13	-.125" (imposed)	.125" north (imposed)
Flanges	.121" down	.163" north
Critical section (Top of thin wall section)	.206 down	.099" north

2. Axial force and bending moment at the critical section

   Axial force F_y=10,948 lb in compression
   Bending moment M_z=19,816 ft-lb (237,792 in-lb)

3. Combined longitudinal stress at the critical section

   Longitudinal stress S=1911 psi

The effects of varying the soil modulus of subgrade reaction by more than 100% are slight, resulting in a total variation in combined stresses of only 2% at the critical section. The critical section compressive force, bending moment and combined stress for various values of k are as follows:

Soil modulus k	Axial force	Bending moment	Combined stress
30 lb/in/in²	10,045 lb	18,854 ft-lb	1883 psi
50 lb/in/in²	10,948 lb	19,816 ft-lb	1911 psi
70 lb/in/in²	11,504 lb	20,221 ft-lb	1923 psi

In order to confirm that a downward movement of 1/8" at Anchor HO13 was more critical than an assumed upward movement of 1/8", the analysis model was modified to impose an upward movement instead of a downward movement. A comparison of the results for the critical section is as follows (soil k=50 lb/in/in², HO13 movement unchanged at 1/8" north):

Mvt at HO13	Axial force	Bending moment	Combined stress
1/8" down	10,948 lb	19,816 ft-lb	1911 psi
1/8" up	2,175 lb	7,794 ft-lb	1561 psi

The maximum single component of the combined stresses is the longitudinal pressure stress of 1291 psi in tension, due to the internal pressure of 58 psi.

CONCLUSIONS

For postulated movements of ±1/8" vertically and 1/8" northward at the 1N71-H0013 anchor, the stresses at the most critical section of the fiberglass piping do not exceed 1923 psi which results in a factor of safety of 2 when compared to a 3800 psi long term strength for the FRP piping. These movements are considered to be the maximum credible movements at the location of this anchor, considering liberal installation tolerances at the anchor. Since the largest single component of the critical pipe stress is the longitudinal pressure stress of 1291 psi, the maximum combined effect of thermal expansion and postulated anchor movement is only 632 psi. Therefore any movement of less than 1/8" in any direction at the anchor or adjacent flange is considered to be trivial with respect to stresses in the fiberglass piping. Wide variability in the soil modulus of subgrade reaction has been shown to have little effect on forces, moments, and stresses in the piping.

APPENDIX II
PART A

SUPPORT STIFFNESS AND EVALUATION

This section documents the methodology and results of analyses used to determine the support stiffness at pipe supports 1N71-H0013 and 1N71-H0021, and the support evaluation of loads obtai[illegible] from the piping analysis. The support stiffness is utilized in t[illegible] [illegible]ping analysis to obtain the support reactions and the resultant pipe stresses.

MOD[illegible]L:

The two pipe supports are very similar in design; however, there are minor differences in the actual as-[illegible]ilt locations of the Drillco Maxibolt anchorages and in the fabrication details of the vertical member which attaches the 36-inch Circulating Water pipe to the support baseplate. These differences are not significant and as a result only one finite element model is used to determine the stiffness and evaluate the support. The support is modelled with the STARDYNE computer program. A sketch of the model is shown in figure II-1 along with the material properties utilized in the analysis.

STIFFNESS:

The support stiffness is calculated by imposing loads at the centerline of the 36-inch pipe in each of the six degrees of freedom. The resulting stiffnesses used for the piping analysis are as follows:

TABLE II-1

[illegible]RECTION	STIFFNESS (kip/in)
X-TRANSLATION	197.4 (149. target crit)
Y-TRANSLATION	1140.0
Z-TRANSLATION	338.9

DIRECTION	STIFFNESS (in-kip/radian)
X-ROTATION	305044.
Y-ROTATION	363459.
Z-ROTATIC[illegible]	151404.

SUPPORT LOADS:

The piping analysis was initially performed for several values of

horizontal soil modulus of subgrade reaction. Based on the results of this initial evaluation and a more detailed review of the analytical data, the expanded piping models were evaluated for two different pairs of values for the soil modulus of subgrade reaction in the horizontal and vertical directions. A further review of the resulting analyses determined that the most critical support loads are caused by the stiffer soil properties. Based on this evaluation, all piping load cases were run with the stiffer soil properties.

The operating, fluid transient, deadweight, and target criteria loads are presented in table II-2. The load combinations used for the STARDYNE computer analysis are presented in table II-3.

TABLE II-2 SUMMARY OF BASIC LOADS ON SUPPORT MK NOS. H0013 & H0021

LOAD CASE	SUPPORT MK NOS. H0013 & H0021 SUPPORT LOADS IN PIPING COORDINATE SYSTEM (lbs, ft)					
	FX (lbs)	FY (lbs)	FZ (lbs)	MX (ft-lbs)	MY (ft-lbs)	MZ (ft-lbs)
DEAD WT	995	-17376	-19	-222	-49	-3301
DESN/OP (H0013)	2118	-3391	-277	-4561	-2998	-173
DESN/OP (H0021)	384	-8277	-364	-5616	-3521	-1280
TRANS (H0013)	-1705	1245	1	-135	238	-477
TRANS (H0021)	1003	-413	-14	48	-266	-94
FLANGE MVMT 2 (.135"N,.125"V)	19928	38386	66	1309	445	8230

TABLE II-3 SUMMARY OF COMBINED LOADS ON SUPPORT MK NOS. H0013 & H0021

LOAD CASE	SUPPORT MK NOS. H0013 & H0021 LOADS IN PIPING COORD SYSTEM AT CENTER OF 36" DIAM PIPE						REMARKS
	FX (kips)	FY (kips)	FZ (kips)	MX (in-kip)	MY (in-kip)	MZ (in-kip)	
H0013: OPER +/- FLUID TRANS	3.823	-2.146	-0.276	-56.352	-33.120	3.648	FX, FY, MZ --- MOST POSITIVE COMB FZ, MX, MY --- MAXIMIZE MAGNITUDE
H0021: OPER +/- FLUID TRANS	1.387	-7.864	-0.378	-66.816	-45.444	-14.232	FX, FY, MZ --- MOST POSITIVE COMB FZ, MX, MY --- MAXIMIZE MAGNITUDE
DEAD + K1*(FLG MVMT 2)	20.923	21.010	0.047	13.044	4.752	59.148	K1 = 1.00
DEAD + K2*(FLG MVMT 2)	17.934	15.252	0.037	10.688	3.951	44.334	K2 = 0.85
DEAD + K3*(FLG MVMT 2)	14.945	9.494	0.027	8.332	3.150	29.520	K3 = 0.70
DEAD + K4*(FLG MVMT 2)	12.952	5.656	0.021	6.761	2.616	19.644	K4 = 0.60
DEAD + K5*(FLG MVMT 2)	10.959	1.817	0.014	5.190	2.082	9.768	K5 = 0.50
DEAD + K6*(FLG MVMT 2)	8.966	-2.022	0.007	3.619	1.548	-0.108	K6 = 0.40

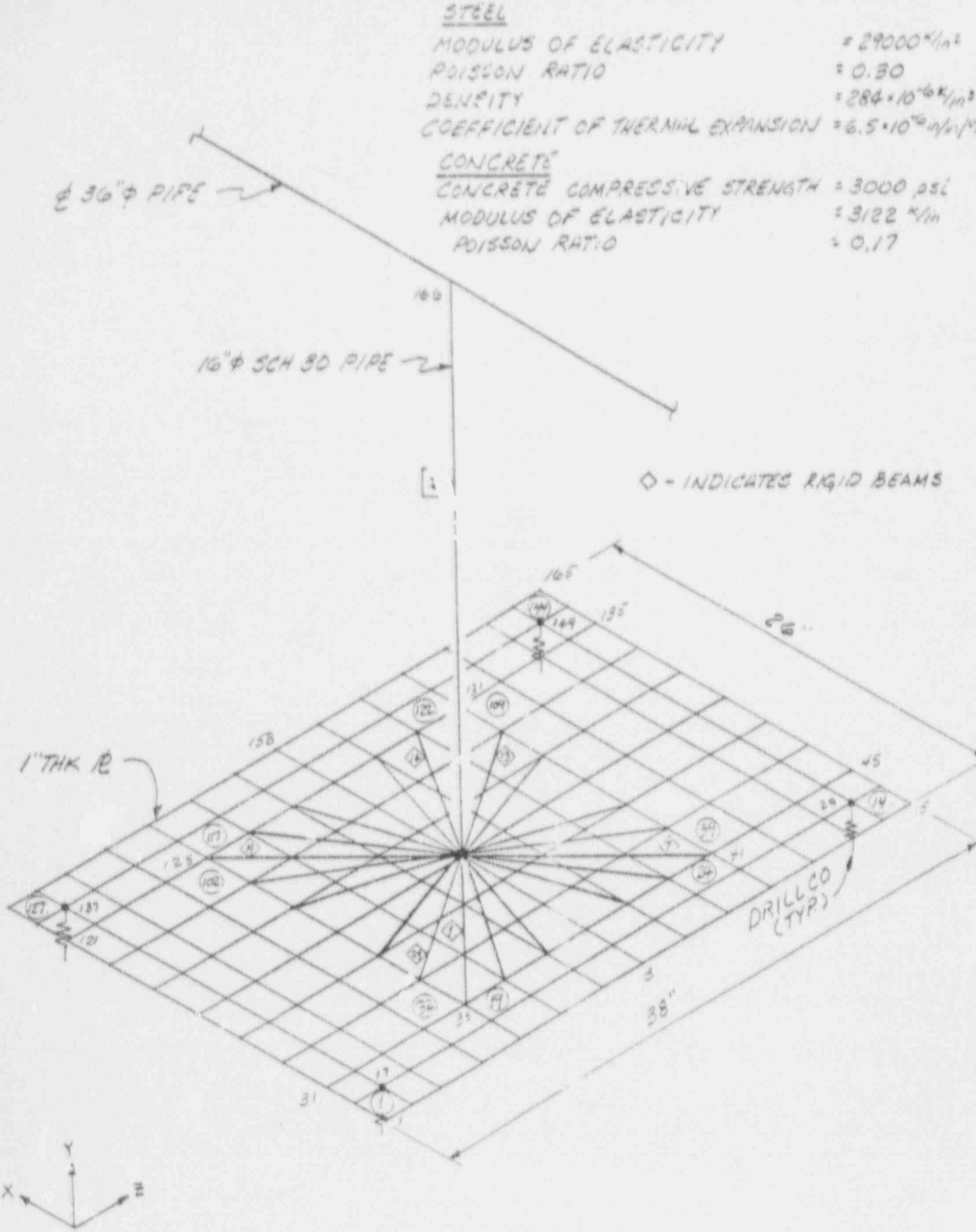

FIGURE II-1

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APPENDIX II
PART B

PIPE SUPPORT ANCHORAGE EVALUATION FOR PRYING EFFECTS

Pipe support base plates attached to reinforced concrete structures using concrete expansion anchors are evaluated in accordance with the PNPP anchorage design guide (Ref. 1). The particular type of anchors used to anchor Pipe Support MK Nos. 1N71-H0013 and 1N71-H0021 are DRILLCO Maxibolts. These anchors require significant preload for proper installation which tends to complicate the determination of the factor of safety provided in the design with regard to pullout.

A straight forward analytical procedure has been developed by G/C for determining the anchor's "engineering tension load" which properly accounts for prying effects. The procedure provides a practical solution to the problem of high anchor tensile forces due to preload effects, which in some cases, may approach or exceed allowable tension loads before any external loads are applied. An outline of the procedure is given in Table II-1.

The STARDYNE computer program (Ref. 2) is used in this task to perform the finite element analysis described in Step 1. This program is used throughout the nuclear industry to perform base plate analyses.

The rigid plate analysis required in Step 2 is analogous to a reinforced concrete beam analysis by working stress design methods in which a plane section remains plane. Also, this conventional cracked section analysis method considers only the compression resistance of the concrete and the tension resistance of the anchors. Prying effects are not considered in the rigid plate analysis.

The end result (step 3) of the procedure outlined in Table II-1 is the engineering tension force in the anchor. This force does not include preload tension which is consistent with engineering design practice for all types of connections. It is also consistent with regulatory requirements and does not account for prying effects.

Resultant shear forces on each anchor can be determined using conventional statics methods or they can be obtained from the finite element analysis results if proper restraints are included in the model. In this task, anchor shear forces are calculated manually for each of the four DRILLCO anchors on each base plate.

The interaction ratio for shear and tension loads on the anchors is calculated using the method outlined in the PNPP anchor design guide which is Attachment No. 3 to Reference 1. Allowable tension and shear loads are obtained by dividing the SSE design allowables in Table 2 by

1.4 which provides the appropriate factor of safety for the loading conditions evaluated.

TABLE II-1
Procedure for Obtaining the
Engineering Tension Load in Preloaded Anchors

1. Perform a finite element analysis of the base plate using conventional industry methods. The model accounts for the compression only contact surface between the underside of the base plate and the concrete surface and the tension only resistance provided by the anchors. Foundation flexibility and plate flexibility effects are also accounted for in this type of analysis.

   In addition to the design load cases, include a load case in which no external loads are applied so that effects of preload only can be obtained. Results of the finite element analysis are used to obtain values for the following variables.

Input Variables:

T_o = anchor "lift off" load from design specifications
K_b = anchor stiffness in tension from design specifications

FEA Output Variables:

d_o = anchor displacement due to preload only
d_i = anchor displacement due to preload plus external loads for load case "i"

Calculated Variables:

T_{bo} = anchor tension after elastic compression of foundation due to preload and without external loads
$T_{bo} = T_o + K_b*d_o$

T_{ba} = anchor tension due to preload and external loads
$T_{ba} = T_o + K_b*d_i$

K_{ce} = equivalent foundation stiffness in the anchor vicinity
$K_{ce} = ABS(T_o/d_o) - K_b$

2. Perform a rigid plate analysis to obtain anchor tension forces, T_{br}, for each of the design load cases. Effects of foundation flexibility are included in this analysis.

3. Using results of the finite element analysis and the rigid plate analysis, the following calculations are made to determine the anchor's engineering tension force, T_{be}.

a. Calculate prying force, T_{bp}

$$T_{bp} = T_{ba} - [T_{bo} + T_{br}/(1+K_{ce}/K_b)]$$

b. Calculate engineering tension force, T_{be}

$$T_{be} = T_{br} + T_{bp} \le T_{ba}$$

REFERENCES:

1. G/C, Inc., Structural Dept. A0414 Design Calculations, Perry Nuclear Power Plant, "Design Guide for Anchors", Calc. ID # 1:39.1, WO# 04-5250-716, Rev. 0, 4/2/91, with Attachment Nos. 1, 2 and 3.

2. GMC, "STARDYNE User Information Manual", General Microelectronics Corp., San Diego, CA, 1987.

Software: STARDYNE, Version 3.5(R), MAY 1, 1989
Hardware: G/C Personal Computer, IBM compatible (386)

APPENDIX III

HYDRODYNAMIC LOADS EVALUATION:

This report documents the results of hydraulic analyses performed to determine potential loads on the three foot diameter Circulating Water Auxiliary Condenser piping for the Perry Nuclear Power Plant.

The Circulating Water system was modeled using the HYTN41 computer program. HYTN-41 is a general purpose thermal/hydraulic system analysis computer program. It can be used to simulate both transient and/or steady state non-isothermal fluid flow in a network. The effect of pump start/stop, valve open/closure and other system control operations can be modeled. For the transients addressed below a transient simulation of the Circulating Water system was performed.

The system model includes the pumps N71-C001A,B and C. The pumps were modeled using homologous curves which provide flow, head, speed and torque characteristics in all four regions of possible pump operation (normal, reverse speed dissipation, dissipation zone and turbine zone). The remainder of the system was hydraulically modeled including the pump discharge valves (F020A,B, and C) flow coefficient vs stroke, the 12 ft. underground piping to the main condenser and associated piping, the discharge piping and the losses associated with the cooling tower. In addition to the condenser loop, a simplified model of the cooling tower blowdown was included.

In addition to the primary loop, a detailed model of the Auxiliary Condenser, inlet and outlet piping, and motor operated inlet valves (F150A and B) was integrated into the overall model. The HYTN41 simulation is used to determine unbalanced piping loads on the Auxiliary Condenser inlet and outlet piping for three different scenarios.

The method used to develop axial piping unbalanced forcing functions is attached.

The System Operating Instruction (SOI-N71) for the Circulating Water System was reviewed for any system operating transients which might cause water hammer. No operational transients were identified that would create a water hammer. Initial fill of the Circulating Water System is very carefully controlled to avoid starting a pump or opening a valve with flow into a voided pipe. The only operational transients which will have any inertial affects, i.e. surge involve starting or stopping a pump or opening or closing a valve with the system full.

The three scenarios evaluated include;

1. Normal system operation with three pumps running. One pump trips and its associated discharge valve closes.

2. System operation with two of the three pumps running. The remaining pump starts and its associated discharge valve opens.

3. Normal system operation (three pumps operating). Auxiliary Condenser Valve F150A closes.

Unbalanced piping forces on the Auxiliary Condenser inlet and outlet piping were calculated for each of the above scenarios.

The results of the analysis are presented in Table III-1 .

TABLE III-1
MAXIMUM PIPING LOADS

Pipe Segment	Scenario 1 Maximum Load Pos.	Scenario 1 Maximum Load (Neg.)	Scenario 2 Maximum Load Pos.	Scenario 2 Maximum Load (Neg.)	Scenario 3 Maximum Load Pos.	Scenario 3 Maximum Load (Neg.)
	Lbf.		Lbf.		Lbf.	
Inlet 1	188.	(327.)	282.	(379.)	188.	(175.)
Inlet 2	73.	(138.)	103.	(141.)	76.	(72.)
Inlet 3	82.	(120.)	194.	(175.)	89.	(86.)
Inlet 4	61.	(135.)	163.	(140.)	65.	(66.)
Inlet 5	200.	(508.)	585.	(455.)	206.	(230.)
Inlet 6	59.	(170.)	178.	(162.)	58.	(64.)
Inlet 7	18.	(44.)	45.	(41.)	14.	(26.)
Inlet 8	7.	(24.)	19.	(18.)	22.	(7.)
Outlet 1	9.	(24.)	14.	(17.)	22.	(5.)
Outlet 2	16.	(43.)	44.	(39.)	12.	(25.)
Outlet 3	46.	(117.)	75.	(89.)	59.	(25.)
Outlet 4	115.	(244.)	177.	(190.)	75.	(70.)
Outlet 5	50.	(105.)	70.	(88.)	37.	(37.)
Outlet 6	50.	(131.)	80.	(110.)	37.	(37.)
Outlet 7	69.	(181.)	111.	(147.)	46.	(51.)
Outlet 8	680.	(1760.)	952.	(1342.)	73.	(146.)
Outlet 9	721.	(2142.)	1350.	(1776.)	838.	(791.)

Note the piping segments are numbered consecutively from the 12 foot diameter line to the Auxiliary Condenser and from the Auxiliary Condenser to the 12 foot return line with the loads occurring at each change in direction.

The analysis is documented in Calculation 2.6.14 Rev. 0.

IMPULSE LOADS:

Although the steady state, impulse loads due to momentum changes at the elbows are normally considered insignificant, calculation N71-08 was prepared to determine the magnitude of these loads. These loads are due to the fact that as the fluid changes direction at the elbows, a force is imparted to the fluid so-as to maintain the conservation of momentum. There is also a reactionary force imparted to the piping that is equal and opposite in direction to the force on the fluid. These impulse loads are over and above the pressure loads, which impart a force of P x A.

Calculation N71-08 documents that these forces are indeed small and are comparable to a 1.7 psig pressure force. Although small, this additional load has been included in the piping stress analysis by utilizing a conservative operating pressure of (58+2) = 60 psig for the inlet piping and (37+2) = 39 psig for the outlet piping.

ATTACHMENT 2

ENCLOSURE 2

SUMMARY OF SIGNIFICANT ISSUES REGARDING AUXILIARY CIRCULATING WATER PIPE RUPTURE

SUMMARY OF SIGNIFICANT ISSUES REGARDING CIRCULATING WATER PIPE RUPTURE

I. CIRCULATING WATER (N71) PIPE RUPTURE

On 12/22/91 at approximately 0200 hours the 36 inch auxiliary circulating water supply line catastrophically failed. The failure was located in a fiberglass elbow in the pipe just prior to the point where the pipe transitions from fiberglass to carbon steel. The pipe was located in the yard area where the pipe exits the ground prior to entering the heater bay building. As a result of the failure, approximately 2.87 million gallons of water spilled into the yard area, the plant underdrain system, and into other plant areas. The plant was shutdown until repairs could be completed

Probable Causes Of Failure

The plant staff immediately contacted a fiberglass piping consultant to evaluate the failure. This individual had been used in other issues surrounding fiberglass piping on this site and others. Shard mapping of the failed fiberglass pieces was completed. Following mapping and photo documentation, the pieces were collected for reconstruction to determine the failure mechanism. Adjacent piping, supports, and adjacent structures were thoroughly inspected as part of the root cause effort. Failed bolts from the piping supports were analyzed at Centerior's analysis laboratories.

Several elements of cause were identified following the above efforts. These causes were examined for their respective contribution to the failure. They are as follows:

A. **ADDED STRESS ON FIBERGLASS PIPE AS A RESULT OF AN IMPROPERLY SPACED O-RING FLANGE SEAL**

An O-ring supplies the sealing mechanism between the flanged portion of the fiberglass piping and the flange of the carbon steel piping. The O-ring sits in a 316 stainless steel O-ring retainer. The O-ring and retainer are manually positioned in the center of the flanged connection and the flanges are bolted together so that the O-ring meets the flange faces to provide a pressure seal. When installed correctly, the O-ring contacts the one flange face and there is an approximate .0625 inch gap between the O-ring retainer and the other flange face. This allows some amount of relative motion of the flange faces. Inspection of the installed O-ring showed that the flange faces were pulled together to the point that they were both contacting the O-ring retainer. Thus, any steel flange motion would be more directly transmitted to the fiberglass piping than originally intended by O-ring flange seal design.

Initial judgments were that this situation may have induced appreciable additional stress into the fiberglass piping such that this item was one of the primary causes of the eventual piping failure. However, follow-up piping analytical work has shown the

relative insensitivity of the fiberglass piping to imposed displacements of such magnitude; thus, the overall contribution of this item is judged to be less important than originally considered.

B. **STRESS CONCENTRATION IN THE ELBOW DUE TO AN APPROXIMATE 8 INCH NON DESIGN AXIAL GROOVE IN THE ELBOW TO PIPE BONDING ZONE**

The vertical section of the failed elbow is joined to the adjacent pipe by a butt type joint. A butt joint is joined together by a sleeve. Typically, the bonding areas are prepared and a primer coat is applied and cured. Following cure of the primer, the sleeve joint is applied to the prepared surfaces and cured. Upon cure, the sleeve joint attains the approximate physical properties of the pipe and provides circumferential support and axial coupling of the pipe and elbow. The maximum thickness of the sleeve is at the butt joint. From this maximum thickness, the sleeve is tapered for a distance of approximately 20 inches on either side of the butt joint on the parent pieces.

A typical elbow is composite material approximately 1/2 inches thick. The interior .090 inches of the elbow is a resin rich mixture which provides good corrosion resistance but little strength. The next approximately 0.400 inches of thickness is composed of woven roving and mat glass fibers in a polyester resin matrix. This provides the strength characteristics of the elbow. The exterior .010 inches is also composed of a corrosion resistant but relatively weak material. Two axial grooves were observed on the exterior of the failed elbow. These axial grooves appeared to be made by a high speed grinder during original construction of the elbow or during initial installation. The axial grooves were in the West by Northwest quadrant of the vertical section of the elbow approximately at ground level. The axial grooves were approximately 60% through the wall thickness of the elbow. The existence of an axial groove in the elbow results in both a net cross-sectional area reduction in the load bearing portion of the elbow and the creation of a stress concentration point at the notch. The end result of the groove is a reduction in the hoop strength of the elbow. This reduced strength/stress riser point was located near ground level, where soil backfill around the piping causes a relatively highly loaded area within the fiberglass piping.

Inspection of the failed elbow revealed that the groove was an initiation site for the initial rupture in the elbow. The characteristics of the tear indicate that it initiated at the groove and traveled axially on the elbow from that zone. The failure was relatively clean at the initiation point. As the failure continued through the elbow, it changed from a "clean" fracture to shredded jagged tears. It is probable that this secondary tearing occurred due to the hydrodynamic force of the water after the pipe initially ruptured. The axial groove within the butt joint bonding area is concluded to be a flaw with primary causative influence leading to the eventual piping failure, with the subsequent elbow damage most probably emanating from the initial flawed area.

C. **ADVERSE PIPE SUPPORT INFLUENCE**

The first support (1N71-H0013) on the N71 steel piping to the south of the fiberglass-steel interface was intended to function as an anchor point. As such, it should have rigidly held the 36 inch diameter steel piping so that minimal loads/displacements were induced into the fiberglass elbow from the steel piping side of the interface.

Subsequent to the 12/22/91 event, inspections indicated significant damage to support 1N71-H0013. All four (4) existing anchors (3/4" diameter HILTI drop-in anchors holding the support to a concrete slab) were fractured. The broken pieces were removed and forwarded to Centerior's testing laboratory for failure analysis. Refer to Attachment 2, Enclosure 1, Addendum A for a completed copy of the analysis/test report. Observations/conclusions from this analysis are summarized as follows:

1. There are some observed fatigue cracks in the bolts located away from the fractured surfaces. There is also some evidence of corrosion influence on this cracking. It is not possible to definitively determine if the fractured surfaces are fatigue driven. However, our judgment is that they are not caused by fatigue due to the presence of significant bolt plastic deformation prior to fracture (fatigue failure would typically be more of a brittle type failure with little distortion while overload failure would typically have relatively large distortion). Refer to Attachment 2, Enclosure 1, Addendum B for photographs of the failed bolts. It therefore follows that the fiberglass piping failed first, with subsequent anchor bolt failure due to extreme overload.

2. Evidence exists that indicates that the nuts on the anchor bolts were "loose" prior to the piping failure. This looseness permitted the 1/2" thick support baseplate, and thus the entire support, to be relatively free to displace minor amounts (essentially within bolt hole clearances). Thread damage on the bolts indicates a long term "hammering" action caused by lateral (horizontal) movements of the baseplate.

   The amount of probable lateral displacement within the piping permitted by the "loose" support, in absolute terms, is not large (estimated at approximately 1/8"). Initial judgments were that this looseness may have had substantial adverse influence (with regard to stress) on the fiberglass piping; with a primary role in leading to the eventual piping failure. Subsequent piping analytical work, however, has shown a piping displacement of this magnitude to be of relative little importance. Therefore, although the presence of a loose anchor support during system operation is a probable contributor to the fiberglass piping failure, it is not considered to be a primary causal factor of the same.

Based on the above discussion, "loose" anchor support #1N71-H0013 is concluded to be a probable contributor to the piping failure; however, it is not an initiator of the failure and not a contributor of primary causal influence.

D. **NON UNIFORM LOADING OF THE EXTERIOR OF THE FIBERGLASS PIPING**

This failure mode was considered, but was determined not to be a contributor to the failure. If the break in the pipe were underground then external loading from fill would be a consideration. The failure was above ground where there was no such loading.

E. **DEGRADATION OF THE MATERIAL STRENGTH OF THE PIPE DUE TO AGE**

This factor would act as a secondary contributor to other primary factors when examining a failure. Many factors contribute to the degradation of the material strength of the fiberglass pipe over time. Two key factors include stress loading of the pipe under wetted conditions and ultraviolet (UV) radiation. It should be noted that this pipe was located on the North face of the building and was insulated. Therefore UV radiation would be at a minimum for an exposed pipe and not a factor for an insulated pipe. This was considered not to be a primary causal factor in the piping failure as compared to other issues as discussed herein.

F. **DEGRADATION OF MATERIAL STRENGTH DUE TO HEAT TRACING**

Severe localized heating of the fiberglass could cause degradation of the strength of the fiberglass piping. Heat tracing is radially wrapped around the elbow to ensure it does not freeze. Although the elbow exhibited some discoloration at the heat trace lines, the elbow did not rupture along those lines. No pattern of rupture that would point to heat trace as the root cause existed.

Conclusions

As stated above, the probable causes were evaluated individually and in combination. It is generally agreed that no individual causal factor precipitated the failure. The most probable and primary cause of the failure was strength weakening of the elbow wall caused by the presence of non-design axial grooves. Under operational loading, these grooves also acted as stress risers and appeared to be the initial site for elbow failure. Some induced stressing of the fiberglass elbow was also probably caused by "loose" anchor support 1N71-H0013. Similarly, incorrect O-ring installation may have caused some additional stressing of the elbow. The latter two factors, however, are not considered as primary causal factors of the piping failure.

Short Term Corrective Actions

To prevent any recurrence of a similar type failure, the following steps were taken.

1. The Auxiliary Condenser inlet line had additional fiberglass material added to the elbow to strengthen it and increase its pressure capacity. Calculations were performed to determine the additional material necessary to eliminate any possible material degradation concerns. This action was completed prior to plant startup.

2. Careful attention to the correct assembly of the O-ring to ensure the optimal gap between the O-ring retainer and the flange faces was met. The discharge line was also inspected and evaluated. These actions were completed prior to plant startup.

3. Design Change Package (DCP) 91-0288 significantly upgraded the strength and resistance to loosening (under operational system loadings) for supports 1N71-H0013 and 1N71-H0021 ("anchors" on both inlet and discharge N71 piping.) This DCP was implemented prior to plant startup.

Long Term Corrective Actions

In addition to the above steps, the Auxiliary Condenser discharge piping fiberglass elbow will be evaluated to determine if reinforcement of this elbow with additional fiberglass is necessary. This evaluation will be performed in light of the contribution of age and strength degradation to the root cause of the failed suction elbow, the lower operating pressure of the discharge piping and the previously stated pipe support modifications. This evaluation will completed by the end of RF03. An evaluation to determine the need for heat tracing on the fiberglass elbows will also be completed by the end of RF03.

The O-ring retainer and flange face spacing for the discharge elbow was inspected during the plant shutdown and did not h the .0625 inch gap required for optimum spacing. This line will be reworked to correct the spacing error by the end of RF03. An evaluation was performed to justify interim operation based on the lower operating pressure of the line, the support modification performed, and the results of inspections performed prior to plant startup. All major portions of the fiberglass piping will be visually inspected for flaw indications during RF03.

II. EQUIPMENT PROBLEMS AND ANOMALIES

Various equipment problems were experienced following the December 22, 1991 circulating water pipe rupture and subsequent plant shutdown. A summary of the significant problems encountered and the associated corrective actions is provided below.

A. Electrical Equipment

1. Bus L11 Failure to Transfer

Upon plant shutdown, i.e., turbine trip, the plant auxiliary loads are transferred to plant startup power sources. This is accomplished automatically by: (1) opening 13.8kV breaker

L1102 and closing breaker L1006 and (2) opening 13.8kV breaker L1202 and closing breaker L1009. Both of these breaker automatic transfer schemes are driven by the same relay logic. The L1202 to L1009 transfer properly occurred, and the L1102 and L1006 transfer failed. Upon inspection of 13.8kV breaker L1006, maintenance found that its closing springs were discharged. All spring charging switches, fuses, etc., were found to be in proper position. Maintenance determined that a subcomponent of the breaker mechanism had broken.

Several additional problems occurred as a direct result of the failure of Bus L11 to transfer and were resolved when power was restored to the bus. They are as follows:

a. Control Rod Drive (CRD) Pump B tripped due to the momentary de-energization of the "loss of oil pressure" relay.
b. Switch S112 (345kV Main Transformer disconnect switch) would not open due to loss of power to the motor which operates the switch.
c. Various containment isolations occurred due to the loss of Reactor Protection System (RPS) Bus "B" and other low voltage buses:

    - Reactor Water Clean Up
    - Reactor Water Sample Line
    - Backup Hydrogen Purge
    - Balance of Plant

d. A Control Room Emergency Ventilation recirculation mode initiation occurred as a result of losing 120 VAC Panel K-1-N.

e. Power was lost to floor and equipment drain sump pumps.

Short Term Corrective Actions

The breaker subcomponent which failed (a control device relay) was replaced and breaker L1006 was successfully retested.

Long Term Corrective Action

No long term corrective measures were required.

2. Motor Feed Pump (MFP) Breaker Failure to Close

The MFP breaker logic was set in AUTO-START response mode at the time of the event. With the two Reactor Feed Pumps turbines tripped, the MFP will feed water into the reactor vessel continuously or until a vessel Level 8 is reached. After the Level 8 signal clears, the operator can reset the Level 8 trip signal and the MFP will again auto start. This

trip/reset action occurred 15 times over a two hour period. On the sixteenth trip reset, the MFP did not automatically start.

Short Term Corrective Actions

An engineering review of the MFP motor's breaker control logic did not reveal any anomalies which explain the breaker's failure to close on the sixteenth close actuation demand. This review included examination of the breaker's anti-pump control logic.

In addition, the breaker was removed from the cubicle and cycled satisfactorily using the breaker testing equipment. The breaker was disassembled and contacts were inspected. The breaker was reassembled and operated several times in the test position in the switchgear. No problems were found. During the initial post event startup of the MFP, the motor was monitored for any unusual noise or vibration. No abnormalities were observed.

Long Term Corrective Actions

A failure of the MFP breaker occurred on January 29, 1992. A failure evaluation is currently in progress and will review any relation between the recent failure and the one which occurred on December 22, 1991.

3. Startup Transformer Deluge Initiation

This Fire Protection System feature functioned per design when the rate of rise sensors detected a rapid temperature rise when the comparatively hot N71 water (approximately 80 - 85 degrees Fahrenheit) hit the much cooler transformer. The amount of water and location of water contact did not pose a problem as evidenced by the continuous operation of Startup Transformer 100-PY-B.

Short Term Corrective Actions

No corrective actions were required.

4. Equipment Problems resulting from Water Intrusion

a. Electrical and communication manholes Nos. 1, 2, 3, 4 and 7 were flooded during the event. Security manholes Nos. 60, 66, and 67 were also flooded. In manhole No. 2 a small amount of water was observed leaking from conduits. This resulted in water in a Division III Unit 2 Motor Control Center (MCC). The MCC, from the partially completed Unit 2 plant, was not energized. The only other electrical equipment damage resulting from manhole flooding was isolated to manhole No. 3. Water from this manhole ran back into the south-east corner of the

Emergency Service Water Pump House (ESWPH) to electrical junction box JB1-2114. The water then passed through a series of conduits into the MCC EF1A12, temperature detector 1P45-N088A, and transmitter 1P45-N090A. Most of the water ran to the floor; however, a small amount of water flowed into MCC compartment C causing a 120 VAC control transformer to short. Two additional instruments in the ESWPH, 1P45-N0100A and 1P45-N0220A were found to have water in them which appeared to be unrelated to the flooding event. No plausible pathway for water entry into these instruments was determined.

b. Ground alarms were experienced on operation of Service Water valves OP41-F0420 and OP41-F0430 which were also suspected to have resulted from flooding. There was no water found in the valve pit for these valves and the valves closed when required.

Short Term Corrective Actions

The conduits entering junction box JB1-2114 in the ESWPH were sealed to minimize water entry. Additionally a hole plug was removed from the bottom of JB1-2114 to allow water to drain to the floor rather than following downstream conduits. The affected instruments in the ESWPH were repaired or replaced as necessary.

The motor operator for Service Water valve OP41-F0430 was found to be grounded and was subsequently replaced. Valve OP41-F0420 was inspected and satisfactorily tested with no problem identified.

Long Term Corrective Actions

Additional affected equipment will be inspected as necessary.

B. Mechanical Equipment

1. Scram Discharge Volume Failure to Drain

The scram discharge volume (SDV) failed to drain following the manual scram insertion due to a failed stem coupling on the outboard drain valve 1C11-F0181. The coupling joins the actuator to the valve stem. A notification was made to the NRC at 2225 hours on December 22, 1991 to report the SDV drain failure pursuant to the requirements of IE Bulletin 80-14. The failure was similar to failures reported in General Electric (GE) Nuclear Services Information Letter (SIL)-422. The consequences of the failed scram discharge drain valve stem connector was not significant. All control rods were fully inserted with the scram signal.

Short Term Corrective Actions

A replacement coupling was installed using the guidance provided in GE SIL 422. Detailed instructions were included in the associated Work Order to ensure proper assembly during the reinstallation process.

Long Term Corrective Action

As an additional enhancement to improve the reliability of this component, Engineering Design Change Request (EDCR) 91-0289 was initiated to evaluate potential design improvements to the stem coupling arrangement.

2. Instrument Air Pressure Not Maintained During Event

It was originally believed that a problem existed in the Instrument Air System due to an inability to maintain system pressure above 86 psig with a scram inserted and the Safety Relief Valves being cycled. A detailed evaluation of the sequence of events, system pressure and overall system response was performed. The analysis concluded that the system had functioned as designed during the event and the Unit 1 Instrument Air Compressor was able to supply all required air for important equipment manipulations. The analysis revealed interrelations associated with operating modes of the compressors which were not immediately understood.

Short Term Corrective Actions

The analysis of suspected Instrument Air System problems resolved previous concerns regarding overall system performance. No additional actions are required.

C. Structural

The only significant structural damage resulting from this event was confined to the pipe support discussed previously and soil displacement in the area where the ruptured piping exited the ground. Some of the soil and stone used around the yard area structures was also displaced as a result of the flooding.

Two security perimeter detection zones in the vicinity of the pipe rupture were affected due to the washout of aggregate under the associated security fencing. Appropriate compensatory measures were taken. Additional areas affected include a concrete walkway which was partially damaged and minor housekeeping problems from displaced silt and debris.

Short Term Corrective Actions

The soil adjacent to the damaged N71 piping and support was replaced per direction of Engineering department personnel. Aggregate which washed away under the perimeter security fence was also replaced.

Areas where housekeeping was degraded as a result of the pipe rupture were cleaned up prior to plant startup.

Long Term Corrective Actions

The remaining corrective measures involve cosmetic repairs to the yard area and repair of the damaged sidewalk. These activities will be prioritized commensurate with ongoing plant activities.

III. RADIOLOGICAL CONSEQUENCES

As a result of the December 22, 1991, event, slightly contaminated water and sludge were deposited in the basement levels of the Intermediate Building, Radwaste Building, Control Complex, and Unit 2 Auxiliary Building. The contamination was spread when floor drains in the buildings backed up during the event. Power to building sump pumps was temporarily lost during the event, which contributed to the water level in the buildings.

A portion of contaminated water which entered the Unit 2 Auxiliary Building was inadvertently discharged to the site storm drain system through an unmonitored pathway. This resulted from a temporary hose connection which connected the Unit 2 Auxiliary Building sump to the Turbine Power Complex sump and ultimately to the environment. The radiological consequences of the event are minimal as indicated by the table below, which compares the conservative exposure estimates to the limits contained in the Perry Technical Specifications.

	Event (mrem)	Tech Spec limit (mrem)	% of Tech Spec limit
Total Body Dose	0.000017	3.0	0.00057%
Organ Dose	0.000031	10.0	0.00031%

Short Term Corrective Actions

Building areas which became contaminated as a result of the pipe rupture event were surveyed and subsequently cleaned up prior to plant startup on January 3, 1992.

The temporary hose connection from the Unit 2 Auxiliary Building sump has been removed, eliminating any potential pathway to the environment.

The site storm drain system was cleaned during the week of January 27, 1992.

IV. SAFETY ANALYSIS

None of the equipment problems or anomalies described impacted equipment required to safely shutdown the plant; therefore, this analysis will focus mainly on the flooding aspects.

The water discharged by the 36" diameter N71 line break located north of the Heater Bay at approximately 620' elevation, generally flooded the yard area in the immediate vicinity of the break. Approximately one to two feet of water could have existed for a short duration at the west boundary of the flooded area.

A. Normal Design Flow Path

Normally, most of the water from the break would be dissipated by surface run-off towards low lying areas away from the plant. (For this break, most of the water would run-off in the north and north-west direction and some in the north-east direction). Some of the water would seep through the class B/C fill (at a very slow rate, as Class B/C fill is nearly impervious to water) around the building and reach the Underdrain system. The Underdrain system consists of a 1'-0" thick porous concrete mat under the building foundations and a 12" diameter porous pipe routed around the perimeter of the plant. The porous pipe carries the collected water to nine (9) individual pumps located in manholes spaced around the nuclear island. The water collected in the manholes would be pumped to the gravity discharge piping (36" to 48" diameter steel pipe, at El. 588' [high point] to El. 579' [low point]). In the unlikely event of the failure of all nine (9) pumps, the water level in the manholes would rise to El. 588' and be drained to the ESWPH via the gravity discharge piping. The underdrain system is designed for a postulated break in the circulating water system (12'-0" diameter fiberglass pipe) and is sized to handle the flow from such a break. The break in the 36" diameter pipe which occurred above grade was determined to be bounded by the break postulated for the design basis of the Underdrain system.

B. Estimate of Actual Flow Path

A walk-down conducted on December 22, 1991, revealed that the cover for manhole No. 20, immediately to the west of the N71 pipe break, had been left open. This provided a direct and a much more rapid path for some of the flood water to the Underdrain system. This, along with the water that seeped through the ground to the Underdrain system, is considered to be the main flow path to the Underdrain system. The pumping capacity of the Underdrain pumps was exceeded for some time (this explains the high water level alarm received in the Control Room after the break; the alarm is set at El. 568.5').

The pumped discharge portion of the Underdrain system was probably subjected to a more rapid flow from the break (due to the open manhole) than anticipated by design. However, this did not create a safety concern since the pumped discharge system is not the primary

system for keeping the water level below El. 590'. The Gravity Discharge system, designed to perform this function, has been shown to be adequate to handle a break in the N71 system which envelopes the current break (discussed above). Further, the ground water level was lowered to El. 568.5' soon after the break as confirmed by a walkdown on December 24, 1991, and piezometer water level readings taken on December 26, 1991. This confirms that the Underdrain system performed its function as designed.

Additionally, due to open manhole No. 20, there is a possibility that the capacity of the gravity discharge portion of the Underdrain system was temporarily exceeded. This would result in the water level rising above El. 590' in the manhole. However, this water would be discharged to the lake via the Gravity Discharge system before it could fill the porous concrete and the Class A fill to El. 590'. Thus, the water level could not have exceeded El. 590' (design basis of the Underdrain system).

The path of ingress of water into the plant buildings has been determined to be as follows:

1. Below El. 590', water most probably entered the safety-related buildings through holes/tears in waterstops/water proofing membranes at the building rattle spaces and piezometer tubes. The amount of in-leakage was also somewhat aggravated for this occurrence by the temporary loss of power to sump pumps within the buildings.

2. Above El. 590', all the water came into the plant when the electrical manholes filled and water ran back through underground duct banks into the plant, into the Service Water pump house and into the ESW pump house. The amount of water intrusion above El. 590' was insignificant and as such had no safety consequences. The cables in the electrical manholes were specified by design to operate for forty years submerged in water. The only safety-related equipment affected was in the ESW pump house where water entered into the building at the south-east zone Junction Box JB1-2114. Water then passed through a series of conduits and boxes and ended up in Motor Control Center (MCC) EF1A12 causing the failure of a space heater transformer. Although this had no safety consequences, it is of concern due to the fact that water flowed into safety-related switchgear. The inlet point for this water has been sealed to prevent any future occurrence.

The extent of in-leakage to plant structures can be attributed to a very rapid entry of flood water into the open manhole, causing the Underdrain system to fill up rapidly. It should also be noted that, for the most part, the floor drains were able to dissipate the water adequately. Thus the items designed to keep the buildings free of water performed in an acceptable manner. The actual flood path for this break was not the path anticipated by design, largely due to the open manhole; however, the systems designed to handle flooding performed adequately as demonstrated by the fact that no essential

safety-related equipment was lost as a result of the flooding. Therefore, this event is not considered to be safety significant.

Short Term Corrective Actions

Flooding damage from this event was primarily attributed to manhole No. 20 being left open. Administrative Procedure PAP-0204, "Housekeeping/Cleanliness Control," was revised to require manhole covers to be in place except when required to perform maintenance and inspections. The procedure change was made effective on January 3, 1992.

The conduits for the electrical junction box in the ESWPH have been sealed, as described previously in Section II.A.4 of this enclosure. It was also suspected that some piezometer tube caps may not have been in place at the time the event occurred, allowing water to enter buildings through the piezometer tubes. A walkdown was performed prior to plant startup to ensure piezometer tube caps were in place. Additionally, applicable procedures were reviewed to ensure that sufficient controls existed to maintain these caps in place after removal for periodic inspections.

Long Term Corrective Actions

No additional long term measures are required.