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SUBJECT: Forwards supplement to 891229 response to NRC Bulletin 88-008 re thermal stresses in piping connected to RCS,per 920623 telcon w/NRC.

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June 24, 1992

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Subject: Oconee Nuclear Station, Units 1, 2, and 3
Docket Nos. 50-269, -270, -287
NRC Bulletin 88-08

By letter dated December 29, 1989 information was provided to the NRC concerning the results of our analysis in response to Action Item 3 of the NRC Bulletin concerning thermal stresses in piping systems connected to the Reactor Cooling System.

A phone conservation conducted on Jun. 23, 1992 between the NRC Oconee Project Manager and Steve Sills of Oconee Civil Engineering indicated that additional information concerning this response was desired.

This letter provides a more detailed description of the HPI analysis performed on the piping referenced in the previous submittal.

J. W. Hampton
Vice President

OCK/ock

Attachments

xc: (W/Attachments)

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US Nuclear Regulatory Commission, Region II

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U. S. Nuclear Regulatory Commission

Mr. P. E. Harmon
NRC Senior Resident Inspector
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File: OS-801.01

6.0 DESCRIPTION OF HPI ANALYSIS

The HPI line was instrumented as shown in Figure 2 to quantify the level of stratification, if any, in the piping. The temperature data was reviewed and reduced into the piping thermal load shown in Figure 3. Figure 4 consists of ten pages of the actual temperature data collected. As noted in Figure 3 and described in detail in this Section, the thermal loading was constructed to envelope variations from the observed temperature data; so, final stress results are not sensitive to reasonable variations from the observed Unit 1 data in terms of flow rate, flow direction or cyclic frequency.

The analysis method used in the HPI analysis corresponds to the method presented in NB-3653 of ASME Section III, '87 Addenda, adapted for stratified conditions. To complete a NB-3653 fatigue evaluation requires that three stress intensities be defined:

Sn = Maximum Secondary Stress Intensity
Sp = Peak Stress Intensity
Salt = Alternating Stress Intensity

However, these code defined stress intensities must be agumented by additional stress quantities due to stratification. A stratified non-linear top of pipe to bottom of pipe temperature distribution can be described by a uniform portion, a linear portion and a non-linear portion. The uniform portion of the profile corresponds to the expansion temperature typically used in thermal expansion analysis. The linear portion, T-linear, produces a bending moment in the pipe. The moment equivalent of T-linear, Meq, can be calculated as follows:

$$Meq = E \alpha Z \text{ T-linear}$$

The resultant moment loads on the piping due to Meq are then multiplied by C_2/Z for inclusion in the maximum secondary stress intensity, Sn; and, multiplied by $K_2 C_2/Z$ for inclusion in the maximum peak stress intensity, Sp. The stress due to the non-linear portion, $\Delta T3$, is calculated as:

$$\frac{E \alpha |\Delta T_3|}{(1-\nu)}$$

and, included in the code equation for peak stress intensity.

Without a clearly defined fluid flow time history the stress due to ΔT_1 and ΔT_2 was approximated. Numerous one-dimensional heat transfer analyses were performed. The analyses were performed on cross-sections varying in thickness from 1/4" to 3/4" in .01" increments. A step change in temperature from 70^0F to 500^0F was applied to the inside surface. The hold time for the hot temperature was varied as was the heat transfer coefficient. Outside surface temperatures were then observed. This heat transfer analysis work was performed in November and December of 1988 as a part of the bounding analysis calculation for NRCB 88-08 (Reference 8).

The outside temperatures for the 3/4" thick section were tracked until the rate of change in temperature and the total change in temperature matched the values reported for Farley in NRCB 88-08. The hold time and heat transfer coefficient that matched the Farley temperatures were then taken as the representative thermal load to be used in the analysis. When applied to a .35 " thick section the analysis showed a rate of temperature change of 156^0F in one minute.

The through wall thermal stresses due to ΔT_1 and ΔT_2 were then time phased with the stress due to the stratified bending stress. The stress due to ΔT_1 and ΔT_2 equalled 7.0 Ksi when the combined stress was a maximum.

A Reynolds number was calculated for the heat transfer coefficient corresponding to the representative thermal load. The number indicated turbulent flow. The maximum rate of temperature change actually observed at the outside surface was 110^0F/min (See Figure 3). As noted in Figure 3, this maximum value was observed only once during the unexpected Oconee 1 reactor shutdown on 3/1/89 (See Figure 4 sheet 3 of 10). The 110^0F/min temperature change was accompanied by a total elimination of the thermal stratification, also indicating turbulent flow inside the pipe. Conclude that the 7.0 Ksi corresponding to an outside temperature change of 156^0F/min will be a conservative value to use in the evaluation of the cyclic thermal stratification event.

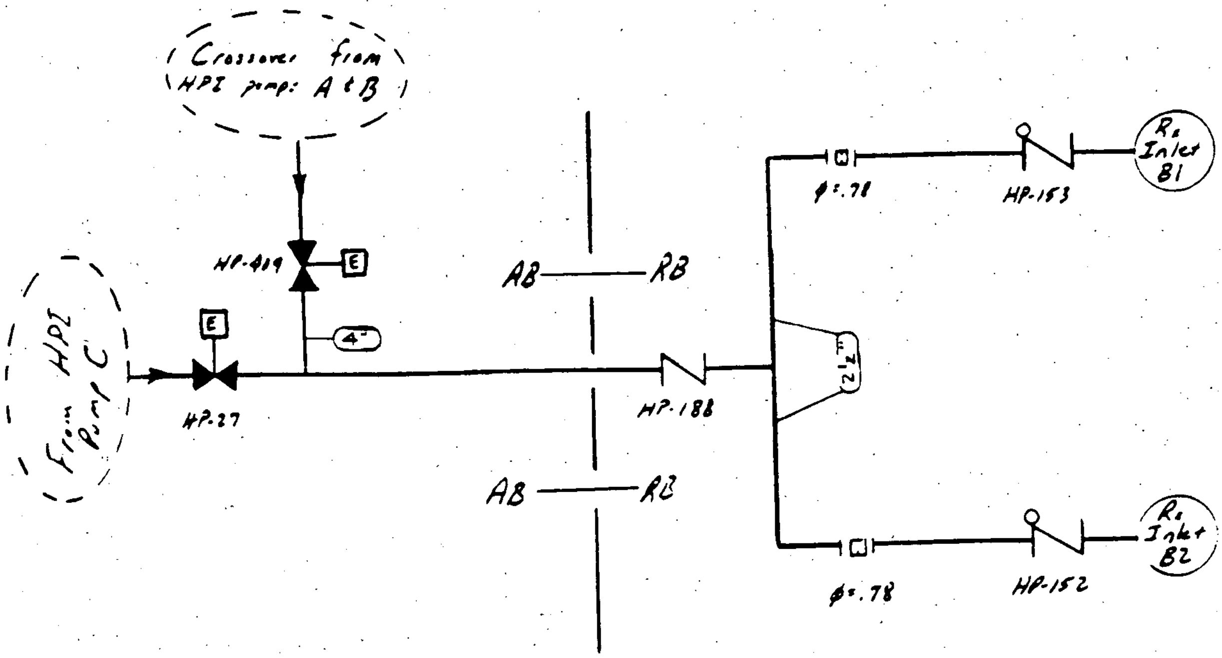
The actual observed temperatures also indicated an essentially linear temperature profile from top to bottom of the pipe. Thus, the stress due to the non-linear portion, ΔT_3, was assumed to be zero. Since the observed temperature distribution was approximately linear with no abrupt well defined boundary layer, any striping effects which could be associated with the stratified conditions were assumed negligible. Due to the relative low rate of heat transfer; and, since there are no significant material discontinuities in the affected HPI piping, the stresses due to the Ta-Tb effect were also considered negligible.

The Oconee RCS Functional Specification (Reference 14) defines 360 cycles of start-up and cooldown. So, 360 cycles of stress were evaluated when going from RCS full power conditions plus stratified conditions to the zero stress state. As shown in Figure 3 2.1×10^6 cycles of stress were evaluated when going from RCS full power conditions, plus stratified conditions, back to RCS full power conditions alone (i.e. 2.1×10^6 cycles of stress due to the stratified conditions).

The minimum cycle time actually observed was 20 minutes (See Figure 1). The maximum number of cycles observed in any two hour period was five, corresponding to 24 minute cycles; and, the maximum number of cycles observed duirng any eight hour period was nine, corresponding to 53 minute cycles. To account for the fact that the cycle time could potentially worsen the minimum observed cycle time (20 min) was cut in half, to 10 minutes (See Figure 3). In light of the actual observed data, assuming one cycle every 10 minutes over the life of the plant is considered conservative. One cycle every 10 minutes corresponds to 2.1×10^6 cycles over the forty year life of the plant.

The 120°F maximum top-to-bottom temperature difference was observed at only one location on the piping, immediately down stream of valve 1HPI-152. The temperature decays as the distance away from the RCS increases. At a point approximately ten feet upstream of valve 1HPI-152 (measured along the pipe and away from the RCS) the temperature decays to a point that stratification should not be significant. But for analysis purposes the maximum temperature difference of 120°F is rounded up to 150°F. This full 150°F stratification gradient is applied to the horizontal piping over the length of piping from points twenty-feet upstream of valves HP-152, 153 to the pipe-to-RCS nozzle weld points.

The maximum cumulative usage factor calculated for all of the Oconee unit HPI piping components was 0.81. The value at first appears to be high, close to the allowable value of 1.0. However, considering the conservative assumptions used in the analysis described above, the results adequately confirm the structural integrity of the line for the 40 year life of the plant.



Notes: 1) HPI Pumps A & B supply normal make-up (i.e. normal high pressure injection). HPI Pump C is used only for emergency safety injection.

2) AB = Auxiliary Building, RB = Reactor Building

3) The portions of HPI piping between HP-153 and Reactor Inlet Line; and, between HP-152 and Reactor Inlet Line, were identi as potentially susceptible to the type of event described in NRC Bulletin 88-08.

FIGURE 1

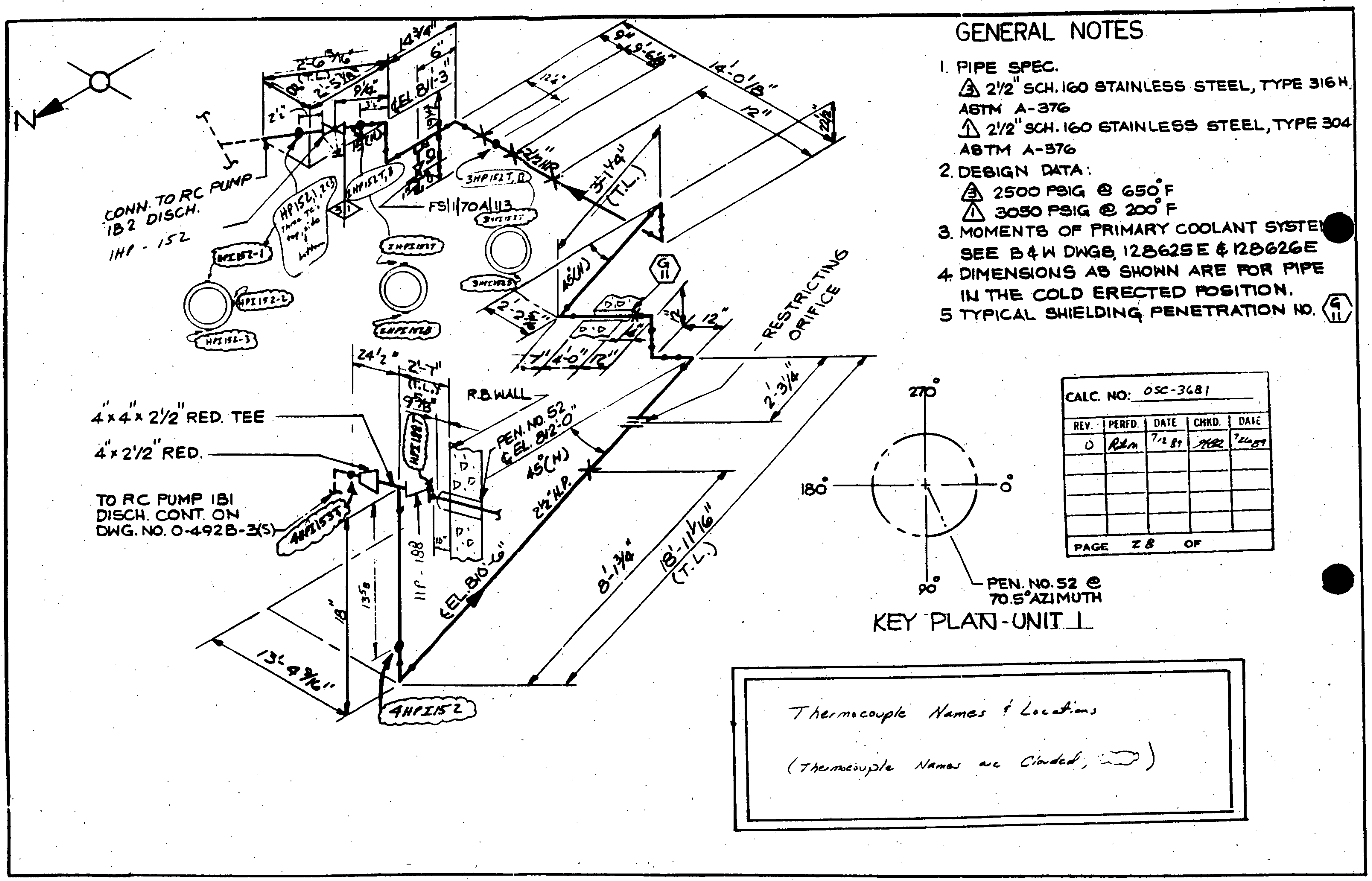
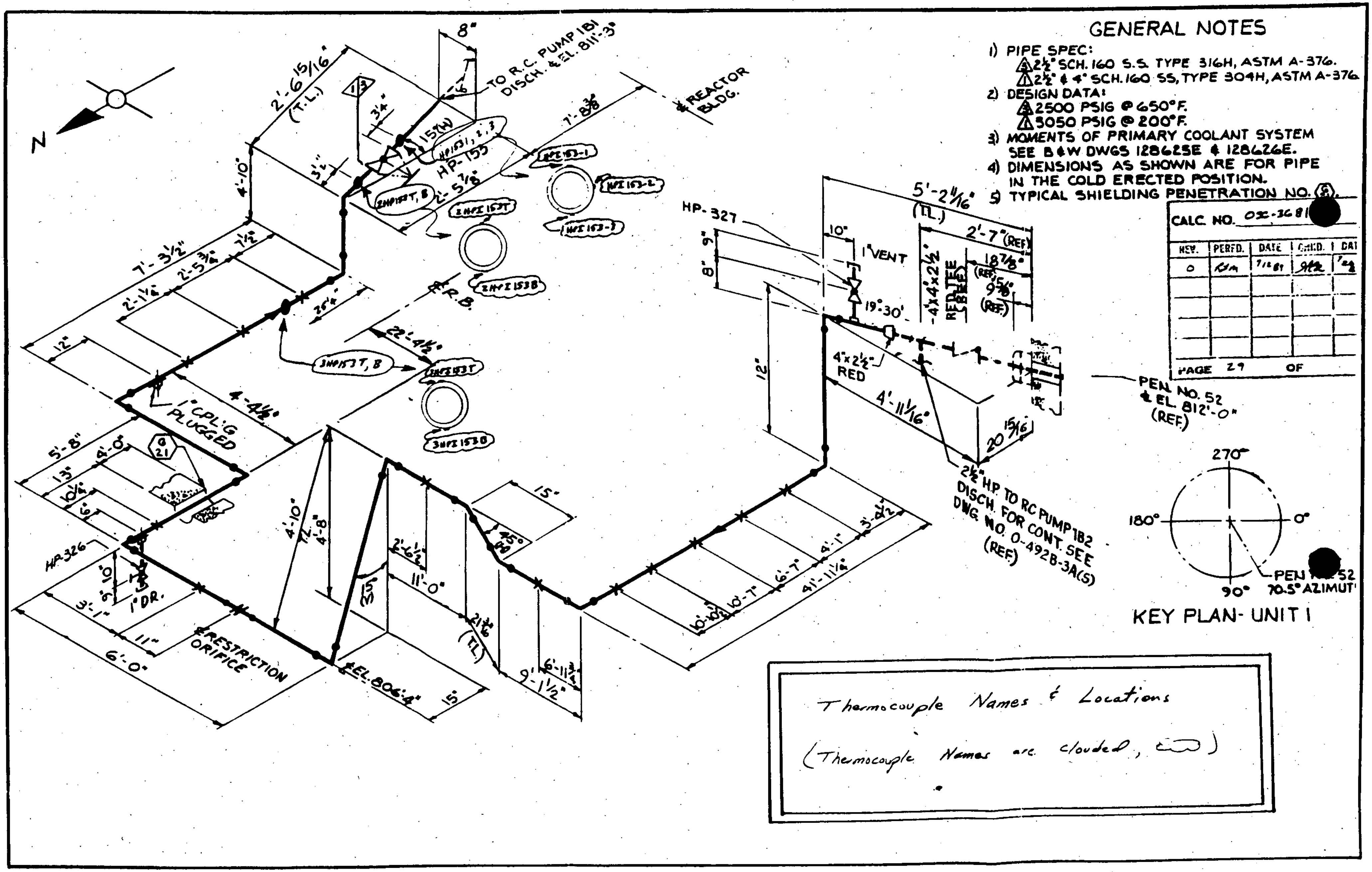

GENERAL NOTES
1. PIPE SPEC.
3 2 1/2" SCH. 160 STAINLESS STEEL, TYPE 316H, ASTM A-376
1 2 1/2" SCH. 160 STAINLESS STEEL, TYPE 304 ASTM A-376
2. DESIGN DATA:
3 2500 PSIG @ 650° F
1 3050 PSIG @ 200° F
3. MOMENTS OF PRIMARY COOLANT SYSTEM SEE B&W DWGS 128625E & 128626E
4. DIMENSIONS AS SHOWN ARE FOR PIPE IN THE COLD ERECTED POSITION.
5 TYPICAL SHIELDING PENETRATION NO. G 11
CALC. NO: OSC-3681
REV. | PERFD. | DATE | CHKD. | DATE
PAGE 28 OF
270°
180°
0°
90°
PEN. NO. 52 @ 70.5° AZIMUTH
KEY PLAN - UNIT 1
Thermocouple Names & Locations
(Thermocouple Names are Clouded,)
CONN. TO RC PUMP 1B2 DISCH.
1HP-152
FS|1|70A|113
RESTRICTING ORIFICE
R.B. WALL
PEN. NO. 52
℄ EL. 812'-0"
45°(H)
2 1/2" H.P.
4"x4"x2 1/2" RED. TEE
4"x2 1/2" RED.
TO RC PUMP 1B1 DISCH. CONT. ON DWG. NO. O-492B-3(S)
℄ EL. 810'-6"
℄ EL. 811'-3"
1HP-188
4HPI152
13'-4 9/16"
8'-1 3/4"
18'-11 1/16" (T.L.)
14'-0 1/8"
3'-1 1/4" (T.L.)
2'-3 1/4"
N

Figure 2


GENERAL NOTES
1) PIPE SPEC:
2½" SCH. 160 S.S. TYPE 316H, ASTM A-376.
2½" & 4" SCH. 160 SS, TYPE 304H, ASTM A-376.
2) DESIGN DATA:
2500 PSIG @ 650°F.
3050 PSIG @ 200°F.
3) MOMENTS OF PRIMARY COOLANT SYSTEM SEE B&W DWGS 128625E & 128626E.
4) DIMENSIONS AS SHOWN ARE FOR PIPE IN THE COLD ERECTED POSITION.
5) TYPICAL SHIELDING PENETRATION NO. 5.
CALC. NO.
REV.
PERFD.
DATE
CHKD.
PAGE 29 OF
N
TO R.C. PUMP 1B1 DISCH. & EL. 811'-3"
& REACTOR BLDG.
HP-155
HP-327
HP-326
1" VENT
4"x2½" RED
1" CPL'G PLUGGED
1" DR.
& RESTRICTION ORIFICE
& EL. 806'-4"
& R.B.
PEN. NO. 52
& EL. 812'-0"
(REF.)
2½" H.P. TO RC PUMP 1B2 DISCH. FOR CONT. SEE DWG. NO. 0-492B-3A(S) (REF.)
KEY PLAN- UNIT 1
270°
180°
0°
90°
70.5° AZIMUT
Thermocouple Names & Locations
(Thermocouple Names are clouded,)

Parametric Comparison Of Cyclic Thermal Stratification Data 'Analyzed' vs 'Observed'

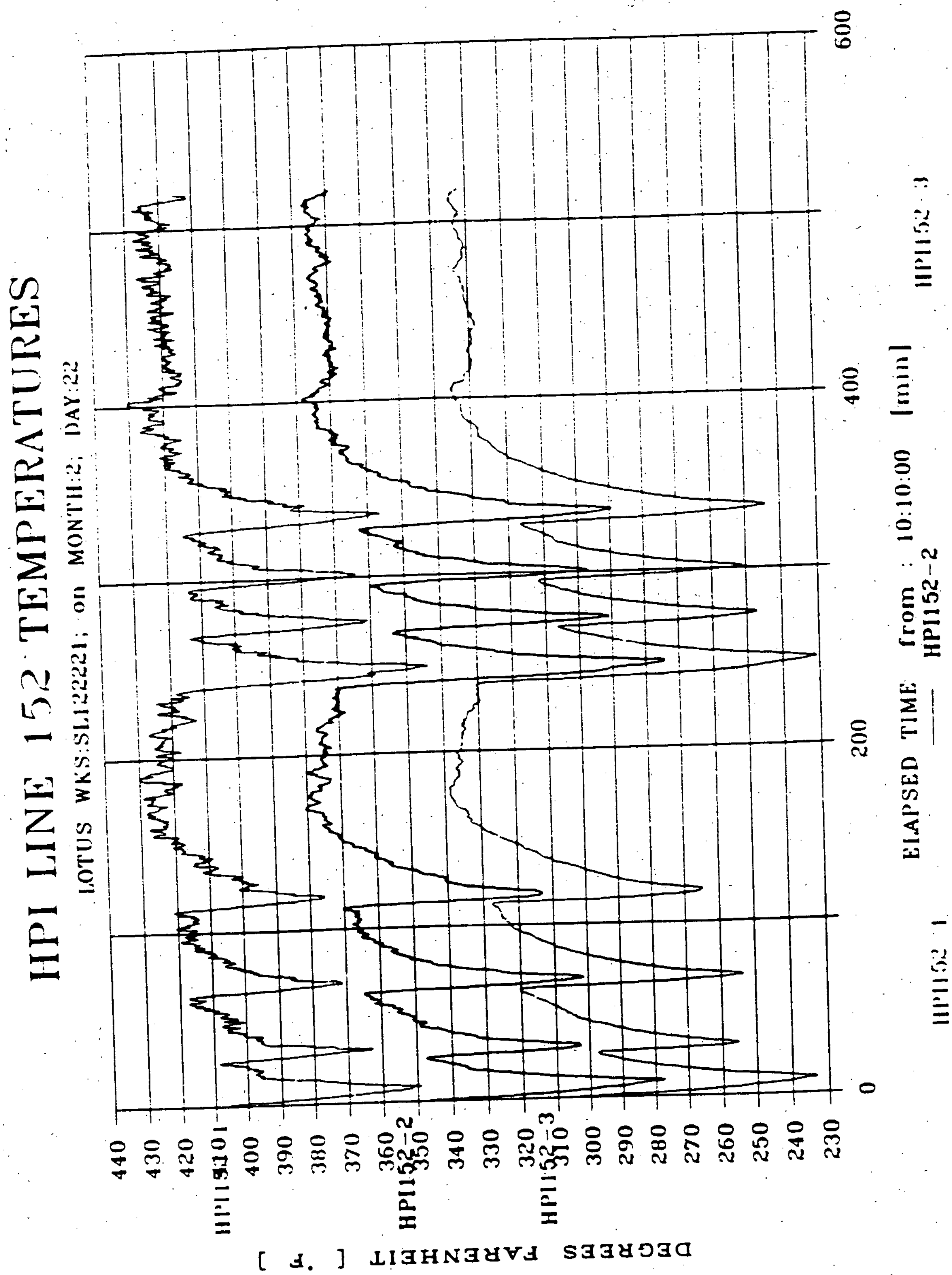
Quantity	Preliminary Bounding Analysis	Actual Observed	As Used in Final Fatigue Evaluation
Maximum rate of temperature change at outside surface	$200^{\circ}F$/min (note 1)	$110^{\circ}F$/min	$156^{\circ}F$ /min
Maximum temp. difference from of pipe to bottom of pipe; and, shape of gradient	200 F stepped at the three o'clock position	120 F linear from top-to-bottom	150 F linear from-top-to-bottom (note 2)
Amount of horizontal piping considered stratified per HPI leg (see Fig. 1)	3ft	10ft	20ft (note 3)
Number of applied cycles	1 cycle / 2 minutes =143,000 cycles / yr	1 cycle / 20 minutes =14,300 cycles / yr	1 cycle / 10 minutes =28,600 cycles / yr

Notes: 1) This maximum was observed only once, during the unexpected reactor shutdown on 3/1/89. The high rate of temp. change was accompanied by a total elimination of the thermal stratification (See discussion on page 7). A more representative value to associate with the 20 minute period cycles would be on the border of $10^{\circ}F$/min. Thus the $110^{\circ}F$/min used in the Fatigue Evaluation is conservative.

2) See discussion on page 8

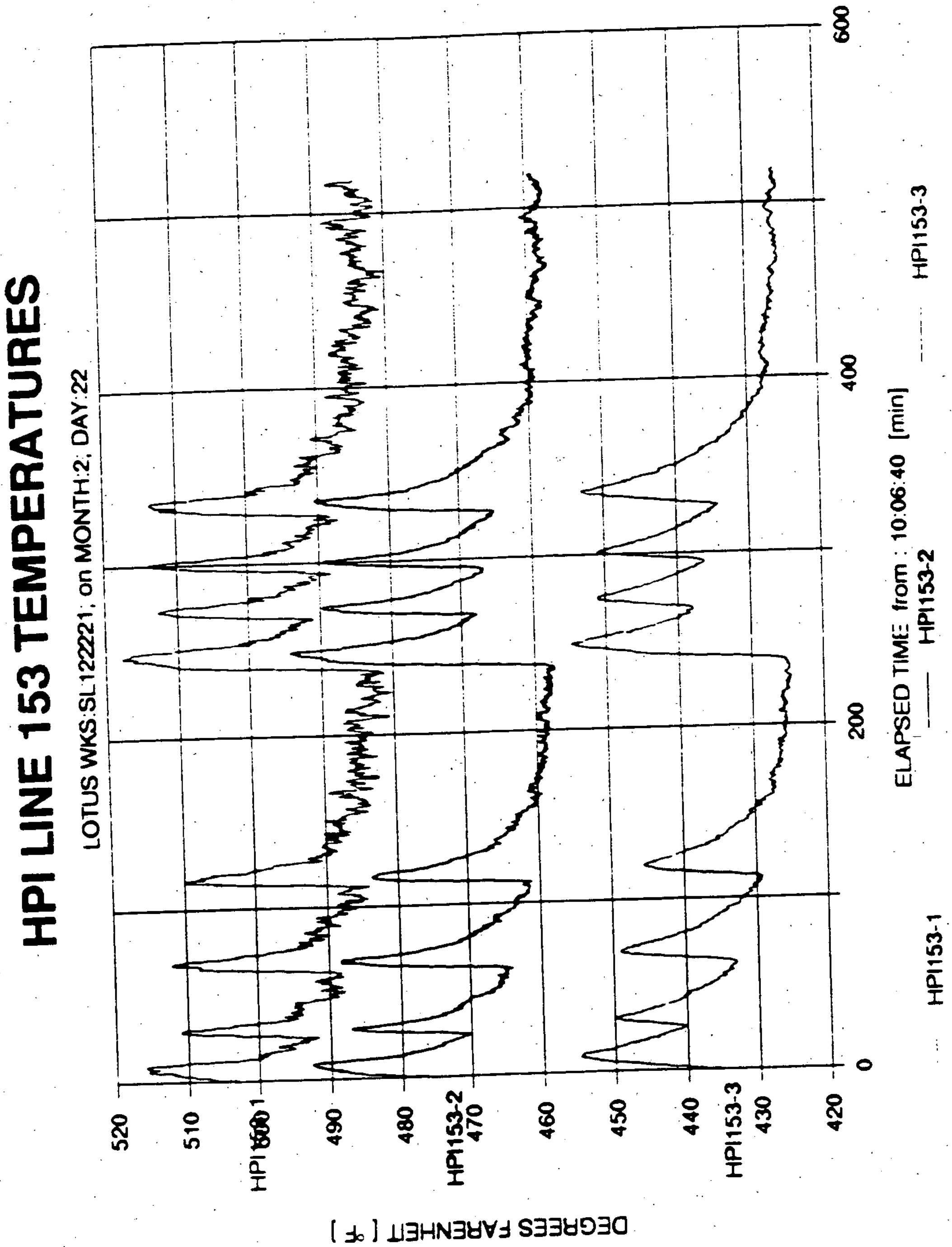
3) See discussion on page 8

FIGURE 3



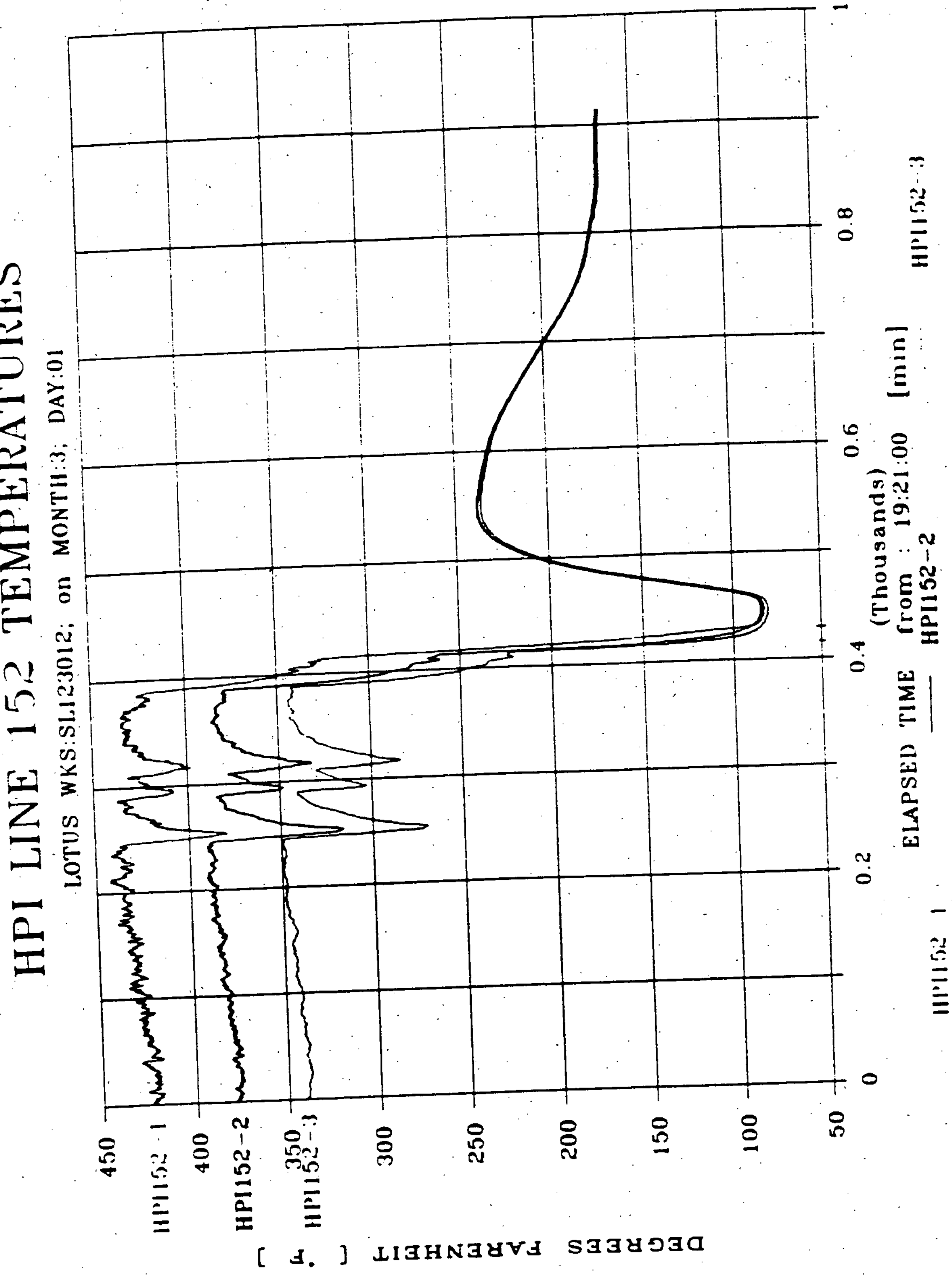
(FIGURE 4)

(Sheet 1 of 10)



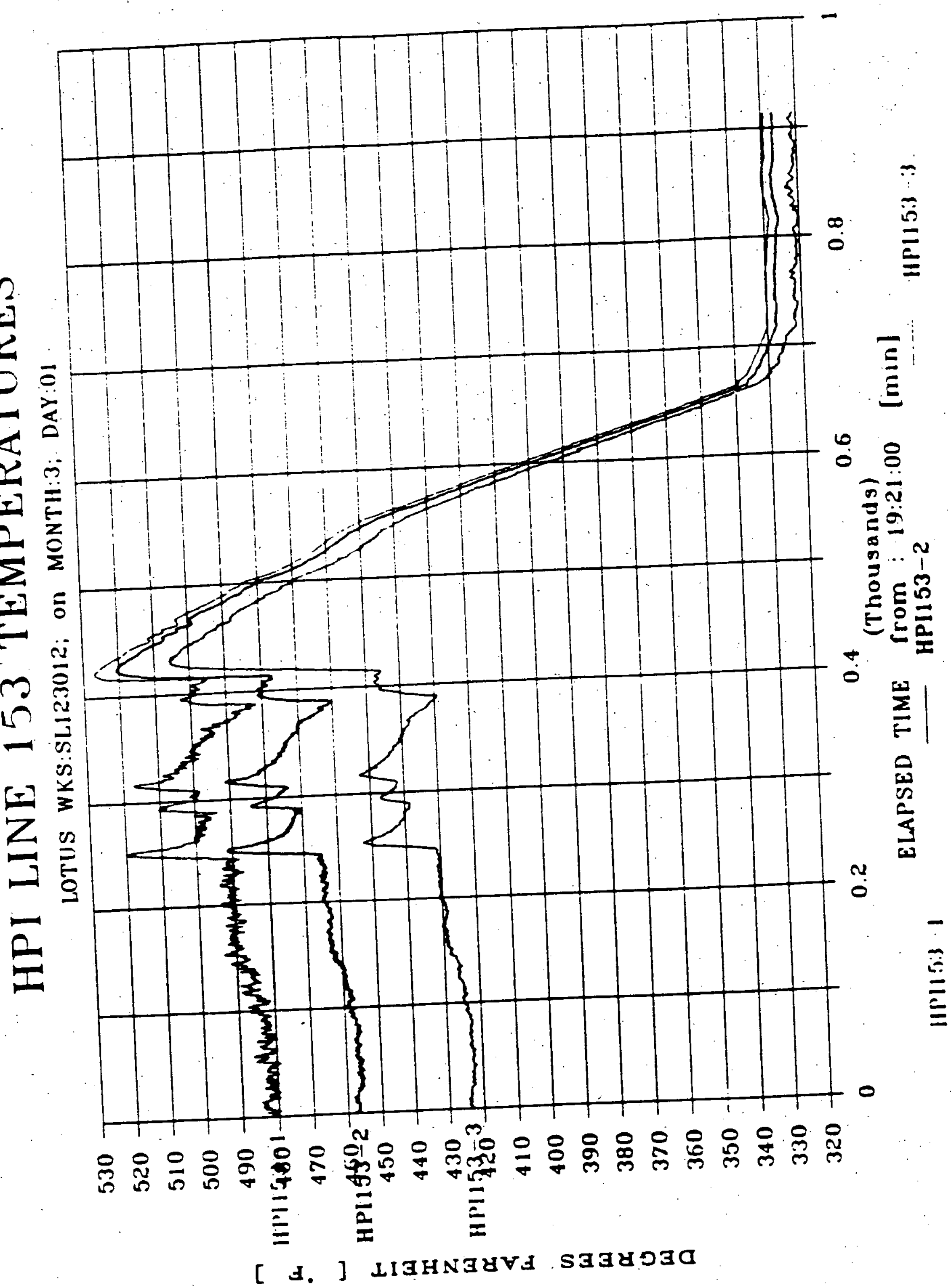
(FIGURE 4)

(Sheet 2 of 10)



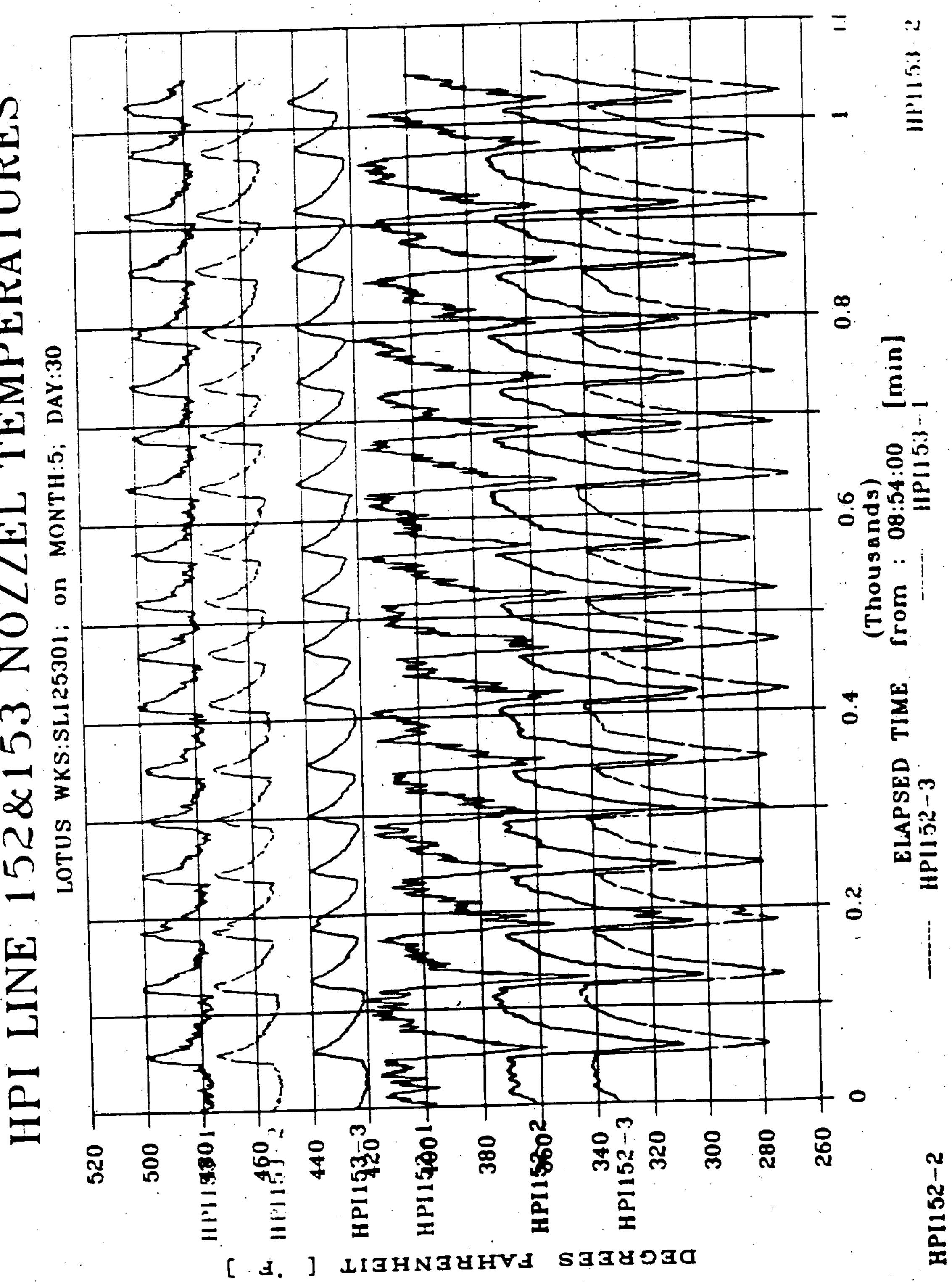
(FIGURE 4)

(Sheet 3 of 10)



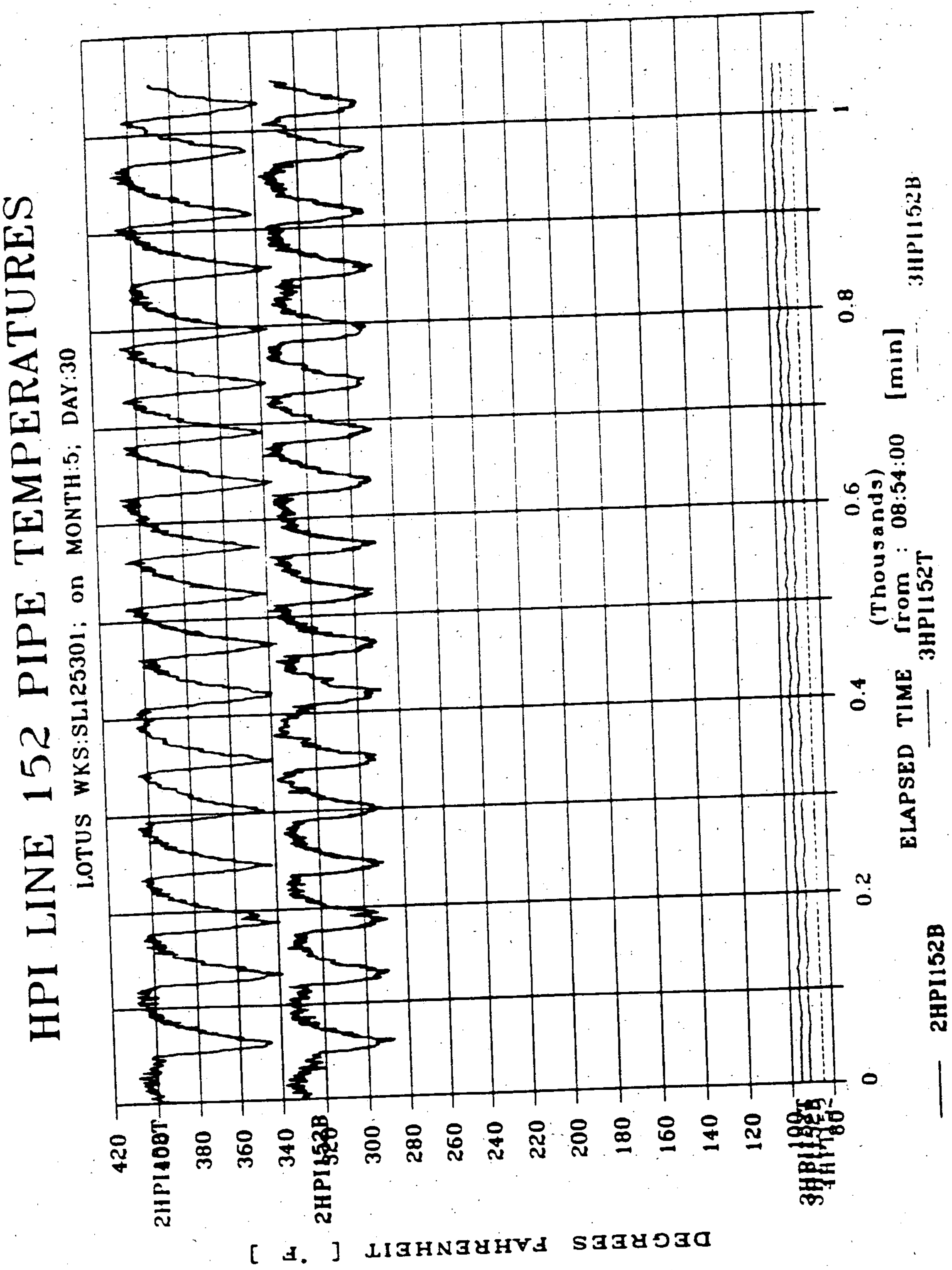
(FIGURE 4)

(Sheet 4 of 10)



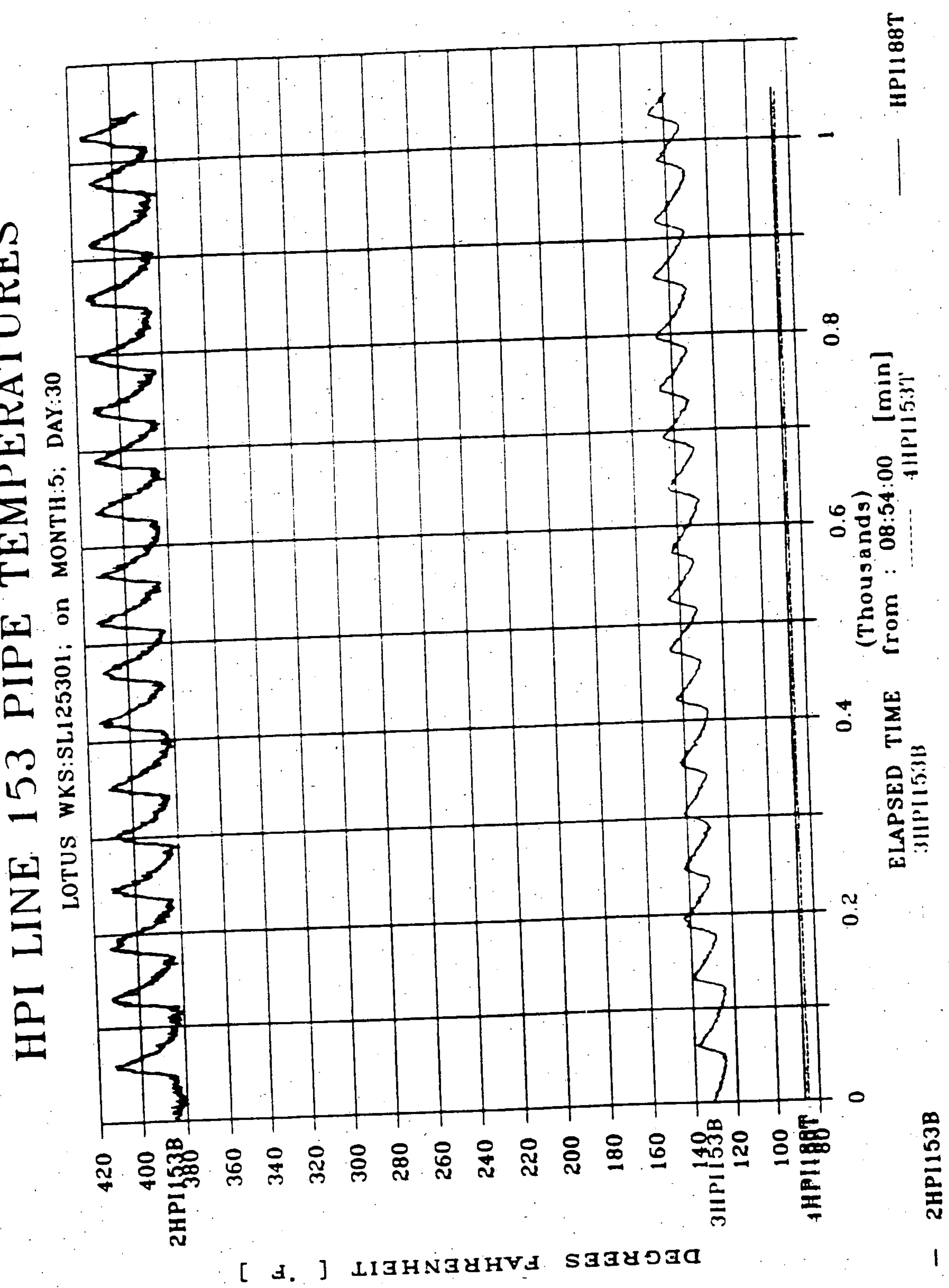
(FIGURE 4)

(Sheet 5 of 10)



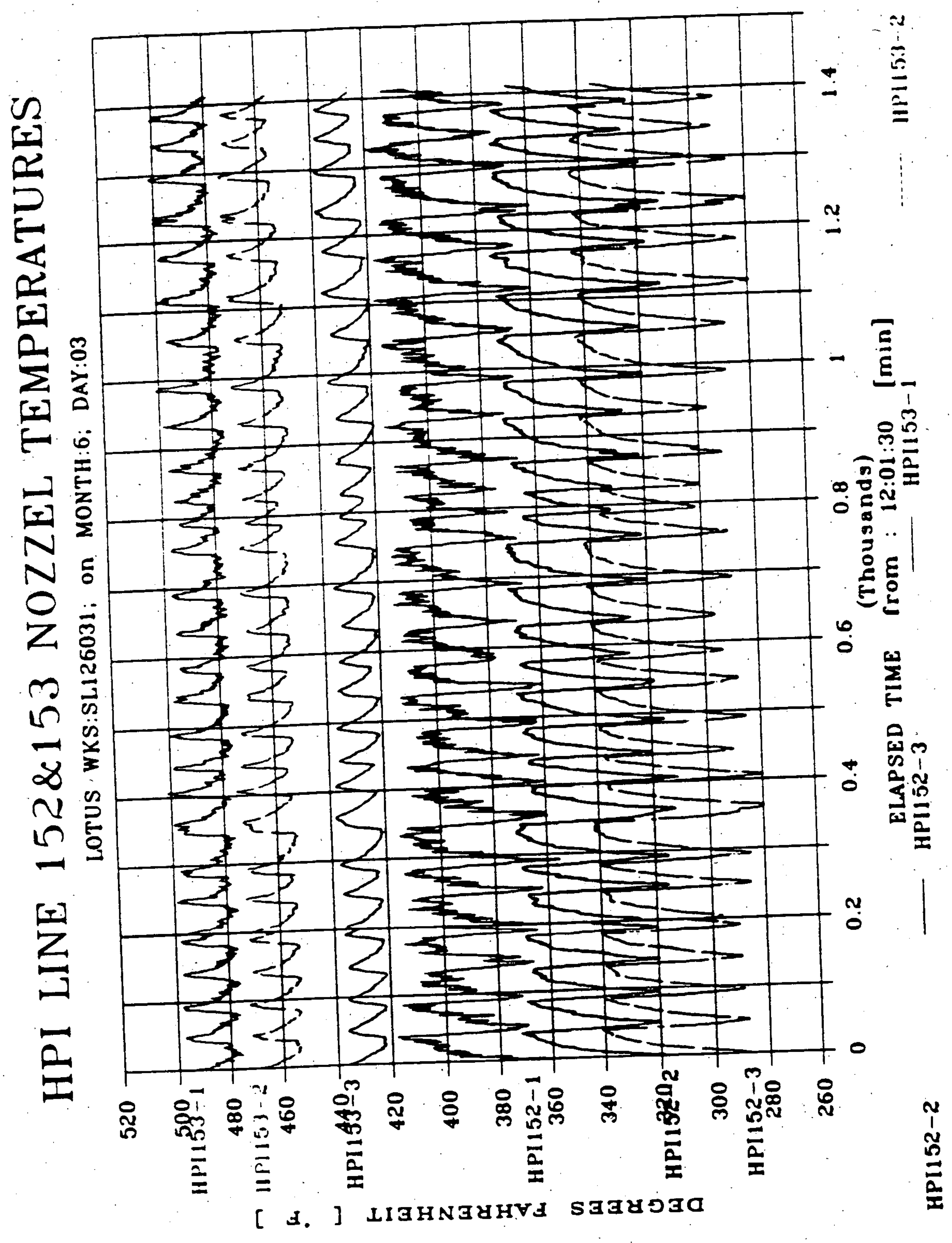
(FIGURE 4)

(Sheet 6 of 10)



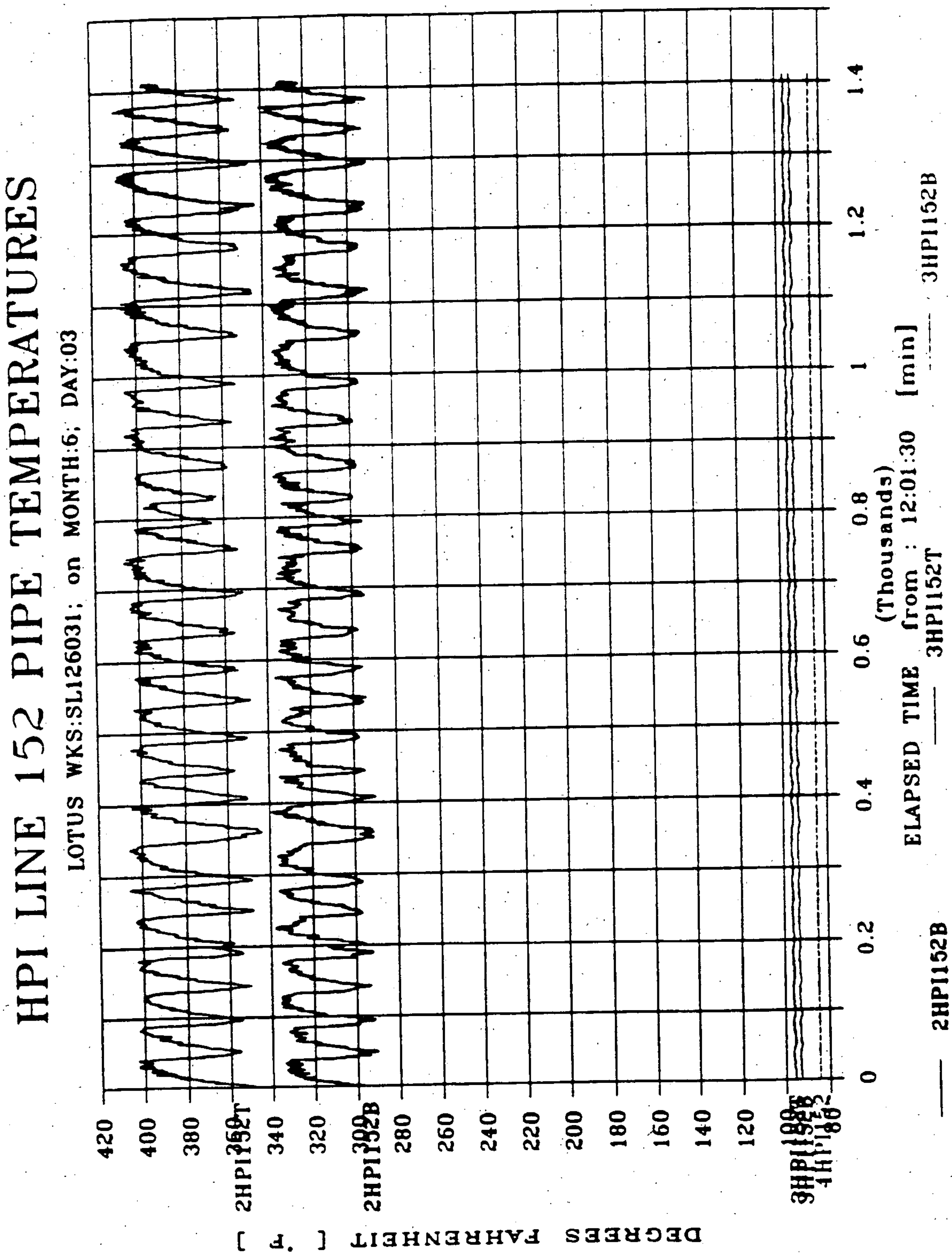
(FIGURE 4)

(Sheet 7 of 10)



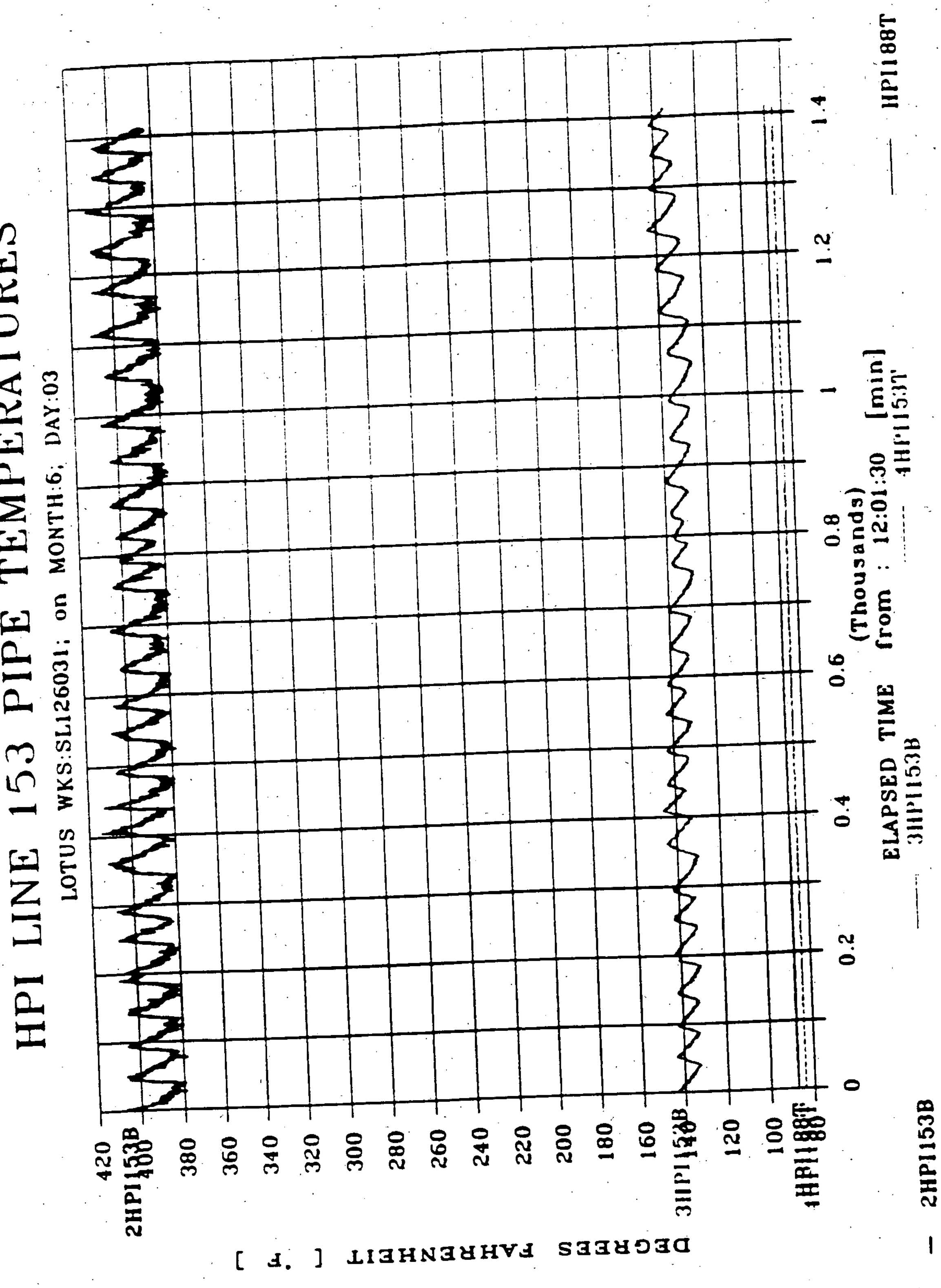
(FIGURE 4)

(Sheet 8 of 10)



(FIGURE 4)

(Sheet 9 of 10)



(FIGURE 4)

(Sheet 10 of 10)