NORTHEAST UTILITIES

NU

P.O. BOX 270
HARTFORD, CONNECTICUT 06101
(203) 666-6911

October 24, 1979

Docket No. 50-336

Director of Nuclear Reactor Regulation
Attn: Mr. R. Reid, Chief
Operating Reactors Branch #4
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

References: (1) E. L. Conner telecopy dated October 16, 1979.
(2) W. G. Counsil letter to R. Reid dated September 28, 1979.

Gentlemen:

Millstone Nuclear Power Station, Unit No. 2
Feedwater System Piping

Please find enclosed as Appendix #1, Northeast Nuclear Energy Company's (NNECO) response to questions raised by NRC relative to fatigue crack growth and repair options applicable to the feedwater system piping cracks. This information is essentially comprised of that which was presented to the NRC Staff orally in Bethesda, on October 19, 1979.

During that meeting, a question was raised by the Staff relative to the probable cause for crack initiation and the rationale for its present depth of approximately 100 mils. As a member of the Westinghouse Owner's Group on Feedwater Pipe Cracking, we are currently involved in an extensive program aimed at assessing this cracking phenomena. Feedwater piping strain, temperature, and acceleration have been measured at several plant sites including Millstone Unit No. 2. This data has not revealed any significant dynamic strain which could be construed to have caused the crack initiation. Significant thermal stratification in the first horizontal run of the feedwater piping has been measured at all plants during plant startup, coincident with low feedwater flow rates. Stresses calculated from this steady-state stratified thermal profile do not reveal levels sufficient to cause crack initiation or appreciable crack growth. It is our belief, however, that this existence of a zone of temperature instability is the cause of crack initiation and crack growth.

NNECO has had considerable experience with two-temperature fluid regimes in feedwater systems as a result of inspections performed on the Millstone Unit No. 1 RPV feedwater nozzles beginning in 1974. This inspection and subsequent thermocouple data revealed a thermal instability phenomena of sufficient magnitude to initiate and grow cracks to a certain depth. At that time, the General Electric Company initiated a comprehensive program to resolve these cracking occurrences.

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This program culminated in the publication of two (2) GE reports, NEDE-21480 and NEDE-21821, which document in detail, experimentation and analysis to support continued safe operation of these BWR plants.

PWR feedwater piping temperature measurements have not confirmed the presence of high cycle (~1 hz) water temperature fluctuations during these periods of thermal stratification. However, tests performed by GE at their two-temperature test facility and the Moss Landing Facility demonstrate a trend toward thermal fluctuations in the vicinity of the two-temperature fluid interface. Assuming that fluid temperature fluctuations on the order of 300°F are present during low flow conditions (Millstone Unit No. 2 measurements reveal a potential of 350°F), it can be seen from Table 3-1 of NEDE-21821 that cracking can initiate after approximately 400 hours of hot standby operation. It is estimated that the thermal skin stresses for carbon steel are approximately 2/3 of those for stainless steel. The depth to which these skin effects penetrate is represented by Figures 3-2 through 3-5. It is noteworthy that very little metal response to water temperature fluctuation is felt beyond the 0.1 inch depth, particularly for the higher frequency cases.

There is no evidence of a driving force which could cause appreciable crack growth beyond the 100 mil depth to occur in the Millstone Unit No. 2 feedwater piping system. This is supported by analytical and experimental observations of the Millstone Unit No. 2 system. Conditions which have caused larger crack growth at other plants could be:

(1) The metallurgical condition of the material.

(2) The residual stress distribution.

(3) Counterbore geometry.

(4) External loading conditions.

Regardless of the cause, it is important to note that none of the above conditions change with time. That is, the state of stress intensity factor at the feedwater pipe crack tips can be described by information obtained from the installed instrumentation and the ultrasonic examinations throughout future plant operation. The reexamination of these crack indications is scheduled to be performed during the upcoming October, 1979 outage. This and the other planned interim examinations will confirm that the crack growth is within the predicted crack growth rates.

As stated in Reference (2), if any increase in crack depth is evidenced, within the tolerance of the ultrasonic examinations, the cracks will be repaired. The results of this inspection will be plotted and compared directly against those taken in August, 1979. It is judged that any appreciable change in crack front geometry or depth will be readily apparent.

With regard to operational philosophy of the auxiliary feedwater system during plant startup, NNECO will continue to operate in the continuous feed mode whenever possible. That is, once auxiliary feedwater flow is established, abrupt changes in flow rate will be avoided in order to minimize the potential for crack propagation.

A permanent repair is planned for the 1980 refueling outage. At that time, sufficient data will have been reduced and causative mechanisms identified such that positive solutions can be employed to minimize the potential for further cracking. This approach results in the significant advantages of minimizing personnel exposure and reducing plant outage time. Performing a repair at this time is further complicated by the recent sick-out organized by the local craft unions. Resolution of this situation may not occur for several weeks. To effect a repair at this time may require solicitation of non-union personnel and qualification and indoctrination to the various repair procedures. It is anticipated that this could add substantially to the duration of the outage, if the repair were to be undertaken at this time. Deferring the replacement, therefore, results in substantial man-rem and economic benefits.

Should NNECO's anticipation of no detectable crack growth be realized, the 1980 replacement program is concluded to be technically defensible and appropriate. An interim ultrasonic examination, prior to March 1, 1980 will be conducted to verify the absence of crack growth. The leak detection equipment will remain functional and be monitored without change from the current program until the issue is permanently resolved.

We trust you find the above information responsive to the Reference (1) requests and questions raised by the NRC Staff during our October 19, 1979 meeting.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

W. G. Counsil
Vice President

Attachments

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DOCKET NO. 50-336

APPENDIX #1

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

RESPONSES TO
ADDITIONAL INFORMATION REQUIRED
TO ASCERTAIN ACTIONS NECESSARY
REGARDING THE FEEDWATER SYSTEM PIPING

OCTOBER, 1979

PURPOSE

In response to the NRC request of October 16, 1979, the additional information required to ascertain actions necessary regarding the feedwater system, which was presented to the NRC on October 19, 1979, in Bethesda, Maryland, is hereby submitted.

Question 1

In your letter of September 28, 1979, you stated that thermal variations (stratification) was observed during low flow conditions. Address the potential for crack propagation during these low flow conditions (low cycle fatigue). Provide a quantitative analysis regarding crack growth rates during the thermal transient cycle.

Response

The inspections conducted in response to NRC I&E Bulletin No. 79-13 revealed linear circumferential indications adjacent to the steam generator feedwater nozzle safe-end to pipe and pipe to elbow welds in both feedwater piping loops. The largest observed linear indications near each weld were subsequently mapped by ultrasonic inspection in terms of through-wall depth and circumferential length. In addition, the area of interest was instrumented in order to establish the mechanical and thermal feedwater piping loading conditions during startup and full-power operation. The results of the instrumentation data specifically applicable to Millstone Unit No. 2 are presented in Attachment #1.

Knowing the crack sizes and orientation of the feedwater piping flaws, Westinghouse assessed the potential for crack growth in a conservative manner considering not only the original design basis transients but also the additional thermal loading derived from the instrumentation results at the subject unit. The assessment of crack growth for the linear indications in the feedwater piping was performed by Westinghouse and it is enclosed as Attachment #2.

The results of the conservative assessment indicate that the largest flaw in the feedwater piping system will not grow significantly. Furthermore, the final flaw size for the worst location is a factor of five (5) smaller than the established critical flaw size.

Question 2

Assuming the analysis requested above predicts crack growth at a sufficiently low rate to ensure adequate safety margins can be maintained until a permanent repair can be made at the June, 1980 refueling outage, provide the details of an augmented inspection program which verifies that crack growth has not occurred at a rate faster than predicted by the analysis.

Response

The results of the crack growth assessment confirm that crack growth will occur at a sufficiently low rate. Therefore, adequate safety margins will be maintained until the June/July, 1980 refueling outage.

The augmented inspection program for the observed feedwater piping flaws between October 31, 1979 and the next refueling outage was evaluated consistent with the present understanding of the feedwater piping cracking phenomena. Based on this and the results of the Millstone Unit No. 2 feedwater piping system instrumentation data, it is important to note that thermal loading conditions exist during plant startup and plant shutdown operations which have the potential to induce further crack growth. Therefore, it is imperative that the inspection frequency be established consistent with the objective to minimize the potential for crack growth in the interim period.

Based on the above, it is proposed that the feedwater piping flaws be inspected as a minimum prior to March 1, 1980 to verify that the actual crack growth is within the predicted crack growth. In addition, it is proposed to conduct additional inspections of the feedwater piping flaws at any plant cold shutdown of more than two (2) days duration between October 31, 1979 and the next refueling outage. However, the time interval between successive inspections shall be more than three (3) calendar months. All results of the additional inspections conducted in the interim period will be submitted to the NRC within seven (7) days following the completion of the examination.

Question 3

In the proposed repair/replacement program you submitted, you stated that the removal of the shield wall section can be made within design bases limitations.

1. Provide the technical information supporting your conclusion.

Response

The original shield wall model was modified to include a six (6) foot diameter by twelve (12) inch deep cutout. Imposing the design basis loading conditions indicates that the shield wall cutout will not degrade the load bearing capability of the shield wall. The design basis loading conditions were derived from the subject unit Final Safety Analysis Report.

Question 3.b

Provide assurance that the method of removing part of the concrete wall by drilling and chipping will not damage the concrete left in place and the existing reinforcing bars. Describe the quality assurance procedures which will be used during the concrete removal operation.

Response

The shield wall removal by drilling and chipping will be performed in accordance with the work procedures submitted to the NRC on September 28, 1979. Industry experience indicates that the proposed removal process will not damage the concrete left in place and the existing reinforcing bars.

As part of the QA Category I work procedures referenced above, Quality Control will monitor and perform a final inspection of the shield wall cutout to ensure that the shield wall removal was accomplished within the specified dimensional requirements and that the minimum specified covers exist for the specified rebar.

Question 3.c

Describe the procedure which will be used if the reinforcing bars must be removed.

Response

A grinding disk will be used to remove reinforcing bars.

Question 3.d

If replacement on the removed shield wall segment is required, address the following:

(1) Define the concrete mix which will be used to fill the recess in the shield wall.

(2) Describe the procedure for reinforcing bar replacement.

(3) Define the method to be used to ensure compatibility of the new and old concrete, especially the measures planned to limit shrinkage of the new concrete. Discuss the degree of working together that can be expected from the new concrete and existing wall.

Response

Based on the fact that the steam generator feedwater nozzle/safe-end to pipe weld will be subject to future periodic inspection, it is concluded that the shield wall cutout will remain as is to provide the required accessibility.

Question 4

Provide the details for material removal as discussed in repair Option B. Also, provide the detailed procedures for the weld repair on the ID of the pipe should the wall thickness be reduced from Code limits. Address the mock-up used to qualify the welding procedures, for training and to qualify the welders/welding machine operators.

Response

The Option B repair method consists of pipe removal outside the shield wall and repair of the steam generator feedwater nozzle safe-end to piping indications from the ID.

CE Chattanooga has developed a grinding fixture which will be positioned inside the pipe. Prior to positioning of the grinding fixture, a liquid penetrant examination will be performed to map the inside pipe/safe-end area containing the linear indications. A six-inch grinding wheel attached to the positioning fixture will be used to remove any linear indications. The width of the grinding wheel is approximately one inch. After the grinding operation, a final liquid penetrant examination will be performed to ensure complete removal of the linear indications.

The weld repair will be performed with the Diametrics internal welding fixture in accordance with applicable code requirements. The weld repair criteria will

be based on fatigue considerations rather than minimum wall thickness limitations specified by the ASME Section III code. Therefore, it is our intent to weld repair all ground-out areas from the ID in order to eliminate all stress intensi fication locations. The final weld repair contour will be polished and blended uniformly to the adjacent base material.

All welders will be qualified to the approved weld procedure. The weld procedure will be qualified in accordance with the applicable code requirements.

Question 5

Describe the simulation for welder training and qualification to account for the limited access between the shield wall and steam generator in Option A. Provide any details regarding the consideration of automated welding to make the nozzle to pipe repair.

Response

The Option A repair requires the specified shield wall removal in order to gain access to the steam generator nozzle safe-end to pipe welds. After shield wall removal, the feedwater pipe will be cut between the steam generator nozzle to safe-end weld and the safe-end to pipe weld as specified in the work procedures submitted to the NRC on September 28, 1979.

The weld procedure for the Option A repair method will be qualified in accordance with the applicable code requirements. All welders will be qualified to position 6G (QW-405 ASME Section IX) which essentially qualifies them to perform welding in any position. In addition, all welders will be trained in the steam generator nozzle/shield wall mock-up to simulate the welding conditions in the limited access area.

Based on our investigation of four manufacturers supplying automated welding tools, it is concluded that no automated welding tools exist at the present time which will physically fit into the limited access area.

Question 6

State if a UT baseline examination will be performed for the nozzle to piping weld if Option A is used.

Response

A baseline volumetric examination will be performed for the repair nozzle to piping welds (Option A). However, based on the requirements for future inspections of the subject welds by radiography and the fact that radiography has been used to detect the feedwater piping indications, it is concluded that the baseline volumetric examination will be accomplished radiographically.

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DOCKET NO. 50-336

ATTACHMENT #1

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

FEEDWATER SYSTEM PIPING

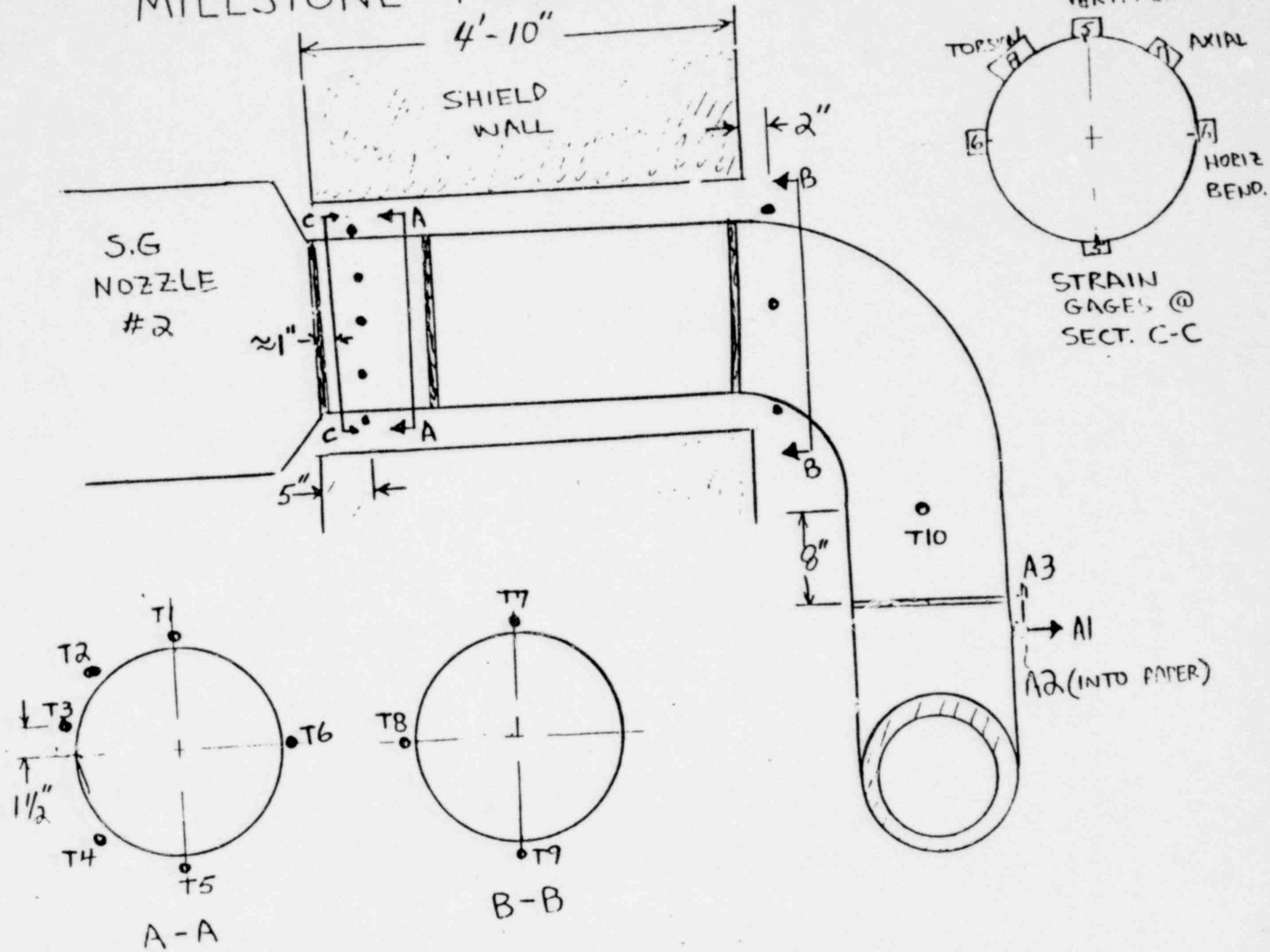
1281 246

OCTOBER, 1979

- SUMMARY OF DYNAMIC STRAINS AND ACCELERATIONS OBTAINED AT MILLSTONE II
- THERMAL STRATIFICATION AS IT OCCURRED DURING THE TESTING PERIOD
- TEMPERATURE PROFILES AS ESTABLISHED FROM PLANT DATA
- SELECTED FLOW TRANSIENTS
- PLANT SPECIFIC STRATIFICATION CYCLES

1281 247

MILLSTONE TRANSDUCER LOCATIONS



1281 249

STEADY STATE DYNAMIC STRAINS AND ACCELERATIONS

POWER LEVEL	ACCELERATION (G'S), 0 - PEAK			STRAIN ($\mu\varepsilon$) 0 - PEAK			
	A1 (HORZ.)	A2 (HORZ.)	A3 (VERT.)	VERT. BEND.	HORZ. BEND.	AXIAL	TORSION
HOT STANDBY	0.12	0.22	0.12	7	5	5	5
50%	0.20	0.33	0.17	9	9	7	7
100%	0.25	0.41	0.22	6	5	4	3

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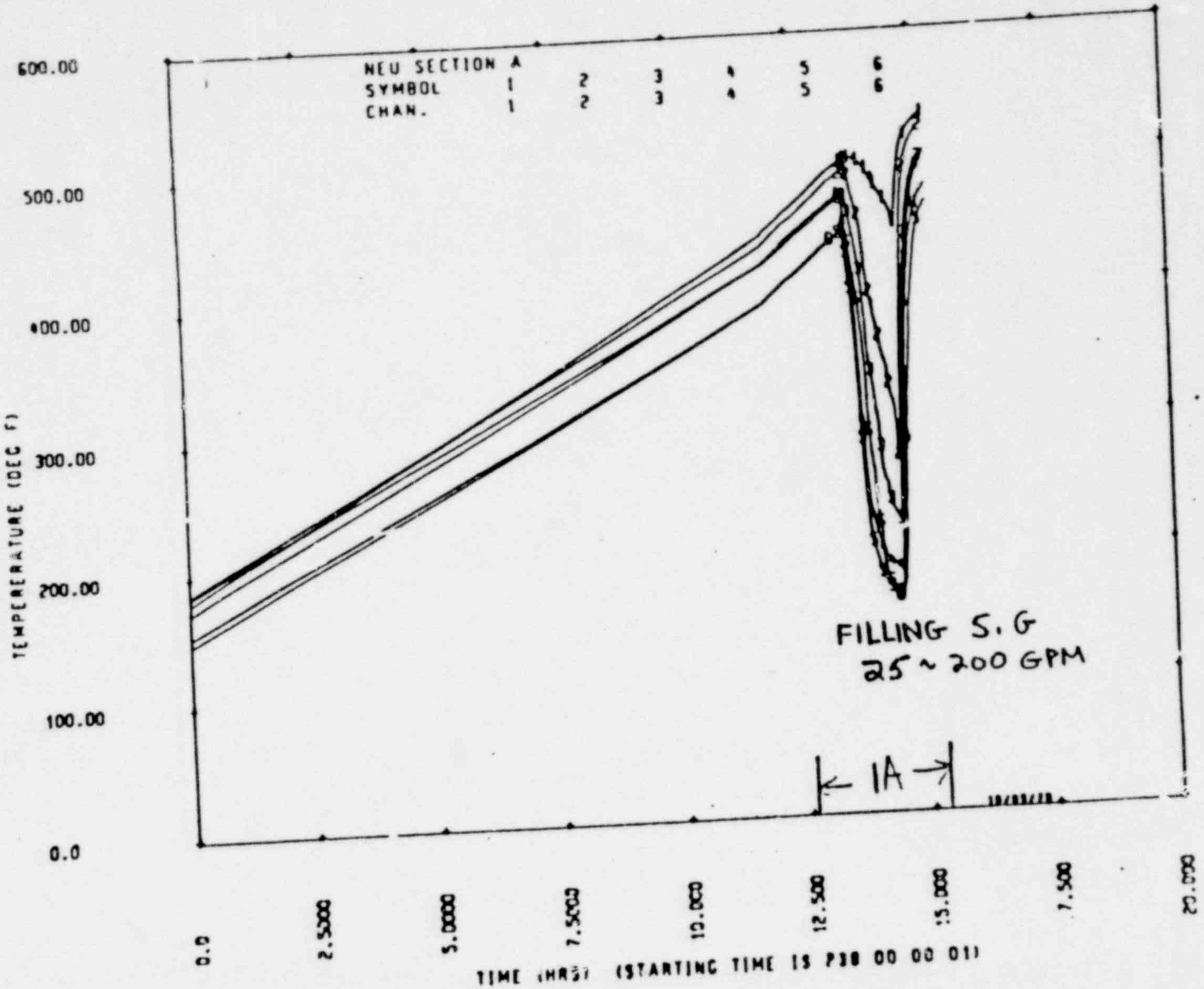
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CHAN. 1 2 3 4 5 6
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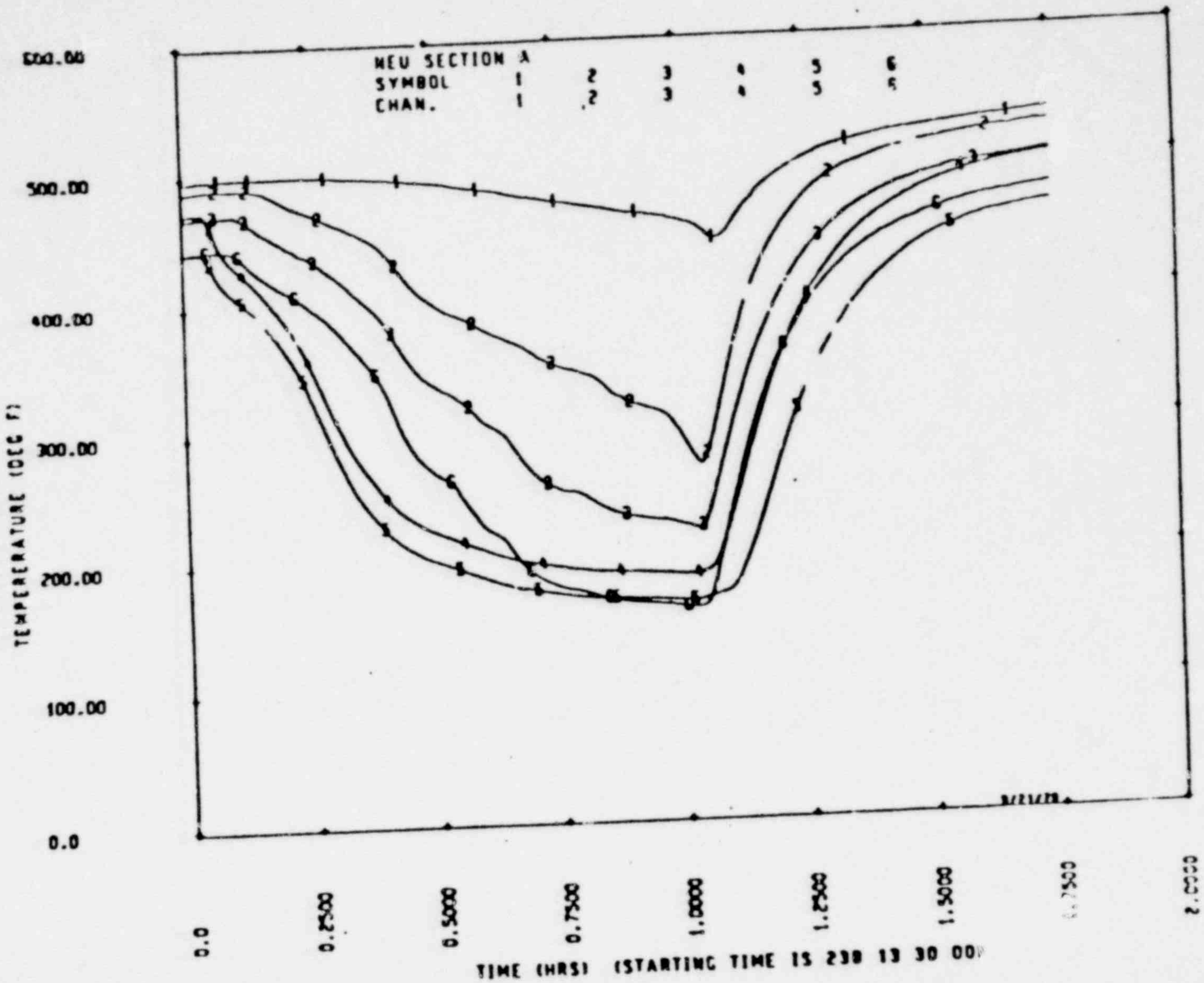
500.00
400.00
300.00
200.00
100.00
0.0
TEMPERATURE (DEG F)
0.0
2.5000
5.0000
7.5000
10.000
12.500
15.000
17.500
20.000
TIME (HRS) (STARTING TIME IS P38 00 00 01)
FILLING S.G
25 ~ 200 GPM
1A

1281 250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200.00
100.00
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0.5000
0.7500
1.0000
1.2500
1.5000
2.0000
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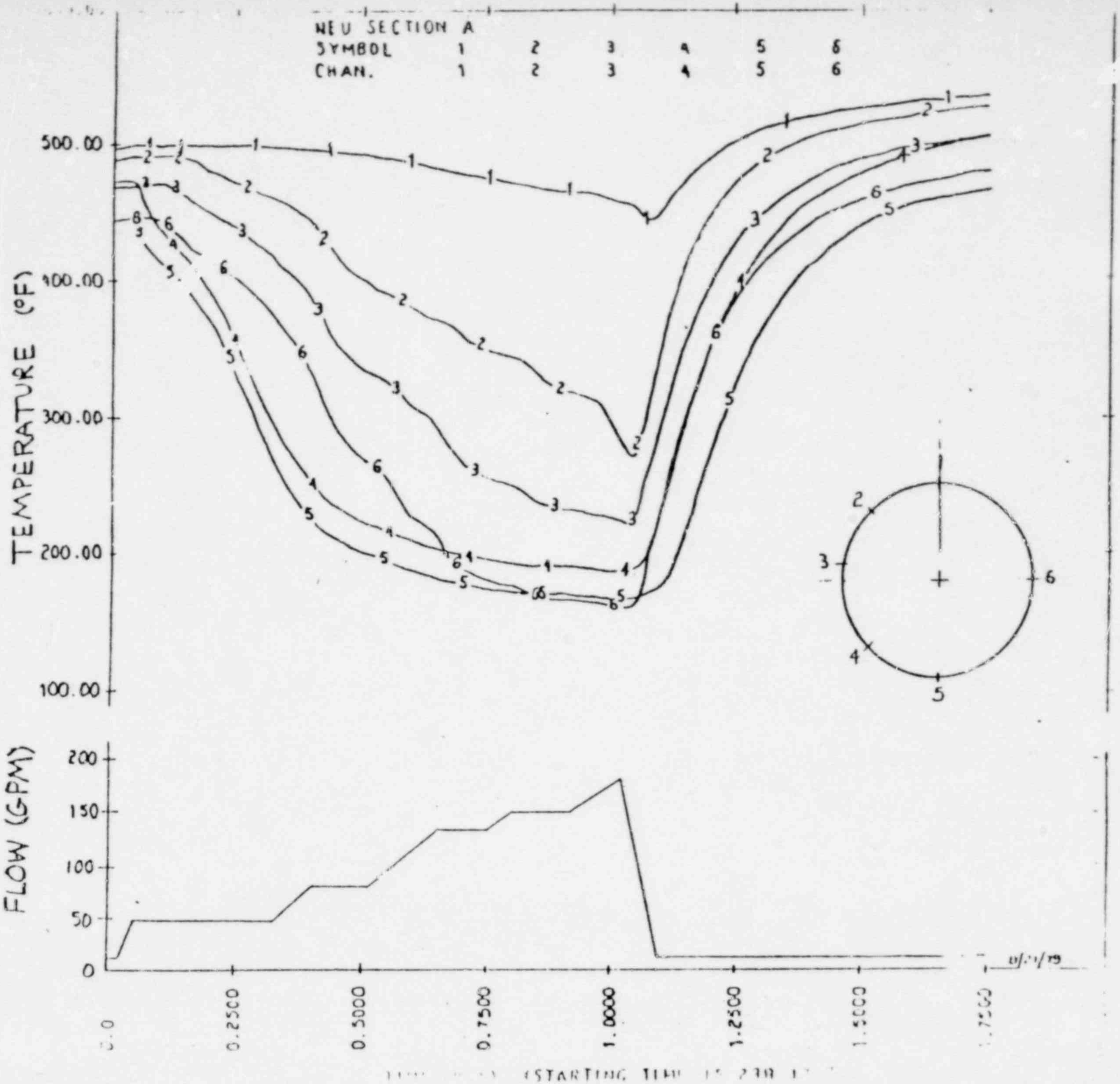
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200.00
100.00
FLOW (GPM)
200
150
100
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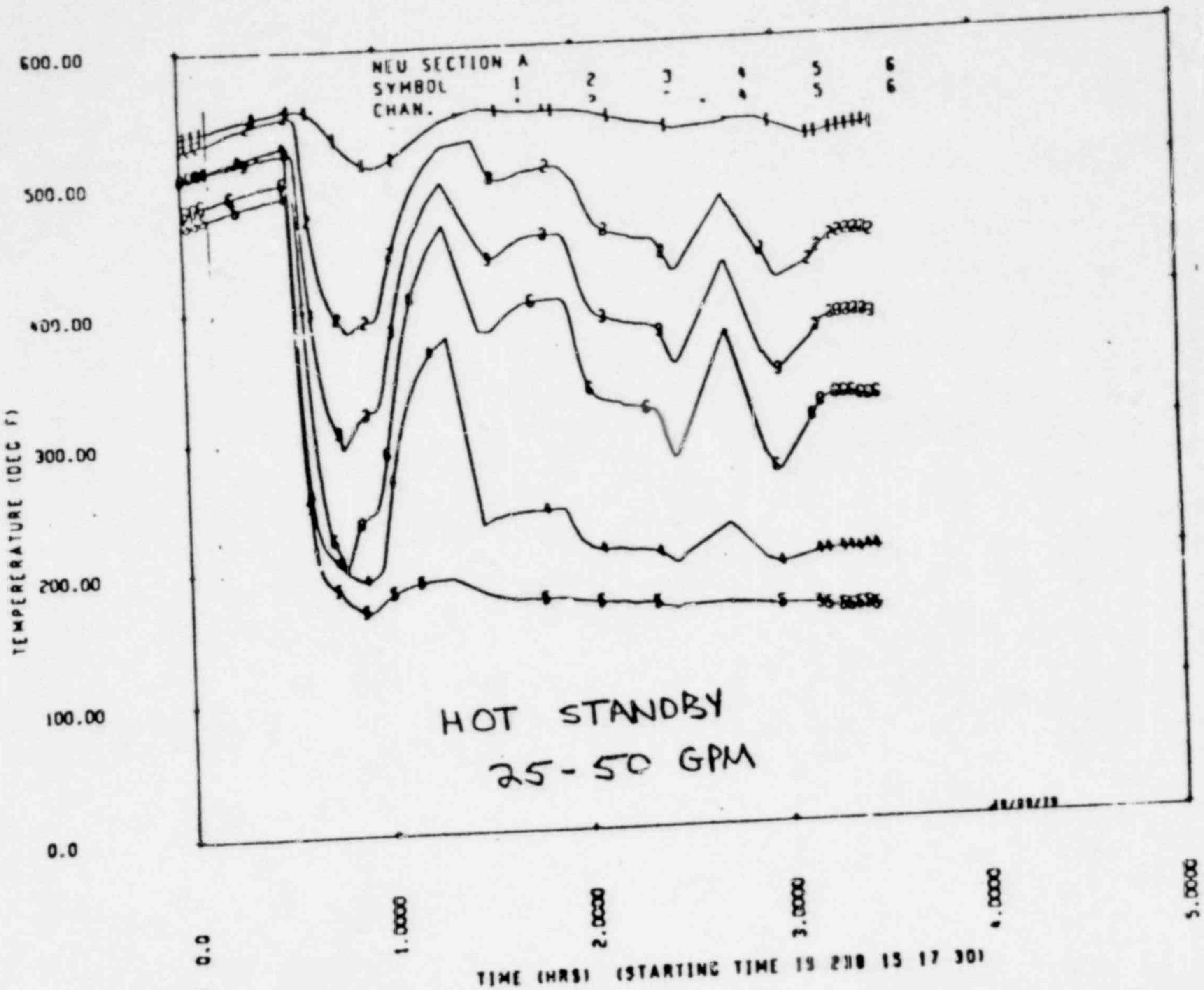
0.5000
0.7500
1.0000
1.2500
1.5000
STARTING TIME

1281 252



600.00
500.00
400.00
300.00
200.00
100.00
0.0
TEMPERATURE (DEG F)
NEU SECTION A
SYMBOL 1 2 3 4 5 6
CHAN.
HOT STANDBY
25-50 GPM
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1.0000
2.0000
3.0000
4.0000
5.0000
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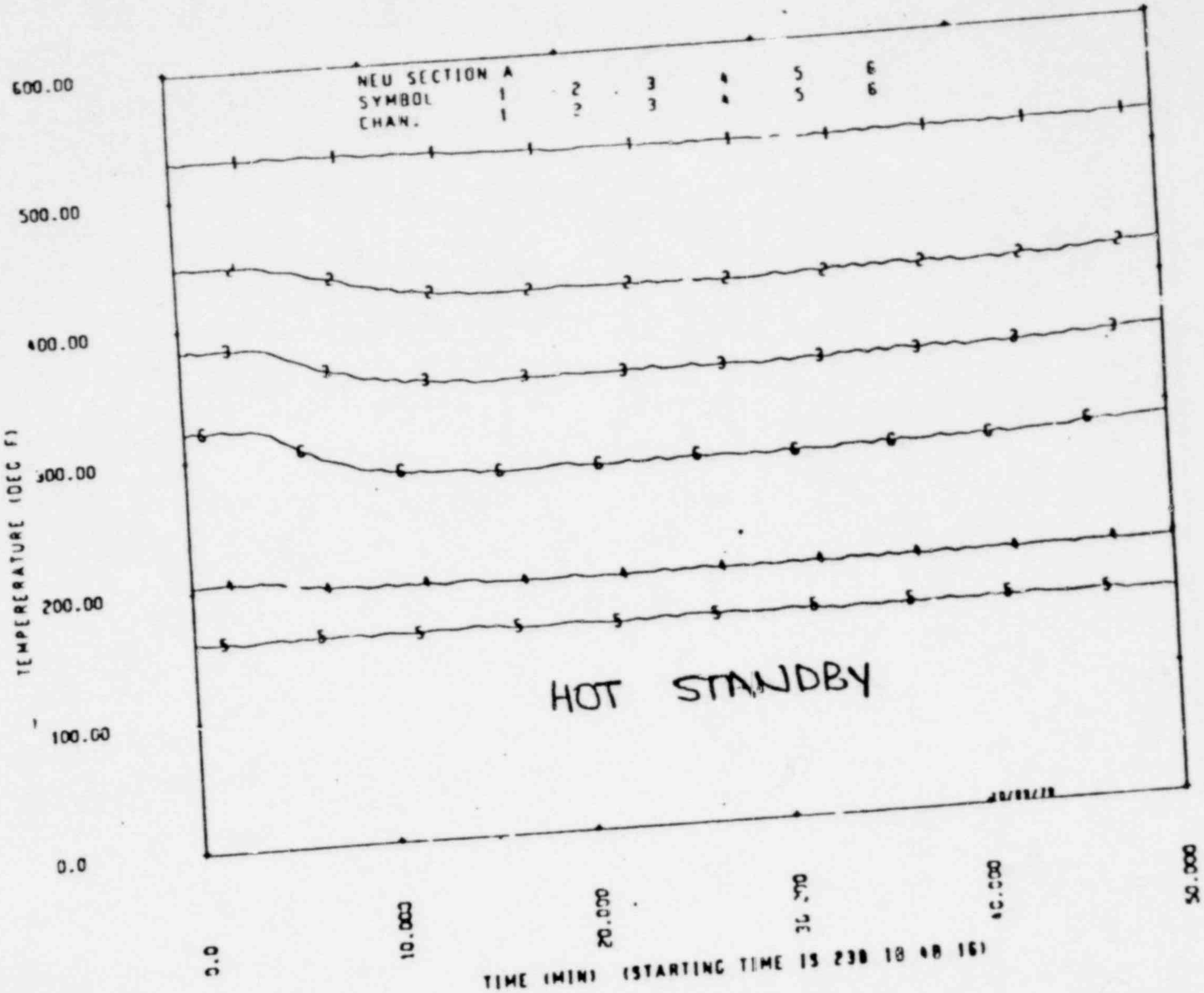
1281 253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300.00
200.00
100.00
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20.000
30.000
40.000
50.000
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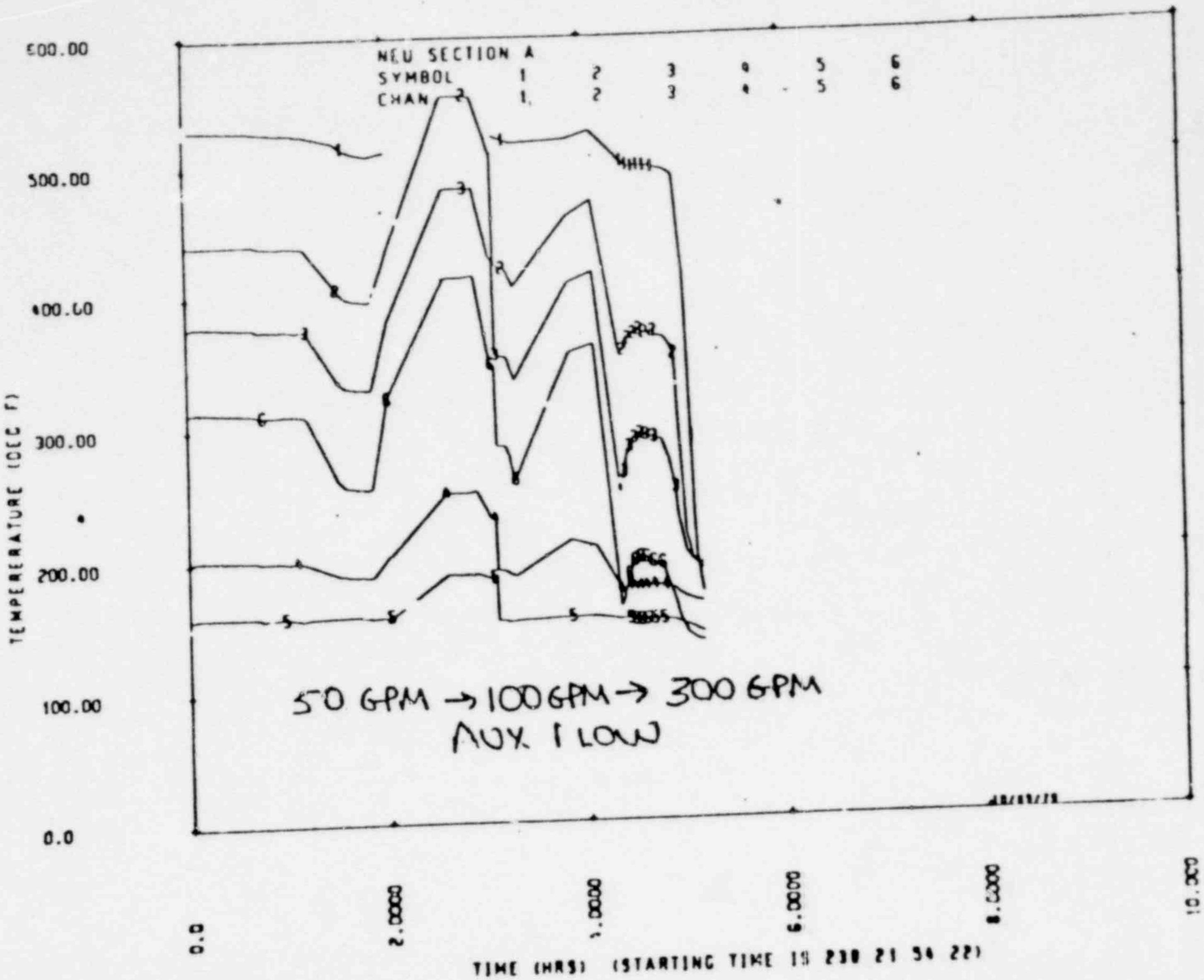
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300.00
200.00
100.00
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TEMPERATURE (DEG F)
0.0
2.0000
4.0000
6.0000
8.0000
10.000
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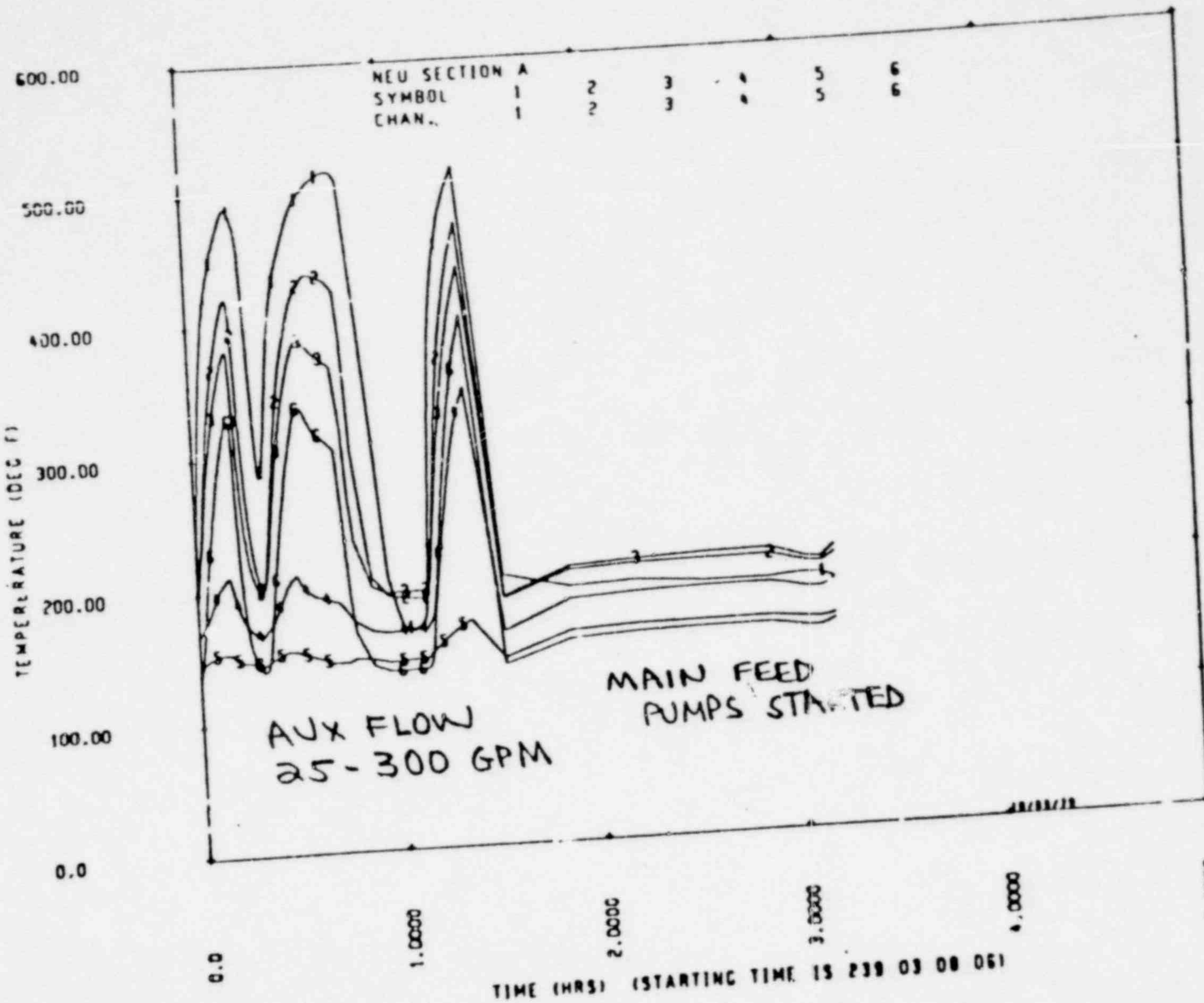
50 GPM → 100 GPM → 300 GPM
AUX. FLOW



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200.00
100.00
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TEMPERATURE (DEG F)
AUX FLOW
25-300 GPM
MAIN FEED
PUMPS STARTED
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2.0000
3.0000
4.0000
5.0000
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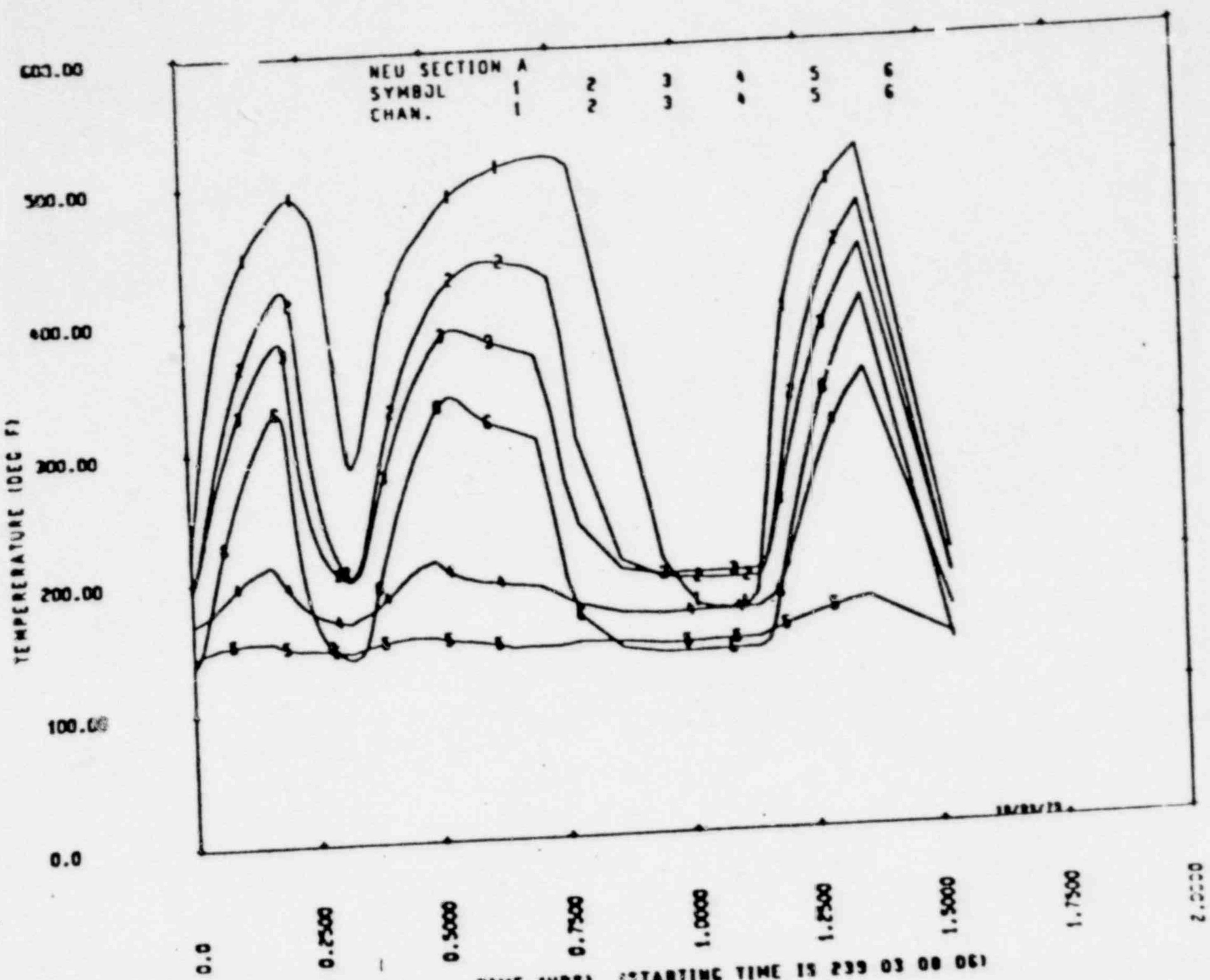
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200.00
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TEMPERATURE (DEG F)
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0.7500
1.0000
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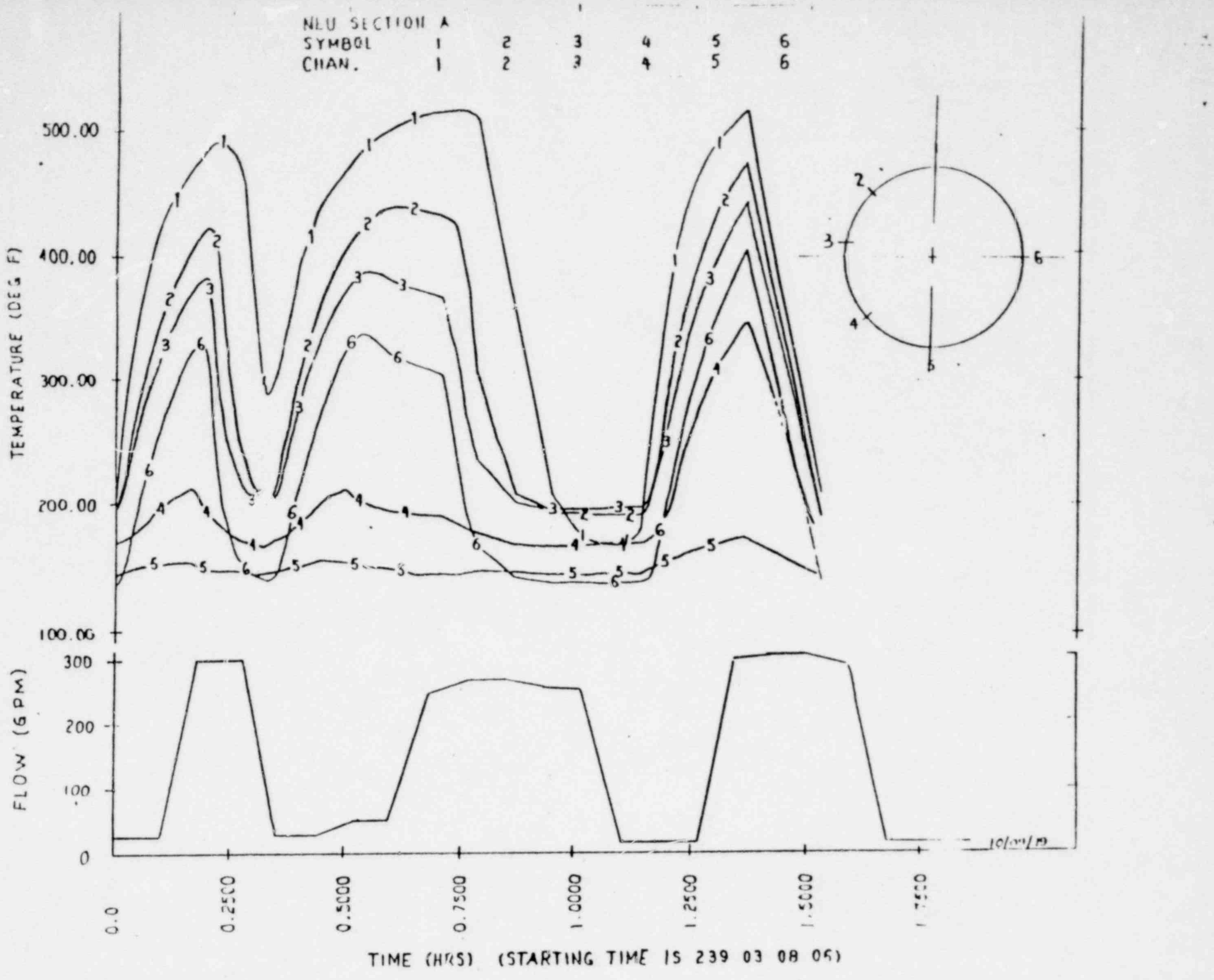
1281 257



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300.00
200.00
100.00
FLOW (GPM)
300
200
100
0
0.0
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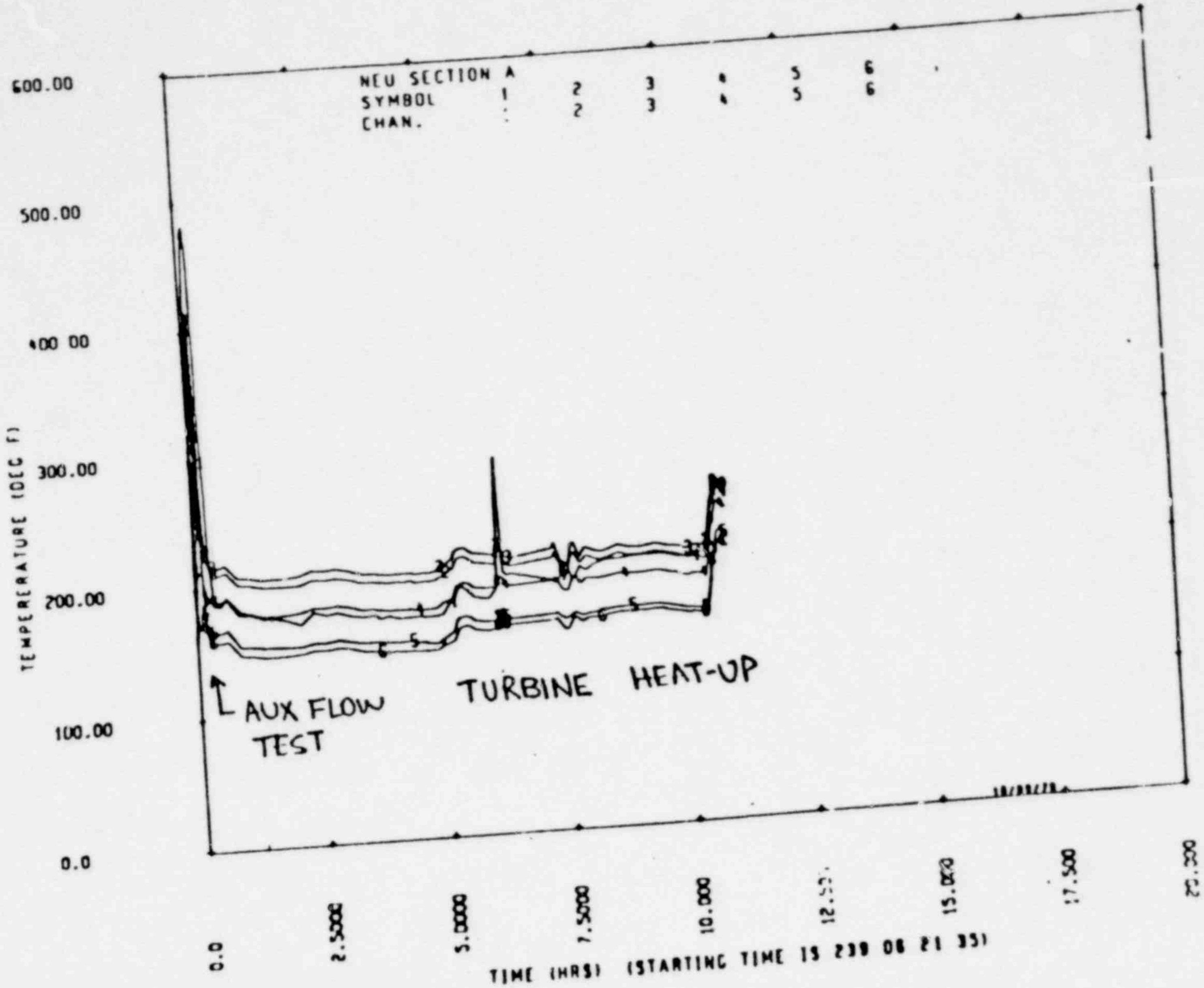
1281 258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5.0000
7.5000
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15.000
17.500
20.000
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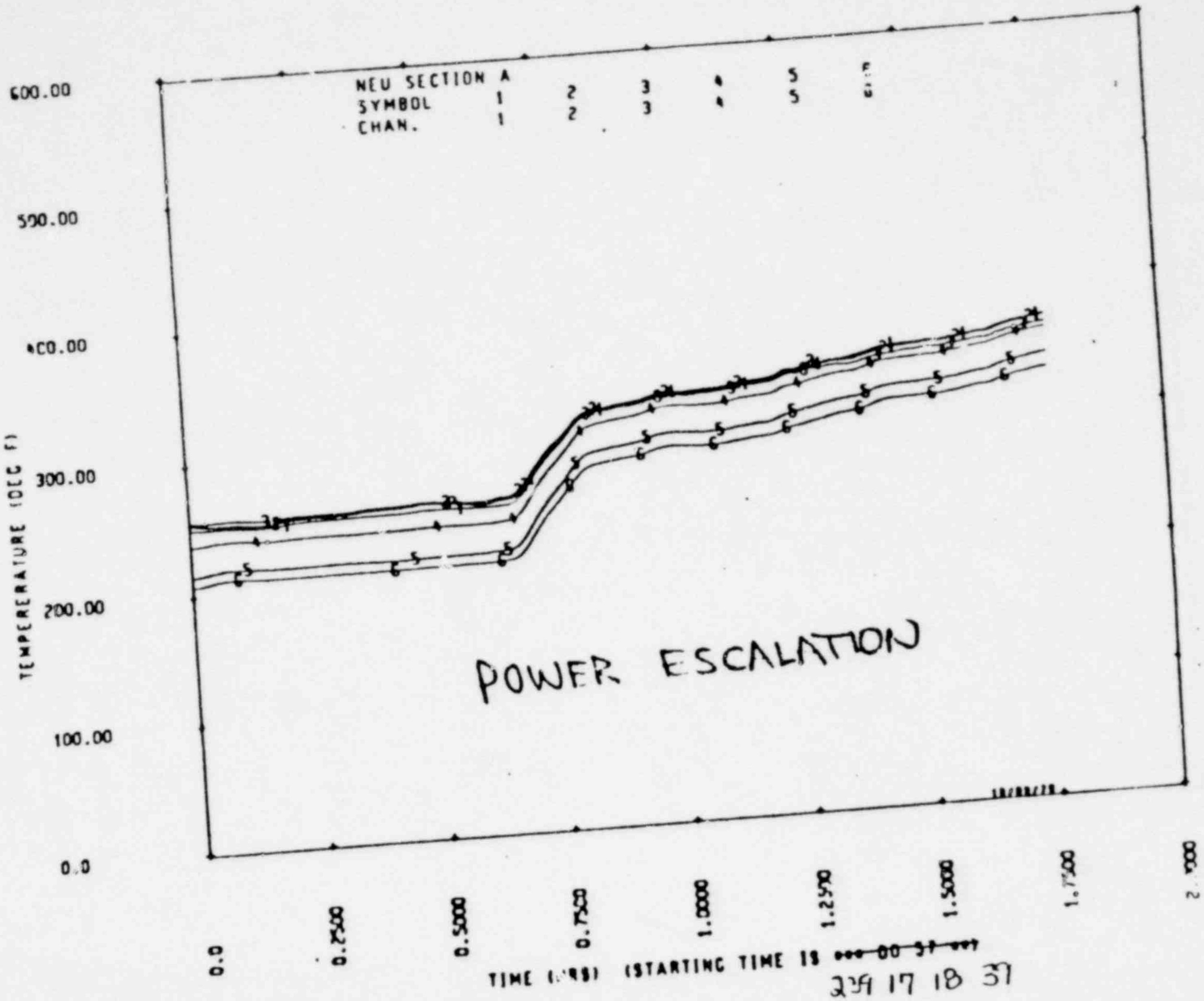
AUX FLOW TEST
TURBINE HEAT-UP



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300.00
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100.00
0.0
TEMPERERATURE (DEG F)
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0.2500
0.5000
0.7500
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1.2500
1.5000
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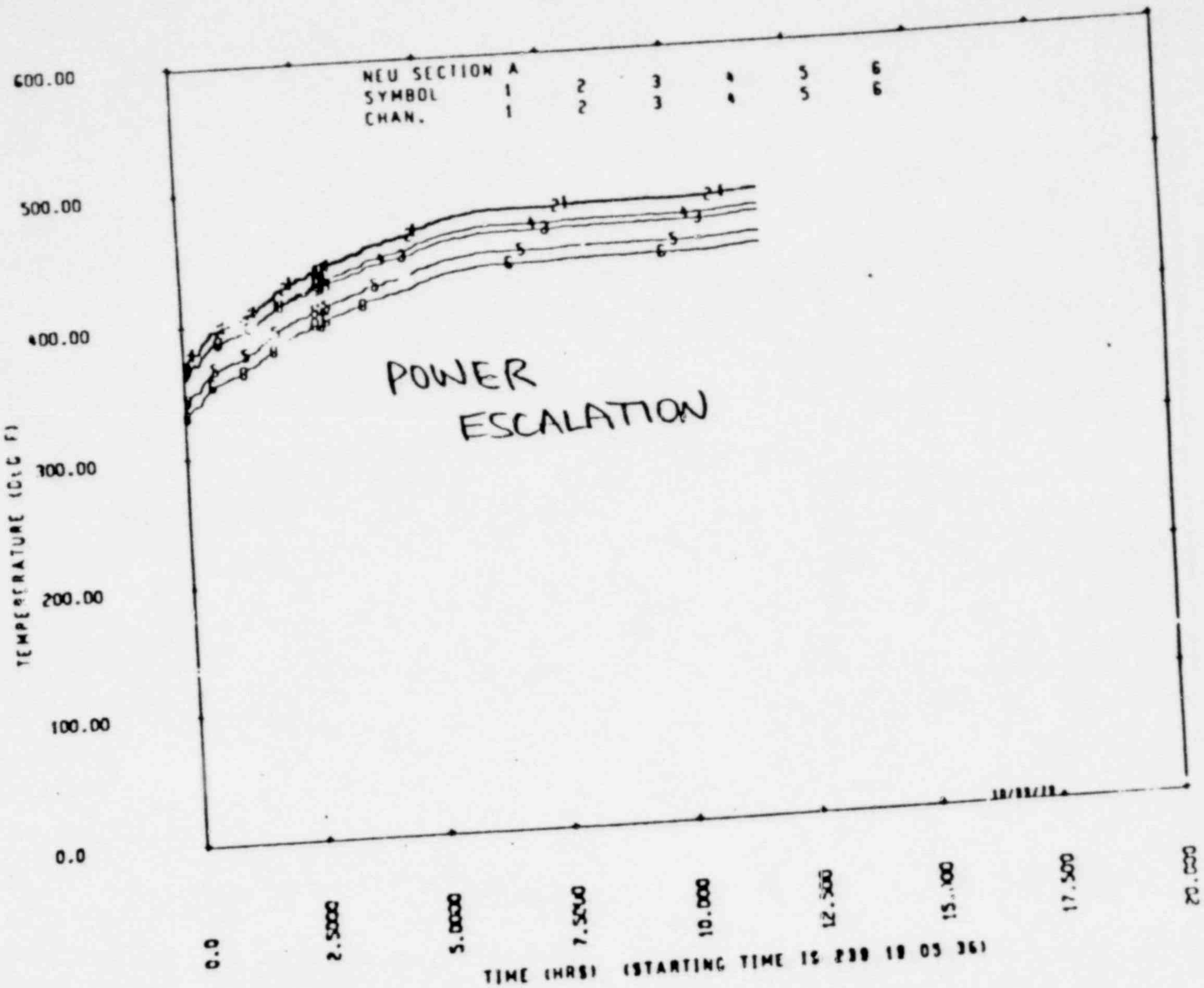
2.0000
TIME (HRS) (STARTING TIME IS 329 17 18 37
POWER ESCALATION

1281 260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CHAN. 1 2 3 4 5 6
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300.00
200.00
100.00
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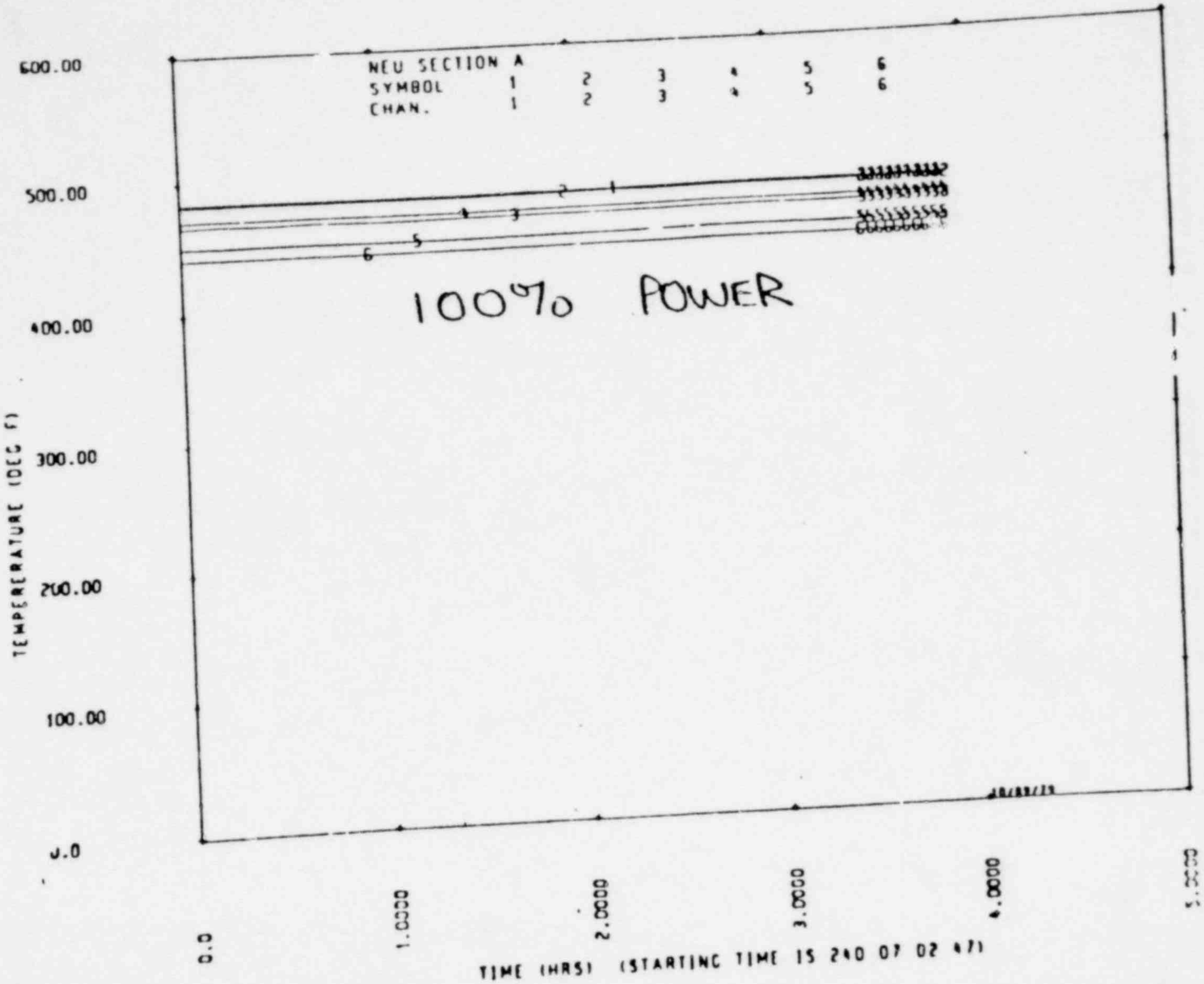
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100% POWER
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0.0
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1.0000
2.0000
3.0000
4.0000
5.0000
TIME (HRS) (STARTING TIME IS 240 07 02 47)

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SUMMARY OF TEMPERATURE PROFILE OCCURRENCES

PLANT	EVENT	NUMBER OF OCCURRENCES(1) OF PROFILE					NUMBER(2) OF EVENTS	RANGE(3)	
		1	2	3	4	5		PROFILE 1	PROFILE 2
MILLSTONE (LINE 2).	HOT STANDBY	6	6	6	5	9	115	276- 1242	276-1242

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(1) NUMBER OF OCCURRENCES (WITH $\Delta T_{TOP/BOTTOM} \geq 300°F$) IS BASED ON AVAILABLE TEST DATA AND MAY VARY BY ± 20%.

(2) NUMBER OF EVENTS IS BASED ON PRESENTLY AVAILABLE PLANT OPERATING HISTORY INFORMATION.

(3) RANGE FOR TOTAL NUMBER OF OCCURRENCES OF THE PROFILE AND IS CALCULATED AS: RANGE = (# OF OCCURRENCES ± ?

X (# EVENTS) X S, WHERE S = EVENT SIMILARITY FACTOR AND $.5 \leq S \leq 1.5$.

DOCKET NO. 50-336

ATTACHMENT #2

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

FEEDWATER SYSTEM PIPING

1281 264

OCTOBER, 1979

ASSESSMENT OF GROWTH OF FEEDWATER LINE FLAWS

MILLSTONE II

POOR ORIGINAL

W.H. Bamford

The purpose of this work is to estimate the future growth of a flaw located in the counterbore region near the feedwater nozzle safe-end-to-pipe weld. The flaw of interest has been confirmed by UT to be approximately 0.10 inches deep, and oriented circumferentially.

As a result of the location of this flaw, instrumentation was installed to monitor the temperature fluctuations in one loop. Results showed that in a certain flow rate range the water stratifies, producing significant stresses which are potentiall important for crack growth. The types of stratification produced were typical of those observed in other plants, but not as severe. The observed stratifications were classified under five different types, as shown in Figure 1. The temperature difference from top to bottom of the pipe for profile 1 was measured at about 350°F, whereas for other plants it has been found to be as high as 450°F.

A three dimensional finite element stress analysis has been completed for each of the five temperature profiles in Figure 1, and transient studies have shown that the five profiles represent limiting conditions compared with the stress results obtained for any transient step in between the profiles.

To accomplish a fatigue crack growth analysis, the system design transients for normal, upset and test conditions were combined with the cycles of stress from stratification, which occurs during hot standby operation. As shown in Figure 2, there are approximately nine cycles of various degrees which for the purpose of this analysis, we will assume, occur each time hot standby occurs.

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A tabulation of the cycle types used in the crack growth analysis, along with applicable stresses, is provided in Table 1. Tables 2 through 5 show the stresses at various locations around the pipe as a result of the stratification.

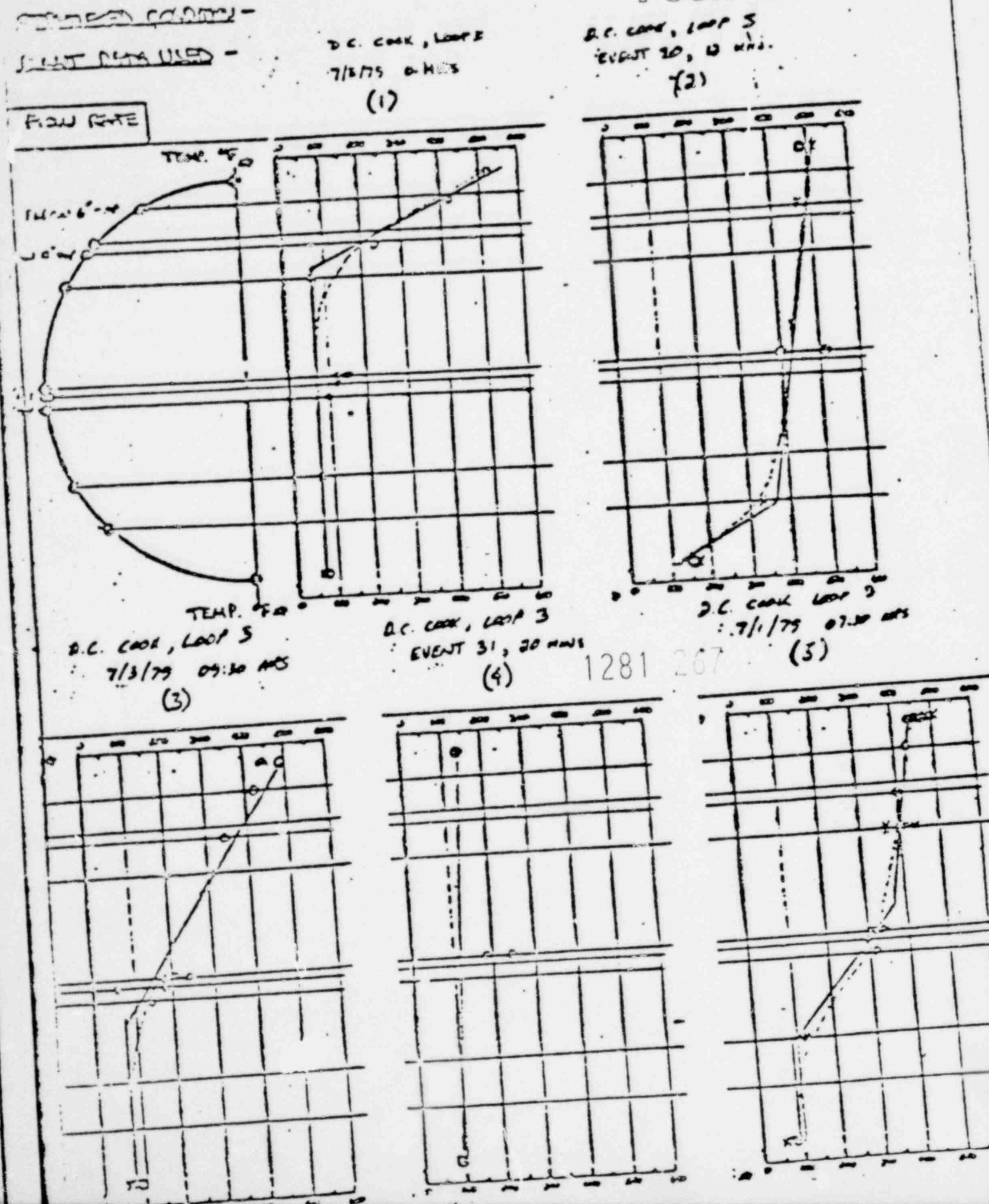
The actual stresses from the three dimensional analysis were used for the fatigue crack growth analysis, except in two cases, where compressive stresses far exceeded the yield stress in compression. The location is at the top of the pipe, and the condition occurs only when the pipe is nearly filled with cold water (profile 1) at low flow. For this case, tensile residual stress values were assumed to exist, equal to the yield strength. This is seen at locations 1 and 2 in Tables 2 and 4. This assumption is considered to be extremely conservative.

Crack growth was calculated at each of thirteen locations around the pipe for periods of 1, 2, 3 and 4 years, assuming an initial flaw of 0.100 inches deep, extending entirely around the inside of the pipe.

A fatigue crack growth law which accounts for mean stress or R ratio (σmin./ σ max.) as well as the presence of the water environment was used. The law is shown in Figure 3.

Results of the crack growth analysis are shown in Table 6, for each of the locations considered. These results show that the observe flaws will not grow significantly during the next years service. The final flaw size for the worst location is a factor of 5 smaller than the critical flaw size for the pipe, as shown in Figure 4.

FIGURE 1. STEADY STATE TEMPERATURE DISTRIBUTIONS



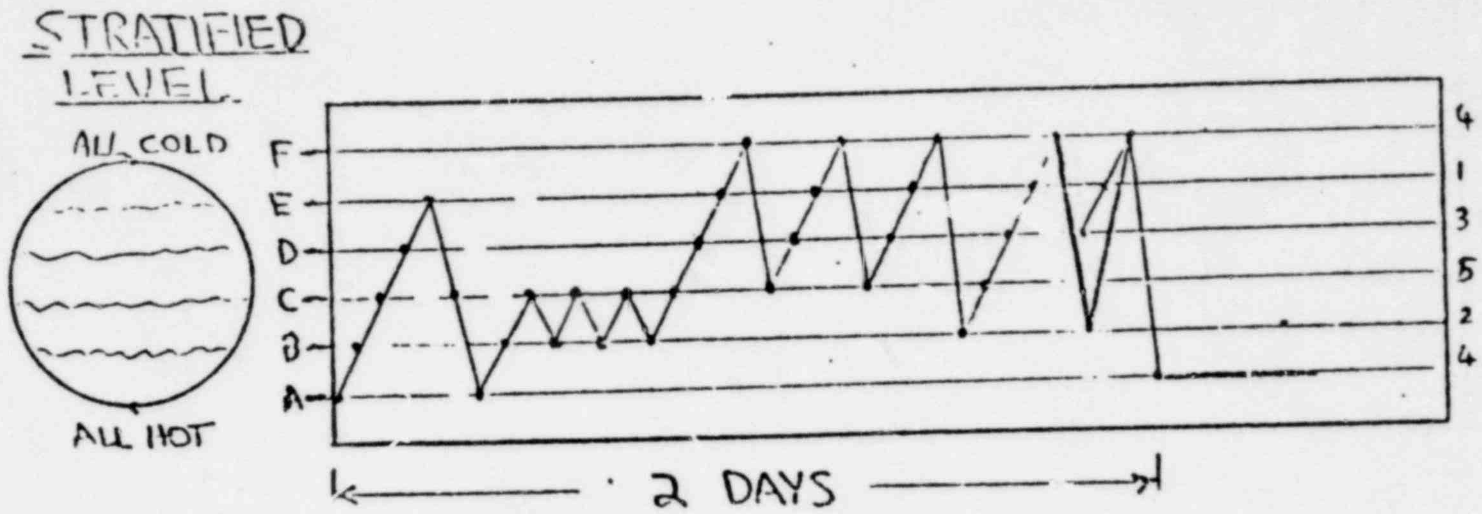


Figure 2: SUMMARY OF TEMPERATURE PROFILE OCCURRENCES

PLANT	EVENT	NUMBER OF OCCURRENCES(1) OF PROFILE					NUMBER(2) OF EVENTS	RANGE(3)	
		1	2	3	4	5		PROFILE 1	PROFILE 2
MILLSTONE (LINE 2)	HOT STANDBY	6	6	6	5	9	115	276- 1242	276-1242
			--						

(1) NUMBER OF OCCURRENCES (WITH $\Delta T_{TOP/BOTTOM} \geq 300°F$) IS BASED ON AVAILABLE TEST DATA AND MAY VARY BY $\pm$ 20%.

(2) NUMBER OF EVENTS IS BASED ON PRESENTLY AVAILABLE PLANT OPERATING HISTORY INFORMATION.

(3) RANGE FOR TOTAL NUMBER OF OCCURRENCES OF THE PROFILE AND IS CALCULATED AS: RANGE = (# OF OCCURRENCES $\pm$ 20%) X (# EVENTS) X S, WHERE S = EVENT SIMILARITY FACTOR AND $.5 \leq S \leq 1.5$.

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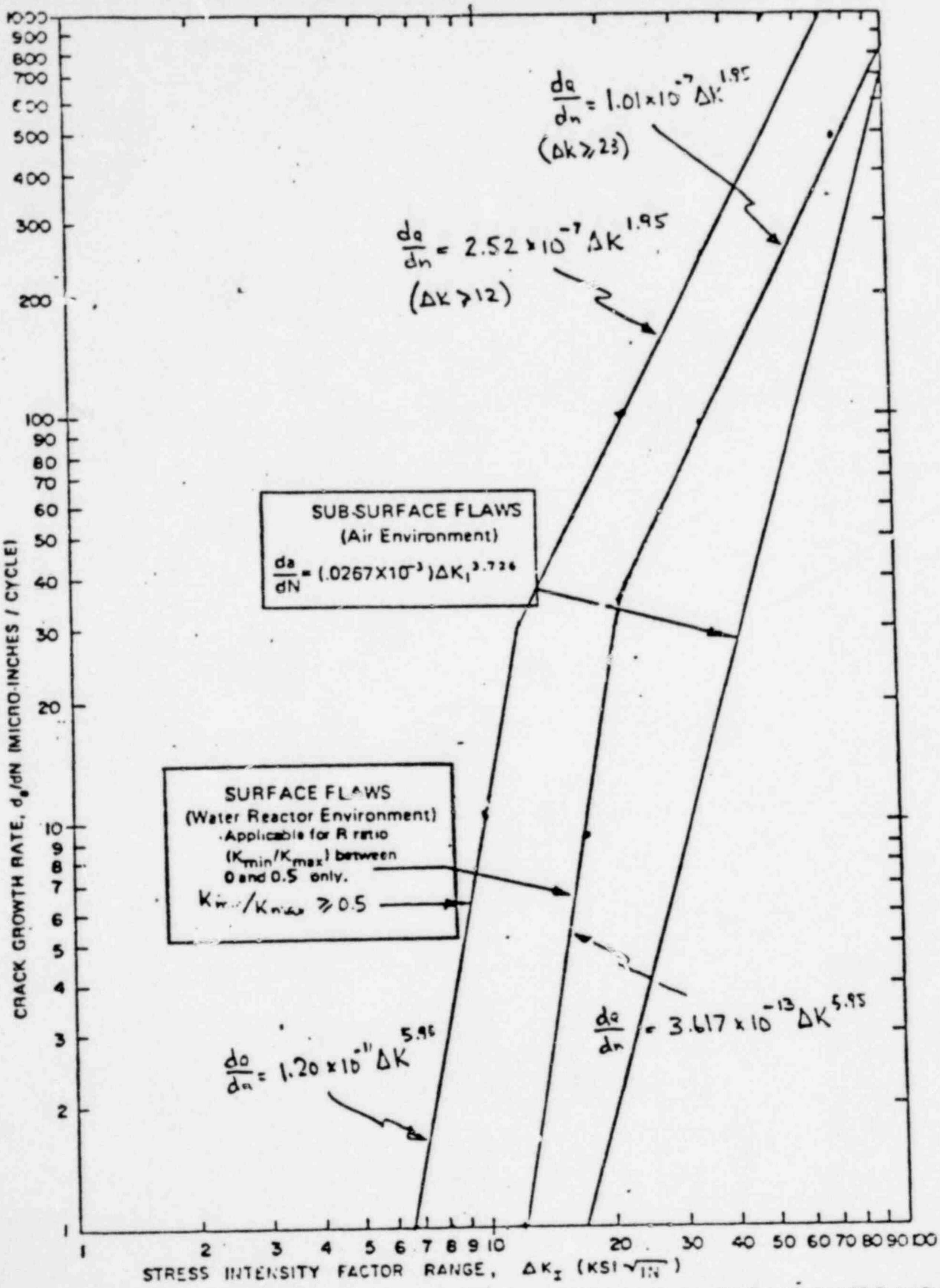

FIGURE 3 FATIGUE CRACK GROWTH DATA FOR SA-508, CLASS 2 AND CLASS 3 AND SA-533, GRADE B, CLASS 1 STEELS

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TABLE 1

TRANSIENTS USED IN FATIGUE CRACK GROWTH ANALYSIS

MILLSTONE II

Description	Cycles (40 years)	Inside Surface Stress Max.	Inside Surface Stress Min.	Outside Surface St... Max.	Outside Surface St... Min.
Hot Standby 1	50)	These stresses are dependent on circumferent... position. See Tables 2 through 5.			
Hot Standby 2	1500)				
Hot Standby 3	500)				
Hot Standby 4	2500)				
Unit Load-Unload	15000	10.47	7.71	8.49	7
Step Increase/Decrease	2000	9.56	7.87	7.89	7
Partial Loss of Flow	40	23.7	8.42	3.79	7.
Loss of Load	40	23.02	8.42	3.18	7.
Reactor Trip	400	22.69	8.21	2.88	7.
Secondary Leak Test	200	11.23	0.0	10.04	0.

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TABLE 2

STRESS RESULTS - AXIAL DIRECTION

CONDITION 5 - 1 - HOT STANDBY # 1

Location	Inside Surface Max. (Ksi)	Inside Surface Min. (Ksi)	Outside Surface Max. (Ksi)	Outside Surface Min. (Ksi)
1	40.0	0.0	-40.0	0.0
2	40.0	0.0	-40.0	0.0
3	9.46	-23.0	8.56	8.29
4	35.12	4.63	11.23	7.02
5	68.97	- 1.43	13.20	4.66
6	66.05	- 7.28	12.61	1.71
7	46.17	- 8.06	10.83	-0.33
8	24.37	7.27	7.34	3.69
9	24.61	7.27	8.98	2.01
10	23.67	- 2.47	6.47	-3.44
11	14.93	- 5.67	- 0.44	-7.05
12	9.30	- 5.44	- 6.03	-8.45
13	7.62	- 4.95	- 8.11	-8.69

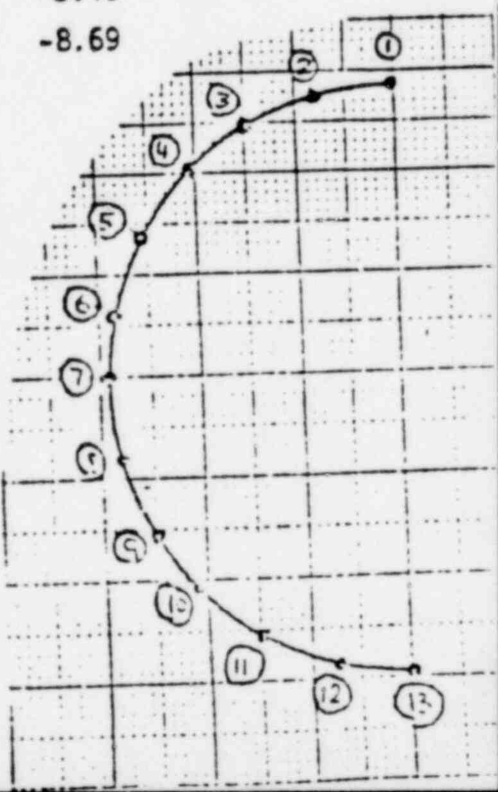

TABLE 3

STRESS RESULTS - AXIAL DIRECTION

CONDITION 5 - 4 - HOT STANDBY # 2

Location	Inside Surface Max. (Ksi)	Inside Surface Min. (Ksi)	Outside Surface Max. (Ksi)	Outside Surface Min. (Ksi)
1	13.49	9.78	9.62	3.24
2	12.57	9.68	9.40	3.25
3	9.46	9.34	8.56	3.24
4	8.76	4.63	3.21	7.02
5	8.23	-1.43	3.17	4.60
6	7.91	-7.28	3.17	+1.71
7	7.69	-8.06	3.18	-0.33
8	7.60	7.27	3.22	3.63
9	24.61	7.71	8.97	3.37
10	23.67	8.02	6.47	3.63
11	14.93	8.44	-0.44	3.96
12	9.30	8.76	-6.03	4.20
13	7.61	8.86	-8.11	4.29

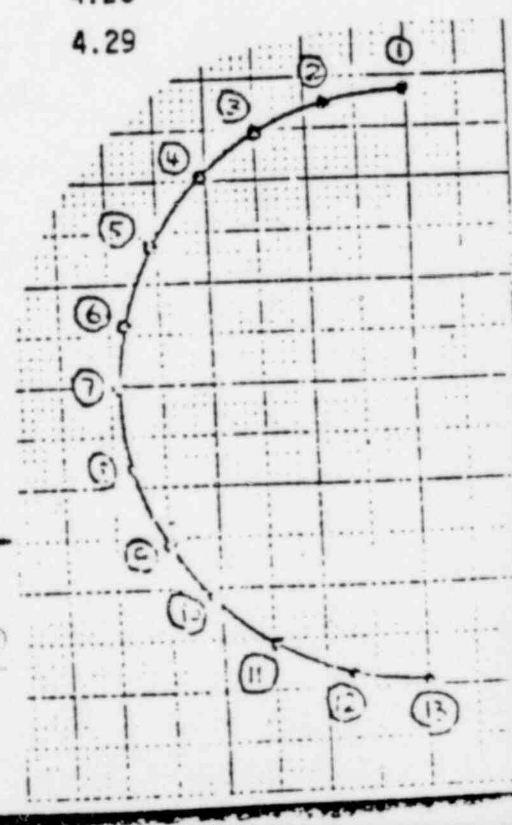

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TABLE 4

STRESS RESULTS - AXIAL DIRECTION

CONDITION 2 → 1 - HOT STANDBY # 3

Location	Inside Surface Max. (Ksi)	Inside Surface Min. (Ksi)	Outside Surface Max. (Ksi)	Outside Surface Min. (Ksi)
1	40.0	0.0	-40.0	0.0
2	40.0	0.0	-40.0	0.0
3	16.19	23.71	9.31	8.30
4	35.12	10.11	11.23	8.45
5	68.97	2.39	13.20	6.52
6	66.05	- 4.85	12.61	3.45
7	46.17	-11.04	10.83	-0.88
8	24.37	-15.29	7.34	-5.64
9	7.27	-14.93	2.01	-8.39
10	- 2.48	- 3.19	- 3.44	-4.21
11	19.41	- 5.67	7.35	-7.05
12	36.44	- 5.44	16.75	-8.45
13	41.23	- 4.95	19.41	-8.69

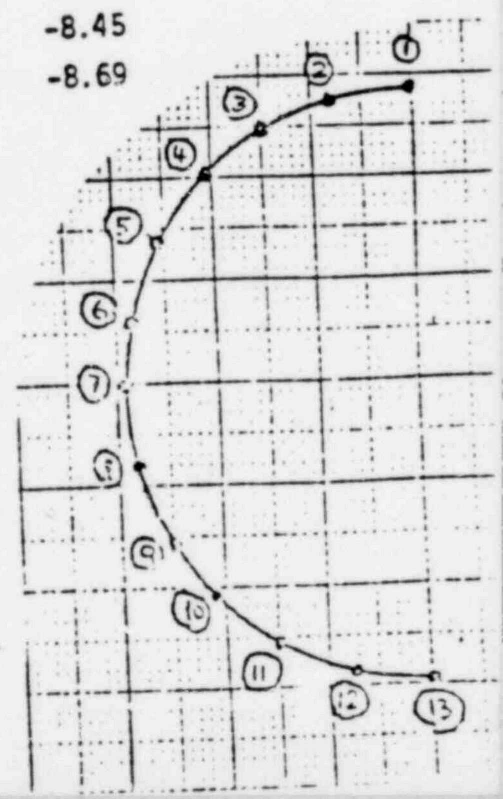

TABLE 5

STRESS RESULTS - AXIAL DIRECTION

CONDITION 2 - 4 - HOT STANDBY # 4

Location	Inside Surface Max. (Ksi)	Inside Surface Min. (Ksi)	Outside Surface Max. (Ksi)	Outside Surface Min. (Ksi)
1	21.51	9.78	9.73	3.24
2	20.0	9.68	9.60	3.24
3	16.19	9.34	9.31	3.24
4	10.11	8.76	8.45	3.21
5	8.23	2.39	3.17	6.52
6	7.91	- 4.88	3.17	3.45
7	7.69	-11.04	3.18	-0.88
8	7.60	-15.29	3.22	-5.64
9	7.71	-14.93	3.37	-8.39
10	8.02	- 3.12	3.63	-4.21
11	19.41	8.44	7.35	3.96
12	36.44	8.76	16.75	4.20
13	41.23	8.85	19.41	4.28

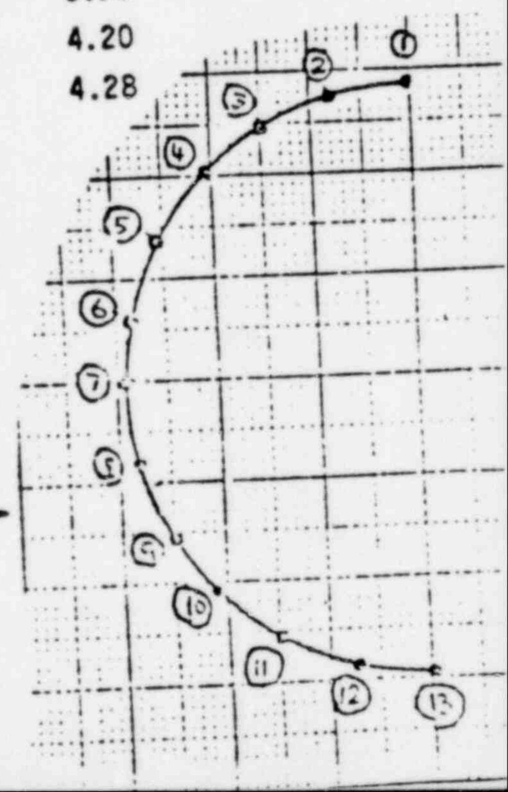

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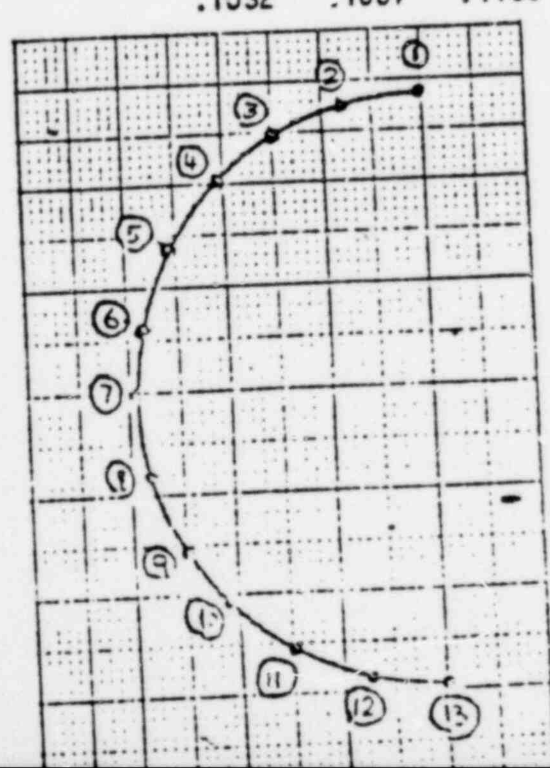
TABLE 6

RESULTS OF FATIGUE CRACK GROWTH ANALYSIS

INITIAL CRACK LENGTH = 0.100 INCHES

Location	Crack Depth After Year .1	2	3	4
1	.1008	.1016	.1024	.1032
2	.1002	.1004	.1007	.1009
3	.1001	.1001	.1002	.1003
4	.1001	.1003	.1004	.1005
5	.1021	.1045	.1067	.1092
6	.1042	.1090	.1137	.1190
7	.1011	.1023	.1034	.1046
8	.1001	.1002	.1003	.1003
9	.1001	.1002	.1003	.1004
10	.1001	.1002	.1002	.1003
11	.1001	.1003	.1004	.1006
12	.1014	.1030	.1045	.1062
13	.1032	.1067	.1105	.1146



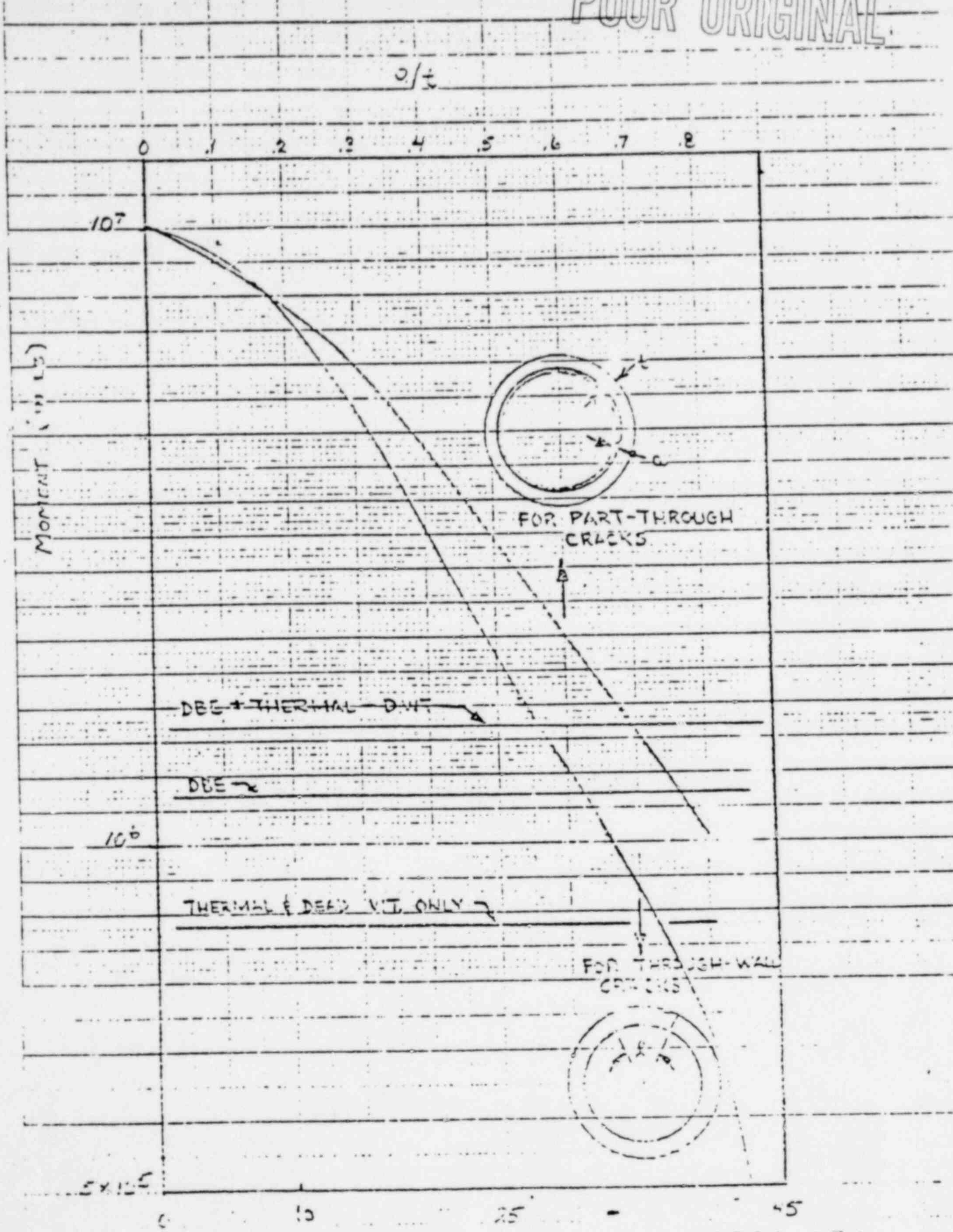


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Fig 6. Failure Predictions - 16" OD Pipe 0.75" Wall