WNET-103

Indian Point Unit No. 2
Docket No. 50-247

EVALUATION OF ULTRASONIC INDICATION IN INDIAN POINT #2 STEAM GENERATOR #21

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2974

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ABSTRACT

During a field modification of the Indian Point Steam Generators, an ultrasonic test was made to verify pre-service inspection results from tests conducted prior to the modification. As a result of some deviation between the tests, further testing and analysis was done. It is concluded that the deviations observed are within the tolerances of the ultrasonic techniques, that the sonic indication is within ASME Section III limits for slag in welds, and that the slag does not present a risk from either fatigue or fracture mechanics considerations.

I. Background

The steam generators for the Indian Point Plant, Unit #2, were designed and built by the Heat Transfer Division of the Westinghouse Electric Corporation during the period between 1966 and 1968. The units were designed and built in accordance with the 1965 edition of the ASME Boiler and Pressure Vessel Code, Section III.

Subsequent to the shipment of the steam generators and after installation in the plant, a requirement was added to perform pre-service inspection in accordance with ASME In-Service Inspection, Section XI. This inspection was completed in July 1970 by the Nuclear Service Department of WNES for Consolidated Edison Company.

As a result of a cladding separation problem, which was discovered at an operating plant in June 1971, the Indian Point Unit #2 steam generators were modified in September 1971.

After the modification was performed, the above mentioned pre-service inspection was repeated. During this reinspection of the Channel Head to Tube Sheet weld, discrepancies, detailed in this report, were observed in the data between the original 1970 inspection and the 1971 post-modification inspection. The resolution of the discrepancies together with a stress analysis of an assumed discontinuity is presented in the report.

II. Results of ASME Section XI, Pre-Service Inspections

A. Results of July 1970

Sonic Test performed as part of the original pre-service inspection requirement revealed an indication extending from 375-1/2" to 376-3/4" from datum at an amplitude of 500% of the calibration. These data were reported as part of the complete inspection report submitted at that time. The particular indication was recorded as Item 19 in the data for Steam Generator #21.

B. Results of September 1971

Sonic tests were repeated after the field modification and by similar technique, i.e. shear wave, the indication was reported to extend from 372" to 374" with an amplitude of 85% of calibration. Since this examination varied in detail technique from the 1970 examination, a repeat of that procedure was attempted and a 500% indication was observed in the same region. At the same time, a longitudinal beam examination was conducted to accurately locate the depth of the indication in the weld. The result of this examination places the indication between 372" and 375-1/2" from datum and at a depth of 5 inches in the seam. In addition, a smaller indication was located at datum 171-3/4" - 172-1/4" with an amplitude also of 85% of calibration. Since this indication is well within ASME Section III limits, it is not considered further.

III. Resolution of the Discrepancies between the original and repeat Ultrasonic examinations.

A. As a result of the two sonic examinations, the following discrepancies were noted:

1. In 1970 the indication was at datum 375-1/2" to 376-3/4" at 500% amplitude, while in 1971 it was at 372" to 374" at the same amplitude.
2. In 1970 the amplitude was 500% while in 1971 the amplitude was 85%.

B. The discrepancy of distance from Datum. The distances from datum between 1970 and 1971 show a discrepancy of approximately 3 inches to the mid-point of the indication. A review of the techniques used to ascertain the datum in both the 1970 and 1971 tests show that the distances were measured by tape from the zero point. The discrepancy was most probably caused by a sag in the tape during the test. Since the 1971 test explored the region on either side of the indication without revealing other indications at the original location and since the 1971 test included a repeat of the 1970 technique and located an indication of the same amplitude, it is concluded that the indication is the same one recorded originally.

C. The discrepancy in amplitude is a direct result of the difference in calibration standards used. In 1970, a rectangular block with flat parallel reflecting surfaces was used. This block allowed a greater reflection of sonic energy from the back reflecting surface than the actual weld seam which has a weld overlay surface of considerable sonic dispersion. In 1971 a calibration standard with weld overlay on the reflecting surface was used and the amplitude from the actual indication was, therefore, reduced from 500% with the smooth flat surface to 85% with the weld clad surface. This phenomenon was confirmed by repeating the 1970 calibration test which again revealed the indication at 500% amplitude. The length of the indication was measured sonically to the "half-angle-point" or "half-amplitude-points". This method gives a conservative measure of indication length since only 50% of the sonic energy is available for reflection from the indication. Because of minor variations in beam-spread angle, operator technique, and electronics, the lengths reported by different operators with different equipment will vary slightly. Based on calibration with a weld clad calibration block, which filters out geometric differences, the length of the sonic indication is less than 1-1/4" as measured by the "half-amplitude" method.

IV. Additional Verification by Radiography

A. On Site Radiography

In an effort to provide additional corraborative evidence that the sonic indications reported in 1970 and 1971 were, in fact, the same and that no change had taken place as a result of the field modification, the area was radiographed from two directions in September 1971. The results of the radiography reveal two pieces of welding slag at a depth of 5 inches in the weld seam. The slag is 11/16" long and 3/16" long respectively and separated spatially in depth by 1/8". The radiographic envelope for the slag is conservatively estimated to be less than one inch long by 3/8" wide. The width assumes cylindrical slag separated by 1/8".

Triangulation of the depth of the slag radiographically reveals that the depth and location coincide precisely with the depth and location as revealed by the September 1971 ultrasonic test. These results are illustrated in the exhibit of the radiographic and ultrasonic constructions in Appendix I.

B. Review of Shop Radiography

As part of the effort in determining the resolution of the sonic and radiographic discrepancy, the shop fabrication records were reviewed. The Inspection Point Program showing the radiographic acceptance of the seam and the daily radiographic logs showing the course of welding and repair and final radiographic acceptance are attached to this report as Appendix II, together with the designations of the unit serial numbers as related to the Westinghouse shop order numbers and radiographic X numbers.

V. Conclusions

A. The discrepancies of location and amplitude of sonic indications from 1970 to 1971 are the result of error in measuring distance by tape (although the difference in the measurements is less than 1%) and changes in calibration standards. Because the 1971 measurements used a weld clad block, these measurements are more realistically comparable to the actual steam generator.

B. The results of the field radiography accurately confirm the sonic data and are interpretable as welding slag. The difference in length between sonics and radiography is well within the limits of accuracy as determined by laboratory studies.

C. Review of shop radiographic records shows that manual repairs were made in the same area. The appearance of small slag is consistent with the shop record.

D. Based on the Non-Destructive Evaluation of the field results, the indication is welding slag less than 2" long (sonic data) and less than 3/8" wide (radiographic data).

E. The fracture mechanics analysis of a "worst case" crack-like indication shows growth is less than 0.08 inches.

F. The indication, as measured from the radiographs, is slag less than 3/4" long and within ASME Section III requirements.

VI. Recommendations for Future Action

Since the indication is slag within ASME Code and since the location and size are well known, it is recommended that future in-service inspections repeat the ultrasonic examinations as a monitor of any future change.

Channel Head Girth Weld Indication Appraisal

Steam Generator #21, Indian Pt. Site

1. Introduction

Two indications have been detected in the girth weld of the channel head to tubesheet in #21 steam generator of the Consolidated Edison Indian Point. Both indications coincide with the plane of the divider plate and are separated by 180° (i.e. at opposite ends of the divider plate).

Application of non-destructive testing techniques to both locations has shown one of the indications to be unequivocally within all operational specifications and therefore further detailed examination of only one indication is required. This report describes the appropriate indication and gives a structural appraisal of its consequences.

The structural appraisal considers two criteria: 1) a Section III of the ASME Boiler and Pressure Vessel Code standard fatigue analysis and 2) a fracture mechanics analysis.

The unit exhibiting the indication is one of the series "44" steam generators, however the duty cycle and structural appraisal appears substantially as though the indication were in a "51" series steam generator. The reason for this dichotomy is because computational technology improved considerably in the periods between "44" and "51" series construction, and it will be shown that this approach results in a more complete and accurate appraisal of the indication behavior. The indication behavior is shown to be of no consequence to the safe and reliable operation of #21 steam generator.

2. Indication Location and Description

The location of the indication is shown in Figures 2.1 and 2.2. Interpretation of Radiographic and Ultrasonic Tests indicates that the indication lies within a cylindrical envelope 2.0" long and 3/8" diameter and has the typical signature of a weld slag inclusion. This latter is particularly important from a fatigue view as it implies that there are no sharp or crack-like discontinuities.

3. SG Duty Cycles

The specified cyclic history of the Indian Pt. #2 "44" Series Steam Generator is tabulated in Table 3.1 together with that of a typical "51" Series Steam Generator. (Note that the following fatigue and fracture mechanics were performed with the number of cycles specified for the "44" Series unit.)

The temperature and pressure histories undergone by both units are shown in Figures 3.1 thru 3.12. Scrutiny of the curves indicates that the "44" unit operates at a somewhat higher temperature than the "51" unit, specifically 612.6°F versus 605°F 554.8°F versus 542°F for primary coolant inlet and outlet respectively. These temperature differences are not considered significant and no numerical effort is shown to accommodate the differences. In general, the transient responses are obviously similar, with the "51" Series usually being somewhat more severe. It is concluded that an assessment of the stress history of a steam generator which has been subjected to the "51" Series thermal history will well and conservatively represent the "44" Series unit.

4. Comparison of "44" and "51"S.G.s

The dimensions relevant to a structural analysis of the indication locale are shown in Figure 4.1. The primary load bearing sections of interest are:

		44	51
Channel head wall adjacent to T.S.	Thickness	5.25"	5.16"
	Mean Radius	62"	65.39"
	T. S. Thickness	22"	21.03"
Secondary Shell Adjacent to T.S.	Thickness	3.25"	3.25"
	Mean Radius	63"	66.345'

It is apparent from the above table and operating pressures that the "51" Series has greater primary loading than the "44" and, therefore, from this stress viewpoint, use of "51" Series stresses represents a conservatism. The secondary stresses, which are section thickness dependent, are obviously very similar.

5.0 Structural Analysis

5.1 Analysis Description

The channel head, as shown in figures 2.2 and 4.1 consists of a hemisphere with the divider plate bisecting the hemisphere into hot and cold regions (i.e. primary coolant inlet and outlet.) An exact analysis would be a three-dimensional treatment of the entire region, however, contemporary proven techniques at the time of writing the "51" Series Stress Report were either two-dimensional or axi-symmetric analyses with a detailed conservative strength of materials examination of regions which were not well represented two-dimensionally. Consistent with this approach, the channel/head tubesheet/stub-barrel complex was represented by two axi-symmetric analyses. A complete transient analysis of the hot side conditions was performed with the properties pertaining in a plane normal to the divider plate assumed acting axi-symmetrically; a similar set of analyses was performed for the cold side conditions. The results of these two analyses gave two complete stress histories and these are shown in figures 5.1.1, 5.1.2, and 5.1.3 for the indication locale.

It is apparent that the hot side stress excursions are the more severe for a fatigue and fracture mechanics appraisal of the indication, and thus the hot side data was used consistently.

Note that the ordinates of figures 5.1.1, 5.1.2, and 5.1.3 describe principal stresses as coinciding with the axial, hoop and radial directions: this was so because the shear stresses were small and gave only slight rotations to the principal stresses.

The indication is located in a position in which the representation by either of the axi-symmetric analyses requires some explanation. The points to be considered are primarily:

1. The hot and cold sides of the channel head grow thermally to different radii and therefore secondary stresses (predominantly hoop) are generated in the head in the plane of the divider plate to maintain the continuity of each half of the channel head.
2. The fluid pressures inside the channel head deform the head in an axially-symmetric manner; however, the divider plate restrains this dilation in its own plane, locally changing the hoop curvature.
3. The tubesheet axial deflection is substantially restrained by the divider plate and no consideration is given to this in either analysis.

The suppressed differential radial growth mentioned in No. 1 above has two effects. First, the axial fibers adjacent to the divider plate are brought closer to alignment, tending to average the axial stresses computed in the hot and cold analyses. This feature is accommodated in the analyses which follow by using the "worst" of the two, namely, the hot side where the axial stress excursions are greatest. The second effect concerns the circumferential accommodation of the differential channel head growth. There is obvious symmetry of the flexibilities at either side of the divider plate and it is reasonable to assume that plane of the divider plate coincides with a point of circumferential inflection and thus with zero (or in actuality an insignificant) hoop bending stress. The consequent shear across this section is not of particular consequence in the indication location because it is adjacent to the surface.

The second feature mentioned above concerns the effect of the line load of the divider plate upon the channel head. Separate studies (ref. 2) of the divider plate in a 51 Series SG, have shown that assuming all of the lack of fit due to thermal and pressure loading between divider plate, channel head and tubesheet is accommodated by the divider plate, a maximum stress of the order of 6000 psi is generated at the surface of the divider plate at the indication height. It is clearly not possible to analyze this three-dimensional region exactly, but several strength of materials approaches were used to scope the magnitude of the perturbation. The dominating feature of all of the analyses was the hoop stiffening effect of the tubesheet, which strongly restrained any radial motion of the shell at the indication height (i.e. of 2.7" from the tubesheet). As a consequence, the radial loads from the divider plate induced insignificant hoop and axial stresses with only the radial stress being of any consequence. The following analyses accommodate these radial stresses in a conservative manner.

The third point, namely the lack of interaction between divider plate and tubesheet, results in calculating a consistently larger tubesheet deflection than actually exists. The interactive effect of this upon the hoop and axial stresses at the point is to move both stresses to a more positive value. In other words, the hoop and axial stress excursions (which are predominately thermally induced) occur about a higher positive mean. Examining this consequence upon fatigue and fracture analyses:

1. The fatigue analysis as explained later does not consider the hoop stress and the more positive axial stress is therefore a conservatism because of its use in the stress difference format of an ASME Section III fatigue appraisal.
2. The effect of this more positive mean stress upon the fracture mechanics appraisal is: the analysis considers each principal stress in turn and increasing the axial stress to a more positive value increases the con-

servatism. The hoop stress, however, fluctuates in sign and it is not apparent whether or not an increase in the positive direction is conservative or not. Examination of the crack growth data shows that with any reasonable appraisal of the hoop stress excursion, the effect upon crack growth is not significant.

5.2 Fatigue Analysis

The axis of the indication or indications lie in a plane normal to the axis of the steam generator as shown in figures 2.1 and 2.2. Therefore there is no expectation from the non-destructive examinations of the indication that there is any significant stress intensification of the hoop stress. Furthermore, inspection of figures 5.1.1, 5.1.2, and 5.1.3 shows that of the three stress differences $\sigma_A - \sigma_R$, $\sigma_R - \sigma_H$, & $\sigma_H - \sigma_A$, the axial minus radial stress is clearly the worst and thus requires most consideration.

Use of reference (9) and with conventional assumed geometries, such as cylinders with hemispherical ends and ellipses, suggests (for 2-dimensional cases) stress concentration factors of around three to five. Reference (3), NB-3222.6(e) (2) specifically states that no stress concentration factor greater than five need to be used in a fatigue analysis. To insure that the problem was adequately scoped, fatigue analyses were programmed (ref. 5) with stress concentration factors of four, five, and six (see input and output data in Tables 5.2.1 through 5.2.6) which resulted in cumulative usage factors of .26, .51 and .86 respectively.

The Section III allowable cumulative Usage Factor is 1. and therefore it is possible to conclude that fatigue at this indication will not be cause of failure.

5.3 Fracture Mechanics

The indication was geometrically idealized into three different crack curves, one for each principal stress: the idealization was to consider any indication shape which has the highest K_I value within the indication envelope and normal to the stress direction.

Stress	Envelope	"Worst" Shape	"Worst" $K_I \div \sigma$
Axial	Rectangle 2.0" x .375"	Ellipse 2.0"x.375"	.77 at minor axis
Radial	Rectangle 2.0"x.375"	Ellipse 2.0"x.375"	.77 at minor axis
Hoop	Circle .375" dia.	Circle .375" dia.	.489

The materials relevant to the indication are the tubesheet material i.e. SA-508CL2 forging and the weld metal i.e. ASTM-A558.

Reference (10) contains completely appropriate data for a SA-508 Cl.2 forging which may be tabulated as:

Temp (^oF)	50	70	550
Yield (Ksi)		70	55
Fracture Toughness (Ksi/$\sqrt{in}$)	150		
Crack Growth Constants, C_o			$6.17*10^{-8}$
n			1.79

The weld metal data was abstracted from separate sources, references (6) and (7). Both references document weld metal tests for nearly identical electrodes to an allied material (specifically SA-533B). Comparison of the electrode chemistry (% by wt) is as follows.

Element	Ch. Hd./T.S. Weld	Ref. (6)	Ref. (7)
C	.120-.180	.100	.090
Mn	1.750-2.250	1.770	1.250
Mo	.400-.600	.420	.520
Ni	.500-.800	.640	1.080
Si	.050	.360	.230
S	.015	.015	.014
P	.010(Max)	.009	.018

The fracture mechanics data may be tabulated as:

Temp(^oF)	0	70	550
Yield (Ksi)		67(6)(7)	57(7)
Fracture Toughness, (Ksi/ in)	115(6)		
Crack Growth Constants, C_o		$.398*10^{-8}$(7)	
n		2.2(7)	

The K_{IMAX} and crack growth evaluations which follow are so far removed from failure that the slightly different electrode chemistries are not considered significant.

5.3.1 Critical Stress Intensity

The maximum value of K_I for each stress may now be computed after reference to figures 5.1.1, 5.1.2, and 5.1.3.

Stress	Event	Magnitude (psi)	(Ksi/$\sqrt{in}$
Axial	Prim. Hydro.	42,440	32.6
Radial	Hypothetical* transient	17,000	13.1
Hoop	Loss of Load	9,741	4.76

The greatest stress intensity occurs during hydro-test (90^{o}F) with the axial stress. References (6), (7), and (10) indicate K_{IC} values of about 150 Ksi/$\sqrt{in}$. and 115 Ksi/$\sqrt{in}$. at temperatures lower than 90^{o}F. There has never been any indication of K_{IC} declining with an increase in temperature for either metal, it is therefore concluded that neither tubesheet nor weld will suddenly fracture during any plant operation condition.

5.3.2 Crack Growth

For the tubesheet material, ref. (10) indicates a crack growth equation of:

$$\text{(Eq. 5.3.1)} \quad \frac{da}{dN} = 6.17 * 10^{-8} \Delta K^{1.79} \text{ @ } 550^{o}F$$

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*Duty cycle never induces significant radial tensile stresses: a hypothetical transient was generated to scope the tensile effect.

and for the weld material ref. (7) indicates the equation:

$$\text{(Eq. 5.3.2)} \quad \frac{da}{dN} = .398 * 10^{-8} \, \Delta K^{2.2} \; @ \; 70^{\circ} \, F$$

where $K = Ksi/\sqrt{in}$; a = inches; N = cycles.

Comparing both equations shows tht crack growth proceeds faster with equation 5.3.2 when ΔK is greater than 6.68 $Ksi/\sqrt{in}$. The fracture mechanics analysis, as shown, uses equation 5.3.2 for both metals, ignoring the anticipated consistency or reduction in crack growth with increase in temperature which has been found at W R&D for this class of metals.

Consider the axial stress excursions shown in Figure 5.1.1. Represent this curve as:

19,501 cycles of 0. to 20. ksi (i.e. 15 to 35)

and 250 cycles of 0. to 56. ksi (i.e. 45 + 11).

Application of equation 5.3.2 yields an increase in ellipse minor radius from .1875" to .229", a growth of .041". In view of the generally conservative structural analysis assumptions, grossly conservative duty cycle assumed above and the well proven crack growth equations, it is not considered worth pursuing the crack analysis further other than to conclude that no crack from any stress will grow more than .041" and that this end of life crack will not reach any surface.

6. Conclusions

Conservative fatigue and fracture appraisals have been made of the worst of the two indications found in the girth weld of the channel head to tubesheet in the Indian Point #21 Steam Generator. Both appraisals show conclusively that the worst indication will have no effect upon the safe and reliable operation of the steam generator.

7. References

1. DeRosa, P. P. and Conway, L., Section 3.1.6 "51 Series Steam Generator Channel Head Tubesheet - Stub Barrel Transient Analysis". Westinghouse Electric Corporation, Aug. 1970.

2. Walker, W. B.; Section 3.3 "51 Series Steam Generator Partition Plate Analysis". Westinghouse Electric Corporation, Aug. 1970.

3. ASME Boiler and Pressure Vessel Code, Section III, 1971.

4. Equipment Specification (Steam Generator), IPP-120, Revision No. 1 (12/26/67), Westinghouse Electric Corp.

5. DeRosa, P. P., "A Computer Program for Evaluation of the Cumulative Usage Factor". Westinghouse Electric Corporation, Tampa Division, WTD-ED(SA)-70-022, June 1970.

6. Shabbits, W. O. Pryle, W. H. and Wessel, E. T., "Fracture Toughness of ASTM-A533 Grade B Cl.1 Heavy Section Submerged Arc Weldments". J. Basic Eng., June, 1971, p. 231-236.

7. Clark, Jr., W. G. and Havan, R. R., "A Fracture Mechanics Evaluation of the Fatigue Crack Growth Characteristics of A533B Steel Weld Metal". Research Rpt. No. 69-7D7-BFPWR-R2 Feb., 1969.

8. Parris, P. C. and SIH, G. C., "Stress Analysis of Cracks". ASTM Symposium Fracture Toughness Testing and Its Applications:, June, 1964, p. 30-83.

9. Peterson, R. E., "Stress Concentration Design Factors", Wiley and Sons, 1953.

10. Mayer, T. R. Unpublished SA-508 Cl.2 data, Westinghouse Electric Corporation, 1970.

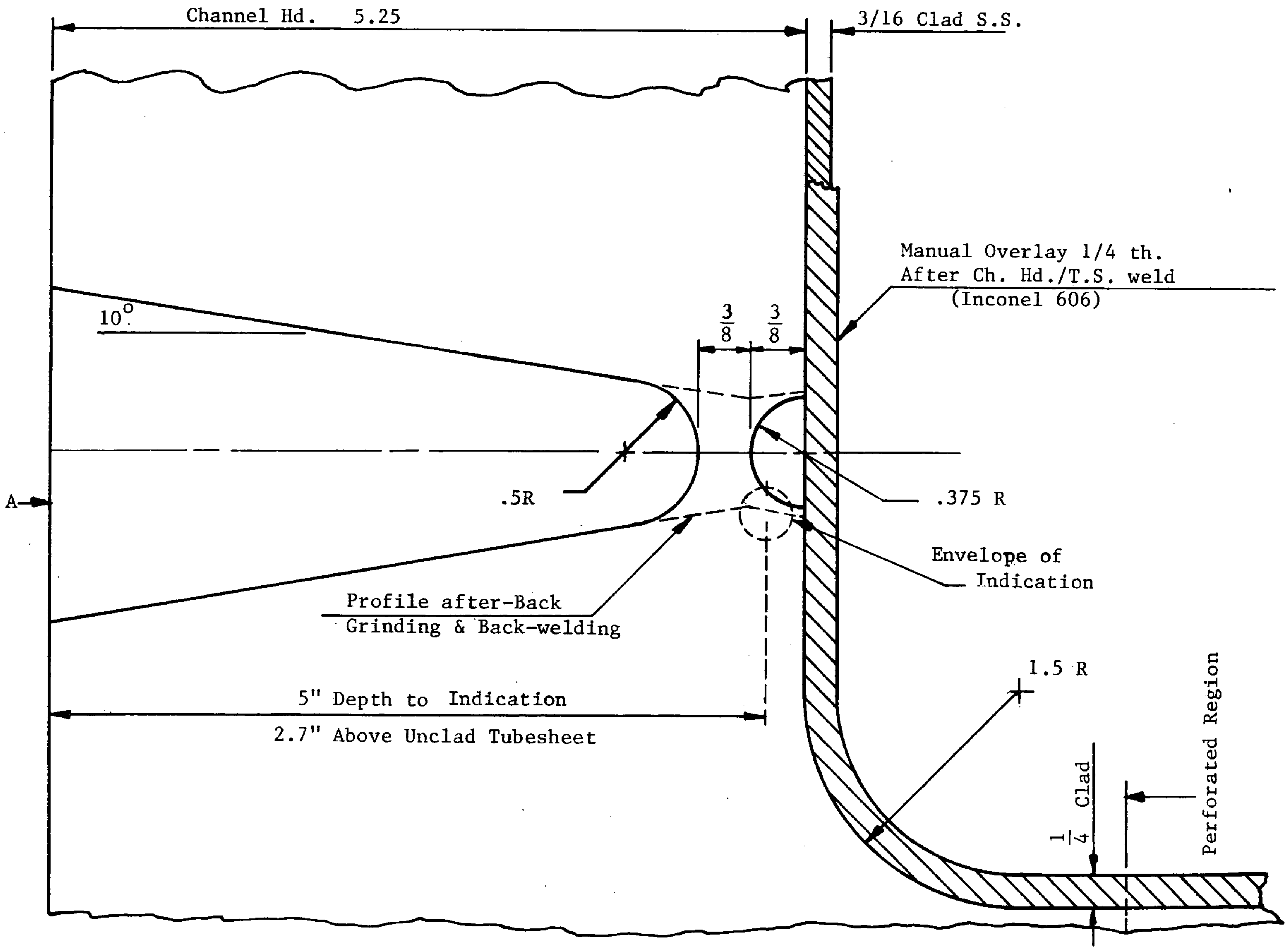


Figure 2.1 Indication Location (Section)
(Full Scale)

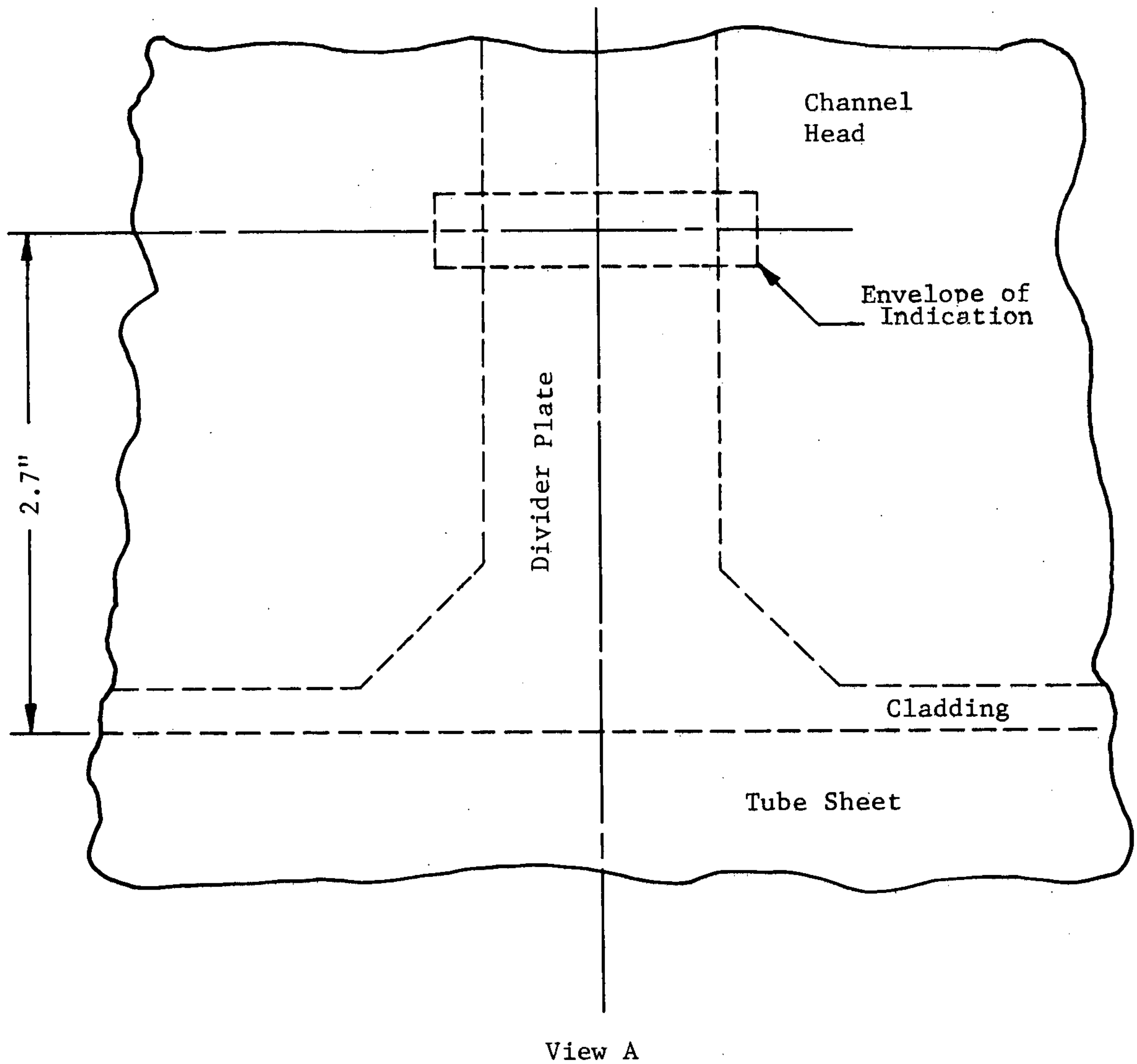


Figure 2.2 Indication Location (Elevation)
Scale = Full

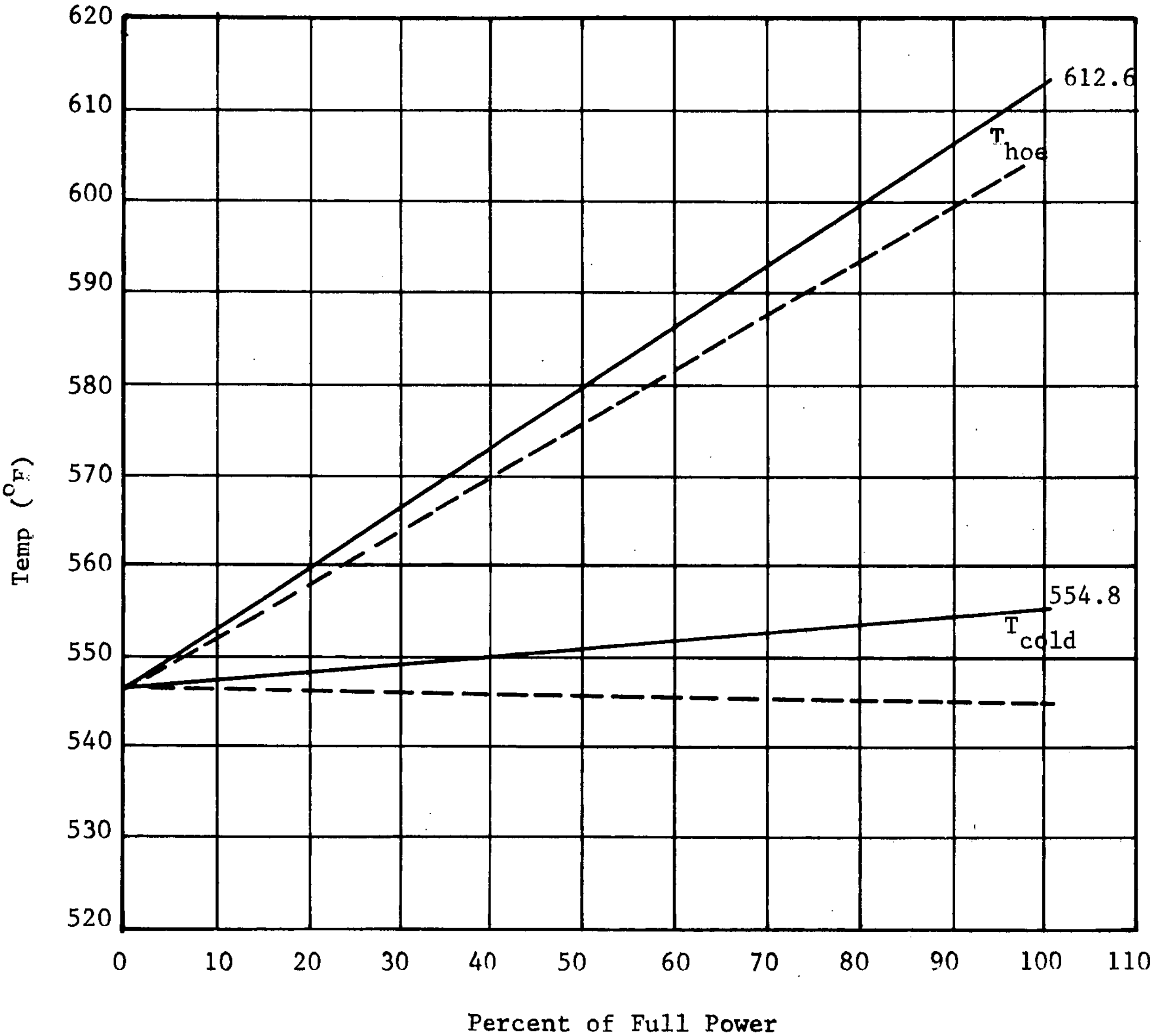


Figure 3.1 Full Power (100%) = 3083.4 MWt

Reactor Coolant Temperature Vs. Load

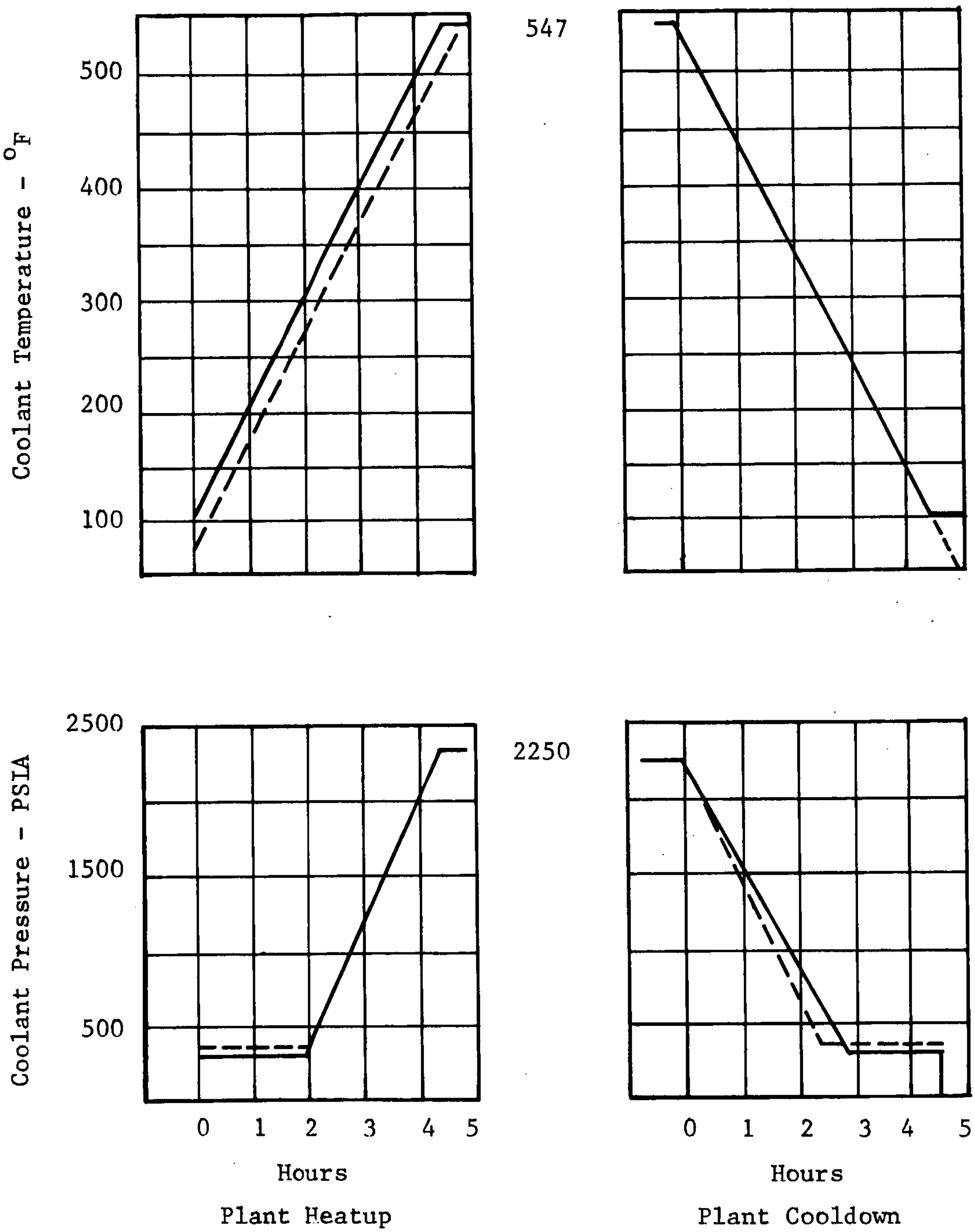


Figure 3.2 Plant Heatup and Cooldown

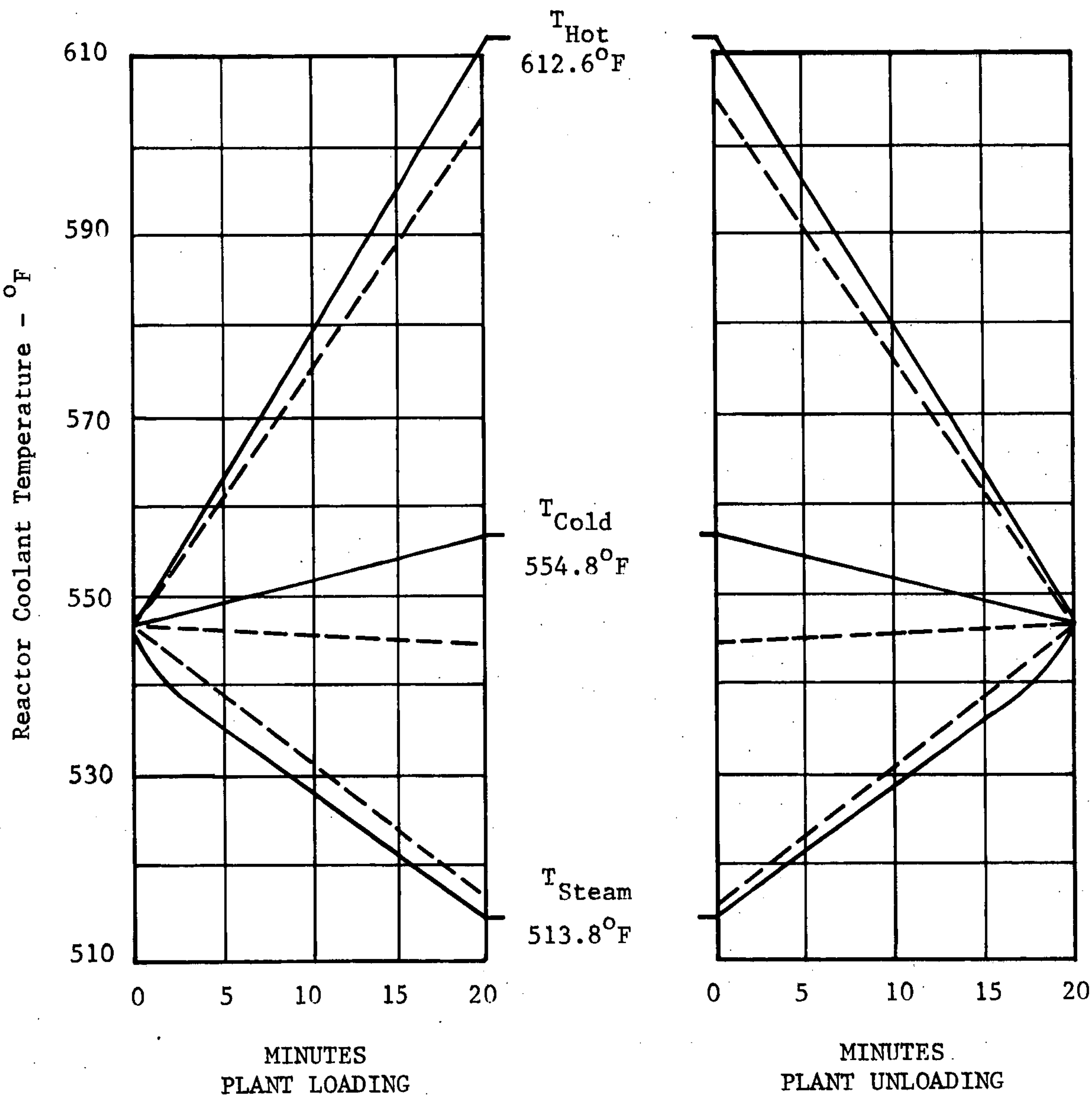


Figure 3.3 Reactor Coolant Pressure - 2250 PSIA
Plant Loading and Unloading

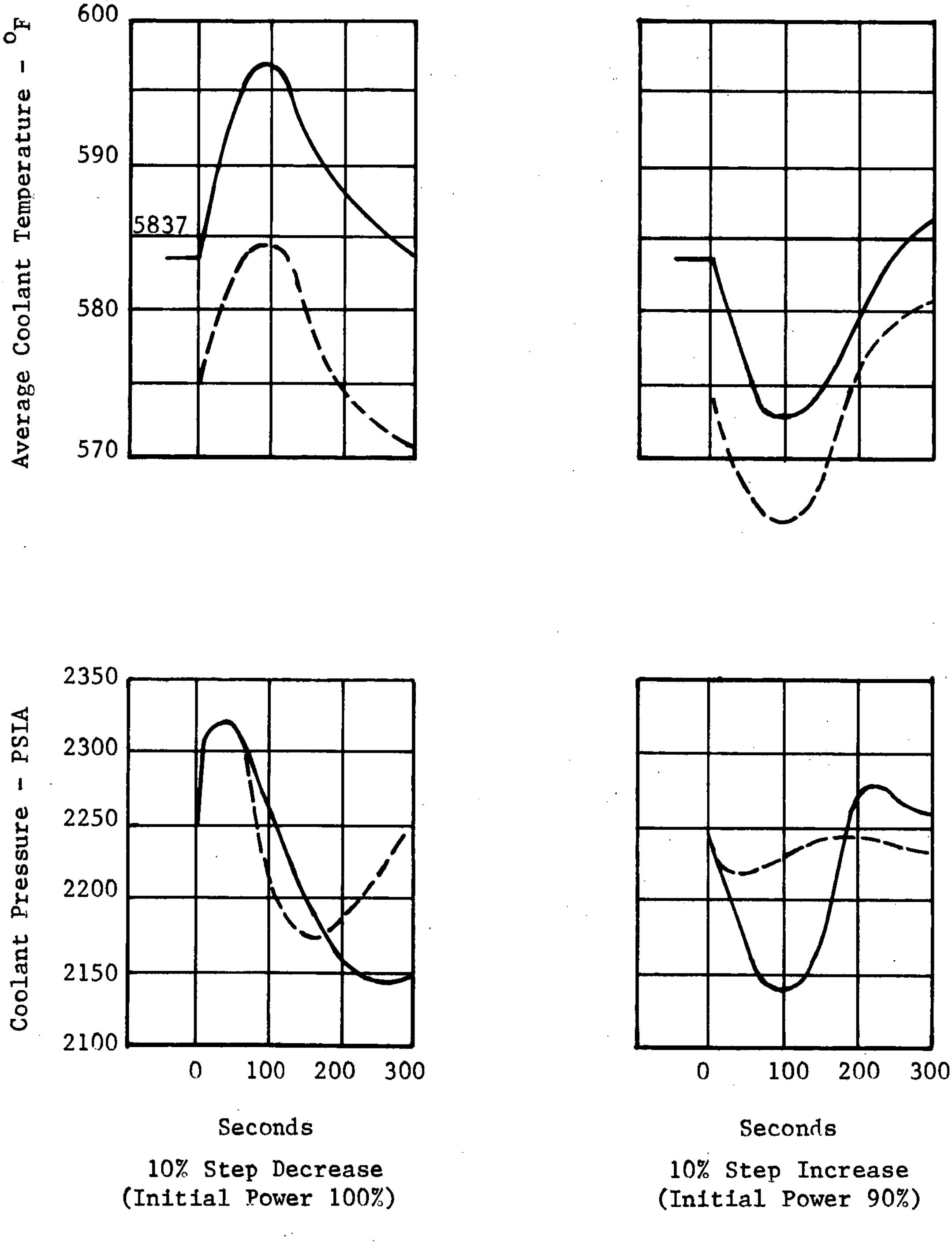


Figure 3.4 Step Load Transients of ± 10% of Full Power

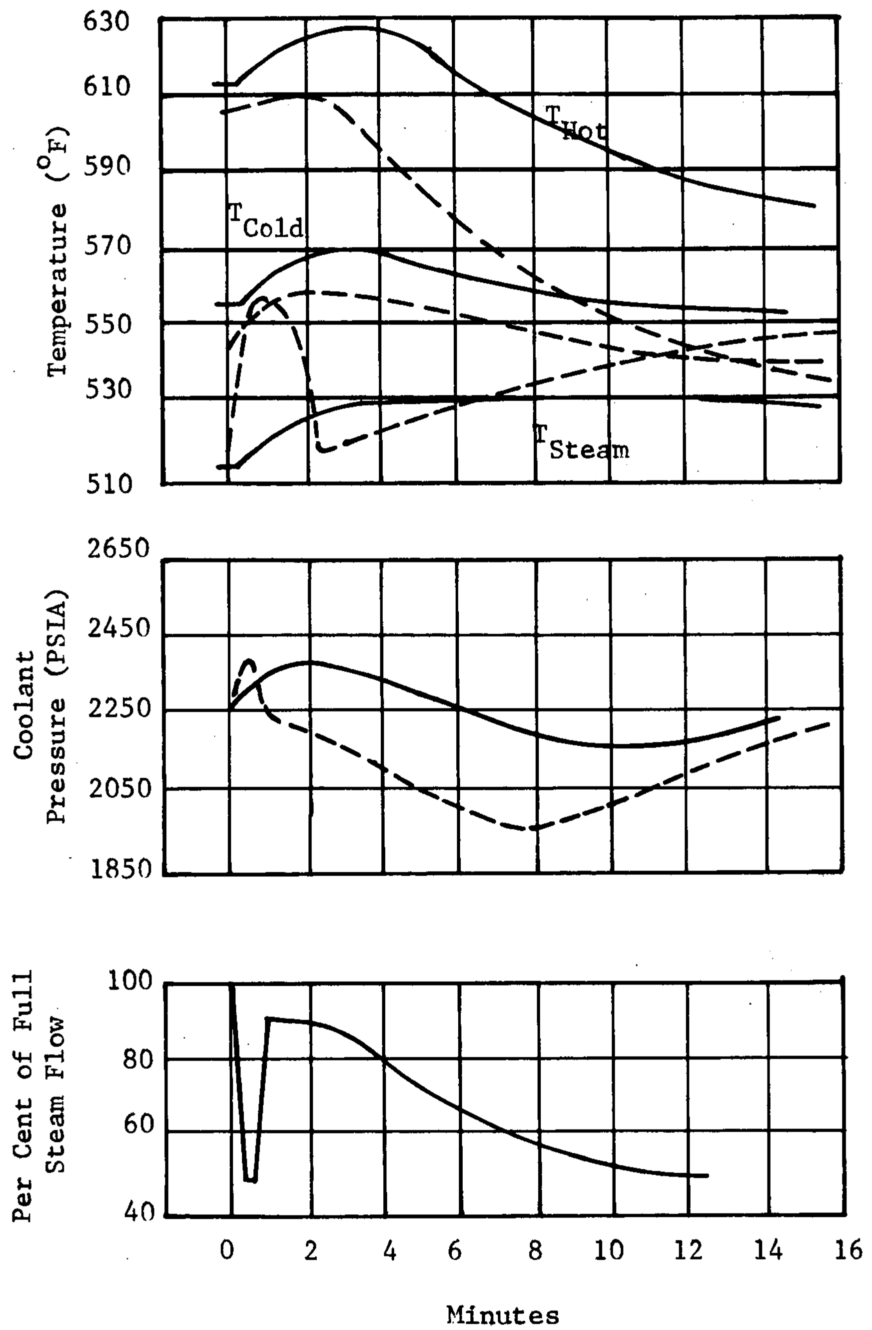
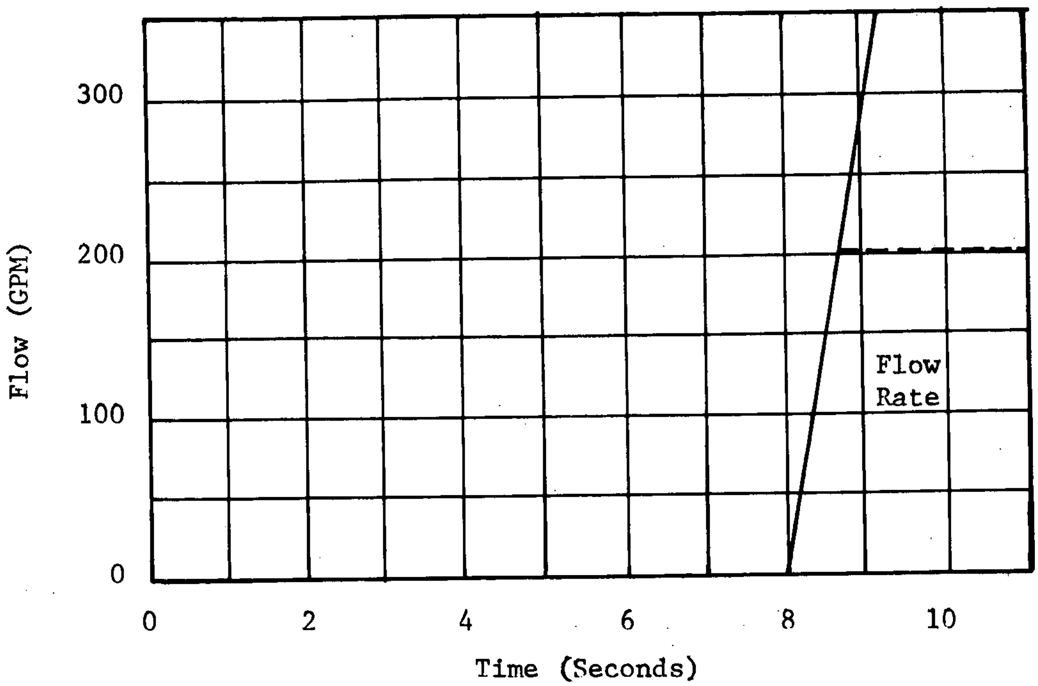


Figure 3.5 Step Reduction From 100% to 50% Load



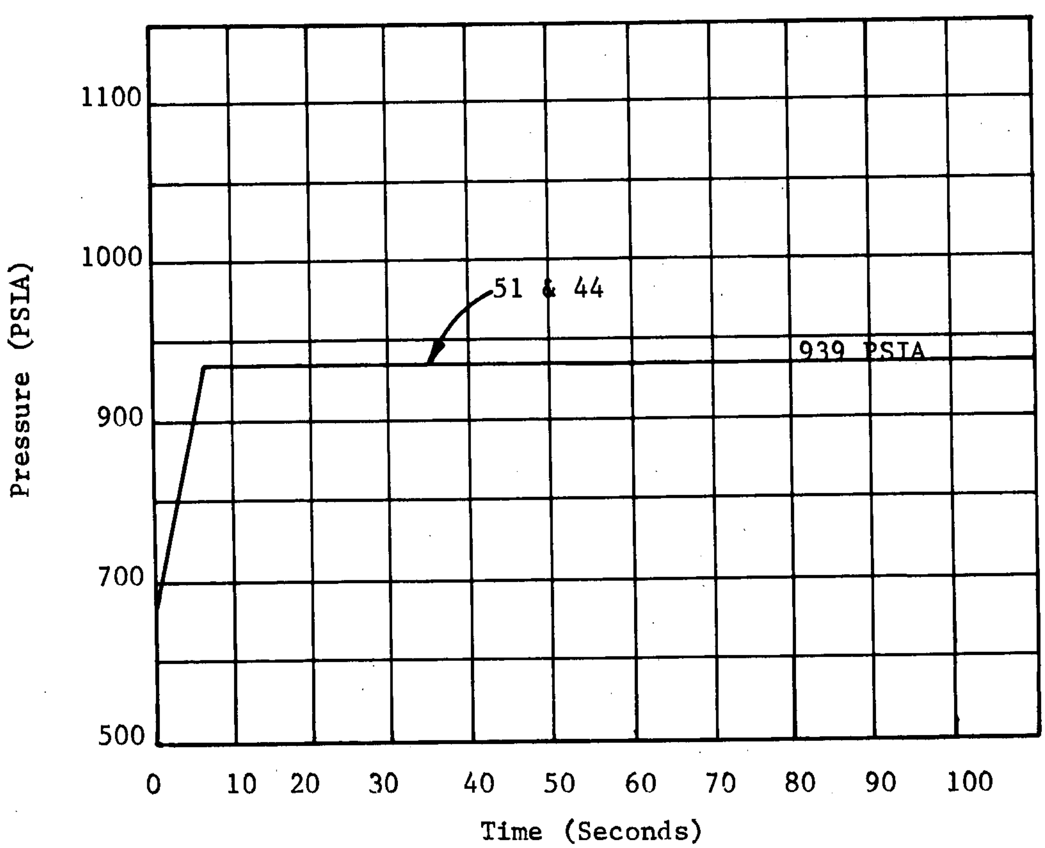


Figure 3.6 Feedwater Injection

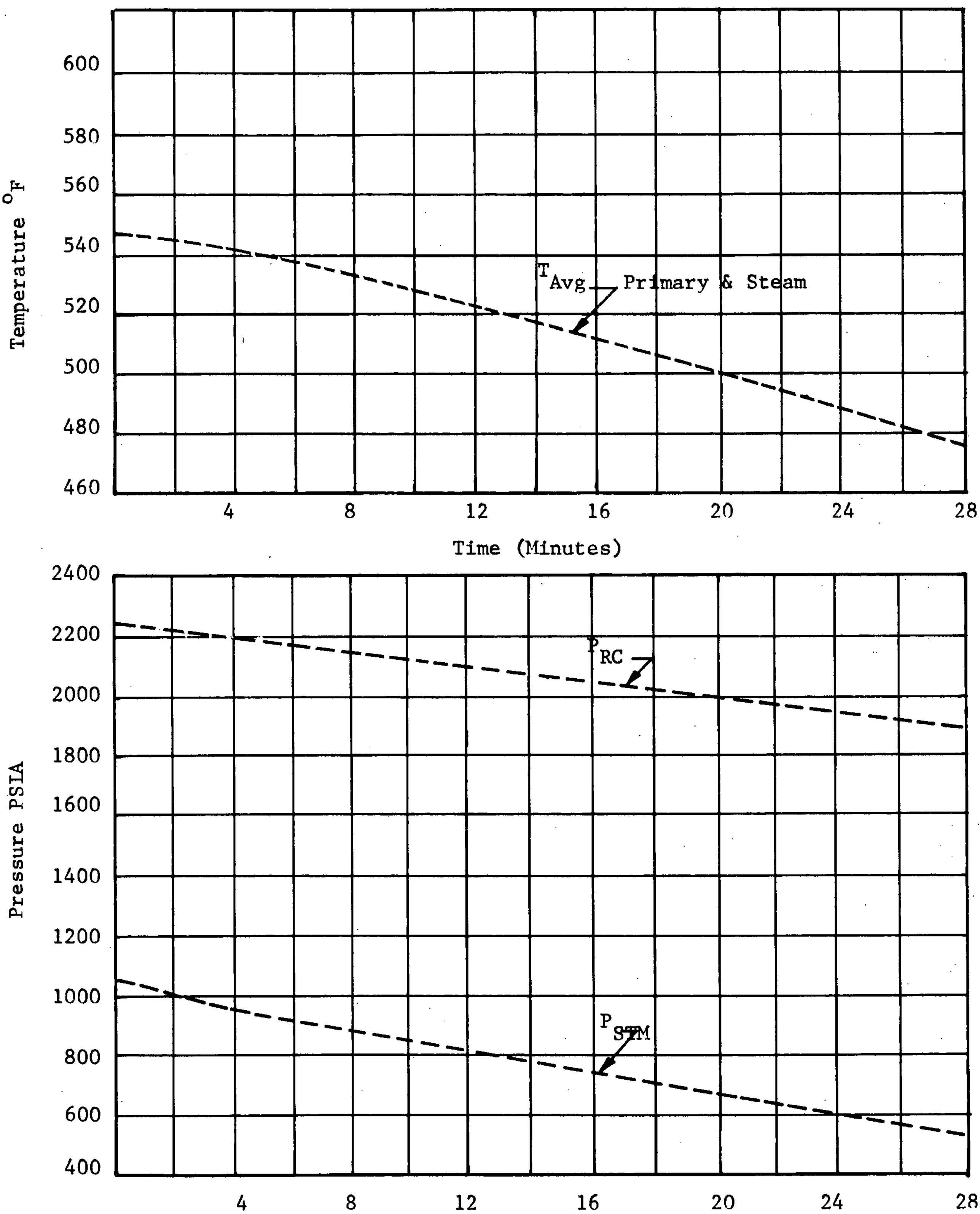


Figure 3.7 Turbine Roll Test

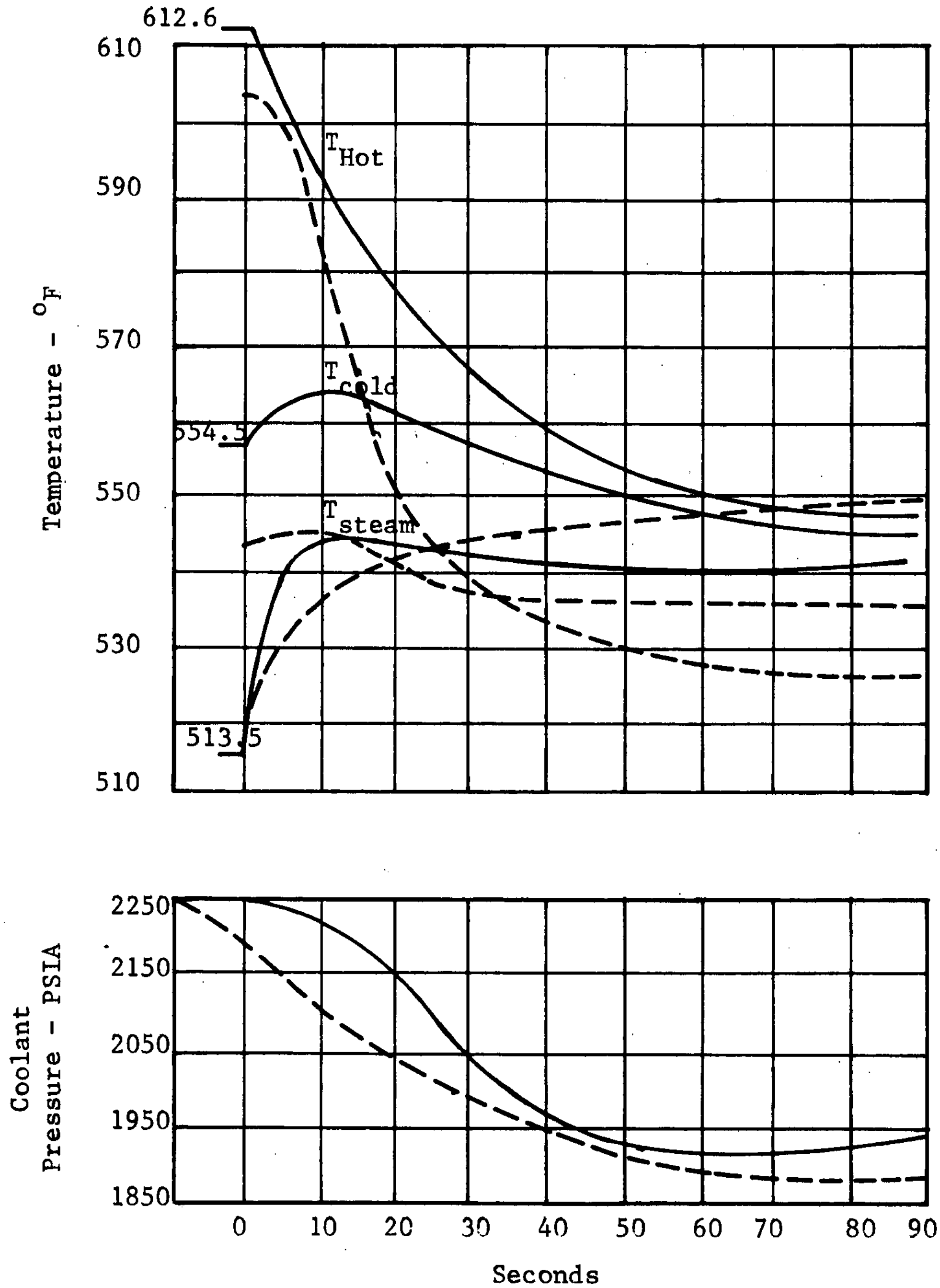


Figure 3.8 Reactor Trip From Full Power

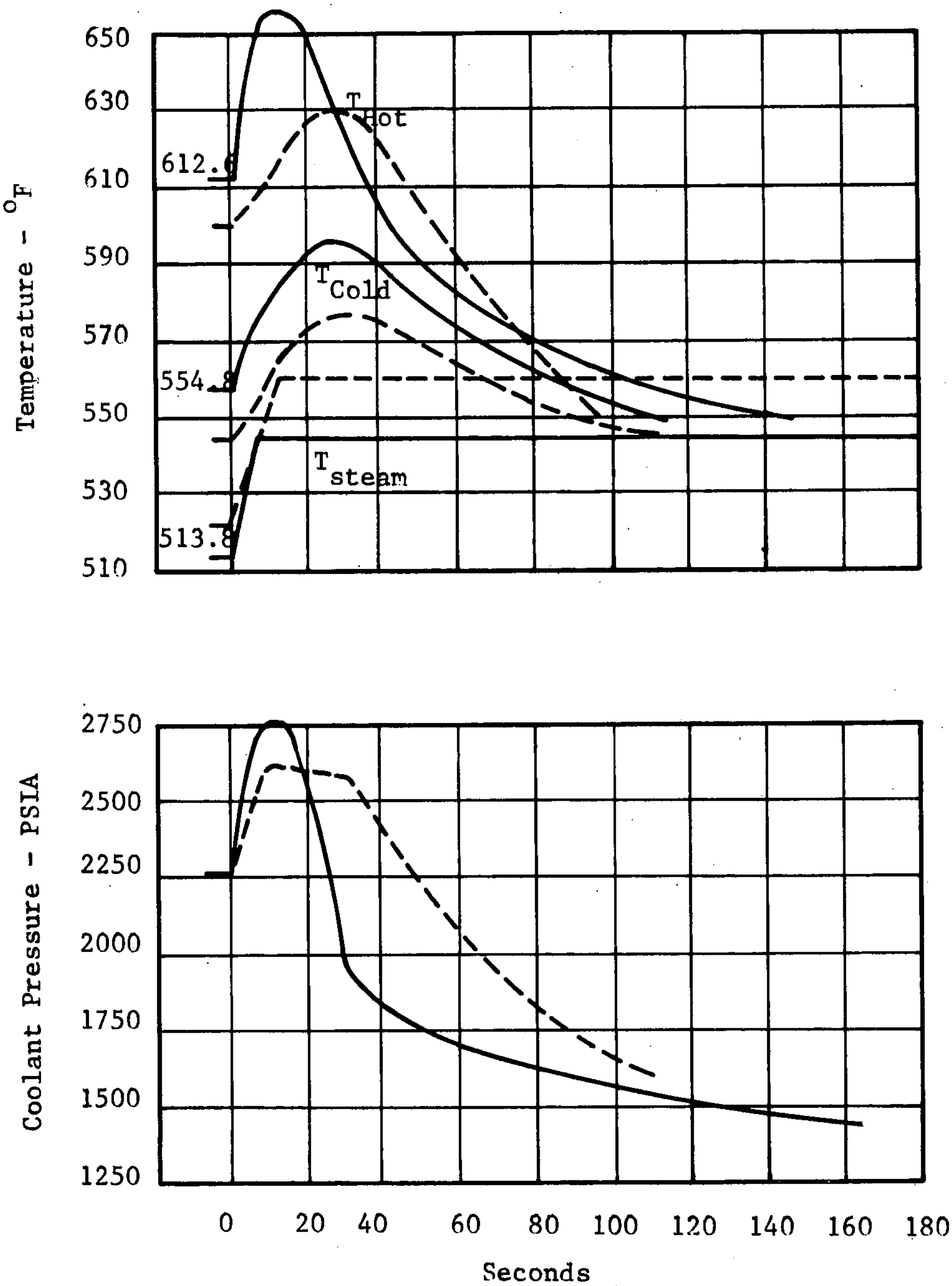


Figure 3.9 Loss of Load

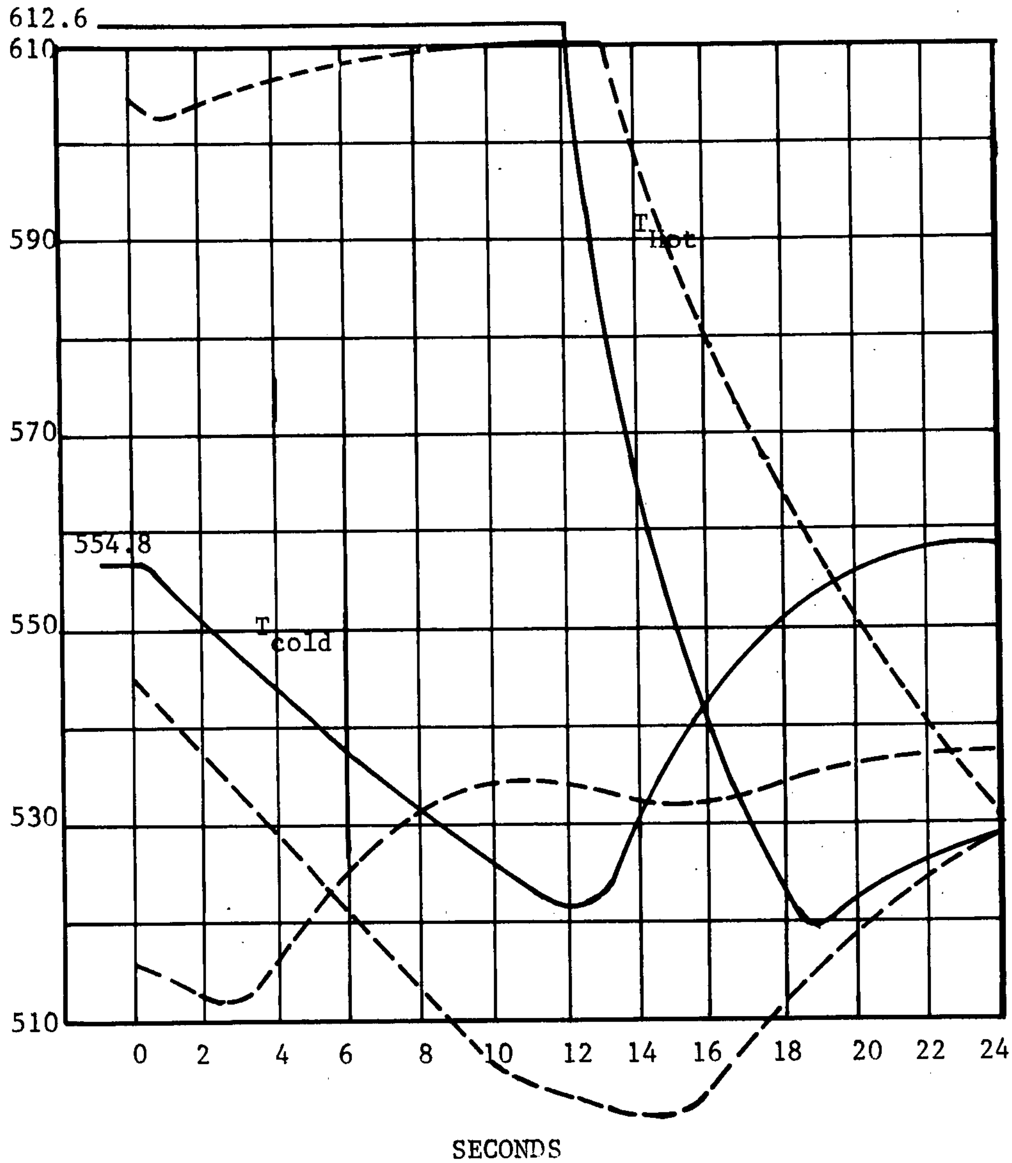
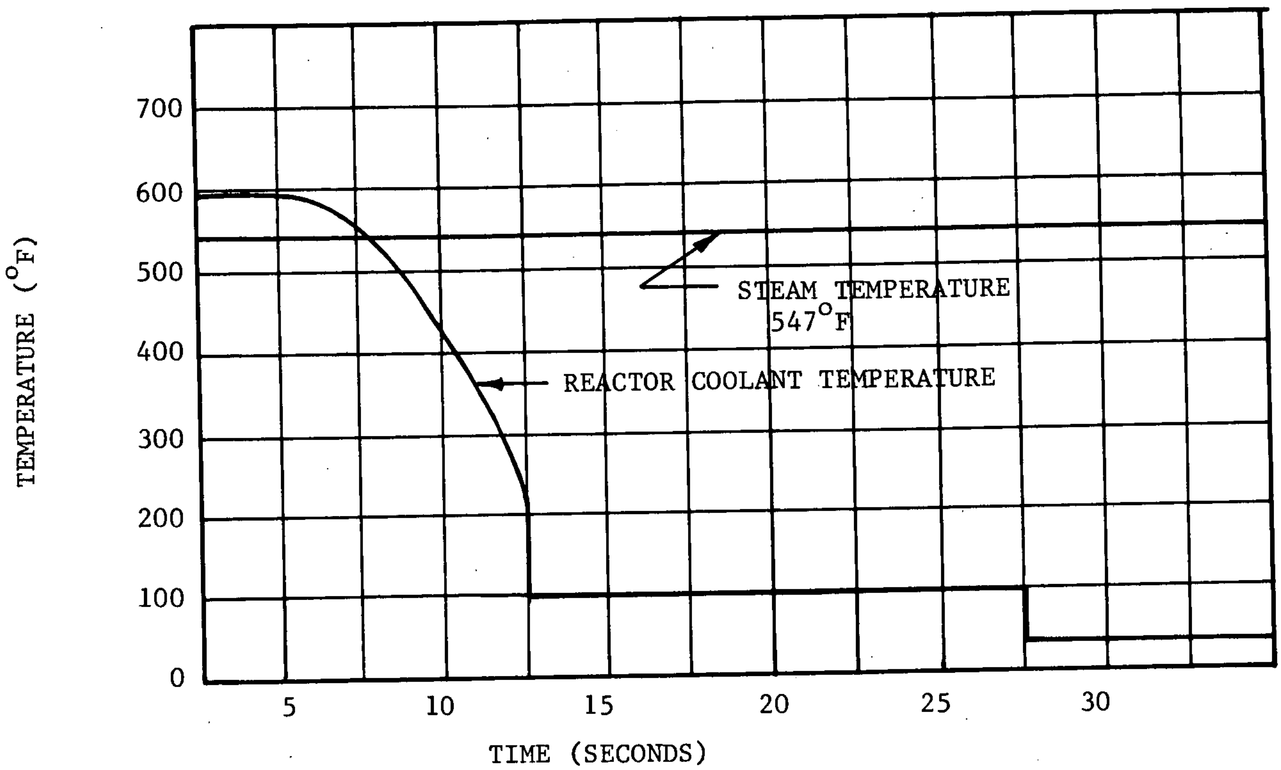


Figure 3.10 Loss of Flow, One Pump (Loss Loop)



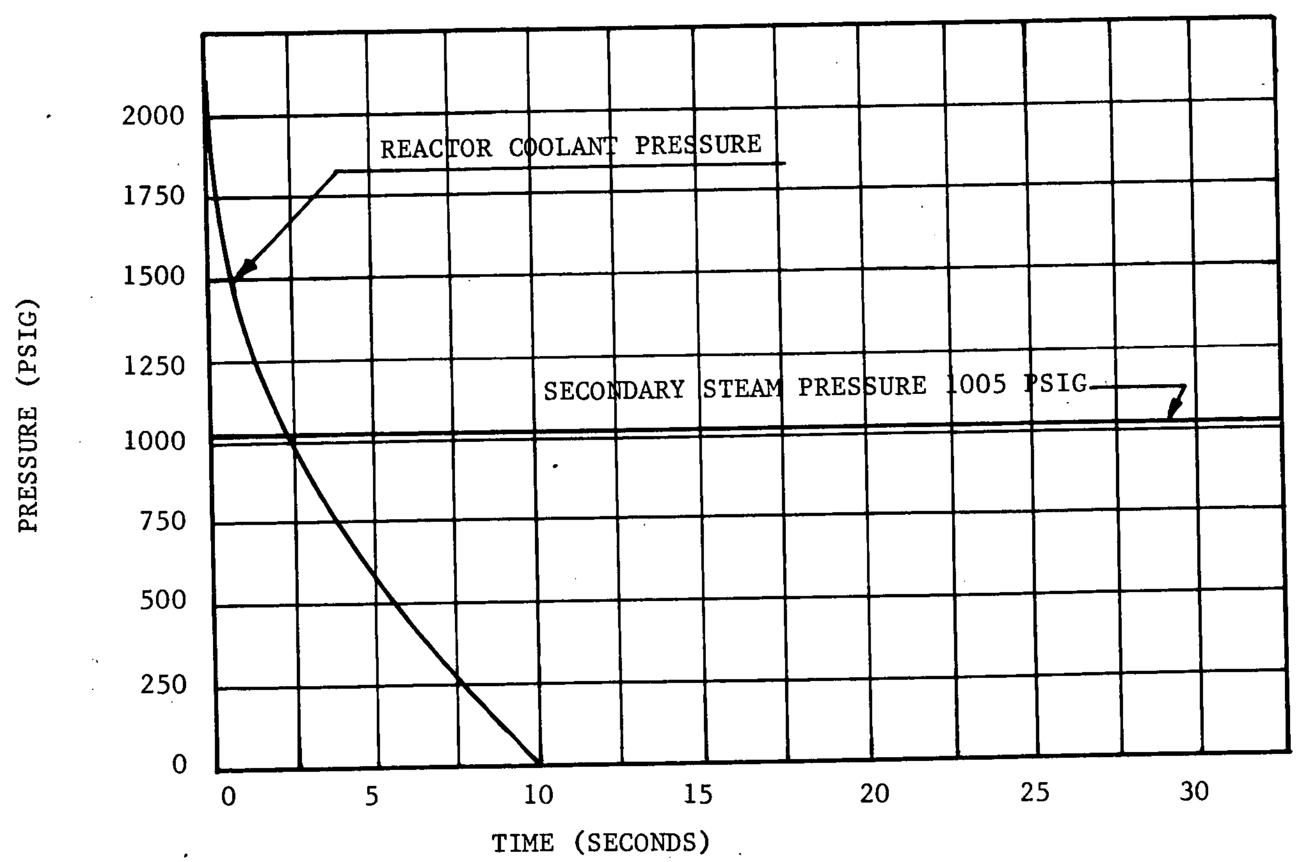
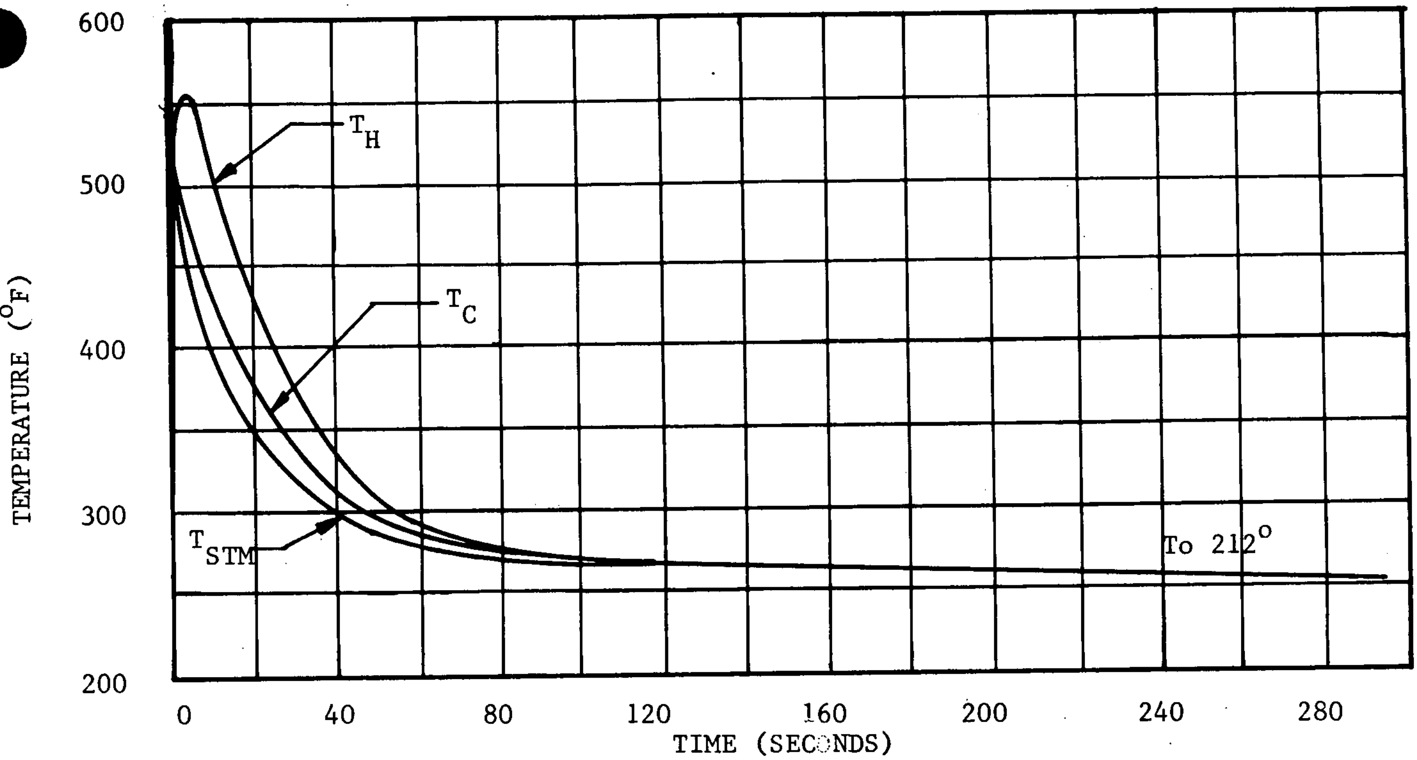


Figure 3.11 Reactor Coolant Pipe Break

(Graphs apply to both 51 and 44 Series S.G.)



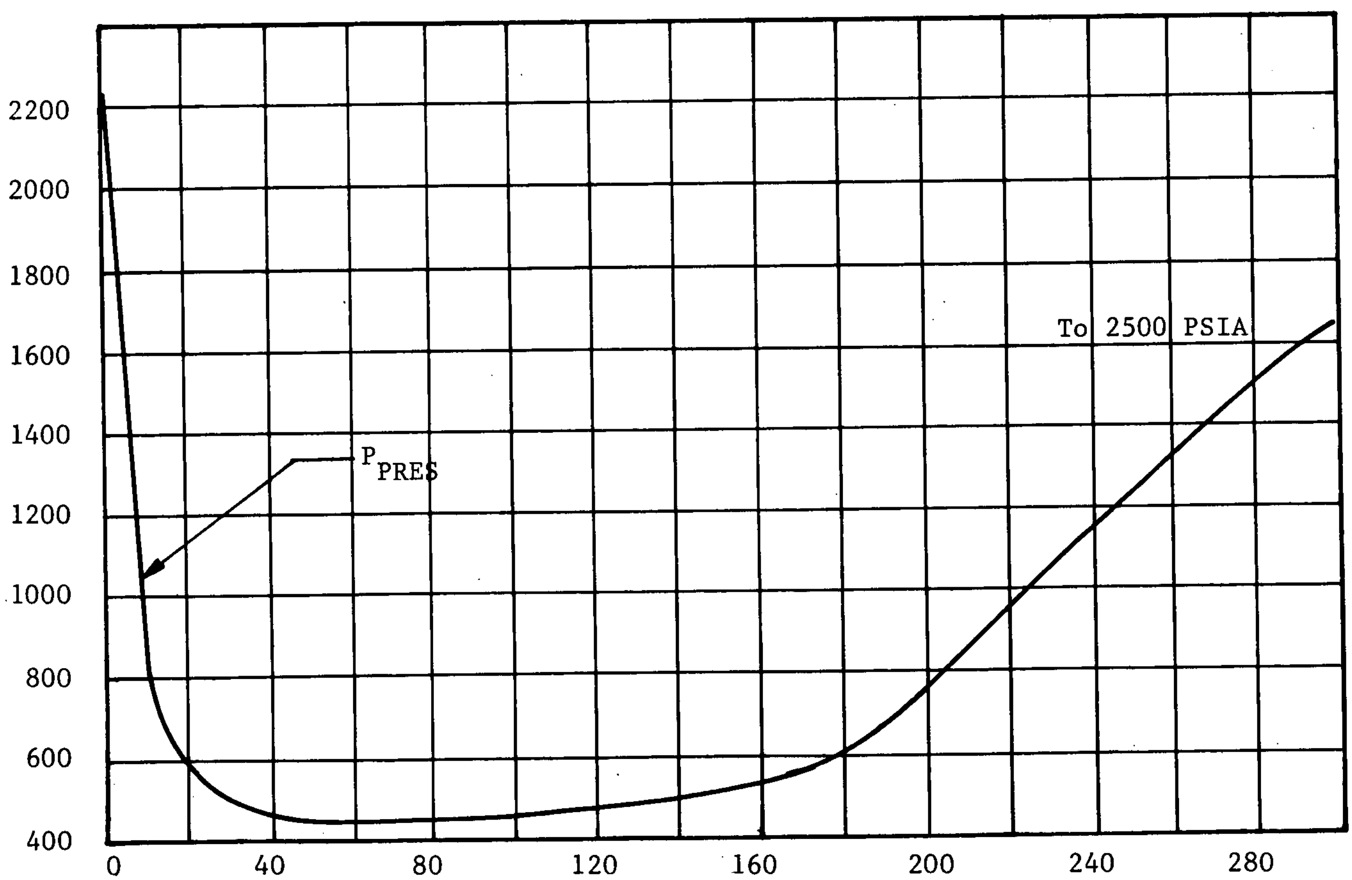


Figure 3.12 Steam Line Break From No Load, 2, 3, & 4 Loop Plants
(Graphs apply to both 51 and 44 Series S.G.)

Table 3.1

Condition	Load States: 51 Series Event	Number of Occurrences	Figure No.	44 Series Event	Number of Occurrences
Normal	Plant Heat Up	200+	3.2	Plant Heat Up	200+
	Plant Cool Down	200+	3.2	Plant Cool Down	200+
	Plant Loading	18,300+	3.3	Plant Loading	14,500+
	Plant Unloading	18,300+	3.3	Plant Unloading	14,500+
	Small Step Load Increase	2,000	3.4	Small Step Load Increase	2,000
	Small Step Load Decrease	2,000	3.4	Small Step Load Decrease	2,000
	Step Reduction from 100% to 50%	200	3.5	Step Reduction from 100% to 50%	200
Upset	Hot Standby Operation	18,300	3.6	Hot Standby Operation	25,000*
	Turbine Roll Test	10	3.7	Not Specified	
	Reactor Trip from 100%	400	3.8	Reactor Trip from 100%	400
	Loss of Load	80	3.9	Loss of Load	80
	Loss of Flow	8	3.10	Loss of Flow	80
	Loss of Power	40		Loss of Power	10
	None Specified			Loss of Secondary Pressure	6
	OBE	5 of 10		"g" loading & normal load	steady state

*25,000 cycles represents manual S.G. water level control. No significant cyclic effect @ T/S locale.

+Maximum transient stress not significantly greater than Steady State values" consequently neglected.

Table 3.1 Cont.

Condition	Load States Cont. 51 Series Event	Number of Occurrences	Figure No.	44 Series Event	Number of Occurrences
Tests	Primary Hydrostatic	5		Primary Hydrostatic	1
	Secondary Hydrostatic (0 psig primary)	5		Secondary Hydrostatic	15
	None Specified			Primary Pressure Tests	5
	None Specified			Primary Leak Test (2250/0)	5
	None Specified			Secondary Leak Test (0/840)	5
Emer.	Design Basis Earthquake (DBE)	3 of 10		None Specified	
Faulted	Reactor Coolant Pipe Break (LOCA)	1		None Specified	
	LOCA + DBE	1		(g) Loading	
	Stream Line Break + DBE	1		(g) Loading + 2485/0	Steady State

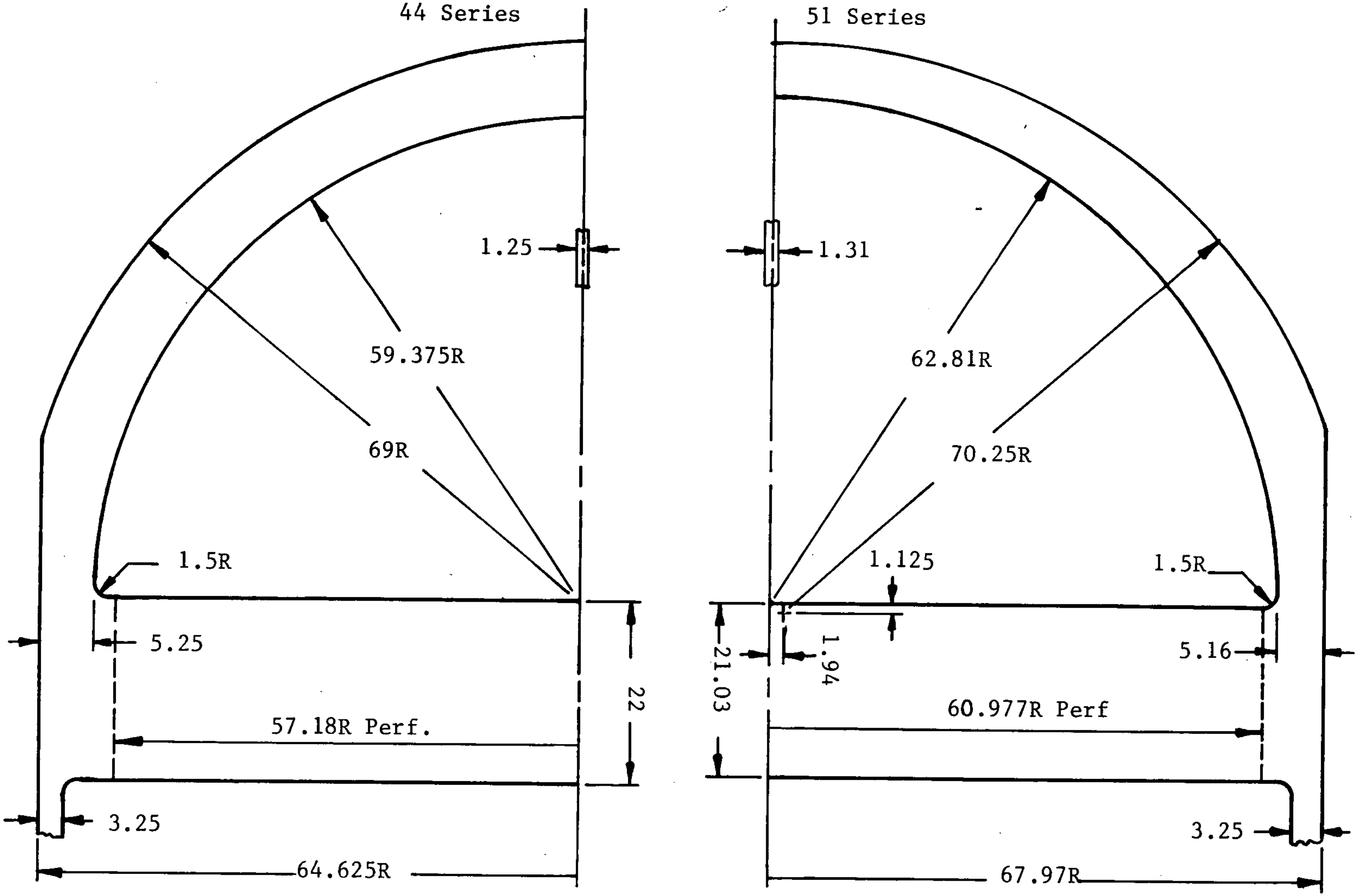
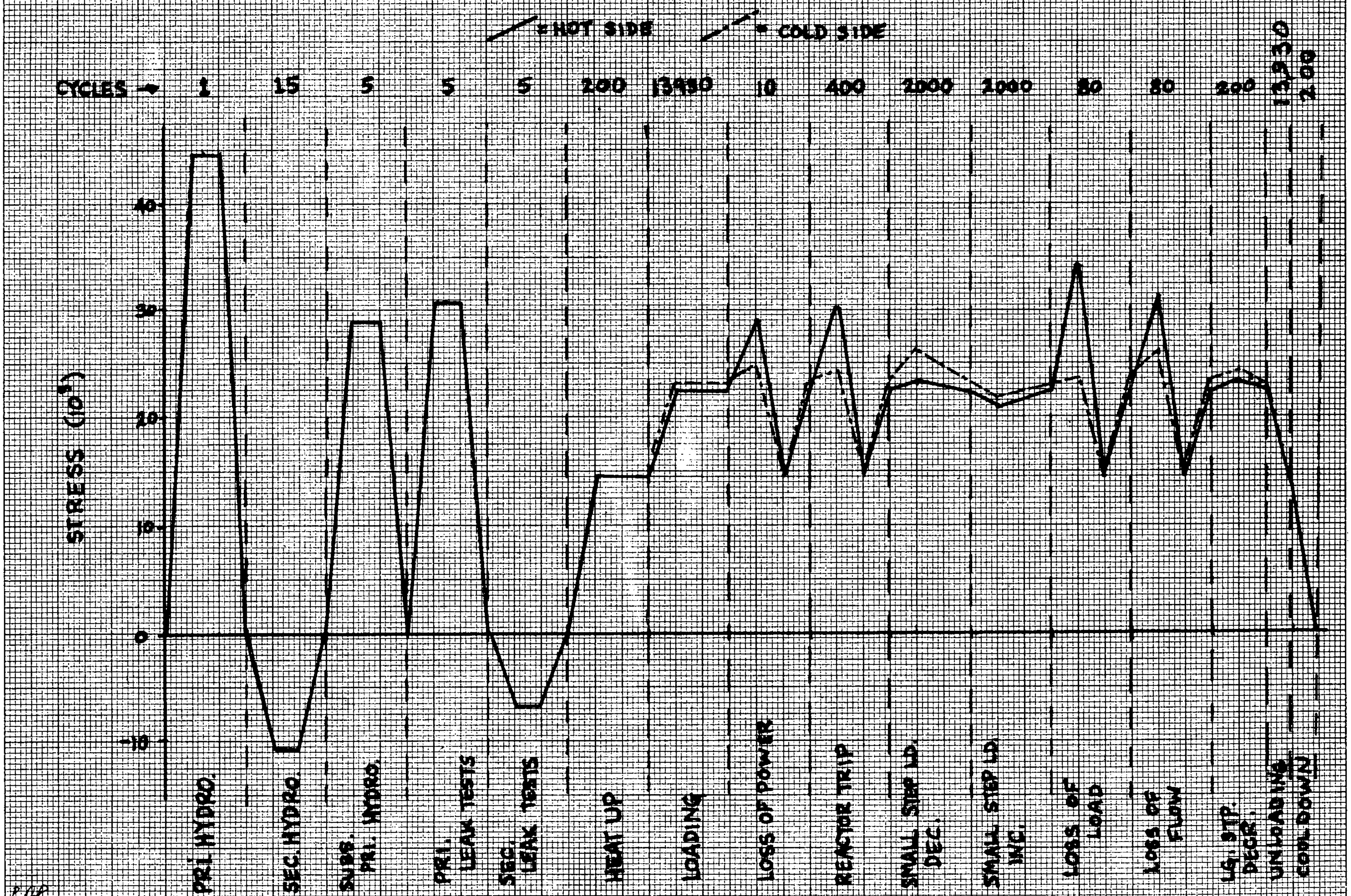
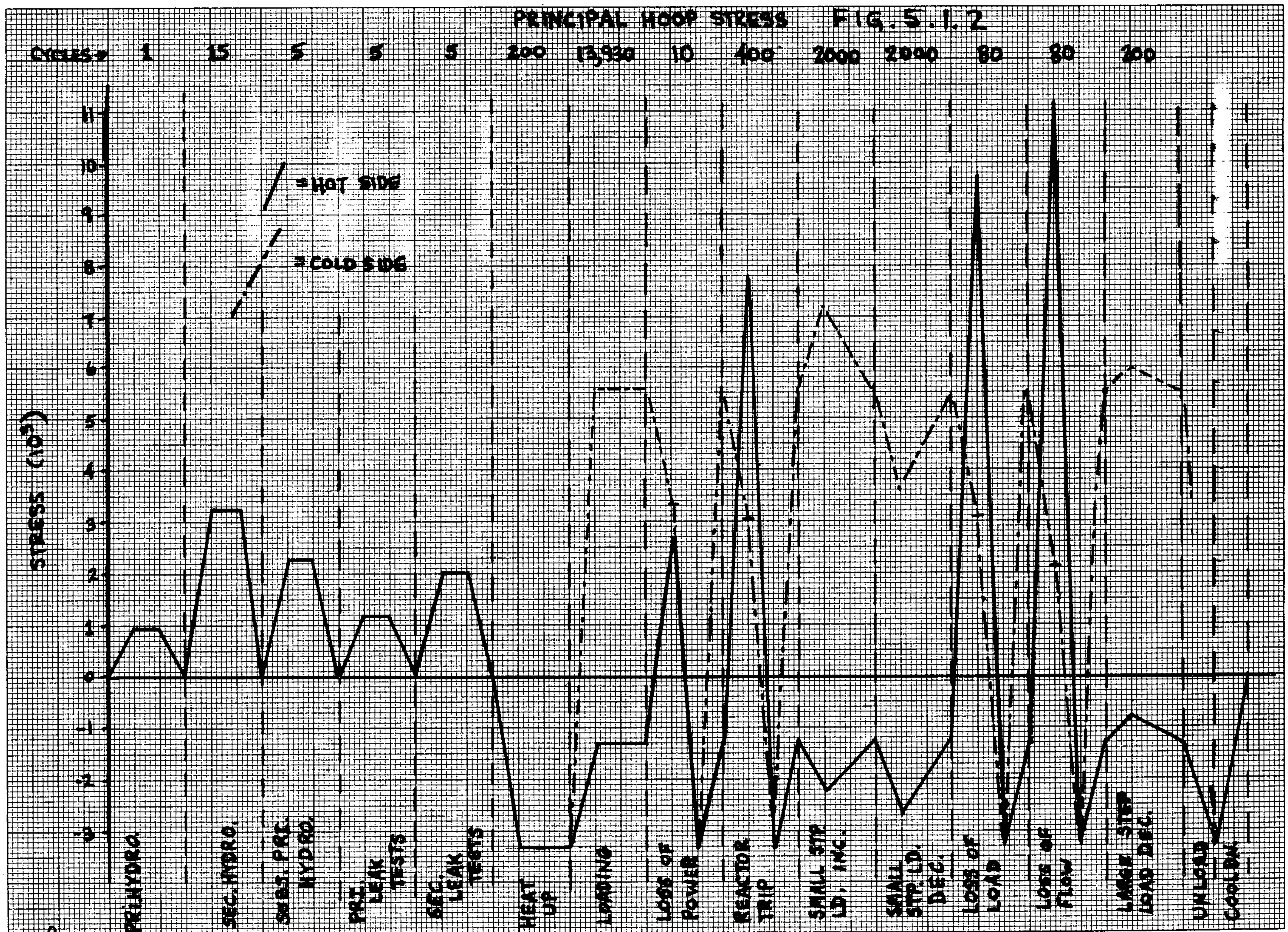


Figure 4.1 Comparative Sketches of "44" & "51" Series S.G.
(No Clad Shown)

PRINCIPAL AXIAL STRESS FIG. 5.1.1



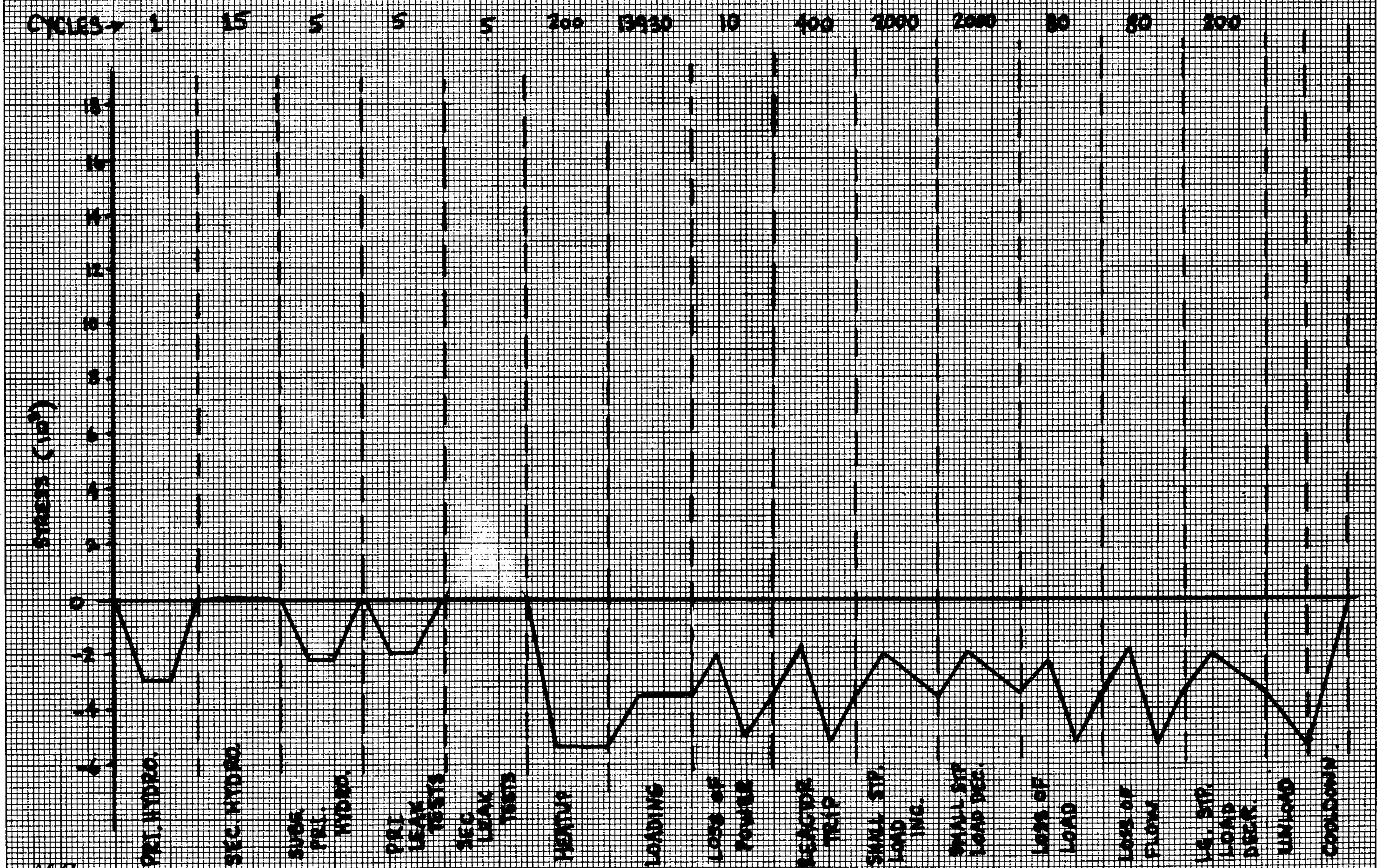
P.G.R.
1/26/72


PRINCIPAL HOOP STRESS FIG. 5.1.2
CYCLES → 1 15 5 5 5 200 13,930 10 400 2000 2000 80 80 200
STRESS (10³)
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
= HOT SIDE
= COLD SIDE
PRI. HYDRO.
SEC. HYDRO.
SUBS. PRI. HYDRO.
PRI. LEAK TESTS
SEC. LEAK TESTS
HEAT UP
LOADING
LOSS OF POWER
REACTOR TRIP
SMALL STP. LD. INC.
SMALL STP. LD. DEC.
LOSS OF LOAD
LOSS OF FLOW
LARGE STEP LOAD DEC.
UNLOAD
COOLDN.

P.D.R
1/26/72

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. 46 1513 MADE IN U.S.A.

PRINCIPAL RADIAL STRESS FIG. 5.1.3



PDR
1/27/72

P.DEROSA TAMPA DIVISION 1/25/72
STRESS CONCENTRATION OF 4 ON RADIAL AND AXIAL STRESSES
HOT SIDE DATA STRESS INTENSITY S12

YOUNGS MODULUS EQUALS 2.6E 07

LEVL0= 0.0
LEVL1= 79436.
LEVL2= 103308.00

INPUT CYCLES

1.00	79436.00	0.0	200.00
2.00	103308.00	79436.00	13930.00
3.00	123428.00	103308.00	10.00
4.00	127240.00	103308.00	400.00
5.00	103308.00	100436.00	2000.00
6.00	103308.00	91736.00	2000.00
7.00	146840.00	103308.00	80.00
8.00	139200.00	103308.00	80.00
9.00	103308.00	101688.00	200.00
10.00	103308.00	79436.00	570.00
11.00	181120.00	0.0	1.00
12.00	0.0	-42608.00	15.00
13.00	124960.00	0.0	5.00
14.00	131012.00	0.0	5.00
15.00	0.0	-26388.00	5.00

TABLE 5.2.1
INPUT SCF=4

USAGE FACTOR OUTPUT DATA
CURVE FOR CARBON AND LOW ALLOY STEELS (TEMPS. LESS THAN 700F)
FIG. N-415(A) OF SEC. 3 OF ASME CODE

NUMBER OF PARTIAL USAGE FACTOR	STRESS	NUMBER OF CYCLES ALLOWED	NUMBER OF ACTUAL CYCLES	PARTIAL USAGE FACTOR	PROGRESSIVE TOTAL USAGE FACTOR
1	129074.	301.	1	0.0033	0.0033
2	109297.	469.	4	0.0085	0.0118
3	109297.	469.	5	0.0107	0.0225
4	109297.	469.	5	0.0107	0.0332
5	99939.	598.	5	0.0084	0.0415
6	84715.	943.	61	0.0647	0.1062
7	80308.	1000.	80	0.0800	0.1862
8	75584.	1213.	5	0.0041	0.1903
9	73408.	1329.	44	0.0331	0.2234
10	73408.	1329.	1	0.0008	0.2242
11	27579.	27381.	355	0.0130	0.2371
12	26264.	32749.	4	0.0001	0.2373
13	26264.	32749.	1	0.0000	0.2373
14	25380.	37202.	10	0.0003	0.2376
15	13772.	597516.	13919	0.0233	0.2608
16	13772.	597516.	1	0.0000	0.2608
17	13772.	597516.	5	0.0000	0.2609
18	13772.	597516.	5	0.0000	0.2609
19	6676.	IN	2000	0.0	0.2609
20	1657.	IN	2000	0.0	0.2609
21	935.	IN	200	0.0	0.2609

TOTAL USAGE FACTOR EQUALS0.2609

TABLE 5.2.2

OUTPUT SCF=4

*****END OF PROBLEM*****

P.DEROSA TAMPA DIVISION 1/25/72

STRESS CONCENTRATION OF 5 ON RADIAL AND AXIAL STRESSES

HOT SIDE DATA STRESS INTENSITY S12

YOUNGS MODULUS EQUALS 2.6E 07

LEVL0= 0.0

LEVL1= 99295.

LEVL2= 129210.00

INPUT CYCLES

1.00	99295.00	0.0	200.00
2.00	129210.00	99295.00	13930.00
3.00	154285.00	129210.00	10.00
4.00	159050.00	129210.00	400.00
5.00	129210.00	125545.00	2000.00
6.00	129210.00	114670.00	2000.00
7.00	183550.00	129210.00	80.00
8.00	174000.00	129210.00	80.00
9.00	129210.00	127110.00	200.00
10.00	129210.00	99295.00	570.00
11.00	226400.00	0.0	1.00
12.00	0.0	-53260.00	15.00
13.00	156200.00	0.0	5.00
14.00	163765.00	0.0	5.00
15.00	0.0	-32985.00	5.00

TABLE 5.2.3

INPUT SCF=5

USAGE FACTOR OUTPUT DATA
CURVE FOR CARBON AND LOW ALLOY STEELS (TEMPS. LESS THAN 700F)
FIG. N-415(A) OF SEC. 3 OF ASME CODE

NUMBER OF PARTIAL USAGE FACTOR	STRESS	NUMBER OF CYCLES ALLOWED	NUMBER OF ACTUAL CYCLES	PARTIAL USAGE FACTOR	PROGRESSIVE TOTAL USAGE FACTOR
1	161342.	169.	1	0.0059	0.0059
2	136621.	260.	4	0.0154	0.0213
3	136621.	260.	5	0.0193	0.0406
4	136621.	260.	5	0.0193	0.0598
5	124924.	328.	5	0.0152	0.0750
6	105894.	511.	61	0.1194	0.1944
7	100385.	591.	80	0.1355	0.3299
8	94480.	697.	5	0.0072	0.3371
9	91760.	756.	44	0.0582	0.3953
10	91760.	756.	1	0.0013	0.3967
11	34474.	12637.	355	0.0281	0.4247
12	32830.	14876.	4	0.0003	0.4250
13	32830.	14876.	1	0.0001	0.4251
14	31725.	16712.	10	0.0006	0.4257
15	17259.	171191.	13919	0.0813	0.5070
16	17259.	171191.	1	0.0000	0.5070
17	17259.	171191.	5	0.0000	0.5070
18	17259.	171191.	5	0.0000	0.5071
19	8388.	IN	2000	0.0	0.5071
20	2114.	IN	2000	0.0	0.5071
21	1212.	IN	200	0.0	0.5071

TOTAL USAGE FACTOR EQUALS0.5071

TABLE 5.2.4
OUTPUT SCF=5

*****END OF PROBLEM*****

P.DEROSA TAMPA DIVISION 1/25/72
STRESS CONCENTRATION OF 6 ON RADIAL AND AXIAL STRESSES
HOT SIDE DATA STRESS INTENSITY S12

YOUNGS MODULUS EQUALS 2.6E 07

LEVL0= 0.0
LEVL1= 119154.
LEVL2= 154962.00

INPUT CYCLES

1.00	119154.00	0.0	200.00
2.00	154962.00	119154.00	13930.00
3.00	185142.00	154962.00	10.00
4.00	190860.00	154962.00	400.00
5.00	154962.00	150564.00	2000.00
6.00	154962.00	137604.00	2000.00
7.00	220260.00	154962.00	80.00
8.00	208800.00	154962.00	80.00
9.00	154962.00	152532.00	200.00
10.00	154962.00	119154.00	570.00
11.00	271680.00	0.0	1.00
12.00	0.0	-63912.00	15.00
13.00	187440.00	0.0	5.00
14.00	196518.00	0.0	5.00
15.00	0.0	-39582.00	5.00

TABLE 5.2.5

INPUT SCF=6

USAGE FACTOR OUTPUT DATA
CURVE FOR CARBON AND LOW ALLOY STEELS (TEMPS. LESS THAN 700F)
FIG. N-415(A) OF SEC. 3 OF ASME CODE

NUMBER OF PARTIAL USAGE FACTOR	STRESS	NUMBER OF CYCLES ALLOWED	NUMBER OF ACTUAL CYCLES	PARTIAL USAGE FACTOR	PROGRESSIVE TOTAL USAGE FACTOR
1	193611.	107.	1	0.0093	0.0093
2	163945.	163.	4	0.0246	0.0339
3	163945.	163.	5	0.0308	0.0647
4	163945.	163.	5	0.0308	0.0954
5	149909.	204.	5	0.0245	0.1199
6	127073.	314.	61	0.1943	0.3142
7	120462.	362.	80	0.2212	0.5354
8	113376.	425.	5	0.0118	0.5471
9	110112.	460.	44	0.0957	0.6428
10	110112.	460.	1	0.0022	0.6450
11	41369.	7132.	355	0.0498	0.6948
12	39396.	8141.	4	0.0005	0.6953
13	39396.	8141.	1	0.0001	0.6954
14	38070.	8923.	10	0.0011	0.6965
15	20658.	83013.	13919	0.1677	0.8642
16	20658.	83013.	1	0.0000	0.8642
17	20658.	83013.	5	0.0001	0.8643
18	20658.	83013.	5	0.0001	0.8643
19	10014.	IN	2000	0.0	0.8643
20	2537.	IN	2000	0.0	0.8643
21	1402.	IN	200	0.0	0.8643

TOTAL USAGE FACTOR EQUALS0.8643

*****END OF PROBLEM*****

TABLE 5.2.6

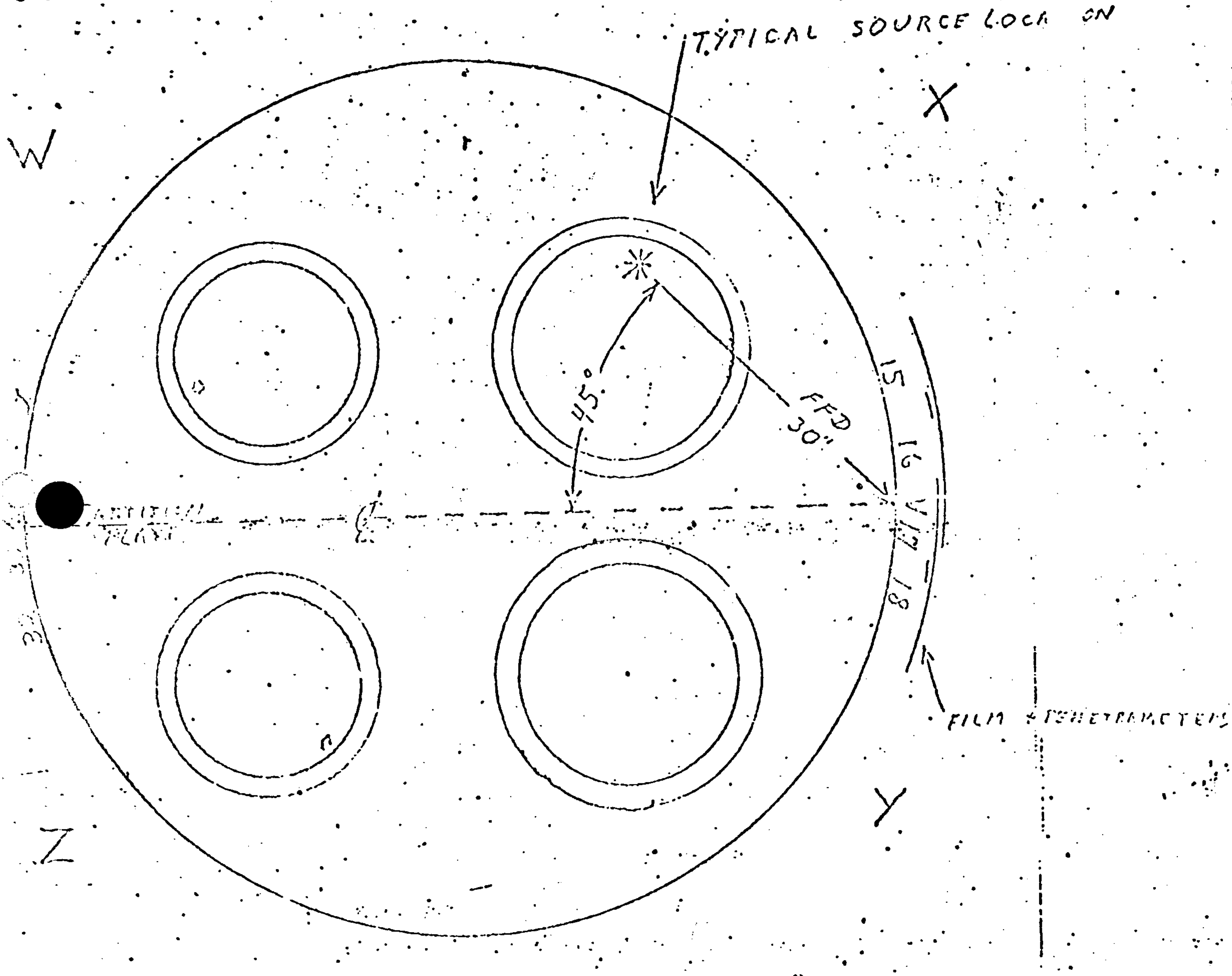
OUTPUT SCF=6

APPENDIX I

RADIOGRAPHIC INSPECTION [illegible]

COMPONENT	SHOP ORDER	SERIAL	X-RAY NUMBER
Steam Generator #21	16-A-5780-3		
LOCATION OF AREA OR WELD: Channel Head to Tube Plate Corner	DRAWING	ITEM	SUB IDENT.
TYPE OF MATERIAL / WELDING PROCESS / SPECIFICATION	SUPPLIER	T	NUMBER

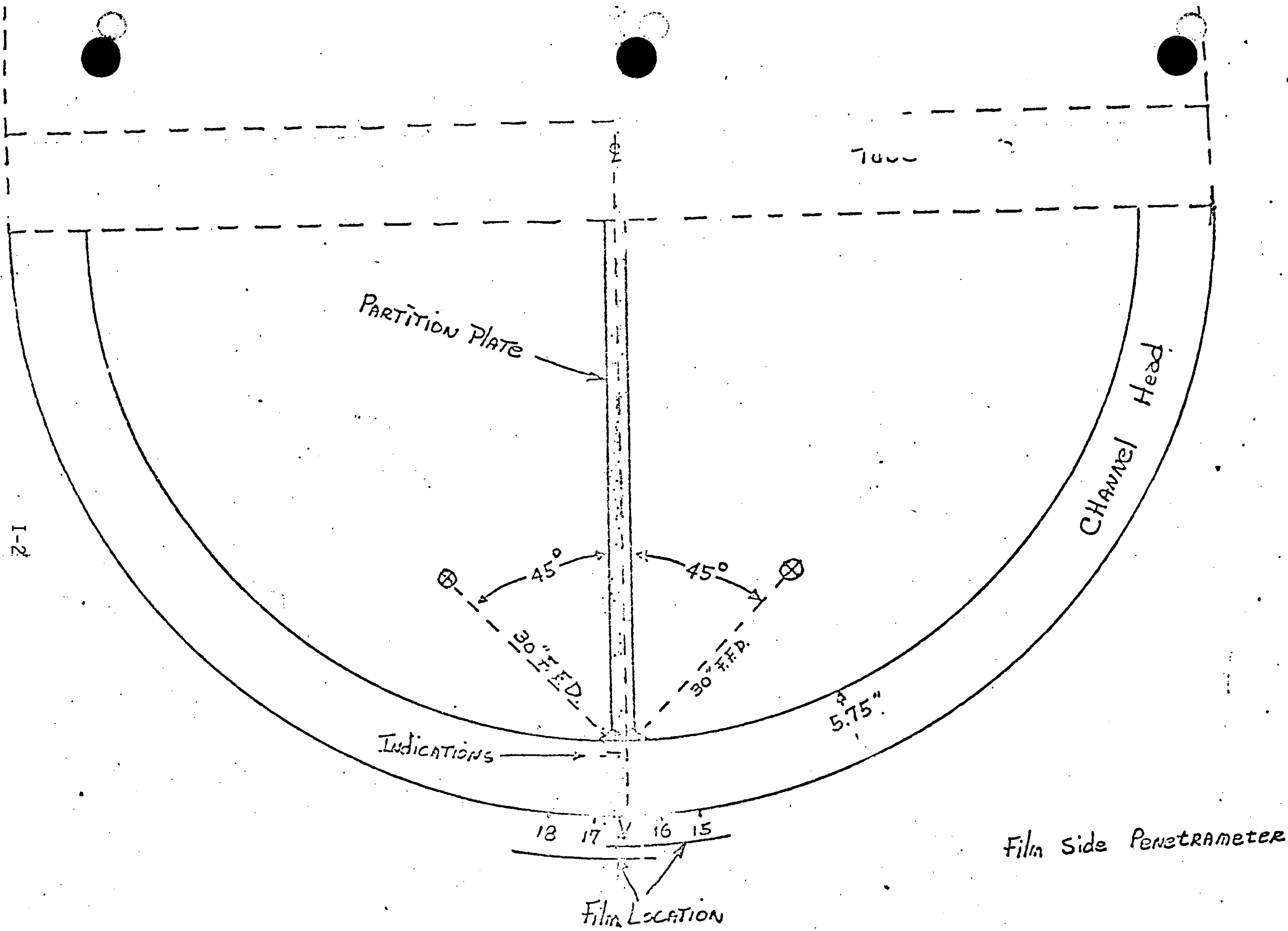
SKETCH



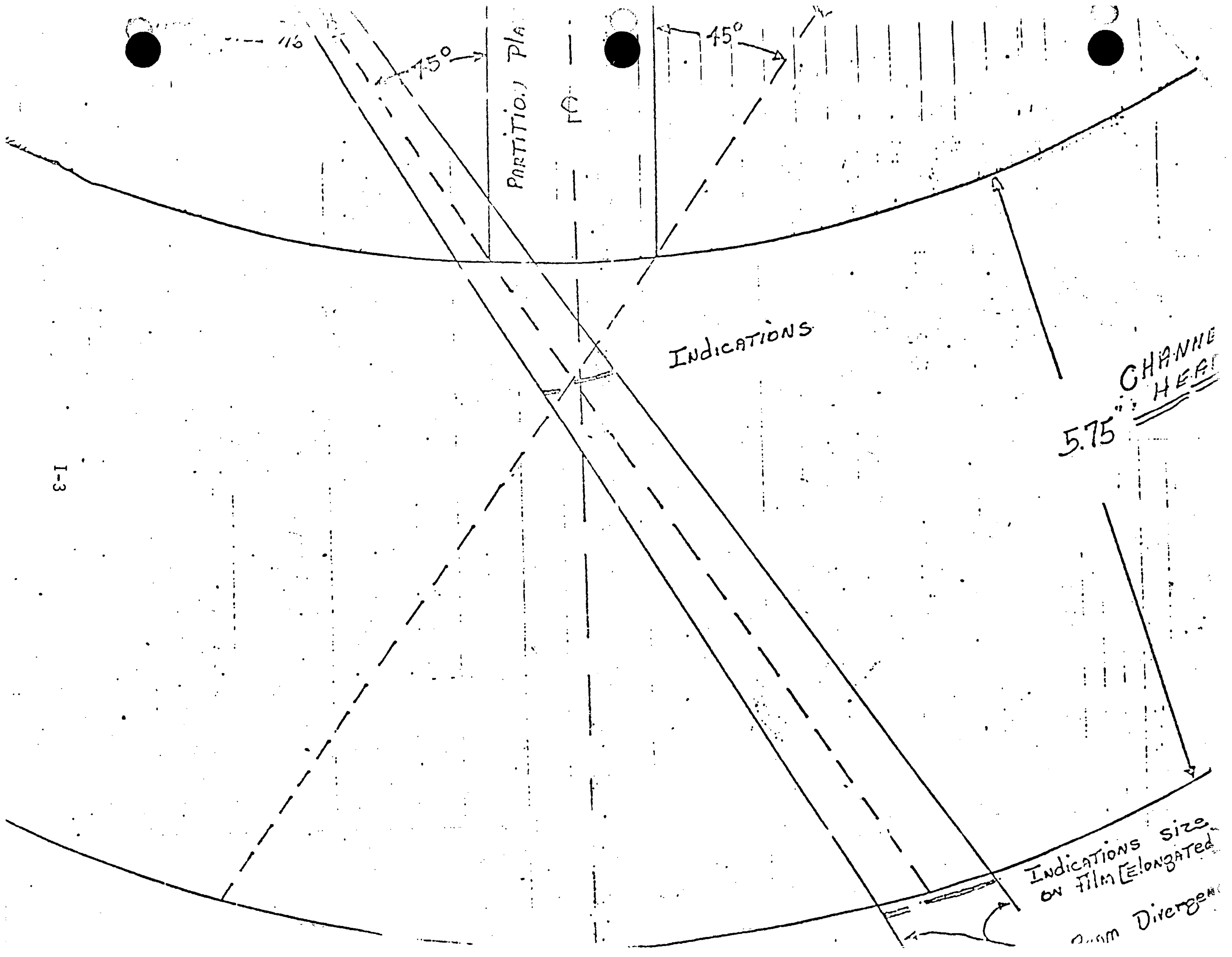
NOTES: Use film side penetr[a]meters, 2 Req. #60 source positioned 3" below tube sheet.

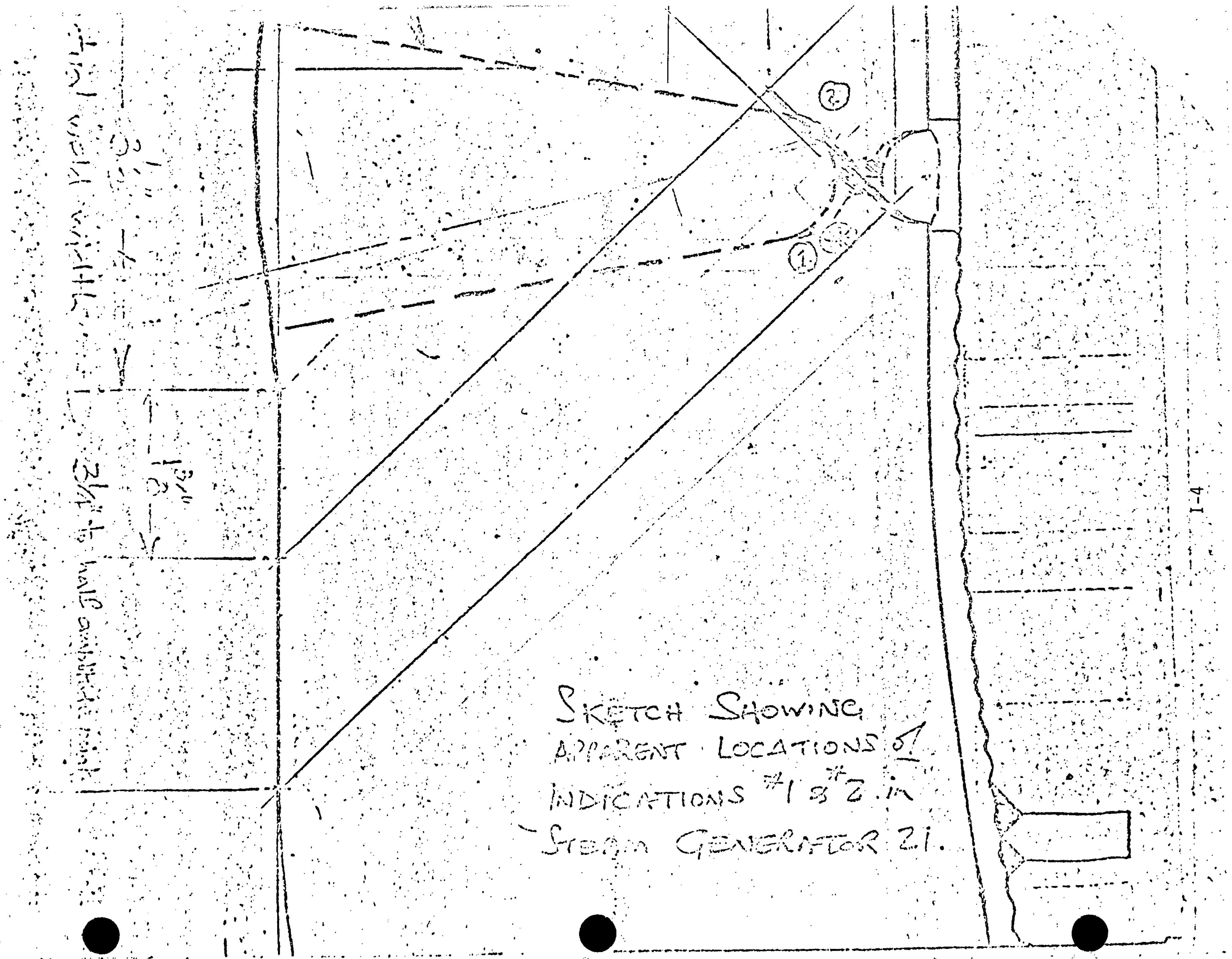
Total of nine (9) fi[lm]s of Indian Point site for Consolidated Edison.

Not taken for code, f[o]r information only 10-10-71.



Partition Plate
Channel Head
45°
45°
30" F.F.D.
30" F.F.D.
5.75"
Indications
18 17 V 16 15
Film Location
Film Side Penetrameter


45°
45°
PARTITION Pla
Indications
5.75"
CHANNE
HEA
Indications size
on film (elongated
Divergen



Sketch Showing Apparent Locations of Indications #1 & #2 in Steam Generator 21.

APPENDIX II

The data included in Appendix II is arranged to identify the steam generators and channel head to tube plate weld seams as they actually exist in the Indian Point Plant, together with the Quality Control Inspection Point Programs and the daily radiographic work log.

All four steam generators were fabricated on Westinghouse Shop Order 16-A-5780 and were assigned serial numbers 1, 2, 3, and 4. The cross reference to the Consolidated Edison designations together with the x-ray number assigned to the channel head-tube plate weld seam is shown in the attached letter. The abbreviations used in the daily review sheets are defined as follows:

L P - Lack of penetration

Trans Indications - Transverse Indications

B S R - before stress relief

A S R - after stress relief

The Inspection Point Program contains a listing of all manufacturing and quality control operations performed on the unit. The extract page 6 of the Inspection Point Program in this Appendix shows operation 40, "X-Ray of Channel Head to Tube Sheet Weld", being approved on 2-19-68 as X-Ray #6338. The daily radiographic work log, which is a diary in chronological order, shows the entries for X-6338 from 2-1-68 to 2-19-68. This chronological record shows that there were defects found in areas 16 and 24. These defects were satisfactorily cut out and repaired and the seam was approved after stress relief on 2-19-68.

From : QUALITY ASSURANCE
WIN :
Date : January 31, 1972
Subject : 16-A-5780 RECORDS AUDIT

TAMPA DIVISION

Mr. F. X. Brown
Manager, Reliability

CC: Mr. R. H. Anderson, Manager, Quality Assurance
Mr. W. H. Beckley, Supervisor, Quality Assurance

In regard to the records audit and review at Lester, Pa., January 5 and 25, 1972, for Shop Order 16-A-5780, Serial 1, 2, 3, and 4, the Channel Head - Tube Plate Closure Welds (Z Seam) were verified as follows:

S.O. 16-A-5780 Serial	Film X No.	Con. Ed. Unit No.
1	5693	24
2	5692	22
3	6338	21
4	6339	23

Verification of ASR (APWHT) is noted in the tube bundle assembly IPP and the daily X-ray work log.

F. W. Dury, Jr.
F. W. Dury, Jr.
Q. A. Engineer

FWD:so

34. MAINTAIN PREHEAT - AUTO WELD O.D. OF CHANNEL HEAD TO TUBE SHEET CIRC. PROCESS 600924. SOAK AS PER SPEC. | XXX

A. Check and record preheat on SP-3385-A.
B. Record welding on SP-3427-C.
C. Check and record post heat on SP-3385-A.

35. BACKCHIP I.D. OF CHANNEL HEAD TO TUBE SHEET - WELD GRIND AND PREP. FOR M.T. | XXX

A. MT back chip.

36. PREHEAT AS PER SPEC. - MANUAL WELD BACKCHIPPED AREA PROCESS 600924 - USE CHIPPER TO REMOVE STOPS AND STARTS. SOAK AS PER SPEC. | XXX

A. Check and record preheat on SP-3385-A.
B. Record welding on SP-3427-C.
C. Check and record post heat on SP-3385-A.

37. GRIND - CLEAN AND PREP. FOR CLAD RESTORATION. | XXX

A. MT final prior to cladding.

38. PREHEAT AS PER SPEC. - MANUAL WELD CLAD RESTORATION PROCESS 600937 - 5X LENS FIRST LAYER - SOAK AS PER SPEC. | XXX

A. Check and record preheat on SP-3385-A.
B. Record welding on SP-3427-C.
C. 5X lens inspect first layer.
D. Check and record post heat on SP-3385-A.

39. GRIND AND PREPARE I.D. AND O.D. WELDS OF CHANNEL HEAD TO TUBE PLATE FOR INSPECTION. | XXX

A. Check that surface of weld is suitable for X-Ray
B. P.T. - final clad restoration.

40. X-RAY CHANNEL HEAD TO TUBE SHEET WELD AS PER SECTION III. PARA. N-624 OF THE ASME BOILER PRESSURE VESSEL CODE NUCLEAR VESSELS - TO BE X-RAY APPROVED BEFORE STRESS RELIEF. | XXX

A. Record X-Ray Number X6338 . Approved A.S.A.

41. LAYOUT ASSEM. AND WELD THERMOCOUPLES FOR INDUCTION STRESS RELIEF - REMOVE TUBE PLATE COVERING.

A. Check induction stress relief spec. for proper location of clips.

I D D FOLDER

16A5780-3 T-D27737

DATE 1-29-69

DAILY RADIOGRAPHIC REVIEW

COMPONENT	S.O.	SER.	X-NO.	SEAM	EXP. REQ.	DISPOSITION	RE-XRAYS TECH.	RE-XRAYS PROC.	COMMENTS
[illegible]	16A6079		X5719		1	[illegible] W/C approved			
						AREAS 16,22 [illegible] AREA 20 TIPS, NO [illegible]			EDGE OF CUTOUT
[illegible] & SHELL ASSY	16A 5696		X6523	D	2	AREA 24 [illegible]			
[illegible] HEAD	16A 5883	121	X6921	LIP [illegible]	6				
1-30-69									
[illegible] Heater	16A6492		X6989		12	N.A.D. - approved B/S/R			
[illegible]	16A5696		X6503		2	slag W/C in 2 areas			
1-31-69									
[illegible] Hd.	16A 5883		X6921		1	slag W/C approved			
[illegible]	16A6266		X 7233			Porosity [illegible] - approved			
" "	16A6268		X7232						
[illegible]	16A 6088		X6368		30	approved after S/R			
2-1-69									
[illegible]	16A5696		X 6503		2	Slag B/C area 1 - area 20 [illegible]			
						AREA 16 L.P. AREA 24 [illegible] INDICATIONS			CUTOUTS
[illegible]	16A 5780	3	X6338		2				
[illegible] TEST [illegible]	9013-535		X9254 TO X9258		5	4-N.A.D. 1-4 [illegible] OF [illegible]			

II-4

DAILY RADIOGRAPHIC REVIEW

DATE 2-2-68

COMPONENT	S.O.	SER.	X-NO.	SEAM	EXP. REQ.	DISPOSITION	RE-XRAYS TECH.	RE-XRAYS PROC.	COMMENTS
[illegible] HEAD	16A6079	1	X5219	L	12	APPROVED A.S.R.	1		
[illegible] HEAD	16A6079	1	X5219	N	13	APPROVED A.S.R.			
[illegible]	9855-569		X7239		10	REJECTED			
[illegible]	16A5980	3	X6358	Z	1	[illegible] — TRANS IND			
2-3-68									
[illegible]	16A5891		X7045		2	[illegible] approved			
" " " "	16A5730	3	X6338		2	[illegible] — [illegible] 16 LD AREA #1 — ANGLED IND — I.D. [illegible] TO WELD			
[illegible]	16A5696		X6523	D	3	AREA #19 — SIDE OF CRACK			
					"W" AXIS	50 TUBES — 1 REJECT			} 200 tubes - 10 rejects
[illegible]	16A6079	1	XXXX		"X" AXIS	50 TUBES — 1 REJECT			
					Y axis				
2-4-68					Y AXIS	50 tubes — 3 rejects			
[illegible]	16A6079	1	[illegible]		Z AXIS	50 tubes — 5 rejects			
[illegible]	16A5696		X6523	D	2	approved B/S/R			
[illegible]			X7240 X7241		2	1 U.N.A.D. 1 — [illegible]			
[illegible]	16A6079								

II-5

DAILY RADIOGRAPHIC REVIEW

DATE 2-8-68

COMPONENT	S.O.	SER.	X-NO.	SEAM	EXP. REQ.	DISPOSITION	RE-XRAYS TECH.	RE-XRAYS PROC.	COMMENTS
Shel Barrel	16A 6058		X7281			Barry Dees - approved			
" "	16A 8054		X7285						
" "	16A 6065		X7286			Phoenix Steel - by agreement - approved			
" "	16A 6022		X7287						
" "	"		X7288						
H.EAT TUBE PLATE	16A 5780	3	X6338	2	3	APPROVED B.S.R.			
STUB BARREL	16A 8310		X7289	LONG	2	APPROVED			
STUB BARREL	16A 6222		X7291	LONG	2	APPROVED			
STUB BARREL	16A 8474		X7292	LONG	4	APPROVED			
HEATER SHELL	16A 6446	1	X7138	A	13	AREAS 8-9 REMOVE AREA			
HEATER SHELL	16A 6446	1	X7138	A	2	APPROVED			
2-9-68									
Shell Barrel	16A 8208		X7293			Biggs United - approved			
Shell Barrel	16A 8473		X7290			approved - spot			
STUB BARREL	16A 6222		X7295		2	APPROVED - SPOT			
TEST PLATES	9855-569		X7296 X7297		2	APPROVED			
TEST PLATES	9-5152-101		X7298 TO X7283		6	FOR L. POOLE			

II-6

DATE 2-19-68

DAILY RADIOGRAPHIC REVIEW

COMPONENT	S.O.	SER.	X-NO.	SEAM	EXP. REQ.	DISPOSITION	RE-XRAYS TECH.	PROC.	COMMENTS
[illegible] PLATE	9-5434-608		X2303		2	APPROVED			
Shell Barrel	16A 8267		X2304			APPROVED –	[illegible]		[illegible]
[illegible]	16A 5780	3	X6318	2	3	APPROVED B.S.R.			
						4-[illegible] APPROVED			
Head [illegible]	16A 5883		X2123		2				
2-20-68									
[illegible]	16A 6339		X6856		30	Approved all S/O	[illegible]	[illegible]	
					57 [illegible]	56 approved [illegible]	[illegible]	[illegible]	[illegible]
Channel Head	16A 5064		X79						
[illegible]	16A 5883		X6921	B	10	APPROVED B.S.R.			9-[illegible]
						[illegible]	B		[illegible]
[illegible]	16A 5883		X6921	B	23	[illegible]			
2-21-68									
[illegible]	16A 8471		X2307			Penetration – Approved			
" "	"		X2108						
"	16A 8472		X2309						
"	"		X2310						
[illegible] Head	16A 5883		X6921	B	3	[illegible]	[illegible]	01	[illegible]
[illegible]	16A 6017		X2306		4	approved			
[illegible]	16A 5883		X6921		1	[illegible]			

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