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SUBJECT: Forwards revised large break LOCA ECCS performance results for limiting break size for facility which justifies incresed steam generator tube plugging limit of up to 1430 Tubes.

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FPL

AUGUST 25 1987

L-87-327

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D. C. 20555

Gentlemen:

Re: St. Lucie Unit No. 2
Docket No. 50-389
Large Break LOCA Analyisis

Florida Power & Light Company (FPL) has reanalyzed the St. Lucie Unit 2 Large Break LOCA Analysis. The new LOCA Analysis supersedes the analysis of record submitted by FPL letter L-86-37, dated January 3, 1986, which supported a steam generator tube plugging limit of 1250 average length tubes per steam generator. The attached revised Large Break LOCA Analysis justifies an increased steam generator tube plugging limit of up to 1430 tubes.

This re-analysis was performed using the NRC-approved June 1985 version of the Combustion Engineering (CE) Large Break LOCA evaluation model. Other plant parameter changes were incorporated in this analysis in an effort to bound future cycles and possible plant changes. The results of the analysis demonstrate a peak clad temperature (PCT) of 2107°F, a peak local clad oxidation percentage of 7.62% and a peak core wide oxidation percentage of less than 0.70%. These results demonstrate compliance with 10CFR50.46 acceptance criteria of 2200°F, 17% and 1%, respectively.

The re-analysis predicts 1°F higher PCT than the PCT predicted in the current Reference Analysis. Although this change in PCT does not require submittal of the revised analysis to the NRC, it is being submitted to justify an increased steam generator tube plugging limit and to call to the staff's attention the use of the June 1985 version of the CE Large Break LOCA evaluation model for St. Lucie Unit 2.

Very truly yours,

C. O. Woody
Group Vice President
Nuclear Energy

COW/EJW/gc

Attachment

cc: Dr. J. Nelson Grace, Regional Administrator, Region II, USNRC
Senior Resident Inspector, USNRC, St. Lucie Plant

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Large Break LOCA ECCS Performance
Results for the Limiting Break Size
for St. Lucie 2

Large Break LOCA ECCS Performance

Introduction and Summary

An ECCS performance analysis was performed for St. Lucie Unit 2 to demonstrate compliance with 10CFR50.46 which presents the NRC Acceptance Criteria for Emergency Core Cooling Systems for light water-cooled reactors (Reference 1). The analysis evaluates various plant changes utilizing the recently approved C-E June 1985 version (Reference 2) of the large break loss-of-coolant (LOCA) evaluation model. This model differs from the evaluation model applied in licensing St. Lucie 2 Cycle 3 (Reference 3).

The revised large break LOCA evaluation model approved by NRC includes changes to:

(1) the cladding deformation/rupture models based on NUREG-0630,
(2) the steam cooling models applied at and above the rupture location for reflood rates below one inch per second.
(3) COMPERC-II allowing safety injection pump delivery before the safety injection tanks have emptied,
(4) CEFLASH-4A numerical methods,
(5) the stagnation properties used in the Moody break flow model,
(6) the nodalization scheme used in CEFLASH-4A, and
(7) the axial power shape used in the analyses.

Of these changes, items (1) and (2) introduce beneficial effects on the calculated results at and above the clad rupture location. Items (3) through (6) have a negligible or small beneficial impact. The axial power shape has an adverse impact on results; however, the Cycle 3 analysis already incorporated the new shape.

The current analysis complies with the conditions for NRC approval of the revised model. These conditions require that application of the model include: a break spectrum study utilizing the adverse axial power shape to determine the limiting break size; a determination of whether no single failure is worse than assuming the worst single failure; and assurance that the revised steam cooling heat transfer is not allowed to exceed heat transfer predictions based on the FLECHT correlation.

A break spectrum analysis was performed to determine the limiting large break. In addition, the analysis assumed 1430 plugged tubes per steam generator, fuel parameters which bound current and expected conditions, augmentation penalty of unity, an initial safety injection tank (SIT) gas pressure of 200 psig, reduced RCS vessel and core bypass flow, and an end-of-cycle temperature coast down. The analysis justifies an allowable peak linear heat generation rate (PLHGR) of 13.0 kw/ft. This PLHGR is equal to the existing limit for St. Lucie Unit 2. The method of analysis and detailed results which support this value are presented herein.

Method of Analysis

The method of analysis is based upon C-E's June 1985 large break LOCA ECCS evaluation model which is described in References 4 through 10 and was approved by the NRC in Reference 2. The Reference Cycle, St. Lucie 2 Cycle 3 analysis (Reference 3) utilized the previously approved large break LOCA evaluation model. Except for the model and various plant parameters differences described above, the method of analysis is identical to the Reference Cycle large break LOCA ECCS performance analysis.

Blowdown hydraulics, refill/reflood hydraulics and hot rod temperature calculations were performed with fuel parameters which bound the current fuel cycle and expected conditions for future cycles at a reactor power level of 2754 Mwt. The blowdown hydraulics calculations were performed with the CEFLASH-4A code (Reference 7) while the refill/reflood hydraulics calculations were performed with the COMPERC-II code (Reference 8). The hot rod clad temperature and clad oxidation calculations were performed with the STRIKIN-II

and PARCH codes (Reference 11 and 12, respectively). Fuel performance calculations were performed using the FATES-3A version of the C-E's NRC approved fuel performance code (Reference 13 and 14) with the grain size restriction as required by the NRC (Reference 15).

Most of the ECCS analysis input parameters are the same as those of the Reference Cycle (Reference 3). In particular the limiting axial shape used is the same as that used in the Reference Cycle and is consistent with the selection procedure documented in Reference 9 and approved by the NRC in Reference 2. A summary of the significant input parameters and initial conditions for the present and the reference analysis are shown in Table 1. The major differences and their impact on the Peak Clad Temperature (PCT) are discussed below.

This analysis accounts for steam generator U-tube plugging of up to 1430 average length tubes per generator compared to 1250 for the Reference Cycle (Reference 3). In addition, this analysis used an initial safety injection tank pressure of 200 psig and an augmentation penalty of unity compared to values of 570 psig and 1.01, respectively, for the Reference Cycle. Based on Reference 16 a favorable increase in the initial containment wall temperature of 90°F (compared to a value of 60°F for the Reference Cycle) was used. A break spectrum analysis was performed incorporating the above.

To bound future fuel cycles, the limiting break determined from the break spectrum analysis was reanalyzed with a limiting set of radiation enclosure data. An assessment was made of the impact of reducing the core bypass flow such that vessel flow can be reduced (from 363,000 gpm to 359,700 gpm) while maintaining the same core flow. An evaluation of a temperature coastdown to 520°F at the end of the cycle was also performed.

Steam generator tube plugging increases the resistance to flow passing through the primary side of the steam generator, thereby inhibiting steam venting from the core outlet plenum to the break. This reduces the refill/reflood rates and increases the peak cladding temperature. This analysis assumes 1430 plugged tubes per generator; however, it also conservatively bounds plugging fewer than 1430 tubes in either or both steam generators, since this would reduce the flow resistance and reduce the peak clad temperature.

The reduction in the augmentation penalty results in an increase of the hot assembly average channel PLHGR. The hot assembly average channel PLHGR influences the radiation heat transfer between the hot rod of the hot assembly and the average rod of the hot assembly. Higher power of the average rod of the hot assembly results in reduced heat transfer from the hot rod to its surrounding rods resulting in a higher PCT.

Reducing the SIT initial gas pressure results in a slight increase in the refill time. Increased refill time means a longer period of adiabatic heat up. This consequently results in a higher PCT.

Increasing the initial containment wall temperature results in an increase in reflood flow into the core. This helps to lower the peak clad temperature.

Reducing the vessel flowrate by less than 1% with a corresponding decrease in core bypass flow has a minimal impact on the PCT. Studies performed for other C-E plants have shown that reducing the vessel and core flowrates by 16% increases PCT by less than 10^{o}F. This slight sensitivity would be further reduced if the core flow remains the same.

Temperature coastdown at EOC does not adversely affect PCT. Explicit physics calculations for EOC coastdown conditions confirmed that the Reference Cycle core parameters (e. g., axial and radial power distributions, and PLHGR) conservatively bound EOC coastdown conditions. The only adverse impact of EOC coastdown is the effect which the reduced coolant temperature has on the blowdown hydraulics. However, previous studies have shown this to be a small effect, and one which is offset by the significantly lower fuel stored energy at EOC burnup relative to the limiting burnup used in the current analysis.

Results

Table 2 provides the results of the break spectrum. Double-Ended Slot at Pump Discharge (DES/PD) breaks were judged to be non-limiting based on fuel average temperatures at TAD (Time of Annulus Downflow) which defines the end of blowdown portion of the transient. As expected, the break spectrum analysis determined the 0.6 DEG/PD break to be the limiting break. The previously approved evaluation model demonstrated a weak sensitivity to PCT due to the various break sizes. This is also true for the June 1985 evaluation model as shown in Table 2. However, the new leak flow model incorporated in the June 1985 evaluation model introduces a shift in the limiting break size due to the small change in the leak flow characteristics. This is consistent with other C-E plants which utilized the June 1985 evaluation model.

Table 3 presents the results of the limiting break reanalyzed with a conservative set of radiation enclosure data. Table 4 presents a list of the significant parameters displayed graphically for the break.

The results of the evaluation confirm that 13.0 kw/ft is an acceptable value for the PLHGR in the present analysis. The peak clad temperature and maximum local and core wide clad oxidation values as shown in Table 3, are well below the 10CFR50.46 acceptance limits of 2200^{o}F, 17% and 1% respectively.

The 0.6 DEG/PD produced the highest clad temperature of 2107°F and a peak local oxidation of 7.62% compared to the acceptance criteria of 2200°F and 17% respectively. The 0.6 DEG/PD also resulted in the highest core wide oxidation of less than 0.70% which is well below the 1% acceptance criteria.

A review of the the effects of initial operating conditions on these results was performed. It was determined that over the ranges of operating conditions allowed by the Technical Specification, a PLHGR of 13.0 kw/ft is an acceptable limit.

Conclusions

The results of the ECCS performance evaluation for the present analysis for St. Lucie Unit 2 demonstrated a peak clad temperature of 2107°F, a peak local clad oxidation percentage of 7.62%, and a peak core wide oxidation percentage of less than 0.70% compared to the acceptance criteria of 2200°F, 17% and 1% respectively. Therefore, operation of St. Lucie Unit 2 at a core power level of 2754 Mwth (102% of 2700 Mwth) and a PLHGR of 13.0 kw/ft is in conformance with 10CFR50.46.

Table 1

St. Lucie - Unit 2

Significant Parameters and Initial Conditions For Break Spectrum Study (1)

Parameters	Reference Cycle	Present Analysis
Core Power at 102% of Nominal (MWt)	2754	2754
Core Average Linear Heat Rate at 102% of Nominal (kw/ft)	4.90	4.90
Peak Linear Heat Generation Rate (PLHGR) Hot Assembly, Hot Channel (kw/ft)	13.0	13.0
PLHGR Hot Assembly, Average Channel (kw/ft)	11.45	11.57
Core Inlet Temperature (°F)	552	552
Core Outlet Temperature (°F)	603.8	603.8
Vessel Flow (1) (10^6 lbm/hr)	136.1	136.1
Core Flow (1) (10^6 lbm/hr)	131.1	131.1
Gap conductance at PLHGR (2) (Btu/hr-ft²-°F)	1416	1460
Fuel Centerline Temperature at PLHGR (2) (°F)	3228	3296
Fuel Average Temperature at PLHGR (2) (°F)	2078	2102
Hot Rod Gas Pressure (psia) (2)	1118	1118
Hot Rod Burnup (MWD/MTU)	1038	1038
Number of Tubes Plugged per Steam Generator	1250	1430
Augmentation Factor	1.01	1.00
Safety Injection Tank (SIT) gas pressure (psig)	570	200
Initial Containment Temperature (°F)	60	90

(1) Hot rod radiation enclosure, and core and vessel flowrates were not changed for the break spectrum study. Their impact is subsequently evaluated based on the limiting break size determined by this study.

(2) STRIKIN-II values at hot rod burnup which yields highest peak clad temperature.

Table 2

St. Lucie - Unit 2

Break Spectrum - Results

Break Size	TAD(a) Time, Seconds	Fuel Average Temperature at TAD, °F	Peak Clad Temperature °F
0.8 DEG/PD*	20.0	1077	2061
0.6 DEG/PD	22.6	1123	2065
0.4 DEG/PD	27.6	1074	2034
0.8 DES/PD**	18.0	991	(b)
0.6 DES/PD	20.2	992	(b)
0.4 DES/PD	25.4	984	(b)

(a) Time of annulus downflow - end of blowdown.

(b) Slot breaks were judged to be non-limiting based on their significantly lower fuel average temperature at TAD, and because the reflood heat transfer applicable to the slot breaks is no worse than the conservative heat transfer applied to the guillotine breaks.

* Double-Ended Guillotine at Pump Discharge.

** Double-Ended Slot at Pump Discharge.

Table 3

St. Lucie - Unit 2

Initial Conditions and Results for Limiting Break Size (0.6 DEG/PD)

	Reference Cycle	Present Analysis
Initial Conditions		
Peak Linear Heat Generation Rate (kw/ft)	13.0	13.0
Radiation Enclosure x-factor[a]	2.19	2.00
Peak Linear Heat Generation Rate (PLHGR) Hot Assembly, Average Channel (kw/ft)	11.45	11.80
Results		
Peak Clad Temperature (°F)	2106	2107
Time of Peak Clad Temperature (Seconds)	259	266
Time of Clad Rupture (Seconds)	55.85	44.74
Peak Local Clad Oxidation (%)	16.12	7.62
Total Core-Wide Clad Oxidation (%)	< 0.70	< 0.70

(a) Lower x-factor indicates flatter power distribution in the vicinity of the hot rod.

Table 4

St. Lucie Unit 2

Variables Plotted as a Function of Time for the Limiting Large Break

Variable	Figure Number
Core Power	1
Pressure in Center Hot Assembly Node	2
Leak Flow	3
Hot Assembly Flow (below hot spot)	4
Hot Assembly Flow (above hot spot)	5
Hot Assembly Quality	6
Containment Pressure	7
Mass Added to Core During Reflood	8
Peak Clad Temperature	9
Hot Spot Gap Conductance	10
Peak Local Clad Oxidation	11
Temperature of Fuel Centerline, Fuel Average, Clad and Coolant at Hottest Node	12
Hot Spot Heat Transfer Coefficient	13
Hot Rod Internal Gas Pressure	14

Reference:

1. Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors, Federal Register, Vol. 39, No. 3, January 4, 1974.

2. Letter, D. M. Crutchfield (NRC) to A. E. Scherer (C-E), "Safety Evaluation of Combustion Engineering ECCS Large Break Evaluation Model and Acceptance for Referencing of Related Licensing Topical Reports", July 31, 1986.

3. Letter C.O. Woody (FPL) to F.J. Miraglia (NRC), "St. Lucie Unit No. 2 Docket No. 50-389 CE Large Break LOCA Analysis", January 3, 1986, L-86-37.

4. Letter, A. E. Scherer (C-E) to J. R. Miller (NRC), LD-81-095, Enclosure 1-P, "C-E ECCS Evaluation Model Flow Blockage Analysis". (Proprietary), December 15, 1981.

5. Letter, A. E. Scherer (C-E) to C. O. Thomas (NRC), LD-86-027, "Responses to Questions on C-E's Revised Evaluation Model for Large Break LOCA Analysis", (Proprietary), June 17, 1986.

6. Letter, A. E. Scherer (C-E) to C. O. Thomas (NRC), LD-85-032, " Revision to C-E Model for Large Break LOCA Analysis", July 3, 1985.

7. CENPD-133, Supplement 5-P, "CEFLASH-4A. A FORTRAN77 Digital Computer Program for Reactor Blowdown Analysis", June 1985.

8. CENPD-134, Supplement 2-P, "COMPERC-II, A Program for Emergency Refill-Reflood of the Core", June 1985.

9. CENPD-132-P, Supplement 3-P, "Calculative Methods for the C-E Large Break LOCA Evaluation Model for the Analysis of C-E and W Designed NSSS", June 1985.

10. Letter, A. E. Scherer (C-E) to C. O. Thomas (NRC), LD-85-050, Enclosure, "Supplemental Material for Inclusion in CENPD-132. Supplement 3-P", (Proprietary), November 5, 1985.

11. CENPD-135, Supplement 2-P, "STRIKIN-II, A Cylindrical Geometry Fuel Rod Heat Transfer Program (Modifications)", February 1975.

CENPD-135-P, Supplement 4-P, "STRIKIN-II. A Cylindrical Geometry Fuel Rod Heat Transfer Program", August 1976.

CENPD-135-P, Supplement 5-P, "STRIKIN-II, A Cylindrical Geometry Fuel Rod Heat Transfer Program", April 1977.

12. CENPD-138-P, and Supplement 1-P. "PARCH, A FORTRAN IV Digital Program to Evaluate Pool Boiling, Axial Rod and Coolant Heatup", February 1975.

CENPD-138 Supplement 2-P, "PARCH - A FORTRAN-IV Digital Program to Evaluate Pool Boiling, Axial Rod and Coolant Heatup", January 1977.

13. CENPD-139-P-A, "C-E Fuel Evaluation Model Topical Report", July 1974.

14. CEN-161(B)-P, "Improvements to Fuel Evaluation Model Topical Report", July 1981.

15. Letter from R. A. Clark (NRC) to A. E. Lundvall, Jr. (BG&E), dated March 31, 1983.

16. Letter, J. L. Perryman (FP&L) to E. L. Trapp (C-E), FRN-86-404, "St. Lucie 2 Large Break LOCA Reevaluation", November 10, 1986.

Figure 1

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

CORE POWER

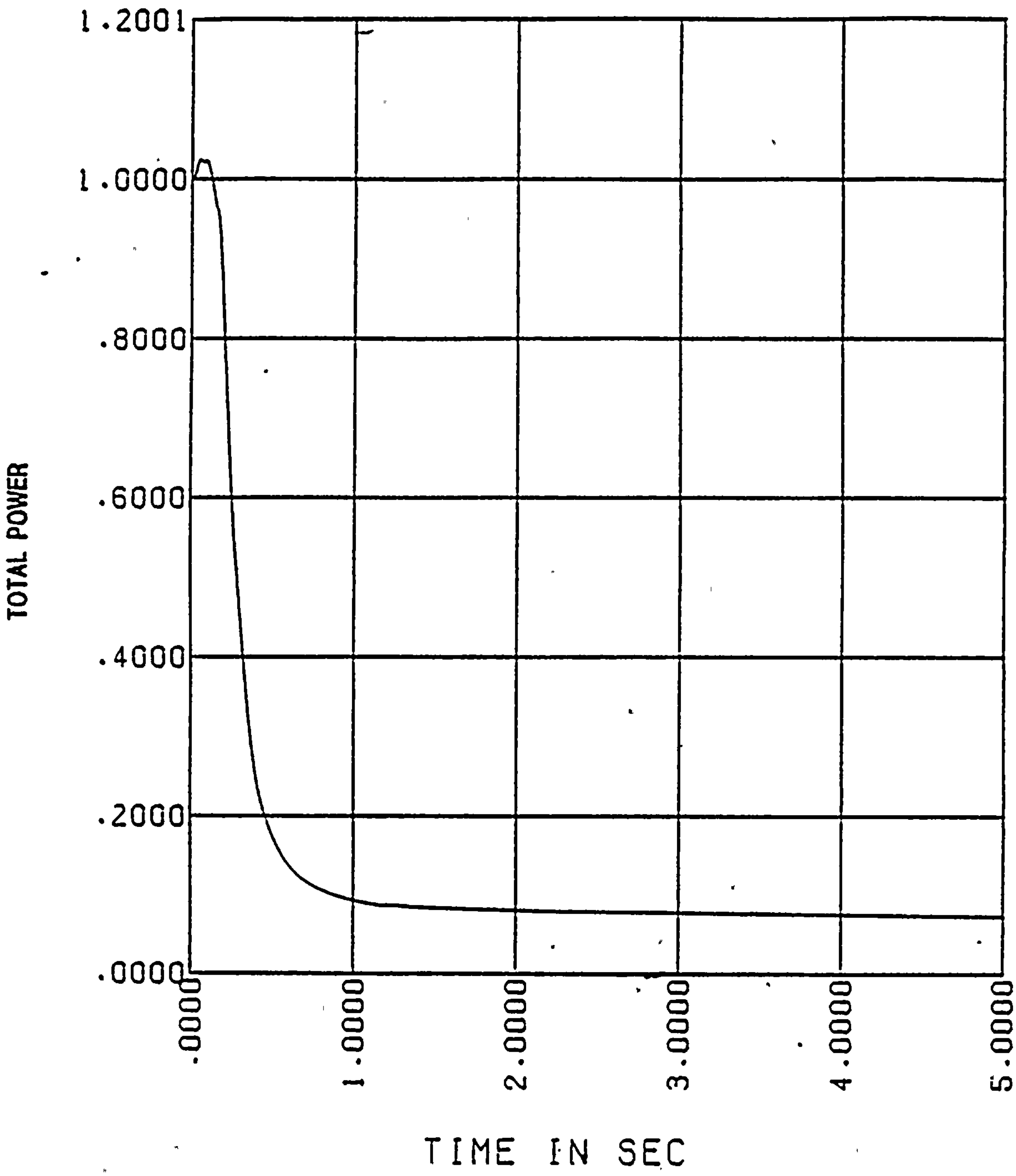


Figure 2

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

PRESSURE IN CENTER HOT ASSEMBLY NODE

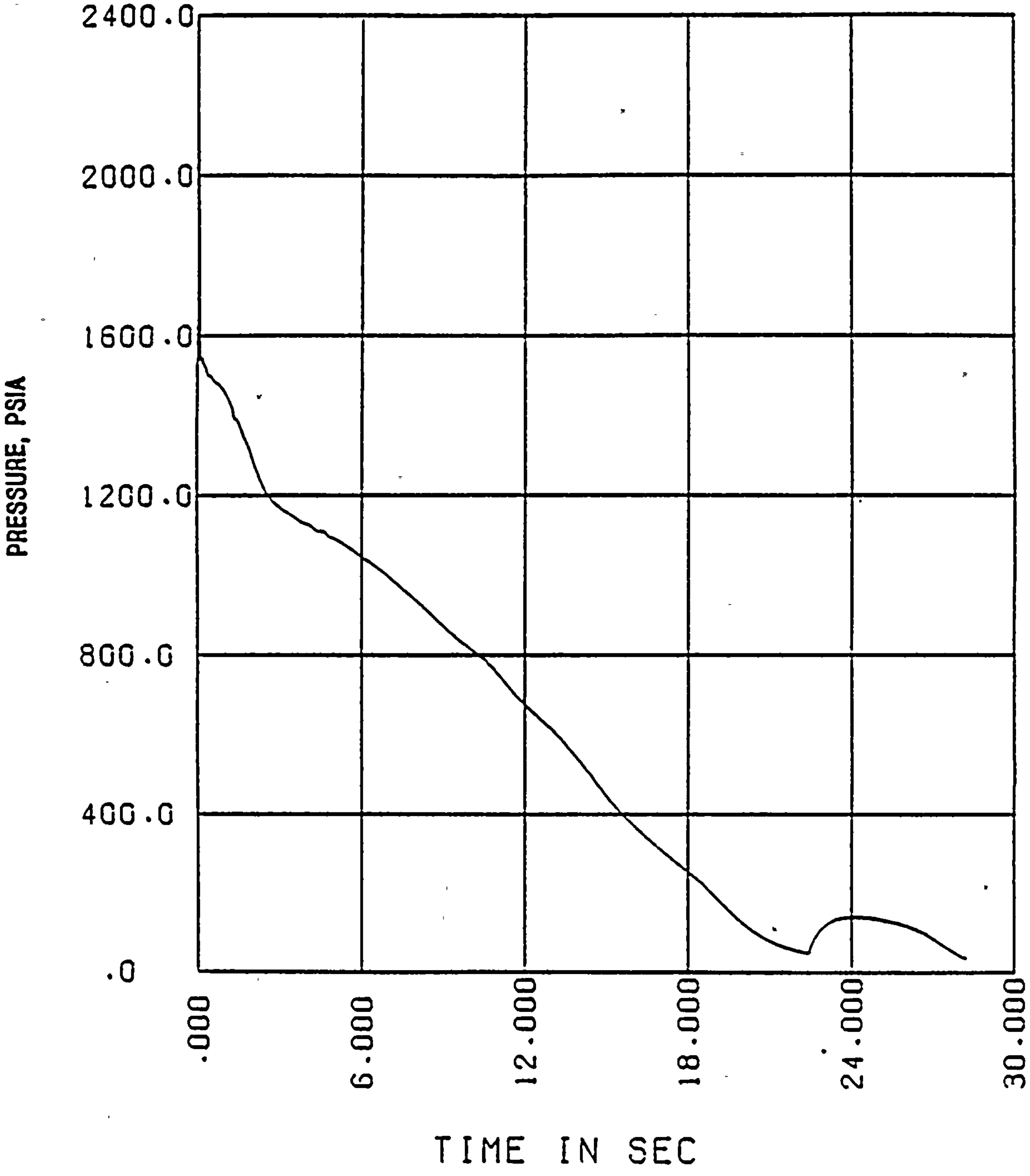


Figure 3

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

LEAK FLOW

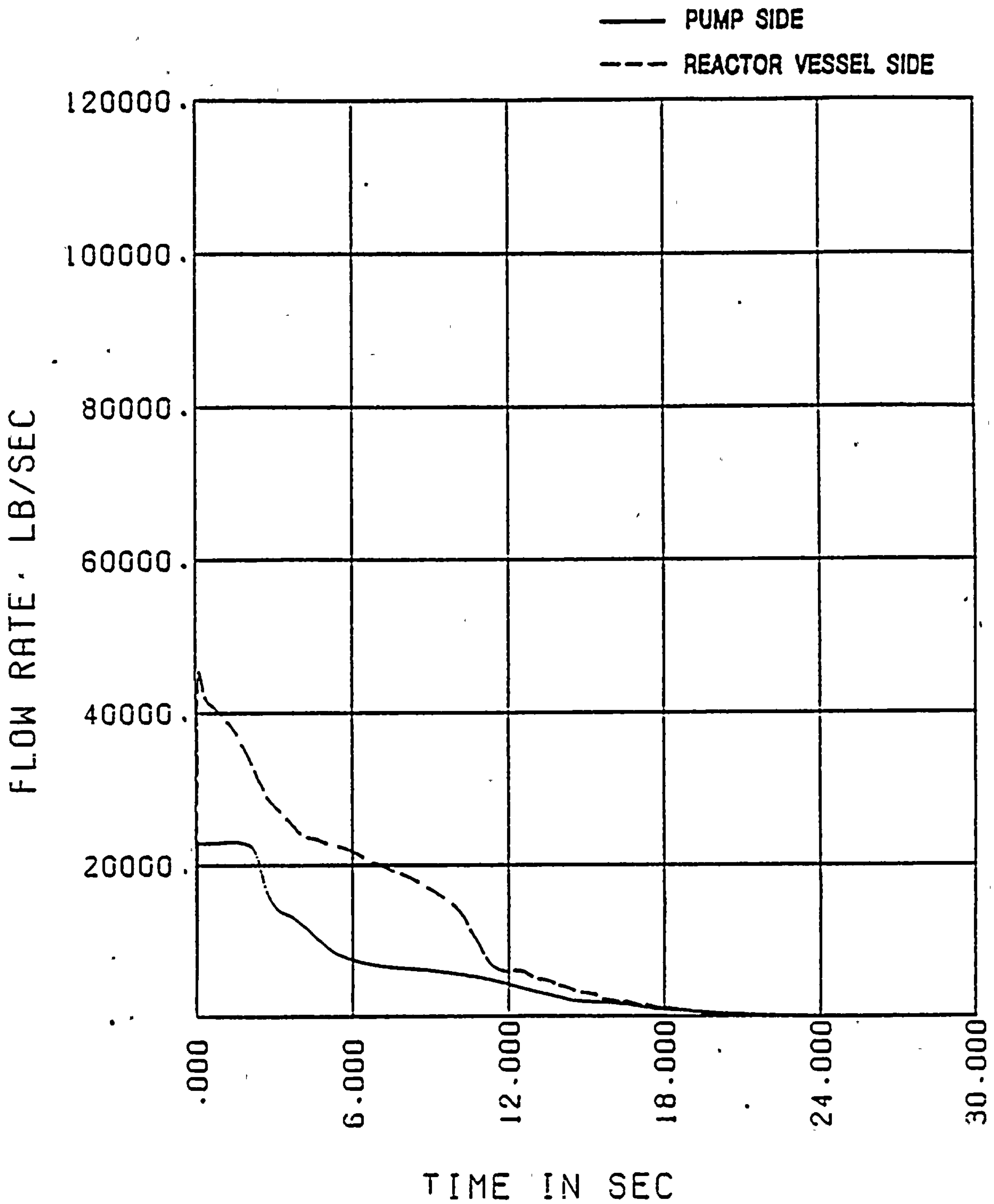


Figure 4

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

HOT ASSEMBLY FLOW, BELOW HOT SPOT

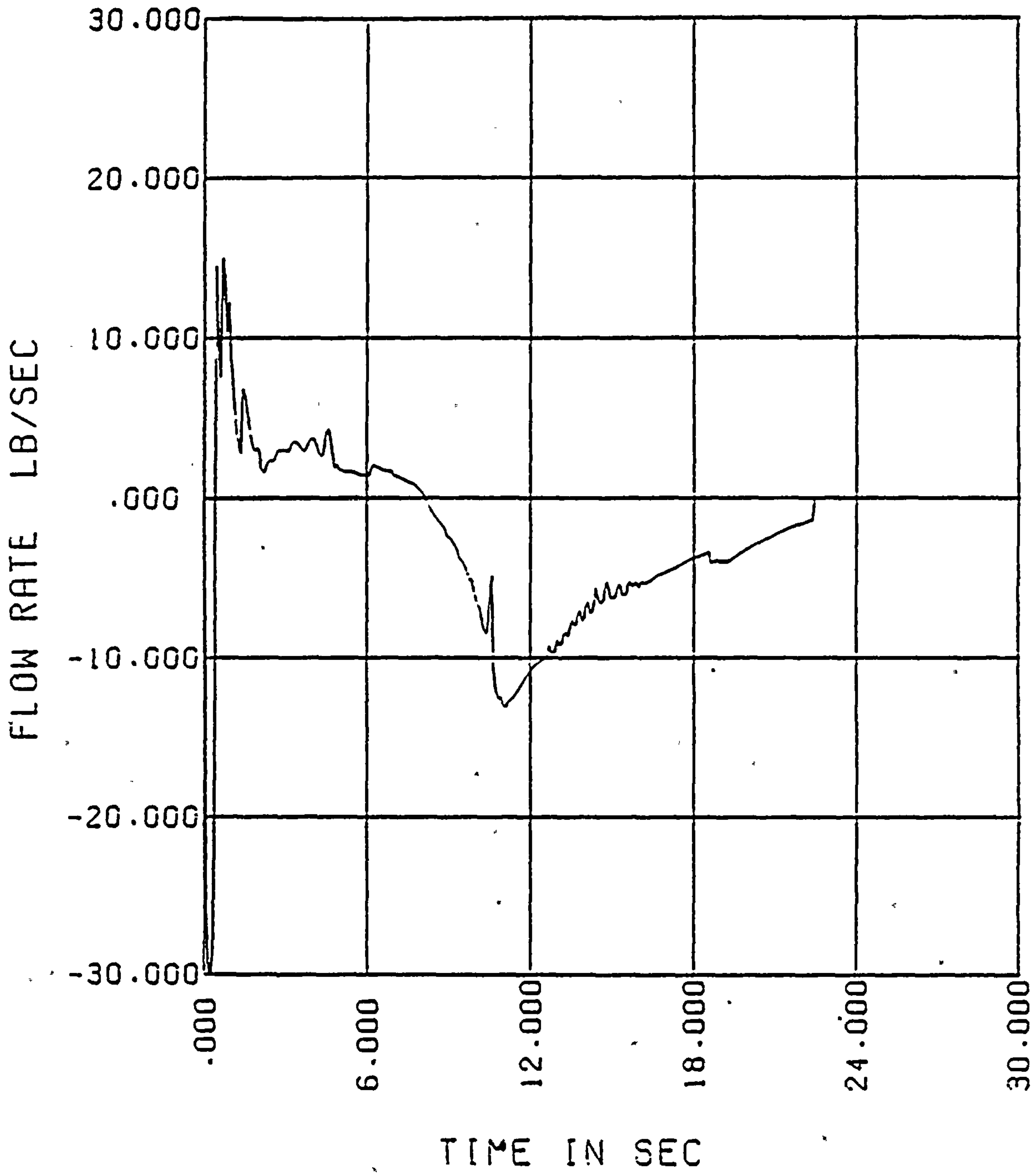


Figure 5

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

HOT ASSEMBLY FLOW, ABOVE HOT SPOT

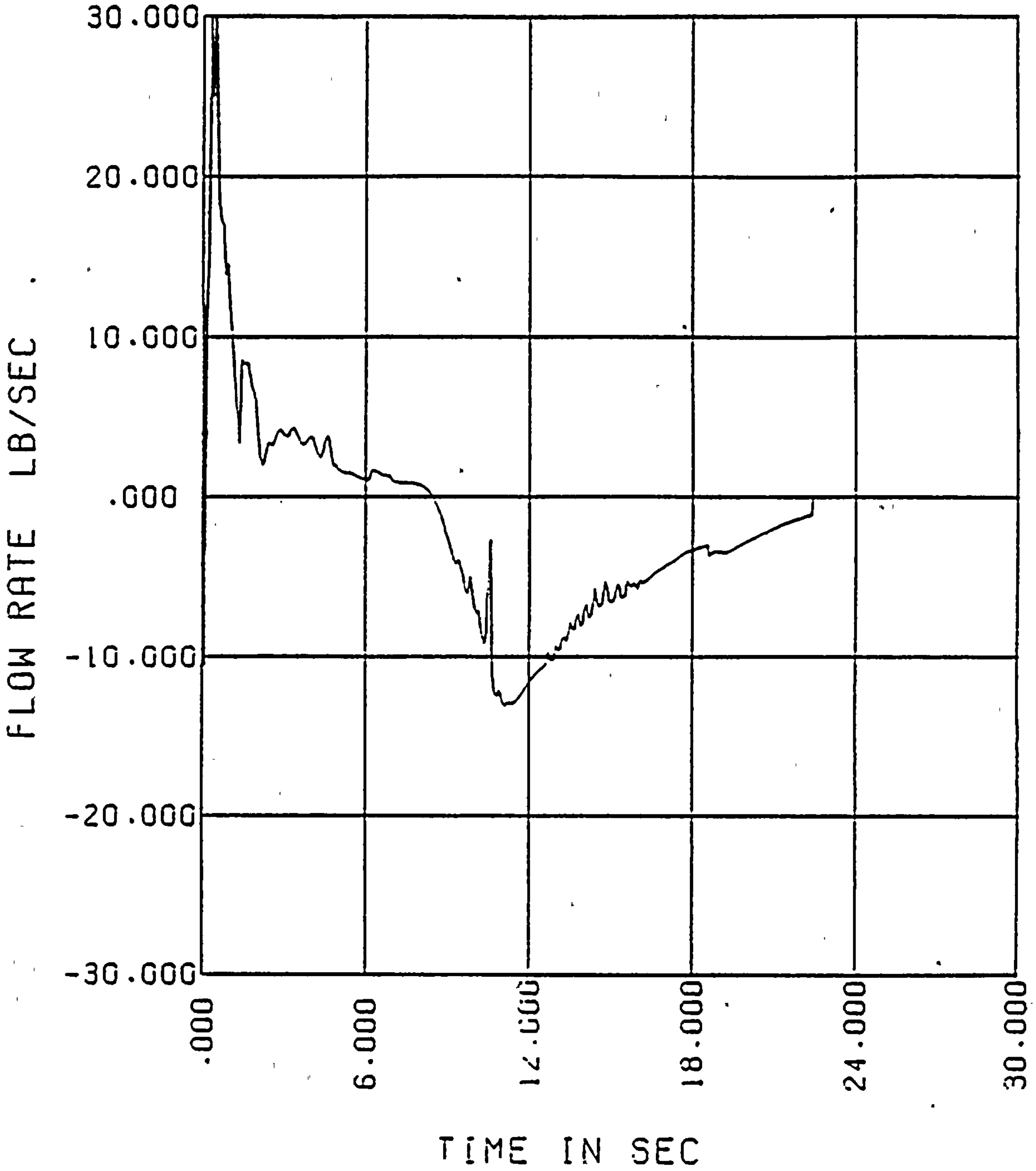


Figure 6

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

HOT ASSEMBLY QUALITY

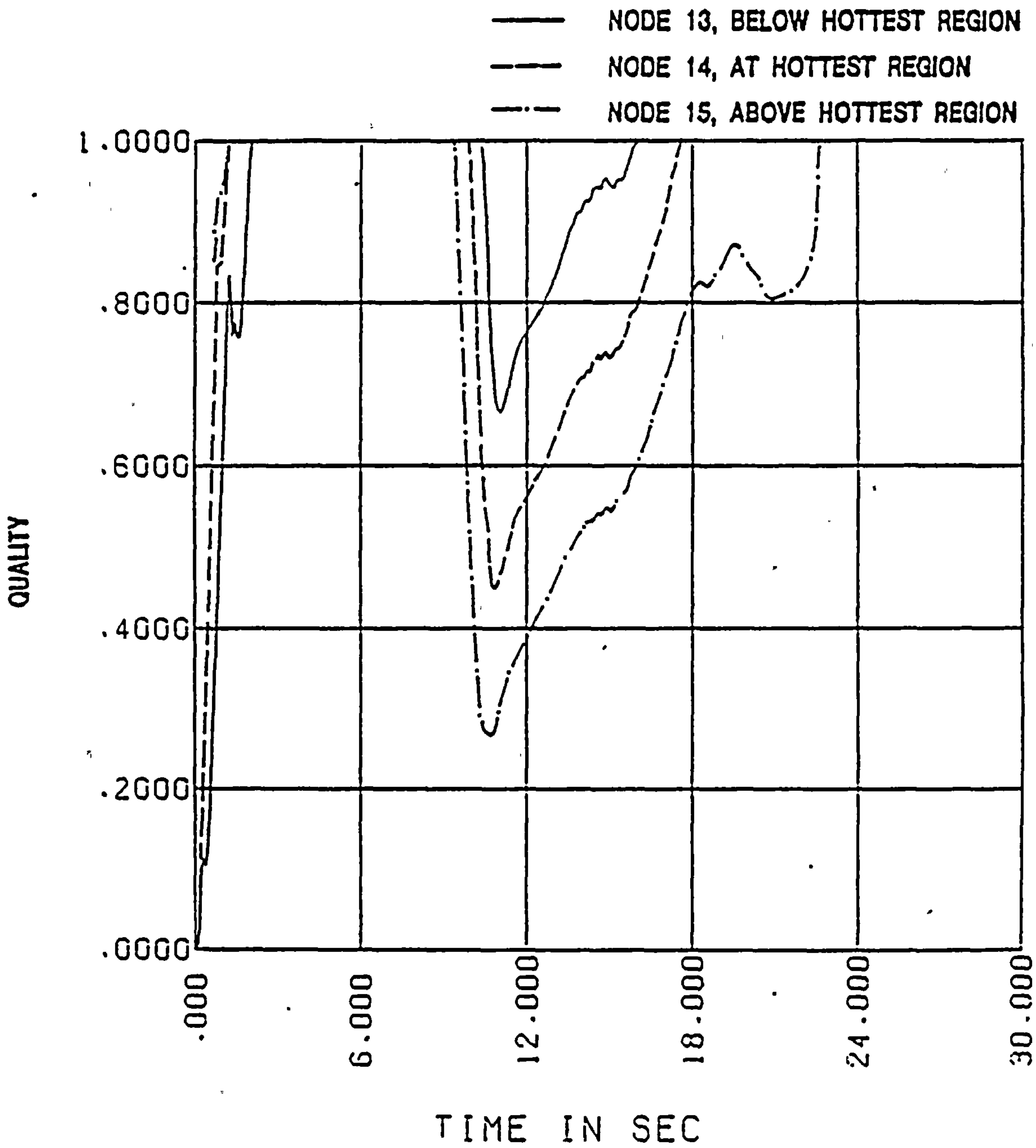


Figure 7

ST. LUCIE UNIT 2

0.8 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

CONTAINMENT PRESSURE

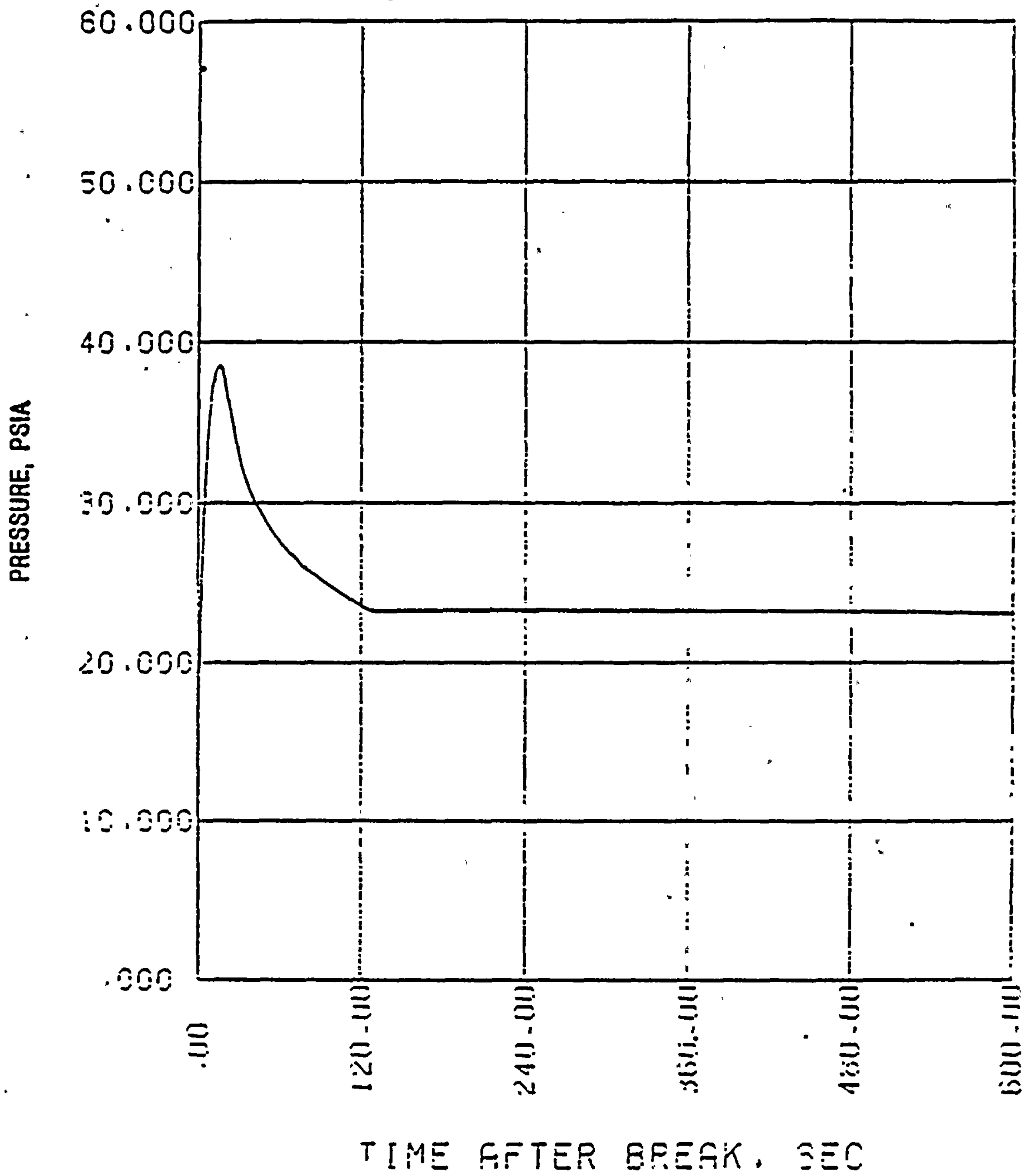


Figure 8

ST. LUCIE UNIT 2

0.8 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

MASS ADDED TO CORE DURING REFLOOD

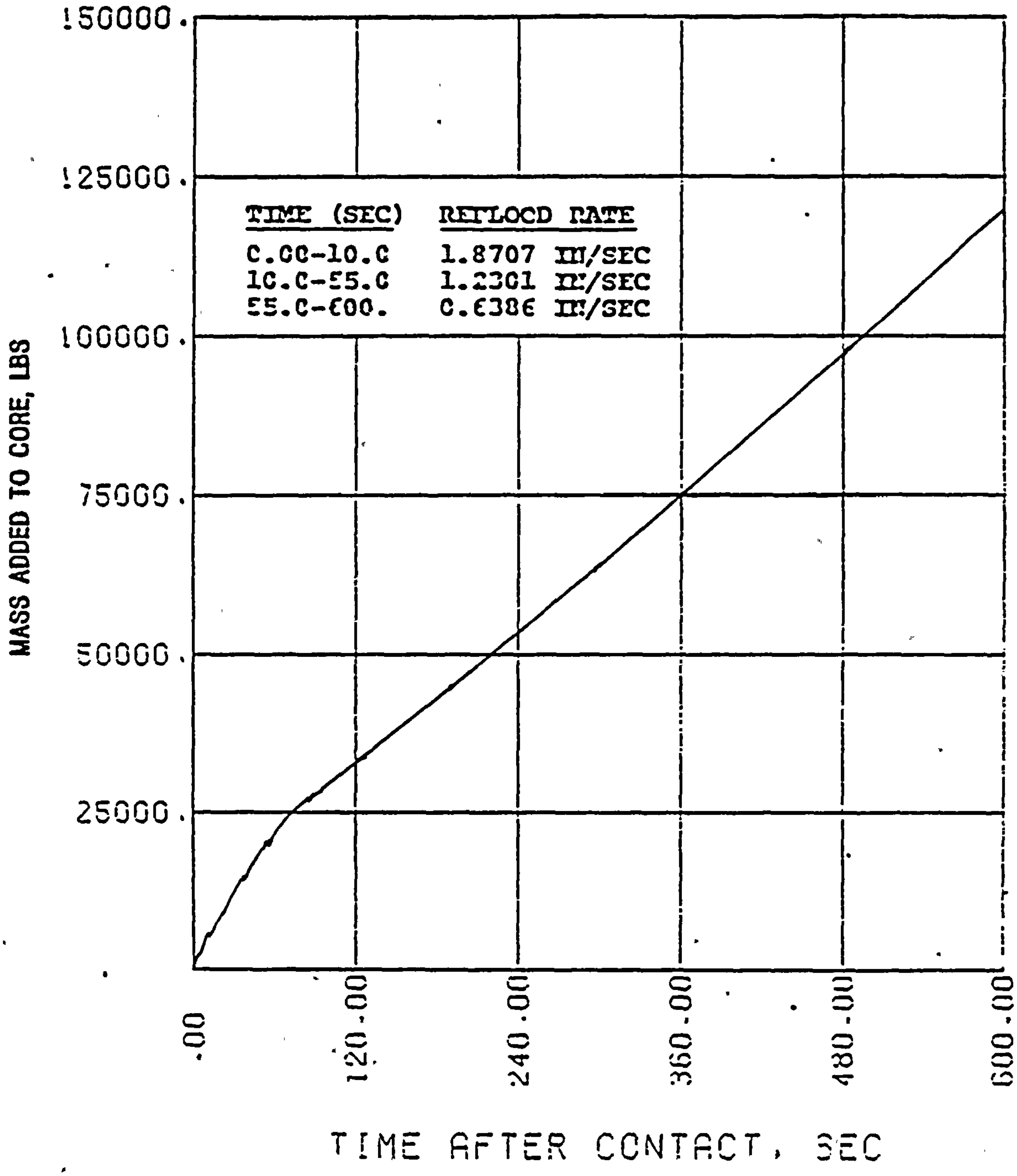


Figure 9

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

PEAK CLAD TEMPERATURE

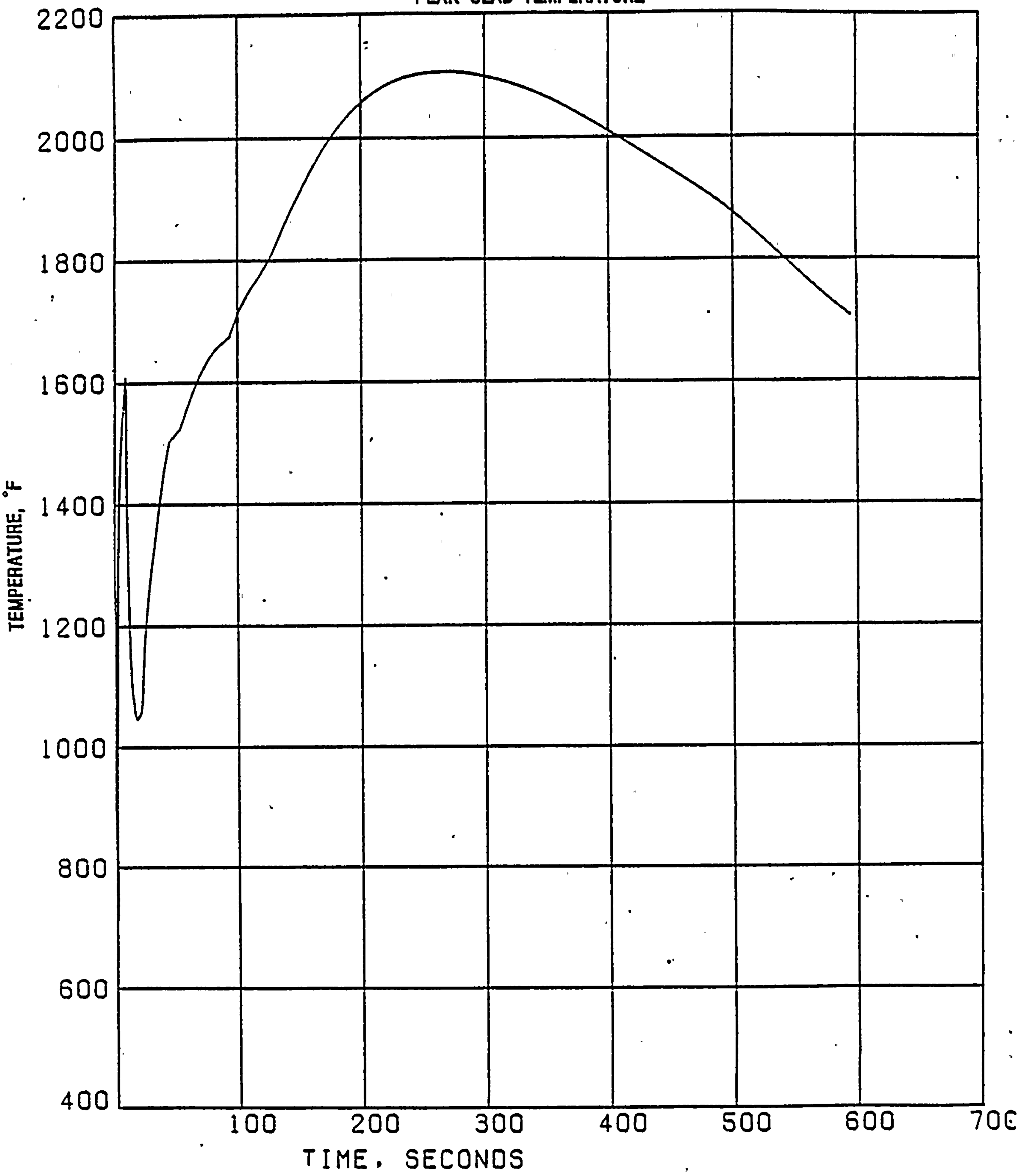
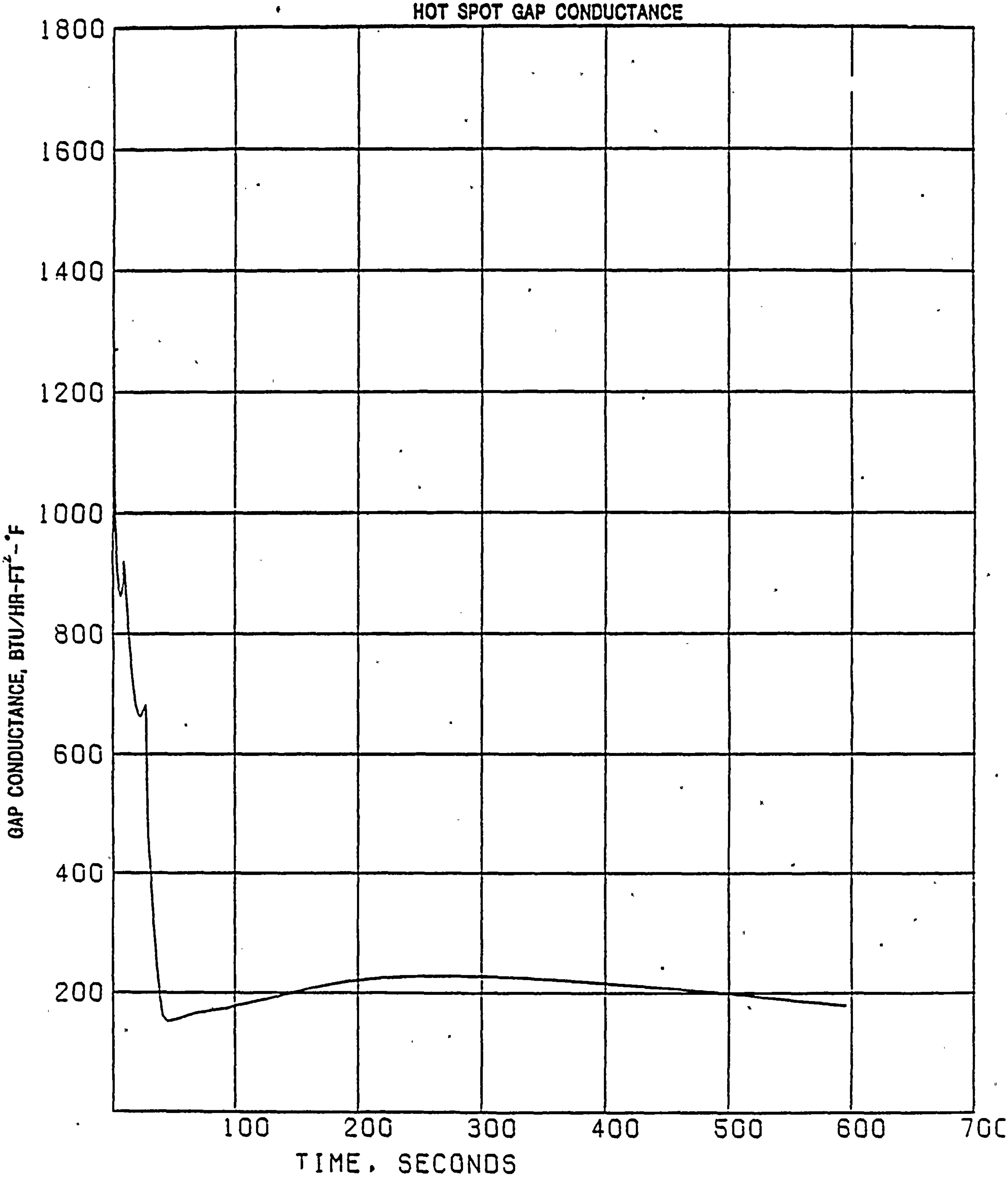


Figure 10

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

HOT SPOT GAP CONDUCTANCE



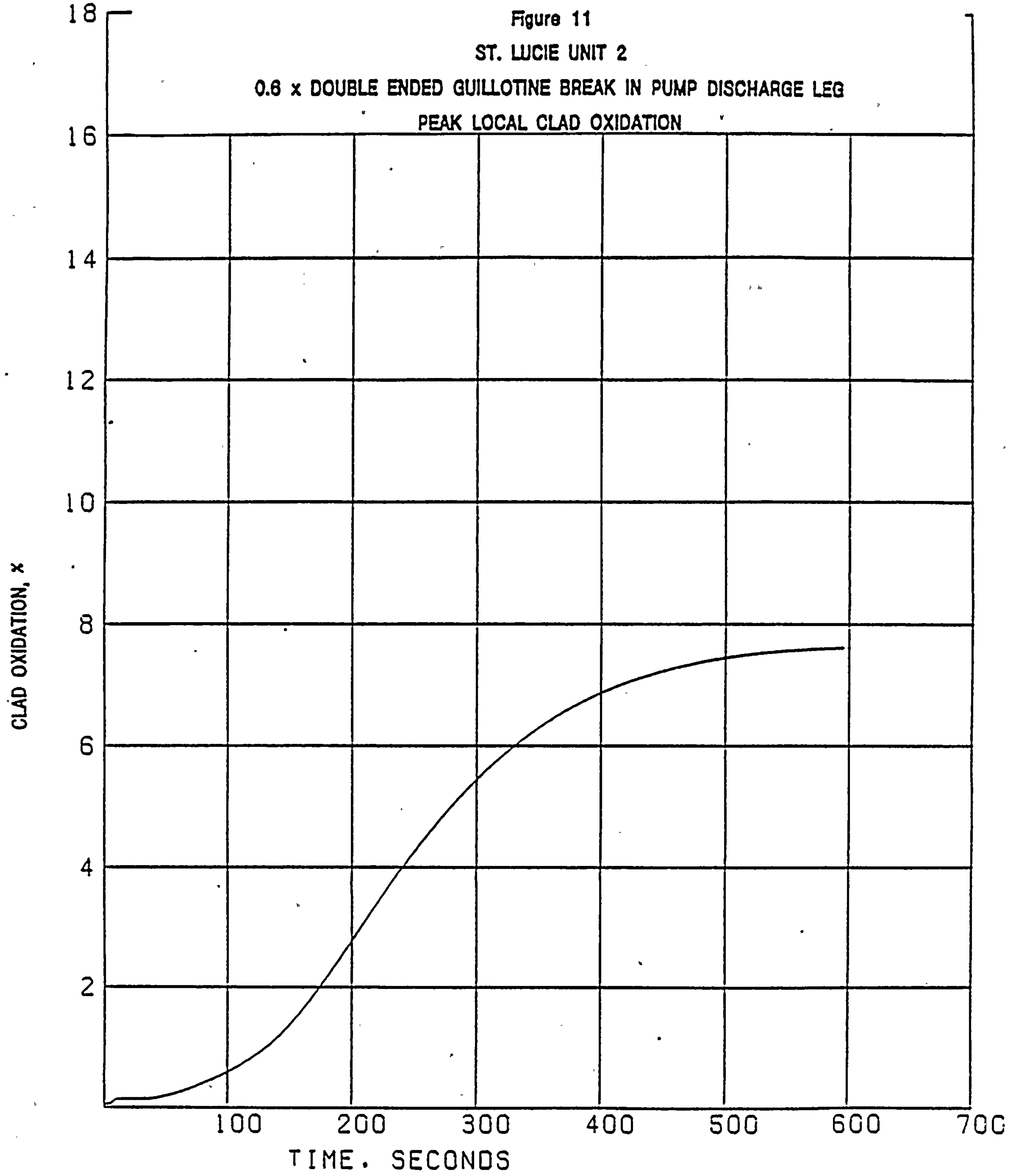
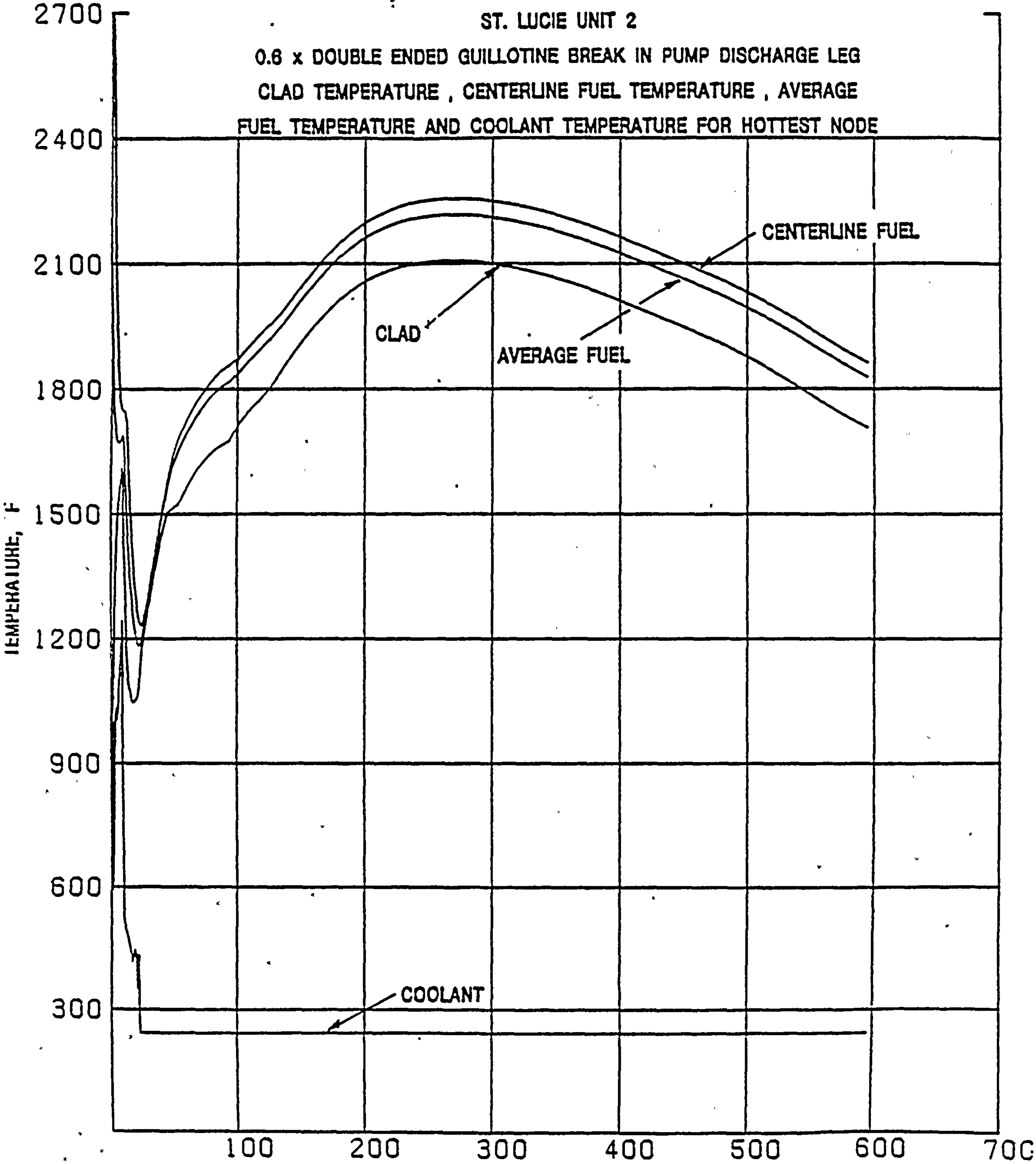


Figure 11
ST. LUCIE UNIT 2
0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG
PEAK LOCAL CLAD OXIDATION
CLAD OXIDATION, x
18
16
14
12
10
8
6
4
2
100
200
300
400
500
600
70C
TIME. SECONDS

Figure 12



ST. LUCIE UNIT 2
0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG
CLAD TEMPERATURE , CENTERLINE FUEL TEMPERATURE , AVERAGE
FUEL TEMPERATURE AND COOLANT TEMPERATURE FOR HOTTEST NODE
TEMPERATURE, F
2700
2400
2100
1800
1500
1200
900
600
300
100
200
300
400
500
600
700
CENTERLINE FUEL
CLAD
AVERAGE FUEL
COOLANT

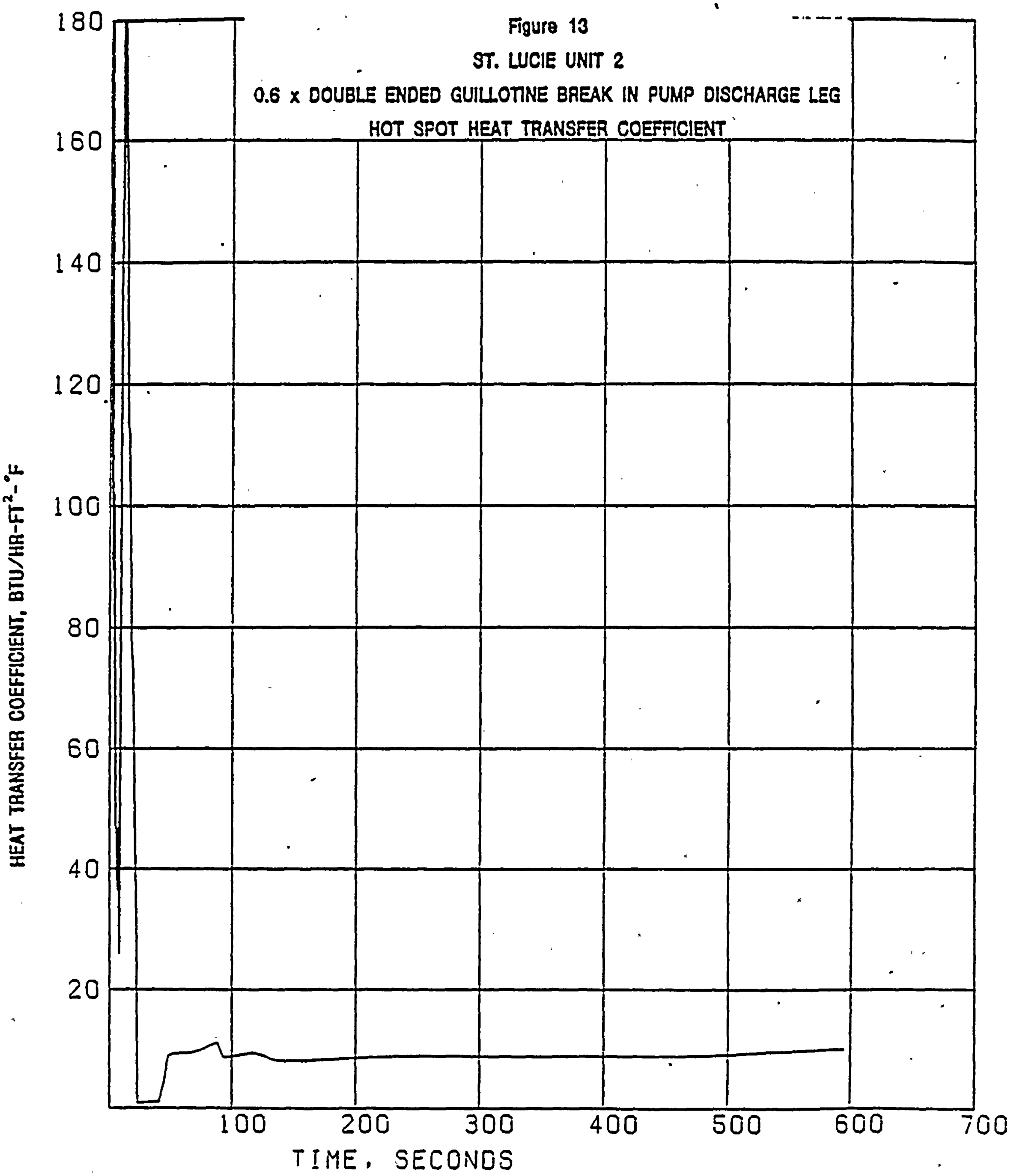


Figure 13
ST. LUCIE UNIT 2
0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG
HOT SPOT HEAT TRANSFER COEFFICIENT
HEAT TRANSFER COEFFICIENT, BTU/HR-FT²-°F
180
160
140
120
100
80
60
40
20
100
200
300
400
500
600
700
TIME, SECONDS

Figure 14

ST. LUCIE UNIT 2

0.6 x DOUBLE ENDED GUILLOTINE BREAK IN PUMP DISCHARGE LEG

HOT ROD INTERNAL GAS PRESSURE