Attachment IV

Evaluation of LTOP Limits Using RG&E Proposed Methodology

Low Temperature Overpressure Analysis Summary Report

Prepared for

Rochester Gas & Electric Corporation

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1.0 INTRODUCTION

B&W Nuclear Technologies (BWNT) updated the analysis of the low temperature overpressure (LTOP) events for the Rochester Gas and Electric (RGE) R.E. Ginna Nuclear Power Station (hereafter referred to as the Ginna plant). Because the steam generators at the Ginna plant will be replaced in 1996, it was decided that the analysis should bound the Ginna plant with either the existing or the replacement steam generators. Therefore, the replacement steam generators manufactured by Babcock and Wilcox International (BWI) were modelled in this analysis.

This analysis becomes the new analysis of record for the Ginna Station. The results of the analyses of the limiting LTOP events were compared with 10CFR50 Appendix G and RHR overpressure limits. In all cases, the peak reactor vessel and RHR system pressures were within the applicable limits.

2.0 DISCUSSION OF LTOP EVENTS

The United States Nuclear Regulatory Commission (USNRC) Regulatory Guide 1.99, Revision 2, dated May 19 discusses the effects of neutron irradiation embrittlement of low alloy steels used in the reactor vessel. Appendix G of Chapter 10, Part 50 of the Code of Federal Regulations gives the fracture toughness requirements for the reactor vessel under low temperature conditions. During LTOP events, the reactor vessel temperatures and pressures approach the Appendix G limits. The LTOP system is designed to ensure that the reactor vessel embrittlement limits are not exceeded.

The LTOP events can occur during cold shutdown or plant heatup and cooldown. To provide protection against exceeding the Appendix G limits, the Power Operated Relief Valve (PORV) on the pressurizer is reset to a low setpoint, which is appropriate for the plant conditions. Two types of overpressurization events that can occur while the plant is operating with low pressure and temperatures are analyzed: The first type of event is a mass addition event and the second type of event is a heat addition event.

2.1 MASS ADDITION LTOP EVENTS

The mass addition events are characterized by addition of mass to a water-solid primary system. This can occur during a shutdown situation, if the charging pumps or if the safety injection(SI) pumps are started inadvertently. Technical Specification limits on SI pump operability and discharge valve position eliminate the mass injection case due to a high head SI pump start. With three SI pumps inoperable, an inadvertent SI signal will not cause a pump start. With the SI system discharge paths isolated, no single inadvertent operator action will result in safety injection. Therefore, the startup of three charging pumps with letdown isolated was analyzed as the bounding mass-addition event.

2.2 HEAT ADDITION LTOP EVENTS

The heat addition events are characterized by an addition of heat to a water-solid primary system. Heat can be added to the primary system by the actuation of pressurizer heaters, loss of the residual heat removal system (RHR) cooling, or two types of reactor coolant (RC) pump startups while a temperature asymmetry exists in the RC loops.

The inadvertent actuation of the pressurizer heaters when the pressurizer is water solid will cause a slow rise in the water temperature and increase in pressure, if the installed automatic pressure control equipment is not in service. Since this pressure transient is very slow, the operator should recognize and terminate the transient before an unacceptable pressure is reached. If the operator does not terminate the transient, the pressure will increase and be terminated by the PORV with little or no over shoot above the PORV setpoint. This case is not significant to the design of the LTOP system.

The loss of RHR cooling when the RCS is water solid could be caused by a loss of flow malfunction in the component cooling water or service water systems, or the closure of the RHRs inlet isolation valves. This would cause a slow rise in temperature and pressure since there would be a continual release of core residual heat into the reactor coolant with no heat removal. This transient is also very slow and the operator has sufficient time to mitigate the event.

The first type of temperature asymmetry can occur if the reactor coolant is at a relatively warm temperature with little or no natural circulation and cold reactor coolant pump seal injection water continues to enter the system. The cooler injection water will settle in a pool in the loop seal. The pressure transient is initiated by starting one reactor coolant pump. As the pump comes up to speed, the reactor coolant flowrate slowly increases in the active loop and the pool of cold water will be drawn up into the pump and discharged out the cold leg piping. Simultaneously, the pool of cold water in the inactive loop will flow backward through the steam generator at a flowrate significantly less than that of the active loop. As this pool of cold water flows through the steam generator, the temperature will increase due to heat transfer from the secondary side of the steam generator. This causes expansion of the primary side water and an increasing pressure transient.

The second type of temperature asymmetry occurs when the RCS has been cooled without sufficient circulation. This could occur when the RHR system is used to cool the RCS without use of any reactor coolant pumps. Under these conditions, the water in the steam generator secondary side and the primary side will be in thermal equilibrium at a temperature higher than that of the reactor coolant. If one RC pump is inadvertently started under these conditions, the RCS flowrate increases and the cold water from the RCS enters the SG tubes. This results in the transfer of heat from the secondary to the

primary system, causing the primary system liquid to expand and the primary system to pressurize. This is a relatively fast event and, because of the transfer of heat from the secondary system to the primary system, this event is the most limiting heat addition transient.

3.0 EVENTS ANALYZED

The limiting mass addition case, the inadvertent startup of three charging pumps, was analyzed at 85 F. This temperature is used because it is the lower temperature limit of the Appendix G limits, and, at the lower limit, the fluid has the minimum compressibility.

The limiting heat addition case is the inadvertent start of a reactor coolant pump following RCS cooldown solely with the RHR system. This event is analyzed at RCS temperatures of 85 F and 320 F with the SG liquid temperature 50 degrees hotter than the RCS. The transient is analyzed at 85 F since it is the lower limit of the Appendix G limits and has the lowest pressure limit for the acceptance criterion. The event is analyzed at 320 F because this is the maximum credible temperature at which a secondary-to-primary temperature difference of 50 F can be achieved. Specifically, the reactor coolant pumps may be tripped at 350 F. With instrument uncertainties , the temperature could be as high as 370 F. If the RCS is subsequently cooled to obtain the maximum allowed temperature difference (50 F), the RC pump start could occur at 320 F. This heat addition event is the most limiting for the RHR overpressurization.

4.0 ACCEPTANCE CRITERIA

The acceptance criteria for the LTOP events are:

1. The pressure and temperature of the reactor vessel can not exceed the Appendix G limits, which are depicted in Figure 1. This figure is obtained from Reference 2.

2. The pressure in the RHR system can not exceed 110 percent of the design pressure of 600 psig, or 660 psig.

5.0 METHODOLOGY

The LTOP transient analyses were performed using the RELAP5/MOD2 B&W Version 20 (Reference 5) computer code, which has received full BWNT certification. RELAP5/MOD2-B&W is a two-fluid, six equation, nonhomogeneous, nonequilibrium

Figure 1

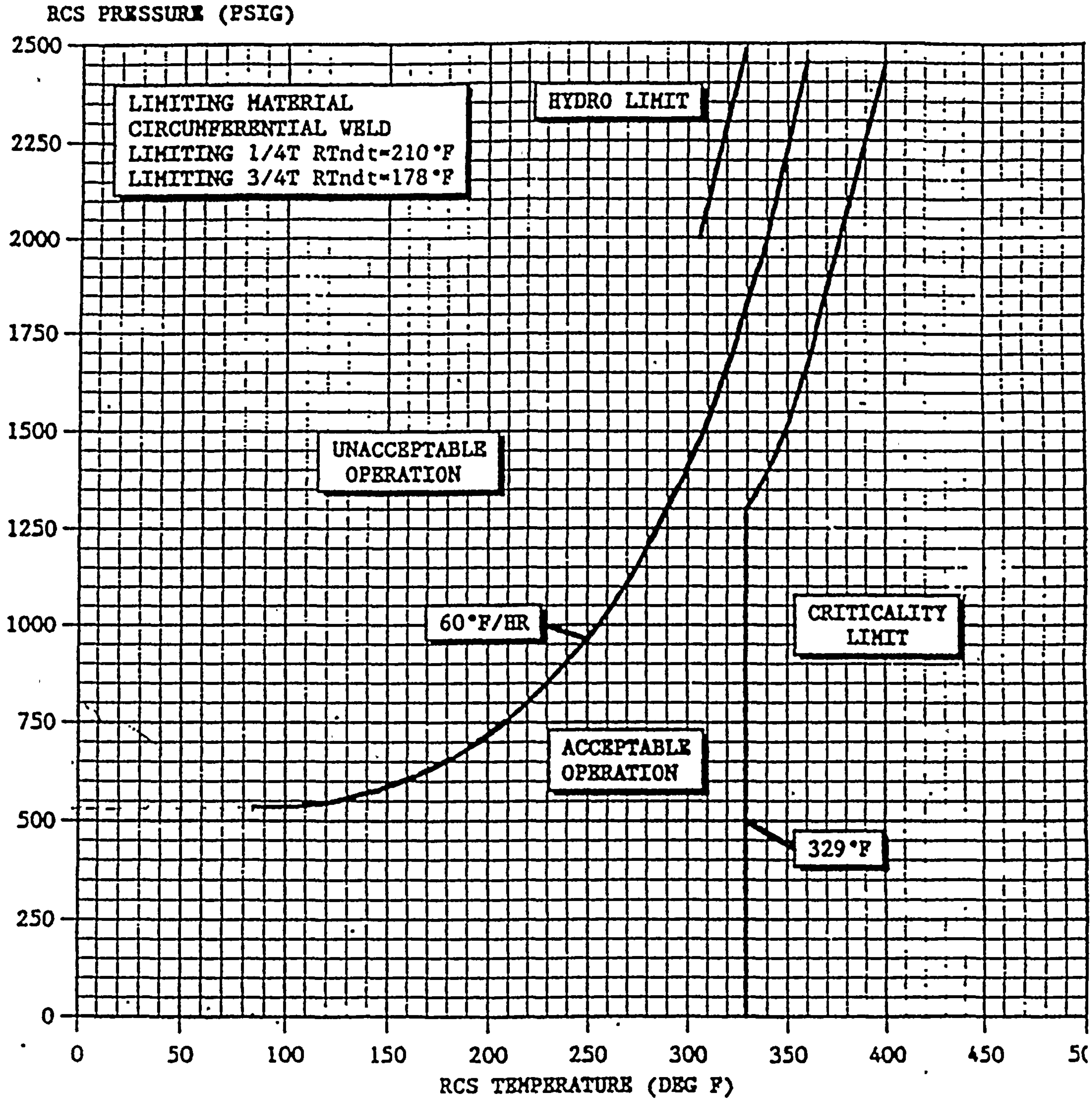


Figure 3.1-1: Ginna Reactor Vessel Heatup Limitations Applicable for the first 21 EFPY using Reg Guide 1.99, Rev. 2

thermal-hydraulic code developed for best-estimate transient analysis of pressurized water reactors and associated systems. The code has options to consider equilibrium, homogeneous hydrodynamic control volumes and a limited ability to calculate conditions for co-existing noncondensibles. The numerical solution technique is semi-implicit finite differencing. RELAP5 is a highly flexible code that, in addition to calculating NSS behavior, can be used for simulation of a wide variety of thermal-hydraulic transients.

RELAP5/MOD2-B&W has special process models that are not available in the industry version of the code. The only such process model used in these LTOP analyses is the Henry-Fauske extended subcooled critical flow model. For those instances when the pressurizer PORV experienced critical flow, the extended Henry-Fauske critical flow model was used rather than the Ransom-Trapp model. The extended Henry-Fauske model was used because it is widely accepted for use over the range of conditions experienced in these analyses and because the Ransom-Trapp model overpredicts the test data using a discharge coefficient of 1.0 (Reference 3).

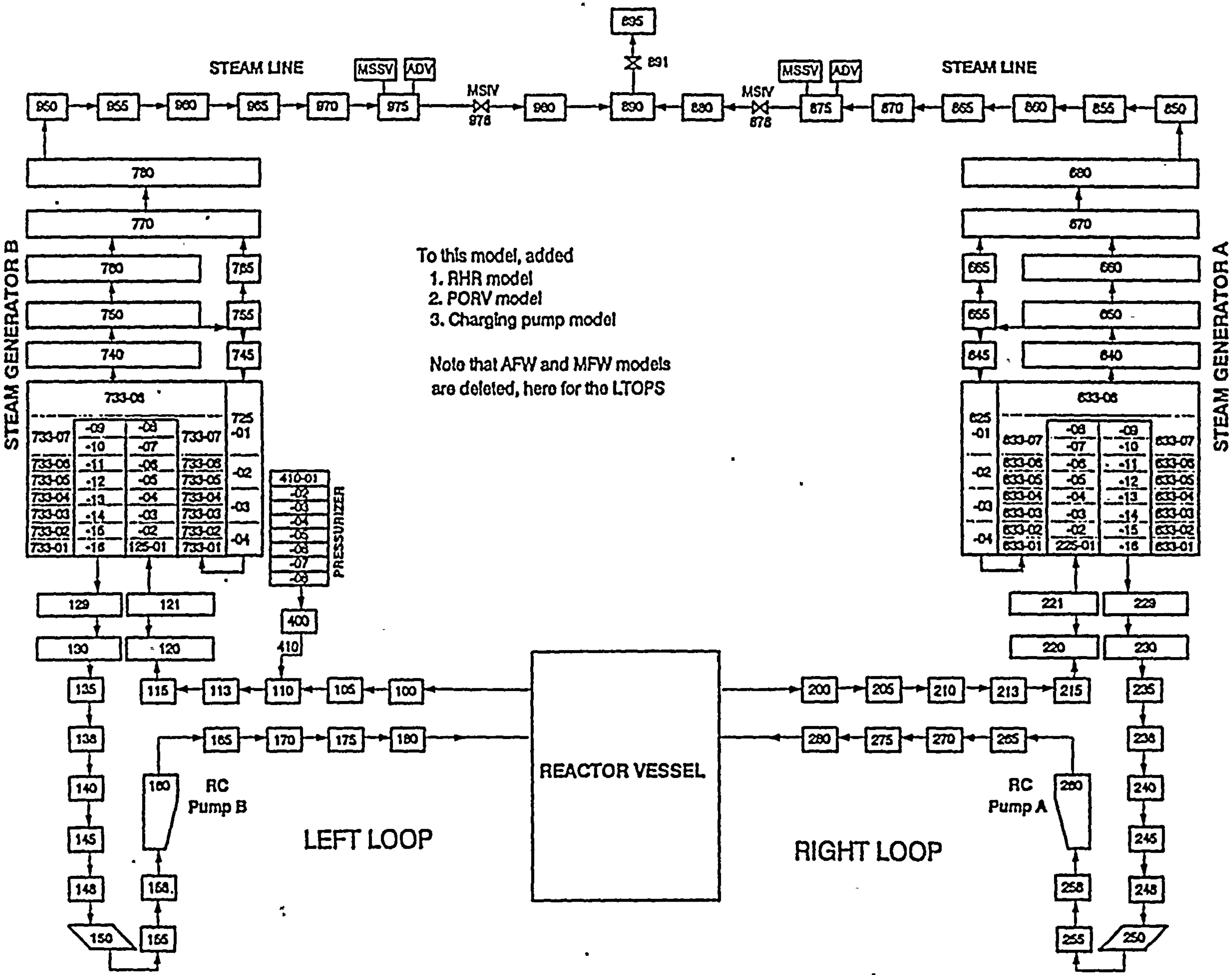
The plant model that was employed for the LTOP analyses included two complete reactor coolant loops including RC pumps and steam generators. The secondary side included steam lines, main steam safety valves (MSSVs), main steam isolation valves (MSIVs), and turbine stop valves. A noding diagram of the RELAP5/MOD2 model is shown in Figure 2. The steam generator model used for the analyses is a simulation of the U-tube replacement steam generator designed by BWI. This steam generator design has 21.3 percent higher heat transfer surface area than the current steam generators used in the R.E Ginna Nuclear Power Station. Use of this model in the LTOP analyses accommodates the steam generator replacement, while bounding the current steam generators. The feedwater systems and the auxiliary feedwater systems are not modelled since these are not functioning during the LTOP events.

The primary system has a reactor vessel model with two equal and parallel core paths for adjusting the mixing of loop flows in the lower plenum. This feature is not used in the LTOP analyses as this is not required. The core has six axial nodes and a core bypass with three nodes. The upper and the lower plenum volumes are common to both the loops, whereas the downcomer is split into two parallel set of volumes. A noding diagram of the reactor vessel is shown in Figure 3.

The pressurizer was modelled as a ten node vertical pipe component and was initialized liquid solid. One PORV is attached to the top node of the pressurizer. Only one PORV is modelled because the other PORV is assumed to fail closed. The PORV was set to lift when the pump suction pressure on the loop with the pressurizer exceeded 430 psig, consistent with the location of the pressure transmitters and instrument error. Instrument error is not normally considered for Appendix G protection but is included in this analysis for RHR overpressure concerns. The PORV model was sized to deliver 49.722 lbm/s

Figure 2

GINNA RELAP5 MODEL



8

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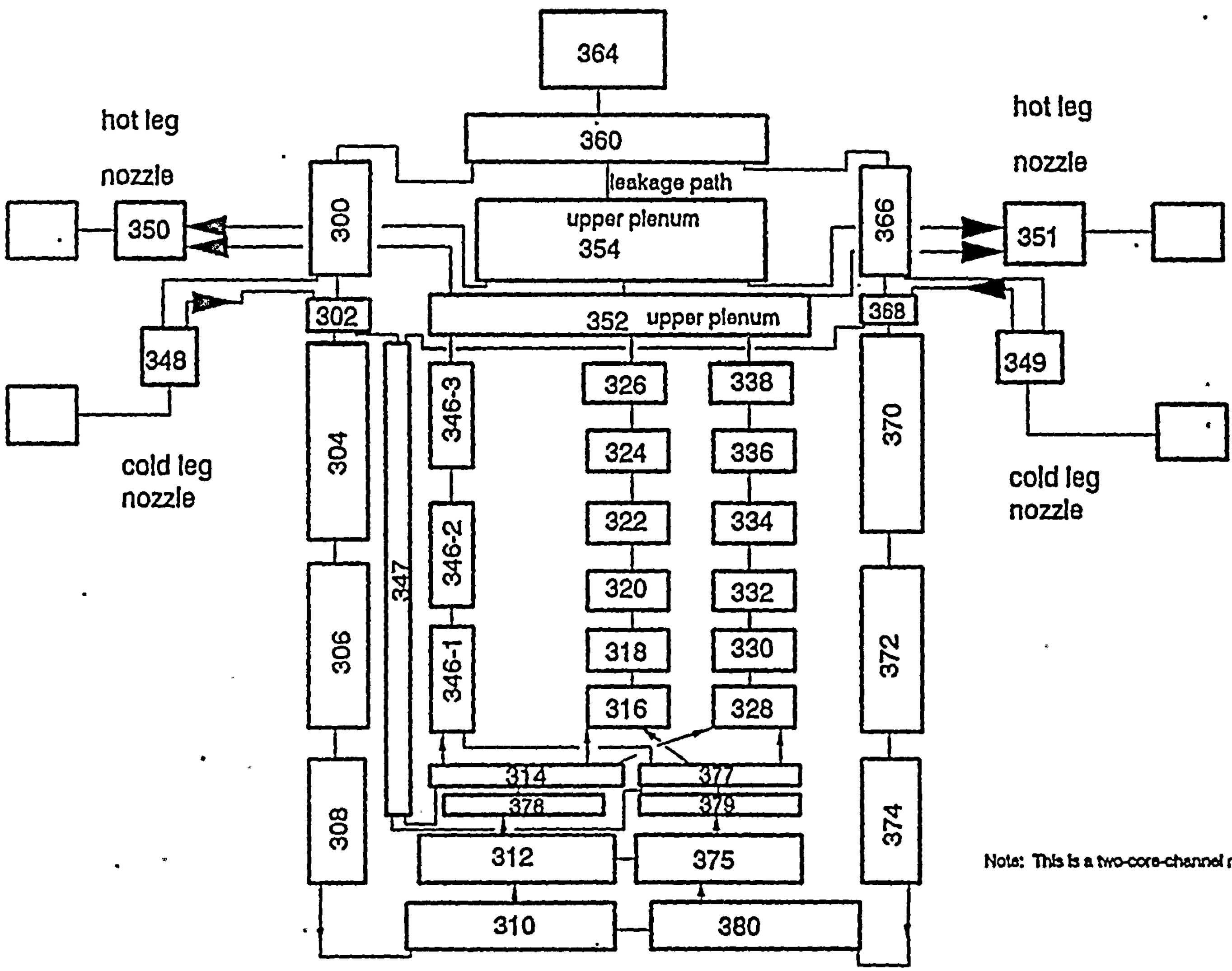
Figure 3.

GINNA REACTOR VESSEL AND CORE MODEL



Note: This is a two-core-channel model - both average cores

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saturated steam at 2335 psig. The opening stroke time was 1.0 second using the C_v characteristics in Table 1. The model contains the piping from the PORV to the pressurizer relief tank (PRT) as well as the PRT with a rupture disc. The nitrogen blanket on the PRT is modelled.

The RC pumps were modelled as centrifugal pumps with the homologous curves representing the performance under various conditions. The pump performance curves shown in the UFSAR were used as the basis for the active octants in this pump model.

The passive metal of the whole system was modelled for the LTOP analyses. The passive metal included the reactor vessel walls, the reactor internals, the fuel end fittings, the hot and cold leg pipe walls, pressurizer walls, the steam generator primary side metal and the steam generator secondary side metal. The steam generator tube metal was modelled as part of the active heat structures. The steam line metal and the RHR system passive metal were not modelled.

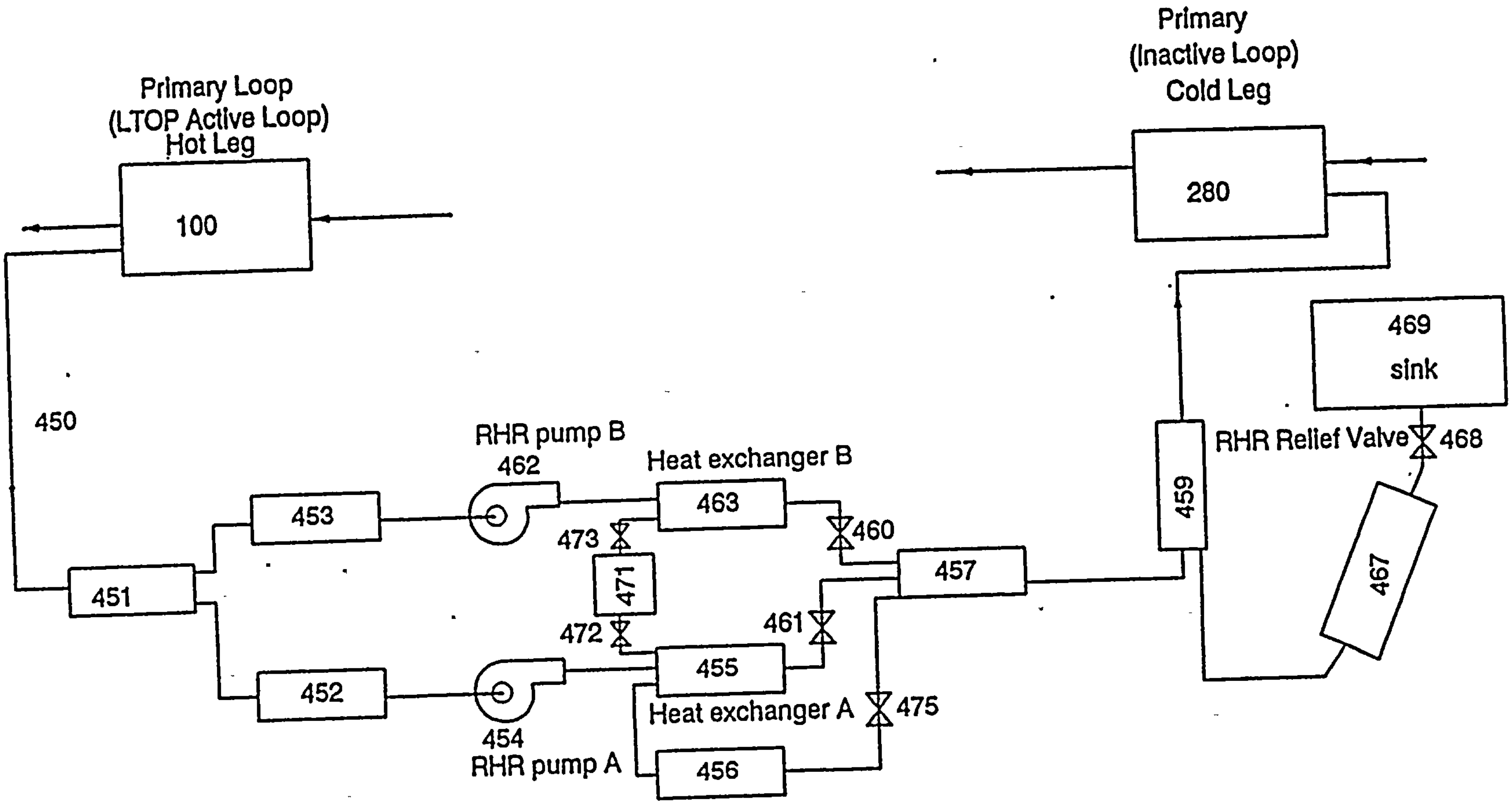
The RHR system was modelled as two parallel trains with two separate pumps and cross connects. Two heat exchangers were modelled as control volumes with no heat removal since the heat exchangers were assumed to maintain a constant temperature in the RCS during the LTOP analyses. The RHR relief valve was attached to the RHR system near the cold leg connection. The RHR relief valve was benchmarked for flow under the design conditions. A noding diagram of the RHR system is shown in Figure 4.

TABLE 1
C_v versus position
Copes Vulcan Valve - Model Number D-100-160

Stroke %	Cv normalized
0.0	0.0
1.9	0.016
7.9	0.067
14.0	0.143
20.0	0.231
26.1	0.346
32.2	0.474
38.2	0.626
44.3	0.734
50.3	0.823
56.4	0.878
62.5	0.924
68.5	0.957
73.6	0.970
78.3	0.977
84.5	0.985
91.6	0.992
98.6	0.999
100.000	1.0

Figure 4

RHR SYSTEM MODEL



12

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For the mass addition case, the primary system was initialized at 85 F and 315 psig with no reactor coolant flow. The primary and secondary systems were decoupled since there was no heat transfer in this case. The event was initiated by starting three charging pumps with a total capacity of 180 gpm. The analysis was terminated after 10 minutes when the operator was assumed to secure charging flow. The peak RCS pressure was compared with the acceptance criteria.

For the heat addition cases, the primary system was initialized to isothermal conditions with no reactor coolant flow. The secondary and primary fluid in the steam generators were initialized at a temperature 50 degrees above the primary system. The RHR system was running with a capacity of 1700 gpm, as specified in Attachment C of Reference 4. The capacity obtained in our model was 1701 gpm. This is an obtained value, not a specified one, and this result was considered adequate. The transient was initiated by starting a reactor coolant pump in the loop that contains the pressurizer. The pump start-up characteristics of Table 3 were used to bring the pump to full speed in 17.4 seconds. The analysis was run until the peak pressure was obtained. The peak pressures in the reactor vessel and the RHR system were compared with the acceptance criteria.

6.0 ANALYSIS

The sections following describe the initial and boundary conditions for each event analyzed, as well as the results. All values were taken from Reference 4.

6.1 Mass Addition Case

The mass addition case was initialized at a primary temperature of 85 F and a primary pressure of 315 psig. Using the initial pressure of 315 psig assures that the transient is well defined by the time the PORV is actuated. There was no flow in the reactor coolant system and the pressurizer was water solid. It was assumed that the RHR system was removing decay

heat, so it was not modelled. The event was initiated by starting three pump charging flow (180 gpm or 25 lb/s). The analysis was run for ten minutes. The sequence of events for this case is shown in Table 2. Plots of Loop B hot leg pressure, Loop A hot leg pressure, and reactor vessel pressure are shown on Figures 5 - 7, respectively.

The peak reactor vessel pressure was 480.2 psia. The allowable pressure, according to the Appendix G limit at 85 F, is 540 psig or 554.7 psia. Therefore, there is 74.5 psi margin to the Appendix G acceptance criterion.

To compare the peak pressure in the RHR system with the acceptance criterion, the pressure drop from the hot leg to the RHR pump discharge (128.1 psi, from Reference 4) was added to the peak hot leg pressure. This case yielded a peak RHR pressure of 598.4 psia. The peak allowable pressure in the RHR system is 674.7 psia. This results in a 76.3 psi margin to the acceptance criterion.

TABLE 2
SEQUENCE OF EVENTS - MASS ADDITION CASE

EVENT	TIME, SECONDS
Charging pumps started.	0.0
Charging pump reach full flow	1.0
Peak pressure of 480.2 psia reached in the bottom of the RV	534.0
Peak pressure of 470.3 psia reached in the hot leg connection to RHR	534.0

LTOP EVENT-MASS ADDITION CASE
CASE 1
Primary temperature 85 ° F, Secondary temperature 135 ° F
Three charging pumps operating

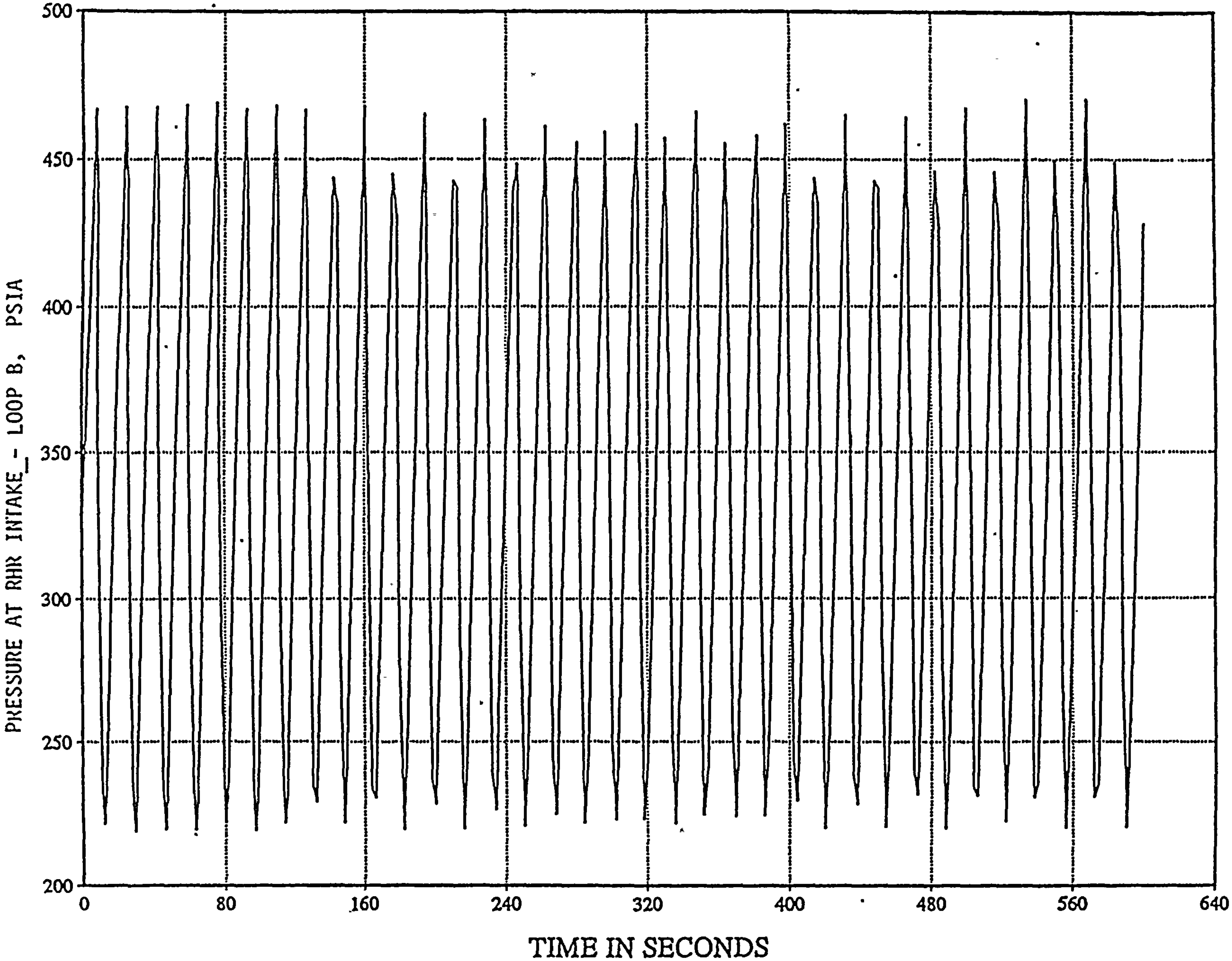

Figure 5

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LTOP EVENT-MASS ADDITION CASE
CASE 1
Primary temperature 85 ° F, Secondary temperature 135 ° F
Three charging pumps operating

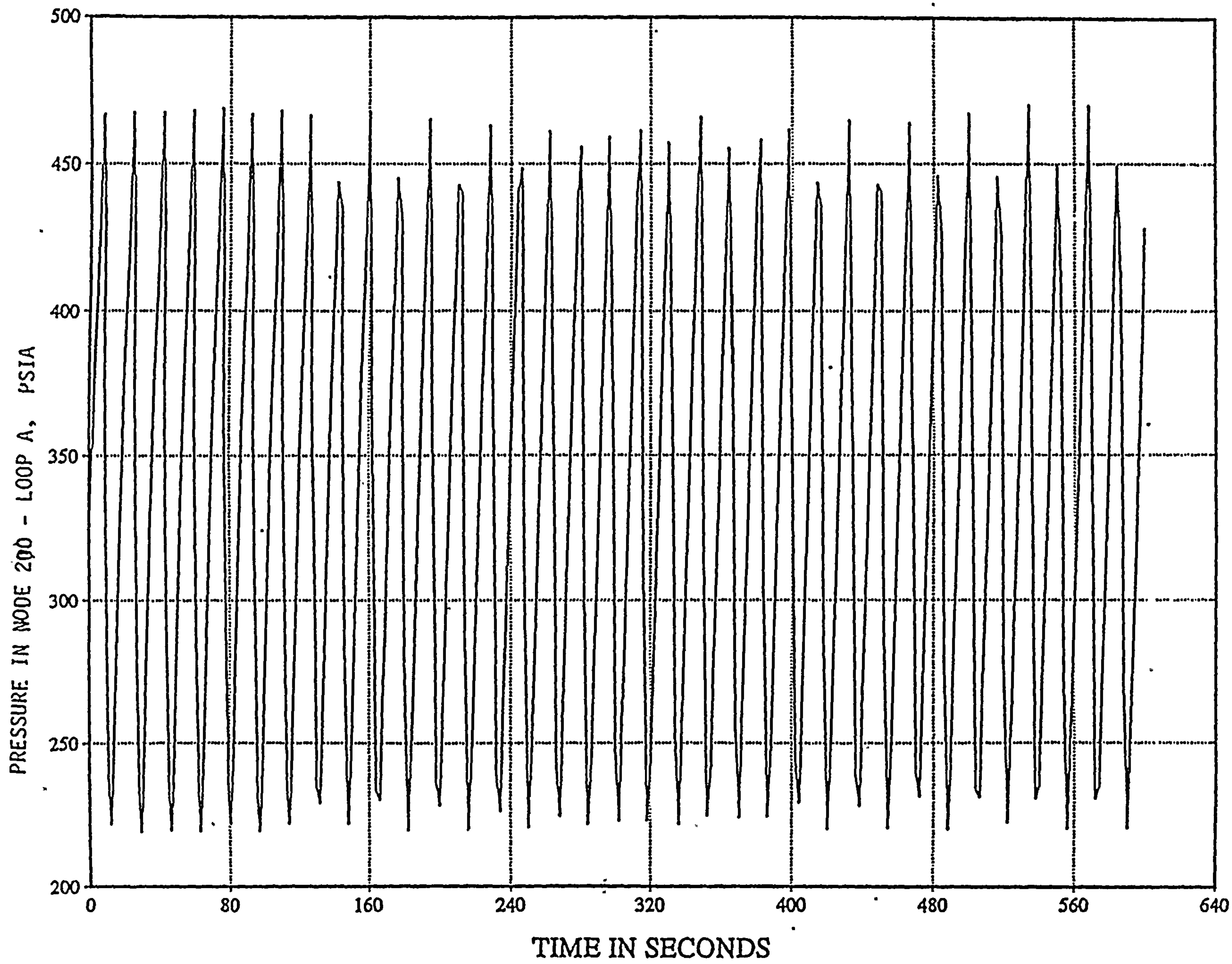

Figure 6

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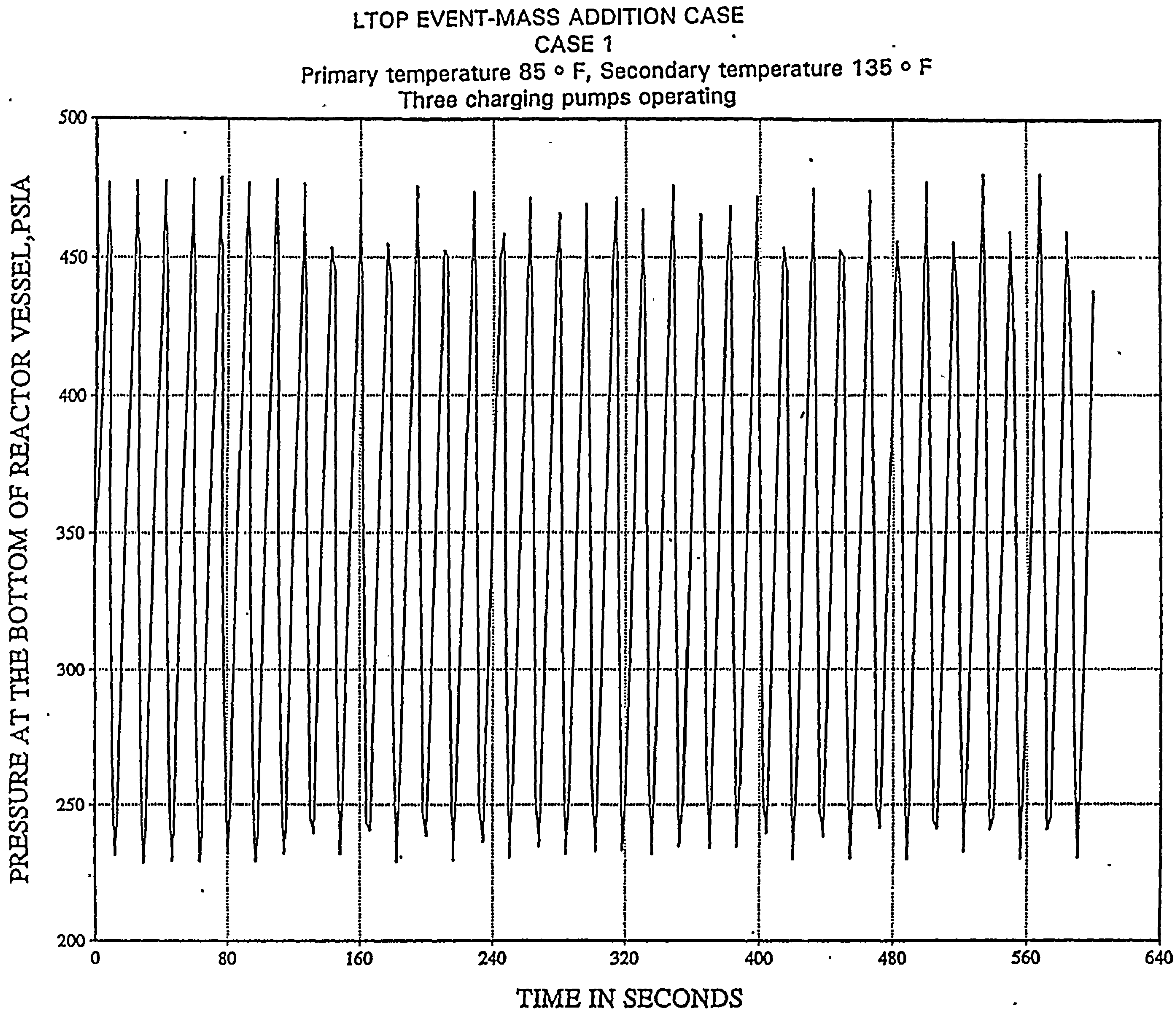

Figure 7

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6.2 Heat Addition at 85 F

The first heat addition case was analyzed at a primary system temperature of 85 F and a primary pressure of 315 psig. The secondary system was assumed to be 50 degrees hotter than the primary system, so the temperature in the secondary system and the primary side of the SG was 135 F. Initially, the RC pumps were not running and cooling was assumed to be provided by the RHR system. The RHR system was operating with a capacity of 1701 gpm, or 236.47 lbs/sec. The pressurizer was water solid. There was no charging flow for this event. The event was initiated by starting the RC pump in the loop that contained the pressurizer. The pump start-up profile that was used in the analysis is shown in Table 3. The transient was analyzed for 40 seconds The sequence of events for this case is shown in Table 4. Figures 8 - 16 show plots of RV pressure, RHR pressure, PORV flow, secondary system temperature in the tube region of Loop B, secondary system temperature in the tube region of Loop A, flow in RC loop B, flow in RC loop A, hot leg temperature in the Loop B, and hot leg temperature in Loop A, respectively. Figure 8 depicts the first pressure peak, which is the highest pressure, as illustrated by the decreasing slope.

The peak pressure in the reactor vessel for this case was 546.8 psia. The allowable pressure for the Appendix G limit at this temperature is 554.7 psia. This yields a 7.9 psi margin. This case is the most limiting for Appendix G.

It is stated in Reference 6 that it is acceptable to exclude the pressure instrument error for the LTOP evaluation because the low temperature overpressure protection system is considered to be a mitigation system, as opposed to a protection system. This analysis assumed a 20 psi instrument error for the PORV setpoint. In a water solid system, it can be expected that a 20 psi reduction in the setpoint can yield at least a 20 psi reduction in the peak pressure. If additional margin to the Appendix G limit is needed in the future, this instrument error could be credited.

The peak pressure in the RHR system was 640.8 psia as compared with an acceptance criterion of 674.7 psia, for a margin of 33.9 psi.

TABLE 3
PUMP STARTUP PROFILE

Time,sec	Speed, rpm
0.0	0
3.5	240
6.6	480 .
9.7	720
13.3	960
15.8	1080
17.4	1189 (FULL SPEED)

TABLE 4
HEAT ADDITION at 85 F - SEQUENCE OF EVENTS

EVENT	TIME, SECONDS
RC pump started in loop that contains the pressurizer.	0.0
RC pump reaches full flow	17.4
PORV opening signal for the first time	23.2
Peak pressure reached in the RV	23.2
Peak pressure reached in RHR	23.2

LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ∘ F, Secondary temperature 135 ∘ F
One RC pump starting

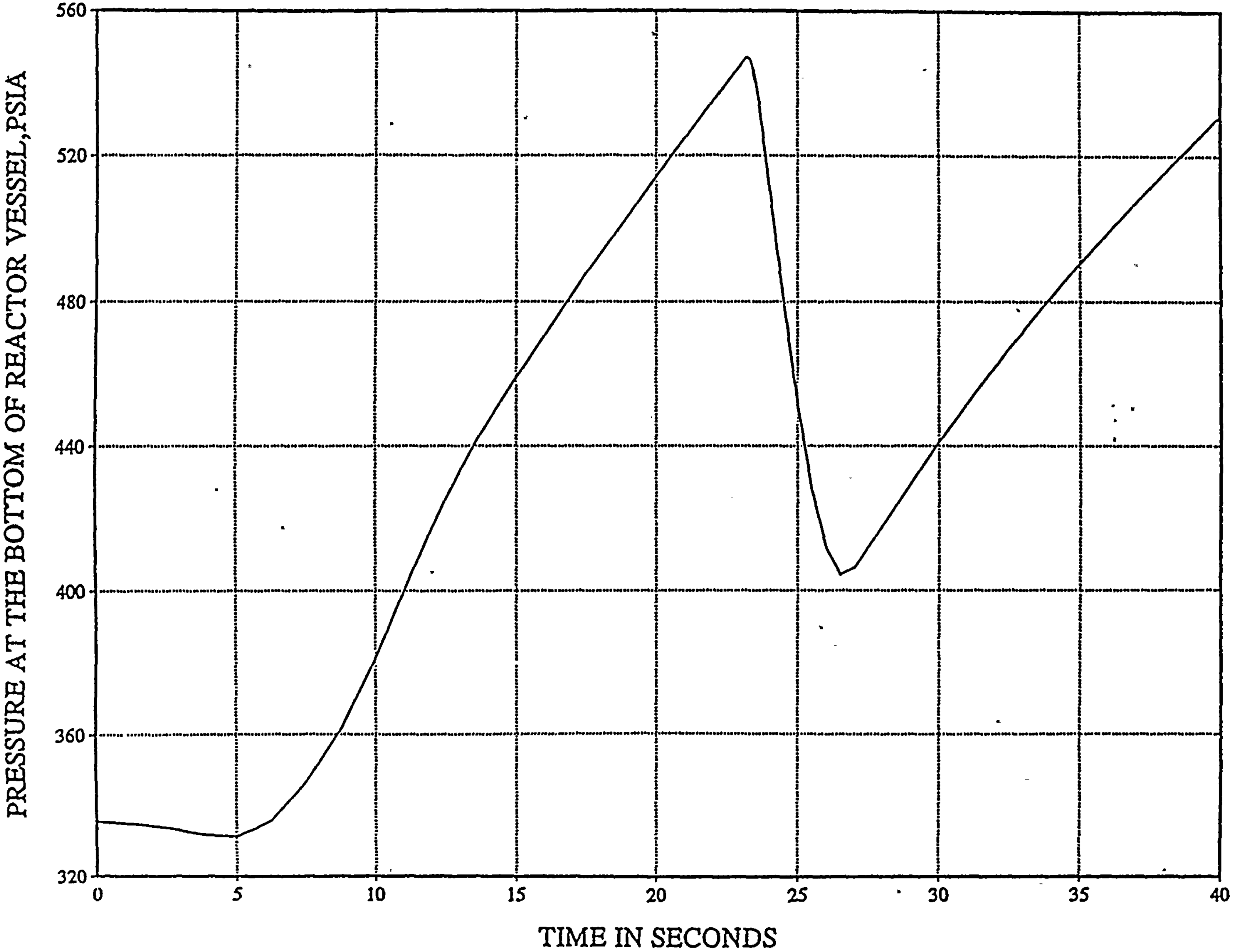

Figure 8

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LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ∘ F, Secondary temperature 135 ∘ F
One RC pump starting

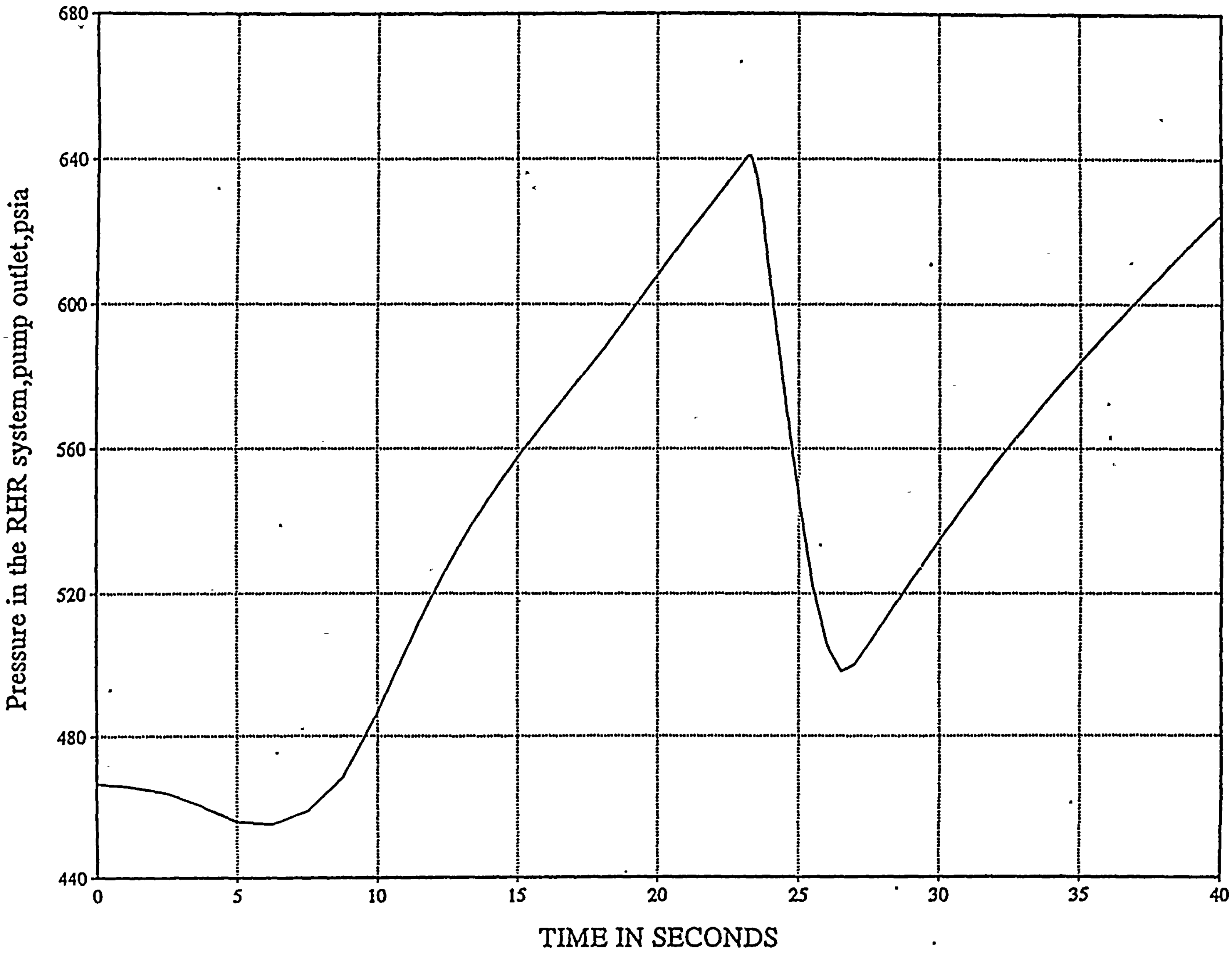

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Figure 9

LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ° F, Secondary temperature 135 ° F
One RC pump starting

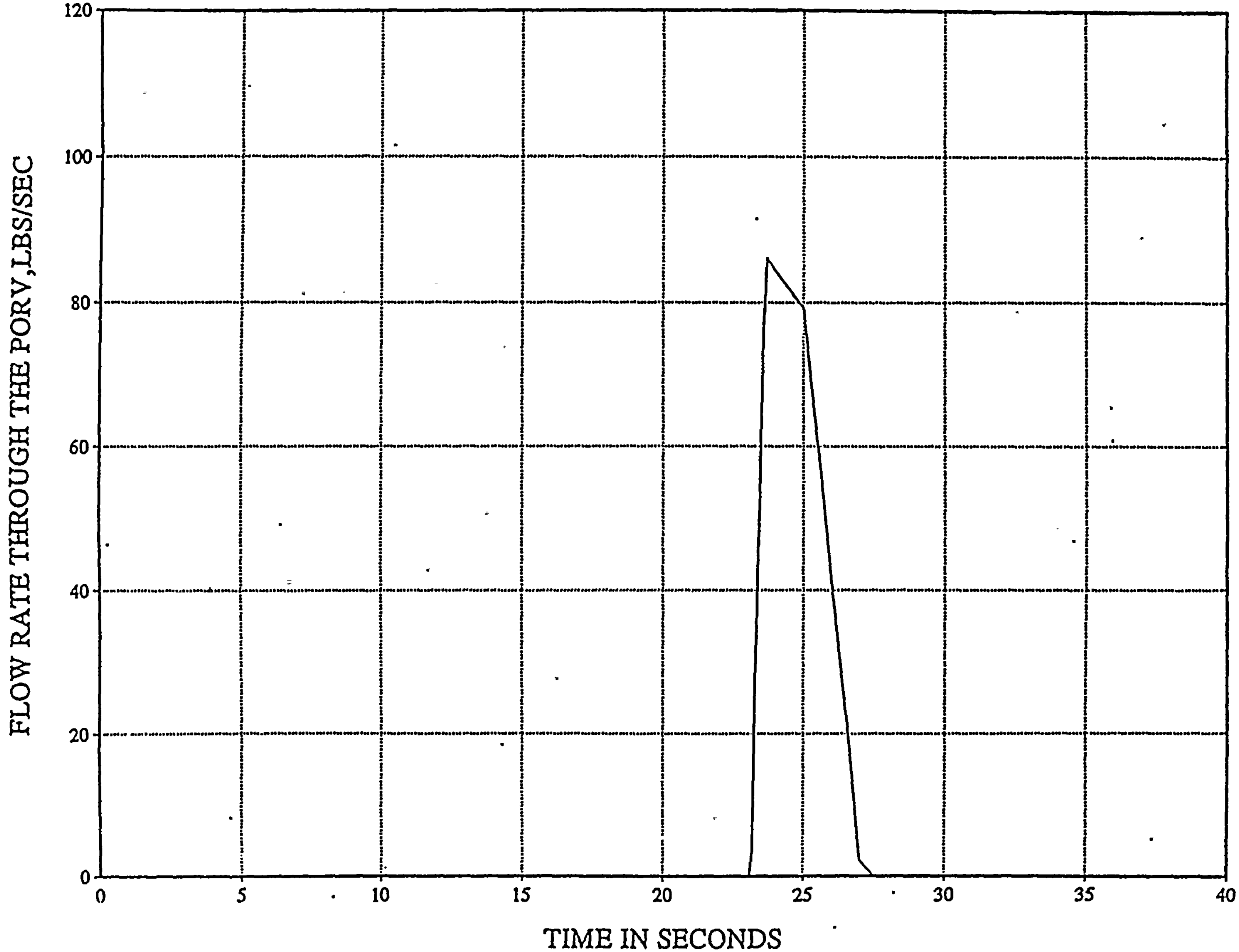

Figure 10

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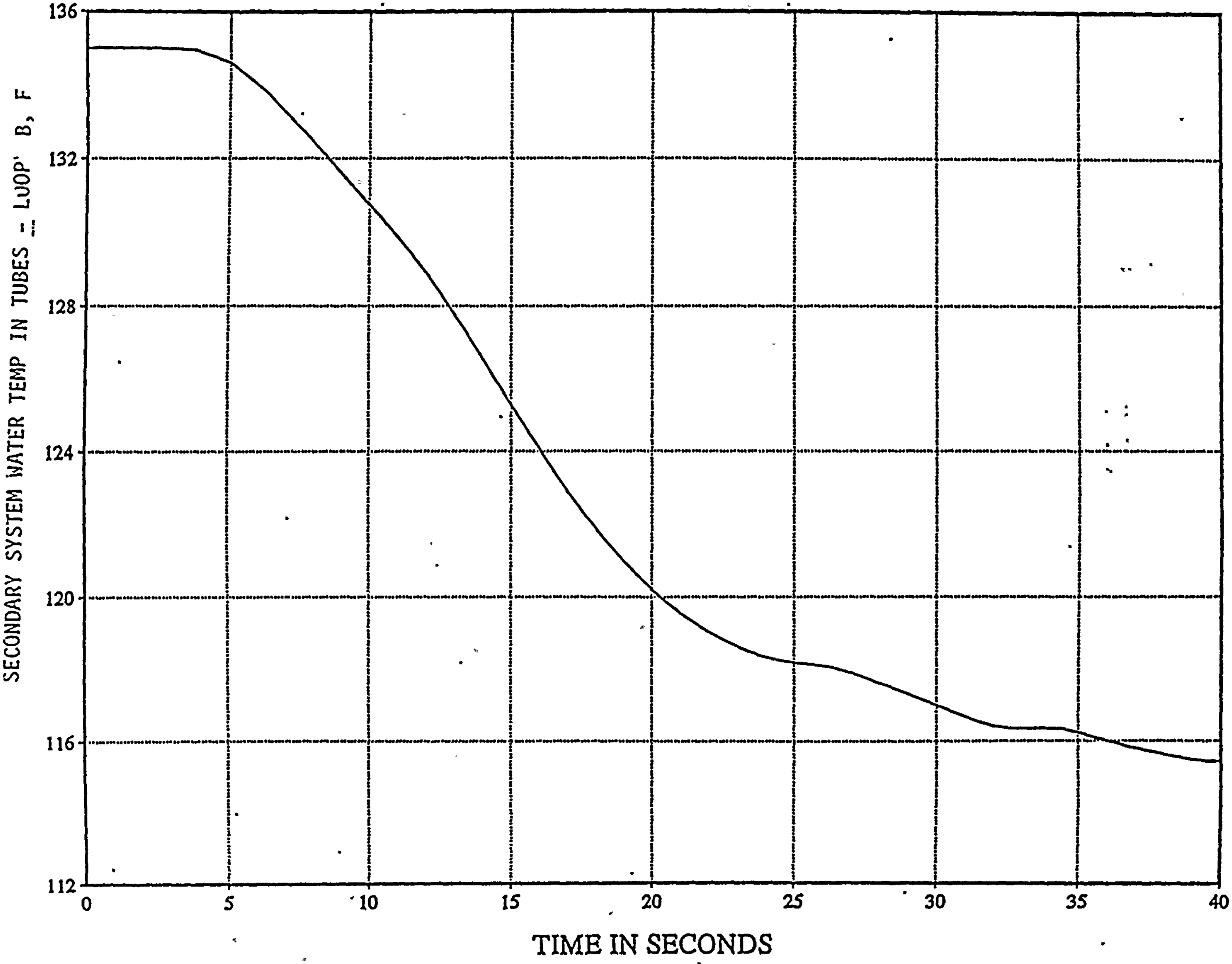
LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ∘ F, Secondary temperature 135 ∘ F
One RC pump starting



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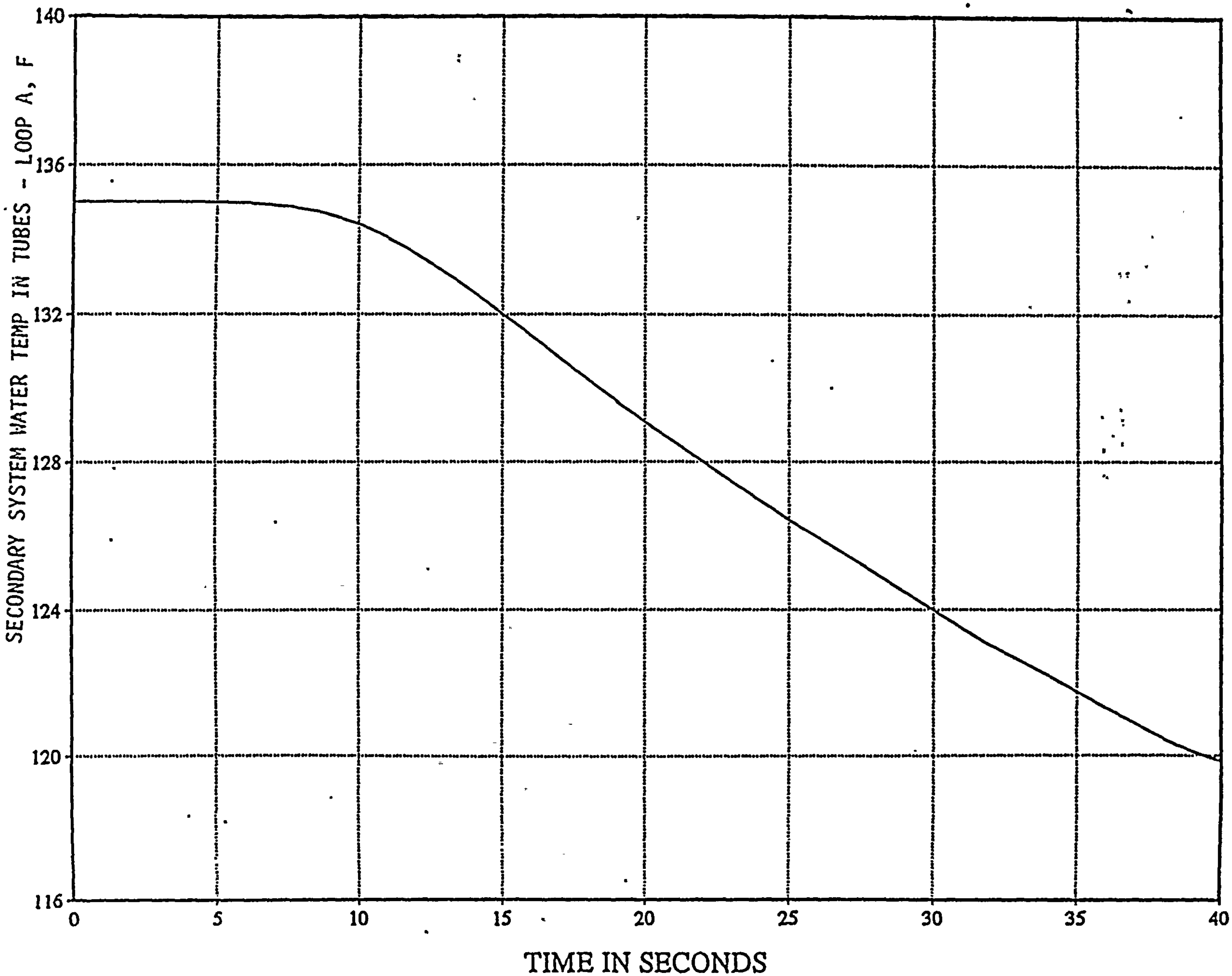
LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ° F, Secondary temperature 135 ° F
One RC pump starting



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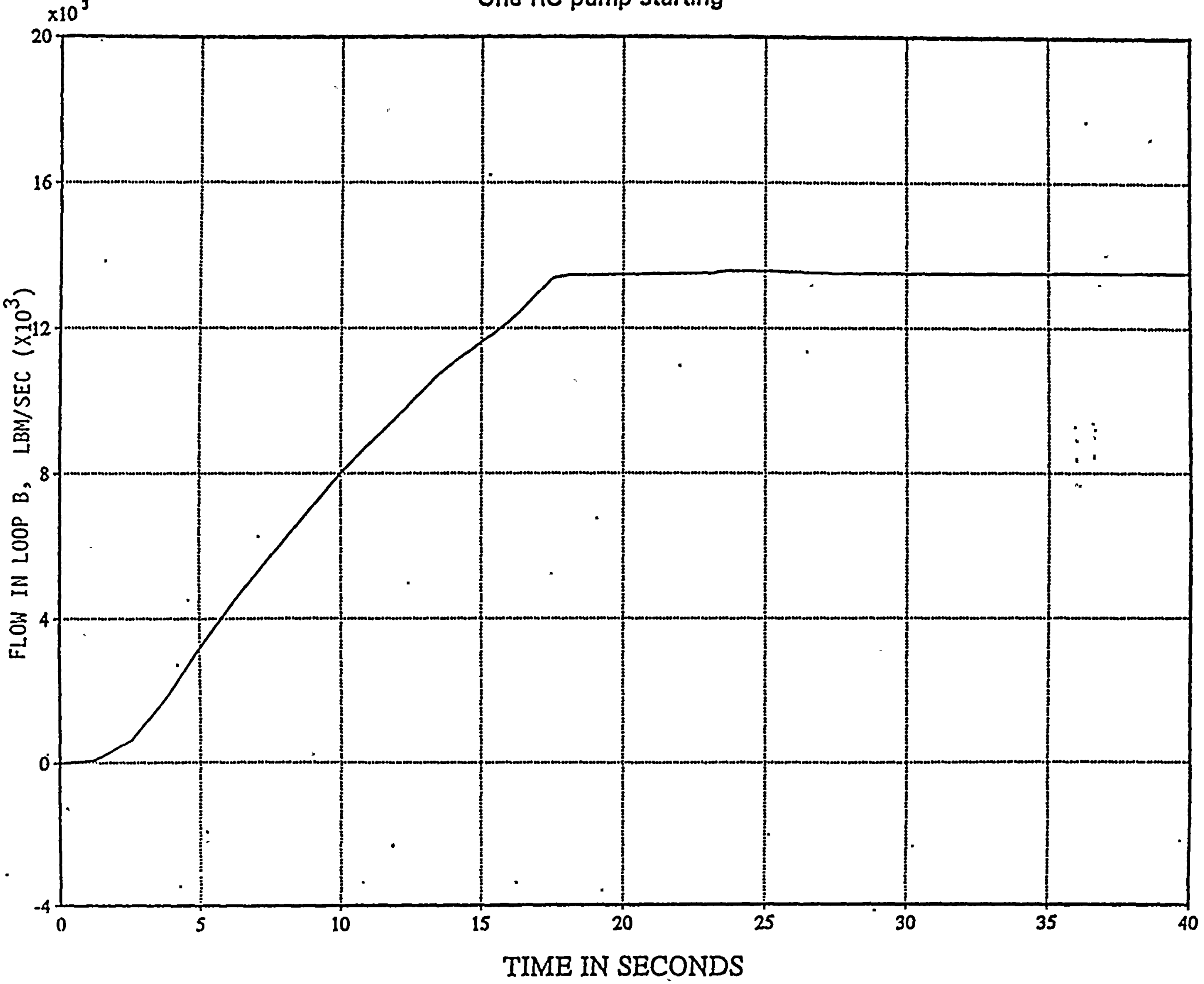
LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ∘ F, Secondary temperature 135 ∘ F
One RC pump starting



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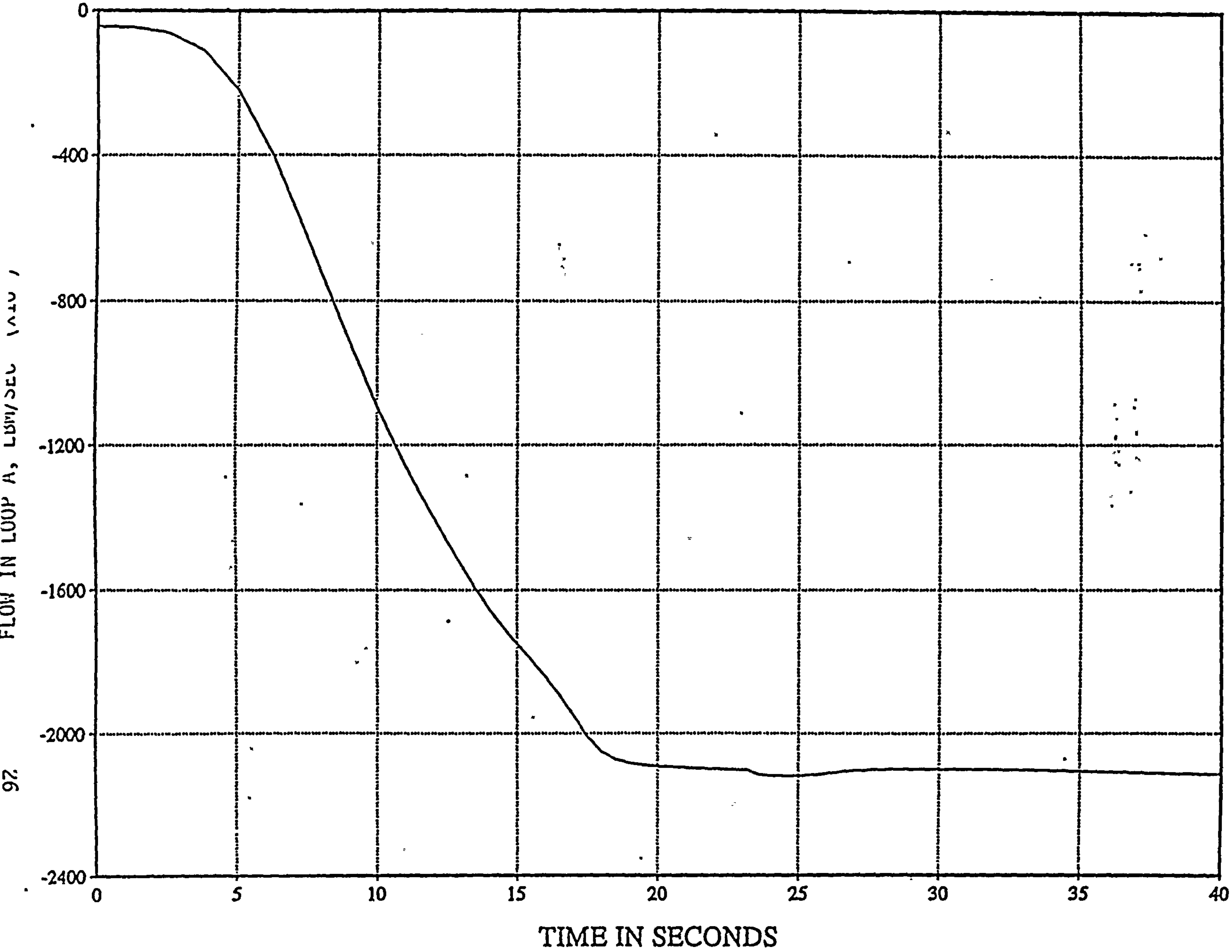
LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ∘ F, Secondary temperature 135 ∘ F
One RC pump starting



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92

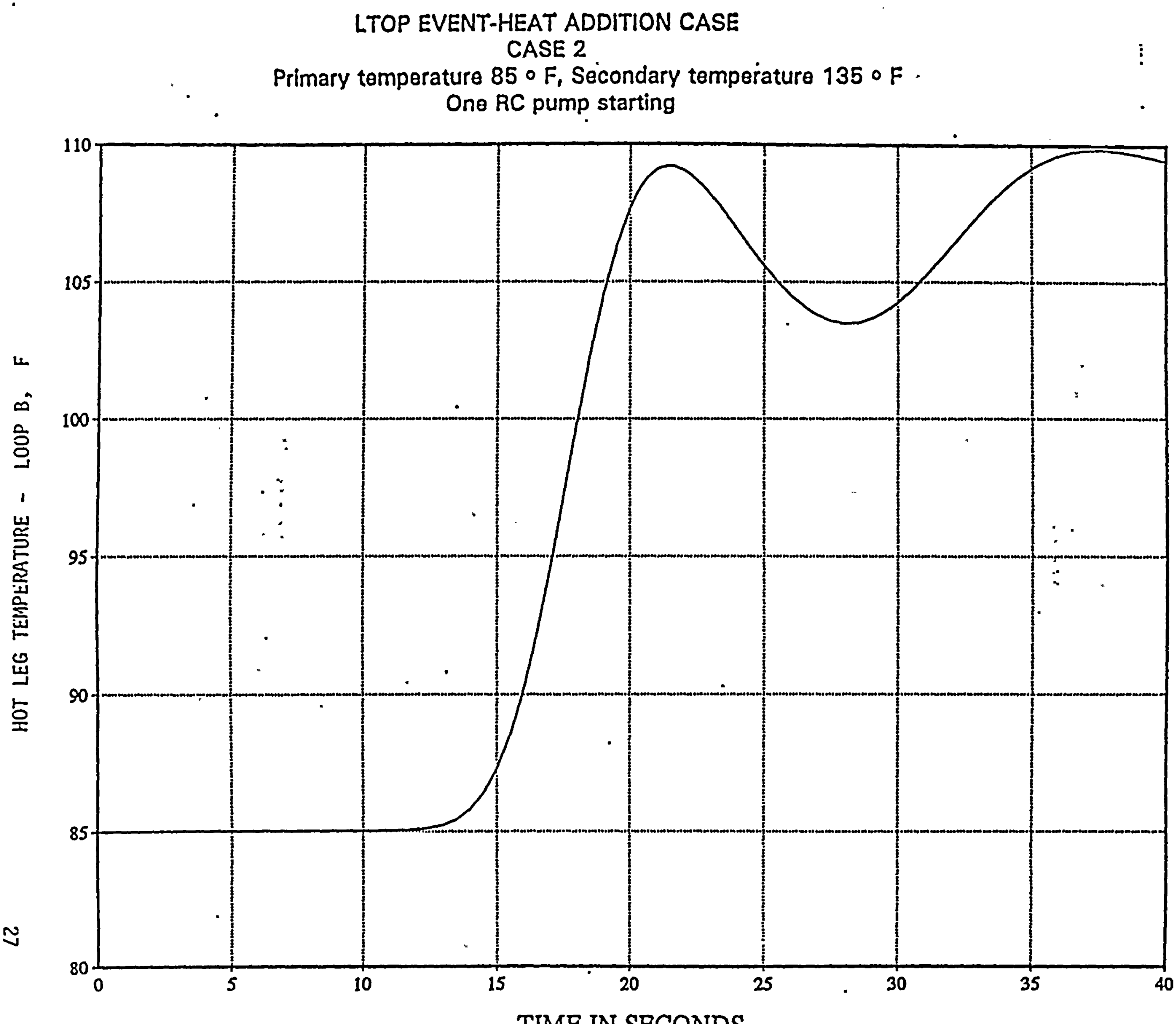

Figure 15

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LTOP EVENT-HEAT ADDITION CASE
CASE 2
Primary temperature 85 ° F, Secondary temperature 135 ° F
One RC pump starting

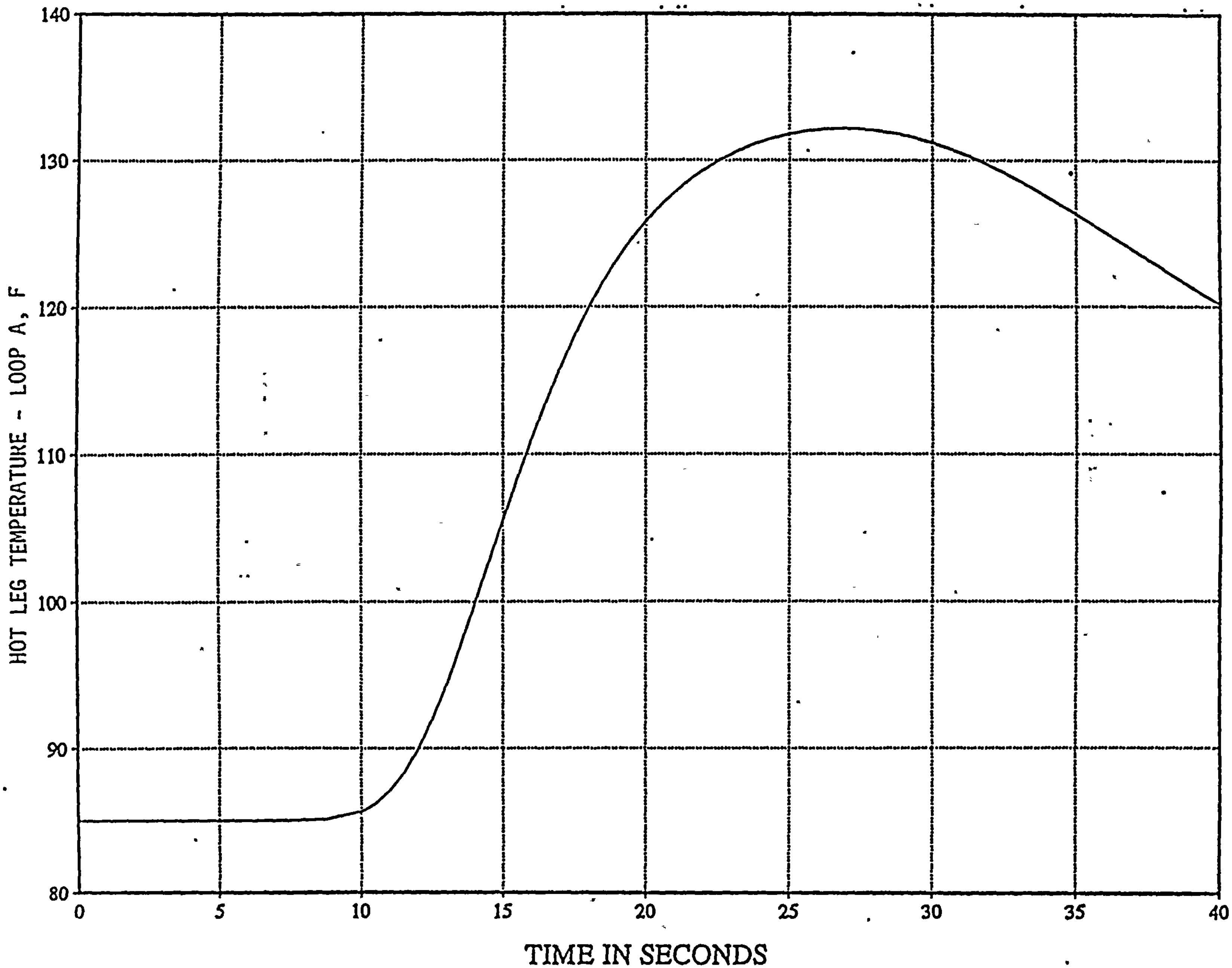

Figure 16

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6.3 Heat Addition at 320 F

The second heat addition case was analyzed with steam generator secondary system temperatures of 370 F. This temperature is the maximum temperature, including instrument uncertainty, at which both reactor coolant pumps can be stopped. The primary system was assumed to be 50 degrees colder than the secondary system, so the temperature in the primary system was 320 F. Initially, the RC pumps were not running and cooling was assumed to be provided by the RHR system. The RHR system was operating with a capacity of 1701 gpm, or 215.75 lbs/sec. The pressurizer was water solid. There was no charging flow for this event. The transient was initiated by starting the RC pump in the loop that contained the pressurizer. The pump start-up profile that was used is shown on Table 3. The sequence of events for this case is shown in Table 5. Figures 17 - 25 show plots of RV pressure, RHR pressure, PORV flow, secondary system temperature in the tube region of Loop B, secondary system temperature in the tube region of Loop A, flow in RC Loop B, flow in RC Loop A, hot leg temperature in Loop B, and hot leg temperature in Loop A, respectively.

The peak pressure in the reactor vessel for this case was 563.8 psia. The allowable pressure for the Appendix G limit at this temperature is 1664.7 psia. This yields a 1100.9 psi margin.

The peak pressure in the RHR system was 655.7 psia as compared with an acceptance criterion of 674.7 psia, for a margin of 19.0 psia. This case is the most limiting for peak RHR pressure.

TABLE 5
HEAT ADDITION at 320 F - SEQUENCE OF EVENTS

EVENT	TIME, SECONDS
RC pump started in loop that contains the pressurizer.	0.0
PORV opening signal for the first time	8.81
Peak pressure reached at RHR pump outlet	10.5
RC pump reaches full flow	17.4
Peak pressure reached in the RV	21.3

LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting

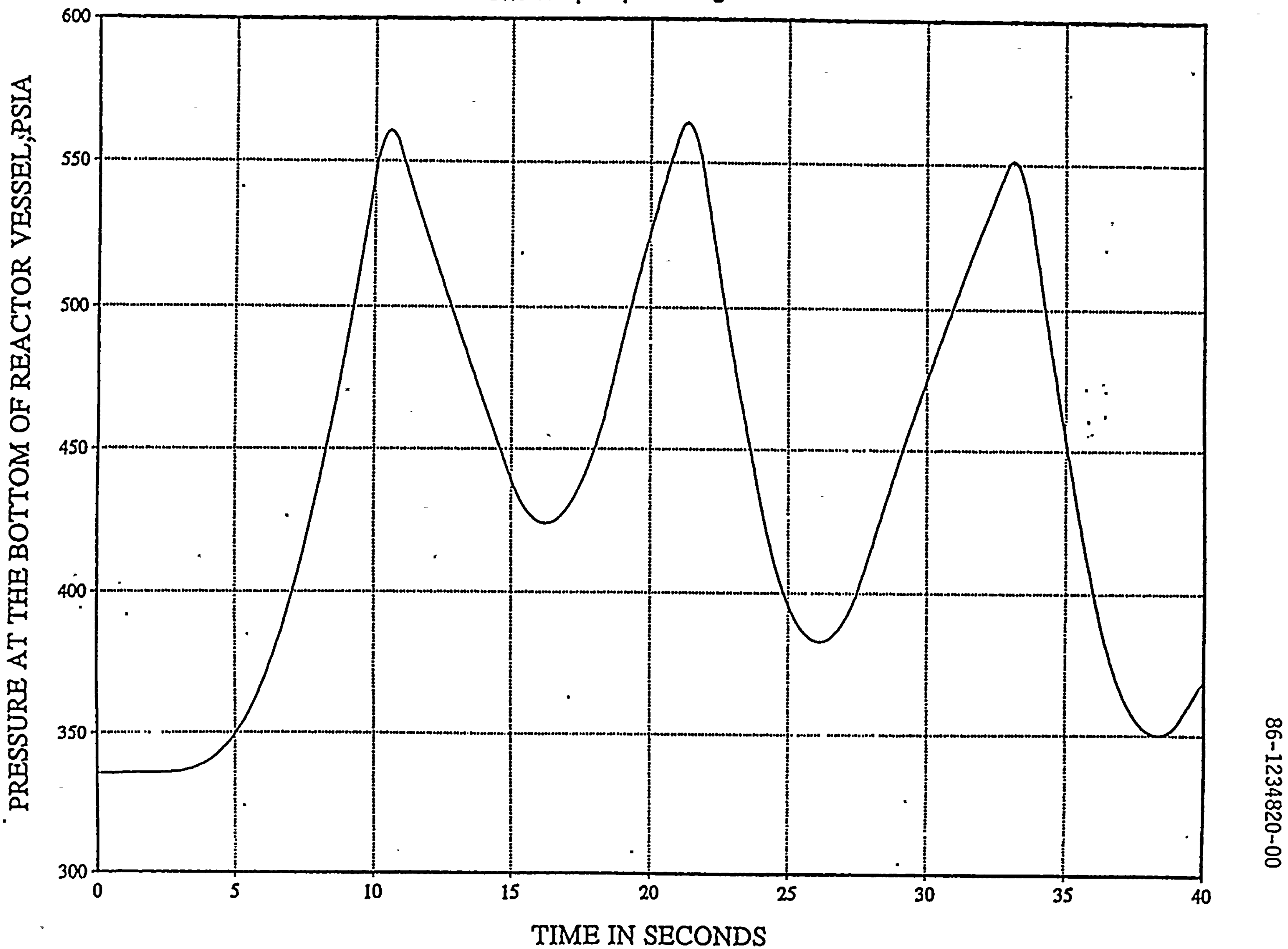

Figure 17

LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting

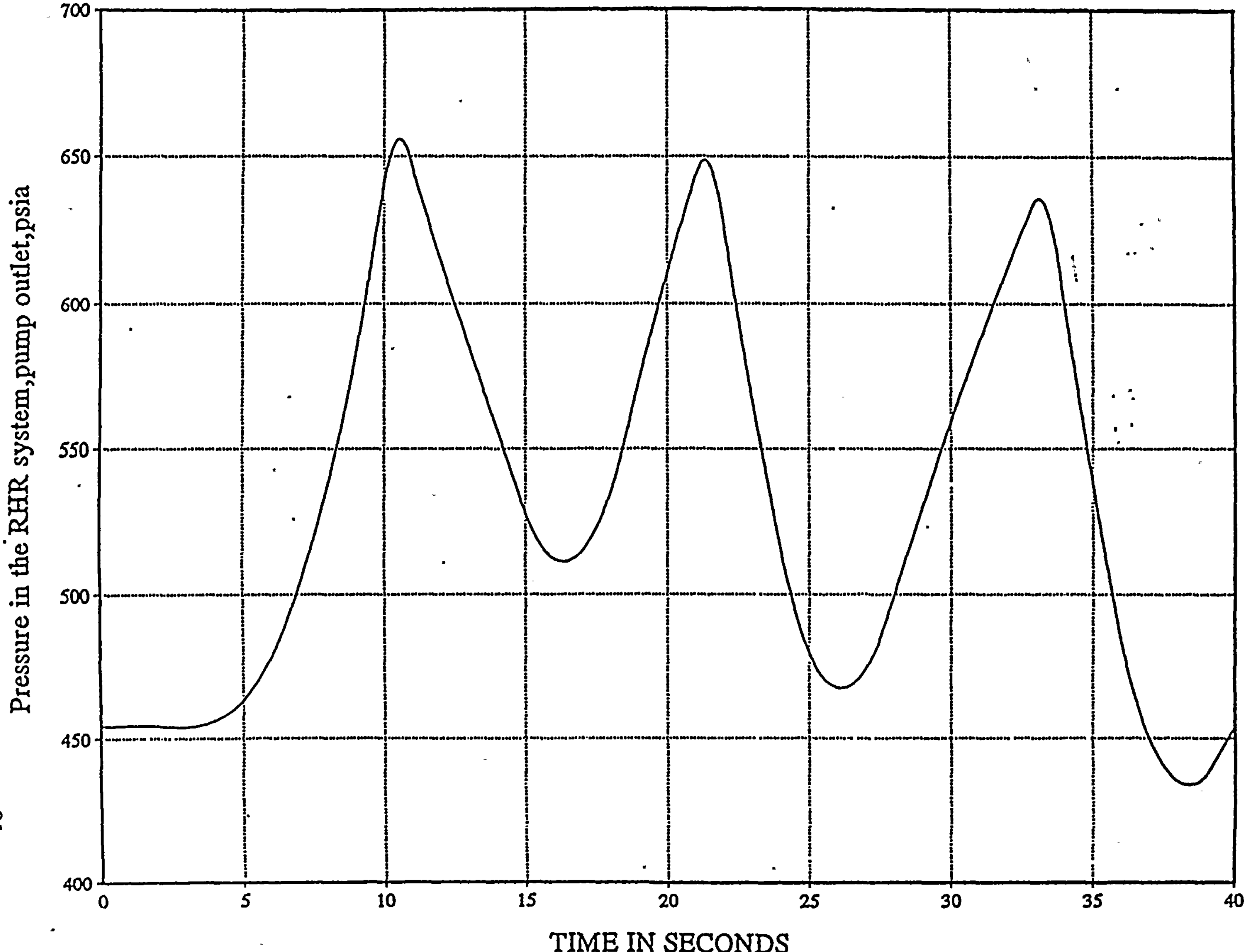

figure 18

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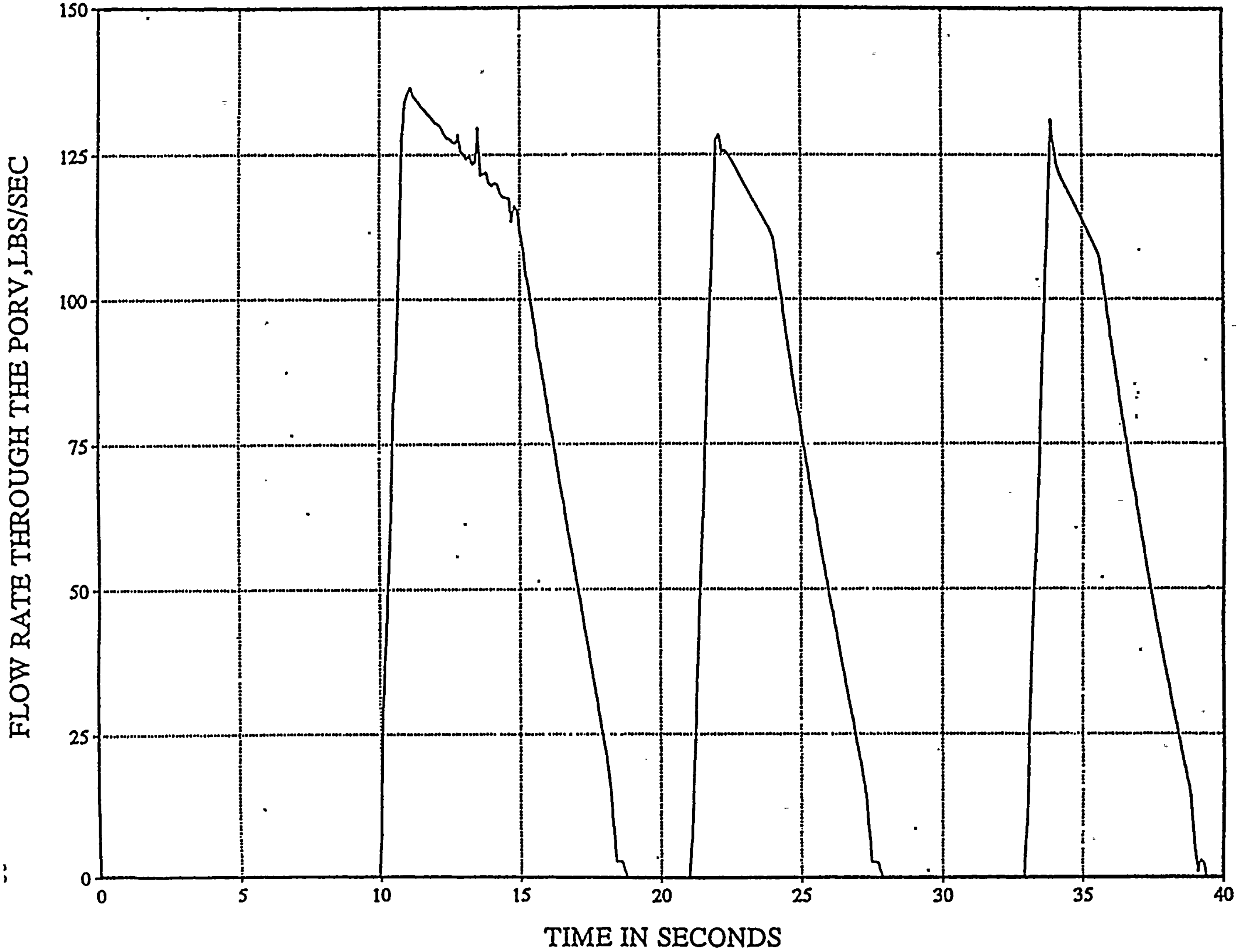
LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting



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LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting

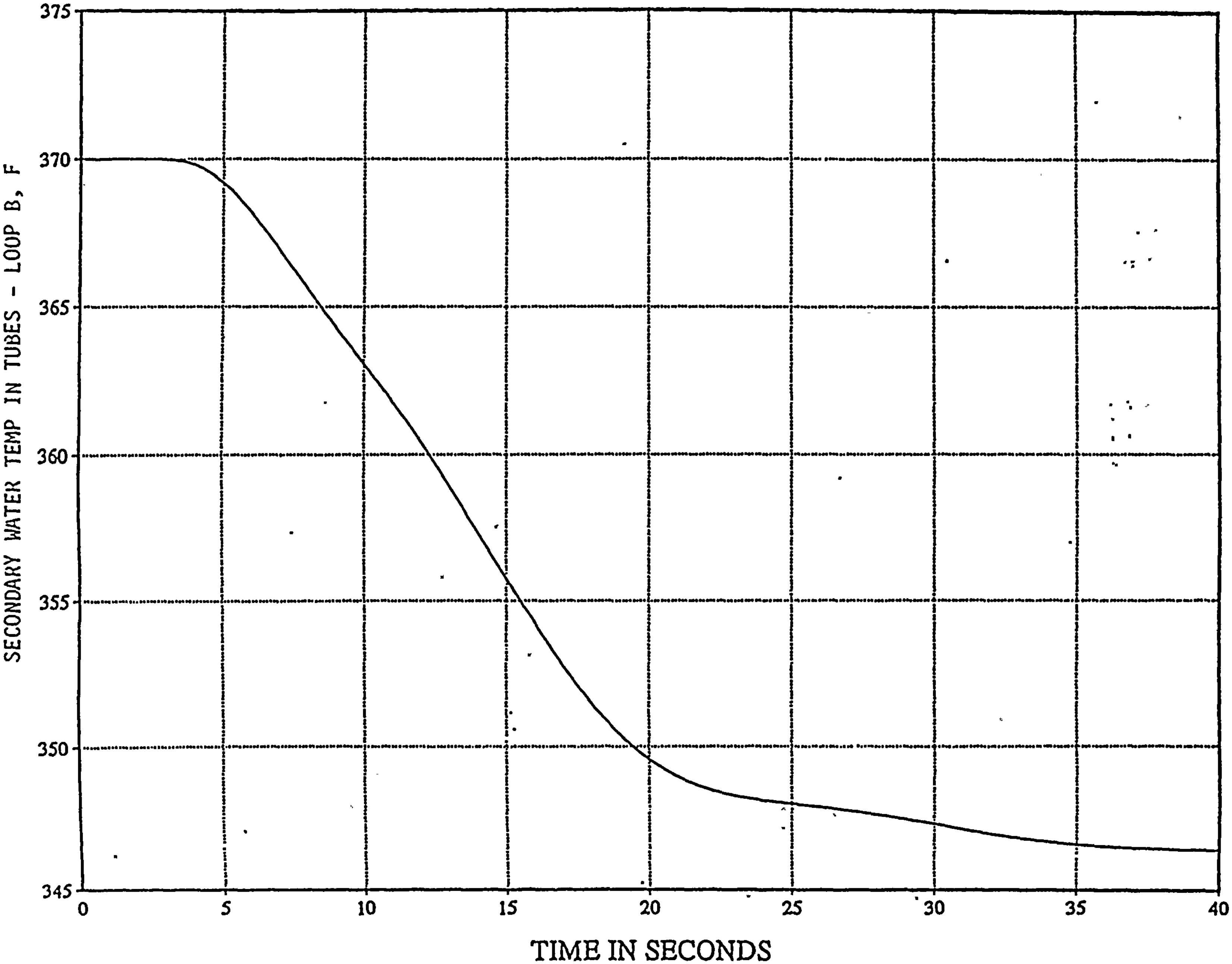

Figure 20

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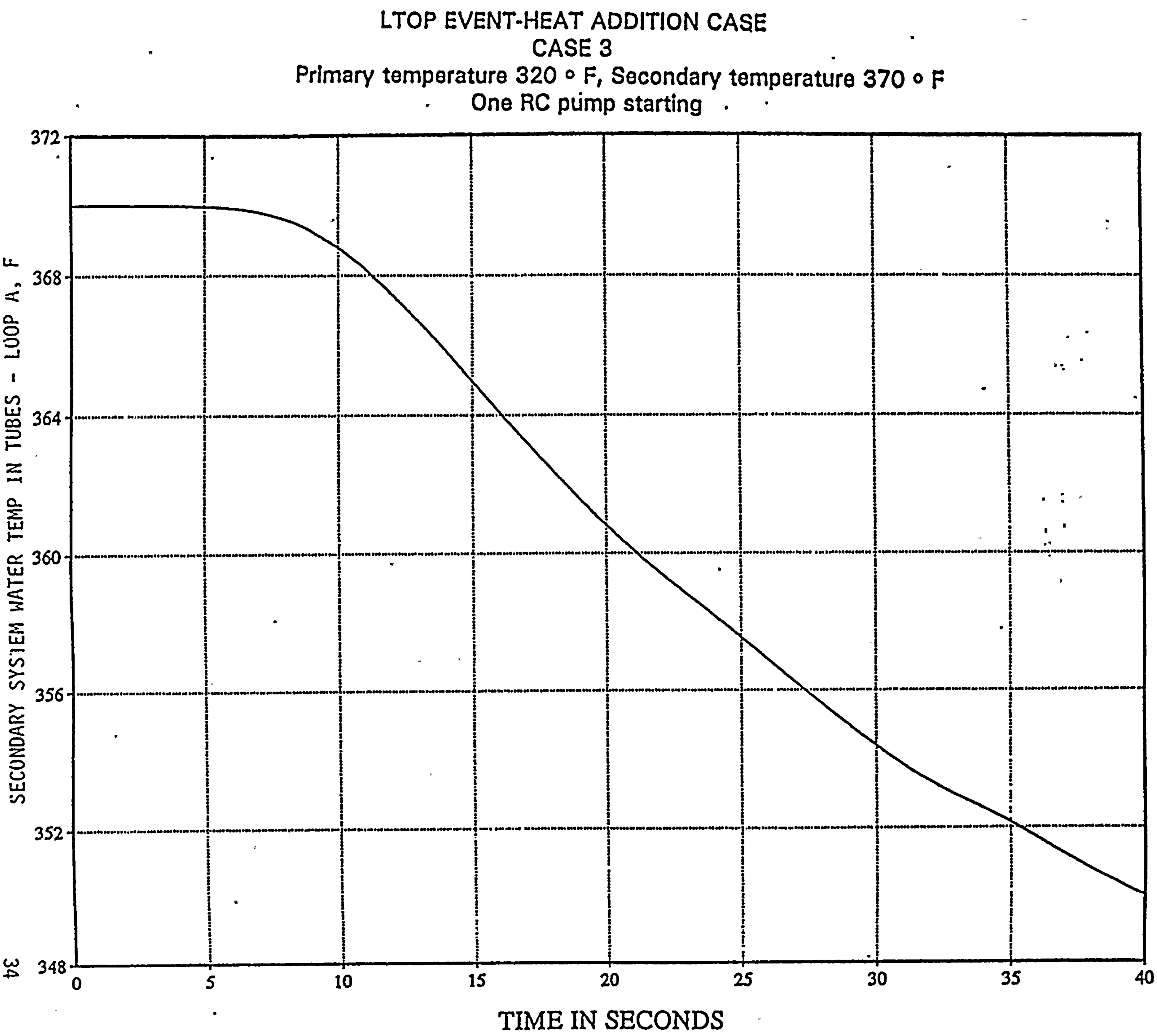

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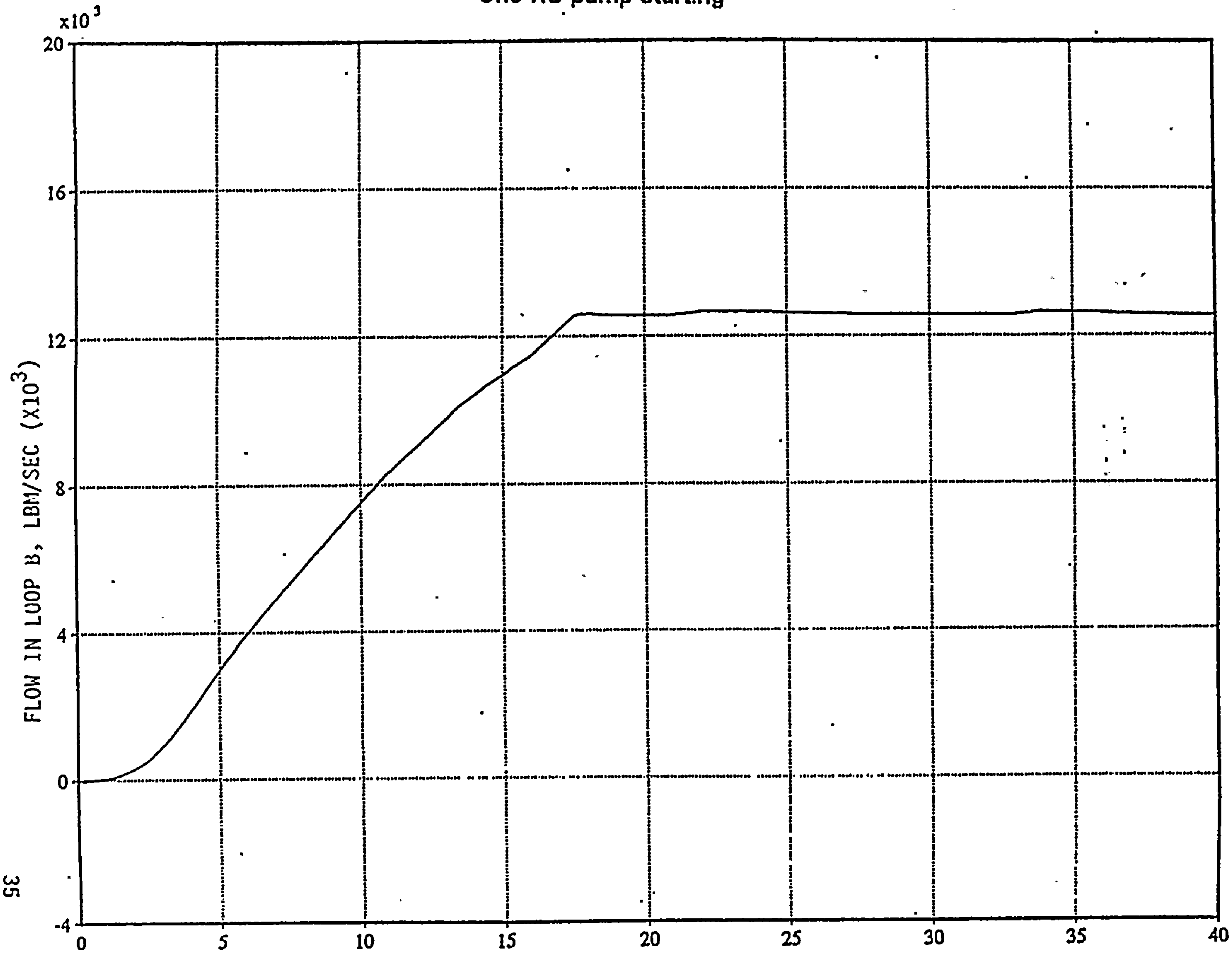
LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ∘ F, Secondary temperature 370 ∘ F
One RC pump starting



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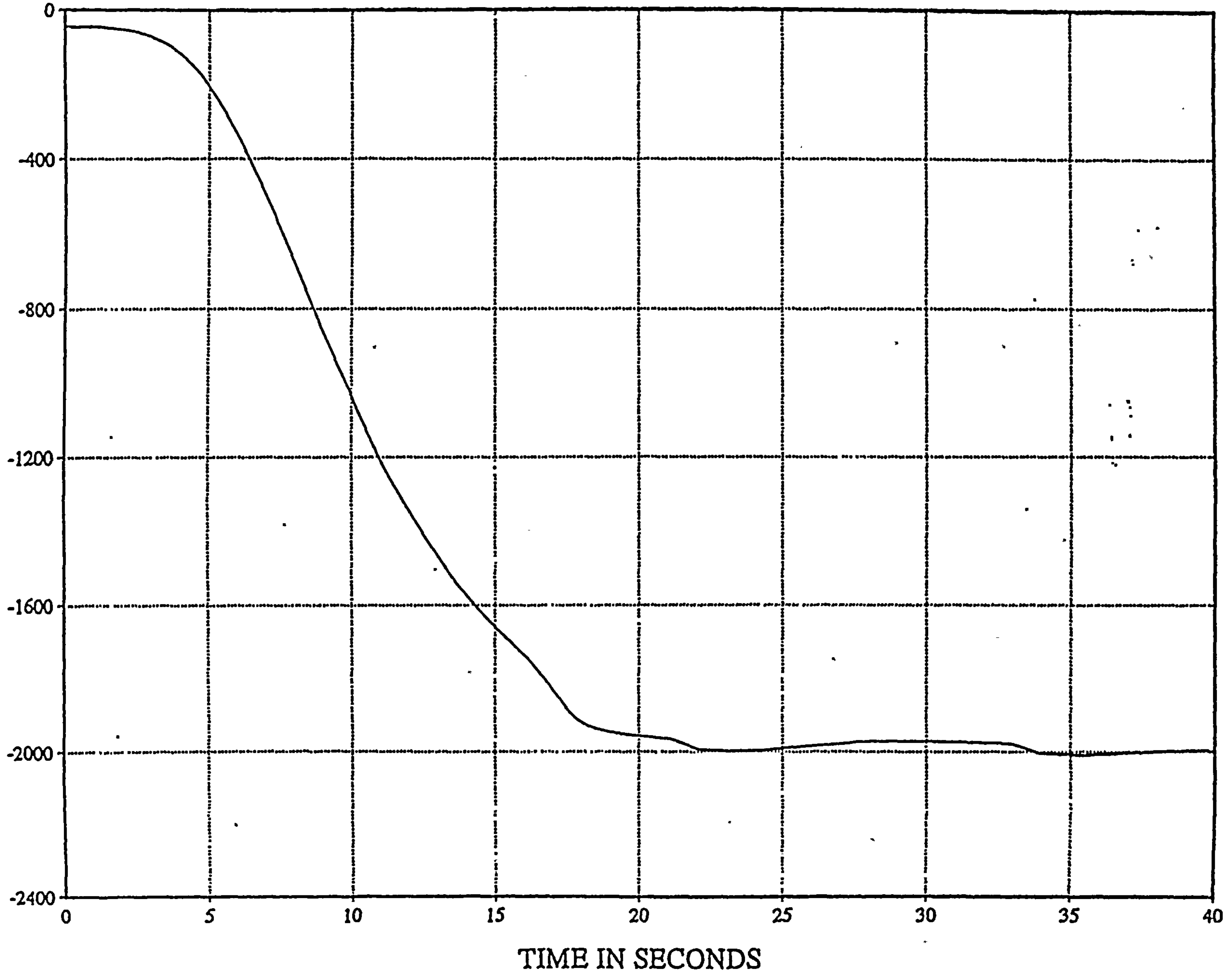
LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting



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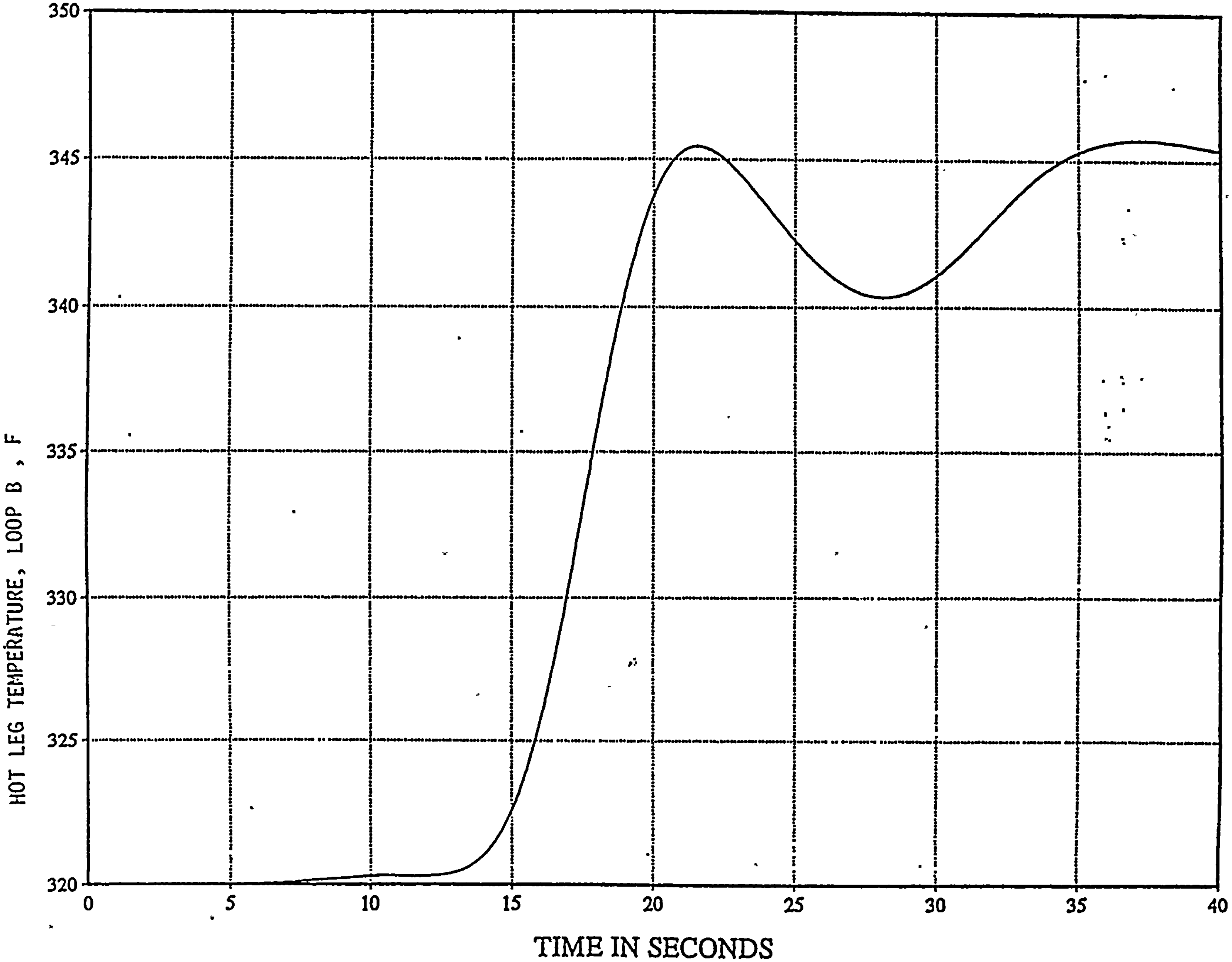
LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F.
One RC pump starting



86-123820-00

LTOP EVENT-HEAT ADDITION CASE
CASE 3
Primary temperature 320 ° F, Secondary temperature 370 ° F
One RC pump starting

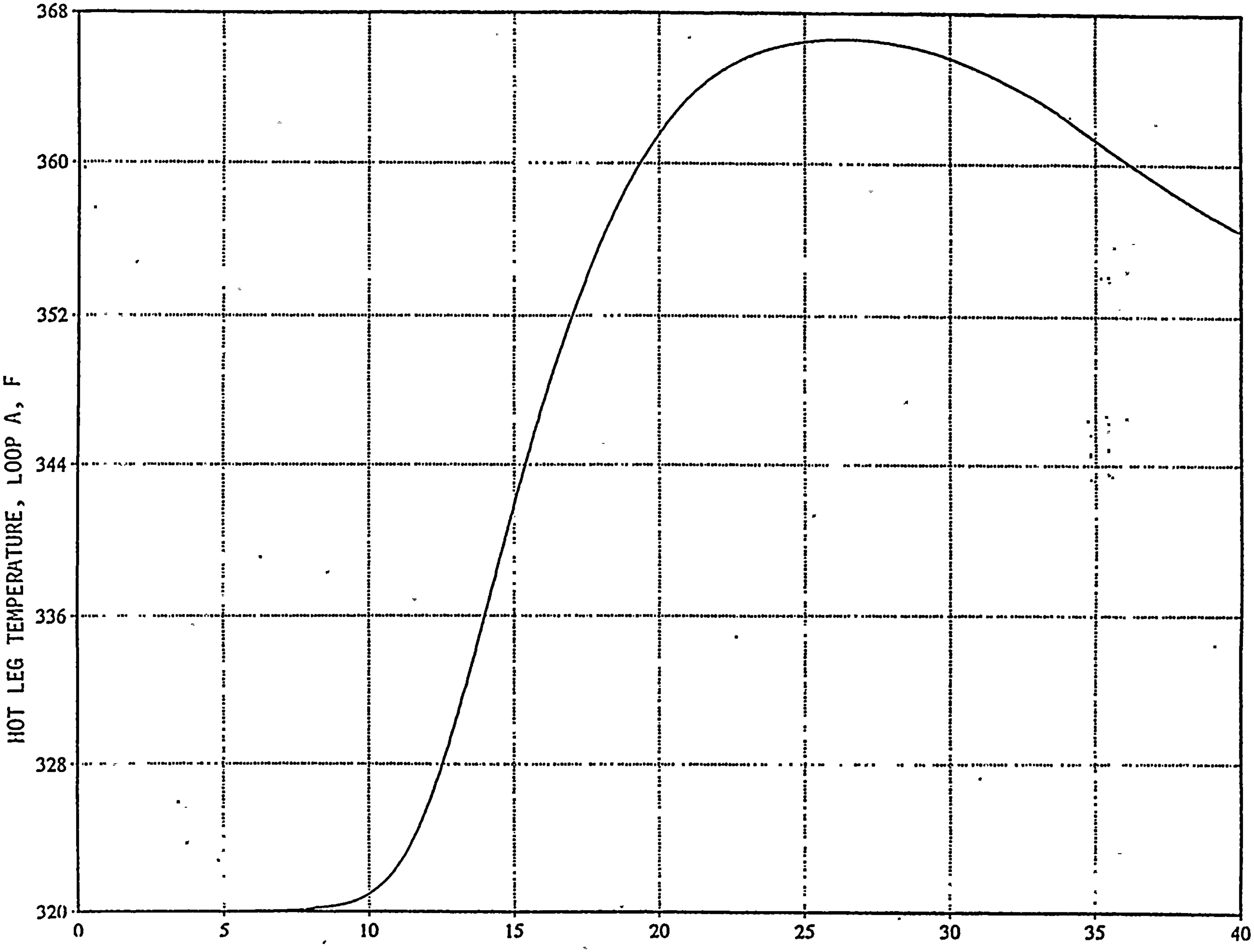


Figure 25

86-123482O-00

[illegible]

7.0 SUMMARY AND CONCLUSIONS

B&W Nuclear Technologies updated the analysis of the low temperature overpressure events for the Rochester Gas and Electric (RGE) R.E. Ginna Nuclear Power Station. This analysis will become the new analysis of record for RGE. In this effort, the most limiting LTOP events were analyzed and compared with the acceptance criteria of the Appendix G limits for embrittlement and the RHR overpressure limit. This analysis was performed with the BWI steam generators, to bound the plant as it exists now and to bound the plant when the steam generators are replaced.

The most limiting mass addition and heat addition cases were analyzed and the results were compared with the acceptance criteria. The mass addition case, which was analyzed at a primary temperature of 85 F, had a peak pressure in the reactor vessel of 480.2 psia. This is 74.5 psi below the acceptance criterion for Appendix G. The peak pressure in the RHR system was 598.4 psia, which is 76.3 psi below the acceptance criterion.

The heat addition case that was performed at a primary system temperature of 85 F yielded a peak reactor vessel pressure of 546.8 psia. The allowable pressure for the Appendix G limit at this temperature is 554.7 psia. This yields a 7.9 psi margin. The peak pressure at the RHR pump discharge for this case was 640.8 psia as compared with an acceptance criterion of 674.7 psia, for a margin of 33.9 psi.

The heat addition case that was performed at a primary system temperature of 320 F yielded a peak reactor vessel pressure of 563.8 psia. The allowable pressure for the Appendix G limit at this temperature is 1664.7 psia. This yields a 1100.9 psi margin. The peak pressure at the RHR pump discharge for this case was 655.7 psia as compared with an acceptance criterion of 674.7 psia, for a margin of 19.0 psia. Therefore, all of the LTOP analyses that were performed with the BWI steam generators were within the acceptance criteria for both Appendix G and RHR overpressure.

[illegible]

8.0 REFERENCES

1. US Nuclear Regulatory Commission Regulatory Guide 1.99, "Embrittlement of Reactor Vessel Materials", Revision 2, May 1988.
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3. NUREG/CR-5194 EGG-2531 R4, "RELAP5/MOD2 Models and Correlations", August 1988.
4. BWNT Document 32-1232650-00, "Low Temperature Overpressure Analysis for RGE - Ginna Plant", February 1995.
5. BAW-10164P, "RELAP5/MOD2-B&W - An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analysis," Code Topical Report, Revision 2, August 1992.
6. "Trojan Unit Low Temperature Overpressure Protection System (LTOPS) Setpoint Evaluation", June 1990, pg. I-1 (attached).