TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

July 2, 1979

Director of Nuclear Reactor Regulation
Attention: Mr. Thomas A. Ippolito, Chief
Branch No. 3
Division of Operating Reactors
U.S. Nuclear Regulatory Commission
Washington, DC 2.555

Dear Mr. Ippolito:

| | | |
|---|---|---|
| In the Matter of the | ) | Docket Nos. 50-259 |
| Tennessee Valley Authority | ) | 50-260 |
| | | 50-296 |

This is in response to A. Schwencer's letter dated January 13, 1978, concerning suppression pool temperature transients at Browns Ferry Nuclear Plant.

As you are aware, we are deeply involved in the Mark I Long-Term Program (LTP) for which you indicated that the requested information will serve as part of the basis for your review. We have examined the five suppression pool temperature transient analyses requested, part A, 1(a) through (e), and note that these are primarily concerned with the performance of SRV discharge through the existing Ramshead devices. Presently, it is our intent as part of the long-term program solution to replace these devices with "T"-Quenchers. Accordingly, we have selected for analysis only those transients which are the most limiting. By this approach we are providing you with the necessary information to demonstrate the satisfactory and conservative design of the Browns Ferry Nuclear Plant while avoiding severe impact on our LTP analysis and modification effort and schedule. Enclosure 1 provides our analysis primarily of your cases part A, 1(a) and 1(b). Although we did not specifically address cases 1(c) and 1(d), we have analyzed the case where two additional valves are opened above 120°F pool temperature with no heat exchangers in operation. This is bounding for cases 1(c) and 1(d). Enclosure 2 contains the requested information (part A,2) concerning the Browns Ferry Nuclear Plant suppression pool temperature monitoring system. Results described in Enclosure 1 are also discussed here. Enclosure 3 discusses the conservatism of the analysis presented in Enclosure 1 in light of the theoretical sequence of events and initial conditions.

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Mr. Thomas A. Ippolito July 2, 1979

It is our understanding that the information requested in part B of your letter has been supplied on a generic basis in a September 1977 letter from E. D. Fuller, General Electric, to Olan D. Parr, Chief, LWR Branch No. 3. This information should be made a part of the Browns Ferry Nuclear Plant dockets. If your staff has any questions regarding the enclosed material, please get in touch with us.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Regulation and Safety

Enclosures

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ENCLOSURE 1

# BROWNS FERRY NUCLEAR PLANT SUPPRESSION POOL ANALYSIS

Description of Temperature Transient
Resulting From A Stuck Open Safety Relief Valve

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## I. Introduction

The General Electric (GE) Mark I containment concept used at the Browns Ferry nuclear plant employs a torus suppression pool design as an intermediate heat sink during normal and accident conditions. The subcooled water in the pool serves a dual role in the Mark I containment system. Primarily it functions to limit containment pressure in the unlikely event of a loss-of-coolant accident by thermodynamically absorbing the energy released in the form of steam. Similarily and secondarily, the pool is designed to accommodate the main steam relief line discharge during normal plant operation. It is this latter function that will be addressed by this analysis.

Concerns have recently developed that unstable steam condensation at the main steam relief line and suppression pool interface may occur during relief valve discharge at elevated pool temperatures. The condensation instability results in pool pressure oscillations and relief line vibrations which are transmitted to the torus shell resulting in unacceptably large structural loadings. This condensation phenomenon is not completely understood at the present time, however, conditions favorable to the instability occur when high steam flowrates are concurrent with high pool temperatures. Therefore, GE has recommended an upper limit on the torus pool temperature for high SRV mass fluxes. The temperature and mass flux criteria suggested for the ramshead discharge device typical of the Browns Ferry design are 160° F (local), 150° F (bulk)[1] for mass fluxes greater than 40 lb /sec ft².

The Nuclear Regulatory Commission has requested that all utilities with Mark I containments perform a plant unique analysis to demonstrate that the GE criteria is not exceeded during a transient resulting from a stuck open safety relief valve. This report summarizes the conservative analysis used to examine this pool temperature problem for the Browns Ferry nuclear plant.

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[1]The bulk pool temperature is the mass average torus pool temperature, whereas the local temperature is confined to a few pipe diameters from the discharge device.

## II. Analysis Description

The stuck open relief valve transient was examined using a combination of hand calculations and two computer models. Initially, a hand calculation was used with the simplifying assumptions listed in the next section, to determine the time required to heat the suppression pool water to the technical specification limit for reactor scram. The calculations were then performed by computer analysis due to the complex system interactions following reactor scram.

An existing RETRAN[2] computer model of the Browns Ferry plant was modified to include the torus pool, RHR piping and the RHR heat exchangers. Several control system models, including the feedwater control system are included which permits feedwater modulation. The RETRAN model was used until 50 seconds following the scram. At this point the Main Steam Isolation Valves MSIV's had been closed and the system was isolated. Beyond this point a simplified program was written to iteratively balance the system energy inputs and losses over small time steps. This technique was used to limit computer costs associated with achieving the required low ramshead mass fluxes using the more elaborate RETRAN code.

This code contains all the major energy inputs including feedwater, decay heat, sensible heat from core steel, coolant inventory, and recirculation system piping as in RETRAN. An energy equilibrium is assumed to exist over each time step such that the energy lost by blowdown is equal to the summation of all energy inputs. Since the sensible heat terms depend on the vessel pressure which in turn depends on vessel blowdown, an iterative technique is employed. The feedwater inlet flow is balanced to the blowdown flow resulting in a net change in core water level of zero. The decay heat curves were taken from NRC branch technical position ASB9-2 Rev 1 assuming fission product decay uncertainty factors of 1.2 before 1000 seconds and 1.1 thereafter. Heavy element decay heat and an infinite operating time were used to be conservative. Figure 1 illustrates the core power versus time used in the analysis. It should be noted that on this plot and others, the initial 400 seconds of time required to heat the pool to 110° F at a constant power are not shown.

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[2]RETRAN is the RELAP4 based computer code developed by EPRI for operational transient simulation (1).

III. Assumptions

Several simplifying and conservative assumptions have been made in this analysis. These assumptions are listed and described in this section. The pool temperature transient is driven by the blowdown energy of the reactor. In order that this energy is maximized, the reactor is considered to be initially at a steady state of 103 percent power. After the reactor scram, the conservative form of the decay heat equation previously described is used, resulting in an upper bound on reactor pow . throughout the transient.

Suppression pool parameters are also bounding. The pool is initially at its maximum technical specification temperature of 95° F and its minimum water volume. This maximizes the initial energy content of the subcooled pool water within the constraint ot plant operating limits.

Two separate trains of residual heat removal system heat exchangers are available to remove energy from the torus pool. Each train consists of two pumps with a design flow rate of 10,000 gpm and two heat exchangers with heat transfer coefficients of approximately 270 Btu/sec °F. The system is initiated as prescribed by the plant technical specifications when the pool temperature is 95° F and rejects heat to service water at 95° F. Significant heat transfer does not occur until the pool temperature rises considerably above its initial value.

The relief valve fails open at time zero and remains fully open during the study. The flowrate selected for the valve is 1.225 times the ASME rated flow for the valve. This flowrate is obtained i the RETRAN portion of the analysis by selecting MOODY cri ical flow and applying the appropriate critical flow contraction coefficient. In the simplified program the flow is directly calculated.

During the SRV transient, the pressure in the vessel would initially decrease due to the larger energy removal rate not immediately accommodated by the reactor system. The turbine control valves automatically adjust during this time in an attempt to maintain the reactor steam dome pressure. The vessel pressure partially recovers due to this action. However, to simplify the analysis, this transient is ignored and it is assumed that the initial pressure in the vessel is maintained through this period.

The reactor system dumps steam to the pool at full power until the pool reaches 110° F at which time the reactor is scrammed by operator action as required by the technical specifications. This action occurs approximately 400 seconds into the transient. Conservatively, the main steam isolation valves are used in this simulation to isolate the core. The MSIV's are assumed to remain open until a core low water level signal is received. Minimization of this time and consequently the energy lost to the turbine is obtained by closing the feedwater input to the vessel at the time of scram and reinstating cooling water only after the MSIV's are closed. This operation maximizes the energy released to the pool since the core is "bottled up" at a higher decay heat power level. No energy is lost to the condenser via the turbine bypass system since these valves are left arbitrarily closed throughout the simulation.

The pool temperature is instantly averaged through the torus at each time step in the simulation and therfore represents the bulk temperature. The analysis is terminated once the ramshead mass flux reaches 40 lb /sec ft².

## SUMMARY OF ANALYSIS PARAMETERS
(Base Case)

| | |
|---|---|
| Reactor Power | 103% full power (3392 Mwt) |
| Reactor Pressure | 1035 psia |
| SRV Flowrate | 122.5% ASME flow (270 lb/sec initial) |
| Torus Pool Temperature | 95° F (initial) |
| Scram Temperature | 110° F Torus Indication |
| Decay Heat | Infinite Irradiation & Heavy Elements |
| No. of RHR Heat Exchangers | 2 |
| RHR Pump Flow | 10,000 gal/min |
| Heat Transfer Coefficient | 270 Btu/sec °F |
| Ramshead Device | 10 Inch Schedule 80 Pipe |

IV. Results and Conclusions

Several studies were performed to determine the options for achieving a low SRV mass flux without exceeding the pool temperature limit. The options examined can be classified into two groups:

1. Opening of additional SRV's to promote a more rapid vessel depressurization.

2. Use of additional heat exchangers to cool the suppression pool.

A base case consisting of one valve (the stuck open valve) and one train of heat exchangers (2 exchangers) was selected since this case requires no operator action beyond scramming the reactor and assuring the RHR system is operating.

The reactor pressure requirement for the realization of 40 lb/sec ft² ramshead mass flux was determined to be approximately 149 psia. Below this pressure the mass flux is acceptably low for elevated pool temperatures. Since the energy inputs from sensible heat depend primarily on the initial and final vessel pressures (temperatures), the time to achieve the reduced pressure only affects the energy input from decay heat. Therefore, a faster pressure decay would result in less energy transfer to the pool. The base case pressure decay is shown in figure 2. The rapid depressurization effect was examined by opening additional relief valves as shown in figures 3 and 4 where reactor scram occurs at time = 0 and a pool temperature of 110° F. The base case is represented by the 1 valve curve and as shown enters the condensation instability region. However, the use of additional valves opened 10 minutes after scram (16 minutes after the valve sticks open) results in acceptable pool temperature behavior. It should be noted that the temperature curves in Figure 4 are terminated at the point where the ramshead mass flux falls below 40 lb/sec ft², thereby giving an indication of the time required to achieve that state. Each additional valve opened has less effect than the previous resulting in no particular advantage to opening more than 2 additional valves. Examination of the valve opening time requirements was performed by comparing the base case to a situation where one additional valve was opened at various times following the reactor scram. Results of this analysis, shown in figures 5 and 6 indicate the opening time can be delayed until 1100 seconds after scram. Avoidance of the condensation instability region can therefore be achieved through the use of at least one additonal SRV prior to 18 minutes after scram.

The operation of additional heat exchangers can also prevent the entry into condensation instability. Figures 7 and 8 indicate the operation of 3 or more heat exchangers (requiring both trains) provides sufficient cooling capacity to terminate the pool temperature rise prior to reaching 150° F even if no additional valves are used. In each case a worst case secondary side temperature of 95° F was used to conservatively minimize the heat transfer per heat exchanger.

Consersely, a study was performed, documented by Figures 9 and 10, to examine the options available if no pool cooling is available. The use of two additional valves, 600 seconds after scram, is found to be sufficient to prevent entry into the region where condensation instability may occur.

One additional option which has not been analyzed is the use of the turbine bypass system. Opening the MSIV and dumping the vessel energy to the condenser will depressurize the core without increasing the pool heatup rate which is characteristic of the use of additional safety relief valves. This method would obviously result in satisfactory pool temperatures. Access to the condenser will be readily available in almost every situation.

The analysis presented here represents a very unlikely set of events which have a low probability of occurrence; however, even if this SORV transient should occur, there is sufficient conservatism in the Browns Ferry Nuclear Plant design to prevent concurrent high mass flux and high torus temperatures by several alternate means. It is concluded, therefore, that the ramshead discharge devices can be operated in a stable environment and that no operational restrictions are needed.

FIGURE 1

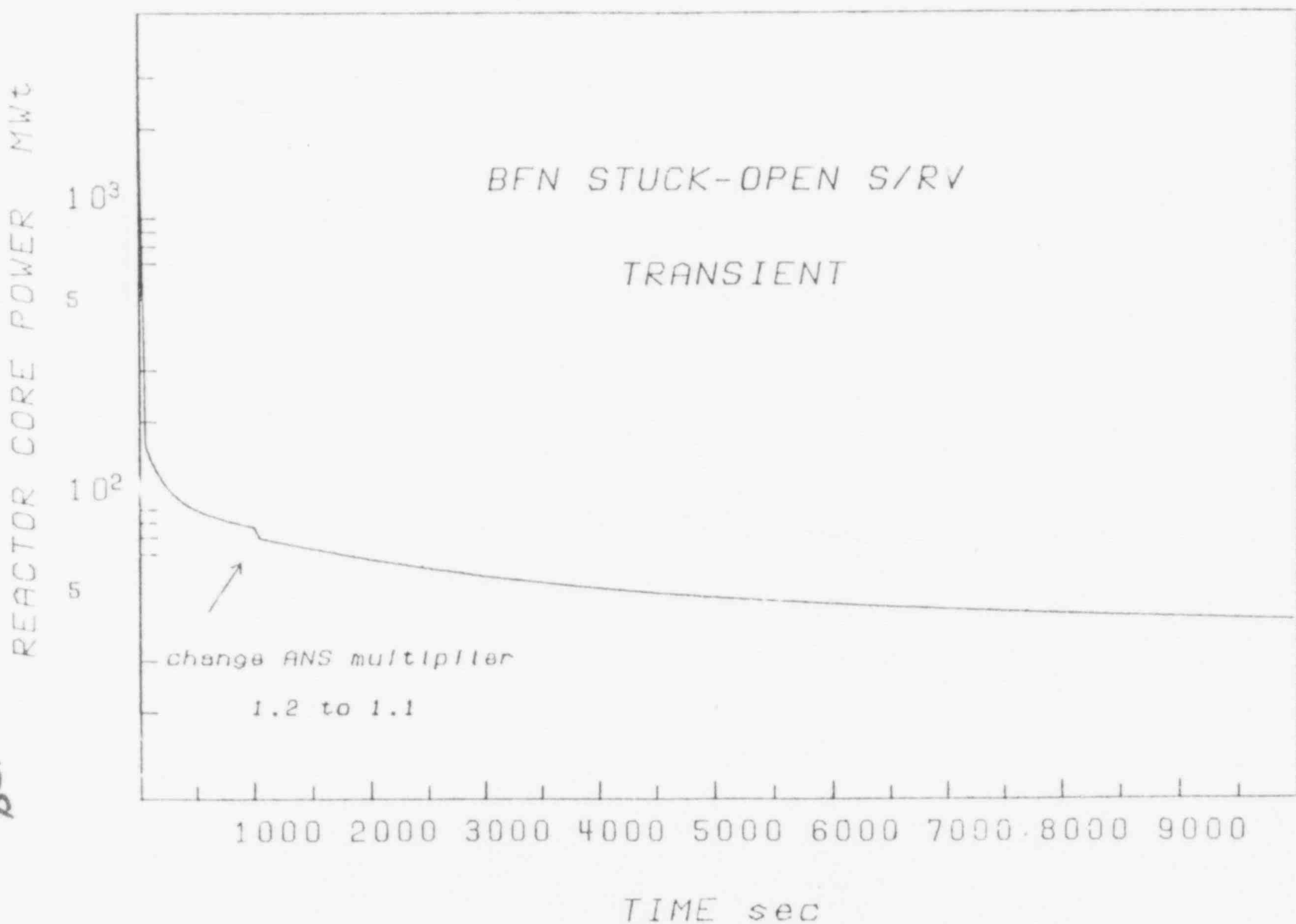


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FIGURE 2

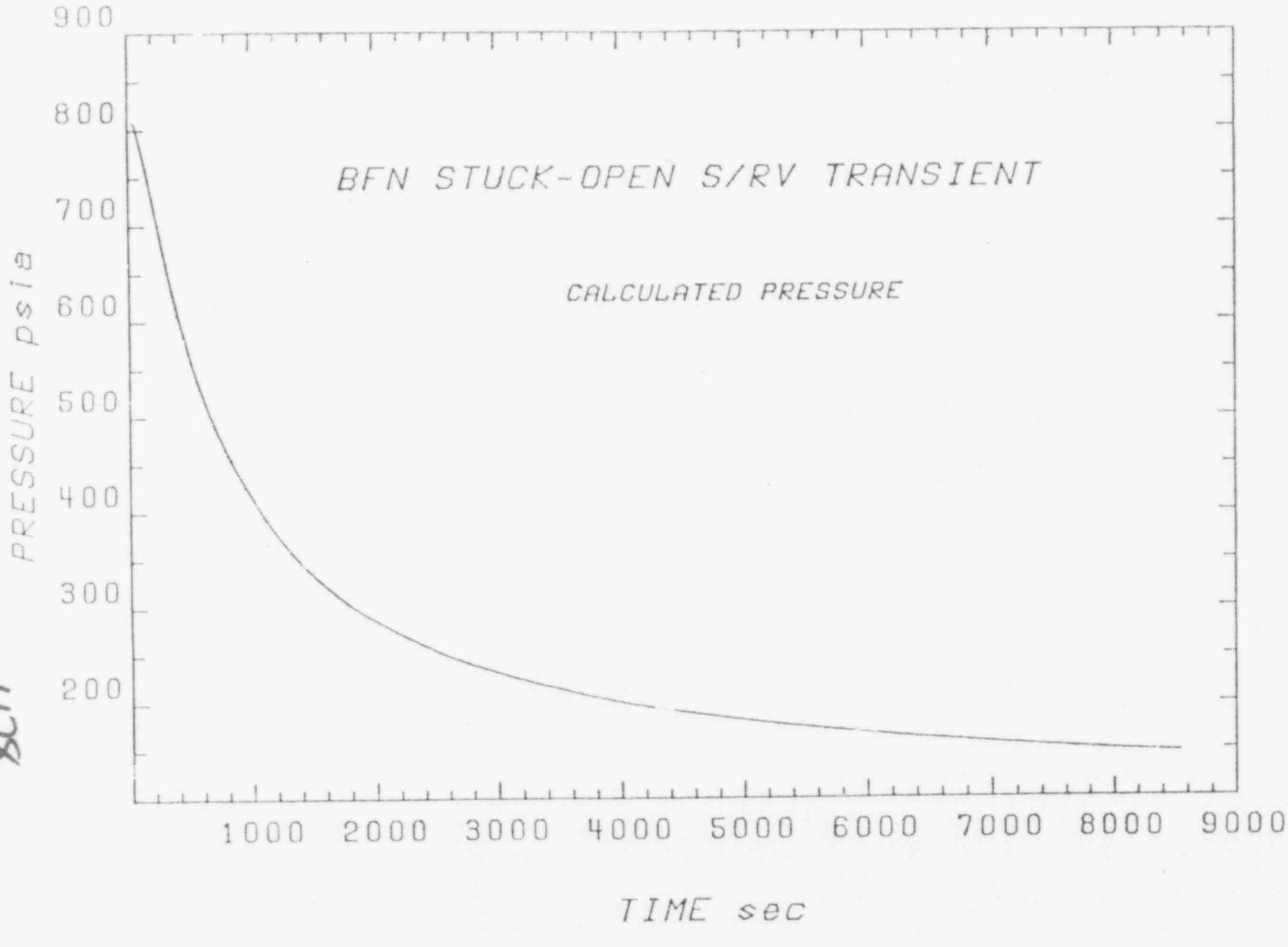
BFN STUCK-OPEN S/RV TRANSIENT
CALCULATED PRESSURE
PRESSURE psia
900
800
700
600
500
400
300
200
1000
2000
3000
4000
5000
6000
7000
8000
9000
TIME sec

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FIGURE 3

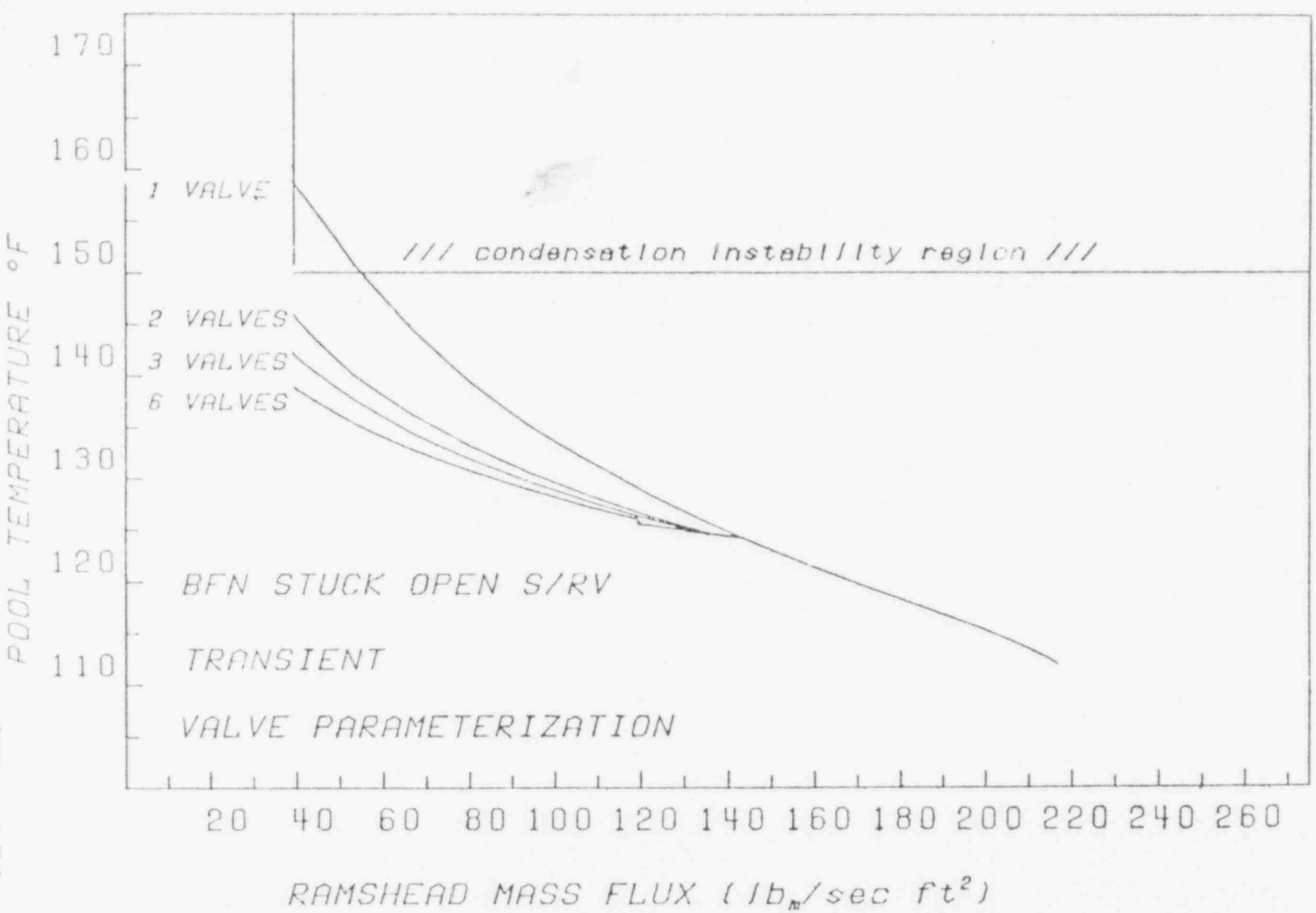


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FIGURE 4

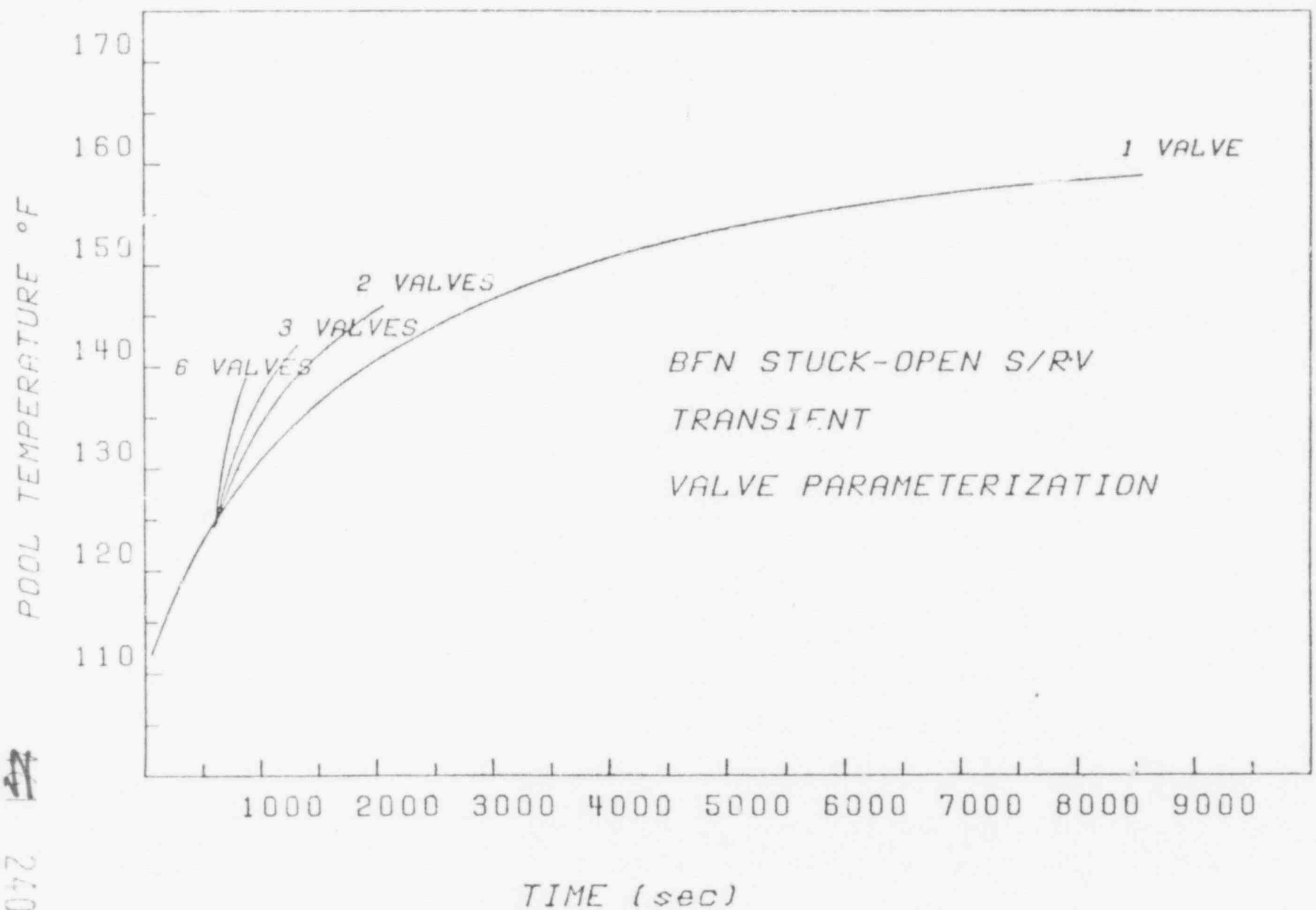


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FIGURE 5

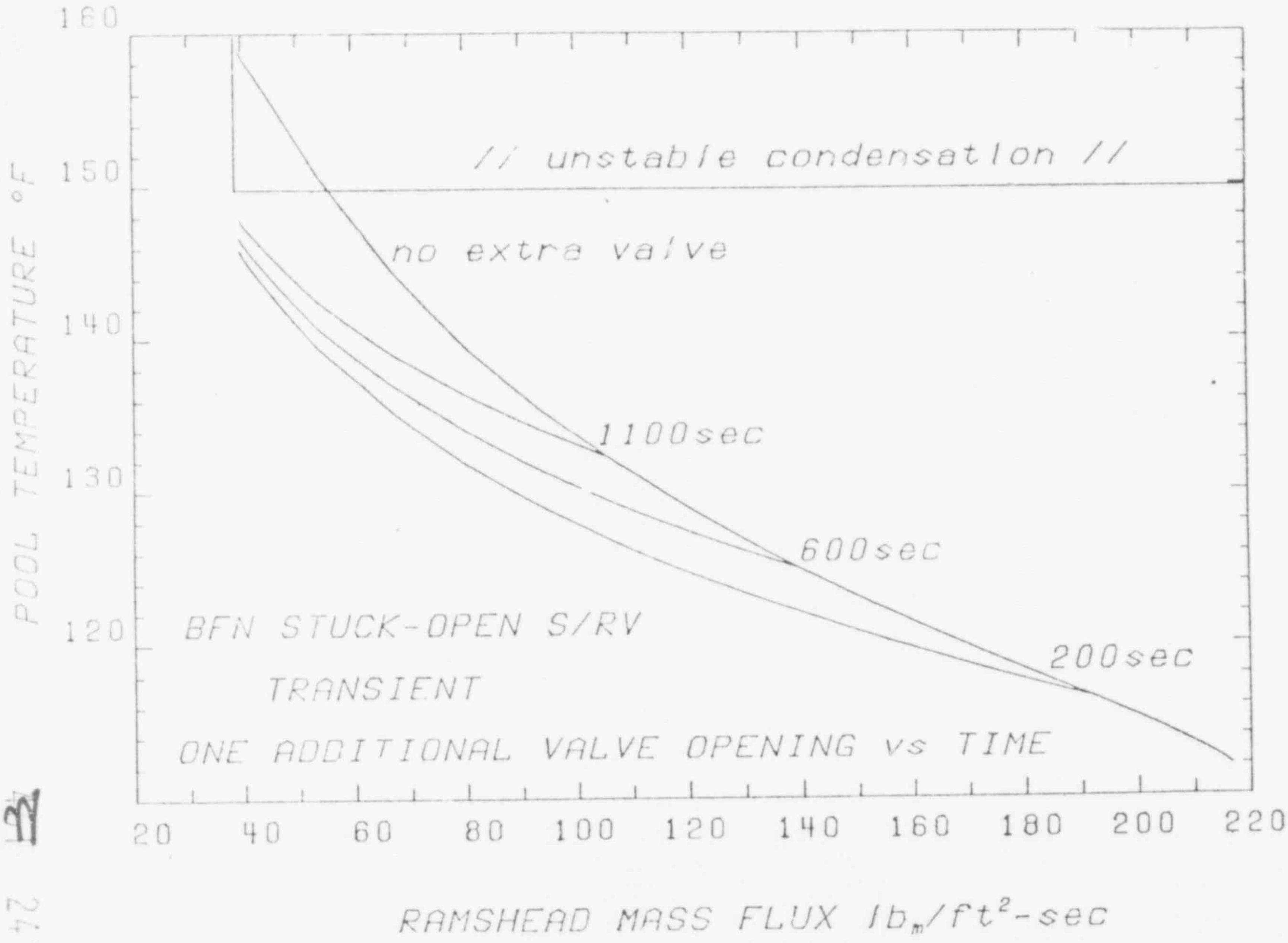


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FIGURE 6

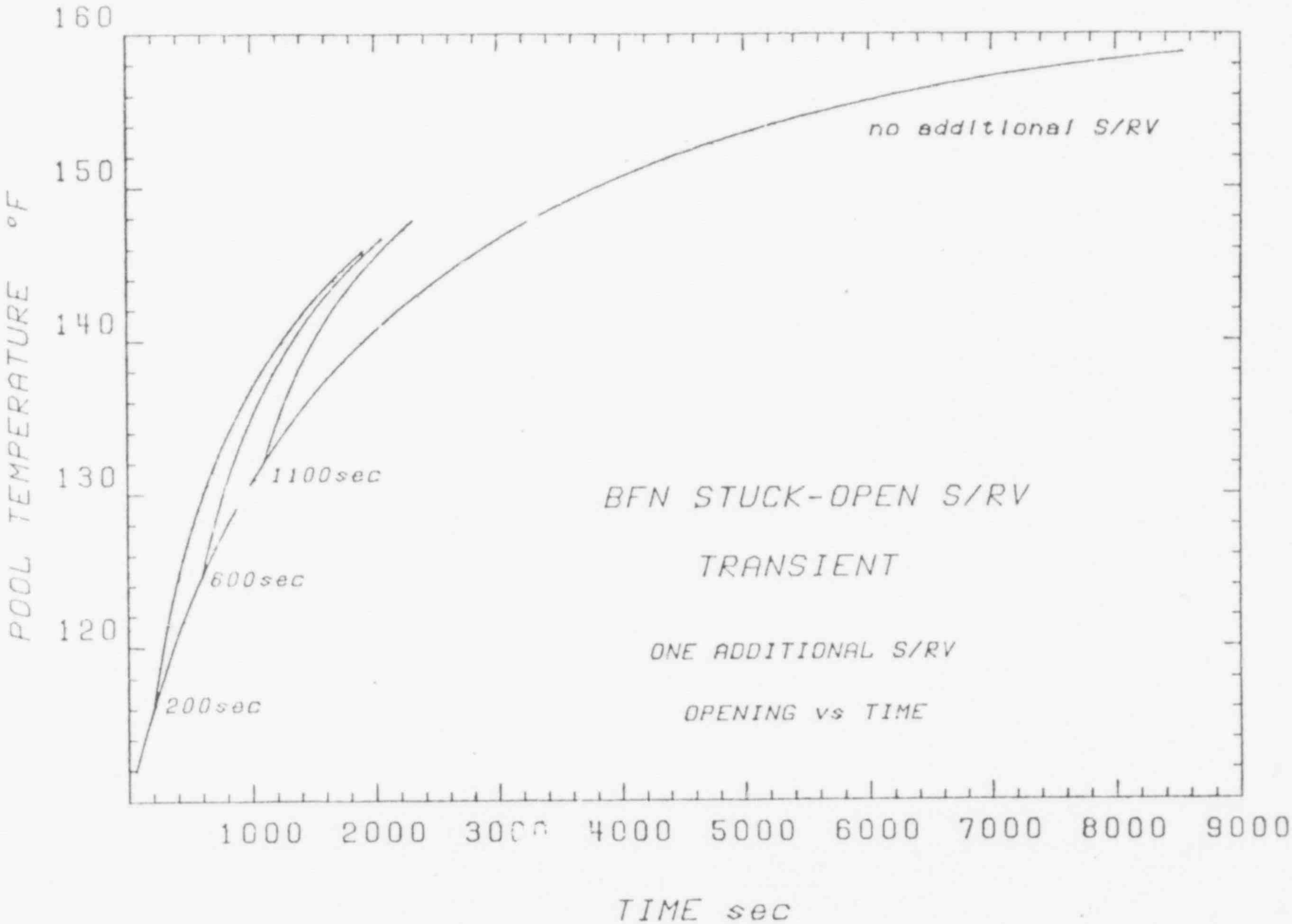


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FIGURE 7

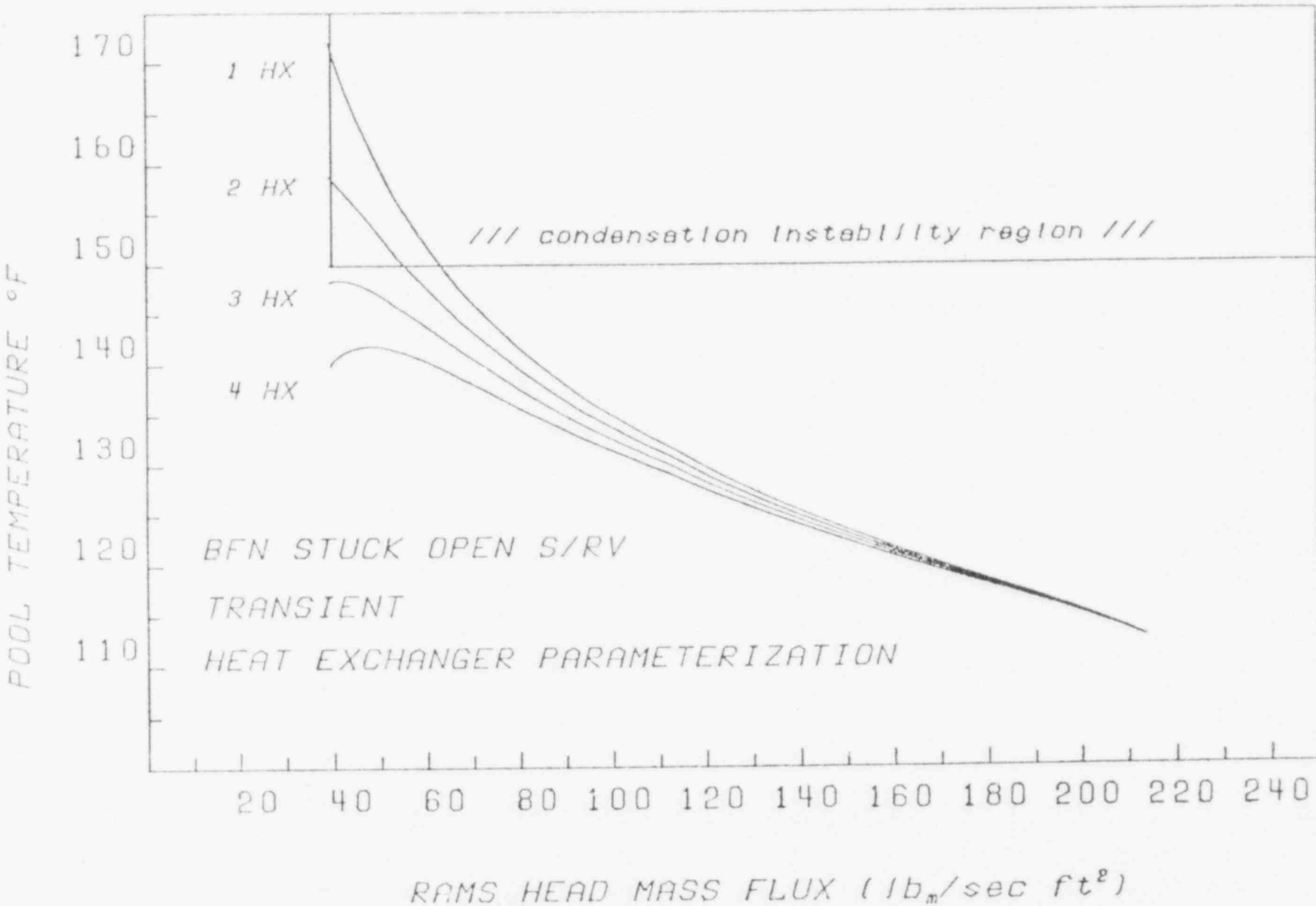


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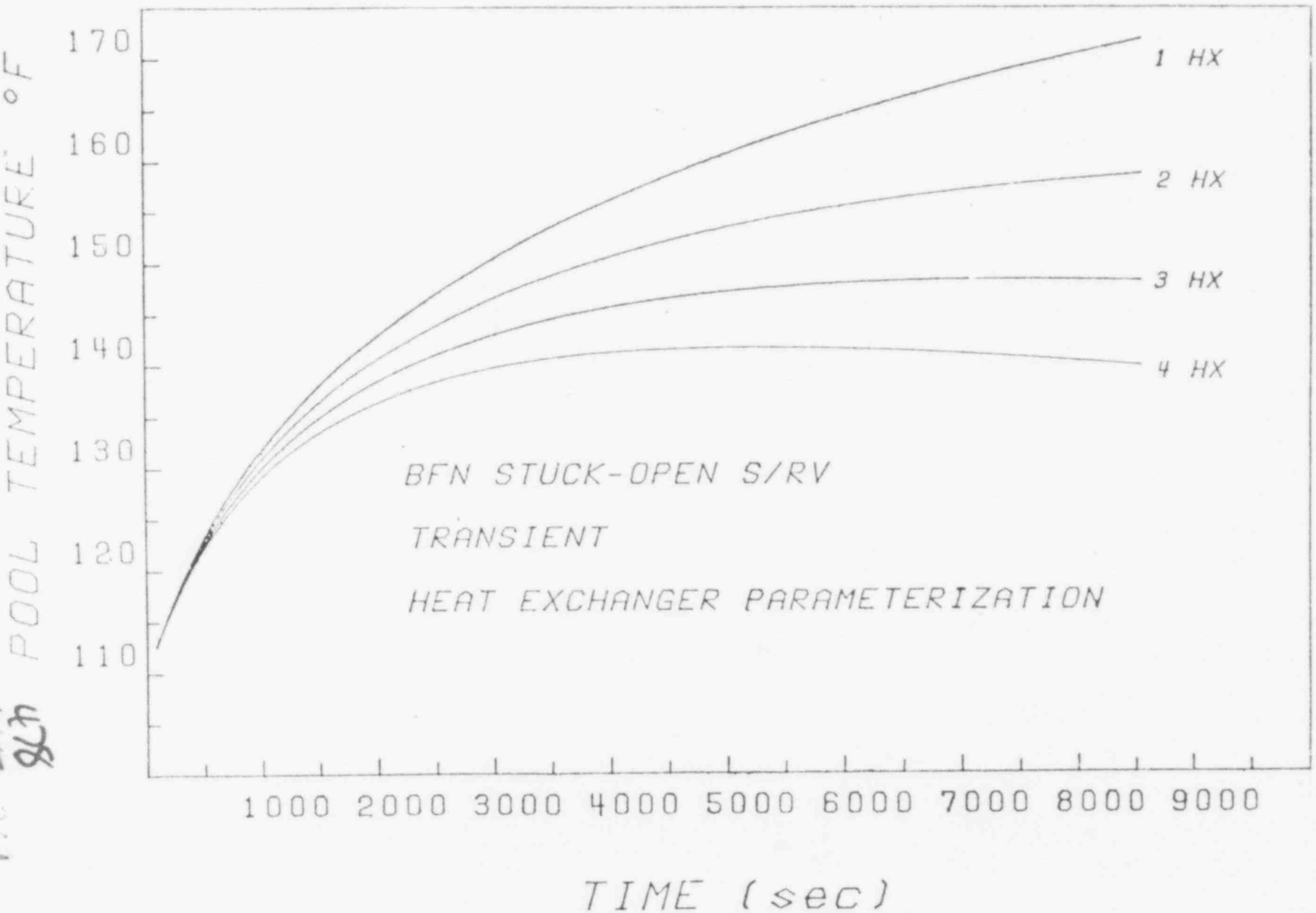
FIGURE 8



POOL TEMPERATURE °F
170
160
150
140
130
120
110
1 HX
2 HX
3 HX
4 HX
BFN STUCK-OPEN S/RV
TRANSIENT
HEAT EXCHANGER PARAMETERIZATION
1000 2000 3000 4000 5000 6000 7000 8000 9000
TIME (sec)

FIGURE 9

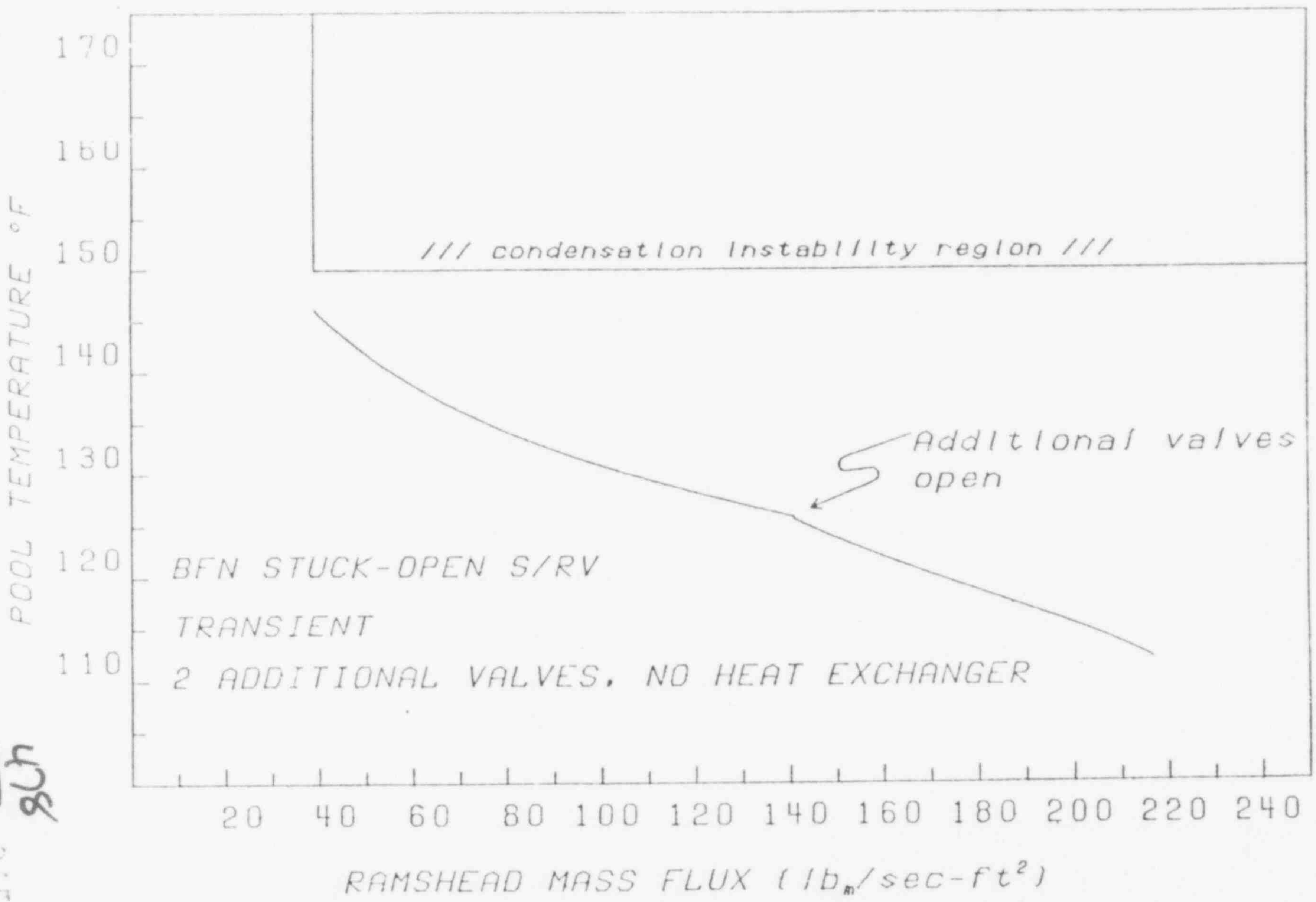

170
160
150
140
130
120
110
POOL TEMPERATURE °F
/// condensation instability region ///
Additional valves open
BFN STUCK-OPEN S/RV
TRANSIENT
2 ADDITIONAL VALVES, NO HEAT EXCHANGER
20 40 60 80 100 120 140 160 180 200 220 240
RAMSHEAD MASS FLUX ($lb_m$/sec-ft$^2$)

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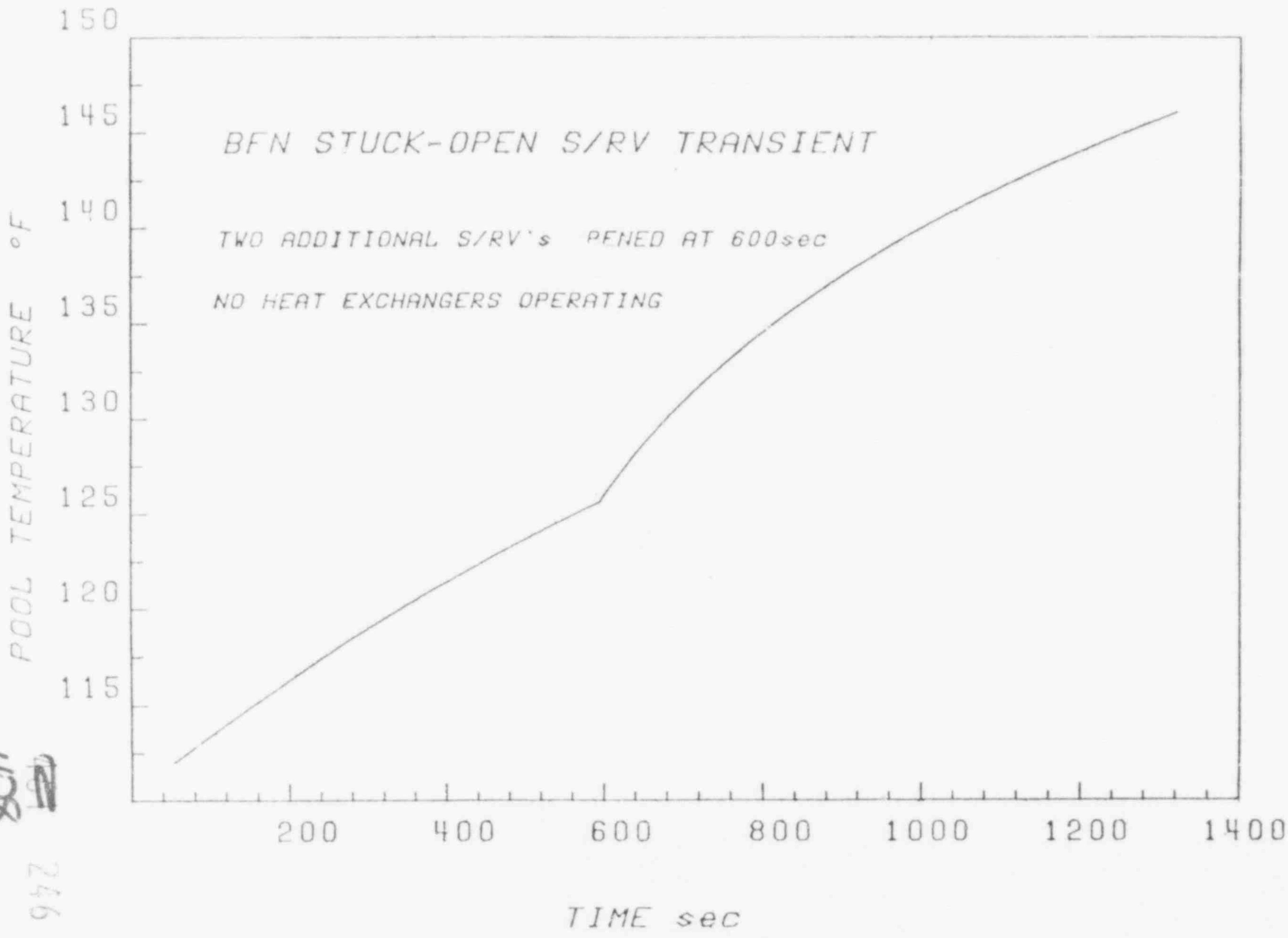
FIGURE 10

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## V. References

1. RETRAN - A Program for One Dimensional Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume I Equations and Numerics, EPRI-CCM-5, December 1978.

2. Residual Decay Energy for Light Water Reactors for Long-Term Cooling, Branch Technical Position ASB 9-2, U.S. Nuclear Regulatory Commission.

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ENCLOSURE 2

A. Stuck-Open Safety Relief Valve Transients

Attachment 1 discusses the various analyses performed for a stuck open relief valve event at the Browns Ferry Nuclear Plant. These analyses have been performed using very conservative assumptions.

The results of these analyses show an adequate margin exists between the predicted maximum suppression pool bulk temperature and the limit for stable condensation (less than 150° F when the exit mass flux is greater than 40 lb /sec $ft^2$) when both trains of heat exchangers are available or when operator action is taken to open an additional relief valve. Appropriate actions such as these already form a part of the plant operating procedure.

B. Suppression Pool Temperature Monitoring System

The suppression pool temperature monitoring system consists of several instruments located in the torus and the lines which take suction from or discharge to the torus. These devices are listed in the following table and their location relative to SRV discharge positions is indicated in the following sketch.

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| Function | Instrument # | Location |
|---|---|---|
| Torus Temperature | TI-64-55 | |
| Torus Temperature | TI-64-55 | |
| RHR Suction | TW-74-9 | Heat exchanger inlet Loop A |
| RHR Suction | TW-74-32 | Heat exchanger inlet Loop B |
| RHR Suction | TW-74-21 | Heat exchanger inlet Loop C |
| RHR Suction | TW-74-43 | Heat exchanger inlet Loop D |
| RHR Cooling Return | TW-74-81 | Heat exchanger outlet Loop A |
| RHR Cooling Return | TW-74-82 | Heat exchanger outlet Loop B |
| RHR Cooling Return | TW-74-83 | Heat exchanger outlet Loop C |
| RHR Cooling Return | TW-74-84 | Heat exchanger outlet Loop D |

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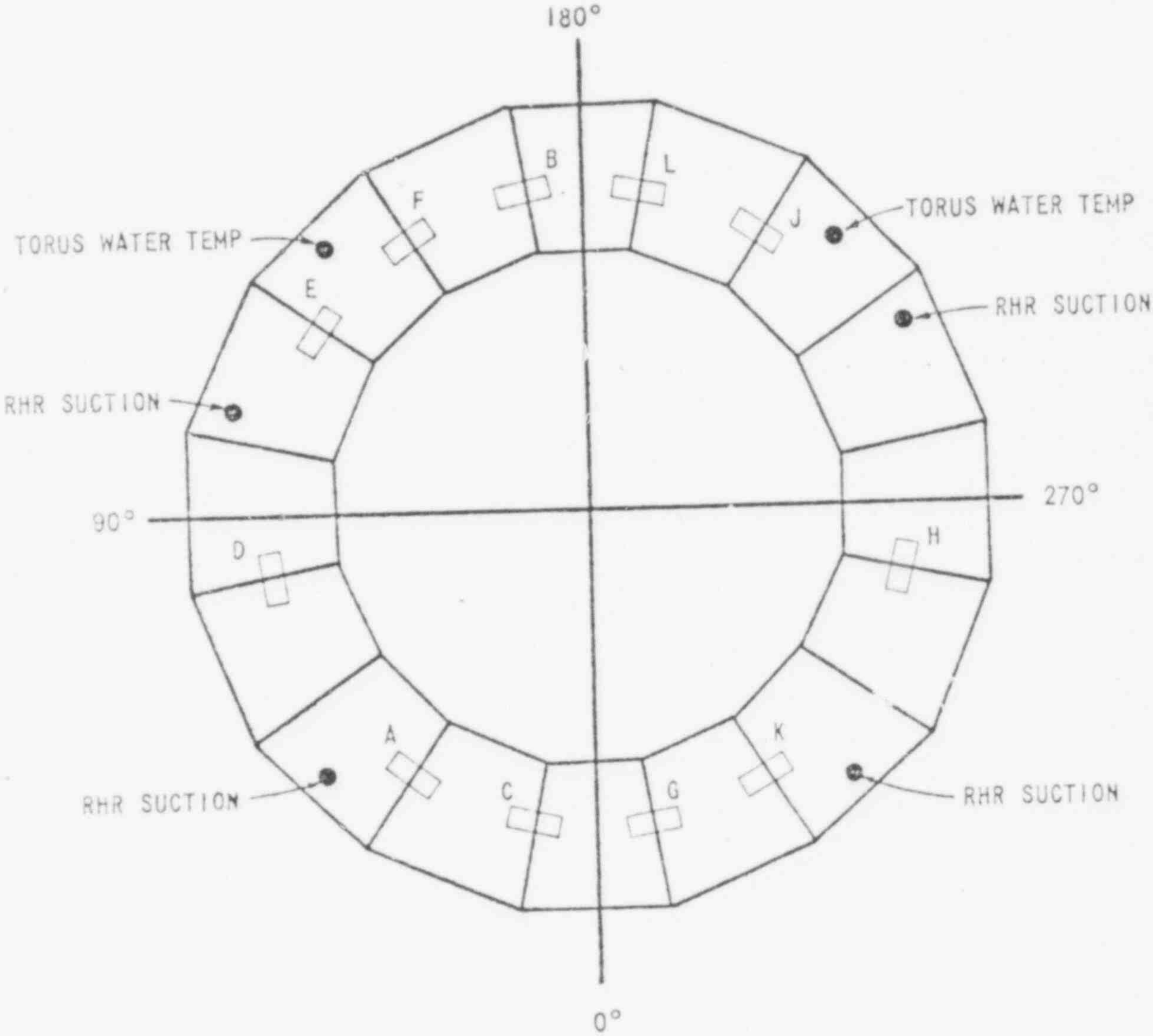
BROWNS FERRY NUCLEAR PLANT UNITS 1-3
TORUS TEMPERATURE MONITORING SYSTEM

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ENCLOSURE 3

## SIGNIFICANT CONSERVATISMS IN THE SORV ANALYSIS

- The analyzed case assumes a valve is opened above 120°F pool temperature with no heat exchangers in operation in one case.

- As in all transients, the reactor is considered to be initially at a steady state power of 103 percent.

- The suppression pool is assumed at its maximum technical specification temperature of 95°F and its minimum water volume.

- 122.5 percent of ASME related SRV capacities have been assumed.

- During the SRV transient, the pressure in the vessel would initially decrease due to the larger energy removal rate not immediately accommodated by the reactor system. The turbine control valves automatically adjust during this time in an attempt to maintain the reactor steam dome pressure. The vessel pressure partially recovers due to this action. However, to simplify the analysis, this transient is ignored and it is assumed that the initial pressure in the vessel is maintained through this period.

- The reactor system dumps steam to the pool at full power until the pool reaches 110°F at which time the reactor is scrammed by operator action as required by the technical specifications. This action occurs approximately 400 seconds into the transient. Conservatively, the main steam isolation valves are used in this simulation to isolate the core. The MSIV's are assumed to remain open until a core low water level signal is received. Minimization of this time and consequently the energy lost to the turbine is obtained by closing the feedwater input (by losing offsite power) to the vessel at the time of scram and reinstating cooling water only after the MSIV's are closed. This operation maximizes the energy released to the pool since the core is "bottled up" at a higher decay heat power level. No energy is lost to the condenser by way of the turbine bypass system since these valves are left arbitrarily closed throughout the simulation. Normal plant operating experience indicates that such isolation does not occur. Without isolation, a significant quantity of steam may be dumped to the condenser throughout the stuck open SRV transient, thereby further limiting the increase in suppression pool water temperature.

- Several indications of SRV opening are available to the control room operator including load reduction, change in measured steam flow, compensating turbine bypass valve closure, rise in SRV discharge line temperature (recording and alarm), and acoustic monitoring of SRV discharges. The above indications assure that the operator will be immediately aware that a SRV has inadvertently opened, and that he can quickly pinpoint which SRV has opened, so that the proper actions may be taken on a timely basis. During actual plant operation, suppression pool cooling is initiated promptly upon SRV opening.

- One-half of the RHR suppression pool cooling capacity has been assumed to be inoperable. Forty years of crud accumulation has been assumed on the RHR heat exchangers.

Based on the above and the analyses presented, TVA believes the Browns Ferry design has been demonstrated to be satisfactory and conservative.

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