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# 1 INTRODUCTION

Plant data shows that following an MSIV closure with scram the feedwater system continues to inject to the RPV for about 35 seconds. In simulating an MSIV-closure ATWS event, it is common practice to assume a similar coast-down of the feedwater flow rate. The purpose of this calculation is to determine if this feedwater coast-down assumption is valid, or if the feedwater system would continue to inject for a significantly longer period of time due to the rapid depletion of reactor vessel inventory under ATWS conditions.

# 2 REVIEW OF PLANT DATA FOR AN MSIV CLOSURE EVENT

A review of plant data for feedwater system response during an MSIV-closure transient (SSES Unit 1 MSIV closure on high Main Steam Line radiation[1], 06/14/83) was carried out to quantify plant parameters during the coast-down of the injection flow. Figures 1 through 18 show the plant response recorded by the GETARS system. A sequence of events is given in Table 1.

Figure 1 indicates that feedwater flow reaches zero at 36 seconds following initiation of the MSIV closure. The MSIV closure was initiated at 72 seconds. Note that the feedwater flow reaches zero while there is still a non-zero output from the feedwater controller (Figure 6). This rapid drop off in flow rate is due to the constant downward trend in the controller output which occurs after about 90 seconds. The downward trend is generated by constantly increasing RPV water level during this time period (see Figure 7).

Apparently, the feedwater flow drops to zero (see Figure 1) because the turbine speed is reduced to the point where the pump discharge pressure cannot overcome the vessel pressure and the head associated with the difference in elevation between the feedwater spargers and the feedwater pumps. In order to verify this assumption, a feedwater pump head curve was constructed from the plant transient data and compared with the known elevation head of the feedwater pumps.

Table 2 contains plant data for the pressure difference between the feedwater pump discharge and the reactor vessel at the elevation of the feedwater spargers for various feedwater injection rates. The following second order polynomial was fit to the data given in Table 2 in order to get an analytical expression for the pump resistance curve (see Appendix A for details of curve-fit calculation):

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[1] GETARS data was extracted from General Office Computer Tape #31, Case #83070615023101.

$$\Delta P = k_1 + k_2 W_{FW}^2 \quad \text{where} \qquad (1)$$

$\Delta P$ = [Feedwater pump discharge pressure] - [RPV pressure at elevation of feedwater sparger] (psig),

$k_1$ = 43.0395 psig,

$k_2$ = 0.22683 psig/(MLb/hr)$^2$, and

$W_{FW}$ = Feedwater flow rate (MLb/hr).

A comparison of the resistance curve defined by Equation (1) and plant data is shown if Figure 19. The constant $k_1$ represents the elevation pressure drop from the pump discharge to the RPV at the elevation of the feedwater sparger. The temperature of the water in the feedwater line is 383 °F (see Figure 3). The density of water at this temperature is 51.9 Lb/ft$^3$. Using this density and the value of $k_1$ given above, the elevation difference between the discharge of the feedwater pumps and the feedwater sparger is calculated as

$$\Delta Z_{Calc} = \frac{k_1(144)}{(51.9)} = 119.8\,\text{ft}. \qquad (2)$$

In order to determine the validity of the system resistance curve given by Equation (1), this calculated elevation difference is compared to the actual value. The elevation at the pump discharge is 678.75 ft (PP&L Drawing DBD-201-1, Rev. 4). The elevation at the bottom of the vessel is 732.3 ft (PP&L Drawing M-142, "P&ID-Unit 1, Nuclear Boiler Vessel Instrumentation", Rev. 30, Sheet 1 of 2). The feedwater spargers are located at 498.5" above the bottom of the vessel (PP&L Drawing FF110760, Sheet 1, "Reactor Primary System Weights & Volumes"). Therefore, the elevation of the spargers is $732.3\,\text{ft} + 41.5\,\text{ft} = 773.8\,\text{ft}$. The difference in elevation between the spargers and the pump discharge is $773.8\,\text{ft} - 678.75\,\text{ft} = 95\,\text{ft}$. This value of the elevation difference agrees reasonably well with the value given in Equation (2) considering that the data was obtained with the feedwater system operating under fairly rapidly changing conditions.

Notice that the elevation estimated from the data point (in Table 2) corresponding to zero flow gives an elevation of $(g_c/g)(37.9\ \text{psi})(144\text{psi/psf})/(51.9\text{Lb/ft}^3) = 105$ ft which agrees much better with the actual elevation. It is therefore concluded that the feedwater flow reaches zero because the pump discharge pressure is insufficient to overcome the RPV pressure plus the elevation head.

During normal plant operation, steam is supplied to the feedwater turbines from the cross-around piping (the steam downstream of the HP turbine and moisture separators). When cross-around steam pressure is too low to generate the required feedwater flow, additional steam is extracted from the Main Steam Lines[2]. With the main turbine off line, the source of steam for the feedwatar turbines is the main steam lines. Figure 3 shows that the steam supply pressure is about 560 psig when the feedwater flow reaches zero. The feedwater turbine design specification sheet[3] indicates that feedwater flow to the vessel is normally maintained with the steam supply pressure at 175 psia (normal steam pressure within the cross-around piping). Thus there is ample pressure energy available within the Main Steam lines to inject coolant to the vessel if a demand for flow existed.

## 3 ESTIMATE OF TIME AVAILABLE FOR FEEDWATER INJECTION FOLLOWING MSIV CLOSURE

An estimate of the time available for feedwater system operation following initiation of MSIV closure was made based on the decay rates of the pressure in the main steam lines (Figure 2). Table 2 shows the rate of pressure decrease at three different feedwater injection rates. For computational purposes, a polynomial representation for the decay rate as a function of feedwater injection rate was developed. The polynomial relation is given by (see Appendix A for details)

$$\lambda_{FW}\left[\overline{W}_{FW}(t)\right] = 2.21 + 1.8249\,\overline{W}_{FW}(t) + 5.2921\,\overline{W}^2_{FW}(t) \quad \text{where} \qquad (3)$$

$\lambda_{FW}$ = decay rate of supply steam pressure (psi/sec), and

$\overline{W}_{FW}$ = Normalized feedwater flow = (flow rate)/(rated flow rate).

Plant data (Figure 2) shows that there is a sudden drop in steam line pressure to about 715 psig following the MSIV closure. At about 80 seconds (8 seconds after initiation of the MSIV closure) the steam line pressure then begins to decay away. The decay of supply steam pressure following initiation of MSIV closure can be approximated by

$$\frac{dP}{dt} = -\lambda_{FW} \quad \text{with} \quad P(8.0) = 715\,\text{psig}, \qquad (4)$$

---

[2] SSES Design Description Manual, Chapter 31.

[3] GEK-38479 (IOM 42).

where $\lambda_{FW}$ given by Equation (3). In Equation (4), t=0 is defined as the time at which the MSIV closure is initiated. The time $t^*$ (seconds) available for operation of the feedwater system, following closure of the MSIVs, is then given implicitly by integrating Equation (4) from 715 psig down to 160 psig [As mentioned above, the feedwater system is designed to inject to the vessel with steam supply pressure ≥ 175 psia (160 psig).]:

$$160-715=-\int_{8.0}^{t^*}\lambda_{FW}\left[\overline{W}_{FW}(t)\right]dt. \qquad (5)$$

The integral in Equation (5) was evaluated for constant values of feedwater flow rate to obtain a plot of $t^*$ versus feedwater flow following MSIV closure. This plot is shown in Figure 20, and the numerical values used to construct the plot are given in Appendix B.

For a BWR/4 operating at natural circulation conditions with normal water level, core power corresponds to about 50% of rated power, assuming operation on the 100% rod line[4]. If the feedwater enthalpy remained constant following the MSIV closure and normal water level was maintained, the required feedwater flow rate for natural circulation operation would be 50% of rated flow. With closure of the MSIVs, feedwater heating would be lost, and core power would begin to increase above 50% power. A comparison of General Electric calculations for a two recirculation pump trip (no loss of feedwater heating) and a turbine trip ATWS (loss of feedwater heating) indicates that the increase in power caused by the loss of feedwater heating leads to ~10% increase in feedwater flow rate[5]. Thus the feedwater flow rate required to maintain normal water level in an MSIV closure ATWS corresponds to about 60% of rated flow. From Figure 20, the feedwater system would continue to inject to the RPV for 115 seconds provided that RPV level does not reach the high level trip (+54") during the early part of the transient.

---

[4] Peterson, C.E., Gose, G.C., Hentzen, R.D., McClure, J.A., Chexal, B., and Layman, W., "Reducing BWR Power by Water Level Control During an ATWS — A Transient Analysis", NSAC-70, Electric Power Research Institute, Palo Alto, CA, August, 1984.

[5] NEDO-32047, "ATWS Rule Issues Relative to BWR Core Thermal-Hydraulic Stability", General Electric Company, February, 1992.

## Table 1 Sequence of Events

| Time (sec) | Time Relative to Initiation of MSIV Closure (sec) | Event |
|---|---|---|
| 72 | 0.0 | Initiation of MSIV Closure. |
| 88 | 16 | Level setpoint setdown occurs. |
| 108 | 36 | Feedwater flow drops to zero. |
| 114 | 42 | Feedwater pump trip on high RPV water level (+54") |
| 123 | 51 | Feedwater controller output signal drops to zero. |

## Table 2 Plant Data Used to Develop FW System Resistance Curve

| Time (sec) | RPV Pressure (psig) | RPV Level Above the FW Spargers (inches)[6] | Elevation Head of Water Above Spargers (psi)[7] | RPV Pressure at Sparger Elevation (psig) | FW Pump Discharge Pressure (psig)[8] | Pressure Drop From Pump Discharge to RPV at Elevation of Spargers (psig) | Feedwater Flow Rate (MLb/hr) |
|---|---|---|---|---|---|---|---|
| 70 | 988 | 59 | 1.58 | 989.6 | 1075 | 85.4 | 13.3 |
| 90 | 994 | 27 | 0.72 | 994.7 | 1070 | 75.3 | 12.8 |
| 95 | 1000 | 34 | 0.91 | 1000.9 | 1067 | 66.1 | 9.0 |
| 105 | 990 | 69 | 1.85 | 991.8 | 1040 | 48.2 | 3.0 |
| 108 | 981 | 77 | 2.06 | 983.1 | 1021 | 37.9 | 0.0 |

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[6] The elevation of the feedwater spargers is -29" with respect to instrument zero (PP&L Drawing FF110760, Sheet 1, " Reactor Primary System Weights and Volumes")..

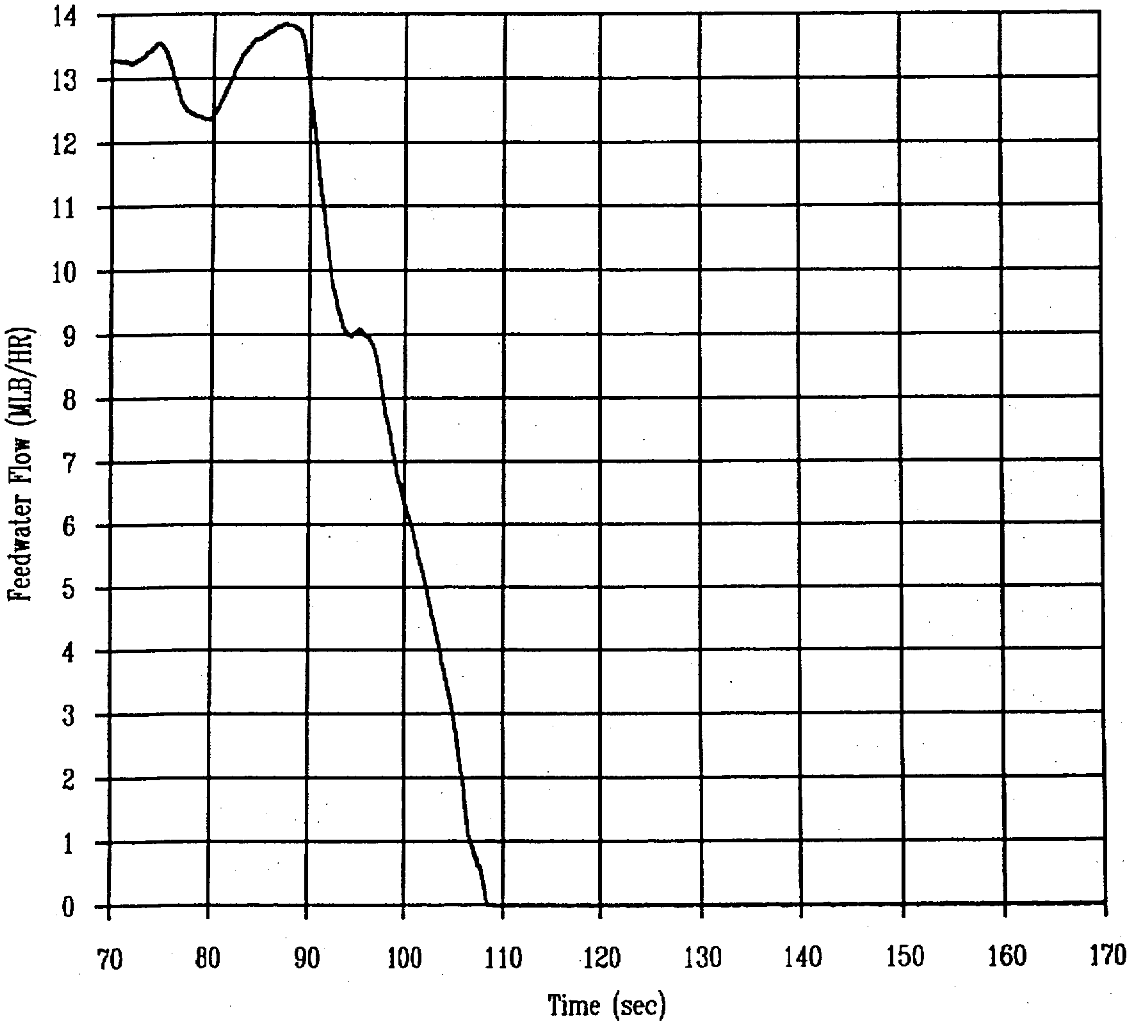
[7] The elevation head of the water above the feedwater spargers was calculated with a fluid density of 46.3 Lb/ft$^3$.

[8] The discharge pressure was determined by averaging the pressures given in Figures 12, 13, and 14.

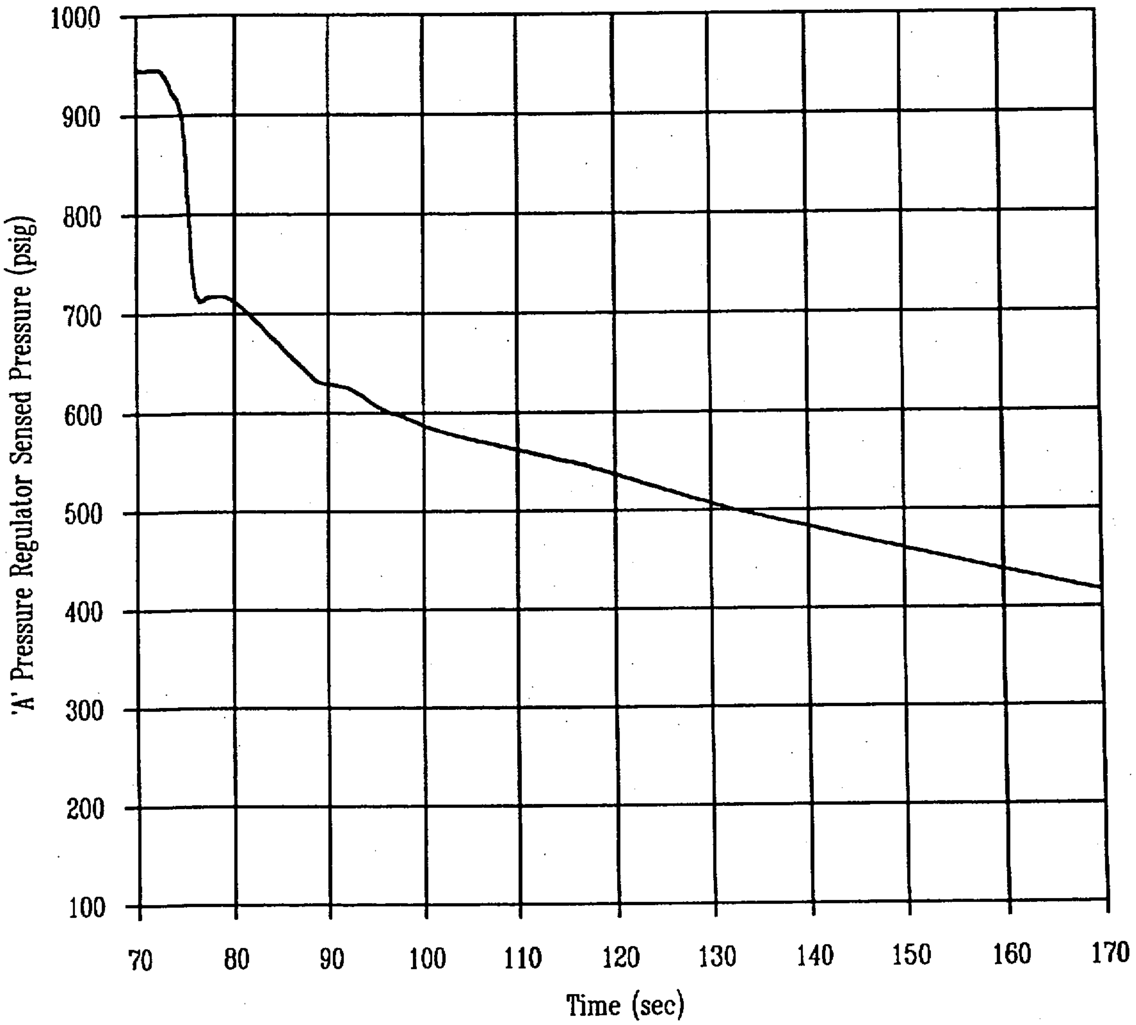
## Table 3 Steam Line Pressure Decay Rates

| Rate of Steam Line Pressure Decay (psi/sec) | Feedwater Flow Rate (MLb/hr) | Data Interval Used to Obtain Decay Rate (sec) |
|---|---|---|
| 2.21 | 0.0 | 150.001 to 169.944 |
| 5.898 | 9.0 | 94.054 to 96.258 |
| 9.327 | 13.3 | 81.038 to 86.077 |

Figure 1
MSIV Closure on High MSLR
06/14/83
31-83070615023101



## Figure 2
## MSIV Closure on High MSLR
06/14/83
31-83070615023101



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MSIV Closure on High MSLR
06/14/83
31-83070615023101

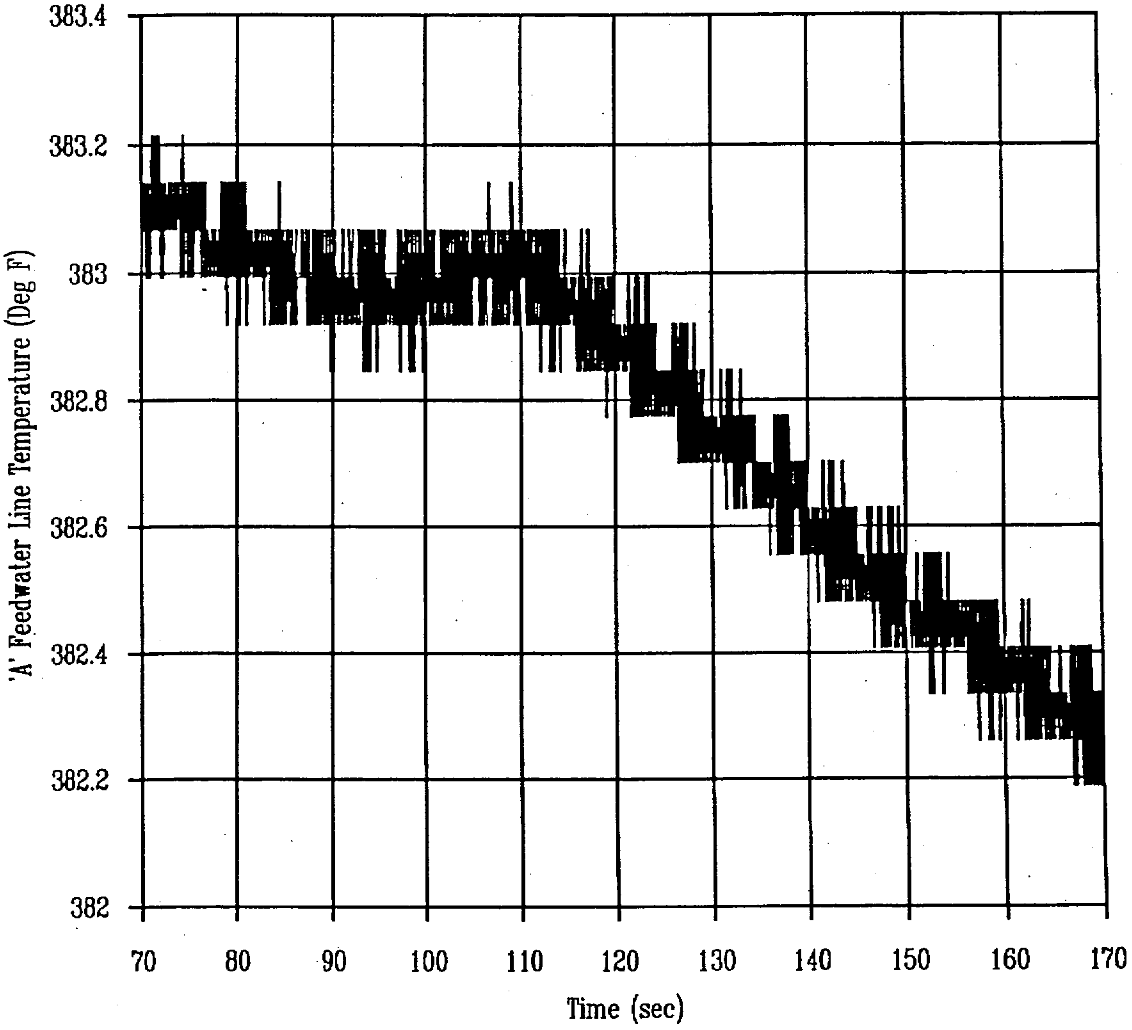
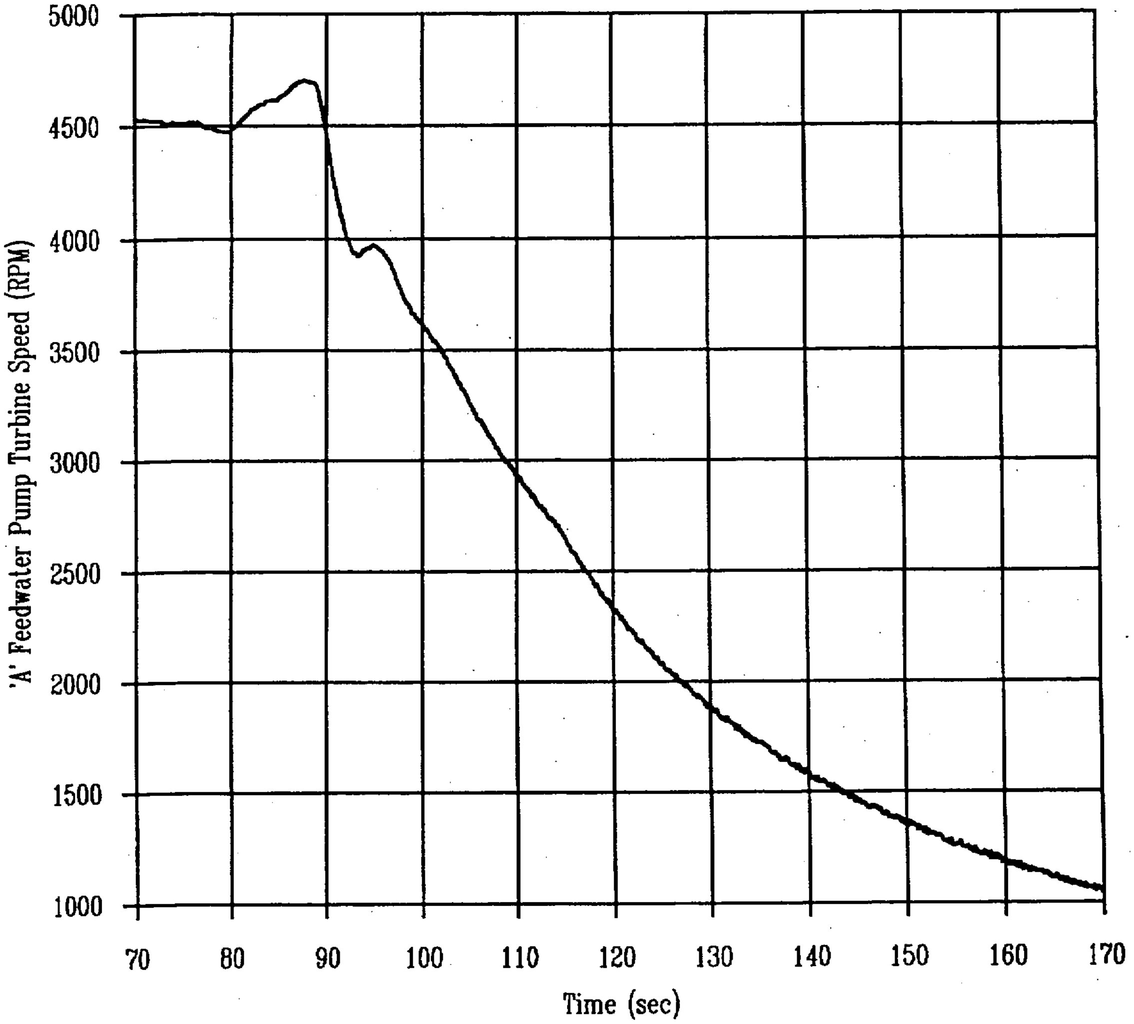


Figure 4
MSIV Closure on High MSLR
06/14/83
31-83070615023101



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MSIV Closure on High MSLR
06/14/83
31-83070615023101

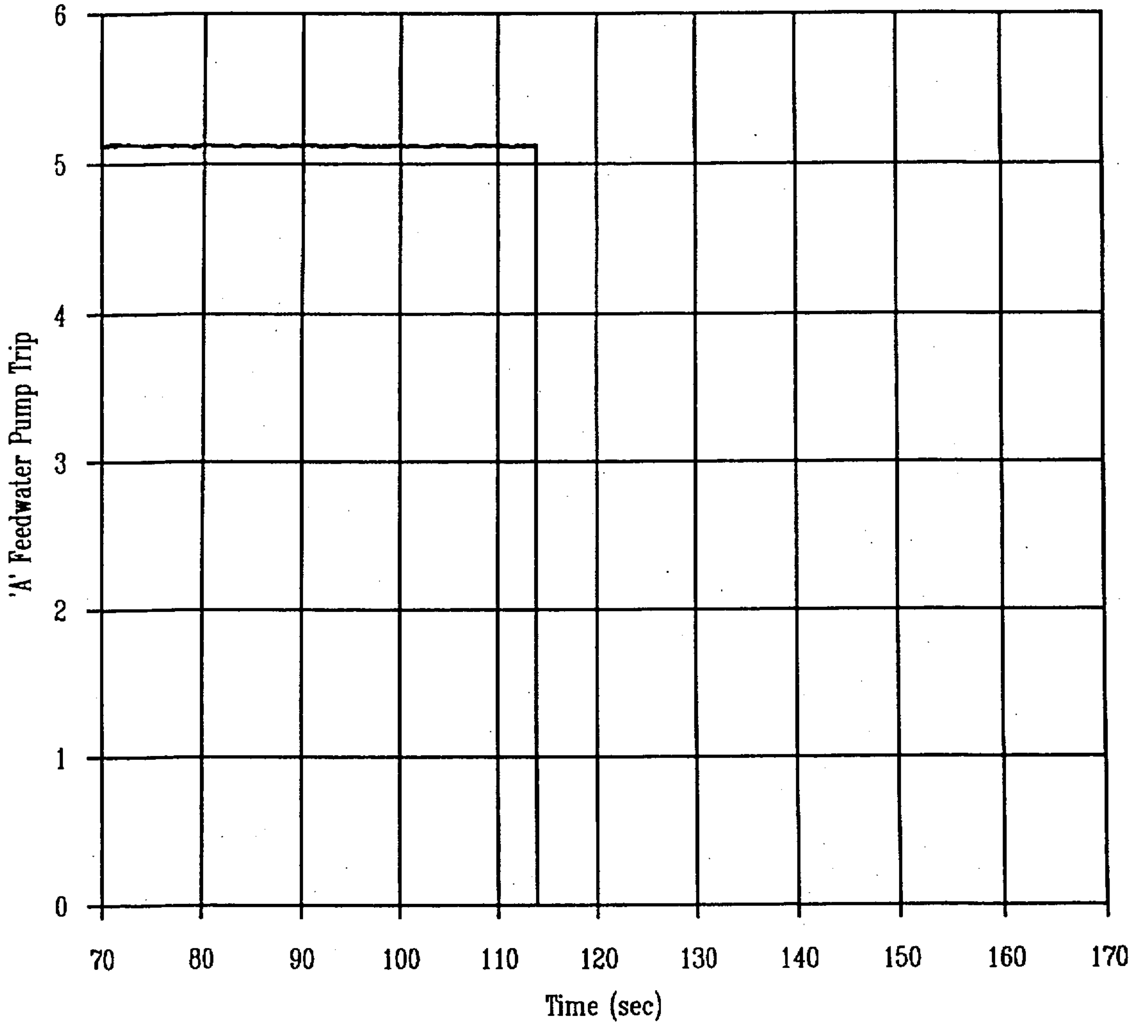

Figure 6
MSIV Closure on High MSLR
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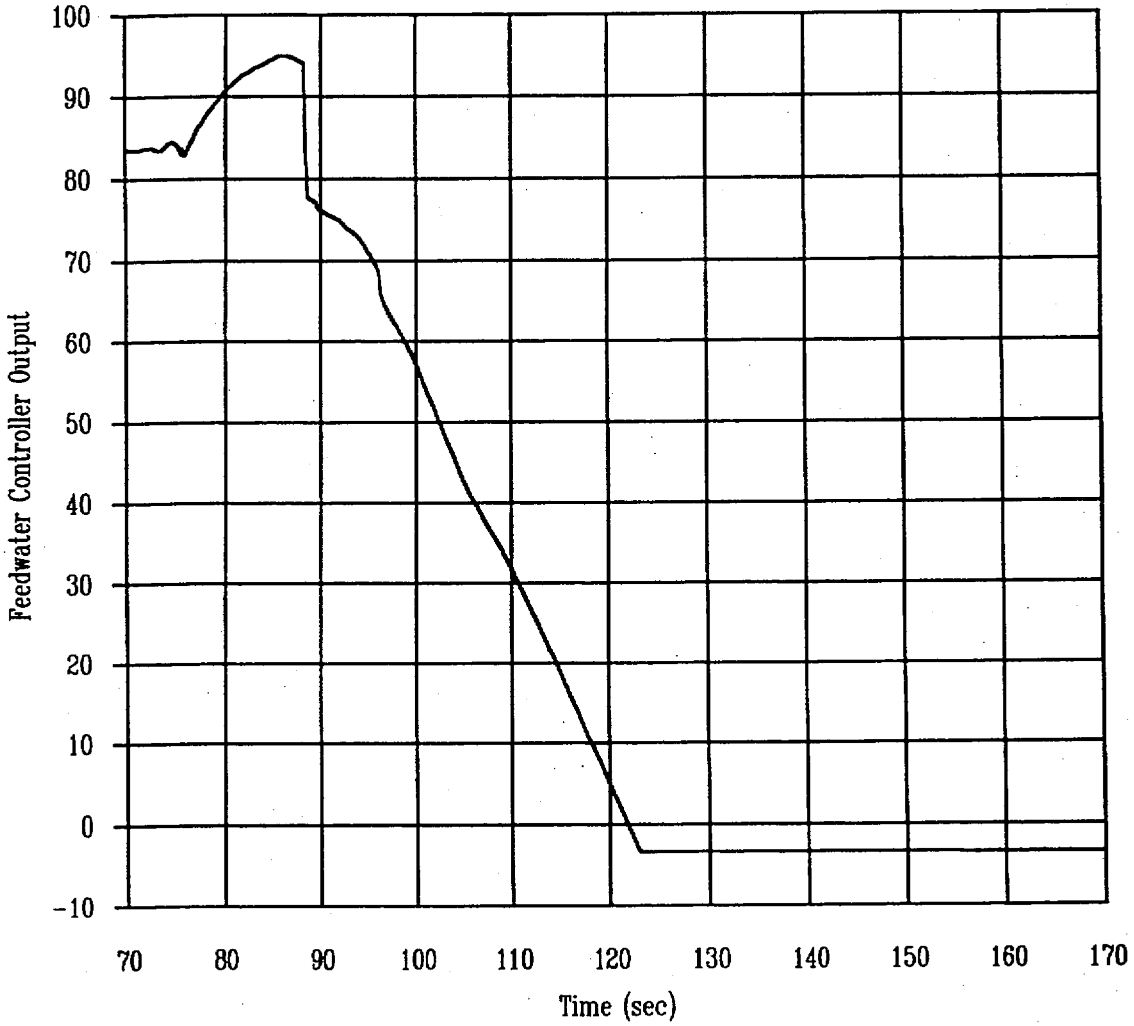

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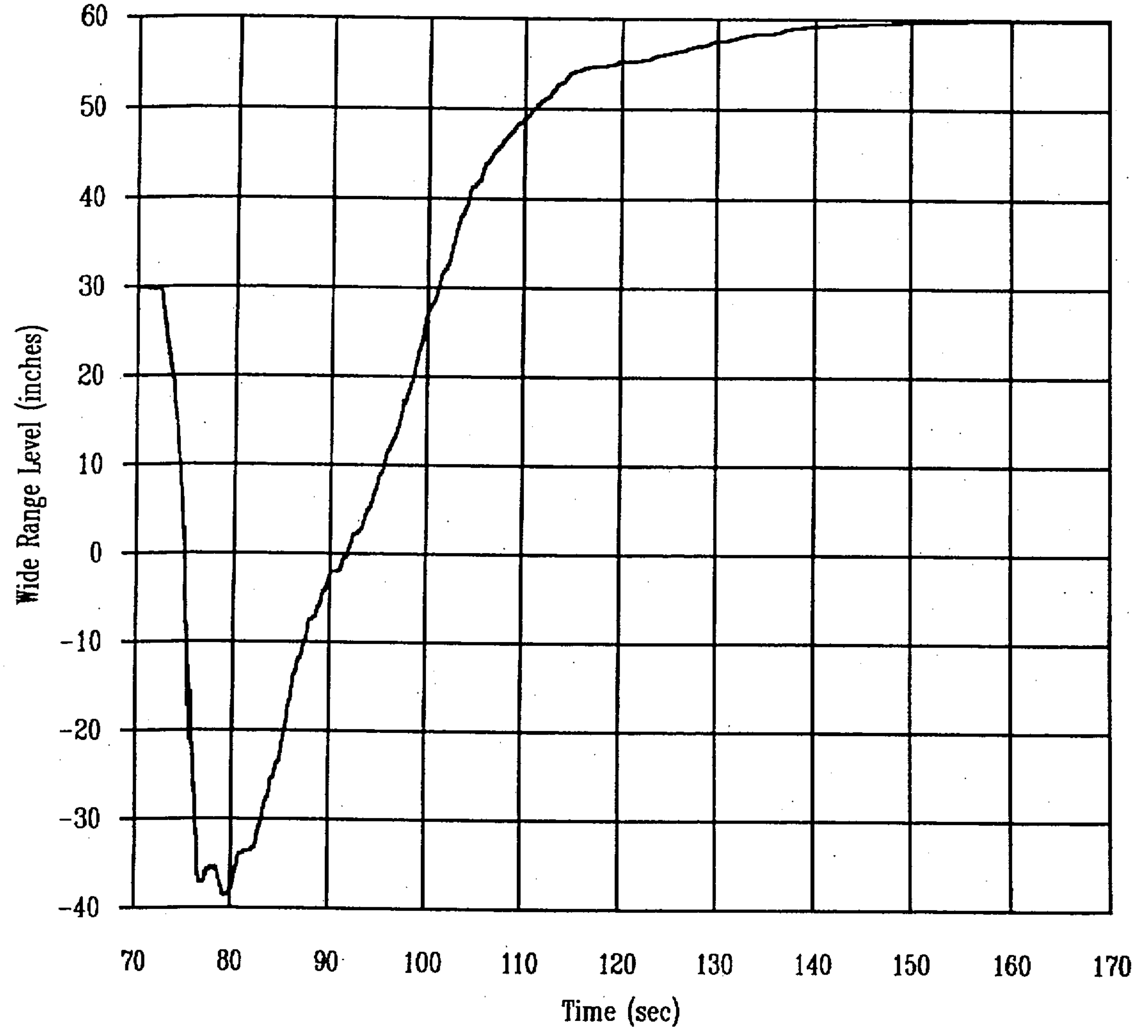

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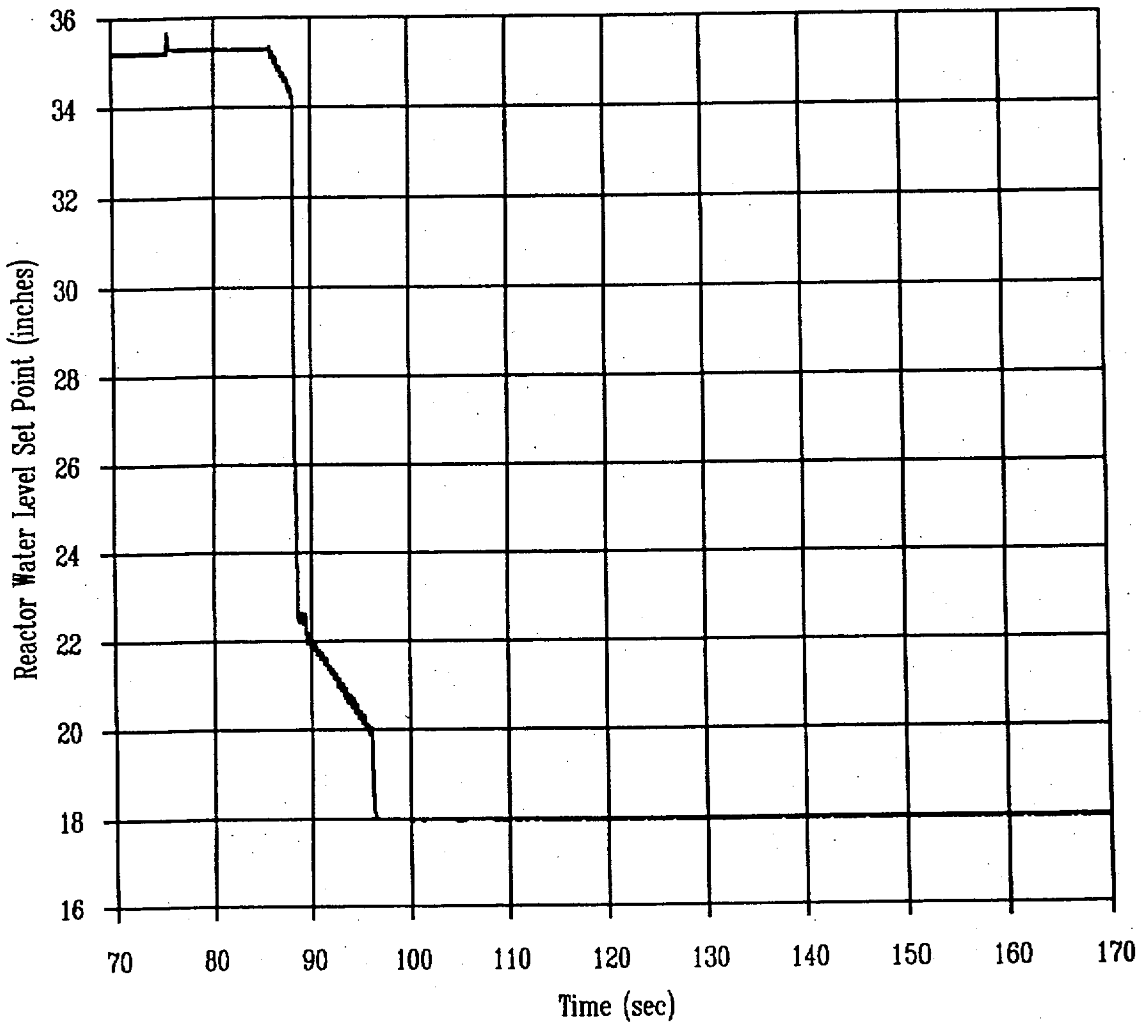

Figure 9
MSIV Closure on High MSLR
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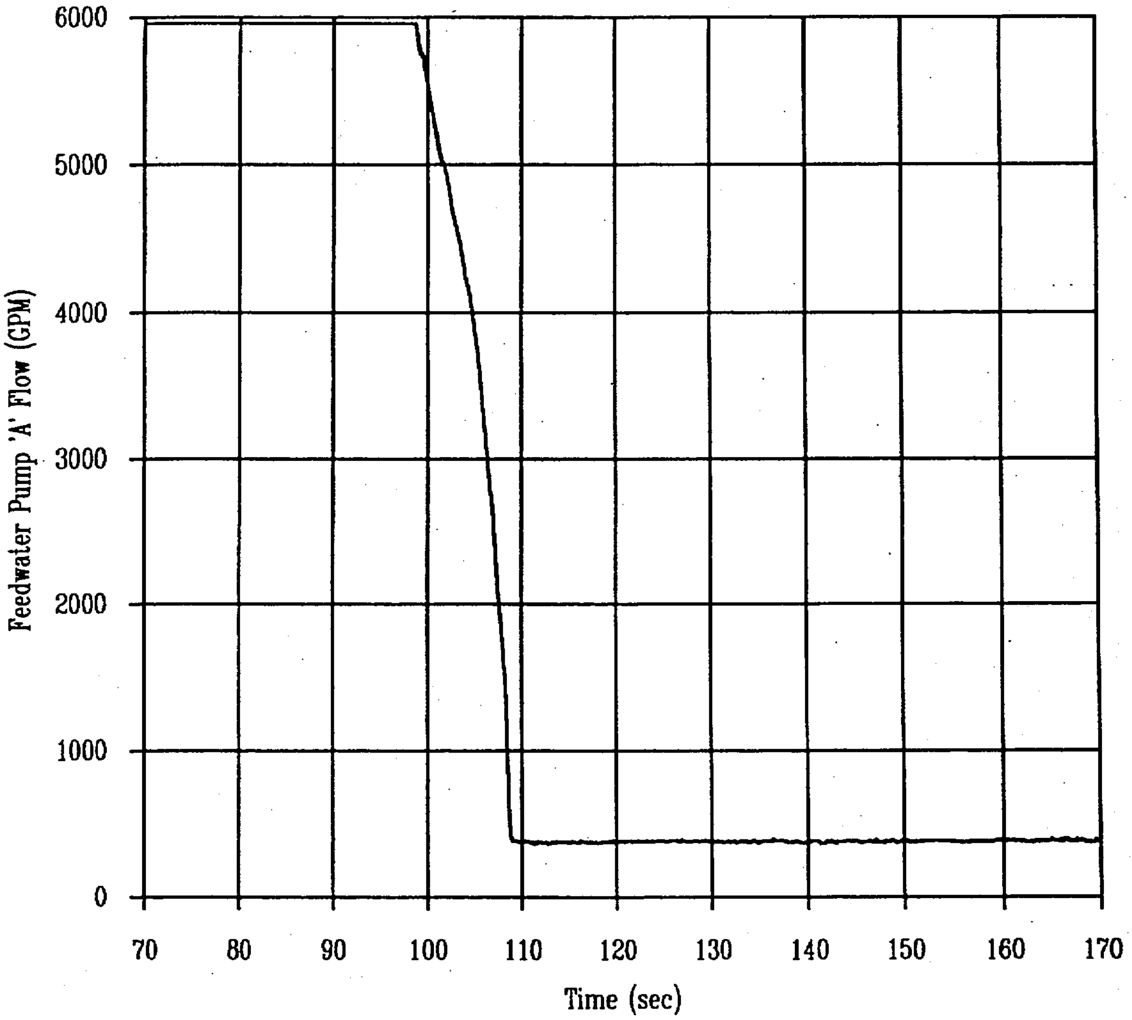

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MSIV Closure on High MSLR
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31-83070615023101

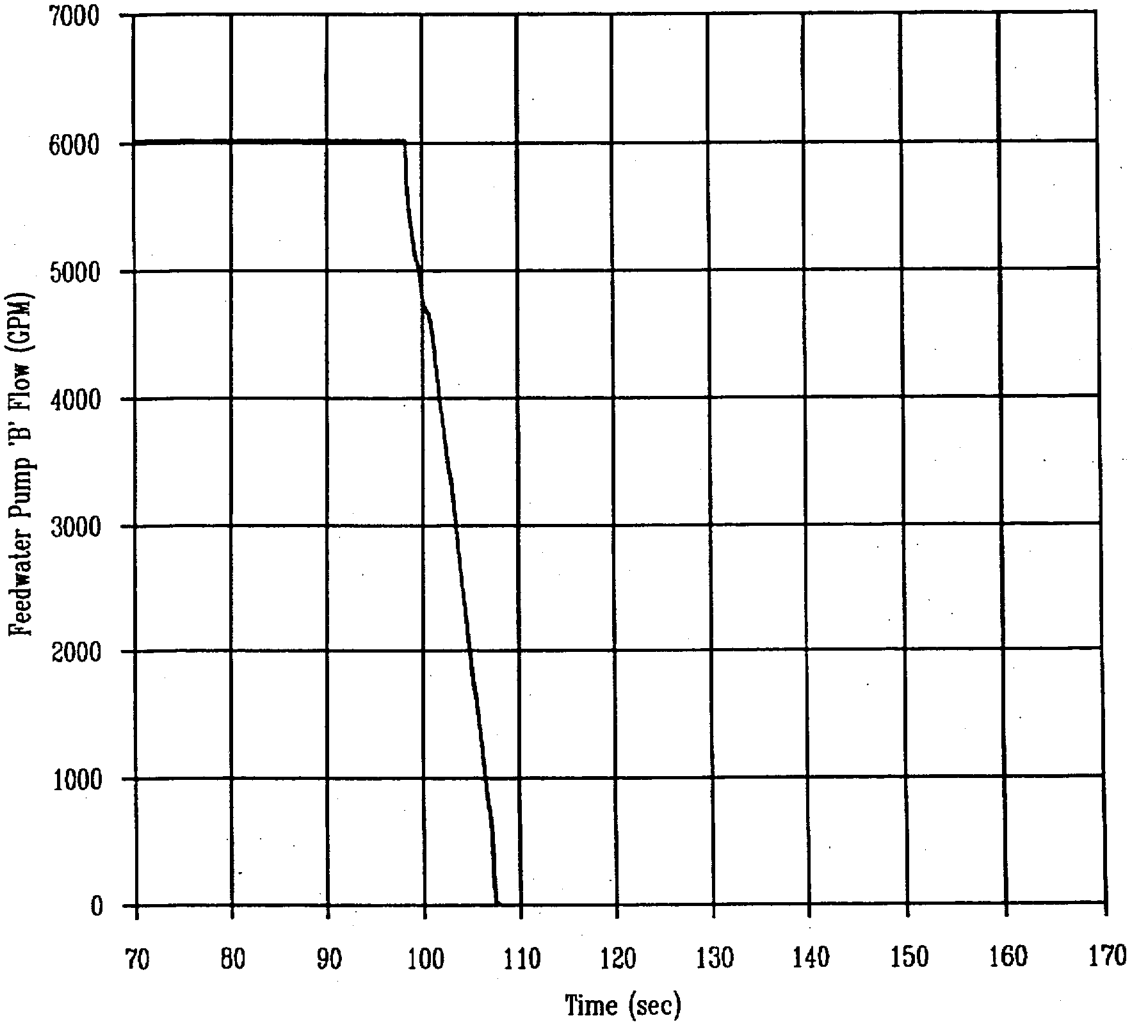

Figure 11
MSIV Closure on High MSLR
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31-83070615023101

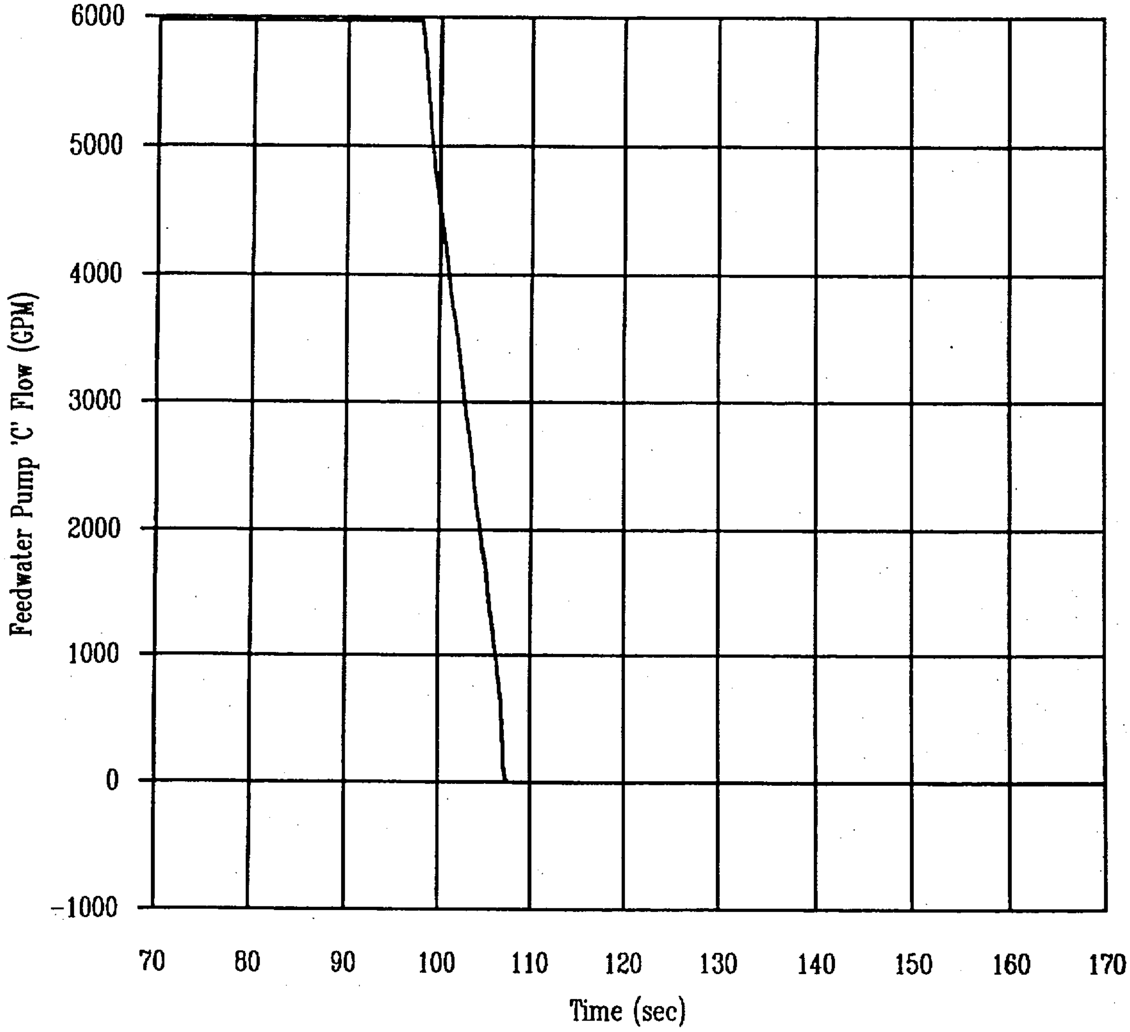

Figure 12
MSIV Closure on High MSLR
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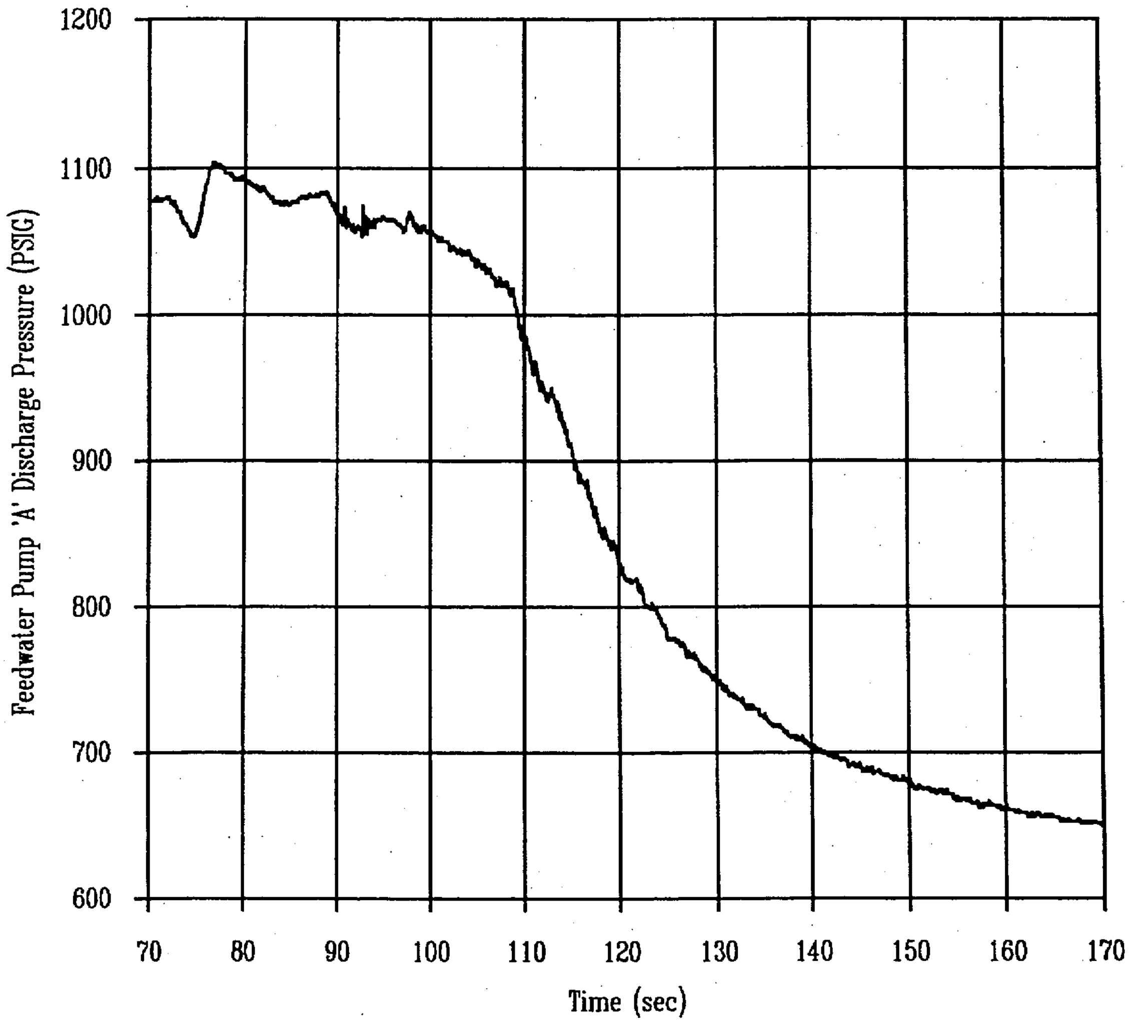

Figure 13
MSIV Closure on High MSLR
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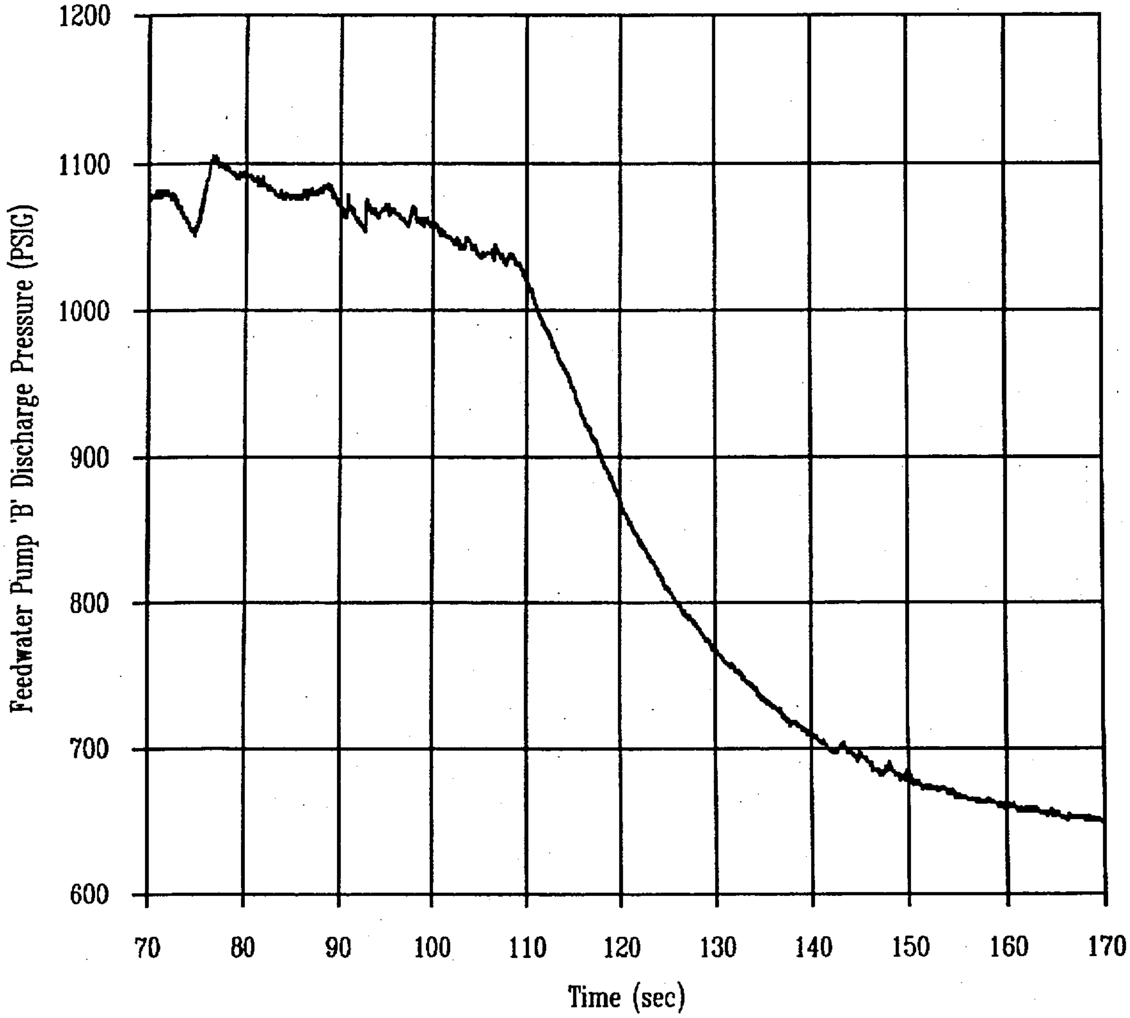

Figure 14
MSIV Closure on High MSLR
06/14/83
31-83070615023101

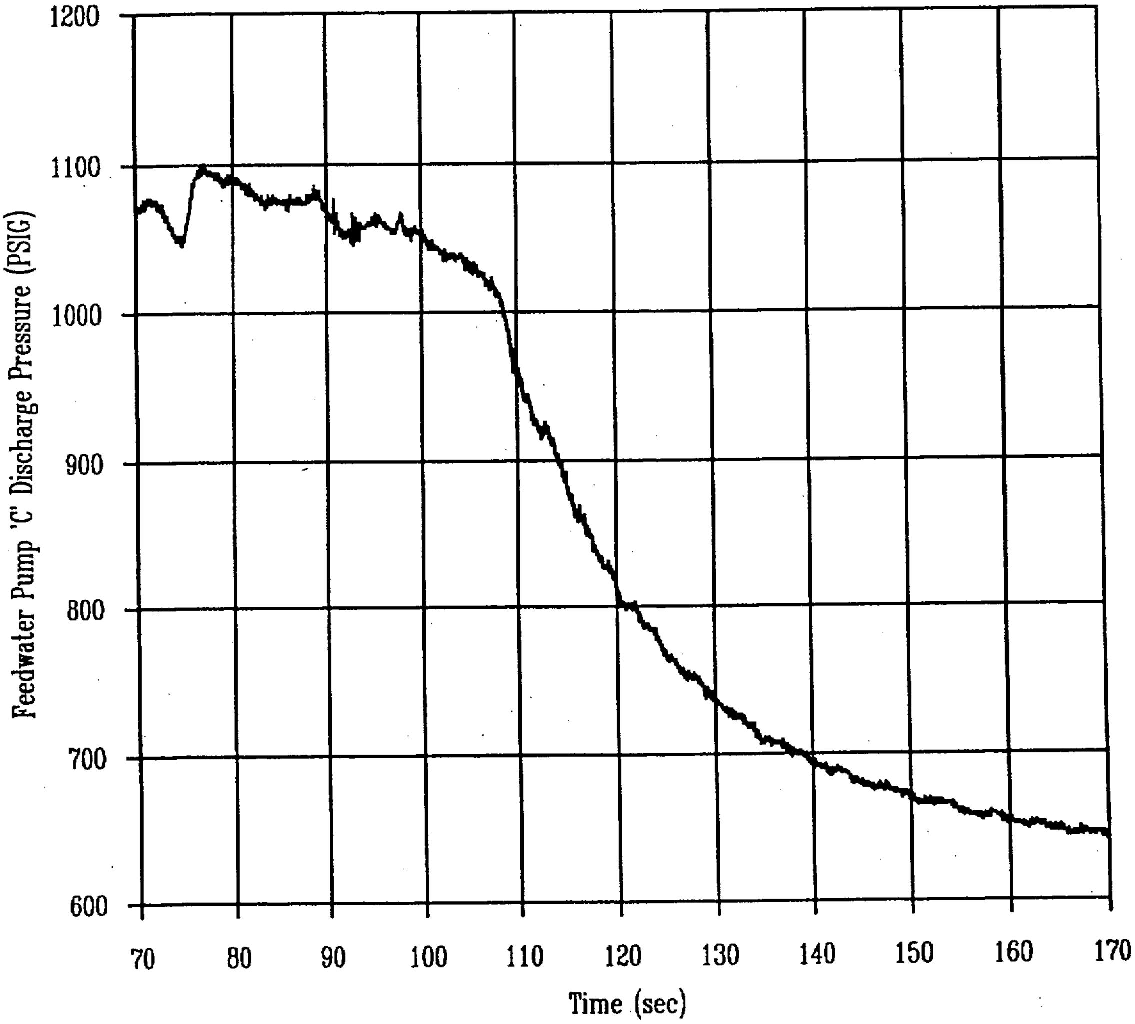

Figure 15
MSIV Closure on High MSLR
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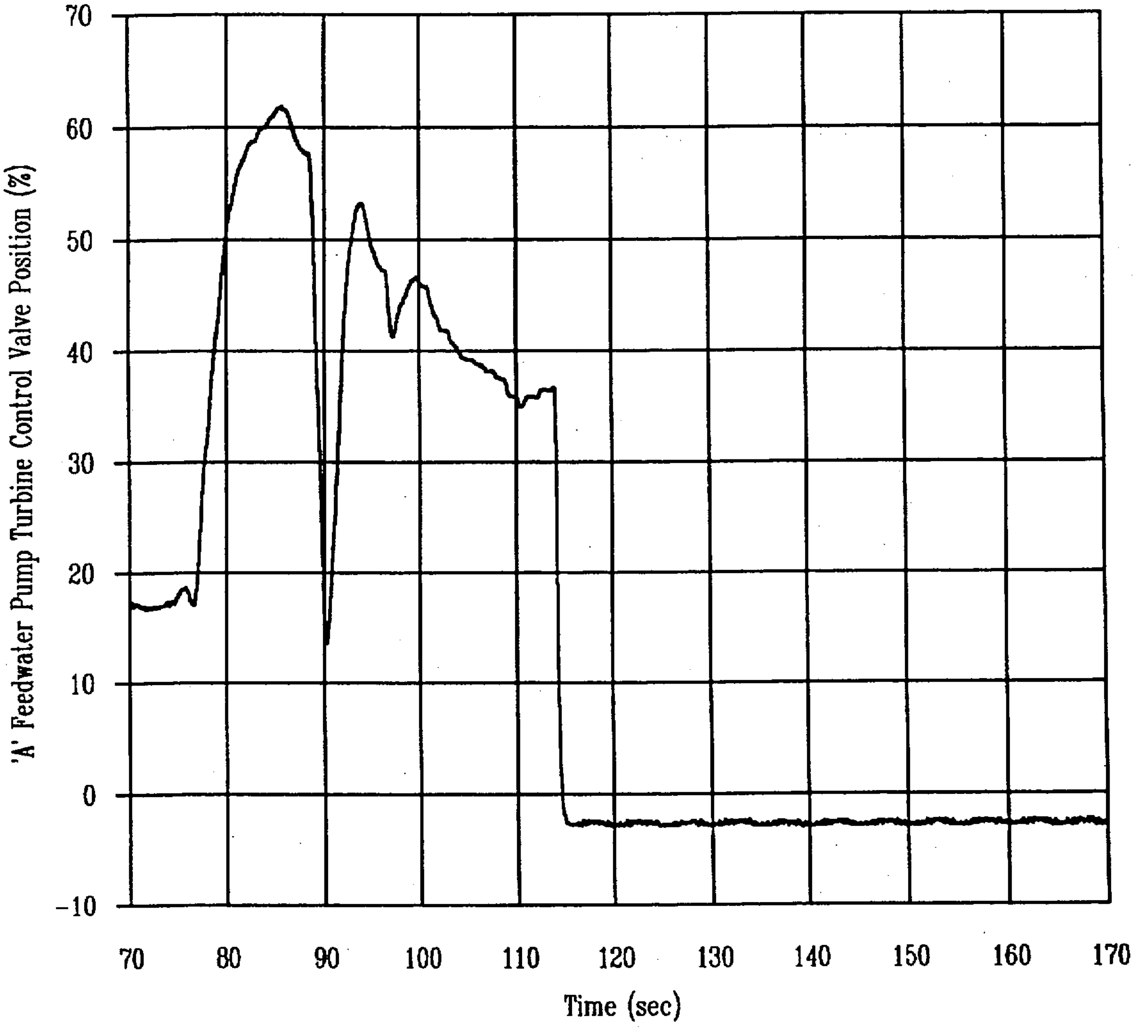
31-83070615023101



## Figure 16
## MSIV Closure on High MSLR
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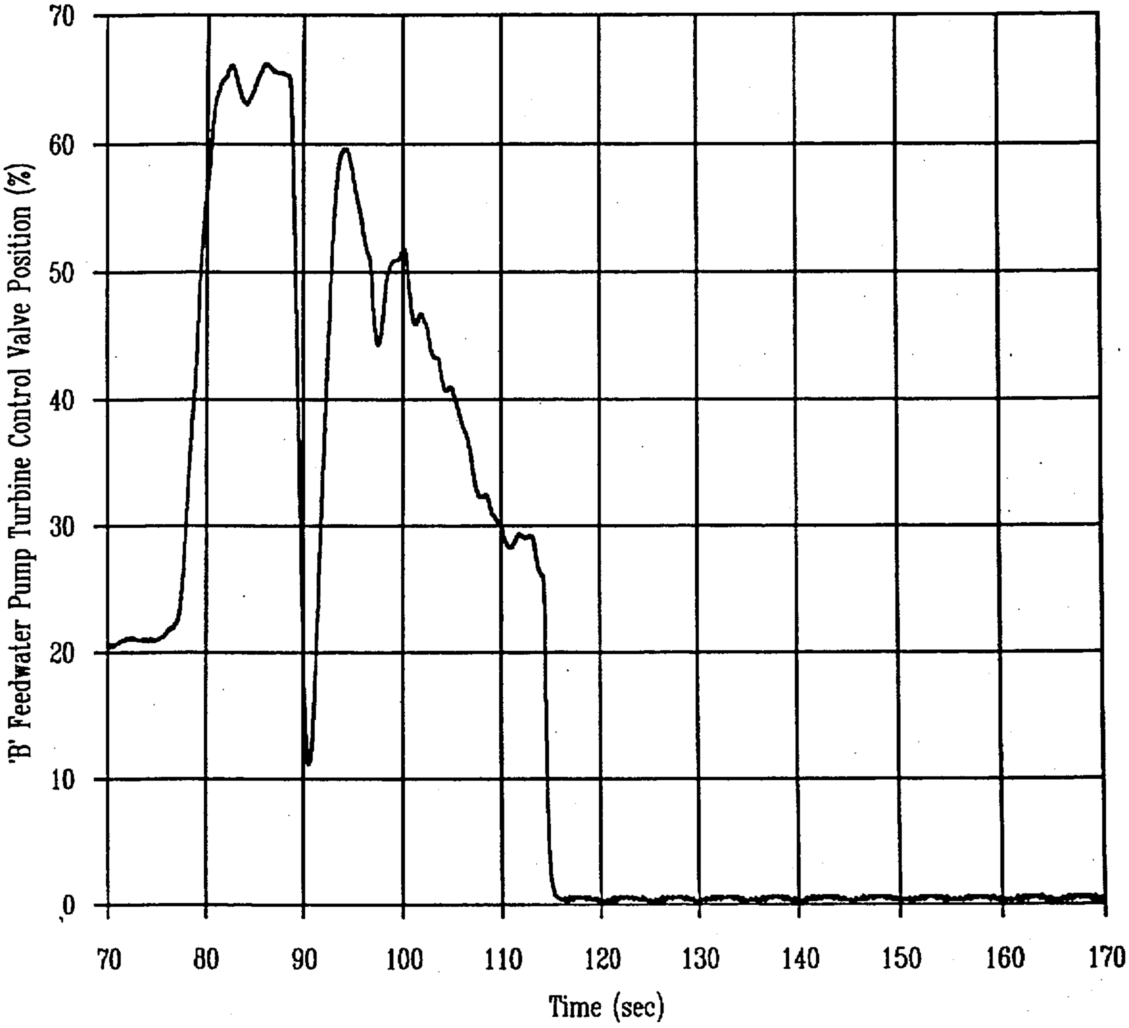
31-83070615023101



## Figure 17
## MSIV Closure on High MSLR
06/14/83

31-83070615023101

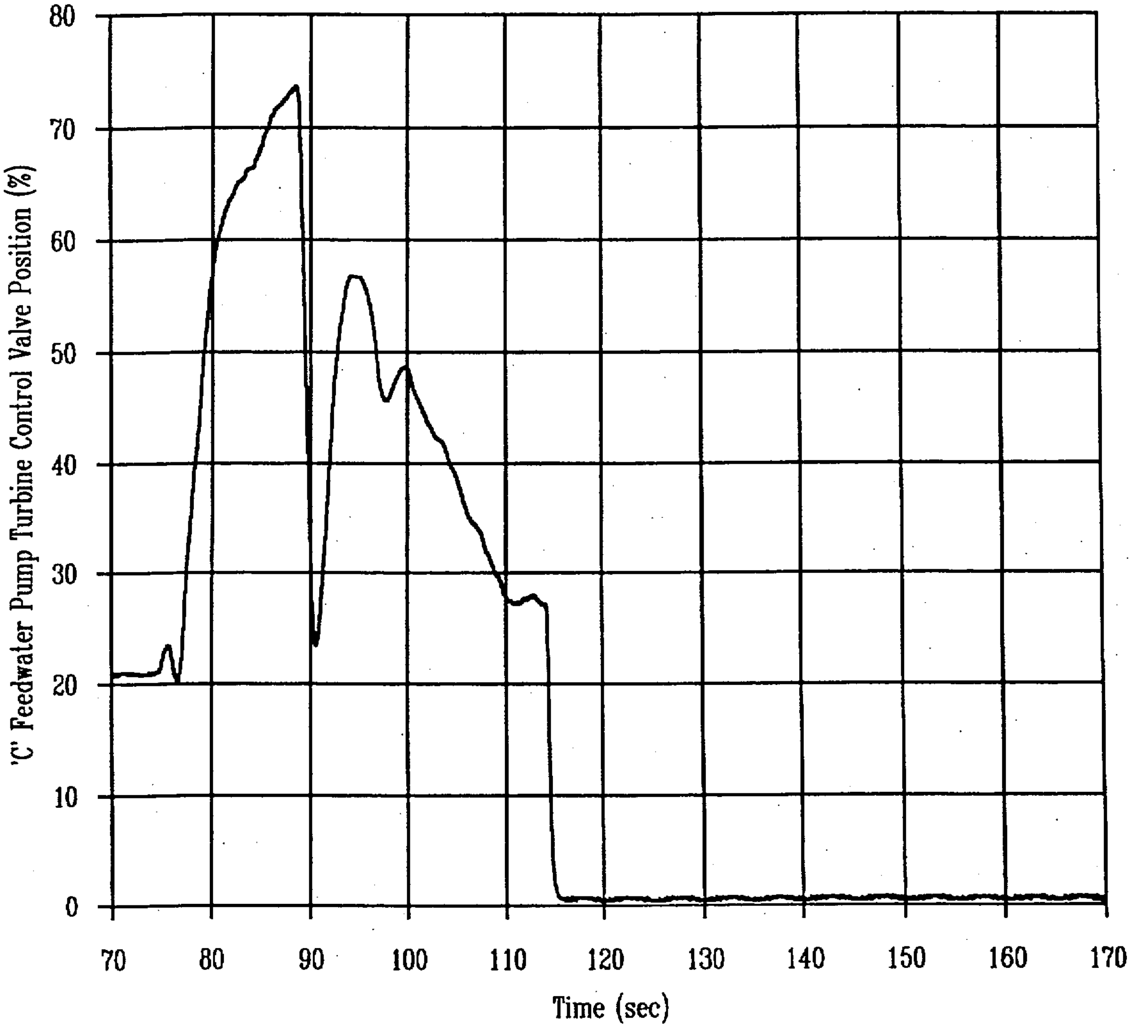


Figure 18
MSIV Closure on High MSLR
06/14/83
31-83070615023101

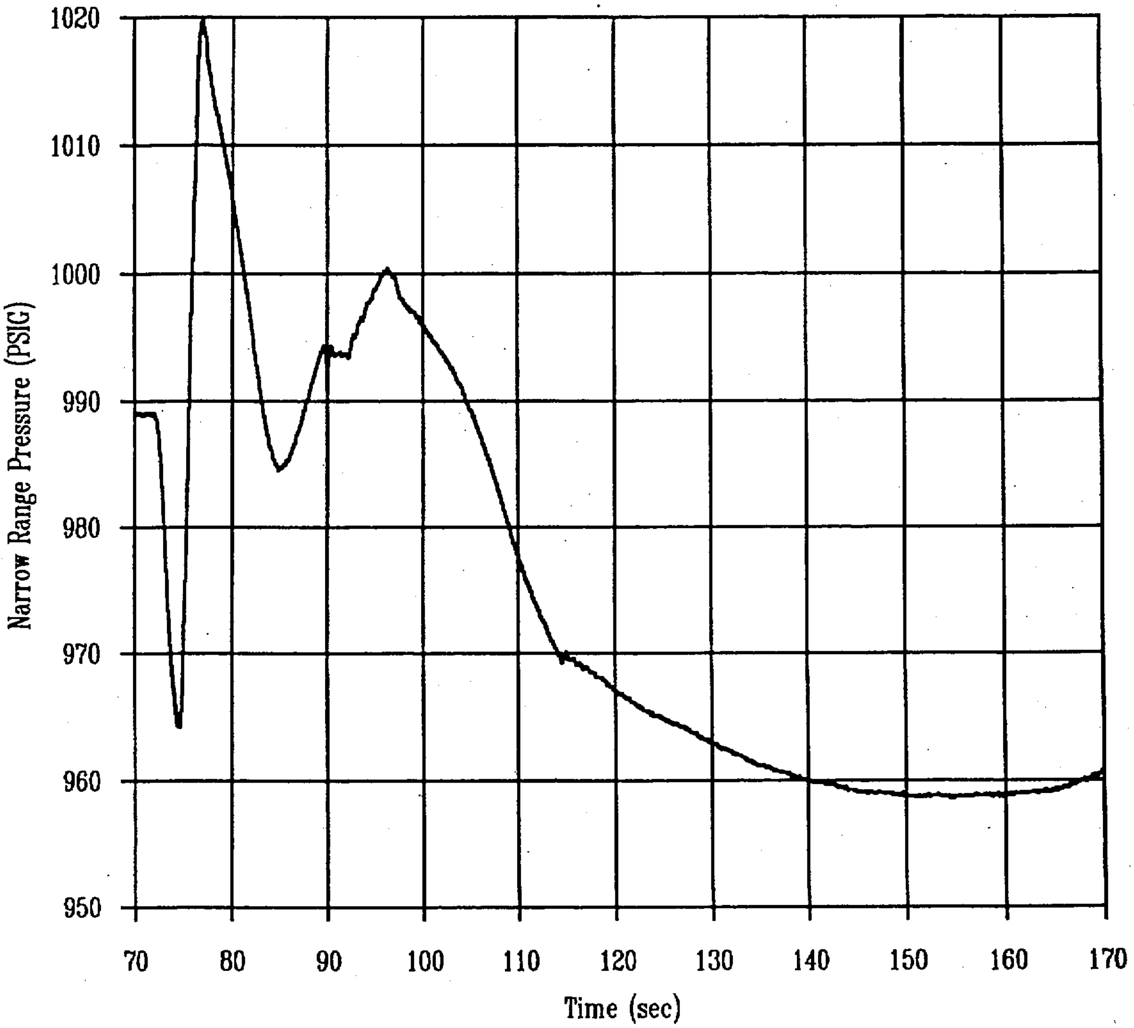
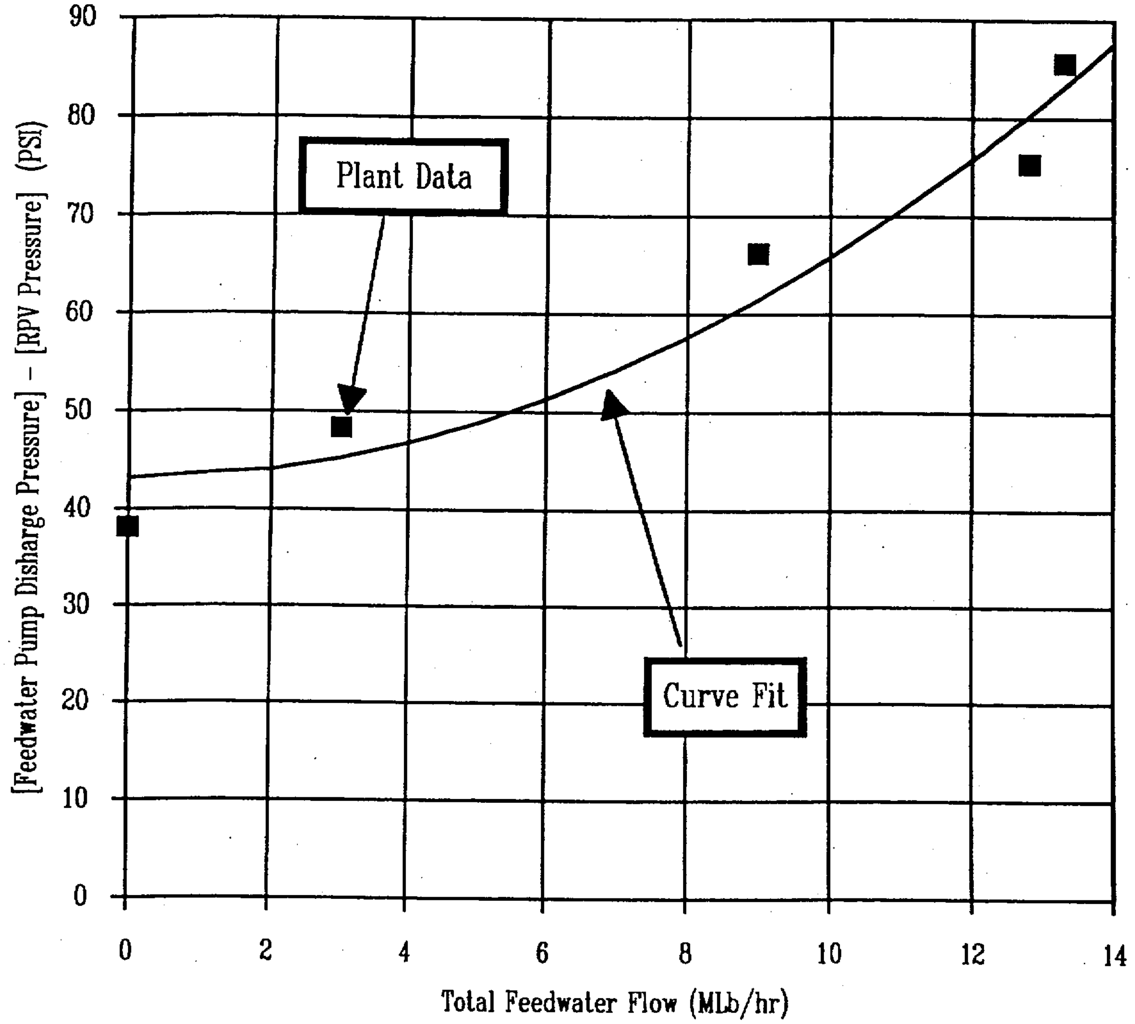
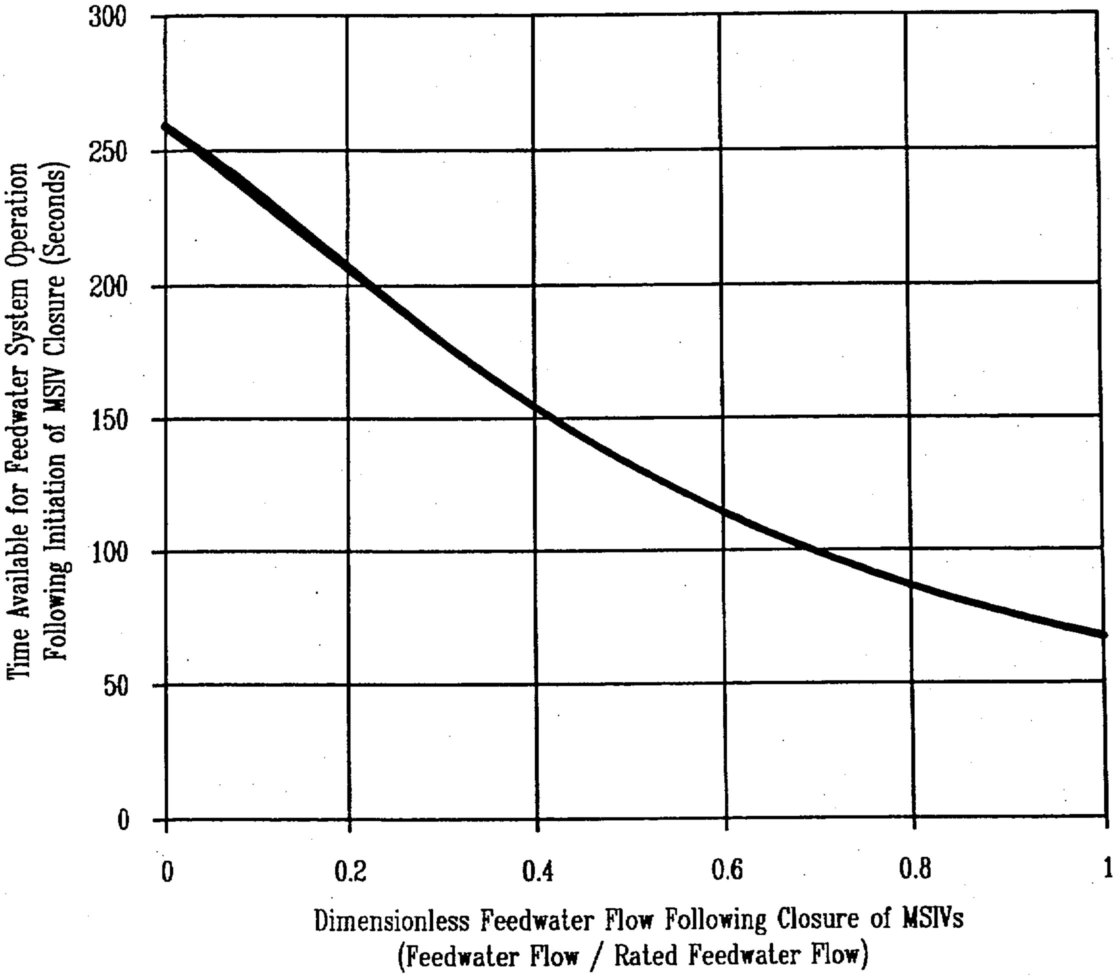


Figure 19
MSIV Closure on High MSLR
06/14/83
31-83070615023101



# Figure 20
Correlation Based on Data from
MSIV Closure on High MSLR
06/14/83
31-83070615023101



# APPENDIX A

## Calculation Details for Results Given in Equations (1) and (3)

The curve fit polynomials given by Equations (1) and (3) were obtained with the Mathematica computer code[9]. The input data files for the Mathematica calculations are given below:

### Input Data File Used to Obtain Equation (1)

*File Name:* D:\CHAIKO\MATH\FIT4.DAT

```
Fit[{ {13.3, 85.4}, {12.8, 75.3}, {9.0, 66.1}, {3.0, 48.2},
      { 0.0, 37.9} },
     {1, x^2   }, x ]
```

### Input Data File Used to Obtain Equation (3)

*File Name:* D:\CHAIKO\MATH\FIT5.DAT

```
Fit[{ {  0.0, 2.21}, {0.68, 5.898}, {1.00, 9.327}
       },
     {1, x, x^2   }, x ]
```

### Mathematica Output

```
In[3]:=                                    In[4]:=
  <<"D:\chaiko\math\\fit5.dat"               <<"D:\chaiko\math\\fit4.dat"
Out[3]=                                    Out[4]=
                                  2                                   2
  2.21 + 1.8249 x + 5.2921 x                 43.0395 + 0.22683 x
```

---

[9] Wolfram, S., *Mathematica-A System for Doing Mathematics by Computer*. Second Edition, p. 110, Addison-Wesley, New York, 1991.

# APPENDIX B
# NUMERICAL VALUES USED TO CONSTRUCT FIGURE 20

| $\frac{\text{(Feedwater Flow)}}{\text{(Rated Feedwater Flow)}}$ | $\lambda_{FW}$ (psi/sec) | $t^*$ (sec) |
|---|---|---|
| .00000 | 2.21000 | 259.13122 |
| .04000 | 2.29146 | 250.20331 |
| .08000 | 2.38986 | 240.23104 |
| .12000 | 2.50519 | 229.53971 |
| .16000 | 2.63746 | 218.42959 |
| .20000 | 2.78666 | 207.16287 |
| .24000 | 2.95280 | 195.95713 |
| .28000 | 3.13587 | 184.98423 |
| .32000 | 3.33588 | 174.37294 |
| .36000 | 3.55282 | 164.21393 |
| .40000 | 3.78670 | 154.56577 |
| .44000 | 4.03751 | 145.46108 |
| .48000 | 4.30525 | 136.91232 |
| .52000 | 4.58993 | 128.91683 |
| .56000 | 4.89155 | 121.46105 |
| .60000 | 5.21010 | 114.52395 |
| .64000 | 5.54558 | 108.07970 |
| .68000 | 5.89800 | 102.09971 |
| .72000 | 6.26735 | 96.55414 |
| .76000 | 6.65364 | 91.41298 |
| .80000 | 7.05686 | 86.64683 |
| .84000 | 7.47702 | 82.22742 |
| .88000 | 7.91411 | 78.12787 |
| .92000 | 8.36814 | 74.32297 |
| .96000 | 8.83910 | 70.78917 |
| 1.00000 | 9.32700 | 67.50466 |

# NUCLEAR ENGINEERING
# CALCULATION / STUDY COVER SHEET and
# NUCLEAR RECORDS TRANSMITTAL SHEET

File # R2-1

1. Page 1 of 33
Total Pages 34

➢2. TYPE: Calc. ➢3. NUMBER: EC-SATH-1007 ➢4. REVISION: 1

5. TRANSMITTAL#: K0010010 *➢6. UNIT: 3 *➢7. QUALITY CLASS: Q

➢9. DESCRIPTION: Installation of SABRE Computer Code in Systems Analysis' Production Library *➢8. DISCIPLINE: T

SUPERSEDED BY: EC-

10. Alternate Number:
11. Cycle:

12: Computer Code or Model used: SABRE3.001 Fichee ☒ Dis ☐ Am't 1 packet

13. Application:

*➢14 *Affected Systems:* NA 10/4/00

* If N/A then line 15 is mandatory.

**➢15. NON-SYSTEM DESIGNATOR: SATH

**If N/A then line 14 is mandatory

16. Affected Documents:

☒ SAR Change Req'd

17. References: EC-ATWS-0505, Rev. 8

18. Equipment / Component #:

19. DBD Number:

| | | |
|---|---|---|
| ➢20. PREPARED BY | Mark A. Chaiko<br>*Print Name* | Mark A Chaiko<br>*Signature* |
| ➢21. REVIEWED BY | Kevin W. Brinckman<br>*Print Name* | *Signature* |
| ➢21A. VERIFIED BY | Kevin W. Brinckman<br>*Print Name* | *Signature* |
| ➢22. APPROVED BY | Casimir A. Kukielka<br>*Print Name* | *Signature* |
| ➢23. ACCEPTED BY PP&L / DATE | *Print Name* | *Signature / DATE* |

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NR-DCS SIGNATURE/DATE Rosemarie Shadle

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## ENGINEERING CALCULATION STUDY
## REVISION DESCRIPTION SHEET

**EVISION NO:** 1

**CALCULATION NUMBER:** EC-SATH-1007

his form shall be used to record the purpose or reason for the revision, indicate the revised pages and / or affected sections and give a hort description of the revision. Check ( x ) the appropriate function to add, replace or remove the affected pages.

| Revised Pages | Affected Sections | Add | Rpl | Rmv | Description / Purpose of Revision |
|---|---|---|---|---|---|
| All | All | | x | | Revised this software QA package for SABRE code because a revision was made to the computer code. Code version is now SABRE3 Version 001. Code changes are documented in EC-ATWS-0505 Rev. 8. |
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☐ SUPERSEDED BY CALCULATION NUMBER EC-

☒ FULL REVISION ☐ PAGE FOR PAGE

# CONTENTS

## 1.0 Purpose

The purpose of this package is to install SABRE3 Version 001 (Ref. EC-ATWS-0505, Rev. 8) in production status on the Nuclear Technology Systems Analysis HP workstation j2240-c under the Systems Analysis Thermal Hydraulic analysis Software Quality Assurance (SQA) procedure EC-SATH-0005 Rev. 2. The software version identifier for this installation is Version 001 as documented on form EC-SATH-0005-1. Concurrently, SABRE3 Version 000 is removed from the production library.

## 2.0 Verification

The verification plan on form EC-SATH-0005-2 contained in this package was followed. The purpose of this verification is to demonstrate that installation of SABRE3 Rev. 001 into the production library j2240-c/d00/appl/sabre3v1 did not alter the results provided in the validation calculation EC-ATWS-0505 Rev. 8. The verification cases listed on EC-SATH-0005-7 were run and numerical results compared with identical cases from the SABRE3 Rev. 001 validation package EC-ATWS-0505 Rev. 8. The results of the verification runs are contained on the microfiche included with this package. Numerical output for the validation runs are contained on microfiche included with EC-ATWS-0505 Rev. 8. Comparison of the numerical results from the validation runs and the current verification runs show identical agreement. It was also verified that the script sabre3.v0, which runs SABRE3 Rev. 000, is no longer active.

## 3.0 Compiler Source Listing

The FORTRAN source code for SABRE3 Version 001 is included on microfiche in the validation package EC-ATWS-0505 Rev. 8.

## 4.0 User Instructions

SABRE3 Version 001 (which runs SABRE source code documented in Calc. EC-ATWS-0505, Rev. 8) is executed from the j2240-c production directory j2240-c/d00/appl by typing the command:

```
"sabre3.vl p1 p2 p3 p4 p5"
```

where p1 through p5 are positional input parameters. These input parameters are defined as follows:

p1: name of SABRE3.001 input file (including absolute path),
p2: name of 1-D cross section file including absolute path (This is a SIMTRAN-E output file as described in EC-ATWS-0505, Rev. 8),
p3: "y" if this is a restart case. "n" if this is not a restart case (do not include quotes).
p4: absolute path defining where SABRE output is to be placed
p5: name of restart file including absolute path if p3=y. If p3=n, this parameter can be omitted.

## 5.0 Ancillary Software

The script "sabre3.v1" used to run the production executable of SABRE3 Version 001 on j2240-c is located on j2240-c in the production applications subdirectory /d00/appl and is documented in Appendix A of this package.

The script "sabre3.v1" calls script "sabre3v1rn" from the j2240-c/d00/appl/sabre3v1 production directory which increments a counter obtained from the file j2240-c/d00/appl/sabre3v1/sabre3v1.cnt to assign the unique run number yy-nnn[‡] to the run, and calls the script "sabre3v1rn" from the production library j2240-c/d00/appl/sabre3v1 which writes the banner page to the output file, calls the SABRE3 Rev. 001 executable "sabre3v1.ex" and redirects the output to the unique file p4/sabre3v1.yy-nnn.out where p4 is the positional input parameter defined above. The script "sabre3v1rn" also calls accounting routines and prints the CPU time used for the current run to the bottom of the output file. The script "sabre3v1rn" is included in Appendix B. A restart file p4/Restart.yy-nnn.out is also generated for each SABRE case that is run.

SABRE cases can be stacked using a script file. The script file included in Appendix C provides an example for submitting stacked SABRE cases. If it is desired to cancel a SABRE run after it has been submitted the user should not use 'Ctrl C' as this will prevent execution of the next SABRE case that is submitted. All jobs should be cancelled using the UNIX 'kill' command.

## 6.0 Code Compilation

The SABRE3 Rev. 001 source code contained in EC-ATWS-0505, Rev. 8 was compiled using the make file listed in Appendix D which creates the executable "/d00/appl/sabre3v1/sabre3v1.ex".

## 7.0 Y2K Compliance

N/A

## 8.0 Restart Capability

Validation problem 1 on the Verification Computer Case Summary Sheet (form EC-SATH-0005-7) was run up to t=60 seconds in Run#00-51. This problem was run to 120 seconds in Run #00-53. Using the restart file from Run #00-51, the problem was restarted from t=60 seconds and run to 120 seconds in Run #00-52. In Figure 1, the reactor pressure calculated in Run #00-52 (t=60 sec to t=120 sec) is compared against the reactor pressure calculated in Run #00-53. There is no noticeable difference in the results. This demonstrates that the SABRE restart option works correctly.

## 9.0 Screening Determination

The Screening Determination for the SABRE code is included in Appendix E.

---

[‡] yy=last two digits of current year, and nnn=unique number for that year.

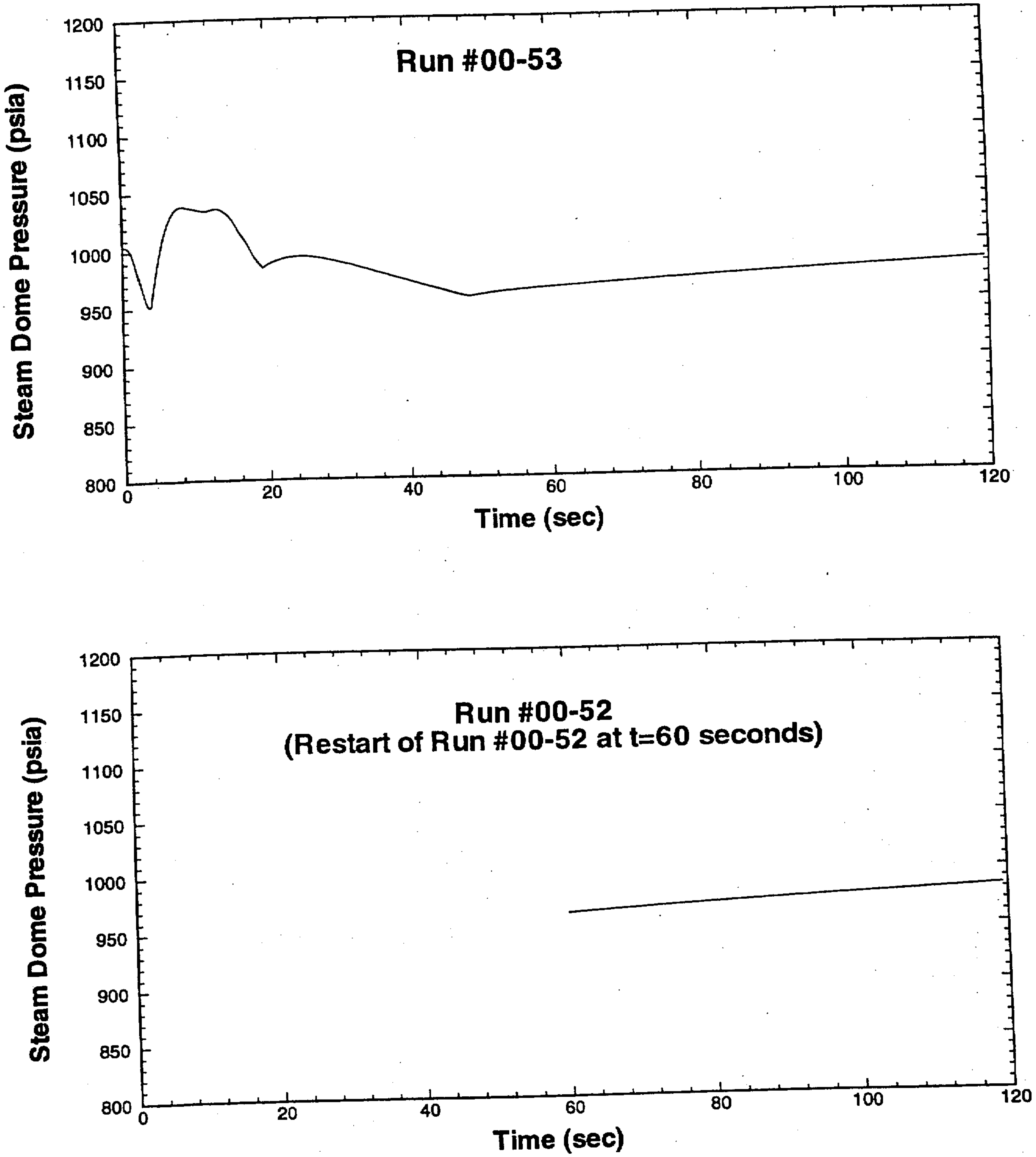

Figure 1 Test of SABRE restart capability.

1 - 0 -

# SATH PRODUCTION SOFTWARE QUALITY ASSURANCE PLAN

a) Software Products Name: SABRE3

Version Identifier (NNN): 001

b) Lead Engineer: Mark A. Chaiko

c) Scope/requirements:

Revision 1 of EC-SATH-1007 installs SABRE3 Version 001, documented in EC-ATWS-0505 Rev. 8, into Systems Analysis HP workstation j2240-c production library /j2240-c/d00/appl/sabre3v1. This is a new installation. SABRE will be used to perform licensing analyses of ATWS events for Susquehanna. Concurrent with this installation, SABRE3 Version 000 will be deleted from the production library.

d) Resource Requirements:

1) Hardware: HP Workstation j2240-c, Host ID 2005192266 with Unix operating system HP 10.20

2) Software: Fortran 77 compiler

3) Technical: SABRE simulates reactor transients involving scram failure. The code simulates reactor shutdown with boron injection and/or with manual rod insertion. Also, primary containment response is simulated.

e) Extraordinary Documentation and/or Review Requirements (if any): None

f) Verification Plan: Validation Document: EC-ATWS-0505 Rev. 8

(1) SABRE3 Version 001 installed on workstation j2240-c (HOST ID 2005192266) is validated in EC-ATWS-0505 Rev. 8 and was benchmarked against plant data and results obtained by other analytical methods.

(2) SABRE3 Version 001 will be installed in test mode on the HP workstation j2240-c in directory /j2240-c/d00/appl/sabre3v1. While in test mode, a warning message will be printed on the banner page so that results will not be unknowingly used in a quality-related calculation.

(3) Acceptance Criteria: SABRE3 Version 001 installed via this package should reproduce the results in the validation package EC-ATWS-0505 Rev.8 for SABRE Cases 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13,14, and 15 (see Computer Case Summary in EC-ATWS-0505, Rev. 8). Any discrepancies must be explained and dispositioned or corrected. The script "sabre3.v1" in production directory j2240-c/d00/appl used to run the production code SABRE3 Version 001 should also be verified to properly echo and increment the unique Run #. Upon satisfying the acceptance criteria, the warning should be removed from the banner page, and SABRE3 Version 001 will be in production status on workstation j2240-c.

(4) In order to verify that SABRE3 Version 000 has been removed from the production library, an attempt will be made to run SABRE3 Version 000 by invoking the HPUX script file "sabre3.v0". It should be verified that sabre3.v0 does not execute SABRE3 Version 000 and no output is generated.

g) Required training:

Users of SABRE3 Version 001 must (1) Review Sections 1 (Introduction), 4 (Code Limitations) and Appendices F and G (Code input) of Validation package EC-ATWS-0505, Rev. 8, and (2) Perform sit-down training with a qualified SABRE3 Version 001 user, who has previously performed a Q analysis with SABRE3 Version 001 or has demonstrated competence with the code by accurately replicating sample problems contained in EC-ATWS-0505 Rev. 8.

Prepared By: Mark A Chaiko

Reviewed By: 9/21/00

Approved By:

Approval Date: 9/21/2000

PCC Number: EC-SATH-1007 Rev. 1

page 1

# SATH SOFTWARE INSTALLATION REQUEST

Lead Engineer: Mark A. Chaiko

Software Name: SABRE3 Version 001

Software Type: Compiled FORTRAN executable w/ production script

Reason For Request: Installation of SABRE3 Version 001 in production library on Systems Analysis workstation j2240-c and removal of SABRE3 Version 000 from production library on Systems Analysis workstation j2240-c

Software Validation Calculation Number: EC-ATWS-0505 Rev. 8

Approval:

Supervising Engineer: Date: 9/21/2000

PCC Calculation Number: EC-SATH-1007 Rev. 0

Form EC-SATH-0005-3

# SATH SOFTWARE Q/A CERTIFICATE

Lead Engineer: Mark A. Chaiko

Software QA Level
2

Software Name: SABRE3 Version 001

Source Code Language: FORTRAN 77

Platform:
Op. System: HP 10.20 Server Host ID: 2005192266

PCC Calculation Number: EC-SATH-1007 Rev. 1

Pre-Production Location Information

| | Absolute Path | Filename | Creation Date |
|---|---|---|---|
| Source Code: | /home/eamac/sabre_31/ source_code | *.f (* represents subroutine names) | 11/19/99 to 09/14/00 |
| | /home/eamac/sabre_31/ source_code/common | *.txt (* denotes common block name) | 08/27/99 to 11/30/99 |
| Executable Module: † | /home/eamac/sabre_31/test | sabre3v1.test | 09/14/00 |

I/O List

| Unit # | I/O Description | Software Internal Filename |
|---|---|---|
| 4 | input data (reactor & containment data) | SABRE_##.inp UNIX standard input redirected from user specified parameter #1 |
| 9 | input data (status of restart) | SABRE_##.temp.inp UNIX standard input redirected from user specified parameter #3 |
| 5 | input data (cross-section file) | SIMTRAN_##.inp UNIX standard input redirected from user specified parameter #2 |
| 3 | input data (restart file) | Restart.dat UNIX standard input redirected from user specified parameter #5 |
| 1 | output file | Rx1.out |
| 15 | output file | Rx2.out |
| 18 | output file | Boron.out |
| 2 | output file | MSL.out |
| 16 | output file | Makup.out |
| 10 | output file | Generl.out |
| 11 | output file | HPCI.out |
| 3 | output file (dump of restart data) | Restart.dat |
| 12 | output file | Cont1.out |
| 17 | output file | Cont2.out |
| 13 | output file | Break.out |
| 14 | output file | Mesg.txt |

Form EC-SATH-0005-4, sh. 1

† Code compiled by the command 'make' typed from directory /d00/appl/sabre3v1/source_code.

## Production Location Information

|  | Absolute Path | Filename | Creation Date |
|---|---|---|---|
| Source Code: | /d00/appl/sabre3v1/source_code<br>/d00/appl/sabre3v1/source_code/common | *.f where * denotes names of subroutines<br>*.txt (* denotes common block name) | 9/21/00 |
| Executable Module: | /d00/appl/sabre3v1 | sabre3v1.ex | 9/21/00 |

## Execution Syntax

Exact Call Name: sabre3.v1 (See Appendix A for script listing)

Positional Parameters:

| PRAM # | Description | Default |
|---|---|---|
| 1 | SABRE reactor and containment data file | none |
| 2 | 1-D cross-section file | none |
| 3 | Restart flag (y/n) | none |
| 4 | Directory where output is to be directed | none |
| 5 | Restart file if #3=y | none |

## User Input, Output File Syntax

| Unit # | Filename |
|---|---|
| 4 | (SABRE reactor and containment data) Name specified as positional parameter #1. |
| 5 | (Cross-section file) Name specified as positional parameter #2. |
| 9 | Status of restart (y=restart, n=not a restart). y or n specified as positional parameter #3. |
| 3 | If positional parameter #3=y, then the name of a restart file must be supplied as positional parameter #5. |
| 3 | Restart.yy-nn.out (Dump of restart data) yy=year, nn=run# for current year |
| 1, 2, 10, 11, 12, 13, 14, 15, 16, 17, 18 | sabre3v1.yy-nn.out This is the SABRE output file. It is obtained by merging files: Rx1.out, Rx2.out, Cont1.out, Cont2.out, Boron.out, Break.out, MSL.out, Makup.out, Generl.out, HPCI.out, and Mesg.txt. |

Updated Software Version Number: 001-00-271

Installation Signoff

System Administrator: Date 9/21/00

Software Verification Signoff:

Lead Engineer: Mark A. Charter Date 9/22/00

Review Engineer: Date 9/22/00

Supervising Engineer: Date 9/27/00

Warning removed from banner page:

System Administrator: Date 9/27/00

# Verification Computer Case Summary Sheet

| Case ID | Case Description | Comparison Case Reference | Notes * |
|---|---|---|---|
| 00-53 | Validation problem 1 | SABRE Case 1 in EC-ATWS-0505 Rev. 8 | |
| 00-54 | Validation problem 2 | SABRE Case 2 in EC-ATWS-0505 Rev. 8 | |
| 00-55 | Validation problem 3 | SABRE Case 3 in EC-ATWS-0505 Rev. 8 | |
| 00-56 | Validation problem 4 | SABRE Case 4 in EC-ATWS-0505 Rev. 8 | |
| 00-57 | Validation problem 5 | SABRE Case 5 in EC-ATWS-0505 Rev. 8 | |
| 00-58 | Validation problem 6 | SABRE Case 6 in EC-ATWS-0505 Rev. 8 | |
| 00-59 | Validation problem 7 | SABRE Case 7 in EC-ATWS-0505 Rev. 8 | |
| 00-60 | Validation problem 8 | SABRE Case 8 in EC-ATWS-0505 Rev. 8 | |
| 00-61 | Validation problem 10 | SABRE Case 10 in EC-ATWS-0505 Rev. 8 | |
| 00-62 | Validation problem 11 | SABRE Case 11 in EC-ATWS-0505 Rev. 8 | |
| 00-63 | Validation problem 12 | SABRE Case 12 in EC-ATWS-0505 Rev. 8 | |
| 00-64 | Validation problem 13 | SABRE Case 13 in EC-ATWS-0505 Rev. 8 | |
| 00-65 | Validation problem 14 | SABRE Case 14 in EC-ATWS-0505 Rev. 8 | |
| 00-66 | Validation problem 15 | | |
| 00-67 | Validation problem 1 | SABRE Case 01 in EC-ATWS-0505 Rev. 8 | 1 |
| 00-51 | Validation problem 1 run to 60 sec | | 2 |
| 00-52 | Restart of 00-51 run to 120 sec | | 3 |

Notes:

(1) This is a re-run of Validation problem 1 after the warning banner was removed. No difference in numerical output was observed.

(2) This is Validation problem 1 run up to t=60 seconds. The validation problem normally runs to t=120 sec.

(3) This is a restart of validation problem 1 at t=60 seconds. The restart is run until t=120 seconds. Pressure result after restart is compared to Run #00-53 in Figure 1. There is no noticeable difference in the calculated pressure.

* If case comparison comment is necessary, insert unique note ID in Notes Column and add comment preceded by note ID in space provided above. Use additional sheets if necessary.

# Appendix A
## UNIX Script File 'sabre3.v1'

```
#!/bin/ksh
### sabre3.v1  executes SABRE Version 3.1 on Systems Analysis Workstation J2240-c
###            see EC-SATH-1007 Rev. 1 for details
### This file reads /d00/appl/sabre3v1/sabre3v1.cnt, assigns a unique run number to the job
### then executes sabre3v1m
###
### This script requires 4 positional input parameters:
###      $1 = SABRE input data file (absolute address)
###      $2 = 1-D cross section file (absolute address)
###      $3 = y or n (y=restart job; n=not a restart)
###      $4 = user directory where output files are to be placed (absolute address)
###      $5 = restart data file if $3=y
###
### Check if sabre3v1 is in use. If in use, exit.
### /d00/appl/sabre3v1/tmp/status:  1=in use  0=not in use
    read check </d00/appl/sabre3v1/tmp/status
    if [ $check = 1 ]
       then echo 'Sabre3.v1 currently in use. Try again later.'
       exit
       else echo '1'>/d00/appl/sabre3v1/tmp/status
    fi

    username=`whoami`
    echo "$username" >/d00/appl/sabre3v1/tmp/uid
### Read previous job number and year
    read prnum pryr </d00/appl/sabre3v1/sabre3v1.cnt
### Get current year
    cyr=`date +%y`
### If the previous year < current year reset job start counter and run counter to zero
### and copy new value to run counter file
    if ((cyr!=pryr))
    then prnum=0
    fi
### Increment job number
    let rnum=prnum+1
### Write current job number and year to /d00/appl/sabre3v1/sabre3v1.cnt
### echo $rnum $cyr >/d00/appl/sabre3v1/sabre3v1.cnt
### Run the job
### Determine if this is a restart case
    restart=$3
    if [ $restart = y ]
       then restart=Y
       else restart=$restart
    fi
    if [ $restart = n ]
       then restart=N
       else restart=$restart
    fi
    if [ $restart = Y ]
       then /d00/appl/sabre3v1/sabre3v1m $cyr $rnum $1 $2 $3 $4 $5
       else /d00/appl/sabre3v1/sabre3v1m $cyr $rnum $1 $2 $3 $4
    fi

#   reset flag in status file
    echo '0'>/d00/appl/sabre3v1/tmp/status
    exit
```

# Appendix B
## UNIX Script File 'sabre3v1rn'

```
#!/bin/ksh
### EC-SATH-1007  Rev. 1  SABRE3.V1 on J2240-c
### This file executes SABRE3.V1, assigns a unique run number to the
### job then prints the production library banner.  In addition, it
### prints date and time and computer usage information
### at the end of the run.

### Set the working directories
    dir="/d00/appl/sabre3v1"
    dirt="/d00/appl/sabre3v1/tmp"

    echo 'sabre3.v1  Execution Initiated'

    yr=$1
    rnum=$2
### Write current job number and year to /d00/appl/sabre3v1/sabre3v1.cnt
    echo $rnum $yr >/d00/appl/sabre3v1/sabre3v1.cnt


### Read the user ID
    read username < $dirt/uid

### Read in current time so that correct accounting data can be
### printed at the end of the run. Decrement hour by one to fix a
### quirk in acctcom, it will increment the input time by one hour
### to give proper time.  "sstr1 and sstr2" set a start time band so that
### acctcom can filter all but the current job.
    hstr=`date +%H`
    mstr=`date +%M`
    sstr=`date +%S`
    let sstr1=sstr-2
    let sstr2=sstr+2
    str1="$hstr:$mstr:$sstr1"
    str2="$hstr:$mstr:$sstr2"


### Assign simple names to output files
    out01=$dirt/Boron.out
    out02=$dirt/Break.out
    out03=$dirt/Cont1.out
    out04=$dirt/Cont2.out
    out05=$dirt/Generl.out
    out06=$dirt/HPCI.out
    out07=$dirt/MSL.out
    out08=$dirt/Makup.out
    out09=$dirt/Mesg.txt
    out10=$dirt/Rx1.out
    out11=$dirt/Rx2.out


    echo '1' >$out05

    echo "\n\n\n\n\n\n\n\n\n\r">>$out01
    echo "\n\n\n\n\n\n\n\n\n\r">>$out02
    echo "\n\n\n\n\n\n\n\n\n\r">>$out03
    echo "\n\n\n\n\n\n\n\n\n\r">>$out04
    echo "\n\n\n\n\n\n\n\n\n\r">>$out05
    echo "\n\n\n\n\n\n\n\n\n\r">>$out06
    echo "\n\n\n\n\n\n\n\n\n\r">>$out07
    echo "\n\n\n\n\n\n\n\n\n\r">>$out08
    echo "\n\n\n\n\n\n\n\n\n\r">>$out09
    echo "\n\n\n\n\n\n\n\n\n\r">>$out10
    echo "\n\n\n\n\n\n\n\n\n\r">>$out11
 ### Print SABRE3.V1 production library banner page with unique run number
    banner " SABRE3 V1">>$out05
    echo "\n\n\n\r">>$out05
    echo " SATH Version# 001-00-271 ">>$out05
    echo "\n\n\n\r">>$out05
    echo '   This program was executed from the Systems Analysis HP Workstation'>>$out05
    echo '         Production Library in accordance with EC-SATH-0005 Rev. 2   '>>$out05


    echo "\r">>$out05
    echo "                        \c">>$out05
    date>>$out05
    echo "\n\r">>$out05
```

```
    echo "                    Run Number $yr-$rnum">>$out05

### Give names to positional parameters
    sf=$3
    kf=$4
    rs=$5
    do=$6
    rf=$7

### If sabre input file exists copy it to appl directory
    if test -f $sf
       then echo 'Reading SABRE Input File  '
            cp $sf $dirt/SABRE_##.inp
       else echo 'SABRE input file does not exist'
            exit
    fi

### If kinetics file exists copy it to appl directory
    if test -f $kf
       then echo 'Reading Kinetics file  '
            cp $kf $dirt/SIMTRAN_##.inp
       else echo 'Kinetics input file does not exist'
            exit
    fi

### Print name of kinetics file in output file
    echo '    ' >> $dirt/Generl.out
    echo "**** Kinetics file is $kf " >> $dirt/Generl.out
    echo '    ' >> $dirt/Mesg.txt
    echo "**** Kinetics file is $kf " >> $dirt/Mesg.txt

### Print name of sabre data file in output file
    echo '    ' >> $dirt/Generl.out
    echo "**** SABRE data file is $sf " >> $dirt/Generl.out
    echo '    ' >> $dirt/Generl.out
    echo '    ' >> $dirt/Mesg.txt
    echo "**** SABRE data file is $sf " >> $dirt/Mesg.txt
    echo '    ' >> $dirt/Mesg.txt

### Determine if this is a restart case
    if [ $rs = y ]
       then rs=Y
       else rs=$rs
    fi
    if [ $rs = n ]
       then rs=N
       else rs=$rs
    fi
    if [ $rs = Y ]
       then echo ' 1 ' >> $dirt/SABRE_##.temp.inp
              cp $rf $dirt/Restart.dat
            echo "**** SABRE restart file is $rf " >> $dirt/Generl.out
            echo '    ' >> $dirt/Generl.out
            echo "**** SABRE restart file is $rf " >> $dirt/Mesg.txt
            echo '    ' >> $dirt/Mesg.txt
       else echo ' 0 ' >> $dirt/SABRE_##.temp.inp
            echo "**** This is not a restart case" >> $dirt/Generl.out
            echo '    ' >> $dirt/Generl.out
            echo "**** This is not a restart case" >> $dirt/Mesg.txt
            echo '    ' >> $dirt/Mesg.txt
    fi

### Run sabre code
###
### Execute SABRE3.V1 and run acctcom
###
    $dir/sabre3v1.ex

    echo "\n\n\n">>$out01
    echo "\n\n\n">>$out02
    echo "\n\n\n">>$out03
    echo "\n\n\n">>$out04
    echo "\n\n\n">>$out05
    echo "\n\n\n">>$out06
    echo "\n\n\n">>$out07
    echo "\n\n\n">>$out08
    echo "\n\n\n">>$out09
    echo "\n\n\n">>$out10
    echo "\n\n\n">>$out11

    echo "Print Accounting Data">>$out09
    /usr/lib/acct/acctcom -n sabre3v1 -ht -S$str1 -e$str2 /var/adm/pacct >>$out09
    echo "Stop Printing Accounting Data" >>$out09
```

```
### Put run number on restart file
    mv $dirt/Restart.dat $do/Restart.$yr-$rnum.dat

### Create unique output file
    f1="$dirt/Generl.out"
    f2="$dirt/Rx1.out"
    f3="$dirt/Rx2.out"
    f4="$dirt/Cont1.out"
    f5="$dirt/Cont2.out"
    f6="$dirt/Boron.out"
    f7="$dirt/Break.out"
    f8="$dirt/HPCI.out"
    f9="$dirt/MSL.out"
    f10="$dirt/Makup.out"
    f11="$dirt/Mesg.txt"
    cat $f1 $f2 $f3 $f4 $f5 $f6 $f7 $f8 $f9 $f10 $f11 >$dirt/sabre3v1.$yr-$rnum.out
    mv $dirt/sabre3v1.$yr-$rnum.out $do

### Change ownership of files
    chown $username  $do/sabre3v1.$yr-$rnum.out
    chown $username  $do/Restart.$yr-$rnum.dat

### Clean up tmp directory
    chmod a+w $dirt/*.out
    chmod a+w $dirt/*.txt
    chmod a+w $dirt/*.inp
    rm $dirt/*.out
    rm $dirt/*.txt
    rm $dirt/*.inp

    exit
```

# Appendix C
## Sample Script File for Stacking SABRE Cases

```
#!/bin/ksh
di=/home/eamac/sabre_31/input/ec-atws-0505
dk=/d00/appl/sabre3v1/data
do=/home/eamac/sabre_31/output/ec-sath-1007
###
###        SABRE Input File    1-D Kinetics File        Restart?    Output Directory    Restart File
###                                                       (y/n)
###
sabre3.v1  $di/c01a.dat        $dk/u2c7.simtran.out        n         $do/c01a
sabre3.v1  $di/c01.dat         $dk/u2c7.simtran.out        y         $do/c01a           $do/c01a/Restart.00*.dat
sabre3.v1  $di/c01.dat         $dk/u2c7.simtran.out        n         $do/c01
sabre3.v1  $di/c02.dat         $dk/u2c10.simtran.out       n         $do/c02
sabre3.v1  $di/c03.dat         $dk/u2c9.simtran.out        n         $do/c03
sabre3.v1  $di/c04.dat         $dk/u2c9.simtran.out        n         $do/c04
sabre3.v1  $di/c05.dat         $dk/u2c10.simtran.out       n         $do/c05
sabre3.v1  $di/c06.dat         $dk/u2c7.simtran.out        n         $do/c06
sabre3.v1  $di/c07.dat         $dk/u2c7.simtran.out        n         $do/c07
sabre3.v1  $di/c08.dat         $dk/u2c7.simtran.out        n         $do/c08
sabre3.v1  $di/c10.dat         $dk/u2c10.simtran.out       n         $do/c10
sabre3.v1  $di/c11.dat         $dk/u2c7.simtran.out        n         $do/c11
sabre3.v1  $di/c12.dat         $dk/u2c9.simtran.out        n         $do/c12
sabre3.v1  $di/c13.dat         $dk/u2c10.simtran.out       n         $do/c13
sabre3.v1  $di/c14.dat         $dk/u2c10.simtran.out       n         $do/c14
sabre3.v1  $di/c15.dat         $dk/u2c10.simtran.out       n         $do/c15
###
###
exit
```

# Appendix D
## Makefile

```
c = common

OBJECTS = main.o\
aalpha.o\
abeta.o\
ak.o\
amu.o\
an2cp.o\
anu.o\
apfnrm.o\
aray.o\
asme1.o\
avgcal.o\
binj.o\
bjetp.o\
bordis.o\
boron_1dk.o\
bract.o\
bromly.o\
bypassv_1dk.o\
cigma.o\
colt.o\
concal.o\
coninc.o\
const.o\
corad.o\
cpliq.o\
crdin.o\
csin.o\
dca.o\
dclev.o\
dcvol.o\
dden.o\
derliq.o\
dervap.o\
dhfp.o\
dhgp.o\
domec.o\
drfp.o\
drgp.o\
dump.o\
dyvis.o\
edit.o\
edit1.o\
effic.o\
emisg.o\
eqnme.o\
eqnmei.o\
eqnvd.o\
fakcl.o\
fakf.o\
falph.o\
falphb.o\
falphl.o\
fapfb.o\
fcpcl.o\
fcpf.o\
fcsflo.o\
fex.o\
fex1.o\
fgcrit.o\
fhfilm.o\
fhtc.o\
fispl.o\
fkmsiv.o\
flowc.o\
frict.o\
fspa.o\
fspl.o\
fstme.o\
ftail.o\
ftpm.o\
ftsurf.o\
fun1.o\
funb.o\
fune.o\
ginert.o\
```

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```
h1ph.o\
h2ph.o\
hcal.o\
hcal1.o\
hcondu.o\
hedit1.o\
hedit2.o\
hpciset.o\
htcf.o\
icindx.o\
ilevel.o\
incord.o\
inital.o\
initl1.o\
integ1.o\
invdet.o\
isolv1.o\
jex.o\
jun1.o\
keff1_1dk.o\
keff2_1dk.o\
keff_1dk.o\
kin_1dk.o\
kprint.o\
locav.o\
lsodes.o\
messag.o\
pascm1.o\
pascom.o\
power_1dk.o\
presdc.o\
pts.o\
rcicset.o\
rcrit.o\
scramb.o\
scrame.o\
shpci.o\
smgr.o\
smooth.o\
solvc.o\
solvc1.o\
solvj.o\
solvj1.o\
sphet.o\
srcic.o\
state.o\
stedy1.o\
step.o\
stepi.o\
subbi.o\
therm.o\
tpbisc.o\
tphv.o\
tptemp.o\
trans_1dk.o\
vapcp.o\
voidl.o\
vphl.o\
vphv.o\
wtemp.o\
wtemp1.o

sabre3v1.ex : $(OBJECTS)
        f77 +O4 +Ovectorize $(OBJECTS) -o /d00/appl/sabre3v1/sabre3v1.ex

main.o : main.f\
$c/alttim.txt\
$c/arloss.txt\
$c/aux1.txt\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/cooldn.txt\
$c/corbyp.txt\
$c/cput.txt\
$c/crd.txt\
$c/csteel.txt\
$c/dads.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
```

```
$c/dwcond.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/inert.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/kin_1dka.txt\
$c/loca.txt\
$c/pmppr.txt\
$c/pregfw.txt\
$c/printi.txt\
$c/propy.txt\
$c/prslag.txt\
$c/prtim.txt\
$c/maxq.txt\
$c/qrate.txt\
$c/qualit.txt\
$c/r9.txt\
$c/r1.txt\
$c/relax.txt\
$c/rmbk.txt\
$c/s1.txt\
$c/s3.txt\
$c/s2.txt\
$c/screen.txt\
$c/sensed.txt\
$c/specfw.txt\
$c/srv.txt\
$c/srv1.txt\
$c/supp.txt\
$c/time5.txt\
$c/timec.txt\
$c/titl.txt\
$c/uprise.txt\
$c/urreg.txt\
$c/wallit.txt
		f77 -K +E1 +00 -c main.f

aalpha.o : aalpha.f
		f77 -K +02 -c aalpha.f

abeta.o : abeta.f
		f77 -K +02 -c abeta.f

ak.o : ak.f
		f77 -K +02 -c ak.f

amu.o : amu.f
		f77 -K +02 -c amu.f

an2cp.o : an2cp.f
		f77 -K +02 -c an2cp.f

anu.o : anu.f
		f77 -K +02 -c anu.f

apfnrm.o : apfnrm.f\
$c/corbyp.txt
		f77 -K +02 -c apfnrm.f

aray.o : aray.f
		f77 -K +02 -c aray.f

asme1.o : asme1.f
		f77 -K +02 -c asme1.f

avgcal.o : avgcal.f\
$c/averge.txt
		f77 -K +02 -c avgcal.f

binj.o : binj.f
		f77 -K +02 -c binj.f

bjetp.o : bjetp.f
		f77 -K +02 -c bjetp.f

bordis.o : bordis.f
		f77 -K +02 -c bordis.f
```

```
boron_1dk.o : boron_1dk.f\
$c/kin_1dka.txt\
$c/corbyp.txt\
$c/fuelcl.txt\
$c/urreg.txt\
$c/dens.txt\
$c/ccf.txt
        f77 -K +04 -c boron_1dk.f

bract.o : bract.f\
$c/ccf.txt\
$c/corbyp.txt\
$c/down.txt\
$c/jetlp.txt\
$c/uprise.txt\
$c/urreg.txt
        f77 -K +02 -c bract.f

bromly.o : bromly.f
        f77 -K +02 -c bromly.f

bypassv_1dk.o : bypassv_1dk.f\
$c/corbyp.txt
        f77 -K +02 -c bypassv_1dk.f

cigma.o : cigma.f
        f77 -K +02 -c cigma.f

colt.o : colt.f\
$c/alfdat.txt\
$c/arloss.txt\
$c/aux1.txt\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/cooldh.txt\
$c/corbyp.txt\
$c/cput.txt\
$c/crd.txt\
$c/csteel.txt\
$c/dads.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/dwcond.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/inert.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/kin_1dka.txt\
$c/loca.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/qrate.txt\
$c/r1.txt\
$c/r9.txt\
$c/regdp.txt\
$c/rrbk.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/s4.txt\
$c/specfw.txt\
$c/srv.txt\
$c/srv1.txt\
$c/supp.txt\
$c/time5.txt\
$c/timec.txt\
$c/titl.txt\
$c/uprise.txt\
$c/urreg.txt\
$c/wallit.txt
        f77 -K  +00 -c colt.f

concal.o : concal.f\
```

```
$c/dwcond.txt
        f77 -K +O2 -c concal.f

coninc.o : coninc.f
        f77 -K +O0 -c coninc.f

const.o : const.f\
$c/conden.txt
        f77 -K +O0 -c const.f

corad.o : corad.f
        f77 -K +O2 -c corad.f

cpliq.o : cpliq.f
        f77 -K +O2 -c cpliq.f

crdin.o : crdin.f\
$c/crd.txt\
$c/hpci.txt
        f77 -K +O2 -c crdin.f

csin.o : csin.f\
$c/inject.txt
        f77 -K +O2 -c csin.f

dca.o : dca.f\
$c/down.txt
        f77 -K +O2 -c dca.f

dclev.o : dclev.f\
$c/down.txt
        f77 -K +O2 -c dclev.f

dcvol.o : dcvol.f\
$c/down.txt
        f77 -K +O2 -c dcvol.f

dden.o : dden.f\
$c/propy.txt
        f77 -K +O2 -c dden.f

derliq.o : derliq.f
        f77 -K +O2 -c derliq.f

dervap.o : dervap.f
        f77 -K +O2 -c dervap.f

dhfp.o : dhfp.f
        f77 -K +O2 -c dhfp.f

dhgp.o : dhgp.f
        f77 -K +O2 -c dhgp.f

domec.o : domec.f\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/crd.txt\
$c/dome.txt\
$c/down.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/hplm.txt\
$c/intl.txt\
$c/inject.txt\
$c/jetlp.txt\
$c/loca.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/regdp.txt\
$c/rmbk.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/srv.txt\
$c/time5.txt\
$c/uprise.txt
        f77 -K +O4 +Ovectorize -c domec.f

drfp.o : drfp.f
```

```
        f77 -K +02 -c drfp.f

drgp.o : drgp.f
        f77 -K +02 -c drgp.f

dump.o : dump.f\
$c/alfdat.txt\
$c/arloss.txt\
$c/aux1.txt\
$c/averge.txt\
$c/ccf.txt\
$c/contm.txt\
$c/conden.txt\
$c/cooldn.txt\
$c/corbyp.txt\
$c/cput.txt\
$c/crd.txt\
$c/csteel.txt\
$c/dads.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/dwcond.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/inert.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/kin_1dka.txt\
$c/loca.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/qrate.txt\
$c/qualit.txt\
$c/r1.txt\
$c/r9.txt\
$c/regdp.txt\
$c/relax.txt\
$c/rnbk.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/s4.txt\
$c/specfw.txt\
$c/srv.txt\
$c/srv1.txt\
$c/supp.txt\
$c/time5.txt\
$c/timec.txt\
$c/titl.txt\
$c/uprise.txt\
$c/urreg.txt\
$c/wallit.txt
        f77 -K +00 -c dump.f

dyvis.o : dyvis.f
        f77 -K +02 -c dyvis.f

edit.o : edit.f\
$c/arloss.txt\
$c/aux1.txt\
$c/ccf.txt\
$c/conden.txt\
$c/corbyp.txt\
$c/cput.txt\
$c/crd.txt\
$c/dbug.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/hpci.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
```

```
$c/kin_1dka.txt\
$c/loca.txt\
$c/maxq.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/regdp.txt\
$c/s2.txt\
$c/s3.txt\
$c/srv.txt\
$c/time5.txt\
$c/titl.txt\
$c/uprise.txt\
$c/urreg.txt\
$c/wallit.txt
          f77 -K +E1 +00 -c edit.f

edit1.o : edit1.f\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/cput.txt\
$c/crd.txt\
$c/crit.txt\
$c/dome.txt\
$c/down.txt\
$c/fuelcl.txt\
$c/hpci.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/loca.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/qrate.txt\
$c/s1.txt\
$c/s2.txt\
$c/screen.txt\
$c/sensed.txt\
$c/srv.txt\
$c/supp.txt\
$c/time5.txt\
$c/uprise.txt
          f77 -K +E1 +00 -c edit1.f

effic.o : effic.f\
$c/conden.txt
          f77 -K +02 -c effic.f

emisg.o : emisg.f
          f77 -K +02 -c emisg.f

eqnme.o : eqnme.f\
$c/alttim.txt
          f77 -K +02 -c eqnme.f

eqnmei.o : eqnmei.f
          f77 -K +00 -c eqnmei.f

eqnvd.o : eqnvd.f
          f77 -K +00 -c eqnvd.f

fakcl.o : fakcl.f
          f77 -K +02 -c fakcl.f

fakf.o : fakf.f
          f77 -K +02 -c fakf.f

falph.o : falph.f
          f77 -K +02 -c falph.f

falphb.o : falphb.f
          f77 -K +02 -c falphb.f

falphl.o : falphl.f
          f77 -K +02 -c falphl.f

fapfb.o : fapfb.f
          f77 -K +02 -c fapfb.f
```

```
fcpcl.o : fcpcl.f
        f77 -K +O2 -c fcpcl.f

fcpf.o : fcpf.f
        f77 -K +O2 -c fcpf.f

fcsflo.o : fcsflo.f
        f77 -K +O0 -c fcsflo.f

fex.o : fex.f\
$c/alfdat.txt\
$c/alttim.txt\
$c/aux1.txt\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/cooldn.txt\
$c/corbyp.txt\
$c/crd.txt\
$c/crit.txt\
$c/csteel.txt\
$c/dads.txt\
$c/dbug.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dersm.txt\
$c/dome.txt\
$c/down.txt\
$c/enth.txt\
$c/flom.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/hplm.txt\
$c/htra.txt\
$c/inert.txt\
$c/initer.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/kin_1dka.txt\
$c/loca.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prslag.txt\
$c/prtim.txt\
$c/qrate.txt\
$c/qualit.txt\
$c/r1.txt\
$c/regdp.txt\
$c/relax.txt\
$c/rmbk.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/s4.txt\
$c/sensed.txt\
$c/specfw.txt\
$c/srv.txt\
$c/supp.txt\
$c/time5.txt\
$c/timec.txt\
$c/uprise.txt\
$c/urreg.txt
        f77 -K +O4 +Ovectorize -c fex.f

fex1.o : fex1.f\
$c/alfdat.txt\
$c/aux1.txt\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/crd.txt\
$c/csteel.txt\
$c/dbug.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dersm.txt\
```

```
$c/dome.txt\
$c/down.txt\
$c/dwcond.txt\
$c/enth.txt\
$c/flom.txt\
$c/flow3.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/hpci.txt\
$c/initer.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/loca.txt\
$c/pmppr.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/qrate.txt\
$c/r1.txt\
$c/regdp.txt\
$c/rmbk.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/s4.txt\
$c/sensed.txt\
$c/specfw.txt\
$c/srv.txt\
$c/supp.txt\
$c/time5.txt\
$c/timec.txt\
$c/uprise.txt\
$c/urreg.txt
        f77 -K +O4 +Ovectorize -c fex1.f

fgcrit.o : fgcrit.f
        f77 -K +O2 -c fgcrit.f

fhfilm.o : fhfilm.f\
$c/fuelcl.txt\
$c/heatt.txt\
$c/htra.txt\
$c/propy.txt
        f77 -K +O2 -c fhfilm.f

fhtc.o : fhtc.f
        f77 -K +O2 -c fhtc.f

fispl.o : fispl.f
        f77 -K +O2 -c fispl.f

fkmsiv.o : fkmsiv.f\
$c/pregfw.txt
        f77 -K +O2 -c fkmsiv.f

flowc.o : flowc.f\
$c/alfdat.txt\
$c/alttim.txt\
$c/arloss.txt\
$c/averge.txt\
$c/ccf.txt\
$c/conden.txt\
$c/corbyp.txt\
$c/crd.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/enth.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/hpci.txt\
$c/inert.txt\
$c/initer.txt\
$c/inject.txt\
$c/intl.txt\
$c/jetlp.txt\
$c/propy.txt\
$c/prslag.txt\
$c/regdp.txt\
$c/relax.txt\
$c/s1.txt\
```

```
$c/s2.txt\
$c/s3.txt\
$c/srv.txt\
$c/time5.txt\
$c/uprise.txt\
$c/urreg.txt
        f77 -K +04 +Ovectorize -c flowc.f

frict.o : frict.f
        f77 -K +00 -c frict.f

fspa.o : fspa.f\
$c/supp.txt
        f77 -K +02 -c fspa.f

fspl.o : fspl.f
        f77 -K +02 -c fspl.f

fstma.o : fstma.f\
$c/srv.txt\
$c/srv1.txt
        f77 -K +02 -c fstma.f

ftail.o : ftail.f
        f77 -K +02 -c ftail.f

ftpm.o : ftpm.f
        f77 -K +02 -c ftpm.f

ftsurf.o : ftsurf.f\
$c/corbyp.txt\
$c/fuelcl.txt\
$c/fuel2.txt\
$c/propy.txt\
$c/time5.txt
        f77 -K +02 -c ftsurf.f

fun1.o : fun1.f\
$c/corbyp.txt\
$c/fuel2.txt\
$c/fuelcl.txt
        f77 -K +02 -c fun1.f

funb.o : funb.f\
$c/corbyp.txt
        f77 -K +02 -c funb.f

fune.o : fune.f\
$c/propy.txt
        f77 -K +01 -c fune.f

ginert.o : ginert.f
        f77 -K +02 -c ginert.f

h1ph.o : h1ph.f
        f77 -K +02 -c h1ph.f

h2ph.o : h2ph.f
        f77 -K +02 -c h2ph.f

hcal.o : hcal.f
        f77 -K  +02 -c hcal.f

hcal1.o : hcal1.f
        f77 -K +02 -c hcal1.f

hcondu.o : hcondu.f
        f77 -K +02 -c hcondu.f

hedit1.o : hedit1.f\
$c/titl.txt
        f77 -K +E1 +00 -c hedit1.f

hedit2.o : hedit2.f\
$c/corbyp.txt\
$c/cput.txt\
$c/time5.txt\
$c/titl.txt
        f77 -K +E1 +00 -c hedit2.f

hpciset.o : hpciset.f\
$c/hpci.txt
        f77 -K +E1 +00 -c hpciset.f
```

```
htcf.o : htcf.f\
$c/fuelcl.txt\
$c/heatt.txt\
$c/htra.txt\
$c/propy.txt
	f77 -K +02 -c htcf.f

icindx.o : icindx.f
	f77 -K +02 -c icindx.f

ilevel.o : ilevel.f
	f77 -K +02 -c ilevel.f

incond.o : incond.f\
$c/averge.txt\
$c/conden.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/dads.txt\
$c/dome.txt\
$c/down.txt\
$c/hpci.txt\
$c/inject.txt\
$c/propy.txt\
$c/prtim.txt\
$c/srv.txt\
$c/supp.txt
	f77 -K +02 -c incond.f

inital.o : inital.f\
$c/alfdat.txt\
$c/arloss.txt\
$c/ccf.txt\
$c/corbyp.txt\
$c/crd.txt\
$c/decayh.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/fuelcl.txt\
$c/jetlp.txt\
$c/presr.txt\
$c/propy.txt\
$c/regdp.txt\
$c/s1.txt\
$c/s3.txt\
$c/uprise.txt\
$c/urreg.txt
	f77 -K +E1 +00 -c inital.f

initl1.o : initl1.f\
$c/ccf.txt\
$c/conden.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/dome.txt\
$c/down.txt\
$c/fuelcl.txt\
$c/hpci.txt\
$c/inject.txt\
$c/jetlp.txt\
$c/loca.txt\
$c/pmppr.txt\
$c/pregfw.txt\
$c/propy.txt\
$c/prtim.txt\
$c/srv.txt\
$c/uprise.txt
	f77 -K +E1 +00 -c initl1.f

integ1.o : integ1.f\
$c/alttim.txt\
$c/ccf.txt\
$c/contm.txt\
$c/corbyp.txt\
$c/dens.txt\
$c/dome.txt\
$c/down.txt\
$c/flow3.txt\
$c/fuelcl.txt\
$c/heatt.txt\
$c/intl.txt\
```

```
$c/jetlp.txt\
$c/kin_1dka.txt\
$c/maxq.txt\
$c/pregfw.txt\
$c/prslag.txt\
$c/prtim.txt\
$c/qualit.txt\
$c/r1.txt\
$c/relax.txt\
$c/s1.txt\
$c/s2.txt\
$c/s3.txt\
$c/srv.txt\
$c/srv1.txt\
$c/time5.txt\
$c/uprise.txt\
$c/urreg.txt
         f77 -K +E1 +02 -c integ1.f

invdet.o : invdet.f
         f77 -K +04 -c invdet.f

isolv1.o : isolv1.f
         f77 -K +00 -c isolv1.f

jex.o : jex.f
         f77 -K +02 -c jex.f

jun1.o : jun1.f\
$c/alttim.txt
         f77 -K +02 -c jun1.f

keff1_1dk.o : keff1_1dk.f\
$c/kin_1dka.txt
         f77 -K +04 -c keff1_1dk.f

keff2_1dk.o : keff2_1dk.f\
$c/kin_1dka.txt
         f77 -K +04 -c keff2_1dk.f

keff_1dk.o : keff_1dk.f\
$c/kin_1dka.txt\
$c/corbyp.txt
         f77 -K +04 -c keff_1dk.f

kin_1dk.o : kin_1dk.f\
$c/kin_1dka.txt
         f77 -K +00 -c kin_1dk.f

kprint.o : kprint.f\
$c/printi.txt
         f77 -K +00 -c kprint.f

locav.o : locav.f\
$c/loca.txt
         f77 -K +02 -c locav.f

lsodes.o : lsodes.f
         f77 -K +04 +Ovectorize -c lsodes.f

messag.o : messag.f
         f77 -K +00 -c messag.f

pascm1.o : pascm1.f
         f77 -K +00 -c pascm1.f

pascom.o : pascom.f
         f77 -K +00 -c pascom.f

power_1dk.o : power_1dk.f\
$c/kin_1dka.txt\
$c/corbyp.txt\
$c/fuelcl.txt\
$c/urreg.txt\
$c/dens.txt\
$c/ccf.txt
         f77 -K +04 -c power_1dk.f

presdc.o : presdc.f\
$c/aux1.txt\
$c/flow3.txt\
$c/inert.txt\
$c/propy.txt
```

```
        f77 -K +02 -c presdc.f

pts.o : pts.f
        f77 +02 -c pts.f

rcicset.o : rcicset.f\
$c/hpci.txt
        f77 -K +E1 +00 -c rcicset.f

rcrit.o : rcrit.f
        f77 -K +02 -c rcrit.f

scramb.o : scramb.f
        f77 -K +00 -c scramb.f

scrame.o : scrame.f
        f77 -K +00 -c scrame.f

shpci.o : shpci.f
        f77 -K +02 -c shpci.f

smgr.o : smgr.f\
$c/propy.txt
        f77 -K +02 -c smgr.f

smooth.o : smooth.f
        f77 -K +00 -c smooth.f

solvc.o : solvc.f
        f77 -K  +02 -c solvc.f

solvc1.o : solvc1.f
        f77 -K +04 -c solvc1.f

solvj.o : solvj.f
        f77 -K +04 -c solvj.f

solvj1.o : solvj1.f
        f77 -K +04 -c solvj1.f

sphet.o : sphet.f
        f77 +04 -c sphet.f

srcic.o : srcic.f
        f77 -K +04 -c srcic.f

state.o : state.f\
$c/propy.txt
        f77 -K +04 -c state.f

stedy1.o : stedy1.f\
$c/corbyp.txt\
$c/fuel2.txt\
$c/fuelcl.txt\
$c/s2.txt
        f77 -K +00 -c stedy1.f

step.o : step.f\
$c/alttim.txt\
$c/propy.txt
        f77 -K  +02 -c step.f

stepi.o : stepi.f\
$c/propy.txt
        f77 -K +00 -c stepi.f

subbi.o : subbi.f\
$c/propy.txt
        f77 -K +E1 +04 -c subbi.f

therm.o : therm.f
        f77 +04 -c therm.f

tpbisc.o : tpbisc.f
        f77 -K +02 -c tpbisc.f

tphv.o : tphv.f
        f77 +04 -c tphv.f

tptemp.o : tptemp.f
        f77 -K +04 -c tptemp.f

trans_1dk.o : trans_1dk.f\
```

```
$c/kin_1dka.txt\
$c/corbyp.txt\
$c/fuelcl.txt\
$c/urreg.txt\
$c/dens.txt\
$c/ccf.txt
        f77 -K +O4 +Ovectorize -c trans_1dk.f

vapcp.o : vapcp.f
        f77 +O4 -c vapcp.f

voidl.o : voidl.f
        f77 -K +O4 -c voidl.f

vphl.o : vphl.f
        f77 +O4 -c vphl.f

vphv.o : vphv.f
        f77 +O4 -c vphv.f

wtemp.o : wtemp.f\
$c/wallit.txt
        f77 -K +O4 -c wtemp.f

wtemp1.o : wtemp1.f\
$c/wallit.txt
        f77 -K +O4 -c wtemp1.f
```

[redacted]

# Appendix E
## 50.59 and 72.48 Screening Determination

# 50.59 and 72.48 SCREENING DETERMINATION

Document No.: EC-SATH-1007 Revision: 1

Document Title: "Installation of SABRE Computer Code in Systems Analysis' Production Library"

EG702Certified Preparer: Mark A. Chaiko Date: 9/25/00

EG702 Certified Independent
Reviewer: Date: 9/26/00

EG702Certified
Supervisor: Date: 9/26/00

**NOTE (1):** The Certified Independent Reviewer and Certified Supervisor can be the same individual when the Certified Supervisor is the only certified individual available.

1. Has the change been reviewed and approved by the NRC?

YES ☐ NO ☒

If yes, provide License Amendment No. ____________

If the answer to question 1 is yes, questions 2 through 10 are not applicable and need not be answered.

**NOTE (2):** Questions 2 through 5 of this 50.59 and 72.48 Screening Determination evaluate the activity described in the identified document versus the FSAR and determine whether or not a 50.59 Safety Evaluation is required. If any question results in a "YES" answer, then a written 50.59 Safety Evaluation is required prior to implementation. Attachment J should be reviewed when developing the answers to questions 2 through 5. For "NO" answers, provide a discussion of the basis used in arriving at the conclusion and include reference to specific FSAR sections. For "YES" answers, provide the 50.59 Safety Evaluation Number.

2. Does the activity involve a change to the facility as described in the FSAR?

YES ☐ NO ☒

EC-SATH-1007, Rev. 1 installs a revised version of the SABRE code into the Systems Analysis' Production Library. The major changes made to the SABRE code involve adding the capability to model superheated steam conditions within the primary containment in a steam break scenario and adding a "rainout" model to prevent the formation of supersaturated conditions in the drywell during a liquid break accident scenario. Section 15.8 of the FSAR discusses the cycle-specific ATWS analysis for Susquehanna. Specifically, Section 15.8.1.5.2 of the FSAR states that the PP&L SABRE code is used to evaluate the peak suppression pool temperature. The enhancements made to the SABRE code do not have any effect on predicted suppression pool temperature response under ATWS conditions. Therefore, this revision to the SABRE does not involve a change to the facility as described in the FSAR.

3. Does the activity involve a change to procedures as described in the FSAR?

YES ☐ NO ☒

No procedures described in the FSAR mention the SABRE code.

4. Does the activity involve a test or experiment not described in the FSAR that might affect SSC's which are described in the FSAR?

YES NO

☐ ☒

The activity does involve a test or experiment.

5. As a result of the activity, could a nonradioactive system become radioactive?

YES ☐ NO ☒

The SABRE code is used to model a beyond-design-basis event (transient with scram failure) it does not involve changes to plant equipment, procedures, or training. Since the ATWS analyses performed using SABRE does not change the way the plant is designed or operated, it cannot cause a nonradioactive system to become radioactive.

**NOTE (3):** Questions 6 through 10 of the 72.48 Screening Determination evaluate the activity described in the identified document for the potential to impact the Dry Fuel Storage Licensing Basis Documents.

**If either question 6 or 7 is answered "Yes", proceed with questions 8 through 10. If both question 6 and 7 are answered "No", questions 7 through 9 are not applicable. Contact Nuclear Licensing if assistance is needed to answer questions 1 through 5**

6. Is the activity associated with any Dry Fuel Storage SSC's as described in FSAR 11.7?

YES ☐ NO ☒

7. Is the activity associated with any of the below listed programs as they are credited applicable in EC-089-1002 to Dry Fuel Storage activities?

| | YES | NO |
|---|---|---|
| Heavy Loads | ☐ | ☒ |
| Radiation Protection (Health Physics) | ☐ | ☒ |
| Training | ☐ | ☒ |
| Security | ☐ | ☒ |
| Quality Assurance | ☐ | ☒ |
| Emergency Planning | ☐ | ☒ |
| Procedure Program | ☐ | ☒ |

**If any of questions 8 through 10 are answered "Yes", Nuclear Licensing must be contacted to determine if a 72.48 Safety Evaluation and/or Dry Fuel Storage Licensing Basis Document change is needed. If questions 8 through 10 are all answered "No", or are not applicable, process change.**

8. Does the activity involve a change to the facility as described in the CSAR, C of C #1004 and 72.212 Evaluation (EC-089-1002)?

YES ☐ NO ☐

**Provide a discussion of the basis used in arriving at the above conclusion. Include reference to specific Dry Fuel Storage Licensing Basis Document sections.**

9. Does the activity involve a change to the procedural steps associated with Dry Fuel Storage as described in the CSAR, C of C #1004 and 72.212 Evaluation (EC-089-1002)?

YES ☐ NO ☐

**Provide a discussion of the basis used in arriving at the above conclusion. Include reference to specific Dry Fuel Storage Licensing Basis Document sections.**

10. Does the activity involve a test or experiment not described in the CSAR, C of C #1004 and 72.212 Evaluation which might affect SSC's which are described in the CSAR, C of C #1004 and 72.212 Evaluation (EC-089-1002)?

**YES** ☐ **NO** ☐

**Provide a discussion of the basis used in arriving at the above conclusion. Include reference to specific Dry Fuel Storage Licensing Basis Document sections.**

DO NOT WRITE ANYTHING ABOVE THIS LINE

# CALCULATION SEPARATOR

DOCUMENT NO. EC-SATH-1007 R1
(20 characters)

BACK up

SECTION
(10 characters)

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File # R2-1

1. Page 1 of 33
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➢2. TYPE: Calc. ➢3. NUMBER: EC-SATH-1007 ➢4. REVISION: 0

5. TRANSMITTAL#: K000/093 *➢6. UNIT: 3 *➢7. QUALITY CLASS: Q

➢9. DESCRIPTION: Installation of SABRE Computer Code in Systems Analysis' Production Library *➢8. DISCIPLINE: T

SUPERSEDED BY: EC-

10. Alternate Number:

11. Cycle:

12: Computer Code or Model used: SABRE3.000 Fichee ☑ Dis ☐ Am't 1 packet

13. Application:

*➢14 *Affected Systems:* , , , , ,

* If N/A then line 15 is mandatory.

**➢15. NON-SYSTEM DESIGNATOR: ATWS EOPC THYD

**If N/A then line 14 is mandatory

16. Affected Documents:

☑ SAR Change Req'd

17. References: EC-ATWS-0505, Rev. 7

18. Equipment / Component #:

19. DBD Number:

| | | |
|---|---|---|
| ➢20. PREPARED BY | Mark A. Chaiko<br>*Print Name* | Mark A. Chaiko<br>*Signature* |
| ➢21. REVIEWED BY | Jack G. Refling<br>*Print Name* | Jack G. Refling<br>*Signature* |
| ➢21A. VERIFIED BY | Jack G. Refling<br>*Print Name* | Jack G. Refling 01/12/00<br>*Signature* |
| ➢22. APPROVED BY | Casimir A. Kukielka<br>*Print Name* | Casimir Kukielka 01/20/00<br>*Signature* |
| ➢23. ACCEPTED BY PP&L / DATE | *Print Name* | *Signature / DATE* |

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➢2. TYPE: Calc ➢3. NUMBER: EC-052-1018 ➢4. REVISION: 2

5. TRANSMITTAL#: K0011025 *➢6. UNIT: 3 *➢7. QUALITY CLASS: Q

➢9. DESCRIPTION: Technical Basis for Elimination of HPCI Auto Suction Transfer on High Suppression Pool Level *➢8. DISCIPLINE: M

SUPERSEDED BY: EC-

10. Alternate Number: 11. Cycle:

12: Computer Code or Model used: SABRE Fichee ☐ Dis ☐ Am't

13. Application:

*➢14 *Affected Systems:* 052 , , , , , .

* If N/A then line 15 is mandatory.

**➢15. NON-SYSTEM DESIGNATOR:

**If N/A then line 14 is mandatory

16. Affected Documents:

☒ SAR Change Req'd

17. References: EC-052-1025, EC-THYD-1007, EC-THYD-1005, DCP 93-3070, DCP 93-3071

18. Equipment / Component #:

19. DBD Number: DBD004

| | | |
|---|---|---|
| ➢20. PREPARED BY | Mark A. Chaiko<br>*Print Name* | Mark A. Chaiko<br>*Signature* |
| ➢21. REVIEWED BY | Kevin W. Brinckman<br>*Print Name* | Kevin W Brinckman<br>*Signature* |
| ➢21A. VERIFIED BY | Kevin W. Brinckman<br>*Print Name* | Kevin W Brinckman<br>*Signature* |
| ➢22. APPROVED BY | Casimir A. Kukielka<br>*Print Name* | *Signature* |
| ➢23. ACCEPTED BY PP&L / DATE | *Print Name* | 11/2/2000<br>*Signature / DATE* |

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# REVISION DESCRIPTION SHEET

**REVISION NO:** 2

**CALCULATION NUMBER:** EC-052-1018

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| Revised Pages | Affected Sections | Add | Rpl | Rmv | Description / Purpose of Revision |
|---|---|---|---|---|---|
| 1, 1a, 1b | N/A | | x | | Replaced cover sheet and revision page. |
| 2 | Contents | | x | | Revised page numbers in Table of Contents. |
| 3 | 1 | | x | | Updated peak pool temperature for ATWS with SLCS failure based on latest revision to Calc. EC-EOPC-0519. Added Summary. Referenced EPG/SAG instead of EPG, Rev. 4. |
| 4 | 2 | | x | | Updated setpoint for HPCI suction transfer to reflect setpoint change. Added discussion about manual transfer requirement. Changed suppression pool level for manual HPCI suction transfer from 26' to 25' to prevent suppression pool water from entering HPCI turbine exhaust piping in the event of a HPCI system trip. This eliminates concern about condensation-induced waterhammer which could occur if HPCI is started with partially-filled exhaust line. |
| 5 | 3 | | x | | Changed "Design Basis LOCA" to "LOCA". |
| 6 | 4.1.1 | | x | | Added references to DBD046 (Hydrodynamic loads DBD). Also, corrected footnotes 11 & 12; footnotes referred to the wrong sections of DAR. Clarified wording in 1st sentence of 4.1.1. |
| 7 | 4.1.1 | | x | | Changed max pool level from 26' to 25'. Changed pressure increase accordingly. |
| 8 | 4.1.1, 4.1.2 | | | | Calculation EC-012-1103 was added as a reference for the stress margin on downcomer bracing. Removed statement that load limit curve applies to actuation of all 16 SRVs because load limit curve is more general in that it applies to any SRV actuation (all 16, ADS, single valve, etc.) Added reference to Fig 8-103 of DAR. |
| 10 | 5.1.1 | | x | | Corrected reference and added concluding sentence. |
| 11 | 5.1.1, 5.1.2 | | x | | Clarified wording. Revised description of the effect of LOOP on plant equipment to reflect changes made to Calc. EC-052-1025. |
| 12 | 5.1.2 | | x | | Indicated that current version of SABRE calculates the reactor pressure corresponding to the onset of Core Spray injection. LOCA simulations in EC-052-1025 were re-run with most recent version of SABRE code (SABRE3.001). Changed "pressure drops to 300 psig at about 700 seconds..." to "pressure drops to 300 psig at about 600 seconds..." based on revised LOCA simulations in EC-052-1025, Rev. 1 |

REVISION TYPE: ☐ SUPERSEDED BY CALCULATION NUMBER EC-

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| PPL, Inc | ENGINEERING CALCULATION STUDY<br>REVISION DESCRIPTION SHEET |
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| **REVISION NO:** 2 | **CALCULATION NUMBER:** EC-052-1018 |

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| Revised Pages | Affected Sections | Add | Rpl | Rmv | Description / Purpose of Revision |
|---|---|---|---|---|---|
| 13 | 5.1.3 | | x | | Changed suppression pool level of 26 ft. to 25 ft based on revision to manual HPCI suction transfer. Changed cooldown rate from 100 F/hr to 90 F/hr based on revision to Calc. EC-052-1025. |
| 14 | 5.1.3 | | x | | Changed cooldown rate from 100 F/hr to 90 F/hr based on revision to Calc. EC-052-1025. Changed 1470 seconds to 970 seconds based on revision to calc. EC-052-1025. Changed reference from DAR Chapter 5 to FSAR Table 3.9-2. Deleted question on HPCI manual transfer capability and potential for pressure locking of F042 valve. Pressure locking is no longer an issue for F042 valve because of plant modification. See Calc. EC-VALV-1041 and DCPs 97-9005 and 97-9006. |
| | | | | | Calculation EC-012-1103 was added as a reference for the stress margin on downcomer bracing. Deleted the words "since the design basis load combination assumes the SSE occurs at the beginning of the small break LOCA." This is irrelevant to the discussion. |
| 16 | 5.1.3 | | x | | Revised problem #2 statement based on OP change: HPCI Operating Procedure no longer refers to Station Blackout procedure (EO-100/200-032) for HPCI start with high pool level. In resolution to Problem 2, changed pool level of 26 ft to pool level of 25 ft. Added information about minimum time available for operator to initiate manual HPCI suction transfer on pool level of 25 ft. Indicated that SPT>140F is not expected for liquid break while HPCI is running. Clarified footnote 37. |
| 17 | 5.1.3 | | x | | Deleted discussion on HPCI manual transfer capability and potential for pressure locking of F042 valve. Pressure locking is no longer an issue for F042 valve because of plant modification. See Calc. EC-VALV-1041 and DCPs 97-9005 and 97-9006. Changed pool level of 26 feet to 25 feet. Indicated that SPT>140F is not expected for liquid break while HPCI is running. |
| 18 | 5.2 | | x | | Stated that condensation loads are within the containment design limits. Added rationale to Sections 5.3, 5.4, and 5.5 as to why SRV/ADS hydrodynamic loads are not an issue for these events. |
| 19 | 5.8, 5.9 | | x | | Used SRV safety setpoint from Tech Spec rather than from GE LOCA report. Clarified wording in Sec. 5.9. |
| 20 | 5.11, 5.12, 5.13 | | x | | Added additional FSAR reference. Revised Section 5.12 based on update to FSAR. Updated peak pool temperature and pool level for ATWS with SLCS failure in Sec. 5.13. Updated references 44 & 45 to latest revisions. |

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| REVISION TYPE: | ☐ SUPERSEDED BY CALCULATION NUMBER | EC- |
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| Revised Pages | Affected Sections | Add | Rpl | Rmv | Description / Purpose of Revision |
|---|---|---|---|---|---|
| 21 | 5.13 | | x | | Revised pool level relative to Load Limit curve based on revision to Calc. EC-EOPC-0519. Added paragraph to discuss potential consequences of high pool level in ATWS event with SLCS failure. |
| 22 | 6 | | x | | Deleted discussion on HPCI manual transfer capability and potential for pressure locking of F042 valve. Changed pool level of 26 feet to 25 feet. Indicated that SPT>140F is not expected for liquid break while HPCI is running |
| 23-32 | 5.1 | | x | | Revised figures based on current Rev. of EC-052-1025. |
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## Summary

The proposed modification eliminates the automatic HPCI suction transfer on high suppression pool level. EOPs are modified to require a manual HPCI suction swap from the CST to the suppression pool if pool level reaches 25 feet, but only if pool temperature is less than the HPCI design limit of 140 °F. The manual transfer is performed from the control room in a LOCA event and is only required for a narrow range of break sizes. Moreover, the earliest the manual transfer would have to be performed is 20 minutes into the LOCA scenario. The modification eliminates the need to manually bypass the auto-swap logic in ATWS and SBO events. Currently, the manual bypass must be performed outside the control room and must be carried out early in the ATWS scenario. For design basis events, containment hydrodynamic loads remain within design limits, and the HPCI system is not adversely affected by the modification.

## 1. Introduction

The Susquehanna Individual Plant Evaluation[1] identified the need to bypass or modify the HPCI suction transfer logic on high suppression pool level. In an ATWS event, high suppression pool temperatures necessitate the manual bypass of the HPCI suction transfer logic so that the operator can realign suction to the cooler CST water. The HPCI system is designed for continuous operation with suppression pool water temperatures up to 140°F, and for short-term operation with temperatures up to 170°F.[2]

In an ATWS event with no additional failures, suppression pool (SP) temperature is expected to reach 170°F which exceeds the maximum temperature considered in the design of the HPCI system.[3] For ATWS events which involve additional equipment failures, much higher pool temperatures are expected. In particular, the MSIV-closure ATWS with SLCS failure results in a peak pool temperature of 316°F which is well beyond the HPCI design temperature.[4]

The EPG/SAG (Rev. 1) instructs the operator to maintain HPCI suction on the CST and to bypass the high suppression pool suction transfer logic whenever the EOPs are entered. The Susquehanna EOPs incorporate this guidance in part. Currently, the operator must manually jumper out the transfer logic circuitry. This has to be done outside the control room, and for the ATWS with SLCS failure, the bypass cannot be carried out in time to assure continued operation of HPCI. Should HPCI fail, rapid depressurization of the reactor is required in order to obtain vessel makeup from low pressure sources. Operation of a critical reactor at low pressure is highly undesirable. There is potential for reactivity-induced core damage caused by high-flow-rate low pressure injection systems (LPCI and Condensate). Core damage from unstable reactor operation is also a concern.

---

[1] "Susquehanna Steam Electric Station Individual Plant Evaluation," NPE-91-001, p. 6-4, December 1991.

[2] DBD004, Rev. 0, Section 2.2.3.1.18.

[3] "Evaluation of Susquehanna ATWS Performance for Power Uprate Conditions", GENE-637-024-0893, p. 9, September 1993.

[4] PP&L Calculation EC-EOPC-0519, Rev. 3.

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In non-ATWS events, the Susquehanna EOPs instruct the operator to manually bypass the suction transfer logic and maintain HPCI suction on the CST only if SP temperature exceeds 140 °F. The temperature restriction of 140 °F prevents conflict with the current plant design basis.

In §2 of this study, the proposed plant modification is described. §3 reviews the design basis of the HPCI suction transfer logic. Primary containment design basis loads are reviewed in §4, and the impact of the proposed modification on the containment design basis loads is examined in §5. Conclusions are summarized in §6.

## 2. Proposed Plant Modification

The proposed modification completely eliminates the HPCI suction transfer logic associated with high suppression pool level. The proposed modification also adds a requirement to manually transfer HPCI suction from the CST to the suppression pool if suppression pool level exceeds 25 feet, but only if pool temperature is less than 140 °F. Currently, HPCI suction will automatically transfer from the Condensate Storage Tank to the suppression pool when pool level reaches 23'-10" and the HPCI injection valve (F006) is open.[5]

The suction transfer logic dependence on injection valve position is not part of the original plant design. The current logic already includes a modification which was installed to resolve operational difficulties with RPV pressure control following a MSIV closure event.

In an isolation transient, RCIC is normally used to maintain vessel inventory, and HPCI is aligned in pressure-control mode (CST to CST). With the original system design, the HPCI suction transfer on high suppression pool level occurred even with HPCI operating in pressure-control mode. Following an isolation event on Unit 1 (7/31/91), the suction transfer occurred with HPCI aligned CST to CST. This prevented the use of HPCI for control of RPV pressure. In order to correct this design deficiency, the suction transfer logic was modified to limit its effect to situations where HPCI is injecting to the vessel (DCP 92-9016/9017).

Since the modification proposed in this study involves complete removal of the suction transfer on high pool level, the modification installed under DCP 92-9016/9017 is no longer necessary and it should be removed from the plant. The HPCI system control logic also initiates a suction transfer from the CST to the suppression pool on low CST level in order to assure a supply of coolant to the reactor. The proposed modification does not affect the suction transfer on low CST level.

## 3. Plant Design Basis for the HPCI Suction Transfer Logic on High Pool Level

The HPCI Design Basis Document (DBD004, Section 2.16.3.3.1) makes the following statement about the design basis of the HPCI suction transfer on high suppression pool level:

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[5] SSES TRM Table 2.2-1 (p. 4 of 7), 3/29/2000.

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> "The basis for the suction transfer on high suppression pool level is to prevent the HPCI System from contributing to the further increase in the suppression pool level. The maximum suppression pool water level is dictated by the need to maintain sufficient air space to accommodate the non-condensable gases that are blown down to the suppression chamber during an accident. If the suppression pool water level was too high, the non-condensable gases would cause the containment pressure to exceed design values. The water level would also be a factor in the calculation of pool swell loads which would arise from the gaseous discharge from the containment drywell to the wetwell during the early stages of a postulated Design Basis Accident, and from the blowdown loads generated by an ADS depressurization event. A small break LOCA with HPCI injection may raise suppression pool level to 24 ft. The design basis for the hydrodynamic loads due to SRV/ADS blowdown are based on a maximum 24 ft. pool level. Exceeding 24 ft. has the potential to produce SRV loads that may exceed the suppression pool design basis."

In summary, the HPCI DBD addresses three concerns with regard to suppression pool water level:

1. HPCI operation contributing to an initial pool level > 24' at the time a DBA occurs.

2. HPCI operation causing the pool level to exceed 24' during the course of a LOCA.

3. HPCI operation causing pool level to increase above 24' during a small break LOCA which subsequently requires initiation of ADS.

Section 6.3.2.2.1 of the FSAR mentions that the HPCI system initially injects water from the CST, and the suction automatically transfers to the suppression pool on low CST level or high suppression pool level. However, the basis for the suction transfer on high pool level is not provided.

In the next section, the primary containment design-basis hydrodynamic loads are reviewed. Plant transients and design-basis accidents, which potentially involve HPCI operation, are then examined in light of the proposed modification which removes the high-suppression pool suction transfer logic.

## 4. Primary Containment Design-Basis Loads

The Susquehanna primary containment is designed to accommodate loads generated by a LOCA and/or SRV discharge. The SRV and LOCA load definitions are reviewed in order to determine the impact of the proposed modification on the containment hydrodynamic loads.

### 4.1 SRV Load Definition

Loads associated with SRV discharge can be divided into two categories:

- Loads on submerged suppression pool structures, and
- Loads on the SRV system.

Both of these loads are discussed in the following subsections.

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### 4.1.1 Loads on Suppression Pool Structures Due to SRV Actuation

SRV steam condensation loads on wetted portions of the suppression pool boundary and submerged structures are bounded by SRV air clearing loads (DBD046, Rev. 1, pp. 3, 42). A conservative SRV load definition for SSES was developed from examination of SRV test results for KWU (Kraktwerk Union) BWRs.[6] Out of the extensive KWU data base, three pressure-versus-time traces (so called KKB traces)[7], which were expected to result in conservatively high loadings, were chosen to define the suppression pool wetted-boundary and submerged-structure design basis loads (DBD046, Rev. 1, pp. 42-43). Frequency and amplitude adjustments were carried out on the data to add further conservatism.

Since the SSES SRV load specifications (based on KKB traces) were derived from test data for a similar, but not identical quencher design, it was deemed necessary to carry out testing with a prototype of the SSES quencher. The purpose of the prototypical testing was to ensure that SRV loads were bounded by the design load specification, and to further verify the steam quenching capability of the KWU quencher.[8] This testing was carried out by KWU at the Karlstein test facility (Germany).

*SRV Actuation Under LOCA Conditions*

The Karlstein tests used to verify SRV loads resulting from ADS actuation were carried out with depressed water level inside the SRV tail pipe. Owing to the SRV tailpipe vacuum breakers and the pressure differential between the drywell and wetwell, the water level inside the SRV tailpipe is independent of suppression pool level during a LOCA. The level coincides with the bottom of the downcomer pipes.[9] [10] When level inside the SRV tailpipe is depressed as a result of the drywell/wetwell pressure differential, there is a larger volume of air within the line. The larger air volume during LOCA conditions is the most significant factor that affects the SRV loads relative to the SRV loads during non-LOCA conditions when the water level inside the SRV line is equal to the water level outside the line. The larger air volume results in a decrease in SRV load frequency and an increase in load amplitude.[11]

Previous KWU testing has shown that the increase in wetwell airspace pressure during LOCA conditions (up to 30 psig) has no effect on the amplitude of the SRV loads.[12] A 30 psig wetwell airspace pressure is equivalent to the hydrostatic pressure due to a pool level increase of approximately 69 feet. It then follows that an increase in pool level has no effect on the amplitude of the SRV loads during LOCA conditions.

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[6] DBD046, Rev. 1, p. 42.

[7] Traces were obtained from SRV in-plant tests conducted at KKB power plant (Germany).

[8] DBD046, Rev. 1, pp. 45-46.

[9] SSES DAR, Section 8.5.3.3.4.6.

[10] The bottom of the downcomer pipes are 12 feet above the bottom of the suppression pool.

[11] SSES DAR, Section 4.1.1.e and Figure 8-169.)

[12] SSES DAR Section 8.5.3.3.3.4.

As discussed later in §5.1.3, the maximum expected suppression pool level increase expected in a design-basis accident is 1 foot (maximum pool level is 25 feet). For SRV performance, this is equivalent to an increase in wetwell pressure of 0.43 psi (0.030 bar). This small pressure change has negligible effect on the SRV load frequency.[13]

Table 1 shows the range of parameters considered in the ADS loading verification tests which were carried out with depressed water level inside the SRV discharge line. Test 11.1 was used to verify the conservatism of the ADS containment load definition since it produced the most severe boundary loads. Notice that the test resulting in the smallest containment hydrodynamic loads corresponds to the lowest reactor pressure (318 psig). Another important point concerning the SRV test conditions is the trending in suppression pool temperature, and accumulator pressure. Tests corresponding to reduced reactor pressure have higher initial pool temperatures. This is consistent with conditions expected in the plant: Low reactor pressure implies that significant reactor inventory has been discharged to the containment resulting in a rise in pool temperature.

**Table 1**
**Initial Conditions and Pressure Amplitudes for SSES ADS Load Verification Tests Conducted at Karlstein Test Facility[14]**

| Test No. | Pool Level (ft) | Accumulator Pressure (psig)[15] | Suppression Pool Temp. (°F) | Discharge Line Level (ft) | Discharge Line Air Temp. (°F) | Pool Boundary Over-Pressure Amplitude (bar) |
|---|---|---|---|---|---|---|
| 10.3 | 22.6 | 1160 | 73 | 11.7 | 126 | 0.40 |
| 11.1 | 24.3 | 1168 | 111 | 12.0 | 120 | 0.60 |
| 12.1 | 24.6 | 647 | 149 | 12.4 | 122 | 0.48 |
| 13.1 | 24.6 | 318 | 174 | 11.7 | 120 | 0.28 |

*SRV Actuation Under Non-LOCA Conditions*

Under non-LOCA conditions, water level inside the SRV tailpipe is approximately equal to the suppression pool level. Consequently, a rising pool level will result in increased loading on submerged containment structures because of the higher vent clearing pressure. However, a rising pool level has a negligible effect on the SRV load amplitude relative to other more significant parameters such as initial SRV discharge line volume, number of quenchers firing, etc.[16] The increase in containment loading associated with higher discharge line water levels can, however, be offset by decreasing reactor pressure. This relationship has been evaluated quantitatively by KWU using the Susquehanna-specific SRV discharge test results obtained at the Karlstein test facility. The following load-limit curve has been developed for Susquehanna.[17]

$$L = -0.01662P_R + 45.6 \qquad \text{where} \qquad (1)$$

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[13] SSES DAR Figure 8-175.

[14] SSES DAR, Tables 8.4 and 8.9. Pressure amplitude value corresponds to wall pressure (point 5.10).

[15] Accumulator pressure is equivalent to reactor pressure.

[16] SSES DAR Section 4.1.1.

[17] PLI-29888, "Suppression Pool Load Limit Curve", File 172-17, 835-02, December 1983.

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L = suppression pool water level (ft), and
$P_R$ = reactor pressure (psig).

If suppression pool water level is maintained below the curve defined by Equation (1), then containment loads for SRV actuation will remain within the design-basis envelope.

In developing the load limit curve, the most limiting component (downcomer bracing) was evaluated to ensure that adequate stress margin was available to accommodate the change in SRV loads anticipated along the load-limit line. The stress margin was conservatively based on the simultaneous occurrence of the following loads (Calculation EC-012-1103, "Downcomer & Bracing Analysis Detached from Containment Wall," Rev. 0):

SRV + SSE + LOCA

where

SRV = loads due to SRV actuation,

SSE = loads due to Safe Shutdown Earthquake, and

LOCA = loads due to LOCA steam condensation (condensation oscillation and chugging).

### 4.1.2 Loads on SRV System

For purposes of calculating loads on the SRV system due to valve actuation, a very conservative initial level of 35.33 ft was assumed for the discharge line.[18] This value is conservative because piping forces and discharge line back pressure both increase with the initial height of the water column within the line. This initial level inside the tailpipe was based on Bechtel calculations of the reflood height within the discharge line subsequent to a valve actuation. In calculating the reflood height, it was assumed that one vacuum relief valve failed to operate. This calculation of the reflood height was recognized to be very conservative because of known computer code limitations. DAR Figure 8-103 shows with one vacuum breaker locked closed that level does not come back to suppression pool level confirming the conservatism in the Bechtel calculation. For comparison, the KWU Karlstein tests confirmed that in only two instances did the reflood height exceed the pool level outside the SRV discharge line. The exceedance was less than 1.5 ft.[19]

## 4.2 LOCA Load Definition

Dynamic pressure loads generated during a LOCA are attributed to two steam condensation phenomenon, condensation oscillations which occur in the early part of the transient and "chugging" which occurs later in the blowdown. The design basis LOCA loads are based on full-scale steam condensation tests conducted by KWU at the GKM II-M test facility in

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[18] Bechtel Calculations PUP-15598-S2, PUP-15598-S6, and PLE-15315 (March 2, 1992).
[19] SSES DAR Section 8.4.2.2.4 and Figure 8-101.

Mannheim, Germany. Single cell tests were carried out at the test facility which consisted of a downcomer pipe and proportionate drywell and wetwell volumes. Downcomer submergence in the testing was 12 feet[20] which corresponds to a suppression pool level of 24 feet.[21]

Four different breaks were considered as part of the testing:[22]

- Complete break of a recirculation loop,
- Complete break of a main steam line,
- 1/3 main steam line break, and
- 1/6 main steam line break.

In carrying out the LOCA tests, a rupture disk is broken and steam flows through a discharge line into the drywell section of the test tank.[23] No water was removed from the suppression chamber section of the facility during the course of the test. The pool level was allowed to increase based on the blowdown rate into the pool. Therefore, the rising pool level realized during these tests was proto-typical of the pool level increase expected at Susquehanna.

## 5. Review of Design-Basis Accident Sequences Against Proposed Modification

This section examines the impact of the proposed modification on the plant response to relevant accidents and transients. The analysis is specific to power-uprate conditions. Events that are considered consist of all design basis events which involve loss of coolant inventory and any other event, within the plant design basis, which may result in HPCI initiation either automatically or by manual operator action. These events are listed below:

- Loss of Coolant Accidents inside containment,
- Inadvertent Safety/Relief valve opening,
- Primary system break outside containment,
- Inadvertent HPCI initiation,
- Loss of feedwater flow,
- Loss of Offsite AC Power,
- Loss of Main Condenser vacuum,
- Inadvertent MSIV closure,
- Turbine trip (with and without bypass),
- Generator Load Rejection (with and without bypass),
- Pressure regulator failure-closed/open,

Two special events, ATWS and Station Blackout, are also considered in the evaluation. Each of these events are discussed in detail below.

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[20] SSES DAR, Section 9.1.2.2.3.

[21] SSES FSAR, Table 6.2-1.

[22] SSES DAR, Section 9.3.

[23] SSES DAR, Section 9.4.1.

### 5.1 Loss of Coolant Accidents Inside Containment

Large, intermediate, and small break LOCAs are addressed separately in the following subsections.

### 5.1.1 Large Break LOCA

With respect to break area, the spectrum of large breaks is bounded by the full recirculation suction line break (4.17 ft$^2$).[24] and a 1 ft$^2$ break in the recirculation discharge line. Both of these breaks were analyzed by GE in the Susquehanna LOCA analysis for power uprate. The results are summarized below.

*Full Recirculation Suction Line Break*

For BWR ECCS performance analysis, the most limiting LOCA is a break of the recirculation line since this is the largest line connected to the vessel at an elevation below top of active fuel. The effective flow area for a suction side break of the recirculation line (DBA) is 4.17 ft$^2$.[25] For the DBA suction line break, HPCI initiation signal (high drywell pressure) is generated at 0.3 seconds.[26] HPCI begins to inject to the vessel at 30.3 seconds and stops at 43.9 seconds due to the rapid rate of vessel depressurization. During this event, the HPCI suction transfer logic has no appreciable influence on the rate of suppression pool level increase because of the very short time period of HPCI operation.

Elimination of the HPCI suction transfer logic does not affect the requirement to maintain the suppression pool level less than 24 feet in accordance with Technical Specification 3.6.2.1. Therefore, the initial pool level assumed in the LOCA analysis corresponds to 24 feet allowed by Tech. Spec. 3.6.2.1, and remains unchanged after the suction transfer modification. Consequently, the proposed modification has no adverse impact on containment response during the large-break LOCA.

*1.0 ft$^2$ Recirculation Discharge Line Break*

This event is analyzed in the GE power uprate LOCA analysis for Susquehanna.[25] In the GE calculation, HPCI is assumed inoperable, and the 1.0 ft$^2$ break of the recirculation line causes rapid loss of vessel inventory which results in depressurization of the reactor vessel. ADS automatically initiates on low reactor water level, but the reactor is substantially depressurized (326 psig) by the time (121 seconds) the ADS valves open.

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[24] Pappone, D.C., "SAFER/GESTR-LOCA Analysis Basis Document for Susquehanna Steam Electric Station Units 1 and 2," General Electric Report NEDC-32281P, Section 5.2.2, pp. 5-7 & 5-8, September 1993.

[25] General Electric Report NEDC-32281P, pp. 4-1 & 4-2, September 1993.

[26] NEDC-32281P, Table 6-2.

Break flows in this event are an order of magnitude larger than the HPCI injection rate. Therefore, HPCI operation (with suction from the CST) is not expected to have a significant impact on reactor and containment response during the early part of the transient. The scenario presented above, for HPCI inoperable, should approximate the rate of vessel depressurization and level decrease with HPCI injecting to the reactor. As a result, suppression pool level and reactor pressure at the time of ADS actuation will be essentially the same as in the case where HPCI is inoperable. Therefore, the containment hydrodynamic loads will be essentially the same as in the case where HPCI is inoperable. These loads are bounded by the design-basis SRV/LOCA load definitions which are based on a higher reactor pressure for ADS initiation.

### 5.1.2 Intermediate Break LOCA

A 0.1 $ft^2$ break area is considered representative of an intermediate break.[27] With regard to peak cladding temperature, the most limiting single failure coincident with the break is loss of a DC power source. Failure of a particular battery disables the HPCI system and one emergency diesel generator.[28] Obviously this scenario is not of much interest in evaluating the impact of eliminating the HPCI suction transfer logic on containment loads. Therefore, the case of an intermediate break (0.1 $ft^2$) with HPCI operable will be analyzed.

A SABRE[29] calculation was carried out to determine the reactor response to a 0.1 $ft^2$ break in the recirculation line with the HPCI system operable (RCIC is assumed to be inoperable because it is not a safety system[30]). A LOOP is also assumed to occur coincidentally with the break to be consistent with the design-basis LOCA analysis. HPCI initiates on high drywell pressure at about 1 second into the event. It is assumed that HPCI always takes suction from the CST, i.e., the automatic suction transfer on high suppression pool level has been eliminated. The LOOP causes a reactor scram, recirculation pump trip, loss of feedwater, and MSIV closure early in the event. Assuming a LOOP maximizes the operating time of HPCI during the accident (feedwater is lost within a few seconds of event initiation). This in turn maximizes the effect of the proposed modification on containment response.

Calculation results are presented in Figures 1-4. For the break considered, HPCI prevents level from dropping to the ADS initiation set point, but injection flow is not sufficient to maintain reactor level above the feedwater spargers. Steam condensation on the subcooled liquid injected by HPCI causes the reactor to depressurize. The difference in DW and WW pressures indicates that the downcomer vents are cleared throughout the entire transient. The LOCA is simulated up to the point where reactor pressure drops below the shutoff head of the core spray system. This

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[27] SSES FSAR, Section 6.2.1.1.3.3.4.

[28] General Electric Report NEDC-32281P, Section 5.2.

[29] Inputs and results of SABRE calculations discussed in this study are documented in PP&L Calc. EC-052-1025, Rev. 1, "SABRE Calculations for IPE HPCI Modification."

[30] Assuming RCIC inoperable is conservative with respect to this analysis. With RCIC operating, reactor pressure is reduced more quickly (more steam condensation on cold makeup flow) and ADS actuation is delayed slightly because of greater makeup flow. Therefore, in cases where ADS initiates, it does so at a lower reactor pressure which results in reduced containment loads.

corresponds to a ΔP of 292 psi between the water source and the reactor vessel.[31] For the LOCA scenarios of interest, Core Spray initiation occurs when reactor pressure drops to about 300 psig. The actual time of Core Spray injection is computed by the SABRE code based on reactor and containment pressures. LOCA simulations are carried out until the code predicts the onset of Core Spray injection to the vessel. At this point it is assumed that the operator will use Core Spray to provide coolant makeup to the vessel, and HPCI operation will no longer be required. This assumption is consistent with the design-basis function of the HPCI system given in the FSAR. Section 6.3.2.2.1 of the FSAR states "The HPCI system continues to operate until the reactor vessel pressure is below the pressure at which LPCI operation or core spray system operation can maintain core cooling."

The oscillations in break flow (Figure 3) occur because of variations in downcomer subcooling. Actual water level is only a small distance below the feedwater spargers (sparger elevation is -24"), and consequently, small changes in level result in substantial changes in steam condensation efficiency. For example, as break flow decreases, level in the downcomer will rise, and the condensation efficiency decreases. This causes subcooling to increase which results in a higher break flow which begins to force level downward. As level drops, condensation efficiency increases, and the downcomer becomes less subcooled. The decrease in subcooling causes a decrease in the break flow which allows level to rise and begin the cycle again.

Figure 4 shows the level response for the SP and drywell pool. The rise is SP level is due to steam discharged from the HPCI turbine (~50 $Lb_m$/sec) and steam discharged to the SP through the downcomer vents. Water level in the drywell does not reach 18" where it would begin to overflow from the drywell to the wetwell through the downcomer vents (the downcomer vents extend 18" above the floor of the drywell).

Since ADS would not be initiated for a 0.1 $ft^2$ break with HPCI operable, the concern raised in the HPCI DBD about HPCI causing suppression pool level to exceed 24 feet prior to initiation of SRV/ADS blowdown is not valid. Moreover, as discussed for the large-break LOCA (§ 5.1.1), elimination of the automatic HPCI suction transfer on high suppression pool level does not affect the Technical Specification requirement to maintain pool level less than 24 feet prior to the occurrence of a break. Containment loads due to the LOCA are based on the initial suppression pool level. The DBA LOCA produces bounding loads which were derived from an initial level of 24 feet and all break flow going into the pool.

Although it is not a licensing requirement to consider a single failure at times other than the initiation of the accident, it is prudent to examine the impact of HPCI failure with SP level greater than 24 feet. In this event, the reactor vessel depressurizes below the shutoff head of the low pressure ECCS (~300 psig) before there is any substantial rise in suppression pool level (see Figures 1 and 4). When reactor pressure drops to 300 psig at about 600 seconds into the event, suppression pool level has only risen to 24′-4″. As discussed in §4.1.1, the water level inside the

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[31] "Susquehanna Steam Electric Station Individual Plant Evaluation," NPE-91-001, Vol. 2, p. A-104, December 1991

SRV tailpipe is depressed when the downcomer vents are cleared, and the larger air volume within the line is the most significant factor that affects the SRV loads relative to SRV loads under non-LOCA conditions. The HPCI suction transfer logic modification has no affect on the discharge line air volume when the downcomer vents are cleared. The modification only affects the back pressure on the line as a result of the slightly higher pool level, and as discussed in §4.1.1, this has no affect on the amplitude of SRV loads and negligible affect on the load frequency.

Since HPCI is running at full flow in this transient, and RPV water level is significantly below the high-level trip of 54", a HPCI trip (on high level) and restart is very unlikely. Therefore, it will not be considered here. The consequences of a HPCI trip and restart are addressed below in the section on small break LOCA.

### 5.1.3 Small Break LOCA

In order to evaluate the impact of eliminating the HPCI high-pool-level suction transfer on a small break LOCA, SABRE calculations were carried out for two small breaks: a 0.02 $ft^2$ break and a 1" line break (0.00545 $ft^2$). DBD004 Rev. 1, p. 32 states that " It [HPCI] is designed to be capable of making up inventory losses for liquid breaks below about 0.02 sq ft, thus maintaining reactor level." With regard to the 1" line break, FSAR Section 6.3.1.1.1 states "One high pressure cooling system is provided which is capable of maintaining water level above top of core and preventing ADS actuation for breaks of lines less than 1 inch nominal diameter." The LOCAs are simulated up to the point where reactor pressure drops below the shutoff head of the core spray system (~300 psig).

For the 1" line break (0.00545 $ft^2$), suppression pool level increases by only 4 inches. The 0.02 $ft^2$ line break is much more limiting and this is discussed below.

Figures 5-9 show the calculated reactor and containment response for the 0.02 $ft^2$ break. In this calculation HPCI takes suction from the CST until SP level reaches 25 feet. When level reaches 25 feet, the operator manually transfers HPCI suction from the CST to the SP. The rationale for the manual transfer is discussed later in this section. RCIC is assumed inoperable in this event because it is not a safety system. The initial suppression pool level is specified as the Tech. Spec. limit (24 feet). A LOOP is also assumed to occur coincidentally with the break. As mentioned earlier, assuming a LOOP maximizes the operating time of HPCI during the accident (feedwater is lost early in the event), which in turn maximizes the effect of the proposed modification on containment response. A controlled cooldown of the reactor, at 90 °F/hr, is initiated at 10 minutes into the event[32]. One loop of SP cooling becomes effective at 15 minutes into the event, and SP letdown via the RHR system to liquid radwaste is initiated at 30 minutes. The SP letdown flowrate is 120 $Lb_m$/sec.[33]

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[32] EO-000-102.

[33] T.S. Yih, "Suppression Pool Let-Down Flow Rate In Suppression Pool Cooling Mode," Calc. EC-THYD-1007, Rev. 0.

Cold water injected by HPCI quickly increases the core-inlet subcooling which lowers the vapor generation rate within the core. Condensation on HPCI injection flow, while the feedwater spargers are uncovered, and steam extraction by the HPCI turbine act to slowly depressurize the vessel. After 10 minutes, the operator occasionally opens a SRV to depressurize the reactor at 90 °F/hr.

With HPCI suction aligned to the CST, SP water level continues to increase during the event. As SP water level significantly exceeds the Tech. Spec. limit of 24 feet, two concerns arise:

1. If HPCI fails while reactor pressure is above the shutoff head of the low-pressure ECCS (CS and LPCI), and an ADS actuation is required, are the resultant containment hydrodynamic loads acceptable?
2. If HPCI trips, on high reactor water level (+54") for example, can it be safely restarted with elevated SP water level?

Although it is not licensing requirement to examine the consequences of a single equipment failure (HPCI failure) or a single operator error (HPCI trip on high level) which occurs during the long-term part of an accident, it is prudent to do so, and therefore, these two concerns are addressed in the following discussion along with the availability of the manual transfer capability.

### *HPCI Failure with High SP Level*

Containment loads associated with a small break LOCA combined with ADS actuation are considered in plant design.[35] As discussed in §4.1.1, whenever the downcomer pipes are cleared, the air volume inside the SRV tailpipe is independent of suppression pool level. Thus, this parameter is not affected by the proposed modification. The higher pool level associated with the modification only results in a higher back pressure on the SRV discharge line, but this has no effect on the amplitude of the SRV loads (see §4.1.1). For the 0.02 $ft^2$ break, the downcomer vents are cleared for the first 970 seconds of the event. After 970 seconds, the downcomer vents begin to refill with water.[36] The downcomer vents refill because the cold HPCI injection decreases the break enthalpy to the point where the coolant discharged to the DW starts to have a cooling effect.

The state of the downcomer vents (open or closed) leads to two distinct situations to consider when evaluating ADS loads with elevated SP level. If the downcomer vents are cleared, the level inside the SRV tailpipe is not influenced by pool level, and as discussed above, the proposed modification has no influence on ADS hydrodynamic loads.

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[35] Susquehanna FSAR Table 3.9-2, Rev. 40, 09/88.

[36] PP&L Calc. EC-052-1025, Rev. 1.

On the other hand, if the downcomer vents are sealed with water, there are no dynamic-pressure LOCA loads (condensation oscillations or chugging) within the suppression chamber, but the ADS loads become dependent on SP water level. In this case, the SRV loads associated with ADS actuation are acceptable as long as SP level is below the Load Limit curve (Eqn. 1).

Figure 10 shows a plot of calculated SP water level versus reactor pressure. The Load Limit curve for Susquehanna is also shown. The plot shows that the SP water level is always well below the Load Limit curve which demonstrates that ADS actuation, necessitated by HPCI failure at any time during the event, is acceptable. For sake of comparison, the pool level versus reactor pressure response for the 0.1 $ft^2$ break and the 1" line break are also included in Figure 10.

As discussed earlier, in developing the Load Limit Curve, the most limiting component (downcomer bracing) was evaluated to ensure that adequate stress margin was available to accommodate the change in SRV loads along the Load-Limit Curve. The stress margin was conservatively based on the simultaneous occurrence of the following design-basis loads (Calculation EC-012-1103, Rev. 0):

SRV + SSE + LOCA

where

SRV = loads due to SRV actuation,

SSE = loads due to Safe Shutdown Earthquake, and

LOCA = loads due to LOCA steam condensation (condensation oscillation and chugging).

For this event, ADS actuation may occur when the downcomer vents are not cleared and so the LOCA steam condensation loads cannot occur. In addition, it is improbable that the SSE would occur simultaneously with ADS actuation. The LOCA and SSE loads comprise a significant portion of the total component stress in developing the Load-Limit Curve. Removing the LOCA and SSE loads increases the stress margin and would allow the Load-Limit Curve to be moved upward. Comparing the ADS loads for this event to the Load-Limit Curve is extremely conservative.

### *HPCI Trip and Restart with High SP Level*

Several potential problems have been identified with a HPCI trip and restart at high SP level. These problems are summarized below along with their resolutions.

**Problem 1.** There was concern over HPCI turbine exhaust line flooding in a small-break accident if HPCI trips with pool level above the exhaust line containment penetration (25.6 feet above the bottom of the pool). It was postulated that water would leak through turbine exhaust line check valve F049, and a water-hammer accident would then occur upon restart of the HPCI turbine possibly disabling the machine.

**Resolution.** Based on expected leakage rates through the F049 valve, Study EC-THYD-1005 concluded that leakage will be contained well within the turbine exhaust line drain pot. The study shows that even if the initial drain pot level is at the high-level alarm set point (75% full), there is sufficient capacity to allow for a leakage rate which is 50 times the measured value. Therefore, a water hammer accident will not occur upon restart of the turbine.

**Problem 2.** With the proposed modification, water level, in a small break accident, may reach 27.2 feet and completely submerge the horizontal section of the turbine exhaust line which penetrates the containment.[37] If HPCI trips with pool level ≥ 27.2 feet, water will flood the horizontal section of piping up to isolation check valve F049. When this occurs, the column length of water in the exhaust line increases by about 25 feet. Due to inertial effects, a higher turbine exhaust pressure will develop as this column of water is expelled upon auto restart of the turbine. This raises a concern that the HPCI pressure-relief diaphragms will rupture upon turbine restart and render the system inoperable.

**Resolution.** The EOPs will be modified to include operator action to manually transfer HPCI suction from the CST to the suppression pool if pool level reaches 25 feet with pool temperature less than 140 °F. If HPCI trips with pool level at 25 feet, there will be no suppression pool water contained within the horizontal section of exhaust piping (20 inch pipe).[38] In a small break accident, pool level can reach 25 feet only for a narrow range of break sizes. Moreover, the operator action to manually transfer HPCI suction from the CST to the suppression pool is not required in the early part of the accident. The earliest the manual transfer could be required is 21 min. into the accident with pool level initially at 24 feet (Calc. EC-052-1025, Rev. 1). If pool temperature is greater than 140 °F when pool level reaches 25 feet, HPCI suction will not be transferred to the pool because adequate cooling of the HPCI pump cannot be assured. For a small liquid break, however, suppression pool temperature is not expected to exceed 140 °F while HPCI is operating.

**Problem 3.** If, in a small-break accident, suppression pool level reaches 28.5 feet, the air intake for the HPCI turbine exhaust-line vacuum breakers (F076 and F077 on the HPCI turbine exhaust line) becomes submerged. The most serious consequence of disabling the vacuum breakers is the potential for water hammer on the turbine exhaust-line check valve (F049) in the event of a system trip. When HPCI trips, the exhaust line is filled with hot steam (no air). As water from the pool flows into the exhaust pipe, steam condensation on the cold water will occur and this will rapidly drop pressure in the exhaust pipe and

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[37] When suppression pool water level exceeds 25.1 ft. and HPCI is not running, pool water will begin to back flow into the horizontal section of the HPCI turbine exhaust line. When pool level reaches 27.2 ft., the turbine exhaust line will be completely flooded up to check valve F049.

[38] The minimum inside bottom elevation of the 20" horizontal HPCI turbine exhaust piping is 25.1 ft per Calculation EC-052-1025 Rev. 3.

accelerate the slug of water. When the slug of water enters the horizontal section of piping, the hydrodynamic behavior at the front is extremely complex. Specifically, churning effects at the front may constantly expose cooler water to the hot steam which would result in rapid condensation and acceleration of the slug. This phenomena is too complicated to be analyzed with a reasonable degree of uncertainty.

**Resolution.** This problem is eliminated by the resolution to problem 2. Note that if pool temperature is greater than 140 °F, there is no point in transferring HPCI suction back to the pool under any circumstance because continued operation of the system cannot be assured. Suppression pool temperature is not expected to exceed 140 °F while HPCI is running in a design-basis small break accident.

**Problem 4.** The HPCI turbine exhaust pressure may exceed design limits.

**Resolution.** The HPCI turbine is designed to operate at a maximum continuous exhaust pressure of 65 psia (HPCI DBD004). Study EC-THYD-1005 shows that there is ample margin to the design exhaust pressure limit of 65 psia.

With the exception of ATWS and Station Blackout, the Susquehanna EOPs currently allow the operator to bypass the HPCI suction transfer logic and maintain HPCI suction on the CST only if SP temperature exceeds the HPCI design limit of 140 °F. The EOP guidance which is proposed along with the HPCI suction transfer logic modification is much less restrictive than the current guidance. If SP temperature is less than 140 °F, it allows HPCI to inject demineralized water from the CST until pool level reaches 25 feet. This reduces greatly the chance of injecting SP water into the reactor especially for a very small break (instrument line break) or an isolation transient in which RCIC fails to start.

## 5.2 Inadvertent Safety/Relief Valve Opening (IORV)

This event is discussed in Section 15.1.4 of the FSAR. Opening of a SRV will cause a mild depressurization transient, but the pressure regulator will adjust the turbine control valves to stabilize pressure. When suppression pool temperature exceeds 90°F, the operator will enter EO-000-103, Primary Containment Control. The procedure instructs the operator to initiate suppression pool cooling to restore pool temperature less than 90°F. If level exceeds 24 feet, the EOP also requires the operator to reduce suppression pool level below 24 feet using suppression pool letdown systems.

If the SRV remains open, pool temperature will continue to increase and will reach 110°F at about 9 minutes into the event.[40] Before the pool reaches this temperature, the operator will initiate a reactor scram in accordance with the EOPs.. (Actually, the scram would occur much

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[40] This time was estimated from the suppression pool heat up curve presented in Calc. EC-059-0532 (SE-B-NA-128).

earlier; for a stuck open relief valve, ON-183/283-002 per Tech. Spec. 3.4.2.b requires a reactor scram within 2 minutes.) Following the reactor scram, the stuck open SRV will begin to depressurize the reactor. The reactor scram may cause a HPCI initiation on low water level (-38").

Prior to the event, HPCI is not operating; therefore, it has no adverse effect on the air clearing load due to the actuation of the IORV. Following the scram when HPCI is operating, the IORV has the potential for producing only steam condensation loads on submerged structures. Air clearing loads cannot be produced since this requires the SRV to close and then reopen. Steam condensation loads are within the containment design limit as long as the suppression pool temperature response is maintained within the limits of NUREG-0783. The design basis IORV transient for power uprate conditions (Calculation EC-059-0532) verifies that the pool temperature response to an IORV event remains within the limits of NUREG-0783. Therefore, SRV steam condensation loads when HPCI is operating do not adversely affect the SRV containment hydrodynamic loads.

### 5.3 Primary System Pipe Break Outside Containment

For a break external to the primary containment, any coolant injected by HPCI will not end up in the suppression pool; it exits the break within the secondary containment. Therefore, in this situation HPCI injection does not cause a rise in pool level. Steam would be added to the pool from the HPCI turbine exhaust, but this steam would also be present without the proposed modification. The addition of steam to the suppression pool from HPCI turbine exhaust would cause a slow rise in pool level compared to a liquid break inside containment, and therefore, there will be ample margin to the Load Limit Curve.

### 5.4 Inadvertent HPCI Initiation

This event is discussed in Section 15.5.1 of the FSAR. Only small changes in plant conditions are expected in this event because of the pressure regulator and water level controller response. Since no SRV actuations are expected, SRV/ADS hydrodynamic loads are not an issue.

### 5.5 Loss of Feedwater Flow

On a loss of feedwater flow, the reactor will scram when level drops to +13". The void collapse caused by the scram will generate a HPCI initiation on low level (-38"). No SRV actuations are expected in this scenario because MSIVs remain open. Therefore, SRV/ADS hydrodynamic loads are not an issue.

### 5.6 Loss of Offsite AC Power

A LOOP initiates a reactor scram, recirculation pump trip, and MSIV closure. The effect of HPCI operation on containment hydrodynamic loads is the same as in the case of an inadvertent MSIV closure which is discussed in §5.8.

## 5.7 Loss of Main Condenser Vacuum

Loss of main condenser vacuum leads to closure of the MSIVs. The relationship between HPCI operation and containment hydrodynamic loads for an MSIV closure is discussed in §5.8.

## 5.8 Inadvertent MSIV Closure

Closure of the MSIVs generates a reactor scram, and HPCI will initiate on low reactor water level. The HPCI suction transfer logic has no impact on containment loads generated by SRV actuations during the pressurization event because HPCI is not operating prior to the MSIV closure. Following the MSIV closure, some cycling of SRVs will occur as decay heat is transferred to the suppression pool, but only the first group of valves (2 valves) will open. With only a small number of SRVs cycling, minor suppression pool level transients are not of much concern with respect to containment hydrodynamic loads.

The safety setpoint for the first group of SRVs is 1175 psig[41]. The design basis event for SRV hydrodynamic loads is the ASME Overpressurization Event which results in the maximum steam dome pressure which envelopes the 1175 psig SRV opening pressure. A SABRE calculation estimates that the pool level will rise only about 1 inch in the first 10 minutes following a MSIV closure.[42] The margin in peak steam dome pressure overwhelms any negative effects associated with the very small increase in suppression pool level. Note that this conclusion can also be arrived at through consideration of the Load Limit Curve (Equation 1). At a reactor pressure of 1175 psig, the Load Limit Curve gives a suppression pool level of 26.1 feet. That is, the containment design allows for actuation of SRVs with suppression pool water level up to 26.1 feet.

In the long-term part of the event (>10 minutes), it is assumed that the operator will initiate a controlled cooldown of the reactor in accordance with the EOPs. The SP level response during the cooldown is certainly bounded by the response for the small-break LOCA. Therefore, pool level is always well below the Load Limit curve, and there are no adverse consequences associated with SRV actuations during the cooldown.

Following a transient such as a MSIV closure, it is not necessary to postulate a LOCA. Consideration of a LOCA following a transient is beyond the plant design basis.[43]

## 5.9 Turbine Trip (with and without Bypass)

The more severe turbine trip case with respect to containment hydrodynamic loads involves failure of the bypass valves because it results in a higher reactor pressure and a larger number of open SRVs. As discussed in the previous section, the HPCI suction transfer logic has no influence on containment loads generated by SRV actuations during the pressurization event

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[41] SSES Technical Specifications, Section 3.4.3, Amendment 178.
[42] PP&L Calculation EC-052-1025.
[43] DBD035, Section 2.2.2.1.7.

because HPCI is not operating prior to the turbine trip. Following a turbine trip event, it is unlikely that HPCI would be used for vessel makeup because feedwater would be available. If for some reason HPCI is used for vessel makeup following the vessel pressurization transient, its impact on containment loads is no different that that already discussed in §5.8.

### 5.10 Generator Load Rejection (with and without bypass)

For purposes of evaluating the impact of the proposed plant modification on the containment loads, this transient is the same as the turbine trip with/without bypass.

### 5.11 Pressure Regulator Failure - Closed

This transient is discussed in Section 15.2.1 of the FSAR. If the backup pressure regulator is also assumed to fail, then a reactor pressurization will result from control valve closure, and the reactor will scram on high vessel pressure or high neutron flux. This pressurization event is less severe than the turbine trip which was discussed in §5.9 (FSAR Section 15.2.1.2.3, Rev. 54, 10/99).

### 5.12 Pressure Regulator Failure - Open

This event is discussed in Section 15.1.3 of the FSAR (Rev. 54, 10/99). Failure of the pressure regulator causes reactor depressurization which initiates closure of the MSIVs. The MSIV closure generates a reactor scram. Here MSIV closure occurs at reduced reactor pressure so SRVs actuations do not occur. Later in the transient, SRV cycling will occur as decay heat is removed from the RPV. SRV cycling following a MSIV closure with HPCI injecting to the vessel has already been addressed in §5.8.

### 5.13 ATWS

As discussed in the Introduction Section of this report, elimination of the HPCI suction transfer on high pool level is needed to prevent HPCI failure in an ATWS event with SLCS failure. In a MSIV-closure ATWS with SLCS failure, the reactor can be brought to Hot Shutdown in approximately one hour by manually driving rods via the Reactor Manual Control System. PP&L calculations show that during this time suppression pool level rises to about 30 feet.[44]

In an ATWS event with SLCS failure, high suppression pool level is tolerated because there are no acceptable alternatives. If HPCI suction is transferred to the suppression pool in order to stop the increase in pool level, then failure of the system is likely as pool temperature is calculated to reach 316 °F which is well above the HPCI suction design limit of 140 °F. If a reactor blowdown is initiated in order to obtain injection with LPCI or Core Spray, then there is a threat to core integrity from unstable reactor operation.[45]

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[44] PP&L Calc. EC-EOPC-0519, "SABRE Calculations to Support Technical Basis of IPE and ATWS EOP," Rev. 3.

[45] Calc. EC-EOPC-0519, Rev. 3.

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The load limit curve (Equation 1) can be exceeded by about 3 feet in an ATWS with SLCS failure. However, for SRV actuation during an ATWS event, the load limit curve represents a conservative criterion. This is because the load combination considered in developing the curve includes SRV loads, LOCA loads, and SSE (Safe Shutdown earthquake) loads. For the ATWS event, the LOCA and SSE loads would not be present. Moreover, the limiting containment component with regard to stress margin is the downcomer bracing which is not an important component in the ATWS event. On the other hand, HPCI is important for ATWS mitigation. Failure of HPCI from loss of cooling would require rapid depressurization of a critical reactor and reflooding of the core with low-pressure ECCS. It is likely that core damage would occur following depressurization. Therefore, the proposed strategy does not transfer HPCI suction to the pool in an ATWS event.

### 5.14 Station Blackout

EO-100/200-032, "HPCI Operating Guidelines During Station Blackout," instructs the operator to prevent the auto swap over from the CST to the suppression pool on high pool level. Manual bypass of the suction transfer logic is carried out in accordance with Emergency Support Procedure ES-152/252-002. Since HPCI and RCIC are the only ECCS pumps available in a SBO, it is crucial to prevent damage to the HPCI system from injection of hot suppression pool water. Removal of the HPCI suction transfer on high pool level will reduce operator burden during a SBO event.

## 6. Conclusions

Elimination of the HPCI suction transfer on high suppression pool level does not lead to a violation of the design-basis for containment hydrodynamic loads. The proposed modification is acceptable for the following reasons:

- LOCA loads are based on a maximum initial suppression pool level of 24 feet. The proposed modification to the HPCI suction transfer logic does not affect the initial pool level. During normal plant operation, suppression pool level is controlled by Technical Specification requirements.

- For LOCAs other than the DBA, the containment is designed for ADS blowdown loads in combination with the LOCA loads. For an intermediate break, the proposed HPCI modification does allow suppression pool level to exceed 24 feet by a small amount. ADS loads are, however, independent of SP level when the downcomer vents are cleared. Therefore, the proposed modification has no influence on ADS hydrodynamic loads for an intermediate break.

- For small breaks, HPCI injection prevents ADS actuation. Nevertheless, SRV actuations occur during the RPV cooldown. Downcomer vents are opened in the beginning part of the accident, but close later on as the break enthalpy decreases. When the downcomer vents are cleared, the level inside the SRV tailpipe is not influenced by pool level, and therefore, the

SRV hydrodynamic loads are unaffected by the proposed modification. During the phase of the accident in which the downcomer vents are sealed with water, there are no wetwell LOCA hydrodynamic loads, but the SRV loads are dependent on SP water level. In this case, SRV loads are acceptable because SP water level is always below the Load Limit curve (Eqn. 1).

- In the small break LOCA there is ample margin to the HPCI design exhaust pressure limit of 65 psia even with elevated suppression pool level.
- ADS actuation would be required in the event of a HPCI failure during a small-break accident. If HPCI fails during the phase of the accident in which the downcomer vents are cleared, then ADS loads would be acceptable because water level (and air volume) within the SRV tailpipes is independent of pool level. Even if HPCI failure occurs in the latter part of the accident where the downcomer vents are sealed, ADS loads are acceptable because water level is always well below the Load Limit curve.
- In a small break LOCA, leakage through check valve F049, following a HPCI trip and prior to restart, will not lead to a water hammer accident upon restart of the turbine because the leakage will be contained well within the turbine exhaust line drain pot.
- Vacuum breakers (F076 and F077) on the HPCI turbine exhaust line prevent water hammer damage to check valve F049 on a trip of the HPCI system. The vacuum breakers will remain operable during a small break accident because an EOP change will be initiated as part of the modification package to instruct the operator to manually transfer HPCI from the CST to the suppression pool if pool level exceeds 25 feet and pool temperature is less than the HPCI suction design limit of 140 °F. If SP temperature is greater than 140 °F, pool level is allowed to exceed 25 feet because transferring suction to the pool could lead to failure of the HPCI system; however, suppression pool temperature is not expected to exceed 140 °F in a small break accident while HPCI is operating. This proposed EOP guidance is less restrictive than the current guidance for HPCI operation, and it reduces greatly the chance of injecting SP water into the reactor vessel.
- If HPCI trips during a small break accident when suppression pool level is elevated, it can be successfully restarted. The modification package includes an EOP change which requires the operator to manually transfer HPCI suction from the CST to the suppression pool if pool level exceeds 25 feet and pool temperature is less than 140 °F. This manual transfer prevents pool water level from reaching the elevation where flooding of the turbine exhaust piping would occur in the event of a HPCI trip. Suppression pool temperature does not exceed 140 °F in a small break accident while HPCI is operating.
- Under non-LOCA conditions, the containment is designed for simultaneous actuation of all 16 SRVs. The Load Limit Line defines the acceptable operating region, in terms of reactor pressure and suppression pool level, for SRV actuation. Following a plant transient involving HPCI operation, the suppression pool level is always below the Load Limit curve, and only a small number of SRVs actuate to remove decay heat from the reactor.

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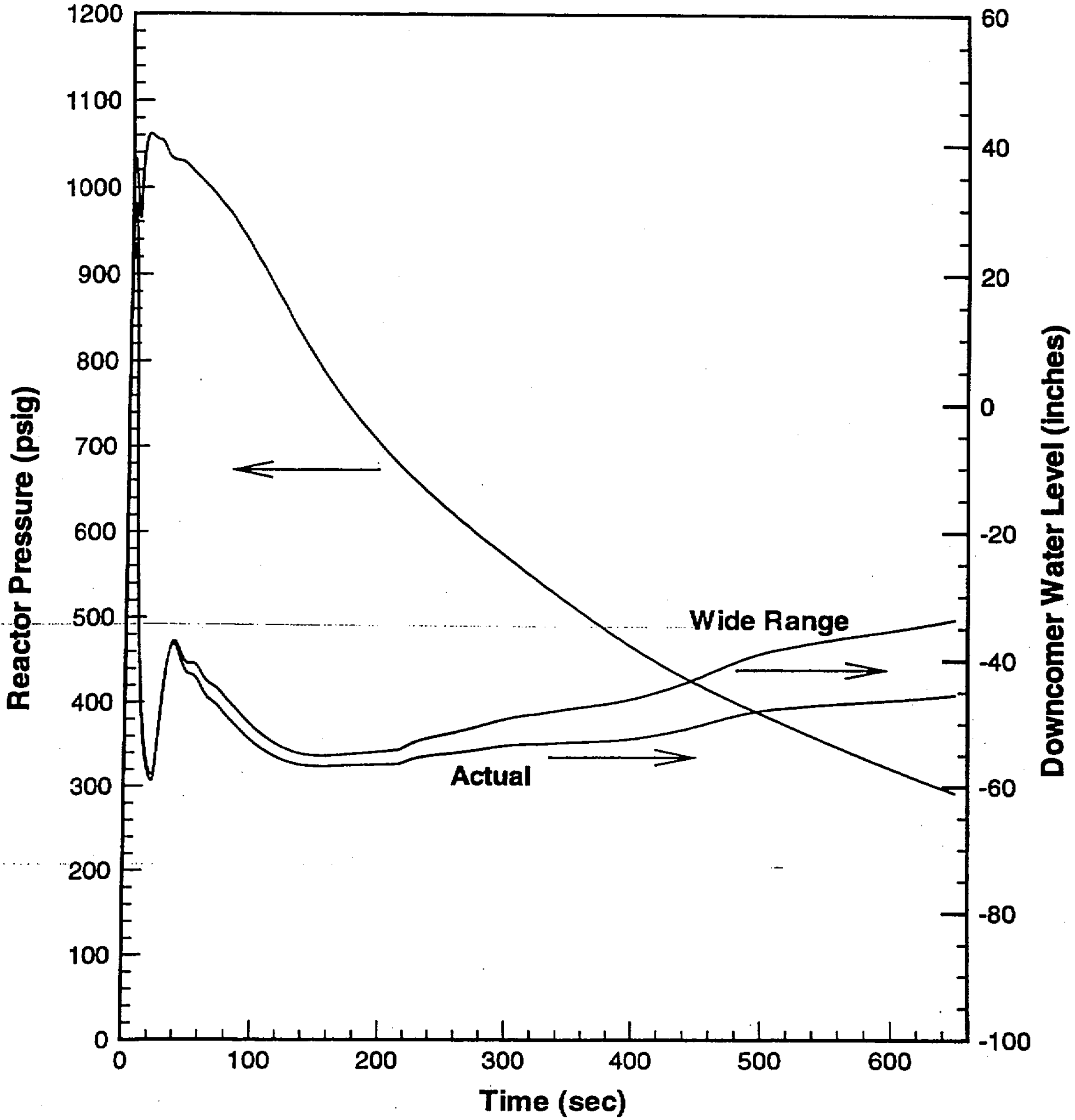

Figure 1 Calculated reactor response for 0.1 $ft^2$ liquid break.

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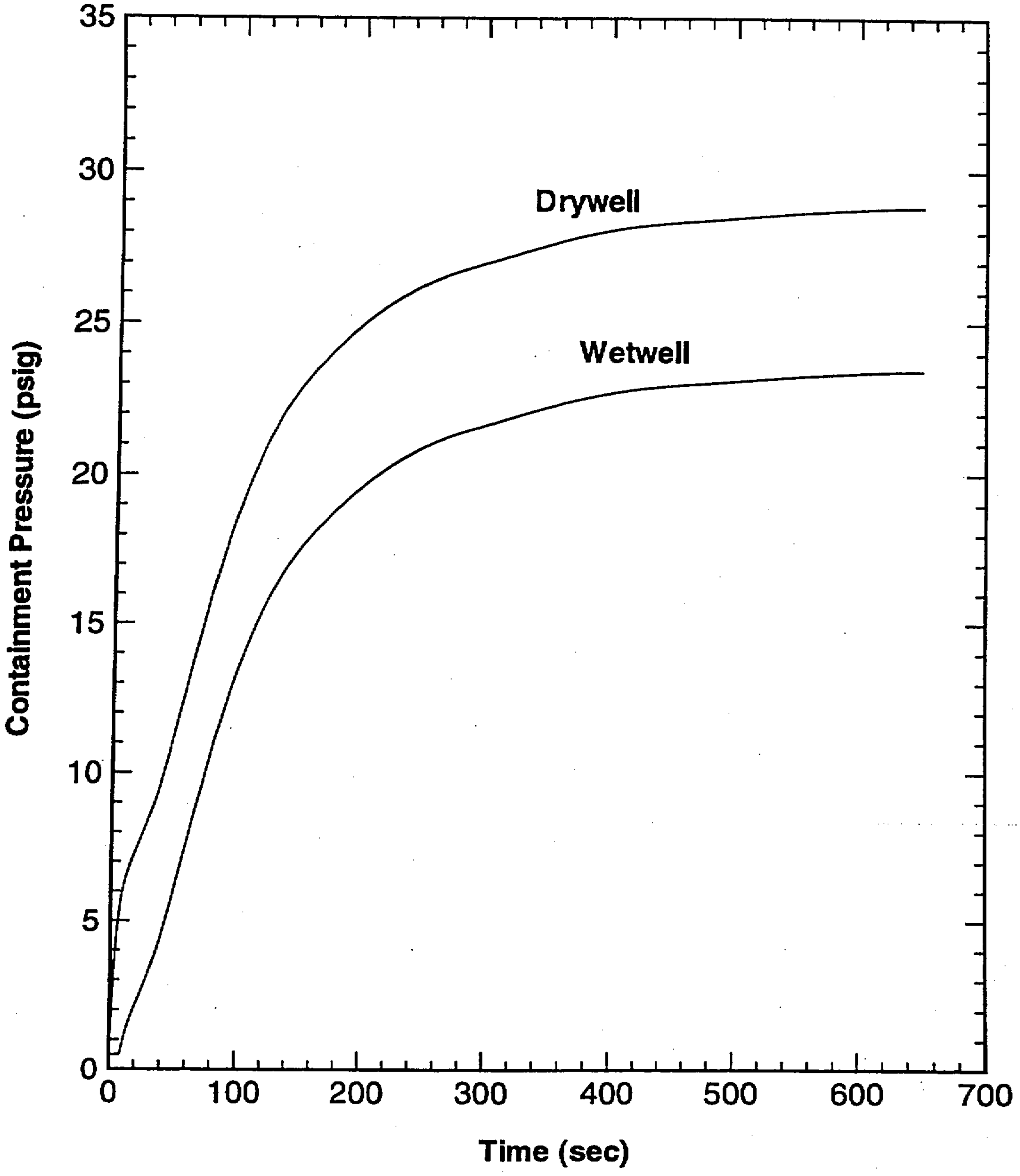

Figure 2 Calculated primary containment response for 0.1 $ft^2$ liquid break.

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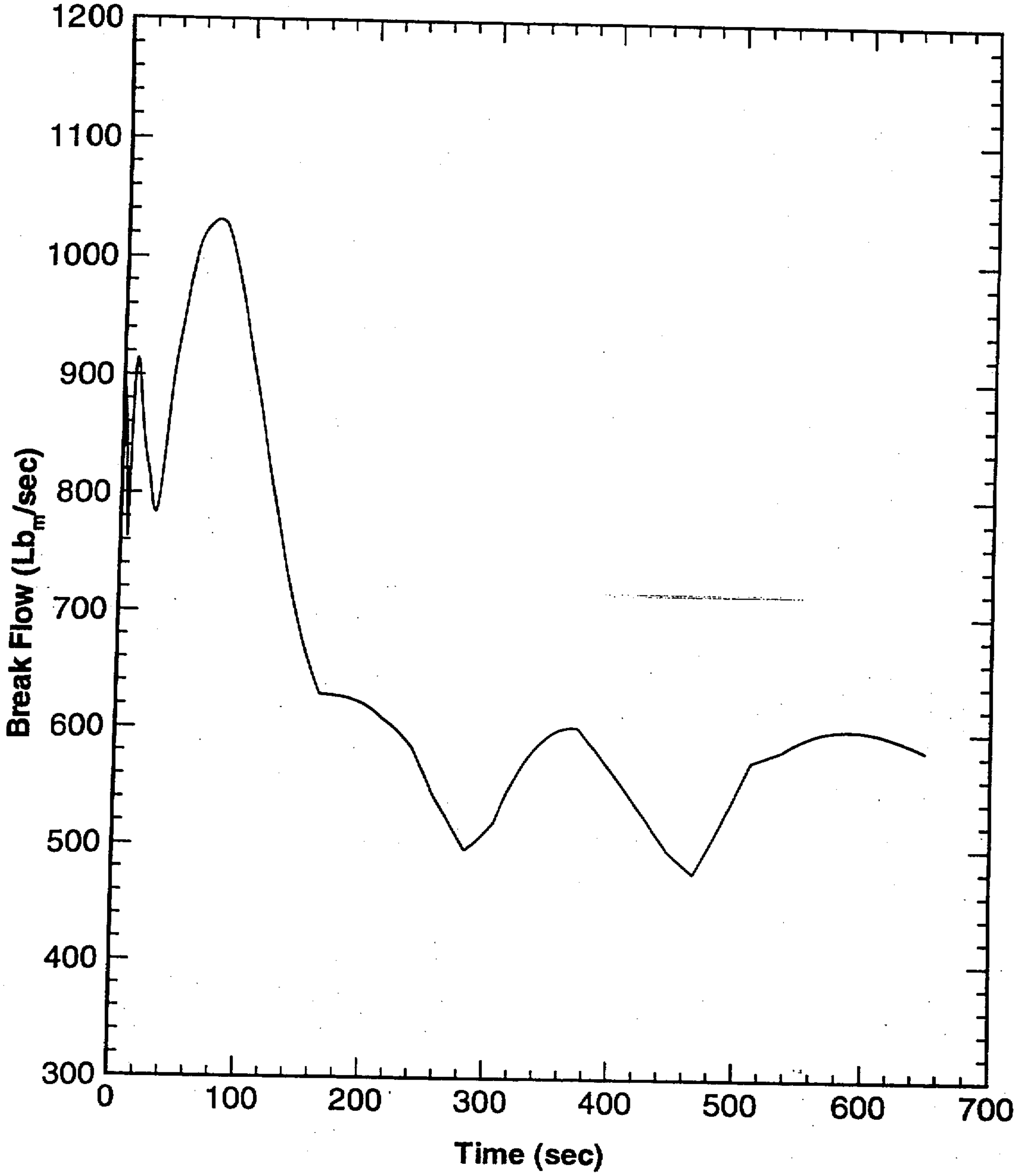

Figure 3 Calculated break flow rate for 0.1 ft$^2$ liquid break.

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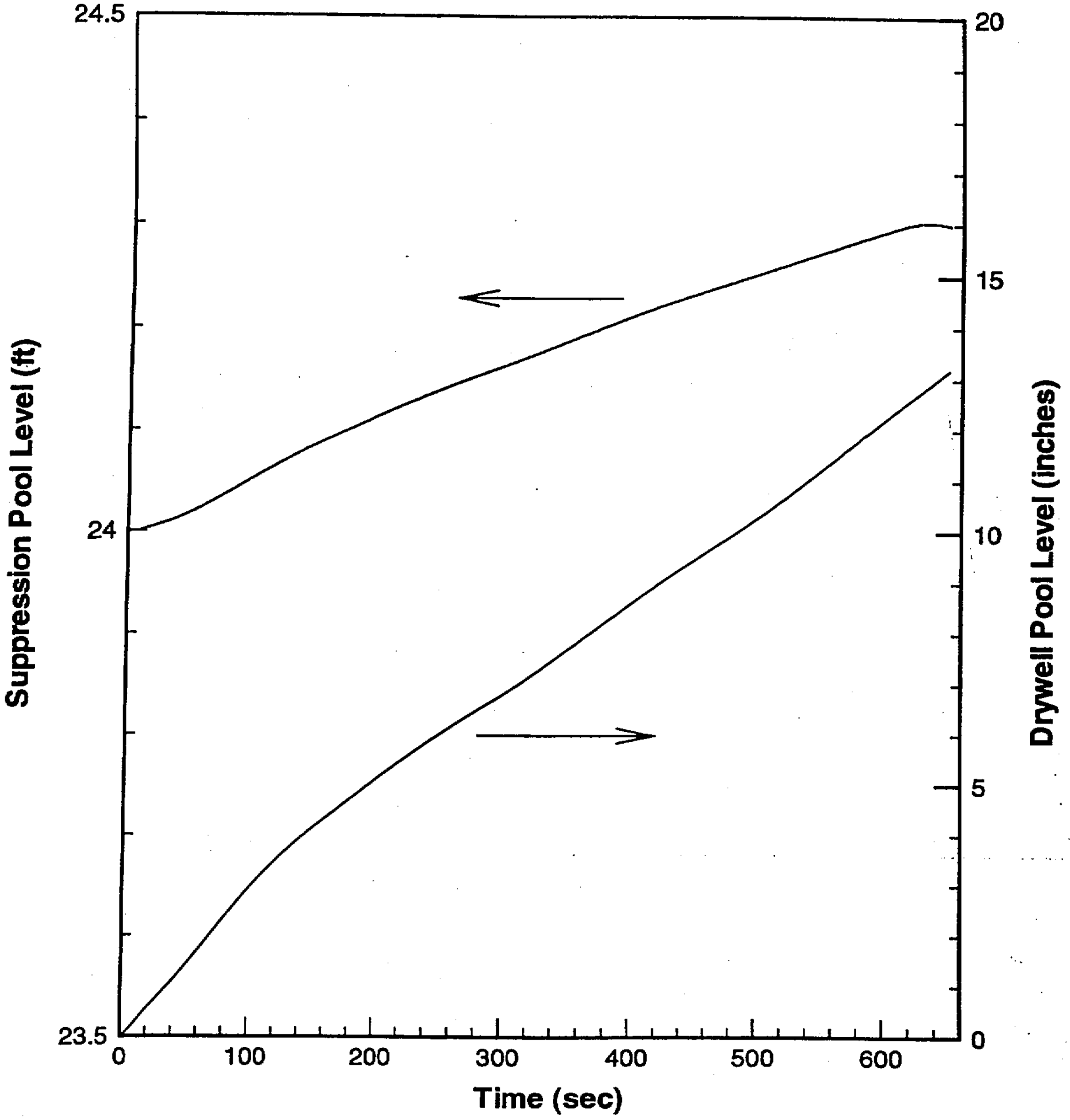

Figure 4 Calculated primary containment water level for 0.1 $ft^2$ liquid break.

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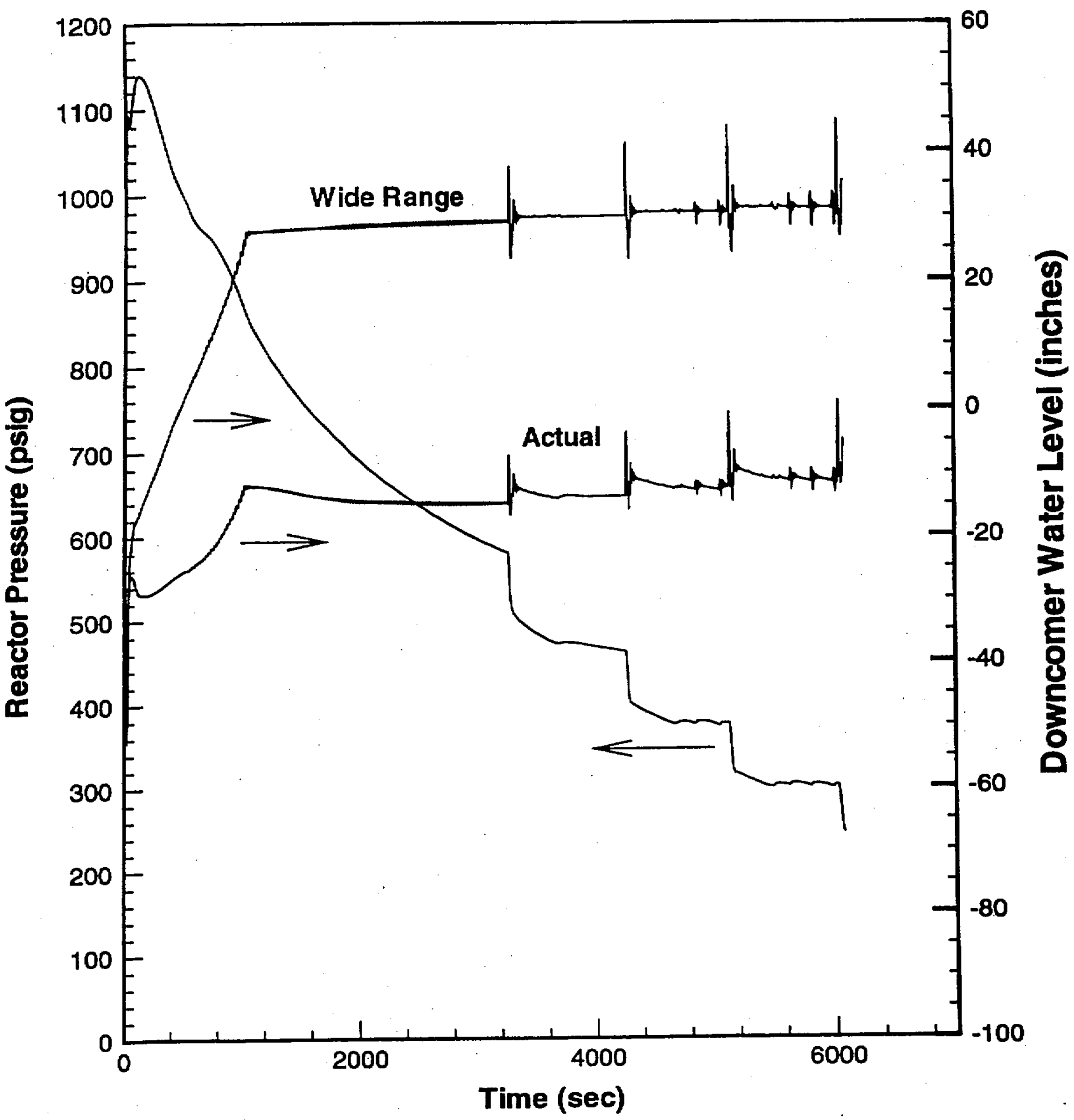

Figure 5 Calculated reactor response for 0.02 $ft^2$ liquid break.

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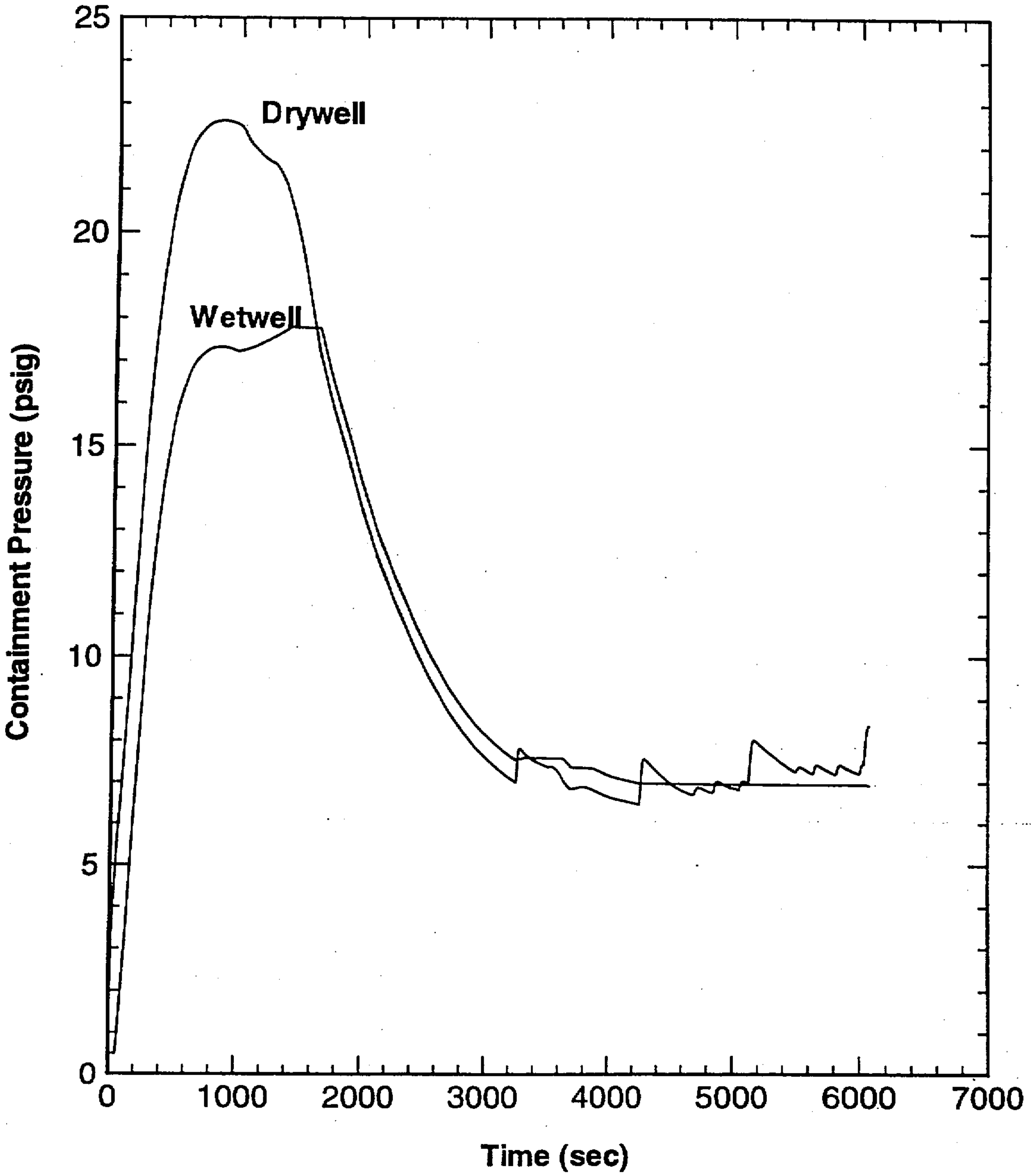

Figure 6 Calculated primary containment response for 0.02 $ft^2$ liquid break.

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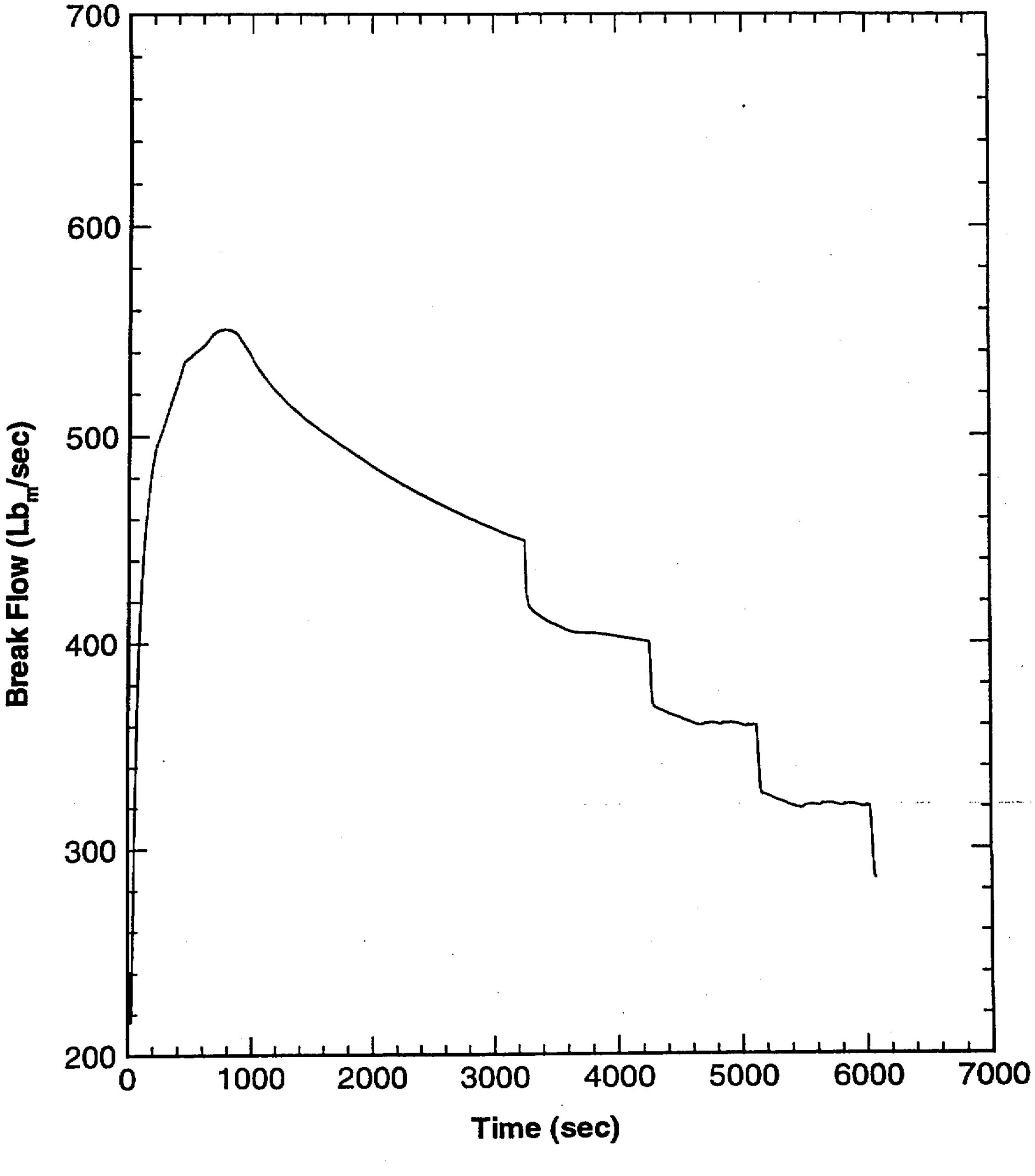

Figure 7 Calculated break flow rate for 0.02 ft$^2$ liquid break.

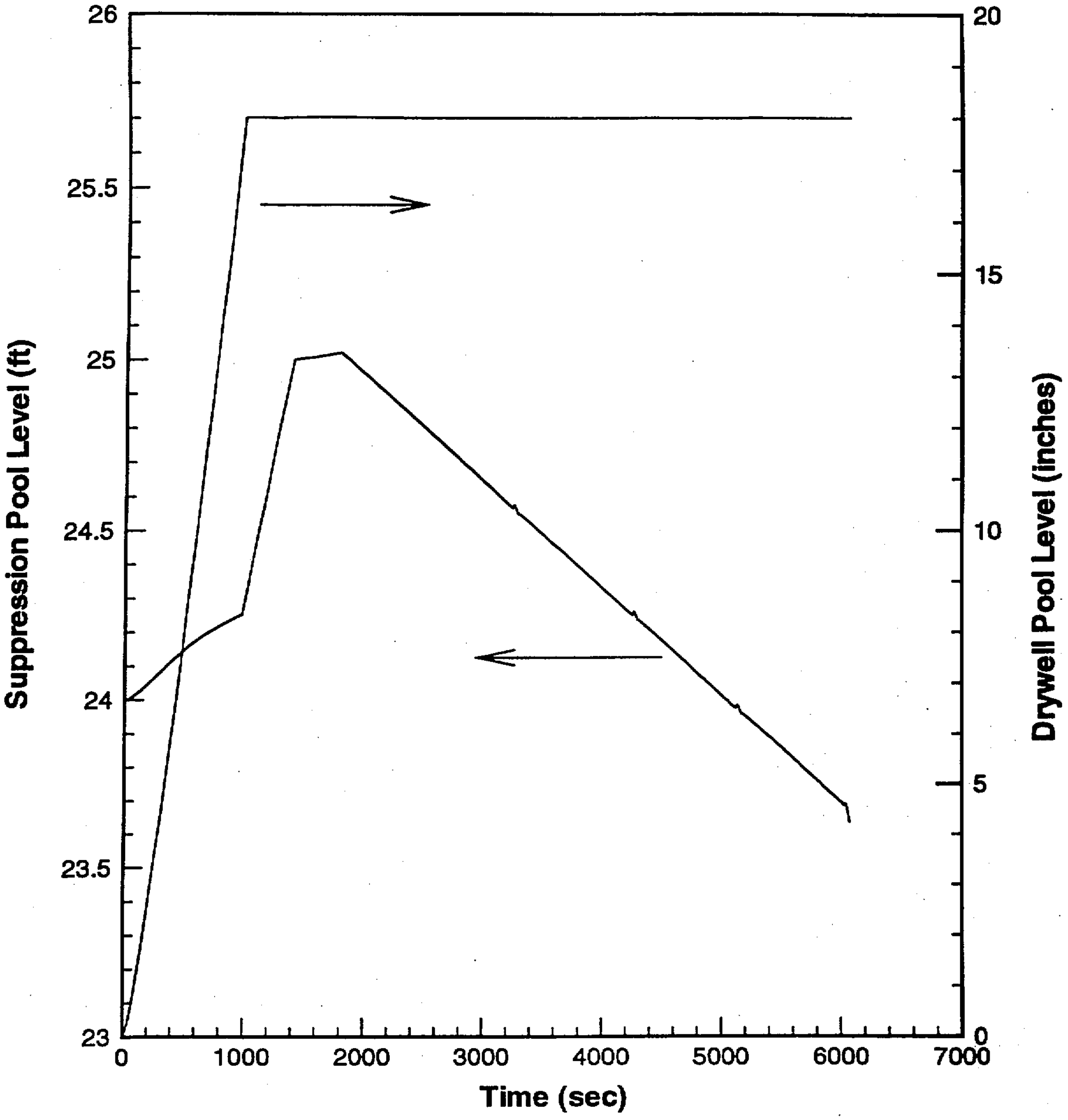

Figure 8 Calculated primary containment water level for 0.02 ft$^2$ liquid break.

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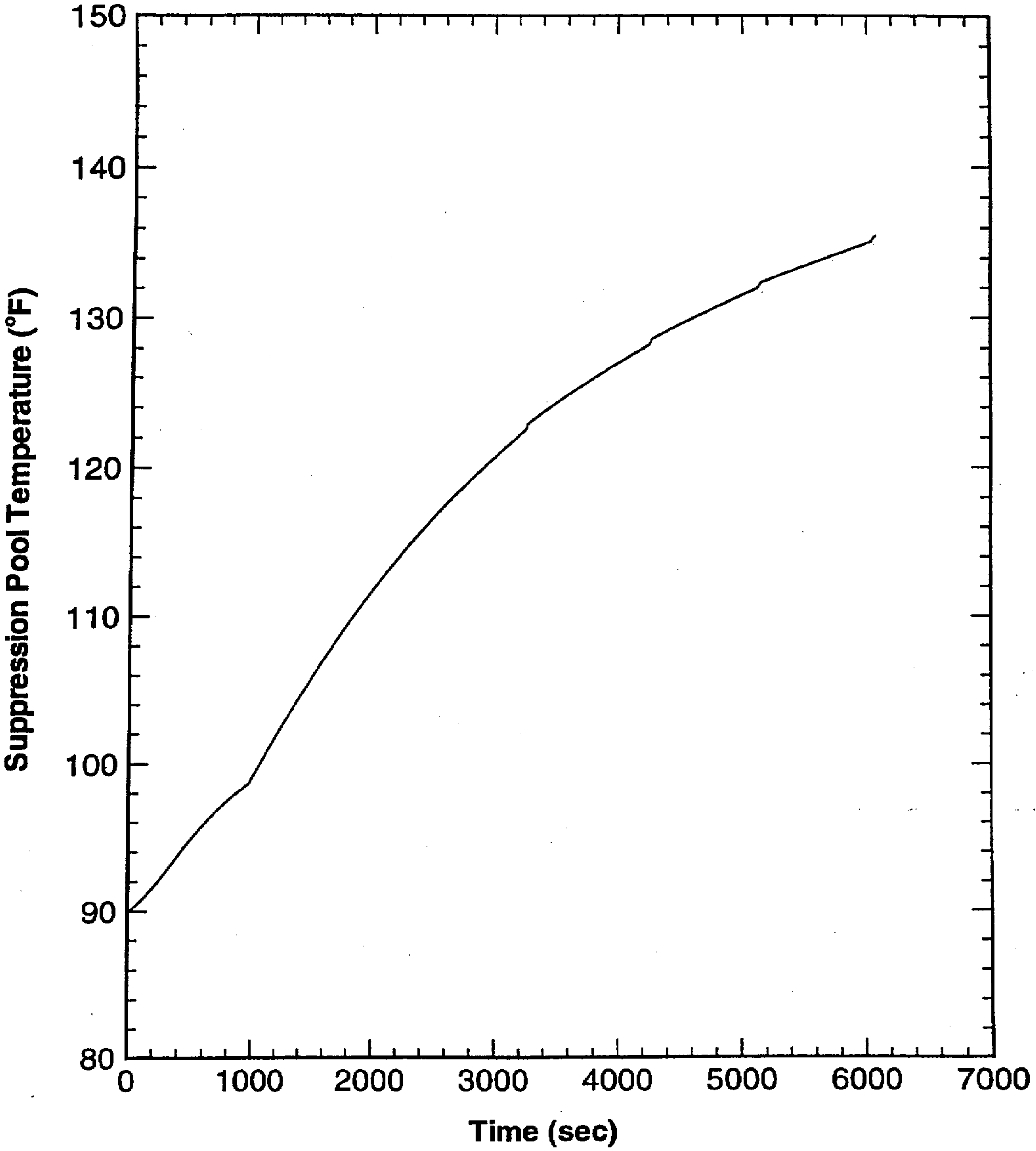

Figure 9 Calculated suppression pool temperature response for 0.02 $ft^2$ liquid break.

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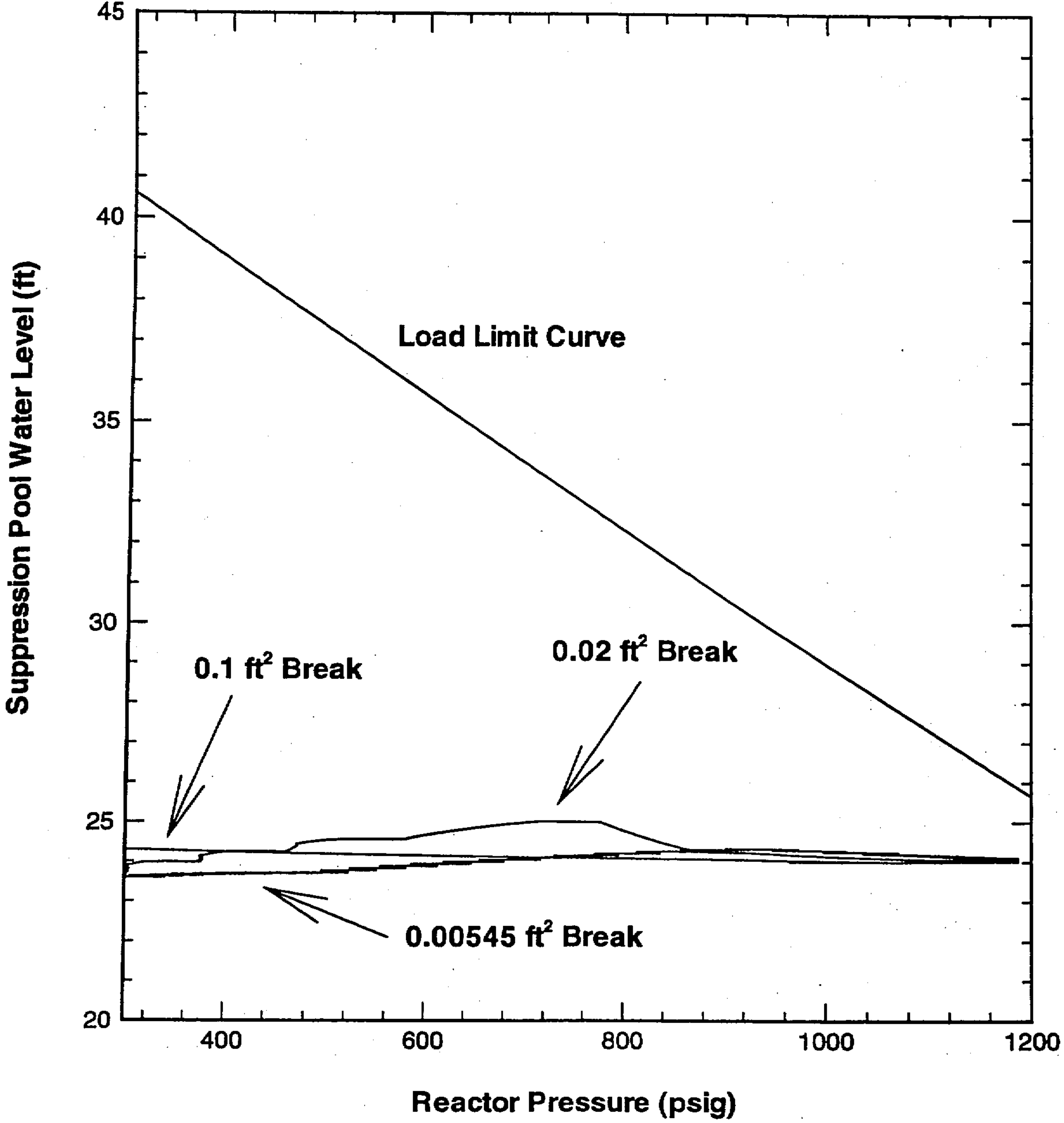

Figure 10 Available margin to Load Limit Curve for intermediate and small liquid breaks.

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# CALCULATION / STUDY COVER SHEET and
# DCS TRANSMITTAL SHEET

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➢2. TYPE: Calc ➢3. NUMBER: EC-052-1025 ➢4. REVISION: 2

5. TRANSMITTAL#: K0107106 *➢6. UNIT: 3 *➢7. QUALITY CLASS: Q

➢9. DESCRIPTION: SABRE Calculations for IPE HPCI Modification *➢8. DISCIPLINE: M

SUPERSEDED BY:

10. Alternate Number:

11. Cycle:

12: Computer Code or Model used: SABRE Fichee x Dis ☐ Am't 1 packet

13. Application:

*➢14 *Affected Systems:* 052 , , , , ,

* If N/A then line 15 is mandatory

**➢15. NON-SYSTEM DESIGNATOR:

**If N/A then line 14 is mandatory

16. Affected Documents:

☒ Lic. Doc Change Req'd

17. References: EC-052-1018

18. Equipment / Component #:

19. DBD Number: DBD004

➢20. PREPARED BY M.A. Chaiko *Print Name* Mark A. Chaiko *Signature*

➢21. REVIEWED BY J.G. Refling *Print Name* *Signature*

➢21A. VERIFIED BY J.G. Refling *Print Name* 7/12/2001 *Signature*

➢22. APPROVED BY C.A. Kukielka *Print Name* 7/12/2001 *Signature*

➢23. ACCEPTED BY PP&L / DATE *Print Name* *Signature / DATE*

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# ENGINEERING CALCULATION STUDY
# REVISION DESCRIPTION SHEET

**REVISION NO:** 2

**CALCULATION NUMBER:** EC-052-1025

This form shall be used to record the purpose or reason for the revision, indicate the revised pages and / or affected sections and give a short description of the revision. Check ( x ) the appropriate function to add, replace or remove the affected pages.

| Revised Pages | Affected Sections | Add | Rpl | Rmv | Description / Purpose of Revision |
|---|---|---|---|---|---|
| 1 | Cover sheet | | X | | Replaced cover sheet. |
| 1a | Revision Description | | X | | Replaced revision description pages with current page. |
| 3 | Computer Case Summary | | X | | Added Cases 2a and 3a. |
| 7 | 3 | | X | | Added discussion concerning sensitivity Cases 2a and 3a. |
| 62 | 4.5 | | X | | Added discussion concerning sensitivity Cases 2a and 3a. |
| [illegible]a | 4.5 | X | | | Added plot of results for Cases 2a and 3a. |
| 63b | 4.5 | X | | | Added plot of results for Cases 2 and 3 to allow comparison with results for Cases 2a and 3a. |
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☐ FULL REVISION

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# COMPUTER CASE SUMMARY

| SABRE Case# | SABRE Run# | Microfiche | Description |
|---|---|---|---|
| 1 | 00-68 | x | SABRE output for Case 1 (§4.1). 0.1 ft$^2$ Liquid Break |
| 2 | 00-69 | x | SABRE output for Case 2 (§4.2). 0.02 ft$^2$ Liquid Break |
| 2a | 01-98 | x | SABRE output for Case 2a (§4.5). 0.02 ft$^2$ Liquid Break. Initial CST volume=300,000 gal, no letdown of water from suppression pool, no operator-controlled cooldown of RPV, no manual transfer of HPCI suction to suppression pool on high pool level. Kinetics data corresponds to U2C11. 2 |
| 3 | 00-70 | x | SABRE output for Case 3 (§4.3). 0.00545 ft$^2$ Liquid Break |
| 3a | 01-99 | x | SABRE output for Case 3 (§4.5). 0.00545 ft$^2$ Liquid Break Initial CST volume=300,000 gal, no letdown of water from suppression pool, no operator-controlled cooldown of RPV, no manual transfer of HPCI suction to suppression pool on high pool level. Kinetics data corresponds to U2C11. 2 |
| 4 | 00-71 | x | SABRE output for Case 4 (§4.4). MSIV Closure Transient |
| 5 | 00-72 | x | SABRE output for Case 1 (§4.5). 0.025 ft$^2$ Liquid Break |
| 6 | 00-73 | x | SABRE output for Case 1 (§4.5). 0.030 ft$^2$ Liquid Break |
| 7 | 00-74 | x | SABRE output for Case 1 (§4.5). 0.035 ft$^2$ Liquid Break |
| 8 | 00-79 | x | SABRE output for Case 1 (§4.5). 0.040 ft$^2$ Liquid Break |
| 9 | 00-76 | x | SABRE output for Case 1 (§4.5). 0.015 ft$^2$ Liquid Break |
| 10 | 00-82 | x | SABRE output for Case 10 (§4.5). 0.0375 ft$^2$ Liquid Break. |

## 1. PURPOSE

The purpose of this calculation is to determine reactor and containment response for intermediate and small break accidents with the IPE HPCI modification in place. Reactor and containment response for an MSIV closure transient is also examined. The IPE HPCI modification removes the HPCI auto suction transfer on high suppression pool level, 23'-10" (SSES TRM Table 2.2-1, 3/29/2000). The proposed modification includes an EOP change which requires the operator to manually transfer HPCI suction from the CST to the suppression pool, if pool level reaches 25 feet with pool temperature less than the HPCI design temperature limit of 140 °F. The manual suction transfer at 25 feet is included in order to prevent water from entering the HPCI turbine exhaust line when the system is not operating. The suppression pool level at which the turbine exhaust piping would begin to flood, if HPCI is not operating, is computed in the appendix to this calculation. If the horizontal section of the HPCI turbine exhaust line becomes partially filled with water, there is potential for condensation-induced water hammer when the system is started.[1] Background information for the IPE HPCI modification and the technical justification for the modification are not presented in this calculation. These issues are discussed in Calculation EC-052-1018.

This calculation documents inputs and assumptions used in the simulation of reactor and containment response with the IPE HPCI modification in place. Calculation results are presented in Section 4 and conclusions are given in Section 5. The implications of the calculation results are discussed in Calculation EC-052-1018.

## 2. METHODOLOGY

Reactor and primary containment simulations are carried out with the SABRE computer code (Version 3.1). Description and benchmarking of the SABRE code is given in Calc. EC-ATWS-0505, Rev. 8. Software Quality Assurance documentation is provided in Calc. EC-SATH-1007, Rev. 1.

Reactor and containment response is computed for a set of design-basis events in which HPCI injection to the vessel significantly influences the evolution of the event. These events consist of intermediate and small break LOCAs and a representative plant transient. For large break LOCAs, the reactor depressurizes so rapidly that HPCI injection has little impact on the progression of the accident.

The intermediate break is chosen to be a 0.1 $ft^2$ recirculation line break, since the FSAR considers this break size to be representative of an intermediate break.[2] Two small breaks are considered: a 0.02 $ft^2$ break and a 1" line break (0.00545 $ft^2$). DBD004 Rev. 1, p. 32 states that " It [HPCI] is designed to be capable of making up inventory losses for liquid breaks below about 0.02 sq ft, thus maintaining reactor level." With regard to the 1" line break, FSAR Section 6.3.1.1.1 states "One high pressure cooling system is provided which is capable of maintaining

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[1] NUREG/CR-5220, Vol. 1, "Diagnosis of Condensation-Induced Waterhammer"

[2] SSES FSAR, Section 6.2.1.1.3.3.4.

water level above top of core and preventing ADS actuation for breaks of lines less than 1 inch nominal diameter."

The LOCAs are simulated up to the point where reactor pressure drops below the shutoff head of the Core Spray system. The SABRE code predicts the time of Core Spray initiation based on reactor and containment pressure. When Core Spray initiates it is assumed that the operator will use the Core Spray system to provide coolant makeup to the vessel, and HPCI operation will no longer be required. This assumption is consistent with the design-basis function of the HPCI system given in the FSAR. Section 6.3.2.2.1 of the FSAR states "The HPCI system continues to operate until the reactor vessel pressure is below the pressure at which LPCI operation or core spray system operation can maintain core cooling." An MSIV closure event is chosen as the representative plant transient which requires HPCI operation.

## 3. INPUTS/ASSUMPTIONS

The following assumptions and input data are used in the SABRE calculations. An echo of the SABRE input data file for each of the four cases listed in the Computer Case Summary is provided in the output for each case. SABRE output is included on microfiche.

1. The initial reactor power is 3510 MWth, initial pressure is 1050 psia, and initial core flow is 100 MLb/hr[3].
2. A LOOP is taken coincident with the LOCA.[4]
3. The initiator for the MSIV closure transient is a LOOP.
4. SRVs actuate on Safety setpoints. Setpoints are taken from Table 4-5 on p. 4-16 of the GE SAFER/GEST LOCA report GE-NE-187-22-0992.
5. MSIV closure occurs at t=2 seconds, recirculation pump trip occurs at t=0, and loss of feedwater occurs at t=4 seconds due to LOOP (FSAR Section 15.2.6.2.2.1, Rev. 54, 10/99)
6. MSIV stroke time is 4 seconds.[5]
7. HPCI initiates on low water level (-38") or high drywell pressure (1.72 psig).[6]
8. RCIC is assumed unavailable because it is not a safety system.[7]

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[3] D.C. Pappone, "SAFER/GESTR-LOCA Analysis Basis Documentation for Susquehanna Steam Electric Station Units 1 and 2," GE-NE-187-22-0992, p. 4-10, September 1993.

[4] GE-NE-187-22-0992, p. 4-1.

[5] "Evaluation of Susquehanna ATWS Performance for Power Uprate Conditions," GENE-637-024-0893, p. 7, September 1993.

[6] Table 2.2-1 of Susquehanna TRM, 04/12/1999.

[7] GE-NE-187-22-0992, p. 4-1.

9. Scram occurs at t=2 seconds due to LOOP (FSAR Section 15.2.6.2.2.1, Rev. 54, 10/99).

10. HPCI suction is maintained on the CST until suppression pool level reaches 25 feet. When level reaches 25 feet, HPCI suction is manually transferred to the suppression pool but only if pool temperature is less than 140 °F.[8]

11. In small break accident, HPCI operates until reactor pressure reaches the shutoff head of the core spray system.[9] When core spray injection becomes available, it is assumed that the operator terminates HPCI injection and the simulation is ended.

12. Initial drywell temperature is 120 °F, and the initial relative humidity is 48%.[10]

13. Initial suppression pool temperature is at the Tech. Spec. limit of 90 °F.[11]

14. Initial suppression pool level is at the Tech. Spec. high level limit of 24 feet.[12] Use of this value minimizes the time available for the operator to manually transfer HPCI from the CST to the suppression pool on high pool level of 25 feet.

15. Initial wetwell atmosphere temperature is 90 °F, and the initial relative humidity is 100%. It is assumed that the atmosphere is at equilibrium with the suppression pool.

16. The initial drywell and wetwell pressures are equal to 15.20 psia.[13]

17. One loop of suppression pool cooling becomes effective at 15 minutes into the event.

18. At 30 minutes into the event, the operator initiates suppression pool letdown to Liquid Radwaste using an RHR pump. The letdown flow is constant at 120 Lb/sec.[14] In order to establish the letdown path, operator actions outside the control room are required.[15] Therefore, in accordance with ANSI/ANS-58.8-1984, "American Nation Standard Time Response Design Criteria for Nuclear Safety Related Operator Actions," Sections 4.1 & 4.2, no credit is taken for pool letdown until 30 minutes into the event.

19. At 10 minutes into the event, the operator takes control of HPCI injection and maintains level within the band of 13" to 54" as required by EO-000-102.

20. At 10 minutes into the event, the operator initiates reactor depressurization (using a single SRV) at a rate of less than 100 °F/hr ( EO-000-102). The cooldown rate is specified as 90°F.

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[8] Calculation EC-052-1018.
[9] HPCI DBD004, Design Requirement 2.2.3.1.9.
[10] Letter from D.R. Pankratz (GE) to J.A. Bartos (PP&L), SPU-9288, April 23, 1992.
[11] SSES Technical Specification 3.6.2.1.
[12] SSES Technical Specification 3.6.2.1.
[13] Letter from D.R. Pankratz (GE) to J.A. Bartos (PP&L), SPU-9288, April 23, 1992.
[14] T.S. Yih, "Suppression Pool Letdown Flow Rate in Suppression Pool Cooling Mode," Calc. EC-THYD-1007.
[15] OP-249-005, "RHR Operation in Suppression Pool Cooling Mode," Section 3.3.

21. Service water temperature is equal to 88 °F.[16]

22. CST temperature is 123 °F.[17]

23. Initial CST volume is 225,000 gal.[18] This is a nominal CST volume.

24. The homogeneous equilibrium critical flow model is used to compute the break flow rate. This model shows good agreement with experimental data for test conditions typical of BWR operation.[19] A break flow multiplier of 1.25 is used for subcooled break flow; for saturated downcomer conditions the multiplier is 1.00 (Table 3-1 of GE-NE-187-22-0992, "SAFER/GESTR-LOCA Analysis Basis Documentation for Susquehanna Steam Electric Station Units 1 and 2," September 1993.)

25. Thermal capacitance of the liner plate and containment structural steel is included in the model, but the thermal capacitance of the concrete structure is neglected.

26. With regard to operator control of HPCI, minimum HPCI flow is 500 gpm.

27. No operator actions are assumed for the first 10 minutes of the event.

28. For the LOCA cases, a value of 5000 Btu/hr-ft$^2$-°F is used for the heat transfer coefficient between the submerged part of the reactor vessel & vessel internals and the coolant. The large value for the heat transfer coefficient is used to account for the possibility of boiling at the metal surface during the reactor depressurization.

29. No credit is not taken for operator initiation of drywell sprays.

Additional modeling assumptions are documented in Calc. EC-ATWS-0505, Rev. 8.

Cases 2a and 3a were run in order to determine if operator actions to (1) letdown water from the suppression pool, (2) manually transfer HPCI suction from the CST to the suppression pool when pool level reaches 25 feet, and (3) cooldown the reactor pressure vessel are necessary to prevent hydrodynamic loads associated with SRV blowdown from exceeding design limits. Hydrodynamic loads produced by SRV blowdown will not exceed design values as long as suppression pool level is maintained below the value defined by the following load-limit equation (see Calculation EC-052-1018, Rev. 2, p. 7)

$$L = -0.01662\,P_R + 45.6 \tag{1}$$

where $P_R$ is reactor pressure (psig) and $L$ is suppression pool water level (ft). Cases 2a and 3a are the same as Cases 2 and 3, respectively, except that kinetics data corresponds to the current fuel cycle (U2C11) rather than U2C10, initial CST level corresponds to full capacity (300,000 gallons per FSAR §9.2.10.2, Rev. 54, 10/99.), and the operator does not perform the three mitigating actions listed above. Calculated suppression pool level versus reactor pressure for Cases 2a and 3a is plotted along with the load limit curve, Equation (1), in Figure 4.5-3 of § 4.5. 2

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[16] "Evaluation of Susquehanna ATWS Performance for Power Uprate Conditions," GENE-637-024-0893, p. 7, September 1993.

[17] GENE-637-024-0893, p. 7.

[18] "Susquehanna Steam Electric Station Individual Plant Evaluation," NPE-91-001, Vol. 2, p. A-71, December 1991.

[19] R.T. Lahey and F.J. Moody, *The Thermal-Hydraulics of a Boiling Water Nuclear Reactor*, Second Edition, pp. 445-446, American Nuclear Society, La Grange Park, Illinois, 1993.

# 4. RESULTS

## 4.1 Case 1: 0.1 ft$^2$ Liquid Break

Table 4.1-1 presents the calculated sequence of events for this accident scenario. Results are plotted in Figures 4.1-1 through 4.1-10. For this break size, HPCI cannot maintain reactor water level above the feedwater spargers which are located at –24" (see Figure 4.1-3).[20] As a result, the reactor rapidly depressurizes because of steam condensation on the cold water injected by HPCI. The sequence of events in Table 4.1-1 shows that Core Spray injection initiates at 615 seconds when reactor pressure drops to 312 psig.. When reactor water level is below the feedwater spargers the break flow rate is substantially reduced because the injection flow is preheated by steam condensation. Thus the coolant within the downcomer region is nearly saturated. On the other hand, if level is above the feedwater spargers, the coolant within the downcomer region would be highly subcooled by the cold HPCI injection flow. This would result in much higher break flows for this break size.

Plots of drywell and wetwell pressure are shown in Figure 4.1-8. The difference in the two pressures corresponds to the pressure required to completely clear the downcomer vents of water. The plot indicates that the downcomer vents remain cleared throughout the entire transient, i.e., until Core Spray initiates.

Because of the short duration of the event, all of the liquid expelled from the break is retained on the drywell floor (Figure 4.1-10).[21] This prevents pool level and temperature from increasing substantially. Suppression pool level increases by 3.6 inches (Figure 4.1-4), and pool temperature increases from 90 °F to 101 °F (Figure 4.1-5). Since suppression pool level does not reach 25 feet, no operator action is required to manually transfer HPCI suction from the CST to the suppression pool.

Suppression pool cooling is not started in this case because the scenario ends in less than 15 minutes.

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[20] Calculation EC-ATWS-0505, Rev. 8, Section D.5.

[21] Water will accumulate on the drywell floor until it reaches a depth of 18 inches which corresponds to the top of the downcomer vents.

# Table 4.1-1
# Sequence of Events Calculated for 0.1 $ft^2$ Liquid Break (Case 1)

```
*** Kinetics file is /d00/appl/sabre3v1/data/u2c10.simtran.out

*** SABRE data file is /home/eamac/sabre_31/input/ec-052-1025/c01.dat

*** This is not a restart case

1   S A B R E  -  Version 3.1
    (01) U2C10 -- 0.1 ft2 liq break -- HPCI aligned to CST


 t(sec)=        .000  Liquid Break
                      Break Area                =         .100 ft2
                      Multiplier on break flow  =        1.000

 t(sec)=        .000  RCIC is Inoperable

 t(sec)=        .000  Low-Pres Condensate Injection Inop.

 t(sec)=        .000  Recirc pump-A trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=        .000  Recirc pump-B trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=       1.133  Scram on high drywell pressure
                      Setpoint(psig) =      .17E+01
                      Scram time (sec) =         2.80

 t(sec)=       1.133  HPCI initiation on Hi Drywell Press.
                      Setpoint for initiation =      .17E+01 psig

 t(sec)=       1.133  DW Cooler Trip on Hi DW Press
                      Trip Setpoint     =        1.720 psig

 t(sec)=       2.003  MSIV closure on specified time

 t(sec)=       3.953  All Control Rods Inserted

 t(sec)=       4.013  Feedwater Trip on specified time

 t(sec)=       6.016  MSIVs are closed

 t(sec)=     614.867  Initiation of Core Spray Flow
                      Reactor Press =      312.39 psig
                      Supp Chamber Press =        23.40 psig
```

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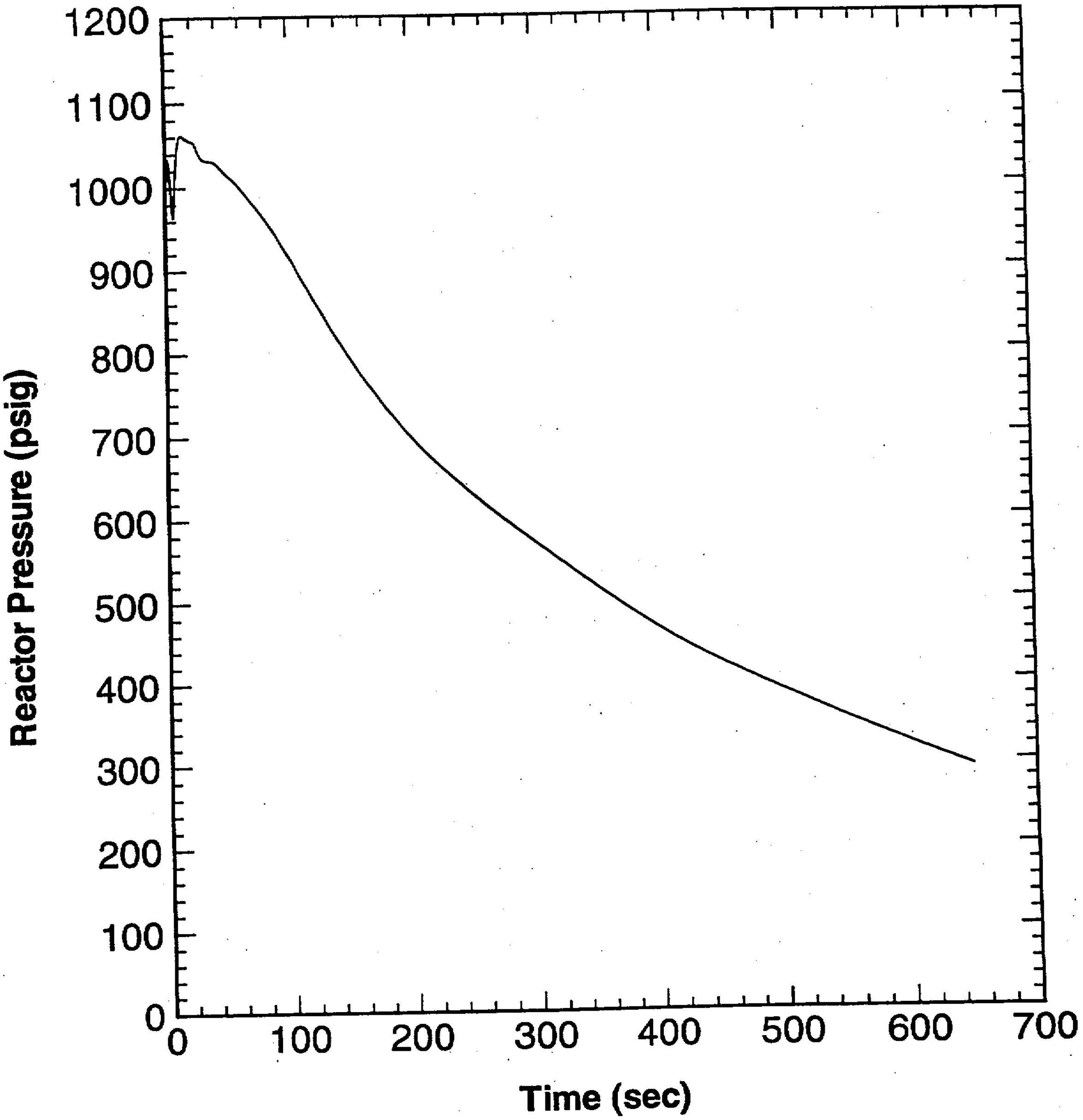

Figure 4.1-1 SABRE calculation of reactor steam dome pressure for 0.1 $ft^2$ liquid break.

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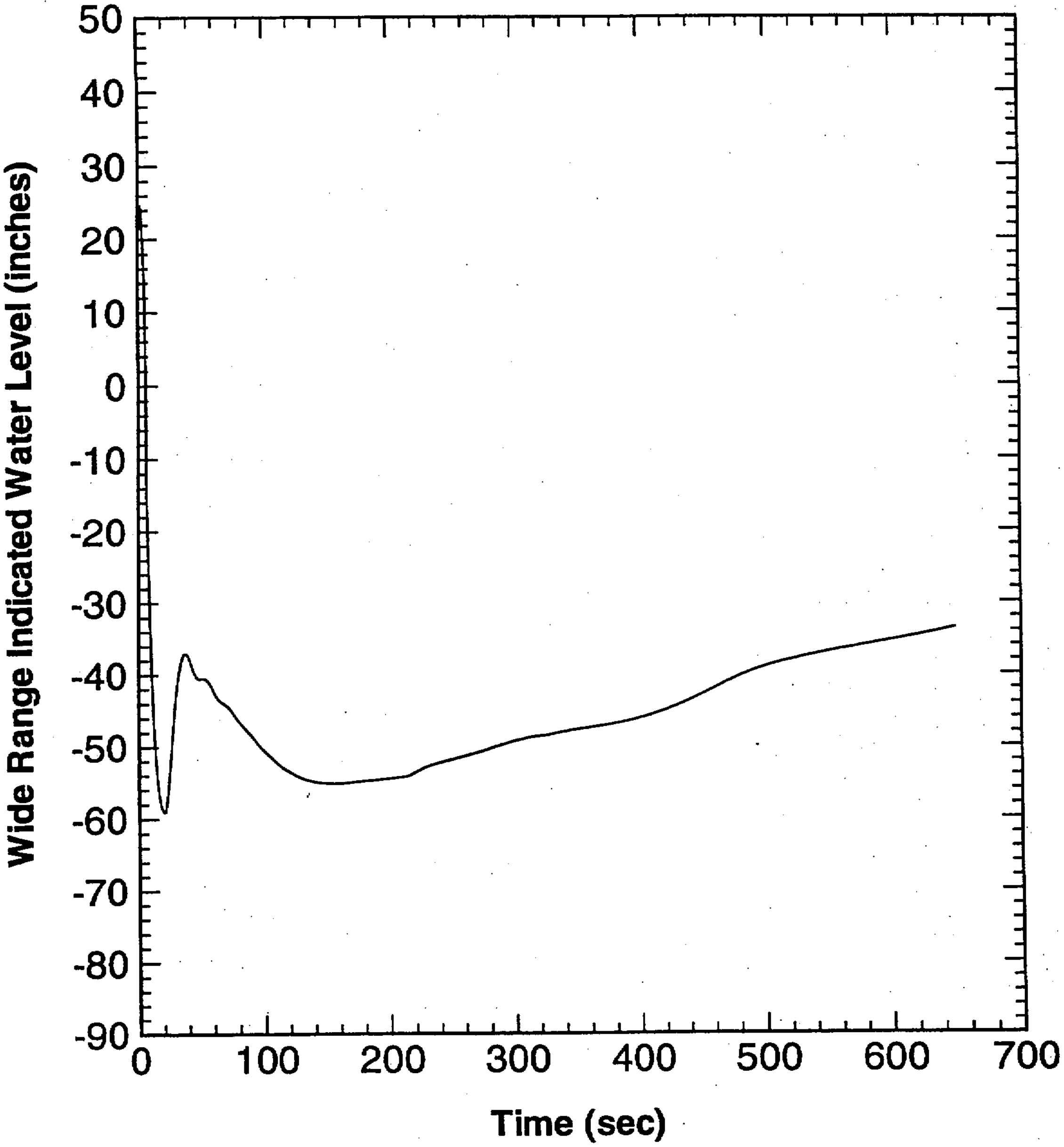

Figure 4.1-2 SABRE calculation of Wide Range Indicated Level for 0.1 $ft^2$ liquid break.

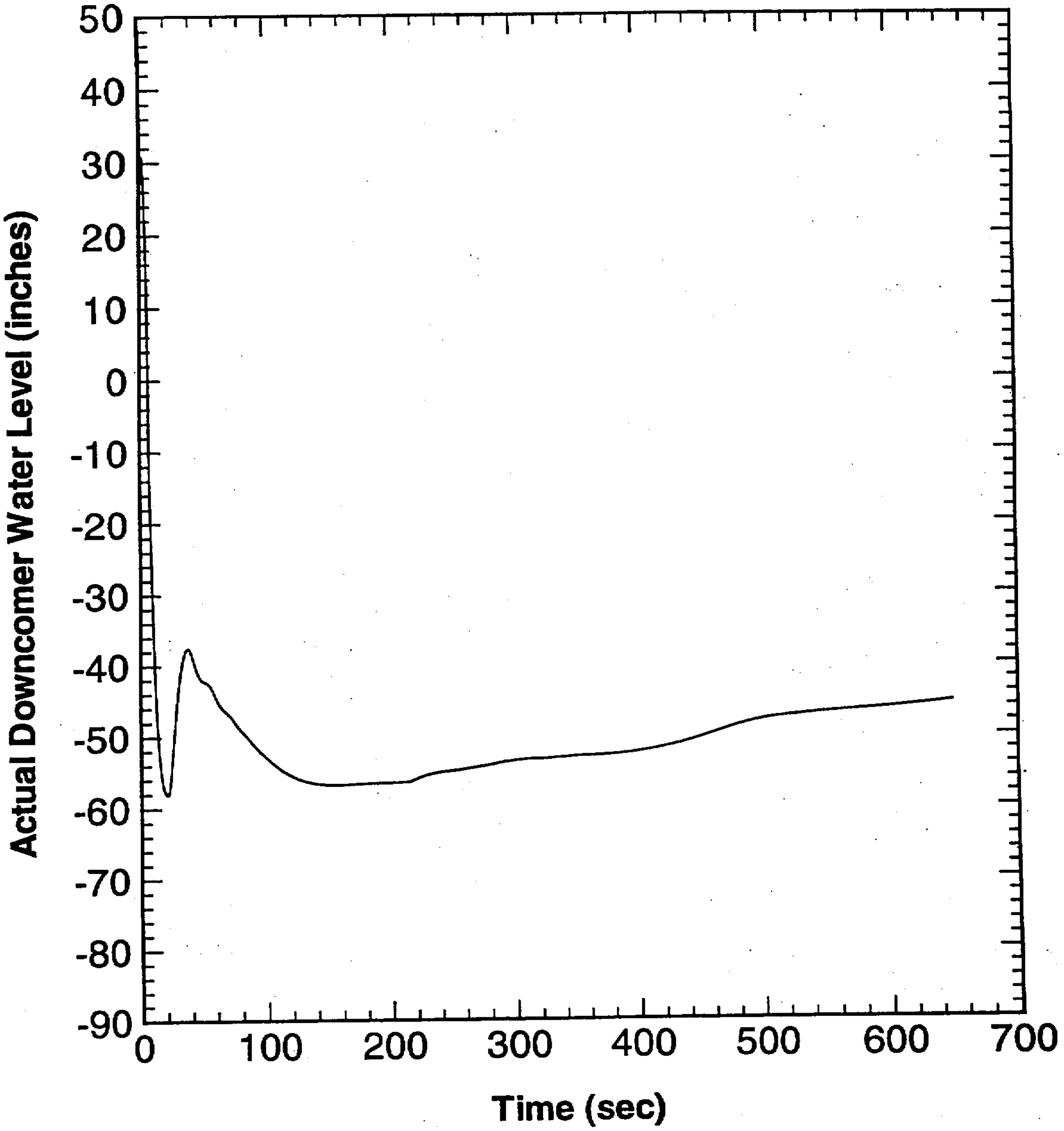

Figure 4.1-3 SABRE calculation of actual downcomer water level for 0.1 $ft^2$ liquid break.

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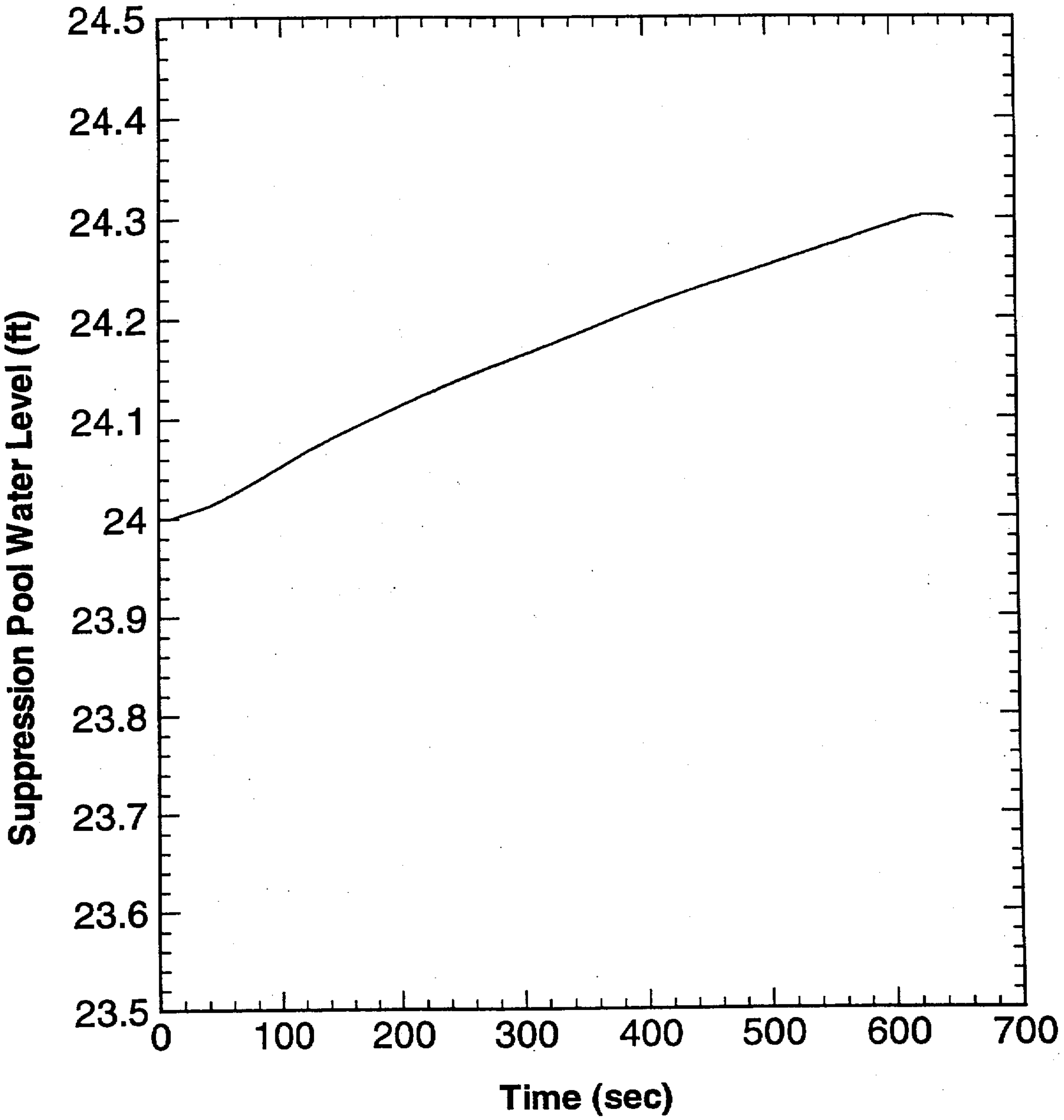

Figure 4.1-4 SABRE calculation of suppression pool water level for 0.1 ft$^2$ liquid break.

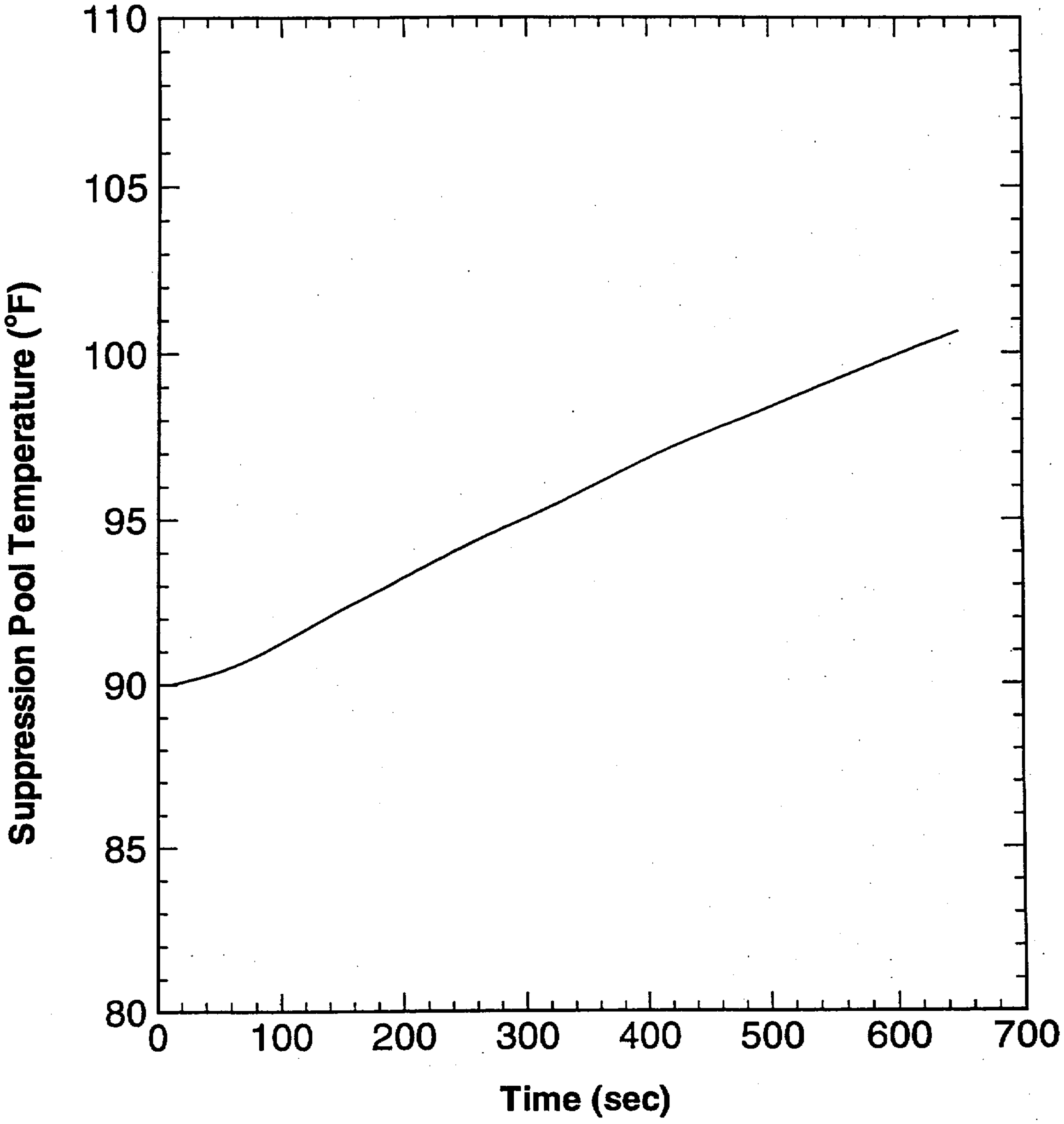

Figure 4.1-5 SABRE calculation of suppression pool temperature for 0.1 $ft^2$ liquid break.

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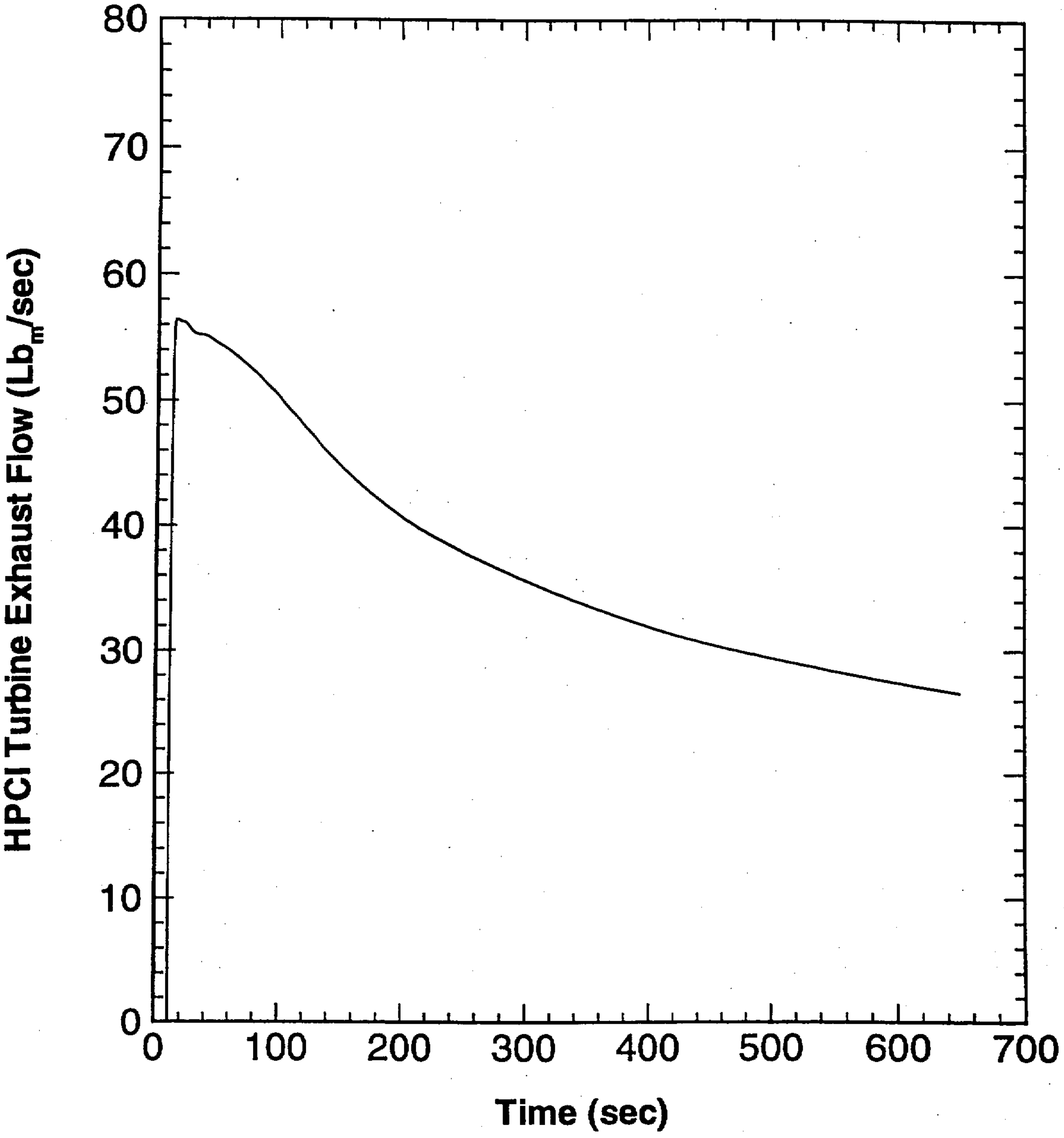

Figure 4.1-6 SABRE calculation of HPCI turbine exhaust flow for 0.1 ft$^2$ liquid break.

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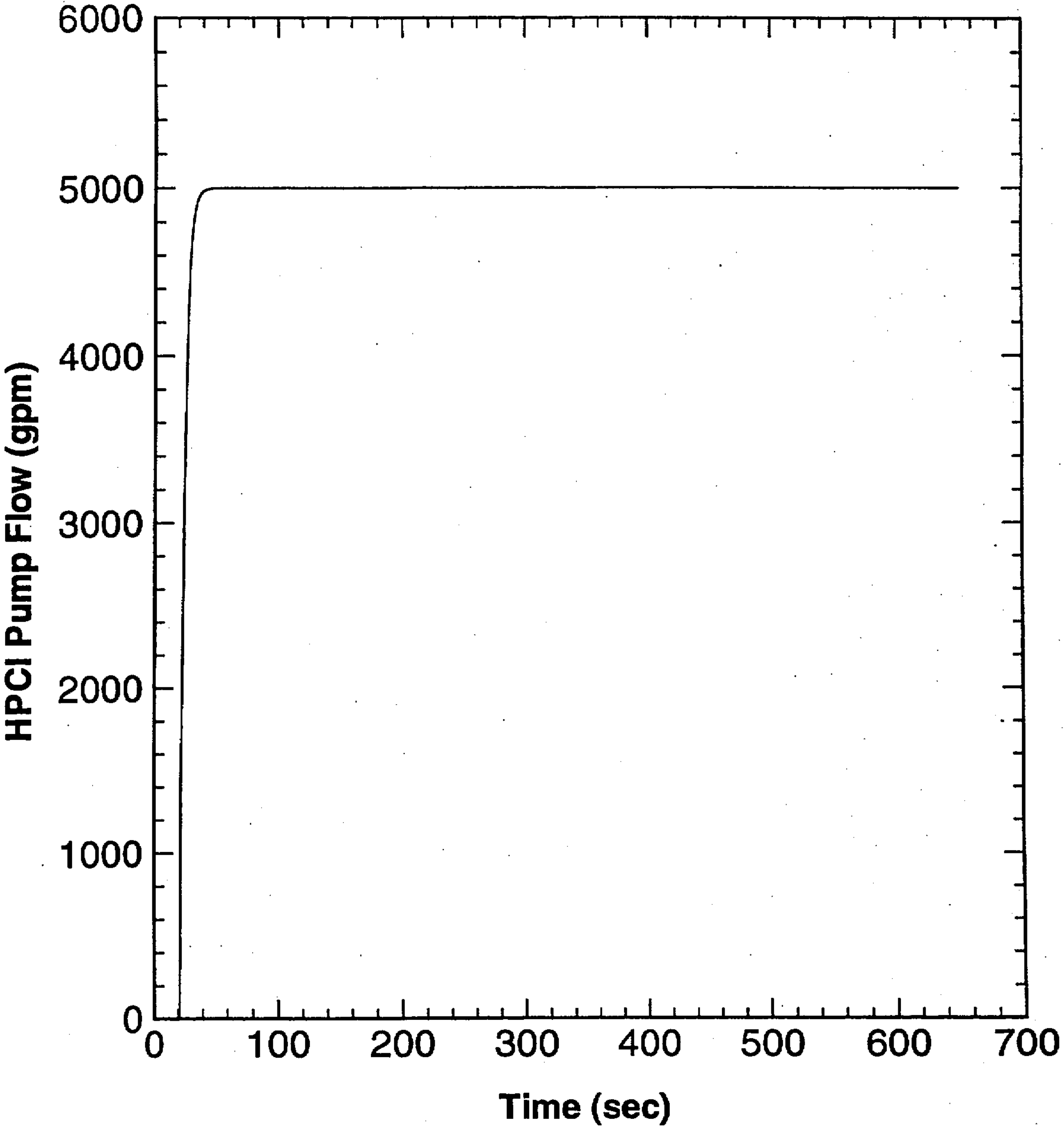

Figure 4.1-7 SABRE calculation of HPCI pump flow for 0.1 ft$^2$ liquid break.

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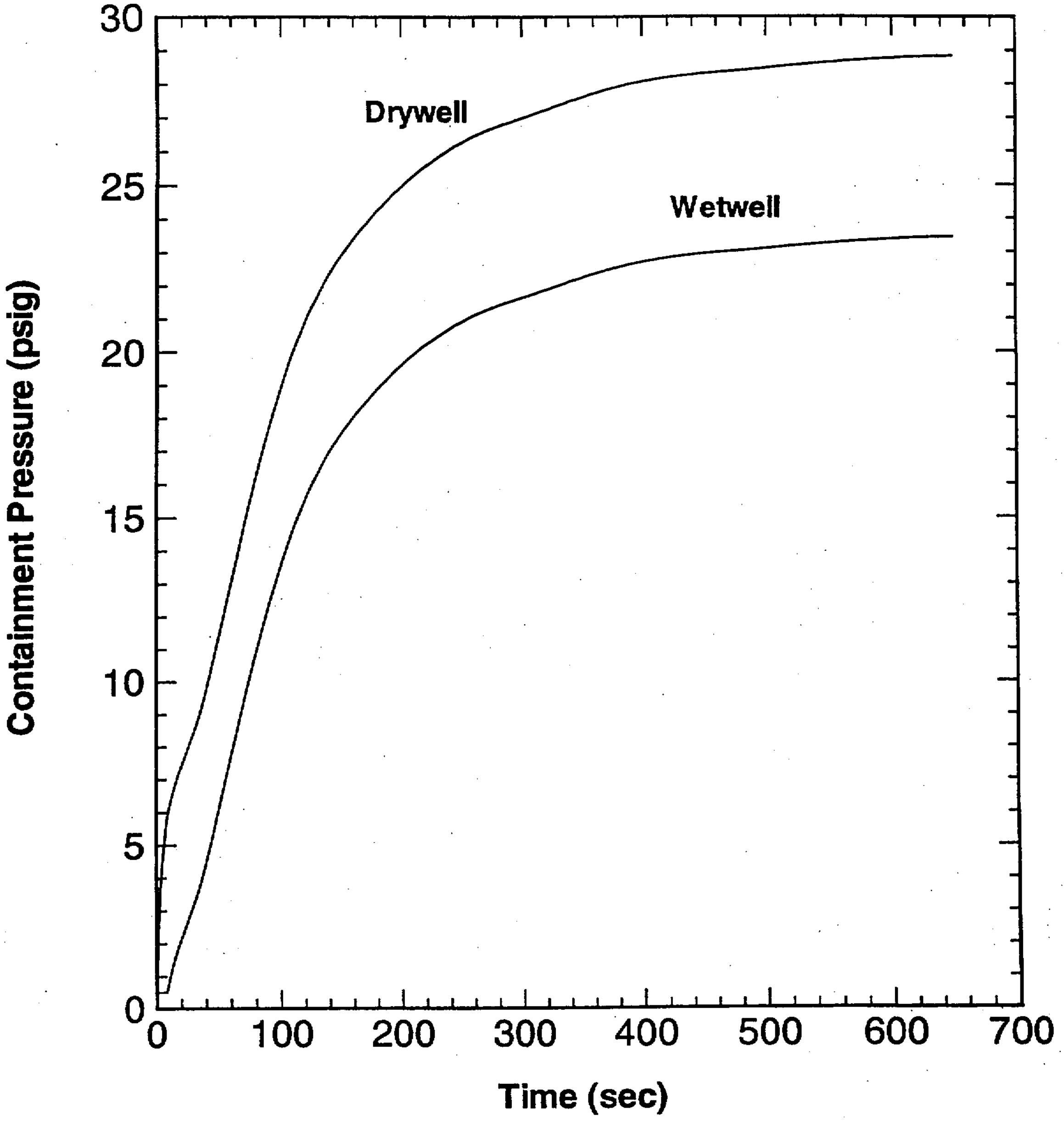

Figure 4.1-8 SABRE calculation of drywell and wetwell pressure response for 0.1 $ft^2$ liquid break.

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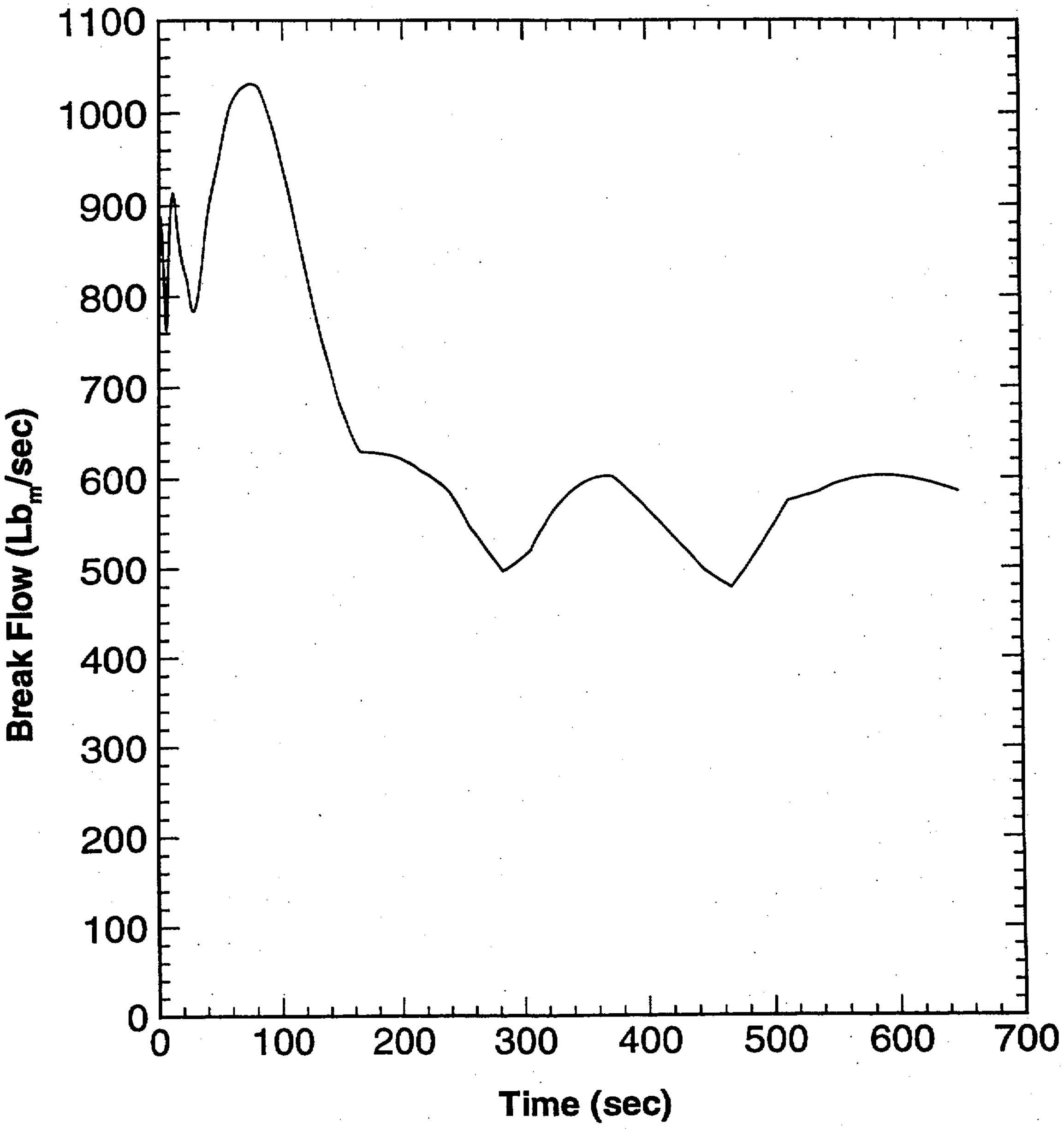

Figure 4.1-9 SABRE calculation of break flow for 0.1 $ft^2$ liquid break.

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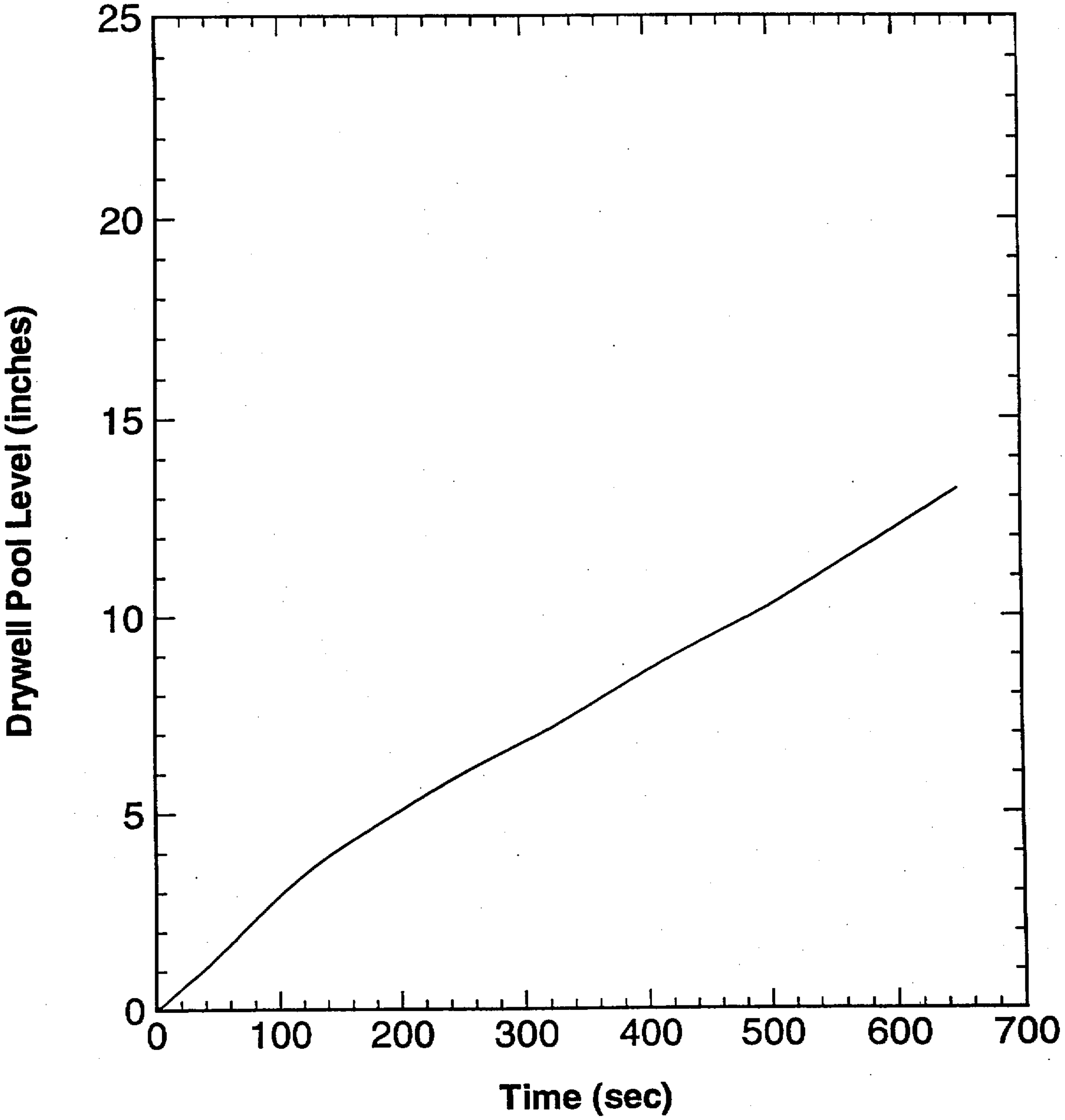

Figure 4.1-10 SABRE calculation of drywell pool level for 0.1 $ft^2$ liquid break.

## 4.2 Case 2: 0.020 ft$^2$ Liquid Break

The sequence of events calculated for this break is shown in Table 4.2-1. Results are plotted in Figures 4.2-1 through 4.2-10. As indicated in Table 4.2-1, reactor pressure drops below the shutoff head of the Core Spray pumps at 6032 seconds (1hr 41min). At this time reactor pressure is 296 psig and wetwell atmosphere pressure is 6.95 psig. For this break size, HPCI is capable of maintaining reactor water level above the feedwater spargers (see Figures 4.2-2 & 4.2-3).

As can be seen from Table 4.2-1 and Figure 4.2-4, suppression pool level reaches 25 feet at 1405 seconds (23 minutes) into the event. At this time suppression pool temperature is less than 140°F (Figure 4.2-5). It is therefore assumed that the operator manually transfers HPCI suction from the CST to the suppression pool to prevent pool level from rising above 25 feet. In the long-term part of this transient, the required HPCI pump flow ranges from 4000 gpm at ~1000 seconds down to 2500 gpm at ~6000 seconds (Figure 4.2-7). The spikes in the HPCI injection flow are artificially indroduced by the level control model in SABRE. At 1800 sec (30 min), it is assumed that the operator initiates suppression pool letdown in accordance with the EOPs (EO-000-103). From this point on, suppression pool level decreases because of inventory letdown to Liquid Radwaste via the RHR system. When reactor pressure drops below the shutoff head of the Core Spray pumps, HPCI is no longer required for injection. At this time suppression pool temperature is 135°F which is less than the HPCI design limit of 140°F, so in this event, there would be no need for the operator to transfer HPCI suction back to the CST to prevent damage to this system from overheating.

Figure 4.2-8 shows a plot of drywell and wetwell pressures. The downcomer vents are cleared for the first 1600 seconds (27 minutes). After this time the drywell pressure begins to decrease because the cold HPCI injection decreases the break enthalpy to the point where the coolant discharged to the drywell begins to have a cooling effect. The decreasing drywell pressure causes the downcomer vents to re-seal. This behavior does not occur in Case 1 (0.1 ft$^2$ break) because HPCI cannot maintain level above the feedwater spargers. When level is below the spargers, the injected coolant is preheated by steam condensation, and this tends to keep the coolant in the downcomer near the saturated state.

Figure 4.2-10 shows that the depth of water on the drywell floor reaches the top of the downcomer pipes at 980 seconds (16.3 minutes). When this occurs, water begins to flow down the vent pipes to the suppression pool. This causes the slope change in the suppression pool level curve shown in Figure 4.2-4.

# Table 4.2-1
# Sequence of Events Calculated by SABRE for 0.020 $ft^2$ Liquid Break (Case 2)

```
*** Kinetics file is /d00/appl/sabre3v1/data/u2c10.simtran.out

*** SABRE data file is /home/eamac/sabre_31/input/ec-052-1025/c02.dat

*** This is not a restart case

1    S A B R E  -  Version 3.1
     (02) U2C10 -- 0.02 ft2 liq break -- HPCI aligned to CST

  t(sec)=        .000  Liquid Break
                       Break Area                =        .020 ft2
                       Multiplier on break flow  =       1.250

  t(sec)=        .000  RCIC is Inoperable

  t(sec)=        .000  Low-Pres Condensate Injection Inop.

  t(sec)=        .000  Recirc pump-A trip on specified time
                       Trip delay =     .000E+00 sec

  t(sec)=        .000  Recirc pump-B trip on specified time
                       Trip delay =     .000E+00 sec

  t(sec)=       2.003  MSIV closure on specified time

  t(sec)=       2.003  Scram initiated on specified time
                       Scram time (sec) =        2.80

  t(sec)=       4.013  Feedwater Trip on specified time

  t(sec)=       4.493  HPCI initiation on Hi Drywell Press.
                       Setpoint for initiation =      .17E+01 psig

  t(sec)=       4.523  DW Cooler Trip on Hi DW Press
                       Trip Setpoint     =        1.720 psig

  t(sec)=       4.823  All Control Rods Inserted

  t(sec)=       6.016  MSIVs are closed

  t(sec)=     600.047  Operator takes control of HPCI inj.

  t(sec)=     900.047  Loop 1 of Supp Pool Cool Effective
                       Service Water Temperature =        88.00 F

  t(sec)=    1404.607  HPCI Suction Trans to SP on high SP level
                       SP water level =    25.00 ft

  t(sec)=    1800.007  SP Letdown Initiated
                       Letdown Rate     =      120.000 Lbm/sec

  t(sec)=    3252.013  SRV #1 Manual Open for RPV Cooldown
                       Cooldown Rate    =       90.000 F/hr
                       Target Pressure  =       98.000 psig

  t(sec)=    3269.352  SRV # 1 Tripped Close

  t(sec)=    4252.858  SRV #1 Manual Open for RPV Cooldown
                       Cooldown Rate    =       90.000 F/hr
                       Target Pressure  =       98.000 psig

  t(sec)=    4276.629  SRV # 1 Tripped Close
```

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```
t(sec)=    5118.237  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =       90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    5147.438  SRV # 1 Tripped Close

t(sec)=    6024.801  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =       90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    6032.007  Initiation of Core Spray Flow
                     Reactor Press =        295.94 psig
                     Supp Chamber Press =           6.95 psig

t(sec)=    6060.619  SRV # 1 Tripped Close
```

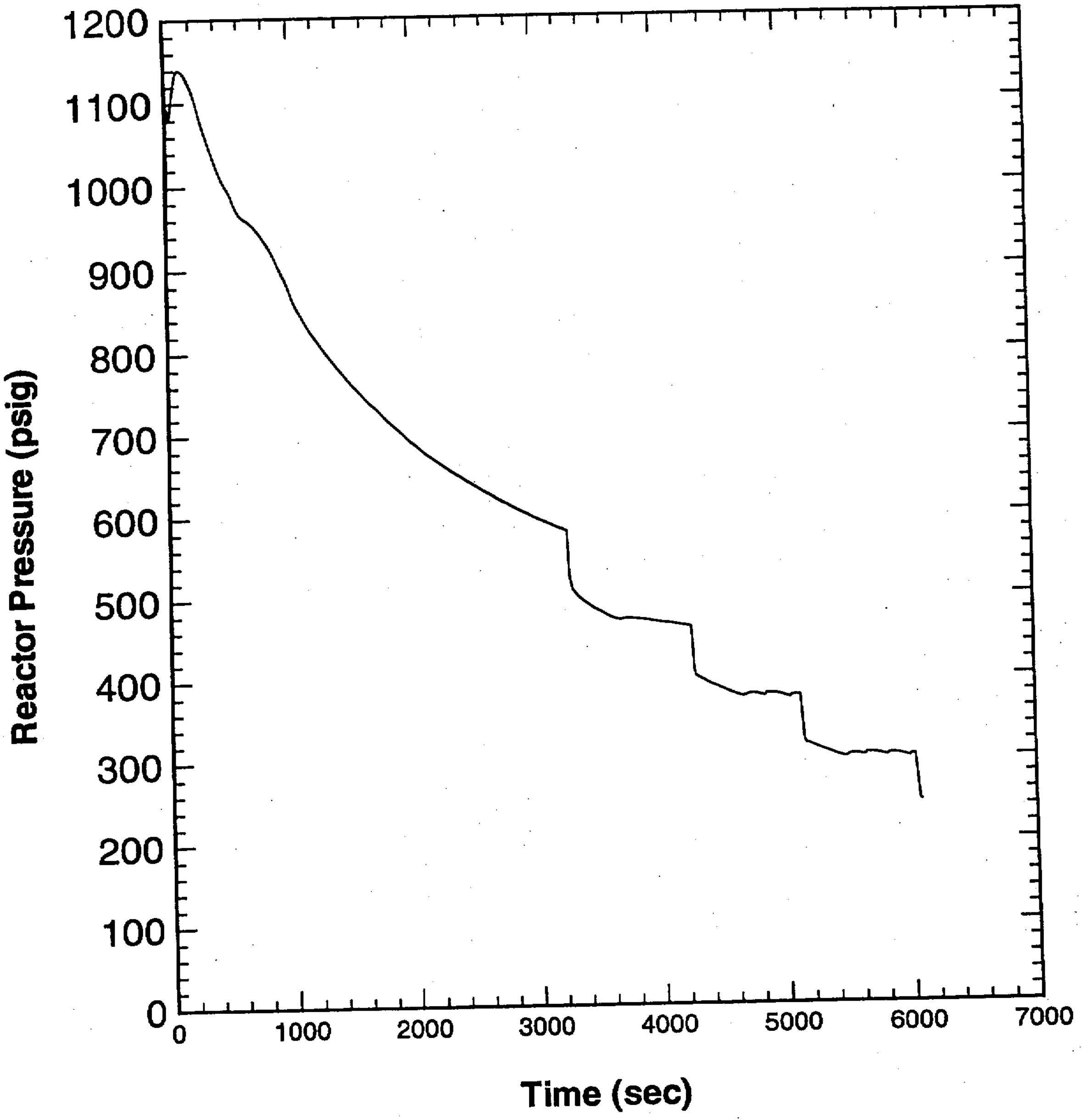

Figure 4.2-1 SABRE calculation of reactor steam dome pressure for 0.020 $ft^2$ liquid break.

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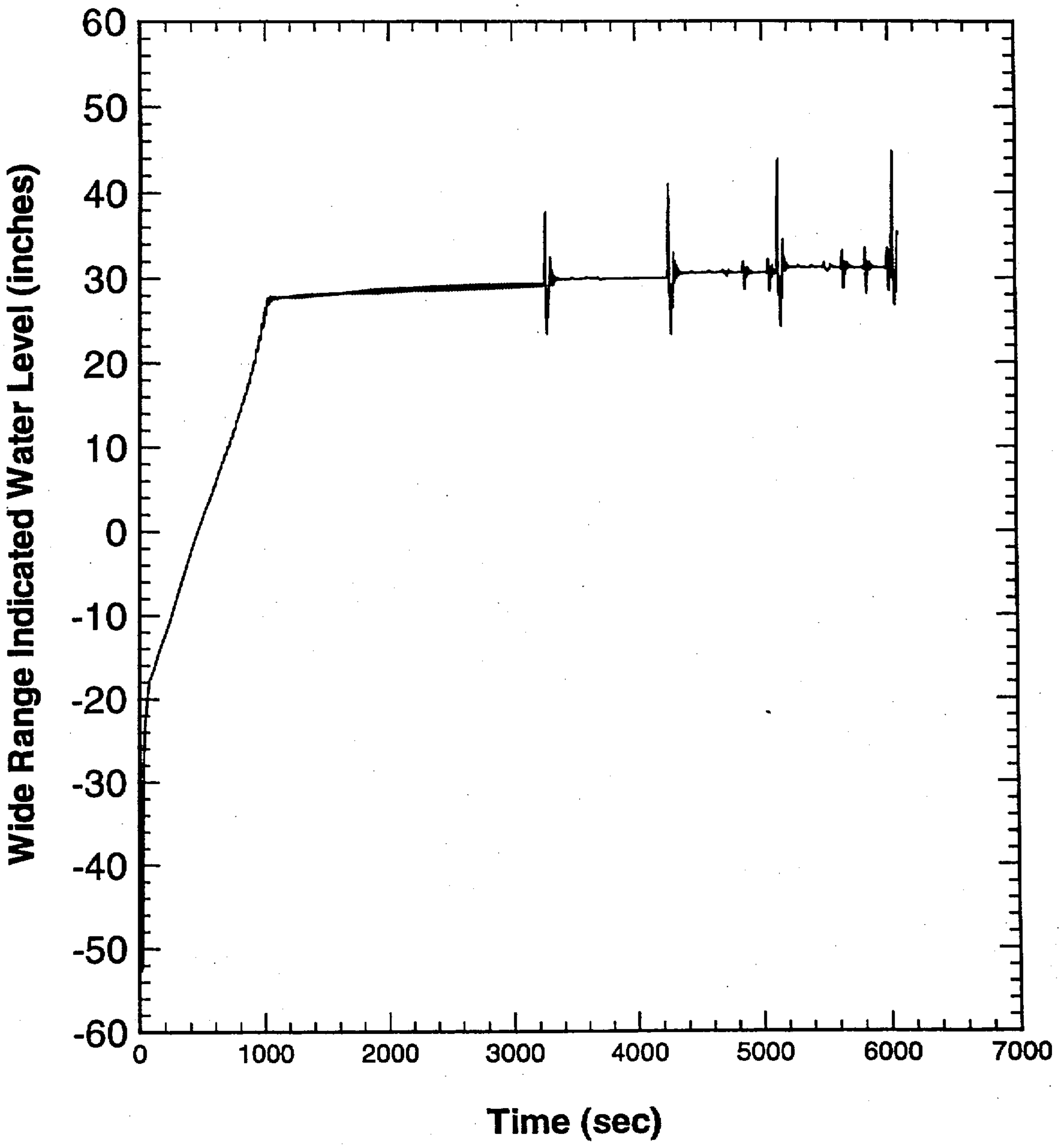

Figure 4.2-2 SABRE calculation of Wide Range Indicated Level for 0.020 $ft^2$ liquid break.

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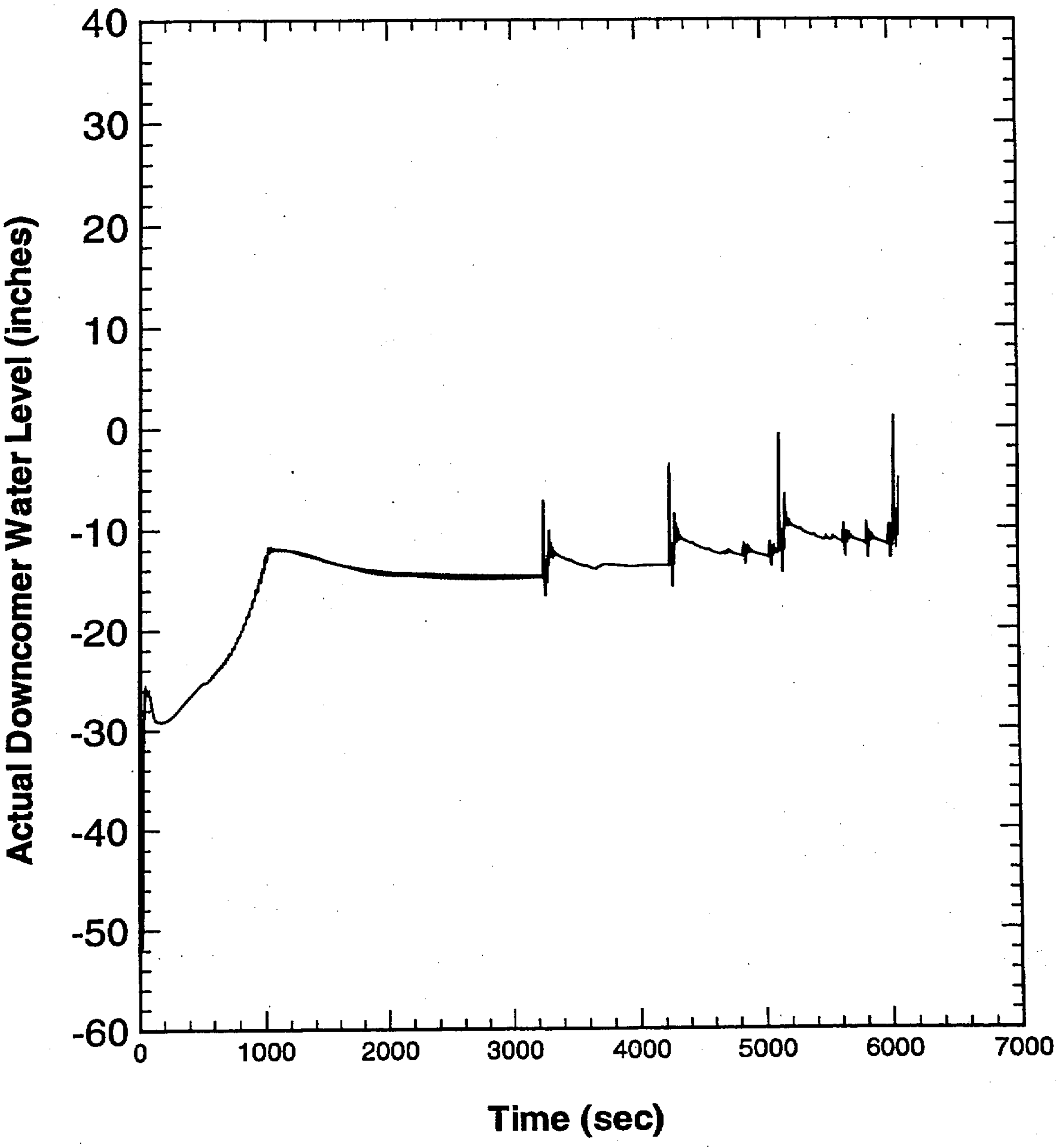

Figure 4.2-3 SABRE calculation of actual downcomer water level for 0.020 $ft^2$ liquid break.

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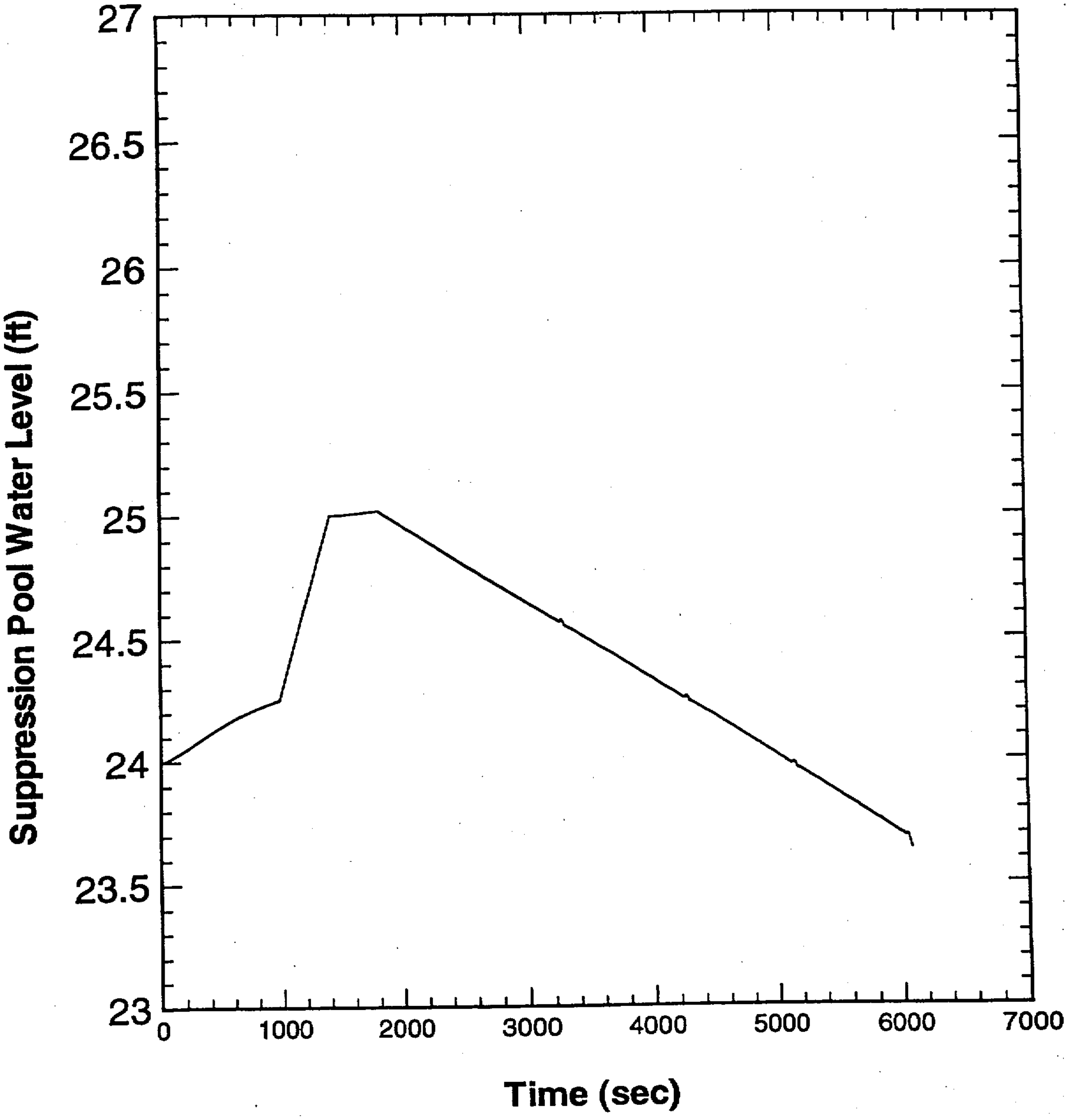

Figure 4.2-4 SABRE calculation of suppression pool water level for 0.020 $ft^2$ liquid break.

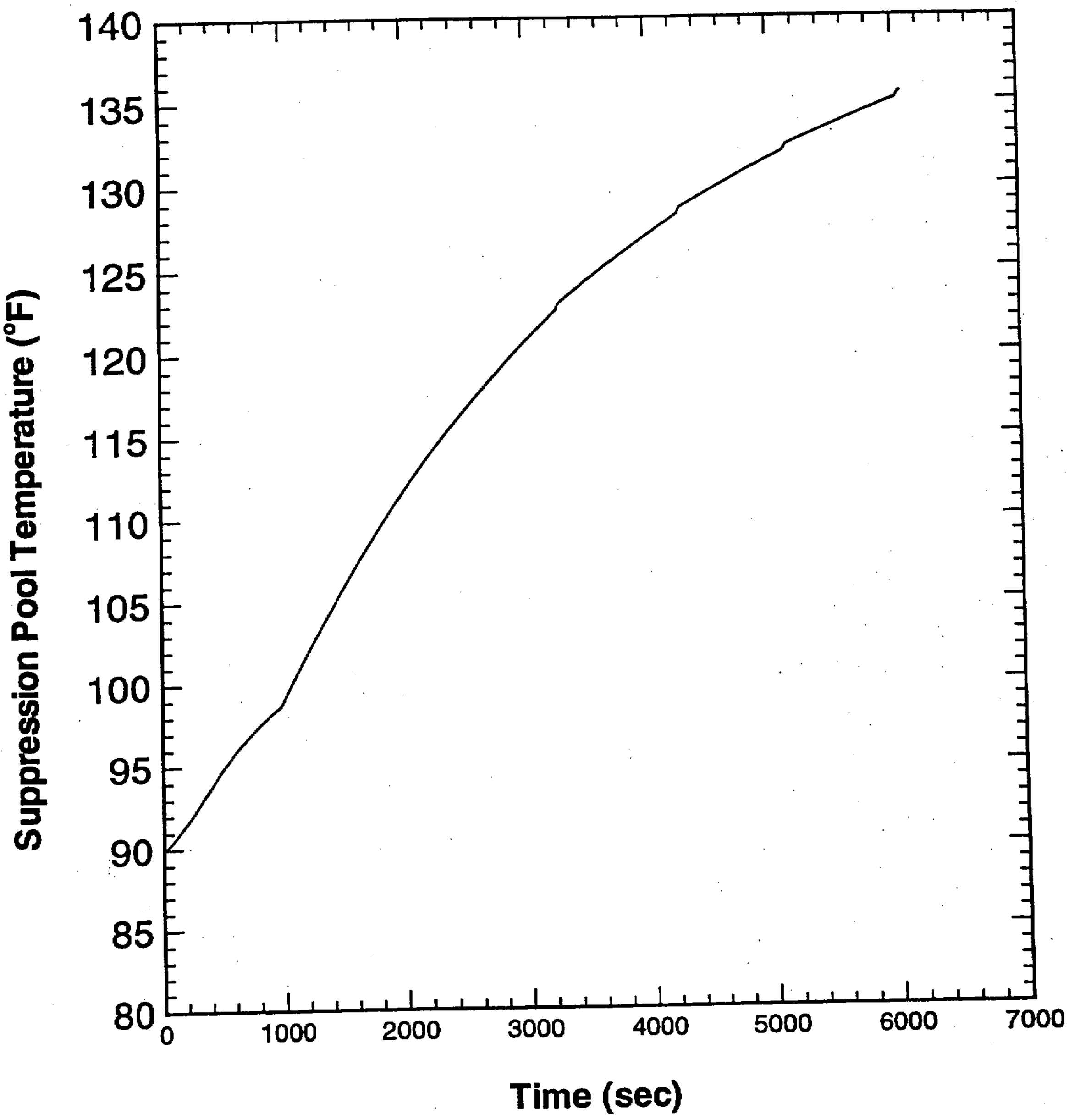

Figure 4.2-5 SABRE calculation of suppression pool temperature for 0.020 ft$^2$ liquid break.

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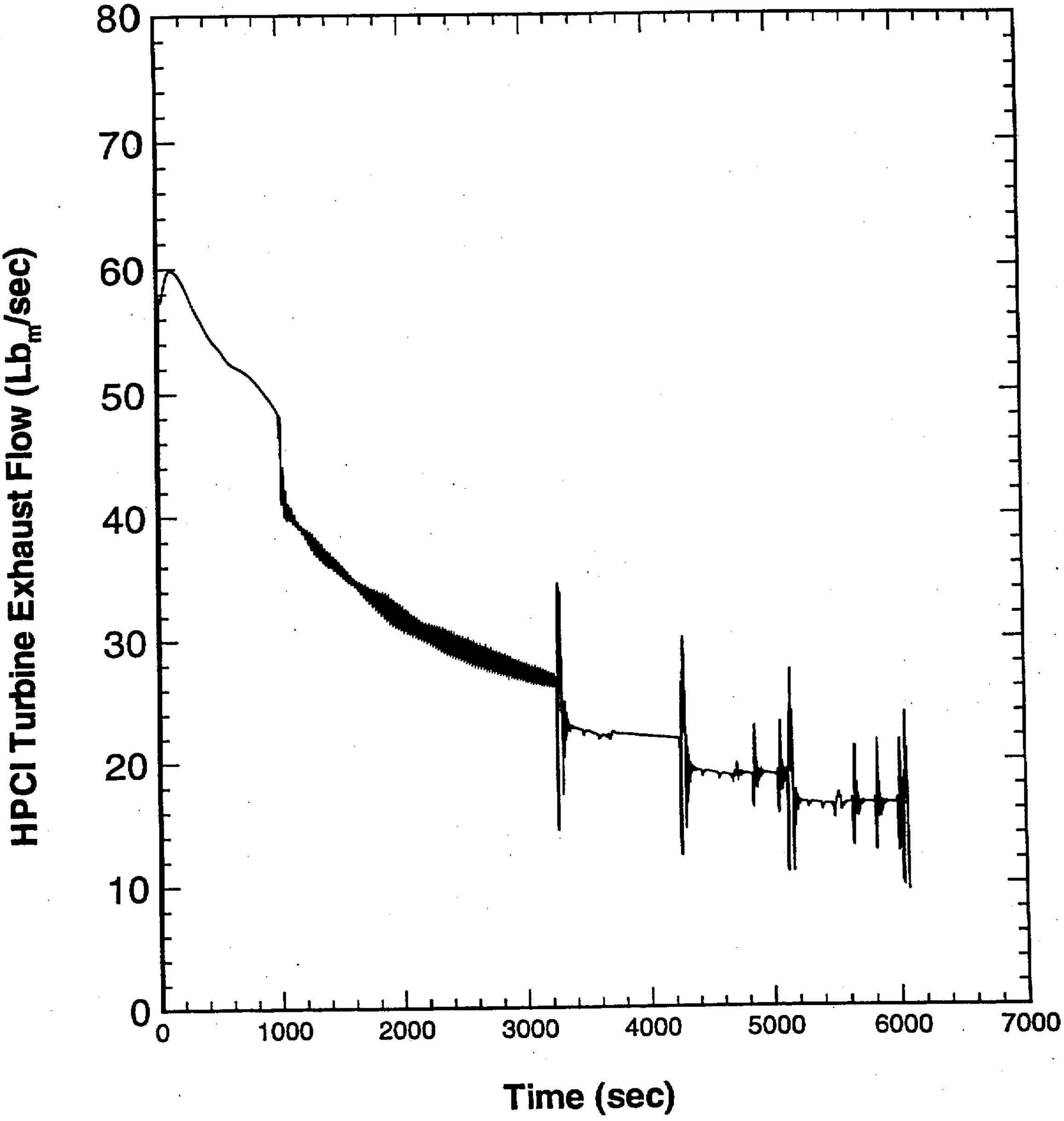

Figure 4.2-6 SABRE calculation of HPCI turbine exhaust flow for 0.020 $ft^2$ liquid break.

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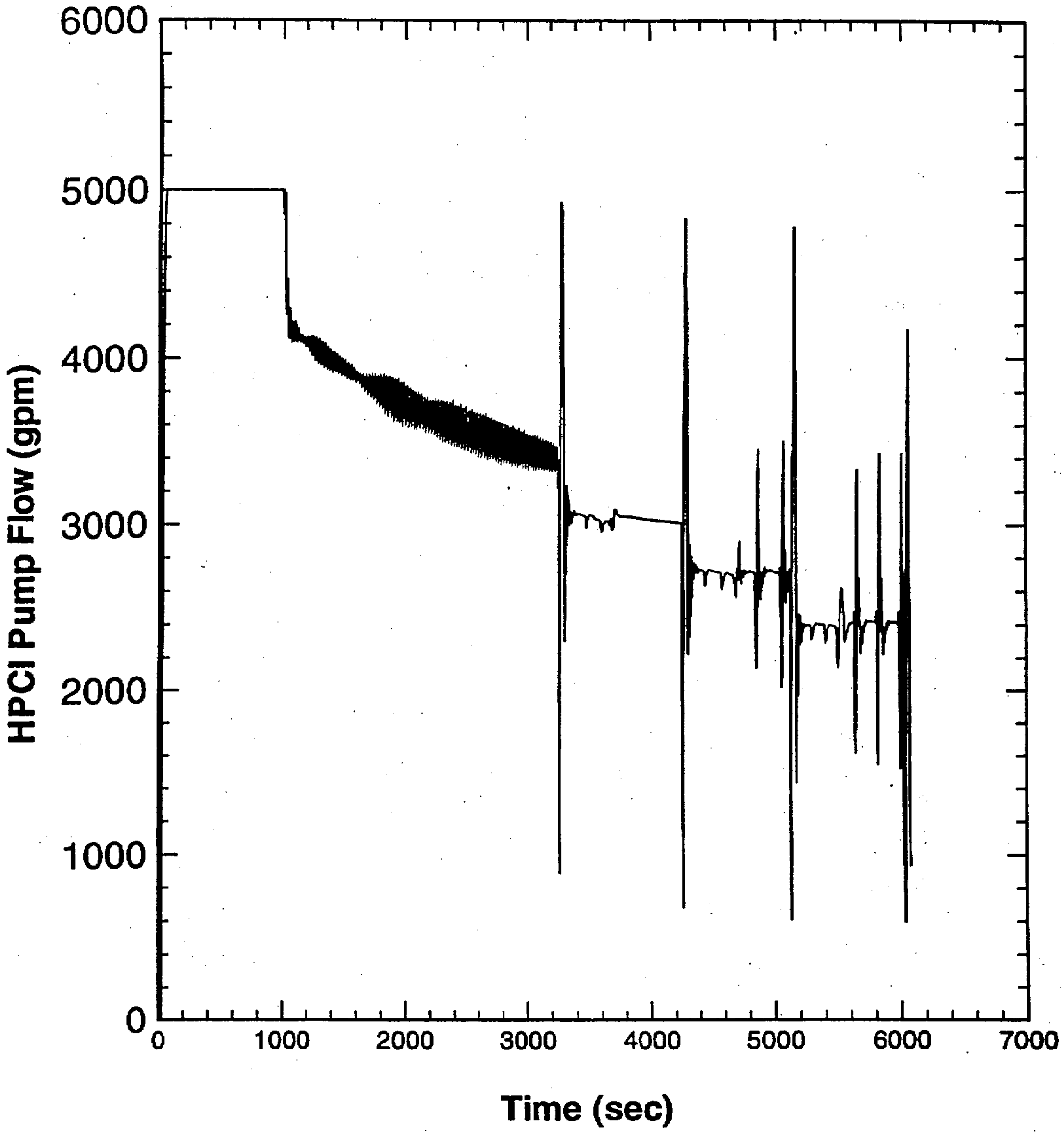

Figure 4.2-7 SABRE calculation of HPCI pump flow for 0.020 ft$^2$ liquid break.

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page 30

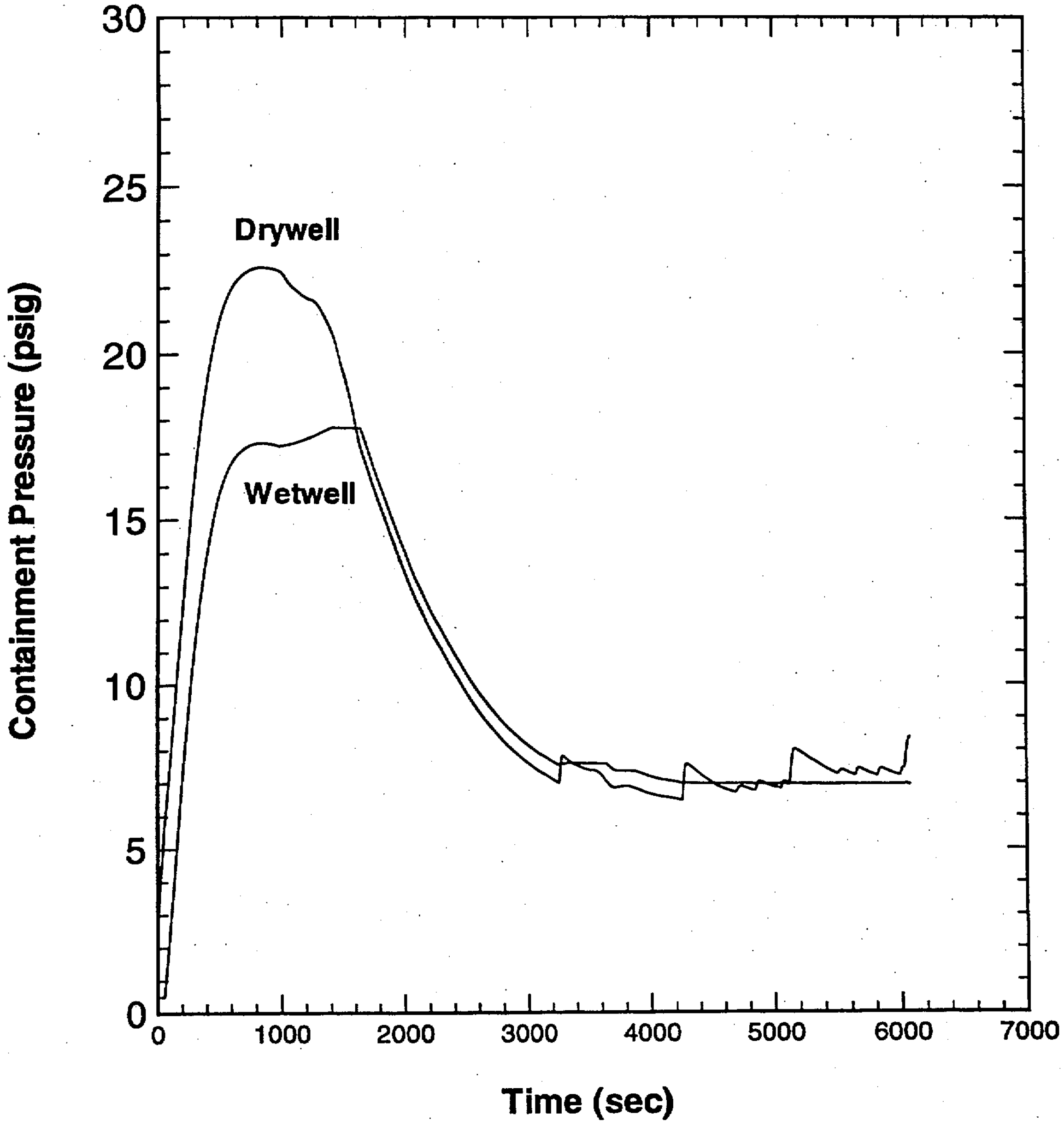

Figure 4.2-8 SABRE calculation of drywell and wetwell pressure response for 0.020 ft$^2$ liquid break.

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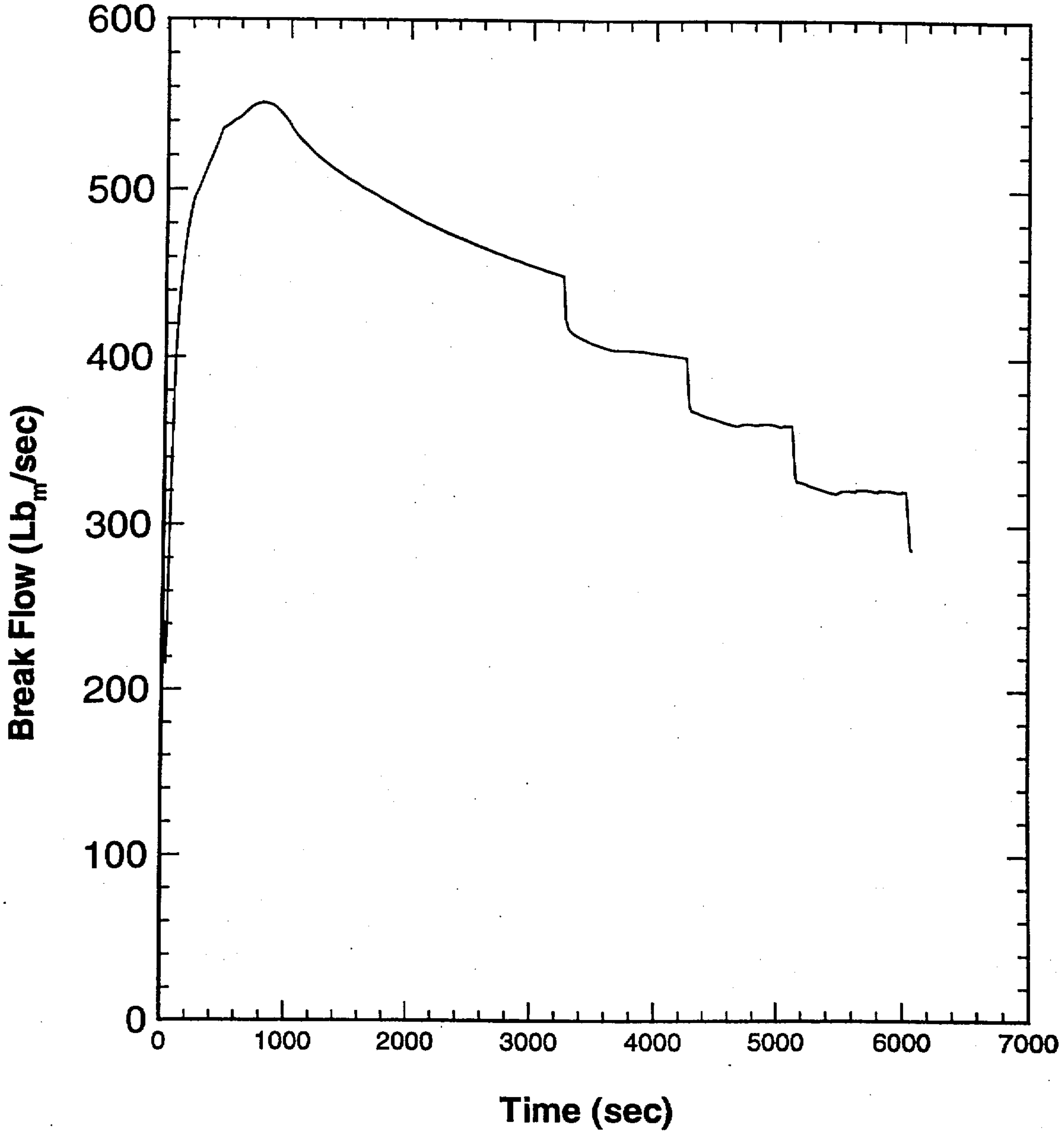

Figure 4.2-9 SABRE calculation of break flow for 0.020 ft$^2$ liquid break.

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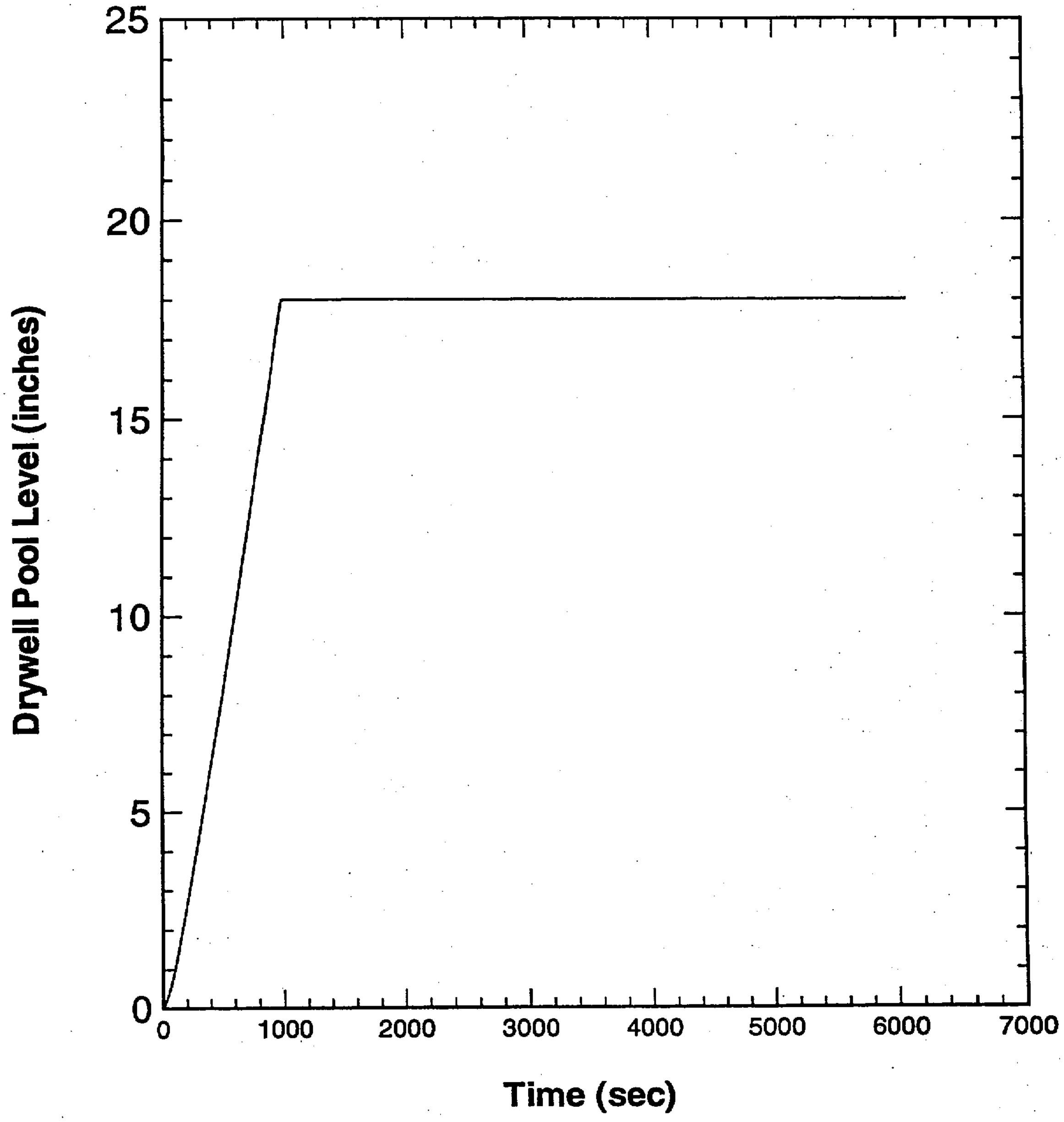

Figure 4.2-10 SABRE calculation of drywell pool level for 0.020 ft$^2$ liquid break.

## 4.3 Case 3 - 0.00545 $ft^2$ Liquid Break (1" Line Break)

The SABRE-calculated sequence of events for the 1" line break is presented in Table 4.3-1. Results are plotted in Figures 4.3-1 though 4.3-10. Table 4.3-1 shows that reactor pressure drops below the shutoff head of the Core Spray pumps at 6260 seconds (104 minutes). Because of the small break size, HPCI can easily restore and maintain level within the +13" to +54" band specified by the EOPs (Assumption # 19).

Suppression pool level undergoes only a small increase in level before pool letdown is initiated at 1800 seconds (Figure 4.3-4). Since pool level stays well below 25 feet, the manual transfer of HPCI suction is avoided in this case. Suppression pool temperature reaches 123 °F by the time reactor pressure drops to the point where Core Spray begins to inject to the vessel (Figure 4.3-5).

The plot of drywell and wetwell pressures (Figure 4.3-8) indicates that the downcomer vents are cleared throughout the entire transient. Even though reactor water level is maintained above the feedwater spargers (-24") in this case, the vent pipes to not re-seal with water as they did in Case 2. This is because the HPCI injection rates are much lower than in case 2, and consequently the downcomer does not become as subcooled. Downcomer subcooling is determined by the relative magnitudes of subcooled injection flow and saturated liquid flow leaving the steam separators. In addition, the break flow is much smaller than in Case 2 so the cooling effect on the containment is less.

Figure 4.3-10 shows that drywell pool level reaches the overflow height of 18" at 4645 seconds (77.4 minutes) into the event. At this time water begins to pour into the downcomer pipes and is transferred to the suppression pool

# Table 4.3-1
# Sequence of Events Calculated by SABRE for 0.00545 ft$^2$ Liquid Break (Case 3)

```
*** Kinetics file is /d00/appl/sabre3v1/data/u2c10.simtran.out

*** SABRE data file is /home/eamac/sabre_31/input/ec-052-1025/c03.dat

*** This is not a restart case

1   S A B R E  -  Version 3.1
    (03) U2C10 -- 0.0054 ft2 liq break -- HPCI aligned to CST


 t(sec)=        .000  Liquid Break
                      Break Area              =        .005 ft2
                      Multiplier on break flow  =      1.250

 t(sec)=        .000  RCIC is Inoperable

 t(sec)=        .000  Low-Pres Condensate Injection Inop.

 t(sec)=        .000  Recirc pump-A trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=        .000  Recirc pump-B trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=       2.003  MSIV closure on specified time

 t(sec)=       2.003  Scram initiated on specified time
                      Scram time (sec) =        2.80

 t(sec)=       4.013  Feedwater Trip on specified time

 t(sec)=       4.823  All Control Rods Inserted

 t(sec)=       6.016  MSIVs are closed

 t(sec)=      11.447  HPCI initiation on Low water level
                      Setpoint for initiation =      -38.00 in.

 t(sec)=      16.727  DW Cooler Trip on Hi DW Press
                      Trip Setpoint     =          1.720 psig

 t(sec)=     263.166  Main Turb Trip on high water level
                      Setpoint(inches) =       54.000

 t(sec)=     263.166  HPCI Trip on hi water level
                      Trip Setpoint =      .54E+02 in.

 t(sec)=     751.066  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =       90.000 F/hr
                      Target Pressure  =       98.000 psig

 t(sec)=     763.416  SRV # 1 Tripped Close

 t(sec)=     803.006  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =       90.000 F/hr
                      Target Pressure  =       98.000 psig

 t(sec)=     816.456  SRV # 1 Tripped Close

 t(sec)=     855.756  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =       90.000 F/hr
                      Target Pressure  =       98.000 psig

 t(sec)=     870.206  SRV # 1 Tripped Close
```

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```
t(sec)=     900.006  Loop 1 of Supp Pool Cool Effective
                     Service Water Temperature =        88.00 F

t(sec)=     908.406  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=     923.956  SRV # 1 Tripped Close

t(sec)=     961.256  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=     978.256  SRV # 1 Tripped Close

t(sec)=    1014.947  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    1033.797  SRV # 1 Tripped Close

t(sec)=    1049.647  HPCI initiation on Low water level
                     Setpoint for initiation =       -38.00 in.

t(sec)=    1049.647  Operator takes control of HPCI inj.

t(sec)=    1254.247  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    1264.897  SRV # 1 Tripped Close

t(sec)=    1484.147  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    1495.297  SRV # 1 Tripped Close

t(sec)=    1729.118  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    1741.401  SRV # 1 Tripped Close

t(sec)=    1800.001  SP Letdown Initiated
                     Letdown Rate     =      120.000 Lbm/sec

t(sec)=    1963.940  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    1977.347  SRV # 1 Tripped Close

t(sec)=    2203.318  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    2217.694  SRV # 1 Tripped Close

t(sec)=    2446.806  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    2462.057  SRV # 1 Tripped Close

t(sec)=    2691.998  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =        90.000 F/hr
                     Target Pressure   =        98.000 psig

t(sec)=    2708.194  SRV # 1 Tripped Close
```

```
t(sec)=    2937.838  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    2954.969  SRV # 1 Tripped Close

t(sec)=    3182.263  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    3200.467  SRV # 1 Tripped Close

t(sec)=    3424.921  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    3444.243  SRV # 1 Tripped Close

t(sec)=    3665.451  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    3686.008  SRV # 1 Tripped Close

t(sec)=    3903.063  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    3924.924  SRV # 1 Tripped Close

t(sec)=    4139.642  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    4163.033  SRV # 1 Tripped Close

t(sec)=    4372.833  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    4397.802  SRV # 1 Tripped Close

t(sec)=    4603.702  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    4630.540  SRV # 1 Tripped Close

t(sec)=    4833.840  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    4862.902  SRV # 1 Tripped Close

t(sec)=    5064.002  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    5095.437  SRV # 1 Tripped Close

t(sec)=    5292.187  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig

t(sec)=    5326.687  SRV # 1 Tripped Close

t(sec)=    5521.887  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =        90.000 F/hr
                     Target Pressure  =        98.000 psig
```

```
t(sec)=     5559.729  SRV # 1 Tripped Close

t(sec)=     5750.829  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =       90.000 F/hr
                      Target Pressure   =       98.000 psig

t(sec)=     5792.829  SRV # 1 Tripped Close

t(sec)=     5982.129  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =       90.000 F/hr
                      Target Pressure   =       98.000 psig

t(sec)=     6029.029  SRV # 1 Tripped Close

t(sec)=     6214.829  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =       90.000 F/hr
                      Target Pressure   =       98.000 psig

t(sec)=     6260.491  Initiation of Core Spray Flow
                      Reactor Press =       311.19 psig
                      Supp Chamber Press =        22.19 psig

t(sec)=     6267.452  SRV # 1 Tripped Close

t(sec)=     6449.485  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =       90.000 F/hr
                      Target Pressure   =       98.000 psig
```

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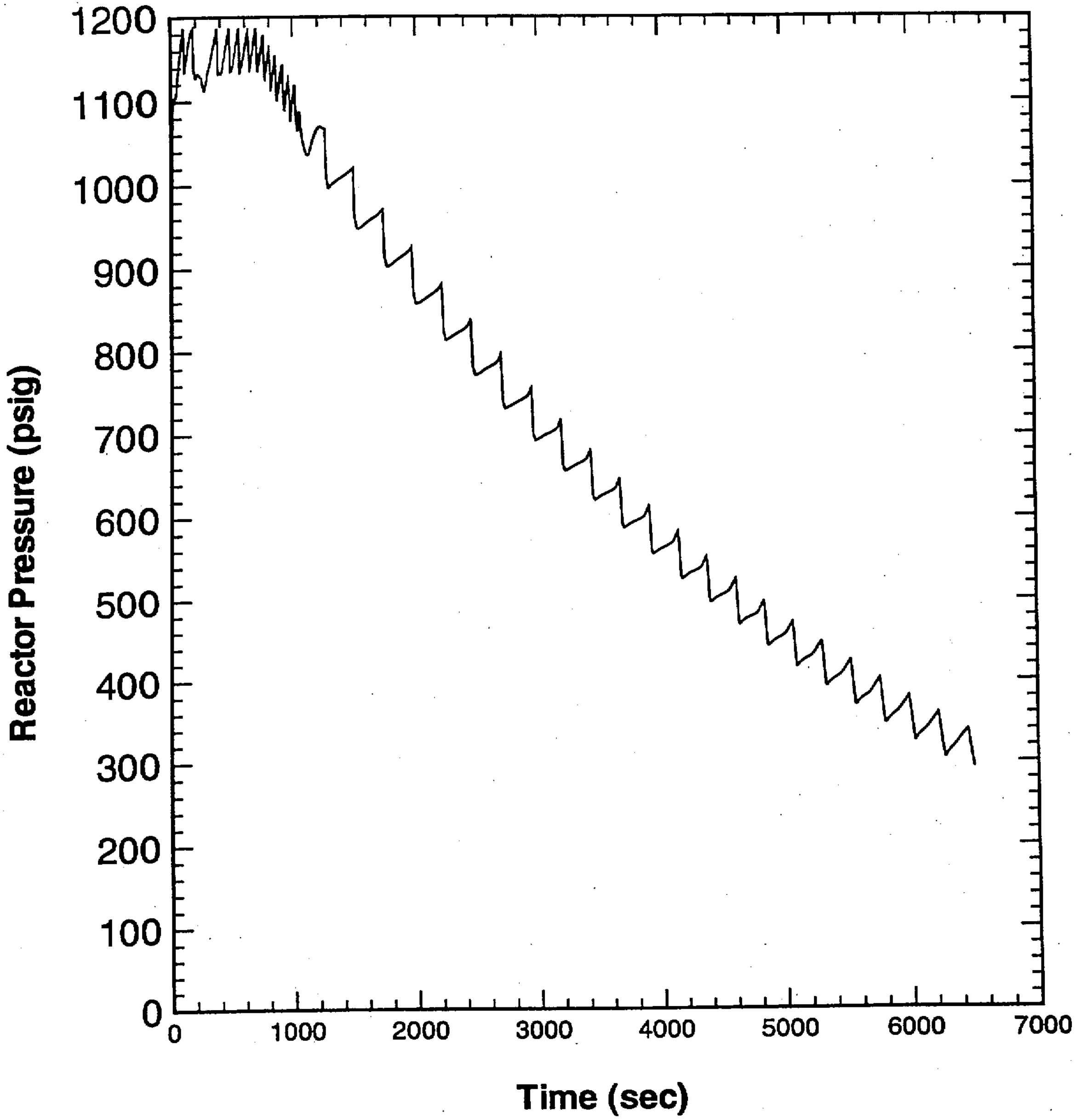

Figure 4.3-1 SABRE calculation of reactor steam dome pressure for 0.00545 $ft^2$ liquid break (1" line break).

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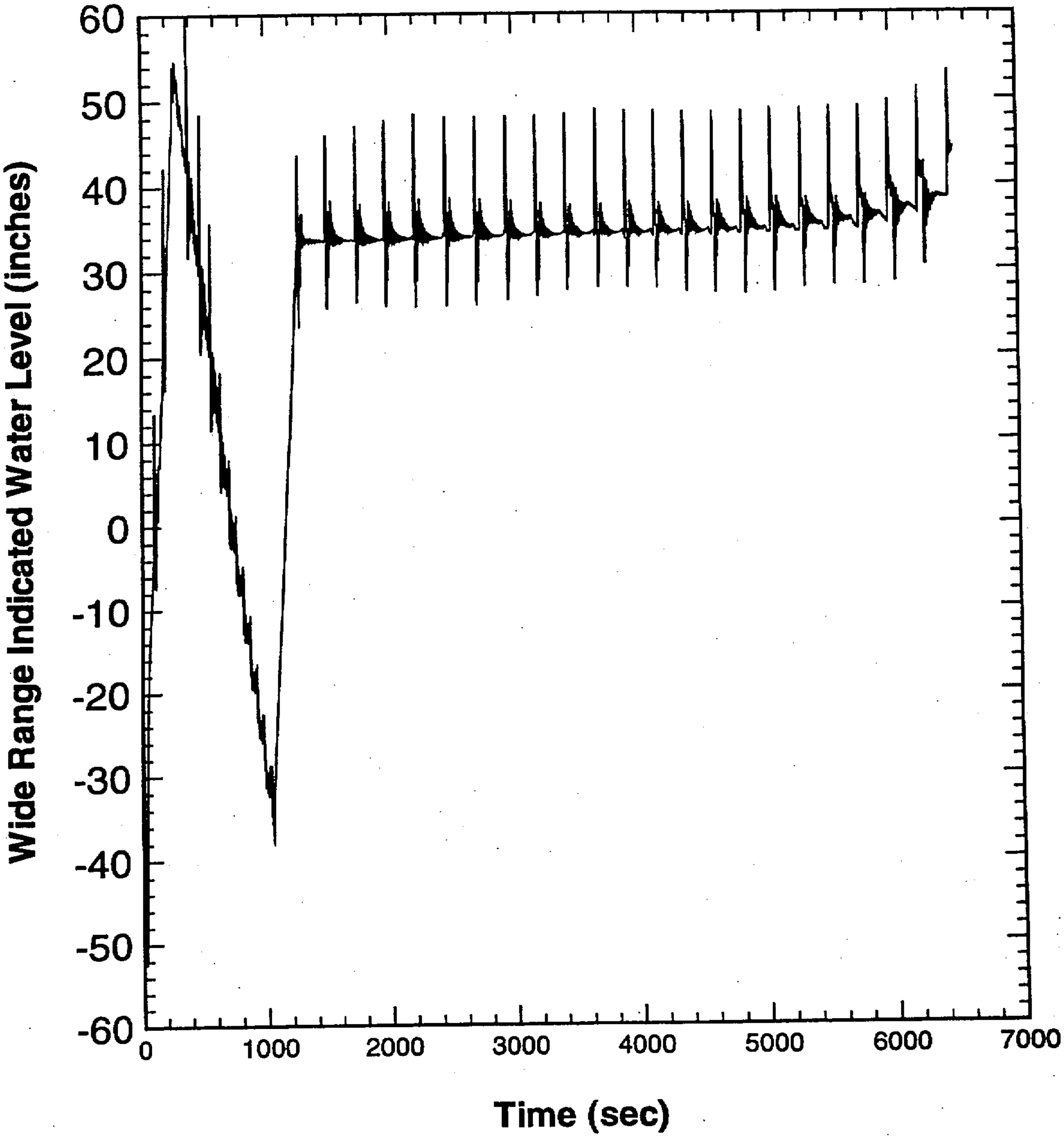

Figure 4.3-2 SABRE calculation of Wide Range Indicated Level for 0.00545 $ft^2$ liquid break (1" line break).

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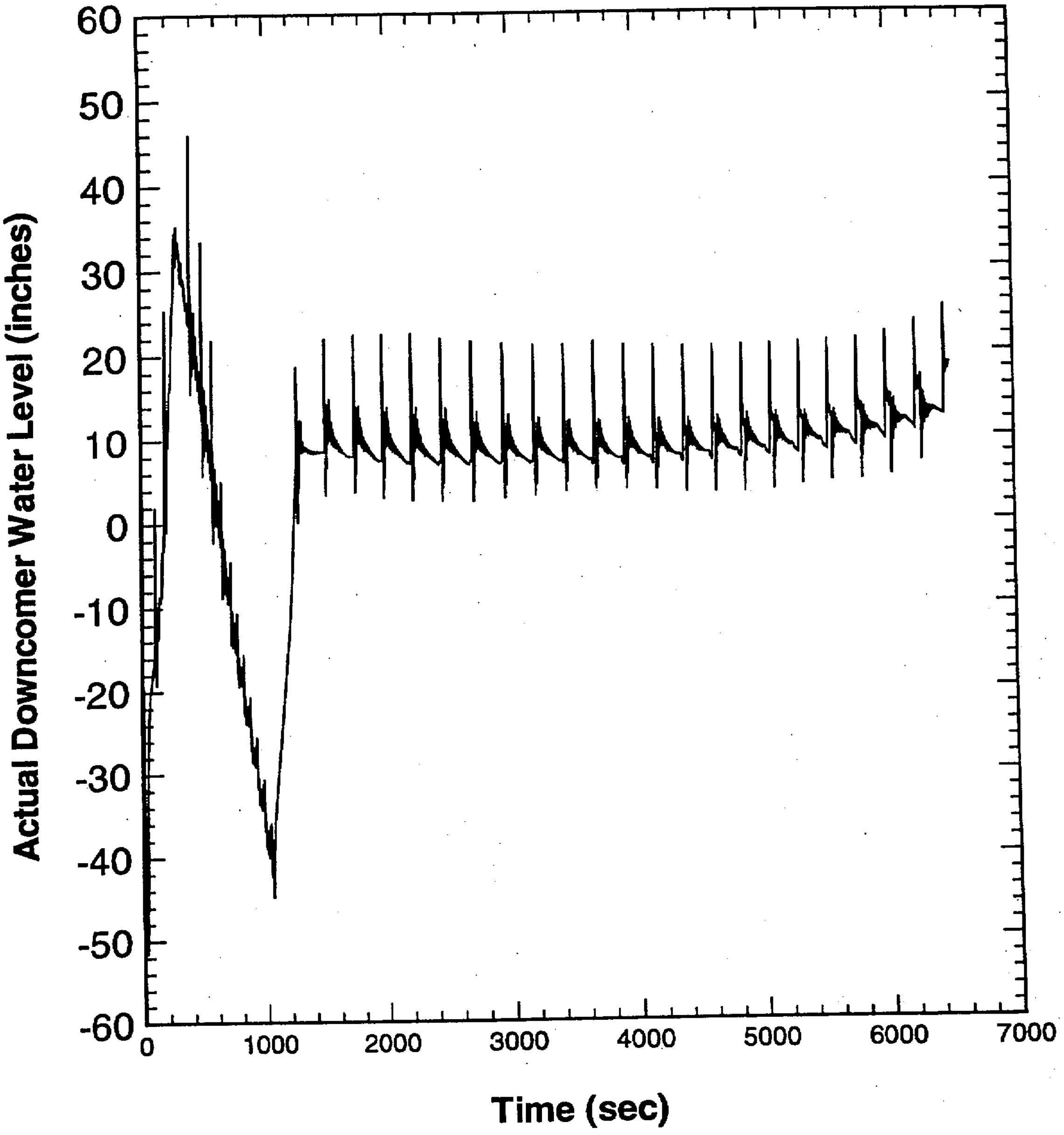

Figure 4.3-3 SABRE calculation of actual downcomer water level for 0.00545 $ft^2$ liquid break (1" line break).

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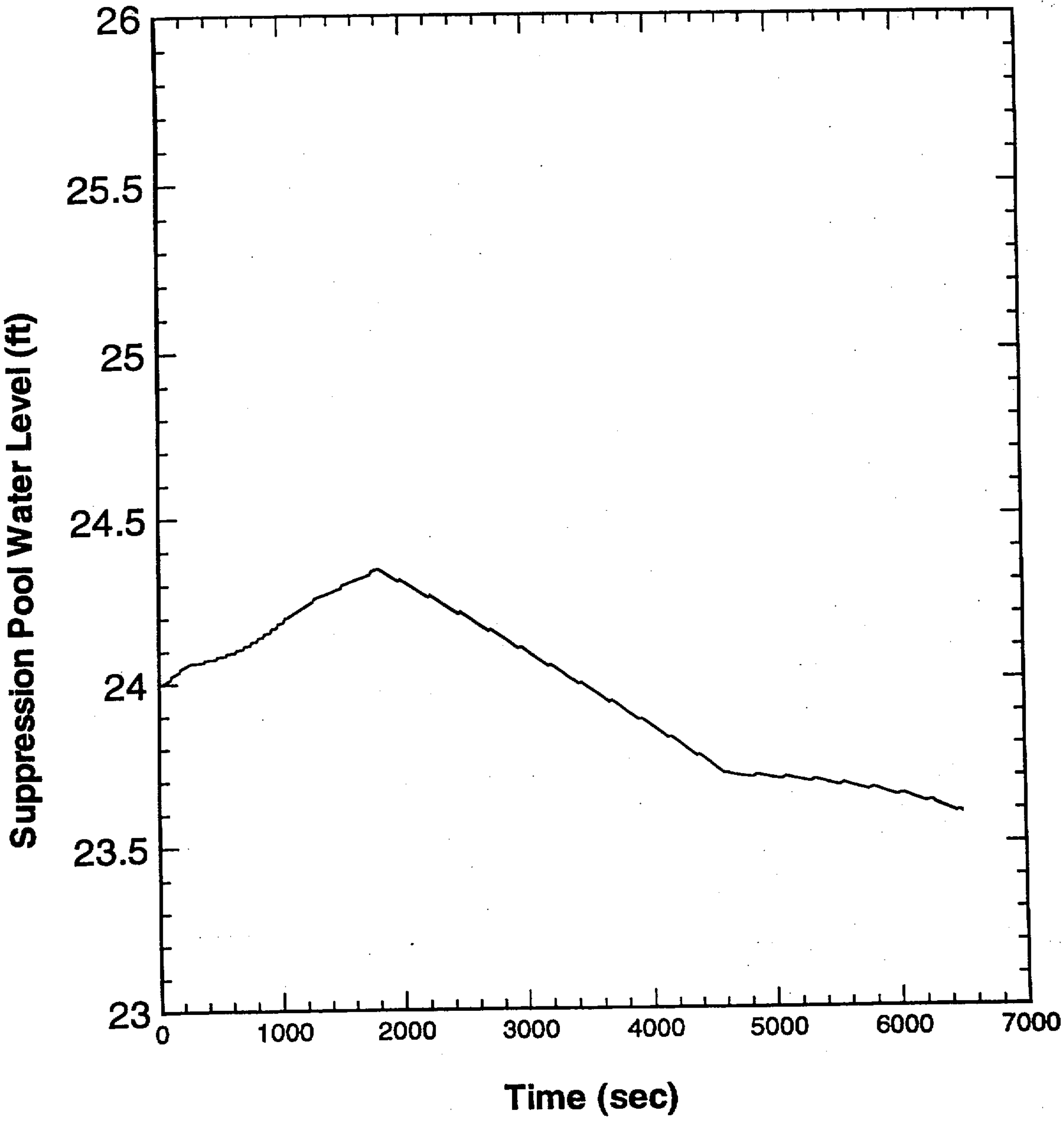

Figure 4.3-4 SABRE calculation of suppression pool water level for 0.00545 ft$^2$ liquid break (1" line break).

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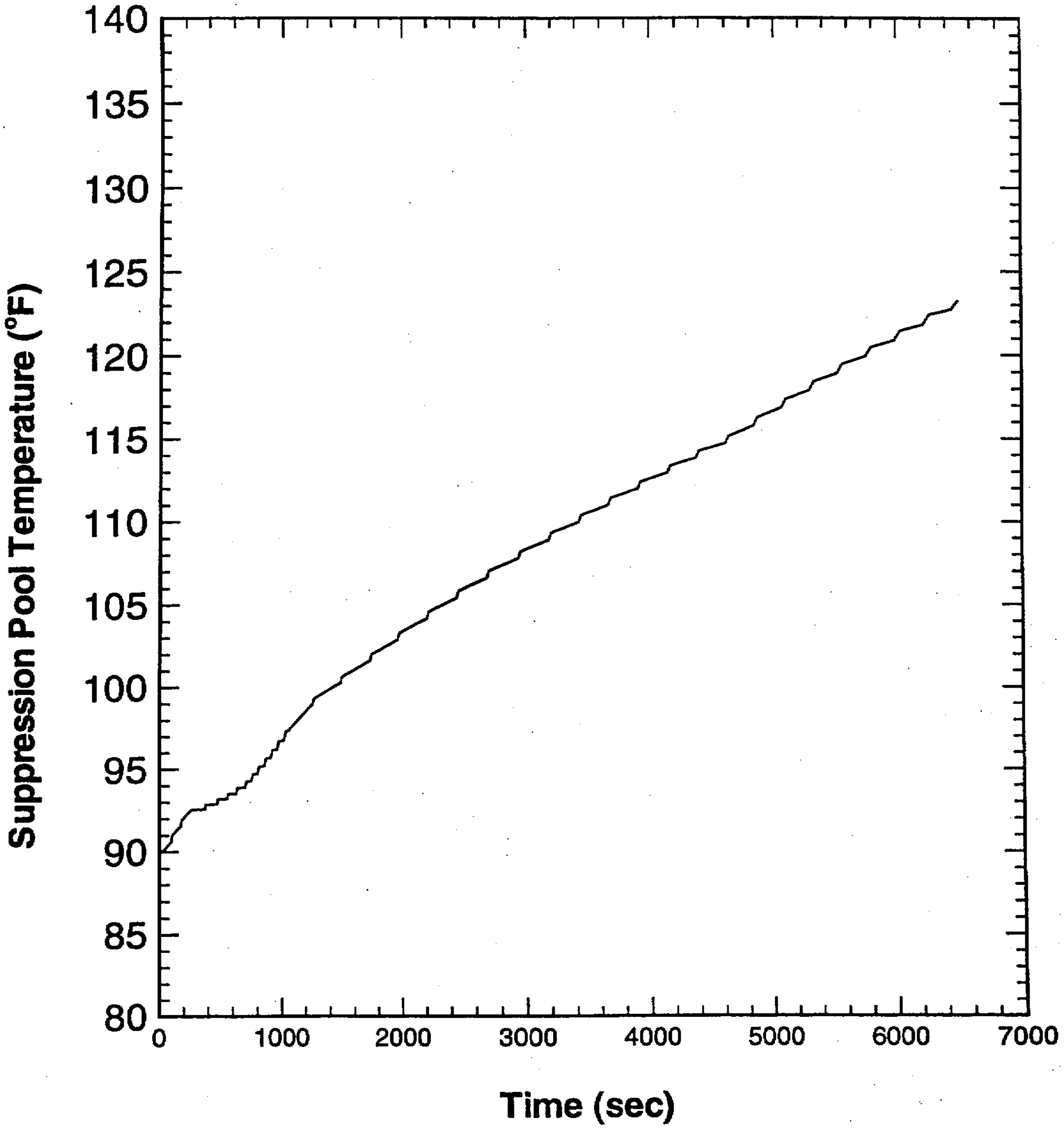

Figure 4.3-5 SABRE calculation of suppression pool temperature for 0.00545 ft$^2$ liquid break (1" line break).

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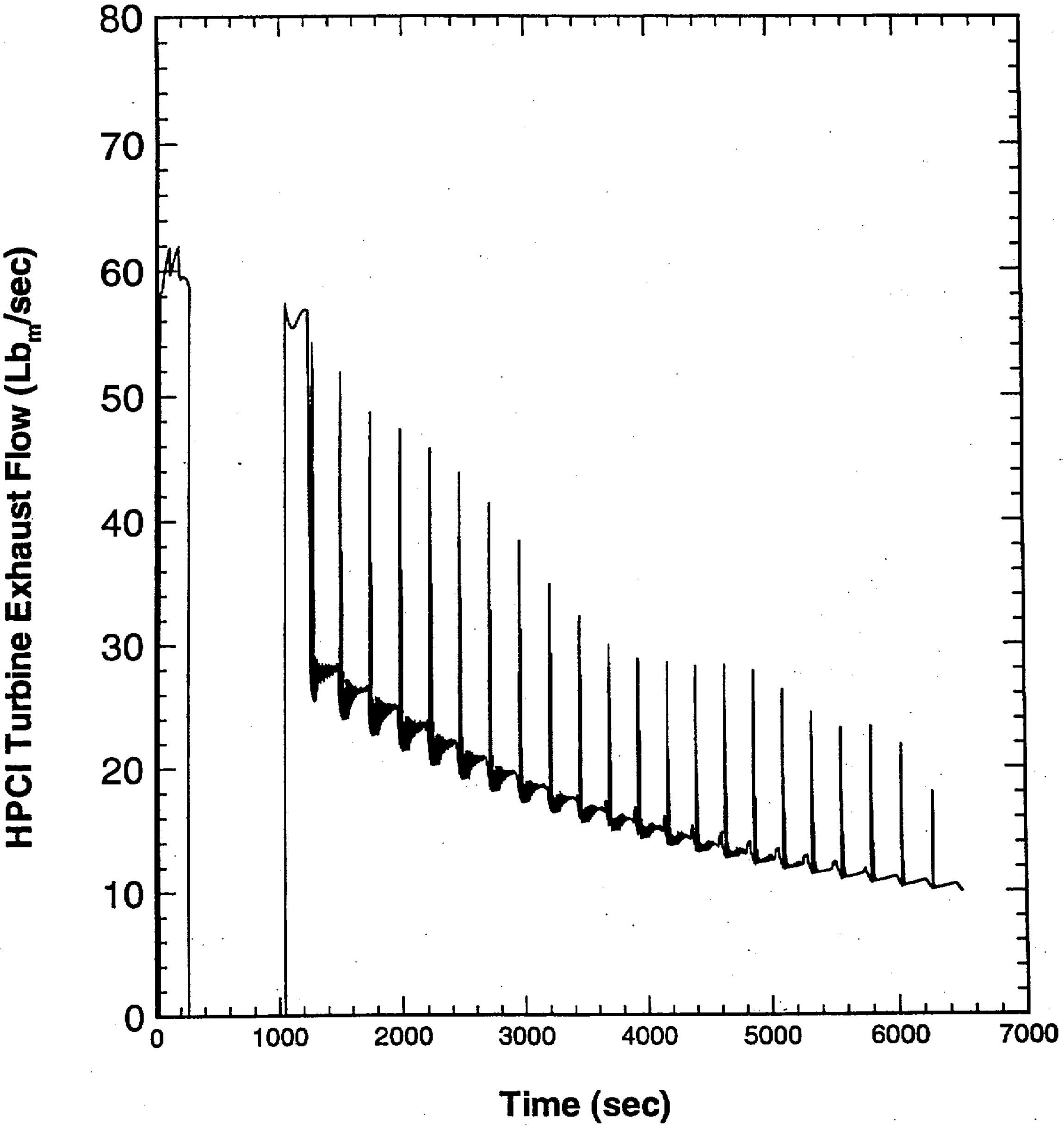

Figure 4.3-6 SABRE calculation of HPCI turbine exhaust flow for 0.00545 $ft^2$ liquid break (1" line break).

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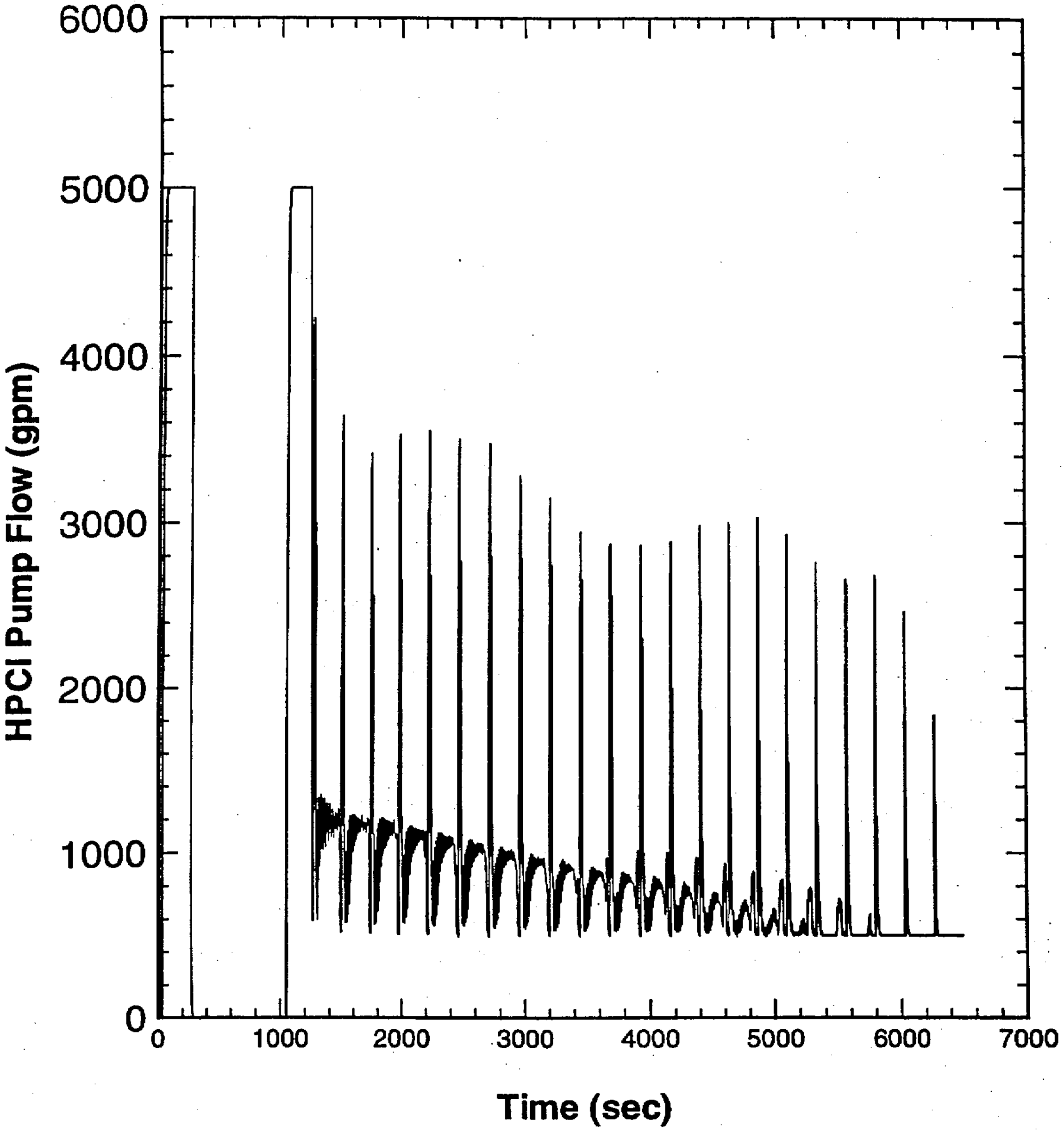

Figure 4.3-7 SABRE calculation of HPCI pump flow for 0.00545 ft$^2$ liquid break (1" line break).

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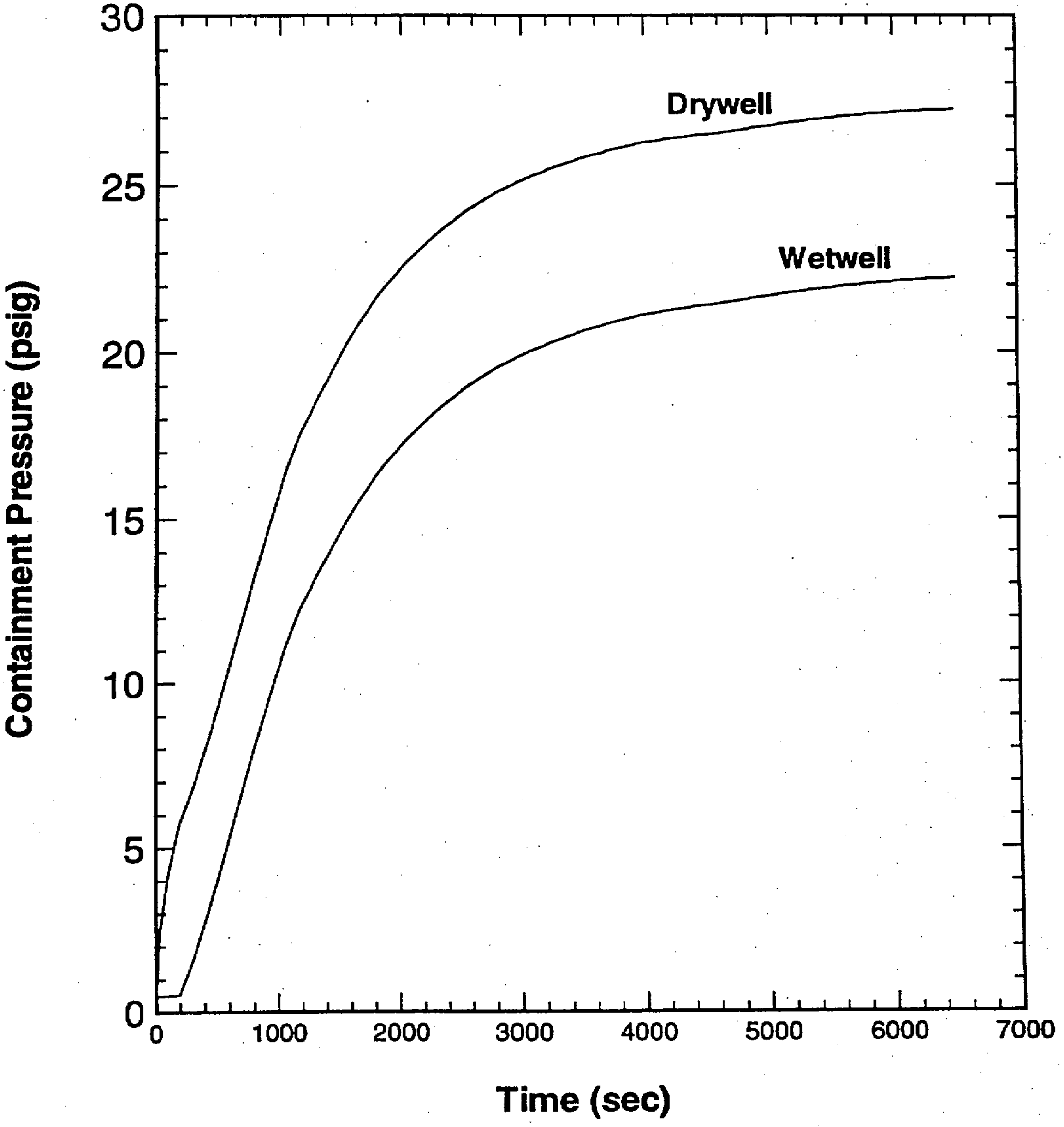

**Figure 4.3-8** SABRE calculation of drywell and wetwell pressure response for 0.00545 $ft^2$ liquid break (1" line break).

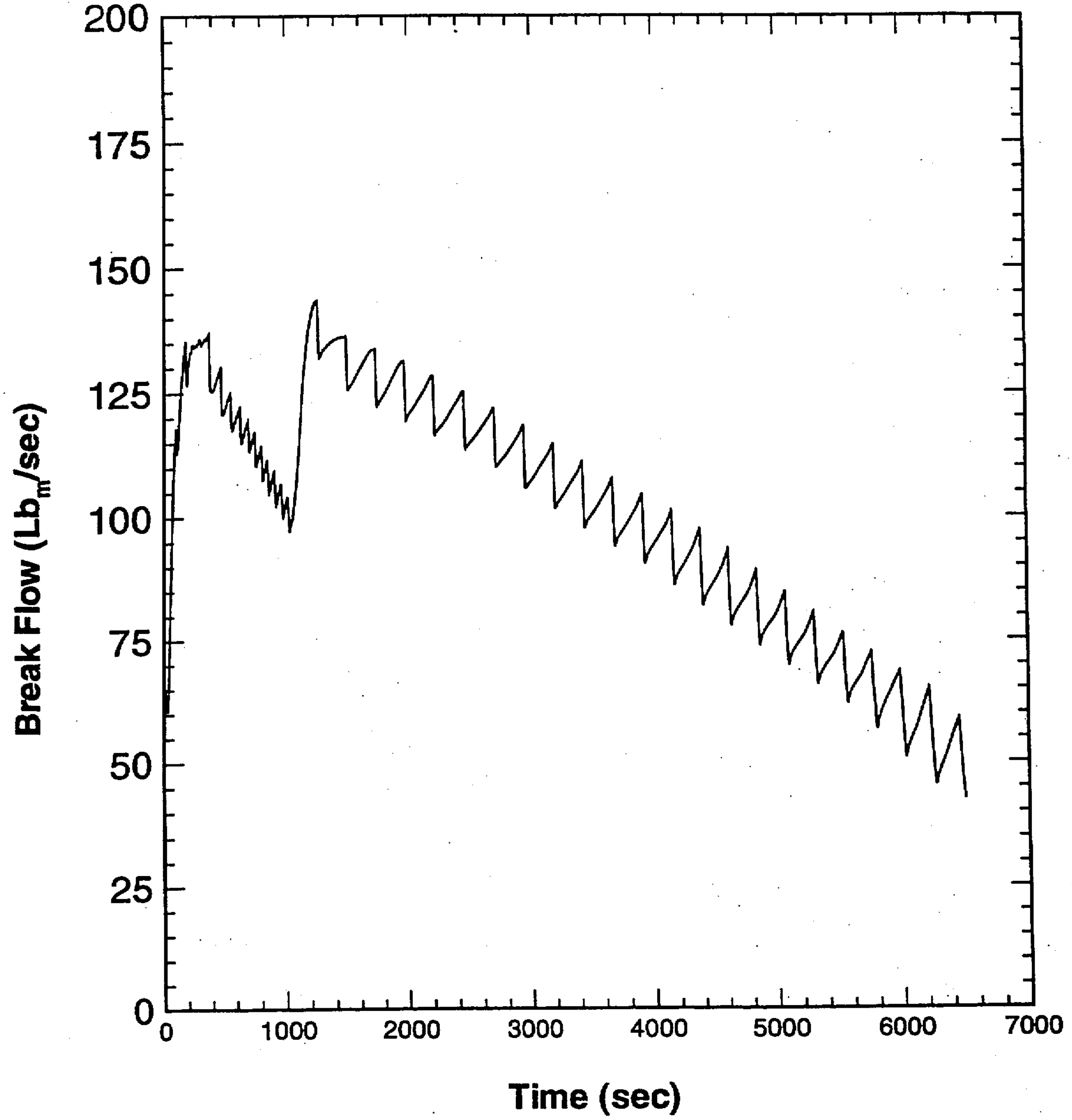

Figure 4.3-9 SABRE calculation of break flow for 0.00545 ft$^2$ liquid break (1" line break).

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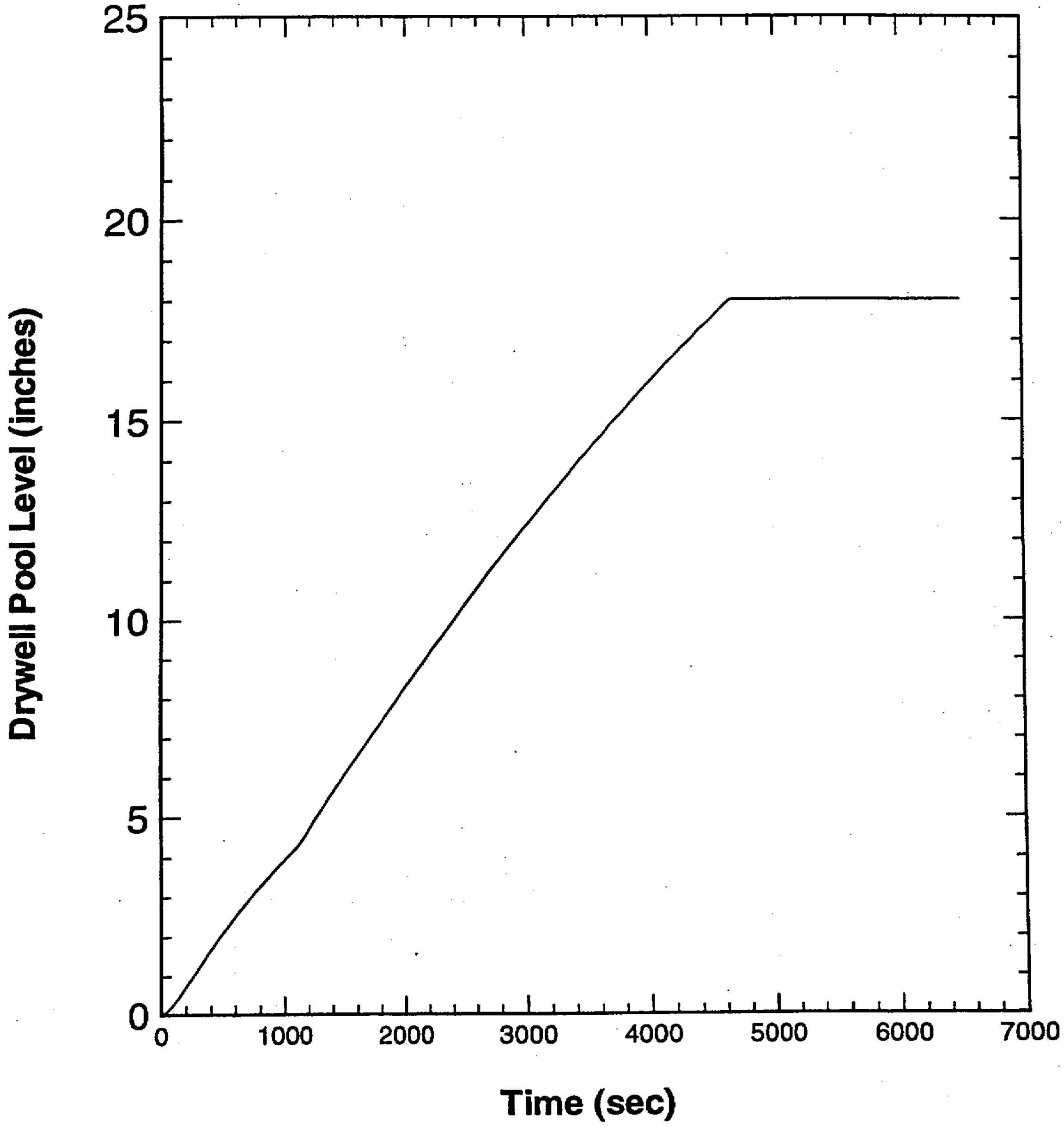

Figure 4.3-10 SABRE calculation of drywell pool level for 0.00545 ft$^2$ liquid break (1" line break).

## 4.4 Case 4 - MSIV Closure Transient

This case examines reactor and containment response for the an MSIV closure transient. The event is assumed to be initiated by a LOOP so there is a loss of feedwater early in the event. This maximizes the amount of water injected by the HPCI system. The sequence of events are presented in Table 4.4-1, and calculation results are plotted in Figures 4.4-1 through 4.4-7.

Suppression pool water level increases to 24'-5" at 1800 seconds. Since pool level never reaches 25 feet, there would be no manual transfer of HPCI suction from the CST to the suppression pool in this event. At 1800 seconds, suppression pool letdown is initiated and pool level begins to decrease. At 6606 seconds (110 minutes), reactor pressure drops below the shutoff head of the Core Spray pumps and injection to the vessel begins. From this time on, HPCI is no longer required for vessel coolant makeup. Suppression pool temperature reaches 138°F when Core Spray initiates.

In this case suppression pool cooling was inadvertently started at 1000 seconds rather than at 900 seconds as specified by Input/Assumption #17 in §3. Starting pool cooling 100 seconds later has negligible effect on the results.

## Table 4.4-1
## Sequence of Events Calculated by SABRE for MSIV Closure Transient (Case 4)

```
*** Kinetics file is /d00/appl/sabre3v1/data/u2c10.simtran.out

*** SABRE data file is /home/eamac/sabre_31/input/ec-052-1025/c04.dat

*** This is not a restart case

1   S A B R E  -  Version 3.1
    (04) U2C10 -- MSIV Closure w LOOP -- No break -- HPCI aligned to CST


 t(sec)=        .000  RCIC is Inoperable

 t(sec)=        .000  Low-Pres Condensate Injection Inop.

 t(sec)=        .000  Recirc pump-A trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=        .000  Recirc pump-B trip on specified time
                      Trip delay =     .000E+00 sec

 t(sec)=       2.003  MSIV closure on specified time

 t(sec)=       2.003  Scram initiated on specified time
                      Scram time (sec) =        2.80

 t(sec)=       4.013  Feedwater Trip on specified time

 t(sec)=       4.823  All Control Rods Inserted

 t(sec)=       6.016  MSIVs are closed

 t(sec)=      11.957  HPCI initiation on Low water level
                      Setpoint for initiation =      -38.00 in.

 t(sec)=     209.117  Main Turb Trip on high water level
                      Setpoint(inches) =      54.000

 t(sec)=     209.117  HPCI Trip on hi water level
                      Trip Setpoint =      .54E+02 in.

 t(sec)=     662.507  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =      90.000 F/hr
                      Target Pressure  =      98.000 psig

 t(sec)=     670.457  SRV # 1 Tripped Close

 t(sec)=     741.197  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =      90.000 F/hr
                      Target Pressure  =      98.000 psig

 t(sec)=     750.077  SRV # 1 Tripped Close

 t(sec)=     816.947  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =      90.000 F/hr
                      Target Pressure  =      98.000 psig

 t(sec)=     825.707  SRV # 1 Tripped Close

 t(sec)=     888.857  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =      90.000 F/hr
                      Target Pressure  =      98.000 psig

 t(sec)=     898.097  SRV # 1 Tripped Close

 t(sec)=     954.827  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate    =      90.000 F/hr
```

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```
                    Target Pressure  =       98.000 psig

t(sec)=     964.367 SRV # 1 Tripped Close

t(sec)=    1000.007 Loop 1 of Supp Pool Cool Effective
                    Service Water Temperature =        88.00 F

t(sec)=    1017.317 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1028.387 SRV # 1 Tripped Close

t(sec)=    1071.767 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1083.407 SRV # 1 Tripped Close

t(sec)=    1119.287 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1132.607 SRV # 1 Tripped Close

t(sec)=    1163.297 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1187.687 SRV # 1 Tripped Close

t(sec)=    1218.227 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1260.827 SRV # 1 Tripped Close

t(sec)=    1292.837 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1337.897 SRV # 1 Tripped Close

t(sec)=    1370.027 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1415.177 SRV # 1 Tripped Close

t(sec)=    1447.247 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1492.337 SRV # 1 Tripped Close

t(sec)=    1524.347 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1569.437 SRV # 1 Tripped Close

t(sec)=    1601.837 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig

t(sec)=    1647.497 SRV # 1 Tripped Close

t(sec)=    1680.917 SRV #1 Manual Open for RPV Cooldown
                    Cooldown Rate    =       90.000 F/hr
                    Target Pressure  =       98.000 psig
```

```
t(sec)=     1728.107  SRV # 1 Tripped Close

t(sec)=     1762.937  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     1800.017  SP Letdown Initiated
                      Letdown Rate      =        120.000 Lbm/sec

t(sec)=     1812.257  SRV # 1 Tripped Close

t(sec)=     1848.077  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     1898.987  SRV # 1 Tripped Close

t(sec)=     1934.777  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     1986.017  SRV # 1 Tripped Close

t(sec)=     2021.447  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2072.537  SRV # 1 Tripped Close

t(sec)=     2107.097  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2157.407  SRV # 1 Tripped Close

t(sec)=     2191.007  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2240.322  SRV # 1 Tripped Close

t(sec)=     2250.522  HPCI initiation on Low water level
                      Setpoint for initiation =        -38.00 in.

t(sec)=     2250.522  Operator takes control of HPCI inj.

t(sec)=     2340.312  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2362.132  SRV # 1 Tripped Close

t(sec)=     2439.650  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2455.250  SRV # 1 Tripped Close

t(sec)=     2574.718  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig

t(sec)=     2578.048  HPCI Trip on hi water level
                      Trip Setpoint =      .54E+02 in.

t(sec)=     2591.308  SRV # 1 Tripped Close

t(sec)=     2674.498  SRV #1 Manual Open for RPV Cooldown
                      Cooldown Rate     =        90.000 F/hr
                      Target Pressure   =        98.000 psig
```

```
t(sec)=    2690.488  SRV # 1 Tripped Close

t(sec)=    2769.658  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    2786.248  SRV # 1 Tripped Close

t(sec)=    2864.788  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    2882.098  SRV # 1 Tripped Close

t(sec)=    2958.808  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    2977.108  SRV # 1 Tripped Close

t(sec)=    3051.568  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3070.948  SRV # 1 Tripped Close

t(sec)=    3142.288  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3162.838  SRV # 1 Tripped Close

t(sec)=    3230.098  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3251.968  SRV # 1 Tripped Close

t(sec)=    3313.018  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3336.448  SRV # 1 Tripped Close

t(sec)=    3391.048  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3417.028  SRV # 1 Tripped Close

t(sec)=    3465.628  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3495.838  SRV # 1 Tripped Close

t(sec)=    3539.518  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3627.238  SRV # 1 Tripped Close

t(sec)=    3673.918  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig

t(sec)=    3798.388  SRV # 1 Tripped Close

t(sec)=    3847.378  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate     =      90.000 F/hr
                     Target Pressure   =      98.000 psig
```

```
t(sec)=    3984.358  SRV # 1 Tripped Close

t(sec)=    4036.318  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    4192.798  SRV # 1 Tripped Close

t(sec)=    4245.898  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    4422.988  SRV # 1 Tripped Close

t(sec)=    4475.158  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    4673.574  SRV # 1 Tripped Close

t(sec)=    4680.474  HPCI initiation on Low water level
                     Setpoint for initiation =       -38.00 in.

t(sec)=    4850.391  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    4882.551  SRV # 1 Tripped Close

t(sec)=    5020.468  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    5022.328  HPCI Trip on hi water level
                     Trip Setpoint =       .54E+02 in.

t(sec)=    5052.538  SRV # 1 Tripped Close

t(sec)=    5172.688  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    5207.728  SRV # 1 Tripped Close

t(sec)=    5327.338  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    5364.688  SRV # 1 Tripped Close

t(sec)=    5473.798  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    5514.388  SRV # 1 Tripped Close

t(sec)=    5607.838  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    5655.028  SRV # 1 Tripped Close

t(sec)=    5733.208  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =       90.000 F/hr
                     Target Pressure  =       98.000 psig

t(sec)=    6606.058  Initiation of Core Spray Flow
                     Reactor Press =       289.88 psig
                     Supp Chamber Press =         .89 psig
```

```
t(sec)=    3984.358  SRV # 1 Tripped Close

t(sec)=    4036.318  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    4192.798  SRV # 1 Tripped Close

t(sec)=    4245.898  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    4422.988  SRV # 1 Tripped Close

t(sec)=    4475.158  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    4673.574  SRV # 1 Tripped Close

t(sec)=    4680.474  HPCI initiation on Low water level
                     Setpoint for initiation =      -38.00 in.

t(sec)=    4850.391  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    4882.551  SRV # 1 Tripped Close

t(sec)=    5020.468  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    5022.328  HPCI Trip on hi water level
                     Trip Setpoint =      .54E+02 in.

t(sec)=    5052.538  SRV # 1 Tripped Close

t(sec)=    5172.688  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    5207.728  SRV # 1 Tripped Close

t(sec)=    5327.338  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    5364.688  SRV # 1 Tripped Close

t(sec)=    5473.798  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    5514.388  SRV # 1 Tripped Close

t(sec)=    5607.838  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    5655.028  SRV # 1 Tripped Close

t(sec)=    5733.208  SRV #1 Manual Open for RPV Cooldown
                     Cooldown Rate    =      90.000 F/hr
                     Target Pressure  =      98.000 psig

t(sec)=    6606.058  Initiation of Core Spray Flow
                     Reactor Press =      289.88 psig
                     Supp Chamber Press =          .89 psig
```

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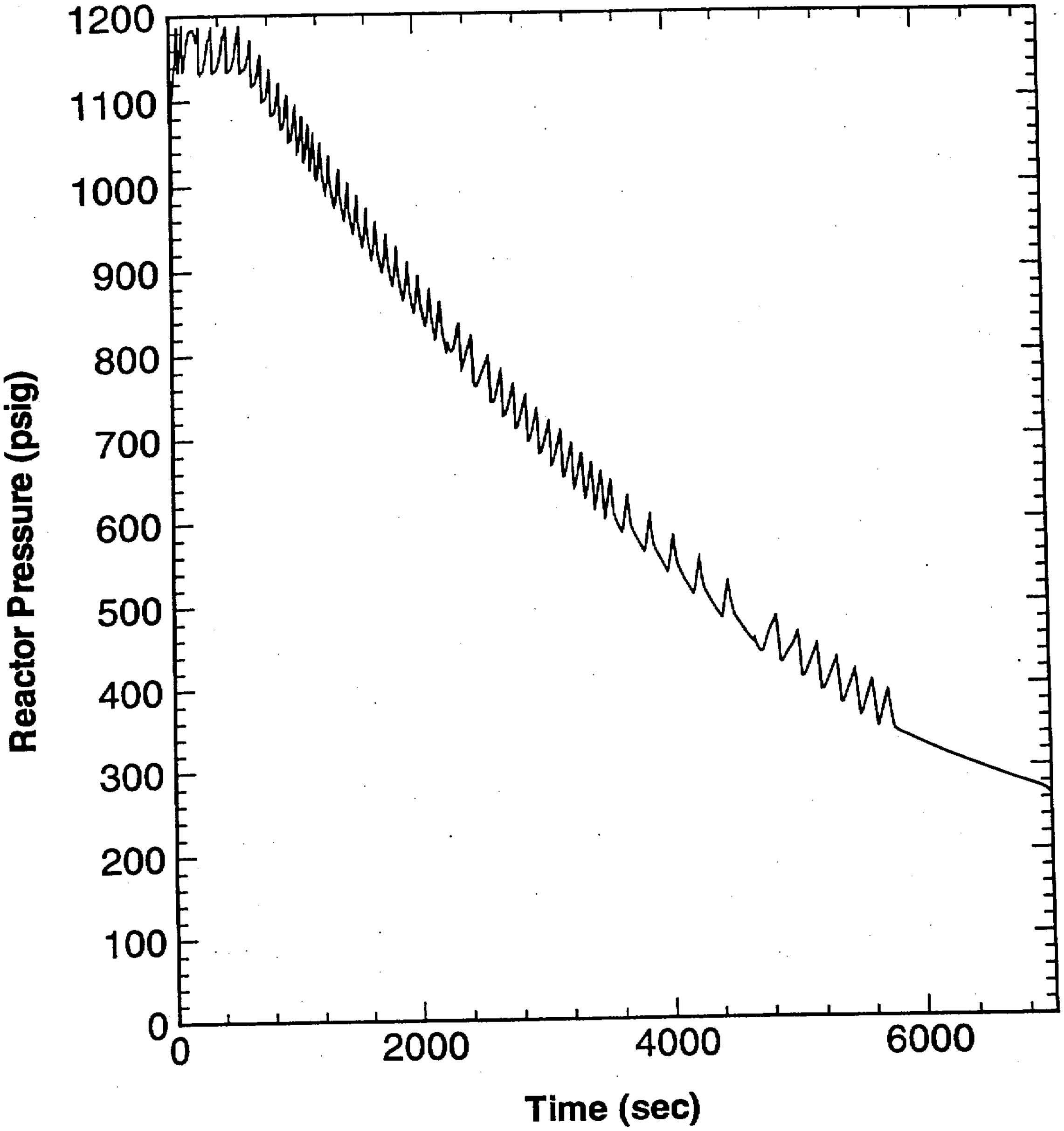

Figure 4.4-1 SABRE calculation of reactor steam dome pressure for MSIV closure transient.

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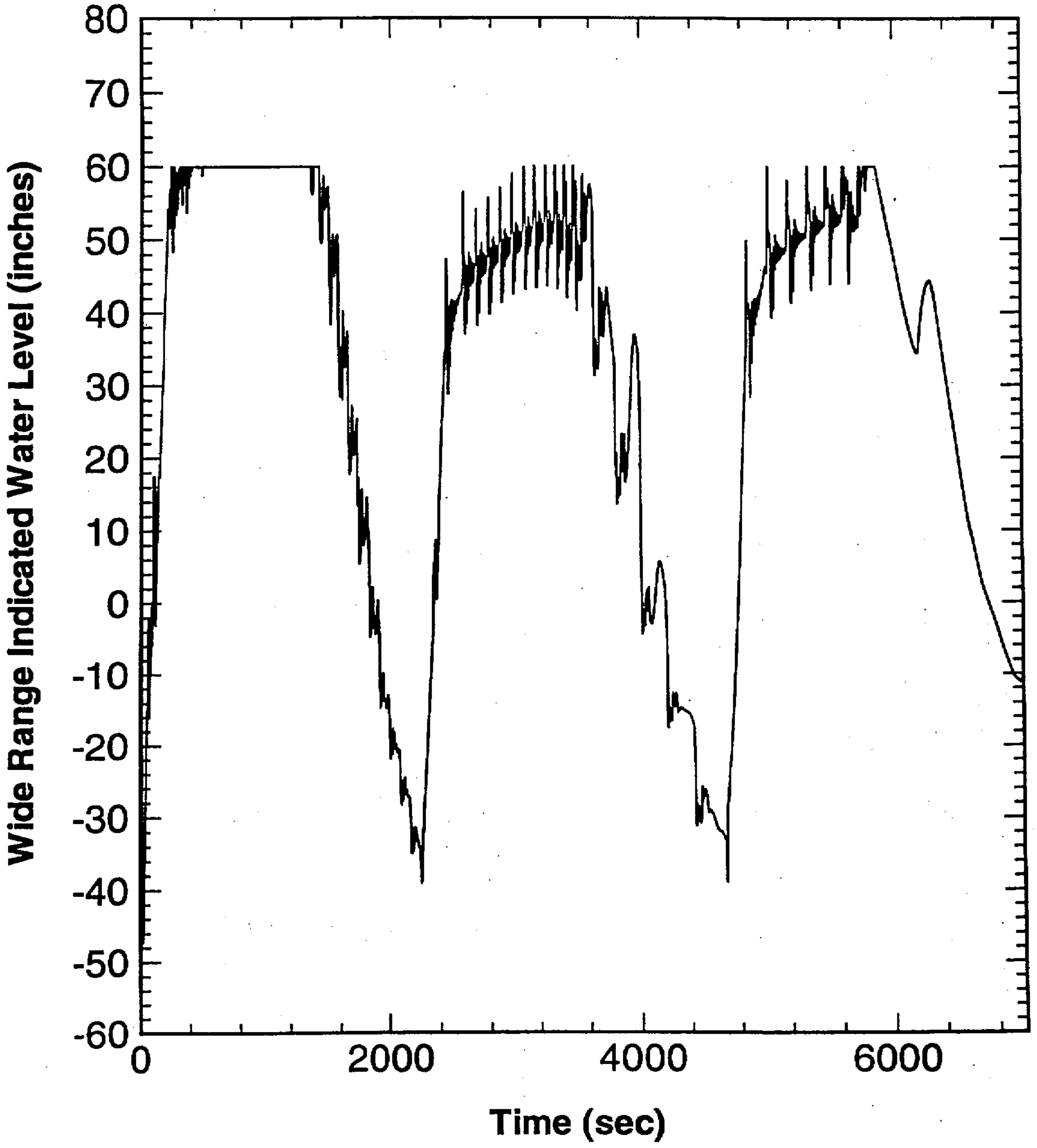

Figure 4.4-2 SABRE calculation of Wide Range Indicated Level for MSIV closure transient.

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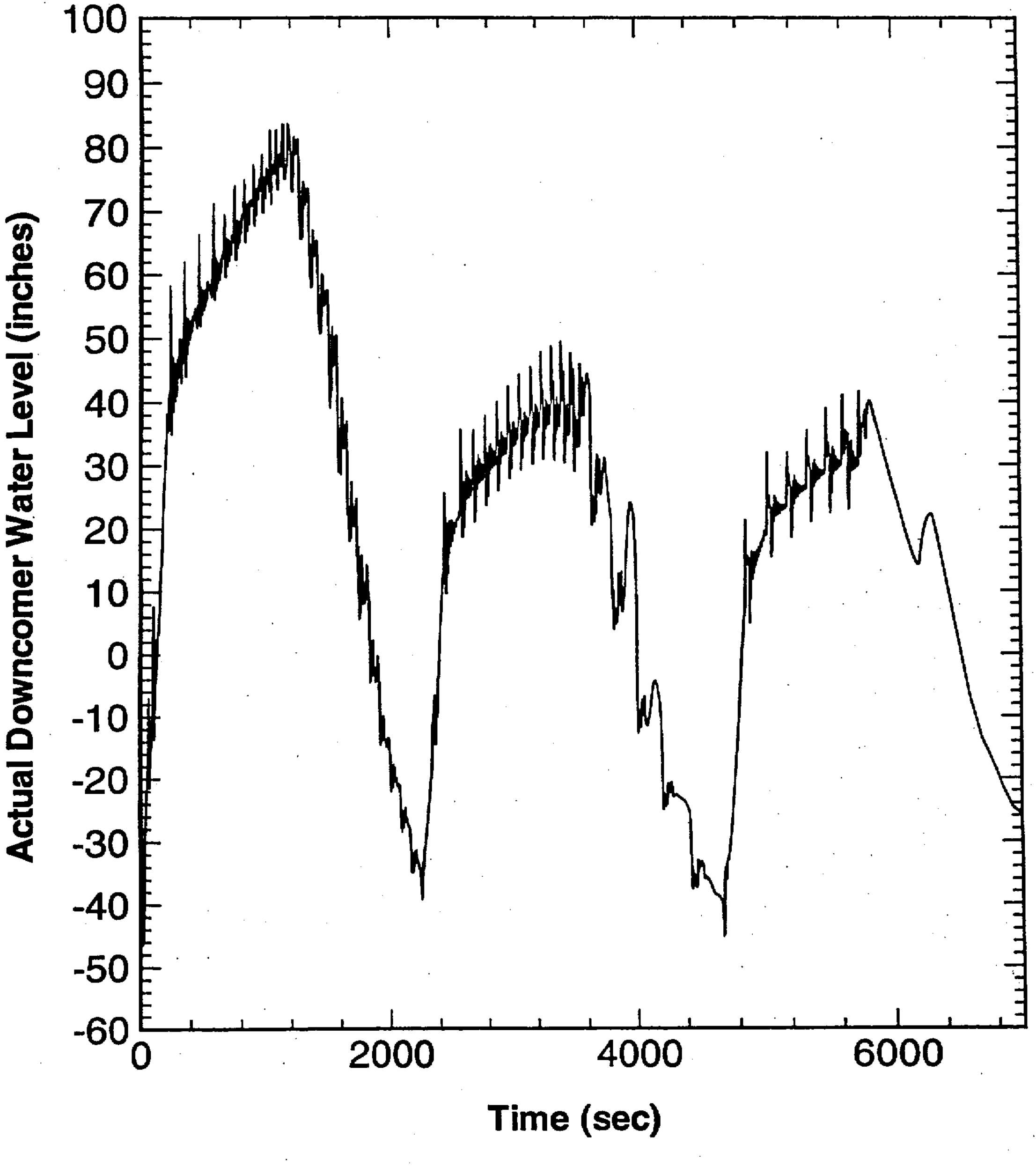

Figure 4.4-3 SABRE calculation of actual downcomer water level for MSIV closure transient.

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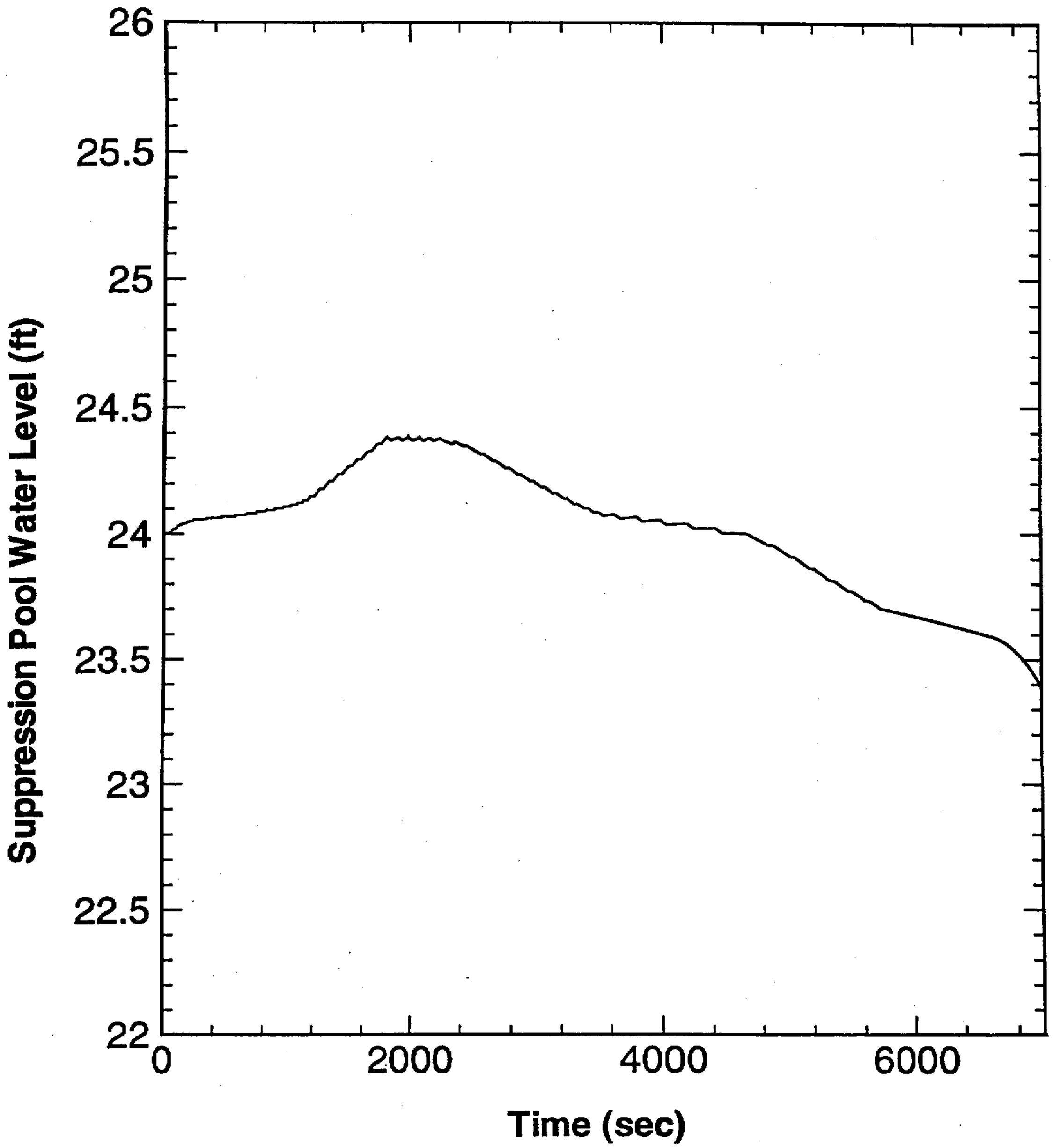

Figure 4.4-4 SABRE calculation of suppression pool water level for MSIV closure transient.

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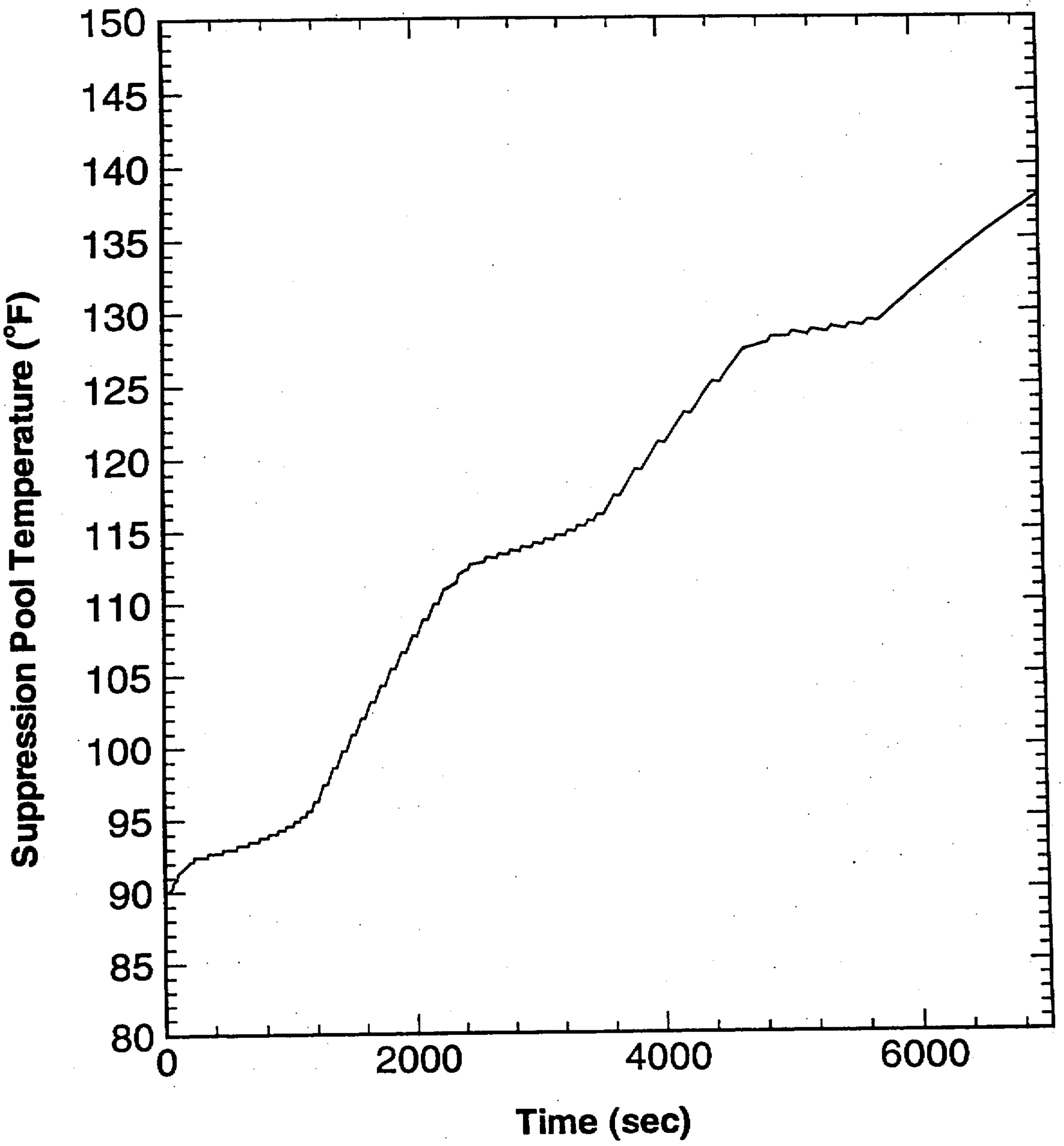

Figure 4.4-5 SABRE calculation of suppression pool temperature for MSIV closure transient.

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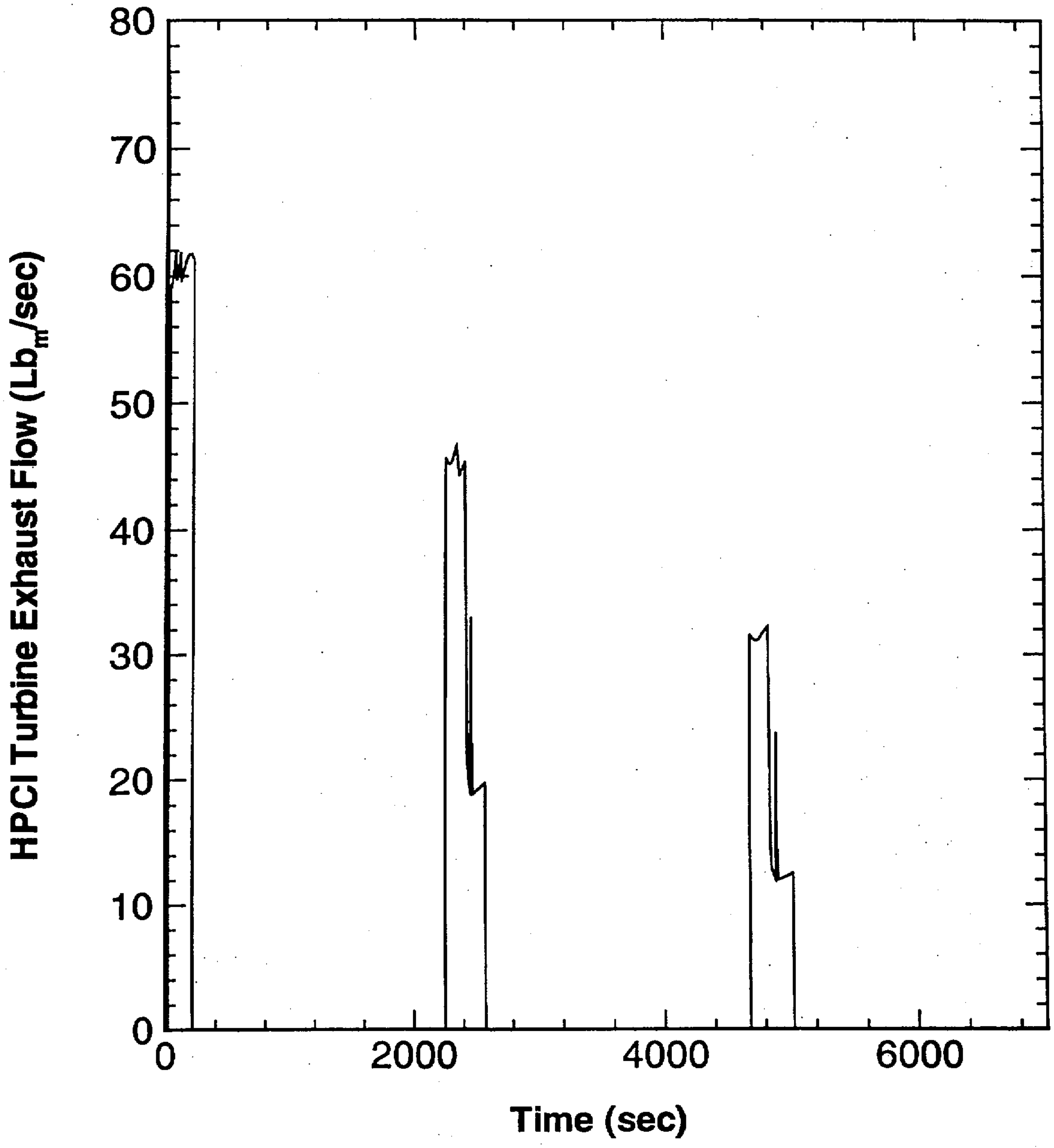

Figure 4.4-6 SABRE calculation of HPCI turbine exhaust flow for MSIV closure transient.

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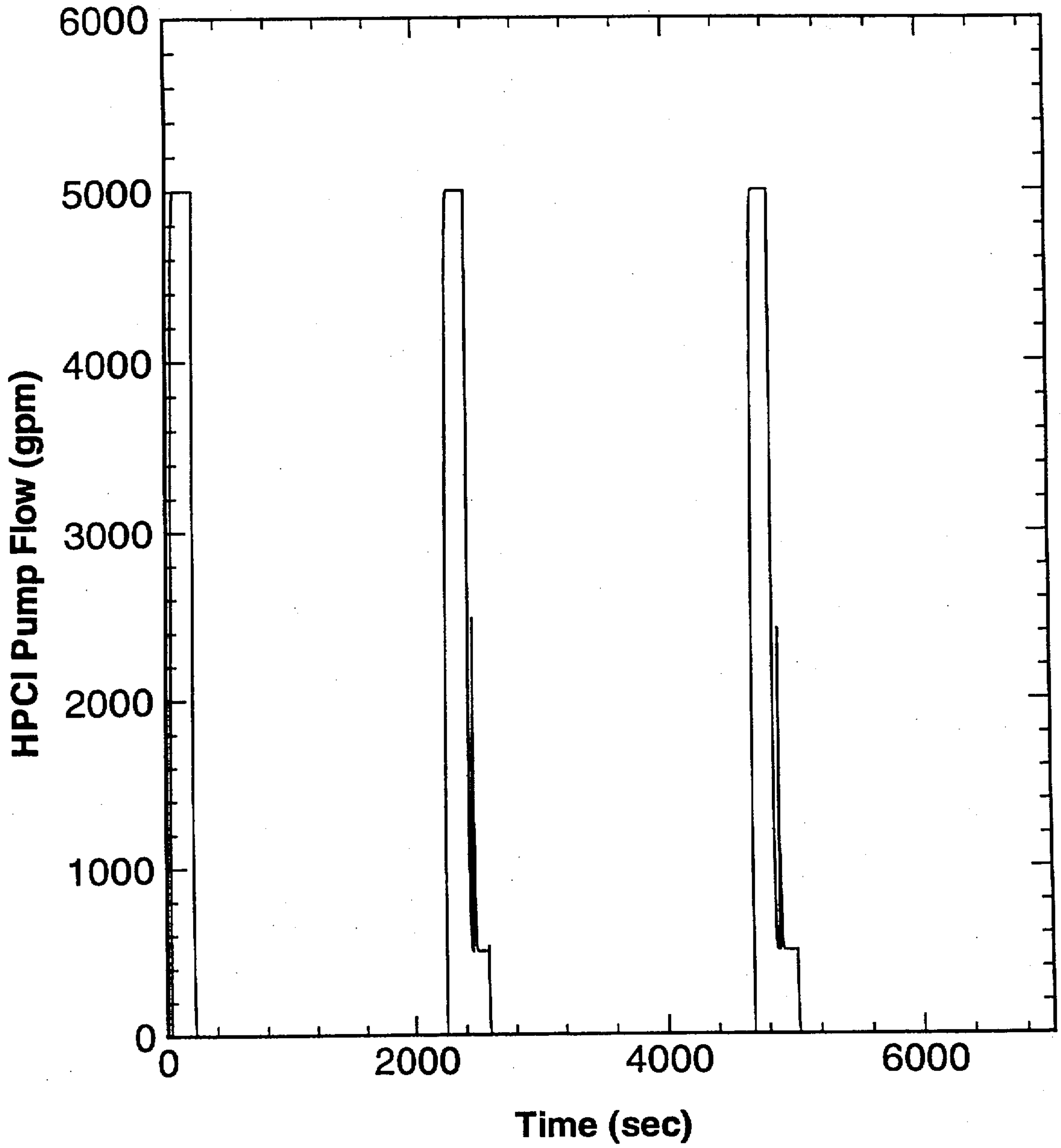

Figure 4.4-7 SABRE calculation of HPCI pump flow for MSIV closure transient.

## 4.5 Sensitivity Studies

In this section, additional small break scenarios are simulated in order to determine the minimum time at which suppression pool level reaches 25 feet. When pool level reaches 25 feet in a small break accident, it is assumed that the operator will manually transfer HPCI suction from the CST to the suppression pool, but only if suppression pool temperature is less than 140°F, to mitigate the rise in suppression pool level. Although the HPCI suction transfer is a manual action it is carried out from the Control Room.

In Figure 4.5-1, the time when pool level reaches 25 feet is plotted as a function of liquid break size. For an initial pool level of 24 feet, the earliest that pool level can reach 25 feet is 21 minutes which corresponds to 0.0375 $ft^2$ break. This time is significantly greater than the 10 minute time delay required for operator actions.[22] For larger breaks (Case 8 and Case 1), Core Spray injection initiates before suppression pool level increases to 25 feet. In Figure 4.5-2, suppression pool temperature at the time of Core Spray initiation is plotted as a function of break size. Since HPCI runs until Core Spray injection initiates, Figure 4.5-2 shows that 135°F is the maximum pool temperature expected during a liquid break with HPCI used for coolant makeup to the reactor. This plot also shows that after HPCI suction is manually transferred from the CST to the suppression pool on high pool level (≥25 feet) it will not be necessary for the operator to transfer suction back to the CST because of high pool temperature (>140°F).

Figure 4.5-3 shows the suppression pool level response as a function of reactor pressure for two small liquid breaks, 0.02 $ft^2$ and 0.00545 $ft^2$ (sensitivity Cases 2a and 3a in Computer Case Summary). Included in Figure 4.5-3 is the primary containment Load Limit Curve defined by Equation (1) on p. 7. As discussed on p. 7, if suppression pool level remains below the Load Limit Curve, then hydrodynamic loads produced by SRV blowdown will not exceed design limits. Sensitivity Cases 2a and 3a are based on the very conservative assumption that the operator takes no action to limit suppression pool level during the small break accident. Specifically, the operator neglects to carry out EOP instructions to letdown water from the suppression pool and to manually transfer HPCI suction from the CST to the suppression pool when pool level reaches 25 feet.[23] Furthermore, the operator fails to initiate a controlled cooldown of the reactor pressure vessel, and the CST is initially at full-capacity of 300,000 gallons. The results in Figure 4.5-3 demonstrate that suppression pool level remains below the Load Limit Curve in a small liquid break accident even if all of the CST inventory is pumped to the suppression pool and no water is removed from the pool. The rate of reactor depressurization associated with the small liquid break is sufficient to maintain pool level below the Load Limit Curve. For comparison, the suppression pool level response as a function of reactor pressure for Cases 2 and 3, which take credit for operator actions #10, #18, and #20 on p. 6 to control suppression pool level and reduce reactor pressure, is shown in Figure 4.5-4. 2

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[22] GE BWR Product Safety Standards, General Electric Company, Document No. 22A8400, Rev. 1, Sh. No. 21, 1981. 1

[23] See assumptions 10 and 18 on p. 6.

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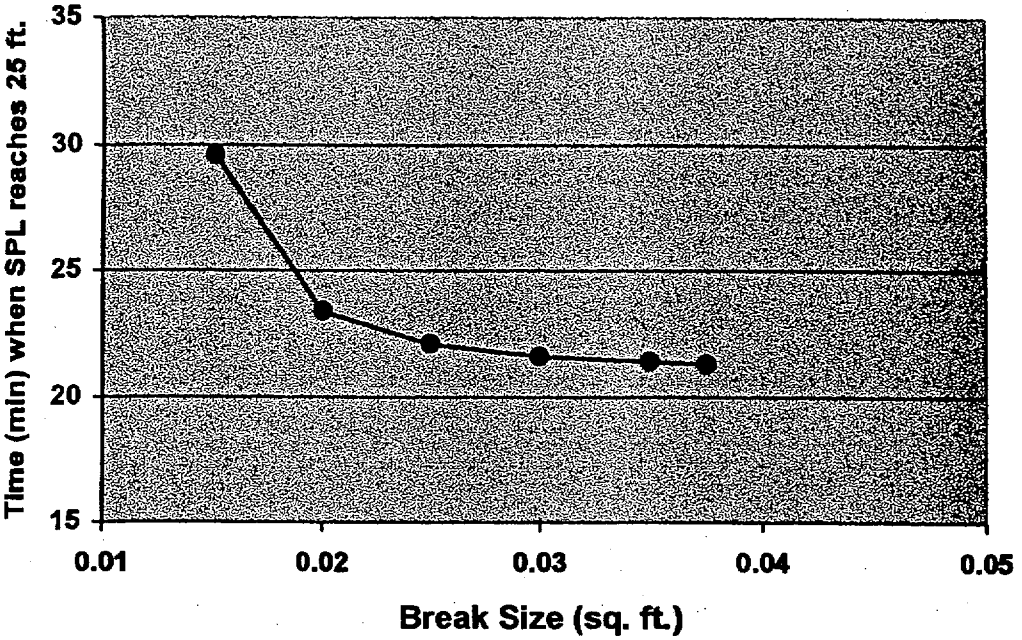

**Figure 4.5-1** Time when suppression pool level reaches 25 feet as a function of break area for small liquid break. Minimum time is 21 minutes.

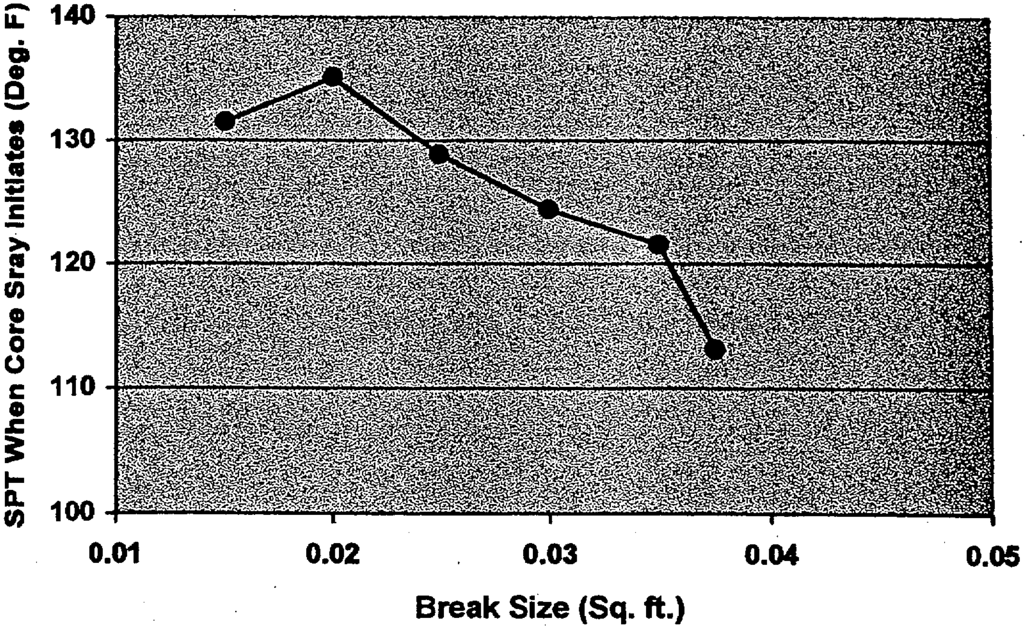

**Figure 4.5-2** Suppression pool temperature when Core Spray injection initiates as a function of break size for small liquid breaks. Maximum suppression pool temperature is 135°F.

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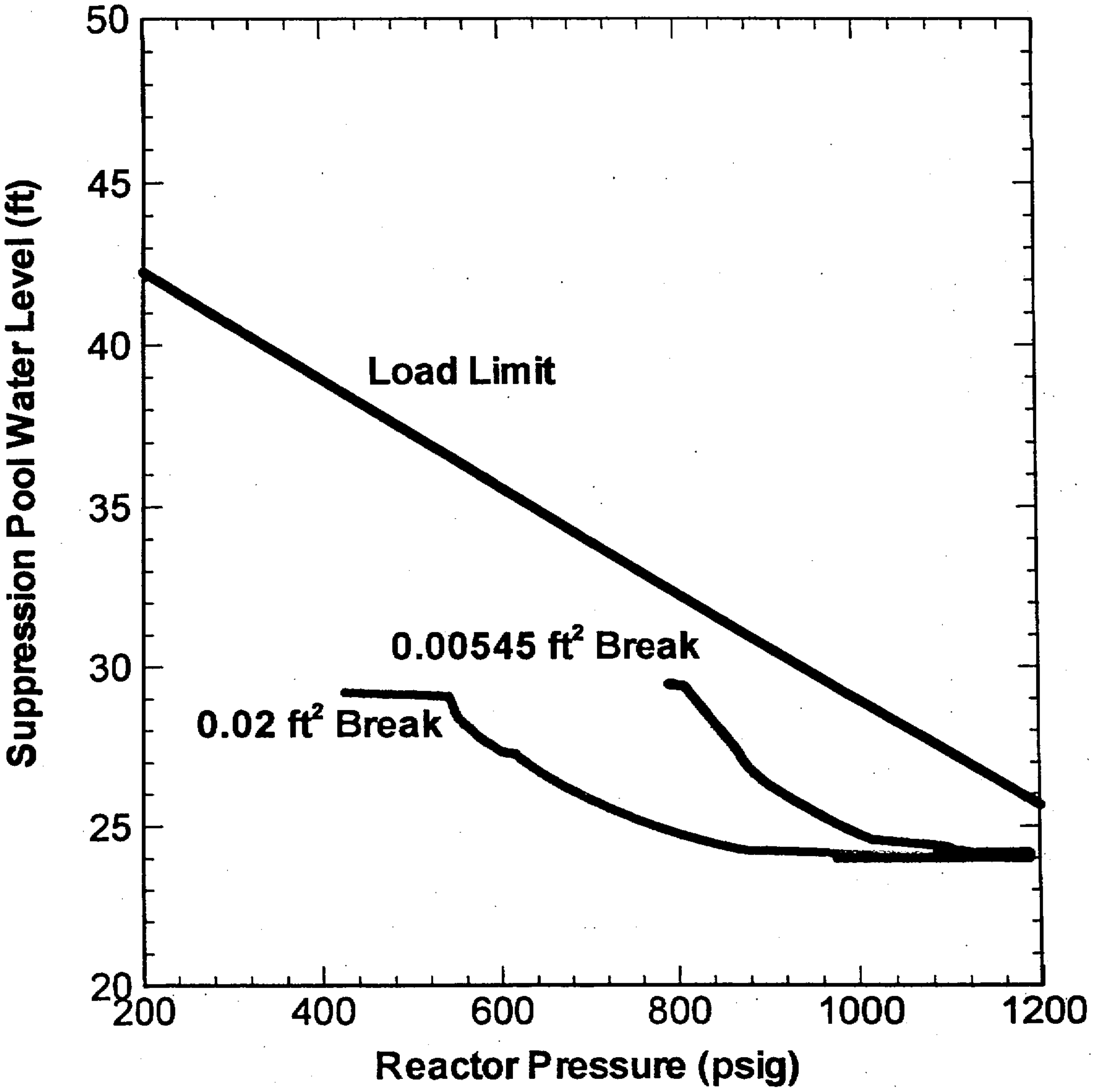

Figure 4.5-3 Comparison of calculated suppression level for 0.02 $ft^2$ (Case 2a) and 0.00545 $ft^2$ (Case 3a) liquid breaks against Load Limit Curve. Cases 2a and 3a are sensitivity cases which assume no RPV cooldown, no manual HPCI suction transfer, no suppression pool letdown, and an initial CST Volume of 300,000 gal.

2

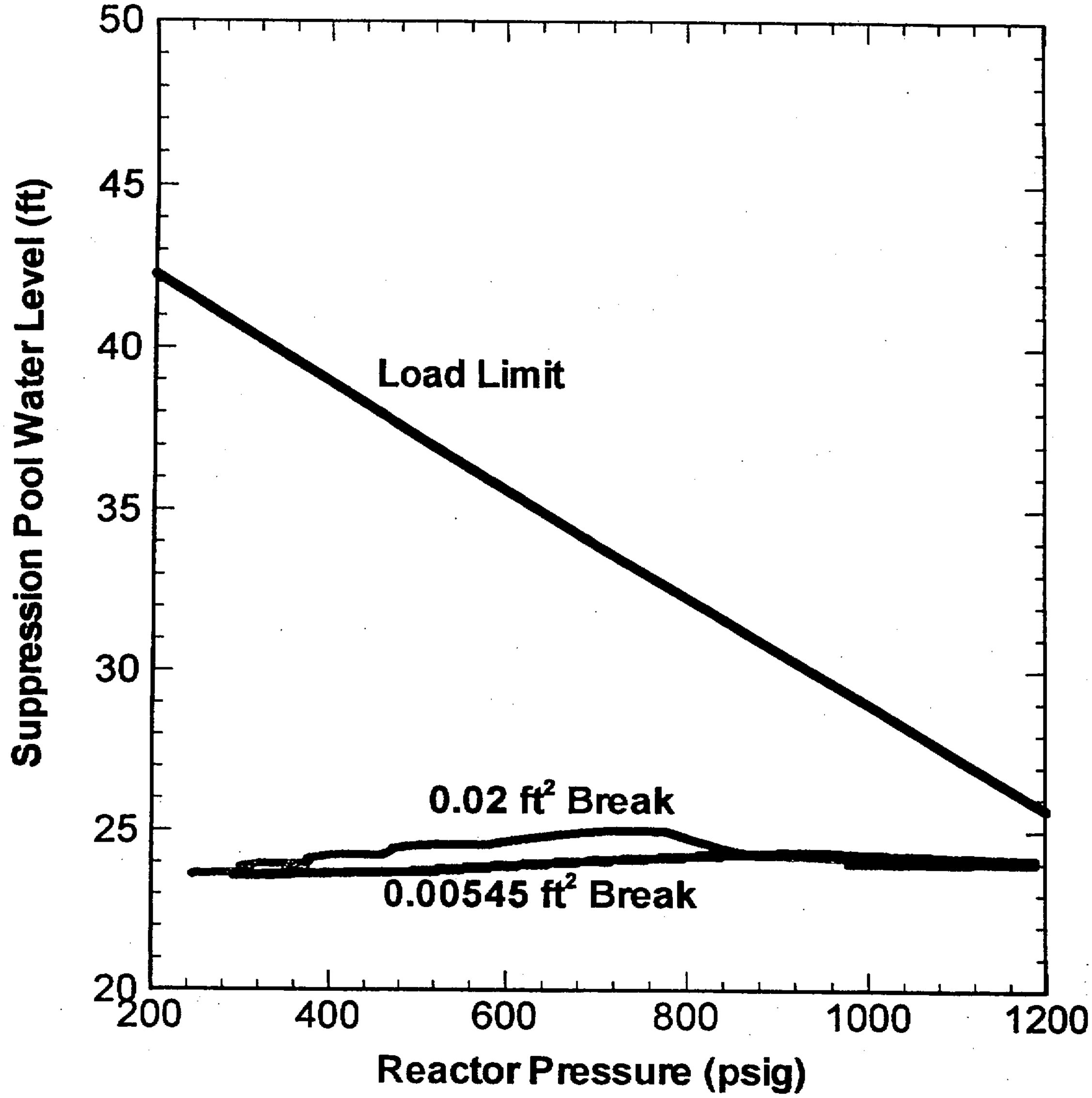

Figure 4.5-4 Comparison of calculated suppression level for 0.02 ft² (Case 2) and 0.00545 ft² (Case 3) liquid breaks against Load Limit Curve. In Cases 2 and 3 it is assumed that the operator initiates RPV cooldown, manually transfers HPCI suction from CST to suppression pool when when pool level reaches 25 feet, and initiates suppression pool letdown.

2

## 5. CONCLUSIONS

Primary Containment response to intermediate breaks, small breaks, and an isolation transient has been analyzed for the case where the proposed IPE HPCI modification in place. The modification involves removal of the automatic transfer of HPCI suction from the CST to the suppression pool on high pool level (23'-10"). Associated with the physical modification is an Emergency procedure change which requires the operator to manually transfer HPCI suction from the CST to the suppression pool if pool level reaches 25 feet, but only if suppression pool temperature is less than 140°F. Based on the simulation results with the proposed modification installed, the following conclusions can be made:

- In an intermediate or large break accident, it will not be necessary for the operator to manually transfer HPCI suction from the CST to the suppression pool because of pool level reaching 25 feet. This is also true for an isolation transient in which there is no break.
- In a small liquid break accident, it will necessary for the operator to manually transfer HPCI suction from the CST to the suppression pool on high pool level (25 feet).
- The earliest the operator will have to make the manual transfer of HPCI suction is 21 minutes into the event.
- Once HPCI suction is manually transferred to the suppression pool on high pool level (25 feet) it will not be necessary to transfer suction back to the CST because of suppression pool temperature exceeding the HPCI design temperature of 140°F.

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# APPENDIX
## ELEVATION OF HPCI TURBINE EXHAUST LINE

This Appendix contains a drawing of the HPCI turbine exhaust line and a calculation of the maximum suppression pool elevation which will not cause flooding of the turbine exhaust line which the HPCI system is not operating and the line is not maintained clear by steam exhaust.

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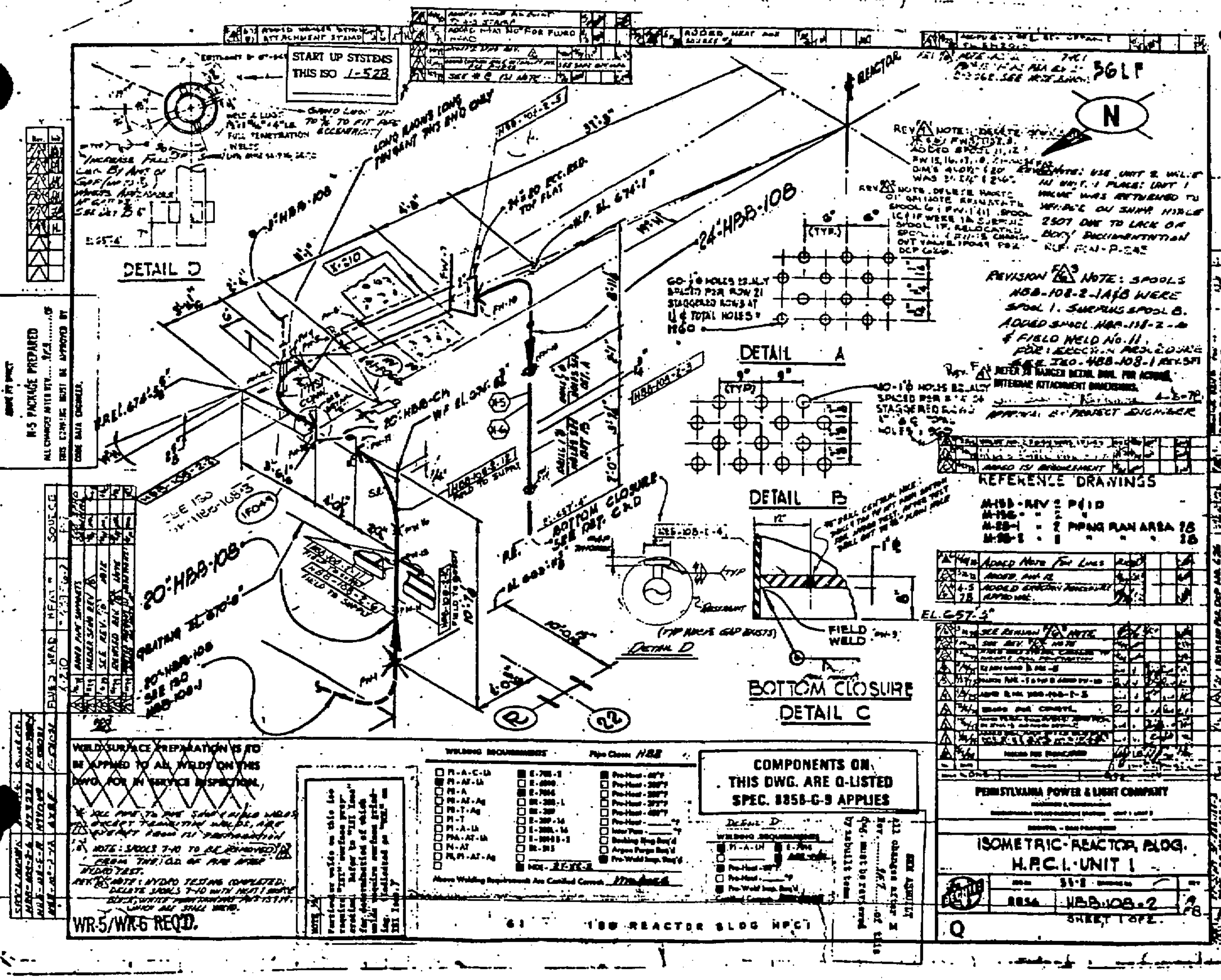

Center line elevation at beginning of horizontal section of pipe is 674'-1" = 674.083 ft.

Pipe is 24" HBB

From M-199, Nominal wall thickness is 0.375". This corresponds to Sch. 20 pipe (see Crane Tech. Paper No. 410). ID = 23.250" = 1.938'

Elevation @ bottom of pipe (on inside) = $674.083' - \frac{1.938'}{2} = 673.114$ ft.

Elevation @ bottom of suppression pool = 648 ft (Drawing C-331)

If water is not to enter horizontal section of turbine exhaust piping, then the max. pool level is

673.114 ft - 648 ft = 25.114 ft

To be conservative, round to $\boxed{25.00 \text{ ft.}}$