Bryce L. Shriver
Senior Vice President and
Chief Nuclear Officer

PPL Susquehanna, LLC
769 Salem Boulevard
Berwick, PA 18603
Tel. 570.542.3120 Fax 570.542.1504
blshriver@pplweb.com

ppl™

JUN 06 2002

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Mail Station OP1-17
Washington, DC 20555

SUSQUEHANNA STEAM ELECTRIC STATION
SUPPLEMENT 4 TO PROPOSED AMENDMENT NO. 239 TO LICENSE NPF-14 AND PROPOSED AMENDMENT NO. 204 TO LICENSE NPF-22: HPCI AUTOMATIC TRANSFER TO SUPPRESSION POOL LOGIC ELIMINATION
PLA-5488

Docket No. 50-387 and 50-388

Reference: 1) *PLA-5322, R. G. Byram (PPL) to USNRC, "Proposed Amendment No. 239 to License NPF-14 and Proposed Amendment No. 204 to License NPF-22: HPCI Automatic Transfer to Suppression Pool Logic Elimination", dated June 8, 2001.*

2) *Letter, NRC to R. G. Byram (PPL), "Susquehanna Steam Electric Station, Units 1 and 2 - Request for Additional Information Re: Elimination of Automatic Transfer of High-Pressure Coolant Injection Pump Suction Source (TAC Nos. MB2190 and MB2191)", dated December 18, 2001.*

3) *PLA-5425, R. G. Byram (PPL) to USNRC, "Supplement to Proposed Amendment No. 239 to License NPF-14 and Proposed Amendment No. 204 to License NPF-22: HPCI Automatic Transfer to Suppression Pool Logic Elimination", dated February 4, 2002.*

4) *PLA-5456, R. G. Byram (PPL) to USNRC, "Supplement 2 to Proposed Amendment No. 239 to License NPF-14 and Proposed Amendment No. 204 to License NPF-22: HPCI Automatic Transfer to Suppression Pool Logic Elimination", dated April 8, 2002.*

5) *Letter, NRC to R. G. Byram (PPL), "Susquehanna Steam Electric Station, Units 1 and 2 - Request for Additional Information Re: High-Pressure Coolant Injection (HPCI) Pump Automatic Suction (TAC Nos. MB2190 and MB2191)", dated April 22, 2002.*

6) *PLA-5470, R. G. Byram (PPL) to USNRC, "Supplement 3 to Proposed Amendment No. 239 to License NPF-14 and Proposed Amendment No. 204 to License NPF-22: HPCI Automatic Transfer to Suppression Pool Logic Elimination", dated May 7, 2002.*

The purpose of this letter is to provide supplemental information as contained in Attachment 1, necessary for the NRC staff to continue its review of the license amendment originally proposed by Reference 1 and later supplemented with additional information in References 3, 4 and 6.

A001

The need for this supplemental information was identified during teleconferences held between NRC and PPL during the week of May 20, 2002. Attachment 1 contains Appendix B to Engineering Calculation EC-052-1025, Revision 3, "SABRE Calculation for IPE HPCI Modification" which was specifically developed to address the requested information. No technical changes were made to the main body of the calculation. Revision 3 of the calculation was approved on May 24, 2002.

In June, 2001, PLA-5322, (Reference 1), proposed deletion from the Unit 1 and Unit 2 Technical Specification Table 3.3.5.1-1 the "High Pressure Coolant Injection (HPCI) System Suppression Pool Water Level – High" (Function 3e). Implementation of this proposed change eliminates automatic transfer of the HPCI pump suction source from the Condensate Storage Tank to the Suppression Pool for a high Suppression Pool level. Implementation of the proposed change and the associated plant modifications are essential to eliminate a vulnerability identified by the PPL Susquehanna, LLC (PPL) Individual Plant Evaluation (IPE).

The Nuclear Regulatory Commission staff reviewed Reference 1 and determined that additional information was required in order to complete the NRC review. The additional information requested was documented in a Request for Additional Information (RAI) dated December 18, 2001, (Reference 2). PLA-5425 (Reference 3) and PLA-5456 (Reference 4) each provided additional information related to this NRC RAI.

Subsequently eighteen additional questions were documented in the April 22, 2002 letter from the NRC to PPL (Reference 5). PLA-5470 (Reference 6) provided additional information to this NRC RAI.

If you have any questions related to this submittal, please contact Mr. Duane L. Filchner at (610)-774-7819.

Sincerely,

B. L. Shriver

Attachment 1 - Appendix B - EC-052-1025, Rev. 3 - (12 pages)

cc: NRC Region I
Mr. S. L. Hansell, NRC Sr. Resident Inspector
Mr. T. G. Colburn, NRC Sr. Project Manager
Mr. E. M. Thomas, NRC Project Manager

BEFORE THE
UNITED STATES NUCLEAR REGULATORY COMMISSION

In the Matter of :

PPL Susquehanna, LLC: Docket No. 50-387

SUPPLEMENT 4 TO PROPOSED AMENDMENT NO. 239 TO LICENSE NPF-14: HPCI AUTOMATIC TRANSFER TO SUPPRESSION POOL LOGIC ELIMINATION UNIT NO. 1

Licensee, PPL Susquehanna, LLC, hereby files Supplement 4 to Proposed Amendment No. 239 in support of a revision to its Facility Operating License No. NPF-14 dated July 17, 1982.

This amendment involves a revision to the Susquehanna SES Unit 1 Technical Specifications.

PPL Susquehanna, LLC
By:

B. L. Shriver
Sr. Vice-President and Chief Nuclear Officer

Sworn to and subscribed before me
This 6TH day of June, 2002.

Notary Public

Notarial Seal
Colleen M. Carver, Notary Public
Salem Twp., Luzerne County
My Commission Expires Aug. 30, 2003
Member, Pennsylvania Association of Notaries

BEFORE THE
UNITED STATES NUCLEAR REGULATORY COMMISSION

In the Matter of :

PPL Susquehanna, LLC : Docket No. 50-388

SUPPLEMENT 4 TO PROPOSED AMENDMENT NO. 204 TO LICENSE NPF-22: HPCI AUTOMATIC TRANSFER TO SUPPRESSION POOL LOGIC ELIMINATION UNIT NO. 2

Licensee, PPL Susquehanna, LLC, hereby files Supplement 4 to Proposed Amendment No. 204 in support of a revision to its Facility Operating License No. NPF-22 dated March 23, 1984.

This amendment involves a revision to the Susquehanna SES Unit 2 Technical Specifications.

PPL Susquehanna, LLC
By:

B. L. Shriver
Sr. Vice-President and Chief Nuclear Officer

Sworn to and subscribed before me this 6TH day of JUNE, 2002.

Notary Public

Notarial Seal
Colleen M. Carver, Notary Public
Salem Twp., Luzerne County
My Commission Expires Aug. 30, 2003
Member, Pennsylvania Association of Notaries

Attachment 1 to PLA-5488
Appendix B - EC-052-1025, Rev. 3

APPENDIX B
EFFECT OF ADDING RECIRCULATION LINE MASS AND ENERGY TO SABRE MODEL

B.1 OBJECTIVE

The mass and energy associated with the reactor recirculation piping and coolant is currently not included in the SABRE computer code, Version 3.1 described in Calculation EC-ATWS-0505, Rev. 8. In this Appendix, a modified version of SABRE is developed which accounts for the mass and energy associated with the recirculation piping and coolant. This modified version of the code is developed for purposes of quantifying the effect of recirculation line mass and energy on suppression pool temperature and reactor pressure.

An additional change to SABRE is made to account for the stored energy of in-channel metal mass other than fuel rods. In SABRE 3.1, the in-channel metal mass was subtracted from the vessel internals mass because the thermal capacitance of the fuel and cladding is modeled explicitly in SABRE. However, the in-channel mass includes the upper and lower tie plates and spacers which are not modeled explicitly in SABRE. Therefore, the in-channel mass, excluding fuel and cladding, is incorporated into the code. The fuel bundle channel metal mass is already included in SABRE as part of the vessel internals mass.

B.2 INPUTS

1. Volume of fluid in recirculation piping = 1168.4 ft^3 (Drawing FF110760, Sh. 103, Rev. 1, "Reactor Primary System Weights and Volumes")

2. Mass of recirculation piping = 101,671 Lbm. Solid volume of recirculation piping = 203.3 ft^3. (Drawing FF110760, Sh. 103, Rev. 1).

3. Mass of fuel in core = 340,317 Lbm (EC-EOPC-0512, "Calculation of Plant Specific Parameters for BWROG Emergency Procedure and Severe Accident Guidelines," Rev. 3, p. 15)

4. Cross-sectional area of cladding, = $\pi\left(r_o^2 - r_i^2\right)$ where r_o is the outside radius of the cladding and r_i is the inside radius. From Sections G.36.2 and G.36.3 of EC-ATWS-0505, Rev. 8, r_o=0.1979 inches and r_i=0.1740 inches. Cladding cross-sectional area $=\pi\left(0.1979^2 - 0.1740^2\right)$ = 0.02792 in^2 = 1.939E-04 ft^2. Per §G.36.6 of EC-ATWS-0505, Rev. 8, the total length of fuel cladding per bundle = 83 x 0.5 ft x 10 + 91 x 0.5 ft x 15 = 1097.5 ft. Volume of cladding per fuel bundle = (1.939E-04 ft^2)x(1097.5 ft) = 0.2128 ft^3. Volume of cladding in core = 0.2128 ft^3 x 764 bundles = 163 ft^3. Density of Zircaloy cladding is 410.7 ft^3 (R.T. Lahey and F.J. Moody, *The Thermal-Hydraulics of a Boiling Water Reactor*, 2nd Edition, p. 292, 1993). **Mass of cladding in core** = (163 ft^3) x (410.7 Lbm/ft^3) = 66,944 Lbm.

5. Mass of Atrium-10 fuel bundle (excluding channel) = 572 Lbm (EC-FUEL-1186, Rev. 1).

6. Mass of in-channel components excluding fuel and cladding = (572 Lbm x 764) – 340,317 Lbm – 66,944 Lbm = 29,747 Lbm ≈ 30,000 Lbm. This is the mass of the upper and lower tie plates, spacers, and water rods.

B.3 METHODOLOGY

The volume of coolant in the recirculation lines is incorporated into the SABRE model by adjusting the downcomer volume versus level table in subroutine *dcvol* and the downcomer level versus volume table in subroutine *dclev*. The downcomer volume versus downcomer level table used in SABRE Version 3.1 is given in Table D.1.9-1 (p. 243) of Calculation EC-ATWS-0505, Rev. 8. The table is modified by adding the recirculation fluid volume, 1168.4 ft^3, to each volume entry in the table while leaving the level entries unchanged. Table B.3-1 below shows the volume vs. level table used in SABRE Version 3.1 and the adjusted table used to generate the results presented in this appendix.

Table B.3-1
Downcomer Level Versus Fluid Volume

Fluid Volume (ft^3) (SABRE 3.1)	Adjusted Fluid Volume (ft^3)†	Downcomer Level (inches above instr. zero)
0.0	1168.4	-406.00
58.72	1227.12	-400.50
743.37	1911.77	-336.38
982.48	2150.88	-311.19
1641.96	3114.48	-211.00
2507.76	3676.16	-161.50
2858.99	4027.39	-113.55
2903.69	4072.09	-108.88
2978.47	4146.87	-102.88
3073.37	4241.77	-96.88
3189.01	4357.41	-90.88
3326.01	4494.41	-84.88
5084.56	6252.96	-13.50
5197.85	6366.25	-6.50
5902.70	7071.1	50.37
6143.75	7312.15	60.13
6613.54	7781.94	80.00
14420.99	15589.39	348.50

By adjusting the volume-versus-level table as described above, the initial fluid volume in the downcomer at the initial specified water level is 1168.4 ft^3 greater than in SABRE 3.1. During the transient calculation, the mass/energy of the fluid in the downcomer region is computed by integration of the fluid conservation equations. The transient level in the downcomer region is then determined from a level-versus-volume table. In the modified SABRE code, a particular

† Includes fluid volume of reactor recirculation loops.

downcomer level will be correspond to a fluid volume that is 1168.4 ft^3 greater than the corresponding downcomer fluid volume in SABRE 3.1. Thus, the adjustment of the downcomer level/volume tables in SABRE has the effect of adding the fluid volume of the recirculation loops onto the bottom of the downcomer. This is a conservative modeling approach for a loss-of-coolant accident because all of the stored energy of the coolant in the recirculation loops is added directly to the in-vessel coolant where it contributes to steam production and heating of the containment.

In SABRE 3.1, heat transfer from the vessel and vessel internals to the reactor coolant is based on the difference between the metal temperature and the fluid saturation temperature which is appropriate for ATWS scenarios. In a small-break LOCA, the downcomer fluid can become highly subcooled due to cold water injection by HPCI, and thus it is more appropriate to use a fluid temperature which accounts for the subcooled conditions in the downcomer and lower head regions of the vessel. Therefore, in the modified version of SABRE, the metal-to-coolant heat transfer is computed using a fluid temperature which is averaged over the height of the vessel. This averaged fluid temperature can be significantly lower than the saturation temperature in some cases.

In the calculations performed in this appendix using the modified version of SABRE, the metal-to-coolant heat transfer coefficient is specified as a conservatively high value of 10,000 BTU/hr-ft^2-°F so that the difference between the metal temperature and the elevation-averaged fluid temperature is always small during the transient, assuring that stored energy of metal is released to the coolant.

In SABRE 3.1, and in the modified version of SABRE, the heat transferred from the vessel and vessel internals to the coolant is added to the decay heat generated within the fuel rods. Thus there is a small delay, corresponding to the fuel rod heat transfer time constant, associated with heat transfer from the vessel and vessel internals to the reactor coolant. For the small break accidents simulated in this calculation package, the time scale associated with the transient is on the order of tens of minutes whereas the time scale associated with heat transfer through a fuel rod is on the order of seconds. Therefore, the heat transfer delay is insignificant with regard to the overall RPV and containment thermal response.

The mass of the recirculation piping, 101,671 Lbm, is incorporated into SABRE by increasing the vessel mass by this amount (see Input #2 in §B.2). In SABRE 3.1, vessel mass is 1.21E+06 Lbm (EC-ATWS-0505, Rev. 8, p. 246); therefore, the **adjusted vessel mass is 1.31E+06 Lbm**. Solid volume of recirculation piping is 203.3 ft^3 (Input #2 in §B.2). From Drawing FF116510, Sh. 1602, "Recirculation Loop Piping," the wall thickness of recirculation piping is 0.586" for 12" pipe, 1.009" for 22" pipe, and 1.285" for 28" pipe. Based on these dimensions, a nominal thickness of 1" is used for the recirculation piping. The vessel thickness is 6.19 inches (EC-ATWS-0505, Rev. 8, p. 246). The mass-average thickness for the vessel and recirculation piping is [(1")(101,671) + (6.19")(1.21E+06)]/1.31E+06 = 5.8 inches = 0.483 ft. The heat transfer area between the reactor coolant and the vessel and recirculation piping is

$$\textit{Vessel and Recirculation piping heat transfer area} = \frac{\textit{Solid Volume}}{\textit{Characteristic thickness}}.$$

The solid volume of the vessel is 2,483 ft^3 (EC-ATWS-0505, Rev. 8, p. 246) and the solid volume of the recirculation piping is 203.3 ft^3. The combined solid volume is 2,686.3 ft^3, and the combined heat transfer area is (2,686.3 ft^3)/(0.483 ft) = 5,562 ft^2. The heat transfer area between the vessel and the reactor coolant is 4,814 ft^2 in SABRE 3.1. Thus, the recirculation piping is accounted for in the modified SABRE code by increasing the vessel mass from 1.21E+06 Lbm to 1.31E+06 Lbm and increasing the **vessel heat transfer area** from 4,814 ft^2 to **5,562 ft^2**.

The mass of in-channel components, excluding fuel and cladding, is incorporated into SABRE by adding 30,000 Lbm to the mass of the vessel internals (see Input #6 in §B.2). The mass of vessel internals in SABRE 3.1 is 6.81E+05 Lbm (EC-ATWS-0505, Rev. 8, p. 246). The **adjusted mass of vessel internals** = 6.81E+05 + 30,000 = **7.11E+05 Lbm.** A density of 489 Lbm/ft^3 is used for the vessel internals (EC-ATWS-0505, Rev. 8, p. 246). The vessel internals heat transfer area in SABRE 3.1 is computed from the formula (EC-ATWS-0505, Rev. 8, p. 246)

$$\textit{Internals heat transfer area} = \frac{2 \times \textit{Solid Volume}}{\textit{Characteristic thickness}}$$

where a characteristic thickness of 1" is used. The heat transfer area associated with the additional 30,000 Lbm of vessel internals is

$$\textit{Additional internals heat transfer area} = \frac{2\,x(30{,}000\,Lbm)\left(\dfrac{ft^3}{489\,Lbm}\right)}{0.0833\,ft} = 1473 \text{ ft}^2.$$

SABRE 3.1 uses a vessel internals heat transfer area of 33,432 ft^2 (EC-ATWS-0505, Rev. 8, p. 246). The **adjusted internals heat transfer area** is 33,432+1473 = **34,905 ft^2**. The vessel mass, internals mass, and heat transfer area are modified in subroutine *fex*. Table B.3-2 shows the coding changes made to SABRE 3.1 to incorporate the mass/energy of the recirculation loops and the bundle tie plates. Changes made to incorporate the elevation-averaged fluid temperature for heat transfer are also shown along with changes made to facilitate printing of metal and fluid temperatures. This table was generated by comparing the modified version of SABRE against SABRE 3.1 using the UNIX side-by-side difference program *sdiff* with option *-s*. The left-hand column corresponds to the modified version of SABRE and the right-hand column corresponds to SABRE 3.1. Only differences are shown. A "|" in the gutter means the two lines of code are different, a "<" means that the line only appears in the modified version of SABRE, and a ">" indicates that the line is only in SABRE 3.1.

Cases 02 and 10, 0.02 ft^2 liquid break and 0.0375 ft^2 liquid break, respectively, were rerun using the modified version of SABRE which uses the elevation-averaged fluid temperature for metal-to-coolant heat transfer and incorporates the additional metal mass and fluid volume associated with the recirculation lines and the additional metal mass corresponding to the bundle tie plates and spacers. These modified cases are denoted as Cases 02m and 10m. Four additional cases, 11, 11m, 12m, and 13 m were also run. Case 11 is a 0.04 ft^2 liquid break run with SABRE 3.1, and Case 11m is a 0.04 ft^2 liquid break run with the modified version of SABRE. Case 12m is a

0.0425 ft^2 liquid break and Case 13m is a 0.06 ft^2 liquid break, both run with the modified version of SABRE.

Case 02 was rerun using the modified version of SABRE because according to Figure 4.5-2, a 0.02 ft^2 liquid break results in the peak suppression pool temperature at the time of Core Spray initiation. Based on Figure 4.5-1, Case 10 (0.0375 ft^2 liquid break) corresponds to the largest break size for which suppression pool water level reaches 25 feet prior to initiation of Core Spray injection. The additional cases, 11, 11m, 12m, and 13m were run to determine if, as a result of the modeling enhancements, there is an increase in the break size associated with the minimum time to reach 25 feet in the suppression pool. Results for Cases 02m, 10m, 11, 11m, 12m , and 13m are presented in §B.4.

In order to run the modified version of SABRE, it was necessary to the change the SABRE input file parameter V00, the combined volume of steam dome and downcomer region, from 14,334 ft^3 to 15,502.4 ft^3 to account for the additional 1,168.4 ft^3 of fluid contained within the recirculation loops. In addition, to correct an oversight in the previous small-break LOCA calculations, the maximum feedwater flow rate was increased by 2% to account for the fact that the simulations are run at 102% of the initially uprated power.

SABRE 3.1 does not model the mass/energy associated with the recirculation fluid and piping. Therefore, an input is included to specify the volume of coolant in the external recirculation loops that contributes to dilution of boron in an ATWS scenario. Since the modified version of SABRE explicitly models the recirculation loop fluid volume, the boron dilution parameter should be set to zero if the modified code is used to simulate an ATWS event. The boron dilution volume was not altered for the cases run in this appendix as no ATWS scenarios were simulated.

In addition to the coding changes identified in Table B.3-2, the second line of common block *csteel* was changed to include the metal temperature of the vessel internals and the elevation-averaged fluid temperature. This was done to allow printing of these variables. The following variables were added to the SABRE output file:

Temp_Rx	= vessel metal temperature, °F,
Temp_Intern	= vessel internals metal temperature, °F,
Tfluid	= elevation-averaged fluid temperature, °F, and
Tsat	= saturation temperature based on reactor pressure, °F.

Table B.3-2
Differences Between Modified Version of SABRE and SABRE 3.1
(Left-hand column corresponds to modified version of SABRE, and right-hand column corresponds to SABRE 3.1)

```
11,18c11,14
      data v / 1168.4, 1227.12, 1911.77, 2150.88, 3114.48,       |        data v /    0.0,  58.72, 743.37, 982.48, 1946.08,
     &          3676.16, 4027.39, 4072.09, 4146.87, 4241.77,      |       &          2507.76, 2858.99, 2903.69, 2978.47, 3073.37,
     &          4357.41, 4494.41, 6252.96, 6366.25, 7071.1,       |       &          3189.01, 3326.01, 5084.56, 5197.85, 5902.70, 6143.7
     &          7312.15, 7781.94, 15589.39  /                     |       &          6613.54, 14420.99 /
C     data v /    0.0,  58.72, 743.37, 982.48, 1946.08,           <
C    &          2507.76, 2858.99, 2903.69, 2978.47, 3073.37,      <
C    &          3189.01, 3326.01, 5084.56, 5197.85, 5902.70, 61   <
C    &          6613.54, 14420.99 /                               <
14,21c14,17
      data v / 1168.4, 1227.12, 1911.77, 2150.88, 3114.48,       |        data v /    0.0,  58.72, 743.37, 982.48, 1946.08,
     &          3676.16, 4027.39, 4072.09, 4146.87, 4241.77,      |       &          2507.76, 2858.99, 2903.69, 2978.47, 3073.37,
     &          4357.41, 4494.41, 6252.96, 6366.25, 7071.1,       |       &          3189.01, 3326.01, 5084.56, 5197.85, 5902.70, 6143.7
     &          7312.15, 7781.94, 15589.39  /                     |       &          6613.54, 14420.99 /
C     data v /    0.0,  58.72, 743.37, 982.48, 1946.08,           <
C    &          2507.76, 2858.99, 2903.69, 2978.47, 3073.37,      <
C    &          3189.01, 3326.01, 5084.56, 5197.85, 5902.70, 61   <
C    &          6613.54, 14420.99 /                               <
17d16
      include 'common/csteel.txt'                                 <
76d74
  192 format(' ', f11.3, 10(f12.3,1x),I12 )                       <
91c89
      write(15,192) timee,                                        |       write(15,102) timee,
94,95c92,93
     & mrod,                                                      |      & mrod
     & tstel1,tstel2,tfluid,tsat                                  | C    & hf-hbarlr,
8d7
      REAL*8 internalmass                                         <
463,466d461
      vesselmass = 1.21D+06 + 101671.D0                           <
      internalmass = 7.11D+05                                     <
      arx = 5562.d0                                               <
      avi = 34905.d0                                              <
474,479c469,474
      tfluid = (dlvlb/876.d0)*tcoold + (1.d0-dlvlb/876.d0)*tsa    |       cons1 = 5.903d-6
      cpsteel = 0.14D0                                            |       cons2 = hsteel*0.351d0
      cons1   = 1.D0/( vesselmass*cpsteel )                       |       arx = 4814.d0
      cons2 = avi*hsteel/( internalmass*cpsteel )                 |       avi = 33432.d0
      qcds  = hsteel*( ( tstel1 - tfluid )*arx                    |       qcds = hsteel*( ( tstel1 - tsat )*arx
     &      + ( tstel2 - tfluid )*avi )                           |      &     + ( tstel2 - tsat )*avi )
490c485
      tstela = cons1*( hsteel*arx*(tfluid - tstel1) -             |       tstela = cons1*( hsteel*arx*(tsat - tstel1) -
492c487
```

EC-052-1025
page 72

```
      tstelb = ( tfluid - tstel2 )*cons2
76,77c76,77
     &_In_W | Core_In_SC |  No_Rods     |  Temp_Rx    |Temp_Inter
     &      |   Tsat     |'  )
79c79
C    &Re    |    (F)     |'  )
83,84c83,84
     &hr)   | (Btu/Lbm)  |              |     (F)     |    (F)
     &      |   (F)      |'  )
81,83c81,112
      open (4,  FILE='SABRE_##.inp')
      open (9,  FILE='SABRE_##.temp.inp')
      open (10, FILE='Generl.out',
85c114
      open (1,  FILE='Rx1.out',
87c116
      open (15, FILE='Rx2.out',
89c118
      open (18, FILE='Boron.out',
91c120
      open (2,  FILE='MSL.out',
93c122
```

```
|          tstelb = ( tsat - tstel2 )*cons2
|        &_In_W | Core_In_SC |  No_Rods    |             |             |
|        &      |'  )
|  C     &Re    |'  )
|        &hr)   | (Btu/Lbm)  |             |             |             |
|        &      |'  )
|  c       open (4,  FILE='/home/eamac/sabre_31/test/SABRE_##.inp')
|  c       open (9,  FILE='/home/eamac/sabre_31/test/SABRE_##.temp.inp'
|  c       open (10, FILE='/home/eamac/sabre_31/test/Generl.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (1,  FILE='/home/eamac/sabre_31/test/Rx1.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (15, FILE='/home/eamac/sabre_31/test/Rx2.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (18, FILE='/home/eamac/sabre_31/test/Boron.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (2,  FILE='/home/eamac/sabre_31/test/MSL.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (16, FILE='/home/eamac/sabre_31/test/Makup.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (11, FILE='/home/eamac/sabre_31/test/HPCI.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (3,  FILE='/home/eamac/sabre_31/test/Restart.dat')
>  c       open (5,  FILE='/home/eamac/sabre_31/test/SIMTRAN_##.inp')
>  c       open (12, FILE='/home/eamac/sabre_31/test/Cont1.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (17, FILE='/home/eamac/sabre_31/test/Cont2.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (13, FILE='/home/eamac/sabre_31/test/Break.out',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>  c       open (14, FILE='/home/eamac/sabre_31/test/Mesg.txt',
>  c      &          STATUS='OLD', ACCESS='APPEND')
>
>
>  c**** open files -- for running in production library
>          open (4,  FILE='/d00/appl/sabre3v1/tmp/SABRE_##.inp')
>          open (9,  FILE='/d00/appl/sabre3v1/tmp/SABRE_##.temp.inp')
>          open (10, FILE='/d00/appl/sabre3v1/tmp/Generl.out',

|          open (1,  FILE='/d00/appl/sabre3v1/tmp/Rx1.out',

|          open (15, FILE='/d00/appl/sabre3v1/tmp/Rx2.out',

|          open (18, FILE='/d00/appl/sabre3v1/tmp/Boron.out',

|          open (2,  FILE='/d00/appl/sabre3v1/tmp/MSL.out',
```

EC-052-1025
Page 73

```
      open (16, FILE='Makup.out',                         |       open (16, FILE='/d00/appl/sabre3v1/tmp/Makup.out',
95c124
      open (11, FILE='HPCI.out',                          |       open (11, FILE='/d00/appl/sabre3v1/tmp/HPCI.out',
97,99c126,128
      open (3,  FILE='Restart.dat')                       |       open (3,  FILE='/d00/appl/sabre3v1/tmp/Restart.dat')
      open (5,  FILE='SIMTRAN_##.inp')                    |       open (5,  FILE='/d00/appl/sabre3v1/tmp/SIMTRAN_##.inp')
      open (12, FILE='Cont1.out',                         |       open (12, FILE='/d00/appl/sabre3v1/tmp/Cont1.out',
101c130
      open (17, FILE='Cont2.out',                         |       open (17, FILE='/d00/appl/sabre3v1/tmp/Cont2.out',
103c132
      open (13, FILE='Break.out',                         |       open (13, FILE='/d00/appl/sabre3v1/tmp/Break.out',
105c134
      open (14, FILE='Mesg.txt',                          |       open (14, FILE='/d00/appl/sabre3v1/tmp/Mesg.txt',
108,136d136
                                                          <
c**** open files -- for running in production library     <
C     open (4,  FILE='/d00/appl/sabre3v1/tmp/SABRE_##.inp')   <
C     open (9,  FILE='/d00/appl/sabre3v1/tmp/SABRE_##.temp.inp <
C     open (10, FILE='/d00/appl/sabre3v1/tmp/Generl.out', <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (1,  FILE='/d00/appl/sabre3v1/tmp/Rx1.out',    <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (15, FILE='/d00/appl/sabre3v1/tmp/Rx2.out',    <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (18, FILE='/d00/appl/sabre3v1/tmp/Boron.out',  <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (2,  FILE='/d00/appl/sabre3v1/tmp/MSL.out',    <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (16, FILE='/d00/appl/sabre3v1/tmp/Makup.out',  <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (11, FILE='/d00/appl/sabre3v1/tmp/HPCI.out',   <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (3,  FILE='/d00/appl/sabre3v1/tmp/Restart.dat') <
C     open (5,  FILE='/d00/appl/sabre3v1/tmp/SIMTRAN_##.inp') <
C     open (12, FILE='/d00/appl/sabre3v1/tmp/Cont1.out',  <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (17, FILE='/d00/appl/sabre3v1/tmp/Cont2.out',  <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (13, FILE='/d00/appl/sabre3v1/tmp/Break.out',  <
C    &          STATUS='OLD', ACCESS='APPEND')            <
C     open (14, FILE='/d00/appl/sabre3v1/tmp/Mesg.txt',   <
C    &          STATUS='OLD', ACCESS='APPEND')            <
                                                          <
1704,1707c1704,1705
      dlvlb  = dlvl + 527.5d0                             |       y(istr+1) = tsat
      tfluid = (dlvlb/876.d0)*tcoold + (1.d0-dlvlb/876.d0)*tsa |  y(istr+2) = tsat
      y(istr+1) = tfluid                                  <
      y(istr+2) = tfluid                                  <
```

EC-052-1025
Page 74

B.4 RESULTS

Calculation results for 0.02 ft^2, 0.037 ft^2, 0.04 ft^2, 0.0425 ft^2, and 0.06 ft^2 liquid breaks obtained with the modified version of the SABRE code are presented in Table B.4-1. Also included are some corresponding results obtained with SABRE 3.1. As discussed earlier, the modified version of SABRE is identical to SABRE 3.1 except that the mass and energy associated with the reactor recirculation loops and bundle tie plates are included, and the fluid temperature used in the metal-to-coolant heat transfer calculation accounts for subcooling in the downcomer and lower head region. Case numbers with suffix 'm' correspond to the modified version of SABRE.

Results of sensitivity studies reported in §4.5 show that the peak suppression pool temperature, at the time of Core Spray initiation, occurs for a 0.02 ft^2 liquid break (see Figure 4.5-2). For this break size, suppression pool temperature at the time of Core Spray initiation was previously calculated to be 135.1 °F using SABRE 3.1 (Case 02). The corresponding result using the modified version of SABRE (Case 02m) is 141.0 °F, which is slightly above the long-term HPCI operating limit of 140°F. The proposed Emergency Operating procedure, EO-000-103, "Primary Containment Control," does allow for the possibility of pool temperature greater than 140°F subsequent to the manual transfer of HPCI suction from the CST to the pool on high pool level. In this situation, the EOP instructs the operator to realign HPCI suction back to the CST. In addition, HPCI has been evaluated for short-term operation with suppression pool temperature greater than 140°F. The HPCI Design Basis Document, DBD004, states that HPCI can perform its function for 30 minutes with suction water temperatures up to 190°F during an ATWS event.

Figure B.4-1 displays plots of vessel temperature, vessel internals temperature, elevation-averaged fluid temperature, and saturation temperature based on reactor pressure for Case 02m. It can be seen that the elevation-averaged fluid temperature is considerably lower than the saturation temperature because of the high degree of subcooling in the downcomer and lower head regions of the vessel. The figure also shows that the vessel and vessel-internals temperatures are essentially equal to the elevation-averaged fluid temperature which indicates that all of the available stored energy in the metal has been used to produce steam.

Results in Table B.4-1 for the 0.0375 ft^2, 0.04 ft^2, and 0.0425 ft^2 liquid breaks obtained with the modified version of SABRE (Cases 10m, 11m, and 12m, respectively) show that the minimum time for suppression pool water level to reach 25 feet, with reactor pressure above the shutoff head of low-pressure injection systems, remains at 21 minutes. Thus, the operator has at least 21 minutes to perform the manual transfer of HPCI suction from the CST to the suppression pool in a small liquid break accident. With the modified SABRE code, the break size which corresponds to the minimum time for suppression pool level to reach 25 feet, with reactor pressure above the shutoff head of low-pressure injection systems, is 0.04 ft^2 as opposed to 0.0375 ft^2 computed with SABRE 3.1 in §4.5.

The results for Case 13m (0.06 ft^2 liquid break) presented in Table B.4-1 show that Core Spray injection initiates and recovers vessel level before suppression pool water level reaches 25 feet. For Case 12m (0.0425 ft^2 break), it takes longer to reach 25 feet in the suppression pool than for Case 11m, even though the break size is smaller in Case 11m (0.04 ft^2). This seemingly inconsistent result is explainable by the fact that Core Spray initiates in Case 12m before suppression pool water level reaches 25 feet. Core spray takes suction from the pool and thus delays the rise in pool level.

The manual transfer of HPCI suction to the suppression pool on high pool level of 25 feet is intended to mitigate the rise in pool level and minimize the potential of a HPCI trip on high turbine exhaust pressure. If suppression pool water level were to exceed 25 feet and HPCI tripped as a result of the operator failing to control RPV water level below Level 8, water from the suppression pool would enter the HPCI turbine exhaust piping. There is concern that turbine exhaust pressure could exceed the trip set point if the system were to be restarted with a partially filled exhaust line. While it is prudent to control pool level at or below 25' in order to avoid the risk of losing a high-pressure makeup system on high turbine exhaust pressure during restart, no credit is taken for the manual HPCI suction transfer in the risk analysis (Calculation EC-RISK-1083, Rev. 1) which supports the proposed license amendment.[1]

Input data files for Cases 02, 02m, 10, 10m, 11, 11m, 12m, and 13m are included on CD. The input file names are c02.dat, c02m.dat, c10.dat, c10m.dat, c11.dat, c11m.dat, c12m.dat, and c13m.dat, respectively. Output files for Cases 02, 02m, 10, 10m, 11, 11m, 12m, and 13m are also included on CD. The SABRE output file names for the eight cases are named as follows:

Case 02:	sabre3v1.00-69.out,
Case 02m:	sabre.c02m.out
Case 10:	sabre3v1.00-82.out
Case 10m:	sabre.c10m.out
Case 11:	sabre3v1.02-28.out
Case 11m:	sabre.c11m.out
Case 12m:	sabre.c12m.out
Case 13m:	sabre.c13m.out

The modified SABRE source code is also included on CD under file name *sabre.mod.f.* A folder containing the common blocks for the code is also included on CD.

[1] PLA-5470, "Susquehanna Steam Electric Station Supplement 3 to Proposed Amendment No. 239 to License NPF-14 and Proposed Amendment No. 204 to License NPF-22: HPCI Automatic Transfer to Suppression Pool Logic Elimination," May 7, 2002.

Table B.4-1
Effect of Adding Mass/Energy of Recirculation Loops and Fuel Bundle Tie Plates on SABRE Results for 0.02 ft^2, 0.037 ft^2, 0.04 ft^2, 0.0425 ft^2, and 0.06 ft^2 Liquid Breaks

SABRE Case	Case Description	Sup. Pool Temp. at Time of CS Initiation	Time to reach 25 ft. in Sup. Pool	Time of CS Initiation
02‡	0.02 ft^2 Liq Break run with SABRE 3.1	135.1 °F	23.4 min	100.5 min
02m	0.02 ft^2 Liq Break run with modified version of SABRE	141.0 °F	22.5 min	105.3 min
10‡	0.0375 ft^2 Liq Break run with SABRE 3.1	113.1 °F	21.3 min	29.3
10m	0.0375 ft^2 Liq Break run with modified version of SABRE	122.1 °F	21.1 min	38.2 min
11	0.04 ft^2 Liq Break run with SABRE 3.1 (Run # 02-28)	103.7 °F	22.4 min	17.6 min
11m	0.04 ft^2 Liq Break run with modified version of SABRE	110.3 °F	21.0 min	22.9 min
12m	0.0425 ft^2 Liq Break run with modified version of SABRE	106.3 °F	21.5 min	18.6 min
13m	0.06 ft^2 Liq Break run with modified version of SABRE	101.7 °F	**	12.7 min

** Level is recovered using low-pressure injection before pool level reaches 25 feet.

‡ SABRE 3.1 production run # is listed in Computer Case Summary on p. 3.

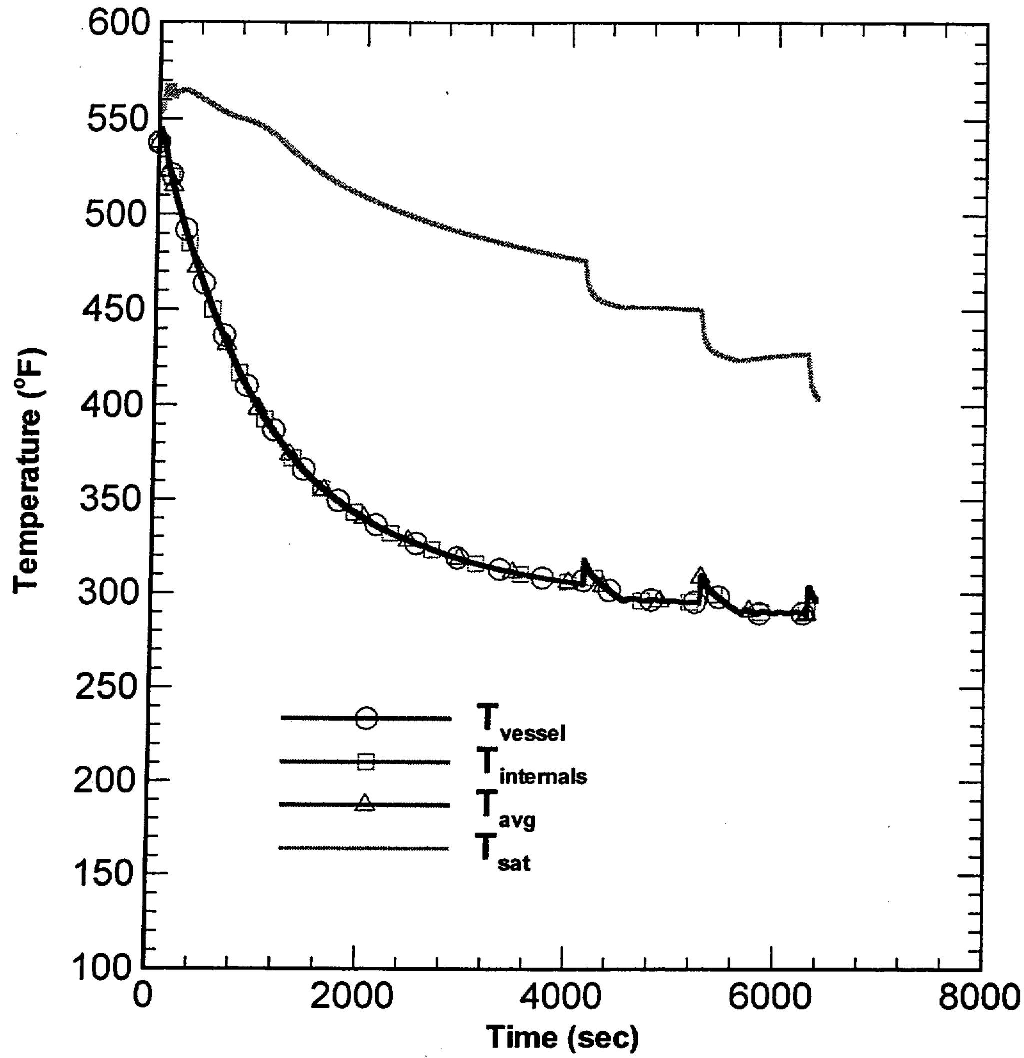

Figure B.4-1 Metal and fluid temperatures for Case 02m.

T_{vessel}=vessel temperature.

$T_{internals}$=vessel internals temperature.

T_{avg}=fluid temperature averaged over height of vessel.

T_{sat}=saturation temperature based on vessel pressure.