CONTEMPT Evaluation

The CONTEMPT input deck from case "CON1H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST21"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 87.76 seconds. The spray delay is 53.1 seconds for a spray start time of 140.9 seconds.

Results

The CONTEMPT run was titled "CON21H" with the peak containment pressure determined to be 26.4 psig at 116.6 seconds post break, and peak containment temperature of 316.9F at 13.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

7.7 Case 22

70% Power

0.9 ft^2 SPLIT

Failure of Diesel Generator

Offsite Power NOT Available

The restart deck from case "SLBC17_1" was reproduced identically with the exception of the following changes:

Break Model

The break valve configuration changes depending on break size and whether the break is a double ended rupture or a split break. For case 22, a split break requires that the communication valve between the two sides of the break (valve 851) remains open, and only the single break valve opens (valves 856). The second break valve will remain closed through the transient (valve 858). The single break size must also be reduced to 1.1 ft^2. Note that the comment card stating break size is incorrect in the deck.

```
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
* BREAK MODEL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
* Break size = 0.9 SPLIT
8560000   A-BRK   VALVE
8560101   673010000   572000000   0.9   1.0   1.0E+6   00100
8560201   0   0.0   0.0   0.0   * 0.0
8560300   TRPVLV
8560301   551
```

```
*
8510000 DER  VALVE
8510101 673010000 674000000 4.929 0.0 0.0 01100
8510201 0 29.90708 93.44495 0.0
8510300 MTRVLV
8510301 501 502 100.0 1.0  * ALWAYS OPEN FOR SPLIT, 0.01 stroke
*
8580000  B-BRK   VALVE
8580101  674000000  571000000  4.4  1.0  1.0E+6  00100
8580201  0      0.0     0.0     0.0        * 0.0
8580300  TRPVLV
8580301  502 *FALSE, ALWAYS CLOSED FOR SPLIT
*
```

Reactor Trip

From a preliminary run, it was determined that a reactor trip would occur substantially faster on a containment building SI signal rather then the trips modeled in RELAP5/MOD2. From a preliminary CONTEMPT run, the building pressure reaches the 12.8 psig signal SI signal (Reference page A17 of Reference 14) just prior to 34.5 seconds. This trip is incorporated in the final RELAP5/MOD2 run by forcing the low SG pressure signal trip (trip 410) to become true at 40.6 seconds post break.

```
* REPLACE SG PRESSURE SI SIGNAL WITH CONTAINMENT SI SIGNAL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
410   "TIME"   0   "GE"   "NULL"   0   190.6   "L"
*
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
```

RELAP5/MOD2 Results

With the documented changes, a 600-second run was performed in "SLBC7_1". Plots showing the behavior of the transient are shown in Appendix C.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON17H" was duplicated with the following changes

Containment Coolers

Only two containment coolers are credited in the present evaluation. This is unchanged from the base deck. The containment cooler start time for a LOOP is 65 seconds after LOOP if the containment pressure reaches 6.8 psig prior to 35.0 seconds. From the preliminary CONTEMPT run, the containment SI signal will occur at 22.2 seconds, with a 2-second SI delay, the LOOP occurs at 24.2 seconds coincident with reactor trip. The containment cooler actuation time is therefore 89.2 seconds.

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST22"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 174.74

seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 227.9 seconds.

The spray flow rate is set to the low flow pump flow rate of 3285 GPM. This corresponds to a flow rate of 450.49 lbm/s as calculated in Reference 20.

Results

The CONTEMPT run was titled "CON22H" with the peak containment pressure determined to be 27.6 psig at 403.5 seconds post break, and peak containment temperature of 251.0F at 31.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

7.8 Case 23

70% Power

0.9 ft^2 SPLIT

Failure of Containment Spray System

Offsite Power Available

The restart deck from case "SLBC18_1" was reproduced identically with the exception of the following changes:

Break Model

The break valve configuration changes depending on break size and whether the break is a double ended rupture or a split break. For case 23, a split break requires that the communication valve between the two sides of the break (valve 851) remains open, and only the single break valve opens (valves 856). The second break valve will remain closed through the transient (valve 858). The single break size must also be reduced to 0.9 ft^2.

```
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
* BREAK MODEL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
*  Break size = 0.9 SPLIT
8560000   A-BRK   VALVE
8560101   673010000   572000000  0.9  1.0   1.0E+6   00100
8560201   0      0.0     0.0     0.0         * 0.0
8560300   TRPVLV
8560301   551
*
8510000  DER   VALVE
```

```
8510101 673010000 674000000 4.929 0.0 0.0 01100
8510201 0 29.90708 93.44495 0.0
8510300 MTRVLV
8510301 501 502 100.0 1.0 * ALWAYS OPEN FOR SPLIT, 0.01 stroke
*
8580000  B-BRK  VALVE
8580101  674000000  571000000  4.4  1.0  1.0E+6  00100
8580201  0     0.0     0.0     0.0        * 0.0
8580300  TRPVLV
8580301  502 *FALSE, ALWAYS CLOSED FOR SPLIT
*
```

Reactor Trip

From a preliminary run, it was determined that a reactor trip would occur substantially faster on a containment building SI signal rather then the trips modeled in RELAP5/MOD2. From a preliminary CONTEMPT run, the building pressure reaches 12.8 psig just prior to 34.0 seconds. This trip is incorporated in the final RELAP5/MOD2 run by forcing the low SG pressure signal trip (trip 410) to become true at 40.1 seconds post break.

```
* REPLACE SG PRESSURE SI SIGNAL WITH CONTAINMENT SI SIGNAL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
410   "TIME"   0   "GE"   "NULL"   0   190.1   "L"
*
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
```

Single SG Separator

During the RELAP5/MOD2 run, water property problems occurred when the swell in the SG filled the separator nodes. To overcome this problem, the void fraction at which the node is allowed to pass liquid was increased from 0.025 to 0.10. While water may pass to the break, only the vapor enthalpy is used to determine the energy addition rate.

```
*
6500000  "S-SGRIS2"  "SEPARATOR"
6500001  3       0
6500101  19.278  9.063  0.0   0.0   90.0  9.063
6500102  4.167-5  0.53  00
6500200  0       1148.4  559.87  1106.0  0.13810
* PROBLEMS WITH WATER PROPERTIES WHEN SG SWELLS
* SEPERATOR ALLOWED TO PASS LIQUID EARLIER: 0.025 CHANGED TO 0.10
6501101  650010000 660000000 19.278   0.0   0.0    01000 0.1 *
6501201   13.661  13.662 0.0
*6502101  650000000 655000000 68.52   0.32   0.53   01000 1.0
6502101  650000000 645000000 68.52   0.32   0.53   01000 0.01
6502201   1.4916  1.4916 0.0
6503101  640010000 650000000 19.278   0.0   0.0   01000
6503201   18.913  18.915  0.0
```

RELAP5/MOD2 Results

With the documented changes, a 600-second run was performed in "SLBC23_1". Plots showing the behavior of the transient are shown in Appendix C. Note that this run had an internal divide by zero at 748.63 seconds (598.63 seconds transient time). A rerun is not required with the peak containment temperature and pressure demonstrated to be much earlier then the time of RELAP5/MOD2 failure.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON18H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST23"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 113.87 seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 167.0 seconds.

Results

The CONTEMPT run was titled "CON23H" with the peak containment pressure determined to be 29.2 psig at 187.6 seconds post break, and peak containment temperature of 252.7F at 30.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

7.9 Case 24

70% Power

0.9 ft^2 Split

Failure of Containment Cooler System

Offsite Power Available

This RELAP5/MOD2 run is identical to case 23 with only a failure of a containment system.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON23H" was duplicated with the following changes

Containment Coolers

Only two containment coolers are credited in the present evaluation. This is accomplished by changing word 11 of card 6 from 4 to 2.

Mass and Energy Release

The mass and energy release was unchanged from case 23.

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 106.29 seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 159.4 seconds. The spray flow rate was also increased to the two pump value of 970.92 lbm/s (Reference 20)

Results

The CONTEMPT run was titled "CON24H" with the peak containment pressure determined to be 30.0 psig at 184.6 seconds post break, and peak containment temperature of 252.7F at 30.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

7.10 Case 25

70% Power

0.9 ft^2 Split

Failure of MFIV

Offsite Power Available

This case was not performed with a comparison between cases 1 and 3 demonstrating that a MSIV failure is more limiting.

7.11 Case 26

70% Power

1.1 ft^2 Split

Failure of MSIV

Offsite Power Available

The restart deck from case "SLBC21_1" was reproduced identically with the exception of the following changes:

Break Model

The break valve configuration changes depending on break size and whether the break is a double ended rupture or a split break. For case 26, a split break requires that the communication valve between the two sides of the break (valve 851) remains open, and only the single break valve opens (valves 856). The second break valve will remain closed through the transient (valve 858). The single break size must also be reduced to 0.9 ft^2.

```
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
* BREAK MODEL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
* Break size = 0.9 SPLIT
8560000   A-BRK   VALVE
8560101   673010000   572000000  0.9  1.0   1.0E+6   00100
8560201   0      0.0     0.0     0.0          * 0.0
8560300   TRPVLV
8560301   551
*
8510000 DER  VALVE
```

```
8510101 673010000 674000000 4.929 0.0 0.0 01100
8510201 0 29.90708 93.44495 0.0
8510300 MTRVLV
8510301 501 502 100.0 1.0 * ALWAYS OPEN FOR SPLIT, 0.01 stroke
*
8580000  B-BRK   VALVE
8580101  674000000  571000000  4.4  1.0  1.0E+6  00100
8580201  0     0.0     0.0     0.0          * 0.0
8580300  TRPVLV
8580301  502 *FALSE, ALWAYS CLOSED FOR SPLIT
*
```

Reactor Trip

From a preliminary run, it was determined that a reactor trip would occur substantially faster on a containment building SI signal rather then the trips modeled in RELAP5/MOD2. From a preliminary CONTEMPT run, the building pressure reaches 12.8 psig just prior to 34 seconds. This trip is incorporated in the final RELAP5/MOD2 run by forcing the low SG pressure signal trip (trip 410) to become true at 40.6 seconds post break.

```
* REPLACE SG PRESSURE SI SIGNAL WITH CONTAINMENT SI SIGNAL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
410   "TIME"   0   "GE"   "NULL"   0   190.6   "L"
*
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
```

Single SG Separator

During the RELAP5/MOD2 run, water property problems occurred when the swell in the SG filled the separator nodes. To overcome this problem, the void fraction at which the node is allowed to pass liquid was increased from 0.025 to 0.10. While water is allowed to pass through the separator earlier, only vapor enthalpy is used to calculate the energy addition rate to the containment building.

```
*
6500000  "S-SGRIS2" "SEPARATOR"
6500001  3      0
6500101  19.278 9.063 0.0  0.0  90.0 9.063
6500102  4.167-5 0.53 00
6500200  0       1148.4 559.87 1106.0 0.13810
* PROBLEMS WITH WATER PROPERTIES WHEN SG SWELLS
* SEPERATOR ALLOWED TO PASS LIQUID EARLIER: 0.025 CHANGED TO 0.10
6501101  650010000 660000000 19.278   0.0   0.0    01000 0.1 *
6501201   13.661  13.662 0.0
*6502101  650000000 655000000 68.52   0.32   0.53   01000 1.0
6502101  650000000 645000000 68.52   0.32   0.53   01000 0.01
6502201   1.4916  1.4916 0.0
6503101  640010000 650000000 19.278   0.0   0.0   01000
6503201   18.913  18.915  0.0
```

RELAP5/MOD2 Results

With the documented changes, a 600-second run was performed in "SLBC26_1". Plots showing the behavior of the transient are shown in Appendix C.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON1H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST26"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 108.53 seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 161.7 seconds.

Results

The CONTEMPT run was titled "CON26H" with the peak containment pressure determined to be 30.5 psig at 210.0 seconds post break, and peak containment temperature of 252.7F at 30.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

7.12 Case 27
70% Power
1.1 ft^2 SPLIT
Failure of Containment Cooler System
Offsite Power Available

The restart deck from case "SLBC24_1" was reproduced identically with the exception of the following changes:

Break Model

The break valve size was increased from 0.9 ft^2 to 1.1 ft^2 (valve 856).

RELAP5/MOD2 Results

With the documented change, a 300-second run was performed in "SLBC27_1. Plots showing the behavior of the transient are shown in Appendix C.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON24H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST27"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 79.13 seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 132.3 seconds.

Results

The CONTEMPT run was titled "CON27H" with the peak containment pressure determined to be 30.8 psig at 155.2 seconds post break, and peak containment temperature of 268.2F at 27.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

8.0 RELAP5/MOD2 30% Evaluation

The base RELAP5/MOD2 deck used is the 102% power case "SLBIC1". The only changes required of this deck are those required for a reduction to 30% power and are as follows.

MFW Pump Suction Conditions

For a reduction in power, the MFW pump suction temperature is reduced. From Reference 5, the feedwater suction temperatures are 277.6F at 23.7%FP and 325.8F at 44.7%FP (The percent full power for these figures was calculated in Section 8 of Reference 6. Interpolating between these values gives a suction temperature of 292.06F. The suction pressure is not changed and is immaterial with the correct flow rate obtained with a combination of suction pressure and control valve position.

```
8000201   0.0   367.4   292.06   *"SUCTION" "P" & "T"
```

MFW Control Valves

The MFW Control valves were closed to 18% open as an initial guess to obtain the correct MFW flow rate.

```
8200301   593  502   0.05   .18
8700301   593  502   0.05   0.18
```

Power Level

The power level was reduced to 30% of 3411 Mwt, or 1023.3 Mwt.

```
30000001   "GAMMA-AC"   .10233E+10  .00000  243.094  1.2  1.0000
```

Turbine Pressure

The turbine pressure was increased to 1156.6 as an initial guess to obtain the correct RCS Tavg of 575.9F .

7960201 0.0 1156.6 540.0 *"SG" "P" & "T"

8.1 RELAP5/MOD2 30% Power Steady State

The changes outlined in section 8.0 were administered to case "SLB70IC1" of Section 4.1. A 100-second run titled "SLB30IC1" was performed that resulted in a RCS Tavg of 575.9°F, and falling. To obtain a suitable steady state, several changes were applied to the deck on a restart titled "SLB30IC2".

The turbine pressure was raised from 1156.6 to 1157.5 psia.

```
7960000  "TURBINE"  "TMDPVOL"
7960101  1.e6 1.e6 0.0  0.0  0.0  0.0  0.0  0.0  10
7960200  003
7960201  0.0   1156.6   540.0    *"SG" "P" & "T"
7960202  100.0  1156.6   540.0
7960203  101.0  1157.5   540.0
*
```

From Table H2 of Reference 12, for SG levels above 70% NRS, the velocity error can be interpolated between the 25% and 50% power levels to a value of 1.94%. The SG level is initialized to 65.6% NRS (Reference 12, Item 3.2.11) plus 2.5% NRS control band tolerance, 5.0% instrument error, and 1.94% velocity error for a total level of 75.04% NRS. The void fractions of the steam generator separator region were adjusted such that at the end of this run, the correct SG levels are obtained. The following void fraction changes were applied to the separator region in restart run "SLB30IC2":

```
6550200  0      1159.0  551.8  1111.6  0.09
7550200  0      1159.1  551.4  1111.0  0.07
```

The MFW flow rate was required to be decreased to match the steam flow rate. The MFW control valves were both opened slightly.

```
8200301   593  502   0.05   0.175
8700301   593  502   0.05   0.17
```

These changes were applied on restart "SLB30IC2", with the steady state run continued for another 100 seconds. The results of this run show that the RCS Tavg is 575.7 with the MFW flow rate too high. To obtain a suitable steady state, several changes were applied to the deck on a restart titled "SLB30IC3".

The turbine pressure was further increased to 1159.5 psia.

```
*
7960000   "TURBINE"   "TMDPVOL"
7960101   1.e6 1.e6 0.0  0.0  0.0  0.0  0.0  0.0  10
7960200   003
7960201   0.0   1156.6   540.0    *"SG" "P" & "T"
7960202  100.0  1156.6   540.0
7960203  101.0  1157.5   540.0
7960204  200.0  1157.5   540.0
7960205  201.0  1159.5   540.0
```

The void fractions of the single steam generator separator region was adjusted such that at the end of this run, the correct SG level is obtained. The following void fraction changes were applied to the separator region in restart run "SLB30IC3":

```
6550200  0       1159.8  554.54  1105.8  0.14
```

The MFW flow rate was required to be decreased to match the steam flow rate. The MFW control valves were both opened slightly.

8200301 593 502 0.05 0.157
8700301 593 502 0.05 0.155

These changes were applied on restart "SLB30IC3", with the steady state run continued for another 50 seconds. The results of this run show that the RCS Tavg and SG levels are steady and correct. The conditions at the end of this run are as given in Table 8.1.

Table 8.1

30% Power Steady State Conditions

Average RCS Liquid Temperature (°F)	575.9 (575.9)*
Pressurizer Pressure (psia) (410-1)	2241.6
RCS Flow Per Loop, Single/Triple (lbm/s) (100-1, 200-1)	10425/31282
SG Dome Pressure, Single/Triple (psia) (670-1,770-1)	1160.3/1160.3
Single SG Level (%NRS) (CVAR 792)	75.04 (75.04)*
Triple SG Level (%NRS) (CVAR 992)	75.6
Feedwater Flow, Single/Triple (lbm/s) (832-1, 882-1)	282.0/833.8
Steam Flow, Single/Triple (lbm/s) (670-1, 770-1)	279.0/821.3

bracketed are desired values

8.2 Case 28
30% Power
4.4 ft^2 DER
Failure of MSIV
Offsite Power Available

The following changes were applied on the RELAP5/MOD2 break restart input deck. Most of these changes are applied to all cases at transient initiation. The base restart deck on which the following changes were applied was the case 21 restart deck of "SLBC21_1". Note that most parameters defined on the restart deck will remain unchanged from "SLBC21_1".

Kinetics

All kinetics control variables are in place for the steady state runs (and therefore initialized correctly). On break restart the kinetics control variables are applied with use of the 3000000 series cards, with the power level updated to 30% full power from the base deck.

30000001 GAMMA-AC .10233E+10 .00000 243.094 1.2 1.0000

MFW Heaters

The MFW heater models developed in Reference 6 were developed from steady state information. During upset conditions, the heaters may perform unrealistically. To avoid possible difficulties, the heater performance is fixed at the steady state conditions. It is conservative to hold shell side temperature and heat transfer to the pre-transient conditions with the shell side steam flow expected to decrease of stop once the steam line break occurs and the turbine trips. The temperature and UA terms applied to the following tables were obtained from the lookup control variables that use these tables at the end of the steady state run.

```
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
* MFW HEATER SHELL SIDE CONDITIONS HELD CONSTANT
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
20201000   REAC-T
*          POWER,MW      SHELL SIDE TEMP, F
20201001     0.          321.211
20201002     4000.        321.211
*
20201100   REAC-T
*          POWER,MW      SHELL SIDE TEMP, F
20201101     0.00         302.928
20201102     4000.        302.928
*
20201200   REAC-T
*          POWER,MW      UA, WATTS/F
20201201     0.00        4194470.
20201202     4000.        4194470.
*
```

Turbine

To avoid an unrealistic back flow from the turbine to the break once the steam lines depressurize, the choking option is applied to the turbine valve, with the time dependent volume downstream of the valve changed to atmospheric pressure, and the valve area adjusted such that the flow through the valve matches the steady state value. From the last major edit of run "SLB30IC3", the flow through the TSV is 1100.4 lbm/s, with a steam enthalpy just upstream (branch 792) of 1186.3 Btu/lbm, and pressure just upstream of 1159.6 psia. From the HEM choked flow tables of Reference 21, a double interpolation is performed to obtain the correct flow area to maintain the steady state flow through the TSV.

For 1000.0 psia inlet pressure:

H (Btu/lbm)	G (lbm/s-ft**2)
1127.90	2101.89
1186.3	? = 2020.75
1192.94	2011.52

For 1200.0 psia inlet pressure:

H (Btu/lbm)	G (lbm/s-ft**2)
1184.81	2429.72
1186.3	? = 2427.64
1201.32	2406.68

For 1140.1 psia inlet pressure:

P (psia)	G (lbm/s-ft**2)
1000.0	2020.75
1159.6	? = 2345.45
1200.0	2427.64

The required area to obtain the correct choked flow mass flow rate is:

Area = (1100.4 lbm/s)/(2345.45 lbm/s-ft**2) = 0.4692

```
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
* TURBINE: AREA CHANGED TO CHOKED AREA
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
7940000   SNG-TSV   VALVE
7940101   792010000 796000000 0.4692   0.0   1.0E+10      30000
```

```
7940201  1   0.00   1100.4   0.0
7940300  TRPVLV
7940301  660
*
```

RELAP5/MOD2 Results

With the documented changes, a 200-second run was performed in "SLBC28_1". Plots showing the behavior of the transient are shown in Appendix C.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON21H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST28"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 92.35 seconds. The spray delay remains 53.1 seconds for a spray start time of 145.45 seconds. This activation time was incorporated into Table 801.

Results

The CONTEMPT run was titled "CON28H" with the peak containment pressure determined to be 26.3 psig at 124.8 seconds post break, and peak containment temperature of 319.7F at 14.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

8.3 Case 29
30% Power
0.9 ft^2 Split
Failure of Containment Cooler System
Offsite Power Available

The restart deck from case "SLBC28_1" was reproduced identically with the exception of the following changes:

Break Model

The break valve configuration was changed identical to case "SLBC22_1" for a 0.9 ft2 split break.

Reactor Trip

From a preliminary run, it was determined that a reactor trip would occur substantially faster on a containment building SI signal rather then the trips modeled in RELAP5/MOD2. From a preliminary CONTEMPT run, the building pressure reaches 12.8 psig just prior to 31.2 seconds. This trip is incorporated in the final RELAP5/MOD2 run by forcing the low SG pressure signal trip (trip 410) to become true at 42.8 seconds post break.

```
* REPLACE SG PRESSURE SI SIGNAL WITH CONTAINMENT SI SIGNAL
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
*
410   "TIME"   0   "GE"   "NULL"   0   292.8   "L"
*
**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_**_
```

Single Failure

The Single failure of the MSIV was removed with no RELAP5/MOD2 failure modeled.

RELAP5/MOD2 Results

With the documented changes, a 200-second run was performed in "SLBC29_1", and then continued for an additional 200-seconds in "SLBC29_2". Plots showing the behavior of the transient are shown in Appendix C.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON24H" was duplicated with the following changes

Mass and Energy Release

The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST29"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501 (See example for case 1).

Containment Sprays

Following this input, a preliminary run was performed to determine the time the containment building reached 24.8 psig (containment spray actuation setpoint) which was determined to be at 102.13 seconds. With this actuation setpoint reached after 35.0 seconds with a LOOP, the spray delay is 53.1 seconds for a spray start time of 155.23 seconds.

Results

The CONTEMPT run was titled "CON29H" with the peak containment pressure determined to be 30.59 psig at 203.5 seconds post break, and peak containment temperature of 251.0 at 31.1 seconds post break. Plots of the containment pressure and temperature response are included in Appendix C.

9.0 RELAP5/MOD2 0% Power Evaluation

The results of the 102%, 70%, and 30% power levels show that the peak containment pressure results occurred for containment cooler failures with split breaks, with the severity of the accident decreasing with decreasing power levels. The peak containment temperature has been shown to be insensitive to the power level. Evaluation of the 0% power level condition is therefore not required to demonstrate that the use of the RSGs does not result in a reduction in the margin of safety.

10.0 Results and Conclusions

The results of the SLB containment responses are provided in Table 10.1. From this table it is seen that the peak containment temperatures occurs very early in the transient for the double ended ruptures with MSIV failure with a maximum temperature of 319.7°F. This very high temperature is due primarily to the assumptions that were required in calculation of the energy content of the mass exiting the break. For the double ended breaks with an initially high steam generator inventory, liquid carryout will occur; however, for this analysis liquid carryout was not permitted per agreement with ComEd in Reference 4. Liquid carryout was unavoidable in RELAP5 even when extremely conservative slip drag models were applied in the steam generators, therefore, to comply with this agreement the total mass was multiplied by only the steam specific enthalpy to determine the energy released to the containment building resulting in an unrealistically high energy release rate to the containment building. It is demonstrated in Appendix A that if only dry steam exits the steam generator, this temperature peak would be reduced by over 80°F.

This highly conservative temperature still resulted in a 0.3°F margin to the EQ envelope (Reference 23). After the early peak temperature, the temperature drops off rapidly below 270°F for all cases for the transient duration. The temperature EQ acceptance criteria have not been exceeded, therefore, there is no reduction to the margin of safety.

The maximum containment pressure occurred for containment cooler failures with split breaks. The results were slightly higher then the analysis of record results (Reference 14), however, this is attributed mostly to the conservative method of energy calculation as discussed above. Even with the split breaks, some liquid is entrained in the steam due to the high initial water level in the steam generators. The peak containment pressure was determined to be 35.8 psig, maintaining a 14.2 psi margin to the containment safety limit. The containment pressure limit acceptance criteria has not been exceeded, therefore, there is no reduction to the margin of safety.

Containment SLB Results

Case	Break Type	Break Size ft²	Pow %	Failure	Offsite Power	Peak P (psig)	Peak T (F)
1	DER[1]	4.4	102	MSIV[2]	AVAIL	26.7	317.2
2	"	"	"	"	NOT AVAIL	25.3	317.2
3	"	"	"	MFIV[3]	AVAIL	25.9	280.8
4	"	"	"	DIESEL	NOT AVAIL	21.9	282.0
5	"	"	"	SPRAY	AVAIL	22.8	280.8
6	"	"	"	COOLER	AVAIL	23.5	280.9
7	SPLIT[6]	1.1	"	DIESEL	NOT AVAIL	33.5	267.5
8	"	"	"	SPRAY	AVAIL	34.8	268.8
9	"	"	"	COOLER	AVAIL	35.6	268.8
9a	"	1.2	"	"	"	35.8	275.4
9b	"	1.6	"	"	"	25.2	283.8
9c	"	1.0	"	"	"	33.0	262.4
9d	SPLIT	1.3	102	COOLER	AVAIL	34.1	281.6

10	"	1.1	"	MFIV	AVAIL	NR[5]	NR[5]
11	"	"	"	MSIV	AVAIL	33.5	268.7
12	SPLIT	0.9	"	DIESEL	NOT AVAIL	32.8	256.5
13	"	"	"	SPRAY	AVAIL	31.7	258.7
14	"	"	"	COOLER	AVAIL	32.8	258.7
15	"	"	"	MFIV	AVAIL	NR[5]	NR[5]
16	"	"	"	MSIV	AVAIL	33.9	258.6
17	DER	4.4	70	DIESEL	NOT AVAIL	22.3	296.8
18	"	"	"	COOLER	AVAIL	25.3	302.2
19	"	"	"	SPRAY	AVAIL	24.5	302.2
20	"	"	"	MFIV	AVAIL	NR[5]	NR[5]
21	"	"	"	MSIV	AVAIL	26.4	316.9
22	SPLIT	0.9	70	DIESEL	NOT AVAIL	27.6	251.0
23	"	"	"	SPRAY	AVAIL	29.2	252.7

24	"	"	"	COOLER	AVAIL	30.0	252.7
25	"	"	"	MFIV	AVAIL	NR[5]	NR[5]
26	"	"	"	MSIV	AVAIL	30.5	252.7
27	SPLIT	1.1	70	COOLER	AVAIL	30.8	268.2
28	DER	4.4	30	MSIV	AVAIL	26.3	319.7
29	SPLIT	0.9	30	COOLER	AVAIL	30.6	251.0

1 DER indicates a double ended rupture in which there is no communication between the two sides of the break.
2 MSIV failure is a failure of the steam isolation valve on the faulted steam generator.
3 MFIV failure is a failure of the main feedwater isolation valve on the faulted steam generator.
4 Not Used.
5 NR is not required due to trends demonstrated in other cases.
6 SPLIT indicates a split rupture in which communication remains between the two sides of the break.

11.0 References

1. B&W Topical Report BAW-10164P, "RELAP5/MOD2 - An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analysis," Revision 3, October 1992.
2. B&W Topical Report BAW-10095A, "CONTEMPT - Computer Program for Predicting Containment Pressure-Temperature Response to a Loss-of-Coolant Accident," Revision 1, April 1978.
3. Framatome Document 32-1244486-00,"B/B SLB Outside Containment". 01
4. Framatome Document 51-1239275-02, "AIS for SLB Containment Responce"
5. ComEd Nuclear Design Informational Transmittal BYR-95-081, "Design Information for the Steam Generator Replacement Project." (heat kits)
6. Framatome Document 32-1239259-00, "Non-LOCA RELAP5 Model"
7. ComEd Nuclear Design Informational Transmittal BWR-95-028, "SGRP - Transmittal of System and Vendor Information". (control logic)
8. ComEd Nuclear Design Informational Transmittal BYR-96-034, "Main Feedwater Regulating Valve Closure Time."
9. ComEd Nuclear Design Informational Transmittal BWR-95-028, "SGRP - Transmittal of System and Vendor Information" (MFIV closure time)
10. ComEd Nuclear Design Informational Transmittal BYR-950028, Data Base (Non-Proprietary).
11. not used
12. BWI Document 222-7720-A19, Revision 00, "Commonwealth Edison RSG Design Data Single-Sources Geometric Reference for BWNS Licensing Analysis."
13. Framatome Document 32-1244466-00, "Byron/Braidwood LOEL Analysis"
14. ComEd Nuclear Design Informational Transmittal BYR-950058, "Containment Steam Generator Replacement Project Containment Analysis Information Transmittal", ComEd Letter Craig G. Holmes (ComEd) to Robert F. Condrac (Westinghouse),

"Byron/Braidwood Containment Response Analysis Input MSLB and LBLOCA", August 21,

15. ComEd Nuclear Design Informational Transmittal BYR-950038, Data Base (Proprietary).
16. ComEd Nuclear Design Informational Transmittal BYR-960043, "ECCS Flows to use for Main Steamline Break Analyses"
17 Westinghouse Memo B.S. Humphries (W) to P.E. Reister, et. al. (CE), "UFSAR Revision for Steam Generator Tube Plugging, Thermal Design Flow Reduction, and Positive Moderator Temperature Coefficient Program," CAE-94-145, CCE-94-158, PS-CAE/CCE-1211, ET-NSL-OPL-I-94-115, Dated March 22, 1994.
18. Byron Units 1 & 2 Technical Specifications, Table 2.2-1, Revised through ammendment 74.
19 Framatome Document 32-1239293-00, "Sequoyah Reanalysis of RWAP", page 534
20 Framatome Document 32-1239266-00, "ComEd B/B CONTEMPT Model Development".
21 BWNT Manual NPGD-TM-414, Revision L,"TRAP2 - GORTRAN Program for Digital Simulation of the Transient Behavior of the Once-Through Steam Generator and Associated Reactor Coolant System".
22 Byron/Braidwood Stations USFAR, Table 6.2-1, Through Revision 3 Dated December 1991.
23. ComEd Nuclear Design Informational Transmittal BYR-950058, ComEd Memo R. John to Ken Kovar, "Byron/Braidwood Equipment Qualification Profile", Dated August 19, 1994, Chron# 21057.

References 5,7,8,9,10,11,14,15,16,17,18,22, and 23 are maintained in a retrievable form by ComEd.

Reference 12 is maintained in a retrievable form by BWI.

WHeld

Project Management Function

12.0 Microfiche Listing

RELAP5/MOD2

Title	Hash	Description
SLBIC1	UWCO	102% SS Run
SLBIC2	FOQX	102% SS Run
SLB70IC1	FSKG	70% SS Run
SLB70IC2	VQOU	70% SS Run
SLB30IC1	VRSH	30% SS Run
SLB30IC2	UVPA	30% SS Run
SLB30IC3	UDEH	30% SS Run
SLBC1_1	TQVK	Case 1
SLBC2_1	VCCX	Case 2
SLBC3_1	VOVX	Case 3
SLBC4_1	VTRY	Case 4
SLBC5_1	TYOR	Case 5
SLBC7_1	TFKT	Case 7
SLBC8_1	FLTP	Cases 8 & 9
SLBC9A_1	UPYO	Case 9a
SLBC9B_1	FDFR	Case 9b
SLBC9C_1	VJWM	Case 9c
SLBC9D_1	VVAO	Case 9d
SLBC11_1	TAKE	Case 11
SLBC12_1	UAPB	Case 12
SLBC13_1	FXLB	Cases 13 & 14
SLBC16_1	USVY	Case 16
SLBC17_1	TSMN	Case 17
SLBC18_1	FSYB	Cases 18 & 19
SLBC21_1	TLUW	Case 21
SLBC22_1	VAVP	Case 22
SLBC23_1	THTX	Cases 23 & 24
SLBC26_1	TRHO	Case 26
SLBC27_1	FVFH	Case 27
SLBC28_1	UYYA	Case 28
SLBC29_1	VIAQ	Case 29
SLBC1L_1	FGVP	Appendix A Run
SLBC1C_1	ULPY	Appendix B run

01

CONTEMPT

Title	Hash	Description
CON1H	FGDR	Case 1
CON2H	FPJS	Case 2
CON3H	FBKU	Case 3
CON4H	FRBQ	Case 4
CON5H	FYOQ	Case 5
CON6H	FTUW	Case 6
CON7H	FVCV	Case 7
CON8H	FKUG	Case 8
CON9H	FASK	Case 9
CON9AH	FIJX	Case 9a
CON9BH	FWCS	Case 9b
CON9CH	FGIX	Case 9c
CON9DH	FUBE	Case 9d
CON11H	FAMG	Case 11
CON12H	FGUL	Case 12
CON13H	FPRP	Case 13
CON14H	FPWH	Case 14
CON16H	FJKL	Case 16
CON17H	FBIU	Case 17
CON18H	FCNT	Case 18
CON19H	FSYB	Case 19
CON21H	FATG	Case 21
CON22H	FLTV	Case 22
CON23H	FTCO	Case 23
CON24H	FCHL	Case 24
CON26H	FMYT	Case 26
CON27H	FXVD	Case 27
CON28H	FLMS	Case 28
CON29H	FYML	Case 29
CON1LEV	FVAC	Appendix A Run
CON1CH	ULPY	Appendix B run

STRIP FILES

Title	Description
ST1	Case 1
ST2	Case 2
ST3	Case 3
ST4	Case 4
ST5	Case 5
ST7	Case 7
ST8	Cases 8 & 9
ST9A	Case 9a
ST9B	Case 9b
ST9C	Case 9c
ST9D	Case 9d
ST11	Case 11
ST12	Case 12
ST13	Cases 13 & 14
ST16	Case 16
ST17	Case 17
ST18	Cases 18 & 19
ST21	Case 21
ST22	Case 22
ST23	Cases 23 & 24
ST26	Case 26
ST27	Case 27
ST28	Case 28
ST29	Case 29
ST1L	Appendix A Run

Appendix A: Dry Steam Release

The previous spectrum investigation demonstrated that the double ended ruptures with MSIV failure will result in the limiting condition for peak containment temperatures during the initial 20-seconds of blowdown with no liquid carryout, however, some engineering judgment was required to evaluate the mass and energy releases during this initial period to avoid inflating the calculated energy release to unrealistic levels with the total energy release calculated by multiplying the steam enthalpy by total mass release (to simulate no liquid carryout).

The purpose of this section is to demonstrate the previous method will result in an overly conservative calculation of the initial peak containment temperature. The case that will be used for demonstration is the 102% power, 4.4 DER, with MSIV failure (case1). Case1 will be reproduced with the SG level lowered to reduce the swell and therefore achieve higher quality steam in the upper dome of the steam generators to simulate no liquid carryout without the penalty of applying steam enthalpy to the liquid water. With the water level reduced, the swell in the steam generator will be maintained below the separators. Note that this method will reduce the SG inventory, however, the initial blowdown M&E results (prior to significant SG depressurization) would be similar for this case, and a high inventory SG where the quality is kept high near the SG nozzle.

The Case1 input deck was reproduced with the SG level decreased with the removal of the liquid in the separator nodes, the nodes just prior to the separators, and the adjacent downcomer nodes. Entire node was reproduced from case SLBIC1, only shown here are the changes to quality:

6400200	0	1134.3	557.93	1106.4	1.0
6450200	0	1134.3	557.93	1106.4	1.0
6500200	0	1134.3	557.93	1106.4	1.0
6550200	0	1134.3	557.93	1106.4	1.0

With these changes, the case was retitled "SLBC1L_1" and run for 20-seconds. Plots of the liquid void fraction and quality in the steam dome are located at the end of this Appendix and demonstrate that liquid did not enter the steam dome in significant quantities.

CONTEMPT Evaluation

The CONTEMPT input deck from case "CON1H" was duplicated with the following changes

Time

The end time was reduced to 20-seconds with the purpose of this appendix only to show the initial temperature peak value.

Mass and Energy Release

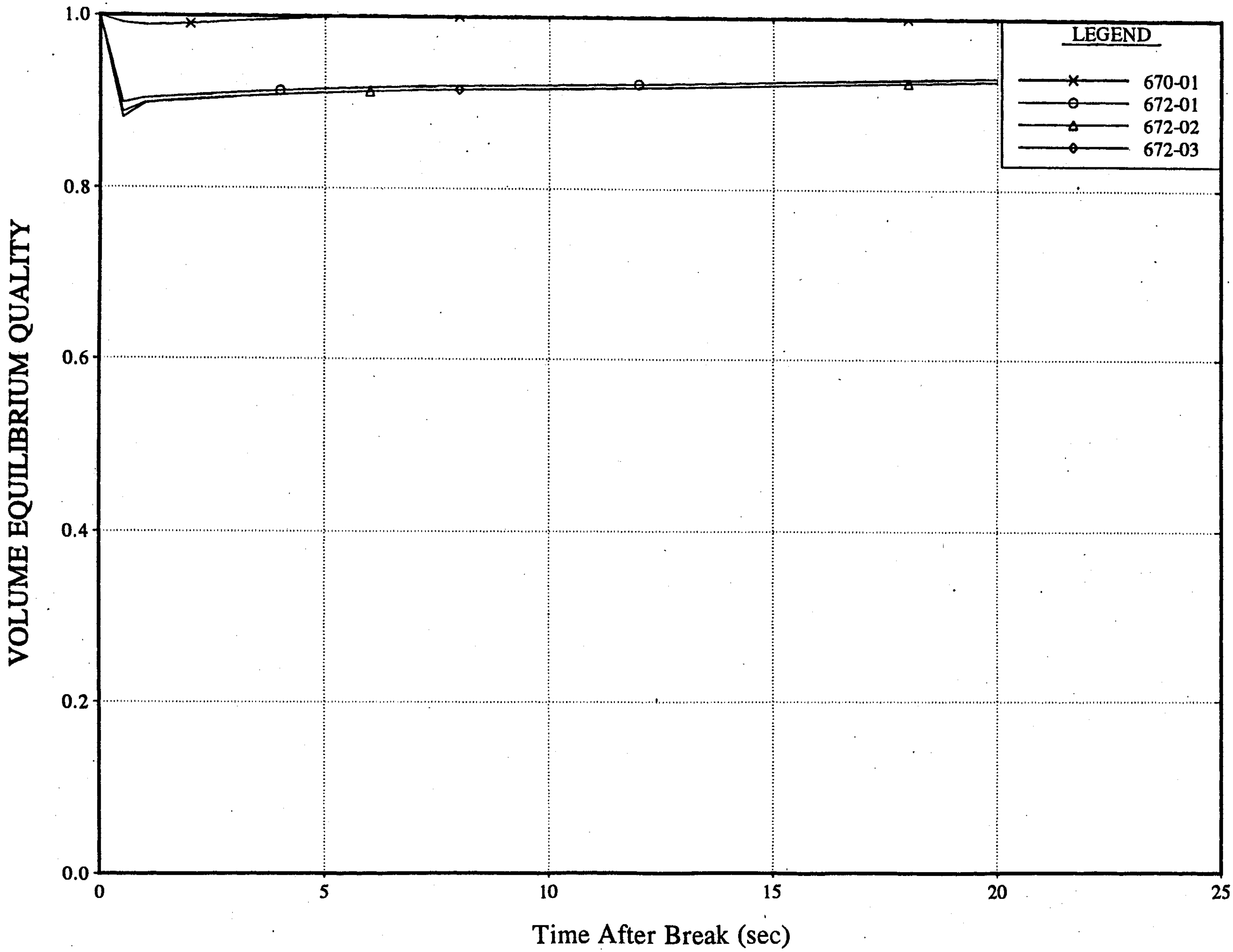
The mass and energy release from both sides of the break are formatted for input into CONTEMPT and are input as Table 501 in the input deck. This is performed by creating a strip file from the RELAP5/MOD2 deck (strip file titled "ST1L"), and formatting the data for input into CONTEMPT by summing the mass releases from both sides of the break, and summing the energy release rates from both sides of the break and input these values into Table 501. Note that with vapor entrainment minimized, the break mixture enthalpy is appropriate for use as the CONTEMPT energy input value.

All other changes to CONTEMPT are not required with the results of the run not dependent upon sprays or coolers due to the short length.

Results

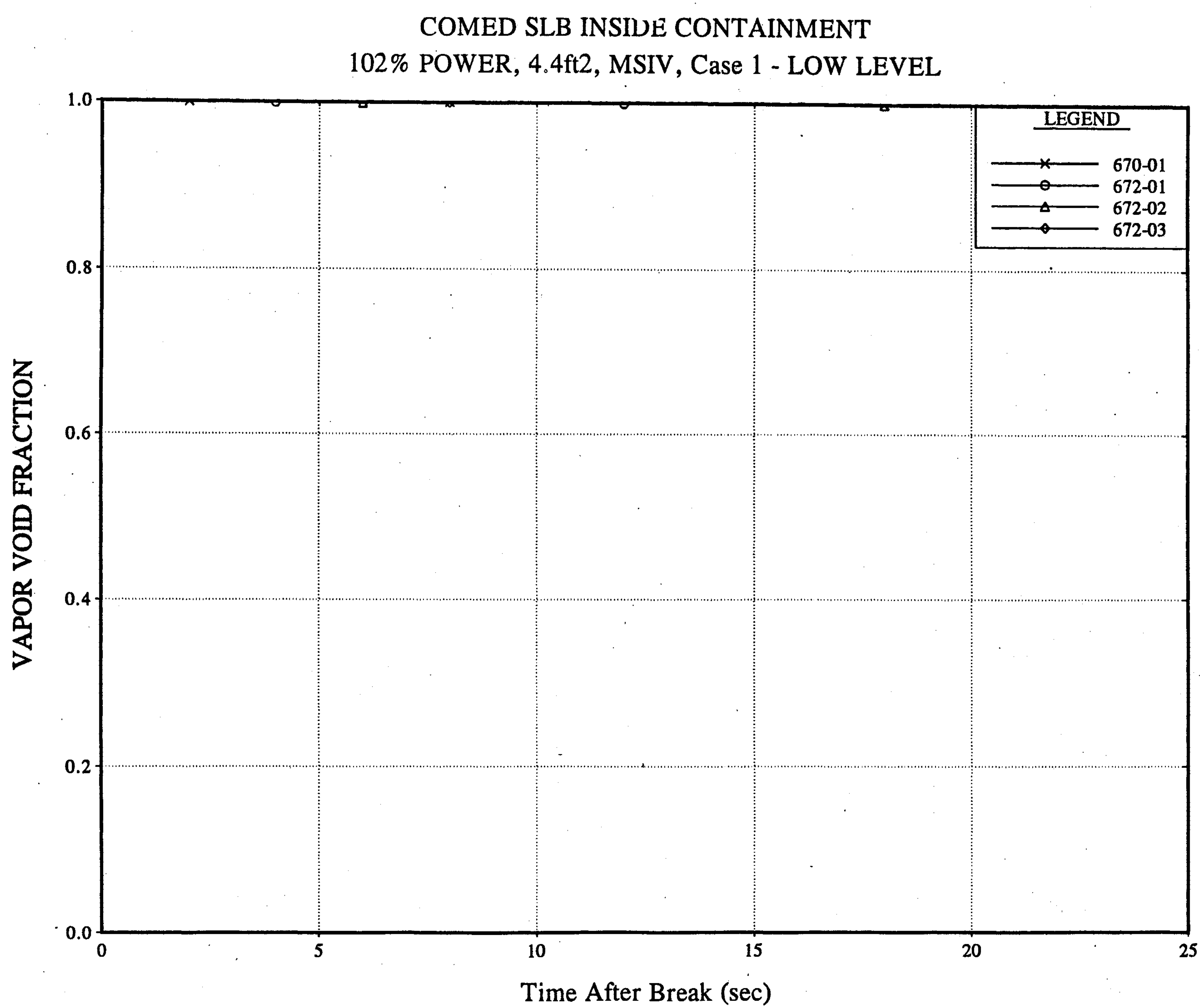
The CONTEMPT run was titled "CON1LEV" with the peak containment temperature determined to be 230.0F at 9.41 seconds post break or a reduction of peak containment temperature of 87.2°F. This demonstrates that the method used in the main body of the document to calculate the mass and energy release rate to containment is highly conservative due to the assumption that what liquid exits the break will exit at the steam enthalpy. Plots of the containment pressure and temperature response are included at the end of this Appendix.

COMED SLB INSIDE CONTAINMENT
102% POWER, 4.4ft2, MSIV, Case 1 - LOW LEVEL



14b.1

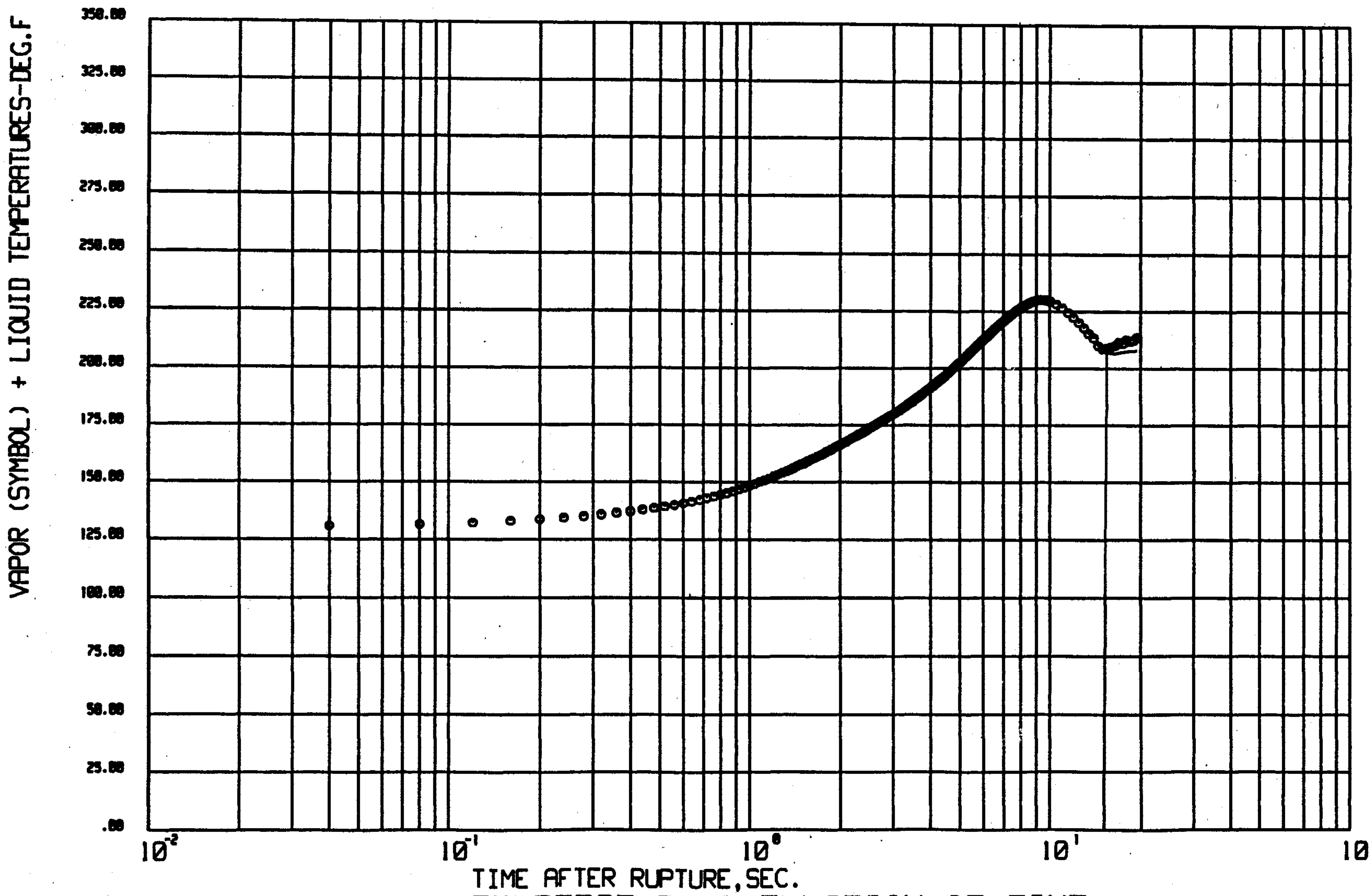
UWCO FOQX FGVP_QUALE054



146.2

UWCO FOQX FGVP_VOIDG064

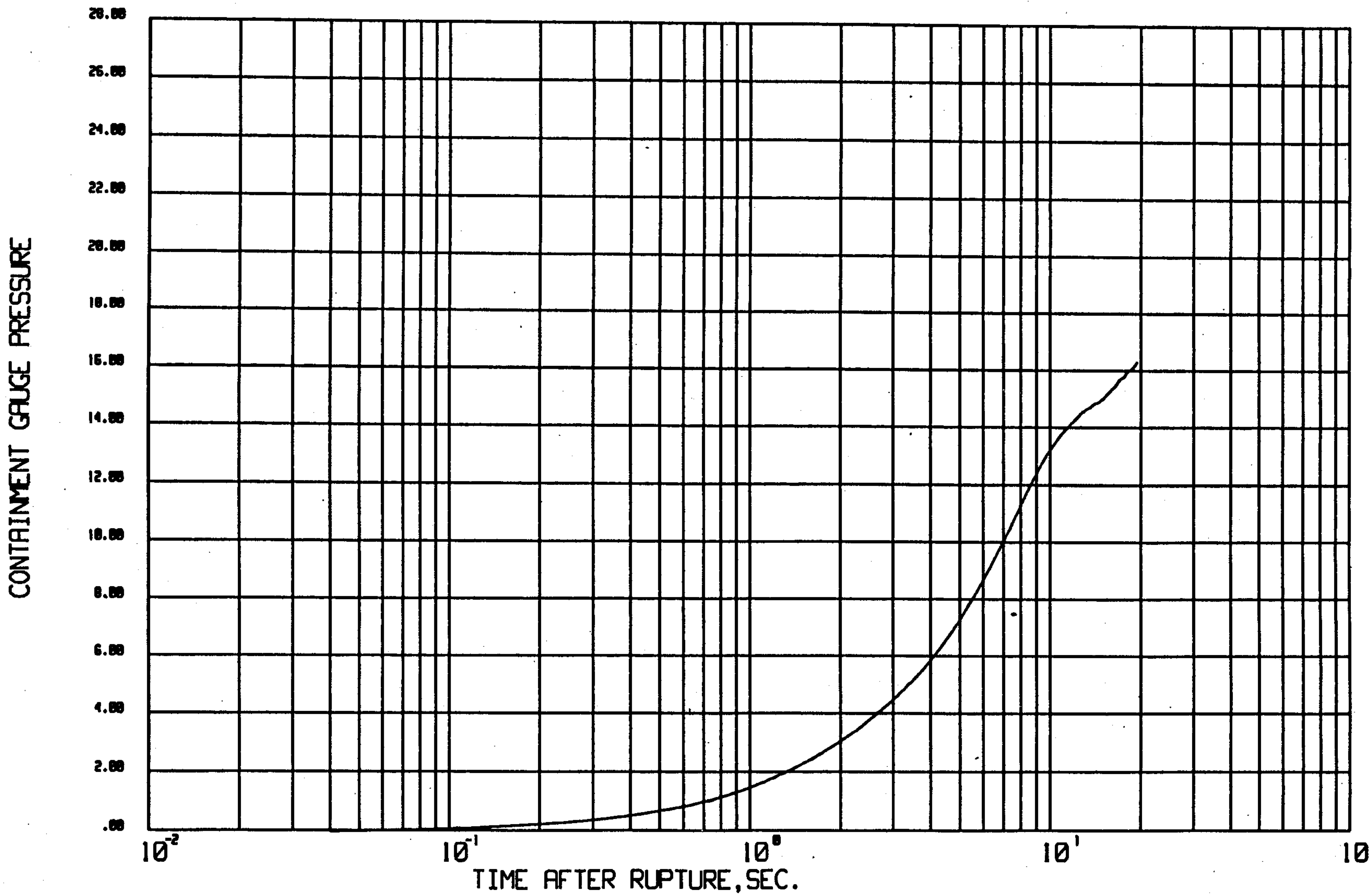
CONTEMPT COMED CASE 1 - low level
VS. 23.0 (APR.,96)



TEMPERATURE A FUNCTION OF TIME

CONTEMPT COMED CASE 1 - low l

VS. 23.0 (APR.,96)



PRESSURE AS FUNCTION OF TIME

Appendix B: Break Location

A concern was raised during the review of this document concerning the break location. The break location was located just upstream of the MSIVs, and the pressure drop from the single SG to the break could potentially reduce the M&E release rate. While the pressure drop would be maximum for the single SG, it would be minimized for the triple SG. To quantify the impact, case1 was reperformed where all frictional and form losses in the steam line piping were removed between the single steam generator and the break location.

Another concern was potential double choking at the SG nozzle and the break location for the single SG may introduce errors in the calculated M&E release. To quantify this impact of the choking location, case1 (DER) was reperformed with the choking option flag on at the single SG nozzle only. This change will in essence negate the change made to form and frictional losses in the steam line between the single SG and break with the conditions in the steam line not influencing the flow from the single SG while choked at the nozzle.

The following changes were applied to case1. All form and frictional losses were removed from the steam lines between the single SG and the nozzle. For node 672:

```
6720000  "ST1"  "PIPE"
6720001  3
6720101  4.929  3
6720201  0.0    2
6720301  43.656 1
6720302  39.713 3
6720601  0.0    1
6720602  -90.0  3
6720701  0.0    1
6720702  -39.666 3
```

```
6720801  0.00015  0.0    3
6720901  0.0      0.0    1
*        ^^^      ^^^ No form losses
6720902  0.0      0.0    2
6721001  10    3
*  No Fric ^^
6721101  01000 2
6721201  0        1125.7  556.75  1106.5  0.99994  0.0    3
6721301   72.385  85.219  0.0     1
6721302   85.693  85.264  0.0     2
```

And for the branch just prior to the break (node 673):

```
* 673 split from 672 for break modeling
*
6730000  "ST2"   "BRANCH"
6730001  1       0
6730101  4.929    21.25   0.0    0.0    0.  0.
6730102  0.00015  0.0   0010
*                 No Friction  ^
6730200  0        1125.7  556.74  1106.5  0.99994
6731101  672010000 673000000  0.0   0.00   0.00   01000
*                        No Form Losses ^^^^   ^^^^
6731201   84.833  85.255 0.0
```

The choking was removed from the break of the single SG with choking remaining only at the nozzle. Node 856 was re-entered with the choking flag turned off:

```
8560101   673010000   572000000  4.4   1.0   1.0E+6   01100
```

• CHOKING REMOVED ^

With these changes, the case was titled "SLBC1C_1" and run for 20 seconds transient time. The results of this run show that the integrated mass release from the single SG at 20 seconds transient time (170.0 seconds RELAP5 time) decreased from 52821. for case "SLBC1_1" to 52932. lbm for case "SLBC1C_1" demonstrating no significant difference.

Appendix C: Transient Plots