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# APPLICATION OF THE MELCOR CODE TO DESIGN BASIS BWR CONTAINMENT ANALYSIS

A. Notafrancesco
H. Esmaili
B. Lee[1]
J. L. Tills (JTA, Inc.)[2]

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Fuel and Source Term Branch
Division of Systems Analysis
Office of Nuclear Regulatory Research
United States Nuclear Regulatory Commission

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[1] Office of Nuclear Reactor Regulation, Containment & Ventilation Branch

[2] Contractor to Sandia National Laboratories, Reactor Modeling & Analysis Department

# ABSTRACT

The MELCOR computer code has been developed by Sandia National Laboratories under USNRC sponsorship to provide capability for independently auditing analyses submitted by reactor manufactures and utilities. MELCOR is a fully integrated code (encompassing the reactor coolant system and the containment building) that models the progression of postulated accidents in light water reactor power plants. To assess the adequacy of containment thermal-hydraulic modeling incorporated in the MELCOR code for application to standard boiling water reactor (BWR) pressure suppression systems, i.e., Mark I, II, and III containment configurations, each design type was analyzed. This report documents MELCOR code demonstration calculations performed for postulated design basis accident (DBA) analysis (e.g., large recirculation line breaks) inside containment which are compared to other code results.

The MELCOR code demonstration calculations performed were compared to CONTAIN code calculations. These code-to-code comparisons reveal an “equivalency” between the calculated results, and therefore, MELCOR can be used for these types of design basis analyses. Moreover it was shown that the MELCOR code was more suited and superior to CONTAIN in the long-term DBA demonstration plant case in which a simplified RPV control volume was modeled. So the modeling efficiency and performance for this type of analysis provided an added benefit when using MELCOR.

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| | |
|---|---|
| BWR | Boiling Water Reactor |
| DBA | Design Basis Accident |
| ECCS | Emergency Core Cooling System |
| EOS | Equation-of-State |
| FSTB | Fuel and Source Term Branch (NRC/RES) |
| HWL | High Water Level |
| LOCA | Loss of Coolant Accident |
| LWL | Low Water Level |
| MSLB | Main Steam Line Break |
| NRC | U.S. Nuclear Regulatory Commission |
| RCS | Reactor Coolant System |
| RES | Office of Nuclear Regulatory Research (NRC) |
| RHR | Residual Heat Removal |
| RPV | Reactor Pressure Vessel |
| SNL | Sandia National Laboratories |
| SP | Suppression Pool |
| SRP | Standard Review Plan |
| DW | Drywell |
| WW | Wetwell |
| CV | Control Volume |

# 1.0 INTRODUCTION

## 1.1 Background

The MELCOR computer code [1,2] was developed by Sandia National Laboratories (SNL) under U.S. Nuclear Regulatory Commission (NRC) sponsorship to provide capability for independently auditing analyses submitted by reactor manufactures and utilities. MELCOR is a fully integrated code (encompassing the reactor coolant system [RCS] and the containment building) that models the progression of postulated accidents in light water reactors. Characteristics of accident progression that can be treated with MELCOR include the thermal-hydraulic response in the RCS, reactor cavity, containment buildings, and a variety of severe accident related processes.

In order to assess the adequacy of containment thermal-hydraulic modeling incorporated in the MELCOR code for application to standard boiling water reactor (BWR) pressure suppression systems, i.e., Mark I, II, and III containment configurations, each design type was analyzed. This report documents MELCOR code [version 1.8.6_YV_3272] demonstration calculations performed for postulated design basis accident (DBA) analysis (recirculation line break) inside containment which are compared to other code results. The NRC provides guidance though a variety of Standard Review Plans (SRPs) to nuclear reactor licensees about what types of calculations need to be performed, and what calculational methods can be used to demonstrate the adequacy of their containment systems designs. As such, these licensing methods were used as a guidepost for assessing MELCOR's performance in design basis containment analysis. Furthermore, advanced BWR designs are not discussed in this report but common aspects can be extracted, such as modeling of the main vents.

The CONTAIN code [3] was also developed by SNL and is a specialized computer code used to perform thermal-hydraulic calculations inside containment following a variety of postulated high energy breaks, and serves as a repository of accumulated knowledge in the area of containment analysis technology. CONTAIN incorporates the best current understanding of all relevant phenomena, and has an extensive validation base. The code is the NRC's principal containment analysis tool used to audit industry's safety analysis calculations. Accordingly, CONTAIN results are used to compare against MELCOR calculations. Specifically, targeted comparisons are evaluated for postulated *short-term* design basis LOCA (recirculation line) sequences inside standard BWR containments. Appropriately, the code user guidance will be similar to the existing licensing framework, e.g., as specified in the relevant SRP section. Thus, the calculated results would tend to be bounding in nature or biased in a conservative manner.

The MELCOR code DBA related assessments documented in this report are based on the CONTAIN code qualification report/user guide for auditing design basis BWR calculations [4]. Moreover, this CONTAIN report should be consulted for underlying insights, and those detailed annotated CONTAIN input files which are in the Appendices of the CONTAIN report are also included in the Appendices in this report.

## 1.2 Accident Phases and Key Phenomena

Generally, a containment functional design basis evaluation includes calculations of the key containment loads, i.e., pressure and temperature effects, associated with postulated large ruptures of the primary or secondary coolant system piping. The focus of this report is to demonstrate that the MELCOR code can be used to obtain peak conditions for auditing the licensing basis of the various BWR pressure suppression systems by providing adequate guidance in performing drywell and wetwell pressure and temperature transient response. Other key results obtained from these types of analysis are peak pressure differentials, such as between the drywell and wetwell volumes.

The qualitative nature of event sequence progression in BWR DBAs is similar for each of the containment types. During the blowdown of the reactor vessel, the mass and energy released from the primary system pressurizes the drywell. As the drywell pressure increases, the water in the main vents is accelerated and flows into the suppression pool. Within seconds, the vents clear of liquid and a two-phase mixture of gas, steam, and suspended water flows into the suppression pool. This two-phase flow initially creates a gas bubble at the downstream end of the vent, which causes level swell and eventually breaks through the pool surface. The relevant bubble dynamics include initial acceleration of the liquid surrounding the bubble, level swell in the suppression pool, steam condensation in the bubbles, and release of the gas and steam to the wetwell atmosphere after bubbles break through the suppression pool surface. This sequence of events is referred to as the vent-clearing transient. The peak drywell pressure is usually calculated in this short-term time period.

It is clear that the short-term peak drywell pressure (and drywell-wetwell pressure difference) is to a large extent controlled by the vent clearing time, the working definition of which is the time required for the gas to penetrate to the far end of the vents on the wetwell side. Therefore, this time should be calculated in a conservative manner. Since the drywell pressure is also controlled to some extent by the pressure rise in the wetwell, a number of complications arise: (1) the two-phase and the single-phase liquid flows related to vent clearing should be modeled conservatively to yield conservative pressure values, and (2) the pool inertia constraining the expansion of the gas bubble that forms on the downstream side of the cleared vents initially impedes two-phase flow. The pool swell associated with this bubble is expected to significantly affect two-phase flow in the vents between the time of clearing and the time of bubble breakthrough of the suppression pool surface. While two-phase flows can be treated with MELCOR, level swell and bubble inertia effects cannot be modeled. However, these effects are expected to be of minor importance.

In the long-term transient response, the peak wetwell pressure and suppression pool temperature responses are calculated, thereby determining the effectiveness of the pool heat exchanger to mitigate the continuing mass and energy input (decay heat) to the pool.

## 1.3 Code Comparisons

This report addresses the adequacy of the MELCOR code for DBA application principally by comparing to the CONTAIN results (with noted refinement stated below) which were previously documented in the CONTAIN BWR qualification report [4]. Chapters 2, 3, and 4 of this report will cover, respectively, the Mark I, Mark II, and Mark III configurations of BWR pressure suppression systems. Each chapter will review the relevant phenomenology for short-term DBA analysis and provide guidance on using MELCOR. Since the long-term transient analysis is common to each design, the demonstration calculation is included only in Section 2 for the Mark I analysis. This guidance is intended to show how to prepare input decks that will produce MELCOR calculations with an equivalent degree of conservatism to traditional approaches to DBA audit calculations. A listing of the plant input files for MELCOR and CONTAIN is provided in Appendices A-D. It is recommended to review the CONTAIN plant input deck first to understand the modeling approach and specifics. Then the MELCOR counter-part input deck would be better understood and could be used in future containment analysis evaluations.

Note that all CONTAIN plant cases were re-ran with the non-ideal water equation-of-state (EOS) option activated to coincide with the MELCOR baseline modeling where non-ideal water EOS is used. Generally, this option will result in slightly lower calculated peak pressures as compared to results using the ideal water EOS (default) option in CONTAIN.

## 2.0 MARK I CONTAINMENT ANALYSIS

In this section, methods are discussed that can be used to model the DBA response of Mark I BWR containments with MELCOR. Figure 2.1 depicts the Mark I containment and shows the reactor pressure vessel, the drywell, the vent system from the drywell to the wetwell, and the wetwell (suppression chamber). The wetwell is a torus-shaped configuration that contains the suppression pool.

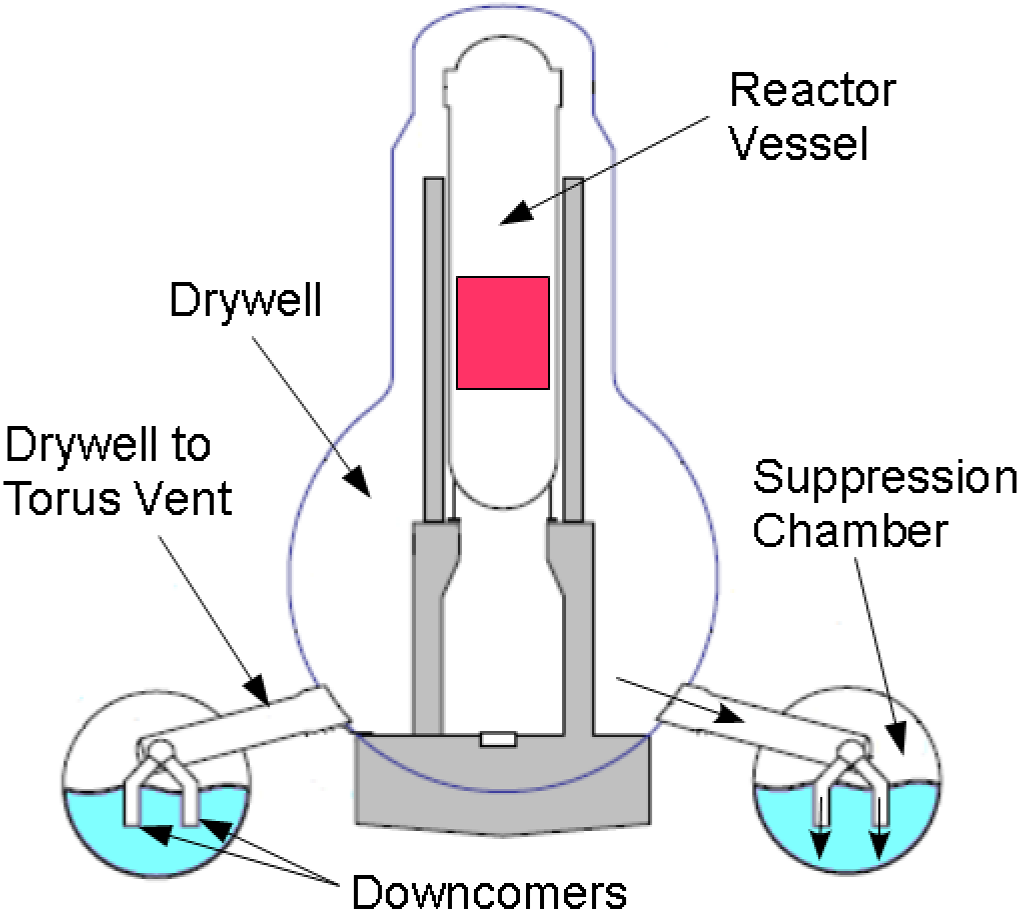

Figure 2.1 BWR Mark I containment

For the Mark I containment, two types of DBA MELCOR calculations are performed: (1) a short-term (blowdown period) for evaluation of the maximum drywell pressure and drywell temperature, and (2) a long-term period for the evaluation of the maximum wetwell pressure and pool temperature that occur some hours after the initial blowdown. These two types of calculations are discussed in Section 2.1 and Section 2.2, respectively. The procedures for the long-term scenario could also be used for evaluating the long-term response in Mark II and Mark III containment designs.

## 2.1 Mark I Short-Term Accident Analysis

### 2.1.1 Scenario & User Guidance

As noted in CONTAIN BWR qualification report [4], the Hope Creek plant analysis was selected as the Mark I demonstration plant, so MELCOR was used to model the same plant. The containment functional design evaluation includes consideration of several postulated accidents, each of which results in the direct release of reactor coolant into the containment. These postulated accidents include (1) an instantaneous guillotine rupture of a recirculation line, (2) an instantaneous guillotine rupture of a main steam line, (3) an intermediate size RCS break, and (4) a small size RCS break. Analysis of this spectrum of accidents indicates that the maximum temperatures and pressures calculated inside the containment may not all result from a single postulated accident sequence. Maximum drywell pressure occurs as a result of the recirculation line break. However, the most severe drywell temperature condition (peak temperature and duration) results from a small-size, steam-line break.

The maximum drywell pressure occurs near the end of the blowdown phase of a postulated large break LOCA. Approximately the same peak occurs for the break of either a recirculation line or a main steam line. However, for demonstration purposes, only the recirculation line break short-term scenario is analyzed for the Hope Creek plant.

The standard MELCOR flow path modeling is used for the suppression pool vent system. This model is used for vent clearing and vent gas flow of a BWR in terms of a serial arrangement of flow paths. As shown in Figure 2.2, the suppression vent system of a Mark I containment can be represented as a separate (vent-system) control volume (CV), with an upstream *horizontal* flow path (connecting the drywell to the drywell vents) and downstream *vertical* flow path (connecting the drywell vent pipes to suppression pool downcomers).

The modeling recommendations for a Mark I short-term scenario analysis are presented in Table 2.1. Furthermore in Appendix A, the CONTAIN input listing is extensively annotated to further explain the basis for the input parameters. The Hope Creek CONTAIN input deck is extracted from the CONTAIN BWR qualification report [4], but re-ran with the non-ideal water EOS option activated to coincide with the MELCOR baseline modeling where non-ideal EOS for water is used. The MELCOR input deck is also listed in Appendix A.

Note that the Mark I demonstration plant is based on the Hope Creek design. Therefore, vent characteristics, number of vents, etc., could be different for other Mark I designs, but the same methodology is still appropriate.

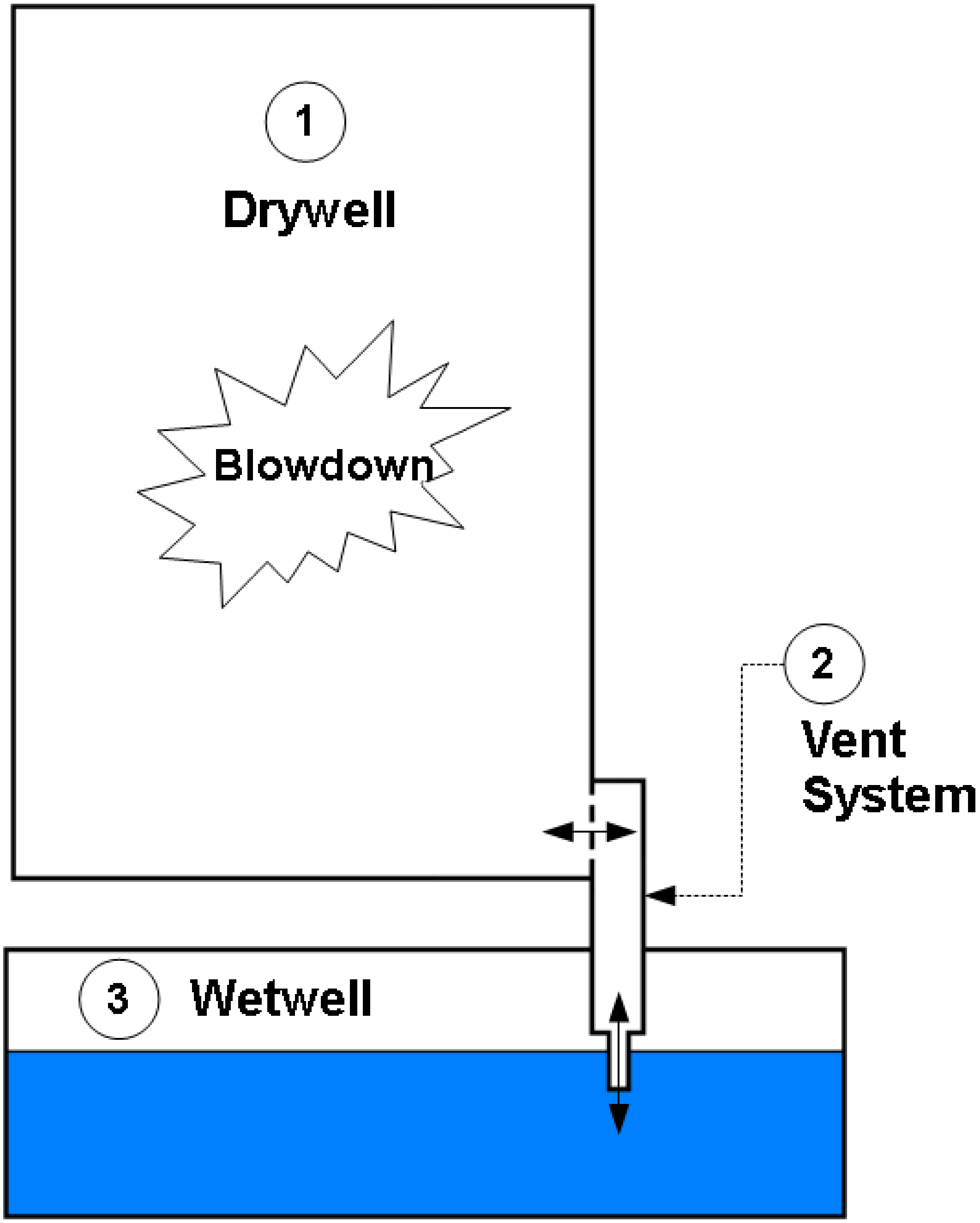

Figure 2.2 MELCOR three-CV model for BWR Mark I short-term analysis

### 2.1.2 Code Comparisons

Figures 2.3 through 2.6 present the MELCOR predicted transient response for various containment parameters for the first 10 seconds of the blowdown. The parameters include drywell and wetwell pressures and temperatures, and liquid and gas main vent flows. Comparisons are made to similarly modeled CONTAIN results. Vent clearing is assumed to occur when the initial liquid in the downcomer has reached the bottom of the downcomer, both codes predict vent clearing occurs at 0.3 seconds. Overall, MELCOR and CONTAIN results show excellent agreement.

If the margin between a plant's design values and the peak calculated values are small, sensitivity studies of significant parameters may be needed to understand the impact of inherent uncertainties. Key parameters for possible sensitivity study include those that affect the determination of the short-term peak drywell pressure. The peak pressure in turn is primarily determined by the dynamic response of the vent system, i.e., the vent clearing time. As a result, key parameters that should be considered for sensitivity analysis are the vent-system water (pool) level and the vent system flow path characteristics (loss and discharge coefficients, inertial length, and flow area).

Table 2.1 Modeling Recommendations for MELCOR BWR Containment Analysis

| Modeling Area | Recommended Approach |
|---|---|
| Drywell, vent system, and wetwell volumes based on a three-CV nodalization shown in Figure 2.2 | The drywell free volume is split between separate drywell and vent system CVs. Maximize the flow density in the atmosphere in order to minimize the two-phase flow rate through the vents by increasing the maximum allowed fog density by including sensitivity coefficient "SC00000 4406 10.0 1" in MELCOR. The vent system atmosphere conditions should be the same as those in the drywell. The vent system pool temperature should be the same as that for the wetwell pool. |
| Blowdown mass and energy rate | Introduce blowdown mass and energy as a drywell atmosphere source. To calculate peak DW pressure, this liquid blowdown water should be allowed to remain suspended in the atmosphere, so that the liquid contributes to the flow density in the suppression vent system. |
| Structural Heat Sinks | Heat and mass transfer to containment passive structures are not modeled. |
| Flow path characteristics | Use (a) the total flow path area, (b) the flow path *inertial length* term is proportional to the sum of the length/area for the individual segments, (c) an appropriate turbulent loss coefficient, and (d) a critical flow discharge coefficient of 0.7. For Mark IIIs, a critical flow discharge coefficient of 0.55 is recommended. |
| Wetwell equilibration between pool and atmosphere (only for Mark I and II designs) | To remove the wetwell superheating effect caused by the work done by compression as DW noncondensible gases bubble through the suppression pool, the CV thermodynamic switch for defining the WW volume should be set to equilibrium. |

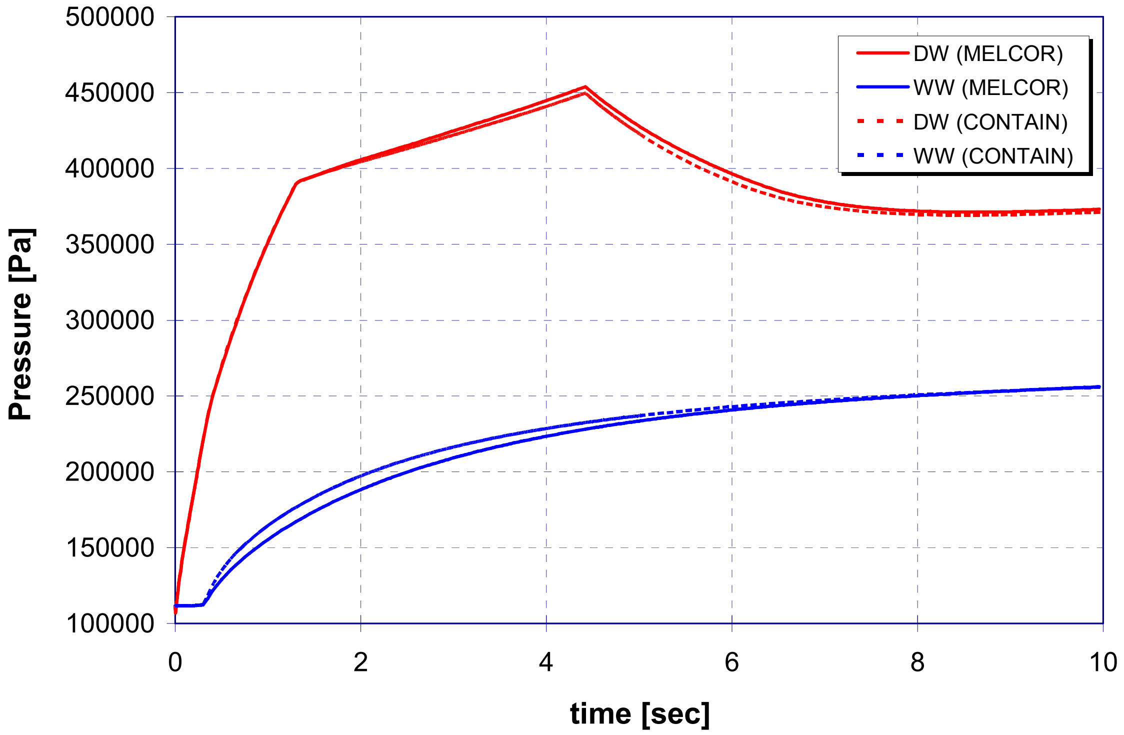

Figure 2.3 Containment pressures for the Hope Creek short-term scenario

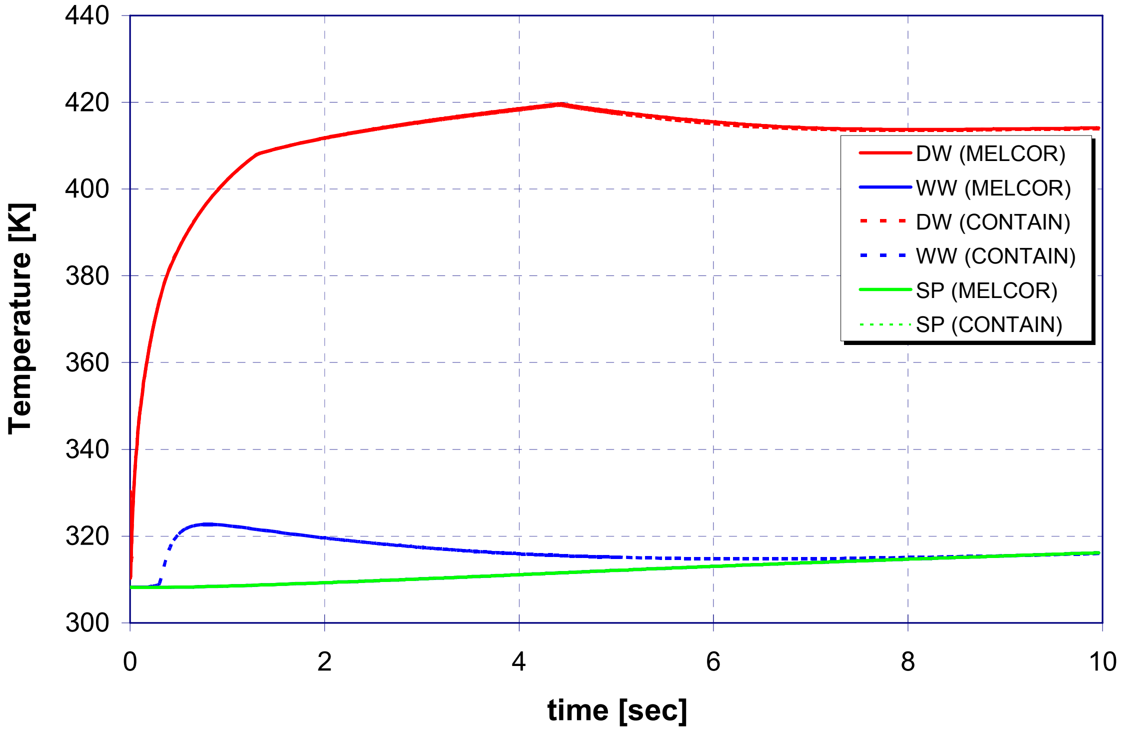

Figure 2.4 Containment temperatures for the Hope Creek short-term scenario

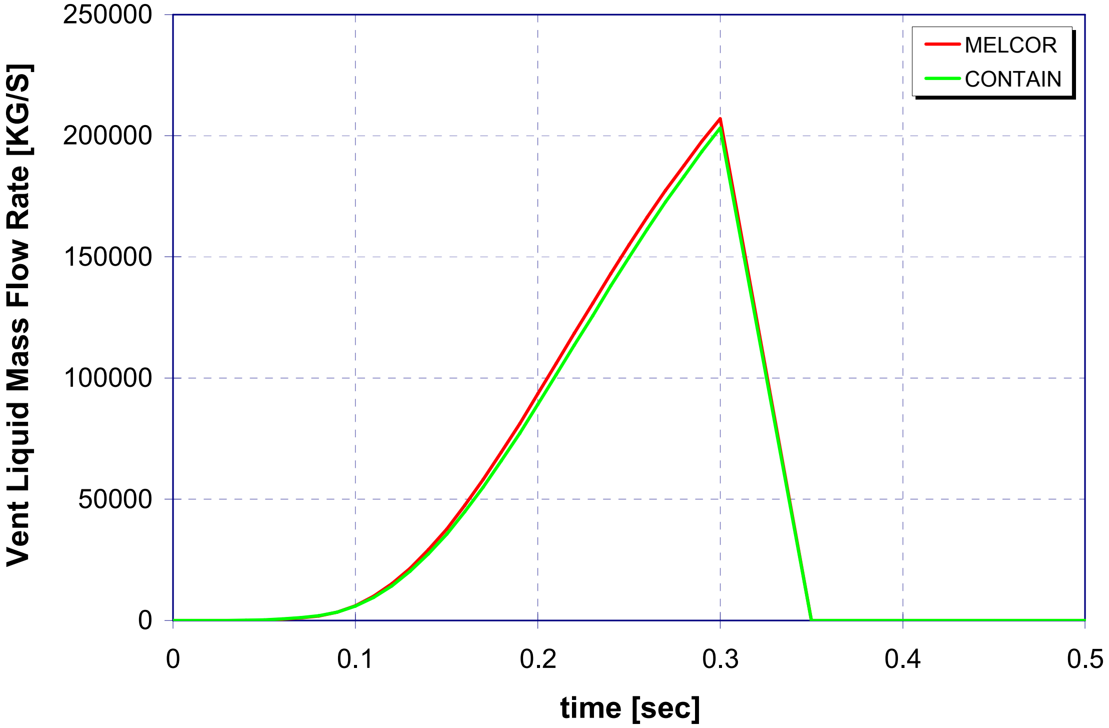

Figure 2.5 Main vent liquid flow rate for the Hope Creek short-term scenario

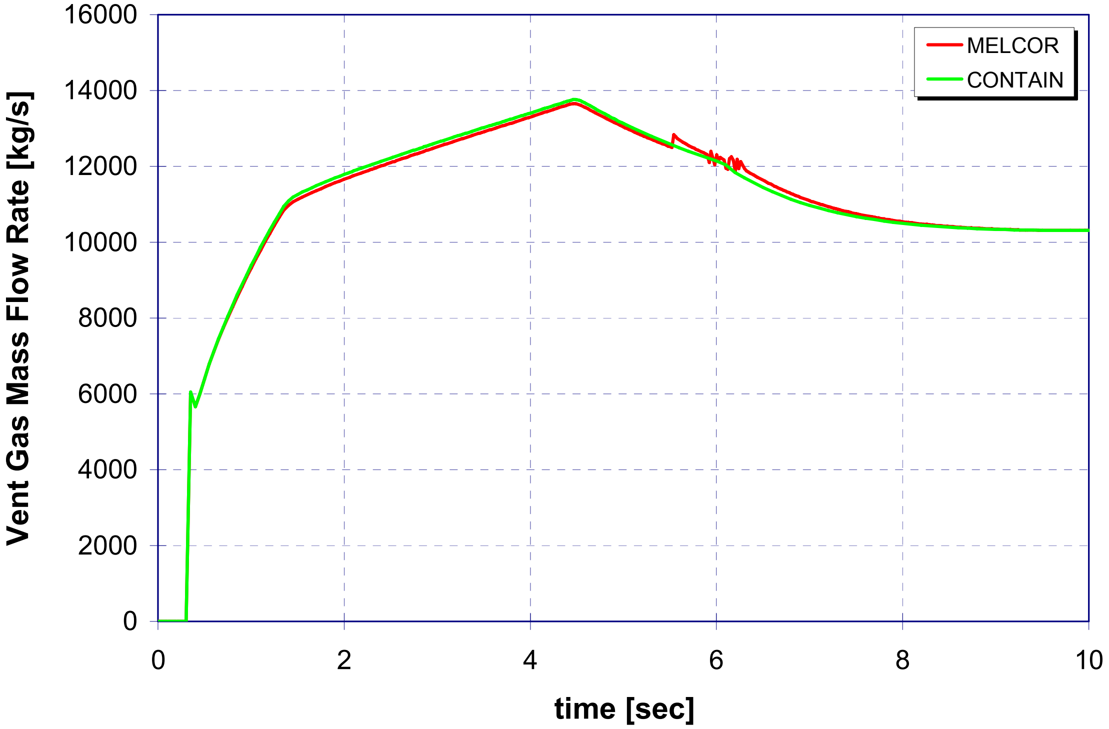

Figure 2.6 Main vent gas flow rate for the Hope Creek short-term scenario

## 2.2 Mark I Long-Term Accident Analysis

### 2.2.1 Scenario & User Guidance

As discussed earlier, the general approach recommended for long-term analysis will be the same for Mark I, Mark II and Mark III containments. Therefore, the approach will be described only in the context of the Hope Creek Mark I configuration. Essentially this analysis is to predict the long-term containment pressure and temperature transient which primarily assesses the effectiveness of the RHR heat exchanger over hours of accident time following the initial blowdown period. Consequently as the RHR heat removal exceeds the RPV heat generation, the steady containment pressure rise turns around, and the containment thermal loads continues to decline and the reactor system is under control.

Modeling to predict the long-term containment conditions, the short-term analysis model is used with the addition of long-term considerations. In particular, the initial conditions, CV dimensions and blowdown sources used for the short-term analysis are used for the long-term analysis with minor differences, such as specifying the suppression pool low water level (LWL) for the long-term analysis instead of what is used in the short-term analysis, i.e., the high water level (HWL). To maximize the heat load going into the suppression pool, retention of the liquid blowdown in the drywell atmosphere is not justified in the long-term analysis.

- For the long-term analysis following the blowdown period, the ECCS continues to provide suppression pool water for core cooling and long-term (mostly decay) heat removal.
- Flow from one RHR pump can be manually diverted from the RPV to the containment sprays. In the Mark I scenario presented here, no containment sprays are activated.
- The effects of decay heat, sensible energy, energy added by ECCS pumps, etc. are accounted for.
- The RHR heat exchanger (through the suppression pool) is the only long-term heat sink available in the containment system.

The modeling recommendations for the Mark I long-term scenario analysis are based on the model shown in Figure 2.7, which is an extension of the short-term model with additional long-term considerations. The major modeling addition is the RPV control volume. And consequently when modeling a “boiling water pot,” important processes need to be incorporated in the long-term model, such as, the RPV heat sources, the circulation of the suppression pool water through the RHR heat exchanger into the RPV, and the treatment of the RPV water over-flowing into the drywell.

Since there is no explicit heat exchanger model in MELCOR, “Control Functions” were used to mimic the selected CONTAIN heat exchanger model option, i.e., single-pass shell and tube geometry. Also, when converting the CONTAIN vent system modeling into the MELCOR counter-part deck, a small drywell pool forms in the MELCOR case whereas in CONTAIN such a pool is avoided. As shown in the next section, this difference has no effect on the results because in the long-term the overall temperatures of the pools and atmosphere are well mixed.

It is noteworthy that MELCOR is an integrated systems code whereas CONTAIN is a specialized code focusing in the containment analysis arena, so obviously the RPV control volume is more suited within the MELCOR framework. Consequently, the MELCOR four-CV model is somewhat simpler as compared to the CONTAIN model documented in the CONTAIN BWR qualification report [4]. In Appendix B, the CONTAIN input listing (with the non-ideal equation-of-state for water invoked to coincide with the MELCOR baseline modeling where non-ideal EOS for water is used) is extensively annotated to further explain the basis for the input parameters. And the counter-part MELCOR input deck is also listed. Note that this Mark I long-term containment analysis is for demonstration purposes of a specific design basis event. The modeling essentials are present which can be extended to other types of long-term sequences.

### 2.2.2 Code Comparisons

Figures 2.8 through 2.10 present the MELCOR predicted Hope Creek long-term transient response showing the “secondary” peak containment pressure where the RHR heat removal matches the RPV heat generation. Also, the drywell, wetwell and RPV thermodynamic conditions equilibrate to the same temperature. Comparisons are made to similarly modeled CONTAIN results. Overall, MELCOR and CONTAIN results show good agreement.

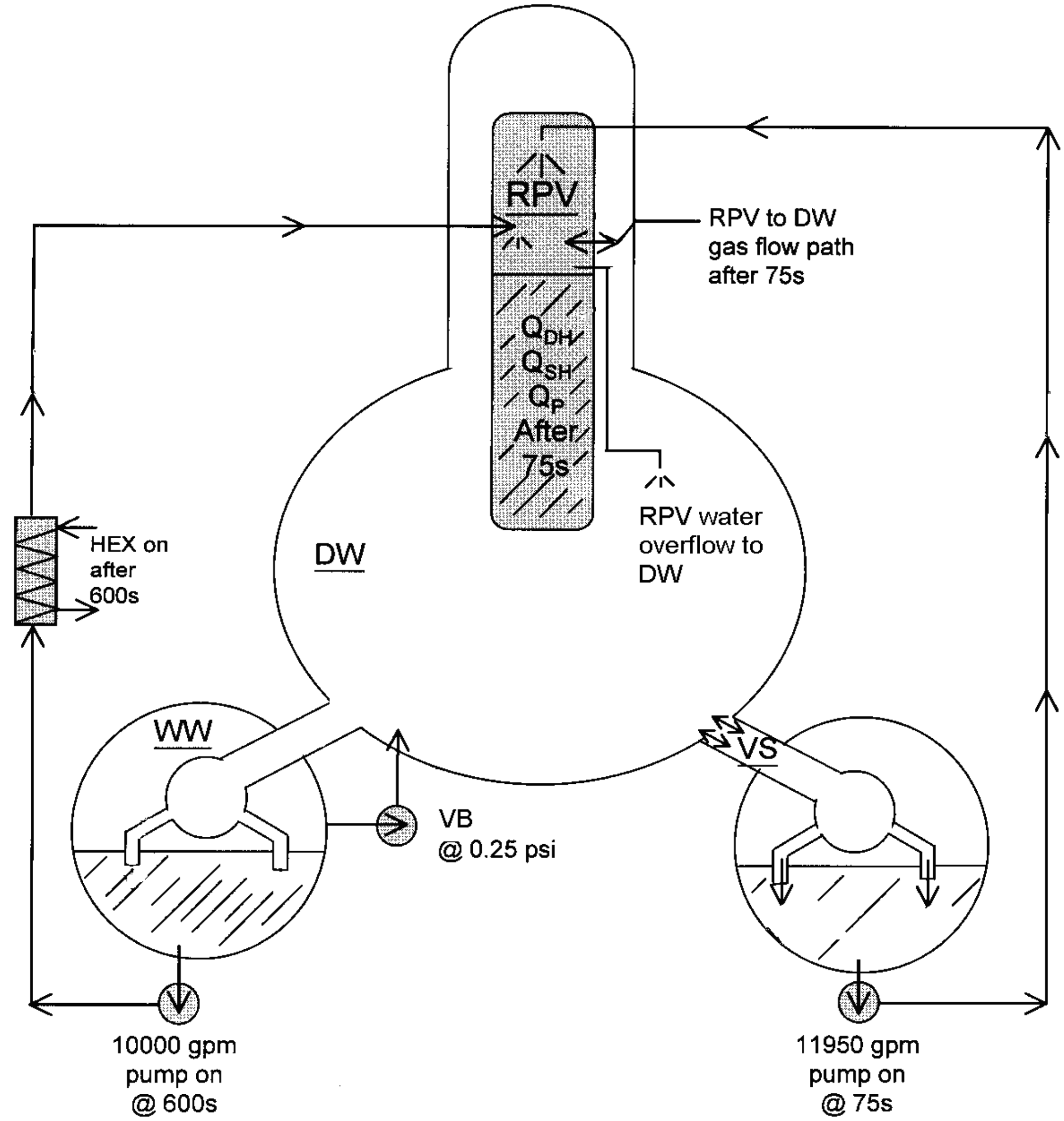

Figure 2.7 MELCOR four-CV model for a BWR Mark I long-term analysis

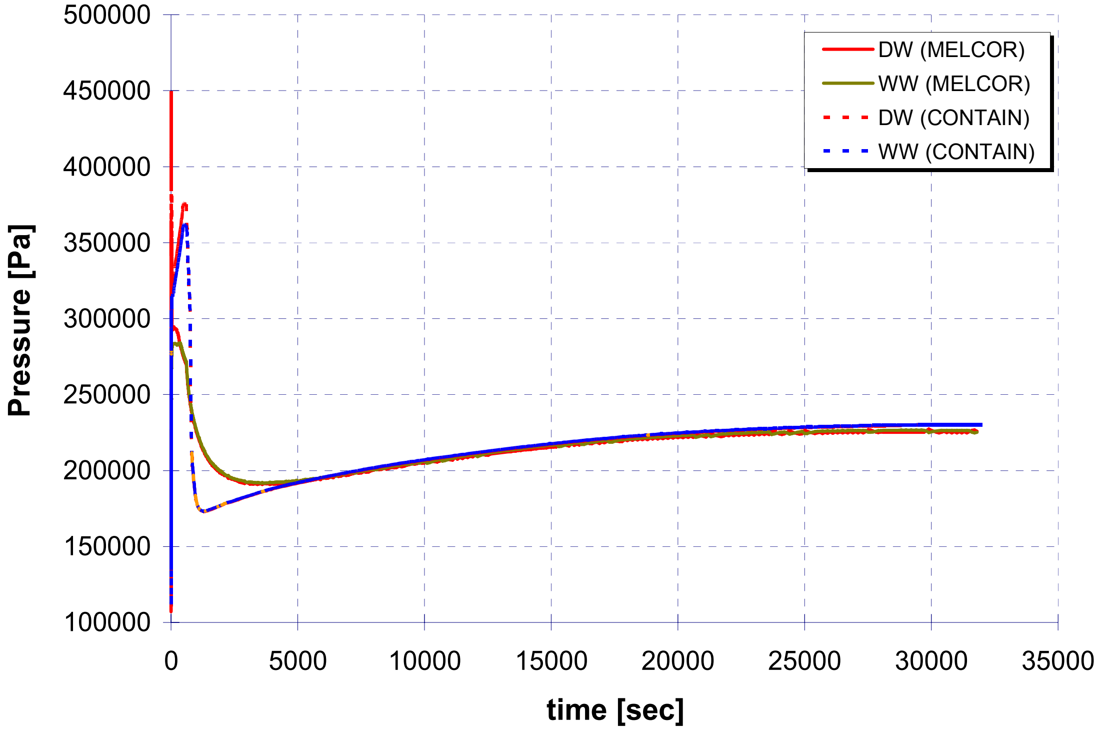

Figure 2.8 Containment pressures for the Hope Creek long-term analysis

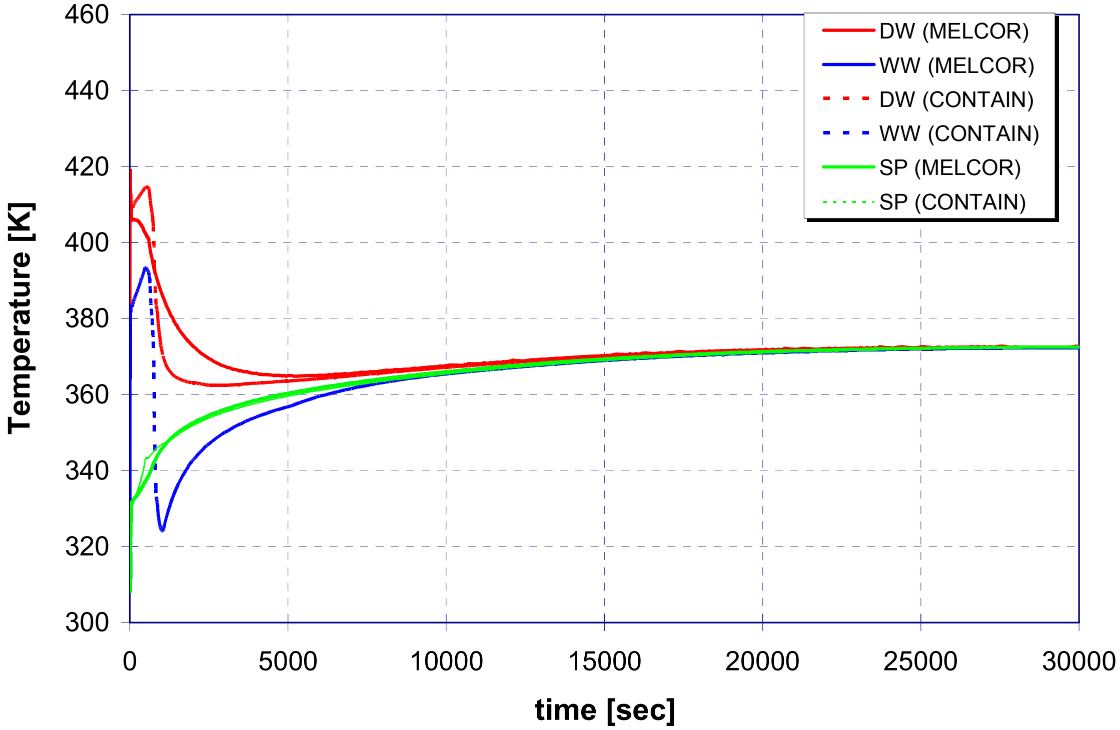

Figure 2.9 Containment temperatures for the Hope Creek long-term analysis

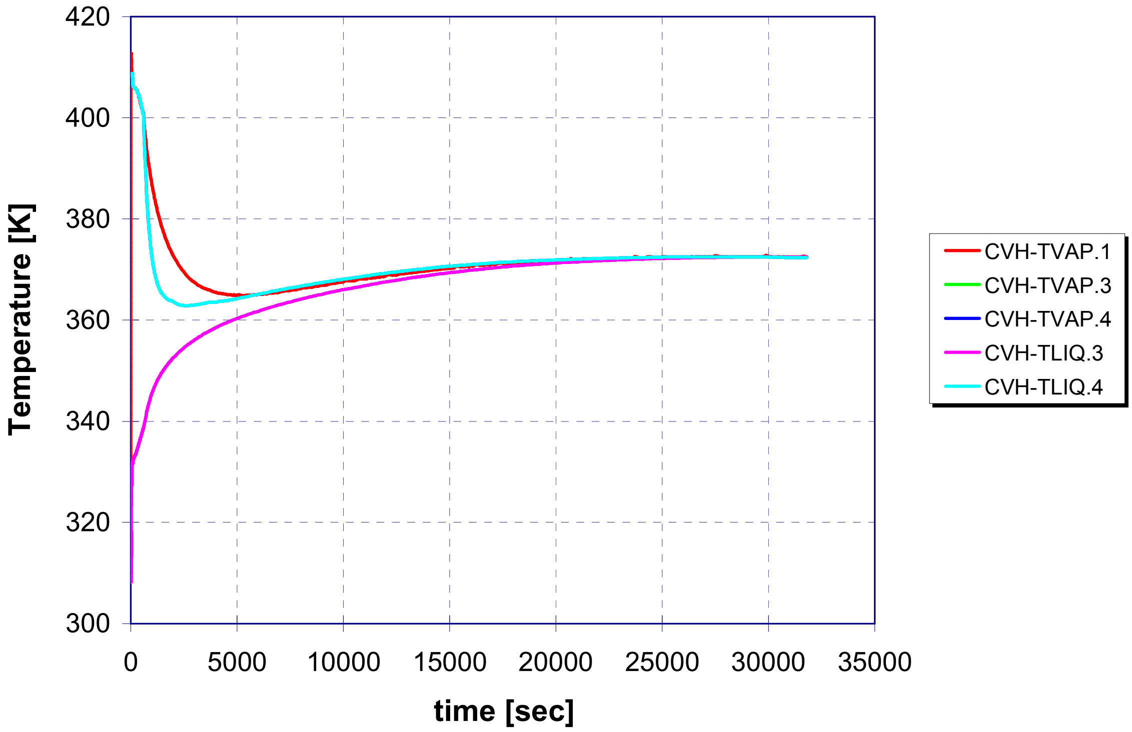

Figure 2.10 MELCOR calculated temperatures for gas and pool regions

## 3.0 MARK II CONTAINMENT ANALYSIS

Figure 3.1 depicts the Mark II containment and shows the reactor pressure vessel, the drywell, downcomers from the drywell to the wetwell, and the wetwell or suppression chamber. In this section, methods are discussed that can be used to model the short-term DBA response of BWR Mark II containments with MELCOR. This evaluation focuses on methods for calculating the maximum drywell pressure. For the long-term scenario, see Section 2.2 where recommendations for long-term analysis are described for the Mark I design.

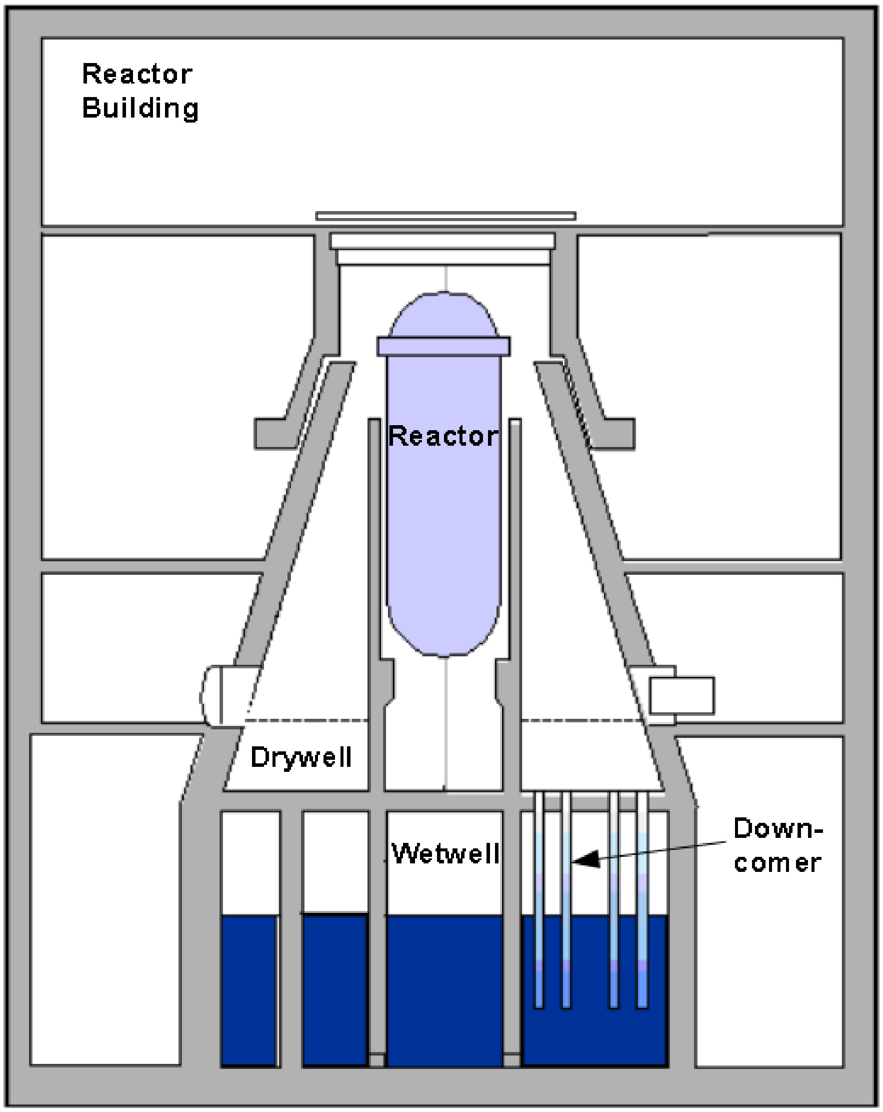

Figure 3.1 BWR Mark II containment

## 3.1 Mark II Short-Term Accident Analysis

### 3.1.1 Scenario & User Guidance

As noted in CONTAIN BWR qualification report [4], the Limerick plant analysis was selected as the Mark II demonstration plant, so MELCOR was used to model the same plant. Similarly as in the Mark I short-term analysis, of the spectrum of DBA accidents indicates that the maximum temperatures and pressures calculated inside the containment may not all result from a single postulated accident sequence. However, for demonstration purposes, only the recirculation line break scenario is analyzed in the Limerick sample calculation presented below.

The recommended approach for modeling the suppression pool vents in the Mark II containment is very similar to that discussed in Table 2.1 for the Mark I containment application. In particular, the downcomers of a Mark II BWR should be represented as a separate CV and its upstream and downstream vent paths are all *vertical* MELCOR flow paths.

In Appendix C, the CONTAIN input listing is extensively annotated to further explain the basis for the input parameters (re-ran with non-ideal water EOS option activated as done in the Mark I analysis). The MELCOR input deck is also provided in Appendix C. Note that the Mark II demonstration plant is based on the Limerick design. Therefore, vent characteristics, number of vents, etc., could be different for other Mark II designs, but the same methodology is still appropriate.

### 3.1.2 Code Comparisons

Figures 3.2 through 3.5 present the MELCOR predicted transient response for various containment parameters for the first 30 seconds of the blowdown. The parameters include drywell and wetwell pressures and temperatures, and liquid and gas vent flows. Comparisons are made to similarly modeled CONTAIN results. Vent clearing is assumed to occur when the initial liquid in the downcomer has reached the bottom of the downcomer, both codes predict vent clearing occurs at about 0.8 seconds. Overall, MELCOR and CONTAIN results show excellent agreement.

As stated before, key parameters for possible sensitivity study include those that affect the determination of the short-term peak drywell pressure, i.e., the vent clearing time. As a result, key parameters that should be considered for sensitivity analysis are the suppression pool water level and the vent system flow path characteristics.

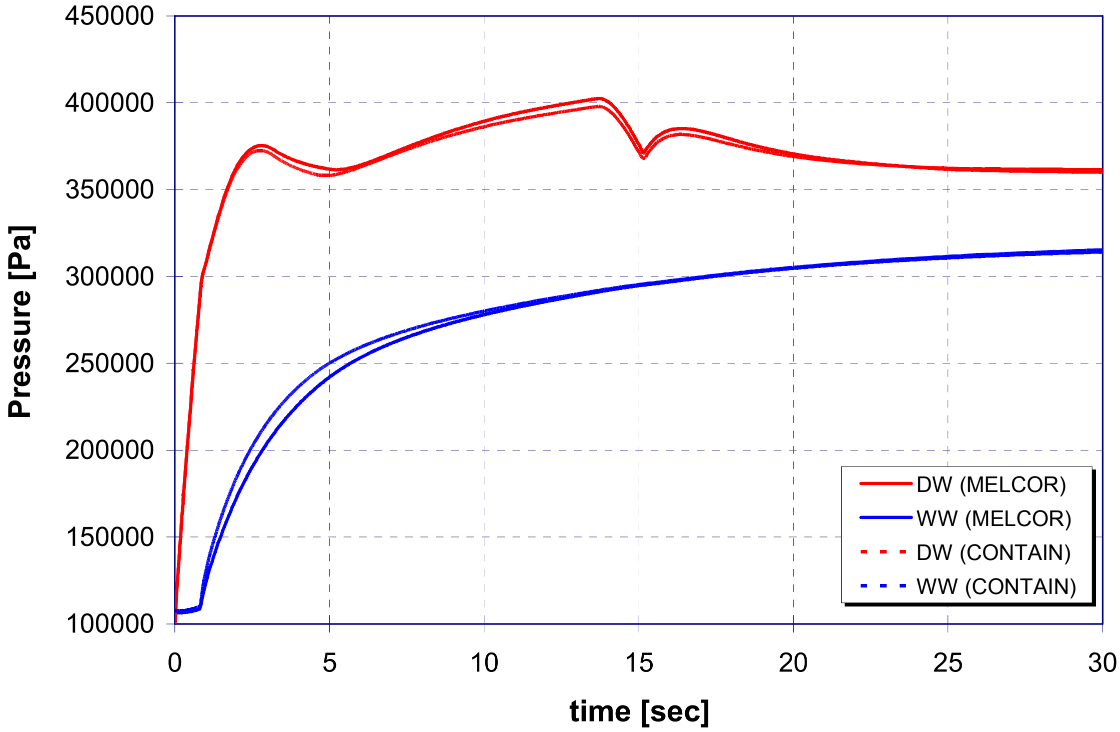

Figure 3.2 Containment pressures for the Limerick short-term scenario

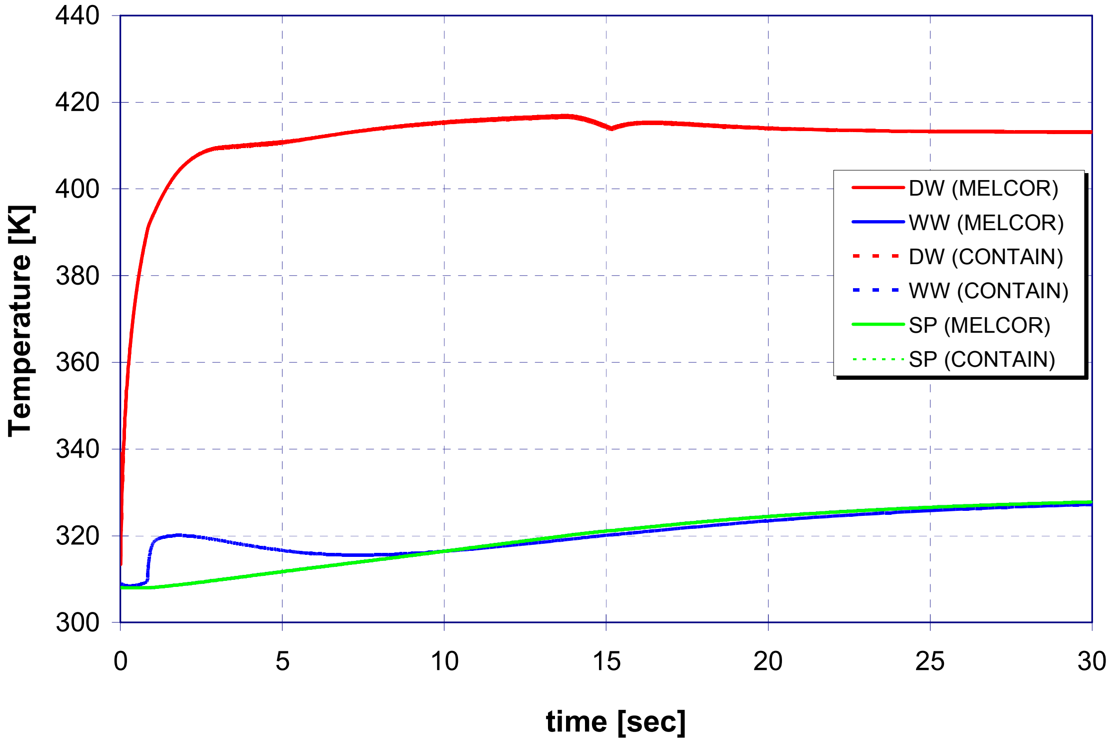

Figure 3.3 Containment temperatures for the Limerick short-term scenario

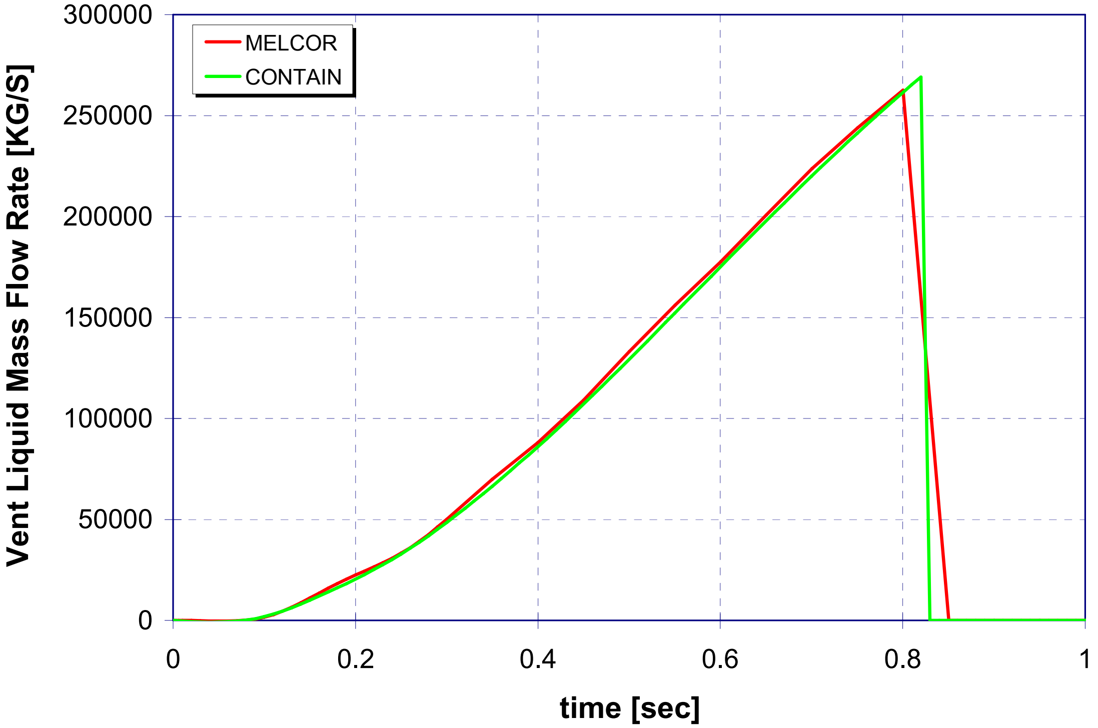

Figure 3.4 Main vent liquid flow rate for the Limerick short-term scenario

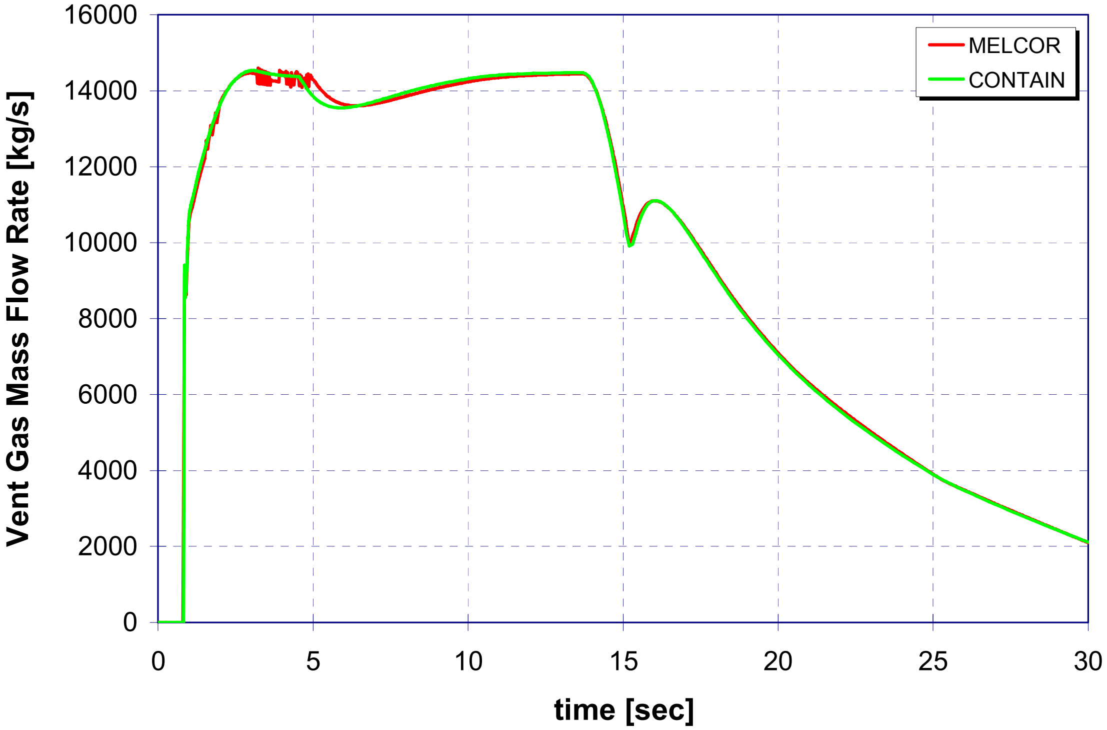

Figure 3.5 Main vent gas flow rate for the Limerick short-term scenario

## 4.0 MARK III CONTAINMENT ANALYSIS

Figure 4.1 shows the Mark III containment with three *horizontal* vents at different elevations from the drywell to the wetwell. In this section, methods are discussed that can be used to model the short-term DBA response (maximum drywell pressure) of BWR Mark III containments with MELCOR. The long-term analysis recommendations are similar to the Mark I design discussed in Section 2.2.

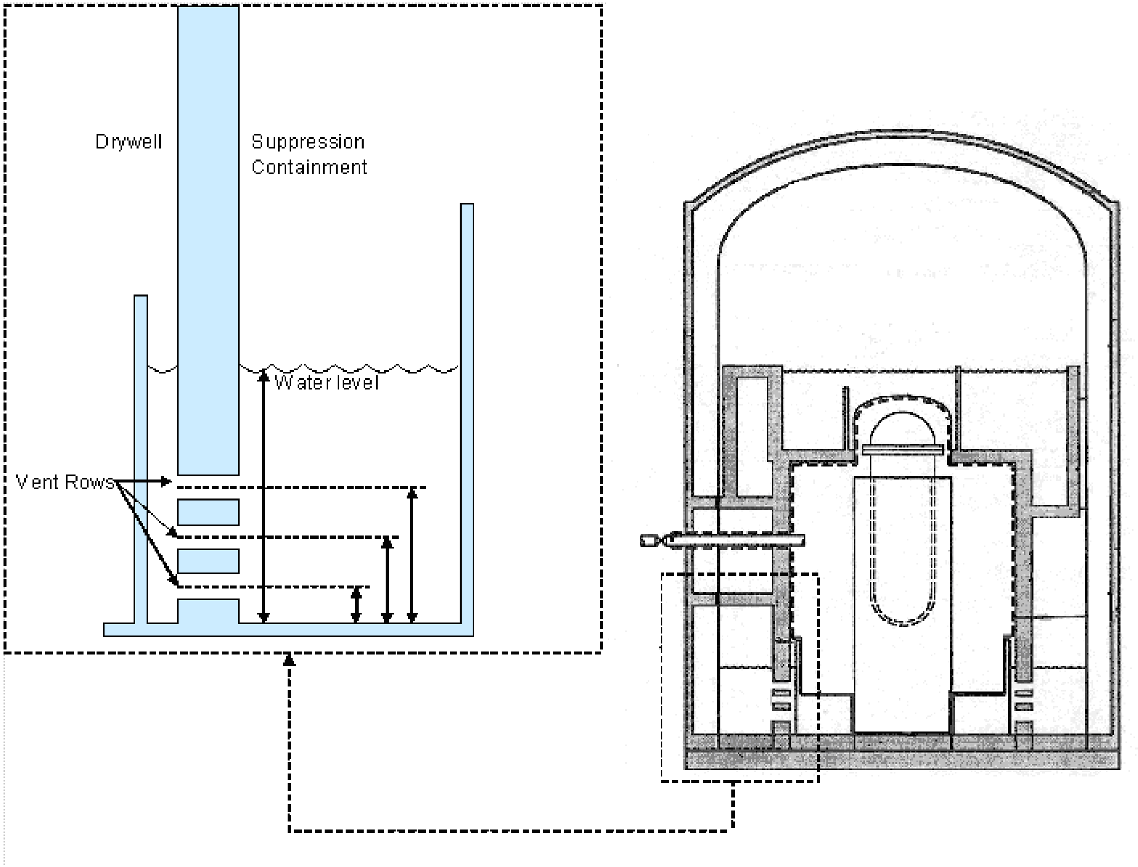

Figure 4.1 BWR Mark III containment

## 4.1 Mark III Short-Term Accident Analysis

### 4.1.1 Scenario & User Guidance

As noted in CONTAIN BWR qualification report [4], the Grand Gulf plant analysis was selected as the Mark III demonstration plant, so MELCOR was used to model the same plant. Analysis of various postulated primary system breaks, including double-ended recirculation line, double-ended main steam line, intermediate-sized liquid line, and small steam line breaks, indicate that the double-ended main steam line break (MSLB) typically yields the maximum pressure difference in a Mark III. However, the recirculation line break produces comparable pressures, and this scenario will be used in the sample calculation presented below.

The recommended approach for modeling the suppression pool vents in the Mark III containment is very similar to that discussed in Table 2.1 for the Mark I containment application. As shown in Figure 4.2, the drywell-annular pool region of a Mark III BWR should be represented as a separate CV; however, the horizontal main vents at three different elevation rows are unique as compared to the other BWR designs. Consequently, a key difference is that a critical flow discharge coefficient of 0.55 is recommended and calculating the main vent inertial lengths is more complicated. So a generalized table of inertial lengths to be used for the flow paths in modeling the main vents is extracted from the CONTAIN BWR qualification report [4] and shown in Table 4.1. Also note that these inertial lengths depend on the initial vent water submergence. And using Grand Gulf design values with the above cited table, Table 4.2 lists the flow path characteristics for developing the Grand Gulf input decks. Note that the Mark III demonstration plant is based on the Grand Gulf design. Therefore, vent characteristics, number of vents, etc., could be different for other Mark III designs, but the same methodology is still appropriate.

Furthermore in Appendix D, the CONTAIN input listing is extensively annotated to further explain the basis for the input parameters (re-ran with the non-ideal water EOS option activated). The MELCOR input file is also provided in Appendix D.

### 4.1.2 Code Comparisons

Figures 4.3 through 4.10 present the MELCOR predicted transient response for various containment parameters for the first 20 seconds of the blowdown. Overall, MELCOR and CONTAIN results show good agreement.

The breaks in the slopes of the CONTAIN pressure in Figure 4.3 are related to vent clearing in the top, middle, and bottom rows of suppression pool vents in the Mark III design; also see the breaks in the slopes in Figures 4.5 through 4.7. It should be noted that the clearing of the top row of vents in the Mark III is not sufficient to terminate the short-term pressure rise in the drywell: the drywell pressure continues to rise while two-phase flow (a mixture of steam, air, and water) occurs in the top vent. The drywell pressure rise terminates only after the second (or in some cases, third) row of vents clear. The key parameters for possible code sensitivity study are the same as for the Mark I and II designs.

Table 4.1 BWR Mark III effective main vents inertial lengths for different designs

| Top vent centerline submergence to initial water level | Vent Separation* = 1.27 | | | Vent Separation = 1.37 | | |
|---|---|---|---|---|---|---|
| | Top | Middle | Bottom | Top | Middle | Bottom |
| 2.43 | 3.82 | 5.43 | 6.69 | 3.79 | 5.50 | 6.88 |
| 2.28 | 3.70 | 5.26 | 6.48 | 3.67 | 5.33 | 6.67 |
| 2.13 | 3.58 | 5.09 | 6.28 | 3.56 | 5.16 | 6.46 |
| 1.98 | 3.46 | 4.92 | 6.07 | 3.44 | 4.99 | 6.24 |

*Refers to vertical distance between vent centerlines. (All values are lengths in meters and includes a 1.25 multiplier applied to the horizontal vent section lengths to correct for end effects.)

Table 4.2 Grand Gulf flow path characteristics

| Flow Path | Area, A ($m^2$) | Inertial Length, L (m) | A/L (m) | Elevation* (m) | MELCOR Loss Coefficient |
|---|---|---|---|---|---|
| Annulus Entry | 51.44 | 1.68 | 30.62 | 7.41 | 0.5 |
| Top Vent | 17.88 | 3.70 | 4.832 | 3.45 | 3.0 |
| Middle Vent | 17.88 | 5.26 | 3.399 | 2.18 | 3.0 |
| Bottom Vent | 17.88 | 6.48 | 2.759 | 0.91 | 3.0 |

* Relative to suppression pool bottom

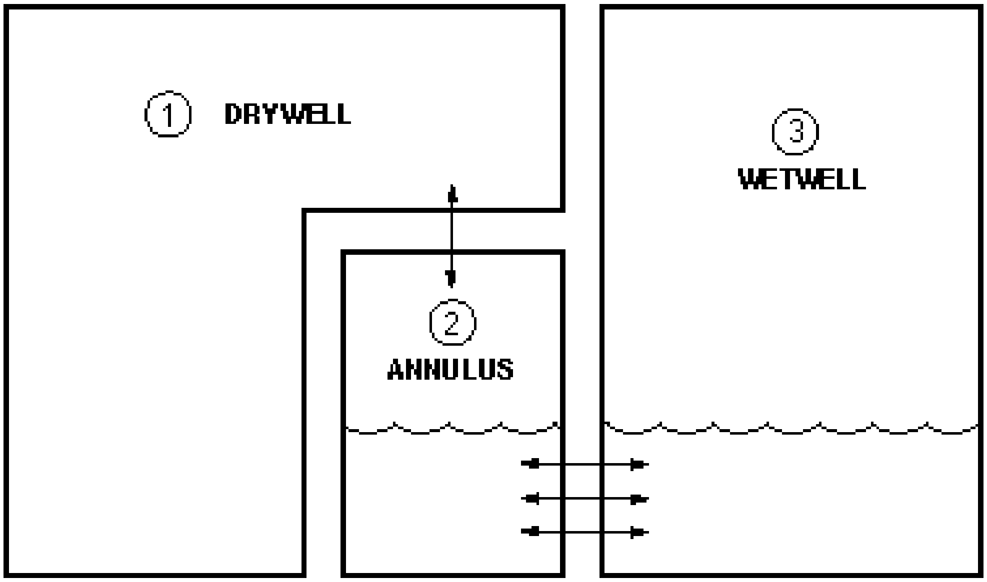

Figure 4.2 MELCOR three-CV model of BWR Mark III containment

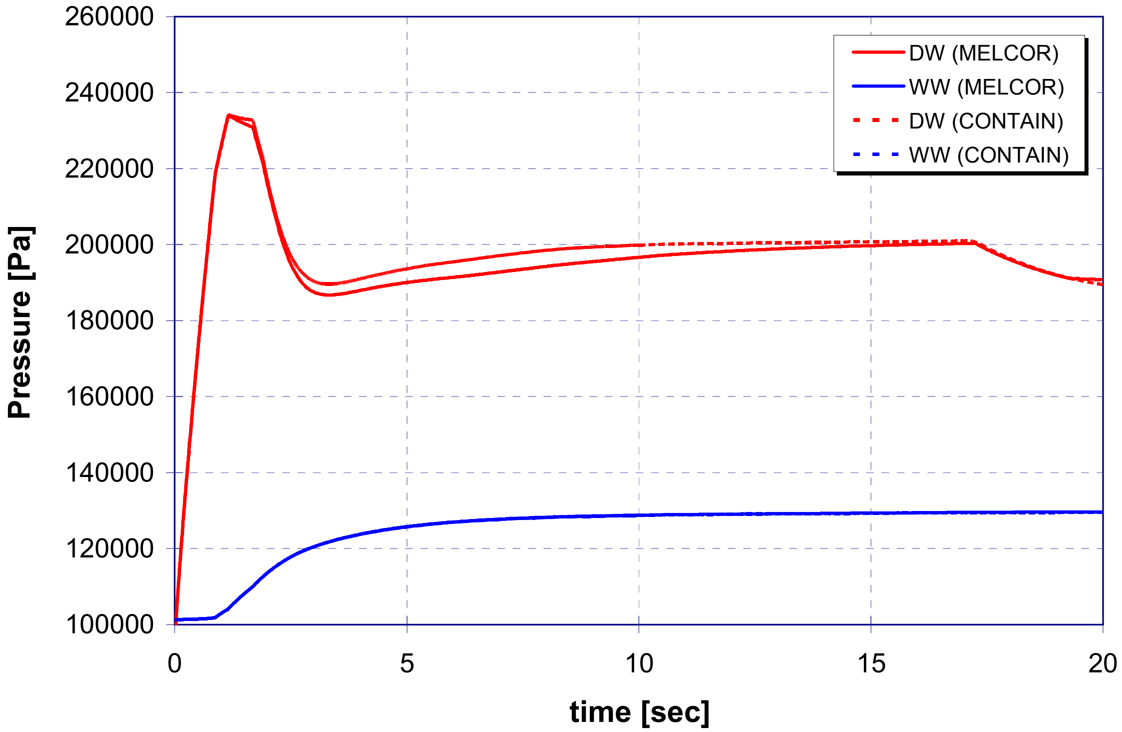

Figure 4.3 Containment pressures for the Grand Gulf short-term scenario

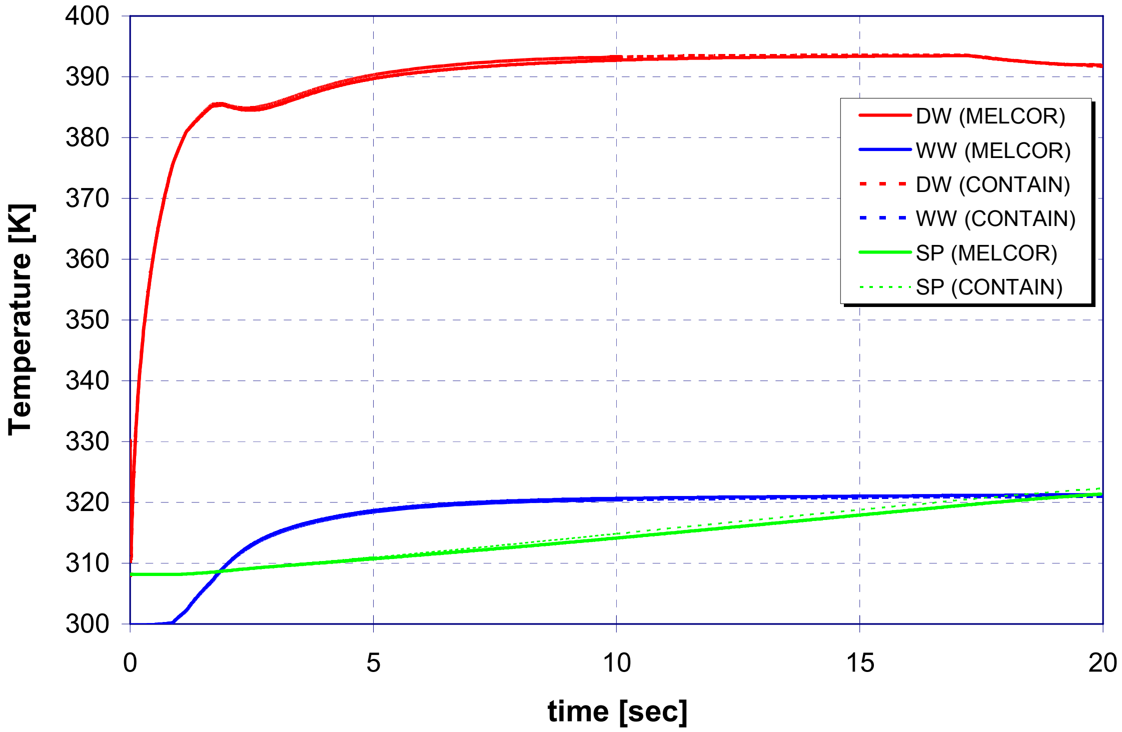

Figure 4.4 Containment temperatures for the Grand Gulf short-term scenario

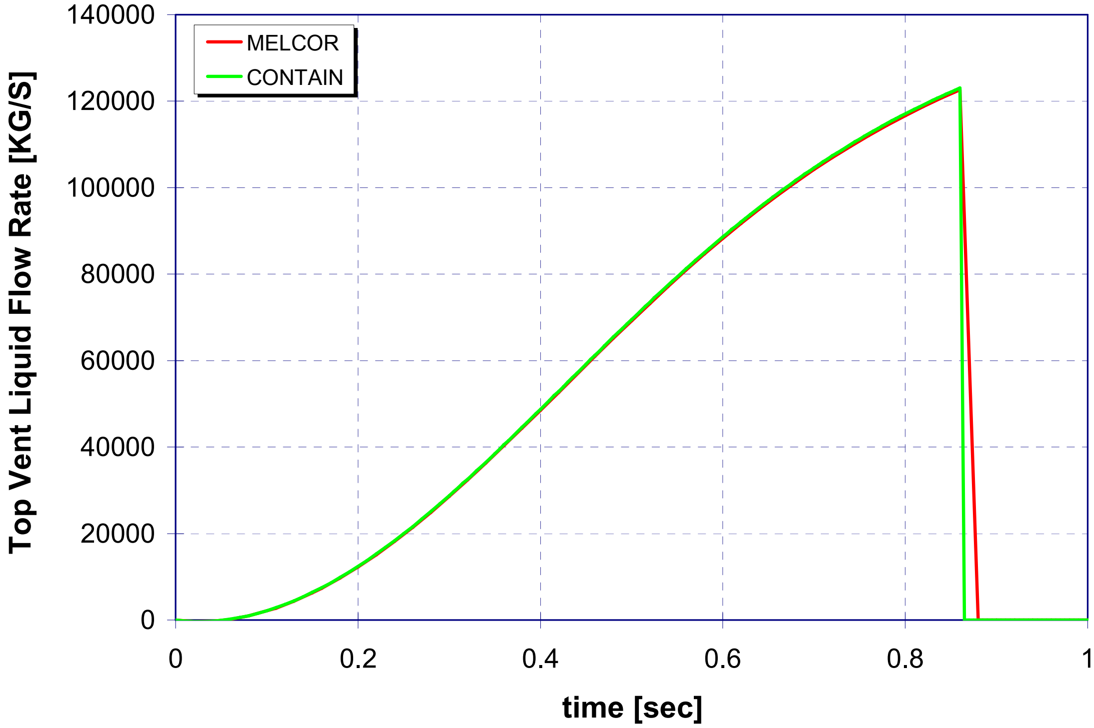

Figure 4.5 Top vent liquid flow rate for the Grand Gulf short-term scenario

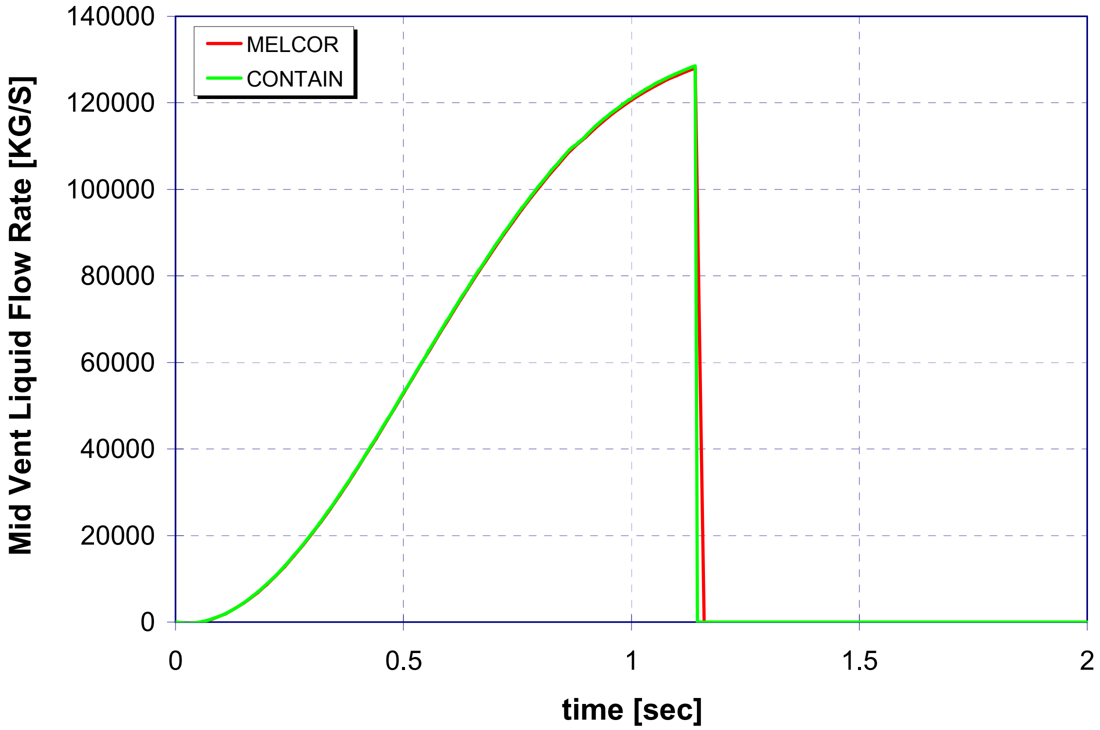

Figure 4.6 Middle vent liquid flow rate for the Grand Gulf short-term scenario

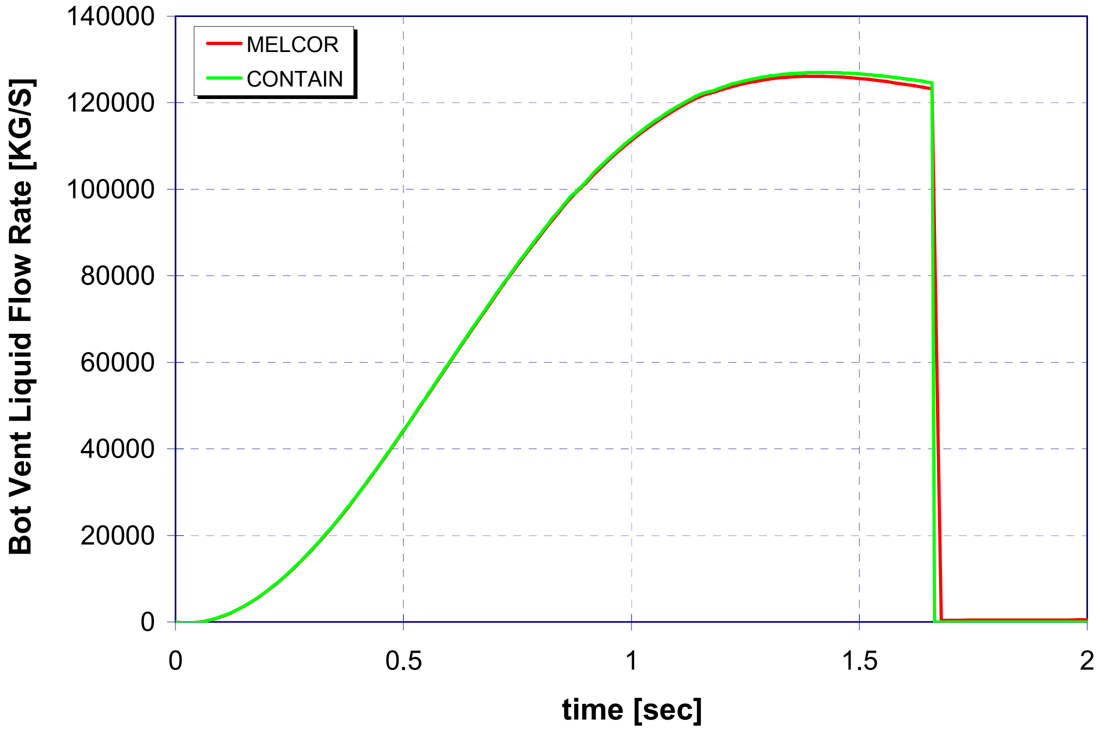

Figure 4.7 Bottom vent liquid flow rate for the Grand Gulf short-term scenario

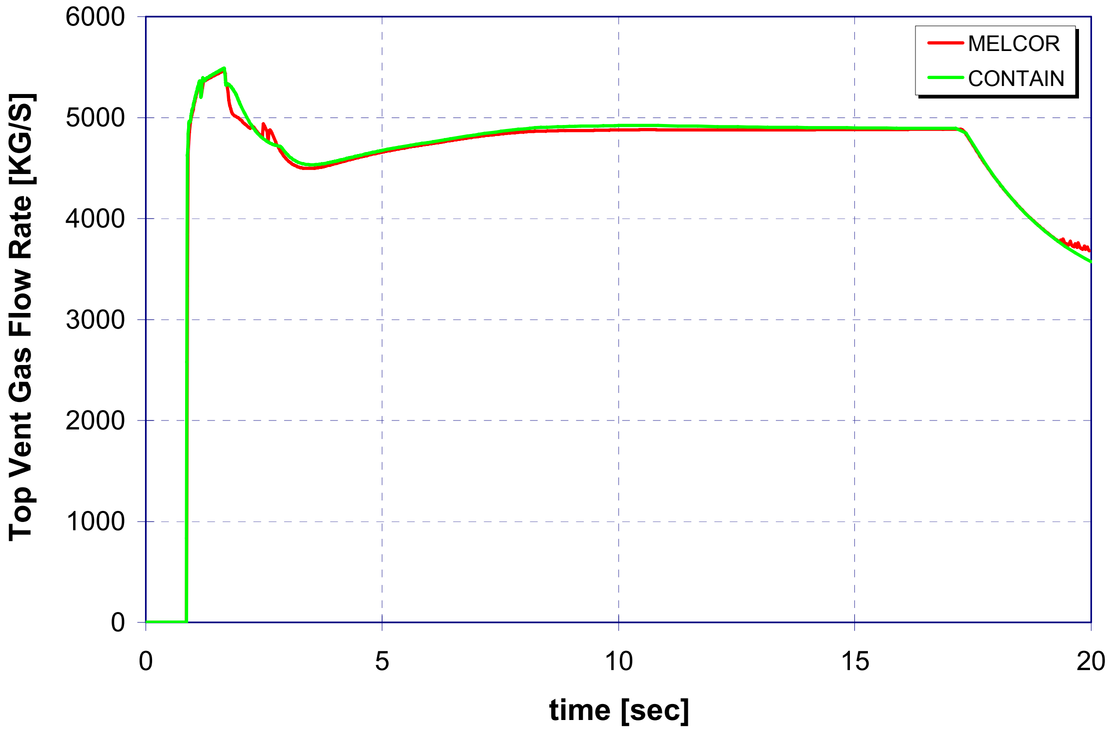

Figure 4.8 Top vent gas flow rate for the Grand Gulf short-term scenario

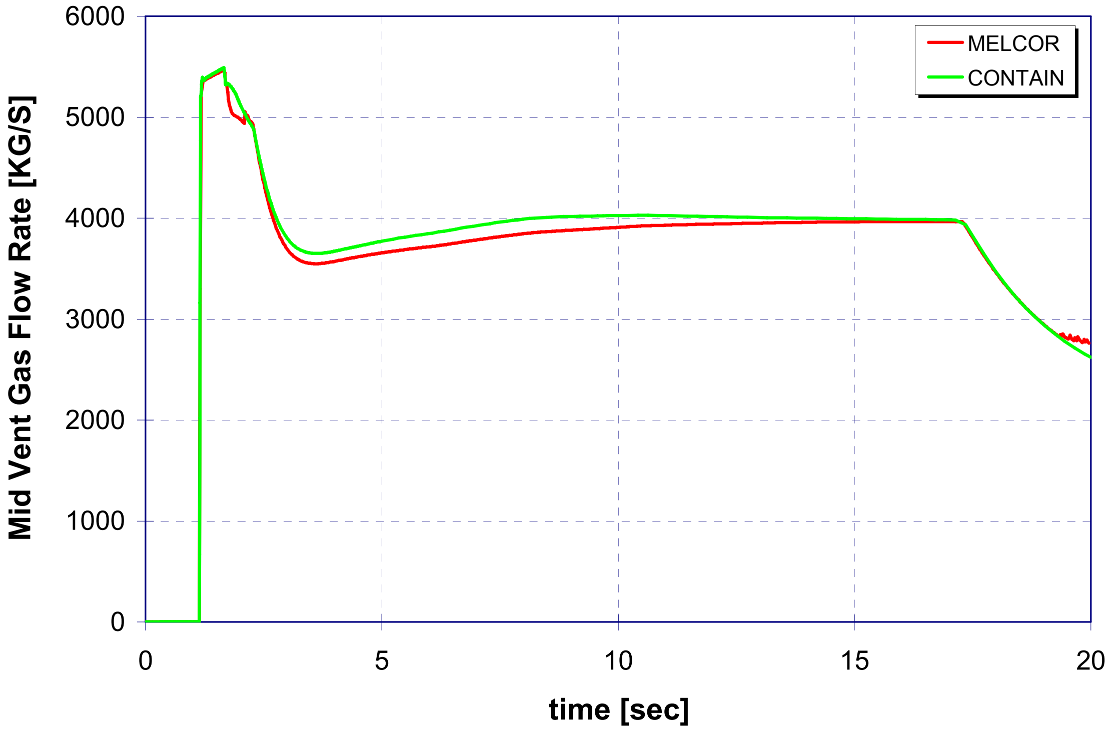

Figure 4.9 Middle vent gas flow rate for the Grand Gulf short-term scenario

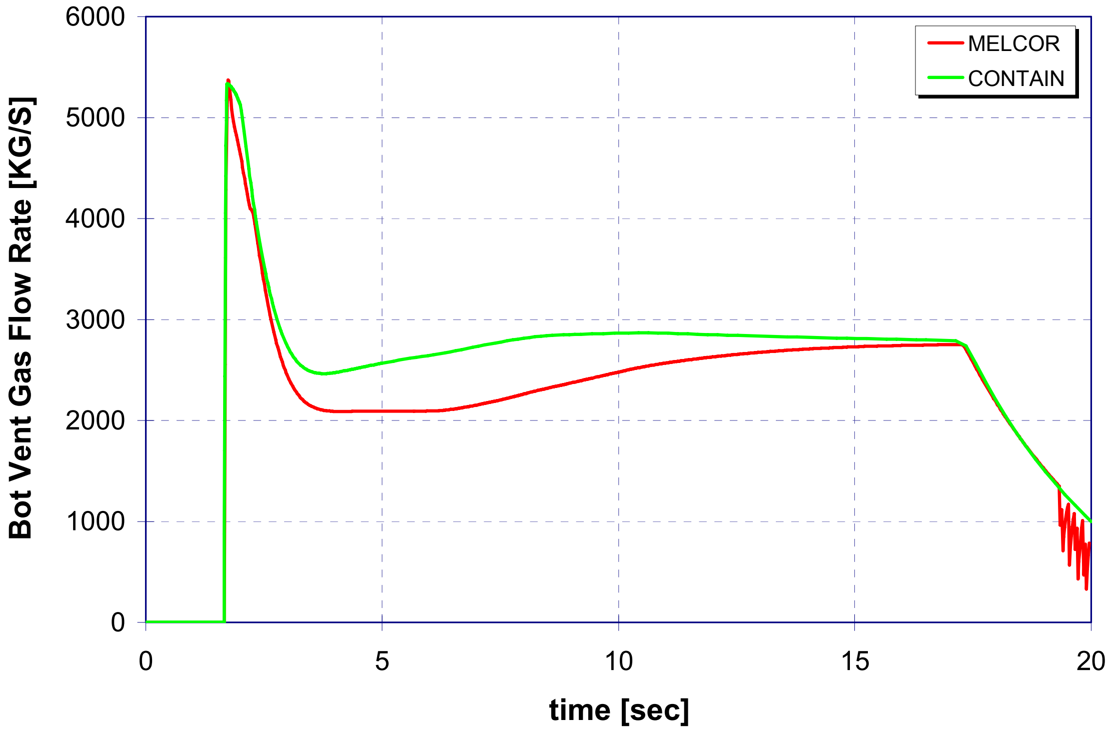

Figure 4.10 Bottom vent gas flow rate for the Grand Gulf short-term scenario

## 5.0 CONCLUSIONS

The main objective of this report was to assess the adequacy of containment thermal-hydraulic modeling incorporated in the MELCOR code to audit industry's safety analysis calculations for standard BWR pressure suppression systems. The BWR Mark I, II, and III containment configurations were analyzed in order to predict peak design basis pressure and temperature conditions inside the drywell and wetwell regions. The MELCOR code demonstration calculations performed were compared to CONTAIN code calculations. These code-to-code comparisons reveal an "equivalency" between the calculated results, and therefore, MELCOR can be used for these types of design basis analyses. Moreover it was shown that the MELCOR code was more suited and superior to CONTAIN in the long-term DBA demonstration plant case in which a simplified RPV control volume was modeled. So the modeling efficiency and performance for this type of analysis provided an added benefit when using MELCOR.

## 6.0 REFERENCES

1. Gauntt, R.O., et al., “MELCOR Computer Code Manuals – Vol.2: Reference Manuals, Version 1.8.6 September 2005,” NUREG/CR-6119, Vol. 2 Rev 3, SAND 2005-5713, Sandia National Laboratories, Albuquerque, New Mexico, September 2005.

2. Gauntt, R.O., et al., “MELCOR Computer Code Manuals – Vol.1: Primer and User’s Guide, Version 1.8.6 September 2005,” NUREG/CR-6119, Vol. 1 Rev 3, SAND 2005-5713, Sandia National Laboratories, Albuquerque, New Mexico, September 2005.

3. Murata, K. K., et al., “Code Manual for CONTAIN 2.0: A Computer Code for Nuclear Reactor Containment Analysis,” NUREG/CR-6533, SAND-1735, Sandia National Laboratories, Albuquerque, NM, December 1997.

4. Murata, K. K., et al., “CONTAIN Code Qualification Report/User Guide for Auditing Design Basis BWR Calculations,” SMSAB-03-2, USNRC ADAMS Accession Number ML030700335, March 2003.

# APPENDIX A INPUT FILES FOR MARK I SHORT-TERM ANALYSIS

Hope Creek (Mark I) Recirculation Line Break, Short-Term Analysis CONTAIN input file is extensively commented to provide the basis for the parameter values used.

## A.1 CONTAIN Input File

```
&& ********** GLOBAL CONTROL BLOCK

control                 && Global storage allocation specification
  ncells=3              && # of cells
  ntitl=3               && # of lines in the title
  ntzone=4              && # of time zones
  nengv=4               && # engineered vents, of which there are 4
                        &&    for the vent system, see discussion
                        &&    in main body
eoi                     && eoi for control

&& ********** MATERIAL BLOCK

material                 && Initiate material block
  compound h2ol h2ov n2 o2

&& ********** TITLE BLOCK

title
Mark I Short-Term Analysis Sample Problem
 Hope Creek Plant - Recirc. Line Break, vent system modeled as a
 cell and 4 engineered vents
&& ********** TIME ZONES
times 50000.  0.0        && cpu time and start time
  0.0005   .01   0.3     && time step, plot interval, zone end time
  0.0005   .05   2.0
  0.001    .02   5.0
  0.02     .10  10.0     && Calculation ends at 10 s

&& ********** PRINT OPTIONS

shortedt=300             && # of time steps between short edits
longedt=10               && # of edit steps between long edits, but a
                         && long edit also at the time-zone end
prheat                   && Print output options
prlow-cl
prflow
prengsys
prenacct

flows implicit           && Implicit for engineered vents
hiprwatr                 && non-ideal EOS
```

```
&& ********** ENGINEERED VENTS

engvent                 && designation for CONTAIN flow paths

&& Drywell (Cell 1) to Mark I vent system (Cell 2) uses 2
&&   engineered vents, one a pool and the other a gas flow path.

&& The flow area is SAR net free vent area of 235.9 ft**2

&& Loss coefficient is SAR conventional value of 5.51 less 1.0
&&   applied at the vent system exit which leaves 4.51 conventional,
&&   i.e., a CONTAIN value of 2.3, to be applied here, the vent
&&   system entrance
&& The inertial A/L term is based on an L/A sum as follows
&&   (L/A)1-2 = (L/A)1 + (L/A)2. For L1, the DW height of 27.4 m
&&   over 2 was used. The resulting L is 27.4/2=13.7 m.
&&   The area A1 is ~ the DW area used in cellhist,
&&   which is 159 m**2. Thus, (L/A)1 = 13.7/159 = 0.086.
&& For L2, ½ of the Cell 2 (vent system) flow path length of
&&   19.4 m we calculated will be used. For A2, the vent system
&&   area of 21.9 m**2 is used. Thus (L/A)2=19.4/2/21.9=0.44
&& The sum of the L/A is 0.53 (=0.086+0.44) so the CONTAIN
&&   A/L input is 1.9 (=1/0.53).

&& velevb (the back of this vent)is assumed to be the top of the
&&   vent system where it exits the DW at the elevation 9.464 m.
&& Also, velevf (the front of this vent) is assumed to be at the
&&   same value elevation.

&& A vena contracta value of 0.7, which has no effect on a pool
&&   path, is used, see discussion in main part of this report

  from 1 to 2
    varea=21.92 vavl=1.9  type=pool vcfc=2.3  velevb=9.464
    velevf=9.464 vcontra=0.7
eoi                     && eoi for this engineered vent

  from 1 to 2
    varea=21.92 vavl=1.9  type=gas  vcfc=2.3 velevb=9.464
    velevf=9.464 vcontra=0.7
eoi                     && eoi for engineered vent

&& vent system (cell 2) to wetwell (cell 3)

&& Flow area is 21.92 m**2 the area of the vent bottom,
&&   i.e., the bottom of the vertical sections of the 80 downcomers
&&   with their internal diameter of 0.591 m.

&& Inertial length for the liquid is based on previous experience
&&   that indicated a value of 1.25 times the submergence length
&&   is appropriate. The submergence length is ~3 ft (0.9 m), so
&&   the inertial length used is 1.25*0.9=1.14 m.
&& Therefore, for the liquid vent, the a/l=21.92/1.14=19.2 m.
&& For the gas vent a/l, an L/A sum was calculated in a manner
&&   like that described above. The resulting vavl is 2.3.
```

```
&& For these exit vents a conventional loss of 1.00 is applied.
&& The remainder of the FSAR total loss of 5.51 is applied at the
&&   inlet as discussed above.
&& Note that the CONTAIN value of 0.5 is used to represent the
&&   conventional loss coefficient of 1.0.
&&
&& velevb, the elevation of the back of this vent, is assumed to be
&&   at the bottom of the vent system, i.e., the bottom of the
&&   downcomers located at 2.455 m.
&& velevf is assumed to equal velevb

  from 2 to 3
    varea=21.92 vavl=19.2  type=pool vcfc=0.5 velevb=2.455
velevf=2.455 vcontra=0.7
eoi                     && eoi for engineered vent

  from 2 to 3
    varea=21.92 vavl=100.  type=gas  vcfc=0.5 velevb=2.455
    velevf=2.455 vcontra=0.7
eoi                     && eoi for engineered vent

&& ******************* CELL #1- DRYWELL **********************

cell=1                  && Beginning of cell 1 input
control
  jpool=1
  nsoatm=2              && Two coolant blowdown sources
  nspatm=25             && To allow 25 blowdown vs. time points
eoi                     && eoi for cell control

geometry
  gasvol=4371.          && 169,000ft3 less vent system gas volume
  cellhist=1 7.64 158.6 35.20
                        && cellhist area and bottom estimated from
                        && SAR drawings of plant
eoi                     && eoi for geometry

atmos=2
  pgas=1.1169e5         && 1.5 psig (SAR)
  tgas=330.4            && 135F (SAR)
  molefrac o2=0.04 n2=0.96
                        && Atmosphere is inerted
  satrat =0.2           && Humidity = 20% (SAR)
eoi                     && eoi for atmos

condense

source=2                && Two sources

h2ov=25                 && The first source
  iflag=2
  t=
   0.0     0.002197  1.313   1.314   2.125   3.563
   4.421  4.422      13.79   17.03   17.04   18.28
  19.6    21.15      22.53   23.78   25.15   26.78
  28.53   30.50      33.37   37.37   42.87   48.31    48.43
```

```
  mass=
   19159.  22836.  22023. 15009.  14845. 15473.
   16091.  10150.  10595. 10568.   4659.  4255.
    3851.   3439.   3086.  2786.   2484.  2157.
    1841.   1543.   1235.  1144.    954.1  516.8  0.0
  enth=
   1.2688e+6  1.2688e+6   1.2653e+6  1.2653e+6  1.2644e+6
1.2681e+6
   1.2728e+6  1.2728e+6   1.2965e+6  1.2951e+6  1.2951e+6      1.273e+6
   1.2481e+6  1.2193e+6   1.1928e+6  1.1681e+6  1.1409e+6
1.1086e+6
   1.0735e+6  1.0323e+6   9.686e+5   8.4744e+5  6.807e+5
5.6465e+5
   5.6256e+5
eoi                     && eoi for source

h2ov=17                 && The second source
  iflag=2
  t=
    0.0    17.03   17.04  18.28  19.65
   21.15   22.53   23.78  25.15  26.78  28.53
   30.50   33.37   37.37  42.87  48.31  48.43
  mass=
      0.0    0.0  1827.  1782.  1720.
   1639.  1557.   1480.  1394.  1290.
   1179.  1042.    815.   364.    72.4   12.4   0.0
  enth=
    .0        2.7651e+6  2.7651e+6  2.7721e+6  2.7767e+6
  2.7837e+6  2.7884e+6  2.7907e+6  2.7953e+6  2.7977e+6  2.8e+6
  2.8023e+6  2.8e+6     2.7907e+6  2.7581e+6  2.7256e+6  2.7256e+6
eoi                     && eoi for source

ht-tran off off off off off
                        && None of these heat-transfer mechanisms
                        &&   needed for this cell
low-cell
  geometry  158.6 bc=330.4
                        && Area from SAR figure, bc temperature
                        &&   same as atmosphere
  pool
    compos=1 h2ol 1.e-6  temp=330.4
                        && Essentially no initial DW water and there
                        &&   will be no additional water
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ******************* CELL #2- Vent System (VS)

cell=2
control
  jpool=1
eoi
&&
```

```
geometry
&&
&& The total VS volume was calculated to be 436.4 m**3 based on SAR
&&   drawings.
&& At HWL, the downcomer is submerged 1.015 m.
&& The 80 downcomer pipes ID is 591 m so their area is 21.92 m**2
&& Thus, the liquid in the downcomers takes up ~22.25 m**3.
&& The VS gas volume is (436.4-22.52=) 414.2 m**3.
&& Note that this volume is used to determine the Cell 1 gasvol

  gasvol=414.2

&& The cellhist for this volume is modeled in two parts as shown
&&   in the main body of this report.
&& The lower part is only the downcomers area of 21.92 m**2 that
&&   goes between the elevations 2.455 m to 3.877 m
&& The downcomers thus account for 31.17 m**3.
&& The remainder of the volume (436.4-31.17=405.2 m**3) is accounted
&&   for by the remainder of the VS elevation going from the downcomer
&&   top (3.877 m) to where the VS exits the DW at 9.464 m.
&& Thus the area for this elevation change is 72.52 m**2
&&   (405.2/(9.464-3.877).

  cellhist=2 2.455 21.92 3.877 72.52 9.464

eoi                     && eoi for geometry

atmos=2                 && Same as the DW (Cell 1)
  pgas=1.1169e5 tgas=330.4
  molefrac o2=0.04 n2=0.96
  satrat =0.2
eoi                     && eoi for atmos

ht-tran off off off off off

low-cell
  geometry 21.92        && Downcomer area for 80 0.591 m ID pipes
  bc=308.2              && Same temp as WW pool 95 F
  pool
                        && From the discussion above, the liquid in the
                        &&   downcomer at HWL is ~22.52 m**3, which at
                        &&  ~1000 kg/m**3 is 2.252e+04 kg.
    compos=1  h2ol=2.252e+04 temp=308.2
                        && Temp is same as WW 95 F
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ******************  CELL #3- WETWELL

cell=3
control
  jpool=1
  naensy=1              && For engineered system spray
```

```
eoi    && eoi for control

geometry
  gasvol= 3758.0        && SAR HWL 133,500 ft**3 less liquid in
                        &&   downcomer
  cellhist=1 0. 995.  7.27
                        && cellhist for (SAR) pool area of 10,710ft2
                        &&   exposed to WW free space and total volume
                        &&   of gas and liquid
eoi                     && eoi for geometry

atmos=2
  pgas=1.1169e5 tgas=308.2
                        && 1.5 psig, 95 F
  molefrac o2=0.04 n2=0.96
                        && Inerted atmosphere
  satrat=1.0            && 100% humidity
eoi                     && eoi for atmos

engineer wwpspry 4  3  3  0.0
                        && Above specifies an engineered safety system
                        &&   with 4 components (as described below)
                        &&   with coolant coming from this cell (#3)
                        &&   and returning to this cell.
                        && The safety system 4 components are a spray,
                        &&     a dummy tank that has no water, a
                        &&    pump, and a dummy heat exchanger that
                        &&    does not change the pumped water
                        &&    temperature
    spray
      spstpr=1.13e+05   && Spray to come on when WW press increases a
                        &&    little
    eoi                 && eoi for spray

    tank
      0.0               && No water mass in the tank
      308.2             && Pool and atmosphere temperature
      5000.             && Same as pump flow

    pump
      5000.             && Arbitrary value to simulate mixing of pool
                        &&    and atmosphere by bubbles bursting above
                        &&    pool

    hex
      user=0.0          && hex to not change pool-water temperature
eoi                     && eoi for engineer

condense                && Enables condensation

ht-tran off off off on off
                        && 4th of these on to have heat transfer
                        &&   between pool and atmosphere

low-cell
  geometry   995.0   bc=308.2
```

```
  pool
    compos=1 h2ol  3.455e6 temp=308.2
                        && Pool mass based on SAR HWL water volume of
                        &&    122,000ft3, 1000 kg/m**3.
                        && Temperature is SAR value of 95F
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

eof                     && end of input
```

## A.2 MELCOR Input File

```
**************************************************
*                                                *
*    Hope Creek Calculation                      *
*         Base                                   *
*                                                *
**************************************************
*
*eor*      melgen
**********************
***                ***
***  MELGEN INPUT  ***
***                ***
**********************
TITLE     'BASE'
***JOBID      BASE
CRTOUT
OUTPUTF   'BASE.out'
RESTARTF  'BASE.rst'
DIAGF     'BASE.gdia'
TSTART         0.
DTTIME    .1
***
***
* External data file with ME for DW source
* file has time, dmdt & dedt
edf00100  s1cv  2  read      * First Source
edf00101  s1cv.txt
edf00102  3e12.4
*
edf00200  s2cv  2  read      * Second Source
edf00201  s2cv.txt
edf00202  3e12.4
*
************************************
* Active                           *
************************************
*
*
ATMCSOPTION FROZEN
ATMCSTABLE
*
r*i*f .\cont.txt
r*i*f .\mp.txt
r*i*f .\fl.txt
*
SC00000 4406 10.0 1      * max fog density
.   * terminate
*eor* melcor
************************
***  MELCOR INPUT    ***
************************
TITLE     'BASE'
***JOBID      ref
*
```

```
OUTPUTF   'BASE.out'
PLOTF     'BASE.ptf'
RESTARTF  'BASE.rst'
MESSAGEF  'BASE.mes'
DIAGF     'BASE.dia'
*
CRTOUT
***CYMESF    10 10
*
RESTART            -1
tend  10.0
***EXACTTIME1         100.
CPULIM             400000.
CPULEFT            400.0
*
*
*       time    dtmax   dtmin   dtedit  dtplot  dtrest
time1     0.0   0.0005  0.0001   10.0     0.01     50.0
time2     0.3   0.0005  0.0001   10.0     0.05     50.0
time3     2.0   0.001   0.0001   10.0     0.02     50.0
time4    200.   0.02    0.0001   10.0     0.1      50.0
*
*
.  * terminate
*********************************
* CVH INPUT                     *
*********************************
*******************************************************
* Hope Creek Mark I                                   *
*******************************************************
*
cv00100  DRYW        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv001a0  3
cv001a1  pvol       111690.0     *
cv001a2  tatm       330.4       *
cv001a3  mlfr.4     0.04         *
cv001a4  mlfr.5     0.96         *
cv001a5  rhum       0.2         *
cv001b1  7.64       0.0
cv001b2  35.20      4371.0       *
cv001c1  mass.3   rate  edf.1.1  * First Source
cv001c2  energy.a rate  edf.1.2  *
cv001c3  mass.3   rate  edf.2.1  * Second Source
cv001c4  energy.a rate  edf.2.2  *
*
cv00200  VS        2  2  1       * Non-Equ Thermo, Vert flow, ctmt
cv002a0  3
cv002a1  pvol       111690.0     *
cv002a2  tatm       330.4        *
cv002a3  mlfr.4     0.04         *
cv002a4  mlfr.5     0.96         *
cv002a5  rhum       0.2         *
cv002a6  zpol       3.493      *
cv002a7  tpol       308.2        *
cv002b1  2.455      0.0        * Base of Downcomer Vent Pipe
cv002b2  3.877      31.17
```

```
cv002b3  9.464      436.4
*
cv00300  WETW        1  2  1     * Equ Thermo, Vert flow, ctmt
cv003a0  3
cv003a1  pvol       111690.0     *
cv003a2  tatm       308.2        *
cv003a3  mlfr.4     0.04         *
cv003a4  mlfr.5     0.96         *
cv003a5  rhum       1.0         *
cv003a6  zpol       3.493      *
cv003a7  tpol       308.2        *
cv003b1  0.0       0.0
cv003b2  3.493     3476.0
cv003b3  7.27      7234.0
*
.                                     * terminator
****************************************************
* FL input                                         *
****************************************************
***       Vent Lines/Vent Header/Downcomers
***       From the Drywell to the Wetwell
***       Eight (8) Vent Pipes From Drywell (CV1 to CV2)
***
fl00100  VENT-OPENING   1    2     8.474   8.474    * Mid-point of Vent
to DW
fl00101  21.92   11.53  1.0    1.88    1.88  *~6' 2" opening (SAR
rev14)
fl00102  3  0  0  0                          * Horiz, Active, No SPARC
fl00103  4.6  4.6  0.7   0.7                 * Form Losses (2xCONTAIN)
fl001S1  21.92   11.53   1.88                * Vent Pipe FArea, L, Dh
***
****************************************************
***        Eighty (80) Downcomers from Ring Header (CV2 to CV3)
***
fl00200  DOWNCOMER-EXIT   2    3    2.455    2.455  * Base of Vent Pipe
to SP
fl00201  21.92   1.14      1.0       0.001   0.001
fl00202  0   0   0   1                           * VERT, ACT, SPARC IN
WW
fl00203  1.0   1.0   0.7  0.7                    * Form
Losses(2xCONTAIN)
fl002S1  21.92   1.14   0.61       * Downcomer Area, L, Dh (2' nom
diamter FSAR rev 14)
*
.
*****************************************************
***   Non-Condensible gases
*****************************************************
***
***   Gas     Material Number
***
NCG000  O2       4
NCG001  N2       5
***
*
.
```

s1cv

```
0.0000E+00,1.9159E+04,2.4308E+10
0.2197E-02,2.2836E+04,2.8974E+10
1.3130E+00,2.2023E+04,2.7865E+10
1.3140E+00,1.5009E+04,1.8990E+10
2.1250E+00,1.4845E+04,1.8770E+10
3.5630E+00,1.5473E+04,1.9621E+10
4.4210E+00,1.6091E+04,2.0480E+10
4.4220E+00,1.0150E+04,1.2918E+10
1.3790E+01,1.0595E+04,1.3736E+10
1.7030E+01,1.0568E+04,1.3686E+10
1.7040E+01,4.6590E+03,6.0338E+09
1.8280E+01,4.2550E+03,5.4166E+09
1.9600E+01,3.8510E+03,4.8064E+09
2.1150E+01,3.4390E+03,4.1931E+09
2.2530E+01,3.0860E+03,3.6809E+09
2.3780E+01,2.7860E+03,3.2543E+09
2.5150E+01,2.4840E+03,2.8339E+09
2.6780E+01,2.1570E+03,2.3912E+09
2.8530E+01,1.8410E+03,1.9763E+09
3.0500E+01,1.5430E+03,1.5928E+09
3.3370E+01,1.2350E+03,1.1962E+09
3.7370E+01,1.1440E+03,9.6947E+08
4.2870E+01,9.5410E+02,6.4945E+08
4.8310E+01,5.1680E+02,2.9181E+08
4.8430E+01,0.0000E+00,0.0000E+00
```

s2cv

```
0.0000E+00,0.0000E+00,0.0000E+00
1.7030E+01,0.0000E+00,0.0000E+00
1.7040E+01,1.8270E+03,5.0518E+09
1.8280E+01,1.7820E+03,4.9398E+09
1.9650E+01,1.7200E+03,4.7759E+09
2.1150E+01,1.6390E+03,4.5624E+09
2.2530E+01,1.5570E+03,4.3415E+09
2.3780E+01,1.4800E+03,4.1302E+09
2.5150E+01,1.3940E+03,3.8966E+09
2.6780E+01,1.2900E+03,3.6090E+09
2.8530E+01,1.1790E+03,3.3012E+09
3.0500E+01,1.0420E+03,2.9199E+09
3.3370E+01,8.1500E+02,2.2820E+09
3.7370E+01,3.6400E+02,1.0158E+09
4.2870E+01,7.2400E+01,1.9968E+08
4.8310E+01,1.2400E+01,3.3797E+07
4.8430E+01,0.0000E+00,0.0000E+00
```

## APPENDIX B INPUT FILES FOR MARK I LONG-TERM ANALYSIS

Hope Creek (Mark I) Recirculation Line Break, Long-Term Analysis CONTAIN input file is extensively commented to provide the basis for the parameter values used.

### B.1 CONTAIN Input File

```
&& Hope Creek (Mark I) Recirculation Line Break,
&& Long-Term Analysis CONTAIN Input Deck
&&
&& ********** GLOBAL CONTROL BLOCK
control                 && Global storage allocation
  ncells=4              && # of cells
  ntitl=2               && # of lines in the title
  ntzone=14             && # of time zones
  nengv=7               && # engineered vents - 4 for the vent system,
                        &&   1 for the RPV overflow, 1 for the RPV to
                        &&   DW flow path, and 1 for the WW to DW
                        &&   pressure relief area vs. Press. Diff
  numtbg=1              && For engvnt table of area vs. Press. Diff.
  maxtbg=10             && Max # of entries for above table
eoi                     && eoi for control

&& ********** MATERIAL BLOCK

material                && to initiate material block
  compound h2ol h2ov n2 o2

&& ********** TITLE BLOCK

title
 Mark I Long Term Analysis Sample Problem
Hope Creek Plant- Recirc. Line Break

&& ********** TIME ZONES

times  1200.  0.0       && Maximum cpu time and start time
                        && Time step, plot interval, zone end time
  0.0005     .01        0.3
  0.0005     .05        2.0
  0.001      .02        5.0
  0.02       .10       10.0
  0.10      1.00       50.0
  0.10      5.00      100.0
  0.10     20.00      600.0
  0.10     20.00      700.0
  0.20     20.00     1000.0
  0.50     50.00     2000.0
  1.00    100.00     5000.0
  2.00    100.00    10000.0
  2.00    100.00    20000.0
  2.00    100.00    32000.0
                        && Calculation end time is 32000 s
```

```
&& ********** PRINT OPTIONS


shortedt=300            && # of time steps between short edit
longedt=10              && # of time steps between long edits, but a
                        &&   long edit at time-zone end

prheat                  && Print output options

prlow-cl
prflow
prengsys
prenacct

flows implicit          && Implicit for engineered vents
hiprwatr                   &&  Non-ideal EOS of water
&& ********** ENGINEERED VENTS

engvent                 && designation for CONTAIN flow paths

&&
&& The following 4 vents describe the 2 flow paths from the DW to
&&   the vents system (VS) and the 2 flow paths from the VS to the WW.
&& Details of the basis for these flow paths is presented in the
&&   main text and the Hope Creek short-term input deck referenced
&&   in Section 2.1.

  from 1 to 2

    varea=21.92 vavl=2.0  type=pool vcfc=2.3  velevb=9.464
    velevf=9.464 vcontra=0.7
eoi                     && eoi for this engineered vent

  from 1 to 2

varea=21.92 vavl=2.0   type=gas  vcfc=2.3 velevb=9.464

velevf=9.464 vcontra=0.7
eoi                     && eoi for this engineered vent

  from 2 to 3
    varea=21.92 vavl=19.2  type=pool vcfc=0.5 velevb=2.455
    velevf=2.455 vcontra=0.7
eoi                     && eoi for this engineered vent

  from 2 to 3
    varea=21.92 vavl=2.3  type=gas  vcfc=0.5 velevb=2.455
    velevf=2.455 vcontra=0.7
eoi                     && eoi for this engineered vent

&& This flow path simulates the RPV liquid overflow to the wetwell

  from 4 to 3           && Area of recirc. line used
type=pool  varea=0.307
```

```
vavl=2.5   vcfc=1.  && Approximate values

velevb=27.03        && This is the initial RPV water level
                        &&   above which we want the RPV pool water
                        &&   to flow directly to the WW pool
                        && Note that the DW is bypassed
    velevf= 7.277       && The top of the WW was used because the
                        &&   liquid is added to the WW pool.


    vtopen=75.          && Prevents any flow until vessel is

&&   reflooded at 75 s.

eoi                     && eoi for this engineered vent

&& The following vents model the flow path between the RPV and the
&&   DW resulting from the broken recirc. line

   from 4 to 1           && Area of recirc. line used

type=gas   varea=0.307

vavl=2.5   vcfc=1.  && Approximate values
    velevb=28.          && This elevation intentionally made a
                        &&   little higher than the 27.03 m
                        &&   elevation at which the liquid (pool)
                        &&   will flow out to minimize possible
                        &&   flow oscillation
    velevf=27.00        && DW elevation slightly lower
    vtopen=75.          && Prevents any flow until
                        &&   vessel is reflooded at 75 s.
eoi                     && eoi for this engineered vent

&& The following vent models the vacuum breakers between the
&&   WW and DW that open when the DW pressure becomes 0.25 psia
&&   (1.724e3 Pa) lower than the WW pressure.
&& There are 8 24 in valves so the full-open area is 25.1 m**2.

  from 3 to 1
    type=gas
    vstatus=closed      && Initially closed
    vdpb=1.e6           && High pressure to prevent back flow from
                        &&   DW to the WW

vdpf=1.724e3        && 0.25 psi opens vacuum relief valves
    rvarea-p            && This table will control the vent area
                        &&   as a function of press. diff.
      flag=2            && flag=2 required by code for this table
      x=5               && The WW to DW Press. Diffs.
      -1.e20  0.0  1.724e3   3.5e3   1.e20

y=5               && The flow path area for each P Diff

0.0    0.0   25.1     25.1     25.1
```

```
eoi                 && eoi for rvarea-p table

    vavl=2.5   vcfc=1.  && Approximate values
    velevb=7.277        && Top of the wetwell
    velevf=7.277        && Top of the wetwell
eoi                     && eoi for this engineered vent

&& ****************** CELL #1- DRYWELL

cell=1                  && Beginning of Cell 1 input
control
  jpool=1
  nsoatm=2              && 2 blowdown sources
  nspatm=25             && 25 blowdown vs. time points
  naensy=1              && 1safety system, a spray
eoi                     && eoi for cell control


geometry

gasvol=4370.           && SAR value including VS free volume is
                        &&   169,000ft**3 (4786 m**3)
                        && For a VS free (gas) volume (see Cell 2
                        &&   below, of ~416 m**2, we get
                        &&   4786 - 416 = 4370. m**3
 cellhist=1 7.64 158.6 35.19
                        && Estimated from SAR figures

eoi                     && eoi for geometry

atmos=2

pgas=1.1169e5         && 1.5 psig from SAR
  tgas=330.4            && 135 F from SAR
  molefrac o2=.04 n2=.96
                        && Atmosphere inerted
satrat =0.2           && Humidity=20% from SAR

eoi                     && eoi for atmos

engineer rpvdwwws  4  4  3  16.57

&& The above defines a 4 component
                        &&   engineer safety system named rpvdwwws

&&   that will pump water from the RPV (Cell 4)
                        &&   pool through the DW as a spray with the
                        &&   water added to the WW pool (Cell 3).
                        && The change of elevation delev is from the
                        &&   bottom of Cell 4 (16.57) to the bottom of
                        &&   Cell 3 (0.0)

&& The flow modeled is arbitrarily taken as
                        &&   the non-RHR flow of 11950 gpm, which is
                        &&   ~754 kg/s.
```

```
&& There is no heat exchanger so user=0.0
                        &&   was used
                        && This reflood overflow does not occur until
                        &&   the RPV is reflooded at 75 s so the tank
                        &&   will be modeled to stop its negligible
                        &&   flow at 75 s after which the spray flow
                        &&   will come from the pool of Cell 4 (iclin).
                        && The tank water temperature was assumed to be
                        &&   the RPV initial temperature.

&& The resulting input follows
   spray
     spdiam=0.0190      && 0.75 in spray diameter larger than default
                        &&   to minimize oscillation because of
                        &&   coupling with atmosphere.

eoi                  && eoi for spray
   tank
       0.75             && Water mass in tank
     407.2              && Tank water temperature
       0.01             && Water flow rate from tank so tank mass is
                        &&   gone at 75 s after which the pump will
                        &&   start

pump

754.               && The assumed overflow

hex

user=0.0           && A required heat exchanger that does nothing

eoi                     && eoi for engineer

source=2                && Two sources

h2ov=25                 && Low-enthalpy (water) source
  iflag=2
  t=
    0.0    0.002197 1.313   1.314  2.125  3.563
    4.421  4.422   13.79   17.03  17.04  18.28
   19.65  21.15    22.53   23.78  25.15  26.78
   28.53  30.50    33.37   37.37  42.87  48.31
   48.43
  mass=
   19159.  22836. 22023. 15009.  14845.  15473.
   16091.  10150. 10595. 10568.   4659.   4255.
    3851.   3439.  3086.  2786.   2484.   2157.
    1841.   1543.  1235.  1144.  954.1   516.8
       0.0
  enth=
   1.2688e+6  1.2688e+6   1.2653e+6  1.2653e+6  1.2644e+6
1.2681e+6
   1.2728e+6  1.2728e+6   1.2965e+6  1.2951e+6  1.2951e+6
1.2730e+6
```

```
   1.2481e+6  1.2193e+6   1.1928e+6  1.1681e+6  1.1409e+6
1.1086e+6
   1.0735e+6  1.0323e+6   9.6860e+5  8.4744e+5  6.8070e+5
5.6465e+5
   5.6256e+5
eoi                     && eoi for source

h2ov=17                 && High enthalpy (steam) source
  iflag=2
  t=
    0.0    17.03   17.04  18.28  19.65
   21.15   22.53   23.78  25.15  26.78  28.53
   30.50   33.37   37.37  42.87  48.31  48.43
  mass=
       0.0    0.0  1827.  1782.  1720.
    1639.  1557.   1480.  1394.  1290.  1179.
    1042.   815.    364.    72.4   12.4    0.0
  enth=
    0.0        2.7651e+6  2.7651e+6  2.7721e+6   2.7767e+6
    2.7837e+6  2.7884e+6  2.7907e+6  2.7953e+6   2.7977e+6  2.8e+6
    2.8023e+6  2.8e+6     2.7907e+6  2.7581e+6   2.7256e+6  2.7256e+6
eoi                     && eoi for source

condense                && Enables condensation

ht-tran off off off off off
                        && None of these heat transfer mechanisms
                        &&   needed in this cell

low-cell
  geometry  158.6       && Approx. area from SAR
  bc=330.4              && Same as atmos. temp
  pool
    compos=1 h2ol 1.e-6  temp=330.4
                        && No water, same temp
    physics

      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell



&& ****************** CELL #2- Vent System (VS)

cell=2
control
  jpool=1
eoi                     && eoi for control

geometry
&& The development of the vents system (VS) is described more
&&   completely in the Hope Creek short-term input deck.

  gasvol=416.4
```

```
  cellhist=2 2.455 21.92 3.877 72.52 9.464

eoi                     && eoi for geometry

atmos=2
  pgas=1.1169e5 tgas=330.4
  molefrac o2=.04 n2=.96
  satrat =0.2
eoi                     && eoi for atmos

ht-tran off off off off off

low-cell
  geometry 21.92        && 80 0.591 m ID downcomer pipes
  bc=308.               && Same temp as WW pool 95 F
  pool

    compos=1  h2ol=2.004e+04 temp=308.
                        && Water mass for LWL, temp is for 95 F
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ******************* CELL #3- WETWELL

cell=3
control
  jpool=1
eoi                     && eoi for control

geometry
  gasvol= 4036.         && gasvol based on the SAR LWL value
                        &&   137,000 ft**3 (3879 m**3) increased
                        &&   by the 1.573e2 m**3 decrease of the
                        &&   pool volume (& mass) discussed below.
  cellhist=1 0. 992.2 7.277
                        && For LWL pool A=10,680 ft**2 (992.2 m**2)
                        && gasvol=4036 & water vol=3184 m**3, i.e.
                        &&   a total volume of 7220 m**3
eoi                     && eoi for geometry

atmos=2

  pgas=1.1169e5 tgas=308.0
                        && SAR gives 1.5psig, 95F, 100% hum
  molefrac o2=.04 n2=.96
                        &&   inerted atmosphere
  satrat=1.0
eoi                     && eoi for atmos

condense   && Want for WW HT (albeit slow) between pool and atmosphere

   ht-tran off off off on  off
```

```
                        && 4th set to on for heat transfer between
                        &&   pool and atmosphere

low-cell
  geometry   992.2   bc=308.0
                        && Area for SAR LWL A=10680 ft**2
  pool
    compos=1 h2ol  3.184e6
                        && Based on LWL V=118,000 ft**3, which is
                        &&   3341 m**3 & ~ 3.341e6kg, less ~ECCS flow
                        &&   of 7700 lm/s from 30 s to 75 s, i.e.,
                        &&   less 3.465 lm (1.573e5 kg).
                        && Total mass is then 3.184e5 kg
      temp=308.0        && 95 F

    physics
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ****************** CELL #4- RPV

cell=4
control
  nsopl=3  nsppl=50     && 3 pool sources, 50 points max
  naensy=2              && For 2 engineered safety (spray) systems
  jpool=1
eoi                     && eoi for control

geometry
  gasvol=  257.4        && From SAR Table 6.2-3, RPV initial condition,
                        &&   steam volume is 9089 ft**3 (257.4 m**3)
                        && Also, from Table 6.2-3, the RPV liquid
                        &&   volume is 11,885 ft**3 (336.5 m**3)
                        && However, the liquid volume for the initial
                        &&    condition was found to be 362.7 m**3,
                        &&    which also will be used
                        && The total RPV volume is then (336.5+362.7)
                        &&  = 620.1 m**3).
                        && From SAR the Fig. 3.8-1 cross section, the
                        &&  approx. RPV ID is 21 ft (6.40 m).
                        && The corresponding area is 346.4 ft**2
                        &&   (32.18 m**2), which for the total
                        &&   volume of 620.1 m**3 results in a RPV
                        &&   height of 19.27 m (63.22 ft).
                        && This height is confirmed by scaling the RPV
                        &&    height in SAR Fig. 3.8-1.
                        && The RPV cellhis parameter can now be
                        &&   specified, but first a bottom elevation
                        &&   is needed.
                        && From Fig. 3.8-1, the difference in elevation
                        &&   from the DW bottom to the RPV bottom is
                        &&   approx. 28.3 ft (8.925 m).

                        && Therefore, for the DW bottom elevation of
                        &&   7.64 m used above for Cell 1,
```

```
                        &&   the RPV bottom cellhist elevation is
                        &&   16.57 m.
  cellhist=1 16.57  32.18 35.84
                        && Total V=620.1 m**3, as desired
eoi                     && eoi for geometry

atmos=3                 && Others had 2, this cell needs h2ov=1.0
      && The RPV conditions, which will enter the calculation at 75 s,
      &&   are set to the DW conditions after the short-term analysis.
      && To get the conditions, the ST analysis was run to 50 s, when
      &&   nothing else will happen

   tgas=407.15          && Code will determine corresponding saturation
                        &&   pressure
                        && Note that attempts to specify press. &
                        &&   temp. values may have been an over
                        &&   specification because we had problems
                        && Note that the h2ov molefrac must be given
                        &&   if only T & no P given

  molefrac o2=0.0 n2=0.0 h2ov=1.0
                        && Saturated steam only
  satrat=1.0
eoi                     && eoi for atmosphere

engineer wwtphso  4  3  4  -16.57

                        && The above defines a 4 component engineer
                        &&   system named wwtphso.
                        && Its main purpose is to pump coolant from the
                        &&   WW (Cell 3) through a cooling heat
                        &&   exchanger followed by a spraying of the
                        &&  coolant into the RPV (Cell 4) atmosphere.
                        && The specification includes the difference in
                        &&   elevation of the bottom of Cell 3 (0.0)
                        &&   minus the bottom of Cell 4 (16.57), i.e.,
                        &&   -16.57 m.
                        && However, the spray is not activated until
                        &&   600 s, so the tank will be modeled to stop
                        &&   spraying its negligible flow at 600s after
                        &&   which the spray flow will be drawn from
                        &&   the pool of Cell 3 (iclin)
                        && The following discusses the basis for
                        &&   the 4 components.
&&   The 4 components are
&&      (1) a dummy tank (required by the code) with liquid mass so
&&          the flow from the tank stops at 600 s after which the
&&          spray flow will come from Cell 3
&&      (2) a pump for the Hope Creek, Case C, RHR flow rate of
&&          10,000 gpm (630.8 kg/s)
&&      (3) a heat exchanger of the type=shell, with cooling water at
&&         308 K (95 F). a cooling water flow rate of 567.7 kg/s
&&         (9000 gpm), heat transfer area of 329.8 m**2 (3550 ft**2),
&&         and a heat transfer coefficient of 2130.0 W/m**2-K
&&         (375 Btu/hr-ft**2-F/unit
&&      (4) a spray to model the recirculation flow to the RPV pool.
```

```
&& The resulting input follows
   spray
     spdiam=1.           && Very large spray drop size used because this
                         &&   flow actually goes to the RPV pool and a
                         &&   large drop essentially will simulate this.

   eoi                   && eoi for spray
   tank
       0.6               && water mass in tank
     308.0               && tank water temperature
       0.001             && water flow rate from tank so tank mass is
                         &&   gone at 600 s
   pump
     630.8               && The RHR flow rate that will start after the
                         &&   tank is empty
   hex
     shell   308.   567.7   329.8   2130.
                         && See above discussion
eoi                      && eoi for engineer

engineer wwtrvrf  4  3  4  -16.57

                         && The above defines a 4 component engineer
                         &&   system named wwtrvrf.
                         && Its only purpose is to pump coolant from the
                         &&   WW (Cell 3) pool to the RPV as a spray of
                         &&   the coolant that then goes to the
                         &&   the RPV pool to which decay-heat, heat-
                         &&   structure sensible, and pump
                         &&   energy is added and this pool flows
                         &&   the heated water to the WW pool.
                         && The flows modeled are, from SAR Table 6.2-6
                         &&   for Case C, the core spray rate of
                         &&   6350 gpm and the (newly-modeled and
                         &&   believed to be conservative) HPCI
                         &&   5600 gpm, which totals 11950 gpm
                         &&   (*3.785e-3 m**3/gal * 1000 kg/m**3 /
                         &&    60 s/m =) 753.8 kg/s.
                         && There is no heat exchanger so user=0.0 will
                         &&   be used.
                         && The specification includes the difference in
                         &&   elevation of the bottom of Cell 3 (0.0)
                         &&   minus the bottom of Cell 4 (16.57), i.e.,
                         &&    -16.57 m.
                         && However, this additional reflood is not
                         &&   activated until 75 s, so the tank will be
                         && modeled to stop spraying its negligible flow
                         &&   at 75 s after which the spray flow will
                         &&   come from the pool of Cell 3 (iclin).
                         && This additional reflood flow rate was
                         &&   assumed to be the Table 6.2-6 core
                         &&   spray rate of 6350 gal/min (400.6 kg/s).
                         && A temperature of 308. K was assumed.
&& The following discusses the basis for the 4 components.
&&   The 4 components are
&&      (1) a dummy tank (required by the code) with liquid mass so
```

```
&&          the flow from the tank stops at 75 s after which the
&&          pump will provide the spray flow from the WW (Cell 3) pool
&&      (2) a pump to provide 753.8 kg/s)
&&      (3) a required heat exchanger that does nothing
&&      (4) a spray for the desired additional reflood flow rate

&& The resulting input follows
   spray
     spdiam=0.003       && Spray diameter larger than default to reduce
                        &&   oscillations because of coupling with
                        &&   atmosphere and thereby avoid possible
                        &&   instabilities
   eoi                  && eoi for spray

   tank
       0.75             && Water mass in tank
     308.               && Tank water temperature
       0.001            && Tank water flow rate so spray will start
                        &&   at 75 s.
   pump
     753.8              && The additional reflood and HPCI rate
   hex
     user=0.0
eoi                     && eoi for engineer

condense                && Want in RPV for HT between spray, atm. &
                        &&   pool

   ht-tran off off off on  off
                        && 4th set to on for heat transfer between
                        &&   pool and upper cell (atmosphere)

low-cell
  geometry   32.18   bc=308.0
                        && RPV area as discussed above.

  pool
    compos=1 h2ol  3.365e5
                        && Mass from Table 6.2-3 value for volume of
                        &&   liquid in vessel=11885 ft**3 (336.5 m**3)
                        &&   at 1000 kg/m**3.
        temp=407.15     && Same as atmos. temp.
physics
&&      boil            && NOTE boil not used

&& Following sources to the RPV pool are from the Hope Creek SAR
&& However, the pump heat is from the Limerick FSAR

   source=3

&& Decay heat source table for Hope Creek, 0-100000 sec,
&&   including fuel relaxation energy
&&
&& Note that the following table of decay heat originally provided
&&   values (which are retained) starting at time=0.0.
&& However, we only are interested in the energy after 75 s
```

```
&&   because the energy before that time is accounted for in the
&&   blowdown energy and mass added to the containment.
&&   Because the original values were given based on the iflag=2
&&   format, two times, one at 75 s and one shortly thereafter, were
&&   required.

  h2ol=22  iflag=2

  t=
&&   0.        2.        6.       10.    20.       30.
&&  60.      120.      200.      600.   800.     1000.
     0.        2.        6.       10.   20.        75.
    75.001   120.      200.      600.   800.     1000.
  2000.     4000.     6000.     8000.     1.e4      2.e4
     4.e4      6.e4      8.e4      1.e5

  mass=
    0.e-5     0.e-5     0.e-5     0.e-5     0.e-5     0.e-5
    1.e-5     1.e-5     1.e-5     1.e-5     1.e-5     1.e-5
    1.e-5     1.e-5     1.e-5     1.e-5     1.e-5     1.e-5
    1.e-5     1.e-5     1.e-5     1.e-5

  enth=
&&   59.0e11 1839.0e11 1817.2e11 1270.4e11  393.3e11  274.1e11
&&   40.1e11  128.0e11  113.0e11   86.6e11   79.4e11   74.9e11
      0.0       0.0       0.0       0.0       0.0       0.0
    137.1e11  128.0e11  113.0e11   86.6e11   79.4e11   74.9e11
     61.8e11   50.8e11   45.4e11   42.2e11   40.3e11   33.9e11
     27.3e11   24.8e11   22.3e11   21.0e11
  eoi   && eoi for 1st source

&& Source table with   48 points
&& Integrated mass = 5.54384E-02  integrated enthalpy = 1.25557E+11
&& Init. int. mass = 5.54384E-02  init. int. enthalpy = 1.25557E+11

   h2ol=48 iflag=1

&& Note that the following table of sensible heat originally provided
&&   values (which are retained) starting at time=0.0.
&& However, we only are interested in the energy after 75 s
&&   because the energy before that time was accounted for in the
&&   blowdown energy and mass added to the containment.
&& Because the original values were given based on the iflag=1
&&   format, the 75 s value is the same as that for the time in
&&   the table before 75 s.
   t=
&&    4.98610E+01  6.12520E+01  7.08260E+01  8.18970E+01  9.70190E+01
      4.98610E+01  6.12520E+01 75.           8.18970E+01  9.70190E+01
      1.12180E+02  1.28160E+02  1.49990E+02  1.69290E+02  1.86500E+02
      2.05460E+02  2.26350E+02  2.52400E+02  2.74720E+02  3.02650E+02
      3.29410E+02  3.49960E+02  3.76320E+02  3.99790E+02  4.24730E+02
      4.62290E+02  4.91120E+02  5.28120E+02  5.74810E+02  6.10670E+02
      6.56660E+02  6.97630E+02  7.50170E+02  8.06680E+02  8.46690E+02
      9.10460E+02  9.67260E+02  1.04010E+03  1.11840E+03  1.20270E+03
      1.29320E+03  1.40760E+03  1.53200E+03  1.66750E+03  1.85940E+03
      2.04840E+03  2.28420E+03  2.60940E+03  2.94520E+03  3.40560E+03
```

```
      3.84370E+03  4.55340E+03  5.59370E+03

   mass=
&&    1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      0.0          0.0          1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  9.99999E-06  1.00000E-05  1.00000E-05  9.99999E-06
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  9.99999E-06
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05  1.00000E-05
      1.00000E-05  1.00000E-05  1.00000E-05

   enth=
&&    0.00000E+00  2.05226E+12  1.24237E+13  1.29937E+13  1.29602E+13
      0.00000E+00  0.0          1.24237E+13  1.29937E+13  1.29602E+13
      1.22960E+13  1.17012E+13  1.22170E+13  1.14172E+13  1.13998E+13
      1.12871E+13  9.80570E+12  1.14443E+13  1.05526E+13  8.81122E+12
      9.56156E+12  1.04357E+13  9.20920E+12  9.45415E+12  7.32393E+12
      8.17857E+12  7.96582E+12  7.15427E+12  8.21905E+12  6.83591E+12
      7.19391E+12  5.98371E+12  5.56334E+12  7.36653E+12  5.23810E+12
      5.53493E+12  4.85560E+12  4.51701E+12  4.19552E+12  3.69097E+12
      3.26339E+12  3.00105E+12  2.75521E+12  2.25262E+12  2.28719E+12
      1.49992E+12  1.14800E+12  8.19195E+11  5.97495E+11  4.93356E+11
      2.76863E+11  1.88872E+10  1.88872E+10
  eoi                   && eoi for 2nd source
&& Pump heat from Limerick FSAR that probably is for 2 pumps, but the
&&   energy amount is small.

   h2ol=4    iflag=1

   t=
     0.       75.     600.       1.e6
   mass=
      0.0       1.e-5    1.e-5    1.e-5
   enth=
      4.58e+11   4.58e+11  4.58e+11  0.
  eoi                   &&  eoi for 3rd source

    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for lower cell

eof                     && End of input file
```

## B.2 MELCOR Input File

```
**************************************************
*                                                *
*    Hope Creek Calculation                      *
*         Base                                   *
*                                                *
**************************************************
*
*eor*      melgen
*********************
***               ***
***  MELGEN INPUT  ***
***               ***
*********************
TITLE     'BASE'
***JOBID      BASE
CRTOUT
OUTPUTF   'BASE.out'
RESTARTF  'BASE.rst'
DIAGF     'BASE.gdia'
TSTART         0.
DTTIME    .1
***
***
* External data file with ME for DW source
* file has time, dmdt & dedt
edf00100  s1cv  2  read      * First source (DW)
edf00101  s1cv.txt
edf00102  3e12.4
*
edf00200  s2cv  2  read      * Second source (DW)
edf00201  s2cv.txt
edf00202  3e12.4
*
edf00300  s3cv  2  read      * decay heat (RPV)
edf00301  s3cv.txt
edf00302  3e12.4
*
edf00400  s4cv  2  read      * sensible heat (RPV)
edf00401  s4cv.txt
edf00402  3e12.4
*
edf00500  s5cv  2  read      * pump heat (RPV)
edf00501  s5cv.txt
edf00502  3e12.4
*
ATMCSOPTION FROZEN
ATMCSTABLE
*
r*i*f .\cont.txt
r*i*f .\mp.txt
r*i*f .\fl.txt
r*i*f .\rhr.txt
r*i*f .\hpci.txt
```

```
*
** SC00000 4406 10.0 1  * max fog density for short term blowdown only
.                       * terminate
*eor* melcor
************************
***  MELCOR INPUT    ***
************************
TITLE     'BASE'
***JOBID      ref
*
OUTPUTF   'BASE.out'
PLOTF     'BASE.ptf'
RESTARTF  'BASE.rst'
MESSAGEF  'BASE.mes'
DIAGF     'BASE.dia'
*
CRTOUT
***CYMESF    10 10
*
RESTART            -1
tend  32000.0
***EXACTTIME1         100.
CPULIM             400000.
CPULEFT            400.0
*
*
*       time    dtmax   dtmin   dtedit  dtplot  dtrest
time1     0.0   0.0005  0.0001   10.0     0.01     50.0
time2     0.3   0.0005  0.0001   10.0     0.05     50.0
time3     2.0   0.001   0.0001   10.0     0.02     50.0
time4     10.   0.02    0.0001   10.0     0.1      50.0
time5     50.   0.10    0.0001   10.0     1.0      50.0
time6    100.   0.10    0.0001  100.0     5.0    1000.0
time7    600.   0.10    0.0001  100.0    20.0    1000.0
time8    700.   0.10    0.0001  100.0    20.0    1000.0
time9   1000.   0.20    0.0001 1000.0    20.0   10000.0
time10  2000.   0.50    0.0001 1000.0    50.0   10000.0
time11  5000.   1.00    0.0001 5000.0   100.0   10000.0
time12 10000.   2.00    0.0001 5000.0   100.0   10000.0
*
*
.  * terminate
*********************************
* CVH INPUT                     *
*********************************
********************************************************
* Hope Creek Mark I                                    *
********************************************************

cv00100  DRYW        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv001a0  3
cv001a1  pvol       111690.0     *
cv001a2  tatm       330.4        *
cv001a3  mlfr.4     0.04         *
cv001a4  mlfr.5     0.96         *
cv001a5  rhum       0.2          *
```

```
cv001b1  7.64        0.0
cv001b2  35.20       4371.0       *
cv001c1  mass.3   rate  edf.1.1  * The first source
cv001c2  energy.a rate  edf.1.2  *
cv001c3  mass.3   rate  edf.2.1  * The second source
cv001c4  energy.a rate  edf.2.2  *
*
cv00200  DC         2  2  1       * Non-Equ Thermo, Vert flow, ctmt
cv002a0  3
cv002a1  pvol        111690.0     *
cv002a2  tatm        330.4        *
cv002a3  mlfr.4      0.04         *
cv002a4  mlfr.5      0.96         *
cv002a5  rhum        0.2          *
cv002a6  zpol        3.21         * LWL
cv002a7  tpol        308.2        *
cv002b1  2.455       0.0          * Base of Downcomer Vent Pipe
cv002b2  3.877       31.17
cv002b3  9.464       436.4
*
cv00300  WETW         1  2  1     * Equ Thermo, Vert flow, ctmt
cv003a0  3
cv003a1  pvol        111690.0     *
cv003a2  tatm        308.2        *
cv003a3  mlfr.4      0.04         *
cv003a4  mlfr.5      0.96         *
cv003a5  rhum        1.0          *
cv003a6  zpol        3.21         * LWL
cv003a7  tpol        308.2        *
cv003b1  0.0        0.0
cv003b2  3.21       3184.0
cv003b3  7.27       7234.0
*
cv00400  RPV         1  2  1      * Equ Thermo, Vert flow, ctmt
cv004a1  pvol        3.179E5      * adjust the pressure to correspond to
                                    DW pressure at end of blowdown
cv004a3  zpol        27.03        *
cv004b1  16.57       0.0          * bottom of RPV
cv004b2  27.03       -336.5       * liquid volume
cv004b3  35.84       -257.4       * gas volume
cv004ca  mass.1   rate  edf.3.1  * decay heat
cv004cb  energy.p rate  edf.3.2  *
cv004cc  mass.1   rate  edf.4.1  * sensible heat
cv004cd  energy.p rate  edf.4.2  *
cv004ce  mass.1   rate  edf.5.1  * pump heat
cv004cf  energy.p rate  edf.5.2  *
*
.                                     * terminator
***************************************************
* FL input                                        *
***************************************************
***
***       Vent Lines/Vent Header/Downcomers
***       From the Drywell to the Wetwell
***       Eight (8) Vent Pipes From Drywell (CV1 to CV2)
***
```

```
fl00100  VENT-OPENING   1    2     8.474   8.474     * Mid-point of
Vent to DW
fl00101  21.92   11.53      1.0    1.88    1.88        * ~6' 2" High OH
in DW (SAR rev14)
fl00102  3  0  0  0                                 * Horiz, Active, No
SPARC
fl00103  4.6  4.6  0.7   0.7                        * Form Losses
(2xCONTAIN)
fl001S1  21.92   11.53   1.88                       * Vent Pipe FArea,
L, Dh
fl00200  DOWNCOMER-EXIT   2    3    2.455    2.455     * Base of Vent
Pipe to SP
fl00201  21.92   1.14      1.0       0.001   0.001     *
fl00202  0   0   0   1                                 * VERT, ACT,
SPARC IN WW
fl00203  1.0   1.0   0.7  0.7                          * Form
Losses(2xCONTAIN)
fl002S1  21.92   1.14   0.61                           * Downcomer
Area, L, Dh (2' nom diamter FSAR rev 14)
*
****************************************************
**  ADDITIONS FOR LONG TERM
****************************************************
***
***       RPV overflow (CONTAIN FL#5)
***
fl00500  RPV-WW   4    1     27.28   10.03             * initial RPV
water level to bottom of DW
fl00501  0.307   0.1      1.0    0.5    0.5            *
fl00502  3  0  0  0                                    * Horiz, Active,
No SPARC
fl00503  2.0   2.0                                     * Form Losses
(2xCONTAIN)
fl005S1  0.307   0.1  0.01                             * Vent Pipe
FArea, L, Dh (L = 0.307/vavl=0.307/2.5=0.1 from CONTAIN)
fl005V0  -1    501    501                              *
***
*
CF50100  FL5-1   ADD   2   1.00   0.00                 * Time > 75 sec
CF50102  3   0.0   1.0
CF50110   1.00   0.00  TIME
CF50111   0.00 -75.00  TIME
*
****************************************************
***
***       RPV gas flow to DW (CONTAIN FL#6)
***
fl00600  RPV-DW   4    1     28.03   28.03             *
fl00601  0.307   0.1      1.0    0.01    0.01          *
fl00602  3  0  0  0                           * Horiz, Active, No SPARC
fl00603  2.0   2.0                            * Form Losses (2xCONTAIN)
fl006S1  0.307   0.1   1.88                   * Vent Pipe FArea, L, Dh
fl006V0  -1    601    601  *(L = 0.307/vavl=0.307/2.5=0.1 from CONTAIN)
CF60100  FL6-1   ADD   2   1.00   0.00                 * Time > 75 sec
CF60102  3   0.0   1.0
CF60110   1.00   0.00  TIME
```

```
CF60111   0.00 -75.00  TIME
*
**********************************************************************
********
***       Wetwell/Drywell Vacuum Breaker Flow Path
***       From the Wetwell through the Vacuum Breakers
***       to the Vent Lines (8 - 24" Lines)
***
fl00700  WET-DRY-VACRV   3   1  6.965    20.0         * elevation (from
                                   top of WW to arbitrary elev. in DW)
fl00701  2.335   10.0     0.0   0.6096   0.6096       * 8 24 in valves
                       D = 0.6096, A = 2.335  (CONTAIN 25.1?)
fl00702  3  0  0  0                                   * HORIZ, ACTIVE
fl00703  2.0  2.0                        * Form Losses (CONTAIN vcfc=1)
fl007S1  2.335   10.0   0.6096          * VB Area, L, Dh (L =
                       25.1/vavl=25.1/2.5=10 from CONTAIN)
fl007V0  -1    2    2                            * CF002 Fixes VB OF
***
***     CF001, CF002, and TF030 open and close the
***       vacuum relief valves at 0.25 psi (1724 Pa)
***       differential pressure between the wetwell and the drywell
***         TF050 = function (CF001)
***         CF001 = P.CV3 - P.CV1
***
CF00200  WW-DW-VAC-RV   TAB-FUN   1   1.00   0.00
CF00203  50
CF00210  1.00    0.00   CFVALU.001
***
***       CF200 = wetwell pressure - downcomer pressure
***
CF00100  VAC-RV-DP    ADD   2   1.00   0.00
CF00110   1.00  0.00  CVH-P.3
CF00111  -1.00  0.00  CVH-P.1
***
TF05000  VAC-RV-AREA   4   1.00   0.00
***
***      PRESSURE   FRACTION
***                   OPEN
TF05010  0.00         0.00
TF05011  1.724E+03    0.00
TF05012  1.724E+03    1.00
TF05013  2.000E+04    1.00
***
***********************************************************
********END OF INPUT
**********************************************************
.
**********************************************************************
******************************************
*
* source to RPV pool
*
CV004C3  MASS.1   452   3   * HPCI MASS FLOW RATE
CV004C4  TE       453   9   * SP TEMP
*
* sink from WW pool
```

```
*
CV003C3  MASS.1   454   3   * HPCI MASS FLOW RATE (negative)
CV003C4  TE       453   9   * SP TEMP
*
***********************************************************************
*******************************************
*
CF45100 'HPCI ON'    L-GT  2  1.0  0.0
CF45105  LATCH
CF45106  2  'RHR ON'
CF45110  1.0    0.0    TIME
CF45111  0.0   75.0    TIME                    *  on at 75 sec
*
CF45200 'HPCI MASS' L-A-IFTE 3 1.0  0.0  *  kg/s
CF45210 1.0   0.0   CFVALU.451   * HPCI ON?
CF45211 0.0 753.8   TIME         * 11,950 gpm = 753.8 kg/s as in
CONTAIN
CF45212 0.0   0.0   TIME         * OTHERWISE, ZERO
*
CF45300    WW-ENTH  equals  1  1.0  0.0
CF45310    1.0  0.0   CVH-TLIQ.3
*
* mass sink for WW
*
CF45400    WW-MASS  MULTIPLY  2 -1. 0.           * M
CF45411    1.0      0.0    CFVALU.452            * injection rate [kg/s]
CF45413    0.0      1.0    TIME                  *
*
.
***********************************************************************
*******************************************
*
* source to RPV pool
*
CV004C1  MASS.1   252   3   * RHR MASS FLOW RATE
CV004C2  TE       259   9   * RHR TEMP at HX EXIT
*
* sink from WW pool
*
CV003C1  MASS.1   260   3   * RHR MASS FLOW RATE (negative)
CV003C2  TE       261   9   * SP TEMP
*
***********************************************************************
*******************************************
*
CF25100 'RHR ON'    L-GT  2  1.0  0.0
CF25105  LATCH
CF25106  2  'RHR ON'
CF25110  1.0    0.0    TIME
CF25111  0.0  600.0    TIME                    *  on at 600 sec
*
CF25200 'RHR MASS' L-A-IFTE 3 1.0  0.0  *  kg/s
CF25210 1.0   0.0   CFVALU.251   * RHR ON?
CF25211 0.0 630.8   TIME         * 10,000 gpm = 630.8 kg/s as in
CONTAIN
CF25212 0.0   0.0   TIME         * OTHERWISE, ZERO
```

```
*
* RHR HX
*
CF25300    HX-DT   ADD  2 1.  0.                * [K]
CF25311    1.0    0.0    CVH-TLIQ.3             * Hot Inlet
CF25312    0.0 -308.0    TIME                   * Cold Inlet
*
CF25400    HX-Qmax MULTIPLY  2 1. 0.            * Maximum Q [W] = C_min
(T_h,i-T_c,i)
CF25412    0.0    2.375E6    TIME               * C_min = C_c = 567.7
kg/s * 4183 = 2.375E6
CF25413    1.0    0.0      CFVALU.253           * Dt
*
CF25500   HX-Q    MAX      2   0.230  0.        * max{0,qmax} eff=0.230
CF25510   0.0    0.0       TIME                 * 0.0
CF25511   1.0    0.0       CFVALU.254           * qmax
*
* now calculate the exit temperature
*
CF25600    HX-M-II MULTIPLY  2 1. 0.            * M Cp [W/C]
CF25611    0.0    630.8    CFVALU.252           * injection rate [kg/s]
CF25612    0.0   4183.0    TIME                 * Cp
*
CF25700   Chmax    MAX     2   1.0  0.          * max{1,C_h} to avoid
divide by zero
CF25710   0.0    1.0       TIME                 * 0.0
CF25711   1.0    0.0    CFVALU.256              * C_h = Cp M
*
CF25800    Tho1 DIVIDE  2 1. 0.                 * (T_h,i-T_h,e)
CF25811    1.0    0.0    CFVALU.256             * C_h = Cp M
CF25812    1.0    0.0    CFVALU.255             * Q [W] = C_h (T_h,i-
T_h,e)
*
CF25900    Tho2   ADD   2 1. 0.                 * T_h,e
CF25911   -1.0    0.0    CFVALU.258             * (T_h,i-T_h,e)
CF25912    1.0    0.0    CVH-TLIQ.3             * T_h,i
*
* mass sink for WW
*
CF26000    WW-MASS  MULTIPLY  2 -1. 0.          * M
CF26011    1.0      0.0    CFVALU.252           * injection rate [kg/s]
CF26013    0.0      1.0    TIME                 *
*
CF26100    WW-ENTH  equals  1  1.0  0.0
CF26110    1.0  0.0   CVH-TLIQ.3
*
.
***   Non-Condensible gases
*****************************************************
***
***   Gas     Material Number
***
NCG000  O2       4
NCG001  N2       5
***
.
```

s1cv.txt

```
0.0000E+00,1.9159E+04,2.4308E+10
0.2197E-02,2.2836E+04,2.8974E+10
1.3130E+00,2.2023E+04,2.7865E+10
1.3140E+00,1.5009E+04,1.8990E+10
2.1250E+00,1.4845E+04,1.8770E+10
3.5630E+00,1.5473E+04,1.9621E+10
4.4210E+00,1.6091E+04,2.0480E+10
4.4220E+00,1.0150E+04,1.2918E+10
1.3790E+01,1.0595E+04,1.3736E+10
1.7030E+01,1.0568E+04,1.3686E+10
1.7040E+01,4.6590E+03,6.0338E+09
1.8280E+01,4.2550E+03,5.4166E+09
1.9600E+01,3.8510E+03,4.8064E+09
2.1150E+01,3.4390E+03,4.1931E+09
2.2530E+01,3.0860E+03,3.6809E+09
2.3780E+01,2.7860E+03,3.2543E+09
2.5150E+01,2.4840E+03,2.8339E+09
2.6780E+01,2.1570E+03,2.3912E+09
2.8530E+01,1.8410E+03,1.9763E+09
3.0500E+01,1.5430E+03,1.5928E+09
3.3370E+01,1.2350E+03,1.1962E+09
3.7370E+01,1.1440E+03,9.6947E+08
4.2870E+01,9.5410E+02,6.4945E+08
4.8310E+01,5.1680E+02,2.9181E+08
4.8430E+01,0.0000E+00,0.0000E+00
```

s2cv.txt

```
0.0000E+00,0.0000E+00,0.0000E+00
1.7030E+01,0.0000E+00,0.0000E+00
1.7040E+01,1.8270E+03,5.0518E+09
1.8280E+01,1.7820E+03,4.9398E+09
1.9650E+01,1.7200E+03,4.7759E+09
2.1150E+01,1.6390E+03,4.5624E+09
2.2530E+01,1.5570E+03,4.3415E+09
2.3780E+01,1.4800E+03,4.1302E+09
2.5150E+01,1.3940E+03,3.8966E+09
2.6780E+01,1.2900E+03,3.6090E+09
2.8530E+01,1.1790E+03,3.3012E+09
3.0500E+01,1.0420E+03,2.9199E+09
3.3370E+01,8.1500E+02,2.2820E+09
3.7370E+01,3.6400E+02,1.0158E+09
4.2870E+01,7.2400E+01,1.9968E+08
4.8310E+01,1.2400E+01,3.3797E+07
4.8430E+01,0.0000E+00,0.0000E+00
```

s3cv.txt

```
0.0000E+00,1.0000E-05,0.0000E+00
0.2000E+01,1.0000E-05,0.0000E+00
0.6000E+01,1.0000E-05,0.0000E+00
1.0000E+01,1.0000E-05,0.0000E+00
2.0000E+01,1.0000E-05,0.0000E+00
```

```
7.5000E+01,1.0000E-05,0.0000E+00
7.5001E+01,1.0000E-05,1.3710E+08
1.2000E+02,1.0000E-05,1.2800E+08
2.0000E+02,1.0000E-05,1.1300E+08
6.0000E+02,1.0000E-05,8.6600E+07
8.0000E+02,1.0000E-05,7.9400E+07
1.0000E+03,1.0000E-05,7.4900E+07
2.0000E+03,1.0000E-05,6.1800E+07
4.0000E+03,1.0000E-05,5.0800E+07
6.0000E+03,1.0000E-05,4.5400E+07
8.0000E+03,1.0000E-05,4.2200E+07
1.0000E+04,1.0000E-05,4.0300E+07
2.0000E+04,1.0000E-05,3.3900E+07
4.0000E+04,1.0000E-05,2.7300E+07
6.0000E+04,1.0000E-05,2.4800E+07
8.0000E+04,1.0000E-05,2.2300E+07
1.0000E+05,1.0000E-05,2.1000E+07
```

`s4cv.txt`

```
4.9861E+01,0.0000E+00,0.0000E+00
6.1252E+01,0.0000E+00,0.0000E+00
7.4999E+01,0.0000E+00,0.0000E+00
7.5000E+01,1.0000E-05,1.2423E+08
8.1897E+01,1.0000E-05,1.2993E+08
9.7019E+01,1.0000E-05,1.2960E+08
1.1218E+02,1.0000E-05,1.2296E+08
1.2816E+02,1.0000E-05,1.1701E+08
1.4999E+02,1.0000E-05,1.2217E+08
1.6929E+02,1.0000E-05,1.1417E+08
1.8650E+02,1.0000E-05,1.1399E+08
2.0546E+02,1.0000E-05,1.1287E+08
2.2635E+02,1.0000E-05,9.8057E+07
2.5240E+02,1.0000E-05,1.1444E+08
2.7472E+02,1.0000E-05,1.0552E+08
3.0265E+02,1.0000E-05,8.8112E+07
3.2941E+02,1.0000E-05,9.5615E+07
3.4996E+02,9.9999E-06,1.0435E+08
3.7632E+02,1.0000E-05,9.2092E+07
3.9979E+02,1.0000E-05,9.4541E+07
4.2473E+02,9.9999E-06,7.3239E+07
4.6229E+02,1.0000E-05,8.1785E+07
4.9112E+02,1.0000E-05,7.9658E+07
5.2812E+02,1.0000E-05,7.1542E+07
5.7481E+02,1.0000E-05,8.2190E+07
6.1067E+02,9.9999E-06,6.8359E+07
6.5666E+02,1.0000E-05,7.1939E+07
6.9763E+02,1.0000E-05,5.9837E+07
7.5017E+02,1.0000E-05,5.5633E+07
8.0668E+02,1.0000E-05,7.3665E+07
8.4669E+02,1.0000E-05,5.2381E+07
9.1046E+02,1.0000E-05,5.5349E+07
9.6726E+02,1.0000E-05,4.8556E+07
1.0401E+03,1.0000E-05,4.5170E+07
1.1184E+03,1.0000E-05,4.1955E+07
1.2027E+03,1.0000E-05,3.6909E+07
```

```
1.2932E+03,1.0000E-05,3.2633E+07
1.4076E+03,1.0000E-05,3.0010E+07
1.5320E+03,1.0000E-05,2.7552E+07
1.6675E+03,1.0000E-05,2.2526E+07
1.8594E+03,1.0000E-05,2.2871E+07
2.0484E+03,1.0000E-05,1.4999E+07
2.2842E+03,1.0000E-05,1.1480E+07
2.6094E+03,1.0000E-05,8.1919E+06
2.9452E+03,1.0000E-05,5.9749E+06
3.4056E+03,1.0000E-05,4.9335E+06
3.8437E+03,1.0000E-05,2.7686E+06
4.5534E+03,1.0000E-05,1.8887E+05
5.5937E+03,1.0000E-05,1.8887E+05
```

`s5cv.txt`

```
0.0000E+00,0.0000E-05,0.0000E+00
7.4999E+01,0.0000E-05,0.0000E+00
7.5000E+01,1.0000E-05,4.5800E+06
6.0000E+02,1.0000E-05,4.5800E+06
1.0000E+06,1.0000E-05,4.5800E+06
```

## APPENDIX C INPUT FILES FOR MARK II SHORT-TERM ANALYSIS

Limerick (Mark II) Recirculation Line Break, Short-Term Analysis CONTAIN input file is extensively commented to provide the basis for the parameter values used.

### C.1 CONTAIN Input File

```
&& ********** GLOBAL CONTROL BLOCK

control                 && Global storage allocation specification
  ncells=3              && # of cells
  ntitl=3               && # of lines in the title
  ntzone=5              && # of time zones
  nengv=4               && # engineered vents, of which there are 4
                        &&    for the downcomers, see discussion
                        &&    in main body
eoi                     && eoi for control

&& ********** MATERIAL BLOCK

material                && Initiate material block
  compound h2ol h2ov n2 o2

&& ********** TITLE BLOCK

title
Mark II Short-Term Analysis Sample Problem
 Limerick Plant - Recirc. Line Break, downcomers modeled as a
 cell and 4 engineered vents

&& ********** TIME ZONES

times 50000.  0.0       && cpu time and start time
  0.01     .01   2.0    && time step, plot interval, zone end time
  0.02     .02   5.0
  0.05     .10   10.0
  0.10     .20   20.0
  0.10     .20   30.0   && Calculation ends at 30 s

&& ********** PRINT OPTIONS ********************************

shortedt=300            && # of time steps between short edits
longedt=10              && # of edit steps between long edits, but a
                        && long edit also at the time-zone end
prheat                  && Print output options
prlow-cl
prflow
prengsys
prenacct

flows implicit          && Implicit for engineered vents
hiprwatr                && non-ideal EOS for water
```

```
&& ********** ENGINEERED VENTS
engvent

&& Drywell (Cell 1) to Mark II downcomers (Cell 2) uses 2
&&   engineered vents, one a pool and the other a gas flow path.
&& The flow area is SAR net free vent area of 256.5ft**2 = 23.830m**2
&& Loss coefficient is SAR conventional value of 2.23 less 1.0
&&   applied at the downcomers exit which leaves 1.23 conventional,
&&   i.e., a CONTAIN value of 0.615, to be applied here, the vent
&&   system entrance

&& The inertial A/L term is based on an L/A sum as follows
&&   (L/A)1-2 = (L/A)1 + (L/A)2. For L1 use the DW height over 2.
&& The area A1 is ~ the DW area used in cellhist.
&& For L2, use ½ of the Cell 2 (downcomers) flow path length
&& The area is the downcomer flow area.
&& velevb (the back of this vent)is assumed to be the top of the
&&   downcomers where it exits the DW.
&& Also, velevf (the front of this vent) is assumed to be at the
&&   same elevation.
&& A vena contracta value of 0.7, which has no effect on a pool
&&   path, is used.

  from 1 to 2
    varea=23.830 vavl=3.2  type=pool vcfc=0.615 velevb=17.526
    velevf=17.526 vcontra=0.7
eoi                     && eoi for this engineered vent
  from 1 to 2
varea=23.830 vavl=3.2  type=gas  vcfc=0.615 velevb=17.526
    velevf=17.526 vcontra=0.7
eoi                     && eoi for engineered vent

&& downcomers (cell 2) to wetwell (cell 3)

&& Flow area is 256.5ft**2 = 23.830m**2
&& Inertial length for the liquid is based on previous experience
&&   that indicated a value of 1.25 times the submergence length
&&   is appropriate. (1.25 X 3.734)/23.83= 0.2 A/L=5.0
&& For the gas vent a/l, an L/A sum was calculated in a manner like
&&   that described above. (here for the gas used the same A/L)
&& For these exit vents a conventional loss of 1.00 is applied.
&& The remainder of the SAR total loss is applied at the
&&   inlet as discussed above.
&& Note that the CONTAIN value of 0.5 is used to represent the
&&   conventional loss coefficient of 1.0.
&& velevb and velevf are at the downcomer bottom

from 2 to 3
    varea=23.830 vavl=5.0  type=pool  vcfc=0.5 velevb=3.658
    velevf=3.658 vcontra=0.7
eoi                     && eoi for engineered vent

  from 2 to 3
    varea=23.830 vavl=5.0  type=gas  vcfc=0.5 velevb=3.658
    velevf=3.658 vcontra=0.7
eoi                     && eoi for engineered vent
```

```
&& The DW & WW volumes below need to be adjusted to account
&&   for the volume of the vent system air space.
&& In particular, this air space is included in
&&   the SAR value for the DW (cell below) volume.
&& Similarly, the WW volume must recognize the vent system
&&   in the WW cellhist vertical area profile.
&& Our vent-system air space determination starts with the
&&   suppression pool SAR volume of 134,600ft**3 (3811.45m**3).
&& This is the HWL value that is used because there is more
&&   liquid water in the downcomer (DC) that must be accelerated,
&&   which delays the time of vent opening and maximizes the
&&   calculated peak pressure.
&& The corresponding water mass, at 1000kg/m**3, is 3.8114e+06 kg.
&& To get the pool area, the HWL pool depth of 24.25 ft is
&&   used.
&& For the volume of 134600 ft**3, the pool area is 5550.5 ft**2
&&   (515.66m**2).
&& Note that this is close to the SAR table 6.2-4a total pool area
&&   of 5267ft**2.
&& For the WW pool area 5550.5ft**2 and the table 6.2-4a wet well
&&   air space volume (including vent system) at HWL of
&&   147,670 ft**2, the WW height above the pool of this air space
&&   is 26.605 ft (8.1092 m).
&& Adding an additional 3 ft for the floor thickness gives us
&&   the increment of elevation of the vent system air space that
&&   is not in the DW to be 29.605 ft (9.024 m).
&& We can now determine the volume of the vent system air space
&&   included in the DW volume.
&& It is the vent area (256.5 ft**2) times 29.605 ft = 7,593.7 ft**3
&&    (215.03 m**3).
&& Note that the above analysis establishes elevations used below:
&&   WW top is at 50.855 ft (25.25+26.605) (15.501 m)
&&   DW bottom is at 53.855 ft (50.855+3.) (16.415 m)
&&   DC bottom (at HWL) is at 12.00 ft (3.658 m) based on it being
&&      12.25 ft below the pool height of 24.25 ft

&& ********** CELL #1- DRYWELL

cell=1                  && Beginning of cell 1 input
control
  jpool=1
  nsoatm=2              && Two coolant blowdown sources
  nspatm=25             && To allow 25 blowdown vs. time points
eoi                     && eoi for cell control

geometry
 gasvol=6662.0          && This is the SAR table 6.2-1 value of
                        &&   242,860 ft3 corrected for the included
                        &&   vent system downcomer (DC) gas volume
                        && From the above analysis, the DC volume is
                        &&   7,593.7 ft**3. thus the DW volume is
                        &&   242,860-7593.7=235,266 ft**3
                        &&   (6662.0 m**3.)
 cellhist=1 16.415 446. 31.352
                        && For an approximate DW cross sectional
```

```
                        &&   area of 4800 ft2, gasvol and the above
                        &&   determined DW bottom height
eoi                     && eoi for geometry

atmos=2
  pgas=1.0652e5         && 0.75 psig (SAR)
  tgas=339.0            && 150 F (SAR)
  molefrac o2=0.04 n2=0.96
                        && Atmosphere is inerted
  satrat =0.2           && Humidity = 20% (SAR)
eoi                     && eoi for atmos
condense

source=2                && Two sources

h2ov=18                 && The first source
  iflag=2
  t=
   0.0      0.733   1.03    1.53   3.16   4.16
   5.16     6.16    8.16   10.16  13.66  15.16
   18.16   20.16   25.0    30.0   35.0   37.5
  mass=
   21645.  21645.  21645. 21645.  14677.  14718.
   14759.  14800.  14864. 14905.  14873   6436.
    4764.   3872.   2176.  1085.   1215.  1139.
  enth=
   1.2793e+6  1.2777e+6   1.277e+6  1.2767e+6  1.2733e+6  1.2767e+6
   1.2774e+6  1.2793e+6   1.284e+6  1.2872e+6  1.2842e+6  1.2523e+6
   1.1842e+6  1.1342e+6   1.0135e+6  9.012e+5   6.948e+5   6.135e+5
eoi                     && eoi for source

h2ov=9                  && The second source
iflag=2
  t=
    0.0    15.15  15.16  18.16   20.16
   25.0    30.0   35.0   37.5
  mass=
       0.0   0.0  2225.  2017.  1843.
    1327.  841.4   277.   121.
  enth=
    0.0         2.774e+6   2.774e+6   2.7893e+6  2.7963e+6
    2.8037e+6  2.7963e+6  2.7626e+6     2.74e+6
eoi                     && eoi for source

ht-tran off off off off off
                        && All heat-transfer processes turned off
low-cell
  geometry  446.0 bc=339.0
                        && Area from SAR figure, bc temperature
                        &&   same as atmosphere
  pool
    compos=1 h2ol 1.e-6  temp=339.0
                        && Essentially no initial DW water and there
                        &&   will be no additional water
    physics
      boil
```

```
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ********** CELL #2- Downcomers (DC)

cell=2
control
  jpool=1
eoi

geometry

&& Total DC volume is its area (256.5 ft**2, 23.830 m**2)) times
&&   its length (45.5 ft, 13.868 m). a value of 11,671 ft**3
&&   (330.47 m**3) results
&& However, the HWL DC submergence is 12.25 ft (3.734 m), so the
&&   DC gas volume is (44.5-12.25)*256.5=8272.1 ft**3 (234.24 m**3)

  gasvol=234.24

&& DC cell top elevation is its bottom elevation (3.658) plus the
&&   vent length 45.5 ft (13.868 m), i.e., 17.526 m

  cellhist=1 3.658 23.830 17.526

eoi                     && eoi for geometry

atmos=2                 && Same as the DW (Cell 1)
  pgas=1.0652e5 tgas=339.0
  molefrac o2=0.04 n2=0.96
  satrat =0.2
eoi                     && eoi for atmos

ht-tran off off off off off

low-cell
  geometry 23.830        && Downcomer area
  bc=308.               && Pool temp
  pool
                        && Mass in downcomer based on 1000 kg/m**3
                        &&   volume for 12.25 ft (3.734 m) HWL DC
                        &&   submergence and area of 256.5 ft**2
                        &&   (23.830 m**2) is 3,142.1 ft**2
                        &&   (88.975 m**3)
    compos=1  h2ol=88.975e+3 temp=308.
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell

&& ********** CELL #3- WETWELL
cell=3
control
  jpool=1
```

```
  naensy=1              && For engineered system spray
eoi                     && eoi for control

geometry
                        && The SAR HWL suppression chamber air
                        &&   volume is 147,670 ft**3 (4181.5 m**3),
                        &&   which includes an accounting for the
                        &&   downcomer vent system in the air space.
  gasvol=4181.5
                        && cellhist accounts for the change in WW
                        &&   cross section
  cellhist=2 0.0 513.2 3.658 489.3  15.94
                        && Note that the cellhist values give a total
                        &&   cell volume of
                        &&   513.2*(3.658-0.0)+489.3*
                        &&   (15.94-3.658)=7887
                        && The otherwise-specified total WW volume is
                        &&   the sum of the above
                        &&  gasvol volume of 4181.5 m**3 plus the below
                        &&   water-pool volume of about 3722.5 m**3.
                        &&   the resulting total is 7904,
                        &&   which is "close enough" to the
                        &&   cellhist based total volume.
atmos=2
  pgas=1.0652e5 tgas=308.0
                        && 0.75 psig, 95 F
  molefrac o2=0.04 n2=0.96
                        && Inerted atmosphere
  satrat=1.0            && 100% humidity
eoi                     && eoi for atmos

engineer wwpspry 4  3  3  0.0
                        && Above specifies an engineered safety system
                        &&   with 4 components (as described below)
                        &&   with coolant coming from this cell (#3)
                        &&   and returning to this cell.
                        && The safety system 4 components are a spray,
                        &&     a dummy tank that has no water, a
                        &&    pump, and a dummy heat exchanger that
                        &&    does not change the pumped water
                        &&    temperature
    spray
      spstpr=1.075e+05  && Spray to come on when WW press increases a
                        &&   little
    eoi                 && eoi for spray

    tank
      0.0               && No water mass in the tank
      308.0             && Pool and atmosphere temperature
      5000.             && Same as pump flow

    pump
      5000.             && Arbitrary value to simulate mixing of pool
                        &&    and atmosphere by bubbles bursting above
                        &&    pool
    hex
```

```
      user=0.0          && hex to not change pool-water temperature
eoi                     && eoi for engineer

condense                && Need for heat transfer between pool and
                        &&    atmosphere
low-cell
  geometry   489.3   bc=308.0
  pool
    compos=1 h2ol  3.722e6 temp=308.0
                        && Above water mass is based on 1000 kg/m**3
                        &&   and the SAR WW water volume 134,600 ft**3
                        &&   (3811.5 m**3) corrected by the submerged
                        &&   downcomer volume.
                        && The submerged downcomer volume is the vent
                        &&   area (256.5 ft**2) times the vent
                        &&   submergence (12.25 ft). which gives a
                        &&   volume of 3,142.1 ft**3 (88.98 m**3)
                        && Therefore, the WW water volume is
                        &&   3811.5-88.98=3722.5 m**3, or about
                        &&   3.722e+06 kg
                        && Temperature is SAR value of 95F
    physics
      boil
    eoi                 && eoi for physics
  eoi                   && eoi for pool
eoi                     && eoi for low-cell
eof                     && end of input
```

## C.2 MELCOR Input File

```
**************************************************
*                                                *
*    Limerick Calculation                        *
*         Base                                   *
*                                                *
**************************************************
*
*eor*      melgen
**********************
**********************
***                ***
***  MELGEN INPUT  ***
***                ***
**********************
TITLE     'BASE'
***JOBID      BASE
CRTOUT
OUTPUTF   'BASE.out'
RESTARTF  'BASE.rst'
DIAGF     'BASE.gdia'
TSTART         0.
DTTIME    .1
***
***
* External data file with ME for DW source
* file has time, dmdt & dedt
edf00100  s1cv  2  read      * First Source
edf00101  s1cv.txt
edf00102  3e12.4
*
edf00200  s2cv  2  read      * Second Source
edf00201  s2cv.txt
edf00202  3e12.4
*
************************************
* Active                           *
************************************
*
ATMCSOPTION FROZEN
ATMCSTABLE
*
r*i*f .\cont.txt
r*i*f .\mp.txt
r*i*f .\fl.txt
*
SC00000 4406 10.0 1      * max fog density
.   * terminate
*eor* melcor
************************
***  MELCOR INPUT    ***
************************
TITLE     'BASE'
***JOBID      ref
```

```
*
OUTPUTF   'BASE.out'
PLOTF     'BASE.ptf'
RESTARTF  'BASE.rst'
MESSAGEF  'BASE.mes'
DIAGF     'BASE.dia'
*
CRTOUT
***CYMESF    10 10
*
RESTART            -1
tend  30.0
***EXACTTIME1         100.
CPULIM             400000.
CPULEFT            400.0
*
*
*       time    dtmax   dtmin   dtedit  dtplot  dtrest
time1     0.0   0.0005  0.0001   10.0     0.01     50.0
time2     0.3   0.0005  0.0001   10.0     0.05     50.0
time3     2.0   0.001   0.0001   10.0     0.02     50.0
time4    200.   0.02    0.0001   10.0     0.1      50.0
*
*
.  * terminate

*****************************
* CVH INPUT                       *
*********************************
*
*******************************************************
* Limerick Mark II                                    *
*******************************************************
*
*
cv00100  DRYW        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv001a0  3
cv001a1  pvol       106520.0     *
cv001a2  tatm       339.0        *
cv001a3  mlfr.4     0.04         *
cv001a4  mlfr.5     0.96         *
cv001a5  rhum       0.2          *
cv001b1  16.415     0.0
cv001b2  31.352     6662.0       *
cv001c1  mass.3   rate  edf.1.1  * The first source
cv001c2  energy.a rate  edf.1.2
cv001c3  mass.3   rate  edf.2.1  * The second source
cv001c4  energy.a rate  edf.2.2
*
cv00200  DC        2  2  1       * Non-Equ Thermo, Vert flow, ctmt
cv002a0  3
cv002a1  pvol       106520.0     *
cv002a2  tatm       339.0        *
cv002a3  mlfr.4     0.04         *
cv002a4  mlfr.5     0.96         *
cv002a5  rhum       0.2          *
```

```
cv002a6  zpol       7.392        *
cv002a7  tpol       308.0        *
cv002b1  3.658      0.0          * Base of Downcomer Vent Pipe
cv002b2  7.392      88.975
cv002b3  17.526     330.47
*
cv00300  WETW        1  2  1     * Equ Thermo, Vert flow, ctmt
cv003a0  3
cv003a1  pvol       106520.0     *
cv003a2  tatm       308.0        *
cv003a3  mlfr.4     0.04         *
cv003a4  mlfr.5     0.96         *
cv003a5  rhum       1.0          *
cv003a6  zpol       7.392        *
cv003a7  tpol       308.0        *
cv003b1  0.0        0.0
cv003b2  7.392      3722.0
cv003b3  15.94      7886.9
*
.                                     * terminator

****************************************************
* FL input                                         *
****************************************************
*
****************************************************
***
***       Vent Lines/Vent Header/Downcomers
***       From the Drywell to the Wetwell
***
***
fl00100  VENT-OPENING   1    2     17.526   17.526     *
fl00101  23.83   7.45      1.0   0.001    0.001        *
fl00102  0  0  0  0                            * VERT, Active, No SPARC
fl00103  1.23  1.23  0.7   0.7                * Form Losses (2xCONTAIN)
fl001S1  23.83   7.45    0.6            * Vent Pipe FArea, L, Dh (2 ft)
***
****************************************************
***
***        ~80 Downcomers (CV2 to CV3)
***
fl00200  DOWNCOMER-EXIT   2    3    3.658    3.658     * Base of Vent
Pipe to SP
fl00201  23.83   4.7      1.0    0.001   0.001      * 1.25 X 3.734
(submergence)
fl00202  0   0   0   1                             * VERT, ACT,
SPARC IN WW
fl00203  1.0   1.0   0.7  0.7                      * Form
Losses(2xCONTAIN)
fl002S1  23.83   4.7   0.6                      * Downcomer Area,
L, Dh (2 ft)
*
***********************************************************************
********
*************************************************************
```

```
********END OF INPUT
**********************************************************
*************************************************************************
********
.

*****************************************************
***
***   Non-Condensible gases
*****************************************************
***
***   Gas     Material Number
***
NCG000  O2       4
NCG001  N2       5
***
*
.

s1cv

0.0000E+00,2.1645E+04,2.7690E+10
0.7330E+00,2.1645E+04,2.7655E+10
1.0300E+00,2.1645E+04,2.7655E+10
1.5300E+00,2.1645E+04,2.7634E+10
3.1600E+00,1.4677E+04,1.8688E+10
4.1600E+00,1.4718E+04,1.8790E+10
5.1600E+00,1.4759E+04,1.8853E+10
6.1600E+00,1.4800E+04,1.8933E+10
8.1600E+00,1.4864E+04,1.9085E+10
1.0160E+01,1.4905E+04,1.9185E+10
1.3660E+01,1.4873E+04,1.9099E+10
1.5160E+01,6.4360E+03,8.0598E+09
1.8160E+01,4.7640E+03,5.6415E+09
2.0160E+01,3.8720E+03,4.3916E+09
2.5000E+01,2.1760E+03,2.2053E+09
3.0000E+01,1.0850E+03,9.7780E+08
3.5000E+01,1.2150E+03,8.4418E+08
3.7500E+01,1.1390E+03,6.9877E+08

s2cv

0.0000E+00,0.0000E+00,0.0000E+00
1.5150E+01,0.0000E+00,0.0000E+00
1.5160E+01,2.2250E+03,6.1721E+09
1.8160E+01,2.0170E+03,5.6260E+09
2.0160E+01,1.8430E+03,5.1535E+09
2.5000E+01,1.3270E+03,3.7205E+09
3.0000E+01,8.4140E+02,2.3528E+09
3.5000E+01,2.7700E+02,7.6524E+08
3.7500E+01,1.2100E+02,3.3154E+08
```

## APPENDIX D INPUT FILES FOR MARK III SHORT-TERM ANALYSIS

Grand Gulf (Mark III) Recirculation Line Break, Short-Term Analysis CONTAIN input file is extensively commented to provide the basis for the parameter values used.

### D.1 CONTAIN Input File

```
&& *********************** CONTROL BLOCK**************************
&&
control                      && global storage allocation
  ncells=3                   && # of cells
  ntitl=2                    && # of lines in the title
  ntzone=5                   && # of time zones
  nengv=8                    && # of engineered vents
eoi

&& *********************** MATERIAL
BLOCK*******************************
material                                && material block
  compound h2ol h2ov n2 o2

&& *********************** TITLE
BLOCK**********************************
title
  Grand Gulf-Mark III- Recirculation Line Break - Short Term Pressure

&& *********************** TIME
ZONES***********************************
times 50000.  0.0
  0.01   .01   0.3
  0.005  .005  2.0
  0.02   .02   5.0
  0.03   .10  10.0
  0.03   .20  20.0

&& *********************** PRINT
OPTIONS********************************
longedt=1                    && # of timesteps between longedits
shortedt=300                 && # of timesteps between shortedits

&& *********************** PRINT OPTION
FLAGS***************************
prheat                       && heat transfer structure output
prlow-cl                     && lower cell output
prflow                       && flow output
prengsys                     && engineered system output
prenacct                     && energy and mass accounting output
&& ********************** FLOW OPTIONS
INPUT****************************
flows implicit               && implicit should always be used
hiprwatr                     && Non-ideal EOS
&&
&& ************************ ENGINEERED VENTS*******************
```

```
engvent
&& Flow path from drywell to annulus at top of weir wall
&&   Elevation reference is the bottom of the suppression pool
&&   Pool conditions assumed to be at HWL = 5.73 m. (18.81 ft) This is
&&   the SAR suppression pool volume at HWL (125398 ft3) divided by SAR
&&     wetwell pool area (6666 ft2)
&&   Flow area = annulus area = 51.47 m2(554 ft2) from SAR.
&& vavl is annulus area/inertial length at HWL. Inertial length is
&&  based on distance from top of weir wall to pool surface at HWL.
&&     Top of weir wall
&&     = 7.41 m (24.31 ft). Thus the inertial length = 1.68 m (5.51
ft)at HWL
&&   Loss coefficient vcfc = 0.25 corresponds to contraction loss
&&   (conventional
&&     value = 0.5)
  from 1 to 2
    varea=51.47 vavl=30.62  type=pool vcfc=0.25 velevb=7.41
    velevf=7.41
   eoi
   from 1 to 2
    varea=51.47 vavl=30.62  type=gas  vcfc=0.25 velevb=7.41
    velevf=7.41  vcontra=0.55
   eoi

&& Top row of vents represented as one gas and one pool path
&&   Vent area = 17.88 m2 (577.3 ft2 divided by 3) taken from SAR
&&   Inertial length = 3.70 from Table 4-2 for submergence of 2.28 m.
&&   Loss coefficient vcfc = 1.5 corresponds to nominal loss
 (conventional
&&     value = 3.0)
&&   Vent elevation = 3.45 m (11 ft 4 in) taken from SAR.
  from 2 to 3
    varea=17.88 vavl=4.832 type=pool vcfc=1.5 velevb=3.45
    velevf=3.45
   eoi
   from 2 to 3
    varea=17.88 vavl=4.832 type=gas vcfc=1.5 velevb=3.45
    velevf=3.45 vcontra=0.55
   eoi
&& Middle vents represented like the top vents except
&&   inertial length = 5.26 (17.26 ft) at HWL from Table 4-2
&&   Vent elevation = 2.18 m (7 ft 2 in) taken from SAR.
    from 2 to 3
     varea=17.88 vavl=3.399 type=pool vcfc=1.5 velevb=2.18
     velevf=2.18
   eoi
  from 2 to 3
    varea=17.88 vavl=3.399 type=gas vcfc=1.5 velevb=2.18
    velevf=2.18 vcontra=0.55
   eoi

&& Bottom vents represented like the top vents except
&&   inertial length = 6.48 (21.26 ft) at HWL from Table 4-2
&&   Vent elevation = 0.91 m (3 ft 0 in) taken from SAR.
  from 2 to 3
    varea=17.88 vavl=2.759 type=pool vcfc=1.5 velevb=0.91
```

```
    velevf=0.91
   eoi
  from 2 to 3
    varea=17.88 vavl=2.759 type=gas vcfc=1.5 velevb=0.91
    velevf=0.91 vcontra=0.55
   eoi
&& ******************* CELL #1- DRYWELL ***********************
cell=1                       && beginning of input for drywell cell,
                             &&   which excludes the annulus region
control
  jpool=1                    && flag indicates pool is present
  nsoatm=2                   && number of source tables
  nspatm=25                  && max. number of table points
eoi
geometry
  gasvol=7551.86             && SAR drywell gas volume of 7645.55 m3
                          && (270000 ft3) less a gas volume of 93.69 m3
                          &&  at LWL in the annulus.  Note the water
                          && level corresponding to the stated drywell
                          && gas volume is not specified, so we
                          &&   conservatively assume it corresponds to
                          &&   LWL.  The annulus pool volume at LWL is
                          &&   (LWL wetwell pool volume)x(annulus pool
                          &&   area)/(wetwell pool area) or 287.70 m3.
                          &&   The total volume of the annulus cell is
                          &&   given by a cross-section of 51.47 m2
                          &&   (554ft2) times a height of 7.41 m
                          &&  (24.3125 ft), which equals 381.39 m3.
                          &&   This leaves a LWL annulus gas volume of
                          &&   93.69 m3.
  cellhist=1 0. 243.02 31.075 && bottom elevation, nominal cross-
section, and
                          &&  top elevation.  Note that total implied
                          &&   cellhist volume should be equal to the
                          &&   total gas and pool volume, otherwise a
                          &&   code diagnostic is issued
eoi

atmos=2                      && refers to number of noncondensible
gases pgas=1.0135e5 tgas=330.22    && corresponds to 1 atm and 120 F
  molefrac o2=.21 n2=.79     && noncondensible gas mole fractions
satrat =.2                   && water vapor saturation ratio
eoi

source=2                     && number of source tables, representing
steam
                             &&   and liquid water in this case
h2ov=15                      && material, number of points in table
  iflag=2                    && linear interpolation indicated
  t=                         && time values (s)
    0.0        17.25      17.26      20.37       25.12
    30.        35.        40.        45.         50.
    54.6       54.7       57.4       59.1        59.4
  mass=                      && mass rate values (kg/s)
    0.0        0.0        1987.66    1816.66     1495.51
    1121.75    692.19     403.7      190.51      75.75
```

```
    33.11      94.35      48.08      11.34        0.0
  enth=                      && specific enthalpy values (J/kg)
    0.0        0.0        2.7639e+6  2.7802e+6   2.7969e+6
    2.8039e+6  2.7995e+6  2.7837e+6  2.7581e+6   2.7323e+6
    2.7125e+6  2.7125e+6  2.6997e+6  2.6958e+6   0.0
  eoi                        && terminator for first table
h2ol=20                      && beginning of second source table
  iflag=2
  t=
    0.0        0.794988    1.450008   1.888992   1.905012
    2.264004   3.99996     6.00012    7.99992    10.24992
    17.25012   17.25984    20.36988   25.12008   29.99988
    34.99992   39.9996     45         50.0004    54.6012
  mass=
    13812.0294 13784.3096  13775.4896 13780.5296 11525.9004
    11535.9723 11630.2277  11725.4831 11793.5226 11829.8104
    11725.4831 5139.25429  3995.30779 2674.45846 1677.80499
    1148.96126 909.00843   871.813481 768.846956 637.303819
  enth=
    1.2814e+6  1.28e+6    1.2793e+6  1.2792e+6  1.2793e+6
    1.2802e+6  1.2893e+6  1.2829e+6  1.3007e+6  1.3039e+6
    1.2937e+6  1.2937e+6  1.233e+6   1.1344e+6  1.0267e+6
    9.1037e+5  7.9192e+5  6.7544e+5  5.8427e+5  5.2262e+5
  eoi                        && terminator for second table

ht-tran off off off off off
                             && turn off all heat transfer
low-cell                     && define lower cell geometry for drywell
sump
  geometry 243.02              && area of pool substrate layers
  bc 330.22                  && boundary condition temperature for
                             &&   bottom-most layer, if any
  pool
     compos=1 h2ol 0.0         && pool assumed dry for now
     temp=330.22
     physics
       boil                    && pool boiling enabled
     eoi
  eoi
eoi

&& ****************** CELL #2- ANNULUS ********************
cell=2
control
  jpool=1
eoi
geometry
  gasvol=80.02               && volume at HWL, less volume of water
added
                          &&   to the annulus to make up for the fact
                           &&   that CONTAIN does not keep track of the
                          &&   water in the vent flow paths (see below)
   cellhist=1 0. 51.47 7.41   && bottom elevation, annulus cross-
section (554
                             &&   ft2) and height of top of weir wall
                             &&   (24.3125 ft)
```

```
eoi

atmos=2
  pgas=1.0135e5 tgas=330.22
  molefrac o2=.21 n2=.79
  satrat=.2
eoi

ht-tran off off off off off

low-cell
  geometry 51.47             && area of non-pool layers, if any
  bc 308.15                  && corresponds to 95 F
  pool                       && annulus pool
    compos=1 h2ol=2.9952e5   && annulus water mass at HWL, plus

&&   allocation of water that should be in the vent flow paths
                       &&   but is ignored by CONTAIN. Since the vent
                             &&   volume is ignored the annulus and
wetwell
                             &&   pool levels are increased so that the
                        &&   correct HWL liquid inventory of 3927.57 m3
                        &&   (13303 + 125398 ft3) is present.  This
                        &&   gives an annulus pool volume of 301.37 m3
                        &&   and a wetwell pool volume of 3626.20 m3
                        &&   when apportioned by the respective areas
&&  of 51.47 m2 (554 ft2) and 619.29 m2 (6666 ft2).
&&  The pool mass assumes a water density = 993.86 kg/m3 at 308.15 K

    temp=308.15              && initial temperature
    physics
      boil
    eoi
  eoi
eoi

&& ****************** CELL #3- WETWELL ********************
cell=3
control
  jpool=1
  numtbc=1
  maxtbc=10
  naensy=1
eoi
geometry
  gasvol=39479.12            && gas volume at HWL less allocation of
                             &&   the water volume that should
                             &&   be in the vents (see below)
  cellhist=1 0. 619.29 69.604 && bottom elevation, area (6666 ft2),
                             &&   and top elevation set to give a
                             &&   total volume of 43105.32 m3
                             &&   (1400000 ft3 + 122250 ft3 for gas
                             &&   and water respectively).  Note as
                             &&   in calculating the drywell volume,
                             &&  the SAR wetwell gas volume is assumed
                             &&   to correspond to LWL
```

```
eoi

atmos=2
  pgas=1.0135e5 tgas=299.82  && set to 1 atm and 80 F
  molefrac o2=.21 n2=.79
  satrat=.6
eoi

low-cell
  geometry 619.29            && area of non-pool layers, if any
  bc=308.15                  && boundary condition temperature
  pool                       && pool in wetwell proper
      compos=1 h2ol 3.60393e6  && water in wetwell at HWL, plus wetwell
                             &&   fraction of water in the vents. The
total
                             &&   wetwell water volume is given in the
                             &&   discussion of the annulus pool as
3626.20
                             &&   m3 and this water is assumed to be at
the
                             &&   same density as that of the annulus
pool
    temp=308.15              && initial temperature 95 F
    physics
      boil
    eoi
  eoi
eoi
eof
```

## D.2 MELCOR Input File

```
**************************************************
*                                                *
*    Grand Gulf Calculation                      *
*    Recirculation line break                    *
*                                                *
**************************************************
*
*eor*      melgen
**********************
**********************
***                ***
***  MELGEN INPUT  ***
***                ***
**********************
TITLE     'BASE'
***JOBID      BASE
CRTOUT
OUTPUTF   'BASE.out'
RESTARTF  'BASE.rst'
DIAGF     'BASE.gdia'
TSTART         0.
DTTIME    .1
***
***
* External data file with ME for Grand Gulf recirculation line break
* file has time, dmdt & dedt
edf00100  s1cv  2  read
edf00101  s1cv
edf00102  3e12.4
*
edf00200  s2cv  2  read
edf00201  s2cv
edf00202  3e12.4
*
************************************
* Active                           *
************************************
*
ATMCSOPTION FROZEN
ATMCSTABLE
*
r*i*f .\cont.txt
r*i*f .\mp.txt
r*i*f .\fl.txt
*
SC00000 4406 10.0 1      * max fog density
.   * terminate
*eor* melcor
************************
***  MELCOR INPUT    ***
************************
TITLE     'BASE'
***JOBID      ref
```

```
*
OUTPUTF   'BASE.out'
PLOTF     'BASE.ptf'
RESTARTF  'BASE.rst'
MESSAGEF  'BASE.mes'
DIAGF     'BASE.dia'
*
CRTOUT
***CYMESF    10 10
*
RESTART            -1
*TEND               86400.0
tend  20.
***EXACTTIME1         100.
CPULIM             400000.
CPULEFT            400.0
*
*
*       time    dtmax   dtmin   dtedit  dtplot  dtrest
time1     0.0   0.01     0.0001   1.0     0.1      5.0
time2     50.   0.01     0.0001   1.0     0.1      10.0
*
*
*
*
.  * terminate
*********************************
* CVH INPUT                     *
*********************************
*
********************************************************
* Mark III Short Term DBA Sample Problem               *
* Recirculation Line Break DBA in the Grand Gulf Plant *
********************************************************
*
*
cv00100  DRYW        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv001a0  3
cv001a1  pvol       1.0135e5
cv001a2  tatm       330.22
cv001a3  mlfr.4     0.21
cv001a4  mlfr.5     0.79
* cv001a6  ph2o       0.0
cv001a5  rhum    0.2
cv001a6  mass.1     1.0e-4
cv001b1  0.0         0.0
cv001b2  31.075      7551.86
cv001c1  mass.3   rate  edf.1.1
cv001c2  energy.a rate  edf.1.2
cv001c3  mass.3   rate  edf.2.1
cv001c4  energy.a rate  edf.2.2
*
cv00200  ANNUL        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv002a0  3
cv002a1  pvol       1.0135e5
cv002a2  tatm       330.22
```

```
cv002a3  mlfr.4     0.21
cv002a4  mlfr.5     0.79
* cv002a6  ph2o       0.0
cv002a5  rhum    0.2
cv002a6  vpol       301.37
cv002a7  tpol       308.15
cv002b1  0.          0.0
cv002b2  7.41        381.39
*
cv00300  WETW        2  2  1     * Non-Equ Thermo, Vert flow, ctmt
cv003a0  3
cv003a1  pvol       1.0135e5
cv003a2  tatm       299.82
cv003a3  mlfr.4     0.21
cv003a4  mlfr.5     0.79
* cv003a6  ph2o       0.0
cv003a5  rhum    0.6
cv003a6  vpol     3.6259e3
cv003a7  tpol     308.15
cv003b1  0.0       0.0
cv003b2  69.604    4.3105e4
*
.                                     * terminator
****************************************************
* FL input                                        *
****************************************************
*
****************************************************
* Drywell to Annulus                              *
****************************************************
*                  Volumes    Junc Elev
*                 FM    TO   FM    TO
fl00100 c#1-c#2    1     2   7.41 7.41
*
* A, L, Frac Open, FLHGTF, FLHGTT
fl00101   51.47   1.680927   1.0  0.1  0.1
fl00102   0    0   0    0
fl00103   0.5   0.5   0.55   0.55    * k(forward), k(reverse),
CDCHKF,CDCHKR
fl001s1   51.47   0.001   8.1
*
****************************************************
* Annulus to wetwell (top vent)                   *
****************************************************
*                  Volumes    Junc Elev
*                 FM    TO   FM    TO
fl00200 c#2-c#3    2     3   3.45  3.45
*
* A, L, Frac Open, FLHGTF, FLHGTT
fl00201   17.88   3.700331   1.0  0.01  0.01
fl00202   3    0   1    1
fl00203   3.0   3.0   0.55   0.55     * k(forward), k(reverse),
CDCHKF,CDCHKR
fl002s1   17.88   0.001   4.8         *
*
****************************************************
```

```
* Annulus to wetwell (mid vent)                   *
****************************************************
*                 Volumes    Junc Elev
*                FM    TO   FM    TO
fl00300 c#2-c#3    2     3   2.18  2.18
*
* A, L, Frac Open, FLHGTF, FLHGTT
fl00301   17.88   5.260371   1.0  0.01  0.01
fl00302   3    0   1    1
fl00303   3.0   3.0   0.55   0.55    * k(forward), k(reverse),
CDCHKF,CDCHKR
fl003s1   17.88   0.001   4.8
*
****************************************************
* Annulus to wetwell (bottom vent)                *
****************************************************
*                 Volumes    Junc Elev
*                FM    TO   FM    TO
fl00400 c#2-c#3    2     3   0.91  0.91
*
* A, L, Frac Open, FLHGTF, FLHGTT
fl00401   17.88   6.480609   1.0  0.01 0.01
fl00402   3    0   1    1
fl00403   3.0   3.0   0.55   0.55      * k(forward), k(reverse),
CDCHKF,CDCHKR
fl004s1   17.88   0.001   4.8
.              * Terminator
*****************************************************
***
***   Non-Condensible gases
*****************************************************
***
***   Gas     Material Number
***
NCG000  O2       4
NCG001  N2       5
***
*     .

s1cv

0.0000E+00,0.0000E+00,0.0000E+00
1.7250E+01,0.0000E+00,0.0000E+00
1.7260E+01,1.9877E+03,5.4938E+09
2.0370E+01,1.8167E+03,5.0508E+09
2.5120E+01,1.4955E+03,4.1828E+09
3.0000E+01,1.1218E+03,3.1454E+09
3.5000E+01,6.9219E+02,1.9378E+09
4.0000E+01,4.0370E+02,1.1238E+09
4.5000E+01,1.9051E+02,5.2545E+08
5.0000E+01,7.5750E+01,2.0697E+08
5.4600E+01,3.3110E+01,8.9811E+07
5.4700E+01,9.4350E+01,2.5592E+08
5.7400E+01,4.8080E+01,1.2980E+08
5.9100E+01,1.1340E+01,3.0570E+07
5.9400E+01,0.0000E+00,0.0000E+00
```

```
s2cv

0.0000E+00,1.3812E+04,1.7699E+10
7.9499E-01,1.3784E+04,1.7644E+10
1.4500E+00,1.3775E+04,1.7622E+10
1.8890E+00,1.3781E+04,1.7629E+10
1.9050E+00,1.1526E+04,1.4745E+10
2.2640E+00,1.1536E+04,1.4768E+10
4.0000E+00,1.1630E+04,1.4995E+10
6.0001E+00,1.1725E+04,1.5042E+10
7.9999E+00,1.1794E+04,1.5340E+10
1.0250E+01,1.1830E+04,1.5425E+10
1.7250E+01,1.1725E+04,1.5169E+10
1.7260E+01,5.1393E+03,6.6487E+09
2.0370E+01,3.9953E+03,4.9262E+09
2.5120E+01,2.6745E+03,3.0340E+09
3.0000E+01,1.6778E+03,1.7226E+09
3.5000E+01,1.1490E+03,1.0460E+09
4.0000E+01,9.0901E+02,7.1986E+08
4.5000E+01,8.7181E+02,5.8886E+08
5.0000E+01,7.6885E+02,4.4922E+08
5.4601E+01,6.3730E+02,3.3307E+08
```