14.3 REACTOR COOLANT SYSTEM PIPE RUPTURE (LOSS OF COOLANT ACCIDENT)

14.3.4 Containment Integrity Analysis

14.3.4.2 Containment Subcompartments

The containment building sub compartments are the fully or partially enclosed volumes within the containment, which contain high-energy lines. These sub compartments are designed to limit the adverse effects of a postulated high-energy pipe rupture within them.

The short term mass and energy sub compartment analysis represents the initial seconds of the blowdown phase of the postulated rupture. The short-term analyses results are used in the design of the sub compartment walls in the ice condenser containment.

14.3.4.2.1 Design Basis

Consideration is given in the design of the containment internal structures to localized pressure pulses that could occur following a postulated pipe break. If a pipe break accident were to occur due to a pipe rupture in these relatively small volumes, the pressure would build up at a rate faster than the overall containment, thus imposing a differential pressure across the walls of the structures.

These sub compartments include the steam generator enclosure, fan accumulator room, pressurizer enclosure, loop sub compartment and upper and lower reactor cavity. Each compartment is designed for the largest blowdown flow resulting from the severance of the largest connecting pipe within the enclosure or the blowdown flow into the enclosure from a break in an adjacent region.

The following sections summarize the design basis calculations.

14.3.4.2.2 Design Features

The basic performance of the Ice Condenser Reactor Containment System has been demonstrated for a wide range of conditions by the Waltz Mill Ice Condenser Test Program (Reference 2). These results have clearly shown the capability and reliability of the ice condenser concept to limit the containment pressure rise subsequent to a hypothetical loss-of-coolant accident.

To supplement this experimental proof of performance, a mathematical model has been developed to simulate the ice condenser pressure transients. This model, encoded as computer program TMD (Transient Mass Distribution), provides a means for computing pressures, temperatures, heat transfer rates, and mass flow rates as a function of time and location throughout the containment. This model is used to compute pressure differences on various structures within the containment as well as the distribution of steam flow as the air is displaced from the lower compartment. Although the TMD Code can calculate the entire blowdown transient, the peak pressure differences on various structures occur within the first few seconds of the transient.

14.3.4.2.3 Design Evaluation

The mathematical modeling in TMD is similar to that of the SATAN blowdown code in that the analytical solution is developed by considering the conservation equations of mass, momentum, and energy and the equation of state, together with the control volume technique for simulating spatial variation. The governing equations for TMD are given in Reference (14).

The moisture entrainment modifications to the TMD Code are discussed in detail in Reference (14). These modifications comprise incorporating the additional entrainment effects into the momentum and energy equations.

As part of the review of the TMD Code, additional effects are considered. Changes to the analytical model required for these studies are described in Reference (14).

These studies consist of:

a. Spatial acceleration effects in ice bed.

b. Liquid entrainment in ice beds.

c. Upper limit on sonic velocity.

d. Variable ice bed loss coefficient.

e. Variable door response.

f. Wave propagation effects.

14.3.4.2.3.1 Application to the Station Design

The containment subcompartments include the steam generator enclosure, the pressurizer enclosure, the fan accumulator room, the loop subcompartment and the upper and lower reactor cavity. Each of these containment subcompartments have been divided into nodes as shown on the following figures which represent the TMD nodalization model for each subcompartment.

- Figure 14.3.4-25 Steam Generator Enclosure
- Figure 14.3.4-27 Pressurizer Enclosure
- Figure 14.3.4-30 Fan Accumulator Room
- Figure 14.3.4-31 Loop Subcompartment
- Figure14.3.4-34 Reactor Cavity

The TMD base model includes Nodes 1-45 as illustrated on Figures 14.3.4-18 through 14.3.4-21. The base model for the loop subcompartment, the steam generator enclosure and the pressurizer enclosure are identical. The fan accumulator room model is similar to the loop subcompartment model with one exception. In the loop subcompartment model, Node 27 represents one fan accumulator room. In the fan accumulator room model, the fan accumulator room is divided into five nodes based on the geometry of the subcompartment and internal equipment. These details are illustrated in Figures 14.3.4-28 and 14.3.4-29. The reactor cavity TMD model is significantly different than the 45 node TMD base model. The reactor cavity TMD model divides the reactor cavity area into 62 nodes, based on the geometry of the reactor cavity area. This basic geometry is shown on Figure 14.3.4-33. Figure 14.3.4-34 illustrates the complete nodalization network.

The division of the lower compartment into six volumes occurs at the points of greatest flow resistance, i.e., the four steam generators, pressurizer, and refueling cavity. Each of these lower compartment sections delivers flow through ice condenser lower inlet doors into a section behind the doors and below the ice bed. Each vertical section of the ice bed is, in turn, divided into nodes. The upper plenum between the top of the ice bed and the top deck doors is represented by another node. Thus, a total of thirty nodes (Nodes 7 through 24 and 34 through 45) are used to simulate the ice condenser. The nodes at the top of the ice bed between the ice bed and top deck doors deliver to Node 25, the upper compartment. Note that cross flow in the ice bed is not accounted for in the analysis; this yields the most conservative results for the particular calculations described herein. The upper reactor cavity (Node 33) is connected to the lower compartment volumes and provides cross flow for pressure equalization of the lower compartments. The less active compartments, called dead ended compartments (Nodes 26, 28, 29, 30 and 32), and the fan accumulator compartments (Nodes 27 and 31) outside the crane wall are pressurized by ventilation openings through the crane wall into the fan compartments.

For each node in the TMD network the volume (refer to Tables 14.3.4-21 through 14.3.4-25), initial pressure, and initial temperature conditions are specified. The ice condenser elements have additional inputs of mass of ice, heat transfer area, and condensate layer length. The required flow characteristics for each flow path between nodes are: loss coefficient (K), friction factor (f), inertia length (L_I), hydraulic diameter (D_H), minimum flow path area (A_T), equivalent length (L_E) and area ratios (A_T/A). In the TMD analysis, the loss coefficient (K) is used to calculate the pressure losses due to flow across equipment, projections, or sudden expansions and contractions. The fL_E/D_H term is used to calculate the frictional pressure loss. A_T is the minimum flow area for the path. The L_I/A_T term is used to account for inertia effects of the fluid in the momentum equation. The area ratios (A_T/A) are used to account for compressibility effects of the fluid. In addition, the ice condenser loss coefficients have been based on the 1/4 scale tests representative of the current ice condenser geometry. The loss coefficient is based on removal of door port flow restrictors. To better represent short term transient effects, the opening characteristics of the lower, intermediate, and top deck ice condenser doors have also been modeled in the TMD Code. The TMD analysis evaluates a range of containment parameters for subcompartment peak pressure and differential pressures. These parameters include containment pressure, containment temperature, containment humidity, and ice condenser temperature. The bounding conditions are listed in each subcompartment evaluation that are described in the following sections.

14.3.4.2.4 Steam Generator Enclosure Evaluation

Two breaks were analyzed for the steam generator enclosure, a main steam line break and a feedwater line break. The largest and most severe break possible in the steam generator enclosure is a double-ended break of the steam line. Based upon the high-energy line break analyses, this break can only occur in the enclosure at the terminal end at the nozzle (at the top of the enclosure). For the feedwater line break event, the break is postulated to occur at the side of the steam generator at the feedwater line inlet nozzle. The limiting mass and energy releases from these breaks are from the hot shutdown condition (no load). Refer to Section 14.3.4.4.1 for the initial conditions and assumptions used to determine the short-term mass and energy releases for the steam line and feedwater line breaks. The mass and energy release rates for the steam generator enclosure analysis are presented in Table 14.3.4-15 for both the main steam line break and the feedwater line break.

The range of initial containment conditions considered for the analyses are as follows:

- Temperature range of 60-185°F (Reference 45).
- Pressure range of 13.2-15.0 psia
- Humidity range of 15-100 percent
- Ice Condenser Temperature range of 10-30°F

The limiting values for containment temperature and pressure are given in Tables 14.3.4-33 and 14.3.4-34. For all cases, the limiting condition for humidity is at 15%. For the steam line break, the limiting ice condenser temperature is 30°F and for the feedwater line break the limiting values are presented in Table 14.3.4-34. In addition, the jet momentum from the steam blowdown from the main steam or feedwater line break within the steam generator enclosure would be large enough to blow the HVAC ductwork out the enclosures.

The steam generator enclosure TMD nodalization network is similar to the models for the pressurizer enclosure and the loop subcompartment for the first 45 nodes. Nodes 46-63 represent the steam generator enclosures. The nodalization network for the steam generator enclosures are illustrated in Figures 14.3.4-18 through 14.3.4-21 and Figures 14.3.4-24 and 14.3.4-25. Figure 14.3.4-18 illustrates the TMD model plan view at the equipment room elevation. Figure 14.3.4-19 provides the TMD model containment section view. Figure 14.3.4-20 is the plan view at the ice condenser compartments. Figure 14.3.4-21 contains the layout of the containment shell for the TMD model. Figures 14.3.4-22 and 14.3.4-23 show the details of the steam generator subcompartment used in the analysis. Figures 14.3.4-24 and 14.3.4-25 show the 18 node TMD steam generator enclosure model (9 nodes per enclosure) which was used in the analytical model.

This TMD model is designed to represent a steam generator pair as denoted in Figure 14.3.4-25 as Enclosure A and Enclosure B. The steam line break was postulated to occur in the steam generator enclosure in either Node 46 or 55. The feedwater line break was postulated to occur in the steam generator enclosure in either Node 54 or 63.

The TMD input flow path characteristics are based upon incompressible flow modeling. The TMD program adjusts the incompressible flow equations with the area ratios (A_T/A) to account for compressible effects in the high subsonic flow regime. The TMD flow path input data for the steam generator enclosure is contained in Tables 14.3.4-26 and 14.3.4-27.

The steam generator enclosure free volumes and vent areas, which represent Enclosure A, and Enclosure B are given in Table 14.3.4-32. As shown in Table 14.3.4-32, the free volume and vent area for the steam generator pair is not identical. The vent area represents the minimum flow path area leaving the steam generator enclosure. The vent area for the steam generator enclosure (Enclosure A) is determined by summing the minimum flow path areas from Nodes 46-47, 48, 49, 50, 55, 47-56, 48-57, 47-51, 48-52, 49-53 and 50-54. The vent area for Enclosure B is determined in a similar fashion.

The maximum calculated differential pressure between the steam generator enclosure and the upper compartment due to a postulated steam line break is 42.77 psid (Reference 45). The maximum calculated differential pressure between the steam generator enclosure and the upper compartment due to a postulated feedwater line break is 16.29 psid. A complete summary of the peak differential pressures across the structures and the steam generator vessel are shown in Table 14.3.4-33 for the steam line break and Table 14.3.4-34 for the feedwater line break. Figures 14.3.4-35 through 14.3.4-52 present the differential pressure time histories for the steam line break. The Steam Line Break (SLB) Figures are for information only, and have not been updated to reflect results of Reference 45, and should not be used as input in other analyses. Figures 14.3.4-53 through 14.3.4-70 present the differential time histories for the feedwater line break.

It should be noted that the analyses discussed above are only for short term pressure peaks and are not applicable to long term type analyses. The dynamic analysis of the affected structures and of the steam generator vessel supports has shown that the effects of the short duration peak pressures will not result in consequences that will adversely affect the public health and safety.

14.3.4.2.5 Pressurizer Enclosure Evaluation

The largest break possible in the pressurizer enclosure, a double-ended break of the spray line from the reactor coolant system, is postulated to occur at the top of the enclosure. The spray line break mass and energy releases are presented in Table 14.3.4-16. The RCS data utilized for the analysis is as follows:

- NSSS Power (MWt) 3600
- RCS Pressure (psia) 2250
- Core Average Temperature (°F) 549.9 - 584.9
- Vessel Outlet Temperature (°F) 582.2 - 615.2
- Vessel/Core Inlet Temperature (°F) 511.7 - 547.6

Measurement uncertainties of +67 psi for system pressure and +/-5.1°F for temperature are applied to the RCS data. The spray line mass and energy releases were determined utilizing the following bounding RCS initial conditions:

- Vessel/Core Inlet Temperature of 506.6°F
- RCS Pressure of 2317 psia

The range of initial containment conditions bounded by the TMD analysis for the pressurizer enclosure includes the following:

- Temperature range of 60-171°F
- Pressure range of 13.2-15.0 psia
- Humidity range of 15-100 percent
- Ice Condenser Temperature range of 10-30°F

The low pressure (13.2 psia), low temperature (60°F), low humidity (15%) case was determined to be bounding for evaluation of the pressurizer enclosure and containment response. Sensitivity studies were performed to evaluate the effect of varying the ice condenser temperature on the peak differential pressure. The analysis for the pressurizer enclosure was performed using an ice condenser temperature of 30°F. Using an ice condenser temperature of 10°F will increase the resulting peak differential pressure acting across the wall between the inside of the enclosure and the upper compartment. This increase is bounded by the margin currently applied to the pressurizer enclosure analysis.

The loop subcompartment model (without the nodalization for the steam generator enclosures) was used as a base model for the pressurizer enclosure. The loop subcompartment model was modified to include Nodes 46-49 which represent the pressurizer enclosure in the model.

The pressurizer enclosure TMD nodalization network is similar to the models for the loop subcompartment and the steam generator enclosure for the first 45 nodes. Nodes 46-49 represents the pressurizer enclosure in the model. The nodalization network for the pressurizer enclosure is illustrated in Figures 14.3.4-18 through 14.3.4-21 and Figure 14.3.4-27. Figure 14.3.4-18 illustrates the TMD model plan view at the equipment room elevation. Figure 14.3.4-19 provides the TMD model containment section view. Figure 14.3.4-20 is the plan view at the ice condenser compartments. Figure 14.3.4-21 contains the layout of the containment shell for the TMD model. Figure 14.3.4-26 illustrates the nodalization specific to the pressurizer enclosure and Figure 14.3.4-27 illustrates the nodalization network and flow paths. The spray line break was postulated to occur at the top of the pressurizer enclosure in Node 46.

The TMD input flow path characteristics are based upon incompressible flow modeling. The TMD program adjusts the incompressible flow equations with the area ratios (A_T/A) to account for compressible effects in the high subsonic flow regime. The TMD flow path input data for the pressurizer enclosure is contained in Table 14.3.4-28. Refer to Section 14.3.4.2.3.1 for definition of table terms.

The net free volume and the vent area for the pressurizer enclosure is presented in Table 14.3.4-32. The vent area represents the minimum flow path area leaving the pressurizer enclosure. The vent area for the pressurizer enclosure is determined by summing the minimum flow path areas from Nodes 47-4, 48-4 and 49-4.

Figures 14.3.4-71 through 14.3.4-75 illustrate the pressure time histories for the upper compartment and the pressurizer enclosure. The maximum calculated differential pressure is 8.82 psid. The maximum calculated differential pressure across the vessel is 0.45 psid. An additional 10% margin is included in the results to bound the results and provide conservatism.

14.3.4.2.6 Fan Accumulator Room Evaluation

The fan accumulator room enclosure is designed for a double-ended break in the 30 inch steam line (inside area of 4.27 ft^2) downstream of the steam line flow restrictor. This is the inline flow venturi downstream of the steam generator nozzle. The break occurs in the longest line with an orifice of 1.4 ft^2 in the cross connection with the steam dump header. This orifice in the turbine building restricts backflow so that the entrained flow from the other three steam generators will not reach the break before the main steam isolation valves close at ten seconds, reducing the pressure peak. The mass and energy release rates for this case are presented in Table 14.3.4-17.

The mass and energy releases consist of both the initial steam blowdown from the steam generator side of the break (forward flow) with choking conditions reached in the inline flow venturi and the reverse flow (steam flow coming out of the turbine end of the break). The blowdown consists of steam at 1192 BTU/lb, which corresponds to the saturation enthalpy at 1020 psia. The TMD computer code assuming unaugmented critical flow was used to calculate the pressurization response inside the fan accumulator room to the postulated break in the main steam line. The range of initial containment conditions considered for the analysis are as follows:

- Temperature range of 60-120°F
- Pressure range of 13.2-15.0 psia
- Humidity range of 15-100 percent
- Ice Condenser Temperature range of 10-30°F

The low pressure (13.2 psia), low temperature (60°F), low humidity (15%), low ice condenser temperature (10°F) case was determined to be bounding for determination of the peak differential pressure. High pressure (15.0 psia), low temperature (60°F), low humidity (15%), high ice condenser temperature (30°F) case was determined to be bounding for the determination of the peak pressure in the fan accumulator room.

The nodalization network for the fan accumulator room is illustrated in Figures 14.3.4-19, 14.3.4-20 and 14.3.4-28 through 14.3.4-30. Figure 14.3.4-28 illustrates the TMD model plan view at the equipment room elevation. Figure 14.3.4-19 provides the TMD model containment section view. Figure 14.3.4-20 is the plan view at the ice condenser compartments. Figure 14.3.4-29 contains the layout of the containment shell for the TMD model. Figures 14.3.4-22 illustrate the noding, flow paths and TMD network for the fan accumulator room subcompartment. Nodes 27, 31 and 54-57, as shown on Figure 14.3.4-28, represent the fan accumulator rooms in the TMD model. The steam line break was postulated to occur in the fan room in Node 55.

The TMD input flow path characteristics are based upon incompressible flow modeling. The TMD program adjusts the incompressible flow equations with the area ratios (A_T/A) to account for compressible effects in the high subsonic flow regime. The TMD flow path input data for the fan accumulator room is contained in Table 14.3.4-29.

The fan accumulator room free volume and vent area are presented in Table 14.3.4-32. The vent area is determined by summing the flow areas leaving the fan accumulator room subcompartment (Nodes 27-3, 28, 29, 54-3, 28, 55-2, 26, 28, 56-1, 26 and 57-1, 26).

Figures 14.3.4-76 through 14.3.4-97 illustrate the pressure time histories for the peak differential pressure across the key internal structures and walls of the fan accumulator room. Figures 14.3.4-98 through 14.3.4-102 illustrate the pressure time histories for the peak pressure in the fan accumulator room. The calculated peak pressure in the fan accumulator room is 15.40 psig. The peak calculated differential pressure between the fan accumulator room and the ice condenser lower plenum is 15.69 psid, between the adjoining instrument room is 15.20 psid and between the upper compartment is 13.00 psid.

14.3.4.2.7 Loop Subcompartments Evaluation

14.3.4.2.7.1 Base Model Analysis

As part of the T_{hot} Reduction Program in the late 1980's, the mass and energy releases for the DEHL and DECL breaks were recalculated. Results showed that the peak rates increased by approximately 10% and 20% for the DECL and DEHL cases respectively when compared to the original analysis. The results of this analysis are shown in the following table:

	Peak Differential Pressure			
Item	DP [1-25] DP [6-25]	DP [2-25] DP [5-25]	DP (7,8,9 TO 25)	Shell Peak Pressure (40, 45)
1988 Base[1]	16.8 psid	12.2 psid	10.7 psid	13.1 psig
1988 Total[2]	18.7 psid	13.0 psid.	11.2 psid	14.0 psig

Figures 14.3.4-103 through 14.3.4-110 present the pressure time histories for the lower compartment elements (1-6), the upper compartment (25) and element 40 on the shell for the DEHL break in compartment 1 case. Figures 14.3.4-111 and 14.3.4-112 present the pressure time histories for element 2 and element 25 for the DEHL in compartment 2 case. Figure 14.3.4-113 present the pressure time history for element 40 on the shell for the DECL case.

[1] 1988 Base refers to the TMD analysis conducted in 1988 that formed the basis for the T_{hot} Reduction Program results in 1988. This item is called "base" because these are the raw results from the TMD computer runs. This information does not include effects of 15% flow blockage, variation in initial subcompartment pressure and temperature, and uncertainty.

[2] 1988 Total refers to the total pressure results that were generated for the T_{hot} Reduction Program in 1988. This item includes the raw results from the TMD computer runs (1988 Base), and the effects of 15% flow blockage, variation in initial subcompartment pressure and temperature, and uncertainty.

These results were used as a starting point for the current analysis. The current analysis for the loop sub compartment utilizes adders and scaling factors to account for changes in initial RCS conditions and uncertainties and as-built data for the compartment.

14.3.4.2.7.2 Current Analysis

The current methodology is an evaluation that includes a representative TMD run that is used to determine the impact of geometric changes associated with as-built plant subcompartment information on past loop sub compartment analysis results. The results from the TMD run was used to scale prior results to include as-built effects.

The loop sub compartment, including the lower crane wall, upper crane wall, containment shell and operating deck are designed to withstand the pressures which are due to a postulated double-ended primary loop break in the loop sub compartments. The TMD computer code assuming unaugmented critical flow was used to calculate the pressurization response inside the loop sub compartments. Both the DEHL and DECL breaks were evaluated for development of differential pressures. The double-ended cold leg break (DECL) results from previous analysis is augmented by the results of the DEHL break to account for changes in TMD input due to as-built plant data.

Mass and energy releases were developed for a double-ended hot leg break (DEHL) and are presented in Table 14.3.4-18. SATAN-V models, consistent with the methodology of reference (21), were developed utilizing the appropriate RCS data, such as enthalpies, pressures and flows. The RCS data utilized for the analysis is as follows:

- NSSS Power (MWt) 3600
- RCS Pressure (psia) 2250
- Core Average Temperature (°F) 549.9 - 584.9
- Vessel Outlet Temperature (°F) 582.2 - 615.2
- Vessel/Core Inlet Temperature (°F) 511.7 - 547.6

Measurement uncertainties of +67 psi for system pressure and +/-5.1°F for temperature are applied to the RCS data. For the short term mass and energy releases, low RCS temperatures and high pressure are bounding. The bounding RCS initial conditions are as noted below.

- Vessel/Core Inlet Temperature of 506.6°F
- RCS Pressure of 2317 psia

The initial containment conditions bounded by the TMD analysis includes the following:

- Temperature range of 60-120°F
- Pressure range of 13.2-15.0 psia
- Humidity range of 15-100 percent
- Ice Condenser Temperature range of 10-30°F

The bounding initial conditions utilized in the analysis for the loop subcompartment are as follows:

- Initial pressure of 15.0 psia
- Lower compartment temperature of 110°F
- Ice condenser temperature of 30°F
- Upper compartment temperature of 75°F
- Fan accumulator/pipe trench temperature of 98°F
- Upper reactor cavity temperature of 110°F
- Steam generator enclosure temperature of 110°F
- Humidity of 15%

Sensitivity studies were performed to evaluate the effect of varying the ice condenser temperature on the peak differential pressure. The analysis for the loop subcompartment was performed using an ice condenser temperature of 30°F. Using an ice condenser temperature of 10°F will increase the resulting peak differential pressures. These increases are bounded by the margins currently applied to the loop subcompartment analysis. Additionally, included in the evaluation of the loop subcompartment is consideration of 15% ice condenser flow blockage and the effects of both DEHL and DECL break locations.

The loop subcompartment TMD nodalization network is similar to the models for the pressurizer enclosure and the steam generator enclosure for the first 45 nodes. Nodes 46-53, which are specific for the loop subcompartment model, represent the steam generator enclosures. The nodalization network for the loop subcompartment is illustrated in Figures 14.3.4-18 through 14.3.4-21 and Figure 14.3.4-31. Figure 14.3.4-18 illustrates the TMD model plan view at the equipment room elevation. Figure 14.3.4-19 provides the TMD model containment section view. Figure 14.3.4-20 is the plan view at the ice condenser compartments. Figure 14.3.4-21 contains the layout of the containment shell for the TMD model. Figure 14.3.4-31 illustrates the specific nodalization network for the loop subcompartment. Contained within this figure are the flow paths from the loop subcompartment.

The TMD input flow path characteristics are based upon incompressible flow modeling. The TMD program adjusts the incompressible flow equations with the area ratios (A_T/A) to account for compressible effects in the high subsonic flow regime. The TMD flow path input data for the loop subcompartment is contained in Table 14.3.4-30. Refer to Section 14.3.4.2.3.1 for definition of table terms.

The DEHL in Node 1 was determined to be the limiting break for determination of peak differential pressure across the operating deck, across the lower and upper crane wall, the ice condenser ice basket uplift force and lattice frame forces and the intermediate and top deck drag forces. The DECL break in Node 1 was determined to be limiting for the differential pressure across the containment shell. Pressure time history plots are included as Figures 14.3.4-114 through 14.3.4-122 for the loop subcompartment analysis.

The following tables provide the peak differential across the operating deck, upper and lower crane wall, containment shell and the peak differential pressure between the steam generator enclosure and the ice condenser.

Peak Differential Pressure				
Item	DP [1-25] DP [6-25]	DP [2-25] DP [5-25]	DP (7,8,9 TO 25)	Shell Peak Pressure (40, 45)
Original base[3]	14.1 psid	10.6 psid	8.2 psid	10.8 psig
2001 Base[4]	18.2 psid	12.2 psid	10.7 psid	13.1 psig
2001 Total[5]	20.2 psid	14.0 psid	11.8 psid	14.8 psig

3 Original Base refers to the TMD analysis conducted in 1974. This item is called “base” because these are the raw results from the TMD computer runs. This information does not include effects of 15% flow blockage, variation in initial subcompartment pressure and temperature, and uncertainty.

4 2001 Base refers to the TMD analysis & evaluation conducted in 2001 that formed the basis for the results. This item is called “base” because these are the raw results from the base TMD run. This information does not include effects of 15% flow blockage, variation in initial subcompartment pressure and temperature, and uncertainty.

5 2001 Total refers to the total pressure results that were generated for the analysis and evaluation program in conducted 2001. This item includes the raw results from the TMD computer runs (2001 Base), and the effects of 15% flow blockage, variation in initial subcompartment pressure and temperature, and uncertainty.

Peak Differential Pressure Between the Steam Generator Enclosure and the Ice Condenser				
Item	DP [46-41]	Time	DP [50-10,11,12]	Time
2001 Base[4]	9.42 psid	0.0621 s	10.03 psid	0.3624 s
2001Total[5]	11.36 psid	0.0621 s	11.97 psid	0.3624 s

In addition to the results provided above, the vertical distribution of peak differential pressure for the ice condenser end wall for the lower plenum is 14.8 psid and 11.8 / 9.2 / 7.4 psid for the bottom/middle/top 16 feet of the ice bed region, respectively. The azimuthal distribution of peak differential pressure for the ice condenser is presented in Table 14.3.4-35. The loop subcompartment analysis also generates the peak blowdown differential pressure across the ice condenser lower plenum floor and horizontal seal acting downward. The peak differential pressure was calculated to be 10.4 psid. Pressure time history plots which can be used for the ice condenser lower plenum and for the fan accumulator room are contained in Figures 14.3.4-121 and 14.3.4-122, respectively.

Early sensitivity studies, illustrated in Table 14.3.4-36 (see Section 14.3.4.5.3.4, "Early Sensitivity Studies"), demonstrated the effects of changes in certain variables on the operating deck differential pressure and the shell pressure. The purpose of that study was to illustrate the sensitivity of the TMD code results to different input and assumption conditions and to illustrate the inherent analysis conservatism. The purpose of the tables was not to supply an extrapolation tool for all subcompartments since the work was done for a specific subcompartment and trends may be different for other compartments. For example, the effect of initial compartment pressure on the peak differential pressure can be either a benefit or a penalty depending upon the flow regime before and during the peak. Additionally, if the peak occurs later in time the trend will be geometry dependent. That is, the pertinent downstream element would pressurize differently based upon specific key variables, such as flow areas and resistance into and out of the element. A combination of both sonic and subsonic flow regime periods could occur over the total transient. Since the new analysis is sufficiently different when compared to the original sensitivity basis, Table 14.3.4-36 should only be used for guidance.

14.3.4.2.8 Reactor Cavity Evaluation

The reactor cavity is designed for a single ended break of an RCS loop at its connection to the reactor vessel nozzle. The break is considered to be a longitudinal split in the loop piping at the primary shield wall of an area equivalent to the cross sectional area of a reactor coolant pipe, i.e. 4.12 ft^2. A circumferential failure of the pipe at this location would result in a much smaller flow discharge area because the vessel, pipe and sleeve arrangement is such that no significant relative movement can take place.

The purpose of this analysis is to calculate the initial pressure response in the reactor cavity to a loss of coolant accident. The reactor cavity pressure analysis was performed for the upper and lower reactor cavities, the reactor vessel annulus and the reactor pipe annulus. The mass and energy releases for the analysis is presented in Table 14.3.4-19 for the single-ended cold leg break (SECL) and Table 14.3.4-20 for the single-ended hot leg break (SEHL). The RCS data utilized for the analysis is as follows:

• NSSS Power (MWt)	3600
• RCS Pressure (psia)	2250
• Core Average Temperature (°F)	549.9 - 584.9
• Vessel Outlet Temperature (°F)	582.2 - 615.2
• Vessel/Core Inlet Temperature (°F)	511.7 - 547.6

Measurement uncertainties of +67 psi for system pressure and +/-5.1°F for temperature are applied to the RCS data. The mass and energy releases were determined utilizing the following bounding RCS initial conditions.

- Vessel/Core Inlet Temperature of 506.6°F
- RCS Pressure of 2317 psia

In this evaluation, the effect of the following initial containment conditions was also assessed:

- Temperature range of 60-160°F in the loop subcompartments.
- Temperature range of 60-120°F in the upper and lower reactor cavities.
- Pressure range of 13.2-15.0 psia.
- Humidity range of 15-100 percent.

The effects of the ice condenser are conservatively neglected in this analysis. Various assumptions concerning reactor cavity insulation and HVAC ductwork are included in the analysis for the reactor cavity. Due to the blowdown forces associated with the break, the insulation on the broken loop pipe was assumed to be displaced outward through the penetration in the primary shield wall. The insulation on the reactor vessel wall will either be crushed or displaced from the reactor vessel region. The HVAC ductwork in the upper reactor cavity is assumed to collapse and the HVAC ductwork in the windows at the top of the biological shield will be crushed and displaced into the loop compartment. In addition, three inspection hatch covers furthest from the break location are assumed to be held closed. This is represented by the flow paths from Nodes 41, 42 and 43 to Node 38.

As described previously, the reactor cavity TMD model is significantly different than the TMD model for the other containment subcompartments. The reactor cavity TMD model nodalization is illustrated in Figures 14.3.4-32, 14.3.4-33 and 14.3.4-34. Figure 14.3.4-32 shows the reactor cavity TMD model containment section view. Figure 14.3.4-33 illustrates the reactor cavity TMD model layout of reactor vessel annulus elements and Figure 14.3.4-34 illustrates the reactor cavity TMD model nodalization network. The break is postulated to occur in Node 1.

The TMD input flow path characteristics are based upon incompressible flow modeling. The TMD program adjusts the incompressible flow equations with the area ratios (A_T/A) to account for compressible effects in the high subsonic flow regime. The TMD flow path input data for the reactor cavity is contained in Table 14.3.4-31.

The Steam Generator Tube Plugging Program, SGTP, parameters affect the Reactor Cavity Pressure Analysis through the mass and energy releases provided as input into the analysis. There is no direct impact of SGTP level on short-term mass and energy release rate calculations. The major impact results from changes to RCS temperature. For short-term effects, higher release rates typically result from cooler RCS conditions. The mass and energy releases used as input for the Reactor Cavity Pressure Analysis reflected limiting conditions and therefore, the NSSS performance parameters for the SGTP Program did not impact the results.

Based upon a review of Reference 34, it was concluded that the analysis assumptions used to perform the Reactor Cavity Pressure Analysis remain bounding. The assumptions and design inputs that are changed in Reference 34 relate to systems and components that do not affect the Reactor Cavity Pressure Analysis.

The net free volume and vent area from the upper and lower reactor cavities is documented in Table 14.3.4-32. The vent area represents the available flow path area leaving the reactor cavities and entering the loop subcompartment. The upper cavity vent area is determined by summing the available flow path areas from Nodes 38-51 and 38-52. The lower cavity vent area is determined by summing the available flow path areas from Nodes 46-51, 47-51, 48-51, 50-51, 41-52, 42-52, 43-52, 49-52, and the limiting area from Nodes 2-60-58-51. As shown in Table 14.3.4-32, vent areas from the upper and lower reactor cavities were 165 and 172 square feet, respectively.

Figures 14.3.4-123 through 14.3.4-129 present pressure time histories for the break compartment (TMD node 1), the lower reactor cavity (TMD node 2), the reactor vessel annulus near the break (TMD node 3), the upper reactor cavity (TMD node 38), the broken loop pipe sleeve (TMD node 46), the loop subcompartments (TMD node 51) and the broken loop inspection port (TMD node 53).

Figures 14.3.4-130 through 14.3.4-132 present the differential pressure time histories for the lower reactor cavity wall, the upper reactor cavity wall, and the missile shield.

14.3.4.2.8.1 Upper Reactor Cavity

The limiting break for the upper reactor cavity is a single-ended break of the primary cold leg. As shown in Table 14.3.4-19, mass and energy releases were developed for this break using SATAN-V models. High initial temperature (120°F), low initial pressure (13.2 psia) and low humidity (15%) are limiting for this analysis for both peak pressure and peak differential pressure. Upper reactor cavity pressurization effects were calculated with the TMD code assuming unaugmented critical flow.

The following results are summarized:

	Peak Upper Cavity Pressure	**Peak Missile Shield Differential Pressure**	**Peak Cavity Wall Differential Pressure**
Calculation current	48.5 psig	50.84 psid	50.0 psid
Original calculation	47.0 psig	44.1 psid	44.1 psid

14.3.4.2.8.2 Lower Reactor Cavity

As in the upper reactor cavity analysis, the limiting break for the lower reactor cavity is a single-ended break of the primary cold leg. Low initial temperature (60°F), low initial pressure (13.2 psia) and low humidity (15%) are limiting for this analysis for peak differential pressure. Low initial temperature (60°F), high initial pressure (15.0 psia) and low humidity (15%) are limiting for this analysis for peak pressure.

The results are summarized below:

	Peak Lower Cavity Pressure	**Peak Differential Pressure Between Lower Cavity And Loop Subcompartments**
Current calculation	17.12 psig	18.22 psid
Original calculation	13.8 psig	12.3 psid

14.3.4.2.8.3 Reactor Vessel Annulus and Reactor Pipe Annulus

The reactor vessel annulus and pipe annuli peak pressures were evaluated using a homogeneous, unaugmented critical flow model. The peak break flow rates for the single-ended cold leg (SECL) and single-ended hot leg (SEHL) breaks were considered. The limiting break was found to be the SEHL break because, even though the peak break flow rate was higher for the SECL, the enthalpy was higher for the SEHL. High initial temperature (120°F), low initial pressure (13.2 psia) and low humidity (15%) are limiting for this analysis for peak pressure. The results are summarized below:

	Peak Pipe Annulus Pressure (SEHL)	**Peak Reactor Vessel Annulus Pressure (SEHL)**
Revised calculation[6]	630 psig	160 psig
TMD Analysis Peak Values	665 psig[7]	675 psig[8]
Original calculation[9]	735 psig	95 psig

The revised calculation results are based upon a manual calculation method consistent with the original licensing methodology. This evaluation was then compared to the TMD analysis results. For the peak pipe annulus pressure, the original manual calculation bounds both the revised calculation and the TMD analysis results. For the peak reactor vessel annulus pressure, the TMD analysis results are considerably higher than the results from the manual calculation. However,

[6] These values represent the average hand calculated values for the two annuli utilizing the M&E release data and volume/flow path data.
[7] This is the broken loop pipe annulus (Node 46).
[8] This is the vessel annulus area directly below the break location (Node 3).
[9] Original calculation refers to the values determined during initial licensing (1973).

this TMD pressure is highly localized near the break. The peak reactor vessel annulus pressure on the opposite side of the vessel is less than 50 psig.

14.3.4.2.8.4 Reactor Vessel Nozzle Inspection Hatch Cover

The above analyses were performed with the replacement inspection hatch covers. Theoretically, the inspection hatch covers could either remain closed or be fully opened. In the subcompartment analyses the most limiting action is assumed. To maximize the resulting pressure in the subcompartment, three inspection hatch covers were assumed to remain closed in the analysis. The selected covers were the three furthest from the break location represented by the flow paths from Nodes 41, 42 and 43 to Node 38. The individual flow paths for each reactor vessel nozzle inspection hatch covers vary . To determine the resulting flow areas, refer to Table 14.3.4-31. In the event of a primary leg break, the hinged door is designed to open. Based on the pressure time histories, it can be determined that all hatch covers would open. This would result in a decreased peak upper cavity pressure.

14.3.4.2.9 Short Term Containment Analysis Conclusions

The results of the short-term containment analyses and evaluations for the Cook Nuclear Power Plants demonstrate that, for the steam generator enclosure, the pressurizer enclosure, the fan accumulator room, the loop subcompartment and the reactor cavity area, the resulting peak pressures/differential pressures remain below the allowable design peak pressures/differential pressures. Refer to Table 5.2-8 for a listing of the equivalent design pressure capabilities. The structural adequacy was confirmed through evaluations using Section 5.2.2.3 of the UFSAR as acceptance criteria.