SAFETY EVALUATION REPORT
OFFICE OF NUCLEAR REACTOR REGULATION
DIVISION OF SYSTEMS SAFETY AND ANALYSIS
CONTAINMENT SYSTEMS AND SEVERE ACCIDENT BRANCH
MASS AND ENERGY RELEASE AND CONTAINMENT RESPONSE METHODOLOGY
OCONEE NUCLEAR STATION
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DUKE POWER COMPANY TOPICAL REPORT DPC-NE-3003-P

ENCLOSURE

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1.0 INTRODUCTION

Containment pressure and temperature analyses are performed to determine the pressure and temperature loads within the containment that would result from postulated pipe breaks inside containment. The results of the containment pressure and temperature analyses establish design criteria, test criteria and environmental qualification criteria for containment systems, structures and components.

By letter dated August 11, 1993, the licensee submitted topical report DPC-NE-3003-P, "Mass and Energy Release and Containment Response Methodology," for staff review and approval. The topical report describes the licensee's proposed new methodology for analysis of mass and energy releases from in-containment high-energy line breaks and the predicted containment pressure and temperature responses. The methodology is applicable to the licensee's three Oconee 2568 MWt Babcock & Wilcox (B&W) "lowered-loop" PWRs located 30 miles west of Greenville, SC.

The purpose of the new methodology is to overcome limitations in the existing methodology which dates to the early 1970s. In particular, the new methodology addresses the absence of an FSAR licensing analysis for the containment long-term response to cold leg breaks. The new analyses also address issues relating to LPI cooler degradation, fan cooler fouling, an increase in the ultimate heat sink temperature above the value assumed in the FSAR analyses, and measured containment temperatures in excess of values assumed in the FSAR analyses. The new methodology is not used for the ECCS net positive suction head analysis as that analysis is encompassed by an NSSS vendor generic analysis.

The staff has reviewed the licensee's submittal using the guidance and criteria of: (1) the Standard Review Plan (SRP), Sections 6.2.1, 6.2.1.1.A and 6.2.1.3 and 6.2.1.4, and (2) ANSI/ANS 56.4-1983, "Pressure and Temperature Transient Analysis for Light Water Reactor Containments." ANS-56.4-1983 has not been formally approved by the staff; however, the staff participated in its development and considers its guidance to be appropriate for use in licensing analyses. Both were used by the licensee for guidance.

Based on the licensee's history relating to Generic Letter 83-11, "Licensee Qualification for Performing Safety Analyses in Support of Licensing Actions," and previously-approved topical reports, the licensee's technical support organization is competent to develop, verify, validate, use and maintain computer codes for transient and accident analyses. The licensee's response to the Generic Letter was provided as part of topical report submittal DPC-NE-3000, "Thermal-Hydraulic Transient Analysis Methodology," May 1989.

The format and organization of this Safety Evaluation (SE), including the paragraph/section numeration is consistent with that of the topical report.

2.0 OVERVIEW OF COMPUTER CODES

The new Oconee containment analysis methodology makes use of four computer codes; (1) RELAP5/MOD2-B&W, (2) BFLOW, (3) RETRAN-02 MOD5,1DKE, and (4) FATHOMS-RS. RELAP5/MOD2-B&W is used to compute loss of coolant accident (LOCA) mass and energy releases. BFLOW is a licensee-developed code used to compute the long-term break flow quality for a large cold leg break. RETRAN-02/MOD5 is used to compute main steam line break mass and energy releases. Output from these codes is used by FATHOMS-RS to compute containment pressure and temperature responses.

It is noted that the RELAP and RETRAN codes are "best estimate" hydraulic-analysis codes. Conservatism of analyses, using these codes, is provided by the users' judicious selection of initial conditions, code options and boundary conditions (See Section 3.3 for a definition of the term "boundary conditions" as used in this report).

2.1 RELAP5/MOD2-B&W

2.1.1 CODE USE AND DESCRIPTION

RELAP5/MOD-B&W is a modified version of the RELAP5/MOD2 advanced thermal-hydraulic code developed by EG&G Idaho for the NRC staff to provide a tool for licensing analyses of small and large break LOCAs. B&W has modified the RELAP5/MOD2, cycle 36.04 code to include an Appendix K model and to improve code capability and execution. The code models the steady-state and transient behavior of any hydraulic system that may contain a mixture of steam, water, non-condensible gas or nonvolatile solute. The fluid system is modeled by discretizing the system into control nodes joined by junctions. The hydraulic flow field treats the liquid and steam phases as separate fluids in a nonhomogeneous, non-equilibrium manner, solving the mass, energy and momentum equations for each phase. Constitutive relationships are used to define flow regimes and model interphase drag, vapor generation and interphase heat and mass transfer, and horizontal and vertical stratification. Empirical relationships are used to model convective heat transfer, energy partitioning between phases, choked flow and wall friction. Various slip options are available. The code supports simulation of the primary system, secondary system, feedwater train, automatic control system and core neutronics. Component models include reactor point kinetics, pumps, valves, heat structures, heat exchangers, turbines, separators and accumulators.

RELAP5/MOD2-B&W has been reviewed by the staff and is the subject of a safety evaluation (Ref.: Letter from A. Thadani to J. Taylor, dated April 18, 1990). The staff found the code acceptable for use, subject to specified limitations, for calculation of transient response for reload analyses of large and small break LOCAs and operational transients for plants having recirculating steam generators. The staff is currently evaluating its use, for those purposes, for once-through steam generator (OTSG) plants. The fact that RELAP5/MOD2-B&W has not yet been approved for analysis of transient responses for OTSG facilities does not preclude its acceptance for use in calculating mass and energy releases for containment analysis, since the objectives of the analyses are different. In reload transient analysis, the focus is on conservative analysis of RCS response and fuel performance rather than mass and energy release.

An emergency feedwater (EFW) module has been added to account for steam condensation inside OTSG tubes. The EFW module estimates the tube external area wetted by the EFW. This area is then used to estimate the internal and external heat and mass transfers. The resulting condensation within the OTSG tubes represents an energy exchange between the primary and secondary systems that is particularly significant in the simulation of small break LOCAs where the energy removed by the break flow may be insufficient to remove decay heat from the primary system.

2.1.2 <u>SMALL BREAK AND LARGE BREAK LOCA MODELS</u>

The topical report describes distinctly different RELAP5 nodalizations for large and small break mass and energy release models. With large breaks, large pressure gradients exist during the blowdown phase, resulting in tight coupling between the primary and secondary systems, thereby permitting a reduced level of noding for the steam generators and coolant loops. Instead, large break analyses require emphasis on the reactor vessel nodalization to reflect the in-vessel check valves, core region, and downcomers and replicate the axial progression on the quench front during reflood. For small breaks, there is increased emphasis on the coolant piping and OTSG nodalization to replicate the phenomena resulting from the "candy cane" hot leg configuration, the EFW flow, and boiler-condenser heat transfer. The licensee's modeling has been developed in consideration of these requirements. The OTSGs are modeled with [ ] effect of the EFW flow.

2.1.3 <u>CODE AND MODEL VALIDATION</u>

The RELAP series of codes was used extensively by its developers for both pre-test and post-test predictions in the LOFT and Semiscale tests. For RELAP5/MOD2-B&W, B&W has assessed the code against the Multiloop Integral System Test (MIST) transients (Ref.: "Multiloop Integral System Test - Final Summary," NUREG/CR-5395, Volume 1). The licensee states that the code results were in generally good agreement with the test results. The Oconee model has not been assessed against actual LOCA data due to lack of experimental data. However, the model has been validated against available data from plant transients. The transients include RCP coastdown data from startup tests, discharges of core flooding tanks, natural circulation data from similar plants. The licensee states that these efforts indicated reasonable agreement between code predications and experimental data.

2.1.4 <u>USE OF RELAP5 FOR CONTAINMENT RESPONSE MASS AND ENERGY ANALYSIS</u>

CRAFT-2 was used for the original Oconee licensing analysis described in the FSAR. The Standard Review Plan (SRP) states that the CRAFT-2 code is an acceptable code for calculation of mass and energy releases for use in containment design basis calculations for B&W plants. While CRAFT-2 is specifically referenced in the SRP, the SRP also states that other methods are acceptable if they are found to be conservative for these calculations.

RELAP5 provides an alternative means to perform mass and energy release calculations. RELAP5 thermal-hydraulic analyses take into account fluid momentum changes, wall friction, gravity forces, and geometric head losses due to bends, contractions and expansions, etc. RELAP5 contains the necessary modeling flexibility and computational capability for use in calculations of large break and small break LOCA mass and energy releases for containment analysis. A variety of break flow and slip option models are available to the user. Based on its known capabilities and the licensee's discussion of the code modifications, the staff acknowledges that the modified RELAP5/MOD2-B&W code is capable of generating conservative LOCA mass and energy release calculations. Additional discussions on the use of RELAP5/MOD2-B&W for the Oconee containment analyses are provided in Sections 3.0 and 4.0 below.

2.2 BFLOW

2.2.1 CODE USE AND DESCRIPTION

BFLOW was developed by the licensee as a tool for use in calculating the long-term liquid and steam mass flow rates out of a large cold leg break. A cold leg break at a lowered-loop B&W plant is characterized by continued steaming from the break during the long-term phase. This is because voiding in the core is necessary in order to induce core flow. The steam or steam-water mixture leaving the core enters the reactor vessel upper plenum, passes into the outlet annulus, then passes through internal vent valves into the upper downcomer region. The vent valve flow will be two-phase at higher decay heat levels when steam production is high enough to carry liquid up through the internal vent valves. At lower power levels, the flow is saturated steam. The steam or steam/liquid mixture (depending on power level) then leaves the vessel by entering the broken cold leg, then discharges into the containment where the steam adds heat to the containment atmosphere.

BFLOW models the core power shape, geometry and elevations of the flow volumes and passages. Mass, energy and momentum balances are utilized to compute values for the break flow quality for a wide spectrum of core power, boron dilution flow rate, LPI flow rate and temperature, and containment backpressure conditions. The qualities are used to partition the break mass flow rate into a steam component, which is added to the containment atmosphere and a liquid component which is added to the sump. The total mass flow rate is assumed to be the LPI mass flow rate minus, if any, the boron-dilution line mass flow rate. Additional description is provided in Sections 3.4 and 6.3.

2.2.2 CODE AND MODEL VALIDATION

The staff has not performed a detailed review of the BFLOW model and no actual experimental data are available to assess the results. However, because BFLOW mechanistically models the physical geometry of the reactor vessel and the nodal mass and energy balances (neglecting certain friction and momentum effects due to low flow rates), the staff acknowledges that BFLOW is suitable for use in Oconee long-term large cold leg break mass and energy release computations.

2.3 RETRAN

2.3.1 CODE DESCRIPTION

The RETRAN-02 MOD5.1DKE code is a modified version of the RETRAN-02 MOD005.0 code. RETRAN was developed by Energy Incorporated for the Electric Power Research Institute to provide utilities with a code capable of simulating thermal-hydraulic transients of interest for both PWRs and BWRs. RETRAN-02 can be used to model a general fluid system by partitioning the system into one-dimensional volumes and connecting flowpaths or junctions. The code solves the mass, energy and momentum equations using numerical methods. Although the RETRAN-02 equations describe homogenous equilibrium fluid volumes, phase separation can be modeled by separated bubble-rise volumes and by a dynamic slip model. Heat transfer across steam generators and to or from structures can be modeled. Component models for fans, heat exchangers, pumps, and valves, are available in RETRAN. Control system and trip logic capability are also provided. A general transport model capable of modeling the distribution of boron is included. RETRAN-02 MOD5.0 has been reviewed and approved by the staff for use in the analysis of non-LOCA transients (Ref.: Letter w/Safety Evaluation from A. Thadani to W.J Boatright, dated November 1, 1991).

2.3.2 OCONEE RETRAN MODEL

The licensee's RETRAN models for the Oconee, McGuire and Catawba facilities are described in topical report, "DPC-NE-3000." The staff has reviewed that submittal and issued safety evaluation reports approving their use. The Oconee OTSG model was found to overpredict primary to secondary heat transfer, however, this is not non-conservative the purpose of analysis of containment mass and energy release.

2.3.3 VALIDATION OF CODE AND MODEL

Validation of the Oconee RETRAN model against data from actual secondary break events or experiments has not been performed as there are no data available.

2.3.4 USE OF OCONEE RETRAN-02 MODEL FOR CONTAINMENT RESPONSE MASS AND ENERGY RELEASE ANALYSES

The SRP, Section 6.2.1.4, cites "TRAP-2" (Ref.: Babcox and Wilcox Company, Reference Safety Analysis Report, B-SAR-205, May 1978) as an acceptable code for use in mass and energy release analysis for postulated secondary steam system pipe ruptures. The SRP also states that other methods will be acceptable if they are found to be conservative for these calculations.

The RETRAN-02 code contains suitable modeling flexibility and computational capability for use in producing conservative calculations of steam line break mass and energy releases for containment analysis. Additional discussions on the use of the code is provided in Section 5 below.

2.4 FATHOMS/DUKE-RS

2.4.1 CODE USE AND DESCRIPTION

The FATHOMS/DUKE-RS code is used in the Oconee containment analysis methodology to determine the short and long term containment pressure and temperature response to the mass and energy inputs from high energy primary and secondary reactor coolant system breaks. The FATHOMS/DUKE-RS code is a derivative of the generic FATHOMS code which is, in turn, a derivative of the COBRA-NC/GOTHIC thermal-hydraulic code. The generic FATHOMS code, a product of Numerical Applications, Inc., is capable of modeling all containment types (i.e., ice condenser, large dry, subatmospheric and suppression pool).

To use FATHOMS, a containment is modeled as a network of control cells connected by fluid flow path junctions. FATHOMS solves the mass, energy and momentum equations for multi-component, two-phase flow. Velocity fields are provided for; (1) vapor/non-condensible gases, (2) continuous liquid, and (3) liquid droplet. Temperature fields are provided for (1) vapor/non-condensible gases, and (2) liquid/droplet mixture. (All liquid/droplets within the same volume must be at the same temperature, similarly, all vapor/non-condensibles within a calculational volume must be at the same temperature. However, vapor/non-condensible mixtures may be in thermal non-equilibrium with liquid/droplet mixtures within the same calculational volume.) Passive thermal conductors, flat plate, cylindrical tube or solid rod models, are simulated with finite-difference conduction models. Active heat sources and sinks may also be included in the volumes. Valves, heat exchangers, pumps, spray nozzles and fans may be included in the flow paths.

The licensee's Oconee FATHOMS model does not utilize all of the features available in FATHOMS. Thus, this evaluation does not encompass all of FATHOMS capabilities.

2.4.2 OCONEE FATHOMS MODEL

The significant difference between FATHOMS/DUKE-RS and the generic FATHOMS code is that FATHOMS/DUKE-RS has been modified to include a model to estimate the long-term mass and energy release used to calculate the long-term (post-reflood) LOCA containment response after RCS conditions have stabilized.

In subsequent chapters of this report, the nomenclature "FATHOMS" and "FATHOMS/DUKE-RS" are used interchangbly.

2.4.3 CODE AND MODEL VALIDATION

The topical report states that the FATHOMS code and its predessor COBRA-NC have been extensively benchmarked. To supplement those efforts, the licensee modeled three steam blowdown tests conducted at the Carolina Virginia Tube Reactor (CVTR) and compared the model predictions to the test results. The model predicted CVTR building temperature and pressure responses with good agreement between the code results and test results. Also, Oconee containment response predicted by the licensee's Oconee FATHOMS model was compared to that of the FSAR analysis performed by the NSSS vendor using the CONTEMPT code. The FATHOMS results compared favorably to the CONTEMPT results.

2.4.4 ACCEPTABILITY OF FATHOMS/DUKE-RS FOR CONTAINMENT RESPONSE MASS AND ENERGY RELEASE ANALYSES

Based on; (a) our review the description of the FATHOMS/DUKE-RS model provided by the licensee, (b) the LOCA validation against the FSAR CONTEMPT analysis depicted in Figure 2.4-2 of the topical report, and (c) the CVTR benchmarking described above, the staff finds the FATHOMS/DUKE-RS code acceptable for use as described in the topical report. Additional information regarding FATHOMS/DUKE-RS usage is provided in Section 6.0 of this report.

3.0 LARGE BREAK LOCA MASS AND ENERGY RELEASE ANALYSIS

3.1 OVERVIEW

Large break LOCA (LB-LOCA) mass and energy release analyses are performed to generate FATHOMS analysis boundary conditions for determining the peak containment pressure following a hot or cold leg double-ended guillotine break (DEGB), and for determining the long-term containment response to a cold leg DEGB. The Oconee RELAP5/MOD2-B&W model was used to generate the mass and energy releases for all but the long-term (i.e., after 30 minutes) segment of a cold leg break for which BFLOW is used. DEGBs were examined for four locations; (1) a hot leg break at the vessel nozzle, (2) a hot leg break at the OTSG inlet, (3) a cold leg break at a RCP discharge, and (4) a cold leg break at a RCP suction. Split breaks and other breaks of lesser discharge were not examined as it is clear that they would produce a lower peak containment pressure. After determining the limiting break location, sensitivity studies were performed to investigate the effect of discharge coefficient selection, offsite power availability (RCP trip), ECCS delays, main feedwater availability, containment backpressure, and vessel refill time. A RELAP5 control system option was used to integrate the mass and energy release for each simulation into a form suitable for input to FATHOMS. For each case examined, the RELAP5 analysis was terminated when the RCS stabilized. BFLOW provides the mass and energy analysis for the remainder of the transient in cases where the analysis is continued further. These studies are described in greater detail in Section 6.0.

3.2 INITIAL CONDITIONS

Initial conditions for LB-LOCA mass and energy analyses were conservatively selected to maximize the energy stored in the primary and secondary systems at the start of the event (i.e., after a converged steady-state solution has been reached). Initial conditions were selected as follows:

Time of life: Time of life was chosen to bound all future reloads and fuel burnups in such a manner as to maximize the combined effects of stored energy (which is highest at BOC) and decay heat (which is highest at end-of-cycle [EOC]). See "core stored energy" boundary condition below.

Initial power level: 2619 Mwt, which is the rated power level with an additional 2% measurement uncertainty was used as the initial power level.

Initial T_{AVG}: 581°F, which is the average coolant temperature maintained by the Integrated Control System (ICS) plus a 2% measurement uncertainty factor was used as the initial T_{AVG}.

Initial RCS pressure: 2185 psig, which is the nominal RCS pressure plus a 30 psi measurement uncertainty allowance was used as the initial RCS pressure.

Initial OTSG pressure: 925 psig was used as the initial OTSG pressure. Turbine header pressure at Oconee is normally maintained at 885 psig. With a 25 psig pressure drop in the steam lines and a 40 psig measurement uncertainty allowance, 950 psig would be the desired initial OTSG pressure. However, in order to initialize a RELAP5 Oconee code run, some parameters must be allowed to vary. The licensee selected OTSG pressure as one such parameter, as it has a minor impact on the mass and energy results.

Initial pressurizer level: At Oconee, high level and high-high level alarms are provided. These alarms are set at 260 and 315 inches respectively. Measurement uncertainty is 25 inches Thus, the first alarm could come in at a level as high as 285 inches. It is assumed the operators would respond to the first alarm in time to maintain true level below 315 inches. Based on these features 315 inches was used as the initial pressurizer level.

Initial secondary coolant mass: [ ] lbm per steam generator was used as the initial OTSG secondary coolant mass inventory. This is the most that can be obtained under initialization conditions and is conservative with respect to the nominal full power steady-state value of [ ] lbm.

Initial CFT liquid volume: 972 ft^3 was selected as the initial core flood tank (CFT) liquid volume, 122 °F as the initial CFT temperature and 655 psig as the initial CFT pressure. Temperature uncertainty was biased high to maximize the break steaming rate. The pressure was biased upward from the technical specifications limit to account for as-left error and instrument error and to maximize the non-condensible gas discharge. The initial volume is the technical specifications nominal volume biased downward in order to minimize the quantity of injection fluid.

Initial RCS flowrate: 366,080 gpm (104% of design flow) is used as the initial RCS flow rate. This value maximizes T_{HOT} and is conservative with respect to RCS stored energy.

The initial conditions selected by the licensee, and described above, have been selected in a manner consistent with the conservative guidance of ANS-56.4-1983, paragraph 3.2.2 to maximize the amount of energy available to be released to the containment. Accordingly, they are acceptable for use in the LB-LOCA containment response mass and energy release analyses.

3.3 BOUNDARY CONDITIONS

Boundary conditions are; (1) the energy sources that transfer mass and energy to the modeled system during the event, and (2) assumptions that specify how the mass and energy are distributed and/or how the components will respond during the event. Boundary conditions are specified by the code user for parameters governed by conditions outside of the problem boundaries. The code imposes the boundary conditions on the system model at the beginning of the transient after the initial conditions have been established.

3.3.1 COMMON BOUNDARY CONDITIONS

The licensee's LB-LOCA containment analysis methodology involves the following boundary conditions that are common to both peak pressure analyses and the RELAP5 segment of the long-term release analysis. (Different boundary conditions are used for peak pressure and long-term analyses in cases where use of a common boundary conditions would be unrealistic or non-conservative for either analysis.)

3.3.1.1 ENERGY SOURCES

When calculating LB-LOCA mass and energy releases for containment response analyses, the analyst considers all significant sources of mass and energy that may be added to the containment. The topical report identifies the following energy sources used as common boundary conditions in the calculation of LB-LOCA mass and energy releases for containment peak pressure analyses and long-term response.

RCS inventory: An initial pressurizer level of 315 inches, which represents an increase of approximately 2% above the normal operating RCS inventory was selected as a conservative boundary condition. Thermal expansion of the RCS volume, from the cold to hot condition, was accounted for increasing the calculated volume of the RCS piping by 1%.

Secondary system inventory: The physical volume of the secondary system was not increased to reflect thermal expansion. Instead, the main feedwater flow boundary condition was chosen so as to conservatively represent the secondary inventory. See 3.3.1.2 "OTSG level" below.

RCS and OTSG metal heat structures: The metal heat structures (e.g., reactor vessel and internals, RCS piping, OTSG) are initially assumed to be in thermal equilibrium with the surrounding coolant, each with a constant initial temperature distribution. This condition maximizes initial stored energy.

Core stored energy and decay heat: Core stored energy is a function of initial fuel average temperature which in turn is highly dependent on burnup. It is highest at beginning of cycle (BOC). [ ] is used as the initial average fuel temperature. This value is based on the weighted linear heat rate in each of three core regions and is consistent with the ECCS analyses. Fission product decay heat and actinide heat input are based on ANS-5.1-1979 with 2σ uncertainty allowance. These heat inputs are greatest at EOC. A time in life is selected that maximizes the combination of core stored energy and decay heat contributions to containment mass and energy releases.

Metal-Water reaction heat: A unique value, as discussed in 3.3.2.1 and 3.3.3.1, is used for each analysis.

Main steam isolation: The turbine stop valves are assumed to close instantaneously when the break occurs. The turbine bypass valves remain closed. All steam relief valves are assumed operable.

Main feedwater supply: Main feedwater, in cases where it is not lost due to loss of offsite power, is assumed to be under the post-trip control of the MFW level controller and thus responsive to OTSG level changes.

CFT nitrogen expansion: The nitrogen mass in the CFTs is assumed to directly enter the containment at at time calculated by RELAP to be equivalent to CFT depletion.

ANS-56.4-1983, para. 3.2.1 provides guidance for the identification and selection of conservative energy source conditions for calculation of mass and energy releases used on containment response to LOCAs. The above selections conform to the ANS guidance and are acceptable.

3.3.1.2 COMMON ASSUMPTIONS USED IN MASS AND ENERGY ANALYSES FOR CONTAINMENT PEAK PRESSURE AND LONG-TERM RESPONSE

Assumptions used in both the peak pressure and long term mass and energy release calculations are identified below.

Axial power distribution: A chopped cosine distribution with a [ ] has been shown to result in the greatest quantity of steam exiting the break and is thus assumed for the LB-LOCA analyses.

Borated Water Storage Tank (BWST): The ECCS and spray pumps draw from the BWST during the injection phase of a LOCA. Prior to the BWST becoming depleted, suction is switched to the containment sump. The sump is warmer and the switchover thus results in reduced heat removal from the RCS and containment atmosphere. For conservatism, the minimum allowable BWST level of 46 feet, plus a 20.2-inch measurement allowance is assumed. A relatively high BWST temperature of 115 °F is assumed.

Main feed water (MFW) temperature: The nominal full power MFW temperature at Oconee is 453°F. The uncertainty of this measurement is 4°F. The licensee has selected a MFW temperature of 460°F as a boundary condition. Also, the temperature is held constant through the transient for additional conservatism although the bleed steam supply to feedwater heaters is lost when the turbine trips. These assumptions increase the secondary system energy contribution and are conservative.

Emergency feedwater (EFW) temperature: For the large break peak pressure analyses, EFW (for sequences in which it is available), is assumed to be at 120°F.

Limiting single failure: Consistent with the guidance of ANS-56.4-1983, paragraph 3.2.3, the licensee evaluated the potential effects of various single active failures on containment long-term response. [Note: The short-term peak pressure response is relatively insensitive to ESF single-failures due to the fact that the pressure peaks quickly, before the containment cooling systems become fully effective.] Failure of a 4160 VAC switchboard was determined to be the single failure that disables the greatest number of containment cooling components and was assumed as the limiting single failure.

OTSG level: If offsite power is available, the MFW system is available and used to control OTSG level. Following reactor trip, the boundary condition assumes that level is controlled at 50% + 10.5% measurement error on the operating range with flow directed to the upper headers, and MFW temperature is 460°F. These assumptions are conservative, as they maximize the available amount of secondary energy available for heat transfer to the blowdown effluent.

The above assumptions are appropriately conservative boundary conditions for short-term (i.e., peak pressure) and long-term mass and energy release calculations.

3.3.2 LARGE BREAK LOCA PEAK PRESSURE MASS AND ENERGY RELEASE BOUNDARY CONDITIONS

Boundary conditions applicable to the LB-LOCA peak pressure analyses, but not common to the LB-LOCA RELAP5 long-term mass and energy release analyses are discussed in this section.

3.3.2.1 ENERGY SOURCES

The boundary conditions identified below describe the energy sources applied to the RELAP5 large-break LOCA mass and energy release analyses used for containment peak pressure response analysis. These boundary conditions supplement those for the common energy sources described in 3.3.1.1 above.

Fission heat: Fission heat calculations are generated by the RELAP5 built-in point kinetics model for the blowdown and reflood phases. The reactivity value used is computed by collapsing weighted nodal reactivities into a single (point) value. Feedback mechanisms for each node include the effects of moderator density, Doppler and boron. Control rods are assumed to remain out of the core.

For the blowdown phase, the combined reactivity feedback effects of the moderator density negative reactivity contribution and Doppler positive reactivity are based on analyses which bound previous and future reloads from beginning of cycle to end of cycle.

During refill boron concentration changes rapidly. For reactivity feedback during refill, a net reactivity function (a function of moderator density, boron concentration and fuel temperature) is developed from the known lower reactivity limit for a voided core at the end of blowdown, a calculated upper limit for the all-rods-out 1% shutdown margin condition, and intermediate points on a third order polynomial fitted to arbitrarily-selected intermediate points.

Metal-water reaction: The RELAP5/MOD2-B&W code includes a user-selectable metal-water reaction model which can be used in a manner similar to an ECCS evaluation model. However, remodeling of the core using this model is unnecessary for puposes of containment mass and energy analyses. The containment analysis methodology uses an alternative approximation methodology based on the results of ECCS analyses performed by B&W and applicable to B&W 177 Fuel Assembly Lowered-Loop B&W facilities. For a cold leg break, the method assumes a [

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ealier. In both cases the energy is assumed to be distributed in an axial profile consistent with neutron power and decay heat.

The above energy sources, along with the common energy sources described in paragraph 3.3.1.1, encompass the energy sources enumerated in ANS-56.4-1983, paragraph 3.2.1, which need be accounted for in conservative calculations of mass and energy releases for the analysis of containment peak pressure. The staff did not closely examine the refill reactivity model or the metal-water reaction approximation methodology described above. However, the staff notes that these simplified models are fundamentally sound in principle, and suitable for mass and energy release calculations for containment peak pressure analyses.

3.3.2.2 ASSUMPTIONS

Assumptions common to RELAP5 large break peak pressure and long-term analyses are described in 3.3.1.2 above. Additional assumptions specific to the peak pressure analyses are described below.

Break location: Four large breaks, two hot leg breaks and two cold leg breaks, were examined. These include hot leg breaks at the vessel nozzle and at the OTSG inlet, and, for the cold leg, one at the RCP discharge and one at the RCP suction. For the hot leg break vessel outlet case, core stored energy release is maximized and moderator density reactivity feedback is maximized, whereas OTSG energy contribution is reduced. [

]. Also a Loop A break is assumed in order to maximize the pressurizer fluid contribution to the break. For the hot leg break at the OTSG, secondary system energy contribution is maximized. These two locations are assumed to bound all intermediate hot leg locations.

For the cold leg case, breaks at the RCP suction and discharge in the A1 loop are assumed to bound all cold leg cases. Loop A1 is chosen because the pressurizer is attached to that loop. [

].

Break flow model: RELAP5/MOD2-B&W has available two mutually exclusive choked flow models. The first option is its built-in Ransom-Trapp model. The other option permits use of table interpolation with any of four correlation tables [i.e, extended Henry-Fauske model (subcooled flow), Moody model (two-phase flow), homogenous equilibrium no-slip model (HEM), or Murdock-Bauman (superheated flow)]. The method employed in the Oconee methodology is to determine the differences between the Henry-Fauske and Moody correlations and the Ransom and Trapp model and adjust the flow coefficients as necessary to bound the Henry-Fauske and Moody correlations. (The suitability of this method was confirmed by sensitivity studies as described in Section 6.0 below.)

ECCS injection: An ECCS injection delay time of 15 seconds is assumed to be bounding for scenarios with offsite power available. For scenarios with loss of offsite power and failure of a 4160 VAC bus, a delay of 35 seconds is assumed. Low pressure injection is assumed to be constant at 3000 gpm plus 311 gpm instrument error. The positive allowance for instrument error is conservative due to the fact that it results in an increased reflood rate and accelerated energy release to containment. High pressure injection flow is represented as a function of RCS backpressure. All injection flow is modeled as being injected low in the vessel downcomer to conservatively minimize steam condensation. For the RCP discharge line break case, all HPI flow into the broken line is assumed to be spilled directly into the containment.

Reactor coolant pumps: Except for the loss of offsite power cases, the RCPs are assumed to continue operating. This conservatively maximizes secondary-to-primary heat transfer and pump heat. Degradation of pump capacity under two phase flow conditions is modeled using Semiscale and pump vendor data.

Emergency feedwater system: For loss of offsite power cases, MFW pumps are lost, coasting down in 10 seconds. At 17 seconds into the event, EFW flow is established to the OTSG upper header. For conservatism, only the steam-driven EFW pump, feeding both OTSGs, is assumed available although using the single-failure criterion one motor-driven MFW pump would also be available. The reduced EFW flow is conservative because relatively cold EFW flow absorbs primary system heat resulting in less break flow energy.

Containment backpressure sensitivity: RELAP5 is not iteratively coupled to FATHOMS in a manner that would enable a calculated backpressure to be used in the mass and energy calculation. Instead, a conservatively high backpressure (i.e., 59 psig, the containment design pressure) is assumed. Section 6.2.6 discusses backpressure sensitivity studies.

Refill phase modeling sensitivity: Vessel refill time (the period between the end of blowdown and the beginning of reflood) has typically, in the past, been considered to be zero seconds. The new analyses assume a 10-second refill period. A sensitivity calculation using a 0-second refill time was performed as described in Section 6.2.6, and confirmed that refill time has no effect on peak pressure response.

The above assumptions are conservative for purpose of analysis of LB-LOCA mass and energy releases for use in calculation of containment peak pressure response.

3.3.3 RELAP5 LARGE BREAK LONG-TERM MASS AND ENERGY RELEASE

Section 3.3.3.1 through 3.3.3.4 below discuss boundary conditions applicable to long-term LB-LOCA mass and energy analyses, but not to the peak pressure LB-LOCA mass and energy analyses.

3.3.3.1 ENERGY SOURCES

Fission heat: For the blowdown, refill and reflood phases, fission heat is calculated as described in 3.2 above. For the long-term segment after reflood and prior to achievement of quasi-steady state conditions, a less rigorous fission heat energy source boundary condition is used. A fission power history from a suitable large break Appendix K LOCA analysis was used, the results of that analysis being normalized to reflect the necessary power level and axial peak conditions appropriate for the new Oconee analyses. The licensee has validated this method against results using the peak pressure analysis method described above, and confirmed that the results are comparable for long-term mass and energy release.

Metal-water reaction: Exothermic heat from metal-water reaction is neglected for the long-term analyses. The licensee determined that the maximum expected energy release to containment from metal-water reaction in the first 30 minutes (RELAP portion) would be approximately 0.56% of the total energy released to containment during that period. Although it is non-conservative to neglect a heat source, this amount is so insignificantly small as to not warrant modeling for the long-term analysis.

These energy sources, along with the common energy sources described in 3.3.1.1 above, encompass all energy sources which must be considered in the analysis of large break long-term mass and energy releases.

3.3.3.2 ASSUMPTIONS

Assumptions utilized in the RELAP large break long-term mass and energy release analyses are discussd below.

Break location: Only one break size and location is analyzed for long-term containment response - a double-ended guillotine break (DEGB) at the A1 cold leg discharge. This selection is based on a consideration of the RCS geometry. An RCS cold leg pump discharge break will continue to steam during the long-term, whereas breaks at other locations will become flooded. This steaming results in a more severe long term containment temperature response notwithstanding the use of containment spray and containment coolers. [The current (original) licensing analyses did not analyze cold leg breaks for long-term response.]

Break flow: The break flow model assumed for the DEGB long-term analysis is the RELAP5 Ransom and Trapp model. This assumption is based on the long-term analysis being insensitive to blowdown phase dynamics and break size.

Borated Water Storage Tank (BWST) depletion - ECCS and containment system flow rates: High ECCS pump flow rates are intentionally established in order to accelerate BWST depletion. Early BWST depletion results in early switchover to the sump recirculation phase. The higher injection temperature (less subcooling) of sump fluid increases the steam release to containment and thus provides a more conservative analysis. The higher ECCS flow rates are established by assuming a 4160 VAC switchgear failure and manual operator action (per guidance of Emergency Operating Procedures [EOPs]) to cross connect HPI trains and throttle containment spray flow. For additional conservatism, it is assumed that the HPI line serving the broken loop has also broken in such a manner as to preclude steam condensation on the spilled injection fluid. Conservative-direction allowances are included to account for possible instrument errors.

Reactor coolant pumps: For cases where offsite power is not lost, RCPs are assumed to be manually tripped two minutes after the break. This assumption is based on EOP requirements to trip the pumps upon loss of subcooling.

Emergency feedwater system: Because MFW temperature is warmer than EFW temperature, it is conservatively assumed that MFW pumps are used to maintain OTSG levels.

Containment backpressure: Containment temperature and pressure conditions for the long-term DEGB analysis are assumed to follow time-dependent profiles which are bounding on the high side. The profiles are based on a FATHOMS analysis which assumes operation of two RBCUs, one train of RBS, and one LPI cooler. The pressure values bound the high side of the FATHOMS response. The temperature profile is chosen so as to specify a slight superheat in order to reduce code instabilities due to the vacuum-creating effect of steam condensation. As noted in ANS-56.4-1983, paragraph 3.2.4.6.1, a conservatively high backpressure assumption is acceptable if the mass and energy release analysis is not coupled to the containment analysis in such a manner that a calculated containment backpressure is available.

The above modeling assumptions are consistent with the guidance of ANS-56.4-1983, paragraphs 3.2.3 through 3.2.5, and are conservative for the purpose of analysis of long-term mass and energy releases from large breaks.

3.3.3.3 BREAK FLOW OSCILLATIONS

Toward the end of blowdown, there is a potential for code instability. The high mass flux inertia of the break flow can cause fluid to continue exiting the break after the RCS pressure has dropped below the containment backpressure. A period of reverse flow, followed by additional, damped oscillations may then occur. Modeling techniques attempt to minimize the number and severity of these oscillations. These measures include; (a) injecting ECCS flow into the vessel downcomer below the equilibrium liquid level, (b) time-averaging of heat transfer coefficients, and (c) holding the in-vessel vent valve open at a constant value and varying the downstream volume. Measures (b) and (c) are implemented only after quasi-steady state conditions are present, and in such a manner as to ensure that the resulting mass and energy release profiles are bounding.

3.3.3.4 HEAT STRUCTURE STORED ENERGY

Whereas a RELAP5 model can account for the energy stored in heat structures, and the heat transfer between the heat structures and fluids, BFLOW, which assumes quasi-stable conditions, cannot. Since RELAP5 is only used for the first segment (not beyond 30 minutes) of the cold leg DEGB mass and energy analysis, a means is necessary to account for, in the BFLOW portion of the analyses, the stored heat remaining at the termination of the RELAP5 portion of the analysis. To facilitate this action, RELAP5 heat structures are grouped.

Each RELAP5 heat conductor is grouped into [

] from FATHOMS heat structures modeled as slabs based on nominal values for volume, initial temperature, specific heat, density and overall heat transfer coefficient. The FATHOMS heat slabs are modeled to be geometrically similar to the RELAP heat slabs. The total stored energy in each group is calculated by a RELAP5 control system and the results provided to FATHOMS. This technique provides a means of accounting for heat structure stored energy release rates while performing the analysis in separate segments as further described in Section 6.0.

3.4 BFLOW LONG-TERM MASS AND ENERGY RELEASE

As discussed in Section 2.0 above, the RELAP5 model calculates the mass and energy release from the assumed break for approximately the first 30 minutes following the break. For the subsequent period, FATHOMS obtains the break boundary conditions from a set of subroutines which utilize BFLOW results. BFLOW results are made available to FATHOMS in the form of [

] of the four key parameters noted in Section 2.2 (i.e, containment pressure, reactor power, LPI flow, and LPI subcooling). At the end of the RELAP5 period, the FATHOMS subroutines use these four parameters to obtain from the matrices the break quality and boron dilution flow for each time step. Through mass and energy balances, this information is sufficient to enable calculation of the liquid and vapor break flow rates and enthalpies. The vapor flow is added to the containment atmosphere and the liquid flow to the containment sump. [

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3.5 LARGE BREAK LOCA PEAK PRESSURE MASS AND ENERGY RELEASE RESULTS

The licensee analyzed thirteen LB-LOCA cases to investigate the sensitivity of peak containment pressure to break location, critical flow model, offsite power assumptions, containment backpressure and refill time interval. The limiting case was determined to a DEGB of the hot leg at the OTSG inlet, with offsite power available, using the Ransom and Trapp critical flow model with flow coefficient adjusted to match the Appendix K evaluation model. The licensee's methodology provides integrated mass and energy release results which are in good agreement with that of the NSSS vendor. The critical flow model sensitivity studies confirmed the validity of using the Ransom and Trapp model in conjunction with critical flow discharge coefficient multipliers to increase the mass flow from the Ransom and Trapp model to those of the Henry-Fauske/Moody (Appendix K) models. See further discussion in Section 6.2.6 below.

3.6 RELAP5 LONG-TERM MASS AND ENERGY RELEASE

RELAP5 is used to calculate large cold leg break mass and energy release for the short-term segment, and for the long-term segment until quasi-steady state conditions are established. As discussed in Section 3.3.3.2, a Loop A1 cold leg RCP discharge line break is modeled for the long-term analysis and is assumed to be the bounding LB-LOCA for long-term considerations. Cold leg break phenomena results in a 26-second blowdown phase. Refill occurs in approximately 35 seconds and reflood is complete at about 200 seconds.

The instantaneous mass and energy release data computed by RELAP5 are integrated and smoothed by a utility program which puts them in a form which facilitates use by FATHOMS.

4.0 SMALL BREAK LOCA MASS AND ENERGY RELEASE ANALYSIS

4.1 OVERVIEW

An SB-LOCA is considered to be a LOCA with a break size less than 0.5 ft^2 and greater than the capacity of the normal makeup system. The normal makeup system at Oconee has the capacity equivalent to a 0.0008 ft^2 break. SB-LOCAs do not challenge the containment from the standpoint of internal pressure stresses in the manner of large break LOCAs, but are investigated to verify that the post-accident containment heat removal systems have adequate capacity to assure that post-accident containment pressure is maintained at or below assumed values. Equipment environmental qualification is the limiting consideration. A deficiency in the current Oconee licensing basis is that only a single break (i.e., 5.0 ft^2 large hot leg break) was analyzed for long-term response. The new DPC-NE-3003-P methodology examines a spectrum of small breaks to determine the limiting break for long-term containment response. Six cases having break areas from 0.0025 ft^2 to 0.10 ft^2 were considered.

For the small break containment analyses, the mass and energy boundary conditions, up to the time that the RCS has been cooled to the extent possible with the OTSGs, are calculated with RELAP5. For the subsequent period, wherein all decay heat removal is accomplished by the break flow, a simplified FATHOMS model is used to determine the mass and energy release.

This section discusses the derivation of the mass and energy release data. The containment responses are discussed in Section 6.4.

4.2 INITIAL CONDITIONS

The initial conditions for the SB-LOCA analyses are identical to those of the LB-LOCA described in Section 3.2 above.

4.3 BOUNDARY CONDITIONS

Boundary conditions for analysis of SB-LOCA mass and energy releases include the energy sources and assumptions described below.

4.3.1 ENERGY SOURCES

The SB-LOCA analyses consider the same energy sources as the large break LOCAs (Ref. Section 3.3.1.1 above) with the exception of metal-water reaction. Metal-water reaction need not be considered in the SB-LOCA because fuel cladding temperatures remain below the threshold for significant reaction.

Fission heat is calculated using the RELAP5 kinetics model in a manner similar to that of the large break peak pressure analysis described in Section 3.3.2.1 above, but the negative reactivity from boron in the ECCS injection fluid is not considered. The reactor is assumed to trip when the first trip setpoint condition is met. The rods begin to drop after an appropriate delay.

4.3.2 ASSUMPTIONS

This section discusses assumptions used in the SBLOCA analyses that differ from those of the large break mass and energy release analyses discussed in 3.3.2.1 above.

> **Break size and location:** As noted above, a spectrum of SB-LOCA analyses (six sizes at one location) were analyzed to identify the most limiting mass and energy release. Each case assumed a split rupture in the A1 cold leg RCP discharge piping. This location was selected because it would result in the least core cooling and greatest steam release to containment for the given break size.

Break flow model: Break flow is calculated using the RELAP5 built-in Ransom and Trapp critical flow model with an assumed break discharge coefficient of 1.0. This is acceptable in lieu of a more precise method for each case, because the potential mass and energy release errors for each case are accounted for by the fact that a sufficiently broad spectrum of break sizes is analyzed.

Reactor building, ESF flow, and BWST depletion: For SB-LOCA case studies, a reactor building model is included in RELAP5 for estimating containment-related boundary conditions which may impact the mass and energy release calculations since FATHOMS is not coupled to RELAP5. The model is similar to the FATHOMS model and includes appropriate representations for; (a) heat structures for the building cylinder, dome, internal concrete, and internal steel, (b) fan coolers, (c) containment spray, and (d) LPI coolers. For the smaller breaks, the reactor building model is used in the calculation of when sump recirculation switchover occurs. For the larger SB-LOCA cases, the event terminates before recirculation is aligned. HPI, LPI and RBS system boundary conditions are chosen to reflect the instrumentation setpoints, single-failures, instrument uncertainties, EOP operator actions, pump performance, etc. as appropriate for each case to generate a correct sump mass and temperature profile.

RCPs: A 4160vac switchgear failure is the limiting single failure. Thus offsite power is assumed to be available. RCPs are conservatively assumed to trip when the reactor trips. This is conservative because the OTSGs are less effective in removing primary system heat.

OTSG level control: The MFW system is used to initially control OTSG level since off-site power is assumed to be available and because it is hotter. If subcooling margin is reduced, the EFW system is used to raise the level per EOPs, after a 10 minute delay.

EFW system: One turbine-driven EFW pump is assumed to be available for the operator to feed both OTSGs as necessary. EFW is injected into OTSGs through the upper header as noted earlier in Section 2.1.1.2.

OTSG pressure control: For the first 30 minutes, it is assumed that pressure is maintained by the relief valves. Secondary cooldown is then begun using ADS valves if the main condenser is unavailable.

Hot leg high point vents: The hot legs are provided with high point vents for venting non-condensibles and for use in restoring natural circulation. These vents are assumed to be closed at all times except for one case. The one case is at 30 minutes into the 0.005 ft^2 break when EOP conditions are met for use of the vents.

4.4 RESULTS OF SIX-CASE SPECTRUM OF SB-LOCA ANALYSES

For the two smallest of the six cases considered, it was clear that they were not limiting for containment response. Primary-to-secondary heat transfer can be maintained and an orderly cooldown accomplished. For the larger breaks, the RCS will depressurize to permit LPI and break cooling is sufficient. For the intermediate size breaks OTSG heat transfer can be interrupted and break cooling is limited. Breaks in this range are thus limiting.

5.0 STEAM LINE BREAK MASS AND ENERGY RELEASE ANALYSIS

5.1 OVERVIEW

In addition to primary coolant system breaks (i.e., LOCAs), containment responses to secondary system pipe ruptures are also postulated and analyzed. A main steam line break in containment presents a significant pressure and temperature challenge to the containment, possibly more limiting than the worst-case LOCA.

As noted in Section 2.3 above, the DPC-NE-3003-P methodology, uses a RETRAN-02 model to predict the mass and energy release for a MSLB. The mass and energy release calculated by RETRAN-02 is input to FATHOMS to determine the containment pressure and temperature response. This section discusses the mass and energy analyses. The containment response is discussed in Section 6.5.

5.2 THERMAL-HYDRAULIC ANALYSIS

5.2.1 MODIFICATIONS TO OCONEE BASE PLANT MODEL

The Oconee RETRAN-02 "base plant model" is a model developed by the licensee for reload transient analyses. That model is described in "Thermal-Hydraulic Transient Analysis Methodology, DPC-NE-3000, July 1987."

The RETRAN-02 containment mass and energy release analysis model differs from the base model in that it has certain provisions to; (a) model the break, (b) include containment backpressure, (c) include asymmetry and thermal mixing in the vessel, and to (d) add additional detail for condensate and feedwater piping systems as described below.

Renodalization of reactor vessel: A MSLB produces an asymmetrical effect across the reactor core. In order to model the asymmetrical effects, the RETRAN base model is renodalized to
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Condensate feedwater model: A condensate/feedwater system model is added to the RETRAN base deck to model the feedwater pumps, condensate pumps, feedwater heaters and feedwater heater drain pumps.

5.2.2 BREAK MODEL

A DEGB of the 34-inch diameter main steam line is modeled using the Moody critical flow model. The Moody model is appropriate for two-phase critical flow conditions. The licensee performed sensitivity studies which indicate that the 34-inch MSLB containment pressure and temperature response bounds smaller breaks.

5.3 INITIAL CONDITIONS

Initial conditions are chosen to maximize the stored energy in the primary and secondary systems. A summary of the initial conditions is provided below.

Power level: For purposes of containment analysis, higher power level is more conservative than lower power due to the larger initial OTSG inventory, higher feedwater flow rate and increased decay heat. Accordingly, an initial power level of 100%, plus 2% power measurement uncertainty, is assumed.

$T_{(AVG)}$: $T_{(AVG)}$ is normally controlled at 579°F. This, plus an additional 2°F added for uncertainty, results in 581°F being used as an initial condition.

RCS pressure: RCS pressure is normally maintained at 2155 psig. This, plus 30 psi for uncertainty, results in 2185 being used as the initial RCS pressure.

OTSG pressure: Turbine header pressure is normally maintained at 885 psig. Pressure loss between the OTSG and turbine header is 25 psi. The pressure measurement uncertainty is 40 psi. Based on these values, 950 psig would be the appropriate initial condition for OTSG pressure. However, 910 psig is a realistic pressure which provides for proper RETRAN initialization with the required steady-state balance, and is acceptable.

Pressurizer level: An initial pressurizer level of 245 inches is used, based on a normal level of 230 inches plus 25 inches to bound uncertainty.

Secondary system inventory: An upper bound total OTSG inventory of [

] that the FSAR assumption value of 62,600, but has been analyzed by the licensee and determined to be a conservative value.

Initial conditions for time-of-life, boron and other core parameters are discussed under boundary conditions below.

5.4 BOUNDARY CONDITIONS

RCS inventory: The RCS inventory is the calculated volume of the RCS plus 1% to account for expansion between the cold and hot conditions. Zero OTSG tube plugging is assumed.

Primary system structures stored heat: Heat conductors are included in the RETRAN model for all structural metal in contact with the primary coolant. These heat conductors are assumed to be in equilibrium with the coolant and to have a uniform temperature.

Secondary system structure stored heat: Secondary structures are assumed to be in equilibrium with the surrounding coolant and to have a uniform temperature.

Core stored energy: Although core stored energy for a given power level is greatest at beginning of cycle (BOC), end-of-cycle conditions are used for the MSLB mass and energy analysis, because of the higher return to power resulting from the greater EOC negative moderator coefficient.

Fission heat: Fission heat is calculated by the RETRAN point kinetics model. The option employed uses one prompt neutron group, six delayed neutron groups, eleven delayed gamma emitters, plus U-239 and Np-239. A low effective delayed neutron fraction and prompt neutron lifetime are selected to maximize the reactivity addition rate. Reactivity feedback for moderator density and Doppler are specified by reactivity feedback tables. The most negative curves are tabulated.

Scram reactivity assumes a top-peaked power distribution and lower bound rod insertion times. These assumptions are non-conservative, but sensitivity analyses indicate the assumptions have little impact on the mass and energy release analyses. The most negative control rod is assumed to fail to insert.

Consistent with the assumed EOC condition, boron concentration is assumed to be zero. The negative reactivity inserted by boration is averaged for the six nodes to obtain a core average boron concentration. The core average concentration is multiplied by boron worth to give reactivity.

A high differential boron worth (i.e., 120 ppm/%Δk/k) is used to minimize the negative reactivity added by HPI and core flood tank discharge.

Decay of actinides and fission products: The ANSI/ANS-5.1-1979 decay heat values for EOC conditions are used.

Main steam line isolation: The turbine stop valves are assumed to trip closed in one second upon reactor trip. Closure of the turbine stop valves isolates the OTSGs from each other. The one second response time is a technical specification requirement.

Condensate and feedwater model: The feedwater/condensate model was previously noted. This model explicitly calculates the feedwater flow rate during the accident. The flow rate is based on pump curves and transient pressure response. Two booster pumps, two D-Heater drain pumps, and two MFW pumps are assumed operating. The third condensate booster pump is on automatic standby. No credit is taken for low suction pressure trips or for MFW pumps trip on high OTSG level. Condensate booster and drain pumps are assumed to trip with a 10-second coastdown if their suction inventory source is depleted.

The main feedwater heaters are supplied with extraction steam to heat the feedwater. The feedwater is heated from about 80°F to 455°F during normal operation. A main feedwater temperature of 458.3°F is used initially. These values provide a code initialization with secondary side heat removal equal to reactor power. When reactor trip occurs, extraction steam is no longer available and condensate temperature decreases. This is accomplished by adjusting the heat input from the feedwater heaters to zero immediately after the break occurs.

Emergency feedwater system: The Oconee EFW system includes three pumps, two motor-driven (one for each OTSG) and one shared steam turbine-driven. Flow from the shared pump is assumed to be discharged to the faulted OTSG. The pumps start automatically on loss of both MFW pumps or low level in either OTSG. EFW water temperature is assumed to be 120°F.

RCS flow rate: A high RCS flow rate maximizes primary-to-secondary heat transfer and is thus conservative. An RCS flow rate of slightly greater than 102% of the nominal best-estimate steady-state flow rate is assumed. This value corresponds to 115% of the design flow rate.

ECCS: The HPI system is modeled using a fill table with one HPI pump injecting through one train. This is conservative, since, in an emergency, all three pumps start, injecting into both loops, but use of one pump results in a higher return to power. HPI initiation is assumed to occur at 1480 psi, reflecting a 1600 psig setpoint with 120 psi measurement uncertainty. Boron concentrations in the BWST and CFTs are assumed to be at the Technical Specifications lower limits. The CFT temperatures are assumed to be 120 °F. The boron concentration in piping purge volumes (piping between CFTs and the RCS and between BWST and the RCS) is assumed to initially be 0.0 ppm.

Limiting single-failure: The failure of one 4160 VAC switchgear is the limiting single failure for the MSLB analyses. This results in loss of one train of HPI and one train of LPI. The licensee plans to perform another single-failure analysis to address a new feedwater isolation system design. At present, as an interim measure, the licensee is being permitted to rely on manual operator action for feedwater isolation.

Reactor protection system (RPS) trips: A delayed reactor trip is a conservative assumption for containment analysis. Accordingly, the variable low pressure trip setpoint assumptions include a 40 psig uncertainty allowance and 0.7 seconds delay time, and 5.04 second $T_{(HOT)}$ temperature sensor lag. The low RCS pressure trip is also modeled. The actual setpoint is 1810 psig. In the analysis, a setpoint of 1780, with a 0.5 second delay is assumed to provide conservatism and account for instrument uncertainty.

Integrated control system (ICS): The control rods and turbine control valves are assumed to be in manual control. For the rods, this is conservative since initial rod motion would otherwise be in the insert direction due to flux instrumentation errors resulting from downcomer temperature changes. For the turbine control valves, the manual control assumption is also conservative. The MFW flow is assumed to rapidly drop to zero within a few seconds after reactor trip reflecting the ICS response. After OTSG level drops to 25 inches, a RETRAN control system models the action of the low level controller to maintain a 25-inch level.

Loss of offsite power: MSLB is analyzed for both the loss of offsite power case and no loss of offsite power case, since it is not obvious or intuitive which case is more limiting for containment temperature or pressure responses.

Containment backpressure: A low backpressure is assumed in the RETRAN analyses. This provides a greater break flow, and is therefore conservative.

Liquid carryout and superheat: For conservatism, the break flow is adjusted such that the flow is [

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The initial conditions, modeling assumptions and boundary conditions described above are consistent with the guidance of ANS-56.4-1983, paragraphs 3.3.2

through 3.3.4, and provide conservative results in the analysis of steam line break mass and energy releases.

5.5 RESULTS OF MSLB MASS AND ENERGY RELEASE ANALYSES

Mass and energy releases were calculated for a 6.3 ft^2 DEGB of the 34 in^2 MSL for the offsite power maintained conditions and for the loss of offsite power condition. In both cases operator action is credited for isolation of the affected OTSG at 170 seconds. (Note: Modifications are planned to provide for automatic feedwater isolation for the faulted OTSG.) These releases were input to FATHOMS for analysis of the containment response. The results are provided in Section 6.5 below.

6.0 CONTAINMENT PRESSURE AND TEMPERATURE RESPONSE ANALYSES

6.1 OVERVIEW

As discussed in Section 2.4 above, the FATHOMS/DUKE-RS (FATHOMS) code is used to determine the containment responses to the mass and energy releases predicted by RELAP5, BFLOW, and RETRAN-02 for postulated high energy lines breaks inside containment. The RELAP5 mass and energy release data for each time step are integrated by a RELAP5 control system, then averaged by a utility program which prepares a data file for use by FATHOMS. BFLOW results are supplied to FATHOMS in the form of matrices giving the quality of the flow exiting the break as a function of decay heat, containment pressure, LPI flow and LPI subcooling. RETRAN data are provided to FATHOMS in a manner similar to that of RELAP.

Each FATHOMS case is run in one or more time segments, each segment representing a different phase of the event. Peak pressure analyses and MSLB analyses are of short duration and therefore may be run in one segment. Long-term large break LOCAs and SB-LOCAs are run in three segments.

A large number of break cases must be examined. For PWRs, it is not clear or intuitive what primary or secondary system pipe rupture event will produce the most limiting peak containment pressure, or harshest temperature response for safety-related equipment. The results of the LB-LOCA analyses are examined carefully for both pressure and temperature responses to determine if the highest peak pressure is bounded by the containment design pressure, and the temperature response is bounded by the EQ envelope. For SB-LOCAs it is recognized that the pressure response is not likely to be limiting; however, it is necessary to analyze these events, due to the possibility that an SB-LOCA produces a more limiting temperature response than LOCAs and MSLBs. MSLBs must be examined closely for both containment pressure and containment temperature responses, either or both of which may possibly be more limiting than any LOCA. Thus, to ensure that the most limiting events for containment pressure and temperature are identified, several cases of different break sizes and locations must be analyzed for each class (i.e., LB-LOCA, SB-LOCA and MSLB) of event.

6.2 LOCA PRESSURE RESPONSE ANALYSES

6.2.1 OVERVIEW

The mass and energy release analyses for large break LOCAs are discussed in Section 3.0. Eleven FATHOMS cases were run to examine containment response for peak pressure sensitivity to break location, critical flow model, offsite power availability, containment back pressure, and refill time.

6.2.2 ANALYTICAL APPROACH

The analytical approach for examination of containment pressure response to LOCAs was to examine hot leg DEGBs at the vessel and at the S/G and cold leg DEGBs on both sides of the RCP. The cases are run for a period of time long enough to ensure that the highest peak for each case is identified (recognizing that a case can have more than one peak). Additional cases are also run to determine the sensitivity of the containment response to changes in break flow model selection and containment back pressure effects. The licensee examined a sufficient number of cases to reasonably conclude that the limiting (i.e., worst case) containment loading events have been identified.

6.2.3 MODIFICATIONS TO FATHOMS BASE MODEL

The Oconee base FATHOMS model is described in Section 2.4.2. For the peak pressure analyses, certain conservative modifications are made to the base model.

Containment volume: For LOCAs, the pressure response is particularly sensitive to containment volume. For conservatism, a 2% reduction in the containment free volume is assumed.

Passive heat sink surface area and heat transfer correlations: The surface area (and thus also, the volume) of passive heat sinks is reduced by 1% for conservatism. The Uchida heat transfer correlation is used to determine the heat transfer coefficients on passive heat structures. This is consistent with Standard Review Plan guidance.

Break discharge droplet size: A 20 μm droplet size is assumed based on a recommendation by Numerical Applications, Inc. (the FATHOMS vendor) for use as a nominal value for break discharge droplet size. A sensitivity study, using a 2 μm droplet size indicated that the containment peak pressure response is insensitive to droplet size selection in this range. The 20 μm droplet size selection is therefore acceptable.

Containment heat removal systems: In the peak pressure analyses no credit is taken for fan cooler or containment spray as these systems may not function early enough into the event to affect the peak pressure response.

6.2.4 INITIAL CONDITIONS FOR PEAK PRESSURE ANALYSES

The containment initial conditions have a potentially significant effect on the peak pressure response. The effect of assuming a cold initial temperature and a high initial pressure is to increase the initial mass of noncondensible gas in the containment. This results in an increased air partial pressure contribution to the peak total (steam+air) containment pressure and is conservative. The effect of low humidity (dry air) is to increase the initial air mass. For conservatism, the peak pressure analyses assume containment initial conditions of 1.5 psig (a Technical Specifications limit), 110 °F, and 0% relative humidity. The temperature and humidity values bound normal power operation.

6.2.5 BLOWDOWN BOUNDARY CONDITION FOR PEAK PRESSURE ANALYSES

The blowdown boundary conditions for the LOCA peak pressure analyses are the mass and energy results of the RELAP5 analyses. The combined steam and water mixture representing both sides of the break is injected into the FATHOMS model via a junction provided for that purpose.

6.2.6 RESULTS OF PEAK PRESSURE ANALYSES

As stated in 6.2.2 "Analytical Approach" above, a large number of cases are analyzed. The following table and discussion provides the results of the LOCA peak pressure case studies.

TABLE 6.2.6 - RESULTS OF PEAK PRESSURE ANALYSES

CASE	BREAK	TIME OF PEAK PRESSURE seconds	PEAK PRESSURE psig	PEAK TEMPERATURE °F
1A	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH OFFSITE POWER AVAILABLE, UNADJUSTED RANSOM AND TRAPP CRITICAL FLOW MODEL	13.9	57.7	283.5
1B	14.1 SQ.FT. HOT LEG BREAK AT OTSG INLET WITH OFFSITE POWER AVAILABLE, UNADJUSTED RANSOM AND TRAPP CRITICAL FLOW MODEL	14.9	58.4	284.4
1C	8.55 SQ.FT. COLD LEG PUMP DISCHARGE BREAK WITH OFFSITE POWER AVAILABLE, UNADJUSTED RANSOM AND TRAPP CRITICAL FLOW MODEL	18.9	51.9	276.1
1D	8.55 SQ.FT. COLD LEG PUMP SUCTION BREAK WITH OFFSITE POWER AVAILABLE, UNADJUSTED RANSOM AND TRAPP CRITICAL FLOW MODEL	23.2	54.4	279.3
2A	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET USING HENRY-FAUSKE/MOODY CRITICAL FLOW MODEL WITH OFFSITE POWER AVAILABLE	THIS CASE RUN FOR MASS AND ENERGY ONLY		
2B	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH RANSOM AND TRAPP CRITICAL FLOW MODEL AND DISCHARGE COEFFICIENT ADJUSTED TO MATCH APP.K MODEL, WITH OFFSITE POWER AVAILABLE	12.8	58.3	284.3
2C	14.1 SQ.FT. HOT LEG BREAK AT OTSG INLET USING HENRY-FAUSKE/MOODY CRITICAL FLOW MODEL WITH OFFSITE POWER AVAILABLE	THIS CASE RUN FOR MASS AND ENERGY ONLY		
2D	14.1 SQ.FT. HOT LEG BREAK AT OTSG INLET USING RANSOM AND TRAPP CRITICAL FLOW MODEL AND DISCHARGE COEFFICIENT ADJUSTED TO MATCH APP.K MODEL, WITH OFFSITE POWER AVAILABLE	13.8	58.9	285.0
2D-80	SAME AS 2D BUT WITH CONTAINMENT AT 80°F INITIAL TEMPERATURE	13.7	58.8	284.0
3A	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH LOSS OF OFFSITE POWER AND WITH ADJUSTED DISCHARGE COEFFICIENT	12.3	57.9	283.8
3B	14.1 SQ.FT. HOT LEG BREAK AT OTSG INLET WITH LOSS OF OFFSITE POWER AND WITH ADJUSTED DISCHARGE COEFFICIENT	14.5	58.9	285.0
3B-80	14.1 SQ.FT. HOT LEG BREAK AT OTSG INLET WITH LOSS OF OFFSITE POWER AND WITH ADJUSTED DISCHARGE COEFFICIENT WITH CONTAINMENT AT 80°F INITIAL TEMPERATURE	14.3	58.8	284.0
3C	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH OFFSITE POWER AVAILABLE AND 30 PSIG CONTAINMENT INITIAL BACKPRESSURE	13.8	58.4	284.4
3D	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH OFFSITE POWER AVAILABLE AND 50 PSIG CONTAINMENT INITIAL BACKPRESSURE	13.5	58.4	284.4
3E	14.1 SQ.FT. HOT LEG BREAK AT VESSEL OUTLET WITH OFFSITE POWER AVAILABLE AND ZERO REFILL TIME	12.8	58.3	284.3

Four cases (1A, 1B, 1C and 1D) were analyzed to examine sensitivity to break location: hot leg breaks at the vessel and at the OTSG, and cold leg breaks on the RCP suction side and discharge side. These Series 1 cases utilized the Ransom and Trapp break flow model with unadjusted flow coefficients. Results of the analyses indicate that the hot leg break at the OTSG inlet produces the greatest peak containment pressure (58.4 psig). The peak pressure for the RPV outlet nozzle break was only slightly less (57.7 psig). Each hot leg break location produces a peak containment pressure earlier and higher than each cold leg break location.

Cases 2B and 2D investigated the two hot leg break locations to compare the Ransom and Trapp critical flow model with adjusted break discharge flow coefficients, to the Case 1 results which used the unadjusted flow coefficients. The Ransom and Trapp critical flow model with discharge coefficients adjusted by use of a multiplier to match the EM model (Appendix K LOCA Evaluation Model) produced slightly higher peak pressures and temperatures than the unadjusted Ransom and Trapp model. The results confirmed that the Ransome and Trapp model with properly adjusted discharge coefficients produces conservative results for peak pressure and temperature response.

The two Series 2 hot leg breaks (Case 2B and Case 2D for RPV outlet and OTSG inlet respectively) were rerun for loss of offsite power sensitivity. These cases, 3A and 3B, indicate that a loss of offsite power assumption results in slightly lower peak pressures and temperatures for the vessel outlet break, but has no significant effect for the OTSG inlet break.

Cases 3C and 3D investigated sensitivity to containment backpressure. As expected, containment backpressure was found to have no significant effect on peak pressure response.

Case 3E investigated sensitivity to refill time for the hot leg break at the RPV. Results were identical for cases with zero refill time and code-calculated refill time. (A zero refill time is simulated by stopping the code execution and fictiously filling the RPV lower plenum, then restarting.) This was expected since refill begins after the initial containment pressure peak.

Cases 2D-80 and 3B-80, were reruns of cases 2D and 3B to investigate the effect of initial containment conditions. 2D and 3B assumed initial containment conditions of 1.5 psig and 110°F. Cases 2D-80 and 3B-80 assumed 1.2 psig and 80°F. Results of these studies indicate that loss of offsite power is a conservative assumption for low containment temperatures and non-conservative for higher temperatures. These cases also indicate that low containment initial temperature combined with increased initial pressure could result in peak pressure exceeding the design limit of 59 psig. However, an 80°F containment temperature is considered unrealistic.

The most limiting case for LOCA peak pressure was 3B, the hot leg break at the OTSG inlet with loss of offsite power, for which the peak pressure 58.9 psig. The current FSAR analysis (Ref.: FSAR Table 15-9) indicates a worst case LOCA peak pressure of 53.5 psig for the (14.1 ft^2) hot leg break.

The licensee examined a sufficient spectrum of break cases to identify the worst case LOCA for containment peak pressure response.

6.3 LONG-TERM LARGE BREAK LOCA ANALYSES

6.3.1 OVERVIEW

In the long-term phase of a LOCA, heat continues to be added to the containment. Heat added in the form of steam is condensed by the containment spray and fan cooler systems. The sensible heat of the liquid recirculated from the sump is removed by the LPI coolers. These systems must maintain the containment temperature and pressure below specified limits. The long-term phase is analyzed for a period of 20 days. During this period, the containment conditions should be bounded by the defined set of equipment environmental qualification (EQ) curves. At Oconee, the fan cooler and LPI cooler capacities have been degraded by fouling and tube plugging. The goal of the long-term analyses is thus to ensure that the fan coolers and LPI coolers have adequate capacity.

6.3.2 ANALYTICAL APPROACH

The mass and energy release analyses were discussed in Section 3.0 above.

The long-term large cold leg break LOCA containment response FATHOMS analyses are run in three segments. Segment 1 utilizes RELAP5 mass and energy data and covers the period up to 30 minutes. Segment 2 utilizes BFLOW break quality data and covers the period from 30 minutes to initiation of sump recirculation at 2808 seconds. Segment 3 covers the recirculation phase out to 15 days. (This period is then extrapolated to 20 days.)

A series of FATHOMS runs is performed to determine the minimum fan cooler heat removal coefficient required for a given cooling water supply temperature (assuming constant LPI cooler heat transfer coefficient and spray flow). Additional runs are subsequently performed to determine the trade-off effect for lower fan cooler capacity and increased LPI cooler capacity and for increased spray flow.

6.3.3 MODIFICATIONS TO BASE CONTAINMENT MODEL

Containment free volume and passive heat sink data: The conservative assumptions for containment volume and heat sinks described in Section 6.2.3 for pressure analyses are also used in the long-term analyses for containment heat removal.

BWST volume and temperature: As noted in Section 2.4.1 above, the FATHOMS code used for Oconee containment analyses includes a long-term mass and energy release model. The BWST contents are initialized at a temperature of 115°F. During Segment 1, the injection flow coming from the BWST is accounted for by the RELAP5 break boundary conditions. During Segment 2, the FATHOMS/DUKE-RS long-term mass and energy model tracks the BWST volume. At the 30 minute point, the BWST volume is initialized using the RELAP5 information. The BWST volume is tracked until it drops to the recirculation setpoint (at approximately 2808 seconds) at which time Segment 2 is terminated. During Segment 3 sump recirculation is the injection flow source.

Heat transfer correlations: The Uchida correlation is used in heat transfer calculations for containment internal concrete and steel heat structures except for the containment base. A relatively large, constant heat transfer coefficient of 20/BTU/hr-ft^2-°F is assumed for the base. This value was selected as a weighted average between the pool-to-concrete heat transfer coefficient between the base and sumpwater (90%), and the atmosphere-to-concrete heat transfer coefficient between the ontainment atmosphere and unsubmerged portion of the base (10%). The large heat transfer coefficient is considered conservative since the base is being cooled rather than heated during the long-term phase.

[ ]

Droplet size of blowdown mass: As in the peak pressure analysis, a 20 μm droplet size is assumed. Use of the the blowdown phase droplet size for the long-term analysis is conservative.

LPI cooler data: LPI cooler performance data are inserted into tables in the FATHOMS input. The data in the tables are based on outage test data. The outage test data provides measured heat transfer performance for known conditions of service water supply temperature and LPI cooler outlet temperature.

Containment fan cooler (RBCU) data: The basic heat removal capacity for RBCUs is for a containment temperature of 110°F and service water inlet temperature of 90°F. A conversion factor is applied for each analysis, adjusted by the analyst, to reflect the degree of water-side fouling. Another factor, provided in the form of input tables is also applied to account for the effect on RBCU performance of changing containment atmosphere conditions. The tables reflect varying conditions of containment temperature and humidity. Another multiplier is applied when the RBCU service water inlet is other than 90°F. All cases assume two RBCUs operating with a volumetric airflow rate of 108,000 cfm.

The 110°F-base heat transfer capacity value for RBCU performance is conservative in that it results in reduced RBCU heat transfer, relative to the heat transfer rate that would result if the 125°F initial containment temperature assumption was used.

Core decay heat: The FATHOMS/DUKE-RS long-term mass and energy model calculates core decay heat based on EOC conditions and using ANS-5.1-1979 with 2σ uncertainty. Heat released from the Group 1 heat structures is added to the decay heat.

6.3.4 INITIAL CONDITIONS

Initial conditions, applicable to the long-term analyses are described below.

Initial building temperature: The initial containment temperature (atmosphere and structure surfaces) is assumed to be 125°F. This value has been determined to be conservatively high for Oconee.

Initial pressure and humidity: The initial containment pressure and humidity are selected as 14.7 psia and 100% respectively.

The results of long-term analyses are not sensitive to small changes in these parameters.

6.3.5 BOUNDARY CONDITIONS

The FATHOMS/DUKE-RS long-term LB-LOCA model includes [ ] junctions, each assigned to a particular boundary condition. Each junction is used to account for a mass and energy sink or source interface with the containment. Certain junctions are not used during certain segments of the analysis (e.g., Junction

6.3.5.1 SEGMENT 1 FLOW PATH

During Segment 1, [.]

These boundary conditions calculated by the RELAP5 mass and energy release analyses discussed in Section 3.6 above.

One boundary condition [ ] is in effect for building spray during Segment 1. The flow is initiated at 96 seconds after the break. The assumed temperature is 115°F (BWST temperature) and droplet size is 7000 μm (a conservative value, as containment spray nozzle nominal droplet size would not be expected to exceed 1000μm).

One boundary condition [ ] is used to account for the injection of the CFT nitrogen. The flow is assumed to begin at 37.6 seconds at a constant rate of 356 lbm/sec and terminates at 44.5 seconds. The nitrogen pressure and temperature conditions are the same as for the CFTs in the RELAP5 analyses.

One boundary condition (#18) supplies make-up water to the sump. This flow corrects for mass imbalances between the RELAP5 analysis and FATHOMS analysis. In RELAP5 the BWST outlet (injection) flow was assumed to be conservatively high to rapidly deplete the tank. In FATHOMS, conservatively low flow rates are assumed for injection and containment spray. The Junction 18 boundary condition makes up the mass imbalance. The spilled HPI fluid from the broken loop (the fluid that doesn't make it to the core) is also added to this flowpath.

6.3.5.2 SEGMENT 2 FLOW PATHS

In Section 2.4.1, it was noted that FATHOMS/DUKE-RS includes a long-term mass and energy release model. This model is used beginning in Segment 2 when sump recirculation begins. There are [

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6.3.5.3 SEGMENT 3 FLOW PATHS

For Segment 3 of the long-term analyses, [

.]

6.3.6 RESULTS OF LONG-TERM LB-LOCA ANALYSES

Twenty-seven long-term analysis cases were run for various combinations of containment spray flow, LPI cooler capacity, fan cooler (RBCU) capacity units, and service water supply temperatures. The analyses demonstrate the relative containment temperature control effectiveness of containment spray, LPI coolers and RBCUs. Unlike the peak pressure analyses, for which the specific containment design pressure value serves as an acceptance criterion for peak pressure, the long-term analyses have a time-dependent EQ temperature profile to be satisfied. The new long-term analyses do not result in a greater peak pressure than the initial short-term blowdown response for hot leg breaks. The long-term analyses demonstrate that the RBCU's contribution to overall long-term containment heat removal is very sensitive to service water temperature which in turn varies seasonally.

6.4 SB-LOCA ANALYSES

6.4.1 OVERVIEW

SB-LOCAs are a long-term containment cooling concern because the RCS pressure and temperature may remain high, with considerable flashing at the break, for an extended period of time. The goal of SB-LOCA analyses is to determine if the required RBCU (containment fan cooler system) capacity is more limiting than for the large-break LOCA. For the SB-LOCA analyses, RELAP5 calculates the mass and energy releases and FATHOMS/DUKE-RS calculates the containment pressure and temperature response.

6.4.2 ANALYTICAL APPROACH

The mass and energy analyses for SB-LOCA were discussed in Section 4.0 above. Six break sizes are analyzed for mass and energy release. If the results indicate by inspection that the resulting containment response would be bounded by a larger break, the case is not run. The RELAP5 mass and energy responses for the two smallest breaks indicate by inspection that the containment responses for those breaks are bounded by more limiting LB-LOCA results.

Operator actions assumed in the analyses are selected and timed to be consistent with Emergency Operating Procedures.

Four analyses were run long enough to determine if the LB-LOCA EQ profile is satisfied. In some cases, the analyses were run for a period of time beyond the available RELAP5 mass and energy data. As discussed in Section 4.1 above, RELAP5 data are [

.]

6.4.3 MODIFICATIONS TO BASE CONTAINMENT MODEL

The following modifications are made to the base Oconee FATHOMS model for SB-LOCA containment response analyses.

Containment free volume and passive heat sink data: For the SB-LOCA analyses, the FATHOMS base model is modified, as in the peak pressure analyses, for a 2% reduction in containment volume, a 1% reduction in passive heat sink surface areas and volumes and use of the Uchida heat transfer correlation.

Reactor coolant system volumes: As noted in 6.4.2 above, a [ ] is added to FATHOMS/DUKE-RS for SB-LOCA analyses.

BWST: For the larger two breaks of the six SB-LOCA cases, a BWST model was added to the FATHOMS model because the RELAP5 analysis had not reached the sump recirculation point when it was terminated and the BWST was still being drained.

Junction changes: During the first part of the FATHOMS analysis, FATHOMS uses RELAP5 mass and energy results as a boundary condition. [

] to provide the mass and energy data. For two of the break cases, a junction for the boron dilution line is opened at 15 hours.

Heat transfer correlation: The Uchida heat transfer correlation is used for passive heat structures.

RCS heat structures: RCS heat structures are modeled as [

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Droplet size of blowdown mass: Consistent with the peak pressure analyses (See Section 6.2.3 above), a 20 μm average droplet diameter value is used. However, due to the short duration of two-phase flow from the break, the SB-LOCA FATHOMS results are not highly sensitive to droplet size assumption.

LPI cooler data: Section 6.3.3 above discusses how, for long-term LB-LOCA FATHOMS analyses, spreadsheet-generated data are used for LPI cooler performance. The same spreadsheet algorithm is used for SB-LOCA FATHOMS analyses. Lower injection fluid flow rates are needed for analysis of portions of the SB-LOCA cases where the HPI pumps alone are supplying the injection flow. The spreadsheet data are given to FATHOMS in tables of data for various flow rates.

RBCU data: The base model modifications described in Section 6.3.3 for long-term large break analyses are also applicable to the SB-LOCA analyses.

6.4.4 INITIAL CONDITIONS

The base model modifications described in Section 6.3.4 for long-term large break analyses are also applicable to the SB-LOCA analyses.

6.4.5 BOUNDARY CONDITIONS

[ ] are utilized in the FATHOMS model, [ ] of which are used for flow path boundary conditions. However, not all junctions are used for all segments of the analyses or for all break sizes. A discussion of the various flow paths follows.

Cold leg break flow junctions: Four junctions are provided for cold leg break flow into FATHOMS, two vapor and two liquid. For the smaller two of the four analyzed break sizes, two pairs of junctions are needed. For the larger small breaks, only one pair is needed. The need for two pairs of junctions in the cases of the smaller breaks is a result of the longer time frame of the RELAP5 analysis.

Containment spray flow junction: During the initial portion of a FATHOMS analysis, while it is using RELAP5 mass and energy data and RELAP5 is tracking the BWST, spray flow into the containment is modeled with one boundary condition junction. The junction becomes active at the point in time when containment pressure rises to 20 psig, plus a time delay and continues to the end of the RELAP5 portion, after which other junctions are used. The spray temperature is 115°F and the flow rate is 1500 gpm minus an uncertainty allowance.

Containment spray - recirculation: Two junctions, one for containment spray sump suction and one for dome discharge, are provided for use during the recirculation phase for the intermediate size small break cases. The spray flow during this period is reduced to 600 gpm. Recirculation phase spray is not needed for the larger break cases.

HPI spill: During the RELAP5 portion of a FATHOMS analysis, one of the four HPI lines is assumed to be broken for the small break. BWST fluid is thus added to the containment sump using this junction. After the RELAP5 portion of the analysis, HPI spill fluid is being drawn from FATHOMS' internal BWST, instead of the RELAP5 BWST, so this junction is no longer used.

HPI junctions: As noted earlier, for SB-LOCAs, RELAP5 is run until the RCS is cooled and depressurized (i.e., the heat removal load is shifted from the OTSGs to the LPI coolers), after which, the [.] For the larger of the small breaks cases (Cases 5 & 6), the RELAP5 portion of the analysis is relatively short (≈1 hour into the event), due to the more rapid cooldown/depressurization. For the intermediate small breaks (Cases 3 & 4), the RELAP5 data are generated for about 10 hours (several hours into the recirculation phase). When the RCS is depressurized, LPI becomes available and HPI is off. Recirculation initiation is determined by which comes first; (a) BWST depletion, or (b) depressurization. If the BWST is depleted prior to depressurization, HPI is continued in the recirculation mode using "piggyback" LPI/HPI pump alignment operation. In order to properly model and account for mass and energy transfer under the various HPI/LPI alignments, six FATHOMS junctions are provided.

Non-boundary condition junctions: There are [

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6.4.6 RESULTS OF SB-LOCA CONTAINMENT ANALYSES

Case 1, 0.0025 ft^2: The RELAP5 mass and energy data indicate that the containment response for this case is clearly bounded by the large break cases. Therefore FATHOMS was not run for this case.

Case 2, 0.005 ft^2: The RELAP5 mass and energy data indicate that the containment response for this case is clearly bounded by the large break cases. Therefore FATHOMS was not run for this case.

Case 3, 0.01 ft^2: Two sets of data were generated, one for the case with 35% fan cooler capacity with 55°F service water, and the other for 90% fan cooler capacity and 90°F service water. The containment EQ temperature and pressure limitations were met for both cases at all points in time. In addition, the results of these plus some additional runs, confirmed that, for the complete range of service water temperatures, the containment response for this break is bounded by the large break cases.

Case 4, 0.025 ft^2: This break is similar to the Case 3 break. Fan cooler capacity and service water temperature are less limiting than for Case 3 and, as for Case 3, are bounded by large break LOCAs.

Case 5, 0.05 ft^2: For Case 5, the RCS cools rapidly and the containment response is mild. EQ limits are not exceeded. As with the above SB-LOCA cases, the containment response for this case is bounded by large break LOCAs.

Case 6, 0.10 ft^2: The containment response was similar to but slightly more severe than for Case 5. As with the above smaller SB-LOCA cases, Case 6 results are within EQ limits and are bounded by LB-LOCA results.

6.4.6.5 SUMMARY - SB-LOCA CONTAINMENT RESPONSE ANALYSES

The results indicate that SB-LOCA containment response is bounded by LB-LOCA response. As with the large breaks, fan cooler fouling and high service water temperature can result in unacceptable results. As a result, SB-LOCAs require a reduction in the containment spray actuation setpoint and opening of the boron dilution flowpath. The Technical Specification for the spray actuation setpoint is 30 psig. However, as a result of the new analysis, the licensee has administratively implemented a lower spray actuation pressure setpoint of 10 psig. Emergency Operating Procedures will be revised, and the Technical Specifications amendment, subject to, and following, approval of the topical report.

6.5 MSLB ANALYSES

6.5.1 OVERVIEW

The mass and energy releases for a MSLB are calculated with the RETRAN-02 code as discussed in Section 5.0 above. A 34-inch MSLB is analyzed with and without offsite power available. The containment response for smaller break sizes would be bounded by the 34-inch diameter break case.

6.5.2 ANALYTICAL APPROACH

The FATHOMS/DUKE-RS (FATHOMS) code is used to calcuate the containment temperature and pressure profiles for a MSLB using the Oconee base FATHOMS model with minor modifications as described below. The objective of the analysis is to verify that the containment pressure and temperature responses are bounded by the containment design conditions and electrical equipment environment profile.

6.5.3 MODIFICATIONS TO OCONEE BASE CONTAINMENT MODEL

Containment volume: The peak pressure analyses are particularly sensitive to containment volume. For conservatism, a 2% reduction in the containment free volume cross-sectional area is assumed.

Passive heat sink surface area and heat transfer correlation: The surface area/volume of passive heat sinks is reduced 1%. The Uchida heat transfer correlation is used for condensing heat transfer coefficients on passive heat structures. Consistent with NUREG-0588 guidance, T_{SAT} rather than T_{BULK} is used in calculations of heat transfer from the containment atmosphere to structures.

RBCUs (fan coolers): Two RBCUs with a reduced capacity of 50% each are credited in the analyses.

6.5.4 INITIAL CONDITIONS

For the MSLB analyses, FATHOMS is initialized with a containment pressure of 16.2 psia (1.5 psig) and temperature of 125°F. The above-atmospheric pressure is conservative because it increases the initial air mass. The 125°F temperature is based on a consideration of the relative effects of the initial temperature assumption on both air mass and heat sink capacity of heat structures. An initial humidity of 0% is assumed to maximize the air mass. These initial conditions are conservative for the MSLB analysis.

6.5.5 BOUNDARY CONDITIONS

The break mass flow, pressure and enthalpy data from the RETRAN-02 mass and energy analyses are supplied to FATHOMS as a boundary condition. Containment spray is a second boundary condition. The spray flow is (1500 gpm minus instrument error of 143 gpm) 1357 gpm. Spray is tripped on at 92 seconds when the containment reaches a pressure of 30 psig. A spray droplet size of 7000 μm is assumed.

6.5.6 RESULTS OF MSLB CONTAINMENT RESPONSE ANALYSES

The following table summarizes the results of the MSLB analyses.

CASE	TIME OF PEAK PRESSURE (sec)	PEAK PRESSURE (psig)	PEAK TEMPERATURE (°F)
Offsite Power Maintained	200	58	397
Loss of Offsite Power	375	58	418

The containment pressure remained below the design pressure. The containment atmosphere temperature exceeded the EQ profile, in both cases, for a short period of time early in the event. As noted in Section 5, operator action is credited for termination of feedwater flow to the affected OTSG at 170 seconds, in both cases. Without this action, containment pressure and temperature response would be more severe.

Because the containment temperature response exceeded the EQ profile, the staff evaluated the potential effect on equipment. Environmental qualification (EQ) of electric equipment ensures that equipment will perform its safety function during and following a design basis event. The licensee prepared calculation number OSC-5460, "Oconee MSLB/EQ Analysis" to determine whether the new MSLB containment temperature response affects the qualification of electrical equipment inside containment. The containment temperature exceeds the EQ test temperature for approximately 50 seconds in the early part of the Main Steam Line Break (MSLB) transient. The licensee performed a thermal lag analysis and concluded that equipment internals would not experience the peak temperatures associated with the MSLB vapor temperature spike. Although the MSLB peak temperature is higher than that of a LOCA, the time period is short. Equipment internal temperatures would actually be higher when subjected to a LOCA. The equipment required to mitigate the consequences of the MSLB is qualified and would perform its safety function. For documentation of qualification, the new MSLB profile will be included in the Oconee EQ Criteria Manual.

7.0 SUMMARY AND CONCLUSIONS

The new analyses described in the topical report expand the scope of analyzed piping failures in containment for the Oconee facilities. The licensee has utilized new methods to reanalyze existing licensing basis pipe failure events in containment, and to examine the potential effects of previously unanalyzed pipe failures in containment. The new methodology utilizes modeling assumptions and initial conditions which the staff finds to be consistent with current staff acceptance criteria or produce equally conservative results.

The staff has reviewed the licensee's analysis of the new MSLB containment temperature response profiles for their impact on environmental qualification of equipment. The licensee responded to staff questions on this subject in a letter dated June 9, 1994. The staff agrees with the licensee's conclusion that the equipment is qualified and will perform its safety function during an MSLB in containment.

The DPC-NE-3003-P basic methodology discussed in this evaluation, with appropriate adjustments to reflect potential plant modifications, may be used by the licensee to perform future reanalyses in support of licensing applications related to containment accident response.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 13, 1995

Mr. M. S. Tuckman
Senior Vice President
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P.O. Box 1006
Charlotte, NC 28201

SUBJECT: RESOLUTION OF GENERIC LETTER 93-04, "ROD CONTROL SYSTEM FAILURE AND WITHDRAWAL OF ROD CLUSTER CONTROL ASSEMBLIES, 10 CFR 50.54(f)," MCGUIRE NUCLEAR STATION, UNITS 1 AND 2 (TAC NOS. M86853 AND M86854)

Dear Mr. Tuckman:

By letters dated August 5 and September 20, 1993, January 6, 1995, and February 23, 1995, Duke Power Company (DPC) responded to Generic Letter (GL) 93-04. In the letter dated September 20, 1993, you committed to implement the Westinghouse Owners Group (WOG) recommendations regarding the current order trace surveillance at the McGuire Nuclear Station (MNS) at each refueling outage. Also in this letter, you indicated an intent to modify the rod control system timing as recommended by the WOG. By letter dated January 6, 1995, you indicated that you were deferring the commitment to implement the timing modification pending the reciept of an evaluation by Westinghouse of MNS control rod drive mechanism performance results. In the letter dated February 23, 1995, you mention that Westinghouse had provided DPC the results of the evaluation and the results indicated that the current order timing was applicable to the MNS. Therefore, you committed DPC to implement the modifications at the MNS.

The NRC staff has reviewed the corrective actions and schedules that you have committed to in response to GL 93-04 and finds them acceptable. Please inform us in writing when implementation is complete, or if your plans change for implementing the modification and surveillance tests. This completes our review of this matter and TAC Nos. M86853 and M86854 are closed.

Sincerely,

Victor Nerses

Victor Nerses, Senior Project Manager
Project Directorate II-3
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Docket Nos. 50-369 and 50-370

cc: See next page

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