APPENDIX 6.2A

WATEMPT - A COMPUTER CODE TO CALCULATE THE SHIELD BUILDING ANNULUS TRANSIENT

→(DRN 05-1247, R14)

Note that the description and results of the WATEMPT analysis of the shield building annulus in this section and in section 6.2.3.3 is based on pre-uprate plant conditions. These original results are conservative and bounding since, due to improved modeling of mass and energy releases, the current 3716 MWt containment pressure and temperature response analysis determined that the peak LOCA pressure and temperature have decreased thereby decreasing the resulting transient in the shield building annulus. It must be noted that the worst case long term LOCA is the double ended discharge leg break with minimum safety injection flow based on the current 3716 MWt containment pressure and temperature response analysis.

←(DRN 05-1247, R14)

Introduction

Many pressurized water reactor (PWR) containment buildings have a multibarrier dry containment system. This consists of a free standing steel containment vessel surrounded by an annular gas space several feet thick (annulus) and a concrete Shield Building. A loss-of-coolant accident (LOCA) causes a pressure buildup in the annulus as a result of containment vessel expansion and heat and mass flow into the Shield Building annulus atmosphere across the primary containment vessel. To limit the pressure rise and to maintain the annulus at a negative gage pressure following the postulated accident, a Shield Building Ventilation System (SBVS) exhausts filtered annulus gas. The WATEMPT computer code determines exhaust rates and sizes the SBVS equipment to maintain a negative annulus pressure following a LOCA inside the primary containment.

The WATEMPT code is primarily an extension of the CONTEMPT[1] code. It uses slightly modified CONTEMPT type calculations to determine the containment and annulus, pressure and temperature, initial and transient conditions, and the distribution of heat across the steel containment structure and concrete Shield Building wall.

In the WATEMPT computer code, the containment and the annulus volumes are divided into two regions, the atmospheric region (water vapor and air mixture) and the liquid region. Each individual region is assumed to be completely mixed and in thermal equilibrium. The temperature of the two regions may be different. Mass and energy additions are made to the appropriate region to simulate the various leakage and heat transfer processes. Account is taken of condensation in the vapor region and mass and energy transfers between regions.

The code represents the heat conducting and absorbing materials in the containment by dividing them into segments with appropriate heat transfer coefficients and heat capacities. The steel containment vessel and the concrete Shield Building are the only heat sinks in contact with the Shield Building atmosphere.

Initial temperature distributions in the heat conducting regions are computed from the steady heat conduction equation and the boundary temperatures specified in the input. The containment vessel is represented by several heat conducting sections whose transient thermal behavior can be described by the one-dimensional multi-region transient heat conduction equation. Heat is transferred from the containment vapor region into the annulus atmosphere through these sections. Any additional energy added to the annulus atmosphere from such sources as annulus equipment operation can be inputed by a tabular representation of annulus energy input rates as a function of time.

→(DRN 05-785, R14)

Following the postulated LOCA, the annulus conditions are calculated to determine the time required to start the Shield Building Ventilation System fans in order to prevent the Shield Building annulus pressure from exceeding atmospheric pressure for an extended period of time. The annulus pressure could become positive for a short period of time when stratification and instrument uncertainty are accounted for in the calculation. The conditions at any time for both the containment and annulus are determined by calculating mass and energy gains and losses during a specified time step. The pressures and temperatures are then calculated in each region based on the mass, volume, and energy balance equations. All of these equations are set up and solved exactly as in the original CONTEMPT code. The convective heat transfer coefficient between the walls of the annulus and the annulus atmosphere is based upon formulas given in References 2 and 3 for natural convection from relatively flat plates in air at large Grasnof numbers. Appropriate factors have been used in the formulas to account for the increased surface area of a concrete surface in comparison to a smooth steel surface and for the actual configuration of the steel dome and the top of the concrete Shield Building. Thermal radiation between concentric or nearly concentric walls is described by the usual gray body radiation heat transfer equations. Radiation heating of the concrete Shield Building from the steel shell is considered in the analysis. Direct radiation heat absorption by the annulus atmosphere is neglected; however, heating of the annulus atmosphere by conduction and convection is considered. The average annulus atmosphere temperature is used in all calculations. The assumed emissivity values are the highest values expected for steel and concrete. The effect of radiant heat transfer is to heat the concrete Shield Building by radiation from the hot steel containment. This results in net convective heat addition to the annulus atmosphere from the concrete Shield Building.

←(DRN 05-785, R14)

Leakage into and out of the annulus is calculated based on pressure dependent leakage rate formulas. The dependency of the annulus and containment volumes on the containment wall temperature and the differential pressure across the containment vessel is considered at all times. The Shield Building Ventilation System is represented by input tables describing fan size, system resistance, and pressure dependent flow characteristics.

Transient calculations in the WATEMPT computer code are performed by evaluating tabular input rates at the midpoint of a time interval, multiplying by the time interval, and adding increments to current amounts in either the containment or annulus. Heat losses or gains to the heat conducting sections are estimated by extrapolating heat transfer rates (including radiant heat transfer) of the previous two time steps (or the steady state conditions for the initial time steps) to the midpoint of the current time interval.

Similar extrapolations are performed for leakage rates into or out of the annulus, including SBVS exhaust rates, and for the containment and annulus volume and energy change resulting from pressure and temperature expansion of the steel containment vessel. The pressure and temperature of the annulus are then calculated. The new annulus conditions are used to obtain heat transfer, leakage and volume change rates at the end of the time step. These are averaged with corresponding values from the beginning of the time step to calculate the current annulus conditions. Annulus pressure and temperature are then recalculated, and the end of time step annulus conditions are used as the initial condition for the next time step.

APPENDIX 6.2A: REFERENCES

1. Richardson, L.C. et al., CONTEMPT - A Computer Program for Predicting the Containment Pressure - Temperature Response to a Loss-of-Coolant Accident, IDO-17220.

2. McAdams, W.H., Heat Transmissions, New York, 1954.

3. Bayley, F.J., "An Analysis of Turbulent Free Convection Heat Transfer", Institute of Mechanical Engineers, 1955, Vol. 169, No. 20, pages 361-368.