Pressure and Temperature Environment of SBLOCA for Wolsong Unit 1

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1. Introduction

To establish pressure and temperature envelope of each room in containment building, thermal-hydraulic behaviors of containment building during small break loss of coolant accident senarios are analyzed for Wolsong-1. These pressure and temperature envelopes are the key information of Environmental Qualification database. Though the peak pressure and temperature at the early stage of small break loss of accident are bounded by those of large break loss of coolant accident, pressure and temperature of small break loss of coolant accident are important in long term.

2. Analysis Methodology

The PRESCON2 VER-0.610b, one dimensional transient thermal-hydraulic code is used to analyze thermal-hydraulic behavior of containment building.[1] PRESCON2 has sub-model for dousing, local air cooler, heat transfer to wall, instrument air flow, additive heat source, containment isolation, blowout panel and flash of break discharge. The mass and energy discharge to containment before the start of emergency core cooling comes from CATHENA analysis results. The long term mass and energy discharge after the start of emergency core cooling is calculated by simple sub-program simulating emergency core cooling recovery stage.

Containment building is divided into 9 nodes, which is shown in Figure 1. Rooms connected with open path are merged into one node. Node 1 is composed of all the rooms in the basement and stair wells connecting the first floor and main access area. Node 2 represents stair well in B-side. Nodes 3 and 4 are fuelling machine maintenance lock of A and C side, respectively. All the rooms in the first floor, R1-201, main access area, rooms in the third and fourth floor and R1-501 and R1-502 on the fifth floor are modeled into node 5. Nodes 6 and 7 are fuelling machine room in A and C side respectively. Node 8 represents steam generator room and node 9 is composed of R1-111 and R1-112 containing moderator system components.[2]

Nodes are linked with flow paths and these flow paths are merged into 26 links. Link area, link length, hydraulic length and flow resistance are prepared for each link. Link area refers to a cross-sectional area of link between two nodes. This area is calculated at the narrowest section of flow path between nodes. In case that there are components or stairway in the flow path, link area is reduced by multiplying the original area by a factor of 0.6 or 0.8. Blow-out panels are modeled as link. These panels, burst out at the differential pressure of 6.9 kPa(d), are isolating accessible area from inaccessible area. Uncertainty of 2 kPa is added to the pre-set burst out pressure of 6.9 kPa(d) and therefore 8.9 kPa(d) is used in the analysis.[2]

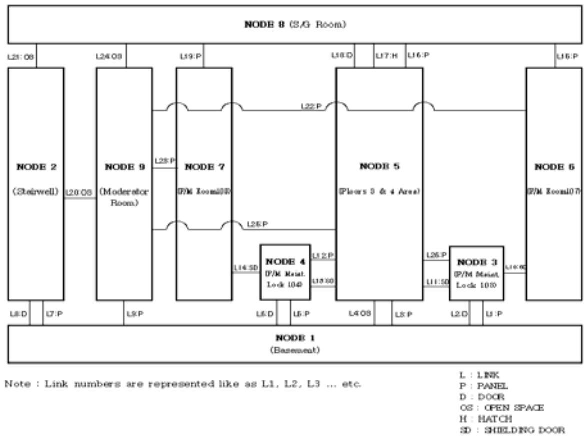

Figure 1. PRESCON2 Containment Nodalization

The surface area of the wall is calculated to consider the heat transfer to walls. The surface area is obtained for concrete and steel walls. To model the heat transfer to wall, the thermal conductivity, specific heat and density of concrete and steel are used and walls are grouped into 31 classes.

Additional heat sources due to lighting, motors, the reactor face, etc. are modeled as a direct energy source into containment. During normal operation, they are balanced by the heat removal capacity of the local air coolers. The additional heat load for fuelling machine rooms is 148.4 kW and for steam generator room is 283.1 kW. After an accident and following a reactor trip, these heat loads will decrease. For the purpose of environmental qualification(EQ), it is assumed that the additional heat load starts to decrease to 50% of nominal at 310 seconds after the event till 910 seconds, decrease again to 25% of nominal till 1810 seconds and maintain constant thereafter.

Inside the reactor building, there are four local air coolers located in each of the fuelling machine rooms and eight medium-sized local air coolers located in the steam generator room. In addition, there are 19 small local air coolers distributed throughout the remaining containment rooms. However, only the local air coolers and associated fans supplied by Class IV and Class III power in the fuelling machine rooms and steam generator room are assumed to be available and functioning and all other air coolers supplied by Class IV power only are ignored. The capacity of local air coolers is assumed to be 75% of nominal.

Dousing system has six dousing headers. For this analysis, 4 out of 6 dousing headers are assumed to operate.

The instrument air discharge into containment is modeled and building leakage is modeled as 0.2% of the reactor building volume per day at the design pressure of 124 kPa(g).

Emergency core cooling recirculation is modeled for the long term cooling. For the long term cooling, the emergency core cooling system uses the water in the reactor building sump which was discharged during dousing and high and medium pressure emergency core cooling discharge. The modeling information is obtained from the manufacturing data, design manual of emergency core cooling system and some drawings. Some of the principle input data, which are independent of accidents, have been obtained from primary thermal-hydraulic model(CATHENA model).[3,4] The additional modeling information is required to provide initial conditions at the start of the low pressure emergency core cooling phase. However, this data is specific to each accident case and must therefore be determined and supplied for each simulation case as appropriate. This data are obtained from the transient simulation results of heat transport system.

3. Analysis cases

To establish pressure and temperature envelope for small loss of coolant accident, breaks of different sizes in a reactor inlet header are simulated, 0.3%, 1.0% and up to a 2.5% reactor inlet header break which is equal in area to twice the inside cross-section of the largest inlet feeder. Accident of 2.5% reactor outlet header break is also considered. For every break size, to get the most conservative result, pressure and temperature behavior of rooms is analyzed for the case all safety system available and following cases accompanying safety system impairment:

-loss of emergency core cooling system
-loss of dousing system
-loss of loop isolation system
-loss of steam generator crash cool down
-loss of emergency core cooling system and steam generator crash cool down.

4. Analysis results

Peak pressure of 36.5 kPa(g) at basement and temperature of 97.8℃ at where break flow discharges are reached for the case of 1.0% RIH break with loss of dousing system. For 2.5% RIH break with loss of dousing system case, pressure goes up to 45 kPa(g) at basement and temperature up to 108℃ at fuelling machine room. Peak pressure of 49.4 kPa(g) is reached for the 2.5% ROH break with loss of dousing. It is higher than that of 2.5% RIH break case, but peak temperature of 106℃ is lower. From an environmental qualification perspective, not only peak pressure and temperature but also the behavior of these parameters as a function of time is important. Figure 2 shows the pressure envelope of containment. Figure 3 shows the temperature envelope of fuelling machine room, steam generator room and moderator room(Region 1) and Figure 4 shows the temperature envelope of the rest(Region 2).

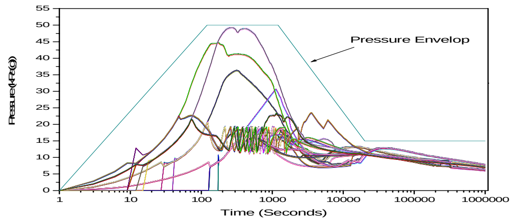

Figure 2. Pressure Envelope

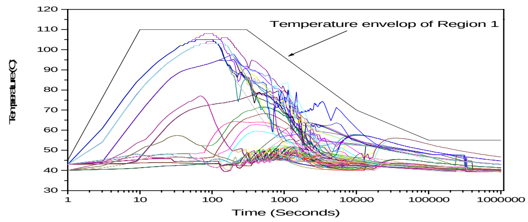

Figure 3. Temperature Envelope of Region 1

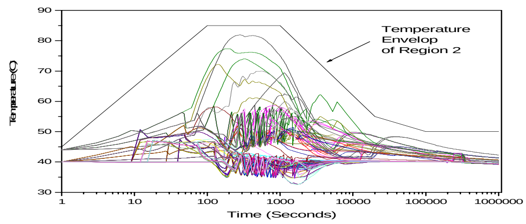

Figure 4. Temperature Envelope of Region 2

5. Conclusion

From the analysis results of thermal-hydraulic behavior of rooms in containment, pressure and temperature envelopes are obtained as shown in the figures. These envelopes will be used to qualify the component having long term(>300,000seconds) mission time.

References

[1] T.H. Nguyen, "PRESCON2 VER-0.610: Supplement to Program Description and User's Manual", TTR-273, Volume 10, 1991 December.

[2] Containment Analysis Models Wolsong-1 CANFLEX -NU, W1-CANFLEX-AR-006, 2002.

[3] CATHENA Above Header Model, W1-CANFLEX-03500 -AR-010, Rev. 0, 2002 January.

[4] CATHENA Secondary Side Model,W1-CANFLEX-03500 -AR-011, Rev. 0, 2001 October.