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MAAP5 Calculation for the Source Term in Auxiliary Building Rooms under Severe Accident for Reducing Workers' Radiation Dose

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1. Introduction

According to the current Severe Accident Management Guidance (SAMG), operators are required to take on-site actions inside the auxiliary building (AB) for equipment error correction or sample collection purposes. However, there has been no research on an evaluation system for operator radiation exposure or improvements for exposure reduction. Therefore, the study for evaluating the expected radiation exposure for each operator's action in the AB and deriving the exposure dose is under developing based on supporting from Korean Government.

In order to minimize the radiation exposure of operators during a severe accident, it is necessary to evaluate the distribution of radiation sources within the operators' activity areas inside the AB and calculate the actual exposure based on this. The radiation sources in the AB are determined by factors such as the progress of the severe accident, the sealing of the reactor building, and the occurrence of bypass accidents. Since the severe accident integrated analysis code, MAAP version 5 [1], primarily simulates accident progress inside the containment, it is necessary to expand the code to evaluate the transport of radioactive materials to the AB and the resulting radiation sources.

The existing researches on AB response during severe accident usually construct very large and bulk nodalization for AB. For example, Ahn et al [2] employed very large AB nodes of whole quadrant or floors above the ground level. Obviously, those bulk nodalizations are not suitable for evaluating the worker's dose over time and along a specific path.

Therefore, as a first step for this purpose, this paper describes the development of the MAAP5 model for source term evaluation in rooms of AB under severe accident conditions. Particularly, the rooms where the workers need to visit based on the current SAMG are of interest to evaluate the source term and effective dose. Leakage area then calculated based on simple assumptions of uniformly distributed leak throughout the inner surface of the containment.

And then, amount of airborne radioactive material and the total activity inside the selected rooms of AB is estimated during the 24 hours for Large break Loss-Of-Coolant Accident (LLOCA).

2. Development of MAAP5 Nodal Model

Three auxiliary building compartments were selected for which workers could enter during a severe accident based on the current SAMG - 100-A13B, 120-A16B, and 137-A11D. These rooms are mechanical penetration rooms at 100 feet and 120 feet elevation, and an electrical penetration room at 137 feet in the auxiliary building, respectively. For example, Fig. 1 shows the drawing of room 137-A11D, which contains the electrical cabinet of hydrogen igniters.

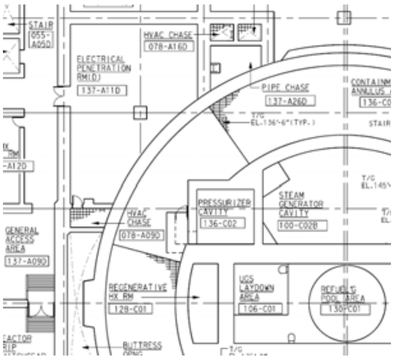

Fig. 1. Drawing for room 137-A11D (Electrical penetration room) in auxiliary building

This study assumes that the containment boundary is intact which means no creep rupture or catastrophic failure of the containment wall. Therefore, the leakage through the containment wall to the rooms in the auxiliary building is dominant passage for the source term transport. To mimic this situation, three new nodes are created for MAAP5 nodal network of the auxiliary building. The junctions connect the neighbor nodes of auxiliary building and containment are also created accordingly. Table I, for example, lists new nodes and junctions that created for node number 72 defined as auxiliary building room 137-A11D. Two junctions are added to model the suction and discharge the flows - the junction #112 for suction from the containment node#34, and the junction #118 for discharge to the neighbor node of AB #54.

Table I: New MAAP Input Model for node 72 represents room 137-A11D

Volume (VOLRB(72))	500 m^3
Floor elevation (ZFRB(72))	11.278 m (37 feet)
Floor area (ASEDRB(72))	80 m^2
Height vs volume lookup table (XRBLK(0,72), VRBLK(0, 72) XRBLK(1,72), VRBLK(1, 72))	 0 m 0 m^3 6.096 m 500 m^3
Area of junction number 112 as a leakage junction to node 72 (AJUNC0(112))	3.56445E-6 × 0.007505 m^2
Area of junction number 118 from node 72 to neighbor node 54 in auxiliary building	9 m^2
New heat sinks in node 72 - for floor: Area (AHSRB(290)) Thickness (XTHSRB(290)) Orientation (NIWALL(290)) - for wall: Area (AHSRB(291)) Thickness (XTHSRB(291)) Orientation (NIWALL(291))	 75 m^2 0.6 m -1 (horizontal) 150 m^2 0.6 m 1 (vertical)

3. Leakage Area Calculation

As noted in Section 2, we assume the containment boundary is intact, the containment leakage rate and the leakage area toward the outside of the containment would be determined before the source term calculation. Containment leakage area is calculated based on 0.1% volume/day leakage at design pressure. The gas mass flow rate can be calculated by

$$w = Af_{CD}\left[\frac{2P_1\gamma r^{\frac{2}{\gamma}}\left(1-r^{\frac{\gamma-1}{\gamma}}\right)}{v(\gamma-1)}\right]^{1/2} \qquad (1)$$

where A denotes the area of the opening, f_{CD} denotes the discharge coefficient (=1.0 in this case), P_1 denotes the pressure in compartment no. 1, γ denotes the ratio of specific heats for the gas in compartment no. 1, v denotes the specific volume of the gas in compartment no. 1, and r denotes a pressure ratio given by

$$r = max(\eta_{crit}, P_2/P_1) \qquad (2)$$

in which η_{crit} denotes the critical pressure ratio for critical flow for a perfect gas [3]:

$$\eta_{crit} = \left(\frac{2}{1+\gamma}\right)^{\frac{\gamma}{\gamma-1}} \qquad (3)$$

and P_2 denotes the pressure in compartment 2. By using the design values for APR1400 plant such as the total containment volume and gas mass, the isentropic process through the leak path and f_{CD}=1.0, total leakage area of containment inner surface becomes 3.56445E-6 m^2.

Further assumptions are then introduced that the leakage is uniformly distributed along the elevations of the containment. Therefore, the fraction of the interface surface between the containment and 137-A11D room (≈90 m^2) (see Fig. 1) to the sum of the surface of the containment shell and the dome (≈12,110 m^2) is estimated 0.007505, as shown in Table I.

4. Activity Calculation in Auxiliary Building Room 137-A11D

For the LLOCA sequence, with the assumption of disable safety features such as safety injection and containment spray system until the first 24 hours from the onset of core damage, the mass of Xe gas and aerosol CsI inside the containment compartment (#34) and electrical penetration room in AB (137-A11D designated as #72) is calculated as shown in Fig. 2 and Fig. 3, respectively. The total activity in compartment #72 is also given in Fig. 4. Here total activity means the activity given by three-phases modeled in MAAP code (i.e., vapor, aerosol, and deposited on the heat sinks) from the whole fission product groups considered in MAAP code.

It is found that mass of Xe gas in the electrical penetration room of AB increases monotonically as 0.0006 kg. Mass of CsI aerosol shows a rapid rise by following the containment pressure until the pressure reaches its peak value, then gradually decreases over the time about 2.0E-7 kg. The total activity is estimated ~ 300 Bq. Those values predicted in the AB room are found to be less than 1/1000 of those value inside the containment compartment, because the containment boundary is preserved.

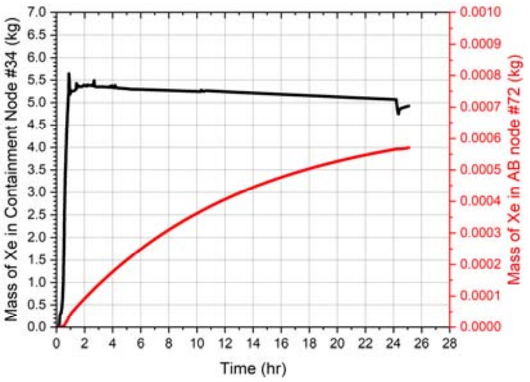

Fig. 2. Mass of Xe vapor inside the containment and AB compartment

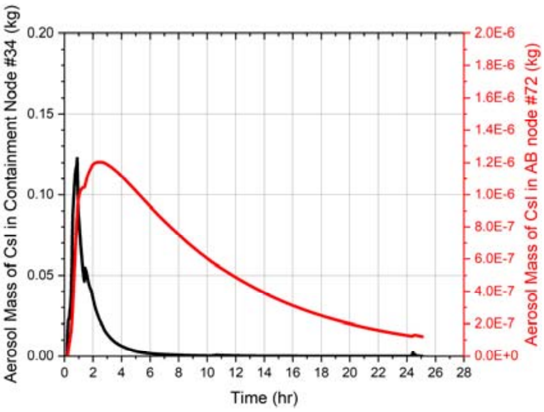

Fig. 3. Mass of CsI aerosol inside the containment and AB compartment

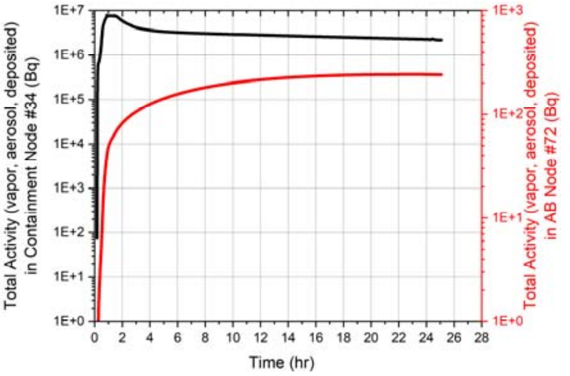

Fig. 4. Total activity inside the containment and AB compartment

5. Summary and Future Works

In the event that workers' actions are required within the auxiliary building compartments during a severe accident, a detailed assessment of worker safety is necessary. To this end, this paper first developed a containment and auxiliary building nodalization of MAAP5 computer code. Three rooms which contains the large penetrations through the containment wall and igniter cabinet are selected as the target compartments in auxiliary building. As a first-kind-approach, simple assumptions are introduced to determine the leakage area through the containment walls. Consequently, the effective leakage area between the containment inside and three auxiliary building rooms are derived.

In the next step, a detailed analysis of the representative scenarios using the MAAP5 code is being conducted, and an evaluation of the source terms of major radionuclides that significantly affect the effective dose values for workers in auxiliary building is underway. Finally, during a severe accident, the exposure dose will be derived by applying the worker's movement path and residence time according to SAMG within the auxiliary building. For dose calculation, two different tools – MAAP-DOSE and Monte Carlo radiation transport code like MCNP would be employed. Based on this, appropriate measures to reduce the radiation dose for workers will be developed.

ACKNOWLEDGEMENTS

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