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ANALYSIS OF AEROSOL BEHAVIOR IN THE IPHWR CONTAINMENT WITH NAUA5-M

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ABSTRACT

As part of the Diagnostic System for Evaluation of Accident Scenarios for 220 MWe Indian Pressurised Heavy Water Reactors (IPHWRs), it is required to assess and analyse the transport of aerosol in containment of IPHWRs in the event of postulated extremely low probability accident scenarios. Aerosols are generated by condensation of volatile fission products during nuclear reactor core meltdown accidents and represent a major fraction of the accidental airborne radioactivity. The thermal-hydraulic and aerosol analysis were performed to investigate the transport and deposition behaviour of aerosols in the containment. The codes used for the analyses are RELAP5/MOD3.2 for thermal-hydraulic simulation, CONTRAN for containment studies and NAUA5-M for aerosol transportation.The present paper gives a brief overview of the code NAUA5-M and results obtained by NAUA5-M for aerosol behavior in multiple compartment configuration.

INTRODUCTION

One of the serious consequence of postulated extremely low probability ($<10^{-6}$) beyond design basis accidents is the possibility of generation of aerosols by condensation of volatile fission products during nuclear reactor core meltdown accidents. During a nuclear reactor core meltdown accident, radioactive fission products are released from the fuel elements and carried into the containment. In order to assess the potential radioactivity release from the containment to the environment, the behaviour of the fission products in the containment must be known. Since most of the important radionuclides are present in the form of aerosols, aerosol deposition on internal surfaces can reduce the release of radioactivity.

The codes used for the analyses are RELAP5/MOD3.2 for thermal-hydraulic simulation, CONTRAN for containment studies and NAUA5-M for aerosol transportation. RELAP5/MOD3.2 calculates water and steam flow rates through the break and the relating enthalpies and aerosol release rates, and then these values are used by CONTRAN. CONTRAN gives temperatures, pressures, steam partial pressures, condensation rates relating to each volume of reactor containment and flow rates between volumes to NAUA5-M for the aerosol transportation calculation. The NAUA5-M gives the concentration of different fission product species suspended in the different containment volumes. The present analysis was performed to investigate the transport and deposition behaviour of aerosols in the containment with code NAUA5-M for 200% Reactor Inlet Header Break (located in fueling machine vault) without the actuation of Emergency Core Cooling System (ECCS). Calculation has been performed with the assumption that the entire fission product inventory released from the core is directly released into the containment.

BRIEF DESCRIPTION OF IPHWR CONTAINMENT SYSTEMS

The containment system of a nuclear reactor performs the important function of protecting the public and environment from any release of radioactivity during normal and accident conditions. The IPHWR uses a double containment envelope viz, a primary and a secondary containment. The primary containment is completely surrounded by the secondary containment. The primary containment is divided into two volumes called V1 (drywell) and V2 (wet well) for efficient accident management. These two volumes are interconnected by a vent system via the suppression pool. The volume V1 houses all the high enthalpy systems like the reactor core, fuelling machine vaults, pump room vaults etc to name a few and is inaccessible during normal operation due to high radiation fields. The volume V2 contains low enthalpy systems like suppression pool and is generally accessible during operation. Figure 1 shows the volume connectivity and geometric parameters used in the NAUA5-M calculation for IPHWR containment (5 Volume configurations).

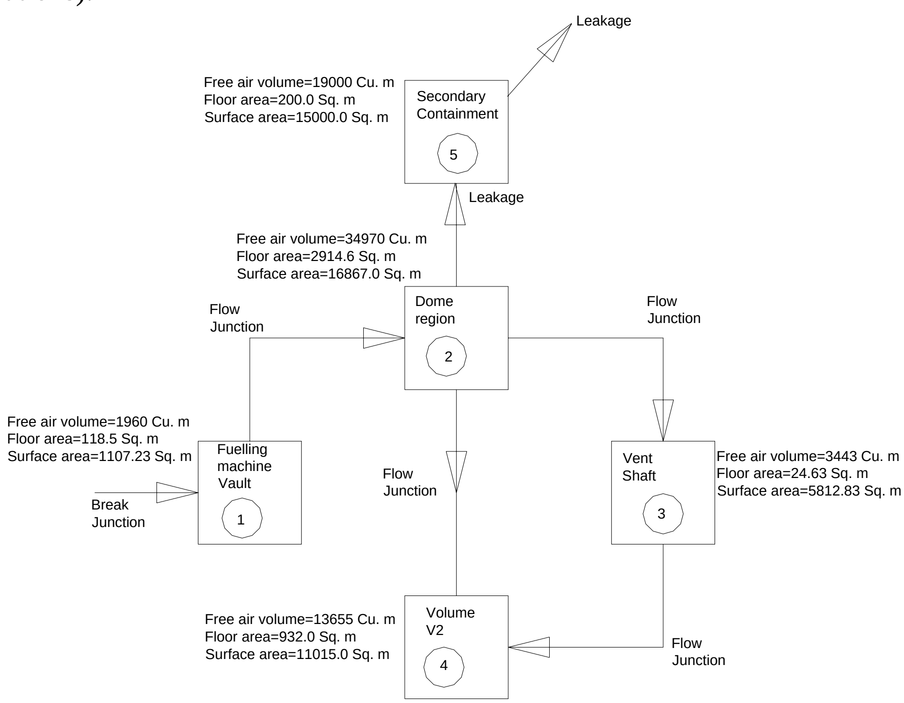

Fig.1 Volume connectivity for IPHWR containment for NAUA5-M calculation

THE NAUA CODE

The NAUA code (Bunz et al., 1983) was developed at KfK around 1983. It simulates coagulation, sedimentation, diffusional deposition and steam condensation on particles. The code uses a numerical representation of the particle size distribution. Thermal hydraulic data must be supplied as input to the code. An extension of the original version is NAUA Mod 5-M (Bunz et al., 1987) for multiple compartment geometries, where the NAUA aerosol transport simulations are performed for several control volumes. In addition, advective flows between different control volumes are taken into account. Thermal hydraulic conditions and intercompartment flow rates have to be specified as input data.

CALCULATIONAL METHODOLOGY

For the IPHWR containment the aerosol source available from RELAP5/MOD3.2, was injected in volume 1 (Fueling machine vault). The aerosol injection period was divided into 9 release phases (table 1), each phase being characterized by uniform values of release rate, effective density and particle size characteristics. Two radionuclide species Cs and I were considered. Separate analysis was done for both the species since they possess different densities. Though the source of iodine is small but its release is accounted from radiation point of view. The Mass median diameter (MMD) of particle log normal distribution was 4 µm and geometric standard deviation (GSD) was 1.9. For the diameter the values have been taken from earlier studies (Haware et. al., 1997). NAUA uses count mean diameter (CMD) instead of MMD. The MMD values reported in the literature have been converted to CMD for the present study. It may be noted that the aerosol behaviour is a strong function of the aerosol particle density and diameter. Owing to uncertainty in the value of these properties, for the present study, NAUA recommended particle densities has been used. The actual density of Cesium and Iodine is 1.9 and 0.01127 gm/cc respectively but based on NAUA recommendation to use an effective density equal to 50% of the actual value, the particle density was assumed as 0.95 gm/cc for Cesium and 0.0056 gm/cc for Iodine. These values of diameter and densities are assumed for all the phases of release.

Table 1 Total cesium and iodine release in to Containment

Time period		Cumulative mass in kg	
Time start in s	Time end in s	Cs	I
0	350	0	0
350	379.7	0.3218	1.809E-04
379.7	383.8	0.6436	3.618E-04
383.8	403.2	0.9655	5.426E-04
403.2	433.7	1.287	7.235E-04
433.7	457.7	1.609	9.044E-04
457.7	461.9	1.931	1.085E-03
461.9	468.3	2.253	1.266E-03
468.3	501.2	2.575	1.447E-03
501.2	533.3	2.896	1.628E-03

RESULTS

Results of the computations for both the species are depicted in figure 2 and 3. In both the cases the figure (a) represents the total airborne mass and deposited mass in all the volumes. Figure (b) shows the air-borne activities in different volumes. The aerosol mass deposited on the containment floor is depicted in figure (c). The junction flow rate is higher at initial time but the aerosol generation starts at 350 sec that is why most of the aerosol inventory remains at the source location around fuelling machine vault and get deposited in the same volume. The mass balance of both the species is good at all the times.

CONCLUSION

Results of the aerosol behaviour in multiple compartment geometry of IPHWR are presented. The amount of radioactive material that is in the containment atmosphere is a prerequisite for evaluating the releases to the atmosphere. Experimental studies on aerosol distribution shows that in the quiescent condition aerosols do not remain homogeneously mixed at all times. NAUA assumes a spatially homogeneous aerosol at all times that is true when strong turbulence effects are prevailing in the aerosol environment. In its present form NAUA5-M does not have any model to simulate this behaviour. The present study would need to be validated further by comparison against analysis performed using other codes i.e. ASTEC. It is also noted that NAUA5-M has been used to simulate experimental data from BARC Nuclear Aerosol Test Facility where the above said limitation were highlighted (Mayya et. al., 2002).

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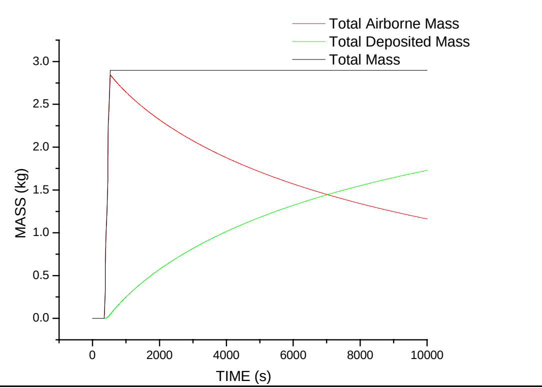

Fig 2(a) Total airborne and deposited mass for Cs in all the volumes

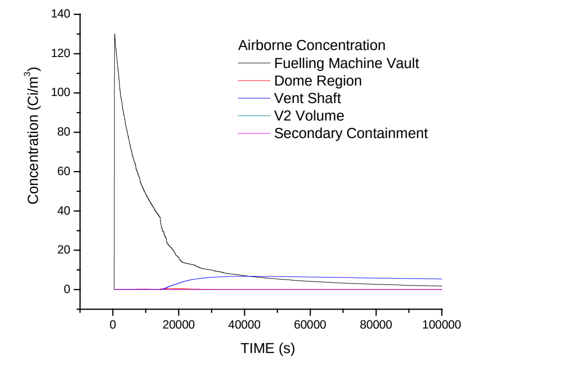

Fig 2(b) Airborne concentration of Cs in Ci/m^3 in different compartments

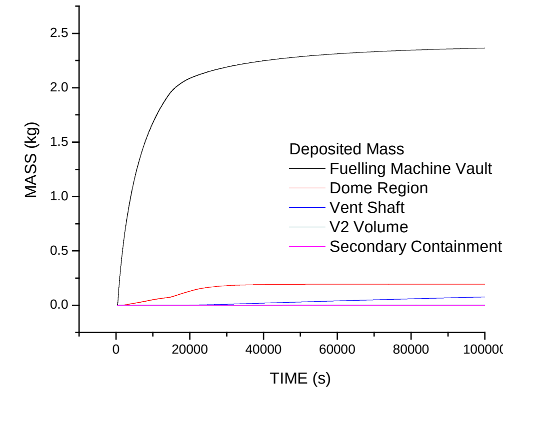

Fig 2(c) Deposited mass of Cs in kg in different compartments

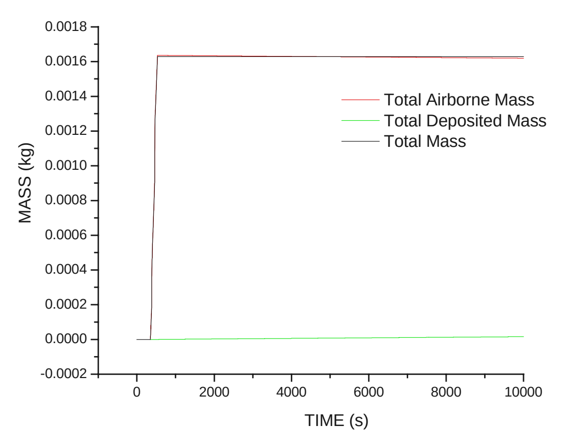

Fig 3(a) Total airborne and deposited mass for I in all the volumes

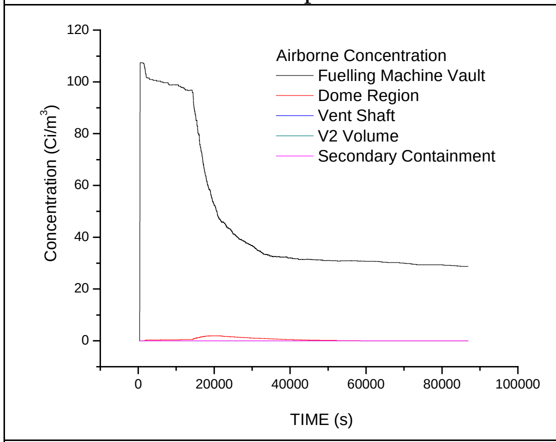

Fig 3(b) Airborne concentration of I in Ci/m^3 in different compartments

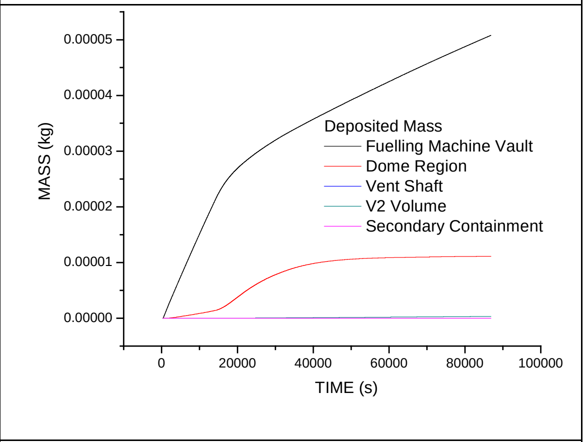

Fig 3(c) Deposited mass of I in kg in different compartments