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6.4 Analyses of CsI Aerosol Deposition in Aerosol Behavior Tests in WIND Project

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ABSTRACT

The aerosol deposition tests have been performed in WIND project at JAERI to characterize the aerosol behavior. The aerosol deposition tests named WAV1-D and WAV2-D were analyzed by aerosol behavior analysis codes, JAERI's ART and SNL's VICTORIA. The comparison calculation was performed for the confirmation of the analytical capabilities of the both codes and improvement of the models in ART.

The deposition mass calculated by ART was larger than that by VICTORIA. This discrepancy is caused by differences in model for FP vapor condensation onto the wall surface. In the WAV2-D test, in which boric acid was placed on the floor area of the test section prior to the deposition phase to simulate the PWR primary coolant, there was a discrepancy in deposition mass between analytical results in both codes and experimental results. The discrepancy may be caused by existence of boric acid which is not considered in the codes.

Keywords : severe accident, aerosol, WIND project, deposition, ART code, VICTORIA code, vapor condensation, cesium iodide

1. Introduction

During a severe accident of a light water reactor, large uncertainties still exist in FP (fission products) aerosol behavior in the RCS (reactor coolant system) due to the complicated phenomena. WIND (Wide range piping INtegrity Demonstration) project has been performed at JAERI (Japan Atomic Energy Research Institute) to investigate the FP aerosol behavior in piping[1, 2]. The aerosol deposition tests have been performed to characterize the aerosol deposition phenomena in the RCS. The aerosol behavior in the piping has been analyzed with the ART[3, 4] and VICTORIA[5] codes developed at JAERI and Sandia National Laboratories, respectively. The ART can calculate the FP behavior in the RCS and the containment vessel. The VICTORIA code can calculate the FP release and transport in the RCS. In order to verify the analytical capabilities of both codes and to highlight the differences between ART and VICTORIA codes, the aerosol deposition tests (WAV1-D and WAV2-D) were analyzed by the two codes.

2. Aerosol Deposition Tests

The schematic diagram of test section is shown in Fig. 1. The test piping was divided into 3 parts, upstream test section, connecting pipe and downstream

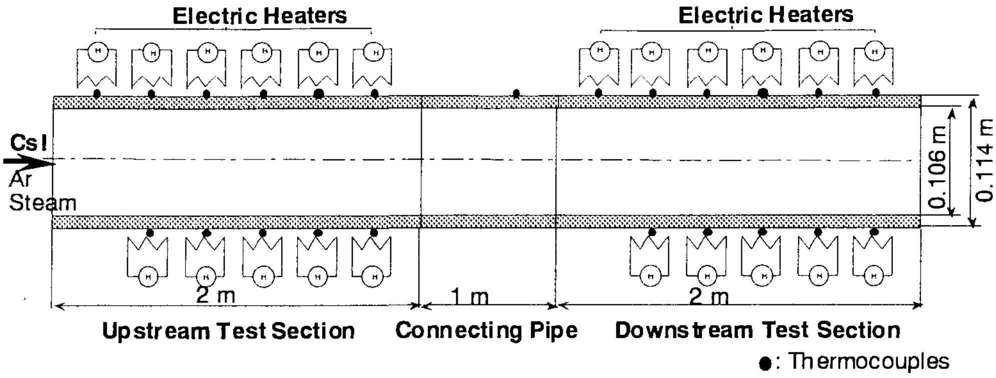

Fig. 1 Schematic Diagram of Test Sections

test section. Test sections were made of a straight stainless steel pipe of 2 m in length and about 0.1 m in inner diameter. Each test section was heated up with electric heaters. The temperature distribution in the piping of two tests is shown in Fig.2. In the WAV1-D test, the controlled maximum temperatures of piping

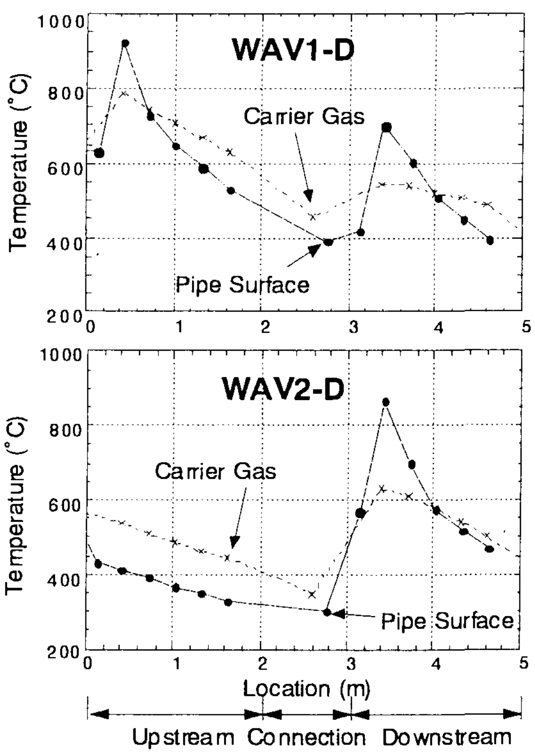

Fig. 2 Temperature of Carrier Gas and Piping Surface

surface were 1,000 °C for upstream test section, 150 °C for connecting pipe and 700 °C for downstream test section. In the WAV2-D test, those were 430 °C, 300 °C and 900 °C, respectively. The temperature of carrier gas was lower than that of the test section wall in the inlet part of both test sections in WAV1-D and the inlet part of downstream test section in WAV2-D, and this nature was reversed at the mid part of test section.

3. Outline of Analyses

The analytical conditions are shown in Table 1. Cesium iodide was used as FP aerosol simulant. The data obtained from experimental results were used for analyses. The boric acid was placed on the floor of test pipe in the WAV2-D test to simulate the PWR primary coolant. The cesium iodide was injected with carrier gas of argon and super heated steam.

Table 1 Analytical Conditions

		WAV1-D	WAV2-D
Injected Source		CsI	
AMMD (μm)		2.2	2.2
GSD (-)		2.4	2.0
Injected Concentration of Aerosol (g/m^3)		2.1	2.7
Carrier Gas	Steam(kg/hr)	2.6	
	Argon(kg/hr)	6.4	

The piping included the connecting pipe was divided into 20 nodes for length, and 1 node was used for the cross section. The temperature of aerosol surface was assumed to be equal to the gas temperature. The concentration of aerosol in a node was assumed to be uniform. It is noted that existence of boric acid was ignored in WAV2-D in present analyses. Because, in both codes, it is difficult to take into account the previous existence of chemical materials as in the experiment.

ART includes models for the aerosol transportation and the growth by agglomeration and vapor condensation of aerosol. ART can take account of removal of FP aerosol by natural deposition and by the engineering safety features such as a spray system. The code is capable of treating the behavior of up to 60 chemical species. The primary and containment systems are represented by an arbitrarily number of volumes. In each volume, radioactive materials can take the forms of gas, aerosol, deposit on structure walls and floors, or solution in water.

VICTORIA can analyze the FP release from the fuel, transport, and deposition of FP aerosol. The primary basis of the modeling in VICTORIA is the calculation of thermodynamic chemical equilibrium. This is based on the assumption that the ultimate driving force for the FP release is the inherent tendency of physical and chemical systems to move toward a state of thermochemical equilibrium. VICTORIA code uses the CHARM model for aerosol species behavior. A combination of the agglomeration and deposition models from MAEROS and TRAP-MELT2 has been used in VICTORIA.

4. Analytical Results

4.1 WAV1-D test

The calculated concentration of suspended cesium iodide vapor and aerosol in WAV1-D test are shown in Fig. 3. In the ART code, there was no aerosol in the inlet part of the test section due to high temperature. Since the VICTORIA code can calculate the thermochemical equilibrium, aerosol exist in this region.

The deposited mass per unit area in WAV1-D test is shown in Fig. 4. Analysis with the VICTORIA code showed a good agreement with experimental data. On the other hand, the ART code overestimated the experimental data. The dominant deposition mechanism in the inlet part was vapor condensation onto the wall surface. This discrepancy is caused by difference of treatment of the boundary layer for vapor condensation model. The thickness of boundary layer in VICTORIA was set in the input to constant value. In the ART, the boundary layer is calculated by using an empirical model proposed by F. Van de Vate(6).

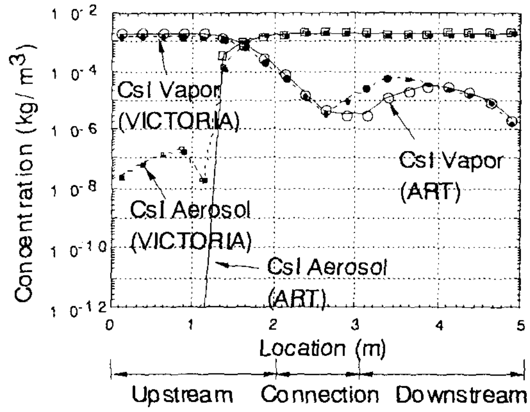

Fig. 3 Suspended Concentration of CsI Vapor and Aerosol in WAV1-D

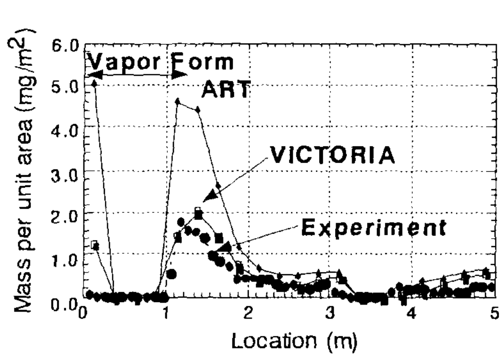

Fig. 4 Deposited Mass in WAV1-D

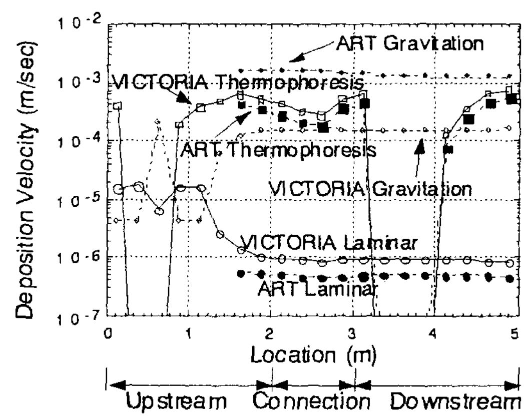

Fig. 5 Deposition Mechanism in WAV1-D

The calculate aerosol deposition velocity for each deposition mechanisms is shown in Fig. 5. Relatively large difference in the gravitational settling deposition velocity between the two codes can be seen. This is caused by difference in calculated aerosol size between both codes. The calculated aerodynamic mass median diameter is shown in Fig. 6. The aerodynamic mass median diameter of ART is larger than that of VICTORIA. In the ART code, when the aerosol is created, initial aerosol size has an input size distribution. On the other hand, in the VICTORIA code, the size distribution is calculated by considering the condensation and the vaporization onto/from aerosol surface.

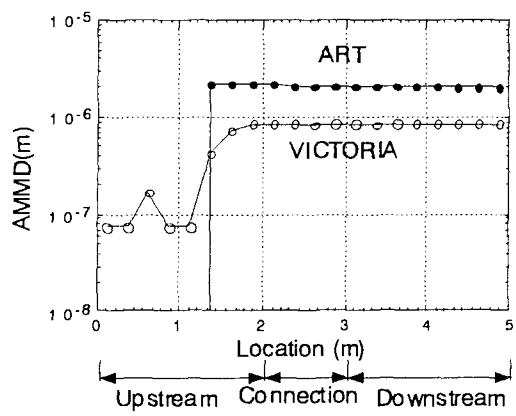

Fig. 6 Comparison of Calculated AMMD in WAV1-D

4.2 WAV2-D test

The calculated concentrations of suspended cesium iodide vapor and aerosol in the WAV2-D test are shown in Fig. 7. In the downstream test section, the ART results were smaller than the VICTORIA results. This is because the ART cannot calculate the revaporization from aerosol particle. The calculated cesium iodide deposited mass per unit area is shown in Fig. 8. At the downstream region, codes still underestimate the deposited mass. It is considered that this would be caused by temperature distribution. The temperature distribution in the downstream test section of separate effect experiment is shown in Fig. 9. It is found that the

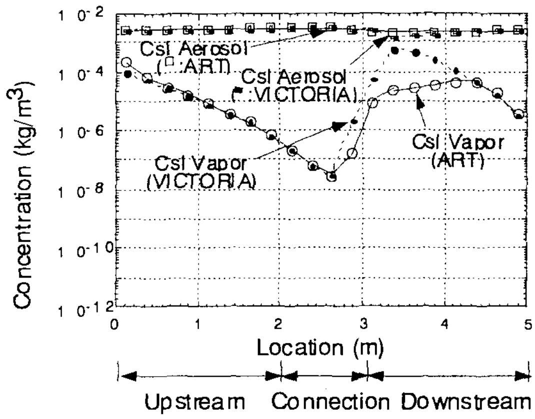

Fig. 7 Suspended Concentration of CsI Vapor and Aerosol in WAV2-D

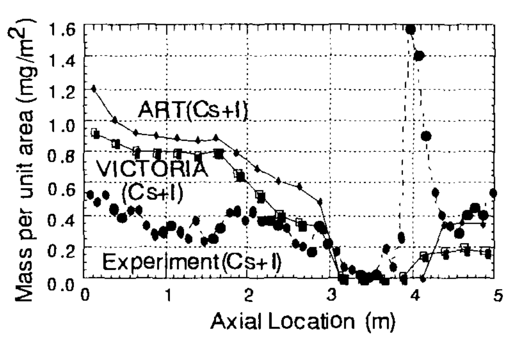

Fig. 8 Deposited Mass in WAV2-D

carrier gas temperature of upper part was higher than that of lower part. Therefore, it would be estimated that the carrier gas temperature was low at that point. In the upstream test section, both codes overestimated the experimental deposition data. In the downstream test section, both codes under estimated the experimental deposition data. The reasons for these discrepancies are due to existence of bo ric acid. It is considered that

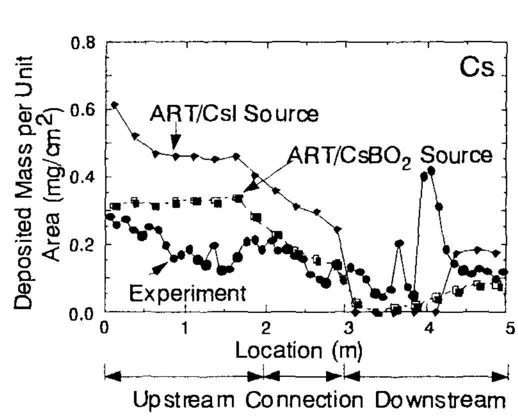

Fig.9 Cs Deposited Mass Comparison between CsI and $CsBO_2$ Source

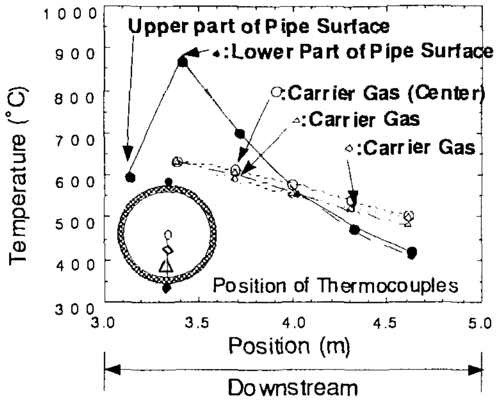

Fig. 10 Temperature Distribution in the Downstream Section

cesium iodide reacted with boric acid or boron oxide to form cesium metaborate ($CsBO_2$) in the test. A sensitivity calculation with cesium metaborate instead of cesium iodide was performe d. The deposited Cs mass comparison between cesium iodide source and cesium metaborate source calculated by ART code is shown in Fig. 10. The cesium deposition in case of cesium metaborate source is closer to experimental deposition data than that in case of cesium iodide source.

5. Conclusions

The deposition phase of aerosol revaporization tests (WAV1-D and WAV2-D) were analyzed by ART and VICTORIA codes. The followings are obtained ;

1. ART and VICTORIA codes generally give similar trends. However, due to pre-existence of boric acid, deposition mass had some discrepancy between the two codes and the experiment.
2. The deposition masses calculated by ART in some cases were different from that by VICTORIA. This discrepancy was caused by the differences in the model for FP vapor condensation onto the wall surface.

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