10.2 Analyses of CsI Aerosol Deposition Tests in WIND Project with ART and VICTORIA Codes

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ABSTRACT

Deposition behavior of cesium iodide (CsI) was analyzed with ART and VICTORIA-92 codes for a test of the aerosol re-vaporization test series performed in WIND project at JAERI. In the test analyzed, CsI aerosol was injected into piping of test section where metaboric acid (HBO_2) was placed in advance on the floor area. It was confirmed in the present analysis that similar results on the CsI deposition were obtained between ART and VICTORIA when influences of chemical interactions were negligibly small. The analysis with VICTORIA agreed satisfactorily with the test results in analytical cases that cesium meta-borate ($CsBO_2$) was injected into the test section instead of CsI to simulate the pre-existence of HBO_2 effect.

Keywords : Severe accident, Aerosol, Deposition, ART code, VICTORIA-92 code, Cesium iodide, Boric acid

1. Introduction

During a LWR (Light Water Reactor) severe accident, FPs (fission products) are released from a reactor core and transported into RCS (Reactor Coolant System) piping. Aerosols and vapors of FPs deposit on the RCS piping and a part of the deposited FPs is revaporized by own decay heating. Due to the complicated phenomena, large uncertainties still exist in FP aerosol behavior in the RCS piping especially in the revaporization phenomena, which result in the late phase release of FPs (1). As a research item of WIND (Wide range piping INtegrity Demonstration) project at JAERI, the investigation of the FP aerosol behavior in the RCS piping under sever accident conditions is in progress (2). The aerosol revaporization test series is being performed in this project. The deposition behavior of the aerosol revaporization test series was analyzed by ART (3) and VICTORIA-92(4) codes in order to confirm the capabilities of the both codes. ART code is being developed at JAERI for the analyses of the FP behavior in the RCS and the containment vessel. VICTORIA code has been developed at SNL for the analyses of FP release and transport in the RCS.

2. Description of Aerosol Revaporization Test Series Analyzed

The schematic diagram of test sections is shown in Fig. 1. Upstream and downstream test sections and connecting pipe are placed in series. The test sections are fabricated from straight stainless steel pipes of about 0.1m in inner diameter. A length of each test section and connecting pipe are 2.0m and 1.0m, respectively. Each test section is covered with 11 electric heaters to form desired temperature profile of the test section wall. Thermocouples are set on the outer surface to measure the pipe wall temperatures. Aerosol of FP simulants was injected into the test sections with a carrier gas of Ar and superheated steam mixture to realize the deposition onto the inner surface (deposition phase). After the deposition phase, the test sections were reheated in order to investigate the revaporization of the once deposited materials.

Primary coolant of a PWR includes boric acid. Fission products could react with boric acid, and affect the FP transportation. In some of the aerosol revaporization tests, HBO_2 was placed on the deposition coupon at the floor area prior to conducting the deposition phase. In the present study, the deposition phase of one of the revaporization tests (designated as WAV4-D) with HBO_2 was analyzed.

Temperature of the carrier gas separately measured after the revaporization tests by installing thermocouples in the test sections as shown in Fig.1.

3. Conditions of Analyses

The analytical conditions of WAV4-D test, based on the measurement, are shown in Table1. Temperature of aerosol was assumed to be equal to the carrier gas temperature. Concentration of aerosol in a node was assumed to be uniform. Axial temperature profiles of the carrier gas and the test section wall used for analyses are shown in Fig. 2. The wall temperature was around 300℃ for the upstream test section and the connecting pipe. The maximum wall temperature was approximately 900℃ for the downstream test section and linearly decreased to approximately 300℃ at the exit. The temperature of the carrier gas plotted in this figure was measured at the center of the test sections. As shown in Fig.1, the test sections and connecting pipe was divided into 20 axial nodes and 1 cross-sectional node.

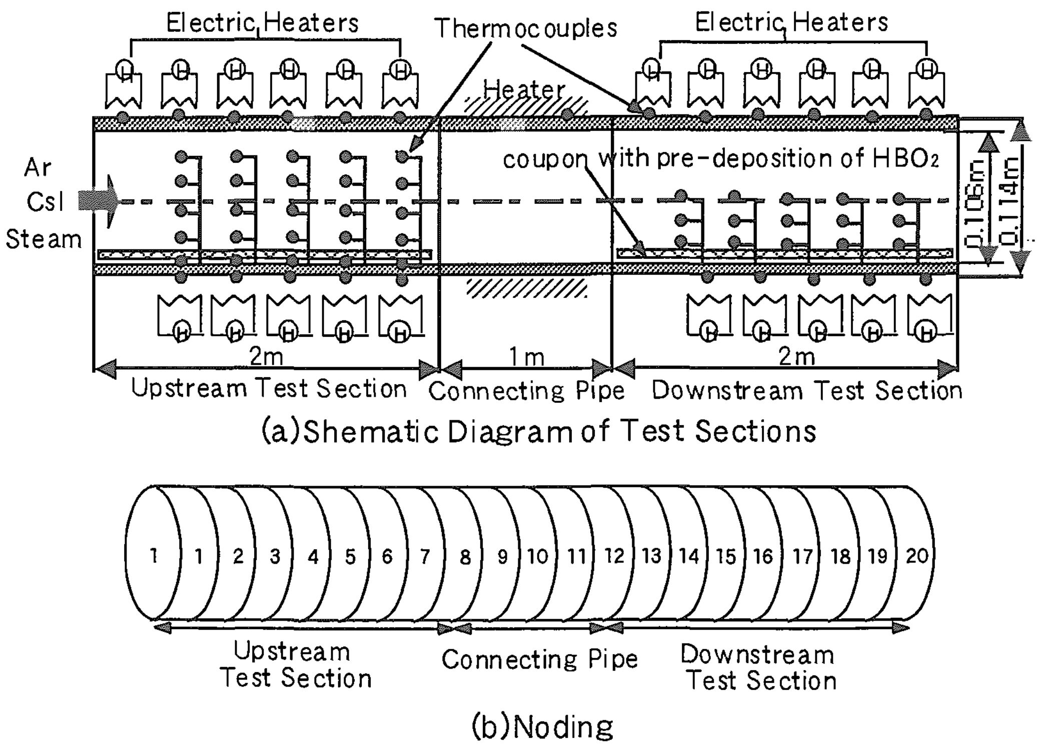

Fig.1 Schematic Diagram of Test Sections and Noding of Analyses

Table1 Analytical Conditions

Condition at Inlet of Upstream Test Section		
Aerosol Source Species		CsI
Aerosol	AMMD*	1.2μm
	GSD**	2.0
Aerosol Concentration		5.4g/m^3
Carrier Gas Species		Argon Steam
Carrier Gas	Velocity	0.7m/sec
	Reynolds Number	725
	Temperature	600℃
Duration of Deposition		3000sec

* AMMD : Aerodynamic Mass Median Diameter
**GSD : Geometric Standard Deviation

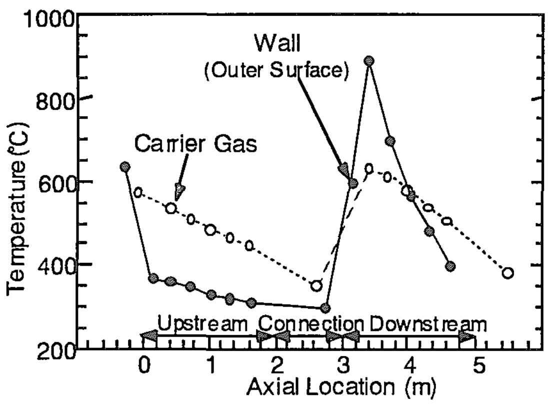

Fig.2 Temperature of Carrier Gas and Test Section Wall

4. Results of Analyses

4.1 Comparison between ART and VICTORIA-92 codes

VICTORIA-92 code has a capability of calculating thermodynamic chemical equilibrium. On the other hand, the chemistry is not sufficiently modeled in ART code. In WAV4-D test, HBO_2 was placed on the floor area of the test section in advance, and it was expected that chemical reaction between CsI and HBO_2 occurred. For the purpose of the comparison between the both codes, the first analysis with VICTORIA-92 was performed without thermodynamic chemical equilibrium model.

The calculated deposition density of cesium and iodine is shown in Fig.3 together with the test results. The major deposition mechanisms identified in the analyses are shown in Fig.4. It was found that the similar analytical results were obtained from the analyses with ART and VICTORIA-92. Thermophoretic deposition and gravitational settling of CsI aerosol were estimated as dominant deposition mechanisms in the both codes.

However, the test result on the deposition

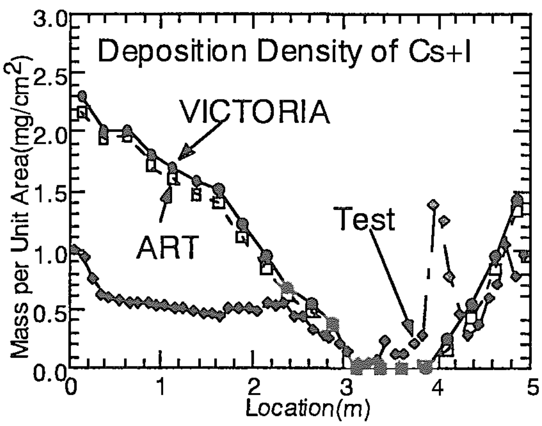

Fig.3 Comparison of Deposition Density of Cesium and Iodine between ART and VICTORIA-92

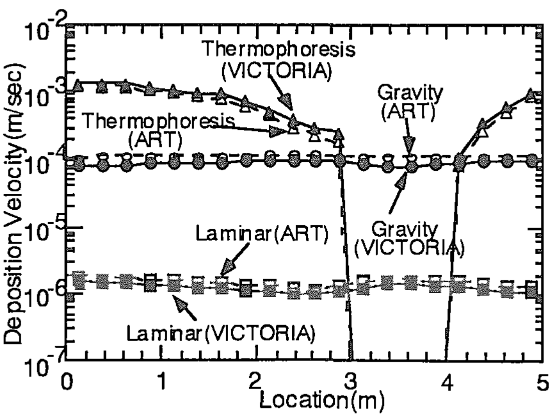

Fig.4 Comparison of Deposition Mechanisms between ART and VICTORIA-92

density was largely overestimated by the both codes for the upstream test section. In addition, a deposition peak at the mid of the downstream test section was not predicted in the both analysis.

4.2 Analyses with VICTORIA-92 Considering HBO_2 Effect

The analysis with VICTORIA-92 code taking the effect of HBO_2 into account was performed. It was difficult to model the pre-existence of HBO_2 in VICTORIA-92 code. Therefore, $CsBO_2$ aerosol was assumed to enter into the test sections in the analysis. The comparison for the deposition density of cesium between the test and the VICTORIA-92 analyses is shown in Fig.5. The difference between the test and the analysis became smaller in case of the $CsBO_2$ injection.

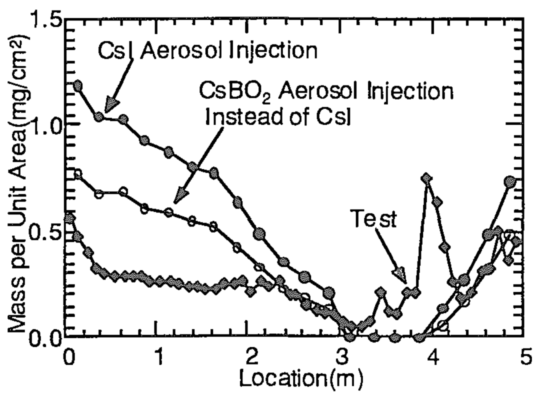

Fig.5 Comparison for Deposition Density of Cesium between Test and VICTORIA-92 Analyses

4.3 Effects of Temperature Distribution

The deposition peak of CsI was observed at the mid of the down stream test section in the test, which was not predicted by the analysis. The more detailed test results on the deposition are shown in Fig.6, for floor, ceiling and wall areas of the test sections. The observed deposition peak in the downstream test section was dominated by the selective deposition on the ceiling area. The location, where the deposition peak was observed, agreed with that the carrier gas temperature became higher than the temperature of the test section wall as shown in the Fig.2.

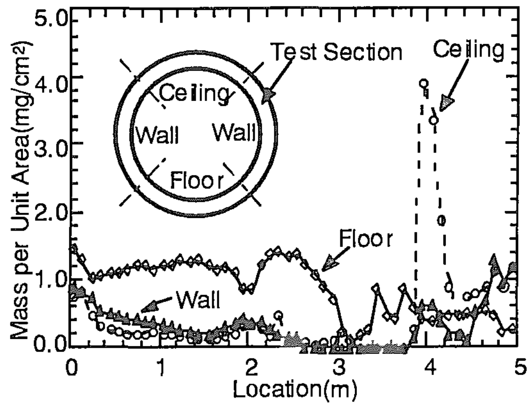

Fig.6 Test Results on Spatial Distribution of Deposition of Cesium and Iodine

The temperature profile of the carrier gas in the downstream test section calculated with WINDFLOW is shown in Fig.7. WINDFLOW is a three dimensional thermo-fluiddynamic analysis code which is being developed at JAERI. At the vicinity of the location where the deposition peak was found in the test, the carrier gas temperature in the ceiling area was predicted to be higher than the wall temperature. It was supposed that vapor condensation or thermophoretic aerosol deposition of CsI occurred onto the ceiling of the mid of the downstream test section.

The excess vapor pressure of CsI based on the temperature profile of the carrier gas predicted with WINDFLOW is shown in Fig.8. The excess vapor pressure was defined in the present study as

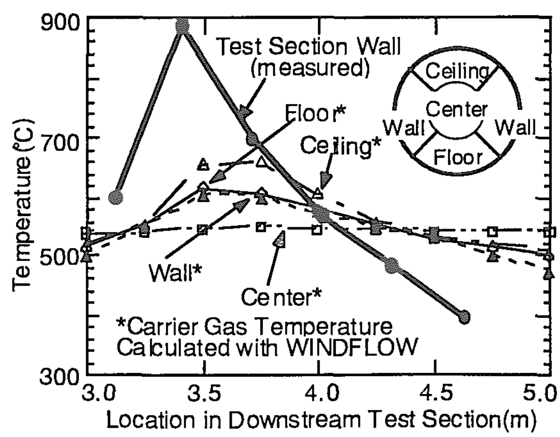

Fig.7 Axial Profile of Carrier Gas Temperature in Downstream Test Section

the difference between saturated vapor pressures of CsI at temperature of the carrier gas and the test section wall. It was found that the excess vapor pressure in the ceiling area was higher than the other areas at the mid of the downstream test section. The localized deposition could not be reproduced by the analyses with ART and VICTORIA-92 code since a representative of the carrier gas temperature was used.

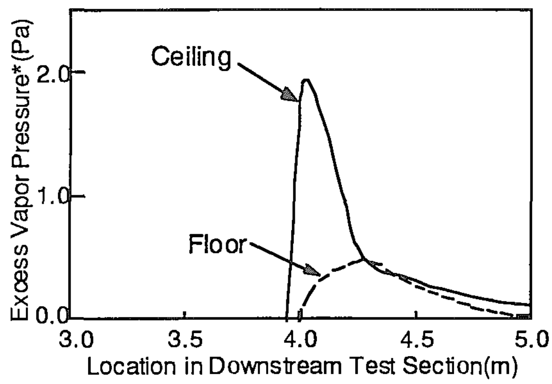

Fig.8 Excess CsI Vapor Pressure Based on Temperature of Carrier Gas Predicted with WINDFLOW

5. Conclusions

The deposition phase of aerosol revaporization test series, designated as WAV4-D, was analyzed with ART and VICTORIA-92 codes. The influence of boric acid on the CsI aerosol deposition was investigated in WAV4-D. The following conclusions were obtained from the present analyses.

(1) In terms of aerosol deposition without chemical interactions, the results of the analyses were in good agreement between ART and VICTORIA-92 codes.
(2) The results of the analysis showed that the reproducibility of VICTORIA-92 was improved when $CsBO_2$, instead of CsI, was assumed to be injected into the test sections.
(3) Cross sectional temperature distribution of the carrier gas should be taken into account in order to increase the predictability for the localized deposition.

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