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A SMART-IST Assessment for Radionuclide Release in the Wolsong 1 NPP

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1. Introduction

Recently, SMART-IST (VER-0.310) [1] code has been introduced to assess the Wolsong 1 refurbishment. The SMART-IST (Simple Model for Aerosol Removal and Transport – Industry Standard Toolset) computer code models radionuclide in CANDU reactor containments during postulated accidents. This code is designed to predict nuclide behaviour within containment considering various aspects such as releases of nuclides from the primary heat transport system, transport of nuclides among various rooms in containment, removal of nuclides from the containment atmosphere through various removal mechanisms, changes in nuclides resulting from radioactive decay and build-up, and releases of nuclides to the outside atmosphere through containment escape paths.

SMART-IST models radioiodine in more detail than other nuclides using the IMOD-2 model developed at AECL [2]. IMOD-2 was incorporated into the overall mathematical framework of SMART-IST as a module modeling the chemical transformations between various iodine species and mass transfer of these species among gas, aqueous and adsorbed phases in containment. IMOD-2 model is very sensitive for paint and chemical information.

This paper presents an overview of the SMART-IST code, and also presents the result of parameter study of IMOD-2 model to decide analysis value for small break (SB) LOCA without ECC.

2. Models

SMART-IST models transport of two forms of nuclides; a) contained in and carried by aerosols and, b) existing in the gaseous form.

The following assumptions are made regarding aerosol and nuclide transport in containment:

- The transient thermohydraulic properties from GOTHIC [3] are used as input data for use in the calculation of nuclides and aerosol transport.
- Gaseous nuclides and aerosols in a room are perfectly mixed, with uniform nodal properties.
- Nuclide and aerosol processes within a room do not contribute to mass, momentum or energy exchange with the gas present in the room.
- Airborne gaseous nuclides and aerosols are transported from one room to another by convection of the carrier gas through links.
- Gaseous nuclides and aerosols are transported from the free volume of a room to the external atmosphere by convection of the carrier gas through specified holes.
- Volumetric source or sink rates of nuclides and aerosols in a room are spatially uniform.

Also, SMART-IST uses a number of aerosol sub-models. The following is a brief description of these models.

2.1 Liquid Aerosol Agglomeration and Gravitational Settling

Agglomeration mechanisms are physical processes that result in the collision and adhesion of aerosol particles to form larger particles.

Aerosol particles settle onto available horizontal areas due to the force exerted on them by gravity.

2.2 Impingement and Stefan Flow

Experiments were conducted in the WALE (Wet Aerosol Leakage Experiment) facility, to study aerosol removal in a vessel, into which water jets were discharged under conditions typical to those of Loss of Coolant Accident discharges [4]. SMART-IST uses an empirical model supported by experimental data for calculation of fractional removal of the jet aerosol mass.

Near surfaces where condensation occurs, an aerodynamic flow may occur toward the surface. This flow is called Stefan flow.

2.3 Turbulent Deposition and Thermophoresis

SMART-IST calculates turbulent deposition using a combination of the Liu-Agarwal model [5] for turbulent-inertial deposition, and the Davies model for turbulent-diffusion deposition [6].

When a temperature gradient occurs in a gas (e.g., due to heat transfer to a surface), the aerosol particles suspended in the gas experience a force in the direction of decreasing temperature [7]. The motion of the aerosol particle that results from this force is called thermophoresis.

2.4 Containment Iodine Chemistry Model – IMOD-2

SMART-IST uses a containment iodine chemistry model, IMOD-2. This model was developed by Wren et al. [2]. The main processes modelled in IMOD-2 are the chemical transformations between non-volatile iodine species and volatile iodine species in the aqueous phase, and the partitioning of volatile iodine species among the gas, aqueous and adsorbed phases.

For the purpose of implementing IMOD-2 in SMART-IST, it is assumed that the aqueous phase in each node consists of two parts. The first part is the bulk liquid pool on the floor formed by the removal of liquid aerosols from the free volume. The second part is the airborne liquid aerosols in the node. The concentration of an iodine isotope in liquid aerosols and in the gaseous state of a node may change as a result of the IMOD-2 calculations.

3. Sensitivity Study

IMOD-2 model is very sensitive for containment building paint and chemical information. The selected parameters which can affect the aerosol behavior and used in code are paint thickness, paint age, dousing water pH, primary heat transport (PHT) coolant pH and pool pH. For sensitivity study, 2.5% reactor inlet header (RIH) break without emergency core cooling (ECC) and I-131 nuclide which is considered as a reference nuclide in aerosol behavior are selected.

In figures, the reference case has 1.0 mm paint thickness, paint age of 0.0 year, dousing and PHT water pH of 9.0 and pool water pH of 7.0.

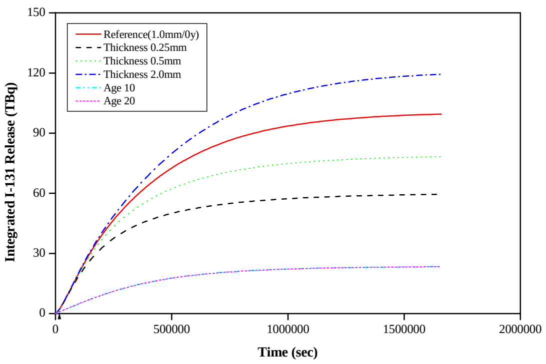

Fig. 1. Comparison of I-131 release through leakage for paint

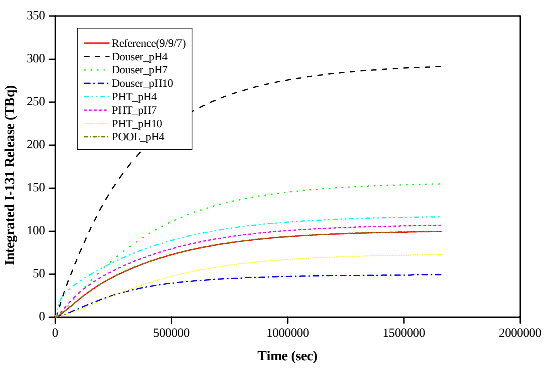

Fig. 2. Comparison of I-131 release through leakage for pH

Through sensitivity study, paint thickness and dousing water pH are very sensitive to be created organic iodine. As the building paint is thickened, I-131 release amount is increased.

In fig. 2, dousing water pH is sensitive. But PHT and pool pH have a small impact on iodine creation.

Table 1 shows the comparison of I-131 release amounts through leakage after SBLOCA. Based on design data, analysis value are selected (reference case) for Wolsong 1 refurbishment. This reference set has more iodine releases compared to design set.

Table 1. Comparison of I-131 Release Amounts

	Analysis value/I-131 Release (TBq)			
Paint_thick (mm)	.25/59.5	0.5/78.3	1.0*/99.5	2.0/119.4
Paint age (yr)	0*/99.5	5/23.3	10/23.3	20/23.3
Dousing pH	4/291.4	7/154.8	9*/99.5	10/49.3
PHT pH	4/116.7	7/106.7	9*/99.5	10/72.6
Pool pH	4/99.80	7*/99.5	10/98.8	-

* Marked values are analysis values for Wolsong 1

4. Conclusions

Overview of new SMART-IST code is presented. SMART-IST models radioiodine in more detail than other nuclides using the IMOD-2 model. The radioiodine release is assessed by using the SMART-IST code for various parameters. IMOD-2 model is very sensitive for paint thickness and dousing water pH.

The selected analysis value set is used to predict nuclide behaviour within containment for Wolsong 1 refurbishment [8].

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