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Radionuclide Release after LBLOCA with Loss of Class IV Power Accident in CANDU-6 Plant

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1. Introduction

A large break in a pipe train of a primary heat transport system discharges coolant, which has high energy and large mass, into the containment building. Reactor shutdown and emergency core cooling water will limit the fuel cladding failure, but cannot prevent it entirely. The containment building is the last barrier of radionuclide release to the environment. Containment isolation and pressure suppression by dousing and local air cooler reduce the amount of radionuclide release to the environment. The objective of containment behavior analysis for large break loss of coolant with loss of class IV power accident is to assess the amount of radionuclide release to the ambient atmosphere. Radionuclide release rates in this event, with all safety system available, that is, the containment building is intact, as well as with containment system impairment, are analyzed with GOTHIC and SMART code.

2. Analysis Method

Various leak paths in the containment building, that is, the ventilation inlet, the ventilation outlet, leaks through containment walls and holes such as the equipment airlock door and personnel airlock door, are considered as leakage paths of radionuclide.

2.1 Containment Model

The compartments of the containment building are modeled with 15 nodes and 76 flow paths [1]. Compartments linked with the opening are lumped into one node. Fig. 1 shows the nodes and flow paths of the model.

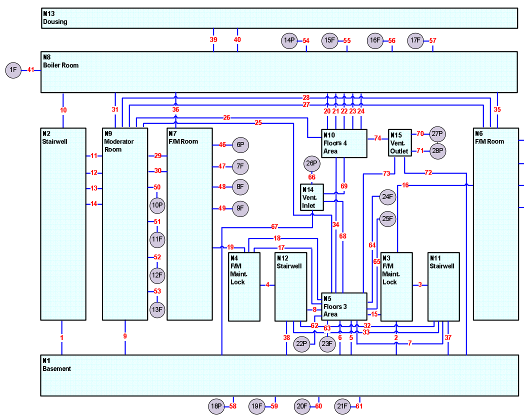

Fig.1. Nodes and flow paths of the containment model

2.2 Assumption

The assumption used for radionuclide release analysis is similar to that used for peak pressure analysis but has a leakage rate of 5% of containment volume per day. For conservative radio nuclide release analysis, the effects of pressure and temperature suppression measures are under-estimated and additional heat sources are considered. Dousing water is sprayed into containment through nozzles mounted on six headers. Four of six headers are assumed to be available to reduce the effect of pressure suppression by dowsing droplets. Among 35 local air coolers, only 8 local air coolers, 4 in the steam generator room, and 2 in each of the two fueling machine rooms, are assumed to be available. At the instance of loss of class IV power, all of these local air coolers and cooling fan stop operation until the class III power is recovered within three minutes. All additional heat sources are assumed to be constant throughout the accident except for the case of the loss of local air coolers. Additional heat sources reduce to 15% one day after the start of an event with the loss of local air coolers.

2.3 Containment System Impairment

Three categories of containment system impairment are considered. The first one is impairments of the containment isolation system. This category includes the total loss of isolation, open ventilation inlet lines and open ventilation outlet lines. For these cases, the ventilation line is the direct release path of radionuclide to the environment. The second one is partial impairments of the dousing system. The last one is impairments of local air coolers. Leakage through the containment perimeter wall is the main leak path for the last category.

2.4 Radionuclide Source

The fission product released from the broken fuel is assessed by ELESTRES[2] code.

2.5 Radionuclide Behavior

Analysis of the behavior of airborne radionuclide, both gaseous and liquid aerosol, inside containment is performed using the computer code SMART[3]. The transport of airborne radionuclide from node to node and leakage from containment is calculated from the inter-nodal flow rate predicted by GOTHIC. Steam condensation rates on coolers and surfaces and surface temperatures at each time step are also transferred from GOTHIC to SMART.

The 17 radionuclides which are modeled directly by SMART are as follows:

- H-3, I-131, I-132, I-133, I-134, I-135, Iodine mixture, Kr-87, Kr-88, Kr-89, Xe-133m, Xe-133, Xe-135m, Xe-135, Xe-137, Xe-138, and Noble gas mixture
- These sources come from failed fuel and coolant.

3. Analysis Result

The mass and energy discharged from the 100% reactor outlet header break with loss of class IV power are taken from primary system thermal hydraulic analysis as shown in Fig. 2.

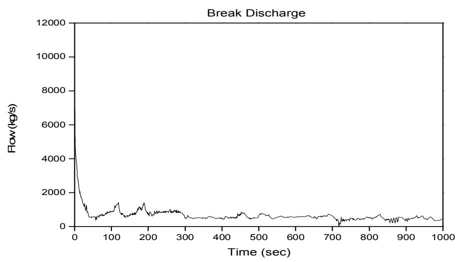

Fig. 2. Mass discharge from the break to inside containment

Fig. 3 shows the energy discharge from the primary heat transport system.

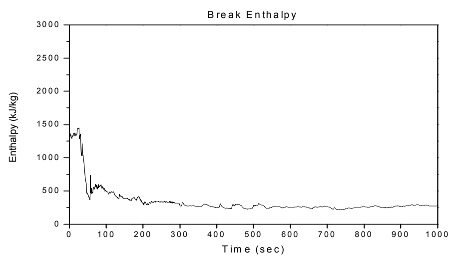

Fig. 3. Energy discharge from the break to inside containment

Analysis results focused on integrated I-131 release into the environment for large break loss of coolant without class IV power with all safety systems available and various containment impairments are shown below.

3.1 All safety systems available

Fig. 4 shows the integrated I-131 release in the case of large break loss of coolant without class IV power with the all safety systems available.

3.2 Loss of Containment Isolation

Fig. 5 shows the integrated I-131 release in the case of large break loss of coolant without class IV power with the loss of containment isolation.

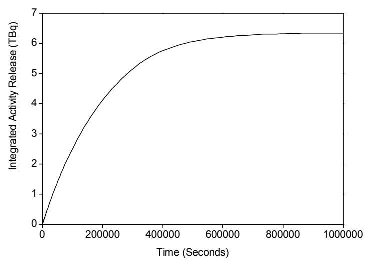

Fig. 4. Integrated I-131 release for ASSA

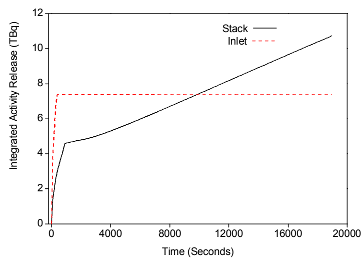

Fig. 5. Integrated I-131 release for LOCI

3.3 Partial loss of dousing system

Fig. 6 shows the integrated I-131 release in the case of large break loss of coolant without class IV power with partial loss of dousing.

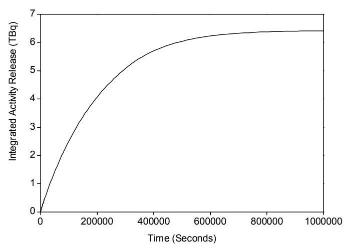

Fig. 6 Integrated I-131 release for PLOD

4. Conclusions

The radionuclide release to the environment in the event of large break loss of coolant without class IV power with all safety systems available and containment impairments was analyzed with GOTHIC and SMART code.

REFERENCES

[1] J. Y. Lee, Containment Analysis Model, 59RF-03500-AR-006 Rev.2, 2010.
[2] G. G. Chassie, “ELESTRES-IST 1.2: User’s Manual,” AECL-153-113370-UM-001, Rev.0, 2006.
[3] S.R. Mulpuru, "Software Theory Manual for SMART-IST VER-0.300", RC-2681, 2001.