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Study of Containment Vent Strategies During Severe Accident Progression for the CANDU6 Plant

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1. Introduction

In March, 2011, Fukushima daichi nuclear power plants experienced a long term station blackout. Severe core damage occurred and a large amount of radioactive materials are released outside of the plants. After this terrible accident Nuclear Safety and Security Commission (NSSC) enforced to increase nuclear safety for all operating plants in Korea. To increase plant safety, both hardware reinforcement and software improvement are encouraged. Hardware reinforcement includes the preparation of the external water injection paths to the RCS and the spent fuel pool, a filtered containment venting system (CFVS), and AC power generating truck. Software improvement includes the increase of the effectiveness of the severe accident management guidance (SAMG) and plant staff training. To comply with NSSC's request, Wolsong Unit 1 has fulfilled the hardware reinforcement including the installation of a CFVS and started the extension of a SAMG to the low power and shutdown operation mode. Current SAMG deals accident occurred during full power operation only. The CFVS is designed to open and to close isolation valves manually. It does not require AC power. The operation of the CFVS prevents the reactor containment building failure due to the over-pressurization but it may release radioactive materials out of the reactor containment building.

This paper discusses the radiological source terms for the containment vent strategy during severe accident progression which occurred during shutdown operation mode. This work is a part of the development of shutdown SAMG.

2. Improvement of ISAAC Code

ISAAC code has been improved continuously since the first version released in 1995. The latest version is ISAAC 5.0.1. As a new system is installed in plant, new models are required to consider new systems installed. The external injection into RCS is already modeled in ISAAC 4.0.3.

ISAAC 5.0.1 has been improved reflecting the technological progress, especially in iodine chemistry, and extended its capability to predict plant response with the new systems installed.

The new version incorporates CFVS model. Fission product filters can be modeled in each containment junction. Up to ISAAC 4.0.3, only aerosol form (CsI) is considered for iodine. Many studies showed that iodine is released as the elemental iodine and the organic iodine in addition to the aerosol form. The results of these studies are incorporated into ISAAC 5.0.1. So filter considered the aerosol iodine, the elemental iodine and the organic iodine. The decontamination factor for each type of iodine is not calculated in the code. Instead, the aerosol decontamination factor can be input either as a constant or as a function of particle size and the elemental iodine and the organic iodine decontamination factors are input as constants. The elemental iodine and the organic iodine are specified as the release group 14 and 15, respectively.

3. Results of Analysis

Initiating event is selected a loss of shutdown cooling with leak at the shutdown cooling pumps. The shutdown cooling pumps failed while plant was cooled down by shutdown cooling system. Coolant leakage through the shutdown pump bearing started 6 hours after the reactor trip and the shutdown pumps stopped simultaneously. Three accident scenarios are studied to examine the effectiveness of containment vent strategy. For the base case, no containment vent conducted. For the CFVS case, a CFVS is used to control the containment pressure. An operator opens the CFVS isolation valves if the containment pressure exceeds the design pressure of the containment building, i.e. 124 kPa(g), and closes the CFVS isolation valves when the containment pressure decreases below 50 kPa(g) [1]. Third case is the containment vent using the containment ventilation system which does not have an effective filter for the radioactive material. The operation of this system is described as an alternated means when there is no means to control the containment pressure [1]. For this case, the operator opens the isolation valves if the containment pressure exceeds 190 kPa(g), and closes the isolation valves when the containment pressure decreases below 150 kPa(g).

For the base case, the containment failed due to overpressure at 134,000 second. After that, the containment pressure is maintained at the atmospheric pressure. For the CFVS case and the vent case, the containment pressure oscillates between the open and the close set pressure as shown in Fig. 1. The containment pressure decreases as an operator opens the isolation valves and increases as an operator closes the isolation valves. This oscillation continues to the depletion of water in the reactor vault.

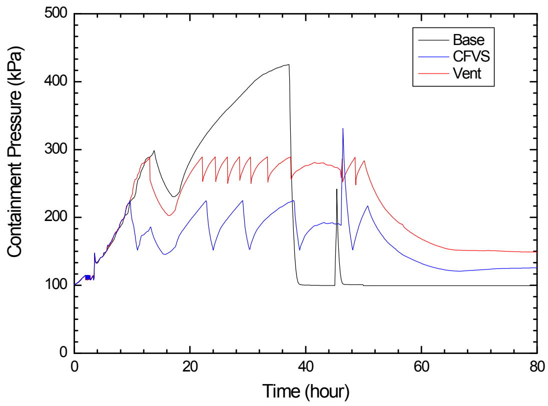

Fig. 1 Containment pressure response

Iodine exists as an aerosol form (CsI), an element (I_2), and an organic iodine (CH_3I) in the containment atmosphere. The aerosol moves randomly and collides and agglomerates with other aerosol and settles down by gravity. As the residence time increases in the containment, less aerosols exist in the containment atmosphere. The release fraction of CsI reaches 0.01 for the base case as shown in Fig. 2.

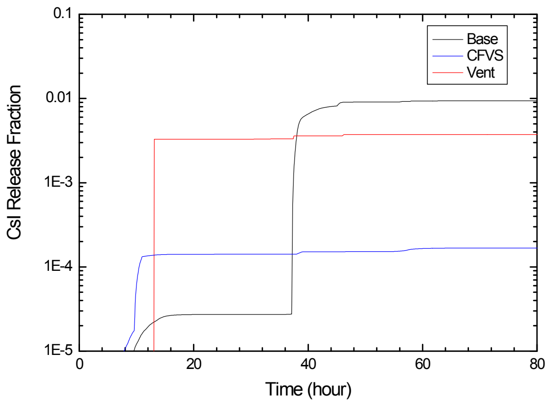

Fig. 2 Release fraction of CsI to the environment

The CFVS is very effective to capture the aerosol in the filter which located on the release path to the environment. The release fraction of CsI is less than $2x10^{-4}$ at the end of calculation for the CFVS case. Decontamination factor is almost 100. For the vent case, most CsI in the containment atmosphere released out of the containment during first opening of the vent valves. After that a little CsI released out of the containment. Total amount of CsI released out of the containment is less than that of the base case, but release time is much earlier than that of the base case. This may cause much public exposure because of short time of public evacuation.

The release fractions of the elemental iodine and the organic iodine are almost same as for the base case and for the vent case, but the release time for the vent case is earlier than for the base case as shown in Fig. 3 and 4. The CFVS is effective to remove the elemental iodine and the organic iodine also. The decontamination factor is almost 100 for the elemental iodine and 10 for the organic iodine. For the vent case, the elemental iodine and the organic iodine released out of the containment during every isolation valve opening.

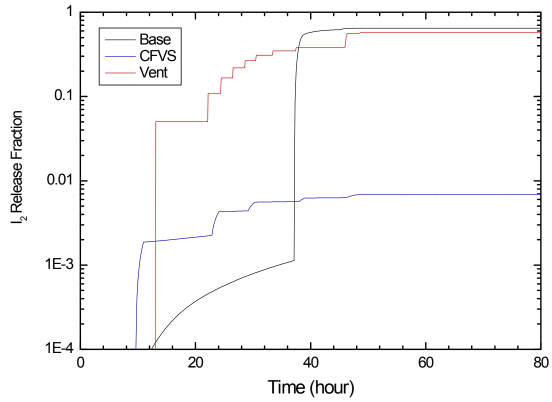

Fig. 3 Release fraction of I_2 to the environment

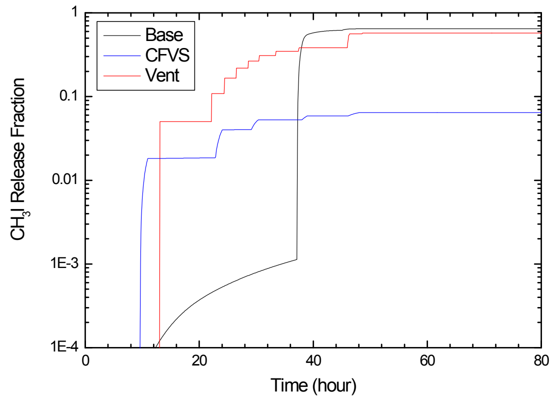

Fig. 4 Release fraction of CH_3I to the environment

Release fraction of the noble gas is presented in Fig. 5. For the base case, the noble gas releases at containment leakage rate until the containment fails by the overpressure. After the containment failure, most of noble gas release out to the environment. The CFVS can't filter noble gas, so the released noble gas increases as time goes on. Duration of isolation valve open for the vent case is less than that for the CFVS case and the amount of noble gas released out of the containment for the vent case is less that for the CFVS case.

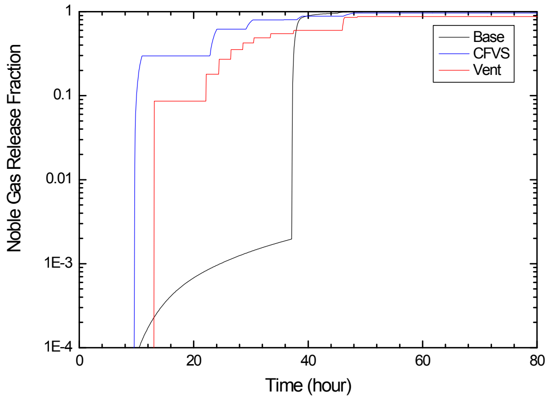

Fig. 5 Release fraction of noble gas to the environment

Release fraction of the CsOH is presented in Fig. 6. It shows the same behavior as for the CsI.

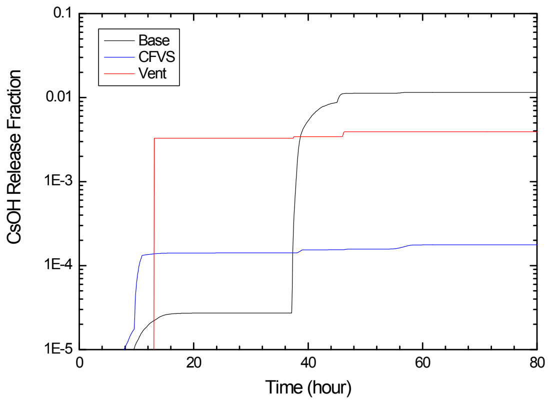

Fig. 6 Release fraction of CsOH to the environment

4. Conclusions

The CFVS is an effective means to control the containment pressure when the local air coolers are unavailable. Radioactive materials may release through the CFVS, but their amounts are reduced significantly. The alternative means, i.e., containment vent through the ventilation system which does not have an effective filter, is not a good choice to control the containment condition. It can maintain the containment pressure below the failure pressure, but it releases a large amount of radioactive materials outside the containment. There exists a chance to contaminate the auxiliary building with radioactive materials. If this happens, all the plant crew who are performing recovery of failed equipment and/or systems in the auxiliary building. This may delay the recovery of the important equipment or the systems which are necessary to control and maintain the affected plant stable state.

REFERENCES

[1] Severe Accident Management Guidance for Wolsong Unit 1, KHNP