Analytical Study of Sodium Fire Characteristics under Sodium Leak Accidents

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1. Introduction

The use of sodium as a coolant in a liquid metal reactor(LMR) has many advantages due to its thermal properties while a disadvantage that a major sodium spill and a pipe rupture of sodium coolant systems will usually result in a sodium fire. The rise of temperature and pressure, the release of aerosol in the buildings as a result of a sodium fire must be considered for the safety measures of a LMR. Subsequent effect of a sodium fire depends upon whether the sodium continues to leak from the pipe or not, whether the ventilation system is running, whether the inert gas injection system is provided, whether the sodium on the floor is drained into the smothering tank or not, whether the building is sealed or not, etc. Therefore, for the safety of a LMR, it is necessary to understand the characteristics of a sodium fire, resulting from various types of leakage.

ASSCOPS(Analysis of Simultaneous Sodium Combustion in Pool and Spray) is the computer code for the analysis of the thermal consequences of a sodium leak and fire in a LMFR that has been developed by JAEA in Japan. Computer code includes two sodium combustion codes called SOFIRE II and SPRAY. SOFIRE II code has been developed to compute 1-cell and 2-cell pool fire cases by Atomics International(AI), and the SPRAY code has been developed to evaluate the consequences of a postulated sodium spray release from LMFR piping leak by Hanford Engineering Development Laboratory(HEDL) in USA.

This study describes a preliminary analysis of sodium leak and fire accidents in the S/G building of KALIMER. Various phenomena of interest are the spray and pool burning, peak pressure, temperature change, the drain system into the smothering tank, ventilation characteristics at each cell with the safety venting system and nitrogen injection system.

2. Computational Model

It is possible for the computer code to treat both the spray fire resulting from the break of a pipe and a pool fire simultaneously. Also pool fire phenomena can be evaluated in 1-cell. Pool combustion by SOFIRE module in 1-cell, pool and spray combustion by spray in 2-cell are calculated. Pool condition (sodium temperature, sodium amount, pool surface area), gas atmosphere condition(gas temperature, gas composition etc.), and structure condition are specified in the input of the SOFIRE module to calculate the heat/mass transfer resulting from a pool combustion. Meanwhile, Spray condition (sodium temperature, sodium leak rate, droplet diameter etc.), gas atmosphere condition(gas temperature, gas composition etc.), and structure condition(property, temperature, surface area etc) are specified in the input of the spray module to calculate the heat/mass transfer resulting from a pool and spray combustion.

3. Analyses of sodium leak accident for KALIMER

The steam generators are located at both sides of the reactor and the S/G dump tanks are just below the SGs. There is an insulated catch pan with suppression deck under the dump tank which collects the spilled sodium. A schematic representation of the S/G building including sodium fire model is shown in Fig. 1. A series of calculations is performed for evaluating the sodium leak and fire accident in S/G building.

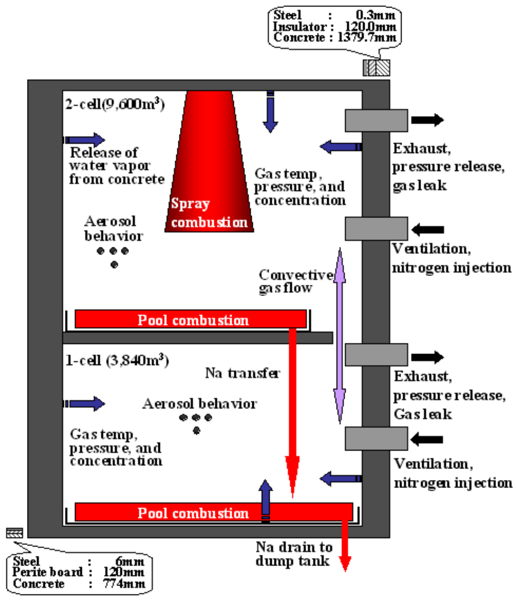

Figure 1. Sodium fire model in S/G building.

The lower part of S/G building is defined as the 1-cell in which the sodium pool fire occurs. And the upper part of S/G building which is connected to 1-cell by opening is defined as the 2-cell, where both a sodium spray fire and a sodium pool fire occur.

The ventilation openings are placed on the sidewall of the building so that air is ventilated from the outside to each cell(1-cell, 2-cell) and exhausted, and nitrogen gas is injected from the gas control system. It is postulated that spray zone is formed by the rain down of a droplet from a sodium jet impact area on the ceiling of 2-cell. It is postulated that a sodium fall down occurs at 23-m high from the floor of 2-cell. If any sodium leak accident occurs in the S/G building, it is modeled so that sodium on the floor of 2-cell, which is sprayed from sodium jet impact area on the ceiling, flows into the floor of 1-cell and then drains into the dump tank through the sodium drain pipe.

4. Results

It is found that the momentary inflow of much nitrogen gas into the cell has a greater effect on the gas pressure, oxygen concentration, and gas temperature than the sodium leak duration time as shown in the Fig.2.

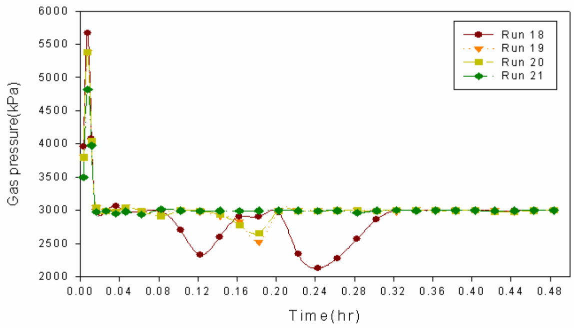

Figure 2. Effect of N_2 injection condition on gas pressure.

The ventilation conditions, drain system, pressure relief system, and nitrogen injection condition for various fire events are simulated to mitigate and minimize the effect of a sodium fire on the cells after the initiation of a sodium leakage.

It is postulated that nitrogen gas is injected at a rate of 3,840m^3/hr(1-cell), 9,600m^3/hr(2-cell) immediately after a ventilation system is shut down to control the sodium combustion at a time of 0.04hr after the initiation of a sodium leakage. And the pressure release plate opens at the pressure drop of -0.1, 3.01 and 100.1kPa, simultaneously the gas flows from each cell to the outside at a rate of 2x10^5m^3/hr to release the pressure of the cell.

It is found that the peak pressure of the S/G building with a sodium fire mitigation system becomes roughly 39 times as low as that of the S/G building without sodium fire mitigation system as shown in Fig.3. Also the gas temperature and the oxygen concentration of the S/G building with a sodium fire mitigation system is kept lower than that of the S/G building without a sodium fire mitigation system as shown in Fig.4.

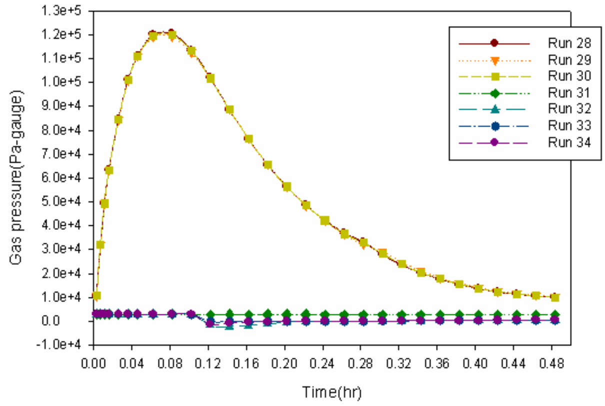

Figure 3. Effect of ventilation, exhaust, pressure release, sodium leak duration, and sodium drain on gas pressure.

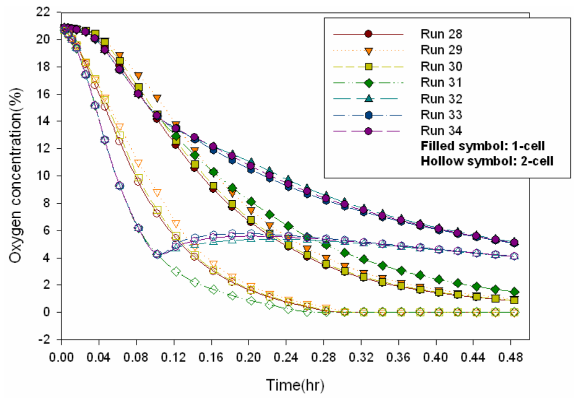

Figure 4. Effect of ventilation, exhaust, pressure release, sodium leak duration, and sodium drain on oxgygen concentration of each cell.

5. Conclusions

The quick shutdown of a ventilation system and the injection of nitrogen gas are very effective against the sodium leakage and fire accidents. The peak pressure of the S/G building with the sodium fire mitigation system becomes roughly 39 times as low as that of S/G building without the sodium fire mitigation system. Also the gas temperature and the oxygen concentration of the S/G building with sodium fire mitigation system is kept lower than that of the S/G building without the sodium fire mitigation system.

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