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Source Term Estimation for Fukushima Unit 1 With and Without Water Injection Scenarios

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1. Introduction

Source terms are estimated for Fukushima Unit 1 for 500 hours (about 20 days) from March 11 to April 1, 2011. A variety of scenarios of water injection from no water injection to full water injection started from 28 hours after reactor trip are simulated with MELCOR 1.8.6 code. Water cannot be injected into RPV or PCV before 28 h due to the high pressure. Water injection start times are 28, 50, 100, 150, 200, and 275 hours. Early injection of water into containment will reduce environmental source term due to the elimination of the molten corium and concrete interaction (MCCI) and revaporization process in RPV or in containment.

2. Methods and Results

MELCOR 1.8.6 code is used for the simulation of thermal hydraulics, core meltdown process, containment pressure buildup and eventually radiation release to environment at Fukushima Unit 1 during 500 h (20 days).

2.1 Accident chronology at the plant

Reactor trip occurs when the earthquake occurs. When the tsunami attack the plant at 40 minutes later, total loss of AC power (station blackout) occurs. Isolation condenser is working during initial 1 hour in Unit 1, but after the loss of AC power the motor operated valve in isolation condenser system is closed and never opened again. After one hour, safety relief valves (SRVs) are opened and closed cyclically depending on the pressure of RPV. Steam, hydrogen gas, and fission products generated in the core are released to the wetwell (or it is also called, suppression chamber) during the opening of SRVs. Hydrogen is generated in the core with zircalloy cladding oxidation with high temperature steam. The steam released from core is condensed in wetwell during the initial transient, but due to the limited capacity of wetwell, it is released into the drywell through vent legs between drywell and wetwell. Fission products can be also scrubbed in the wetwell initinialy. But, they also transported to the drywell through the opening of vent legs.

Accumulation of steam in drywell make PCV pressure buildup that eventually drywell head flange leakage occurs. Drywell head flange is usually uplifted during refueling operation. Fission products start to release to the environment at 14 h at the site. Hydrogen gas also leaked to the operating floor of the reactor building. Hydrogen explosion occurs at 25 h in the plant.

In the plant accident log, alternative external water (sea water or fresh water) is injected to the RPV or PCV by fire truck. External water injection rate is shown in Fig. 1.

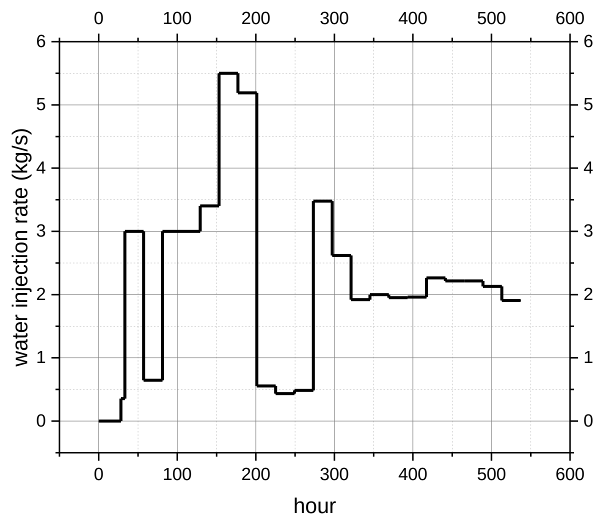

Fig. 1 External water injection rate of Fukushima Unit 1

2.2 PCV Pressure Behaviors

RPV and PCV pressure behaviors are shown in Fig. 2.

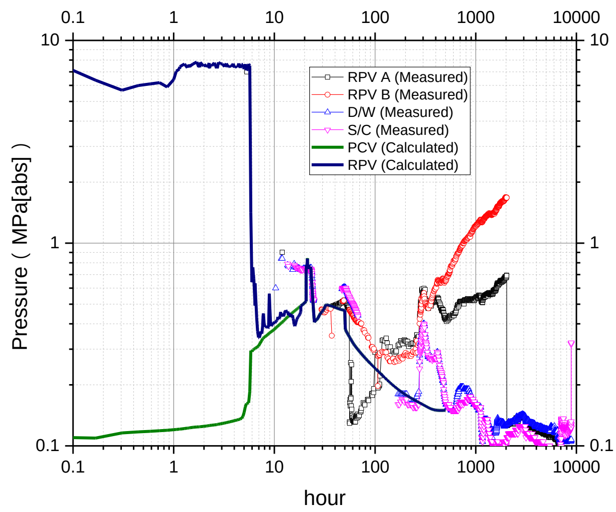

Fig. 2. RPV and PCV pressures simulated and measurements

Note that the real measurement data have discrepancies among them. Therefore, we try to follow DW data as far as possible.

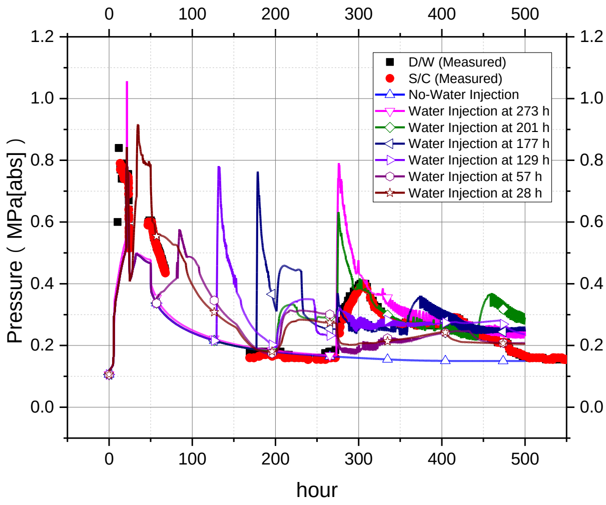

Fig. 3. PCV Pressure Simulation depending on Water Injection Time

Fig.3 shows the PCV pressure predictions depending on the water injection starting time. It shows that water injection rates of 3 or 5 kg/s seem to be too high compared to real plant DW and SC pressure measurements. It explains that not all the water tried to be injected by fire truck cannot be reached to the RPV or containment due to various reasons. One of the reasons may be the too high RPV or PCV pressure and the other reason may be bypass of water injection due to impacted piping in the injection pathways.

2.3 Source Term Behaviors

Fig. 4 shows Cs release fraction to environment depending on the water injection stating time.

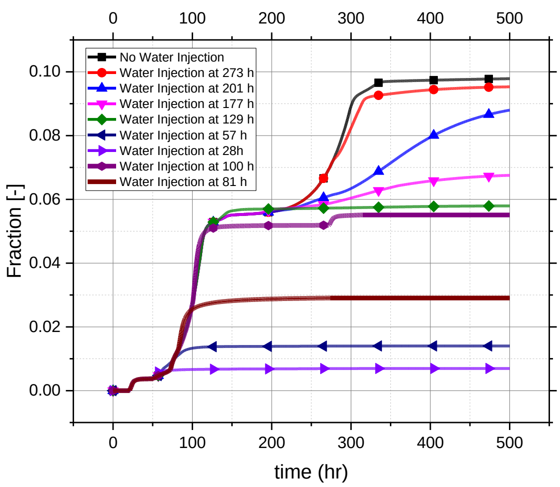

Fig. 4. Cs release fraction to environment depending on the water injection stating time

3. Conclusions

Depending on the external water injection starting time, Cs release rate to environment is estimated. If water is injected at 28 h, then Cs release fraction to environment is only 0.05 % of initial core inventory. However, if water injection is effective after 57 h, then Cs release fractions to environment are 5 to 10 % of initial inventory.

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