The Preliminary Analysis for SBO accident in SMART with PCCS system

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1. Introduction

This paper shows the preliminary analysis results for the effect of PCCS system on the containment pressure from the SBO accident in SMART (365 MWt). This simulation has performed with MELCOR version 1.8.6 YT. The analysis on the source term was not performed.

The purposes of these calculations are to estimate the maximum level of pressure being occurred in the containment from SBO accident with considering PCCS system. For this purpose, PSI (passive safety injection) system , PRHR systems, shut-down cooling system, Fan cooler and Spray system were assumed as malfunction.

From these calculations, the PCCS system showed the positive effect that the containment keeps at low pressure level (~1 bar) without its rapid increase. But the attack from hydrogen burn (maximum ~5.0 bar) against the integrity of containment will be a problem. Also the high gas temperature CAP (>1,700 K) in CAP space after the reactor vessel ruptures may cause the CAP boundary structure fail.

2. Methods and Results

2.1 Backgrounds

In SMART with the thermal power of 365 MW, new passive safety features of PCCS system are included to enhance the level of safety [1]. PCCS system consists of the CAP structure, IRWST, the pressure discharge line, sparger, IRWST vent and ECT heat exchanger (HX). Fig .1 shows the conceptual view of the PCCS system.

The CAP structure is planning to include the reactor vessel and CMT for trapping the released fission products and it is the closed space.

The IRWST system has a pool-tank, The initial pool temperature was at 323 K. The ‘pressure discharge line’ from CAP is submerged into the pool from the top space of CAP. The hot steam in the CAP is to discharge into pool through the sparger of the ‘pressure discharge line’.
IRWST vent was opened to the containment. The ECT heat exchanger system includes the pool tank and the heat exchanger tubes of 500 with axial length of 1.5 m.

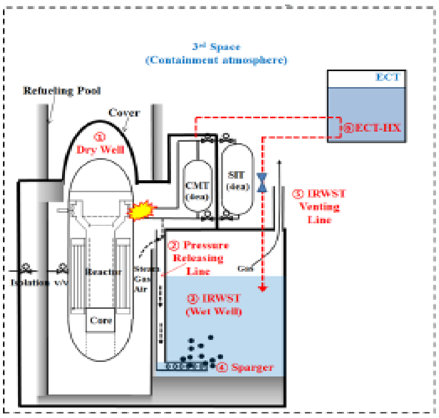

Fig. 1. Conceptual view of PCCS system

Table I is the general PCCS system related data.

Table I: PCCS system Data

components	Volume & etc
drywell	4000 m^3
IRWST	4000 (g*:832, p:3168) m^3
ECT-pool	900 (g:180, p:720) m^3
Pool temperature	50 ° C (IRWST/ECT)
number of ECT-HX tubes	500 (=1 train), length=1.5 m
containment	51920 m^3
	* g=gas p=pool

The input deck still used that of SMART for 330 MWt except the core and decay power [2]. The calculation was completed up to 500,000.0 seconds (more than 5 days). To make clear the effect of PCCS and hydrogen burn phenomena on the containment pressure behaviors, three types of calculations were performed and were compared together.

The first case was the calculation that the PCCS system was included but H_2 burn phenomena were neglected (case1). In the second case, both the PCCS system and the H2 burn phenomena were considered in the calculation (case2). In the last case, the PCCS system was omitted but the H_2 burn phenomena were included (case3)

2.2 Containment pressure

For the containment pressure behaviors, both the case 1 and 2 kept around 1 bar before the reactor lower vessel head fails. But after the reactor lower vessel head fail, the containment pressure for the case1 continue to increase and finally has reached 1.37 bar at 5 days (432,000 sec).

But during this period, hydrogen burns of two times were occurred in the case2 and the resulting maximum containment pressures has reached 4.96, 4.85 bar respectively. The case3 showed the higher containment pressure around 1.5~2.0 bar over the transient. It is because the case3 does not have a condensation line to discharge of steam to IRWST.

Consequently, the PCCS system was very effective to reduce the steam content and pressure in the containment. But the reduction of steam contents in the containment may cause the containment fail due to the hydrogen burn.

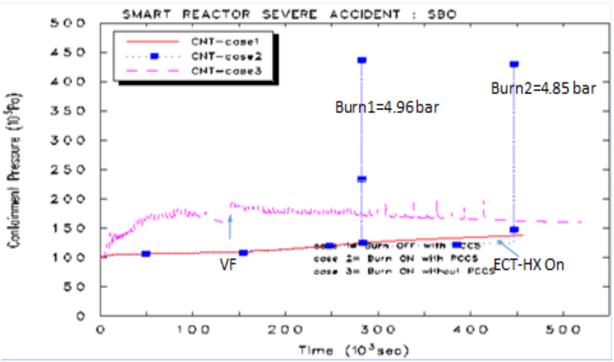

Fig. 2. Containment pressure change for SBO

2.3 Hydrogen generation from the core & the cavity

Fig. 3 showed the amount of hydrogen generation from core and cavity. For the case 2, total amount of hydrogen production from core was ~120 Kg from SBO for the SMART and it means that around 60 % of the initial zircalloy (4,396 Kg) was oxidized in the core.

Also important thing to be reviewed is the amount of hydrogen generation from MCCI phenomena after reactor vessel lower head fails. Total amount of hydrogen production from only MCCI was tantamount to around 1 ton at 500,000.0 sec. For example, based on 300,000.0 sec, the amount of hydrogen production are 83.5 kg from core, 101 kg from zircalloy in concrete and 502.6 Kg from the re-bar.

Therefore, the main source of the hydrogen generation from MCCI was the re-bar in the concrete. This large amount of hydrogen generation from not only the core but also the concrete may require the evaluation on the installation of the 'PAR' or 'Igniter' system in the containment.

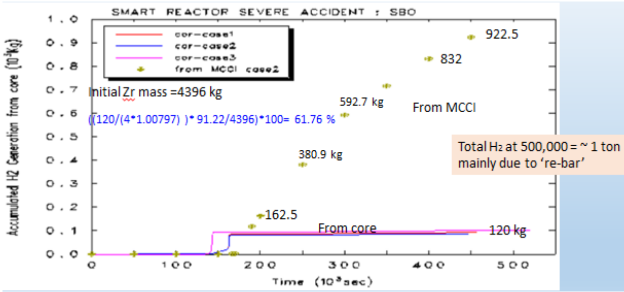

Fig. 3. Mass of hydrogen generation from core and cavity

2.4 Summary of the accident progression for SBO

Table II is the summary table of SBO accident in SMART with the PCCS system and the consideration of hydrogen burn in the containment (case2).

Table II: Summary table of SBO accident (case2)

Events	Time [s]
Rx trip/ RCP trip/ MFW trip	0
TAF uncover	9,500
H_2 generation start	53,500
BAF uncover	68300
LP dry-out	107,900
Lower Head Failure and debris ejection	159,716
Cavity dry-out	NA
Gas release from MCCI	166,300

3. Conclusions

The PCCS system was very effective to reduce the steam content and pressure in the containment. But the reduction of steam contents in the containment may cause the containment rupture due to the burn of hydrogen. The ECT heat exchanger system showed negligible effect to reduce the steam content and the pressure in the containment over the transient. The high gas temperature (>1600 K) in the CAP after reactor vessel lower head fails may damage the boundary structure of CAP.

ACKNOWLEDGEMENT

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REFERENCES

[1] Soon-Joon, Hong, Sung-Soo Jeon,"PCCS 설명회", November, 22, 2016, FNC.

[2] Jong-Hwa Park, Dong-Ha Kim, Young Jong Chung etc. "MELCOR Severe Accident Scoping Calculations in the Integral Type Reactor (SMART)", CSARP / MCAP meeting, Sept, 13~17, 2010, Washington, USA.