Assessment of CAP Code using the ISP-42(PANDA Phase C)

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1. Introduction

As a result of efforts to develop domestic nuclear power plant design codes, CAP (Containment Analysis Package) 2.0 was released last year. CAP code was developed in an object-oriented manner by using C++. CAP code can be applied to the analysis of thermal-hydraulic behavior in the containment building of NPP. Various basic thermal-hydraulic problems and integrated effect tests were used to validate and verify the capability of this code. Assessment results of CAP with PANDA test which was designated as international standard problem 42 are shown in this paper

2. ISP-42

The ISP-42 PANDA test was performed on 21/22 April 1998. The configuration used for ISP-42 was corresponding to the European Simplified Boiling Water Reactor containment and passive decay heat removal system at 1:40 volumetric and power scale, and full scale for time and thermodynamic state [1]. The main issues and phenomena covered in the ISP-42 test are following:

- Transient and quasi steady-state operation of a passive containment cooling system
- Coupled primary system and containment behavior and phenomena
- Venting of steam/non-condensable gas mixture
- Steam condensation in the presence of non-condensable gases in tubes

2.1 Test Scenario

The ISP-42 PANDA test consists of six phases. These phases represent a sequence of concatenated processes as used for the simulation of the behavior of advanced LWR containment's with passive safety system. Each of these phases in fact a separate experiment, with its own initial and boundary condition. The six different test phases are listed as below:

Phase A: Passive Containment Cooling System (PCCS) Start-up
Phase B: Gravity Driven Cooling System Discharge
Phase C: Long-Term Passive Decay Heat Removal
Phase D: Overload at Pure-Steam Condition
Phase E: Release of Hidden Air
Phase F: Release of Light Gas in Reactor Pressure Vessel

The objective of phase C is to investigate the system response during normal operation of PCCS in case of LOCA. Phase C simulates the long-term decay heat removal from the containment with three PCC's operating. The phase C was selected to assess the heat transfer due to condensation and convective heat transfer, heat conductor model and mass transfer of CAP code.

2.2 Test Facility

The PANDA test facility consists of large interconnected vessels. A Reactor Pressure Vessel (RPV) provides steam produced by electric heater. Two vessels are representing drywell, two representing wetwell and one large vessel representing Gravity Driven Cooling System (GDCS) tank. In the upper part of the facility, there are three pools, which are containing PCC units as shown in Fig. 1 [2].

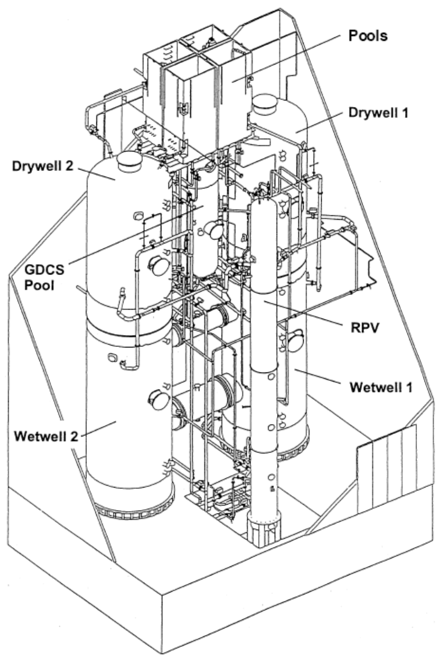

Fig. 1. 3D view of PANDA test facility

2.3 Phase C: Configuration

In phase C, the RPV with decay heat provides steam into the each drywell through main steam lines. The empty GDCS is connected to the wetwell through the pressure equalization line. Vacuum breakers are connecting wetwells and drywells. All three PCC's are connected to the drywells. The condensate is drained directly to the RPV and non-condensable gas or excess steam is vented into the wetwells through the vent lines [3].

3. Simulation Results

Each tank was modeled as one lumped parameter node. Decay heat of RPV was modeled using heater with tabled power history. Each PCC pool was divided into 6 nodes to simulate convective flow. Mass flow rate of main steam line 1, PCC feedwater line and PCC vent line are shown in Fig. 2 to 4, respectively. CAP predicts main steam flow and feed flow very closely to the measured data.

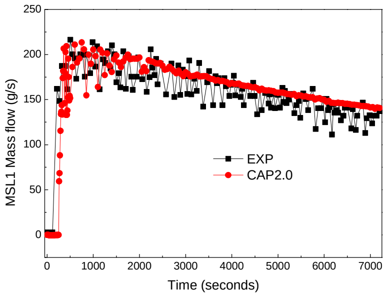

Fig. 2. Mass Flow Rate of Main Steam Line #1

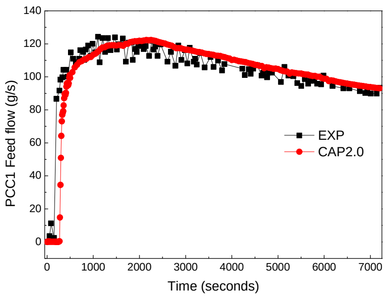

Fig. 3. Mass Flow Rate of PCC Feed Line #1

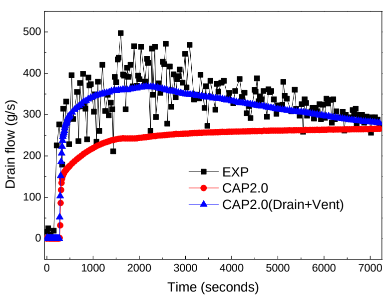

Fig. 4. Mass Flow Rate of PCC Drain Line

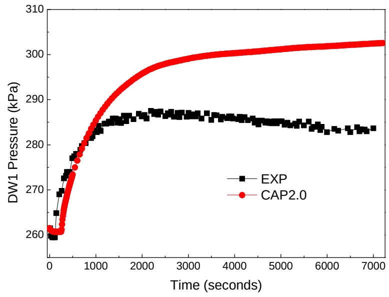

Fig. 5. Pressure in Drywell #1

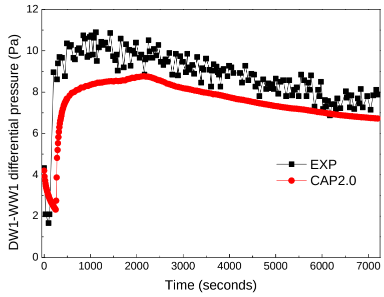

Fig. 6. Differential Pressure between DW and WW

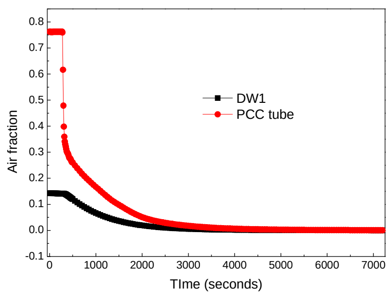

Fig. 7. Air Fraction in Drywell and PCC tube

4. Conclusions

CAP code predicts flow between nodes well, but the application of Uchida model as condensation heat transfer model causes less condensation during the first 2000 seconds when the air fraction is relatively high as shown in Fig. 7. Consequently, CAP code predicts pressure in Drywell higher by 20 kPa as shown in Fig.5.

REFERENCES

[1] D. Lubbesmeyer and S.N. Aksan, ISP42(PANDA Tests) Open Phase Comparison Report, NEA/CSNI/R(2003)7, p. 31, 2003.

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