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VERIFICATION OF THE CODE ATHLET BY POST-TEST ANALYSIS OF TWO EXPERIMENTS PERFORMED AT THE INTEGRAL TEST FACILITY CCTF

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1 Introduction

In the framework of the external validation of the thermohydraulic code ATHLET Mod 1.2 Cycle C, which has been developed by the GRS, post test analyses of two experiments were done, which were performed at the Japanese test facility CCTF. The experiments C2-04/62 and C2-19/79 simulate a double end break in the cold leg of the PWR with ECC injection into the cold leg and with combined ECC injection into the hot and cold legs. The evaluation of the calculated results shows, that the main phenomena can be calculated in a good agreement with the experiment. Especially the behaviour of the quench front and the core cooling are calculated very well.

2 The CCTF Test Facility

The CCTF test facility (Fig. 1) is a 1:25 volume-scaled model of a 1000 MW pressurized water reactor, [1-2]. CCTF is designed to investigate the refill-reflood phenomena after a large break loss of coolant accident. All four loops of the reference reactor are modelled in the test facility. The broken cold leg is connected to two containment tanks. The reactor core consists of 1824 electrically heated rods. In the core a radial and axial power profile is simulated.

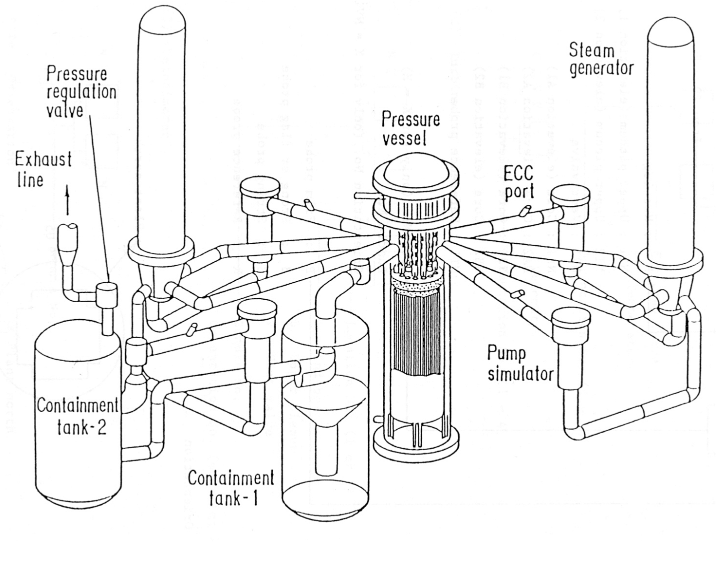

Fig. 1: Sketch of the CCTF Test Facility

3 Thermohydraulic model

The presented calculations were performed with ATHLET Mod 1.2 Cycle C, [3]. The input deck models the four loops of the test facility in a two-loop representation, one broken loop and one loop for the three intact loops. The reactor core is modelled by a two-channel representation with 62 % of the nominal power in the central channel and 38 % in the periphery. In all control volumes the 6-equation two-phase flow model was used. For calculation of the rewetting process, in the reactor the Quench Front Model was applied. The containment tanks were simulated by time dependent volumes.

4 Results of the ATHLET calculations

4.1 Experiment C2-19/79

The experiment C2-19/79 simulates a double end break in the cold leg of a PWR with combined ECC injection into the hot and cold legs. With the start of the transient the reactor power is increased from zero to a specified decay heat level. The initial pressure in the primary loops and in the containment tanks was 0.6 MPa and 0.3 MPa respectively. Apart from the lower plenum, the test facility is filled with steam. The break valves between cold leg and containment are opened at t=83 s, simulating the end of the blowdown-phase of a large break loss of coolant accident. At the same time the power decay of the reactor is initiated. The ECC injection into the hot and cold legs is started at t=83 s and t=85 s respectively. The LPIS is initiated at t=174 s.

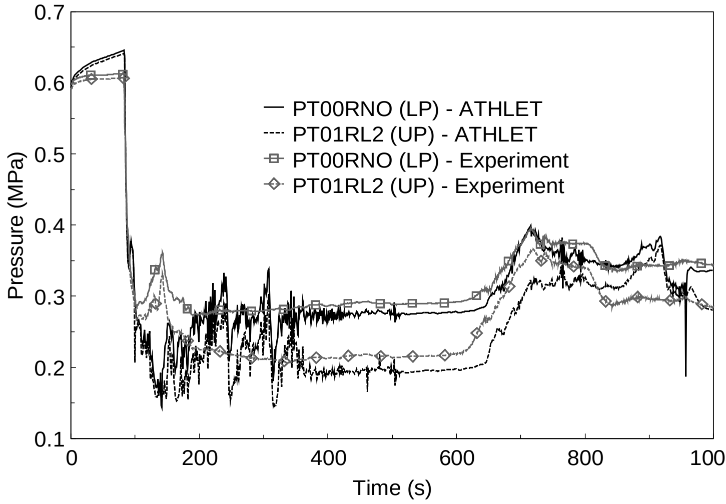

Fig. 2: Pressure in the reactor model (LP and UP)

Fig. 2 shows the measured and calculated pressure in the lower plenum (PT00RNO) and the upper plenum (PT01RL2) of the reactor. The rising reactor power leads to a pressure increase up to t=83 s. By opening the break valves a fast depressurization of the primary system can be observed. Due to the very high condensation rates near the ECC injection points, the pressure decrease is overestimated by ATHLET. In the calculation, the containment tanks are modelled as time dependent volumes. Apart from the first 200 s the calculated pressure corresponds to the experimental results.

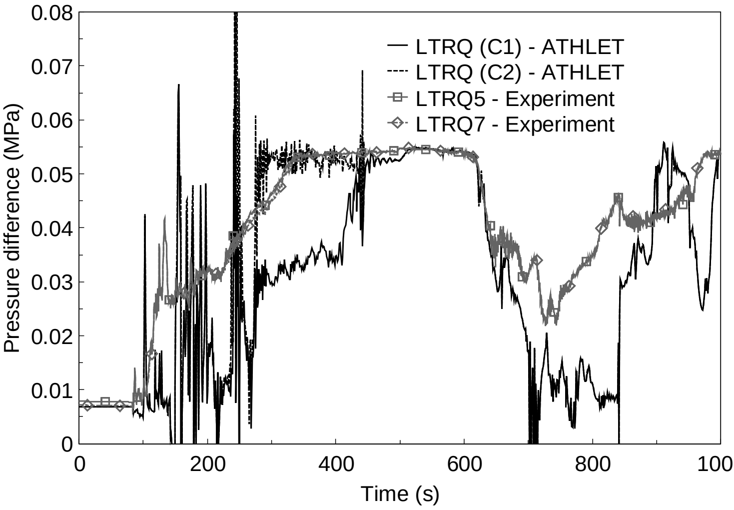

Fig. 3: Pressure difference between LP and UP

An important aspect is the behaviour of the quench front. In the case of a combined ECC injection, the development of the upper quench front will be delayed by the steam flow produced in the reactor core. The formation of the quench front can be observed by the course of the pressure difference in the reactor model. Fig. 3 shows the pressure difference between the lower plenum and the upper part of the reactor core for the central channel (C1) and the periphery (C2). In comparison to the experiment, the calculated quench front starts with a delay of 50 s. In the experiment and also in the calculation the reactor level decreases after t=600 s. Up to the end of the transient the reactor level rises again.

Due to the quench front development, the rise of the cladding temperatures will be stopped. Both measured and calculated cladding temperatures indicate, that the quench front develops faster in the lower plenum than in the upper plenum (Fig. 4 for the central channel and Fig. 5 for the periphery). The core cooling from the upper plenum is impeded by the upward steam flow from the core. In general the calculated cladding temperatures show a good agreement with the experiment. The results from the experiment show, that the quench front formation at the periphery of the core is faster than in the centre. This behaviour could be also modelled by the two-channel representation in ATHLET.

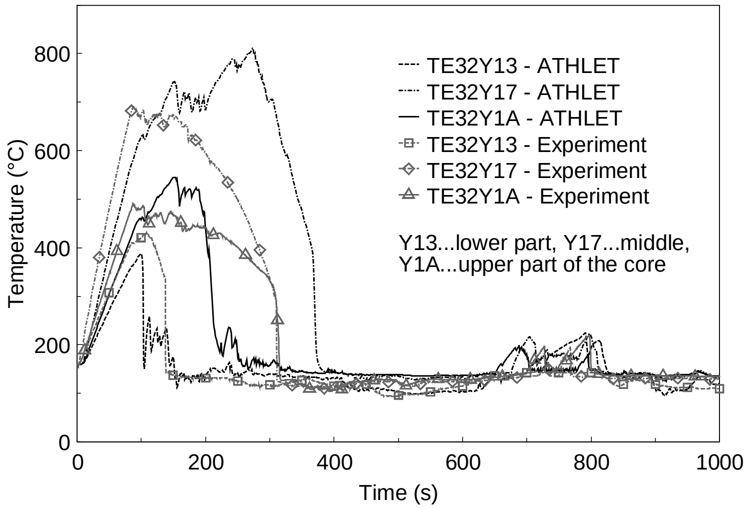

Fig. 4: Cladding temperatures in the center of the core

4.2 Experiment C2-04/62

The experiment C2-04/62 simulates a double end break in the cold leg of a PWR with ECC injection only into the cold leg. The initial pressure in the primary system and in the containment was 0.26 MPa and 0.2 MPa respectively. As in the previous experiment, at the start of the transient the reactor power is increased from zero to the specified level. The depressurization of the primary system starts at t=84.5 s by opening of the valves between broken cold leg and containment. At the same time the accumulator injection into the lower plenum is initiated. The power decrease starts at t=93.5 s and the accumulator injection into the cold legs is initiated at t=99.5 s. The LPIS is activated at t=120 s.

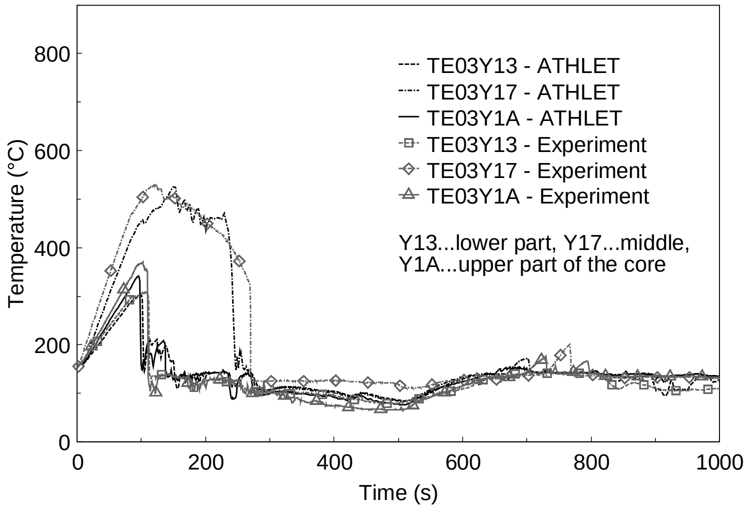

Fig. 5: Cladding temperatures in the periphery of the core (Y13-lower part, Y17-middle and Y1A-upper part)

Fig. 6 shows the measured and calculated pressure in the lower plenum (PT00RNO) and the upper plenum (PT01RL2) of the reactor. The rise of the primary pressure up to t=84.5 s is caused by the power increase in the reactor core. After opening the break valves a pressure balance between primary system and containment is achieved. Afterwards the primary pressure rises very fast in the experiment. In the calculation, the primary pressure temporary decreases. This deviation between calculation and experiment is caused by very high condensation rates in the cold legs. In the further course of the transient, the calculated pressure is lower than in the experiment.

Due to the quench front development, the rise of the cladding temperatures will be stopped. In the case of the cold leg ECC injection, the quench front starts only from the lower plenum. The cladding temperatures in the central channel of the core are presented in Fig. 7. The different behaviour of the quench front for the central region and the periphery of the core could be also successful modelled with the applied two-channel representation.

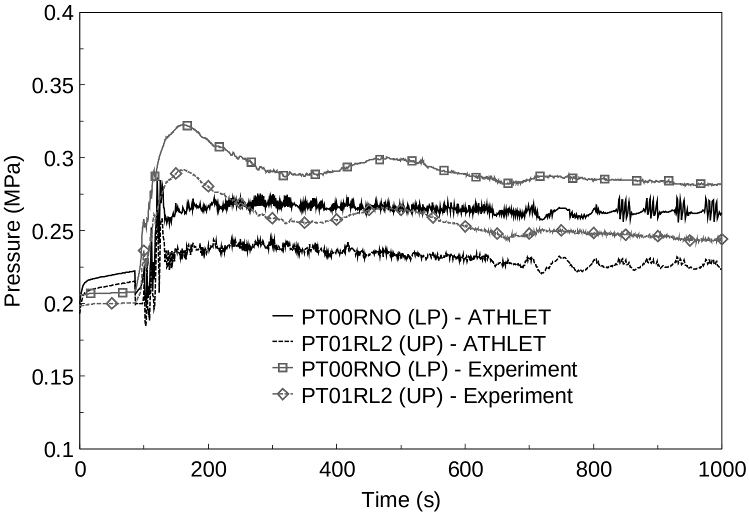

Fig. 6: Pressure in the reactor model (LP and UP)

5 Conclusions

The evaluation of the calculated results shows, that the behaviour of the quench front and the core cooling can be calculated very well. In the experiments, the thermohydraulic behaviour is influenced by radial effects in the core region. The calculated results show a good agreement with the experimental data for the central channel and also for the periphery of the reactor model. The safety relevant statements of the experiments could be reproduced by the code ATHLET.

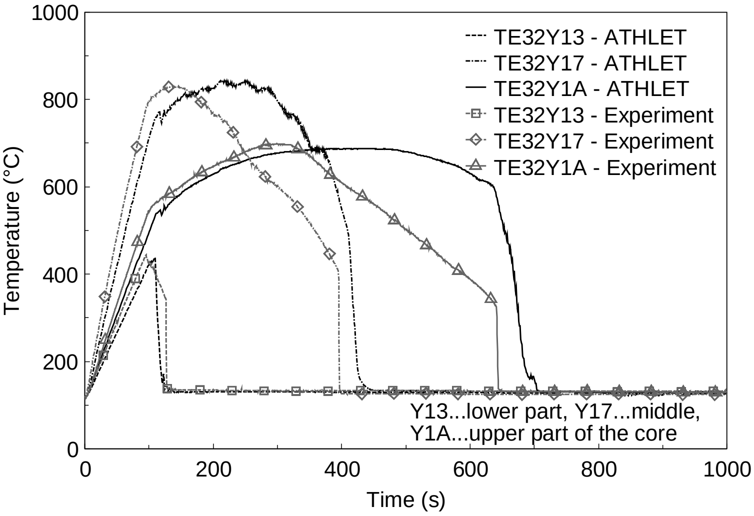

Fig. 7: Cladding temperatures in the center of the core (Y13-lower part, Y17-middle and Y1A-upper part)

References

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