TRACE Assessment for Application to Anticipated Operational Occurrences in Boiling Water Reactors[1]

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INTRODUCTION

The TRAC-RELAP Advanced Computational Engine (TRACE) is a consolidated system analysis code is being developed by the U. S. Nuclear Regulatory Commission (NRC) [1]. TRACE is intended to be the tool of choice for the NRC to perform best estimate and confirmatory calculations for application to reactor licensing issues. The TRACE code has been assessed in the past against various separate effects and integral tests [2]. These include assessment of models against separate and integral effects data for application to Loss of Coolant Accident (LOCA) and transient conditions.

This paper focuses on the assessment of TRACE against tests representative of Anticipated Operational Occurrences (AOOs) in Boiling Water Reactors (BWRs). The aim of this study has been to evaluate the adequacy of the code in predicting both steady state and transient conditions consistent with the measured BWR Full Integration Simulation Test (FIST) facility data [3].

DESCRIPTION OF WORK

The FIST facility was planned to be representative of a full height BWR/6 design with a 1:624 volume scaling ratio. The reactor core region was simulated by an 8x8 heater rod array representative of a prototypic BWR/6 bundle. The bundle in the facility consisted of 62 heater rods and 2 water rods and was housed in a BWR/6 Zircaloy channel box. All BWR/6 Emergency Core Cooling Systems (ECCS) were simulated in the FIST facility. Six valves were connected to the steam line on the FIST vessel to simulate a variety of BWR/6 steam line functions including the Safety Relief Valves (SRVs) (for additional details, see Reference [3].

The TRACE model of FIST incorporates all the key features of the facility. Control schemes were also implemented in the TRACE model for the main steam line valve and all the SRVs in the FIST facility. In addition, various control schemes were also incorporated in the model to properly simulate scenario-dependent boundary conditions and the ECCS.

TRACE has been benchmarked against seven FIST tests [4-5] that are applicable to BWR AOOs. Selected results from the simulation of one of these tests, Test 6PMC3-B, are described here.

Test 6PMC3-B simulated natural circulation condition at low system pressure in a BWR/6 [5]. This test was performed at a system pressure of 1.381 MPa. Make-up water injection was not available during the test and the pressure control valve on the main steam line was manually operated to maintain the system pressure. The power during the test was 372 kW. The initial conditions for test 6PMC3-B and the corresponding TRACE steady state results are listed in Table 1.

Table 1. Initial conditions for FIST Test 6PMC3-B

Parameter	**Test 6PMC3-B [5]**	**TRACE**
Bundle power, MW	0.372 ± 0.002	0.372
Steam dome pressure, MPa	1.381± 0.01	1.381
Channel flow, kg/s	5.30	5.36
Downcomer water level[a], m	11.02	10.98
Steam flow rate, kg/s	0.185± 0.05	0.185
Feed water flow rate, kg/s	0.16	0.185
Downcomer temperature, K	468 ± 2	467.5
Available ECCS	None	None

[a] relative to the lower jet pump support plate

[1] Work performed under the auspices of the United States Nuclear Regulatory Commission (NRC).

RESULTS

The differential pressure in the downcomer region is shown in Fig. 1. The pressure drop between two different elevations can indirectly provide information about the collapsed water level. Figure 1 shows that the pressure drop (indicative of water level in the downcomer) decreases until the end of the test due to inventory loss through the steam line and lack of any make-up water.

A noticeable decrease in the differential pressure predicted by TRACE in the downcomer can be seen at around 450 seconds. This is attributed to the rapid decrease in the water level in the downcomer.

The natural circulation flow rate through one of the jet pumps in the downcomer region is shown in Fig. 2. The TRACE-predicted flow rate is slightly higher than the experimental data until 100 seconds, after which it is comparable to the measured data. The reduction in the natural circulation flow at 100 seconds is consistent with the decrease in the downcomer water level beginning at about 100 seconds as shown in Fig. 1. The natural circulation flow rate drops sharply at 430 seconds and subsequently recovers at 520 seconds. The sudden reduction in the natural circulation is related to the rapid drop in the measured water level in the downcomer, which is due to the transition in the flow regime in the upper downcomer at the elevation of the separator return; once the effective two-phase level drops below axial level 16, natural circulation from the upper plenum through the separator to the downcomer is shut down. However, the reason for the recovery of the natural circulation flow at approximately 520 seconds is not known.

In summary, the TRACE predictions for Test 6PMC3-B compare reasonably well with the majority of the corresponding data. In general, the long-term trends in the measurements are well predicted by TRACE, even though, quantitative temporal variations of the key figures-of-merits are not reproduced by the TRACE simulations. This conclusion also holds true for the results of the seven tests simulated as part of the TRACE assessment.

REFERENCES

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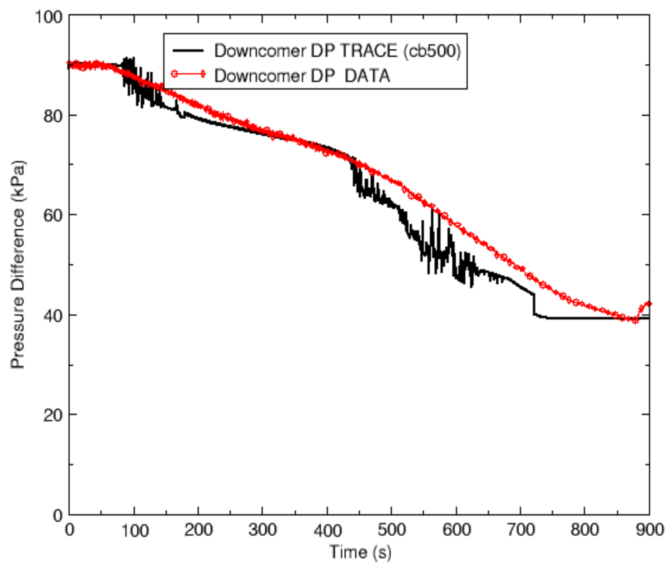

Fig. 1. Differential pressure across the downcomer during Test 6PMC3-B

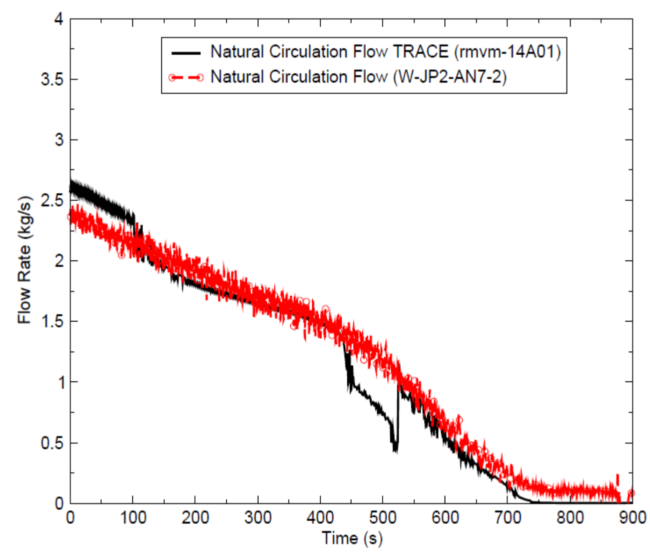

Fig. 2. Natural circulation flow rate through one of the jet pumps during Test 6PMC3-B