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International Agreement Report

Modelling of ROCOM Mixing Test 2.2 with TRACE v5.0 Patch 3

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ABSTRACT

Experimental data on non-uniform flows in reactor pressure vessel downcomer has been recently produced at the ROCOM test facility at Helmholtz-Zentrum Dresden-Rossendorf, within the framework of the OECD/PKL2 project. This data can be used for validation of three-dimensional thermal-hydraulic codes.

The transient ROCOM test 2.2 is calculated with the system-code TRACE v 5.0 Patch 3, using the new vessel junction component in order to produce local calculation grid refinement within the lower plenum.

The simulation results obtained with TRACE are qualitatively in good agreement with the experimental measurements, but quantitatively there is more diffusion in the calculated temperature distributions and some bias from the outlet boundary condition utilized in the simulation.

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1. INTRODUCTION

In general, thermal-hydraulic safety analyses of nuclear power plants have to be conducted using system-scale analysis tools due to the limited available computational power and computer memory. The system-scale codes are typically based on one-dimensional description of the two-phase flow, which makes the solution of the flows in the nuclear reactor core and the coolant loops much faster and less memory consuming in comparison to proper computational fluid dynamics (CFD) codes. However, certain asymmetric events, such as the non-uniformity of the flow field in the reactor pressure vessel (RPV) downcomer when for example the flow rates, temperatures or boron concentrations in the cold legs are not equal, cannot be properly described with one-dimensional models. In order to respond to this need, specific three-dimensional component models have been incorporated into such widely-used analysis codes as RELAP5 [1], CATHARE [2] and TRACE [3].

The three-dimensional models in the system-scale tools are intended to capture only the large-scale three-dimensional effects, and they are typically used with very coarse nodalizations utilizing the porous-medium approach. Details of the flow field such as small-scale fluctuations and pressure distribution in the vicinity of flow obstructions cannot be captured by these tools.

When making predictions with tools based on such simplified methodologies, one has to assure that the used models and methods work as intended, i.e. that they capture all the relevant phenomena they are supposed to capture, and also to assess how well the simplified model corresponds to the physical reality in the end. These tasks can be achieved through validation against experimental data, or alternatively through code-to-code comparison if another, already-validated code, is available.

Experimental data on non-uniform flows in reactor pressure vessel downcomer has been recently produced at the ROCOM (Rossendorf Coolant Mixing) test facility at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) [4], within the framework of the OECD/PKL2 project [5]. The ROCOM test facility, which is a model of the German KONVOI type Pressurized Water Reactor (PWR), is specifically designed for coolant mixing studies in the RPV downcomer.

The purpose of this work is to examine the three-dimensional modelling capabilities of the system code TRACE for temperature distribution behaviour in the reactor pressure downcomer and at the core inlet, by calculating the recent ROCOM Test 2.2 [9, 10].

2. ROCOM TEST FACILITY

The ROCOM test facility at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) is a model of a German KONVOI-type PWR, and it is intended for coolant mixing studies in the reactor pressure vessel downcomer. The facility includes all the important details of the reference plant at linear scale of 1:5, including the pressure vessel and the four coolant loops with fully controllable coolant circulation pumps. The pressure vessel at the test facility is made from acrylic glass, and the experiments are conducted at ambient temperature and near atmospheric pressures. The reactor core at the test facility is represented by a core basket, which simulates the hydraulic resistance provoked by the fuel rods in the real reactor core, and no core heating is provided. A schematic view of the facility is presented in Figure 1.

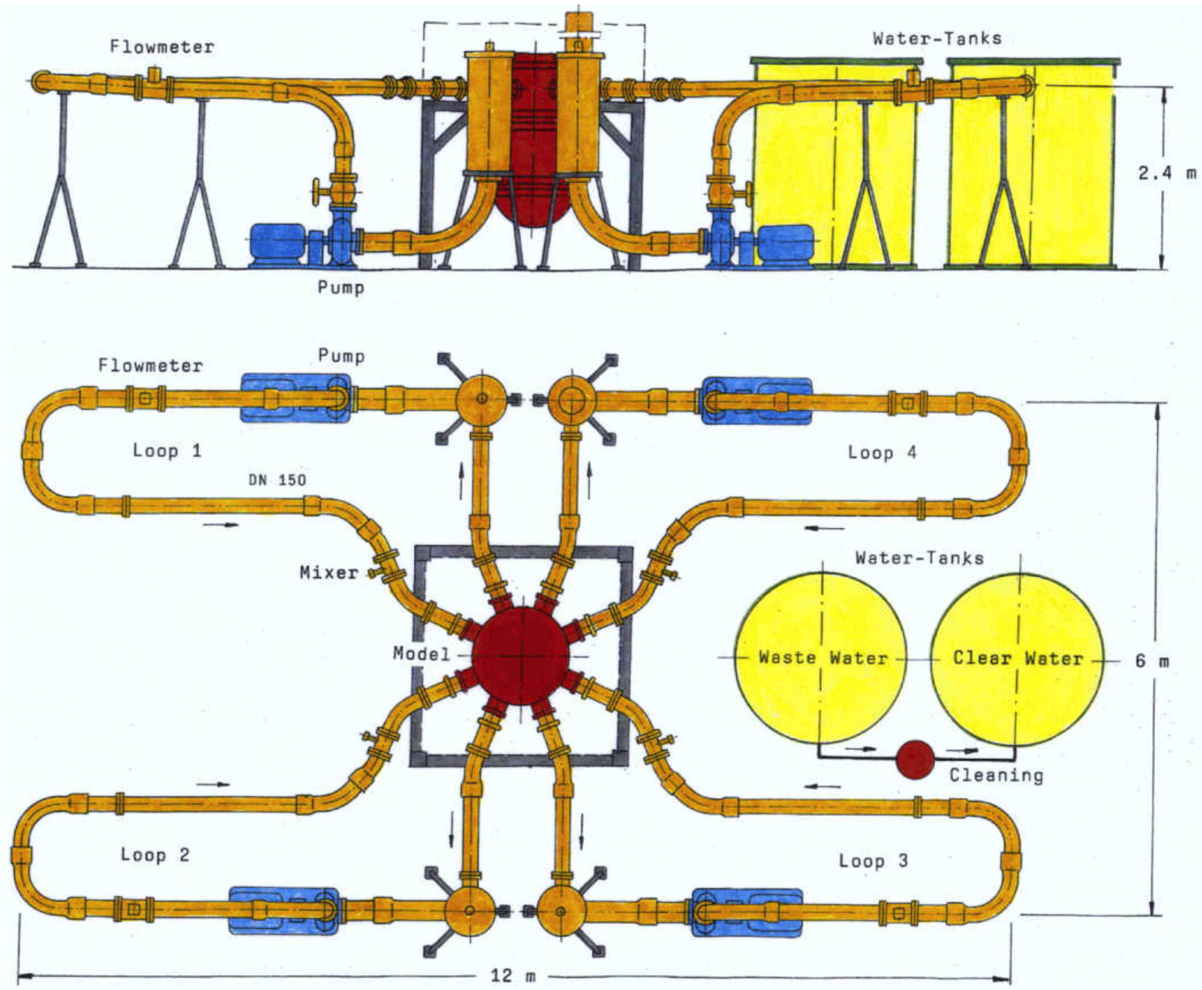

Figure 1. Schematic view of the ROCOM test facility [4].

Sugar and salt are used to alter the density and electric conductivity of fluid injected to a specified cold leg, so that its mixing can be measured by means of electric conductivity sensors. This can be used for simulating overcooled or under-borated slugs of the coolant. Special wire-mesh sensors that allow high-resolution measurement of the transient salt or brine concentration with regard to space and time are installed into the whole of the pressure vessel downcomer and the core inlet plane.

The measurements obtained from the test facility are described by a dimensionless mixing scalar, which characterises the local instantaneous share of fluid originating from the specified cold leg. The mixing scalar $\Theta_{x,y,z}(t)$ is calculated by relating the local instantaneous

conductivity $\sigma_{x,y,z}(t)$ to the amplitude of the conductivity change at a reference point (σ_1) according to the formula

$$\Theta_{x,y,z}(t) = \frac{\sigma_{x,y,z}(t) - \sigma_0}{\sigma_1 - \sigma_0} \qquad (1)$$

The lower reference value σ_2 is the initial conductivity of the water in the test facility before starting the experiment. For comparison to the PKL experiments, the corresponding temperature distribution can be reproduced from the mixing scalar using weighted interpolation between the average temperature of the intact coolant loops $T_{2\text{-}4}$ and the temperature of the broken loop T_1:

$$T_{x,y,z} = \Theta_{x,y,z}\left(T_1 - T_{2-4}\right) + T_{2-4} \qquad (2)$$

2.1 ROCOM test 2.2

The ROCOM test 2.2 was performed under transient conditions. The main objective was the assessment of influence of changing mass flow rate in the non-affected loops on the mixing pattern inside the reactor pressure vessel; earlier tests at the ROCOM facility had showed that varying the boundary conditions caused a transition from a sector-shaped temperature distribution to a nearly-homogeneous temperature distribution.

The initial conditions of the test are summarized in Table 1. The experiment was carried out so that the equal flow rates were first established in loops 2 through 4, and then, at time instant zero, injection was started to loop 1 and at the same time the decrease of flow rates in the other loops was commenced. The measured loop flow rates during the experiment are presented in Figure 2.

Table 1. Initial conditions of the ROCOM test 2.2.

Loop	1	2	3	4
Normalized volume flow rate [-]	0.0	12.2	12.2	12.2
Volume flow rate [l/s]	0.0	6.27	6.27	6.27
Relative density [-]	1.12	1.00	1.00	1.00
Temperature [°C] (PKL)	153	236.1	236.1	236.1

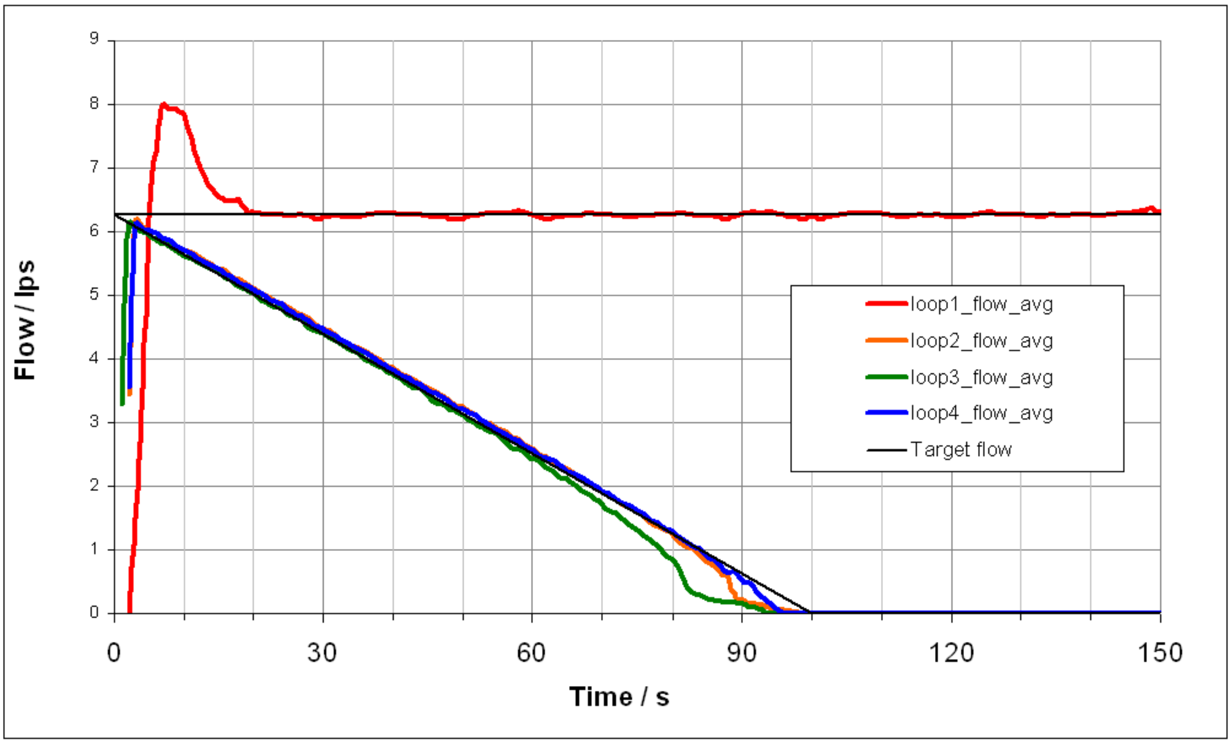

Figure 2. Measured loop flow rates in the ROCOM test 2.2 /8/.

3. TRACE MODEL OF THE ROCOM PRESSURE VESSEL

The TRACE model of the ROCOM test facility used in this work consists of the reactor pressure vessel starting from the cold legs up until the beginning of the hot legs. The pressure vessel is modelled using two VESSEL components, the cold and hot legs using PIPE components, and FILL and BREAK components are used to define the boundary conditions on the inlet and outlet sides respectively. The RPV is the divided into two VESSEL components in order to achieve local mesh refinement in the lower plenum.

The TRACE model of the facility as seen through the graphical interface SNAP is presented in Figure 3.

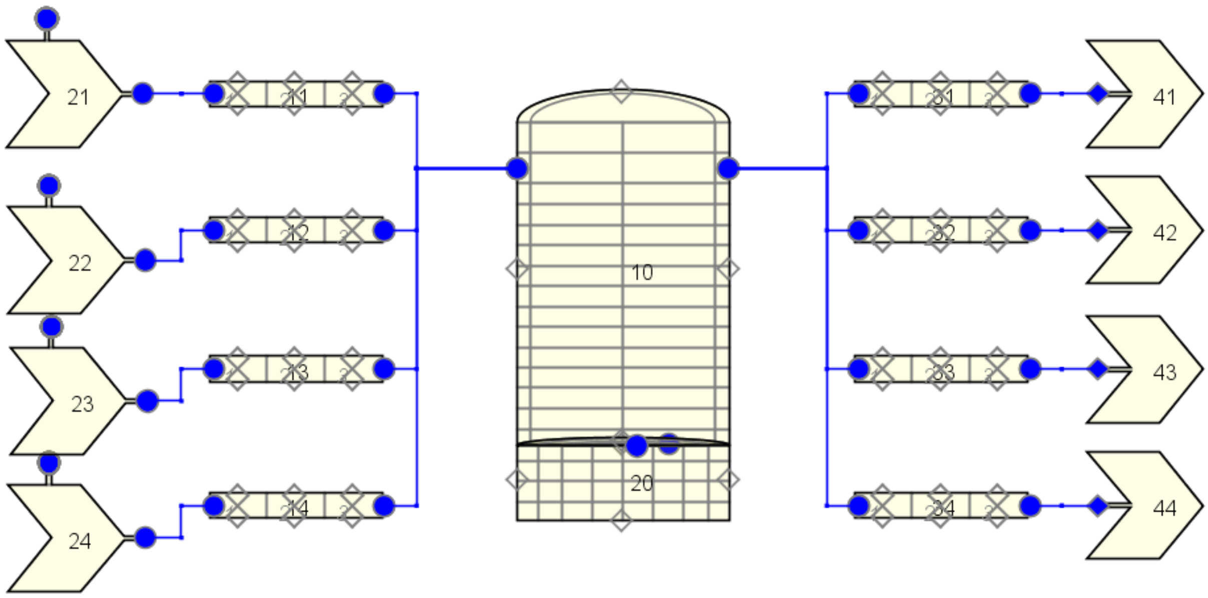

Figure 3. TRACE model of the ROCOM facility.

Since TRACE is not capable of connecting a one dimensional pipe component to multiple cells of a three dimensional vessel component, the inner diameter of the cold legs determines the minimum mesh scale that can be used for the pressure vessel — connecting a cold leg to a too small vessel node would cause unrealistic throttling of the inlet flow. On the other hand, validation calculations such as the one under discussion have to be performed using similar meshings to those that would be used in real analysis applications. Since the condition imposed by the inlet diameter results in a maximum of 24 calculation cells in the azimuthal direction, which is already a somewhat large number for a system-scale analysis, this limitation is hardly of concern.

The axial meshing is set up so that:

- The inlet (and outlet) cells have centre-point at the correct elevation, and the cell height is in reasonable proportion to the length in the azimuthal direction
- 10 axial cells cover the area of the downcomer wire-mesh sensor measurements
- All the cell heights are in mutually reasonable proportions

This leads to 15 axial cells in the downcomer region.

Within the radial direction, one cell suffices for the downcomer, and also only one cell is used for the core region because the core flow distributions are not of interest in the present work

(there are no measurements in core region of the ROCOM facility). The lower plenum is modelled with another VESSEL component, with 4 cells in the axial direction, 4 cells in the radial direction, and 24 cells in the azimuthal direction. The additional radial cells compared to the upper part of the RPV are needed to properly model the sieve drum. Volumetric and surface porosities were set as so to roughly emulate the half-spherical shape of the lower plenum with the cylindrical grid.

The nodalization of the reactor pressure vessel is illustrated from side in Figure 4 and from top in Figure 5. The node sizes are listed in Tables 2 through 5. The volumetric porosities in the lower plenum are listed in Table 6.

The loss coefficients of the sieve drum and the core support plate are very difficult to estimate without measurements. In the absence of a better estimate, we use the formula presented by Idel'Chik [11] for perforated plates. This gives the loss coefficient in the form of

$$\zeta = \left(\zeta_0 + \lambda \frac{l}{D_\mathrm{h}} \right) \frac{1}{f^2}, \tag{3}$$

with the constant ζ_0 calculated as

$$\zeta_0 = \left(0.5 + \tau \sqrt{1-f} \right)(1-f) + (1-f)^2, \tag{4}$$

where τ is a coefficient dependent on l/D_h. This gives the loss coefficients $\zeta = 36$ for the sieve drum, and $\zeta = 5$ for the core support plate[1].

[1] The values used in calculation of these calculations are:
Drum thickness $l = 8$ mm, drum hole diameter $D_\mathrm{h} = 15$ mm, drum porosity $f = 21\%$, friction coefficient $\lambda = 0.02$
Core support plate thickness $l = 106$ mm, hole diameter $D_\mathrm{h} = 38$ mm, drum porosity $f = 43\%$, friction coefficient $\lambda = 0.02$

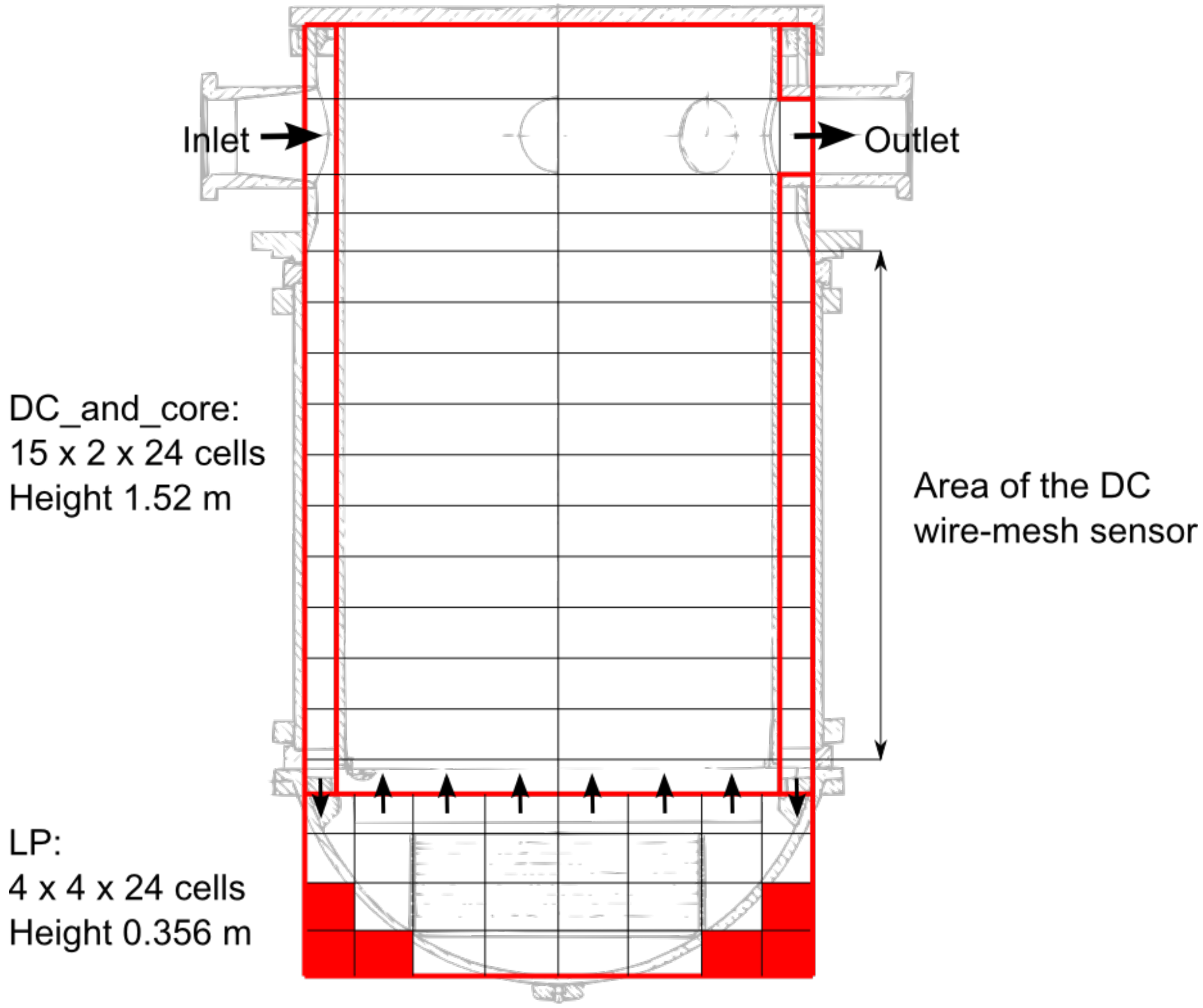

Figure 4. Side view of the RPV nodalization in the TRACE model. The no-flow edges are displayed in red.

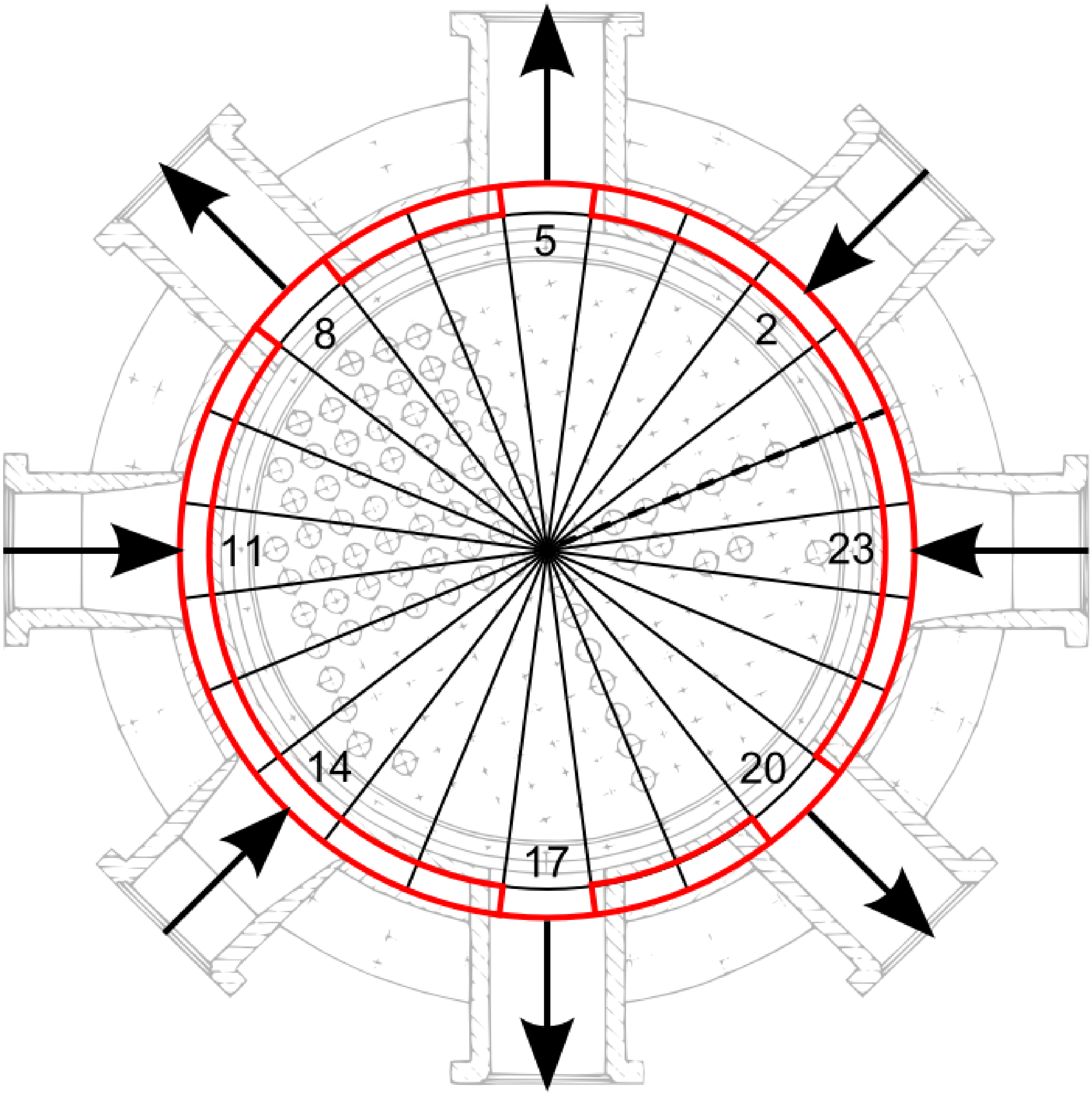

Figure 5. Top view of the RPV nodalization. The thick red lines represent the no-flow edges at the axial level of the RPV inputs and outputs. Marked also are the cell numbers within the azimuthal direction for the inlet and outlet cells.

Table 2. Axial nodalization of the downcomer and core region.

#	Δz	z bottom	z top
15	0.1440	1.3761	1.5201
14	0.1440	1.2321	1.3761
13	0.0987	1.1334	1.2321
12	0.0987	1.0347	1.1334
11	0.0964	0.9383	1.0347
10	0.0964	0.8419	0.9383
9	0.0964	0.7455	0.8419
8	0.0964	0.6491	0.7455
7	0.0964	0.5527	0.6491
6	0.0964	0.4563	0.5527
5	0.0964	0.3599	0.4563
4	0.0964	0.2635	0.3599

3	0.0964	0.1671	0.2635
2	0.0972	0.0699	0.1671
1	0.0699	0.0000	0.0699

Table 3. Radial nodalization of the downcomer and core region.

#	Δr	r in	r out
1	0.4370	0.0000	0.4370
2	0.0630	0.4370	0.5000

Table 4. Axial nodalization of the lower plenum.

#	Δz	z bottom	z top
4	0.076	0.2800	0.3560
3	0.095	0.1850	0.2800
2	0.095	0.0900	0.1850
1	0.090	0.0000	0.0900

Table 5. Radial nodalization of the lower plenum.

#	Δr	r in	r out
1	0.1430	0.0000	0.1430
2	0.1430	0.1430	0.2860
3	0.1155	0.2860	
4	0.0985	0.4015	0.5000

Table 6. Volumetric porosities in the lower plenum.

#Z / #r	4	3	2	1
4	0.6	0.5	0.5	0.5
3	0.3	1.0	1.0	1.0
2	0.0	0.5	1.0	1.0
1	0.0	0.0	0.4	0.9

Because TRACE obviously doesn't contain fluid material properties for the sugar/water solution used in the real test, the simulation was carried out in thermodynamic conditions corresponding to the PKL tests rather than the atmospheric conditions of the ROCOM tests. This means that the geometry and flow rates are taken from the actual ROCOM test, but pressure is considerably higher than the pressure at the ROCOM facility (3.8 MPa), and the density differences are achieved through heating of the fluid rather than through altering its chemical composition. Since thermal conductivity of the fluid plays insignificant role in the simulated scenario, the results are expected to correspond to the measured "temperatures" reasonably well.

The time-dependent flow velocities and PKL temperatures were used as inflow boundary conditions, and constant PKL pressure as the outflow boundary condition. The initial

boundary conditions are listed in Table 7, and the time-dependent inflow velocities based on the measured flow rates are presented in Figure 6.

The assumption of the constant pressure at the outlet is not completely realistic, since the pressure is produced by the circulation pumps, which in the transient scenario are not working at constant power. However, keeping in mind that the reactor pressure vessel is filled with (essentially incompressible) liquid for the whole duration of the transient, the outlet flow should at all times correspond to the inlet flow rate, and thus the small errors in the outlet pressure should cause no visible effect in the simulation results.

Table 7. Initial conditions used in the TRACE calculation.

Loop	1	2	3	4
Mass flow rate [kg/s]	0.0000	5.7436	5.7436	5.7436
Temperature [K]	426.15	509.24	509.24	509.24
Outlet pressure [MPa]	3.8	3.8	3.8	3.8
Relative density	1.12	1.00	1.00	1.00

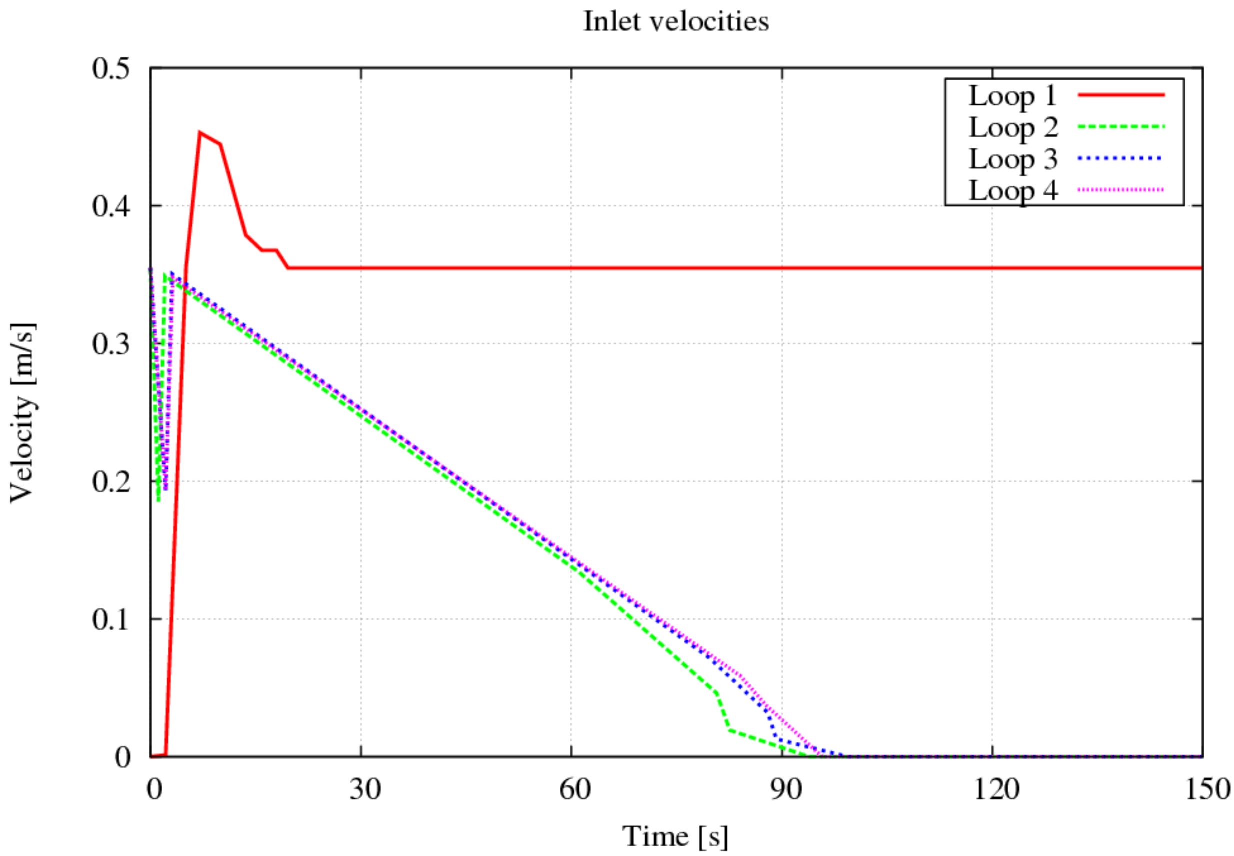

Figure 6. Inlet flow velocities for the TRACE calculation.

4. SIMULATION RESULTS

Snapshots of the simulated temperature distributions in the downcomer are presented alongside the experimental results in Figure 7 and in Figure 8. Likewise, snapshots of the simulate temperature distributions at the core inlet plane are presented together with the experimental distributions in Figure 9. The simulated distributions have been sampled from the cylindrical calculation grid to match the locations of the core inlet passages for easy comparison to the experimental data; there is still only 3 radial rings x 24 azimuthal sectors = 72 different data points from the simulation results.

The initial phase of the transient, i.e. penetration of the cold injection water jet from loop number 1 into the pressure vessel is presented in Figure 7. In the experimental results, the shape of the jet, and especially its tip, is fluctuating while it progresses through the height of the downcomer. This effect cannot be captured by TRACE due to the relatively large cell sizes and time-step sized used in the simulation.

Figure 8 shows five snapshots covering the rest of the duration of the transient. TRACE is able to predict the filling of the downcomer with cold water reasonably well, i.e. an interface between the lower region of cold water and the upper region of hot water can be recognized, and this interface rises roughly at the same velocity as in the experiment. However, the interface becomes more and more blurry as the simulation proceeds and heat diffuses from the hot upper part to the cold lower part, decreasing the temperature in the upper part and rising the temperature at the lower part ahead of time. In the experimental results a strict division into the lower cold part and the upper hot part is clearly visible throughout the experiment, unlike in the TRACE simulation.

The simulated core inlet distributions, presented in Figure 9 are also in a reasonable agreement with the experimental data. Although the core inlet flow distribution stays practically homogeneous throughout the simulation, the benefit of the more detailed modelling of the lower plenum and the sieve drum is still evident from the snapshots of the earlier stages of the transient: the sieve drum causes the cold water flow to initially spread in the outer part of the lower plenum instead of being directed straight towards the core inlet.

For a more quantitative assessment, characteristic integral variables can be selected. For the present purpose, such variables are the average and minimum temperature within different parts of the pressure vessel. While the average temperatures should correspond fairly well to the measurements since they are governed by the mass and energy balances in a rather straight-forward way, the minimum temperature is more prone to be biased by both physical and numerical diffusion in the simulation code.

In Figure 10 and in Figure 11 the average temperature and the minimum temperature in the downcomer and at core inlet plane, as calculated by TRACE, are compared to the measurements from the ROCOM facility. The qualitative behaviour of the curves is again similar between the experimental and calculated results, but on a quantitative level, the simulated temperatures remain much higher than the experimental ones.

The deviations between the simulated and experimental curves in Figure 10 and in Figure 11 are mainly caused by the coarse modelling — that is typical for system-scale analyses — of the downcomer and the lower plenum, which enhances mixing through the fact that constant properties (i.e. perfect mixing) are assumed within a calculation cell, and also partly the numeric diffusion from the semi-implicit method that TRACE uses for the solution of the fluid flow field equations. This enhanced mixing then results in averaging-out the local

temperature minima, and also causes the average temperatures to stay above the experimental values; in the simulation the whole contents of the downcomer — even above the region of the wire mesh sensors — become mixed at least to a degree, while in the experiment the downcomer remains thermally stratified for the duration of the transient. As a consequence of this, in the simulation there is more heat in the downcomer wire mesh sensor region (i.e. the heat that in the experiment remains accumulated in the top part of the downcomer) at each instant, explaining why the simulated average temperatures stay well above the experimental values. To support this conclusion, the following verification calculation can be made.

In the experiment, the cold water level reaches the upper end of the downcomer wire mesh sensor region at 120 seconds (see Figure 8). At this point the average temperature in the downcomer is about 170 °C (Figure 10), corresponding approximately to value 0.80 of the mixing scalar defined by Equation (2). If at this point the mixing scalar (i.e. salinity in the experiment) would be evenly distributed into the whole downcomer area, including also the top part above the wire mesh sensor, the mixing scalar would get value of around 0.50, corresponding to temperature ≈ 200 °C. This demonstrates that the heat accumulated above the wire mesh sensor can account for the whole of the discrepancy between the simulated and the experimental average downcomer temperature.

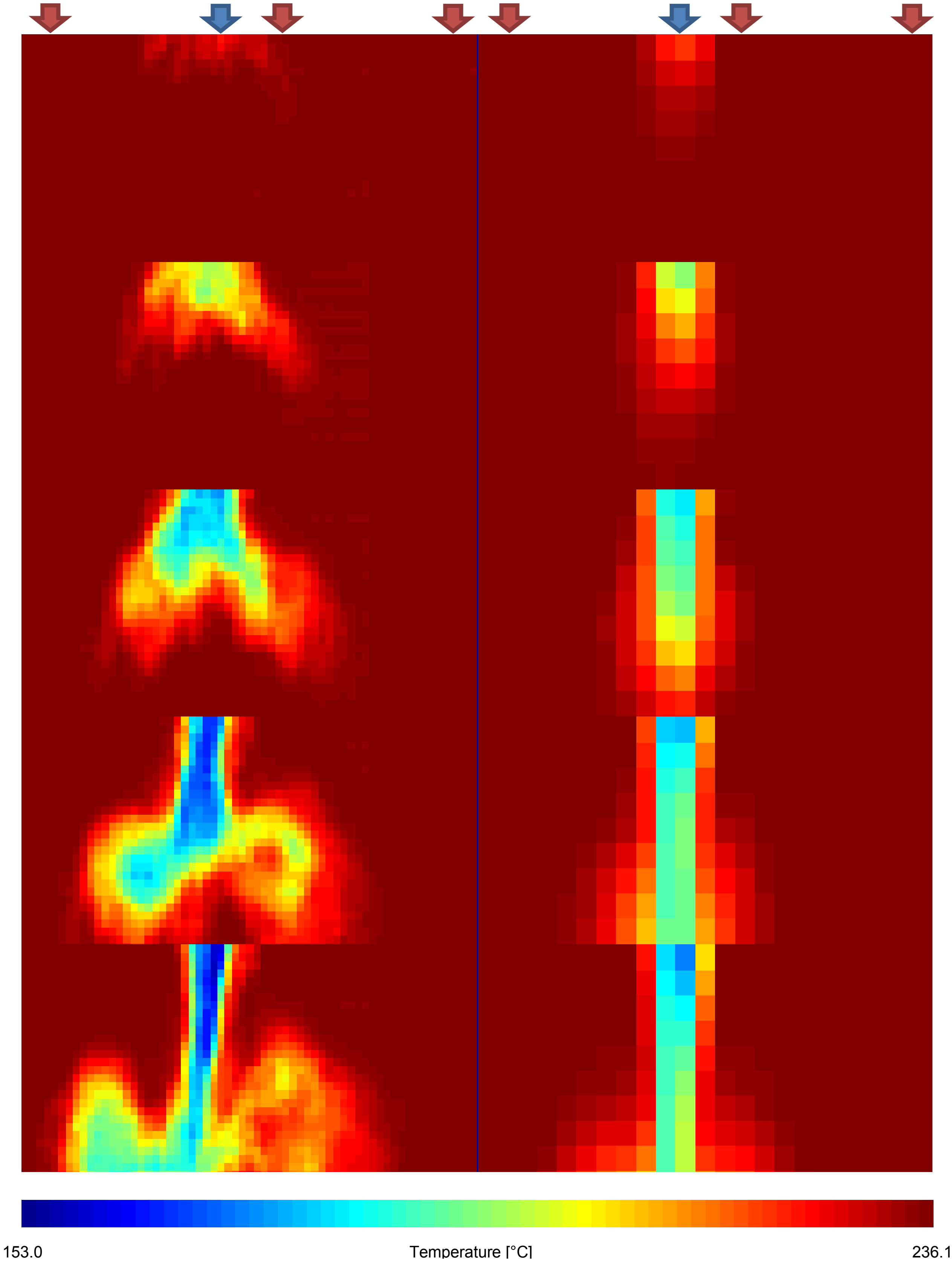

Figure 7. Snapshots of the temperature distributions in the unwrapped downcomer during the initial phase of the transient, with one second (1 s) interval. Experimental data on left and TRACE calculations on right. Approximate locations of the four RPV inlets are marked by arrows.

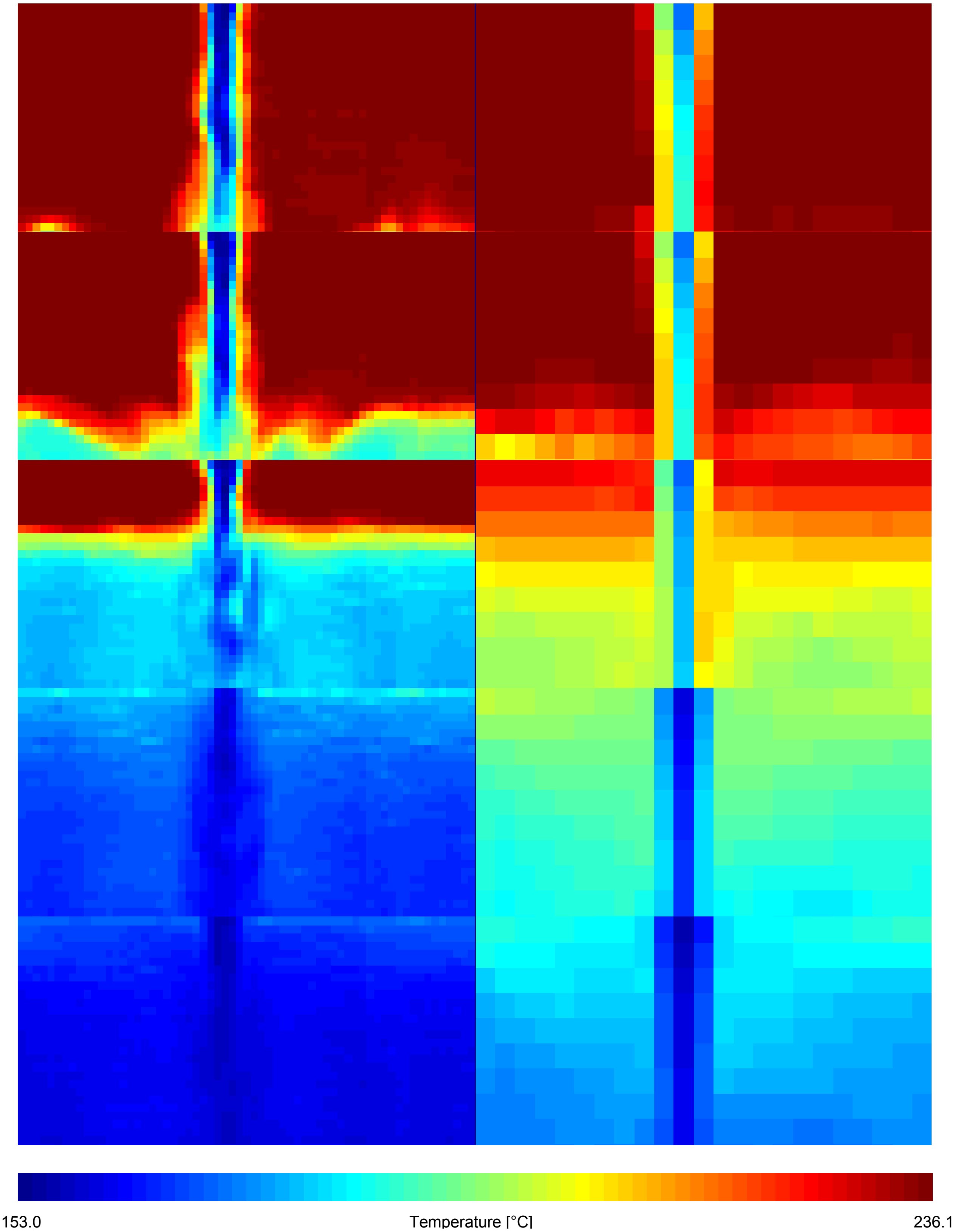

Figure 8. Snapshots of the temperature distributions in the unwrapped donwncomer at time instants 30 s, 60 s, 90 s, 120 s and 150 s. Experimental data on left and TRACE calculations on right. Approximate locations of the four RPV inlets are marked by arrows.

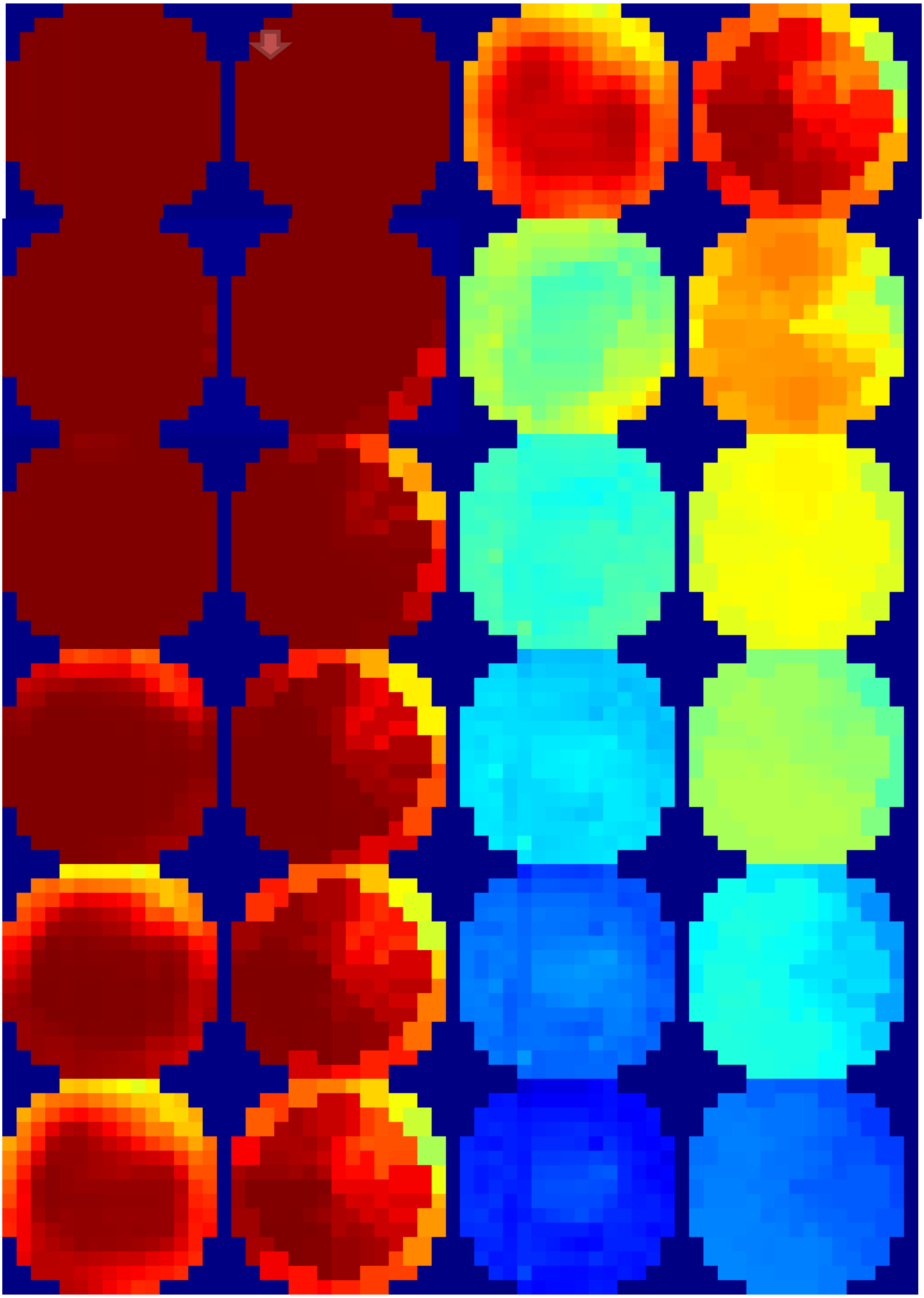

Figure 9. Snapshots of the core inlet distributions from time instants 10, 11, 12, 13, 14, 15 (in the left column) and 16, 30, 60, 90, 120, 150 (in the right column). Experimental data on left and TRACE calculations on right. For the TRACE results, the temperatures values have been sampled to match the location of each core inlet passage from the cylindrical calculation grid used in the simulation.

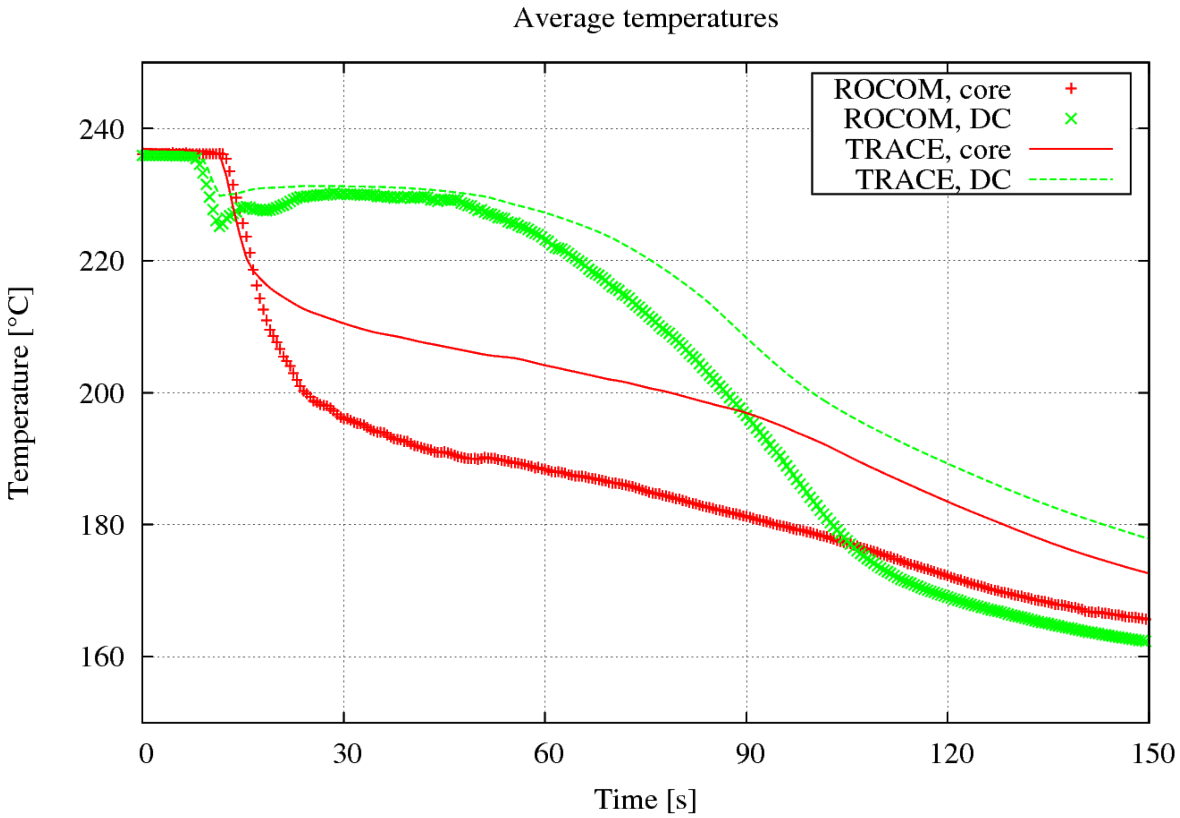

Figure 10. Average temperatures at the core inlet plane, the inner downcomer and the outer downcomer.

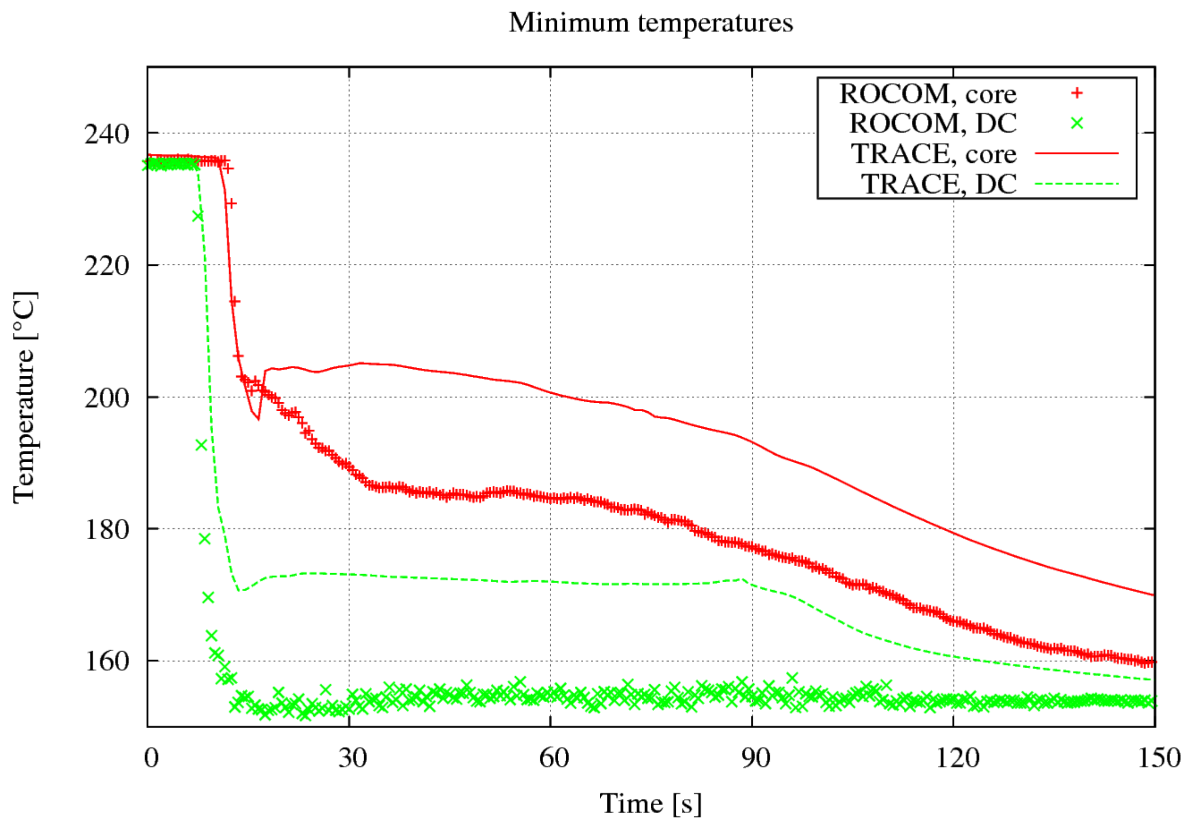

Figure 11. Minimum temperatures at the core inlet plane, the inner downcomer and the outer downcomer.

5. SUMMARY

The transient ROCOM test 2.2 has been calculated with the system-code TRACE v 5.0 Patch 3, using the new Vessel junction component to divide the reactor pressure vessel into two distinct cylindrical grids and thus obtaining local grid refinement within the lower plenum.

The simulation results obtained with TRACE are qualitatively in a fairly good agreement with the experimental measurements, but quantitatively there is clearly more diffusion in the calculated temperature distributions. This diffusion seems to arise mainly from the coarse nodalization used in the simulation, and also partly from the numerical scheme used to solve the fluid flow field equations. However, despite the over-prediction of the average and minimum temperatures that are caused by this increased diffusion, the simulation results obtained here are in such an agreement with the experimental data that can be expected from a system-scale analysis.

The grid refinement within the lower plenum made it possible to model the internals of the lower plenum, such as the sieve drum, more reasonably. These enhancements in the modelling should manifest themselves in the core inlet distribution, which is actually the main motivation for three-dimensional modelling of the reactor pressure vessel in the first place; in a real-life safety analysis application we are interested in any non-uniformities in the core inlet distributions of temperature or boron concentration as they have a direct effect on the neutronic behaviour of the nuclear reactor core. Even though the transient case simulated here is such that the core inlet distribution remains largely uniform, the benefit of the grid refinement within the lower plenum became evident.

6. REFERENCES

1 The RELAP5-3D Code Development Team: RELAP5-3D Code Manual Volume I: Code Structure, System Models and Solution Methods, Idaho National Laboratory, INEEL-EXT-98-00834, Revision 4.0 (2012)

2 G. Geffraye et al.: CATHARE 2 V2.5_2: A single version for various applications, Nuclear Engineering and Design, **241**, pp. 4456 – 4463 (2011).

3 U.S. Nuclear Regulatory Commission, TRACE V5.0 User's Manual (2012).

4 S. Kliem et al.: Experiments at the mixing test facility ROCOM for benchmarking of CFD codes, Nuclear Engineering and Design, 238, pp. 566 – 576 (2008)

5 OECD/NEA PKL-2 Project, http://www.oecd-nea.org/jointproj/pkl.html, (Retrieved 9th October 2012).

9 S. Kliem & R. Franz, Quick-look report of the ROCOM Tests 1.3, 2.1 and 2.2 conducted within the OECD PKL2 Project, Institute Report HZDR\FWO\2012\02, Helmholtz Zentrum Dresden Rossendorf (2012)

10 S. Kliem & R. Franz, OECD PKL2 Project — Final Report on the ROCOM Tests, Institute Report HZDR\FWO\2012\03, Helmholtz-Zentrum Dresden-Rossendorf (2012).

11 I. E. Idel'Chik: Handbook of Hydraulic Resistance – Coefficients of Local Resistance and of Friction, AEC-TR-6630, U.S. Department of Commerce, National Technical Information Service (1960).

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11. ABSTRACT (200 words or less)

Experimental data on non-uniform flows in reactor pressure vessel downcomer has been recently produced at the ROCOM test facility at Helmholtz-Zentrum Dresden-Rossendorf, within the framework of the OECD/PKL2 project. This data can be used for validation of three-dimensional thermal-hydraulic codes.

The transient ROCOM test 2.2 is calculated with the system-code TRACE v 5.0 Patch 3, using the new vessel junction component in order to produce local calculation grid refinement within the lower plenum.

The simulation results obtained with TRACE are qualitatively in good agreement with the experimental measurements, but quantitatively there is more diffusion in the calculated temperature distributions and some bias from the outlet boundary condition utilized in the simulation.

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