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Nodalization of MISTRA facility for ISP-47 experiment using lumped parameter code COCOSYS

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1. Introduction

The ISP-47 computer simulation experiment aimed to determine the capabilities of lumped parameter and Computational Fluid Dynamics (CFD) codes in the analysis of thermo-hydraulic phenomena associated with the containment of nuclear reactors. Researchers from more than 20 institutions in 14 countries participated in the experiment assessment, carrying out independent modeling using different computational tools and comparing the results obtained with experimental data from three test facilities. [1]
The objective of this study is to carry out a modeling of one of these experiments, more specifically one of those carried out at the MISTRA facility, and compare the results with those obtained by other participants in ISP-47. For modeling, temperature, pressure and condensation rate data were extracted from the simulation and then compared with those from the reference [2]. By comparing the results, it is possible to evaluate the activities and steps necessary to qualify users of the COCOSYS code.

2. Methodology

The MISTRA facility consists of a vertical cylinder with a flat cap and rounded base with an internal volume of approximately 99.5 m³, isolated from the external environment by a layer of rock wool. Inside, the MISTRA containment does not have temperature regulation on its walls, but has three controlled temperature condensers with an accuracy of ± 1°C. The experiment under study has five phases:

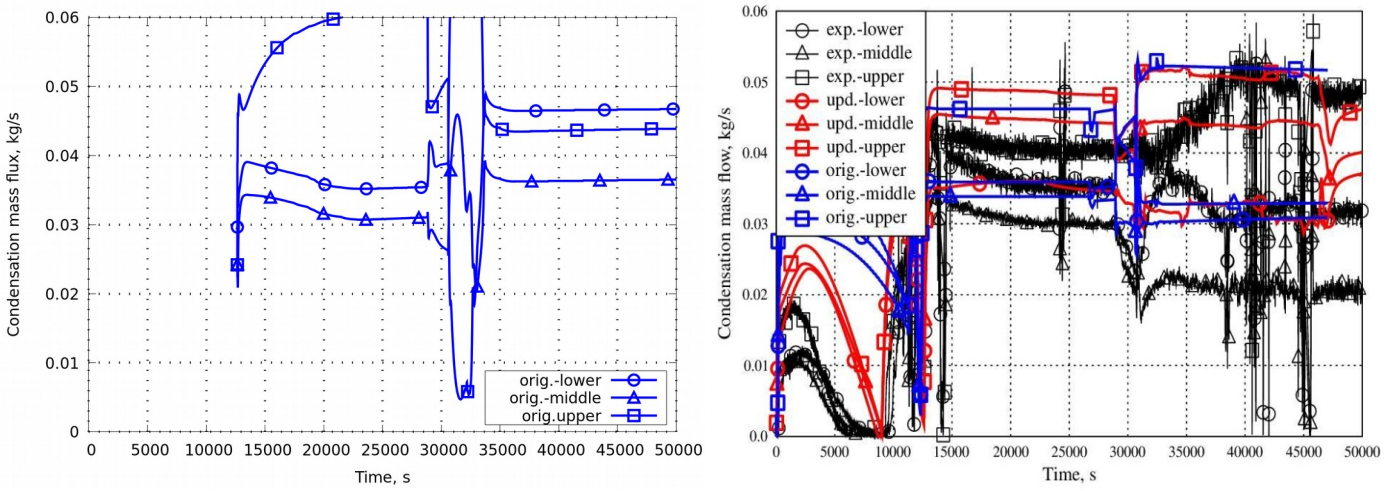
- **0 to 11300 s:** steam injection into the dead volume between condensers and walls in order to regulate wall temperature. During this phase the temperature of the condensers was gradually raised from room temperature to 134°C;
- **11250 to 12630 s:** injections shutdown and allowing condenser to cool to a temperature of 115°C, which is maintained until the end of the experiment;

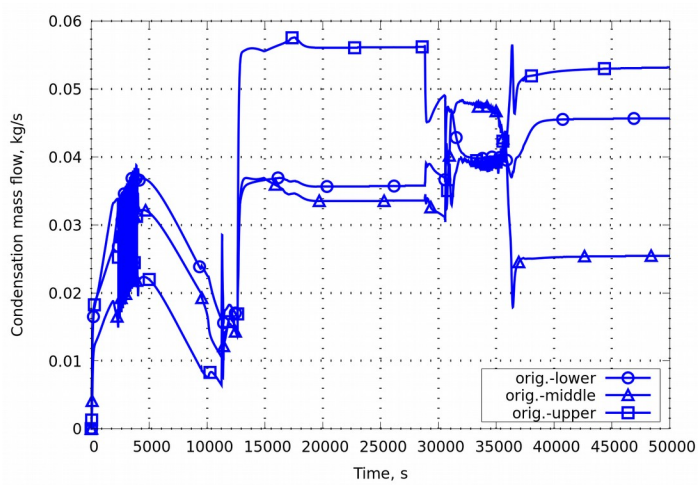
- **12630 to 28835 s:** steam injection aimed at the center of the containment;
- **28835 to 30575 s:** injection of steam and helium in the center of the containment; and
- **30575 s onwards:** steam injection into the center of the containment.

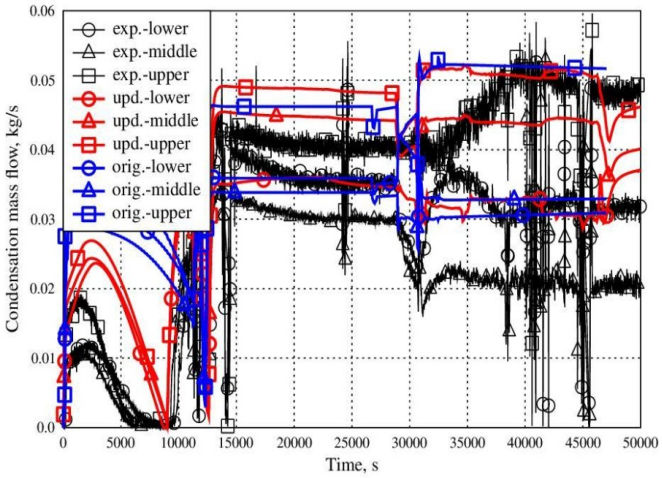
Since the first two steps refer to the establishment of boundary conditions for the experiment, it was decided to start the COCOSYS simulation in the third phase, establishing the appropriate boundary conditions in the input. Information on the characteristics of the MISTRA facility and experiment parameters were obtained from references [2] and [3], opting for the "original nodalization" of reference [2] for simplicity, and available literature was consulted to determine material properties where necessary.

3. Results and Discussion

Following the determination of starting the simulation after the establishment of the boundary conditions, the temperatures and pressure obtained showed very good agreement with those found in reference [2]. On the other hand, the results related to the condensation mass flow showed greater divergences. This is probably related to the fact that condensation and the flow of water running down the walls are dependent on previous steps of the process. At the beginning of the simulation the walls would be "dry", and the condensation on these surfaces is different from the real condensation on a surface that is already covered by a film of water due to the previous stages of the experiment, as seen in Figure 1.

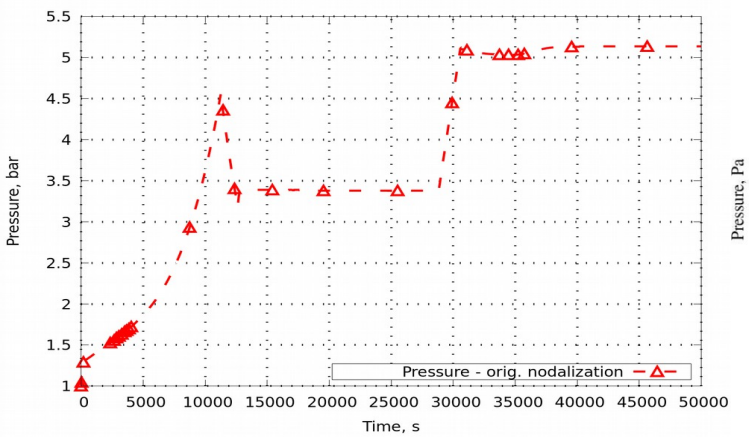


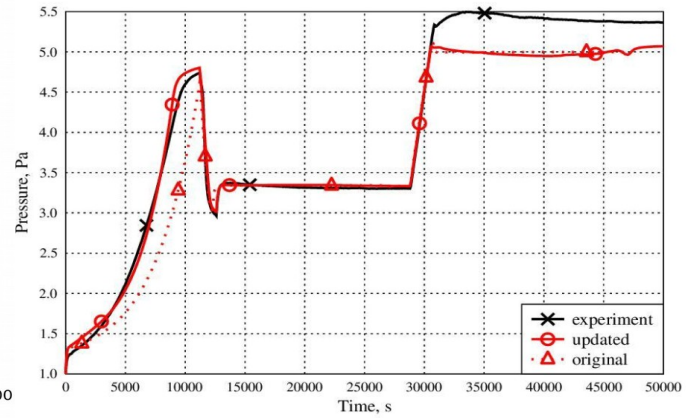




(a) (b)

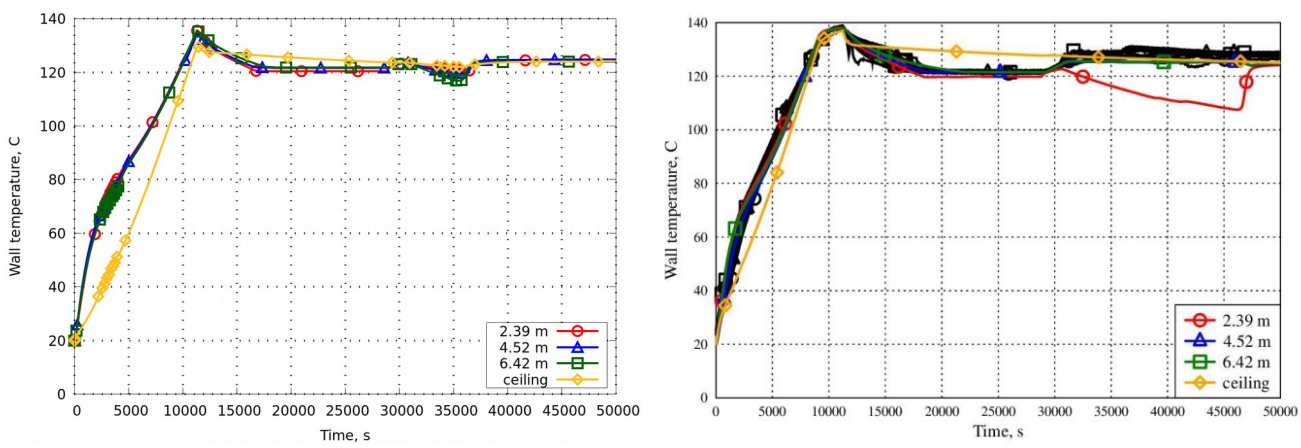
Figure 2: Updated evolution of condensation mass flow for ISP-47 experiment simulation starting at 0 s (a) and reference values taken from reference [2] (b).





(a) (b)

Figure 3: Temporal evolution of pressure simulation starting at 0 s (a) and reference values taken from reference [2] (b).



(a) (b)

Figure 4: Temporal evolution of wall temperature simulation starting at 0 s (a) and reference values taken from reference [2] (b).

4. Conclusions

Although the updated simulation presents similar behavior to the experimental data collected in MISTRA, condensation is often overestimated, and the simulation does not agree numerically with the pressure obtained after helium injection. It is believed that these discrepancies are due to an unsatisfactory modeling of steam distribution. Lumped parameter codes are less suitable for modeling gas distribution in containment, but the use of a special nodalization makes it possible to compensate for this deficiency. Future activities in this study include the development of a nodalization that better models the injection steam jet; an investigation of best modeling practices for materials behavior; and an evaluation of the influence of parameter combinations on simulation results. Such evidence will serve as a basis for defining the activities and steps to be followed to qualify users of the COCOSYS code.

References

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