TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Mechanical Science and Engineering Institute of Power Engineering Chair of Hydrogen and Nuclear Energy

EXPERIMENTAL INVESTIGATION OF THE DEVELOPING TWO-PHASE FLOW IN A SLIGHTLY INCLINED HEATED TUBE

F. Viereckl, C. Schuster, W. Lippmann, A. Hurtado

Motivation

The containment cooling condenser is a part of the passive decay heat removal chain of the KERENA reactor design. The system operates without the supply of external energy and is heated by the condensation of steam and driven by natural circulation.

The containment cooling condenser can enhance the reactor safety.

For the safe operation of this system, a reliable prediction with numerical codes is required. But numerical codes are not yet validated within the operating range of the containment cooling condenser.

The experimental investigation of the thermal hydraulic behavior concerning the containment cooling condenser is necessary.

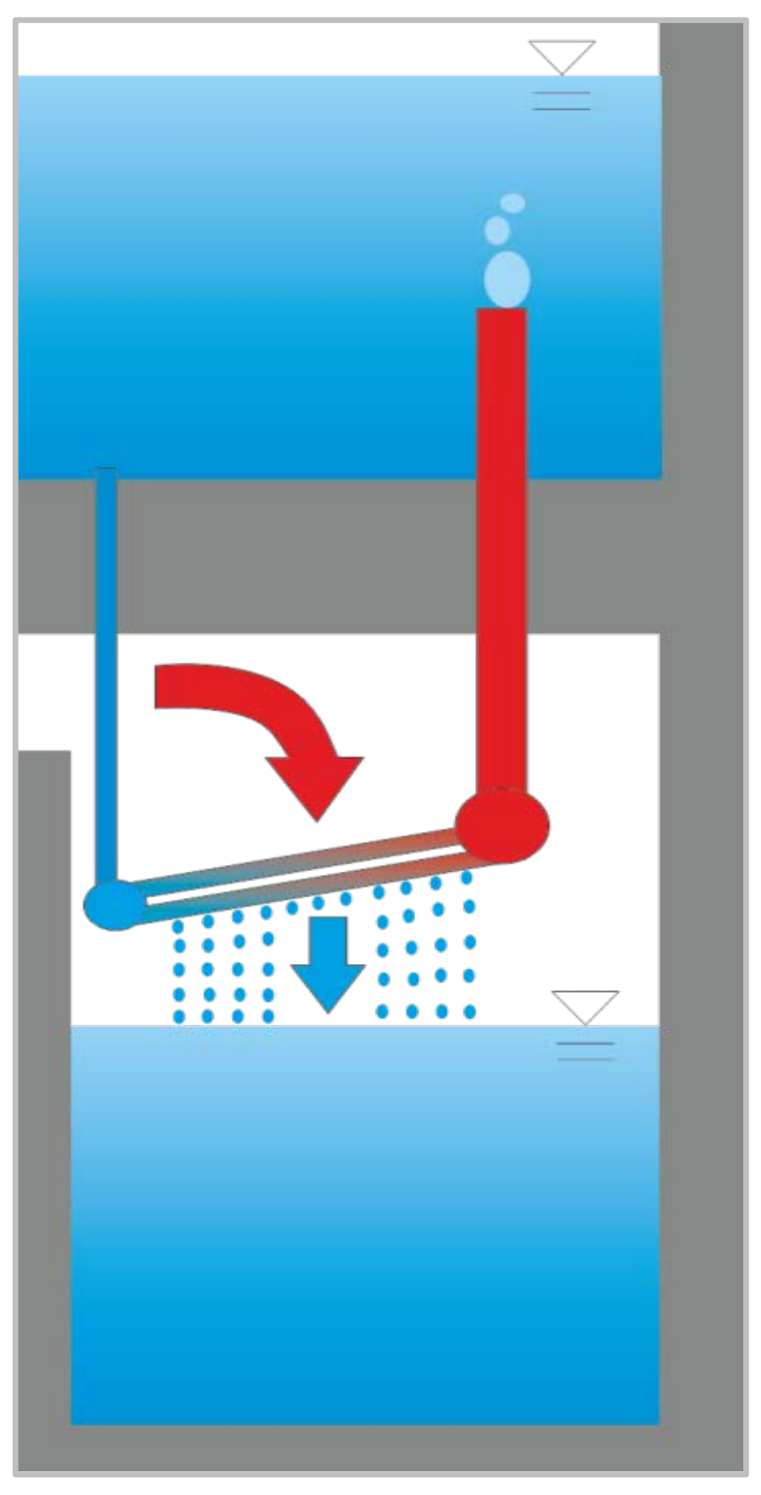

Fig. 1: Containment cooling condenser of the KERENA reactor

Purpose

The natural circulation loop in the containment cooling condenser operates at low pressure and saturation conditions. The heat is transferred through a slightly inclined tube bundle, inside which a two-phase flow develops (fig. 1).

The thermal hydraulic behavior of the developing two-phase flow is investigated experimentally at the test facility GENEVA, which provides geometrical and thermodynamic similarities to the containment cooling condenser.

With the experimental data, the thermal hydraulic behavior of a two-phase flow inside a slightly inclined tube can be described generically.

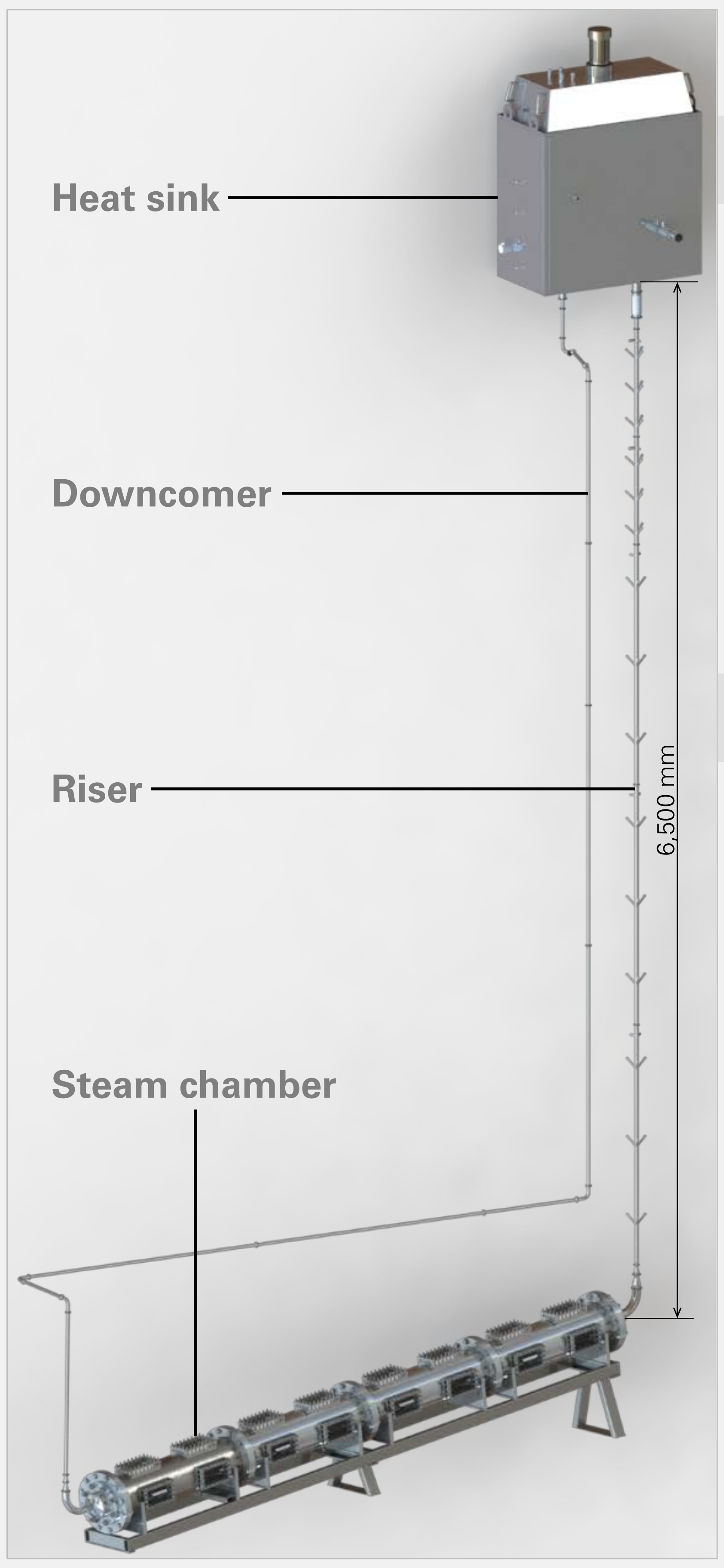

Fig. 2: 3D model of the test facility GENEVA

Test facility GENEVA

Instrumentation

The two-phase flow develops inside the slightly inclined tube, which is located in the steam chamber of the test facility GENEVA (fig. 2).

For a sufficient description of the thermal hydraulic behavior, the profiles of the temperature and void fraction are necessary.

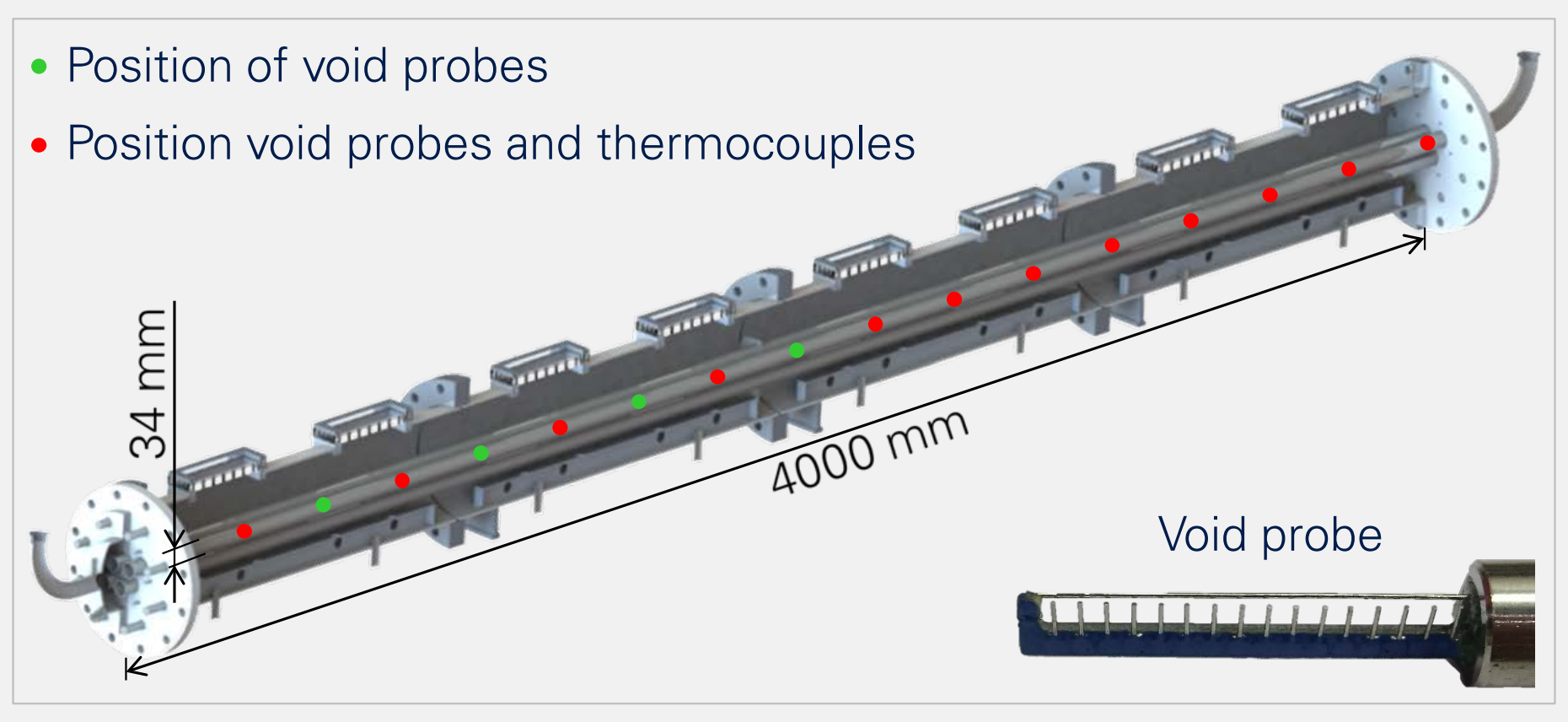

Fig. 3: Positions of the instrumentation concerning the developing two-phase flow in the steam chamber of the test facility GENEVA

For measuring the axial and radial temperature profile inside the tube, 48 thermocouples are implemented (fig. 3).

Concerning the axial and radial void fraction inside the tube, 16 conductivity probes each with 16 measuring points are implemented (fig. 3).

Experimental results

The adjustable parameters for the experiments are the power of two external evaporators (P) and the inlet temperature into the tube (ϑ).

The two evaporators provide steam to the steam chamber, where it condenses at the outside of the inclined tube. The latent heat drives the natural circulation. The inlet temperature into the tube can be adjusted by cooling the heat sink to realize stationary measuring points.

Figures 4 to 6 show an extract of the recent experimental results within this experimental matrix.

No.	1	2	3	4	5	6
P in kW	15	20	25	30	35	40
ϑ in °C	30 to 95	35 to 95	35 to 95	35 to 95	35 to 95	40 to 95

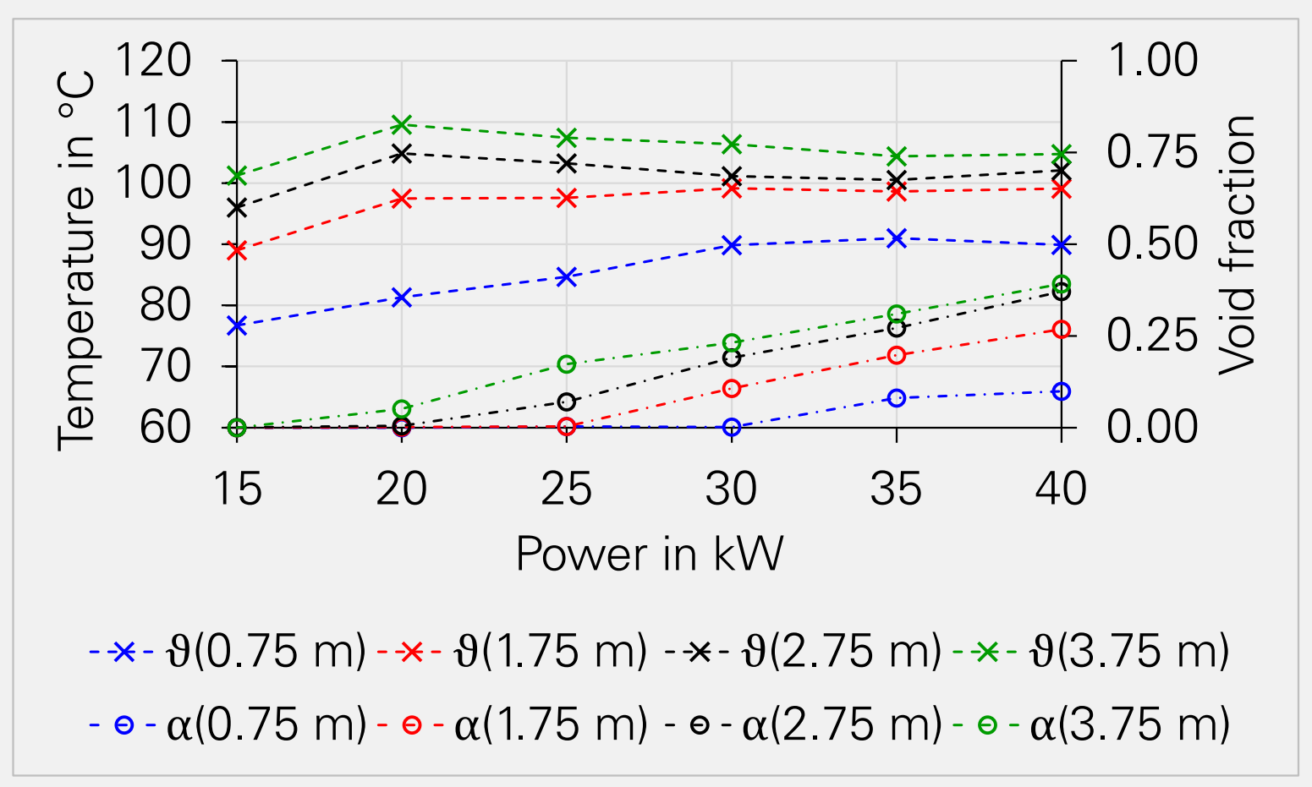

Fig. 4: Development of the temperature and void fraction depending on the evaporator power P and axial position

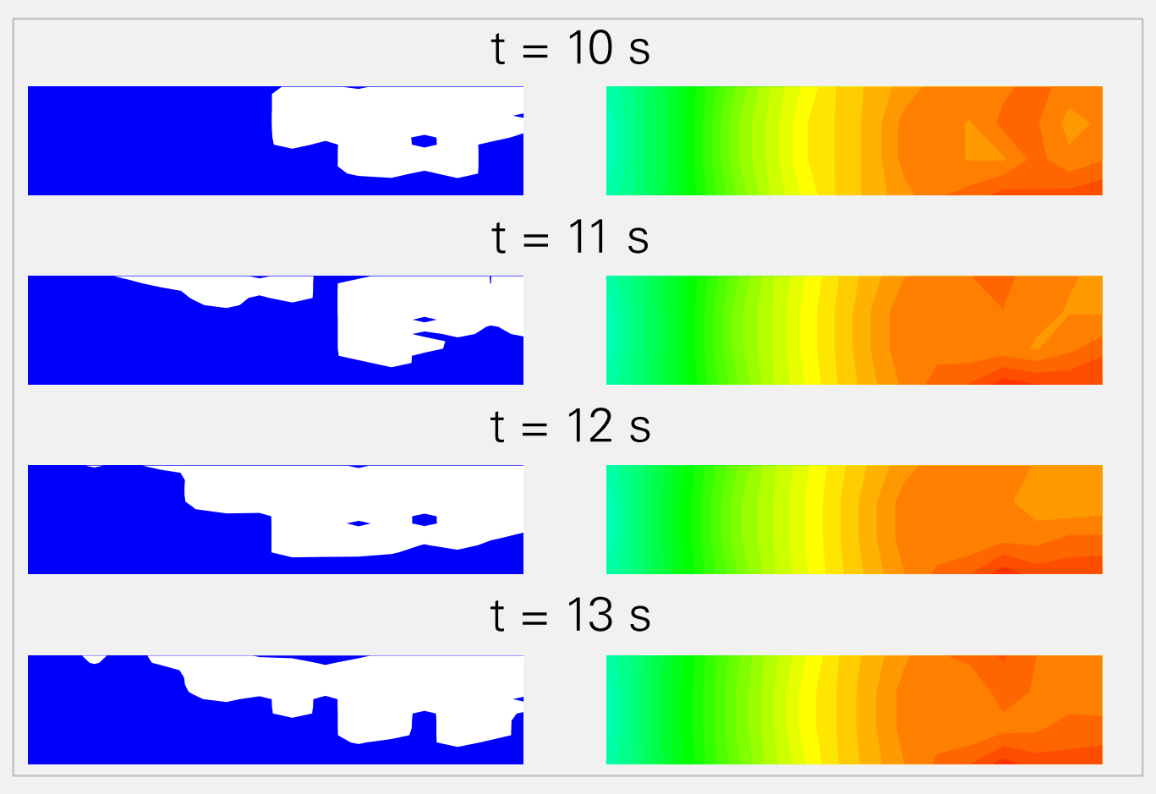

Fig. 5: Time-dependent profiles of the void fraction (left) and temperature (right) (P = 35 kW, ϑ = 95 °C)

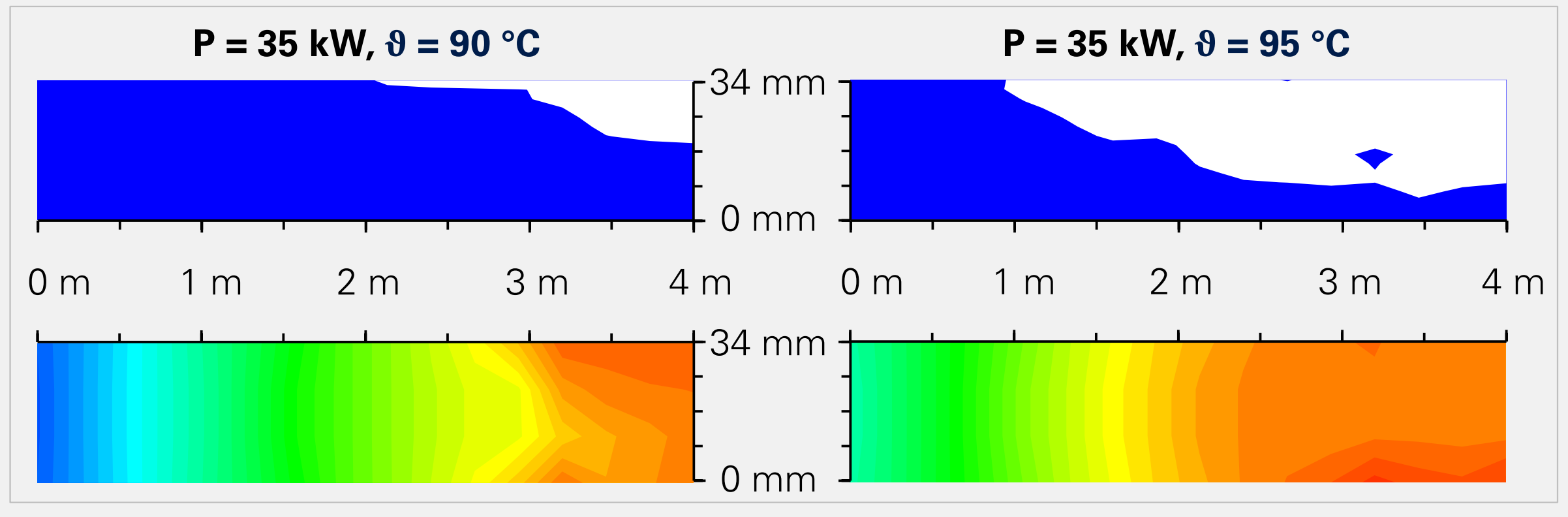

Fig. 6: Time-averaged profiles of the void fraction (top) and temperature (bottom) for experiments with the same evaporator power (P = 35 kW) and different inlet temperatures (ϑ)

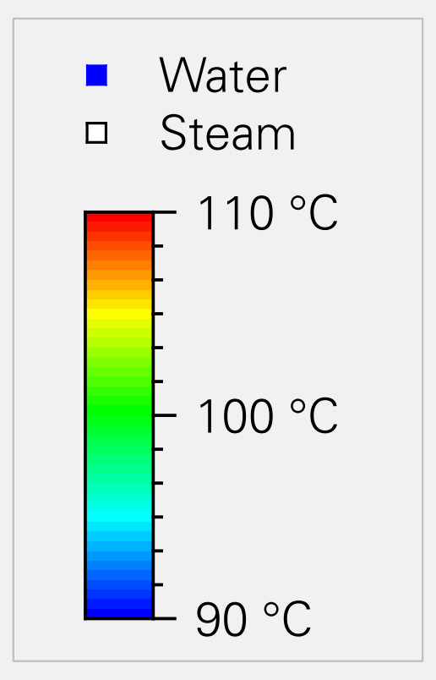

Fig. 7: Color legend (fig. 5 to 6)

Conclusion

The outlined experimental investigations of the developing two-phase flow in a slightly inclined tube at the test facility GENEVA contribute to a better comprehension of the thermal hydraulic behavior in passive systems and therefore to an enhancement of the safe operation of these systems.

A broad amount of experimental data with various initial conditions are available due to the dense and high quality instrumentation. With these experimental data, statements concerning the heat transfer and flow characteristics are possible.

Outlook

Additional experiments at the test facility GENEVA will be performed to investigate the thermal hydraulic behavior during condensation at the outside of the tube as well as to determine the influence of a tube bundle.

By these experimental data the theoretical descriptions of the investigated heat transfer in passive systems will be reviewed and, if it is necessary, revised as well as validated. In the end, a reliable description of the thermal hydraulic behavior of passive systems is available.

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CONTACT

Frances.Viereckl@tu-dresden.de
Christoph.Schuster@tu-dresden.de
Wolfgang.Lippmann@tu-dresden.de
Antonio.Hurtado@tu-dresden.de