

*Gravimetric measurement of water adsorption on heat exchangers as adsorbers or evaporators/condensers for water in the low pressure range.*

investigate the transport and distribution processes in the wet steam range, especially for flammable refrigerants. Here we analyze the influence of reduced refrigerant charge on the performance.

Together with manufacturers, we develop geometries that enable a significant reduction in refrigerant charge, thus further reducing potential hazards.

When using air as a heat source, a particular challenge is frost formation on the fin surface. We investigate surface modifications to reduce frost formation using experiments at different scales. For this purpose, we have several air channels with different flows at our disposal. Additionally high-resolution optical flow analysis is used to evaluate the performance and compare the simulations.

For thermally driven sorption heat pumps, test stands and simulation tools are available to design, determine and evaluate the heat transfer characteristics of adsorber heat exchangers and evaporator/condenser heat exchangers as well as the module performance.

*Cover photo: Bake-out of a heat pipe during the evacuation process.*

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# Efficient Heat Transfer in Buildings

Efficient heat exchangers provide an essential contribution to an energy efficient, compact and cost effective supply of heat and cold in buildings.

Efficiency is based not only on the quality of the heat transfer but also on the required effort for the pumps and fans, the material resources, the installation size and the overall costs. These criteria define a complex set of requirements for a development, which we specify together with our industrial partners for each specific application and address using suitable methods and tools.

## Our Services

- investigation and evaluation of novel heat exchangers and heat pipes for ventilation and air conditioning technologies, adsorption and refrigeration technologies
- prototyping of heat exchangers according to customer-specific requirements
- optical analyses by means of thermography, laser Doppler anemometry, particle image velocimetry and shadowgraphy to investigate refrigerant distribution or frost formation on finned heat exchangers
- measurement of the dynamic and steady state boiling and adsorption characteristics of water at low pressure on structural surfaces and heat exchangers



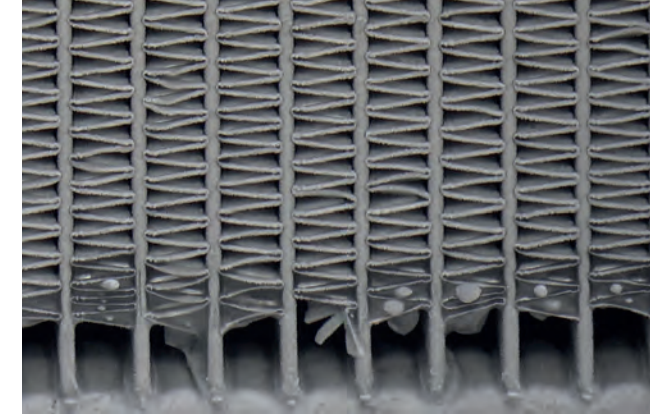
*Evacuation and filling of a heat pipe according to customer-specific requirements.*

The competence and experience at Fraunhofer ISE extend from experimental and simulation-based evaluations through the development of new heat exchanger structures up to design and prototype development. For thermally and electrically driven heat pumps as well as for air-conditioning and ventilation technologies, we have special test stands for measuring the performance, heat transfer and pressure drop of the individual components. For simulation-based evaluation and design, we use the tools COMSOL Multiphysics®, OpenFOAM®, MATLAB®, TRNSYS, Modelica® as well as IMST-ART® and CoilDesigner®, depending on the research question.

Our expertise on components is complemented by our knowledge of system requirements, which is updated constantly due to close industry cooperation. This combined know-how enables us to optimize components at the system level and to perform development work in a targeted and resource-efficient manner.

## Development of Heat Exchangers and Heat Pipes

Heat exchangers that use structures made of woven and knitted metal wires to transfer heat show great potential for reducing mass and saving energy. Since the use of individual thin wires makes more surface area available per unit mass,



*Analysis of icing of a microchannel heat exchanger when using air as heat source and R290 as refrigerant.*

higher heat transfer coefficients are achieved. At our designated test stands we analyze the boiling behavior on the surface of these complex wire structures.

Also for the development and testing of heat pipes, specific test stands are available. We construct and analyze heat pipe test samples according to specific customer requirements. Our research focus is primarily on new manufacturing processes (such as 3D printing) and alternative materials (e.g. film heat pipes).

## Heat Exchangers for Heat Pumps

Heat exchangers for use as evaporators or condensers in electrically and thermally driven heat pumps and chillers are another research focus. We analyze compression heat pumps, fin-tube heat exchangers as well as plate-fin heat exchangers on both the component and system level in the refrigeration circuit. For both designs, the uniform distribution of the two-phase refrigerant is particularly challenging. Optical analyses by thermography, laser technology, and ultrasound, for example, allow a detailed evaluation.

Geometrical adaptations of the distribution units based on these results lead to improvements in the refrigerant distribution. Using experiments and simulations, we can