GreenHP: Heat Exchangers for Next Generation Heat Pump

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Overview

- **Introduction**
- **Evaporator – air-side**
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  - Numerical Methods
  - Core-Design
- **Evaporator – propane-side**
  - Distributor-Design
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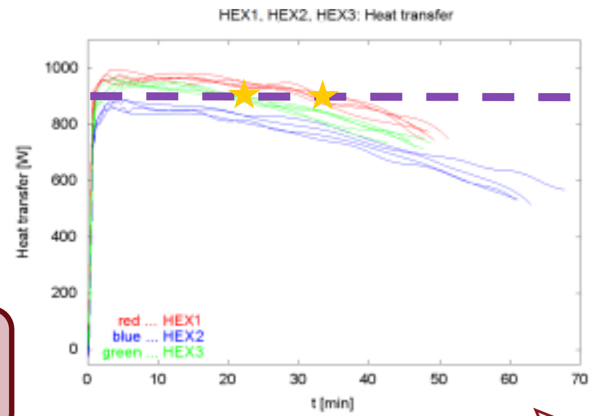
- **Evaporator – Assembly**
- **Summary, Conclusions & Next Steps**

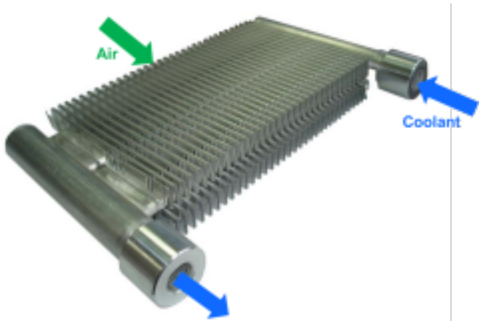
Introduction

- **Evaporator – Air-side** optimisation targets:
  - High performance fins
  - Low noise emissions by combined sizing of evaporator and a **customised fan**
  - Fins robust against ice formation and easy to defrost
  - Corrosion resistant fin material
- **Evaporator – Propane-side** optimisation targets:
  - Low pressure loss @ low refrigerant charge
  - Pressure resistant system for equal distribution of 2-phase flow
  - Utilization of a bionic distributor with up to 64 passages
- **Numerical** and **experimental** analyses have been performed

Air-Side of the Evaporator – the selection of the fin geometry

		Mean values	
Fin / Name of the sample		t_{ICE}	$\dot{Q}_{mean}$
Plain fin #1		3059 s	156 W
Plain fin #2		4688 s	104 W
Wavy fin #1		2380 s	166 W
Wavy fin #2		3767 s	135 W
Lanced fin #1		1300 s	163 W
Louvered fin #1		1766 s	167 W
Plain/louvered fin #1		883 s	117 W





After the selection of the fin geometry, the frosting performance of the **advanced** heat exchanger has been compared to a **standard** heat exchanger configuration.

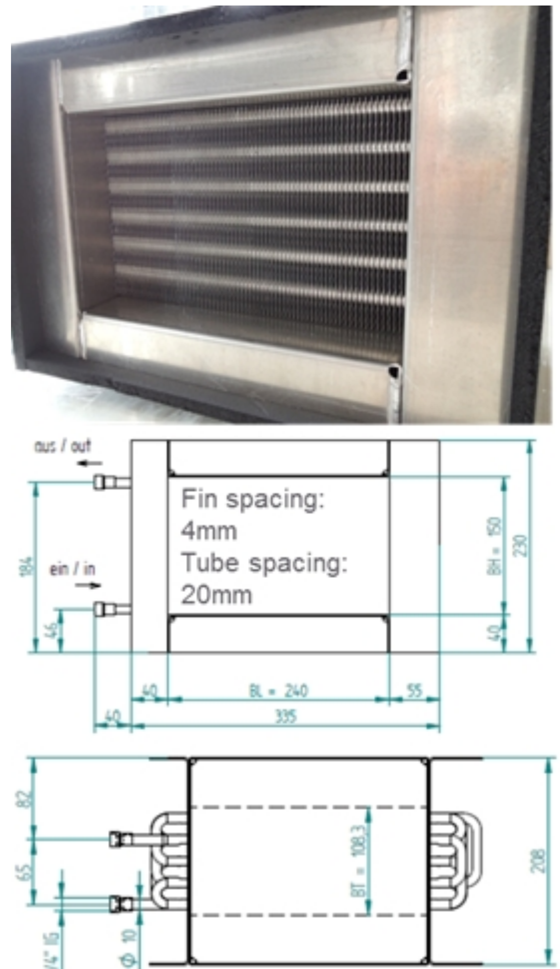
Air-Side of the Evaporator – the aim of the comparison

- The aim was to compare two heat exchanger types w.r.t the **frosting performance**;

- The outcome was meant to indicate how the multi-port extrusion fin heat exchanger (MPEfin, right) performs, compared to the conventional tube fin heat exchanger (CTfin, left) on **low cooling temperatures**;

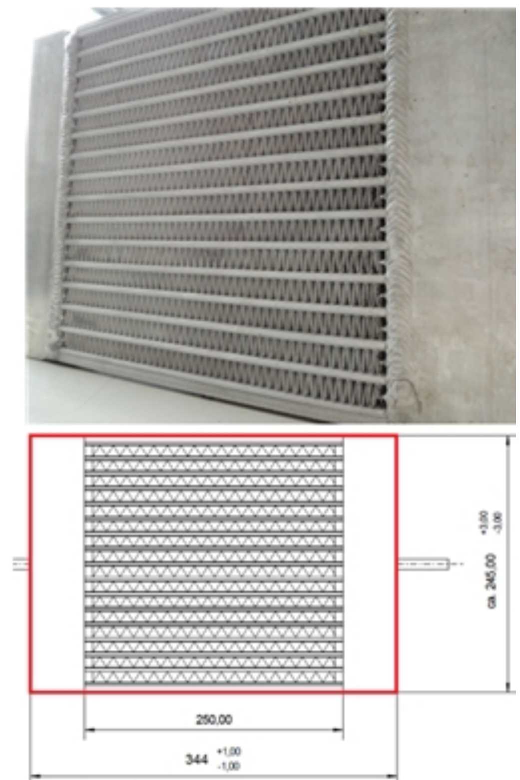
- In order to have a representative comparison, the operating points have been selected in such a way that the **power** of heat exchangers are close to each other.

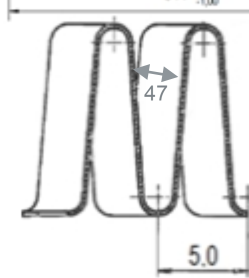
CTfin (vol=0.00389m³)



W x H x L
240x150x108

MPEfin (vol=0.00288m³)





W x H x L
250x245x47

Air-Side of the Evaporator – the experimental characteristics

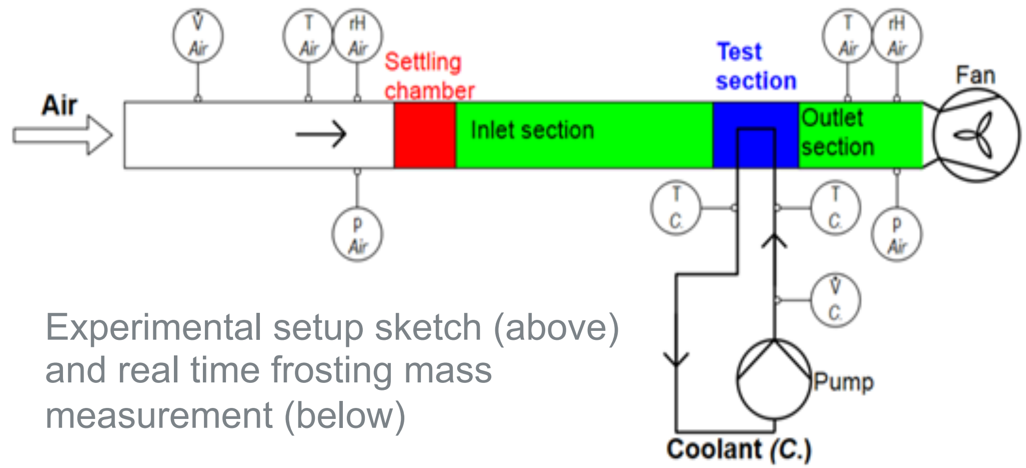
- The experiment has been performed within the climatic chamber, in which the **temperature** and relative **humidity** are being controlled;

- For both heat exchangers the frosting measurements have been performed at two **ambient** temperatures: **10 °C** and **-25 °C**.

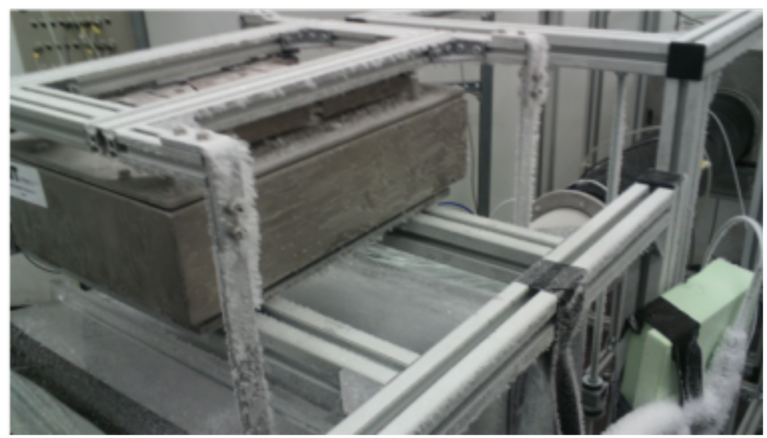
- In both cases the **coolant** temperature was kept **30 °C** below the ambient temperature;

- In both cases the **volumetric flow rate** was kept the same;

- The balance was recording the growth of frost mass in the **real time**.

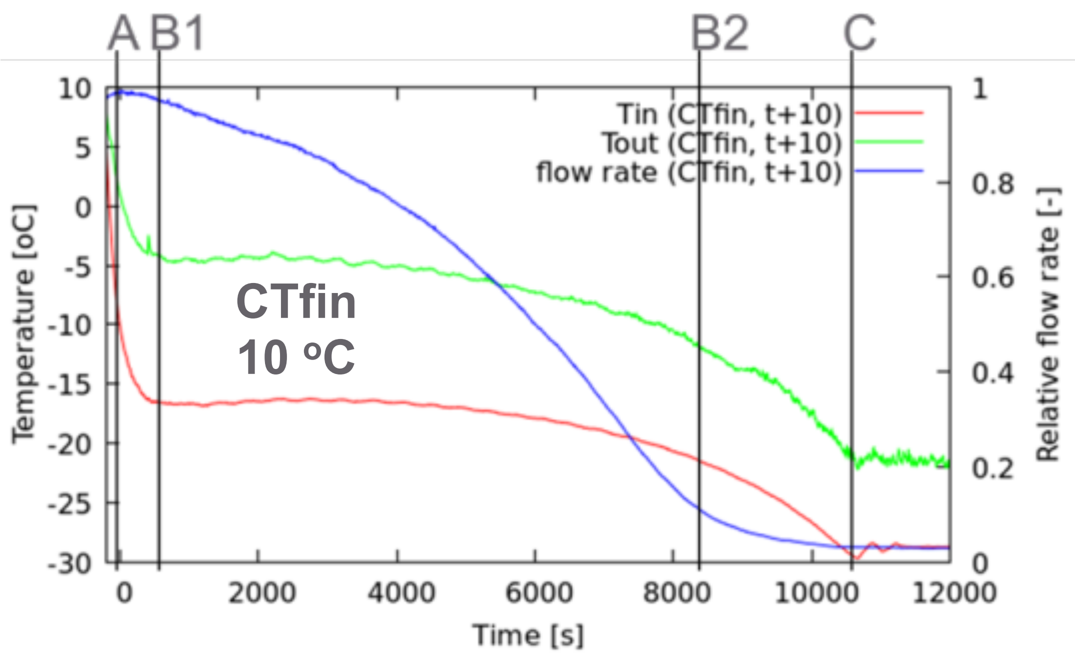


Experimental setup sketch (above) and real time frosting mass measurement (below)



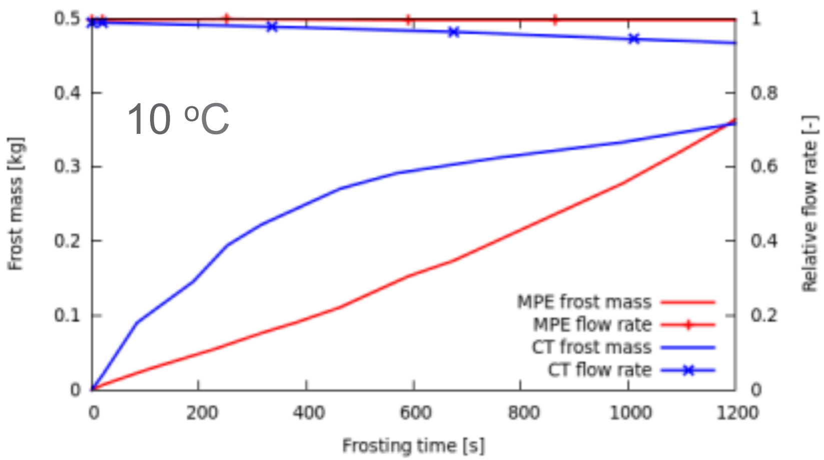
Air-Side of the Evaporator – the frosting process

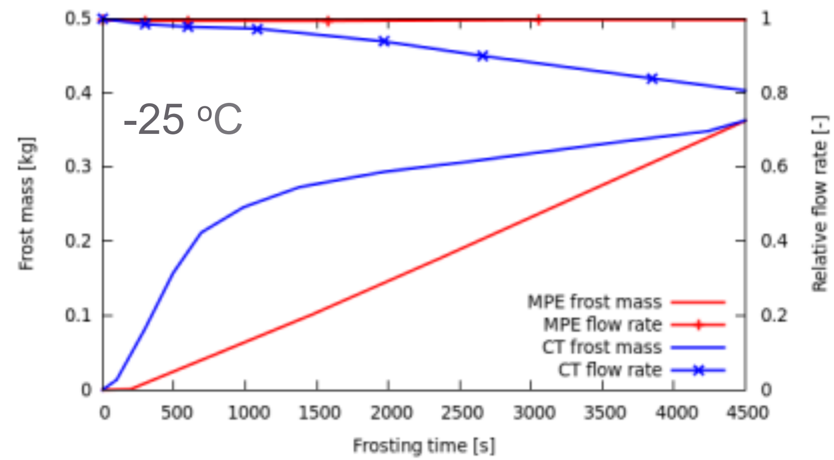
- In the **initial phase** the thermal mass of the heat exchanger is accommodated to the **tempering conditions** (A to B1), and then the **main frost growth** takes place (B1 to B2);
- Afterwards, the **rapid change** of the heat exchanger thermal state (at air flow rate curve steepest gradient) takes place (B2), and frost creation continues until the heat exchanger is **fully blocked** and the temperatures do not change any more (C).



Air-Side of the Evaporator – the accumulated frost mass

- In the **initial phase**, the properties of MPE show their efficiency (note the **gradient of the frosting curve**), but in the later stage (fin surface mainly covered by the frost layer) the process is dominated by the **main geometrical characteristics** (fin spacing).





The frost mass growth of MPE and CT heat exchangers at ambient temperatures 10 °C (left) and -25 °C (right), and the corresponding reduction of the flow rate through the heat exchanger.

Air-Side of the Evaporator – the main findings

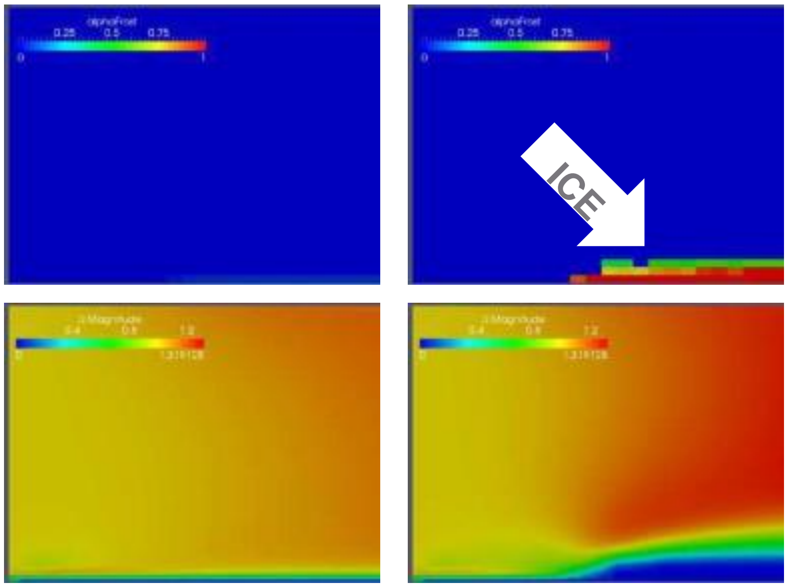
- The fin geometry design of **MPEfin** heat exchanger has a positive impact on the frost creation in the **initial** frosting phase;

- As the frost creation progresses over the entire fin surface, the process is further dominated by the **main geometrical characteristics** – here the advanced heat exchanger type characteristics have lower impact, as compared to a standard CTfin type;

- This effect is more pronounced at the ambient conditions with more absolute humidity.

Air-Side of the Evaporator – Numerical Methods

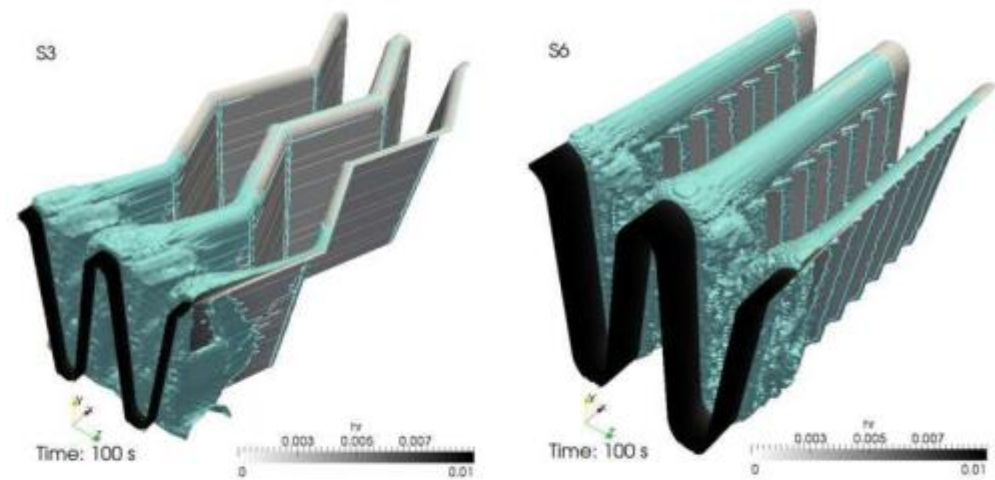
0 min **4 min**



Ice built up (upper row) and **air flow** (lower row) over a cooled flat plate.

left: initial boundary flow – no ice is built up;

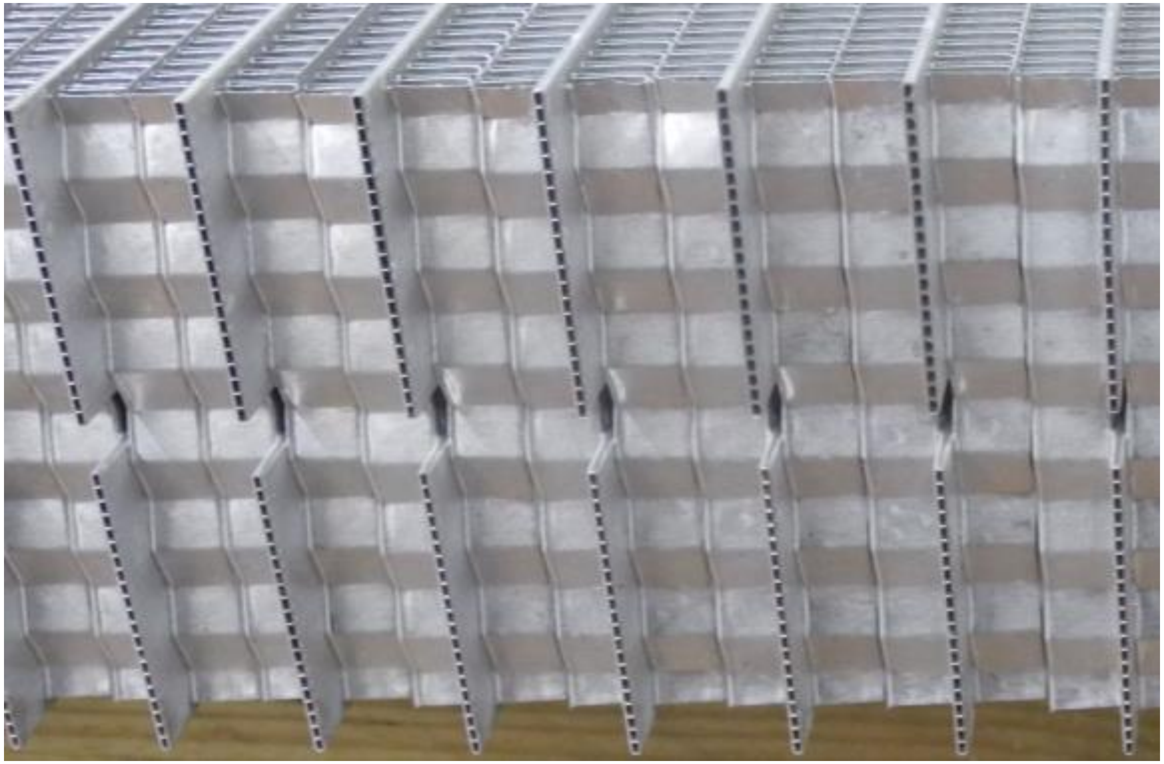
right: situation after *4 minutes*: the ice has grown and the air flow is distorted.



wavy fin **louvered fin**

Ice aggregation patterns on wavy fin and louvered fin configurations after 100s

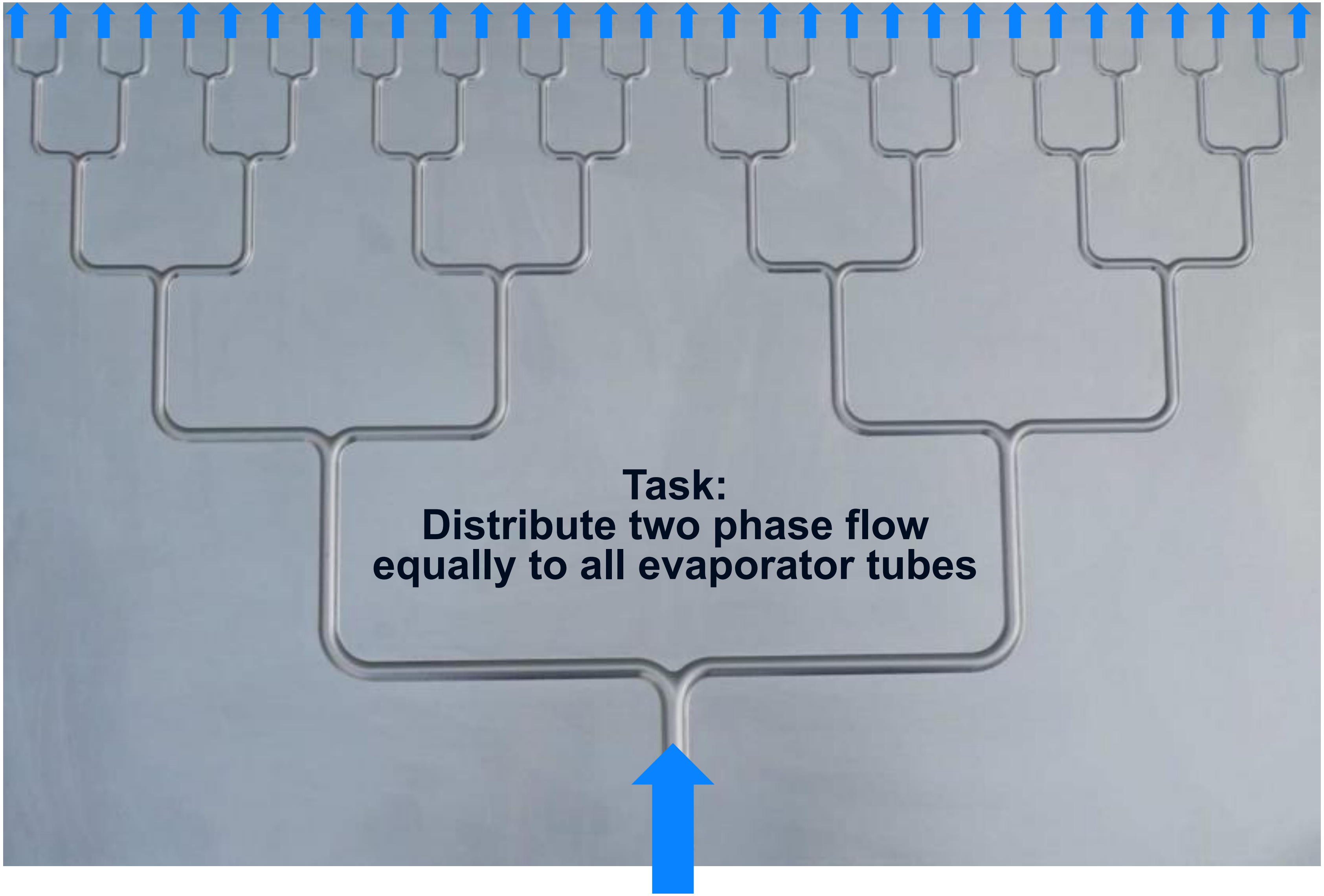
Air-Side of the Evaporator – Brazed Core and Connector



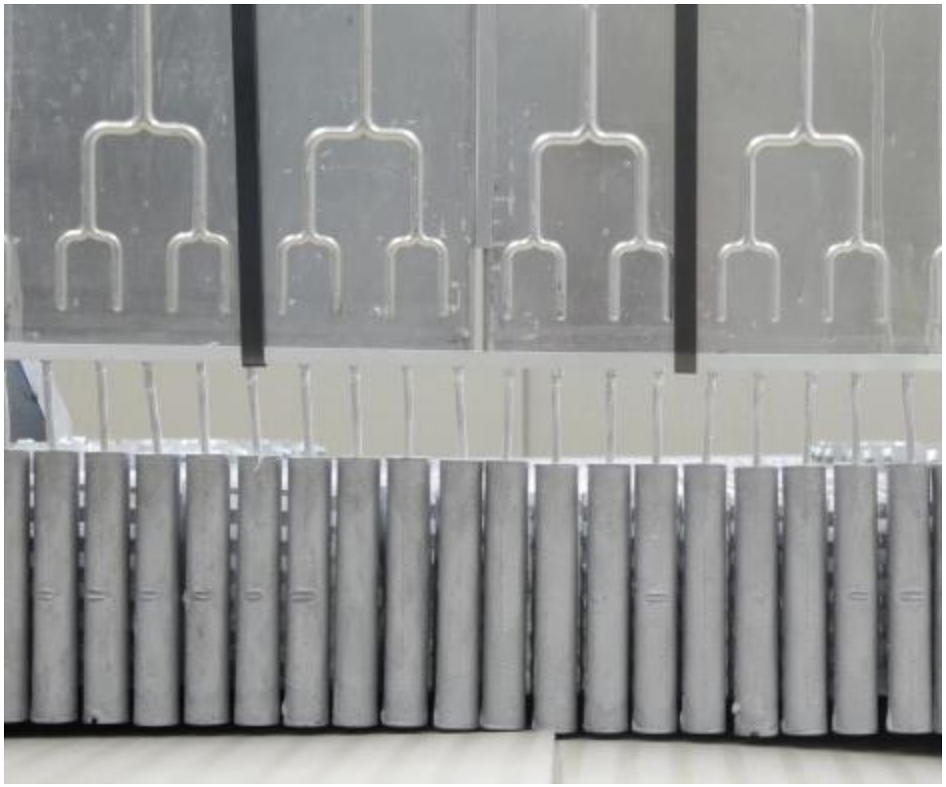
Detail of evaporator core with two rows of MPE-tubes paired with two wavy fins

Tube-in-tube element to join 2 MPE-tubes to one exit of the distributor

Propane-Side of the Evaporator – Bionic Distributor

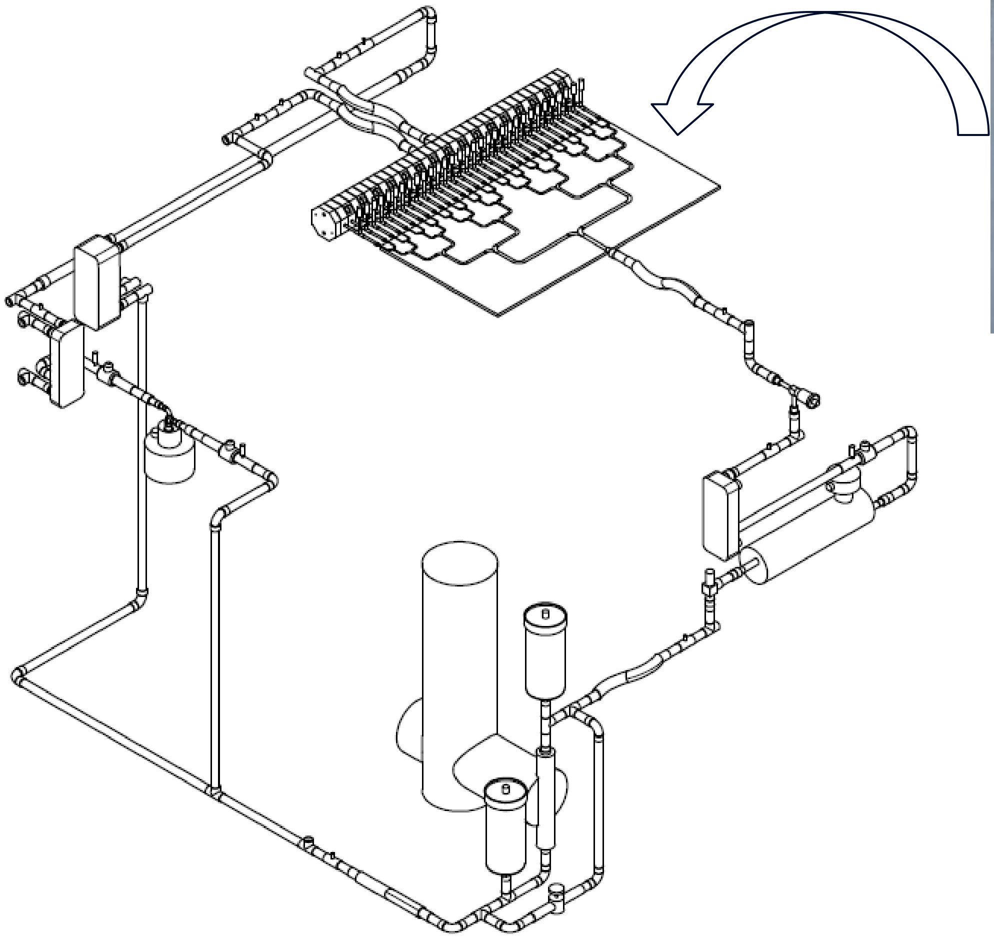


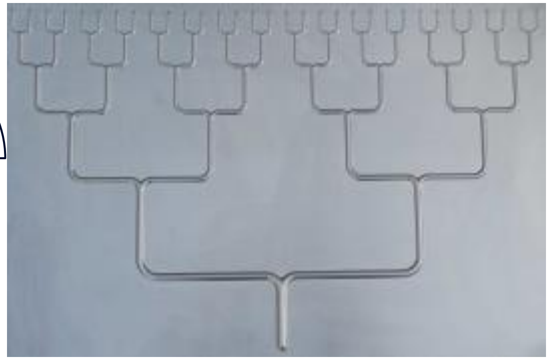
Propane-Side of the Evaporator – Bionic Distributor



Connection between **Bionic Distributor** and **MPE-tubes**.

Propane-Side of the Evaporator – Experimental Setup





Test bench for the testing of **two-phase fluid distribution**.

Propane-Side of the Evaporator – results

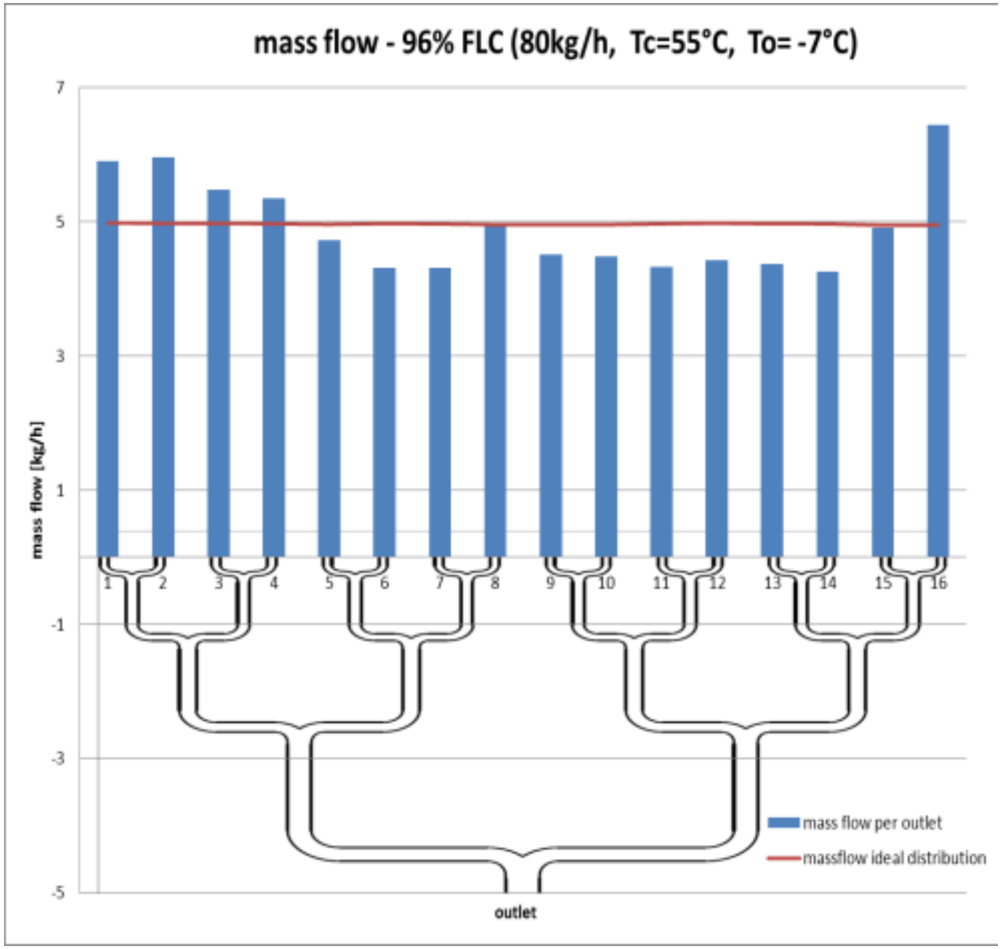
Two phase (liquid-gas) flow influenced by curves; liquid pressed to outside due to centrifugal forces.

Straight sections before bifurcation designed to allow flow to become more symmetric.

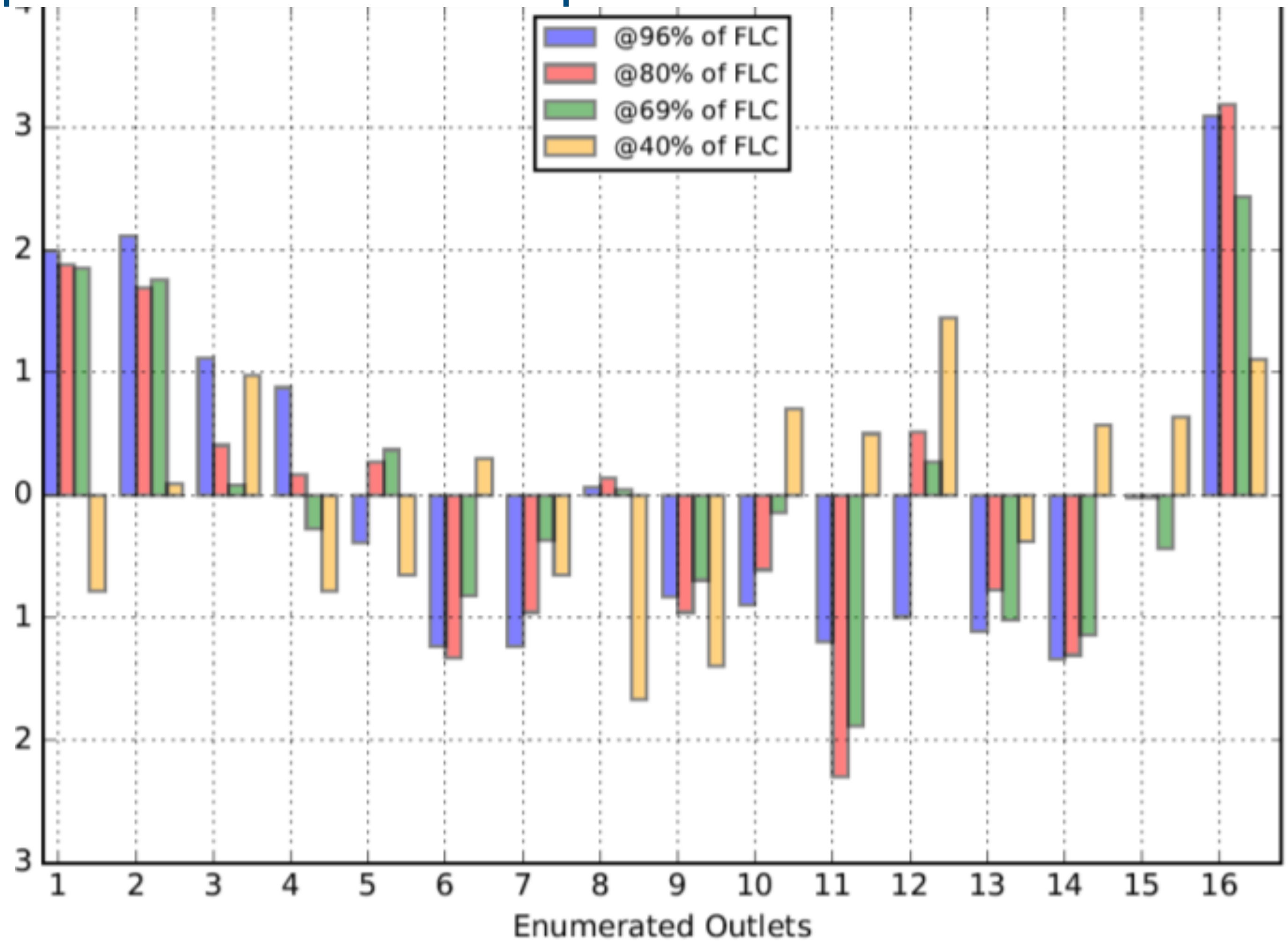
Measurements show, that centrifugal effect is still visible: Valve 1 and 16 are highest, 6 and 11 are lowest.

Higher mass flow in the inner exits would be more desirable than in the outer exits

At low load (low mass flow and vapour quality), the centrifugal effect is not measurable.



Propane-Side of the Evaporator – Fluid Distribution



Test results for two-phase fluid distribution.

Evaporator – Assembly

MPE-core with bionic distributor at inlet and conventional headers at outlet

Summary & Conclusions

- **Icing characterisation** of different fin geometries and surface structures (coatings) with experimental numerical analyses
- **Fin geometry** has an influence on icing properties and mean heat transfer – **wavy fins** show a good compromise between good heat transfer and proper icing times
- **Distributor test bench** allows for characterisation of new and existing flow distribution technologies
- **Bionic distributor** developed and tested to be pressure resistant and to provide a good distribution quality for two-phase refrigerant flows

Conclusions & Next Steps

- The innovative approaches for condenser and evaporator combined with a low noise fan lead to a system with
  - high heat transfer
  - small refrigerant charges
  - good handling of icing conditions

  ⇒ interesting components for future heat pump systems

- **Next step:**

  Experimental characterization of the full-size heat pump system and comparison with systems based on conventional components