HPEx® HighPerformanceHeatExchanger
- Innovative Wärmeübertrager für anspruchsvolle Einsätze -

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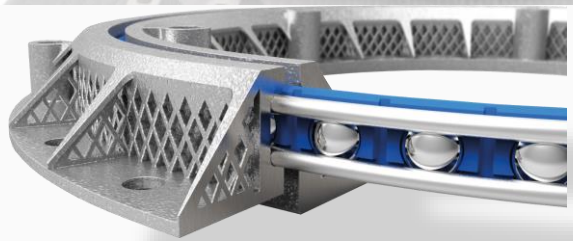
HPEx® – High Performance Heat Exchanger

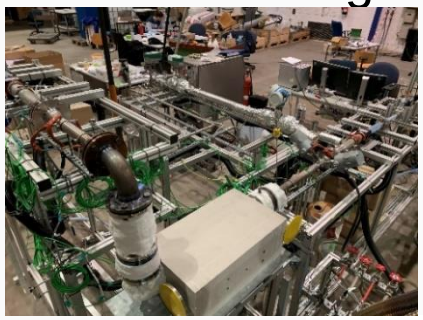
Hülsenbusch Apparatebau GmbH & Co KG
Engineering and manufacturing of thermal and process plants

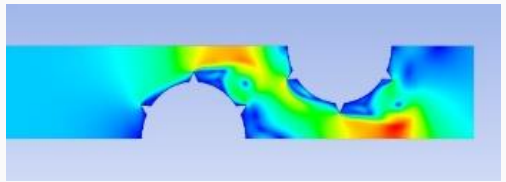
Partner

ROSSWAG engineering
Metal 3D printing service provider with holistic process chain



Institut für Thermodynamik
Leibniz Universität Hannover
Development and optimisation of heat engineering apparatus





HPEx® – High Performance Heat Exchanger

HPEx® is a new heat exchanger → motivation for development

- new energy conversion technologies
  - fuelcells and electrolysers
  - hydrogen production from waste gas etc.
  - mobile use of fuelcells / with and without hydrogen reforming
    - Ships
    - Trains
    - Aircraft (lightweight cooler)
  - handling with „new“ media as Hydrogen, MeOH, NH3, e-fuels etc.
    - e.g. hydrogen filling stations
- **heaters, coolers, evaporators and condensers were needed in all applications**

HPEx® – High Performance Heat Exchanger

- Challenging **requirements** for apparatus engineering and manufacturing
  - high temperature
  - high pressure
  - small space
  - long lifetime
  - gastight (in combination with h2 = **high operational safety)**
  - lightweight
- These requirements in various combinations are not the standard for the usual heat exchangers.

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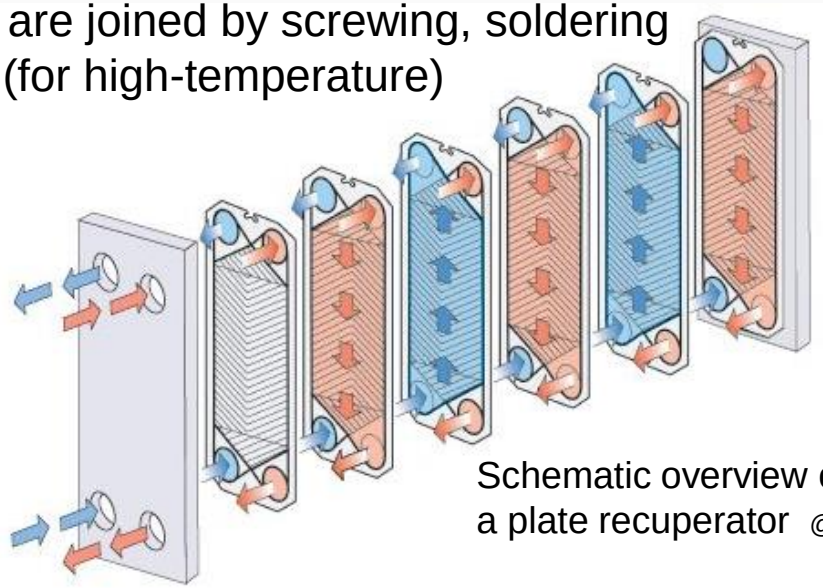
Notes on conventional tube heat exchangers

- Heat exchangers for many applications, preferably in the industry
- Flue gas temperatures up to 1.600°C, dust-laden flows are possible
- Volume flows from 10 m³/h up to 150.000 m³/h (i.N.)
- High operational reliability due to solid construction with welded seams
- Welding procedures require space and prevent high heating surface values
- Permanent challenge to reduce size by improved heat transfer

HPEx® – High Performance Heat Exchanger

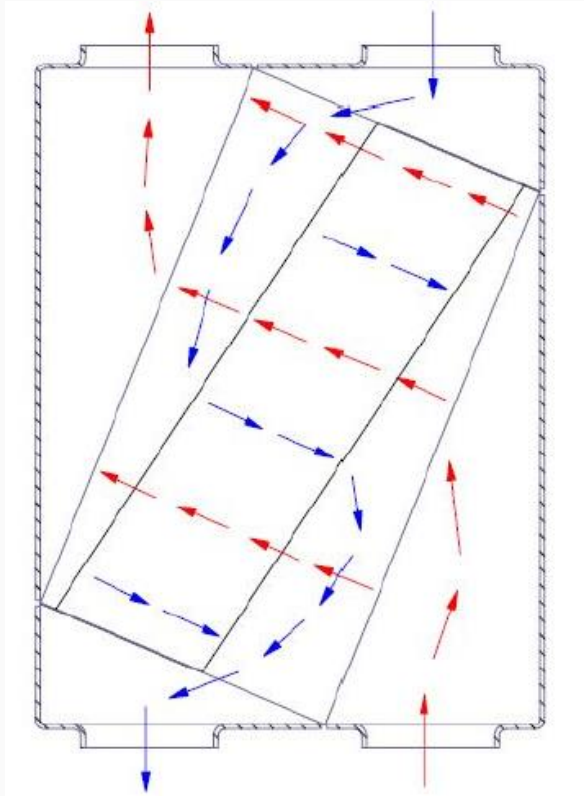
Notes on conventional plate heat exchangers

- Heat exchangers for many applications
- Flue gas temperatures up to 800°C,
  dust-laden flows are not possible
- Volume flow from 0,1m³/h (i.N.) and higher
- Plate recuperator is based on thin and structrured plates
- This creates a large inner heating surface
- The pressure drop is high
- The plates are joined by screwing, soldering or welding (for high-temperature)



Schematic overview of a plate recuperator @alfalaval

Photo
plate recuperator @bosal



Flow directions inside a plate recuperator @bosal

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Tube Heat Exchanger

- Small heating surface
- Large dimensions
- High operational safety
- Long term stability
- Low pressure drop

Additive Manufacturing

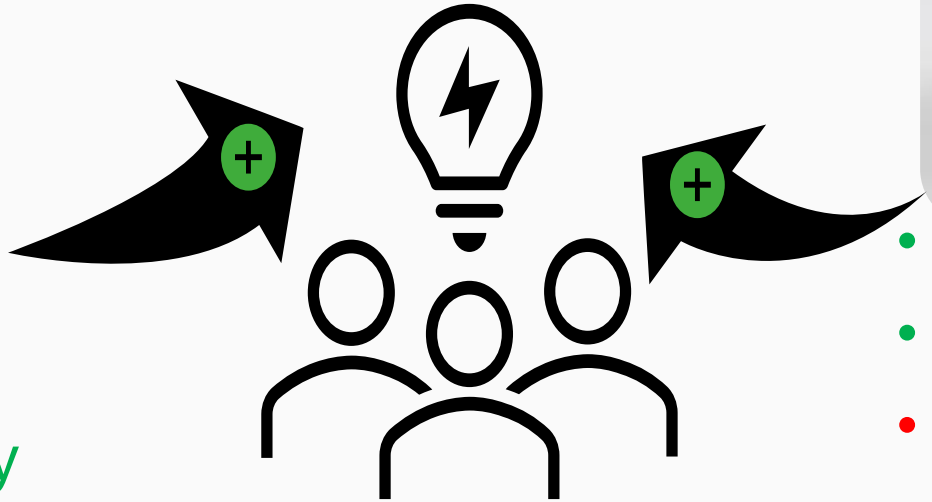


Plate Heat Exchanger

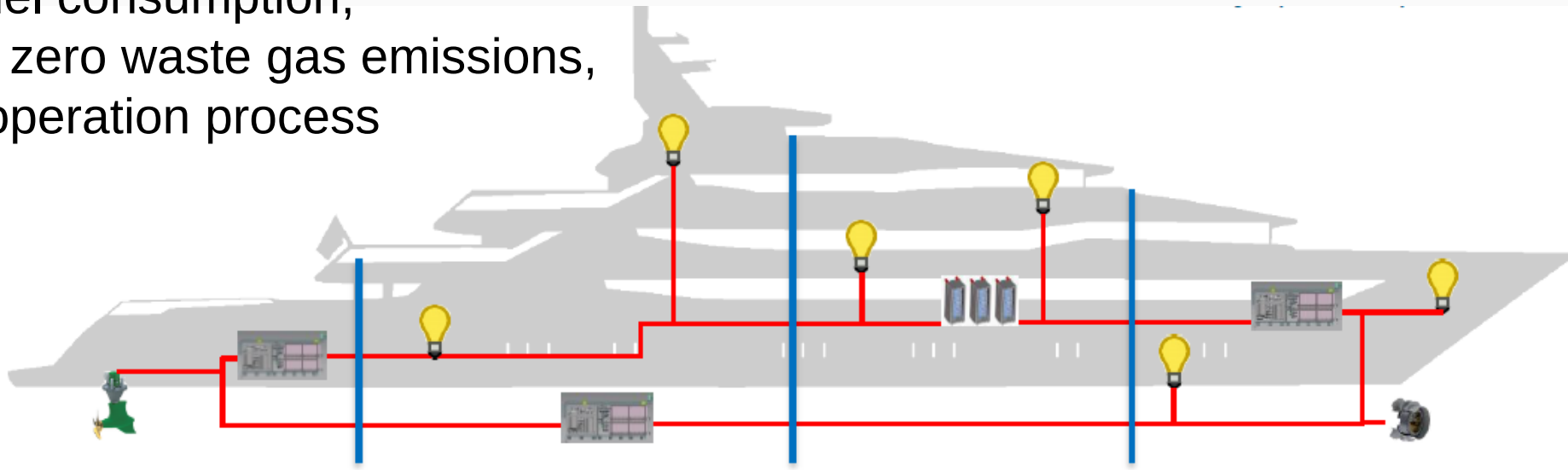
Source: Bosal

- Large heating surface
- Small size
- Lower operational safety
- Short service life
- High pressure drop

HPEx® – High Performance Heat Exchanger

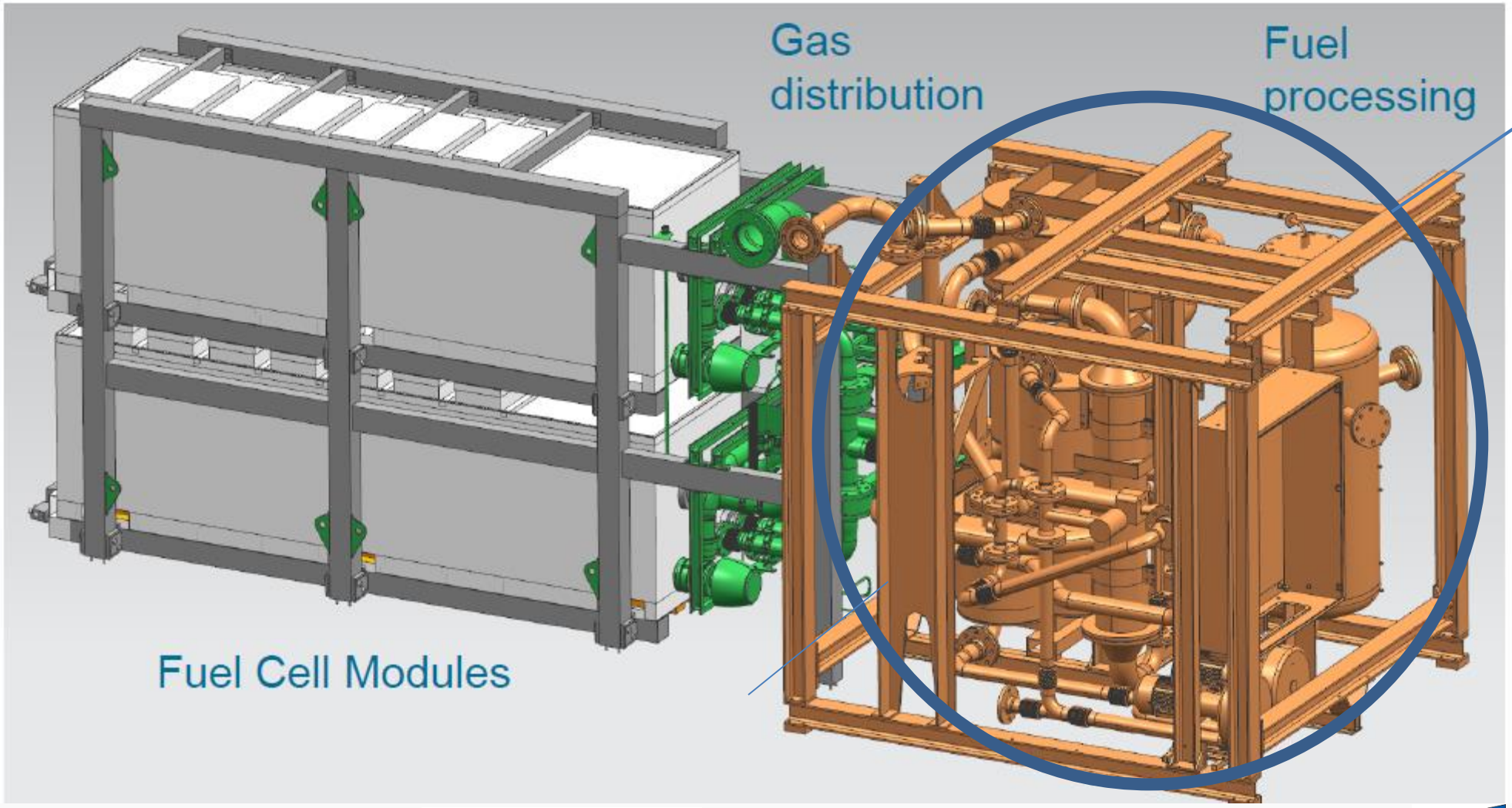
E4ships: SOFC – solid oxide fuel cells for power generating on board

- Today: centralized engine space,
  fuel: gas or diesel
- New: decentralized fuel cell spaces,
  combined with storage units
  hydrogen produced by reforming CH-fuels
- Advantages: higher efficiency
  less fuel consumption,
  nearly zero waste gas emissions,
  quiet operation process



HPEx® – High Performance Heat Exchanger

Process gas module (PGM) for hydrogen production and fuel cell supply



up to five heat exchangers in a PGM at temperatures up to 900°C with hydrogen

HPEx® – High Performance Heat Exchanger

Task definition for HPEx for use on board for PGM and fuelcell supply

- **Small size**
- High efficiency and high specific power
- **High operating temperature** and good thermal shock resistance
- Low heat losses via the surface
- **Gas tightness and high operational safety** when using hydrogen
- **Stability under intensive mechanical stress**
- Compensation of thermal expansion
- Low maintenance effort
- **Long lifetime, up to 10a**
- Integration of the new HPEx into complex systems
- **Certification by DNV, LR** or other ship certifiers

HPEx® – High Performance Heat Exchanger

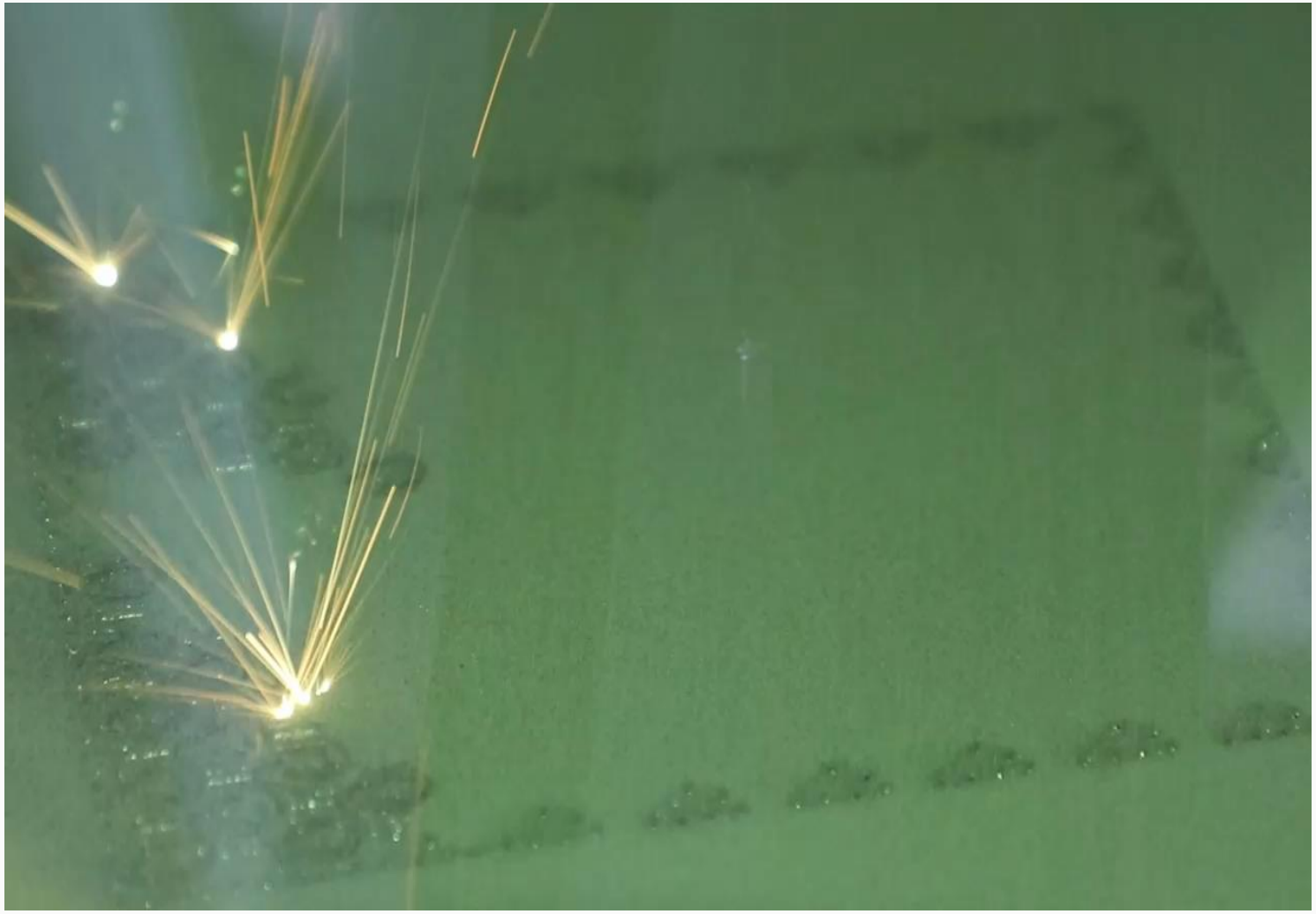
HPEx® – required properties and tasks for AM

- Material resistance for high temperature, more than 900ºC
- High and uniform material density
  - to avoid gas slip through the material itself
- The material properties and the additive manufacturing process must be matched to each other
- Complex and filigran geometric structures must be realized to increase the heat transfer coefficient and the heating surface
  - ribs, swirl generators, flow fixtures
- Additive manufacturing of large structures for HPEx-modules with uniform properties and without defects

HPEx® – High Performance Heat Exchanger

HPEx® - challenges for addivitve manufacturing of metals

- Limited part sizes possible (LPBF, SLM Systems)
- Qualification of new materials for AM
- Nickel-based alloy (Inc718, Inc625) as material for very high temperatures
- Design and Engineering for AM (overhangs, etc.)
- Manufacturing of modules for later assembly



HPEx® – High Performance Heat Exchanger

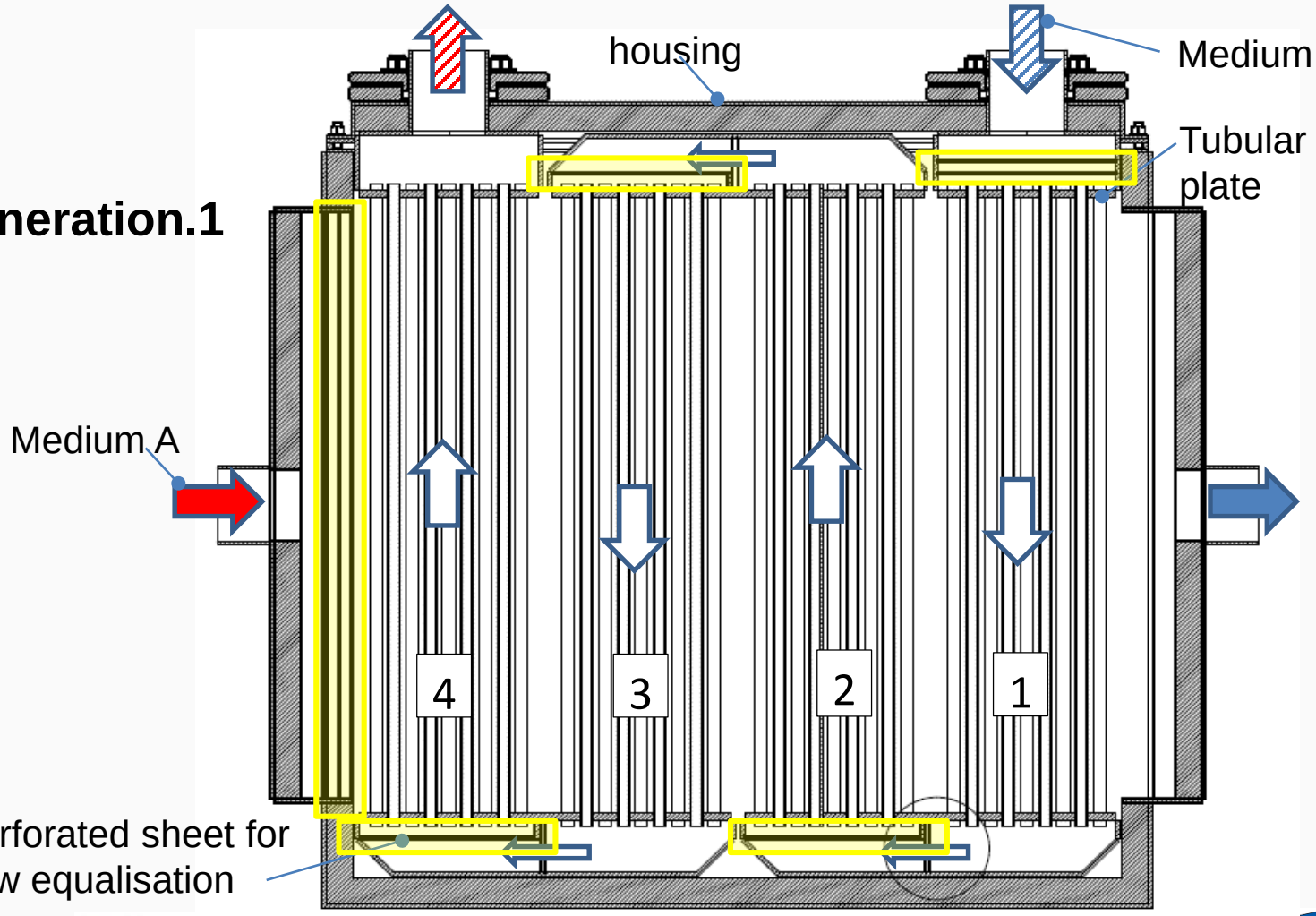
Development and testing of HPEx in several steps

- Minimising a nearly conventional tube recuperator **(HPEx_B)**
  - Improvement of internal heating surface
  - Improvement of internal heat transfer rate
- Development of a strict counterflow recuperator **(HPEx_A)**
  - Modular design to use many standard components
  - Modular design to improve the use of machines for additive manufacturing

HPEx® – High Performance Heat Exchanger

Minimising the design of a near-conventional tube recuperator – HPEx_B

Generation.1



HPEx® – High Performance Heat Exchanger

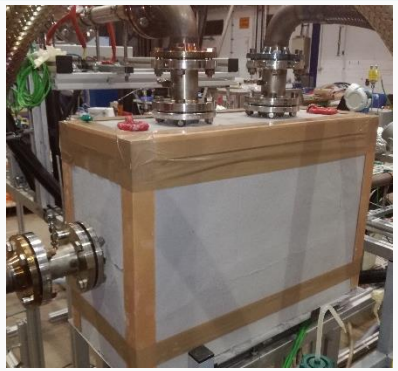
First protoype of AM heat exchanger

Smooth tubes, only increasing of heating surface
Material: Inc.718 (2.4668) T_max~800°C

HPEx® – High Performance Heat Exchanger

Improvement of internal heating surface and heat transfer rate

Generation 1 → Generation 2 → Generation 3 → Generation 4

size ⟶

power density ⟶




HPEx® – High Performance Heat Exchanger

Conventional tube recuperator for industrial appplication

HPEx_B Generation.2

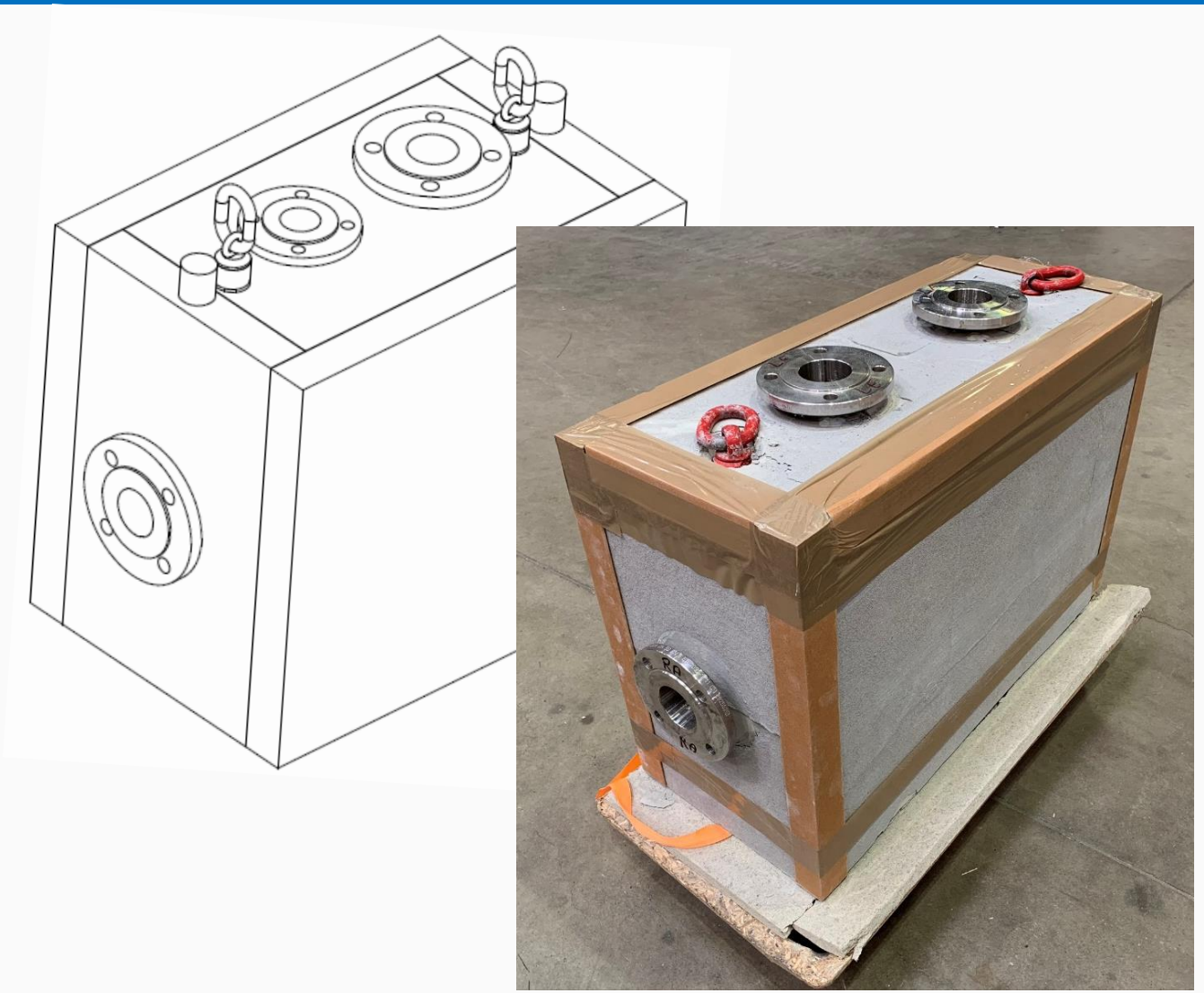
New high-performance recuperator

- Tube bundle produced using the 3D printing process (SLM)
- Specific power up to 8 MW/m³
- 25x smaller than a conventional tube recuperator
- Gas-tight and high-temperature resistant up to 1.000°C
- Long service life due to solide material and construction

HPEx® – High Performance Heat Exchanger

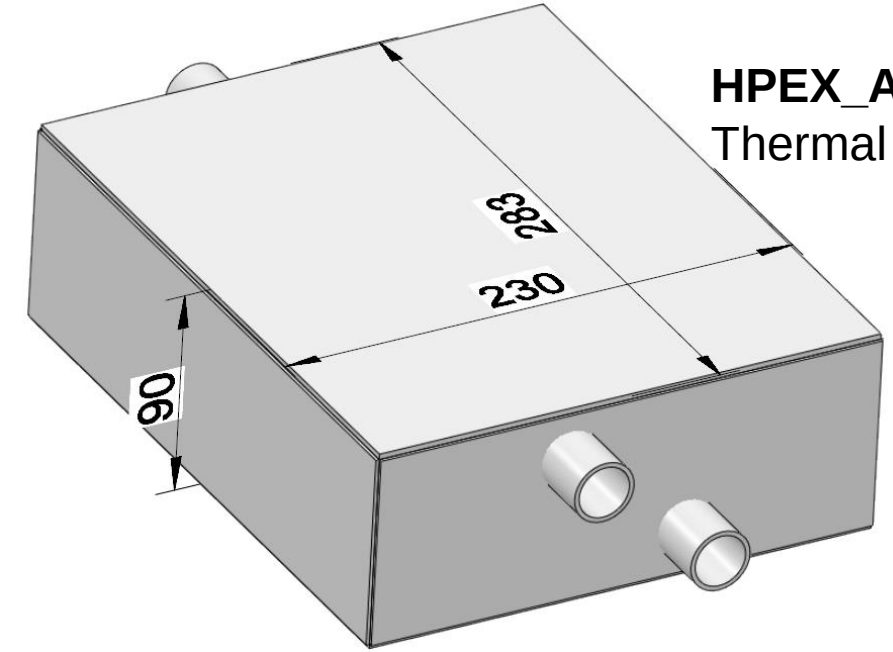
HPEx_B_Generation.2

- Heating power up to 50kW
- Max. temperature of media up to ~1,000ºC
- Gastight, even with hydrogen
- Dimensions of HPEx® w/o insulation: 450x385x280 [mm]
- High qualitative thermal insulation
  - temperature_surface~45ºC
  - heat losses lower than 250W/m²



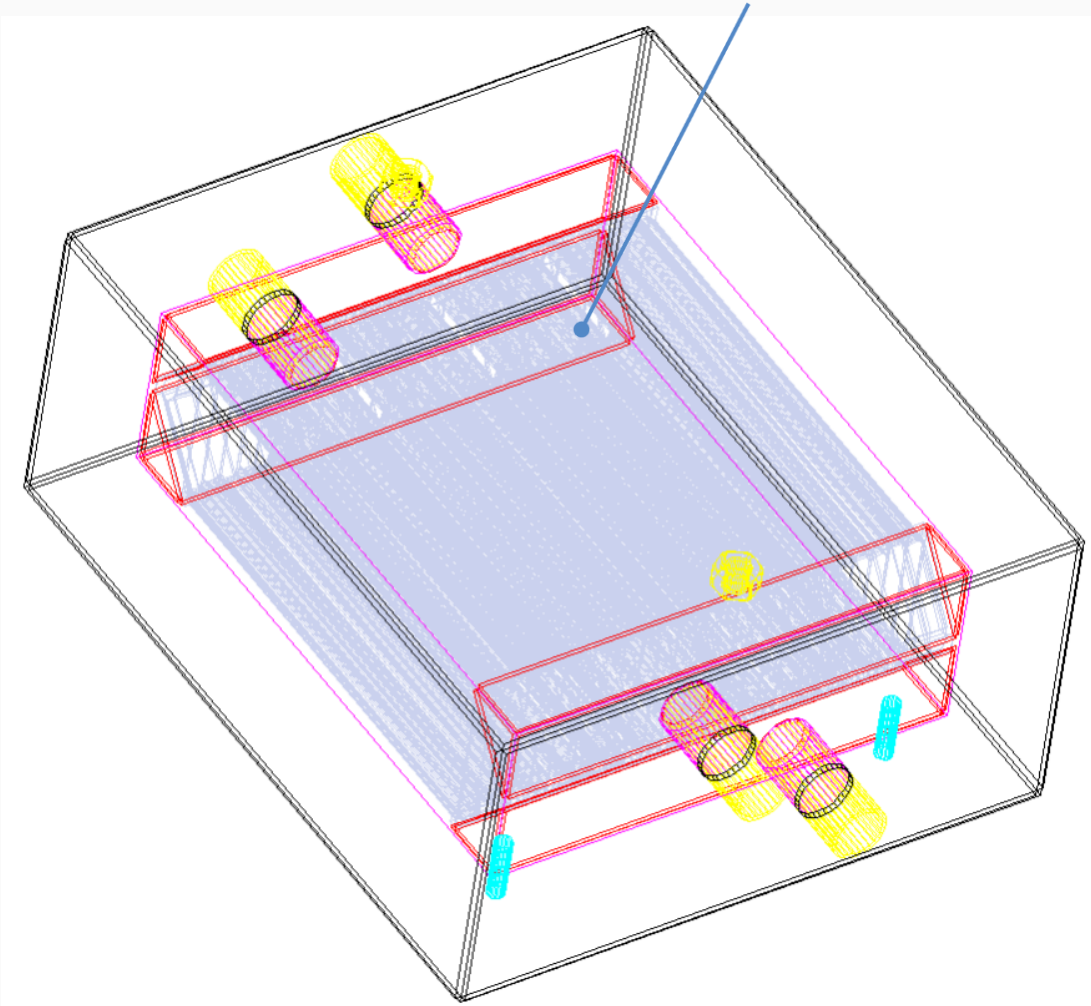
HPEx® – High Performance Heat Exchanger

- Development of a strict counterflow recuperator to improve the heat transfer and minimise size
- Modular design to make final assembly more flexible and to use many standard components
- Modular design with optimised geometry to increase the efficiency of machines for additive manufacturing



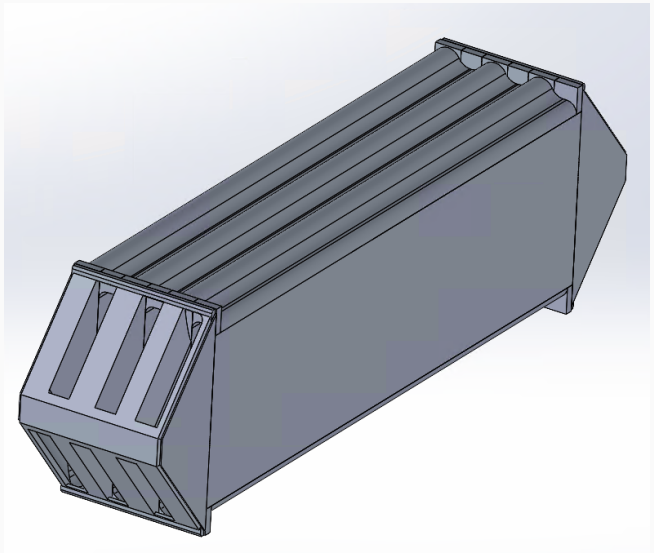
HPEX_A_02
Thermal Power 15kW

Four HPEx-modules combined

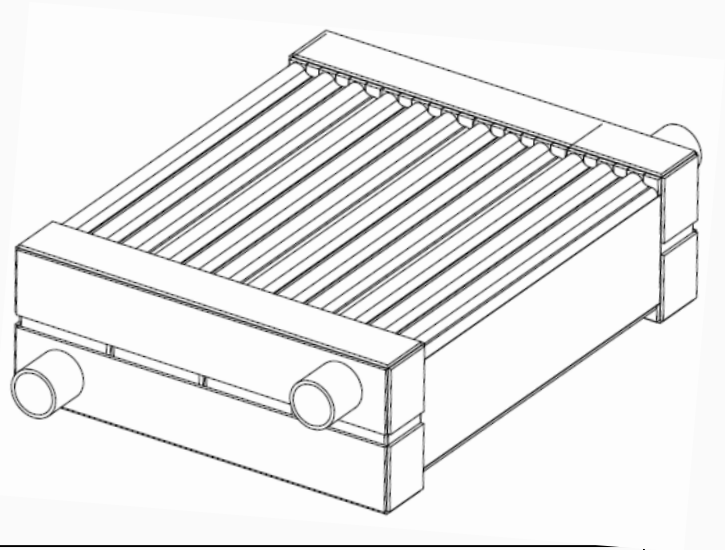


HPEx® – High Performance Heat Exchanger

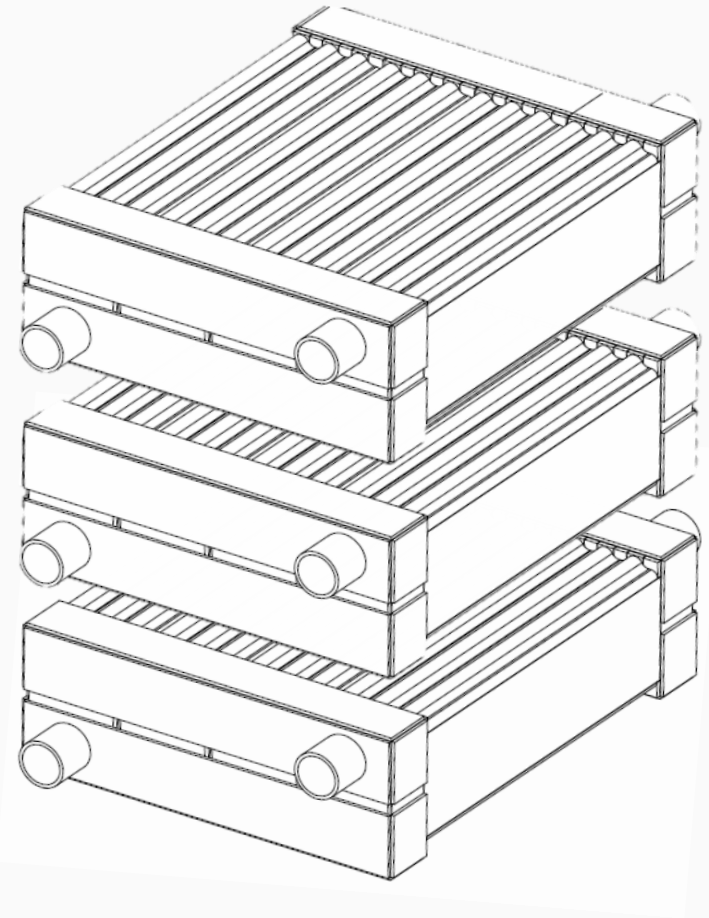
1 Module



4 Modules



12 Modules

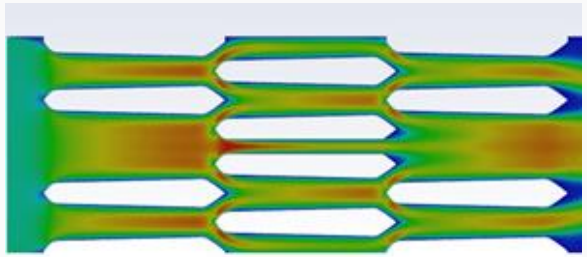


Size: DIN A4
Thermal Power:15kW

HPEx® – High Performance Heat Exchanger

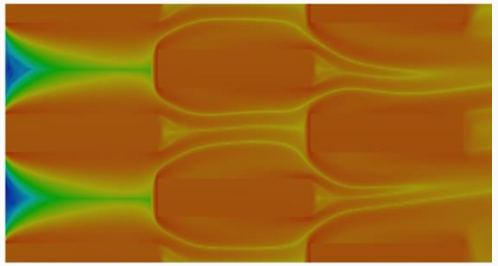
Heat Exchanger Development

- Numerical calculations for optimal design parameters
- Experimental testing of the heat exchangers

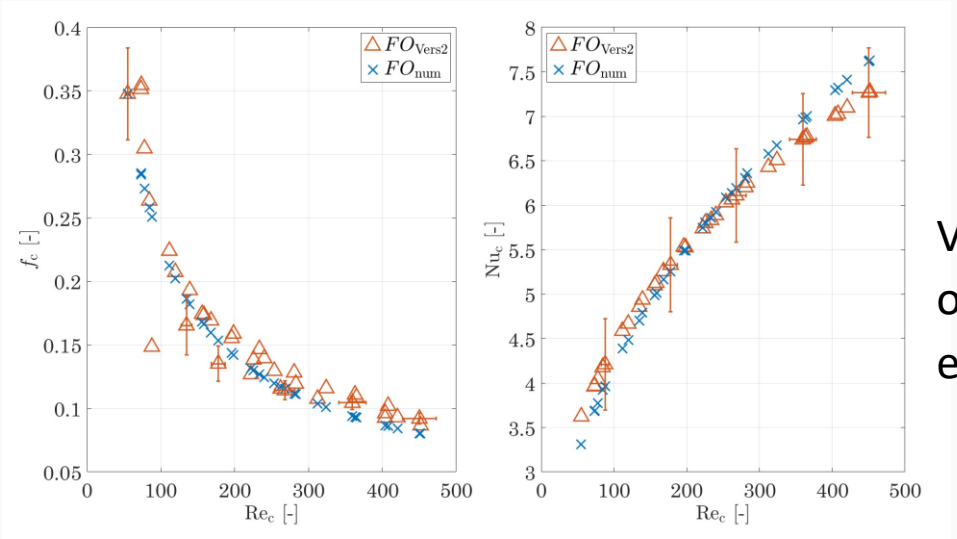


Shape Optimization to increase efficiency

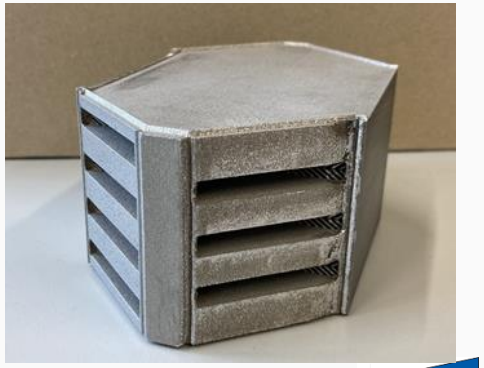
Detect losses with local irreversible entropy generation



Add. Plate-Fin Type HX



Very good agreement of numerical and experimental results



HPEx Type

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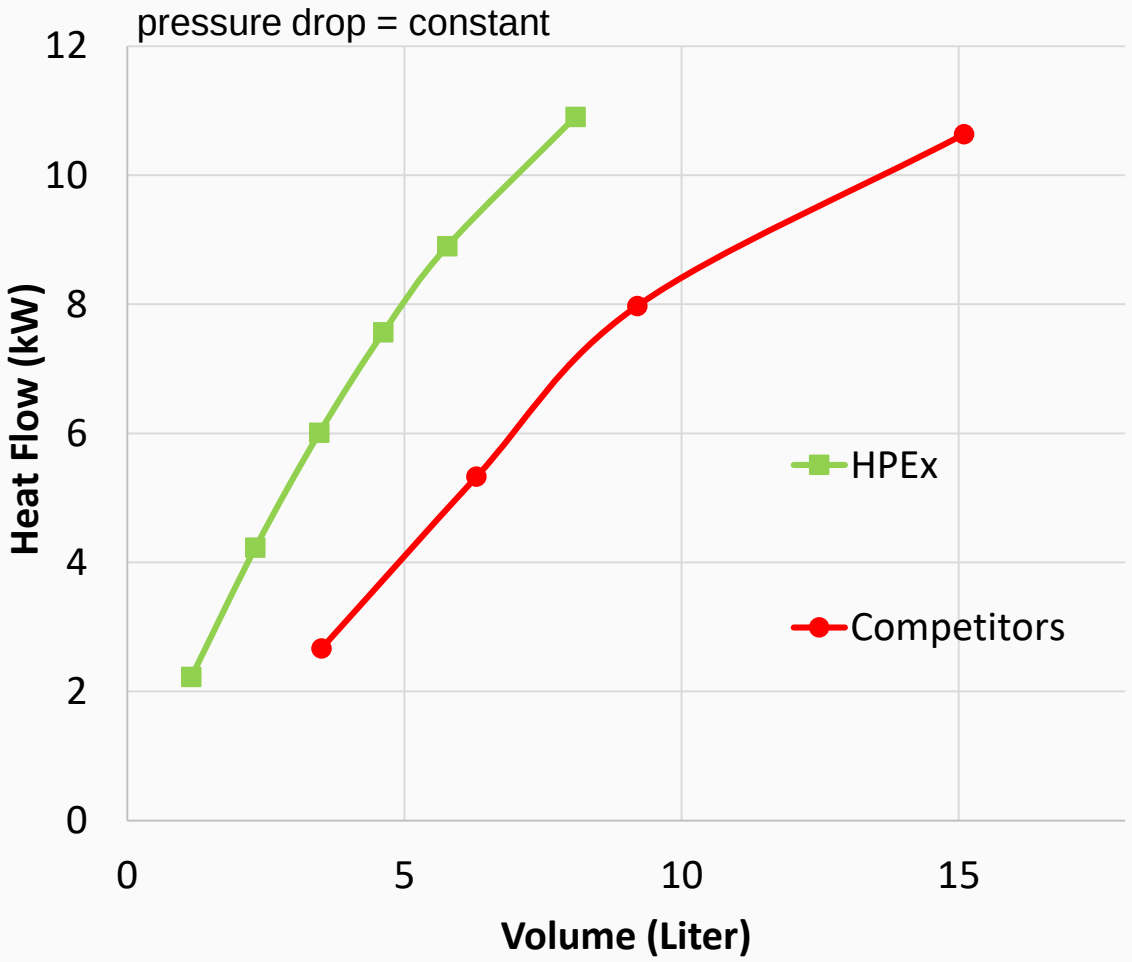
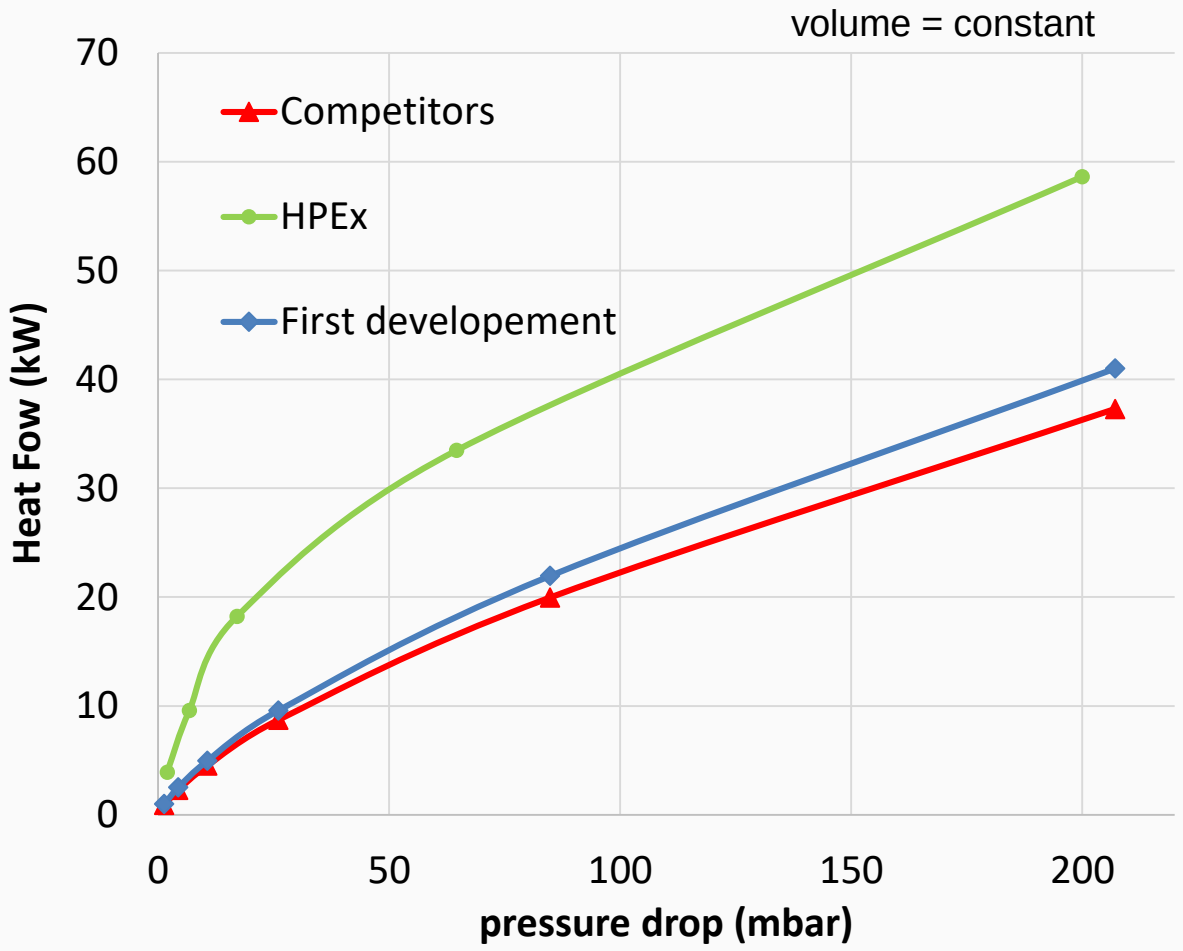
Numerical and experimental results

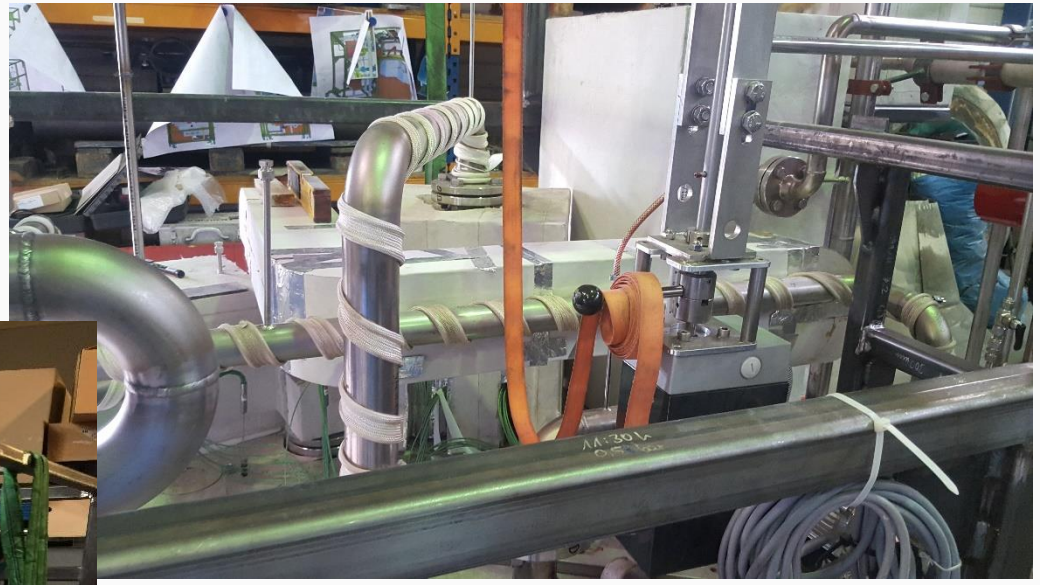




HPEx® – High Performance Heat Exchanger

Gas-preheater at H2 reforming plants for fuelcell supply

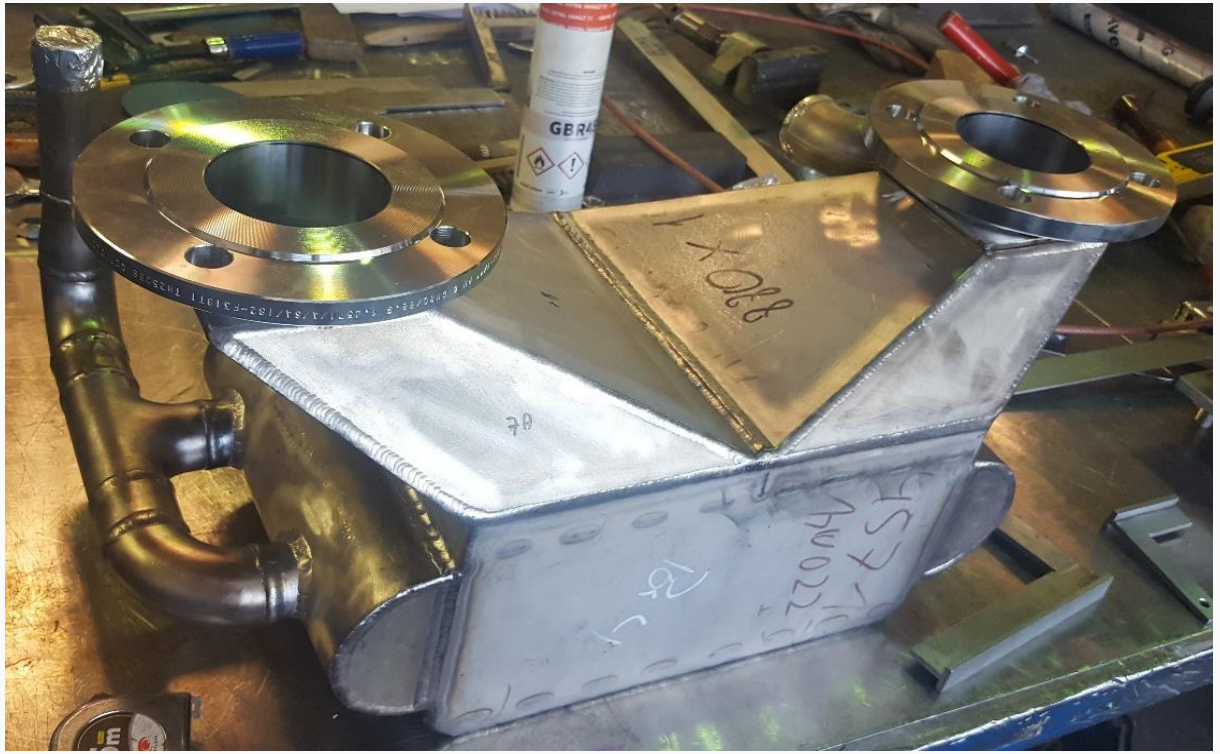
- Hydrogen gas mixture
- T_max ~ 900°C



HPEx® – High Performance Heat Exchanger

MeOH reforming process – evaporator

- replacement of a plate heat exchanger
- T_max ~ 400°C
- p_test ~ 4bar
- P ~ 35kW



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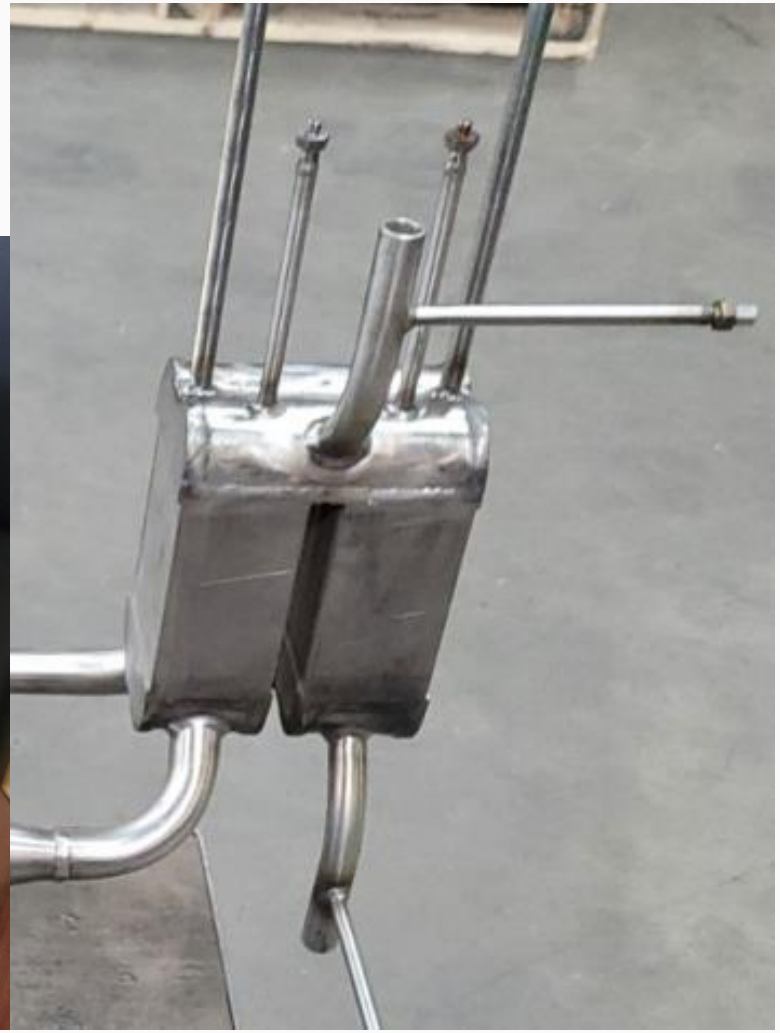
Evaporator for hydrogen production from biomass



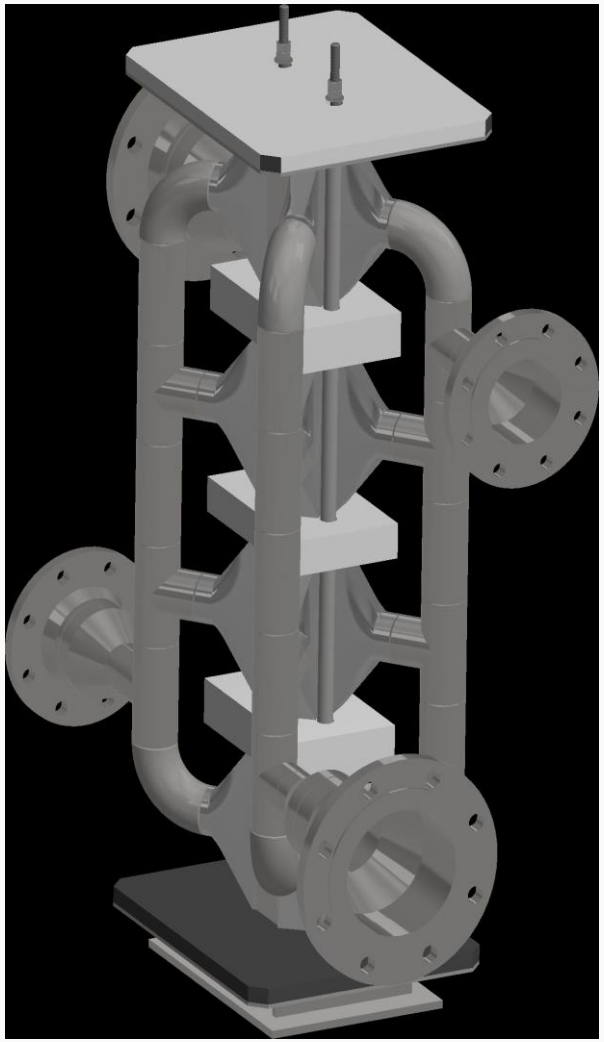
HPEX_A

- T_max ~950°C
- p~1,5bar
- Inc. 625
- P~3kW
- P_max~8kW

HPEx® – High Performance Heat Exchanger

Heat exchanger in refinery

- M_flow ~ 500kg/h
- T_max ~ 1.000°C (gas)
- p_drop < 15mbar
- H ~ 1.000mm
- Smaller (~1/8 size of conventiomal he)
- Cheaper



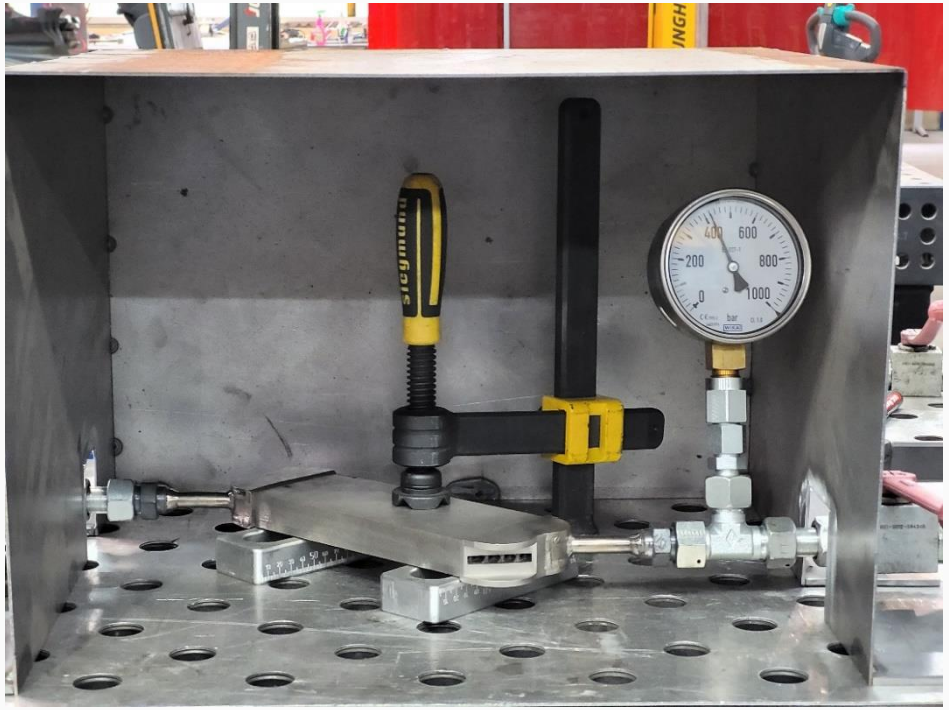
HPEx® – High Performance Heat Exchanger

Cooler at a hydrogen filling station for continuous operation

Requirements:
- T ~ -40°C to +40°C
- p ~ 700bar (op. pressure)
- p ~ 1.000bar (test pressure)

Tests of first prototype:
- Wall thickness ~ 1,2mm
- p_max ~480bar

Next steps:
- Optimise inner structures
- Increase wall thickness



HPEx® – High Performance Heat Exchanger

Summary and outlook

- HPEx® is not the standard equipment for conventional industrial furnaces
  - It only tolerates dust in low concentrations
  - For low temperatures up to 800°C, the HPEx® is expensive
    - For higher temperatures above 800°C it might be cheaper
  - One advantage is small space, usually there is no need at industrial furnaces
- HPEx® is interesting for industrial furnaces
  - Heat treatment furnaces with clean atmosphere
  - Heating tasks with Hydrogen or NH3
  - Heat recovery
    - Of inert gas
    - With electric power generation
      - …and hydrogen production

Thank you for your attention

Please ask your questions!

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