Key developments to counter freezing & fouling of brazed plate heat exchangers in reversible systems.

Technical – TT4
Presentation Objectives

• Latest development on BPHE technology as well as systems solutions to counter freezing and fouling.

• Freezing behavior of brazed plate heat exchangers
• Latest development in BPHE technology
• System implementations to counter risk of freezing and fouling
• Market change
• Solutions and their challenges
• SWEP Fouling and Freezing projects
  – Freezing
  – Fouling
  – Outcome
• Conclusion
What drives the industry?

**Refrigerant:**
- Most common refrigerants have a significant Global Warming Potential:
  - Replacement of R410A is unclear
  - Trend to lower refrigerant charge is advantageous for GWP and economic reasons. (KIGALI Agreement)

**Efficiency:**
- Electricity and oil price are increasing again:
  - Increased energy prices favor more energy efficient solutions

**Incentives (Energy Star):**
- Incentives program has not been extended for heat pumps
- Payback will drive the industry
- Lower installed costs and improved operational savings vs competing technologies.
How to maintain the growth pace?

- **10%**
  Higher performance – Improve system efficiency and Pay-back
- **80%**
  Smaller physical size – Allowing for smaller system solution
- **75%**
  Lower weight – Easier to assemble, transport and install
- **30%**
  Lower total system cost – at the same efficiency level
- **67%**
  Reduced refrigerant hold-up volume – less refrigerant
What are the challenges?

SWEP

GSHP Manufacturer

Efficiency

Refrigerants

Market changes

Freezing

Competition

Fouling

CUSTOMER
Project scope:

Background:

- Fouling and Freezing has been identified as one of the main customer issues when using Brazed Plates Heat Exchangers in reversible systems.
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- The fouling and freezing risk of the BPHE in a system is highly dependent on the system design and control strategy:
  - In **Penetrated Markets**, due to increased focus on Life Cycle Cost and seasonal efficiency, BPHE fouling and freezing resistance/sensitivity become more noticeable.
  - In **Non Penetrated Markets**, system manufacturers are used to applying other technologies which have different freezing and fouling behaviors.

Objectives:

Capture and derive knowledge regarding freezing and fouling in BPHE for reversible systems by

- Providing Anti-fouling and Anti-freezing guidelines (component/system)
- Establishing BPHE capability with regards to operational boundary conditions
- Use knowledge to improve BPHE design for higher freezing resistance and lower fouling sensitivity
- Develop pro-active and re-active solutions
Theory behind Freezing:

Background:

- There is no risk of freezing if wall temperature remains above freezing temperature.
- For a turbulent flow regime, film coefficients are a function of the respective mass flow:
  \[
  a_{water} = Re^n \times \frac{Cst \times Pr^a \times \frac{\mu}{\mu_{wall}} \times \Delta T_{wall}}{\delta h} = \dot{m}_{water}^{0.5 \text{ to } 0.7} \times k_{water}^* *
  \]
  \[
  a_{ref} = Re^n \times \frac{Cst \times Pr^a \times \frac{\mu}{\mu_{ref}} \times \Delta T_{ref}}{\delta h} = \dot{m}_{ref}^{0.5 \text{ to } 0.7} \times k_{ref}^{**}
  \]
- Wall temperature can be expressed as:
  \[
  Wall \; Temperature = T_{ref} + f(Mass \; flow \; ratio) \times (T_{water} - T_{ref})
  \]

Conclusion:

- Freezing risk can be evaluated based on:
  - Water temperature
  - Evaporating temperature
  - Mass flow ratio (Water Mass flow \ Refrigerant Mass flow)
  - BPHE’s design

* Bogeart et al. (1994)
** Jokar et al. (2006)
BPHE Freezing behavior evaluation – Macro Level:

SWEP Freeze Test results:

Lower Water Temp  Lower Water Flow
BPHE Freezing behavior evaluation – Micro Level:

SWEP CFD Simulations:

Design A:

Design B:
BPHE Freezing behavior evaluation – Macro Level:

SWEP Freeze Test results:

Product A

Product B
Freezing evaluation – System Level:

- Condensing Temperature
- Enter Water Temp.
- Leaving Water Temp
- Evaporating Temperature
- SWEP's recommended Minimal Evap. Temp

Defrost cycle

110°F
32°F
-15°F
Theory behind Fouling:

Background:
- There is no risk of fouling for applications with clean and soft water.
- The corrugations of the plate gives very high flow turbulence, even at low flow rates. In a normal pipe, the Re of the flow has to reach over 2000 in order to achieve turbulence. In a SWEP BPHE however, turbulent flow is achieved at a Re close to 150.
- High turbulence together with small hydraulic diameter prevents particles from settling on the surface.

Conclusion:
- Fouling risk can be evaluated based on:
  - Water temperature
  - Water quality
  - Reynolds Number \ Shear stress value
  - BPHE’s design
BPHE Fouling behavior evaluation:

SWEP Fouling Test:

Test Purpose:
- Evaluate fouling effect on BPHE with various water quality
- Establish system and BPHE design recommendation

Test description:
- Tests are performed running water circuit, F2/F4
- BPHE is monitored with pressure and temperature sensors.

Test procedure:
- Running the BPHE under specified conditions
- Monitor fouling effect over the time by measuring BPHE’s thermal and hydraulic performance
- Evaluation of fouling distribution by destructive test
Conclusion

- BPHE sensitivity and resilience is evaluated through SWEP’s Freezing and Fouling test
- SWEP defined the operating envelope to avoid freezing in a BPHE
  - Water Temperature
  - Evaporation Temperature
  - Mass flow ratio
- SWEP defined the operating envelope to avoid fouling in a BPHE
  - Shear stress guidelines
- Different BPHE design results in different operating envelopes

**ENGINEERING GUIDELINES FOR REVERSIBLE HEAT PUMPS**
Project outcome – BPHEs Optimized for GSHP

SWEP BPHE product range for reversible heat pumps
8LAS, 26F, 80, 80AS, 85, 250AS, D310

Main features:
- AsyMatrix Design
- Optimized chevron angle and press depth
- Optimized evaporator distribution systems
- SWEP Freeze and Fouling tested

8LAS V26F F80AS P250AS DP310
Project outcome – SWEP & SIKA Anti Freezing package

Flow Switch cooperation:

- SWEP and SIKA have defined a flow switch solution for heat pumps in capacities 2 – 6 RT
- Optimized set points per capacity size assure turbulent flow in the SWEP BPHE
- Eliminates most common reason for freezing in heat pump systems
Questions?

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