Experimental Investigation on a Hybrid Enhanced Surfaces Absorption Heat Transformer Generator

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Introduction: Low Temperature Waste Heat

European industry’s energy demand was reduced by 28% between 1990 and 2012.
• Economic crisis,
• Energy decoupling.

However, still demands the fourth part of the Europe’s energy demand. Approximately 70% of energy industrial demand has thermal proposes, ~30% of this energy is directly wasted.
Introduction:
Low Temperature Waste Heat

¿LOW TEMPERATURE? → Accumulative

High Temperature became Low Temperature

Waste Heat

Temperature

Low Temp.  High Temp.

US Energy Protection Agency

> 175 °C

< 175 °C

“... almost 60% of heat lost is at low temperature”
Introduction:
Low Temperature Waste Heat

Absorption Heat Transformer
Type II Heat Pump

Publications related to AHT
Introduction:
Low Temperature Waste Heat
Introduction:
Low Temperature Waste Heat

Experimental Investigation on a Hybrid Enhanced Surfaces Absorption Heat Transformer Generator.
A. Martinez-Urrutia. Lleida, June de 2017.
Experimental Test Bench
Experimental Test Bench:

Hybrid Generator: 10-15kW

Falling film part:
- 4 columns,
- 12 rows,
- Tubes:
  - Low finned enhanced tubes,

Pool Boiling part:
- 16 tubes,
- Tubes:
  - Low finned enhanced tubes,

Distributor:
- 49 holes,
- 2x7 mm,
- pitch of 3 mm.
Experimental Test Bench:

Generator – Condenser Vessel
GENERATOR PART

Generator – Condenser Vessel
CONDENSER PART
Experimental Test Bench:
Results and Discussion
Results and Discussion: Falling Film

Lithium Bromide Aqueous Solution:
• Tests in falling film mode with variable solution flow rate:
  – $\Gamma_{\text{inlet}} = 0.005 - 0.033 \text{ kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$.
  – $Re = 7.84 - 65.85$.
• Generator inlet concentration $X_{\text{inlet}} \sim 55\%$

External Temperatures and velocities:
• Generator:
  – External heating inlet temperature $T_{\text{gen,inlet}} \sim 95^\circ\text{C}$
  – $v_{\text{gen,ext}} \sim 1.0 \text{ m} \cdot \text{s}^{-1}$
• Condenser:
  – Cooling water temperature $T_{\text{cd,inlet}} \sim 25^\circ\text{C}$
  – $v_{\text{cd,ext}} \sim 1.4 \text{ m} \cdot \text{s}^{-1}$
Results and Discussion: Falling Film

- Increase in heat flux and overall heat transfer coefficient with increasing mass flow rates, reaching a heat flux between almost 4,000 and a maximum of ~10,000 W·m⁻².

- Mass transfer fluxes of between 1.40 and 3.80 g·m⁻²·s⁻¹, when mass flow rate is increased.

- Kim et al. (1999)* studied falling film generators using enhanced copper tubes: knurled and spirally grooved tubes. Bibliography-data with enhanced knurled surfaces laid between 1.44 and 3.5 g·m⁻²·s⁻¹, which are in good agreement with values in this work.

Results and Discussion:  
Pool Boiling

Pool boiling performance under different external water inlet temperatures:
• $T_{\text{gen,inlet}} \sim 80 - 105 \, ^\circ\text{C}$.

Lithium Bromide Aqueous Solution:
• $m_{\text{sol,in}} \sim 0.04 \, \text{kg} \cdot \text{s}^{-1}$.
• Generator inlet concentration: $X_{\text{inlet}} \sim 55\% \ (53.49 - 55.11\%)$

External Temperatures and velocities:
• Generator:
  – Variable temperature.
  – $v_{\text{gen,ext}} \sim 1.0 \, \text{m} \cdot \text{s}^{-1}$
• Condenser:
  – Cooling water temperature $T_{\text{cd,inlet}} \sim 25^\circ\text{C}$
  – $v_{\text{cd,ext}} \sim 1.4 \, \text{m} \cdot \text{s}^{-1}$
Results and Discussion:

Pool Boiling

- Results in pool boiling mode show a linear increase in heat flux, obtaining heat fluxes between ~11,500 and 36,500 W∙m⁻².

- Mass transfer fluxes show a linear increase. Results obtained are between 4.62 and 13.76 g∙m⁻²∙s⁻¹ for 85 and 105 °C respectively.

- Estiot et al. (2005)* compared data of several authors. Under the range of LMTD = 5–10K the performance agrees with data obtained by other authors, although the heat transfer flux and are higher for other authors in the same range temperature differences.

Conclusions
Conclusions:

• AHT is considered as very interesting technology for European intensive industry.
• Experimental work is considered very important in order to understand heat and mass transfer processes in the components, which have some differences with the working conditions of the Absorption Chillers.

This work presents the performance of the elements composing a hybrid generator:

• Falling Film generator:
  ✓ Enhanced surfaces.
  ✓ Optimum flow rate $\Gamma_{\text{inlet}} \sim 0.020 - 0.025 \text{ kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$
  ✓ Heat flux $q \sim 10,000 \text{ W} \cdot \text{m}^{-2}$
  ✓ Mass transfer flux $\beta \sim 3.50 \text{ g} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$

• Pool Boiling generator:
  ✓ Enhanced surfaces.
  ✓ Heat flux $q \sim 30,000 \text{ W} \cdot \text{m}^{-2}$
  ✓ Mass transfer flux $\beta \sim 11.0 \text{ g} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$
Conclusions:

• AHT is considered as very interesting technology for European intensive industry.
• Experimental work is considered very important in order to understand heat and mass transfer processes in the components, which have some differences with the working conditions of the Absorption Chillers.

This work presents the performance of the elements composing a hybrid generator:

50kW Design
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http://www.indus3es.eu/
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