Advanced heat driven hybrid refrigeration and heat pump systems

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1. Introduction

2. Conceptual Hybrid systems

- Configuration 1 (Description & Performance)
- Configuration 2 (Description & Performance)

3. Conclusions
1 - Introduction

- Domestic heating
  - 37% (Primary Energy)

- UK Energy landscape
  - 25% Contribution

- Advanced Heat Pump (up to 40 kW): Prospect of CO2 emission reduction through better performance than condensing boiler (by factor of about 2 to 3).

Source: DECC Report 2014 (UK)
2. Conceptual Hybrid systems: Configuration 1

ADSORPTION CYCLE WITH TURBINE (AdSC / AC-R717)

CONVENTIONAL MECHANICAL VAPOUR COMPRESSION CYCLE (VCC / R717)
2. Conceptual Hybrid systems: Configuration 1

ADSORBER
AC 208C-R717
Shell-and-tube (40 off: 1m x 1”OD x 0.91mm Thickness) / SS
Packed density: 750 kg/m³
Thermal conductivity: 0.44 W/m K
Internal wall contact HTC: 750 W/m² K
External wall convective HTC: Infinite
Bed operating pressure: 37 bar
Maximum driving temperature: 250°C

\[ \Delta T_s = 7 \text{ K} \]
\[ \Delta T_{s/c} = 4 \text{ K} \]
2. Conceptual Hybrid systems: Configuration 1 Performance

Module temperature profiles

Module Ammonia concentration profiles

Ammonia mass flowing out of a Module

Module Overall specific heat of Desorption

**Module temperature profiles**
- Temperature (°C) vs. Time (s)
- Graph shows temperature profiles over time for different components.

**Module Ammonia concentration profiles**
- Ammonia concentration (kg/kg) vs. Time (s)
- Graph shows concentration profiles over time.

**Ammonia mass flowing out of a Module**
- Ammonia gas mass (kg) vs. Time (s)
- Graph shows the mass of ammonia flowing out over time.

**Module Overall specific heat of Desorption**
- Overall specific heat of Desorption (J/kg K) vs. Carbon mean temperature (°C)
- Graph shows the relationship between specific heat and carbon mean temperature.
2. Conceptual Hybrid systems: Configuration 1 Performance

Hybrid AdSC-VCC: Tc = 40°C

- COP
  - TE = 15°C
  - TE = 10°C
  - TE = 5°C
  - TE = 0°C
  - TE = -5°C

- Total Heating Power output (kW)
  - TE = 15°C
  - TE = 10°C
  - TE = 5°C
  - TE = 0°C
  - TE = -5°C

AdSC Contribution: Tc = 40°C

- AdSC Heating Power output (kW)
  - TE = 15°C
  - TE = 10°C
  - TE = 5°C
  - TE = 0°C
  - TE = -5°C

VCC Contribution: Tc = 40°C

- VCC Heating Power output (kW)
  - TE = 15°C
  - TE = 10°C
  - TE = 5°C
  - TE = 0°C
  - TE = -5°C
2. Conceptual Hybrid systems: Configuration 2

RANKINE CYCLE (RC / R718)

CONVENTIONAL MECHANICAL VAPOUR COMPRESSION CYCLE (VCC / R717)

$\eta_t = 80\%$

$\eta_c = 80\%$

$\Delta T_s = 7 \text{ K}$

$\Delta T_{s/c} = 4 \text{ K}$

$m_f = 5 \text{ g/s (18 kg/h)}$
2. Conceptual Hybrid systems: Configuration 2 Performance

![Graphs showing Performance of Hybrid RC-VCC](image)

- **COP**: Efficiency of the system as a function of the driving temperature.
- **Total Heating Power output (kW)**: Total heating power output for different temperatures.
- **RC Contribution**: Contribution of the RC part to the total heating power output.
- **VCC Contribution**: Contribution of the VCC part to the total heating power output.

**Key Points**:
- The COP and total heating power output increase with the driving temperature for all cases.
- The contribution of the RC and VCC parts also shows an increasing trend with the driving temperature.
- The performance is affected by the temperature difference (TE) across the system.
2. Conceptual Hybrid systems: Configuration 2 Performance

Hybrid RC-VCC: TE = 5°C

COP

0 1 2 3 4

100 150 200 250

Driving Temperature (°C)

TC = 40 °C
TC = 45 °C
TC = 50 °C
TC = 55 °C
TC = 60 °C

RC Contribution: TE = 5°C

Total Heating Power output (kW)

0 10 20 30 40

100 150 200 250

Driving Temperature (°C)

TC = 40 °C
TC = 45 °C
TC = 50 °C
TC = 55 °C
TC = 60 °C

VCC Contribution: TE = 5°C

RC Heating Power output (kW)

9 9.5 10 10.5 11

100 150 200 250

Driving Temperature (°C)

TC = 40 °C
TC = 45 °C
TC = 50 °C
TC = 55 °C
TC = 60 °C

VCC Heating Power output (kW)

0 10 20 30 40

100 150 200 250

Driving Temperature (°C)

TC = 40 °C
TC = 45 °C
TC = 50 °C
TC = 55 °C
TC = 60 °C
3. Conclusions

**Hybrid AdSC-VCC:**
- Limited COP (1.2 to 1.4)
- Less cost effective
- Simple AdSC could be better instead

**Hybrid RC-VCC:**
- Good COP (1.5 to 2.6)
- Better than Hybrid AdSC-VCC
- Better than condensing boiler
- Could be cost effective
- Space heating and DHW
Thank you