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Activated Carbon–Hydrogen Based Continuous Sorption Cooling in Single Adsorbent Bed with LN_2 Heat Sink

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Outline

- Introduction
- New concept
- Objective
- Theory and validation
- Results and discussion
- Conclusions

Introduction – Solid Sorption Cooling

Advantages

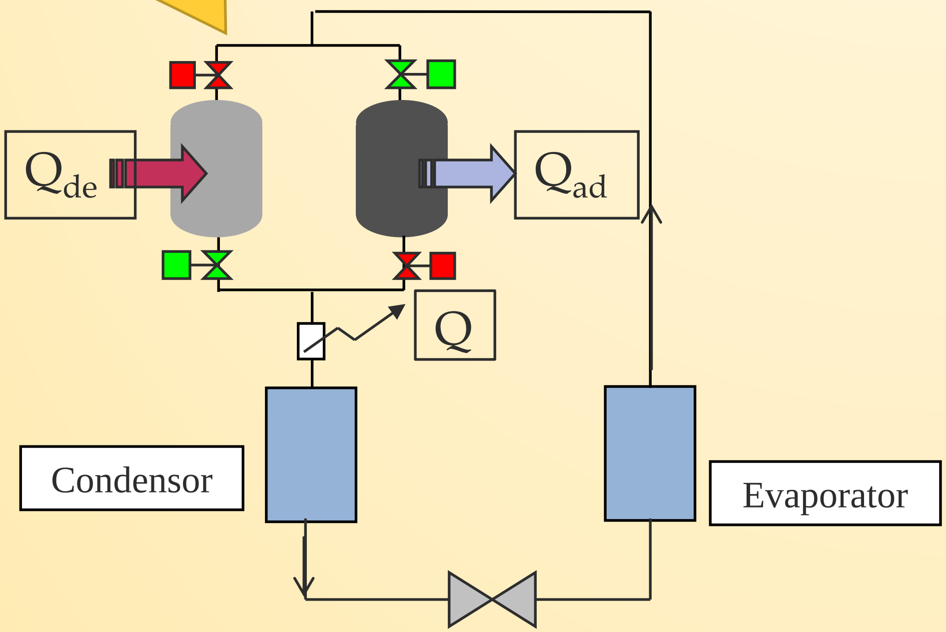
- Zero global warming potential
- High heat of adsorption of working fluid
- Wide temperature domain

Different Domain of Application

- Air conditioning
- Refrigeration
- **Cryogenic cooling**

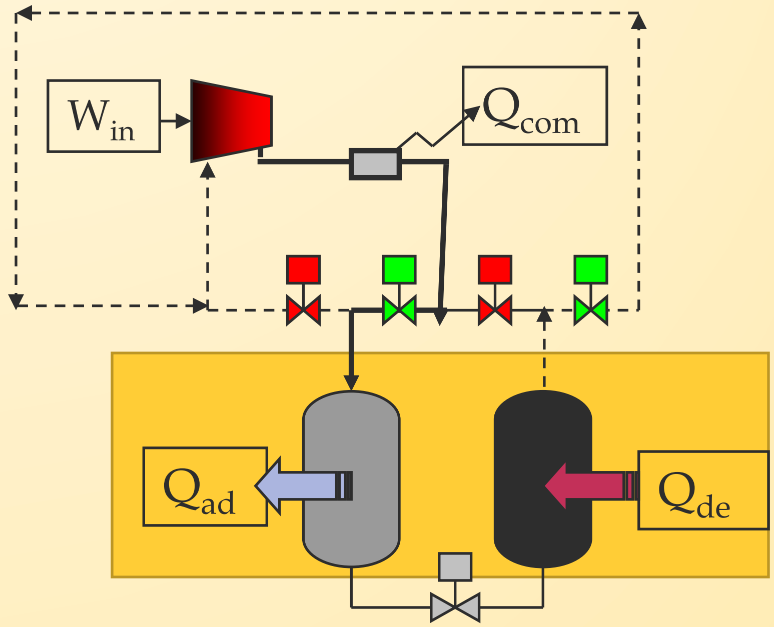
Classification

well-documented



Thermal compressor driven cycle

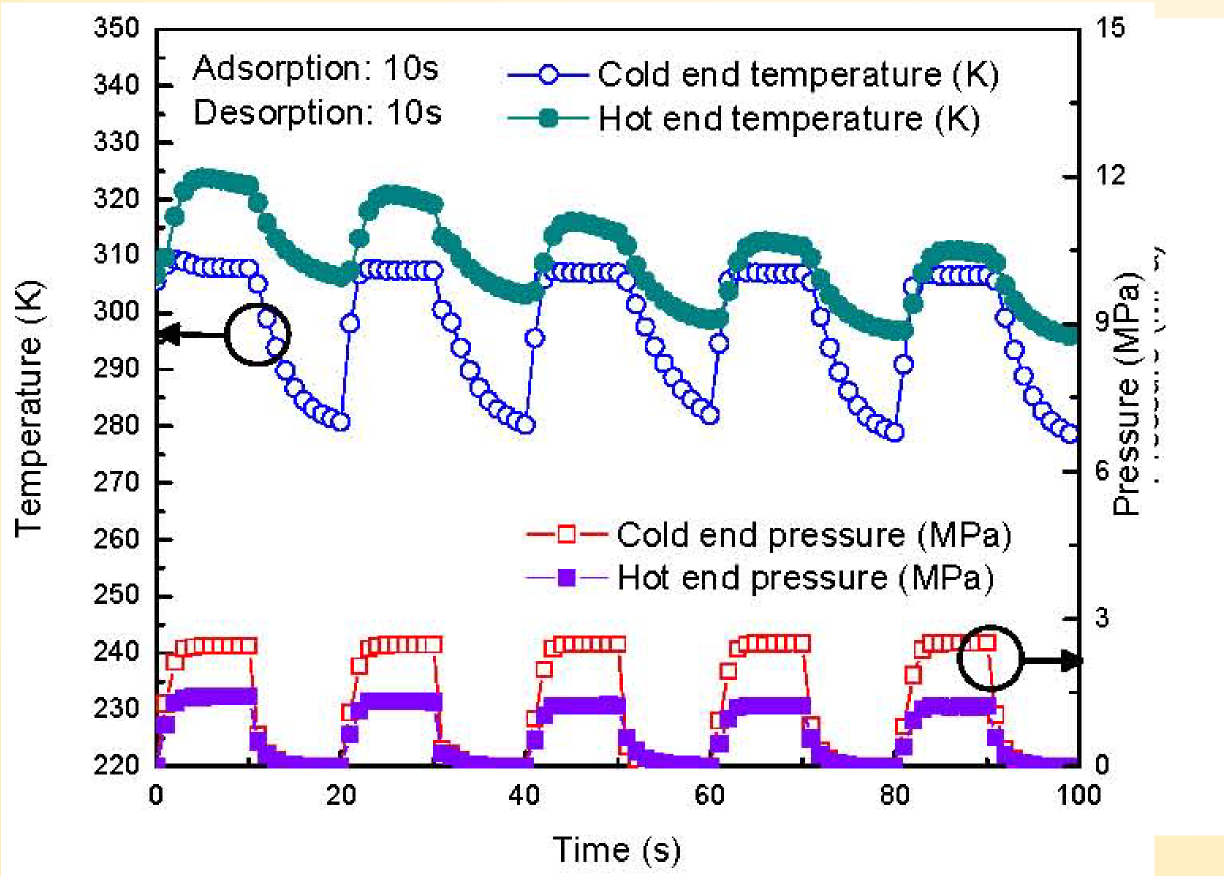
less-familiar

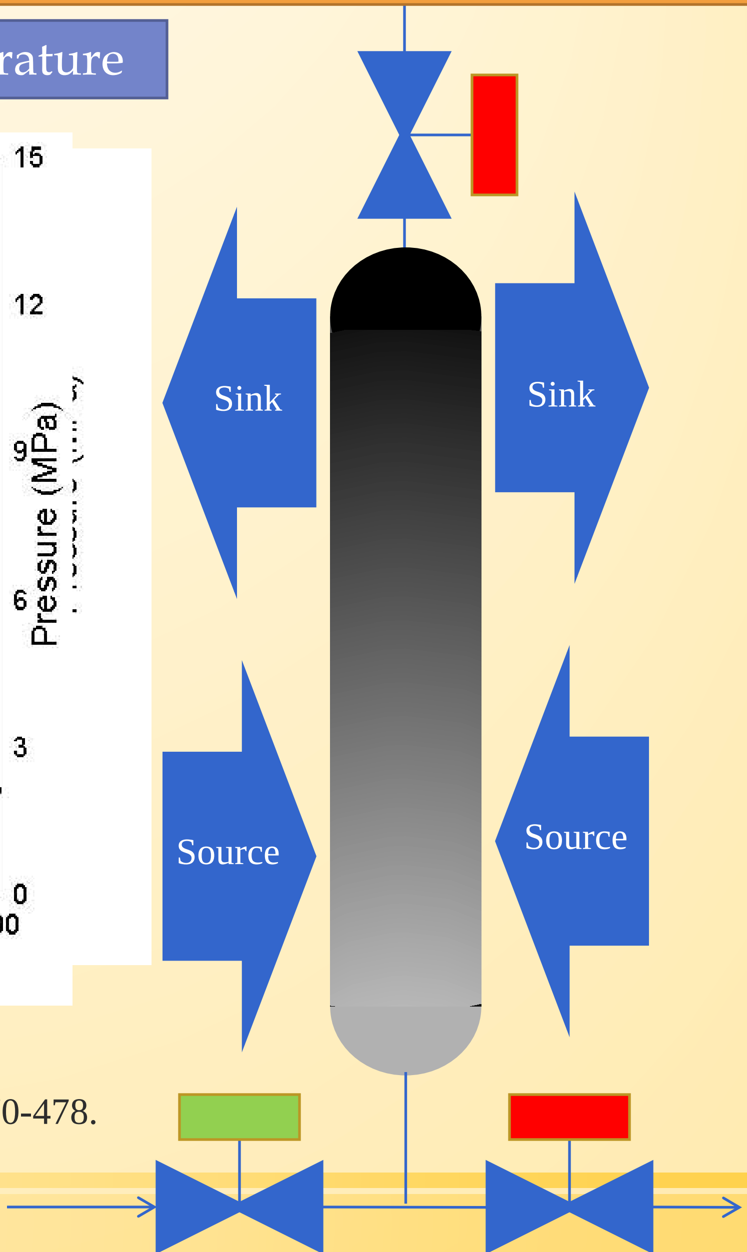


Mechanical compressor driven cycle

Novel Concept

Activated carbon-Nitrogen system at room temperature



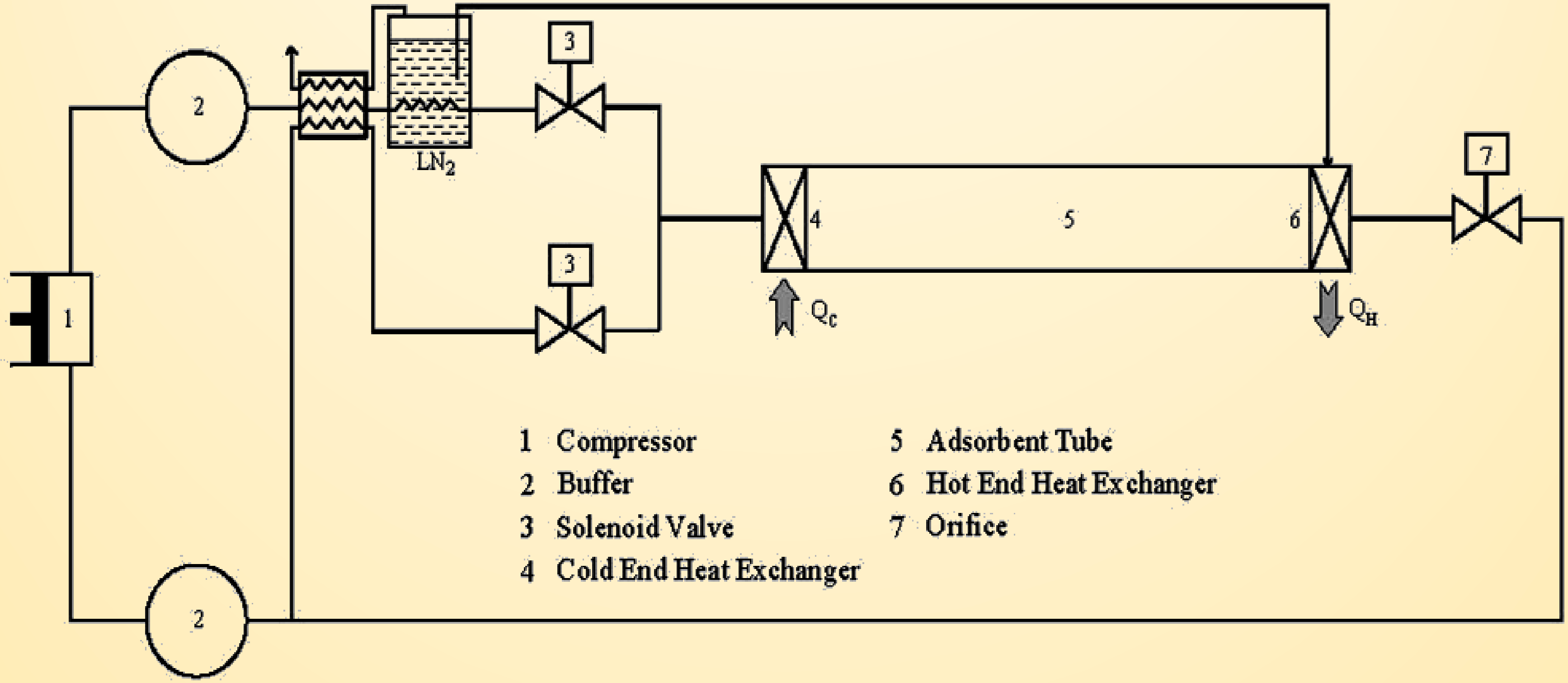


- Koley S. Ghosh I., 2013. Applied Thermal Engineering; 55, 33-42.
- Koley S., Ghosh I., 2014. Int. Journal of Heat and Mass Transfer; 72, 470-478.

Objective

- Theoretical investigation of LN_2 pre-cooled continuous solid sorption cooling in activated carbon-hydrogen system
- Parametric studies of the cooling process

Physical Model



Governing Equations

Mass Balance Equation

$$\varepsilon\frac{\partial\rho}{\partial t}+\varepsilon\frac{\partial}{\partial x}\left[u\rho-D_{ax}\frac{\partial\rho}{\partial x}\right]+(1-\varepsilon)\rho_s M_g\frac{\partial q(x,t)}{\partial t}=0$$

Energy Balance Equation

$$\left[\varepsilon A_1\rho C_p+(1-\varepsilon)A_1\rho_s C_{ps}+\varepsilon A_2\rho_w C_{pw}-\varepsilon A_1\bar{R}\rho\right]\left(\frac{\partial T}{\partial t}\right)-(1-\varepsilon)A_1\Delta H\rho_s\frac{\partial q(x,t)}{\partial t}$$
$$=\frac{\partial}{\partial x}\left[A_1 k_b\frac{\partial T}{\partial x}-\varepsilon A_1\rho C_p uT\right]-h_{amb}(\pi D_0)(T-T_0)$$

Initial Conditions for Adsorption

$\rho(x,\ t=0)=\rho_0$ and $T(x,\ t=0)=T_0$

Initial Conditions for Desorption

$\rho(x,\ t=0)=\rho_x(T_x,\ P_x)$ and $T(x,\ t=0)=T_x$

Boundary Conditions

At x=0;

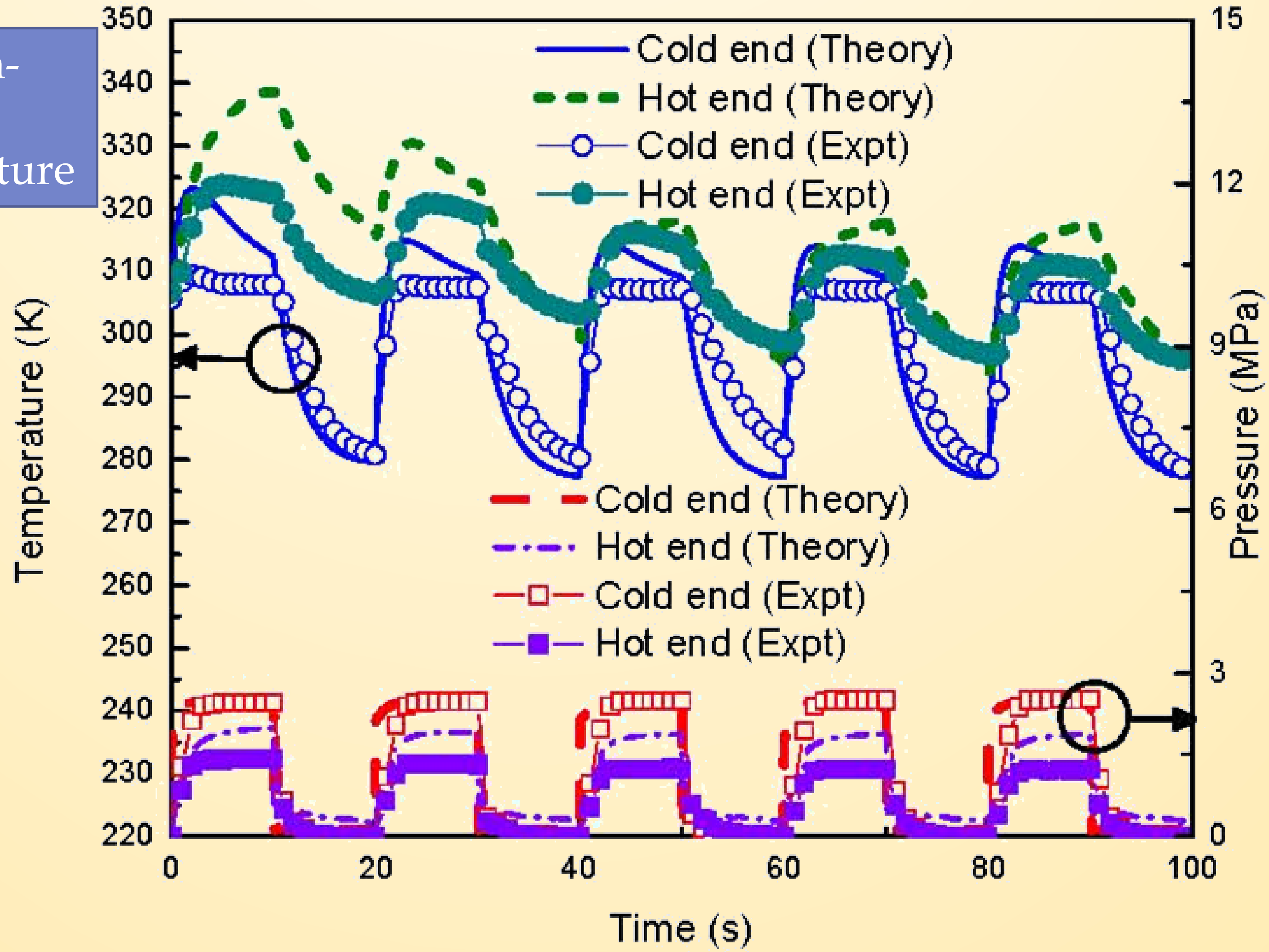
$u\rho(0,t)-D_{ax}\frac{\partial\rho}{\partial x}(0,t)=u\rho_0$ and $T(0,\ t)=T_0$

At x=L

$\frac{\partial\rho}{\partial x}(L,t)=0$ and $\frac{\partial T}{\partial x}(L,t)=0$

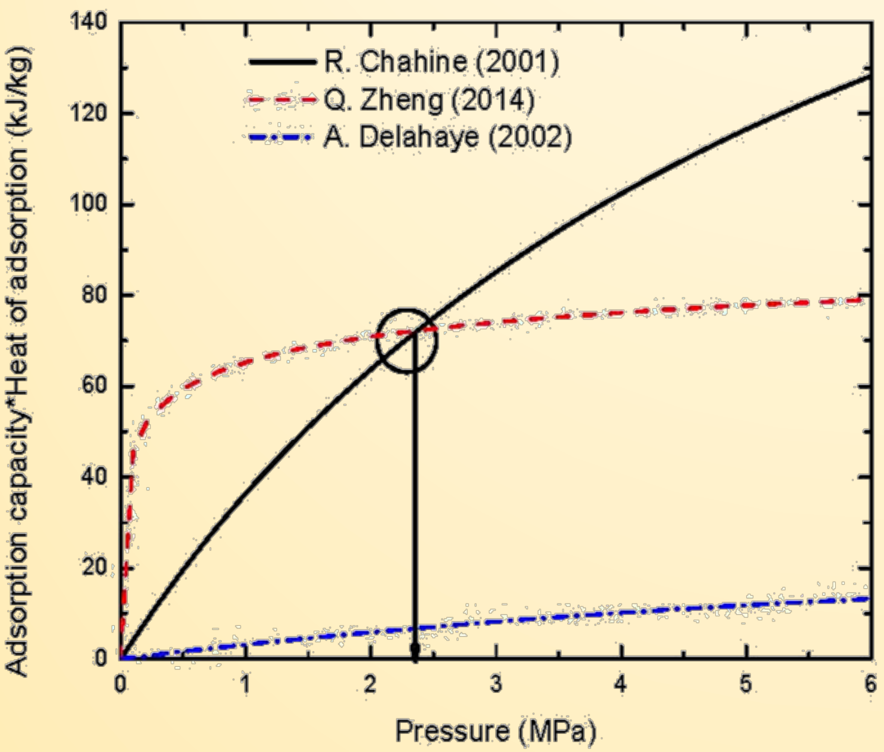
Validation

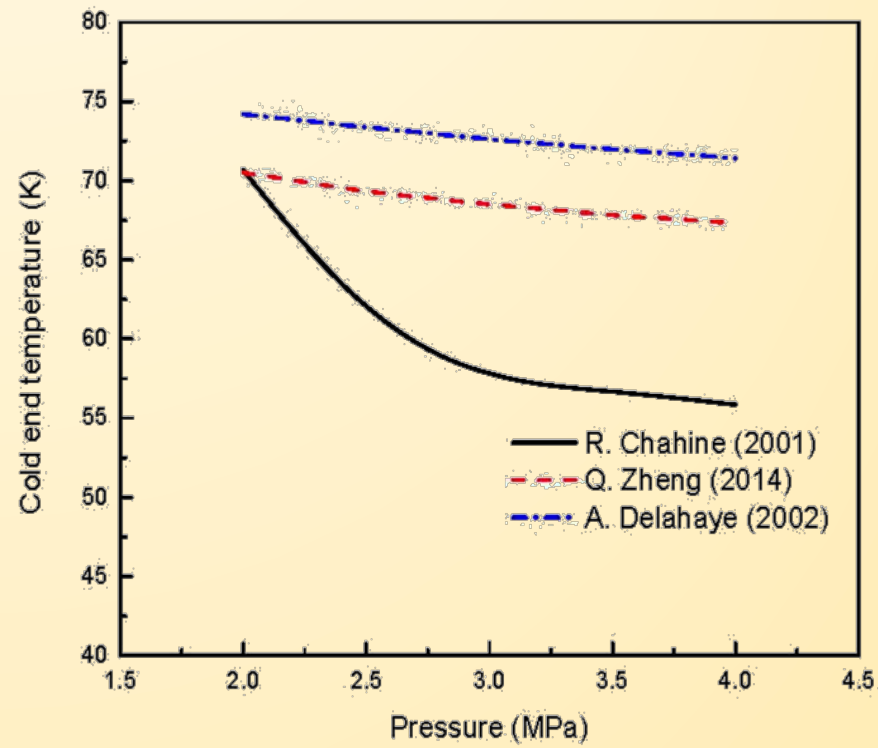
Activated carbon-Nitrogen system at room temperature



Results and Discussions

Different activated carbon

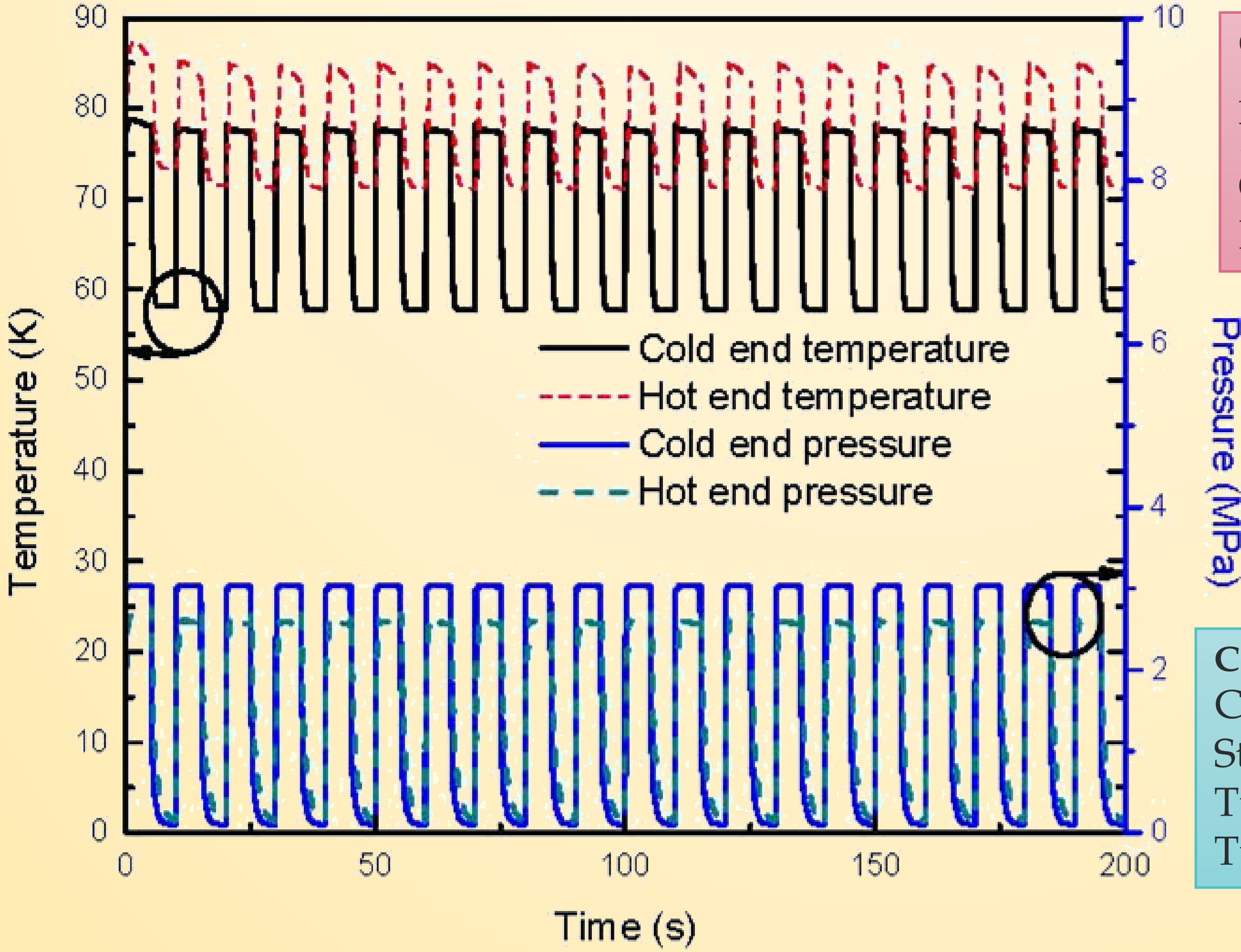




- Benard P., Chahine R., 2001. Langmuir 17, 1950-1955.
- Zheng Q., Wang X., Gao S., 2014. Cryogenics 61, 143-148.
- Delahaye A., Aoufi A., Gicquel A. Pentchev I., 2002. Energy and environmental engineering 48, 2061-2073.

Theoretical Results

Time-temperature-pressure profile

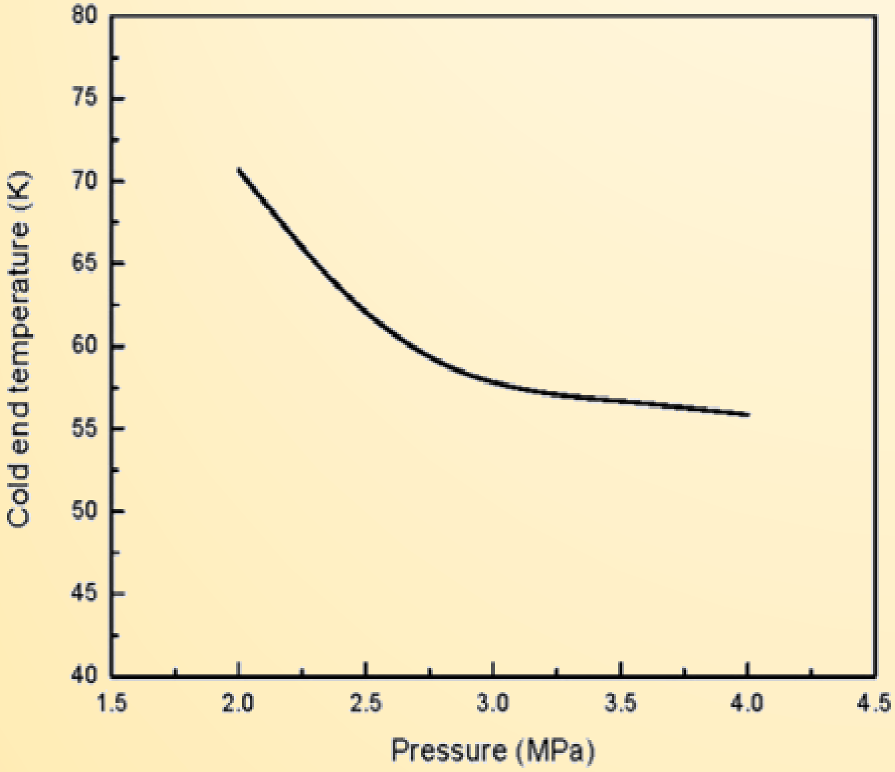


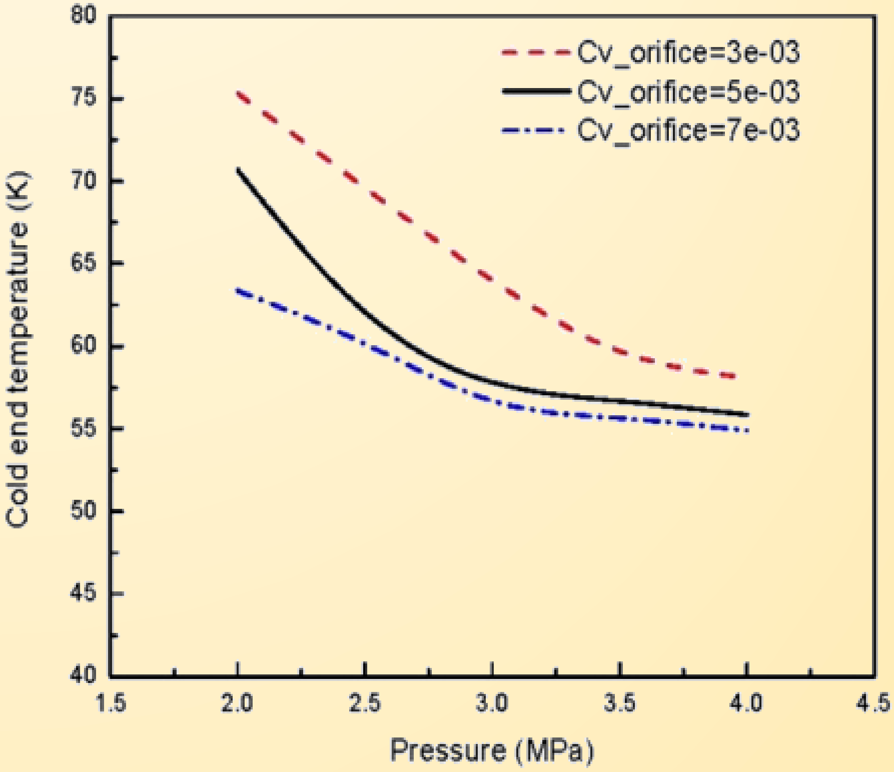
OPERATING CONDITION
Adsorption time: 5s
Desorption time: 5s
Operating pressure: 3MPa
Initial Temperature: 77K

CONSTRUCTION PARAMETER
C034 Activated carbon
Stainless steel tube
Tube length: 250mm
Tube diameter: 28mm

Theoretical Results

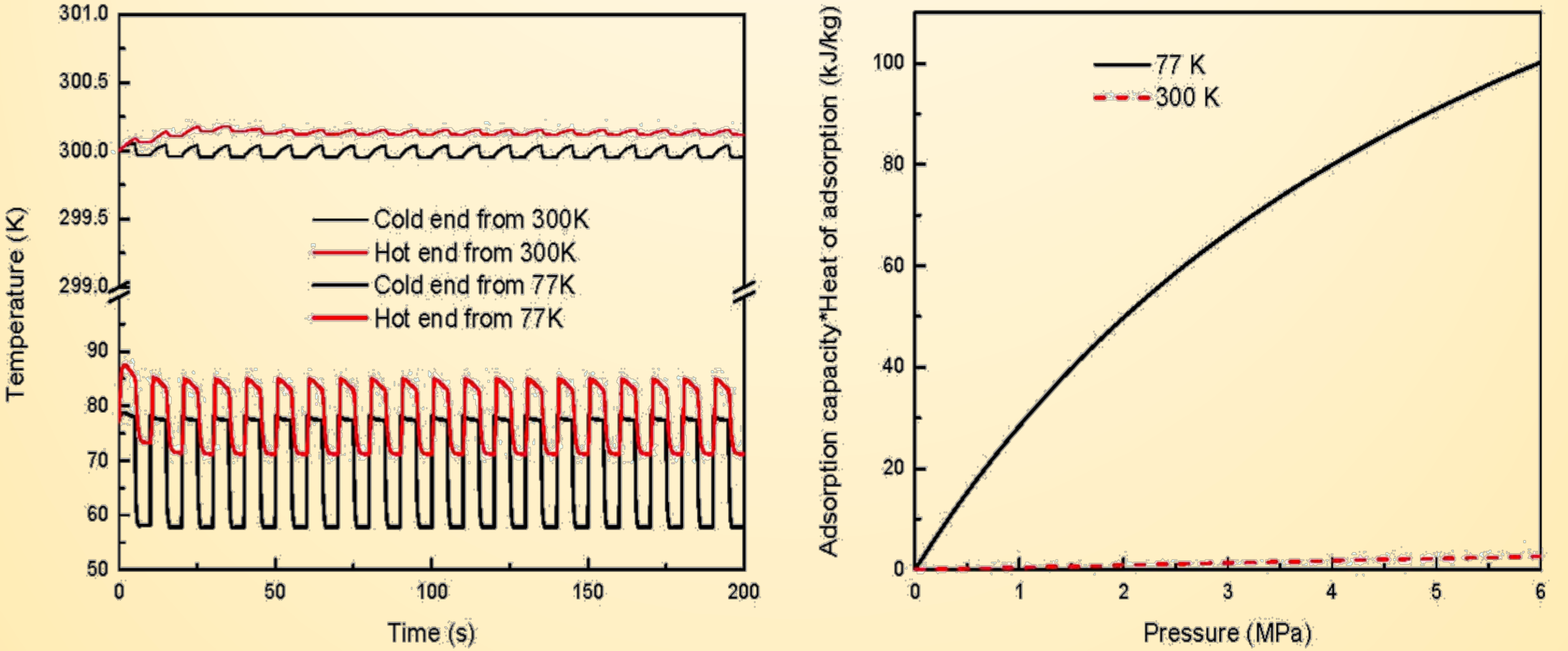
Different orifice opening





Theoretical Results

Effect of pre-cooling



$$\left[\varepsilon A_1 \rho C_p + (1-\varepsilon) A_1 \rho_s C_{ps} + \varepsilon A_2 \rho_w C_{pw} - \varepsilon A_1 \overline{R} \rho\right]\left(\frac{\partial T}{\partial t}\right) - (1-\varepsilon) A_1 \Delta H \rho_s \frac{\partial q(x,t)}{\partial t}$$

$$= \frac{\partial}{\partial x}\left[A_1 k_b \frac{\partial T}{\partial x} - \varepsilon A_1 \rho C_p u T\right] - h_{amb}(\pi D_0)(T - T_0)$$

Conclusions

- Generation of cooling at LN_2 temperature is possible using activated carbon and hydrogen as adsorbent/adsorbate pair
- Higher operating pressure and wider orifice opening are favorable for larger temperature drop
- Suitability of working pair for a given temperature and pressure zone of interest is decided by the product of equilibrium adsorption capacity and heat of adsorption

THANK YOU

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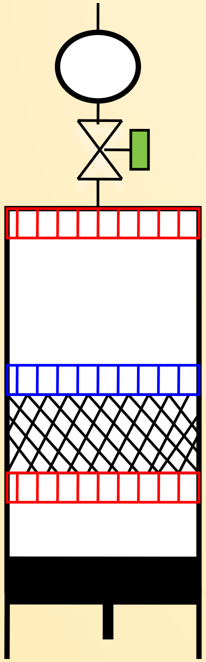
Comparison with Pulse-Tube Refrigerator



- Empty tube
- Heat of expansion causes cooling
- Frequency in Hertz order

- Filled with adsorbent
- Heat of desorption causes cooling
- Frequency in mili-Hertz order