COOLING WITH A SORPTION OPEN CYCLE USING CO_2 AS THE REFRIGERANT.

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Introduction

Numerous industrial applications such as air purification, drinking water treatement and gas separation use the adsorptive properties of activated carbons. Adsorption refrigerating machines constitute another application of these materials which is currently undergoing rapid development, especially since the new regulation on the use of CFC. The Paris Symposium [1] and more recently the Absorption Conference of Montreal took stock of the topicality and the state of development of the research. One of the most important advantage of sorption is the natural stocking function that enables a large time lag between the cold production and the phase of regeneration. The basic cycle allowing a pseudo-continuous cooling involves four elements, an evaporator, a condenser and two fixed bed reactors working in a dephased sequence. This leads to some limitation when one's is only interested in a stocking application, with criteria of compactness and leightness. In the objective to increase the ratio, stocking energy divided by the mass of the system, this paper presents the study of a new open sorption process where the refrigerant fluid, after being stocking by the adsorbent, is released in the environment. Cooling happens by the endothermic desorption of the gas. As a function of toxicity consideration, and thermodynamic working conditions, the dioxide of carbon has been selected. Figure 1 presents the working mode of the process. At the beginning the activated carbon is at the weak adsorbed quantity of CO_2 at the ambient temperature and a pressure of 1 bar of CO_2. During the first phase, the adsorbent is charged in CO_2 according the increase of pressure of CO_2 (travel from A to B in dashed line). It is made with the connection of the reactor containing the adsorbent to a bottle containig pure CO_2 in liquid/gas equilibrium. The heat of adsorption is released in the environment. Then the reactor is closed and the cooling happens, when desired, simply by opening the valve. The cooling energy is linked to the endothermic desorption of the CO_2 (travel from B to A) which is released. The interest of a sorption process is the high enthalpy of desorption of the order of 500 kJ.(kg of CO_2)$^{-1}$ compared to the enthalpy the liquid-gas phase change of 189 kJ.kg^{-1} at 10°C. The application presented is the design of a portable system of thermal assistance for the air-conditionning of bodies equiped with total insulation garment. The objective is a minimum cooling power of 100W during one hour.

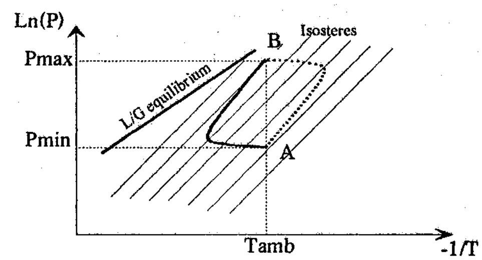

Figure 1. Presentation in the Clapeyron's diagram of the thermodynamic working mode for cold production with an open soption process.

Choice of the activated carbon

We can count for many activated carbon which are commercialized or studied in laboratories. Then, the choice of an adapted activated carbon is an important step in the design of a performant process. For this application, the comparison has been made on the useful stocking mass of CO_2 per kilogram of adsorbent but also on the stocking energy. By useful, one's means the mass of CO_2 released by the reactor during the cooling phase.

Activated Carbon	(kg CO_2/kg ads)	Energy (Wh/kg ads)
MAXSORB	1.23	160
KF1500	0.47	74
TA90 (Pica)	0.43	63
BPL	0.31	45
MSC5A	0.14	25

Table 1 : Comparaison of performances of several activated carbon , the thermodynamic conditions are for the point B (P=35 bars, T=303K) and for the point A (P=1.2 bars and T=303K).

The results presented Table 1 come from the use of the Dubinin Astakhov equation [2] whose parameters (W_o, E_o, n) have been determined at the laboratory with a volumetric method [3]. From these results it is obvious that the MAXSORB is the most adapted activated carbon.

Experimental air-conditionner

The air is blown by a ventilator, it is cooled by heat exchange with the surface of the reactors in desorption (Fig. 2). The measurement of the mass flow of the air and the inlet and outlet temperatures of the air allows to calculate experimentally the cooling power. The instrumentation is completed by a pressure sensor and several thermocouples inside the adsorbent. The reactant consists of a mixture of MAXSORB with natural expanded graphite [4] which is compressed inside the reactor at a density of 500 $kg.m^{-3}$. The use of expanded graphite at a mass ratio of 30% ensures an enhancement of the transfer properties of the reactive bloc. The characteristic transfer parameters which have been measured are an equivalent heat conductivity upper than 8 $W.m^{-1}.K^{-1}$ and an equivalent permeability of 0.01 Darcy.

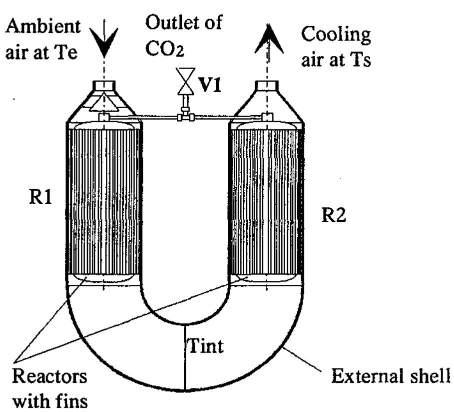

Figure 2. Experimental reactors ; the lenght of each reactor is of 0.3 m and the internal diameter is of 0.08m.

Results and discussion

The experimental plant is placed in a chamber regulated in temperature at 35 °C. The reactor are charged at a pressure of 35 bars. The air is flowing at a rate of 6$m.s^{-1}$ around the fins that ensure a heat exchange coefficient air-surface of the reactor around 40 $W.m^{-2}.K^{-1}$. At t = 0 the valve V1 is opened. During the 60 mn of the experiment the mean outlet temperature of the air is of 20°C and the mean cooling power is of 110W (Fig.3). Two phases can be distinguished in the working mode of the reactors. A first one which is during two minutes (Fig. 4) corresponding to the decrease of the pressure from 35 to 1.2 bars with a rapid evolution of the temperatures inside the adsorbent , this makes it possible a quasi-instantaneous cooling. A second one that corresponds to the desorption of CO_2 at a constant pressure with a slow increase of the outlet temperature of the air that is the result of the evolution of the composition of the adsorbent inside the reactors.

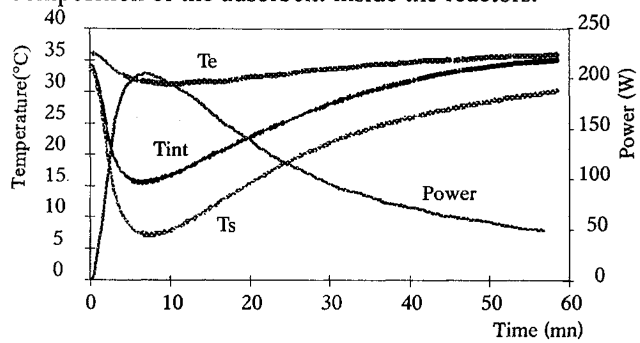

Figure 3. Experimental outlet temperature of the air and cooling power as a function of the time.

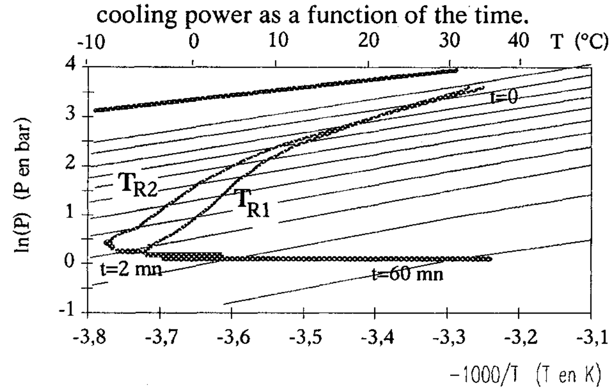

Figure 4. Experimental thermodynamic path of the adsorbent in the Clapeyron's diagram.

For a practical direct air-conditioning of a person, the air blown inside the insulation garment should be at a temperature from about 20 to 25 °C ; a too low temperature can be dangerous for the physiological equilibrium of the person. That can be easely achieved by the regulation of the cooling power with the control of the mass air flow or/and the mass flow of CO_2.

References

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3. Guillot, A., Follin, S., Poujardieu, L., in *Int. Symp. On the Characterisation of Porous Solid*, Bath, 1996, (to be published).
4. Coste, C., Mauran, S., Crozat, G., *French Patent n° 8309885*, 1983.