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ScienceDirect
Applied Thermal Engineering 27 (2007) 988–993
APPLIED THERMAL ENGINEERING
www.elsevier.com/locate/apthermeng

Experimental study on HFC125 critical heat pump

Xiangjiang Zhou [a,b,*], Zhiwei Lian [a], Zhihua Li [a], Ye Yao [a]

[a] Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, 200030, PR China
[b] Jiaxing University, 314001, PR China

Received 4 April 2005; accepted 10 August 2006
Available online 18 October 2006

Abstract

A critical cycle heat pump with HFC125 was studied experimentally. The experimental result indicates that the heat pump with HFC125 can use the general components of the conventional heat pump well. Hot water with wide-range temperature can be conveniently got by the critical heat pump system through water flow control. The COP_h of the critical cycle drops a little when the temperature of outlet water rises from 60 °C to 75 °C. And adding heat recovering exchanger cannot improve the performance of the cycle, but can reduce the working pressure of the cycle. Comparing with the CO_2 trans-critical heat pump, HFC125 critical heat pump has a better performance of refrigeration, lower working pressure, which is especially suitable for dual-function of supplying hot water and refrigeration in the civil and industrial buildings.

Keywords: Critical cycle; HFC125; Heat pump

1. Introduction

Because of the environmental problem, the coal-burning boilers, especially the smaller ones are limited. They are the main traditional heat sources of civil and industrial hot water systems in China. Large numbers of oil, gas and electric boilers are used to replace them. But the heat pump, as a kind of energy saving equipment, has not taken an effect, as it should have. The main problem is, that the traditional heat pump is unsuitable to the temperature that is required. For example, living hot water for residents and hotels, hot water for industry, these systems normally have the dual-need for air conditioning refrigeration and hot water, are required to heat water from ambient temperature to the temperature of 60–95 °C, where the hot water generally has a big temperature rise in heating process. It is found that the trans-critical CO_2 heat pump has an excellent performance in heating water. Its trans-critical cooling process in super critical pressure accords with the heating process of hot water perfectly. There are many studies on it [1–3]. Carbon dioxide is a nature substance and may be the better one for the environment as a refrigerant, but it is not an excellent refrigerant for the refrigeration cycle. Its critical pressure (7.38 MPa) is too high, and the critical temperature (31.18 °C) is too low. The equipment of the system has to endure very high pressure, and its thermodynamic efficiency is rather poor in refrigeration. Therefore its applications are limited.

2. The critical heat pump with HFCs

Indeed, the cooling characteristic of the trans-critical cycle is universal for all refrigerants. The question is that whether there are critical cycles of other refrigerants suitable for heating water in this condition or not? The answer is sure. Many hydrofluorocarbons (HFCs) are used as the long-term alternatives of the chlorofluorocarbons (CFCs). They have no ozone depletion potential and higher energy efficiency, lower critical pressure, suitable critical temperature

* Corresponding author. Address: Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, 200030, PR China. Tel./fax: +86 5733640236.
E-mail address: nickzhou@sjtu.edu.cn (X. Zhou).

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doi:10.1016/j.applthermaleng.2006.08.018

Table 1
The properties of some HFCs refrigerants (including HCs and FCs)

Refrigerants	Molecular formula	Critical temperature (K)	Critical pressure (MPa)	COP[a]	Security	ODP	GWP_{100}
HC170	C_2H_6	305.32	4.87		A3	0	20
HC290	$CH_3CH_2CH_3$	369.38	4.25	4.4	A3	0	20
HFC41	CH_3F	317.39	5.87		A2	0	140
HFC32	CH_2F_2	351.31	5.81	4.3	A2	0	880
HFC23	CHF_3	299.12	4.8		A1	0	14,800
FC116	CF_3CF_3	293.03	3.04		A1	0	11,400
HFC125	CHF_2CF_3	339.18	3.62	4.0	A1	0	3800
HFC134a	CH_2FCF_3	374.08	4.61	4.5	A1	0	1600
HFC143a	CH_3CF_3	345.97	3.77	4.23	A2	0	5400
HFC152a	CH_3CHF_2	386.4	4.51	4.6	A2	0	190
HFC236fa	$CF_3CH_2CF_3$	403.75	3.18	4.17	A1	0	9400
FC218	$CF_3CF_2CF_3$	345.01	2.66	2.88	A1	0	8600

[a] The coefficient of performance of refrigeration in standard air conditioning working condition (i.e. 5 °C of evaporation temperature, 40 °C of condensing temperature) when the isentropic efficiency of the compressor is 65%.

and good thermodynamic and chemical properties. Numbers of alternatives studied or applied as the refrigerants that have no ozone depletion potential are listed in Table 1. They may be chosen as the refrigerant of the critical heat pump in certain low-grade heat source condition. HFC125 is chosen as the agent to experiment the characteristics of the critical cycle water heater in this paper. As a component of the mixture of R407C and R410A, HFC125 is studied a lot for using in refrigeration and heat pump systems [4,5]. It has lower critical pressure (3.62 MPa) and appropriate critical temperature (66 °C), good physical and chemical properties, better thermodynamic property. The main disadvantage of it is the GWP value is high. There are many arguments about the using of the higher GWP refrigerants. But two factors are true. First, they must be used before better nature or environment-friendly refrigerants are found. Second, studies indicated that the indirect global warm potential is a main factor of making global warm in the airtight chillers [6,7]. Therefore, it is a question of energy efficiency. The characteristics of HFC125 critical heat pump near the critical zone are studied experimentally in this paper.

2.1. Thermodynamic principle of the critical heat pump

The most notable feature of the critical cycle is that a cooling process in a so-called gas cooler replaces the condensing process in condenser of the conventional sub-critical cycle. The big temperature glide of the discharging heat process in high-side pressure of the critical cycle just matches the temperature rise of the hot water. The absorbing heat process of constant temperature in the evaporator of the system will make the least of thermodynamic loss. When the heat pump systems use the nature sources such as air, water, geothermal, and solar energy as the low-grade heat sources, and require a big temperature rise of hot water. Indeed, the ideal cycle of this condition is a special Lorenz cycle. The critical cycle is the most suitable [8]. The good thermodynamic performance of the trans-critical cycle in heating water was verified by the studies on CO_2 trans-critical heat pump. So the bright application future of the critical cycle in heating water can be anticipated. The *T*–*S* chart of the critical cycle is showed in Fig. 1. The broken curve in the figure is the temperature change curve of the temperature rise of hot water in the condenser (or cooler). It can be seen there has a better accordance of the hot water temperature with the refrigerant temperature in the condenser (or cooler).

2.2. HFC125 critical heat pump

As a substance of hydrofluorocarbons, HFC125 has good thermodynamic property, excellent physical and chemical properties, and no ozone depletion potential. It is the one of alternatives attracted attention. Its performance of refrigeration is not as good as HCFC22's, mainly because of its lower critical temperature. Although studies are few about HFC125 as a refrigerant by oneself, but it was a component of many alternatives of mixture. The mixtures numbered as refrigerant that use HFC125 as a main component are R507, R402, R404, R407, R408 and R410. The basic character of HFC125 is showed in Table 2. Differing with the conventional refrigeration and heat

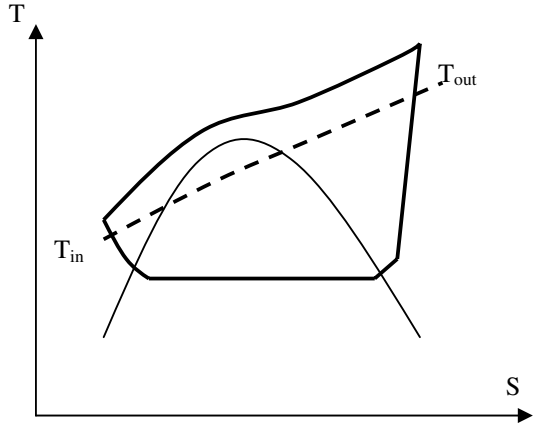

Fig. 1. The *T*–*S* chart of the critical cycle.