EXPERIMENTAL STUDY ON A NEW ABSORPTION REFRIGERATION SYSTEM USING R134a+R32/DMF[1]

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Abstract

A new heat-driven absorption refrigeration system is proposed to be used for –20º~–40ºdeep-freezing. The mixture refrigerant R32/R134a and an absorbent DMF are used as its working fluid. An experimental apparatus has been setup. The characteristics of this new system are investigated under different operation conditions by experiments. The lowest refrigeration temperature obtained by experiment reaches as low as –34.8º while the generating temperature is only as high as 150•. According to a survey by the authors, this refrigeration temperature is the lowest one obtained by absorption refrigeration in the literatures up to now. The results of experimental analysis show this new absorption system is can be used for deep-freezing by utilizing low-grade thermal energy. It has great potential for engineering applications.

KEYWORDS

absorption refrigeration, new cycle, deep-freezing

INTRODUCTION

Environment protection initiatives of international and national environment agencies have led the intensification of research efforts on development of ozone and global warming safe refrigeration technology [1]. Absorption refrigeration system, which can be driven by low-grade thermal energy, such as solar energy, geothermal energy and wasted heat etc., has advantages of saving energy and using environment-friendly refrigerant. The increasing attentions of international researchers and a lot of national policy are being given to absorption refrigeration technology in recent years in the whole world. However, traditional absorption refrigeration system cannot achieve low refrigeration temperature [2, 3, 4]. For example, NH_3/H_2O absorption refrigeration system can only be applied at 0º ~ -20ºmedium temperature [5, 6]. This limitation greatly restricts engineering application fields of absorption refrigeration technology in industry, for there are not only a lot of available wasted heat but also a great deal of demand for low temperature freezing in many production processes, such as freezing of food, chemical engineering and so forth [5, 6, 7, 8]. Therefore, a low temperature absorption refrigerator can not only save energy and protect environment but also have extensive application potential in engineering.

On the other hand, the auto-cascade compression refrigeration (ACR) cycle, which is driven by compressor and uses non-azeotropic mixture as working substance, was proposed to achieve low temperature and has been applied in liquefaction system for natural gas [9]. Little W. A. has carried out a lot of investigations on ACR cycle since 1982, which is used as cryogenic machines to achieve 120K or lower refrigerating temperature [10]. Recently, Vjacheslav Naer and Andrey Rozhentsev utilize Kleemenko’s ACR cycle as micro cryogenic cooler for cryosurgical installation and the refrigeration temperature can reach to about 88K [11]. In addition, researchers have been working on many researches on ACR cycle in Zhejiang University, China [12]. As much as aforementioned investigations proved, the ARC cycle is especially fit for being used as low temperature refrigerator or cryogenic machines and takes on many prominent advantages, such as excellent operation

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characteristics, simple configuration etc..

In this paper, a new system is investigated, which combines the advantages of absorption refrigeration principle with auto-cascade compression refrigeration one, used for –20~–40ºdeep freezing. We call this new cycle as auto-cascade absorption refrigeration (ACAR) cycle. The new absorption system uses environment-friendly non-azeotropic mixture of Difluoromethane (R32) and 1,1,1,2-Tetrafluoroethane (R134a) as refrigerant, and N, N-Dimethylformamide (DMF) as absorbent. The characteristics on ACAR system under different working conditions, such as composition of refrigerants, generating temperature, refrigerating temperature and COP etc., are investigated in the followed sections.

EXPERIMENTAL APPARATUS

The new absorption system is mainly made up by solution pump, generator, absorber, heat exchanger and valve etc., shown as Fig.1. The components are similar with traditional absorption refrigeration system. The principle of ACAR system is introduced as follows. Firstly, the mixture refrigerant vapor bubbles up from generator in which DMF solution is heated, and flows into condenser. After the vapor is cooled by coolant in the condenser, it goes into separator via throttling valve 2. The refrigerant is separated into vapor and liquid streams in the separator. The main component of vapor stream is low-boiling point refrigerant (R32), named S1 and flows out from the top of separator, while the main component of liquid stream is high-boiling point refrigerant (R134a), named S2 and flows out from the bottom. After this, the stream S2 flows into condenser-evaporator via throttling valve 3, where S2 vaporizes, refrigerates and condenses S1. After vapor stream S1 is condensed by the stream S2 in the condenser-evaporator, it passes through a regenerator, flows into evaporator via throttling valve 4 and evaporates. Finally, the stream S1 converges with S2 which comes from the condenser-evaporator, enters into absorber and is absorbed by weak DMF solution. The refrigeration circulation of the new cycle is just as aforementioned, and the rest of the cycle is similar to that of traditional single-effect absorption cycle, which is shown in Fig.2.

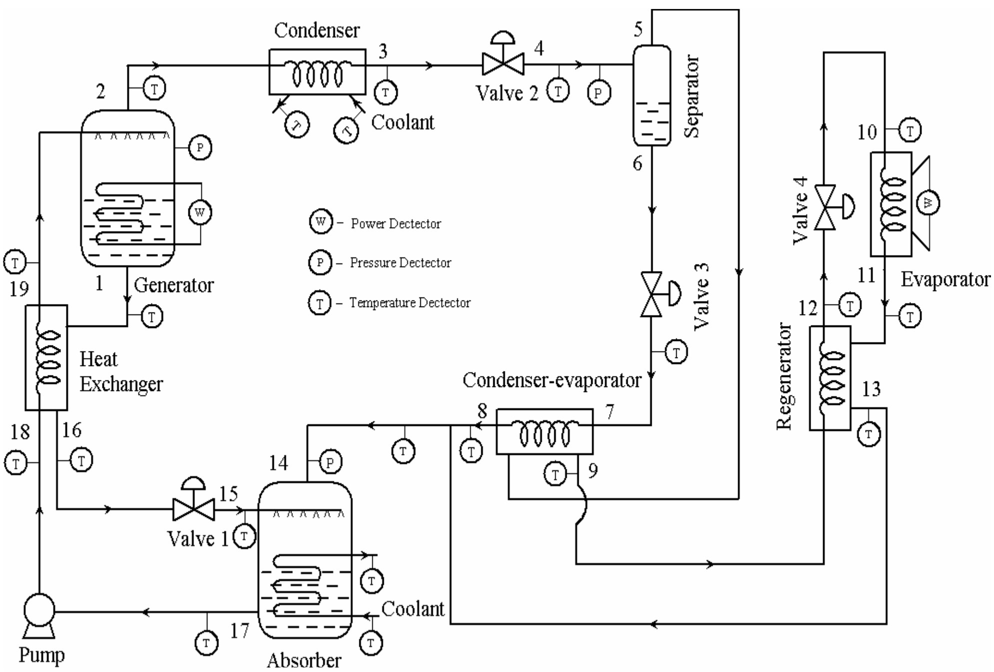

Fig.1 Diagram of auto-cascade absorption refrigeration system

The measurement system of the experimental set consists of three parts, which are respectively used for testing temperature, pressure and heat load, measured parameter points are shown in Fig.1. The temperature parameters are measured by copper-constantan couple and collected per second by computer digital data collection system. The class of accuracy is 0.5 and the deviation is ±0.5º. The pressure parameters, such as generating pressure (P_g), medium pressure in separator (P_m) and absorption pressure (P_a), are measured by precise pressure meter. The accuracy class of pressure meter is 0.4. The heating load to the generator is supplied by single-phase alternate current power supply. The heat loads are measured by digital power meter and collected with temperature parameters in real time. The accuracy class of power meter is 0.5.The refrigeration capacity of the system is measured by measuring the power consumption of the electric heater in the evaporator supplied by a precise 0~30 voltage direct power supply.

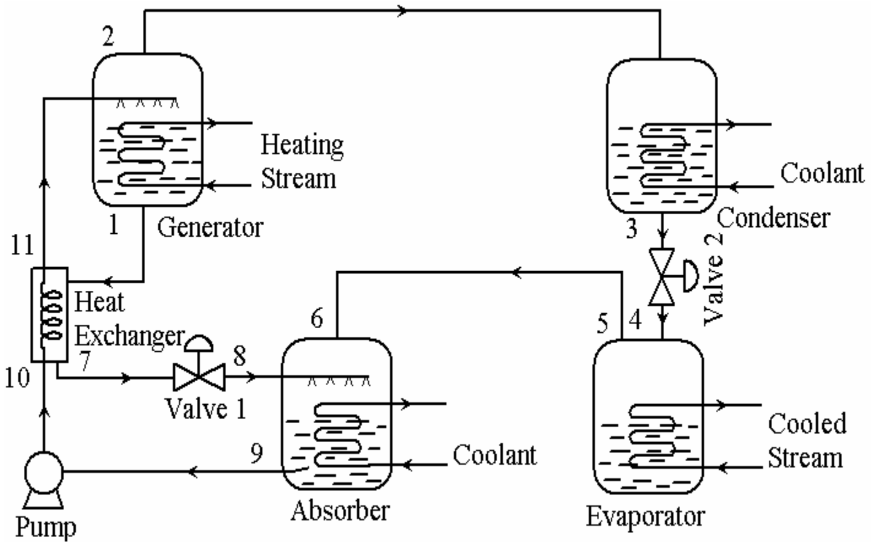

Fig.2 Schematic diagram of traditional single-effect absorption refrigeration system

EXPERIMENTAL RESULTS

The effects of operation conditions on characteristics of new absorption refrigeration system are carried out. The relationship between temperatures of inlet and outlet evaporator and time is shown as Figure 3. The COP at different refrigeration temperature is shown in Figure 4. The lowest refrigeration temperature obtained by experiment at different generating temperatures is shown as Figure 5. The aforementioned experiments are carried out when the mole ratio between R32 and R134a equals to 0.95.

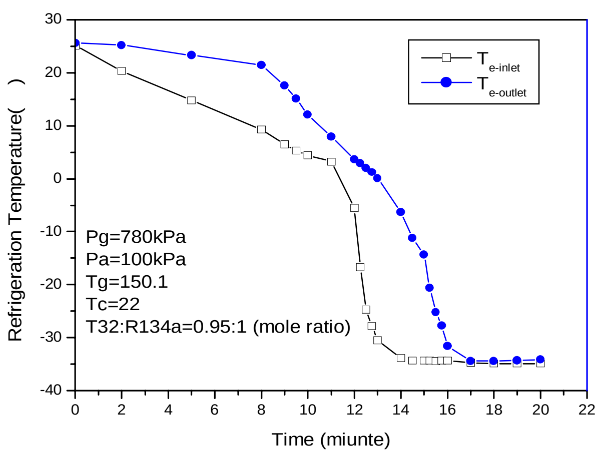

Fig.3 Refrigeration temperatures with time

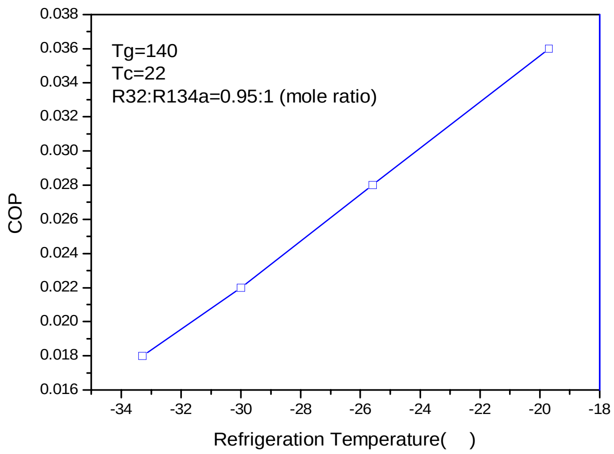

Fig.4 COP at different refrigeration temperature

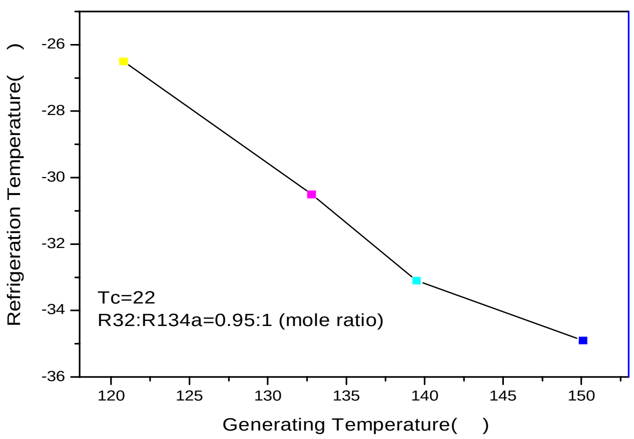

Fig.5 The lowest refrigeration temperature obtained by experiment

DISCUSSIONS AND CONCLUSIONS

The characteristics of an auto-cascade absorption refrigeration system are investigated in this paper. The lowest refrigeration temperature obtained by experiment reaches as low as –34.8º while the generating temperature is only 150°. According to the survey by the authors, this refrigeration temperature is the lowest one obtained by absorption refrigeration in the literatures up to now.

The new refrigeration system can be used for –20°~–40° refrigeration temperature range, where ammonia/water absorption refrigeration system is almost impossible to reach. It can be concluded from the investigation that this new refrigeration system can achieve rather low refrigerating temperature by using low-grade thermal energy such as industrial wasted heat. The new absorption refrigeration system is especially suitable for –20°~–40° deep freezing and has great potential for engineering applications. For further research purpose, COP should be improved. The improvement of performance for ACAR system is expected and deep investigations should be carried by optimizations of refrigerant compositions, system design and operating parameters.

Nomenclature

	General	Subscript	
ACAR	Auto-cascade absorption Refrigeration	a	Absorber
COP	Coefficient of performance	e	Evaporator
P	Pressure (kPa)	g	Generator
T	Temperature ( )	c	Coolant
W	Electric power (W)	m	Medium point

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