

## Development of an air conditioning and hot water supply heat pump system using HC refrigerants

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### Abstract

The fourth report of the international panel of climate change states that “There is no doubt of Global Warming”. The average global atmospheric and oceanic temperatures have risen, the amount of ice at both the Arctic and Antarctic as well as on mountains has decreased, the average global sea level has been reported to rise. These are all a clear indications of global warming.

In the field of air conditioning and refrigeration, use of natural refrigerants is eagerly anticipated. We, therefore, developed a central air-conditioning system using mixed hydrocarbon refrigerants. The unit is composed of a screw compressor with an explosion proof semi-hermetic motor to minimize refrigerant leaks. Tests were carried out in six operation modes with a combination of two sources (air and water) and three supplies (cooling and heating and hot water production). This paper reports on the basic performance tests of the heat pump.

**Keywords:** hydrocarbon refrigerants, zeotropic refrigerant mixtures, air conditioning, hot water supply, heat pump system

### 1 INTRODUCTION

To preserve the global environment, it is necessary that refrigerants used in heat pump systems are friendly to the environment with the Ozone Depletion Potential (ODP) of 0 and very low Global Warming Potentials (GWP). MYCOM recommends use of five natural refrigerants friendly the environment and named the "natural five" (water (H<sub>2</sub>O), carbon dioxide (CO<sub>2</sub>), ammonia (NH<sub>3</sub>), air (Air), hydrocarbon (HC) for use in air conditioning and refrigeration. Hydrocarbon refrigerants (here after referred to as HC refrigerants) are currently mainly limited to household refrigerators and vending machines because they are highly flammable. In order to explore ways of introducing HC refrigerants in commercial air conditioning, MYCOM participated in the New Energy and Industrial Technology Development Organization (NEDO) project "Development of Non-fluorinated Energy-saving Refrigeration and Air Conditioning Systems" from 2005 for three years and developed an air conditioning, hot water supply heat pump system for commercial applications. The main aim was to explore ways for the spread of HC based systems in the commercial field. The main contents of the development project are as follows. In the first year, a study was carried to examine the working refrigerants, refrigerating oil, the system, and production and design of the refrigerant diffusion experimental device, In the second year, experiments on refrigerant diffusion, simulation of air flow

and necessary amount of ventilation was carried out as well as design and production of the semi hermetic compressor and design and production of prototype system. In the third and final year, experiments were carried out on the prototype system to confirm performance.

## 2 SYSTEM CHARACTERISTICS

The system uses isobutane and propane mixed refrigerants which are zeotropic. To minimize refrigerant leakage, plate and shell heat exchangers, and a semi hermetic motor were used.

All electronic equipments in the machine casing are explosion proof.

### 2.1 Refrigerant

Table 2.1 shows characteristics of the HC refrigerants used in the system. Propane and isobutane are highly flammable refrigerants with the flammability ranges of 2.1vol%~9.5vol%, and 1.8vol%~8.4vol% respectively. Changing the proportional of refrigerants can allow for wide applications from air conditioning to hot water production.

**Table 2.1 Refrigerant Characteristics**

	Chemical Formula	ODP	GWP	Boiling Point	Critical Temperature	Critical Pressure
	—	—	—	°C	°C	Mpa
Propane	C <sub>3</sub> H <sub>8</sub>	0	3	-42.1	96.8	4.3
Isobutane	C <sub>4</sub> H <sub>10</sub>	0	3	-12.0	135	3.5

### 2.2 Drive modes

The basic driving modes in this system are cooling, heating and hot water production. In addition the system can use air and water as both heat source and heat sink.

### 2.3 Minimized refrigerant leakage and explosion proof

To minimize refrigerant leakage and improve safety, the compressor is a semi hermetic screw type equipped with a built-in motor without mechanical seals. The motor and compressor are shown in figure 2.1. As further measure to minimize refrigerant leakage, all welded shell and plate exchangers were used. A blazed heat exchanger was also test for performance and cost comparisons with the plate and shell. All electronic equipments and blower fans in the machine casing are explosion proof. Furthermore, there are concentration sensors in the machine casing for leak detection and a fan to secure the necessary amount of ventilation in case refrigerant leakage.



**Fig. 2.1 Semi-hermetic motor and compressor. (left : motor, right ; built compressor and motor)**

### **3 SPECIFICATIONS AND EQUIPMENT DESIGN**

#### **3.1 Choice of refrigerant mixture ratio**

In order to cover the wide operation range of the system, an appropriate refrigerant ratio was chosen with highest operating pressures in the hot water production mode not exceeding 1.8MPa.

#### **3.2 Selection of refrigerant oil**

HC refrigerants are highly soluble in mineral oil therefore, to reduce solubility synthetic oil was considered. From the synthetic oils considered PAG refrigeration oil was chosen.

#### **3.3 Components of the heat pump system**

Figure 3.1 shows the flow of the heat pump while figure 3.2 shows over view. The heat pump is composed of semi hermetic compressor, oil separator, oil cooler, receiver, condensers, evaporators and an air heat exchanger. The air heat exchanger can be used as an evaporator or condenser depending in the operation mode. The heat exchangers can be changed to cooling, heating or water production mode using air controlled valves

#### **3.4 Load system**

The heat pump system has 230kW cooling tower and 233kW boiler to balance the load during tests. A 4m<sup>3</sup> water storage tank was also for temperature control.

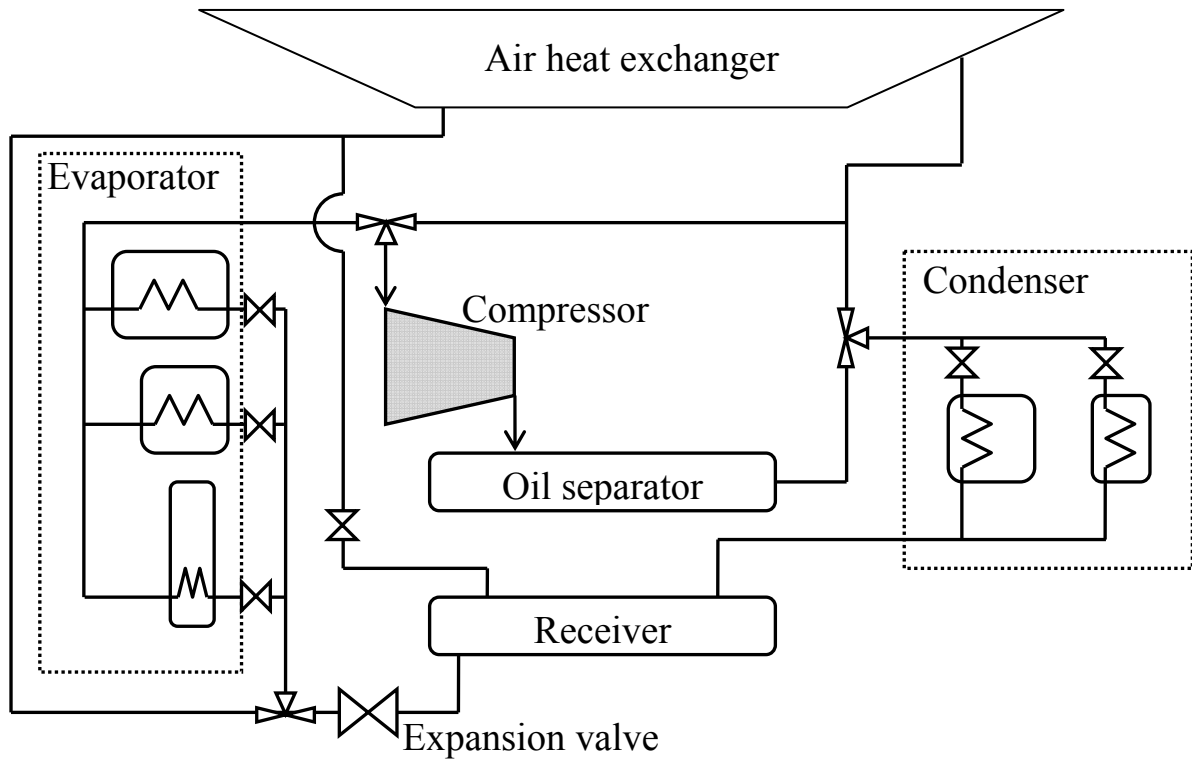


Fig. 3.1 Test Equipment Flow



Fig. 3.2 Test equipment over view and inside view

## 4 TEST RESULTS AND CONSIDERATIONS

### 4.1 Test conditions

Table 4.1 shows the test condition for each mode. For cold water production the inlet and outlet temperatures are set at 12C and 7C respectively. For the heating mode the outlet is set at 45C while in the hot water production mode the outlet temperature is 65C.

**Table 4.1 Test conditions**

Test mode	Hot water inlet temperature	Hot water outlet temperature	Cool water inlet temperature	Cool water outlet temperature	Evaporating temperature	Condensing temperature
	°C	°C	°C	°C	°C	°C
Air sink cold water production			12.0	7.0	5.0	45.0
Water sink cold water production	24.0	35.0	12.0	7.0	5.0	38.0
Air source heating mode	34.0	45.0			0.0	50.0
Water source heating mode	34.0	45.0	15.0	7.0	5.5	46.5
Air source hot water production	10.0	65.0			0.0	70.0
Water source hot water production	10.0	65.0	15.0	10.0	5.0	70.0

### 4.2 results and considerations

Table 4.2 shows test results of each mode. Since the compressor used in these experiments does not have a variable vi mechanism, the wide operation range especially in the cooling and heating modes caused losses and hence decrease in COP. The effect of solubility of oil and performance is also under investigation. A brazed heat exchanger offers the same performance as shell and tube heat exchanger offering prospects for reducing costs of the system.

Table 4.2 Test results

		Compress or suction pressure	Compressor discharge pressure	Compre ssor road	Evapor ating temper ature	Conde nsing temper ature	Cooling or heating capacity	COP
		MPaG	MPaG	kW	°C	°C	kW	-
Air sink cold water production	design	0.154	0.673	51.7	5.0	45.0	183.0	3.54
	Test result	0.130	0.680	49.7	2.2	44.5	168.0	3.38
Water sink cold water production	design	0.154	0.546	47.5	5.0	38.0	196.3	4.13
	Test result	0.140	0.610	47.2	2.3	40.4	175.3	3.48
Air source heating mode	design	0.114	0.772	52.4	0.0	50.0	203.2	3.88
	Test result	0.120	0.779	52.2	0.3	49.3	196.1	3.75
Water source heating mode	design	0.154	0.772	52.7	5.5	46.5	241.1	4.57
	Test result	0.140	0.770	52.9	2.7	49.1	211.8	4.00
Air source hot water production	design	0.114	1.262	68.5	0.0	70.0	245.1	3.58
	Test result	0.119	1.203	67.9	0.1	66.9	229.7	3.38
Water source hot water production (using shell plate heat exchanger)	design	0.154	1.262	71.0	5.0	70.0	284.7	4.01
	Test result	0.150	1.220	69.5	3.8	67.4	262.6	3.74
Water source hot water production (using blazing plate heat exchanger)	design	0.154	1.262	71.0	5.0	70.0	284.7	4.01
	Test result	0.148	1.214	69.5	3.9	67.2	262.8	3.78

## 5 CONCLUSIONS

Tests results show that the performances of this system are the same as those of a system with the conventional R134a as a refrigerant. It is expected that optimizing compressor and heat exchanger performances would further improve the system and make it an alternative to HFCs.

This system was used in the last Toyako Summit in Hokaido Japan as the air conditioning facility for the media center.

## 6 REFERENCES

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