

EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF A HIGH TEMPERATURE WATER SOURCE HEAT-PUMP

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Abstract: Heat pumps are used in industrial process especially in recovering the heat of wasted water in oil industry process and the oil heating in oil field. In this paper, the research on the performance of a high temperature water source heat-pump with the heating capacity of 200 kW was carried out experimentally. The thermodynamic properties of some new refrigerants were investigated on the high temperature water source heat-pump. Based on the results, measurement error and heat pump performance were presented. The heat pump can reliably with the out let water temperature up to 85°C. So this research indicates the high temperature has higher coefficient of performance and well market prospect.

Key Words: *high temperature heat pump, experimental investigation, performance*

1 INTRODUCTION

Heat pumps could be used in many industrial processes. Many countries used industry heat pumps since 1960s. Figure1 shows the ratio of heat pump using in 2000. Nowadays a large amount of hot water by 80-95°C is often needed in industrial processes, such as building heating, medical hot water, oil industry processes and other industrial processes. Traditionally such hot water comes from boilers burning fossil fuels. Also in the industrial processes, there are much more waste heat energy at 30-50°C which can't be used. Such waste energy will cause thermal pollution if it is discharged directly to the surroundings. A high temperature heat pump might be a good way to use such heat properly. Such heat pumps could recover waste heat by 30-50°C, which is widely available but has not been well used. And the high temperature heat pump would provide a good way for satisfying such high temperature (80-95°C) heating demands.

High temperature water source heat pump has been paid more attention and been

investigated for a long period. For example, A. Migara tested a heat pump with R22/R114 in 1993 (the inlet and outlet temperatures of the condenser are, respectively, 40 and 60°C, and those temperatures of the evaporator are, respectively, 30 and 10°C). L. Liebenberg took R22/R142b as working fluids of a high temperature heat pump to provide 60°C hot water in 1996. K. Nakatani compared the performances of heat pumps filled with R22/R134a, R22/R152a, R22/R142b, R22/R123 at the condensing temperature of about 60°C. Liu Nanxi, Shi Lin in Tingshua University set up a high temperature water source heat pump and get the water temperature at 85°C. According to these studies, non-azeotropic refrigerants are always used in these heat pumps. But there are still some problems such as leakage problem. So in this study, we used R134a as heat pump working fluid.

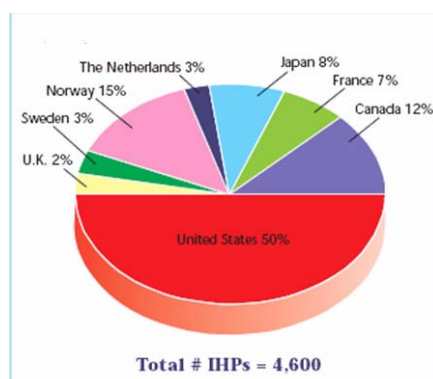


Figure 1: Diagram of the IHPs used in per country in the world

In this study, we developed a high temperature water source heat pump system with a screw compressor. The research on the performance of a high temperature water source heat-pump with the heating capacity of 200 kW was carried out experimentally. The thermodynamic properties of some new refrigerants were investigated on the high temperature water source heat-pump. Based on the results, measurement error and heat pump performance were presented. The heat pump can reliably with the out let water temperature up to 85°C.

2 THEORETICAL ANALYSIS

In a high temperature heat pump cycle, it consists of four thermodynamic processes as in Figure 2.

In the calculating, we can suppose the compression process is adiabatic with inner evaporative cooling. The cooling is necessary because the discharging temperature would exceed 150°C at the design pressure ratio without cooling, according to our preliminary calculation. We can use the oil-injecting for inner spray cooling. The position, size and amount of injection holes need to be optimized by experiments according to the structure of the compressor. In order to control the discharge temperature, the oil cooling system is added to the heat pump system.

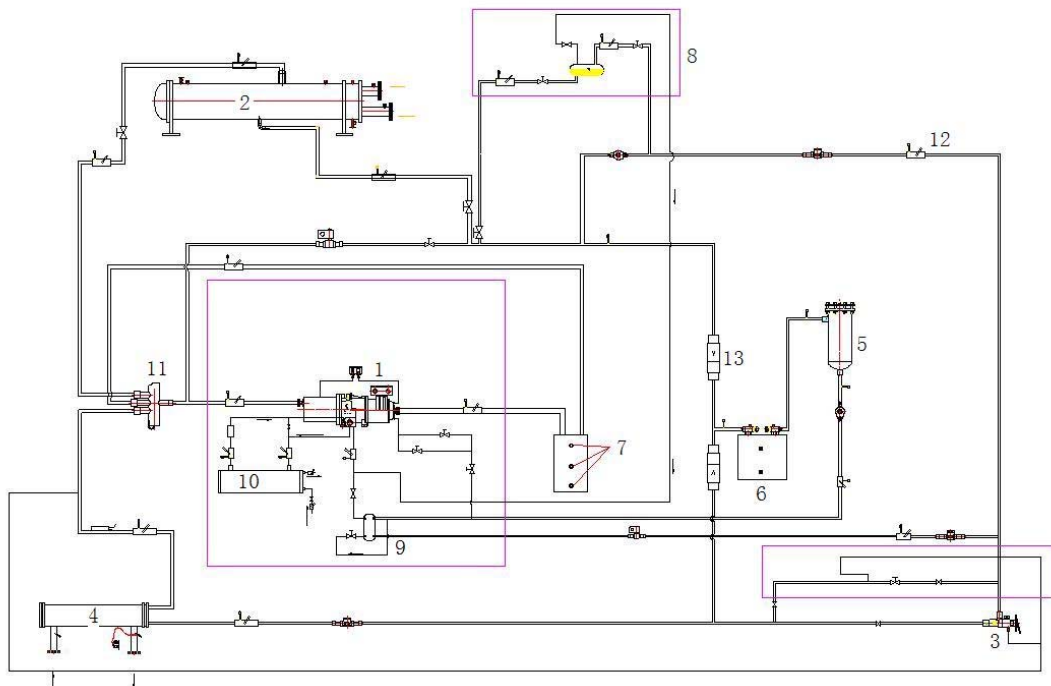


Figure 3: Schematic of the heat pump system

1-compressor; 2-condenser; 3-expansion valve; 4-evaporator; 5-drier-filter; 6- high pressure receiver; 7-vapor-liquid separator; 8-economizer; 9- economizer; 10-oil cooling; 11-four-way valve; 12-pressure-temperature sensor;13-check valve

4 Results and discussions

4.1 Performance in different operating conditions

In this study, the in/out water temperature range of the evaporator is 25~45°C by constant temperature adjustment. The condensing temperature was 60~85°C.

In the experiment, the data was recorded after reaching an approximate steady state, which may be judged by the outlet temperature fluctuation of less than 1°C, within 30 or more minutes. For different operating conditions, it usually takes two to three hours in the laboratory

The performance of the high temperature water source heat pump was investigated in different operating conditions. Table1 is part of the test results of the experiment. COP is the heating coefficient of performance. The COP, discharge temperature (T_d) of the compressor and pressure ratio (ϵ) were measured in different operating conditions. Figure4 is the heating capacity in different operating conditions. The high temperature has a better performance when the condensing temperature (T_c) is 85°C. When the ϵ of compressor is higher, the heating capacity and COP is also high as in Figure 4. When the ϵ is 7.4, the COP is still larger than 2.5. The discharge temperature can be successful controlled under 110°C. Figure 4 is

the heating capacity of the heat pump in different conditions.

Table 1: Performance in different operating conditions

$T_c/^\circ\text{C}$	$T_e/^\circ\text{C}$	ε	$T_d/^\circ\text{C}$	COP
70	30	6.44	94	3.29
70	35	5.68	96	3.31
75	30	6.90	97.5	2.79
75	35	5.90	101	2.85
80	30	7.82	107	2.65
80	35	6.84	108	2.71
85	35	7.41	109	2.51

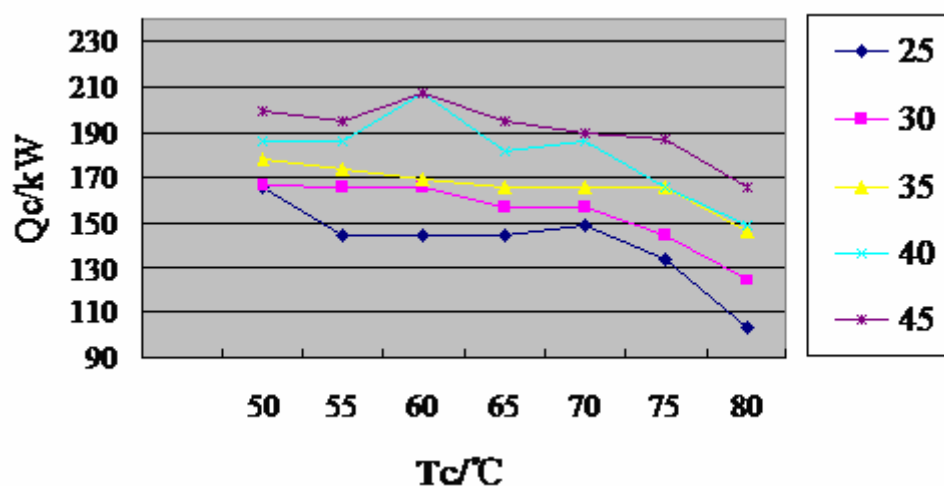


Figure 4: Heating capacity in different operating conditions

4.2 Effect of the condensing temperature on the performance of the heat pump

The effect of the condensing temperature on the performance of the heat pump is experimentally investigated in this study. The inlet water temperature was fixed in this test. Figure 5 is the variety of COP in different condensing temperatures. The COP decreased with the increasing of condensing temperature. The COP decreased by 11.43% with the condensing temperature increased by 5°C . Figure 6 is the variety of power consumption in different condensing temperatures. The power consumption increased by 9.90% with the increasing of condensing temperature by 5°C .

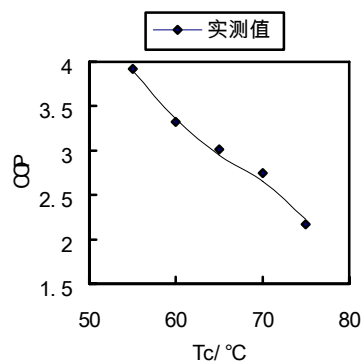


Figure 5: COP variety with the increasing of condensing temperature

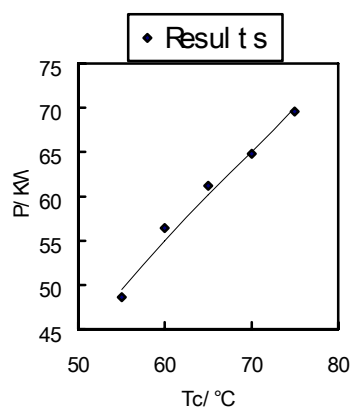
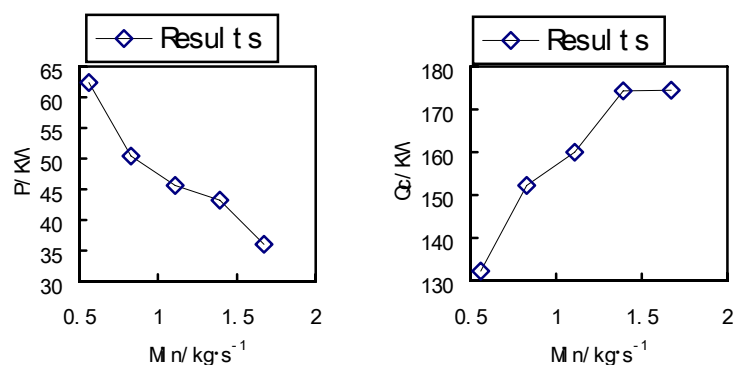


Figure 6: power consumption variety with the increasing of condensing temperature

According to the comparison and analysis, the heating capacity and COP has a linear downtrend when the condensing temperature increases. The reason is when the condensing temperature is higher, the pressure ratio and the discharge temperature will be so larger, the oil temperature also become higher, the quantity of the gas leakage increases, therefore the efficiency of the compressor decreases, so the power consumption increases. Another reason is the power consumption increases and the temperature of the electromotor became higher, so the suction temperature and super heat increased, therefore the suction specific volume increased, the volumetric efficiency decreased.

4.3 Effect of the water flux on the performance of the heat pump



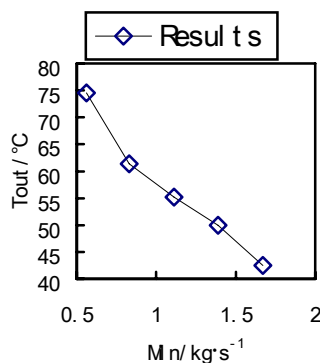


Figure 7: Effect of the water flux on the performance of the heat pump

Figure 7 shows the variety of power, heating capacity, outlet water temperature with different water flux from 0.5 kg/s to 2kg/s. With the increasing of the water flux, the heating capacity increased but the power consumption decreased. The reason is when the water flux increased but the outlet water temperature decreased, the pressure ratio dropped, it caused the condensing temperature decreased, the flow rate of the refrigerant increased, so the heating capacity increased. This means that when the water flux decreased, the power consumption will increase, and the heating capacity will decrease.

5 Conclusions

In this present work, the research on the performance of a high temperature water source heat-pump with the heating capacity of 200 kW was carried out experimentally. Based on the results, measurement error and heat pump performance were presented. The heat pump can reliably with the out let water temperature up to 85°C. From the above experiment and results, the following conclusions can be obtained:

- (1) In a high temperature water source heat pump using R134a as the working fluid, the outlet water temperature can be 85°C when add oil cooling system. The discharge temperature can be successful controlled by 110°C.
- (2) The inlet and outlet water temperature affect the performance of the heat pump unit. The COP decreased by 11.43% with the condensing temperature increased by 5°C. The power consumption increased by 9.90% with the increasing of condensing temperature by 5°C.
- (3) The water flux also affects the performance of the heat pump unit such as heating capacity and COP.
- (4) Using these kinds of high temperature heat pumps in oil fields for crud oil heating and waste heat recovery is a better way to saving energy. The further research shows that the key point for these heat pumps is the quantity of oil injection. It determines the discharge temperature and reliability of compressor.

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6 References

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