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PERFORMANCE OF R-407C AND HCFC-22 IN CHILLERS WITH BRAZED PLATE HEAT EXCHANGERS

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ABSTRACT

Brazed Plate Heat Exchangers (BPHX) have been in use for several years as condensers and evaporators. BPHX design permits easy implementation of counter current flow configuration. This feature potentially benefits zeotropic mixtures in HVAC systems as the refrigerant's temperature glide can be matched with that of the other fluid. Also, the size of BPHX for a given heat transfer area aids in building compact systems. In the current study, tests with R-407C and HCFC-22 have been conducted for an industrial chiller unit with BPHX for the condenser and evaporator. The key performance parameters cooling capacity and energy efficiency were found to be respectively 5.6% and 0.3% greater for R-407C as compared to HCFC-22 for the range of tests conducted.

INTRODUCTION

HCFC-22 is one of the most widely used refrigerant in chillers but is being phased out due to its ozone depletion potential (ODP) and R-407C (R32/R125/R134a : 23/25/52 wt%) is considered as one major replacement for HCFC-22. A majority of the previous studies [1-3] report that the energy efficiency of R-407C is 3-7% less than that for HCFC-22 in "drop-in" tests in conventional split system air-conditioners and heat pumps that use traditional air-refrigerant coils. So the purpose of this study was to investigate if the use of brazed plate heat exchangers for condenser and evaporator with countercurrent flow conditions would benefit the system performance of R-407C.

Brazed plate heat exchangers have been in use as condensers and evaporators for several years. They are basically a stack of parallel plates that serve as channels for the hot and cold fluids to flow in the alternate passages. They are brazed along the edges to withstand high pressures. The flow configuration can be arranged to obtain counter flow conditions resulting in good heat transfer characteristics, especially for zeotropic mixtures. This is because the heat transfer is optimized when the refrigerant's temperature glide matches with that of the other fluid. System compactness is another advantage since the size of BPHX for a given heat transfer area is less.

Previous Work

Previous work here implies comparison of system performance for R-407C with HCFC-22 and not using BPHX. Bivens et al. (1994) presented a paper at ASHRAE symposium, Orlando, Florida (OR-94-1-5) comparing performance of R-407C with HCFC-22 in a conventional split system heat pump that had regular evaporator coils. They found that the cooling capacity for R-407C was about the same as that for HCFC-22 while the energy efficiency was 2-3% less. Murphy et al. (October 1995) presented a paper in the CFC conference at Washington D.C. with modified flow configuration to attain counter flow conditions at the evaporator. Interestingly, with this change they observed that the cooling capacity and the energy efficiency for R-407C relative to HCFC-22 increased by 7% and 5% respectively.

EXPERIMENTS

Equipment

The test unit was an approximately 3 ton (12.4 kW) capacity industrial chiller with brazed plate heat exchangers (BPHX) for evaporator and condenser. The unit had evaporator BPHX (insulated), scroll compressor, TXV expansion device, and a liquid receiver. The other circuits involve providing cooling water to the condenser BPHX and chilled water to the evaporator BPHX. Two electric water heaters of each 50 gallons (190 liters), 4.5kW capacity were used, one each for evaporator and condenser, for providing desired temperatures and were pumped by separate centrifugal pumps.

Flow circuits - Apparatus description

The two main circuits for the experimental setup given in Figure 1 are refrigerant and water. The flow directions of the refrigerant and water at the condenser and the evaporator (BPHX) are counter flow. The refrigerant circuit follows a typical refrigeration cycle. For the condenser and evaporator water circuits, the building chilled water was used in a closed loop for supply and return, thereby eliminating sumps. The building chilled water was fed with desired flow rate of up to 9 gpm (34 liter/min) at 45-50F (7-10C) to evaporator and condenser water circuits preheated by two spiral heat exchangers to about 65-70F (18-21C).

Instrumentation

On the refrigerant circuit, the temperature and pressure of the refrigerant were measured at the inlet and outlet for compressor, condenser and evaporator BPHX. All the temperatures were measured using T-type copper constantan thermocouples and pressures by diaphragm type pressure transducers 0-500 psig (100-3450 kPa). Water temperatures were measured using T-type copper constantan thermocouples at several places (see Figure 1), the important ones being inlet and outlet of water heaters, condenser and evaporator BPHX and spiral heat exchangers. Water flow rates were measured for evaporator and condenser circuits using pulse type flow meters read in gpm on digital read outs. Compressor power was measured using two power meters. Provision was made at the compressor suction side to tap refrigerant samples using the flask-bubble method to determine the circulating composition for R-407C. All the instruments were connected to the data acquisition system to indicate steady state conditions.

Tests and Data reduction

We conducted many tests and repeated them to have a high degree of confidence in the data and also to understand the variability of the data. Table 1 indicates the range of tests: 52 for HCFC-22 and 84 for R-407C. For all the tests, we held the water flow rate constant for the condenser at 0.26 kg/sec (4.0 gpm) and varied for the evaporator from 0.32 to 0.44 kg/sec (5 to 7 gpm) as shown in Table 2. The refrigerant charge was 3.0 kg (6.6 lbs) for both R-22 and R-407C. We collected the data for 12 min. at every 10 sec time intervals under steady state conditions; it took usually 30 min. to 1 hour to reach steady state conditions. The last 10 min. of data were used for the analysis. The water side sensible heat gain was used as the Cooling capacity at the evaporator and several performance parameters such as EER were calculated. In addition, refrigerant samples were taken during tests for R-407C to determine the circulating composition.

RESULTS AND DISCUSSION

The testing conditions for water and refrigerant sides (Table 2) indicate that for R-407C, the average temperature drop for water at the evaporator (4.8 ^{o}C) is close to that on the refrigerant's temperature glide (3.9 ^{o}C). This is an indication of good counter flow conditions at the evaporator. Table 3 shows a representative sample of the variation of data for a given water flow rate of 0.35 kg/sec (5.5 gpm) at the evaporator. It can be seen that the variation of the water flow rate at the evaporator is

0.35 ± 0.002 kg/sec for HCFC-22 and 0.35 ± 0.003 kg/sec for R-407C. Similarly the variation in EER can be seen to be 9.14 ± 0.3 for HCFC-22 and 9.18 ± 0.2 for R-407C, which are an indication of reasonably good repeatability of tests.

Figure 2 indicates that the discharge pressure for R-407C is higher than HCFC-22 by about 15%. Similarly, Figure 3 shows that the discharge temperature is less for R-407C than HCFC-22 by about 6 ^{o}C consistent with earlier studies (Patron et al. 1995). The lower discharge temperature will cause less stress on the compressor. Figure 4 shows that the average evaporator temperature is higher by 1^{o}C for R-407C compared to HCFC-22. Higher evaporator temperatures usually indicate improved energy efficiency and in the current study, we believe is an indication of counter flow effects at the evaporator. Figure 5 shows that the cooling capacity is about 5% higher for R-407C compared to HCFC-22 on an average which is a benefit of the counter flow conditions observed also by Murphy et al. (1995). Figure 6 shows the measured EER (energy efficiency ratio, Btu/hr/W) is about 0.5% higher for R-407C than HCFC-22 on an average. This is a positive result since earlier studies using air-side systems reported that EER for R-407C was less than HCFC-22 by 3-7%.

SUMMARY

R-407C compared to HCFC-22 had on an average for the total range of tests 5.6% higher Cooling capacity and 0.3% higher EER. R-407C samples taken and analyzed during the tests indicate the circulating composition as 25.1/25.9/49.0 (wt% : R32/R125/R134a) vs. the nominal composition of 23/25/52 (wt% : R32/R125/R134a). The EER values for R-407C and HCFC-22 differing by only 0.3% (within the data variability limits) indicate that R-407C performs at least equally well as HCFC-22 when BPHX are used for condenser and evaporator which is an improvement of 3-7% in energy efficiency vs. previously reported test results in air/refrigerant systems with R-407C.

REFERENCES

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3. Patron D. M. et al., DuPont Internal Report, "Effects of a Liquid-Suction Heat Exchanger on the Performance of SUVA 9000 in a Heat Pump", 16th February 1995.

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Table 1 Range of Tests

Refrigerant	Evaporator Water Flow rate (kg/sec)					Total tests
	0.32	0.35	0.38	0.41	0.44	
HCFC-22	13	11	7	12	9	52
R-407C	23	14	15	13	19	84

Table 2 Testing Conditions

Parameter	HCFC-22	R-407C	Remarks
WATER SIDE			
Cond. Flow rate (kg/sec)	0.26	0.26	Held constant
Evap. Flow rate (kg/sec)	0.32-0.44	0.32-0.44	Varied
Average Cond. Inlet temp. (C)	23.7	23.4	For total range of tests
Average Temp. gain, Cond. (C)	11.3	12	For total range of tests
Average Evap. Inlet temp. (C)	8.6	8.3	For total range of tests
Average Temp. drop, Evap. (C)	4.6	4.8	For total range of tests
REFRIGERANT SIDE			
Refrigerant Mass (kg)	3	3	Same for HCFC-22 and R-407C
Average Cond. Pressure (kPa)	1467	1624	For total range of tests
Average Cond. Pressure drop (kPa)	37.2	42.8	For total range of tests
Average Cond. Temperature (C)	38.2	39.8	For total range of tests
Average Temp. Glide, Cond. (C)	1	6.1	Pressure drop taken into account
Average Evap. Pressure (kPa)	491	520	For total range of tests
Average Evap. Pressure drop (kPa)	16.7	20.5	For total range of tests
Average Evap. Temp. (C)	-0.4	0.6	For total range of tests
Average Temp. Glide, Evap. (C)	0.8	3.9	Pressure drop taken into account
Average Inlet quality, Evap. (%)	21.4	24.6	Calculated

Table 3 Data Variability

Parameter	Data Variability, Evaporator Water Flow rate = 0.35 kg/sec (11 Tests) HCFC-22	Standard Deviation	(14 Tests) R-407C	Standard Deviation
WATER SIDE				
Cond. Flow rate (kg/sec)				
Evap. Flow rate (kg/sec)	0.26	0.003	0.26	0.003
Cond. Inlet temp. (C)	0.35	0.002	0.35	0.003
Evap. Inlet temp.(C)	23.7	1.5	23.4	0.5
	8.8	1	8.4	0.4
REFRIGERANT SIDE				
Cond. Superheat (C)				
Cond. Subcool (C)	23.4	3.2	12.3	1.3
Suction Pressure (kPa)	2.1	0.22	2.7	0.11
Evap. Temperature (C)	481	15.9	506	4.8
Suction Superheat (C)	-0.5	1	0.4	0.44
Evap. Inlet quality (%)	4.8	0.11	3.3	0.6
	21.4	0.6	25.4	0.3
PERFORMANCE				
Cooling Capacity (Watts)	7250	250	7630	174
Compressor Power (Watts)	2710	114	2838	37
EER	9.14	0.3	9.18	0.2
COP	5.9	0.8	6.1	0.2
Refrigerant circulation (kg/min)	2.63	0.09	2.77	0.09

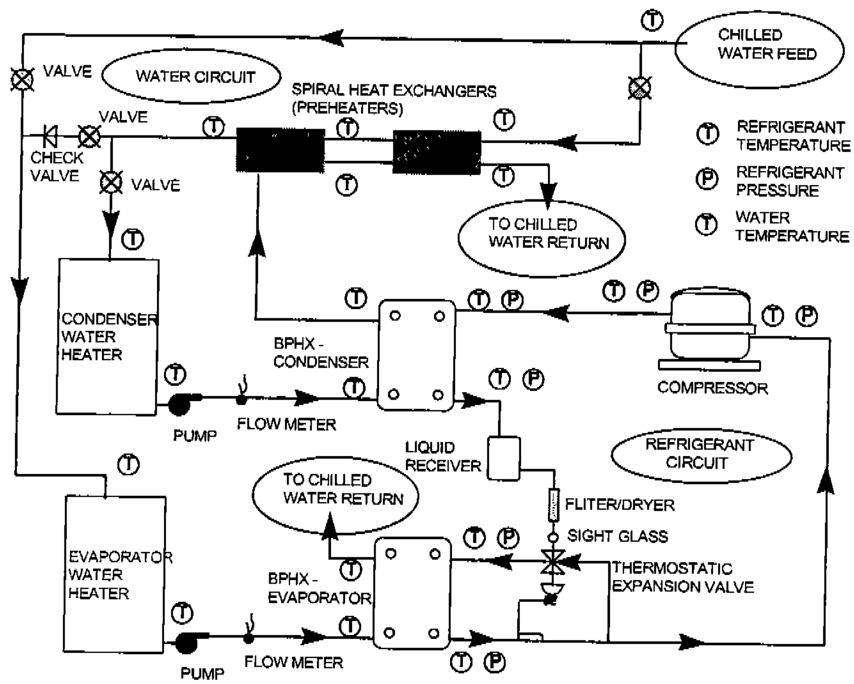

Figure 1 Schematic of Experimental set up

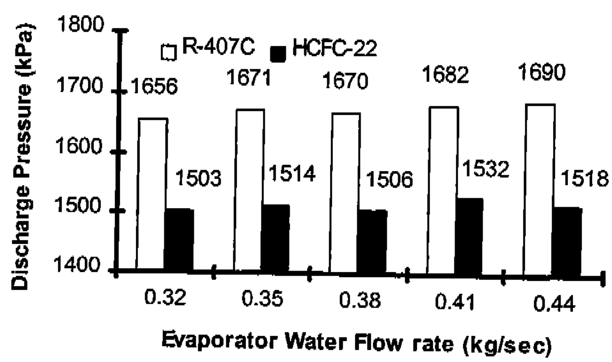

Figure 2 R-407C vs. HCFC-22 : Discharge Pressure

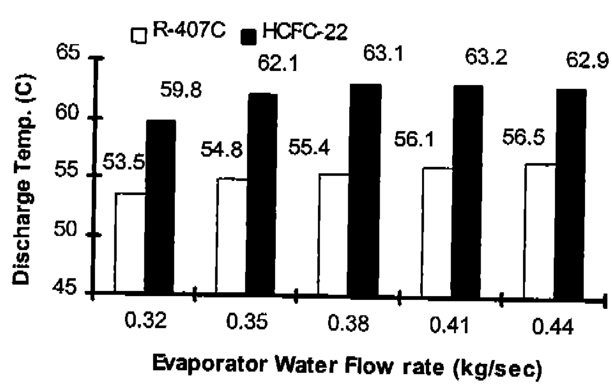

Figure 3 R-407C vs. HCFC-22 : Discharge Temperature

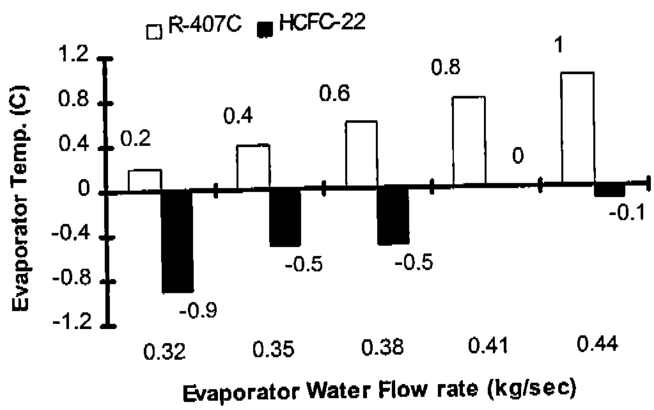

Figure 4 R-407C vs. HCFC-22 : Evaporator Temperature

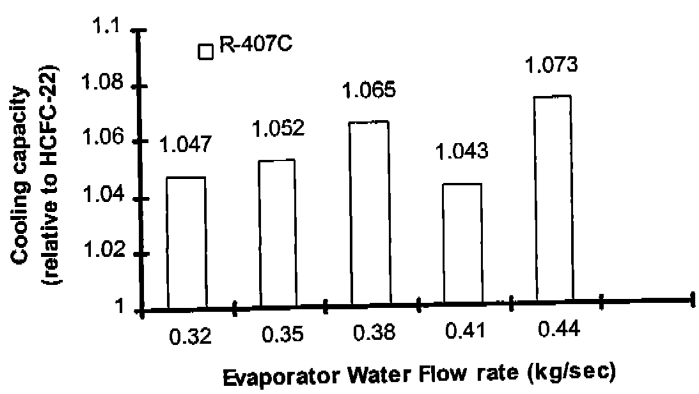

Figure 5 R-407C vs. HCFC-22 : Cooling Capacity

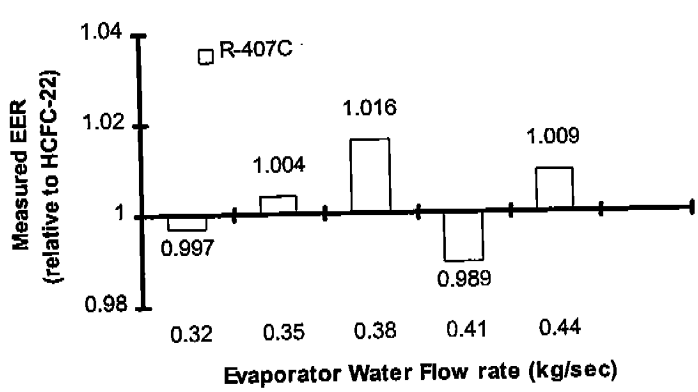

Figure 6 R-407C vs. HCFC-22 : Measured EER