

Numerical Study on the Performance of Air Source Heat Pump with R407C and R22

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Abstract: The steady and dynamic performance characteristics of Air Source Heat Pump with refrigerant R22 and R407C is studied. Results shows that both refrigerants have similar performance properties and R407C refrigerant can be used in either existing systems or in new systems that were originally designed for R-22.

Keywords: R407C, R22, Air Source Heat Pump, Performance

1. INTRODUCTION

In response to the international agreement, the Montreal Protocol on Substances that Deplete the Ozone Layer, that was signed in September 1987 and later amended, the production and consumption of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) came under control and will eventually be phased-out. HCFC-22 has been the primary refrigerant for air conditioning and refrigeration for many years and continues to be used today as a replacement for CFCs in many applications. Hydrofluorocarbons (HFCs) materials are some of the leading options for replacing HCFC-22 in air conditioning and heat pump applications and the performance characteristics of these refrigerants is studied by many researchers^{[1][2][3]}. For the reason that the comparisons between R22 and R407C on exiting system is rare, the paper is focus on this topic.

2. THERMODYNAMIC PROPERTY OF R22 AND R407C

R-407C has capacity and pressure close to R-22. It is a zeotropic refrigerant with a temperature glide of approximately 6°C which can lead to greater concerns about maintaining composition control during the distribution, installation, and servicing of this product^[4]. Table 1 is the property comparison of R22 and R407C and Fig. 1 is the graphical comparison saturation pressure versus temperature of R407C and R22.

The most common diagram frequently used in the analysis of the refrigerant cycle is the Pressure Enthalpy diagram (also known as a Mollier diagram). Fig.2 shows a skeletal Pressure - Enthalpy diagram for refrigerant fluid R22 and R407C. Enthalpy is a property of a fluid which represents the work and heat energy contained in a fluid. It is pressure and temperature dependant, and is usually measured in units of kJ/kg. Note that the evaporation of the refrigerant occurs at a constant temperature.

Refrigerant R22 has a single boiling point for a given pressure, and although there is a minimal pressure drop in the system components resulting in a small temperature difference, the temperature "glide" effect can be ignored.

Table 1 Part Thermodynamic Property Comparison of R22andR407C

Physical Characteristics	Units	Refrigerant	
Type		R407	R22
Constitutes		R32, R125, R134a	R22
Boiling Point @ 1.013 Bar	°C	-43.6	-40.8
Molecular Weight		86.2	86.5
Flammability in Air Vol	%	Non Flammable	Non Flammable
Practical Limit (BS4434)	kg/m ³	0.31	0.3
ODP (R11=1)		0	0.06
GWP (CO ₂ =1, 100yrs)		1600	1700
Evaporating Pressure (0°C)	Bar	4.6	5
Condensing Pressure (40°C)	Bar	16.5	15.4
Pressure Ratio		3.6	3.1
Critical Temperature	°C	87.3	96.1
Specific Heat Ratio (5°C)		1.14	1.18
Discharge Temperature	°C	59.3	63
Total Latent Heat (0°C)	kJ/kg	212	205.4
Theoretical Coefficient of Performance		5.6	5.8
Refrigerant Capacity (0 °C/40°C)	kJ/m ³	3456	3430.8
Temperature Glide in Evaporator	°C	4.93	0

Refrigerant R407C is a zeotrope, which is a fluid mixture, whereby the components boil over a range of temperatures, albeit temperatures which are within a reasonably close range.

The characteristics of zeotropes are:

1. Different compositions for vapour and liquid
2. Boil and condense over a range of temperatures
3. Possible heat transfer reduction

Now R407C is a mixture of refrigerants R32, R125 and R134a, and as a zeotrope has the ability to fractionation, whereby refrigerants will boil at different temperatures in the vapour stage. This causes the temperature of a zeotrope to noticeably increase as it

passes through the evaporator and noticeably decrease in the condenser. A pressure enthalpy diagram for R407C has different terminology, in as much that the bubble line and dew line replace the saturated liquid line, and saturated vapour line respectively. As the refrigerant boils at different temperatures there is a change of vapour content and composition. As the components evaporate or condense, at differing rates, lines of constant quality are not shown on the pressure/enthalpy diagram. With R407C as it does not have a single boiling point, the lowest temperature at which it begins to boil is the bubble point. When condensing the temperature of the first component to reach saturation is known as the dew point.

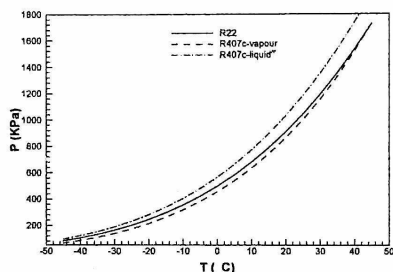


Fig. 1 Graphical Comparison Saturation Pressure v Temperature of R407C and R22

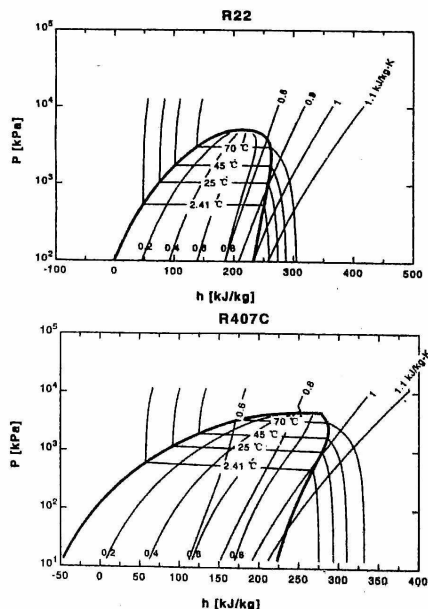


Fig. 2 Pressure - Enthalpy diagram for a. Pure Refrigerant R22 and R407C

3. STEADY PERFORMANCE CHARACTERISTICS OF ASHP WITH R22 AND R407C

A theoretical comparison of refrigerant R407C and R22 in the cooling and heating mode is given in Table 1 and Table 2 based on the calculation programmer developed in our laboratory^{[5][6]}. In the cooling mode, the system employed the cross-flow heat exchanger as the condenser and the counter-flow heat exchanger as the evaporator. In the heating mode, the functions of the heat exchangers were reversed, i.e., the cross-flow evaporator and counter-flow condenser were used. The simulation of the system were performed with 0°C superheat at the evaporator outlet. Other operating parameters were maintained within national standard limits.

Table 2 Cooling Performance Comparison of R22 and R407C in Standard Condition

	R22	R407C
Refrigerant Charge (kg)	74	74
COP	3.44	3.25
Cold Capacity (kW)	265.5	273.5
Compressor Power (kW)	77.2	84.15
Mass Flow Rate (kg/s)	1.97	2.01
Evaporator Pressure (kPa)	535.4	540.3
Suction Line Temperature (°C)	2.2	5
Condenser Pressure (kPa)	1470.8	1682.5
Discharge Temperature (°C)	76.6	67
Pressure Ratio	2.75	3.11
Superheat of Evaporator (°C)	0	0

Table 3 Heating Performance Comparison of R22 and R407C in Standard Condition

	R22	R407C
Refrigerant Charge (kg)	74	74
COP	4.12	3.95
Heat Capacity (kW)	293.5	301.2
Compressor Power (kW)	71.2	76.3
Mass Flow Rate (kg/s)	1.76	1.78
Evaporator Pressure (kPa)	508.5	518.3
Suction Line Temperature (°C)	0.6	3.8
Condenser Pressure (kPa)	1627.8	1832.5
Discharge Temperature (°C)	75.5	67
Pressure Ratio	3.2	3.54
Superheat on Evaporator (°C)	0	0

Table 2 and Table 3 contain a summary of simulation results in cooling model and heating model. The cooling capacity of R407C was a few percent greater than the capacity of R22, while the heating capacities were almost the same. However, the COP of R407C was lower than COP by 4 to 6 percent in both the cooling R22 and heating modes. Overall, the performance of R407C is very similar to the performance of R22 except small differences between capacity and COP. Unlike the other candidates, this refrigerant can be used in either existing systems (requires some changes, e.g. oil) or in new systems that were originally designed for R22. The efficiency of these systems is somewhat lower with this refrigerant (~5% or so lower than R22), especially in systems designed for R22.

4. DYNAMIC CHARACTERISTICS OF ASHP WITH R22 AND R407C

The cyclic performance comparisons of R407C to R22 were simulated in the heating modes under frost and defrost^[6].

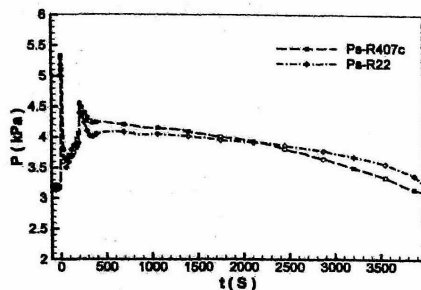


Fig.3 Suction pressure of R22 and R407C versus time

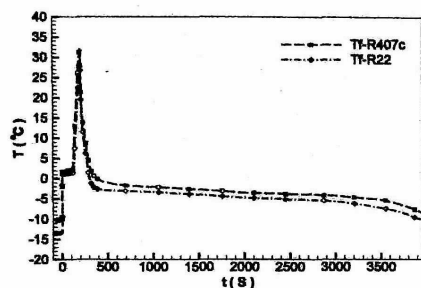


Fig. 4 Fin Temperature of R22 and R407C versus time

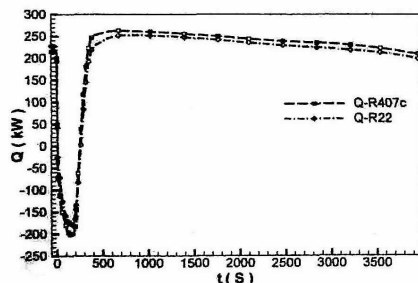


Fig.5 Heating capacity of R22 and R407C versus time

Fig. 3 indicates that R407C attains its steady state performance faster than R22. R407C reaches its steady state performance faster than R-22 because it attains its steady state mass flow rate more rapidly than R22. This occurs because of the temperature glide of the mixture. The temperature glide of the mixture results in a higher refrigerant temperature leaving the evaporator during the early

transients. Fig. 4 also directly support the conclusion that R-407C attains steady state faster than R22. The Fig.5 and Fig.6 shows that the heating capacity of R407C is higher and the power consumption is more than that of R22 also, and both contribute to a performance degradation of R407C

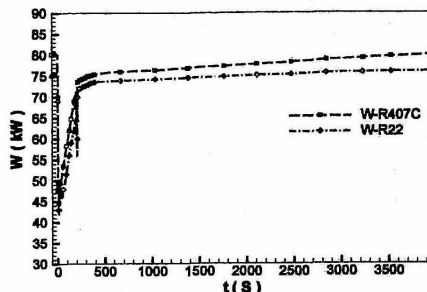


Fig.6 Compressor power of R22 and R407C versus time

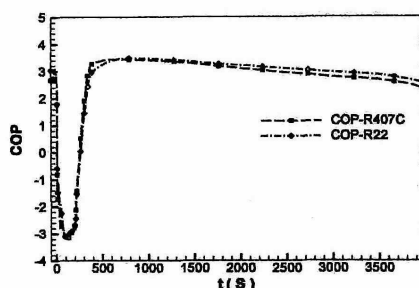


Fig.7 COP of R22 and R407C versus time

5. CONCLUSION

R407C is widely considered as a "drop-in" replacement for R22. In the heating and cooling mode both refrigerants have similar performance properties, and therefore R407C in terms of thermodynamic performance properties is an acceptable alternative to R22. The most important technical difference between R407C and the R22, is that R22 has chlorine as part of its chemical structure, which now makes it totally unacceptable as a refrigerant for the future. The refrigerant can be used in either existing systems (requires some changes, e.g. oil) or in new systems that were originally designed for R-22.

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