IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 1, January 2020, ||Series -V|| PP 07-12

Performance Evaluation of Air Source Heat Pump Water Heater with R407C and R22 under Induce Draft Splited Evaporator Coil

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Received 02 January 2019; Accepted 16 January 2020

Abstract: Air source heat pump water heaters are a promising technology and it uses the same mechanical principle asrefrigerators and air conditioners. The thermal performance of the Air Source Heat Pump for Water Heating system is influenced by refrigerants, system structure, ambient temperature, water temperature, etc. The HCFC refrigerant that were once expected to be permanent replacement fluid are now on the list of regulating substances due to their impact on climate change and there is growing concern about future use. The transition to ozone friendly chlorine free substances is not finished yet as the HCFC fluids still need to be replaced.The refrigerant R-22 is being phased out in developed countries because of high global warming potential and ozone depletion. By January 2020 HCFC's like R-22 will be 99.5% phase out worldwide and will no longer be produced. So new refrigerants are to be searched with lower ozone depletion potential such as propane, pentafluoroethane and blend mixtures of HFC's.

The purpose of the work presented in this paper is to investigate the performance of heat pump under suction fan condition with split evaporator coil. In this work the performance of heat pump is tested for different refrigerants (R22, R407C). The results show that both refrigerant systems have similar performance characteristics. COP of R407C is 1.75% less than that of R22. R407C refrigerant can be used either in existing systems or in new systems that were originally designed for R22.
Keywords: Air source Heat pump, Water heating, Heat pump

I. INTRODUCTION AND BACKGROUND

As well known, an air source heat pump water heater based on the vapour compression refrigeration cycle has wide residential and commercial applications for its outstanding energy saving performance [1]. Over the past decades, conventional refrigerants such as HCFCs and HFCs have been used extensively in heat pump fields owing to their excellent chemical and thermodynamic properties. They have played an important role in many fields of modern life, especially in the refrigeration and freezer industry. However, the increasing attention to environmental problems such as global warming, ozone depletion and atmospheric pollution has led to a large number of studies related to the selection of environmentally friendly refrigerants and refrigerants mixtures as working fluids for heat pump water heater applications in recent years [2]. Current research and industry trends show that HCFCs and HFCs will gradually be replaced by HFC mixtures [3-5].

Reduction of CFCs emissions into the ambient in the refrigeration based industry can be achieved by various measures. These measures can be classified as short term and long term measures. Short term measures; include a more accurate design of the plants, better maintenance operations and by recycling the refrigerants whenever possible. By paying attention to the short term measures, a real time saving in refrigerant, in the order of 50% or more, can be achieved. Long term measures involve the substitution of the actual refrigerants with non polluting ones that could meet the requirements of absence of toxicity, flammability and all demand from the thermodynamic and thermo physical points of view [6].

Zeotropic mixtures as alternative to pure fluids in heat pump and refrigeration plants have been employed since the discovery of several advantages of mixtures over pure refrigerants. A large number of zeotropic mixtures may be formed with the refrigerants that are suitable for compression type heat pumps. As R22 is gradually phased out, non-ozone depleting alternative refrigerant are being introduced. Various substitutes to R22 have been proposed R134a, R404A and R407C [7]

R407C is considered the best replacement for R22 because R407C its thermodynamic properties are very close to those of R22. Therefore, it is a good drop in substitute. It is a zeotrope of R32/R125/R134a (23%, 25%, 52% by weight) with a glide of about 7˚C [8].

Table 1 Characteristic feature of R22 and possible substitutes to R22 [9]

Refrigerant	R22	R134a	R404A	R410A	R407C
Composition (wt %)	-	-	R125/143a/134a (44/52/4)	R32/125 (50/50)	R32/125/134a (23/25/52))
Molar mass (kg/kmol)	86.48	102.03	97.6	72.59	86.2
Boiling point at 1 atm (°C)	- 40.80	-26.1	- 46.5	-51.81	- 43.7
Freezing point (˚C)	-160.00	-101.06	72.1	70.17	86.05
Critical temperature (°C)	96	101.06	72.1	70.17	86.05
Critical pressure (bar)	49.9	4.064	37.32	47.70	46.34
Latent heal of vaporization (kJ/kg)	234.7	215.5	208.9	271.6	243.8
Glide	-	-	0.8	0.1	7.2
Ozone depletion potential	0.055	0	0	0	0
Global warming potential	1700	1300	3700	1900	1600

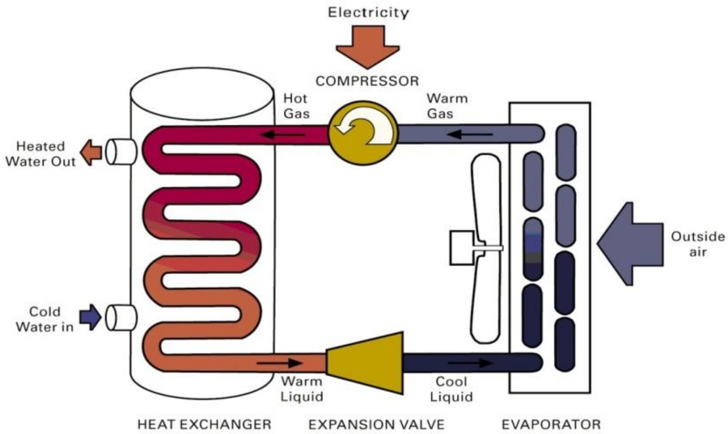

Fig.1 Schematic diagram of a heat pump

II. LITERATURE REVIEW

Since the 1950s, researches have been performed on heat pump water heaters (HPWHs), including structure, thermodynamics, working fluids, and operation controlling, numerical simulation and economical analysis. The performance of a heat pump with alternative refrigerants has been reported by many investigators

Ragazzi and Pederen [10] studied the thermodynamic optimization of various evaporator designs with zeotropic refrigerant mixtures using an irreversibility-based function. Their main goal was to find a replacement for R22. They showed that the zeotropic mixtures are less irreversible than the pure refrigerants with cross counter- flow heat exchanger. Choi and Kim [11] investigated the effects of the expansion device on the performance of a water to water heat pump using R407C, which has been considered as one of the alternative refrigerants to replace R22 at various charging conditions. Zhang et al. [12] developed a dimensionless correlation on the basis of experimental data to predict the mass flow rate of R22 and its alternative refrigerant R407C through an electronic expansion valve. Several other authors studied the R22 replacement issues.Aprea et al. [13] studied the mean heat transfer coefficients of R22 and R407C in a coaxial counter flow evaporator of a refrigerating vapor compression plant. Bigot et al. [14] measured the performance of a coil with 7 mm outside tube diameter using R407C in a reversible heat pump. The outcome of the test showed that an appropriate design of the air-refrigerant counter flow heat exchanger using R407C allows a 20% increase in the global heat exchange coefficient at the evaporator and 10% at the condenser. Wang et al. [15] measured on the spot the performance of double coupling heat pump system applying in Beijing area and the data showed the heating coefficient of the system is higher in low temperature. Cao et al. [16] developed theoretical and experimental research on air source heat pump water heater with enhanced enthalpy injection, the results that the ratio of refrigerant injection should not be higher than 5% were obtained, and more over injection circuit had helpful effect on the system when the temperature ranged from 15 to 20 ºC. Ma et al [17] proposed air source heat pump system consisting of scroll compressor with subcooler, it could operate properly under the condition of -15 ºC.

Theliteraturereviewdescribesthepaststudiesonthevariousissuesofheatpumpincludingtheory,operationand design.Theperformanceofheat pumpdependson variousparameters such as evaporator design, type of refrigerant, fin spacing, operating conditions etc. The studies are also limited in the field of evaporator and fan arrangement in the heat pump. Ito and Miura [18] investigated the mechanism of heat pump for hot water supply using dual heat sources of Gang et al. [19] established A comparative experiment prototype of an air source heat pump water heater system for the comparative study between instantaneous and cyclic heating modes. Castro et al. [20] carried out study on an air to water reversible heat pump unit using two different fin-and-tube heat exchanger coil designs and propane (R290) as the working fluid. Li et al. [21] proposed a frost free air source heat pump water heater system with integrated solid desiccant, in which frosting can be retarded by dehumidifying air before it enters the air source heat pump water heater evaporator. Zali et al. [22] studied thermodynamic properties of refrigerants, condenser and evaporator Secondary fluid using artificial neural network. They used Wilson-Plot method to compare performance of refrigeration cycle with R22 and R407C refrigerants. The result shows that decreasing evaporator temperature, behaviour of R407C approach to R22. Therefore R407C can be a suitable alternative for replacing R22 in all the refrigeration systems with low evaporation temperature

This paper is focused on performance comparisons between R22 and R407C on an existing system and changing the evaporator coil. The main aim of the experimental work is to test the system performance, such as the COP.

III. EXPERIMENTAL SETUP AND TEST PROCEDURE

3.1 Experimental Setup

The schematic diagram of the experimental test facility is shown in Fig. 3.5. It is composed of heat pump, water tank, and control system. The heat from atmosphere is absorbed in evaporator. The superheated vapour enter in scroll compressor, it compress the gas in to high pressure. The high temperature and pressure refrigerant which is then condensed into liquid and release heat in to the water in plate type heat exchanger works as condenser.

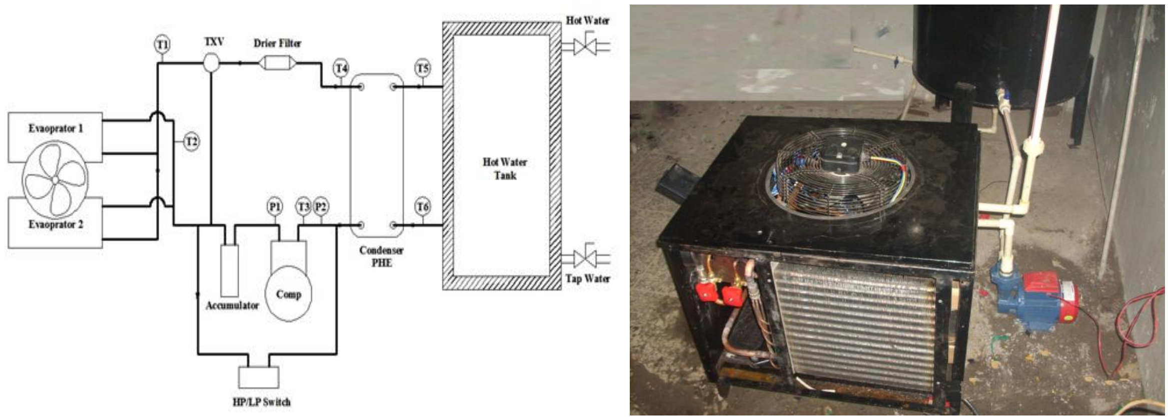

Fig.2 Experimental and photograph of test setup

After the condenser the refrigerant enters in dryer and filter. The superheat is controlled by sense the evaporator exit by Thermal expansion valve. HP and LP switch is located at compressor discharge and compressor suction line relatively for safety of the compressor.

3.2 Test Procedure

After completion of setup nitrogen is filled in the system to carry out the leak test. The gas is filled up to 10 bar and is kept for 24 hours. The pressure of the gas is checked after 24 hours. Soap test is done over the joints to detect the leakage. No change in pressure in 24 hours implies leak proof system. Vacuum is created in the system by using vacuum pump for an hour. Subsequently system was charged with R22 refrigerant. The system is filled with about 2.15 kg of refrigerant was charged is checked by weighing machine. The starting time of fan and water pump is kept on 90 seconds before the start of compressor. After steady state the temperature and pressure at various points are measured with interval of 15 minutes. This procedure is continued till the set temperature of 50˚C is achieved in the tank.

The same procedure is repeated from creating vacuum and charging the gas onwards for R407C. As R407C iszeotropicin nature, it should be charged as a liquid to prevent fractionation.

IV. RESULTS AND DISCUSSION

An experimental set-up is developed to carry out the experiments on air source heat pump. The ambient temperature was considered constant during test. The water was heated 29˚C to 50˚C. A series of experiments are performed to evaluate the performance of the system. A comparative study is carried out with R22 and R407C.

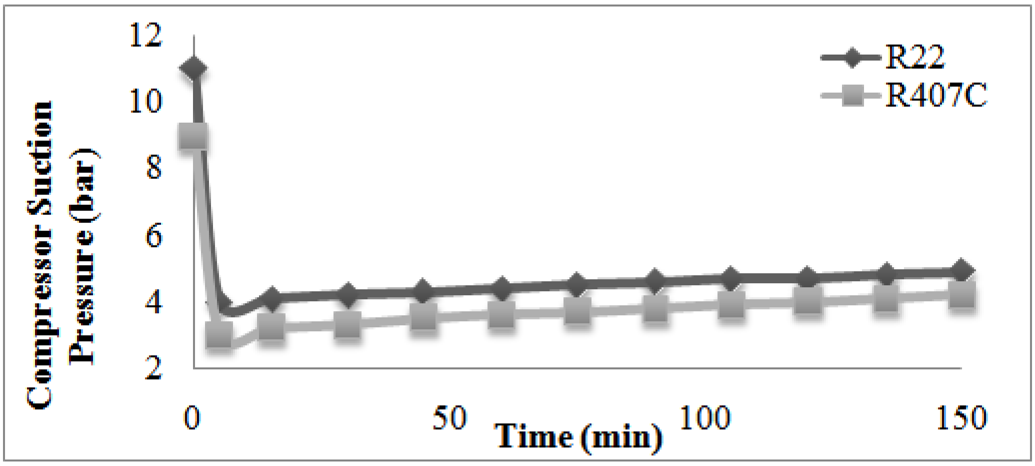

Fig.3 Compressor suction pressure of R22 and R407C vs. Time

Fig.3 shows the suction pressures of R22 and R407C versus time; It shows that the compressor suction pressure drops suddenly as the system is started, it reaches the minimum pressure of 3 bar in case of R407C and 4 bar in R22. As time passes, with increase in air flow rate over the evaporator and water getting heated up the suction pressure increases steadily. The compressor suction pressure of R407C is lower than that of R22 .At all times the suction pressure of R407C is lower than that of R22.

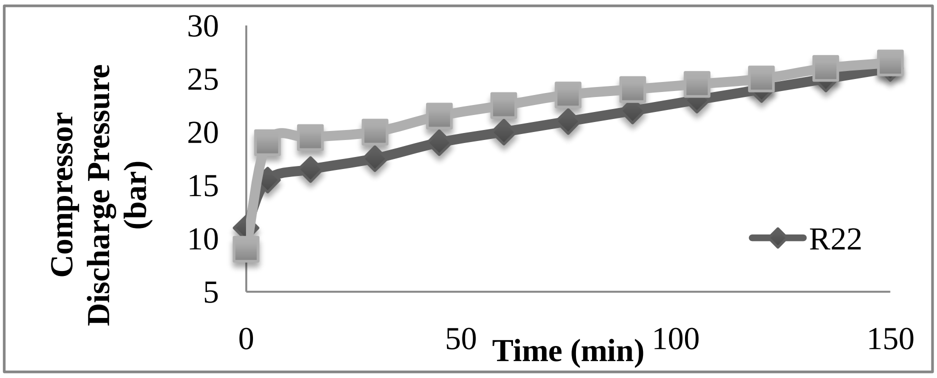

Fig.4 Compressor discharge pressure of R22 and R407C vs. Time

Fig. 4 shows the variation of compressor discharge pressure of R22 and R407C during the heat pump operation. It shows that the pressure increases suddenly as the setup is started and then it goes on increasing steadily. R407C has higher discharge pressure as compared to that of R22. Rise in pressure is more for R407C; 9 bar to 26.5 bar in comparison to R22; 10 bar to 26 bar.

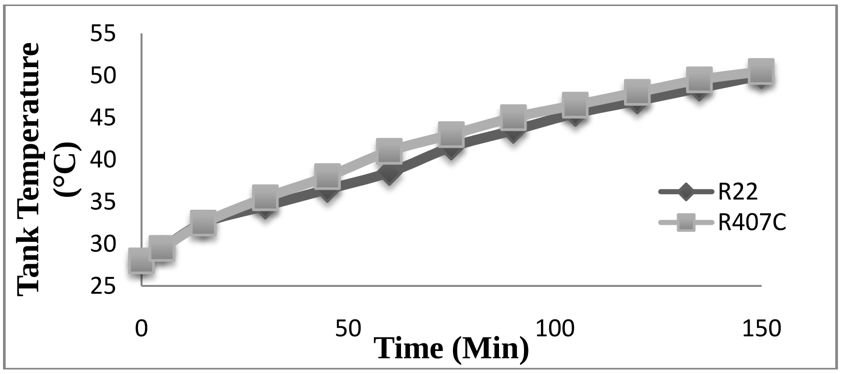

Fig.5 Tank temperature of R22 and R407C vs. Time

Fig.5 shows the comparison of tank temperature versus time, the tank temperature increase with time, water is initially at 28˚C and it goes on increasing steadily. It takes almost 150 minutes to reach water temperature at 50°C which is recommended temperature by ASHRAE.

The variation of Compressor power of R22 and R407C with respect to time is shown in Fig.6. It is self explanatory that the compressor power increases with running time, however power consumption with R407C is more compared to R22. There is steady rise in power consumed due to heating of water at condenser. The highest value of power consumed is1.95 kW for R22 while that for R407C it is marginally higher 1.99 kW.

Fig.7 shows that COP decreases as the time increases. R22 system shows marginally higher COP than R407C. The decrease in COP is due to increase in water temperature. As the water temperature increases the heat gain capacity of water decreases which results in decrease of COP of the system. The maximum COP of R22 heat pump unit is 4.57 and that for R407C is 4.49.

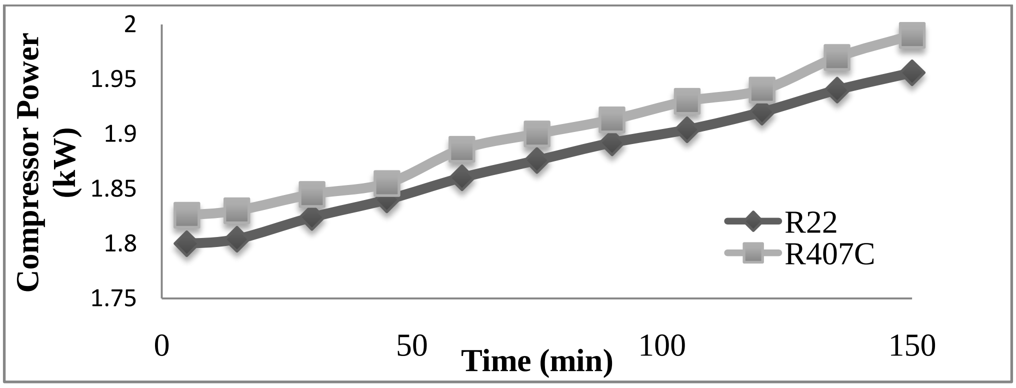

Fig.6 Compressor power of R22 and R407C vs. Time

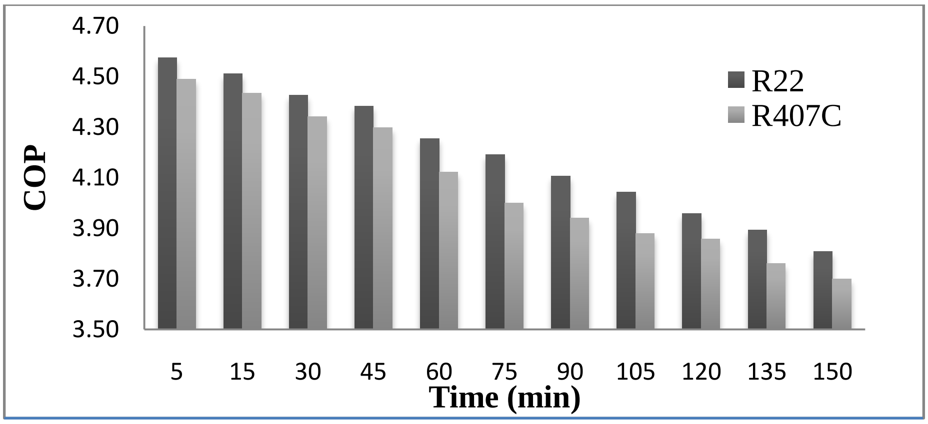

Fig.7 COP of R22 and R407C vs. Time

V. CONCLUSION

A prototype of setup is developed to carry out experiments of refrigerant R22 and R407C. A series of experiments are performed and performance of system is evaluated. R22 heat pump system performs marginally better in comparison toR407C. R22 exhibits maximum cop 4.57while R407C heat pump system shows 4.49. Heating capacity of R22 is better in comparison to R407C.It can be concluded that in view of finding drop in substitute of R22, R407C can be a good option for heat pump application.

REFERENCES

[1]. M. Mohanraj, S. Jayaraj, C. Muraleedharan, Environment friendly alternatives to halogenated refrigerants a review, International Journal of Greenhouse Gas Control 3 (2009) 108–119.

[2]. G.G. Haselden, J. Chen, A computer simulation program for mixed-refrigerant air conditioning, International Journal of refrigeration. 17 (1994) 343-350.

[3]. S. Shangli, D. Wang, R. Wang, Advances in the research of heat pump water heaters, in: Proceedings of the Sixth International Conference for enhanced building operations, 12 (2006) 1-6.

[4]. M. Kim, M.S. Kim, J.D. Chung, Transient thermal behaviour of a water heater system driven by a heat pump, International Journal of Refrigeration 27 (2004) 415-421.

[5]. JJ. Guo, JY Wu, RZ. Wang, S. LI. Experimental research and operation optimization of an air-source heat pump water heater. Applied Energy 88 (2011) 4128-4138

[6]. P. Byrne, J. Miriel, Y. Lenat. Experimental study of an air-source heat pump for simultaneous heating and cooling -part 1: Basic concepts and performance verification. Applied Energy 88 (2011) 1841-1847

[7]. P. Gang, L. Guiqiang, J. Jie. Comparative study of air-source heat pump water heater systems using the instantaneous heating and cyclic heating modes.35 (2008) 25-34

[8]. F. Madonna, F. Bazzocchi. Annual performances of reversible air-to-water heat pumps in small residential buildings. Energy and Buildings 65 (2013) 299-309.

[9]. A. Greco, R. Mastrullo, A. Palombo. R407C as an alternative to R22 in vapour compression plant: an experimental study, International Journal of Energy Research 21 (1997) 1087-1098.

[10]. F. Ragazzi, C.O. Pederen, Thermodynamic Optimization of Evaporators with Zeotropic Refrigerant Mixtures, Air Conditioning and Refrigeration Centre. College of Engineering.University of Illinois at Urbana-Champaign, 1995.TR-74.

[11]. J. Choi, Y. Kim. Influence of the expansion device on the performance of a heat pump using R407C under a range of charging conditions. International Journal of refrigeration 27 (2004) 378–384.

[12]. Zhang, R.Z. Wang, J.Y. Wu, System optimization and experimental research on air source heat pump water heater, Applied Thermal Engineering 27 (2007) 1029–1035.

[13]. Aprea C, de Rossi F, Greco A. Experimental evaluation of R22 and R407C evaporative heat transfer coefficients in a vapor compression plant. . International Journal of refrigeration 23 (2000) 366–377.

[14]. G. Bigot, L. Palandre, D. Clodic, Optimized design of heat exchanger for reversible heat pump using R-407C, in: International Refrigeration and Air Conditioning 24 (2001) 823–833.

[15]. Wang, W., Z. Ma and Y. Jiang, Field test investigation of a double-stage coupled heat pumps heating system for cold regions. . International Journal of refrigeration. 28 (2005) 672-679.

[16]. Cao, F., J.Y. Fei and Z.W. Xing, Review of air source heat pumps for low temperature climates study on performance of a heat pump water heater using suction stream liquid injection. Applied Thermal Engineering. 29 (2009) 2942-2948.

[17]. Ma, G., Y.Q.H. Chai and Y. Jiang.Experimental investigation of air-source heat pump for cold regions International Journal of refrigeration. 26(2003) 12-18.

[18]. S. Ito and N. Miura. Studies of Heat pump using water and air heat sources in parallel. Heat Transfer Asian Research 29 (2000) 473-490.

[19]. P. Gang, L. Guiqiang, J. Jie. Comparative study of air-source heat pump water heater systems using the instantaneous heating and cyclic heating modes.35 (2008) 25-34

[20]. JB. Castro, JF. Urchueguia, JM. Corberan, Gonzalvez J. Optimized design of a heat exchanger for an air-to-water reversible heat pump working with propane (R290) as refrigerant: Modelling analysis and experimental observations. Applied Thermal Engineering 25 (2005) 2450-2462

[21]. Z. Li, F. Takeshi, S. Michiyuki. A new method for preventing air source heat pump water heaters from frosting. International Journal of Refrigeration 35 (2012) 1327-1334.

[22]. S. Zali, R. Hashemi, M. Naggaashzagadan. Performance Comparison of R407C and R22 in Off-Design Point Using Wilson-Plot Method.Middle-East Journal of Scientific Research 9 (2011) 177-183.