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Research Article

Performance Evaluation of Water Cooler with Modification of Liquid Suction Heat Exchanger

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Abstract

It is necessary to modify the simple vapour compression refrigeration systems in order to improve the performance. The coefficient of performance of the system can be increased either by decreasing the work of compression or increasing the refrigerating effect or by the combination of both. The refrigerating effect can be increased by maintaining the condition of refrigerant in lower temperature liquid stage, at the entrance of evaporator. This can be achieved by expanding the refrigerant very close to the liquid line i.e. by sub-cooling the refrigerant and by removing the flashed vapour. The present work describes the design of a VCRS and the design of the liquid suction heat exchanger. A tube in tube type heat exchanger is incorporated in the system, in between the liquid line i.e. pipe joining the condenser and the expansion device and the suction line i.e. pipe joining the evaporator and the compressor. So it is called as Liquid Suction Heat Exchanger (LSHX) or Suction line heat exchanger (SLHX). Effect of reduced flashing was found dominant, compared with the effect of sub-cooling on the refrigeration capacity. The effects of different flow rates of refrigerant and initial temperature of water on COP, work of compression, refrigeration effect of the system, heat exchange capacity of the LSHX, effectiveness of the LSHX & refrigeration capacity of the evaporator are calculated and analyzed. On the basis of experimentation and analysis, it is found that, use of liquid suction heat exchanger in the VCRS, increases the COP of the refrigeration unit for different initial temperatures of water. The power consumption by the compressor gets reduced by using the liquid suction heat exchanger. The optimum effect of the LSHX is seen at different flow rates of the refrigerant for lower initial temperature of water (30 to 35 °C).

Keywords: *LSHX, water cooler, VCC, heat exchanger, COP*.

1. Introduction

To reduce the energy consumption, by using new energy saving technologies and equipments is an important task now-a-days, in order to reduce the energy consumption in refrigeration. Required degree of sub cooling and superheating may not be possible, if one were to rely only on heat transfer between the refrigerant and external heat source and sink. Also, if the temperature of refrigerant at the exit of the evaporator is not sufficiently superheated, then it may get superheated by exchanging heat with the surroundings as it flows through the connecting pipelines (useless superheating), which is detrimental to system performance. One way of achieving the required amount of sub cooling and superheating is by the use of a liquid-suction heat exchanger (LSHX). A LSHX is a counter flow heat exchanger in which the warm refrigerant liquid from the condenser exchanges heat with the cool refrigerant vapour from the evaporator. Since the temperature of the refrigerant liquid at the exit of condenser is considerably higher than the temperature of refrigerant vapour at the exit of the evaporator, it is possible to sub cool the refrigerant liquid and superheat the refrigerant vapour by exchanging heat between them.

1.1 Literature Review

Evaluation of the influence of liquid-suction heat exchangers installed in vapor compression refrigeration systems considering 29 different refrigerants in a theoretical analysis (Domanski, 1994). The study of the performance of liquid-suction heat exchanger using different refrigerants revealed that the liquid-suction heat exchanger is detrimental to system performance in systems using R22, R32, and R717 Refrigeration system performance using liquid-suction heat exchangers (Klein *et al*, 2000). The study of the influence of heat exchangers to the efficiency of a household refrigerating system was carried out and the presented guidelines and recommendations can be used for design and modernization of household refrigerators and freezers with Liquid–gas heat exchanger for household refrigerator (Dagilis *et al***,** 2004). A chart for predicting the possible advantage of adopting a suction/liquid heat exchanger in

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refrigerating system described different parameters those may affect to the performance of LSHX in a chart (Mastrullo *et al*, 2007**)**.

The present research work focuses on the use of and effect of LSHX on the performance of the vapour compression cycle refrigeration system of a water cooler.

2. Experimental Investigation

2.1 Experimental Setup

The experimental set-up is composed of an insulated tank which holds the evaporator inside, temperature sensors, temperature display, rotameter with flow control valve, pressure gauges, immersion water heater, flow control valves, ammeter, voltmeter, a miniature water pump and the refrigeration system - compressor, condenser, capillary and evaporator- with a tube in tube type liquid suction heat exchanger.

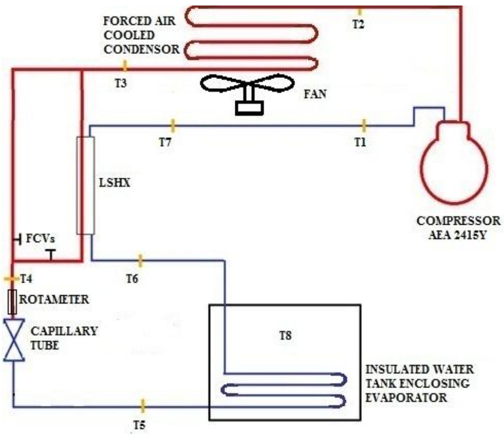

Fig.1 Schematic diagram of experimental setup

Fig.1 Experimental set-up

2.2 Experimental procedure

Experiments were performed with different initial temperatures of the water in the storage tank. The temperature is varied by using an immersion water heater. The flow of the refrigerant through the system is measured and controlled by using a rotameter with a flow control valve. The valves V_1 and V_2 are used to connect or disconnect the liquid suction heat exchanger. Prior to start of data record, the system was allowed to attain the steady state.

Experimental Procedure is as follows,

1. Ensure that evaporator tank is filled with known amount of water.
2. Put the temperature sensor T8 in the evaporator tank.
3. Note down the reading of temperature T8i.
4. Open valve V2 to operate the system without LSHX, keep valve V1 closed.
5. Switch ‘ON’ the condenser fan and compressor.
6. Switch ‘ON’ the pump for 30 seconds after every 10 minutes to ensure the circulation of the water in the evaporator tank.
7. With the use of flow control valve, set the flow rate of refrigerant.
8. Note down the flow rate of the refrigerant.
9. Note down the voltage and current.
10. Note down the volume of water in the evaporator tank.
11. Note down the time.
12. Note down the reading of suction and discharge pressures.
13. Note all the readings for every 5 °C drop in water temperature till the temperature of water in the evaporator comes 15 °C.
14. Repeat the procedure except step-4, for same refrigerant flow rate by operating the system with LSHX by closing the valve V2 and opening the valve V1.
15. Switch ‘ON’ the heater to increase the temperature of the water again to the desired temperature.
16. Repeat the same procedure for different initial temperatures of the water.

3. Results, Graphs and Discussion

In present study, experiments are conducted for the operation of the water cooler using vapour compression refrigeration system (VCRS) with and without using the LSHX. The present system has been analyzed for different initial temperatures of water that is to be cooled by varying the refrigerant flow rate in the system. The results obtained from the experimental investigation of water cooler setup operated with & without liquid suction heat exchanger various operating conditions are studied in detail and presented here.

3.1 COP variation analysis

Percentage rise in COP of system without & with LSHX at different flow rates of refrigerant for different initial temperatures of water is presented in the following table.

Table 1 Percentage rise in COP of system without & with LSHX at different flow rates of refrigerant for different initial temperatures of water

Q_R	16 LPH	14 LPH	12 LPH
T_{8i} (°C)	Rise in COP (%)		
50	24.54	23.85	14.09
45	26.13	19.69	26.13
40	32.88	34.10	24.71
35	40.96	34.88	17.31
30	36.57	22.76	11.41

It is observed from the above table that the % rise in the COP of the system without and with the LSHX is maximum at the flow rate of 16 LPH and initial temperature of water of 35 °C as compared to 14 & 12 LPH.

3.2 Effect on work of compression (W_c):

Table 2 Percentage fall in Wc of system without & with LSHX at different flow rates of refrigerant for different initial temperatures of water

Q_R	16 LPH	14 LPH	12 LPH
T_{8i} (°C)	Fall in Work of compression, W_c (%)		
50	6.14	4.10	4.44
45	5.78	4.76	4.76
40	6.10	3.74	6.46
35	10.03	3.11	4.58
30	10.70	2.79	3.47

It is observed that the % fall in required work of compression is much more at the initial water temperature of 30 & 35 °C for a system with LSHX as compared to without LSHX. The % fall is higher at a refrigerant flow rate of 16 LPH as compared to 14 & 12 LPH flow rate.

Refrigeration effect (Qe) - variation analysis

Table 3 Percentage rise in Q_e of system without & with LSHX at different flow rates of refrigerant for different initial temperatures of water

Q_R	16 LPH	14 LPH	12 LPH
T_{8i} (°C)	Rise in Refrigeration capacity, Q_e (%)		
50	17.12	19.44	9.43
45	19.09	13.91	17.27
40	24.07	28.70	23.76
35	25.66	31.36	11.93
30	21.90	31.78	25.26

It is observed that the higher % rise in the refrigeration capacity of the system at a refrigerant flow rate of 14 LPH for 30 °C initial temperature of water as compared to 16 and 12 LPH for a system with LSHX. It is also clear that at 35 °C the optimum % rise is obtained for 16 & 14 LPH. Hence 14 & 16 LPH flow rate of refrigerant through the system is suitable to obtain the desired effect.

Conclusions

Experimental study of vapour compression refrigeration system with & without liquid suction heat exchanger performed for different flow rates of the refrigerant, shows that the cooling time increases (3% to 5%) for the same initial temperature of water at different flow rates of the refrigerant through the system. This is because the less availability of the refrigerant in the evaporator, which reduces the evaporator capacity. Use of liquid-suction heat exchanger in the VCRS reduces the possibility of liquid carry-over from the evaporator which could harm the compressor, by superheating the refrigerant vapours after evaporator, by the heat of hot liquid refrigerant available after condensation. The refrigeration capacity of the system is increased by 9% to 32% for different flow rates of the refrigerant in the range of 12 to 16 LPH, which is obtained due to the sub cooling of the liquid refrigerant in the LSHX, leading to the efficient throttling. For lower flow rates of the refrigerant the effectiveness of the LSHX is maximum as compared to higher flow rates, because the time available to exchange heat is more in case of the low flow rate. The optimum effectiveness (0.65) is obtained at 40 °C of initial water temperature. Use of LSHX in the vapour compression refrigeration system, increases the COP of the refrigeration unit for different initial temperatures of water by 10 % to 40 % . The compressor work gets reduced by 3% to 11%, by using the liquid suction heat exchanger in the vapour compression refrigeration system that means less power consumption by the refrigeration unit has been observed. The LSHX sub-cools the liquid refrigerant before passing to the expansion valve which leads to the rise in evaporator capacity which is much more than the heat rejected in sub-cooling. Thus the LSHX is found to be a device which is useful for avoiding flashing of refrigerant in expansion device that raises the amount of liquid refrigerant in evaporator. Ultimately, it increases the refrigeration effect and COP of the system (10 % to 40 %). The optimum effect of the LSHX is seen at different flow rates of the refrigerant for lower initial temperature of water (30 to 35 °C).

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