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Experimental investigation of hot gas defrosting system for domestic refrigerator

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Abstract
In vapor compression refrigeration system, during the defrosting process there was interruption of cooling in compressor shutdown method, electric heater defrosting, reverse cycle defrosting method etc. The hot gas bypass method is developed to remove the frost from evaporator coils and to provide continuous cooling without any interruption. The experimentation was carried out with two evaporator chambers in domestic refrigerator. At the time of defrosting of one evaporating chamber, another chamber provides continuous cooling. Based on the test results the effects of hot gas bypass cycle were studied. In addition the operating characteristics of hot gas defrosting cycle were compared with those of simple VCRS cycle. The experimental study analyzes the possibilities of minimum hot gas bypass for defrosting so that COP obtained during defrosting was nearly equal to COP obtained during simple VCRS cycle.

Keywords: hot gas bypass defrosting, COP, refrigeration effect, input power

1. Introduction

When the frost forms on the evaporator coils maintained below 0^0C, the freezing point of water in domestic refrigerator, the moisture from the air would not only be condensed but also freeze on the coil surface which was inevitable. Also it was obvious that lower the evaporator temperature, greater would be frost formation. The frost formed on the evaporator coil would act like insulation, retarded heat transfer and reduced the temperature of evaporator.

With decreased heat transfer, the temperature of evaporator would tend to go down, causing thicker frost and further decrease in the evaporator temperature and capacity. If the frost was allowed to accumulate further, even liquid flooded back to the compressor could be occurred due to a substantial reduction in the evaporator capacity. Therefore it was necessary to melt the frost periodically B [1]. This process of removing the frost by melting was called as defrosting the evaporators. In recent years, the various defrosting methods have been used like compressor shutdown, electric heating, reverse cycle, hot gas bypass etc [1-6].

When these methods were utilized to melt the frost on the evaporator coils there was no cooling during the process of defrosting, thus there was interruption of cooling. In electric heater defrosting, compressor and fan remained off and part of heat provided by the electrical heater was transferred to the refrigerated compartments. The electrical heaters consumed more energy, increased air side pressure drop and were subjected to corrosion problems but much cheaper method for frost removal in low capacity evaporators of refrigerators [3]. The most common types of heaters were classified in to – (i) aluminium tube (distributed), (ii) glass tube, and (iii) tubular metal sheathed (calrod). The aluminium heaters were widespread used in household frost-free refrigerators[4]. In that case conduction heat transfer was dominant, since heater was in direct contact with the evaporator fins. In addition, the distributed heater rarely damaged the internal plastic and polystyrene parts near the evaporator. On the other hand, it considerably increased air side pressure drop, corrosion problems and installation problems which were more complex.

The reverse cycle defrosting process [5] was completed by using four way reversing valve. During reverse cycle defrosting the refrigerant flow was reversed, evaporators temperature increases, during the defrosting process hot gas was blown on the evaporator surface for melting the frost. A sudden pressure shooting & falling in the compressor suction and discharge lines during switching the reversing valves of the RCD cycle caused the mechanical shocks to the compressor and the refrigerant lines.

The problem with reverse cycle defrosting, electric heater defrosting was the requirement of interruption of cooling during defrosting. In the hot gas defrosting method there was utilization of only a hot gas bypass valves to remove the frost from the evaporator coils enabling supply of cooling without any interruption. Yaqub *et al.* [6]. investigated a refrigeration system for HFC 134a by injecting hot gas and liquid refrigerant to the suction side of compressor.

The hot gas bypass could be carried out by three ways-

1. By passing hot gas refrigerant from the discharge side of compressor was injected back in to compressor suction side, hot gas mixed with vapors coming out of evaporator. Due to this pressure increased in evaporator, it reduces the flow of refrigerant through the evaporator & hence reduced capacity of the system. The remaining hot gas passed from compressor to the condenser where the process of condensation was carried out. Then the liquid refrigerant from condenser passed through expansion

valve, there was pressure drop in expansion valve. Then that low pressure and low temperature refrigerant evaporated in evaporator coils and passed to compressor.

2. By passing hot gas directly from compressor discharge side to compressor suction side, the delivery temperatures may become excessive and result in high superheat in the suction line. This problem could be avoided by injecting liquid refrigerant from the condenser in to suction line to cool the vapor entering the compressor. It was necessary to note down that vapor entering the compressor should be in vapor form. Therefore, there was a limiting value for liquid injection, which keeps the refrigerant in saturated vapor form after mixing with the hot gas.
3. In the third scheme hot gas was injected directly to the liquid refrigerant before entering the evaporator. The hot gas was passed through expansion valve which caused increased in enthalpy of liquid refrigerant entering the evaporator and thus reduced the cooling capacity of evaporator.

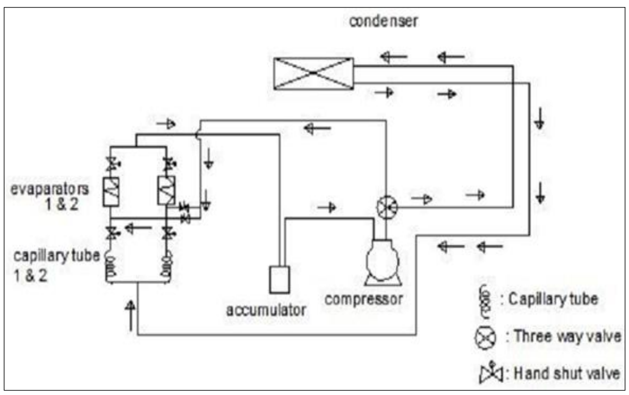

Fig 1: Schematic diagram of experimental setup

2. Experimental Apparatus and procedure

2.1 Experimental setup

Fig. shows a schematic diagram of experimental setup. The refrigeration system which was originally designed to work with R 134a, was equipped with two pressure gauges, eight thermocouples, Digital temperature indicator (D.T.I), Rotameter, One three way valve, six hand shut off valves and an energy meter.

The test unit included one hermetically sealed reciprocating compressor with displacement volume of 0.00074 m^3/sec, one condenser, two evaporators, and two capillary tubes. The condenser consisted of three rows. The condenser unit was located outer side of refrigerator, and the evaporators were installed inside the evaporator chamber.

The hot gas flow was regulated by rotating three way valve and by controlling the hand shut off valves. When evaporator #1 was defrosted, the hand shut off valves for evaporator #1 in the bypass line was opened and the capillary exit was closed therefore the high temperature refrigerant existing from the compressor directly entered in to evaporator #1, which would melt the frost of evaporator #1. During the defrosting process, the evaporator #2, operated normally to provide cooling capacity for the refrigerator, by closing the hand shut off valves for these evaporators in the bypass line. Once the defrosting of evaporator #1 completed, the defrosting of evaporator #2 started with the provision of hot gas refrigerant from the compressor while evaporator #1 worked normally. This defrosting cycle continued alternately for both evaporators in an optimum time interval.

The temperatures and pressures at measure locations, refrigerating capacity, system COP, compressor power was calculated for simple VCRS cycle, 11.25% hot gas bypass and 5.6% hot gas bypass. The compressor power input was measured with energy meter. The refrigerant flow rate was measure by rotameter installed at the exit of the condenser. The pressure gauges were installed to measure the pressure at the inlet and exit of the compressor. The thermocouples were fixed to measure the temperature at the inlet and exit of condenser, compressor and evaporating chamber. The different temperatures can be obtained from 8 point D.T.I by rotating its regulator switch. The energy meter was used to record the instantaneous power input to the refrigerator, condenser axial fan and the integrated energy consumption of the system. To make the system leak-free, a soap bubble test was performed. In leak test, first the nitrogen gas was filled in the system and soap water is applied at different joints, the appearance of bubbles indicates the leaks in the system. Service ports were installed at the inlet of compressor for charging and recovering the refrigerant. The system was charged with R134a with the help of a charging system and evacuated with the help of a vacuum pump.

2.2 Test procedure

As shown in fig.1 the performance of hot gas system was measured by varying the hot gas bypass valve opening during the process of defrosting.

For the simple VCRS cycle the testing was done for 300 min, after that the testing was done for 11.25% hot gas bypass for an interval of 30 min. and then the testing was done for 5.6% hot gas bypass for an interval of ½ an hour for 300 min. The variation of pressure was from 0 to 30 bars. The hot gas bypass valve opening for both evaporators were fixed at 11.25% opening and then at 5.6% opening. For the hot gas bypass defrosting method as shown in fig.1 the evaporators were defrosted alternately in an interval of 30min. Therefore, the whole cycles including defrosting procedure took 300 min. The hot gas bypass valve openings for the evaporators were altered to 11.25%, 5.6% of the opening.

3. Results and Discussions

To investigate the performance variation of hot gas system under different defrosting conditions, the system was continuously operated without having the defrost mode. As the frost continuously grew the heat transfer rate decreased. When the capacity of evaporator decreased below certain limit defrosting was required to maintain an adequate capacity and to improve the system performance.

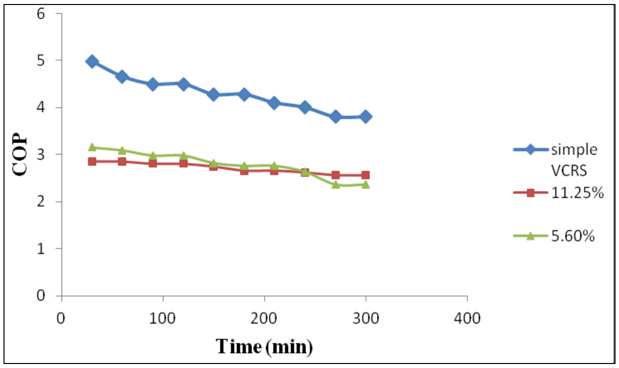

Fig 2: Variation of COP with time for different defrosting conditions.

Fig.2 shows the variations of COP with time for simple VCRS cycle, 11.25% hot gas bypass for defrosting, 5.6% hot gas bypass for defrosting. It was found that COP decreased by 36.5% for 11.25% hot gas bypass and for 5.6% hot gas bypass COP decreased by 35% than COP during simple VCRS cycle. It was clearly exhibited that COP was slightly decreased during 5.6% hot gas bypass as compared to 11.25% hot gas bypass.

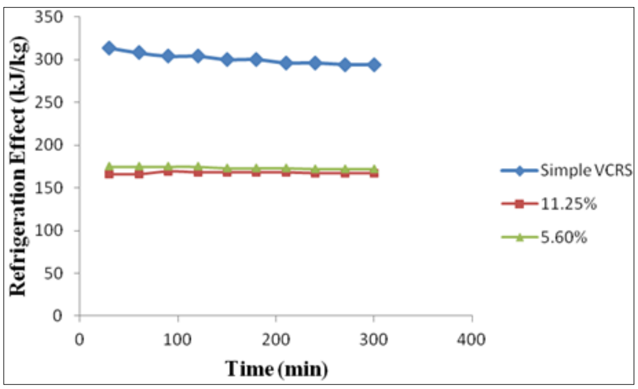

Fig 3: Variation of Refrigeration effect with time for different defrosting conditions

Fig.3 shows the variation of R.E for normal VCRS cycle (No defrosting condition), 11.25% hot gas bypass for defrosting, and 5.6% hot gas bypass for defrosting. The refrigeration effect decreases by 44.36% for 11.25% hot gas bypass and for 5.6% hot gas bypass refrigeration effect decreases by 42.34% than COP during normal VCRS cycle.

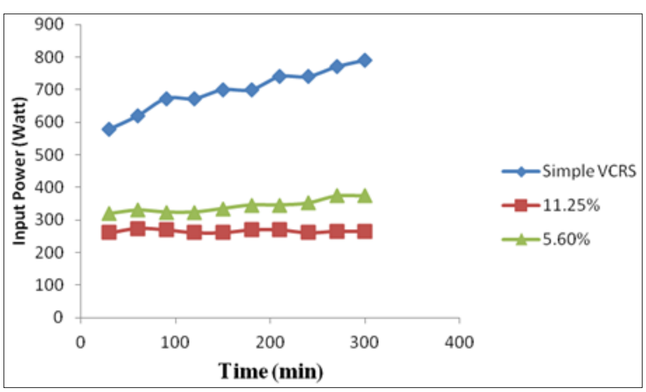

Fig 4: Variation of Power Input with time for different defrosting conditions.

Fig.4 shows the variation of Power Input for normal VCRS cycle (No defrosting condition), 11.25% hot gas bypass for defrosting, and 5.6% hot gas bypass for defrosting. It was found that as the discharge temperature increased the power input was also increased with time for simple VCRS cycle, 11.25% hot gas bypass, 5.6% hot gas bypass.

4. Conclusions

The performance of hot gas bypass cycle in domestic refrigerator with two evaporators were measured. In the hot gas bypass defrosting method, hot gas existing from compressor was used to melt the frost of the evaporator surface and both the evaporators were sequentially defrosted with constant time interval. The performance of each hot gas bypass defrosting mode was compared in terms of COP, refrigeration effect and compressor power input. The results obtained from the experimental analysis can be summarized as under.

1. The COP of the system decreases by 36.5% for 11.25% hot gas bypass and for 5.6% hot gas bypass COP, decreases by 35% than COP during normal VCRS cycle.
2. The refrigeration effect decreases by 44.36% for 11.25% hot gas bypass and for 5.6% hot gas bypass refrigeration effect decreases by 42.34% than COP during normal VCRS cycle.
3. The input power increases for simple VCRS cycle, 11.25% hot gas bypass system and 5.6% hot gas bypass system for defrosting with time as compressor discharge temperature increases with time.
4. As compared to 11.25% hot gas bypass, at 5.6% hot gas bypass the COP is slightly reduced than simple VCRS cycle.

5. Reference

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