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Performance Enhancement of Domestic Refrigerator by Using Thermoelectric Cooler and Advance Condenser

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Abstract**-- As refrigeration has become one of the basic needs people of this era. The permanent demand of refrigerator is continuously increases in India and also in the whole world. The energy consumption in the refrigeration is also increases. Approximately it contribute around 13% energy consume in this sector. In the kitchen appliances, only the refrigerator consumes power continuously throughout a day. In refrigerators compressor is major power consuming device. In this study use advanced condenser design to improve condensation of refrigerant and modification done in the evaporator section by adding thermoelectric cooler and it reduces the load on compressor and simultaneously achieve cooling effect and reduces the net power consumption during period of cycle and enhance the net COP of the refrigerator**

Keywords**-- COP, Power Consumption, Modification of condenser, Thermo electric Cooler & Domestic refrigerator.**

I. INTRODUCTION

The cabinet and the cooling system are the main components of a household refrigerator/freezer. Now a day, polyurethane foam is used as insulation material to minimize the thermal leakage. In Europe, cyclopentane is the favoured blowing agent4 which gives a typical thermal conductivity of with reference to 0.02 W/m K. The foam is either expanded directly into the insulation space between the plastic inner liner and the steel outer shell, that gives a rigid sandwich construction, or is used to build slabs that are mounted together to form a cabinet.

The cooling system typically operates by the vapour compression principle. In Figure 1.

The Coefficient of Performance (COP) is higher than other available techniques. It should be noted, however, that the absorption technique can also be directly operated by heat instead of electricity which in certain applications is a benefit for this technique.

Figure 1 Different cooling principles and their typical efficiencies (ASHRAE handbook, 2010 and Granryd et al., 1999). COP (Coefficient of Performance) is a quality number defined as the ratio between the useful cooling energy and the supplied work.

In vapour compression the fixed relation between saturated vapour pressure and temperature (the vapour pressure curve) is used to create two thermal conditions; one at a high temperature where heat is rejected and one at a low temperature where heat is absorbed. By combining a compressor with an expansion device to separate a high pressure side condenser (from which heat is rejected while refrigerant is condensing) and a low pressure side evaporator (into which heat is absorbed while refrigerant is evaporating) a heat pump has been formed. At the price of mechanical work, thermal energy is transferred from a lower to a higher temperature. The cooling system, used in household refrigeration, is essentially a heat pump that absorbs thermal energy from the cabinet's inside and rejects it to the outside to maintain a climate at reduced temperature.

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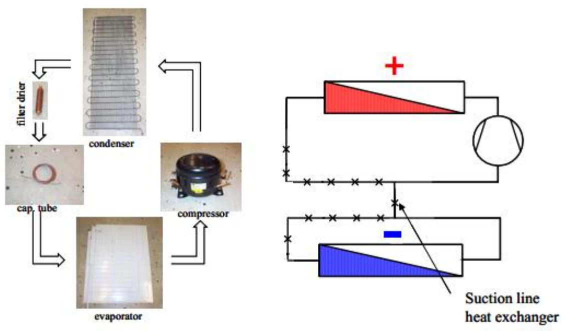

Figure 2 Main components (left) and a schematic view (right) of a typical household refrigerator cooling system. An arrows show the path of the working media (refrigerant) between the different components.

Figure 2 shows the basic components used in a vapour compression refrigerator in a "component- depicted" and schematic view.

- The hermetic compressor is normally reciprocating with an induction split-phase motor. It is capsulated in a robust steel shell to stand high pressure and to minimize noise. It is mounted on the bottom of the cabinet on rubber feet to further lower the noise level. The typical capacity ranges between 50 and 250 W.
- The steel pipe condenser is designed to stand high pressures. Into this the compressed refrigerant gas is pumped and brought to condensation. As doing so heat is rejected. The condenser seen in Figure 5 is a wire on tube condenser. Other than the common condenser types are plate on tube and various forced convection fin packages.
- After the condenser the filter drier follows. This device prolongs system's lifetime by filtering out particles and by absorbing water that may remain in the cooling system after manufacturing. The drier is filled with small Zeolite pellets, each with a porous, molecular sieve surface.
- Next, the capillary tube follows. This is essentially a narrow pipe section through which the throttling or expansion occurs. The thin copper tube (d = 0.33-1.5 mm, L = 2-5 m) restricts the refrigerant flow and maintains a pressure differential between the high and low pressure side of the system. As well being a simple and reliable low cost component the capillary tube allows the system pressure to equalize in every off-cycle, which reduces the starting torque requirement of the compressor.

  Normally a part of the capillary tube is heat exchanged with the suction line using a suction line heat exchanger (SLHX) in order to avoid external sweating (water condensation on the suction line surface close to the compressor) and to increase the overall efficiency.
- Finally, the evaporator follows. This is prepared of aluminium to prevent corrosion. In this, refrigerant is vaporized while heat is absorbed from the internal cabinet. An accumulator has been located at the evaporator outlet, either as an incorporated part of the evaporator or as an external device. To whole the cycle, the refrigerant vapour is being sucked back to the compressor where it is compressed. As it was mentioned in the previous point, this suction line runs in parallel with the capillary tube to form a suction line heat exchanger. Other types of evaporators are wire on tube (freezers) and various fin packages (forced convection).
- Not shown in the Figures is the refrigerant. The phase out of Ozone depleting refrigerants, the refrigerants used is R134a & Isobutane (R600a). A typical quantity of charge is 20-200 g.

One can summarise that the cooling systems in household refrigeration are characterized by low cooling capacities (50-250 W), low quantities of refrigerant charge (20-200 g), a refrigerant accumulator located at the evaporator outlet, a hermetically sealed cooling system, a capillary tube expansion device which is in heat exchange with the suction line, and a cooling capacity typically controlled by intermittent run (on-off cycling).

II. Configurations Of Household Refrigeration

Household refrigerators & freezers are thermally insulated compartments in which food can be stored at reduced temperatures hereby extending the shelf life. The refrigerator (or fridge) has a storing temperature above 0 °C (typically 0 to 10 °C) making it suitable for fresh food and vegetables.

The freezer has a temperature below 0 °C (typically -6 to -18 °C) making it suitable for frozen food and longer storing times. There also exist special-purpose compartments within the refrigeration unit to provide a more suitable environment for storage of specific food. For example, a warmer compartment for maintaining butter is often found in the refrigerator door. A high-humidity compartment for vegetables and fresh food are also common in a refrigerator.

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Refrigerators and freezers are available in several styles. All-freezers could be found as upright freezer or as chest freezer. Combination of refrigerators and freezers can be found as top-freezers, bottom- freezers, side-by-side or as a separate freezer compartment located within the larger refrigerator compartment. All-refrigerators.

The configurations vary considerably by region, but at a universal level, top freezers are the most common (nearly 40 %), bottom freezers are next at about 33 % and side-by-side combinations are about 13 %. The remaining types are mostly all-refrigerators or other configurations including separate freezer compartments (Harrington, 2009).

Good Features which are desirable in a good cabinet

1. Maximum food-storage volume for the floor area occupied by the cabinet.
2. The best in utility, the performance, the convenience, and reliability.
3. Minimum heat gain.
4. Minimum cost to the consumer.

Other ways to classify the household refrigeration units is how heat is transferred at the heat exchangers. The difference between the natural convection and forced convection is that no fan is used in the first case. Every so often natural convection heat exchangers are referred to as “static” or “passive”. Opposite, forced convection heat exchangers, are every so often referred to as “dynamic” or “active”.

The way to defrost is either automatic or manual. In the automatic defrosting one can separate cycle defrost (where defrosting occurs in the off-cycle) from the heater defrost (where a heater is activated during defrost). The cycle of defrost is only possible in an on-off cycling refrigerator where the cabinet air temperature is higher than 0 °C. In manual defrosting the defrosting must actively be started, for instance by switching on an electrical heater or by turning off the cooling system. The latter is typically used for natural convection freezers.

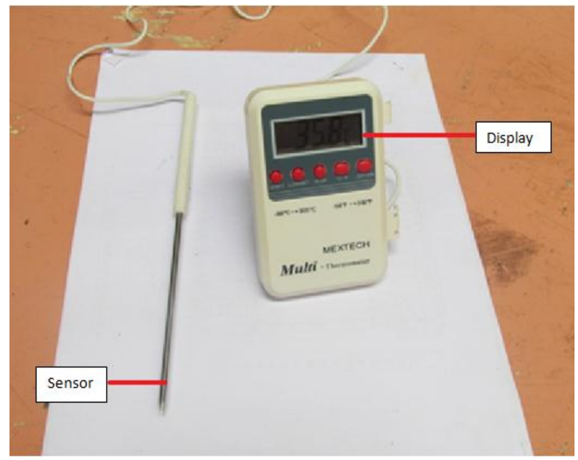
One can also separate the way to control the capacity. In on and off cycling the compressor is switched on and off with the relative on-cycle being longer with increasing capacities. This is the dominating technique to control capacity in household refrigeration. In variable speed capacity control the compressor is varying its capacity through speed-modulation. However, normally in combination with on-off cycling since it is difficult to achieve a sufficient reduction of the compressor speed to perfectly match the heat load.

III. Proposed Methodology

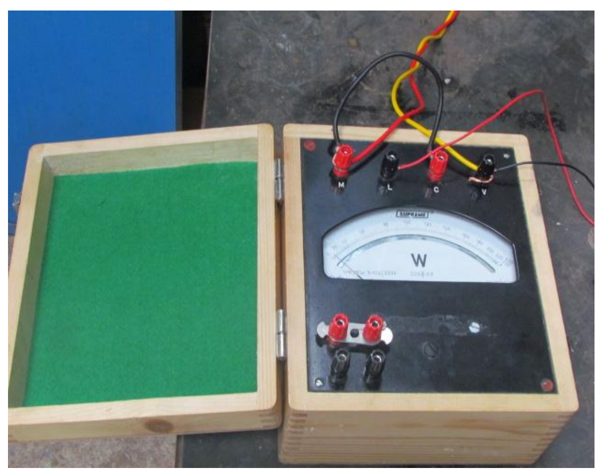
Form the above literature review discussion it found that so many research is continuous conducted to improve the performance of refrigerator in this work two option will be used for carried out this work by enhancing the surface area of condenser fins and by installing the Thermoelectric cooler in the evaporator sections.

Equipment Used:

1. Digital Thermometer by Mextech range -40^{0}C to 200^{0}C.



Wattmeter for energy measurement make by supreme range 0 to 230W.



Experimental Procedure: Firstly conduct experiment on the conventional refrigerator and measure all parameter such as like temperature of water and power required for compressor at interval of 5 min. time and tabulate the data.

Option I. In this the heat transfer rate enhance from the condenser by increasing the surface area of the condenser once heat is dissipated from the condenser it improves the performance of refrigerator. To increase the surface area in contact with ambient are install a heat sink on condenser as shown in fig.

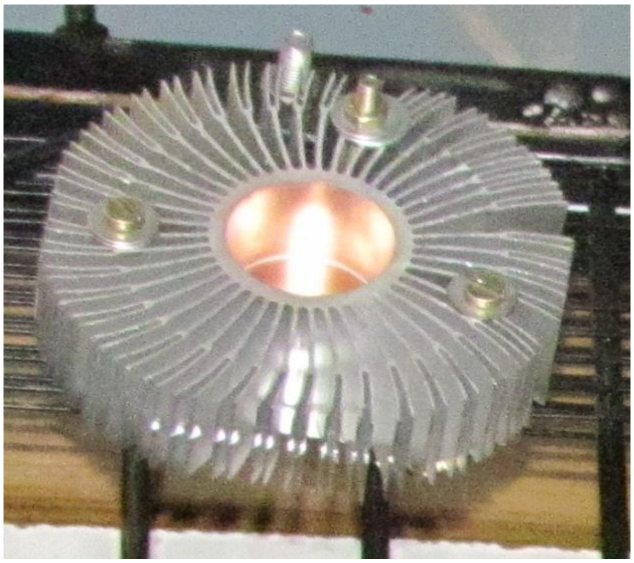


Fig 3: Heat sink install on condenser.

Option II: in this install a Thermoelectric cooler in to the refrigerator. The Thermoelectric cooler is also provide cooling effect simultaneously with Vapour compression cycle. The peltier element install by modification of evaporator section. As given in fig.

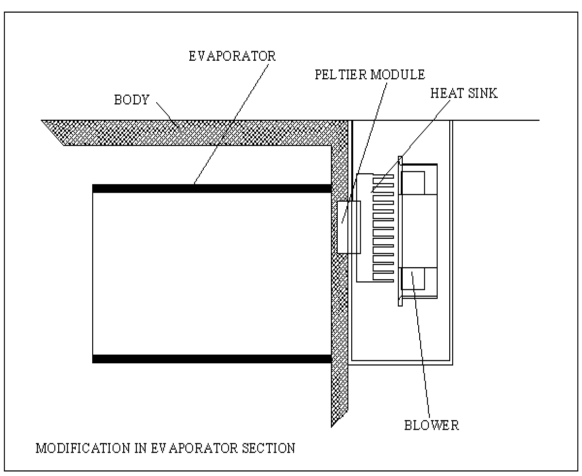


Fig 4: Experimental setup for novel refrigerator

Correlation used

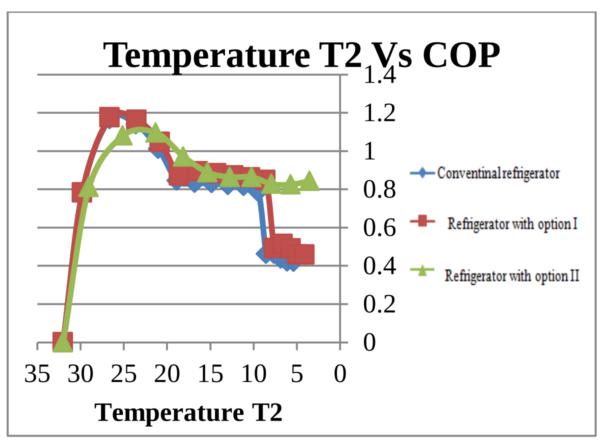
Coefficient of performance of refrigerator is define the ratio of heat extracted from the substance to the work consume by the compressor.

$$COP = \frac{Refrigeratinf\ Effect}{Work\ consume\ by\ the\ comressor}$$

$$COP = \frac{m*Cp*\Delta T}{W*Ti*1000}$$

IV. Experimental Results And Discussion

When the calculated values of COP at drop in final temperature in 5 minutes of interval using improvement by modification of refrigerator in two options are compared to that one of conventional refrigerator, the process showed almost similar behavior.



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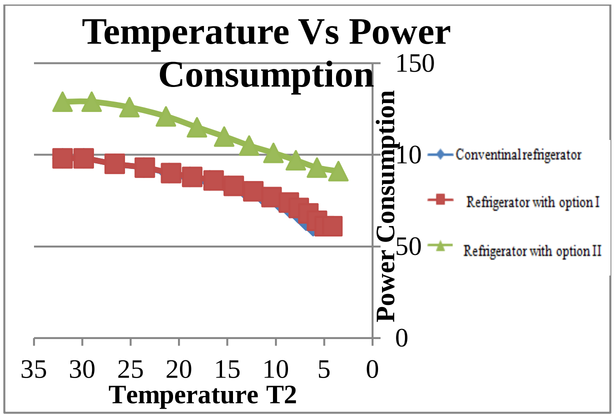
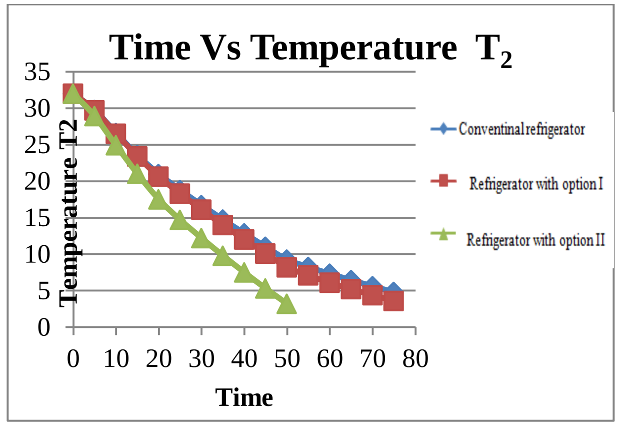
Initially it same as and the curves overlap to existing one and then after some drop in temperature its shows slightly improvement in COP for option B i.e. by modification of condensor design throughout total time span but it achieve slightly more temperature drop within same time of cycle, But in next option after by adding Thermoelctric cooler it shows form the curves the COP is initially reduces and then more shifted toward the upper area of graph than the remaining two option and the COP is consistently maintain constant at low temperature instead of two option COP is reduces at low temperature and achieve less temperature as compared to last two cycle.



When the measured values of power consumption in 5 minutes of interval using improvement by modification of refrigerator in two options are compared to that one of conventional refrigerator, the process showed almost similar behavior. There is same power consumption in option B i.e. by modification of condensor design throughout total time span but it achieve some more refrigerating effects within same time of cycle, But in next option after by adding Thermoelctric cooler it shows that the curves more shifted toward the upper area of graph than the remaining two and more power consume during the cycle but it reduce the time span of cycle to achieve desired temperature.



When the measured values of final temperatures after 5 minutes of interval using improvement by modification of refrigerator in two options are compared to that one of conventional refrigerator, the process showed almost similar behaviour. The slightly improvements in Temperature drop using option B i.e. by modification of condensor design throughout total time span, But in next option after by adding Thermoelctric coolerit shows that the curves more steeper than the remaining two overlap and reduced the final temperature of water and also it reduce the time span of cycle to achieve desired temperature.

V. Conclusion

Initially its COP variation with final temperature is same as and the curves overlap to existing one and then after some drop in temperature its shows slightly improvement in COP for option B i.e. by modification of condensor design throughout total time span but it achieve slightly more temperature drop within same time of cycle, But in next option after by adding Thermoelctric cooler it shows form the curves the COP is initially reduces and then more shifted toward the upper region of graph than the remaining two option and the COP is consistently maintain constant at low temperature instead of two option in which COP is reduces at low temperature and achieve less temperature as compared to last two cycle.

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REFERENCES

[1] Abdel-Wahed R. M., Hifni M. A., Sherif S. A., 1984, Heat and mass transfer from a laminar humid air stream to a plate at subfreezing temperature, International Journal of Refrigeration, Volume 7, Issue 1, Pages 49-55.

[2] Aihara T., Gakumasawa H., Maruyama S., Hongoh M., 1989, Frost formation and defrosting on tube- array evaporators in a fluidized bed and an impinging jet, Experimental Thermal and Fluid Science, Volume 2, Issue 1, Pages 65-71.

[3] Andersson B., 2005, Personal communication, Electrolux AB, AB-CD (R&D, domestic refrigeration) ASHRAE handbook, equipment volume, 1988, ISBN: 0-910110-52-2, pp. 19:21-19:30 ASHRAE handbook, Refrigeration (SI).

[4] Bansal P.K., Rupasinghe A.S., 1996, An empirical model for sizing capillary tubes, International Journal of Refrigeration 19, 497-505.

[5] Bansal P.K., Wang G., 2004, Numerical analysis of choked refrigerant flow in adiabatic capillary tubes, Applied Thermal Engineering 24, 851-863.

[6] Bansal P.K., Xu B., 2003, A parametric study of refrigerant flow in non-adiabatic capillary tubes, Applied Thermal Engineering 23, 397-408.

[7] Bansal P., Vineyard E., Abdelaziz O., 2011, Advances in household appliances- A review, Applied Thermal Engineering, Volume 31, Issues 17-18, Pages 3748-3760.

[8] Bergles A.E. and Rohsenow M., 1964, The determination of forced-convection surface-boiling heat transfer, Journal of Heat Transfer, vol. 86, pp. 365-372

[9] Bird R.B., Stewart W.E., Lightfoot E.N., 1960, Transport Phenomena (New York: John Wiley & Sons, Inc.)

[10] Bjork E., 2000, Effektivare förångare till kyl- och frysskåp, Final report Klimat 21 (in Swedish) Björk E., 2001, Slug formation in a domestic refrigerator with plate evaporator, Proc. International Conference on Multiphase Flow, New Orleans, USA.

[11] Nordenberg J., 2001, Redistribution of migrated refrigerant, Master of Science thesis, Department of energy technology, Royal Institute of Technology, Stockholm, Sweden.

[12] Smith M.K., Wattelet J.P., Newell T.A., 1993, A study of evaporation heat transfer coefficient correlations at low heat and mass fluxes for pure refrigerants and refrigerant mixtures, ASME HTD, Heat transfer with alternate refrigerants, vol. 243, pp. 19-26.

[13] Vjacheslav N., Rozhentsev A., Wang C., 2001, Rationally based model for evaluating the optimal refrigerant mass charge in refrigerating machines, Energy Conversion and Management 42, 2083- 2095.

[14] Setiawan A., T., Understanding cyclic losses in a plate evaporator of domestic refrigerators, Master of science thesis, Department of energy technology, Royal institute of technology, Stockholm, Sweden 2002.

[15] Yu W., France D. M., Wambsganss M. W., Hull J. R., 2002, Two-phase pressure drop, boiling heat transfer, and critical heat flux to water in a small-diameter horizontal tube, International Journal of Multiphase Flow, Vol. 28, pp. 927-941.

[16] Yoon W. J., Jung H. W., Chung H. J., Kim Y., 2011, Performance optimization of a two-circuit cycle with parallel evaporators for a domestic refrigerator–freezer, International Journal of Refrigeration, Volume 34, Issue 1,, Pages 216-224.

[17] Xu B., Bansal P.K., 2002, Non-adiabatic capillary tube flow: a homogeneous model and process description, Applied Thermal Engineering 22, 1801-1819.

[18] Zhang C., Ding G., 2004, Approximate analytic solutions of adiabatic capillary tube, International Journal of Refrigeration.