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EVALUTION OF VAPOUR COMPRESSION REFRIGERATION CYCLE AND APPLICATION OF HEAT PUMP

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ABSTRACT

The performance of heat transfer is one of the most important research areas in the field of thermal engineering. There are a large number of refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapour compression refrigeration system. Hot water production as well as space heating using heat pumps is a proven energy efficient heating method. By the application of air source heat pump offer the advantages of reducing energy consumption, improving heating performance and reducing the negative effects on the environment compared with other heating methods. The further improvement of performance of vapour compression refrigeration cycles acting as heat pumps has been targeted by several researchers so that heat pumps will be able to achieve wider penetration into the building heating market. The major objective of this paper is to provide a comprehensive understanding of both simple and complex refrigeration cycles and to review the current status achieved in the performance of improved vapour compression refrigeration cycles. Suggestions for further improvement of performance of heat pumps refrigeration cycles and their components are also made.

1. INTRODUCTION

The basic vapour compression or mechanical refrigeration cycle involves the circulation of refrigerant, which in the process of boiling (evaporating) absorbs large amounts of heat and gives up heat when condensing. This heat which must be gained or lost during the change of state is called latent heat of vaporisation. It is in general more than the specific heat that is the heat lost or gained during a one degree change in temperature.

An example of a basic vapour compression circuit for an air conditioning application is shown above.

1. The refrigeration cycle start with high pressure liquid (eg 9 Bar) in the liquid line passing through a restrictor device, which typically could be a capillary line or an expansion valve. Here it is allowed to expand and its flow is regulated.
2. Next it passes into the evaporator where with its pressure greatly reduced eg 1.5 Bar; it will be boiling at –5°C. But in order for it to boil it must absorb heat, which it gets from the metal of the coils which in turn absorbs the heat from the room space which, in this example might be around 5°C.
3. Once the refrigerant has been vaporised it moves from the evaporator into the suction line and on to the compressor. The compressor compresses the vapour into a smaller volume and in doing so raises its pressure (eg 9 Bar) and its condensing temperature (40°C).
4. The high pressure refrigerant vapour now passes into the condenser (also a matrix of finned pipes), where it is condensed back into a liquid state, by use of a fan drawing ambient air over it.
5. The high pressure refrigerant now moves to the bottom of the condenser coil and sometimes into a vessel called a liquid receiver, where the cycle begins again! The zone temperature can be controlled by simply cycling the compressor on and off according to the desired set point of a thermostat or controller, where it is monitored by a bulb or sensor usually found in the return air to the evaporator or a suitable place in the area.

1.1 HEAT PUMP

Heat pump is the devise which is used to heat the room winter seasons. All the components of heat pump are exactly same as the air conditioner and refrigerator, the only difference is that they work in reverse direction.
We know that the air-conditioning system is used for cooling the room in summers when atmospheric temperatures are very high, but do you know that the air-conditioner can also be used to heat the room during winter conditions? Actually the air-conditioner which is used for heating the room is called as heat pump. The components of the heat pump are exactly same as the air conditioner; the only difference is that the heat pump works in direction opposite to that of the air conditioners. The heat pump is reverse air conditioner or refrigerator.

1.2 Components of the Heat Pump

There are four important components of the heat pump:

1. Compressor

2. Condenser

3. Expansion valve

4. Evaporator

1.3Types of Heat Pump

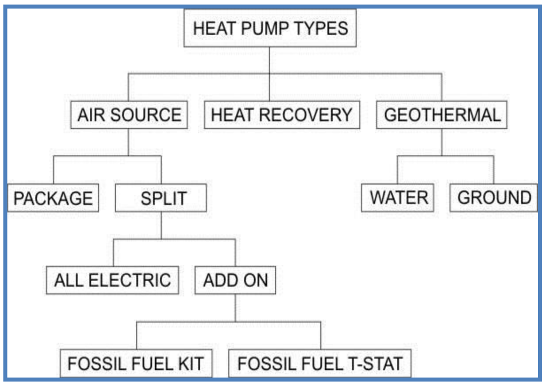

FIG-1 TYPES OF HEAT PUMP

1.4 Difference between Heat Pumps and Refrigerators

All the components of the heat pumps are same as the refrigerator and even they perform the similar functions; the only difference is that in the heat pumps the components work in a reverse manner. The heat pump is the reverse refrigerator.
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2. LITERATURE REVIEW

Keshwani and Rastogi [1] determined the optimum inter stage pressure in a two stage VCR system for refrigerant CFC12. They concentrated their research on minimization of overall compressor work.
Arora and Dhar [2] used the discrete maximum principle, discusses by Katz (1962), to solve the problem of optimum inter stage pressure allocation in multistage compression systems for R-12, with and without intercooling between the stages. They concluded that the optimum inter stage pressure approximately equals the geometric means of the condensation and evaporation pressure but when the flash inter cooler was incorporated, they found a considerable difference between the geometric means and the optimal pressure values.
Prasad [3] determined the optimum interstate pressure in a two stage vapour compression refrigeration system for the refrigerant R-12 with a view to maximize the COP. They concluded that the inter-stage temperature of a two-stage refrigeration cycle is given by the geometric mean of the condensation and evaporation temperatures.

Kumar et al [4] explained a method of carrying out exergy analysis on a vapour compression refrigeration system using R-11 and R-12 as refrigerants. They presented the exergy-enthalpy diagrams to facilitate the analysis. They explained the procedure to calculate various losses in different components of the system.

3. RESEARCH AND METHODOLOGY

Vapour compression heat pumps are refrigeration systems whose operational cycle is based on the reversed Rankine cycle, requiring work input to accomplish their objective of transferring heat from a lower temperature source to a higher temperature sink as shown in Fig. 1.

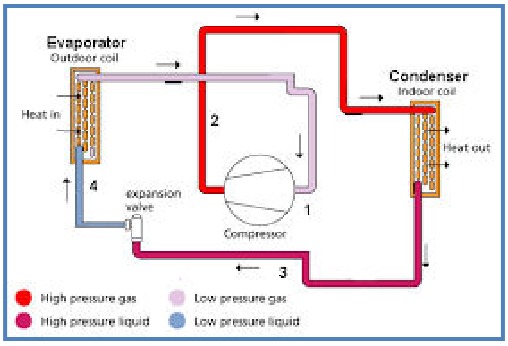

Table -1Various refrigerants and their properties

PROPERTIES	REFRIGERENTS				
	R12	R22	R134a	R404A	R717
Mol.Mass (kg/Mol)	120.9	86.42	102.03	97.60	17.0
Freezing point °C	-157.2	-160	-103.4	-	-77.7
Normal boiling point at 1 atm °C	-29.7	-40.76	-26.0	46.6	-33.3
Critical Temperature (°C)	112	96	101.1	72.1	132.5
Critical Pressure (kPa, abs)	4136	4974	4059	3735	11330

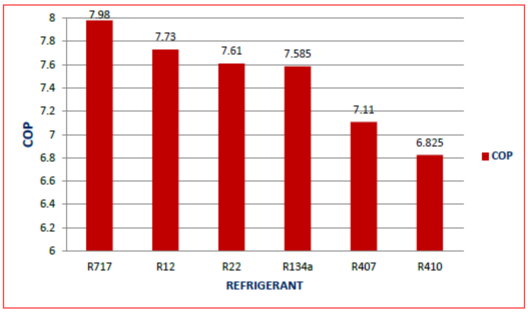

Fig 2: COP vs. refrigerants

4.RESULT AND ANALYSIS

Coefficient of Performance (COP)

The COP is a measure of the amount of power input to a system compared to the amount of power output by that system

$$COP = \frac{POWER\ OUTPUT}{POWER\ INPUT}$$

$$COPmax = \frac{T_C}{T_H - T_C}$$

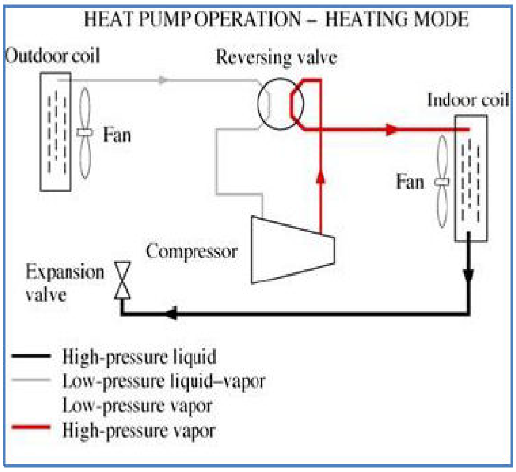

Fig- 3 layout of heat pump cycle

4.1 Sizing Considerations of Air Source Heat Pump

As a rule, an air-source heat pump should be sized to provide no more than 125 percent of the cooling load. A heat pump selected in this manner would meet about 80 to 90 percent of the annual heating load, depending on climate zone, and would have a balance point between 0°C and –5°C. This generally results in the best combination of cost and seasonal performance.

4.2Installation Consideration of Air Source Heat Pump

The following are general guidelines that should be taken into consideration when installing an air-source heat pump:

1. In houses with a natural gas, oil or wood furnace, the heat pump coil should be installed on the warm (downstream) side of the furnace.

2. If a heat pump is added to an electric furnace, the heat pump coil can usually be placed on the cold (upstream) side of the furnace for greatest efficiency.

3. The outdoor unit should be protected from high winds, which may reduce efficiency by causing defrost problems. At the same time, it should be placed in the open so that outdoor air is not recirculated through the coil.

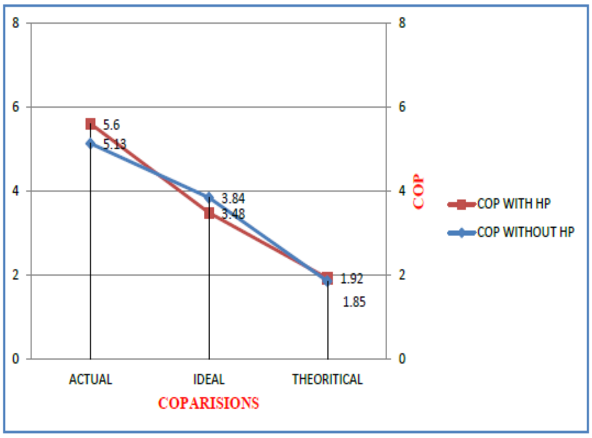

Fig- 4 cop with vs. cop without heat pump

5. CONCLUSION

Typical COP values for vapour compression refrigeration system and heat pump systems are in the range 3 to 5, or about a tenth of the theoretical maximum. However, this helps to explain where the power is used in such a system. Consider the air source heat pump application, The heat pump takes power from the environment and uses electrical power to move that power to the inside space. More power is put into the house than used in electricity. The COP of this system is 5.6 (power into the house ÷ power consumed). Observe that the electrical power consumed goes into the building. In practice some is expended as heat outside the building, so the actual COP will be slightly less than 4.

As vapour compression refrigeration system operates in the same way, their cop is 5.13 on theoretically and actual is slightly greater than from without using air source heat pump which is 3.84 instead of 3.48 as the uses of air source heat pump but actually increases the actual cop with the uses of heat pump 1.92 instead of 1.85.

Heat pump and refrigeration system/air conditioning system works on the reverse manner if we use heat pump utilizing more heat which is waste.

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