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Heat Pump System Strategy for Energy Saving in Domestic Buildings

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Abstract

The heat pump system is a technology that makes an important contribution to mankind in many applications including the tourist sector, health sector, domestic sector, industrial sector, etc. Without heat pump systems our mankind's existence would be difficult despite 19% of the total electrical power is consumed to operate these heat pumps.

The use of these systems driving power in an inefficient way is excessive of important resources and increase the universal heating. Almost universal heating results from heat pump systems introduced from producing power to derive these systems, but enough part produced from the rejection of some types of refrigerants. The present study illustrates the methods that the heat pump system efficiency can be increased hence decreasing the universal effect on the environment. A case study representing heat pump strategy for energy saving is given.

Keywords: Heat pump, Refrigerant, Efficiency, Strategy, Environment, Saving.

1. Introduction

Heat pump is the discipline of production heat-flow "uphill" or downhill from small to large surrounding temperatures or vice versa Refs. [1,2]. A heat pump system removes heat quantity from the enclosure being refrigerated e.g., that is called a cold tank, and gives out this quantity to the surrounding at a larger temperature e.g., that is called the hot tank as shown in Figure 1. This is similar to raising the water from a lower reservoir to a higher reservoir, Refs. [3,4]. The power used in a heat pump is approximately proportional to the amount of heat released (quantity of water pumped) and to the temperature raise by which the heat is left (elevated water is pumped), Ref. [5]. Heat pumps usually maybe energy convergent systems which often are used in different situations Refs. [6,7]. These systems are classified into four categories. They are known as first 1-large sized buildings heat pumps with a double bundle condenser 2- industrial heat pumps, 3- packing heat pumps with a reversible cycle; and 4-decentralized heat pumps for air conditioning moderate. The Main functions these systems are used to perform required cooling or needing heating extracting which is considered as an easy application. The term COP (Coefficient of Performance) is usually used instead of efficiency for these situations. This term is known as the ratio of heat (added] to heat used. These systems are referred to as refrigeration systems. For any of these systems used is usually a basic function is reducing the used heat absorbed. This is to preserve the variation between the temperature Te (temperature of condenser) and temperature to (temperature of the evaporator) as low as can be. Reducing heat removed is carried out by using insulation room minimizing the temperature of different parts of the system and also reducing ambient air temperature in used filter e.g., (door leakage, windows ..etc.). and minimizing energy waste in different application of cooling and air conditioning e.g., blowers and lifts …etc., Ref. [8]. Minimizing the difference in temperatures (Te-To) is carried out using lower pressure drop of the refrigerant in intake and outlet pipelines Ref. [9&10].

2. Description of a Reversible Heat Pump System

The standard system of heat pump contains 1-the compressor 2-the condenser 3-the Valve for expansion 4- evaporating device 5- interconnecting piping system. As shown in Fig. [11]. The compressor contains a refrigerant in a closed circuit comprising. The condenser is used to compressed high pressure refrigerant vapour by heat transfer to surrounding Ref. [11]. The expansion valve is used to lower the high-pressure refrigerant to liquid pressure. The liquid refrigerant at low pressure will evaporate by absorbing heat from the surrounding to be cooled down. Then is compressed to high pressure in the compressor once again. The sum of heat given out in the condensers and heat absorbed from the cooling enclosure and the required power for the compressor, Ref. [12].

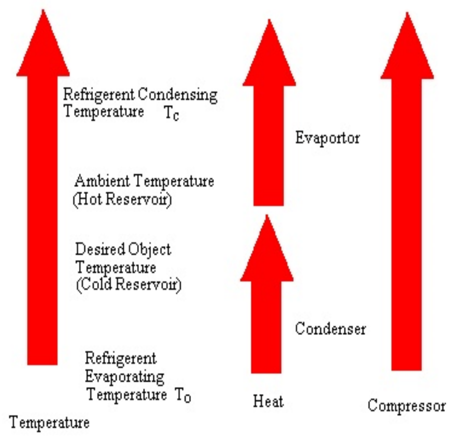

Fig. 1 Schematic Diagram of Temperatures and Heat Flows for a Heat Pump System.

The amount of system's losses have an important rule to determine the reliability of refrigerant system therefore the important factor is preventing the refrigerant system to suffer from any leakage, and it should be very tight. There are more than two Billion domestic refrigeration each filled with a certain low amount of refrigerant. There may run for about 15 years or less before they need an additional quantity of refrigerant. However, these have a major effect on the universal worming although all maybe because of carbon dioxide made when generating electricity to these devices.

3. Effect of System Parts on Heat pump Efficiency

Small numbers of refrigerants have suitable properties to be used and very few have been tested for some time to be considered as appropriate refrigerants. As illustrated in Figure 2 selected materials have been considered as suitable refrigerants. They have considered for many years, Refs. [15&16]. Of course, the perfect refrigerant is not known yet, however, the appreciation among them are first the cost; simply of production, their poisonousness, their flammability, ecological effect, and corrosiveness. Also, their thermal properties as well as their COP factor. A significant property is the temperature and pressure correlation.

Usually, for COP factor, the important point for the refrigerants is their critical point e.g., their temperature higher or behind their ability for condensing in relation to the temperature the heat taken into or given out of the system. Also, significant characteristics are the carrying and moving heats are vital for COP power factor since they decrease operating cost and permit lower temperature variation for being considered between the evaporator and the condenser, therefore, lower overall temperature raises. Usually, refrigerants of small viscosity and small molecular weight are known to have good characteristics, Ref. [14].

Two important factors affect the compressor thermal efficiency; the first is the raise of intake temperature and the second is the existence of any droplets of substance liquid in the intake pipe. These two factors will cause loss of compressor efficiency Preservation lubricant oil quality and care of the compressor operating conditions are necessary to maintain compressor efficiency. Usually, part load operation conditions for screw and the centrifugal compressors are often low efficiency and also low performance. Better characteristics are obtained with full load operation which means always trying to avoid part-load running conditions. Also, suitable control and variable speed drive would reduce these power penalties losses, but it may increase the total cost but decrease running cost Ref. [15].

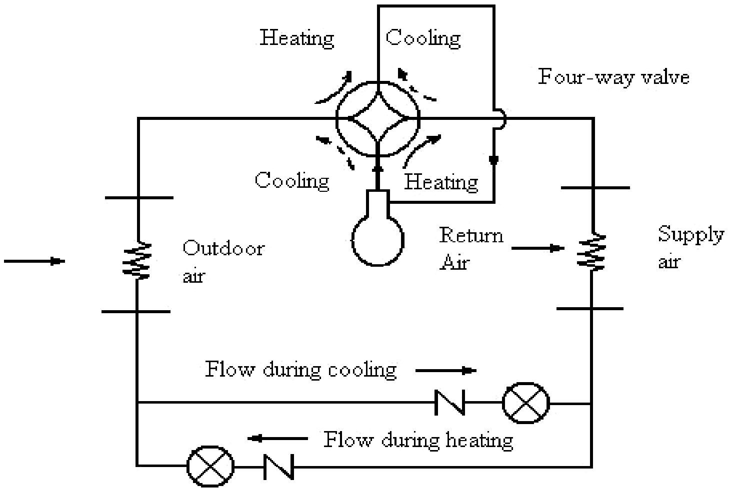

Fig 2 Schematic of a Simple Vapour Compression Heat Pump System

4. The condenser

The condenser optimum performance occurs when the temperature of refrigerant rejected heat is preserved as small as can be and heat moved out is as large as possible. Also, the chilling temperature is low as possible. Often, condensers of evaporation are usually having higher efficiency for being giving heat out ambient wet-bulb temperature. So, for example, if air humidity at 25°C is having relative humidity 60% and temperature of wet bulb of 16°C. To prevent pollution cautious preservation is needed. Circulated water-cooled in condenser with cooling water in cooling tower method together, however, and an extra temperatures variation to move the heat from the media into the coolant, therefore, heat is taken away usually larger.

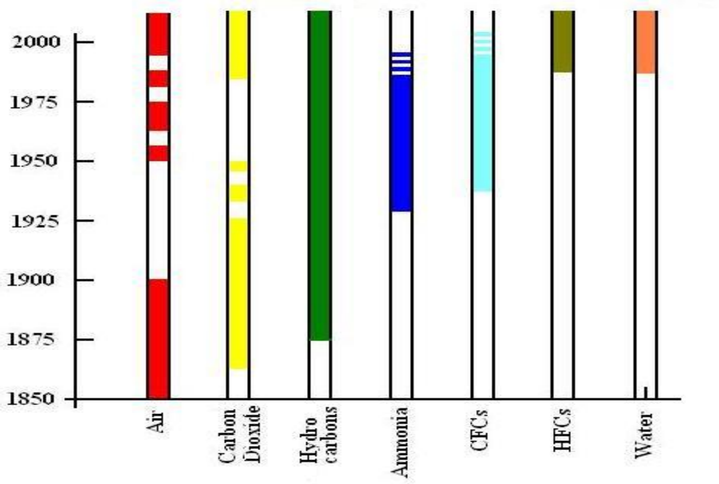

Fig 3 Typical Refrigerants and Their Historical Use

To minimize the water used a cooling tower usually is used. Of course, air cooled condenser has in general less efficiency methods since heat rejection to ambient dry bulb temperature, that is usually an important increase over wet bulb temperature. But usually, small systems are considered since they are less cost, simple and need less maintenance. different types of condensers need to be clean and free from polluting. Usually, the condenser needs a huge amount of water since heat rejects to ambient and to prevent air from recirculating back through the inlet. These types of systems should operate with inlet pressure less than ambient pressure will use the device to prevent mon-condesable from the refrigerant (special at small temperature ammonia) or in some cases for air conditioning with HCFC-123.

5. The expansion devices

Normally, the expansion valve needs a certain pressure range to permit appropriate procedure. Thus, this pressure range is usually kept at a theatrically large level, since at small atmospheric temperature. Normal, the cause to choose usually the thermostatic expansion device for its very small cost. Another selection is to consider an electrical control expansion device.

6. The evaporators

A very important design requirement is for both the evaporator and the condenser to run at lower cost i.e., small temperature variation in which the refrigerant heat removal temperature should be large for a required material temperature. Also, for the designer as raising the heat removing decreases the compressor size needed.

This is like evaporator size, refrigerant supply, path and speed, the use of extended surfaces, air velocity, these all are important issues for calculating either the COP or the system efficiency. The Air used for cooling which runs at a temperature under freezing should be melted frequently to return to normal performance. Using electricity for melting is easy, however, is lower efficiency therefore appropriate for a small system. This well cost twice as much, to set the electrical heat into the cooler absorbed it out once more. Melting of water and hot gases and melting by the path of hot fluid from the cooler, are all theoretically more efficient, however, it is vital to improve both occurrence and period of melting. This is to prevent unrequired melting.

7. The interconnecting piping system

The designer should be carefully selecting the piping system for interconnecting to ensure the pipes diameters are suitable and all pipe fittings are correct suitable to cause the required pressure losses.

8. The Selecting the *c*ontrol components

The most important aim for heat pump designers is to select system components matching with each other to obtain a higher efficient system. However, the major task is to select perfect control devices for obtaining efficiently power consumption. The conditions for selecting efficient power convergent heat pump control system to optimize efficiency:

- slide regulator without loading of large-sized screw compressors.
- hot gas bypass of compressors.
- throttling controllers between evaporators and compressors.
- evaporator regulator by thrusting refrigerant supply,
- also, regular melts,
- condenser head pressure regulators excluding when required.

9. Refrigerant Usage and Ozone Depletion Global Warming Potential

The use of CFCs and HCFCs is a worldwide worry. Approximately two-third of all total halogenated CFCs have used outside in most of the world countries in the mid-1980s. Since 1985, the whole procedure of halocarbons in most of universal has over hundreds of millions of pounds.

These halocarbons have been used in foam insulation, motorized air conditioners, air conditioning, and refrigeration in new systems and additional goods. Foam insulation driven by CFCs was the biggest user.

Table I Various Refrigerant Index of Ozone Depletion Potential (ODP)

Refrigerant	*Chemical Formula*	*ODP value*
CFC-11	CCl_3F	1.0
CFC-12	CCl_2F_2	1.0
CFC-13B1	$CBr F_3$	10
CFC-113	CCl_2FCClF_2	0.8
CFC-114	$CClF_2CClF_3$	1.0
CFC-115	$CClF_2CF_3$	0.6
CFC/HFC-500	CFC-12(738%)/HFC-152a	0.74
CFC/HCFC-502	HCFC-22(48.8%)/CFC-115(51.2%)	0.33
HCFC-22	$CHClF_2$	0.05
HCFC-123	$CHCl_2CF_2$	0.02
HCFC-124	$CHClFCF_3$	0.02
HCFC-142b	CH_3CClF_3	0.06
HFC-125	CHF_2CF_3	0
HFC-134a	CF_3CH_2F	0
HFC-152a	CF_3CHF_2	0

Automotive air conditioners prepared up 22 percent of all usage, and CFCs purchased by air conditioning new systems prepared up to nearly 12 percent of the total usage. Of the CFCs and HCFCs purchased by air conditioning new systems, HCFCs made up 77 percent, but CFC-11 and CFC-12 each created about 15 percent.

To compare the relative ozone depletion caused by various refrigerants, an index called ozone depletion potential (ODP) has been developed. The ODP of a compound is defined as the ratio of the total amount of ozone destroyed by that compound to the amount of the ozone destroyed by the same mass of CFC-11. The ODP of CFC-11 is assigned a value for various refrigerants:

Like the ODP, global warming potential (GWP) is used to compare the effects of CFCs, HCFCs, and HFCs on the global warming index using CO_2 as a reference gas. For example, 0.5 kg. of HCFC-22 has the same effect on global warming as 2050 kg. of CO_2 in the first 30 years after it is released into the atmosphere. Its impact drops to 750 kg. at 100 years. Both ODP and GWP should be considered carefully before selecting a refrigerant.

10. Factor Affecting Energy Saving and Environmental Problems

No one would doubt the desirability of air-conditioning, but what is generally questioned is whether the cost is justified. In tourist sector application, the return on the cost of installing and running an air conditioning system can be assessed quantitatively and the economic justification is clearly demonstrated. Improving tourist quality needs more economical prices for tourist groups in order to spend much more time and to be more attractive when they compare between different tourist places.

In this work two items are considered, firstly is aiming to reduce the universal impact on the environment, secondly, to contribute to energy savings for minimizing the universal impact on the environment, selection of proper refrigerant has minimum effect on ozone layer must be applied, as well as, minimizing heat delivered from air-conditioning system to surrounding atmosphere, in order to reduce universal warming. Secondly, the objective of this paper is to discuss parameters affecting energy saving for such systems. The contribution of evaporative and condensing temperatures for energy saving is considered through the present work effect of surrounding temperature on compressor energy consumption has been discussed. The use of delivered heat from the system in some useful applications is mentioned in the case of cooling systems. In the case of a heating system, the contribution of different sources of dissipation thermal energy in adding more heat to the evaporator is studied. Comparing the heating effect of heat pump system with direct electrical heating on energy saving is also considered.

11. Case study

Considering a heat pump system operating under standard vapour compression cycle as that shown in Figure 3. The working fluid used in such a system in refrigerant 22, which has 0.05 as ODP value (see Table I) and is widely used in commercial applications range of evaporating temperature considered are (-10 to +10) and range of condensing temperature are (25-55). Calculation had been made for a heat pump system which can be used as refrigerating or heating unit and the heat capacity, the heat delivered in condenser and compressor power are represented in kilowatts. The following equations Ref. [12]; are used for estimating q_e, $q_{c,}$ and P compressor power:

$$q_e = 137.402 + 4.60437\, t_e + 0.061652\, t_e^2 - 1.118157\, t_c - 0.001525\, t_c^2 - 0.0109119\, t_e t_c - 0.00040148\, t_e^2 t_c - 0.00026683\, t_e t_c^2 + 0.000003873\, t_e^2 t_c^2$$

$$P_c = 1.00618 - 0.893222\, t_e - 0.01426\, t_e^2 + 0870024\, t_c - 0.0063397\, t_c^2 + 0.033889\, t_e t_c - 0.00023875\, t_e^2 t_c - 0.00014746\, t_e t_c^2 + 0.0000067962\, t_e^2 t_c^2$$

and

$$q_c = q_e + P$$

where, q_e refrigerating capacity kW, q_c condenser capacity, kW, P power required by the compressor, kW, t_e °c, evaporating temperature, t_c °c condensing temperature, °c. The results are shown in Figure 4. It is clear that the consumed power for compressor driving is reduced when the difference between t_e and t_c becomes smaller. That means t_e becomes higher and t_c becomes lower. This can be achieved when reducing the surrounding temperature around the condensing unit by shading devices outside the building where the condensing unit was installed, that in case of cooling in summer. In winter for the heating cases, elevating t_e can be occurred by using a different dissipated of heat to add to the evaporator coils.

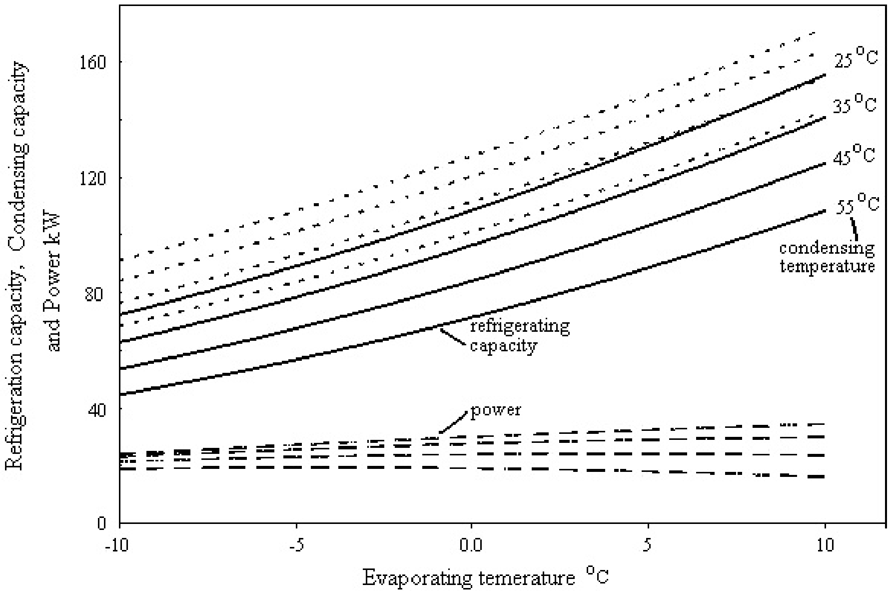

Fig. 4 A relationship of refrigeration capacity, condensing capacity, and power as a function of evaporative, condensing temperatures

The energy saved for each case can be determined for each degree of temperature reduced in the condenser and of each temperature elevating in the evaporator. The heat dissipated in the condenser and recovered in some useful applications depends on its efficiency on the degree of effective heat exchange devices as the effectiveness of heat exchanger used heat dissipated from other application to recover it for adding heat in the evaporator in the winter heat pump.

12. The conclusion

Increasing the system efficiency is easy and could be increased for advantaged environments. Normally, designers are compromising between basic costs and running costs. Usually, costs drive the productive side to look for cheap solutions, when they are not concerned about the running costs of the systems. Important rules should be established to keep a certain efficiency consideration for all types of these systems. The administration's authorization should establish laws to guarantee that the sellers are fined for equipment that do not have certain efficiency and that the customers have the advantage by more than that the due to the reduction in operating costs. Suppose this is carried out, it is expected that power used for these systems should be decrease at least by 25 % in a quick period. A governmental aim is to obtain 30 to 35 % decrease up to a year's 2030-2035 to be reach.

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