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Experimental Investigation of Energy Saving in Referigeration System

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Abstract

This Research deals with experimental investigation of energy saving in refrigeration system. We have all experienced a sensation of heat when passing behind a functioning refrigerator or air conditioner. The cause of this phenomenon is due to thr air condenser, a heat exchanger made up of tubes with air fins attached to the back of the device. This is where the cooling fluid condenses by releasing its heat into the ambient air. To utilize this heat, a water fine water droplet is project to absorb this ambient hot air to the atmosphere. so by decreasing condenser temperature we obtain the system's energy consumption, humidification processes were initiated. The principle consists of saturating the ambient air in contact with the exchanger by projecting fine water droplets. Humidification of the air intensifies the heat exchange on the air side and reduces the cooling fluid's condensation temperature. This lowers the compression rate in the cooling cycle and improves the compressor's consumption of electrical power. The study is mainly focused on the Condenser to reduce the condenser work to save the electrical power.

Keywords: condenser , projecting fine water droplet , thermometer, Vapor Compression refrigeration system

Introduction

Electricity concern has become a significant motivating factor in recent times in design and development of any domestic or industrial products. India is second highest population country in the world due to which more and more energy is required to fulfill the human need and comfort life become easy with minimum energy to save the environment. Consumers have become increasingly aware of the electricity consumption and need to try and preserve the world in which all live. It is challenge for developing energy efficient product for day to day use in any applications so that ecological foot print of the product will be very less. Today's modern trends and facility give the human life in the comfort zone but this is not possible without energy The Refrigeration and air conditioning system are not to be exceptions to these trends. As per estimation, more than one third of world's produced power goes into refrigeration sector. At present in India alone 7-8 million of small capacity air conditioning and refrigeration system are working and consuming whooping 14 to 15 thousand MWh electrical energy per day [1]. To improve the performance of air-cooled condensers, multiple techniques can be achieved such as enhancements on inner pipe surface, changing the tube geometry from a round to flat shape and external fins. [3]. The development in industrial refrigeration has always been with the important objective of reducing electrical power consumption. The developments which have direct relation to energy consumption, are development in designing the components and their operations, improvement in the design and operation of the cold storage, improvements in storing operations, etc.[4] Sheng-shan Bi et al. [5] experimentally investigated the performance of a domestic refrigerator with SUNISO 3GS mineral oil and nano particles in the working fluid. The results indicated that the energy consumption of the HFC134a refrigerant using SUNISO 3GS mineral oil and 0.06% mass fraction of nano particle mixture as lubricant reduced the energy consumption by 21.2% when compared to that of HFC134a and POE oil system. One of the most important energy consumption sectors in a hypermarket is the energy used related with the refrigeration activity. This cost represents a mean value about 30% of the final energy used in this activity [7]. So the scope of this article is to discuss

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the possibility of energy savings related to the refrigeration systems and equipment in supermarkets and hypermarkets. Nevertheless, many of the aspects discussed in this article, can be extended and applied to refrigeration systems of other refrigeration plants, industrial and commercial.[6] in the case of a water-cooled condenser. Tetrafluoroethane (HFC134a) refrigerant was now widely used in most of the domestic refrigerators and automobile air-conditioners and are using POE oil as the conventional lubricant.Heat can be recovered by using the water-cooled condenser and the system can work as a waste heat recovery unit. The recovered heat from the condenser can be used for bathing, cleaning, laundry, dish washing etc. The modified system can be used both as a refrigerator and also as a water heater. Therefore by retrofitting a water-cooled condenser it produce hot water and even reduce the utility bill of a small family. In this system the water-cooled condenser is designed as a tube in tube heat exchanger of overall length of 1m. It consists of an inlet for the cooling water and an exit for collecting the hot water. The hot water can be used instantly or it can be stored in a thermal storage tank for later use [8]. The survey of the literature regarding the waste heat recovery and using of various compressor oils in the household refrigerator and air-conditioners are listed.S.S. Hu, B.J. Huang et al [9] conducted an experimental investigation on a split air conditioner having water cooled condenser. They developed a simple water-cooled air conditioner utilizing a cooling tower with cellulose pad filling material to cool the water for condensing operation. The experimental investigation verified that the water-cooled condenser and cooling tower results in decreasing the power consumption of the compressor.H.I. Abu-Mulaweh [10] In this work the air-cooled conventional condenser is replaced by another heat exchanger to heat the water. The results show that water at a temperature of 60ºC was produced by the system. This paper also analysed the economic importance of the waste heat recovery system from the energy saving point of view.The working of vapor compression refrigeration system that when low temperature and pressure vapor enters the compressor where its pressure is raised. The temperature will also increase, because a proportion of the energy put into the compression process is transferred to the refrigerant. When this the superheated vapor passes from the compressor into the condenser. The initial part of the cooling process (2-3) superheats the gas before it is then turned back into liquid (3-3'). The cooling for this process is usually achieved by projecting fine water droplet water. A further reduction in temperature happens in the pipe work and liquid receiver (3' - 4), so that the

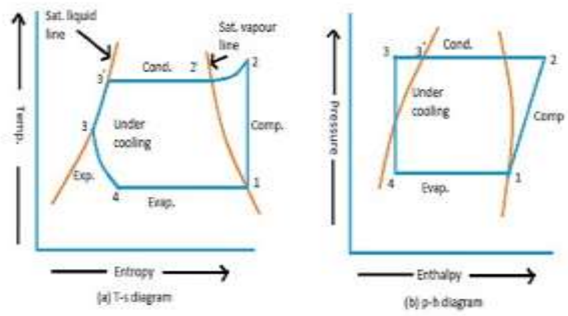

Figure 1 T-s & p-h diagram of VCRS with undercooling or subcooling

refrigerant liquid is sub-cooled as it enters the expansion device. The high-pressure sub-cooled liquid Passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator. Low-pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

Description of the Test Rig

The Refrigeration test rig works on simple vapor compression refrigeration cycle and uses R134a as a refrigerant. It is environment friendly. The system is fabricated such that we can observe and study vapor compression cycle, its component principle & working. The arrangement of parts such that, all the parts are visible and working can be easily understood.

Technical details:

- Cooling Capacity: 450 Watts at rated test conditions* (1/8 TR)
- 1/4 HP Hermetically sealed
- Make: Emerson Climate Technologies Ltd or Danfoss Ltd or Tecumseh Products India Compressor Ltd or any equivalent make
- Forced convection air cooled condenser
- Refrigeration System Condenser fan with axial flow type
- Molecular sieve type drier/ filter
- Expansion device: Direct expansion type
- Shell & Coil type provided
- Evaporator: Copper/M.S. shell suction line accumulator provided
- Accumulator is R-134 a

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- Refrigerant 2 nos. dial type pressure gauges one for suction and the other for pressure indication for discharge pressure
- Controls and indicators: Multi-channel LED digital temperature indicator
- Refrigerant flow indication glass tube rota-meter with 220-240 Volts, 50 Hz, 1 phase
- Supply is 1.0 kW
- Input power is 4.5 Amps
- Main switch and piano type switches for compressor and heater
- High quality operating switches and indicating lamps for compressors are present
- Energy-meters panel: 1.2 mm thick
- CRCA material construction
- Powder coating [19]

Experimental Set Up

The system was calibrated with a water-cooled condenser instead of the conventional air-cooled condenser by projecting a fine water droplet. Water-cooled condenser is a closed type in which a tube heat exchanger having an inlet for the cooling water

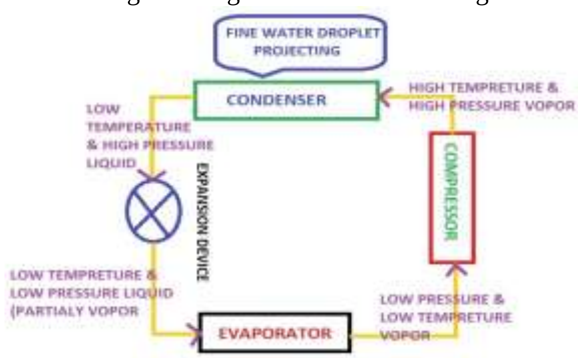

Figure 2 Vapor Compression Cycle

and an exit for collecting the hot water. The modified household refrigerator was properly instrumented with temperature indicators, pressure gauges and digital energy meter. The temperature at various points was noted using calibrated K-type thermocouples. Pressure gauges used in this experiment are of bourdon tube type gauges. Evaporator and condenser pressure are noted using calibrated pressure gauges. The power consumption of the domestic refrigerator was measured by using a digital energy meter. Figure 3. Shows the experimental test rig.

Figure 3 Experimental set up

The calibrated water-cooled condenser can also been seen. Refrigerant flows through tubes and external water droplet remain in the condenser. Refrigerant R-134a flows through copper tubes inside
diameters 6.5 mm throughout including condenser and evaporator both. Supply water can flow through the condenser and there is arrangement for control and measurement of water flow rate. The refrigerant , after condensation process, is cooled below the saturation temperature before expansion by throttling. so these undercooling or Subcooling of the refrigerant is generally done along the liquid line.
The ultimate effect of the undercooling is to increase the value of coefficient of performance under the same set of conditions. The process of undercooling is generally brought about by circulating more quantity of cooing water through the condenser .in actual practice, the refrigerant is superheated after compression and undercooled before throttling.
In this case, the refrigerating effect or heat absorbed or extracted,

$$R_E = h_1 - h_4 = h_1 - h_{f3} \qquad (1)$$

Work Done by the Compressor =

$$W = h_2 - h_1 \qquad (2)$$

$$\text{C.O.P.} = \frac{R_E}{W} = \frac{h1 - hf3}{h2 - h1} \qquad (3)$$

We know that power required to drive the compressor ,

$$P = m \frac{(h2 - h1)}{60} \text{kw} \qquad (4)$$

where $m = \frac{210\ Q}{h1 - hf3}$

Actual COP -: R_{act} = Actual refrigerating heat = heat produced heat

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$R_{act} = \frac{10}{N_h} \times \frac{3600}{T_h}\ KW =$

W = Actual energy supplied to compressor = $R_{act} = \frac{10}{N_c} \times \frac{3600}{T_c}\ KW$

therefore Actual COP $= \frac{R_{act}}{W}$

Where

Nc = Energy meter constant for compressor = 1600 Rev/KW Hr

N_H = Energy meter constant for heater 3200 Rev/KW Hr

Results and discussion

As per experimental investigation the result found that the cop and energy consumption is increasing with increasing load.

Table. 1: Comparision of COP

COP	RESULT OBTAINED	COMPARED WITH
Actual COP	**1.4**	**1.2**

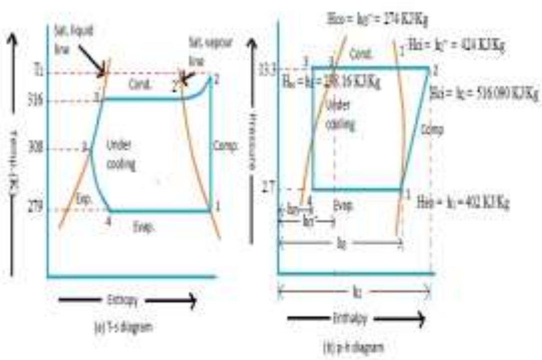

Figure 4 (ph) diagram:

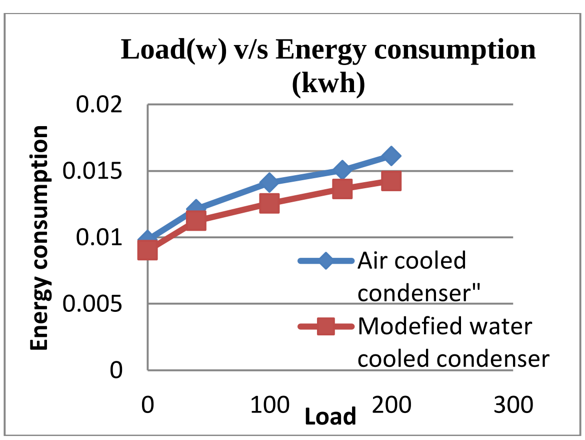

Chart 1 Variation of energy consumption with load

Chart 2 gives the comparison of the energy consumption by the compressor with simple air condenser and Modified water condenser . On all load conditions, the energy consumption done by the compressor was greater for the simple air condenser system than the Modified water condenser system. This was because the condenser-evaporator pressure difference was high for the system when operating with simple air condenser than the Modified water condenser system. As the work done by the compressor increases the power consumption also increases

Table- 2 Energy consumption against various load

S.no	Load Applied	Ideal Energy Consumption	Modified Energy Consumption	% Energy saving
1	0	0.01025	0.00935	10.35
2	40	0.01230	0.01140	8.46
3	100	0.01365	0.01255	9.65
4	160	0.01550	0.01400	8.92
5	200	0.01621	0.01496	10.56

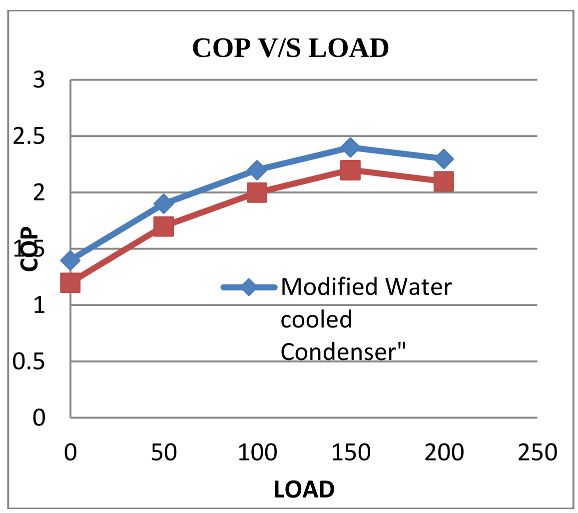

Chart 2 COP versus LOAD

Chart 3 shows the COP variation of simple air condenser and Modified water condenser. The COP was greater for the Modified water condenser system. This may be due to the inverse proportionality of COP to work done on all load conditions. These results confirmed that the performance of household refrigerator with water-cooled condenser and the Modified water condenser system was better than that of the simple air condenser system. The experimental result also shows that about 160 litres of hot water at a temperature of about 45ºC over a day from the outlet of water-cooled condenser and thus analyzed the economic importance of this waste heat recovery system from the energy saving point of view. Table 2 Provides the energy consumption of the system at steady state for a time period of seven minutes.

This research is being conducted to improve the energy efficiency of the condensers of cooling devices using humidification techniques. The objective is to develop an efficient and economical process that can be adapted to mid- and high-power refrigerating devices, as low as 10 kWh. 15% of the electrical energy produced in industrialized countries was consumed by cold production (12%) and air conditioning (3%)? Yet consuming kilowatts is increasingly expensive, reduces fossil fuel resources, and increases greenhouse gas emissions. In the majority of refrigeration installations, the operating condition of the air condenser, located at the back of the unit, in contact with ambient air, is a decisive element in the amount of power consumed by the refrigeration unit.

Conclusion

The major advantage of this modified refrigeration system to save the electrical energ which is very much costly It has smaller size for given capacity of refrigeration. The running cost of this plant is same as compare to ideal plant. It can be employed over a large range of temperatures .The coefficient of performance is quite high. The limitation of this system is that cooling water is required for projecting the water droplet on heat exchanger tube. the maintenance required for proper cooling of water and temperature drop is depend on the cooling water. For utilize this refrigerant R134a, all the tubing within the heat exchanger and between the components of the system would need to be significantly larger, to minimize the drops and maintain an acceptable operating efficiency. The major application of this system that it is used in small scale refrigeration plant, in water cooler and cold storage plant. This vapor compression refrigeration system is reduced the condenser temperature to some degree of temperature so that we get more cooling effect or refrigeration effect by which we save the electrical energy by 15 % . In future we used the waste water recovery system to utilize the waste water going to dump area.

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