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Enhanced Performance and Decreased Power Consumption in a Water Cooled Air Conditioning Unit

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Abstract: ***Electricity has become an indivisible part of our lives. It is a boon to us and so must be used judiciously. The reason lies in the fact that it is an outcome of natural resources which indeed are limited. Air conditioner is more likely to consume large amount of power than any other household device. Due to global warming there has been an alarming hike in the global temperature. Now the Air Conditioner units work on the phenomenon of temperature difference between the system and the surrounding i.e. the more the temperature difference the more work needs to be done by the compressor and as a result of this, the compressor in Air conditioners demands increased pressure ratio .The higher the pressure ratio the more will be the work input to the compressor and in turn more will be the power consumption. This paper implies the simple and efficient methodology to decrease the pressure ratio of the compressor in Air conditioner units. This is achieved by replacing the air cooled system by a water cooling system and predicts the performance of Air conditioner units and decrease in power consumption.***

Keywords: Air conditioner, water cooled system, work done, power consumption, coefficient of performance

1. Introduction

Refrigeration is the cooling effect of the process of extracting heat from a lower temperature heat source, a substance or cooling medium and transferring it to a higher temperature heat sink, probably atmospheric air, or water, to maintain the temperature of the heat source below that of the surroundings. [1]

As over one third of the global CO2 emissions are attributed to the combustion of fossil fuels to meet the energy demands of buildings, many energy conservation projects are targeted at reducing energy consumption in this area. Water-cooled air-conditioning systems (WACS) are in general more energy efficient than air-cooled air-conditioning systems (AACS), especially in subtropical climates where the outdoor air is hot and humid. This has led to a lot of recent investigations on widening the application of the more energy-efficient water-cooled air-conditioning systems (WACS). [2]

The most common refrigeration systems are vapor compression systems. The use of water mist in decreasing the air temperature entering the condenser will definitely increase the efficiency of heat exchange at the condenser and so increase efficiency of the condenser and the coefficient of performance (COP) of the air conditioning unit. [3,4]
Almost all air conditioning units used in residential buildings are air cooled whether it be a window-air conditioning unit or split-air conditioning unit. So power consumed by these air conditioners can be reduced to a great extent just by decreasing the temperature of air at the inlet of condenser and this can simply be done by replacing the air cooled system by a water cooled system.

2. Literature Review

Water-spray mist cooling system is used to assess its performance, which is based on the pre-cooling air entering the condensers to decrease compressor power consumption of air-cooled chillers with a nominal capacity of 600 kW. It mainly consists of atomization nozzles, water pipe work, a filter assembly, mounting brackets and a high pressure pump with around 70 bars of pressure. Based on the experimental data obtained from the measurements under ambient temperatures ranging from 25°C to 39°C, the reduction in air temperature were 5 to 20°C. The energy efficiency ratio (EER) increased by a 13.5%, while an increase of 5.9% in the cooling capacity was obtained. [5]

By using a water cooler and air cooler as a room cooler you can save 80% of the energy consumed by a 1.5 ton wall AC. [6]

It is possible to improve the energy efficiency of air-cooled condensers by installing water mist system to pre-cool the outdoor air before entering condensers. The water mist pre-cooling system is not a new concept, and has been applied successfully in the industries. [7]

The chiller performance can be improved by using water mist to pre-cool ambient air entering the condensers to decrease compressor power. A simulation analysis on an air-cooled chiller equipped with a water mist pre-cooling system under head pressure control shows that applying water mist pre cooling enables the coefficient of performance (COP) to increase. They concluded that the application of water mist pre-cooling could increase the COP in various degrees by up to 30%, especially when the relative humidity is low. Furthermore incase of using a water mist system, the chiller power could reduce by 16.2% or 15.8%. [8]

3. Analysis

The temperature during summers in sub tropical regions reaches to 45 deg. celcius and to reject heat, the condenser coils should be at 50 deg. celcius but in case if water cooling is done that is the temperature of air entering the condenser is decreased, the temperature of air raised during compression will reduce. This decrease in air temperature during compression will decrease the pressure ratio of compressor. Less power will be required by the compressor to raise pressure less than that produced during air cooling. This will further reduce the power consumed by the compressor. Picture of an air condenser used in residential and offices applications is shown below in figure 1 [6].

Figure 1: Air condenser used in residential and offices

The coils used in air condensers are generally made up of copper which is an expensive metal but if is done water cooling instead of air cooling of condenser coils, the amount of coils required will reduce and it will further reduce the manufacturing cost of air conditioning units. Air cooling system can be converted into a water cooling system by simply replacing the fan by a pump of less power rating as it is used in air coolers. We can use a small water drum near the condenser coils and water can be made fall over the condenser coils by using the pump. The same water can be circulated again and again. Since we do not require drinking water for cooling purpose thus it will not affect the environment in a negative way.

The refrigeration cycle of the air conditioner with water mist system is changed from the cycle 1-2-3-4-1 to 1'-2'-3'-4'-1'. As the condensing pressure decreases, the work of the compressor will also decrease. [1]

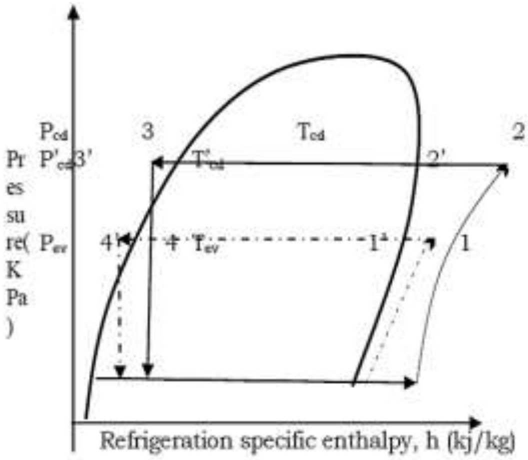

Figure 2: Vapour compression refrigeration cycle

The measured operating data for the air-cooled air conditioner included the power of compressor, WCP; the power of refrigeration cycle, WRP, which equal to the power of compressor plus the power of fan, cooled air supply temperature, $T_{ea,s}$, cooled air return temperature, $T_{ea,r}$; evaporating temperature, T_{ev} and condensing temperature, Tcd of refrigeration cycle. The cooling capacity of the air conditioner, QE is:

Where m_a is the cooled air mass flow rate, C_a is the specific heat capacity of air, Where: $h_{ea,r}$, $h_{ea,s}$ are enthalpies of the air at evaporator inlet and outlet, respectively (kJ/kg).

Heat rejection, QR was calculated by Eq. (2). The heat rejection airflow, V_a was determined by Eq. (3), where $T_{ca,l}$ is the temperature of air leaving the condenser.

QR = QE + WCP … (2)

$V_a = Q_R/(\rho_a C_a (T_{ca,1} - T_{ca,e}))$ … (3)

The air conditioner COP is expressed as cooling capacity, QE over power consumption WCP, as follow: COP = QE/ WCP … (4) For any given cooling capacity, QE, compressor power, WCP and heat rejection, QR will vary according to the condensing temperature, T_{cd}.[9]

The Formulae has been written in reference to figure 2.

$$W_{air\ cooling} = P_1 V_1 \frac{n}{n-1}\left[\left(\frac{T_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$W_{water\ cooling} = P_1 V_1 \frac{n}{n-1}\left[\left(\frac{T''_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]$$

$$\%\ saving = \frac{W_{air} - W_{water}}{W_{air}}$$

$$= \frac{\left[\left(\frac{T_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right] - \left[\left(\frac{T''_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]}{\left[\left(\frac{T_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]} * 100$$

$$= \left[1 - \frac{\left[\left(\frac{T''_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]}{\left[\left(\frac{T_2}{T_1}\right)^{\frac{n-1}{n}} - 1\right]}\right] * 100$$

In terms of temperature at compressor outlet

$$\%\ saving = \left[1 - \left(\frac{\frac{T''_2}{T_1} - 1}{\frac{T_2}{T_1} - 1} - 1\right)\right] * 100$$

$$= \left[1 - \left(\frac{T''_2 - T_1}{T_2 - T_1}\right)\right] * 100$$

Where

T''_2 =Temperature of Air entering into the condenser coils in the case of water cooling=35°C = 308 kelvin

T_1 =Temperature to be maintained = -15°C= 258 kelvin

T_2 = Temperature of Air entering into the condenser coils in the case of air cooling =50°=323 kelvin

From the above analysis, the total reduction in power consumption of compressor in case of water cooling is 23.07%.

Now we know that the coefficient of performance(COP) can be given by the equation :

$$COP = \frac{[illegible]}{[illegible]}$$

The amount of work consumed by an Air condition unit comprises mainly the work of a compressor.Consider the refrigeration effect as 1 ton(3.51 kW) ,generally the work consumed is 1.5 kW.

$$COP=\frac{3.51}{1.5}=2.34.$$

In case of water cooling:

$$COP = \frac{3.51}{(0.769*1.5)}=3.04.$$

$$\%\ \text{increase in COP} = \frac{(3.04-2.34)}{2.34}*100=29.91.$$

By switching to water cooling system, COP increases from 2.34 to 3.04 or can say by 29.91%.

4. Results and Discussions

As mentioned, the decrease in temperature of air at the inlet of condenser decreases the cycle pressure and subsequently decreases the work consumed by the compressor. Considering the the ambient temperature as 45 °C and water used for cooling at 30 °C -

- Percentage reduction in power consumption is 23.07% .
- Percentage increase in cop of the air conditioning unit for same refrigeration effect is 29.61%.

Decrease in compressor power consumption and also the replication of fan by a pump of comparatively low power rating will decrease the running cost of air conditioning unit by approximately 25%. In previous research performed, no calculation has been done regarding reduction in power consumption and COP. Moreover, in this research paper air cooling system has been completely replaced by water cooling system.

5. Conclusion

By simple modifications in the design of an air conditioning unit which includes complete replacement of air cooling system by water cooling system can reduce the power consumption of compressor by 23.07% and increases the coefficient of performance by 29.61%. This will lead to decrease in running cost of air conditioning unit by 25% approximately. As we are not using drinking water for cooling purpose, energy can be conserved in an efficient manner. The manufacturing and installation cost of air conditioning unit will not be affected too.

6. Future Scope

This research paper emphasize on the use of water cooling in Air Conditioning units instead of air cooling. Using this minute change we can save up to 30% power and energy, leading to reduced running cost of Air Conditioning units. It also increases the coefficient of performance of Air conditioning unit from 2.34 for present coolant to 3.04 for water cooled Air conditioning units. This technological change will be a boon in the area of air conditioning and refrigeration. The future of this modification will reduce the electricity consumption leading to reduced bill hence saving valuable resources. The low power compressor will lead to low cost Air Conditioning units making it available to wider audience.

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