Experimental investigation of an air conditioner unit by varying different air flow rates using air and evaporatively cooled condenser

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Abstract. An air conditioning system consumes enormous amount of energy particularly in the areas having hot and humid weather conditions. Thus, improvement in the performance of an air conditioner for such climatic conditions can be obtained by incorporating evaporative cooling instead of conventional air cooling. In this paper, effectiveness of an air conditioner unit using air cooled condenser and evaporatively cooled condenser is performed experimentally by varying three different air flow rates i.e (4.5, 6.0 and 7.5 m/s). Experimental results indicate that utilization of evaporatively cooled conditioning unit has a remarkable effect on the COP (Coefficient of performance) and rate of improvement is also better than conventional air cooled conditioning unit.

1. Introduction

Air conditioning systems are used in numerous stationary and mobile applications to provide required comfort zone for occupants and thus maintaining appropriate temperature and humidity. The total energy consumed by the air conditioning systems in buildings is more than 20% [1,2]. Especially in office buildings, the consumption of electricity for air conditioning systems has a huge share and it is also constantly increasing [3,4]. This increasing air conditioning and cooling demand can be reduced by utilizing the thermally operated low temperature technologies having lesser effect on environment [5]. Sensible and latent heat loads both constitute cooling load of a building. The sensible heat load is because of difference between the outdoor and indoor temperature conditions, while the latent heat load is due to the difference in the outdoor and indoor humidity contents. Within the building, both these sensible and latent heat loads may also be produced [6,7]. The Psychometric process dehumidification of air is obtained by achieving the temperature below dew point in evaporator coil so as to condense the water vapour present and then further reheating it to required desired temperature. An air conditioner when operated at elevated ambient temperatures, it results in a lower performance of air conditioner unit [8]. The energy efficient HVAC processes are greatly influenced by coupling between latent and sensible energy. In conventional VCRS, required cooling can be achieved by evaporation of refrigerant at very less temperature (3–5°C) which produces condensation of water vapour presented to moist air. But the main problem faced by such devices is that these consumes a huge amount of the electrical power for running the compressor especially in humid and hot weather conditions [9]. In market of air conditioning, the evaporative cooling devices is in high demand and currently dominates than other systems. The evaporative cooling system has a lot of benefits such as emission control, no CFCs usage, reduction in peak power demand, easy integration with built-up systems and savings on energy and cost [10]. Nikolaidis and Probert [11] studied two stage vapour compression refrigeration plant and determined analytically the effect of variation in temperatures of evaporator and condenser. Venkataramanamurthy et al. [12] performed an experimental test for VCRS and analysed the comparisons of second law efficiency and energy flow of R22 and its substitutes R-
In this paper, the central theme of my work is to calculate COP of an air conditioning system using different types of condensers. These different arrangements of condensers have different outlet conditions of each condenser and thus our main focus is to see its effect on the remaining parts of VCRS. In the performed study, we plan to develop an evaporatively cooled device to have higher COP in VCRS. Also, the energy analysis of an air conditioning system and comparison of various performance parameters using air and evaporative condenser by varying different air flow rates i.e (4.5, 6.0 and 7.5 m/s) is studied.

2. Experimental setup

Figure 1. Air Conditioner unit

Figure 2. line diagram of setup

Table: INSTRUMENTS USED

| T-Temperature | 1) Blower | 5) Sight glass | 9) Anemometer |
|--------------|----------|---------------|--------------|
| F- Pressure  | 2) Compressor | 6) Expansion valve | 10) Variable speed drive |
| Rh. Relative humidity | 3) Condenser | 7) Cooling oil |
| F- Flow rate | 4) Refrigerant flow meter | 8) Duct connection |

Figure 1. presents the set-up of an air conditioning system. R-410a refrigerant is used in this experimental set-up. The major parts of an air conditioner unit are compressor, condenser, throttling device and evaporator. The low pressure side of the system consists of suction line, compressor-suction head, expansion line and evaporator. Whereas, the high-pressure side of the system include discharge line, compressor-delivery head, condenser and liquid line.

Figure 2. describes line diagram of set-up.

INSTRUMENTS USED

- Hygrometer is used for measuring humidity of air at multiple points.
- Blower is used to maintain air velocity throughout the experimental setup.
- Anemometer is used for measuring air velocity.
- Temperature sensing device is used for measuring temperature at multiple points.
- Pressure gauges are used for measuring suction and discharge pressures.

FORMULAE USED
- Compressor work \( W_c = V*I = m_{ref}*(h_2-h_1) \)
- Refrigeration effect \( Q_r = m_{ref}*(h_1-h_4) \)
- \( \text{COP} = \frac{Q_r}{W_c} \)

Where,
- \( h_1 = \text{Enthalpy of refrigerant at inlet side of compressor in kJ/kg} \)
- \( h_2 = \text{Enthalpy of refrigerant at exit side of compressor in kJ/kg} \)
- \( h_4 = \text{Enthalpy of refrigerant at entry side of evaporator in kJ/kg} \)
- \( m_{ref} = \text{Flow rate of mass of refrigerant} \) (R-410a).

**3. Experimental data and results**

This experiment is performed once with air condenser and then by the usage of evaporative condenser by varying three different air flow rates i.e (4.5, 6.0 and 7.5 m/s). Table (1-5) shows the readings and results obtained for air and evaporative cooled condenser.

**Table 1.** Air conditioner unit with air cooled condenser at a fixed outer temperature of 29°C

| Parameters                  | Value | Value | Value |
|-----------------------------|-------|-------|-------|
| Inlet velocity (m/s)       | 7.5   | 6.0   | 4.5   |
| \( Q(m^3/s) \)             | 0.178 | 0.151 | 0.123 |
| CFM                         | 372   | 320   | 268   |
| Outlet temperature(°C)     | 18    | 20    | 22    |
| BPF                         | .32   | .30   | .27   |
Table 2. Air conditioner unit with evaporatively cooled condenser at a fixed outer temperature of 29°C

| Parameters                  | Value | Value | Value |
|-----------------------------|-------|-------|-------|
| Inlet velocity (m/s)        | 7.5   | 6.0   | 4.5   |
| Q(m³/s)                     | 0.178 | 0.151 | 0.123 |
| CFM                         | 372   | 320   | 268   |
| Outlet temperature(°C)      | 15    | 17    | 20    |
| BPF                         | .33   | .31   | .28   |

Table 3. The following experimental data is obtained for air and evaporative cooled condenser after steady state condition is achieved at flow rate 4.5 m/s and fixed outer temp 29°C

| Parameters                  | Air condenser | Evaporative condenser |
|-----------------------------|---------------|-----------------------|
| Pressure of evaporator (bar)| 4.9           | 4.5                   |
| Pressure of condenser (bar) | 21            | 16.7                  |
| Evaporator inlet side temp(°C) | 8            | 6                     |
| Evaporator outlet side temp(°C) | 12           | 9                     |
| Compressor outlet side temp(°C) | 62           | 56                    |
| Condenser outlet side temperature(°C) | 47          | 40                    |
| COP                         | 2.63          | 2.91                  |
Table 4. The following experimental data is obtained for air and evaporative cooled condenser after steady state condition is achieved at flow rate 6.0 m/s and fixed outer temp 29°C

| Parameters                        | Air condenser | Evaporative condenser |
|-----------------------------------|---------------|-----------------------|
| Pressure of evaporator (bar)      | 4.5           | 4.1                   |
| Pressure of Condenser (bar)       | 18            | 14                    |
| Evaporator inlet side temp(°C)    | 6.5           | 4                     |
| Evaporator outlet side temp(°C)   | 10            | 6                     |
| Compressor outlet side temp(°C)   | 57            | 51                    |
| Condenser outlet side temperature(°C) | 42         | 36                   |
| COP                               | 2.92          | 3.23                  |

Table 5. The following experimental data is obtained for air and evaporative cooled condenser after steady state condition is achieved at flow rate 7.5 m/s and fixed outer temp 29°C

| Parameters                        | Air condenser | Evaporative condenser |
|-----------------------------------|---------------|-----------------------|
| Pressure of evaporator (bar)      | 4.3           | 3.9                   |
| Pressure of condenser (bar)       | 15            | 11.5                  |
| Evaporator inlet side temp(°C)    | 4             | 2                     |
| Evaporator outlet side temp(°C)   | 8             | 4                     |
| Compressor outlet side temp(°C)   | 52            | 46                    |
| Condenser outlet side temperature(°C) | 37         | 33                   |
| COP                               | 3.19          | 3.51                  |
4. Graphs and discussion

4.1 Effect on COP by varying air flow rate
COP of the system continuously decreases with decrease in flow rate of air for both air cooled and evaporative cooled condenser (figure 3.). But for the evaporative cooled condenser the COP is higher as compare to air cooled condenser. This is because evaporative cooling reduces the condenser outlet temperature thus enhancing the refrigeration effect at evaporator, thus more cooling is obtained and it also increases the heat transfer rate at the evaporator.

![Figure 3. Variation of COP with air flow rate](image)

4.2 Effect on outlet temperature of air by varying air flow rate
As flow rate of air keeps on increasing, the air outlet temperature going to conditioned space also gets affected. Because of evaporative cooling, lower temperature can be obtained at conditioned space as compare to air cooled condenser (figure 4.).

![Figure 4. Variation of outlet temperature of air with air flow rate](image)

4.3 Effect on By-pass Factor by varying air flow rate
By-pass factor also gets affected due to change in air flow rate as shown in figure 5.

![Figure 5. Variation of By- pass factor with air flow rate](image)
5. Conclusions

Evaporative cooled condenser coupled to an air conditioning unit is an reliable, efficient way to improve the efficiency of VCRS as compare to air cooled condenser. With increment in rate of flow of the air COP of the system continuously increases for both air and evaporative cooled condenser. But at same flow rate of air, performance of an evaporatively cooled condenser attached to an air conditioner system is more effective as compare to air cooled condenser.

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