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Waste Heat Recovery in R & AC Systems

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Abstract: ***The field of mechanical engineering has a theme word "CHANGE" as its backbone. Our project is maiden venture into field of air temperature controlling and also deals with human comfort. This report deals with design and fabrications of an three in one air conditioner. Human efforts conditions deal with the conditions of the environment around us, viz. hot and cold. The control of temperature of air around us is done by controlling the output water cooler. Our project is a novel idea to control air temperature around us by the incorporation of cooling system in a single unit. This unit would be an economic utility at all places to provide comfort conditions to the people. In addition to comfort phases of air conditioning many industries have found that air conditioning of their plants has made complete control of manufacturing process and material and improves the quality of the finished products. This is entirely based on the vapor compression cycle. An evaporative cooler produces effective cooling by combining a naturals process-water evaporation with a simple, reliable air moving system evaporative cooling is the most economical and effective means of refrigeration and air cooling since its inception particularly in the areas where climatic conditions are hot and dry. In desert region like Rajasthan (India), during summer Dry Bulb Temperature (DBT) of air may reach up to 48 ˚C while relative humidity stays below 50%.[1] During present study efforts were made to make evaporative cooling system more versatile. In the process of study a cooler cum refrigerator has been developed which can be utilized for the purpose of air cooling, drinking water cooling viz. storing the vegetables and medicines without altering the performance of desert cooler[1]. The energy saving by doing so is saved more than 30 W. A small size desert cooler can cool more than 24 liter water per day up to the Wet Bulb Temperature (WBT) of outside air.***

Keywords: Compressor, Evaporator, Condenser, vaporizer, water, Refrigerant gasses.

1. Introduction

"Faster, mightier & smaller" is still the keyword for every invention and development. In day-to-day world we concentrate on the compactness and efficiency of every product. Keeping this in our thought we have designed and fabricated an economical and reliable unit known as "Water cum room cooler"

(Three in one air conditioner).

"Human comfort is that condition of mind which expresses itself with the thermal environment". In our project two rival properties of cool water and cool air are obtained. This system can be used continuously. By using our system there is no need of going for a separate air conditioner or air cooler and water cooler. As both purposes are served by a single system, the cost is lowered to a considerable level.

1.1 Ultimate Aim

Three in one air conditioner can be widely used in low cost and reliable. It acts as an eco-friendly resource which can be recycled in an effective manner.

1.2 Air Conditioning & Refrigeration

The term air conditioning refers to the control of temperature, humidity, motion and purity of atmosphere in the confined space. Out of all the refrigeration systems, the vapor compression system is the most important system from the view point of commercial and domestic utility. It is the most practical form of refrigeration. [2]In this system the working fluid is a vapor. It readily evaporates and condenses or changes alternatively between the vapor and liquid phases without leaving the refrigerating plant. During evaporation, it absorbs heat from the cold body. This heat is used as its latent heat for converting it from the liquid to vapor. In condensing or cooling or liquefying, it rejects heat to external body, thus creating a cooling effect in the working fluid [2]. evaporator during the suction stroke of the compressor. During compression stroke the pressure and temperature increases until the vapor temperature is greater than the temperature of the condenser cooling medium.

Types of refrigeration systems:
- Ice refrigeration.
- Air refrigeration.
- Vapor compression refrigeration system.
- Vapor absorption refrigeration system.
- Special refrigeration system

(i) Adsorption refrigeration system
(ii) Cascade refrigeration system
(ii) Mixed refrigeration system
(iii) Vortex refrigeration system
(iv) Thermoelectric refrigeration system
(v) Steam jet refrigeration system

2. Refrigeration

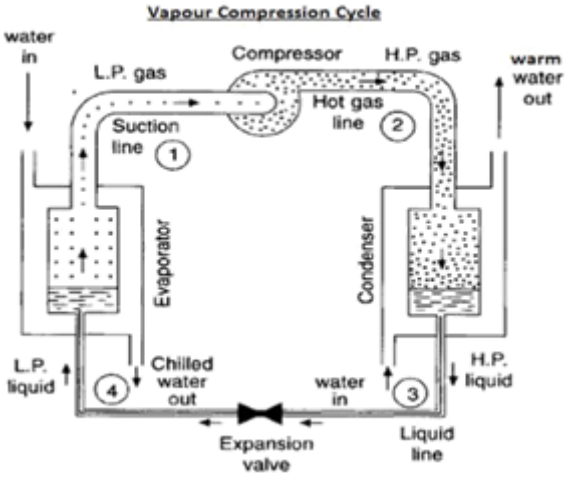
The science of producing and maintaining temperatures below that of surrounding atmosphere. In simple words, refrigeration means cooling of or removal of heat from the system.

2.1 Principle

It works based on the principle of vapor compression cycle. In this system it readily evaporates and condenses or

changes alternatively between vapor and liquid phases without leaving the refrigeration plant. In simple vapor compression system fundamental processes are completed in one cycle. They are (i) compression, (ii) condensation, (iii) expansion, (iv) vaporization.

Schematic flow diagram of vapor compression cycle: figure:1



The principle part of a simple vapor compression refrigeration system is shown.

a) Evaporator

Its function is to provide a heat transfer surface through which heat can pass from the refrigerated space into the vaporizing refrigerant.

- **Suction line**
  It carries the low pressure vapour from the evaporator to the suction inlet of the compressor.
- **Compressor**
  A compressor is considered to be the heart of the vapor compression refrigeration system it pumps the refrigerant through the system and circulates it again and again in cycles. It produces high pressure and hence high temperature to enable the refrigerants to reject its heat in the condenser. It also helps to produce low pressure in the evaporator to make the refrigerant to pick up maximum amount of heat from the space to be refrigerated. The compressors used in the modern vapor compression system can be either of positive displacement or non-positive displacement type.
- **Discharge line**
  It conveys the high pressure and high temperature refrigerant from the compressor to the condenser.

b) Condenser

The function of the condenser is to provide a heat transfer surface through which heat passes from the refrigerant to the condenser medium which is either water of air.

c) Receiver tank

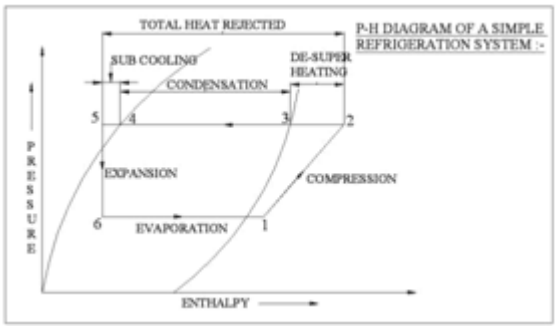
It acts as a reservoir which stores the liquid refrigerant coming from the condenser and supplies it to the evaporator according to the requirement.

d) Liquid line

It carries the liquid refrigerant from the receiver and conveys it to the expansion valve.

e) Expansion valve

Its function is to supply a proper amount of refrigerant to the evaporator after reducing its pressure considerably so that the refrigerant may take sufficient amount of heat from the refrigerating during evaporation.



2.2 Arrangement of Working Model

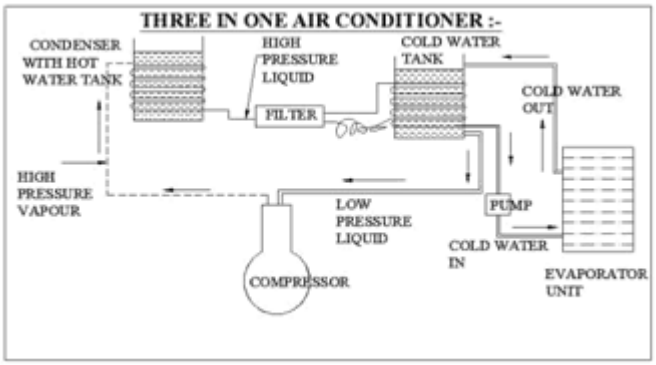


Figure 2.1

2.3 Parts of Vapor Compression System

The following are the various parts of a vapor compression systems, (i) compressor, (ii) discharge line, (iii) condenser, (iv) receiver tank, (v) liquid line, (vi) expansion valve, (vii) evaporator, (viii) suction line.

(i) Compressor

The function of the compressor is to remove the vapor from the evaporator, and to raise its temperature and pressure to a point such that it (vapor) can be condensed with available condensing media.

(ii) Discharge line

A hot gas or discharge line delivers the high pressure, high temperature vapour from the discharge of the compressor to the condenser.

(iii) Condenser

The function of a censor is to provide a heat transfer surface through which heat passes from the hot refrigerant vapor to the condensing medium.

(iv) Receiver tank

A receiver tank is used to provide storage for a condensed liquid so that a constant supply of liquid is available to the evaporator as required.

(v) Liquid line
A liquid line carriers the liquid refrigerant from the receiver tank to the refrigerant flow control.

(vi) Expansion valve
It‟s also called as refrigerant flow control valve. Its function is to meter the progress amount of refrigerant to the evaporator and to reduce the pressure of the liquid entering the evaporator so that liquid will vaporize in the evaporator at the desired low temperature and take out sufficient amount of heat.

(vii) Evaporator
An evaporator provides a heat transfer surface through which heat can pass from the refrigerant space into the vaporizing refrigerant.

(viii) Suction line
The suction line conveys the low temperature vapor from the evaporator to the suction inlet of the compressor.

2.4 Advantages and Disadvantages of Vapour Compression Refrigeration System Over Air Refrigeration System

Advantages

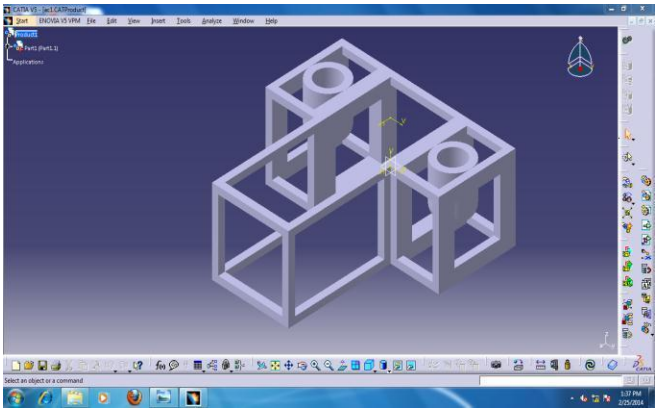
- The coefficient of performance is quite high as the working cycle of this system is near the Carnot cycle
- The among of refrigerant circulated is less per ton of refrigeration than air refrigeration system because the heat carried away by the refrigerant is the latent heat. As a result of this, the size of evaporator is smaller for the same refrigerating effect.
- This system can be employed over a large range of temperatures. By adjusting the expansion valve of the same unit, the required temperature in the evaporator can be achieved.
- The running cost of this system is less than air refrigerating system. The air refrigeration system requires five times more power than a vapour compression refrigeration system of the same capacity.

Disadvantages

- Prevention of leakage of refrigerant in this system is the major problem.
- First investment cost is high than the air refrigeration system.

2.5 Design of Three in One Air Conditioner

Design is shown in PRO - E:



2.6 Advantages

- Simple in construction
- This system is noiseless in operation
- It is portable, so it can be transferred easily from one place to other place
- Power consumption is less
- Maintenance cost is low

2.7 Applications were it can be used are

- Can be used in AC Coaches in trains and in automobile sector vehicles like cars, vans, etc.,
- Can be used in the desert regions due to the deficient quantity of water in their regions
- Can be used in all the air conditioners since it is an eco friendly and can be recycled easily.
- Useful in schools and colleges in the desert regions.
- Can be also used in the domestic office and bank applications.

2.8 Specification

- Diameter of the chamber vessel (D) = 0.18m
- Base height of the chamber vessel (H) = 0.60m
- Breadth of the frame (B) = 0.30m
- Length of the frame (L) = 0.70m
- Diameter of the duct made of copper (d) = 0.01m

3. Calculations

Mass of water present in the cold chamber : $\rho = m / v$

$m = \rho * v$

$m = 1000 * 200 / 84$

$m = 2.38 * 10^{-3}$ Kg/s

Power input of the compressor (P_i) = 230* 0.45

$P_i = 0.1035$ KW

Quantity of heat rejected from the system in evaporater $Q_2 = m * C_{pw} * \Delta T$

= 2.38 * 10 -3* 1.005 * 13

= 0.1297 KW

Coefficient of performance C O P = 0.1297 / 0.1035 = 1.25

Capacity of air conditioner :

Volume of water inside the vessel $V_w = L* b * h$

= 0.35 * 0.35 * 0.2
= 0.0245 m^3

Mass of water $M_w = \rho_w * v_w$

= 1000 * 0.0225
= 24.5 Kg.

Mass flow rate of water = 24.5 / 3600

= 0.0068 Kg/sec

Quantity of heat removed
$Q_{r1} = M_w * C_{pw} * (T_{w\,1} – T_{w\,2})$

$T_{w1} = 28\ ^0C$; $T_{w2} = 12\ ^0C$

= .0068 * 4.186 * (28 – 12)
= .45543 KJ / Sec.

Capacity of water cooling unit

= .45543 / 3.5
= .13012 T O R

Cooling capacity of room Cooler: Mass of air = $\delta_a * A_d * V_a$

$A_d = \pi / 4 (d^2) * h$

$V_a = (\pi * d * N) / 60$

= $1.2*\pi / 4 * 0.21^2 * (\pi * 0.21* 1360) / 60$

= 0.6209 Kg / Sec.

Assume that fan efficiency = 80 %

Therefore Ma = 0.6209 * 0.8

= 0.49692 Kg / Sec.

From the psychrometric chart;

DBT 1 = 37 ^0C

WBT 1 = 22 ^0C

DBT 2 = 26 ^0C

WBT 2 = 16 ^0C

From table;

h 1 = 65 KJ / Kg; h 2 = 45 KJ / Kg

Heat rejection $Q_r = M_a * (h1 – h2)$

= 0.49692 * (65 – 45) Q_r = 9.9344 KJ / Sec.

Cooling capacity of room cooler 9.9344 / 3.5

= 2.8384 T O R

4. Air Conditioning

Air conditioning means conditioning of air for maintaining specific conditions of temperature, relative humidity and low dust levels inside an enclosed space.

Generally air-conditioning is subdivided into industrial air-conditioning and comfort air-conditioning. The controlled atmosphere which gives maximum comfort to the human being is known as comfort air-conditioning. The controlled atmosphere which is required for the manufacturing process for engineering goods is known as industrial air-conditioning.

The comfort air-conditioning is further subdivided into summer air-conditioning and winter air-conditioning. The air cooling and dehumidification used in summer is known as summer air-conditioning and the heating and humidifying used in winter is known as winter air-conditioning.

Need for air-conditioning

Human beings give off heat around an average of 100 kcal per hour per person, due to what is known as „metabolism". The temperature of around 56.9 degree C (98.4 degree F). But the skin temperature varies according to the surrounding temperature and relative humidity. To dissipate the heat generated by metabolism in order to maintain the body temperature at the normal level, there must be a flow of heat from the skin to the surrounding temperature is very low, as on a cold winter day the rater of heat flow from the body, and so there cannot be flow of heat from the skin to the surrounding, thus the person feels hot. In such a situation water from the body temperature. But if the surrounding air is not only hot but highly humid as well, very little evaporation of water can take place from the skin surface and so the person feels hot and uncomfortable.

(i) No loss of energy
(ii) Higher efficiency when compared to normal Air Conditioner
(iii) Power consumption can be minimized
(iv) Low economic cost
(v) Very effective in all applications

5. Photography

6. Results and Conclusions

From the above prototype the three in one Air Conditioner is one of the reusable and an eco friendly project which can be implemented in our day to day life for the effective management of power consumption factor. Hence it plays a major role for the people who are living in the desert regions. This is one maiden venture in the field of refrigeration system from the stream of mechanical engineering as term leads to change in the recent trends to the favour of ecological systems. The main advantage in this system depicted as,

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