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Air Conditioning cum Water Dispenser System

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Abstract: ***This project "Air Conditioning Cum Water Dispenser System" makes the study of the development of a water dispenser system using a normal air conditioner. The main aim behind developing this device is to develop a multifunctional unit which can provide hot water, cold water along with regular space/air conditioning cycle. The design mainly consists of compressor, condenser, evaporator, expansion valve, copper coil, temperature and pressure gauges. It comprises of air cycle and water cycle combined with a common compressor. In the air cycle, heat is transported from a colder location to a hotter area. An air conditioner is an example of such a system, as it transports the heat out of the interior and into its environment (i.e. the room). The refrigerant is used as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. This heat of the refrigerant is used to heat or cool the water, which can be then used for various purposes. The air cycle is the conventional vapor compression cycle whereas the water cycle is the adaptation of the same. It consists of five modes- water-heating only, space cooling and water heating, space heating and water heating, space cooling, space heating. They are controlled by means of valves. Systematic analysis after the completion of project was carried out. The readings obtained were noted down in a proper tabular column. Then calculations for determination of COP of air cycle, COP of water cycle, effectiveness of condenser and evaporator, heat transferred by evaporator and friction factor of capillary tube were carriedout.***

Keywords: Compressor, condenser, copper coil, evaporator, expansion valve, pressure and temperature gauges.

1. Introduction

Due to the increase in temperature of the earth due to global warming, the use of air conditioners has drastically increased. Waste heat from air conditioners may be used to produce hot water. The benefits of doing this are twofold. One is elimination of the need to install an electric water heater, and the other is saving of electrical energy otherwise used in the electric water heater and water cooler. These may be accomplished while the usefulness of the air conditioner for cooling is maintained.

At present, water heaters using waste heat from small split type air conditioners are commercially available in India and are generally mechanically made to the specific requirements of the users. Even though split type air conditioners with water heaters are successfully used, their performance and system design for application in India have not been fully investigated, especially when both cooling and heating effects are desirable. The need for the development of an integrated air conditioning cum water dispenser system at low cost was overcome by using a common compressor for both the systems. The use of common compressor eliminates the use of a separate electrical energy for the operation of water heaters and water coolers. A parallel connection can be bypassed from the compressor of a normal air conditioner in order to make the system suitable for all the three purposes i.e. water heating, water cooling and space conditioning. In such a system there are two cycles involved: air cycle and water cycle. In evaporator of air cycle, the air is cooled. In condenser of air cycle, the air is heated. In evaporating coil of water cycle, the water is cooled and in condensing coil of water cycle, the water is heated. An attractive point is that this air conditioner cum water dispenser system can produce hot & cold water as well as hot & coldair.

System Design

1.1 Introduction

An Air-Conditioning cum Water dispenser system is an unique combination of air-cycle and water-cycle into a single unit. "Air-conditioning" is the simultaneous control of temperature, humidity, motion and purity of the atmosphere in confined space. The important factors which control the air-conditioning are

1) Temperature Control
2) Humidity Control
3) Air movement and circulation
4) Air filtering, cleaning and purification

Complete conditioning provides simultaneous control of these factors. In addition to comfort phases of air conditioning many industries have found that this process ha made possible more complete control of manufacturing processes and materials and improves the quality of finished products.

"Water-dispenser system" is sequential process of controlling the temperature, motion and purity of water which is being circulated in the closed system. Factors controlled by water dispenser are

1) Temperature control
2) Water motion and circulation
3) Water filtering, cleaning and purification

Thus in an "Air-conditioning cum Water-dispenser system" controlled, cleaned, purified, filtered air and water is obtained with better efficiency.

1.2 Components of Air-Conditioning System

The basic elements of an air-conditioning system are

1) Fans – for moving air
2) Filters – for cleaning air, either fresh, recirculated or both.

3) Condenser – for exchanging heat with the surrounding atmosphere and provides hot air
4) Compressor–for compressing the refrigerant at high pressure and temperature
5) Evaporator–for exchanging heat with the atmosphere and provides cold air
6) Control system– for automatic regulation of amount of heating and cooling

1.3 Working of Air-Conditioning System

Air conditioning comprises of the following steps
1) The fan forces air into the duct work which is in connected to the openings in the room called as terminals.
2) The duct work directs the air into the room through the outlets.
3) The air enters the room and either heats or cools as required. Dust particles from the room enters the air stream and are carried along with it.
4) The compressor initially is filled with the refrigerant in the form of gas.
5) On switching on the system the compressor compresses the gas to high temperature and pressure and then sends the super-heated gas to the condenser.

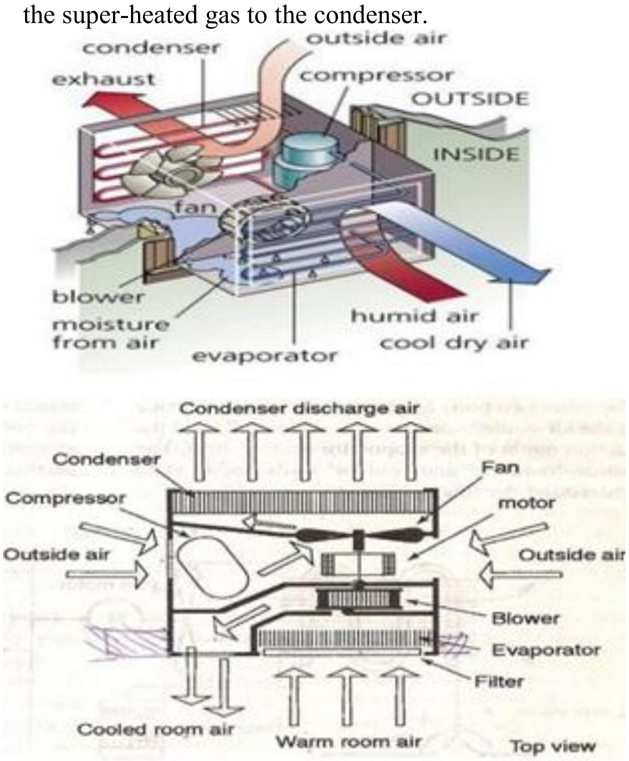


Figure 1.1: Working of air –conditioning system

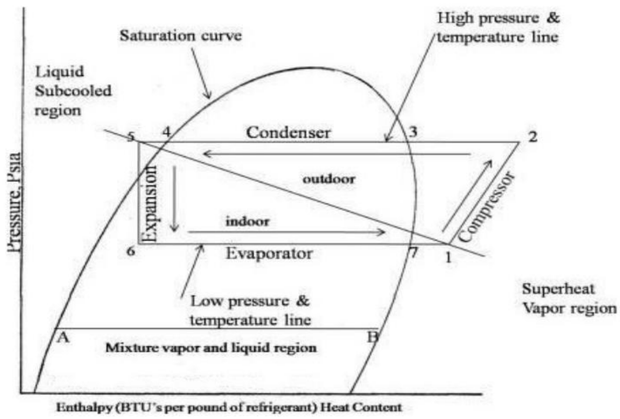


Figure 1.2: p-h graph

1) At the inlet of the condenser the refrigerant is in the gaseous form as well as at high temperature. When a flow of air at room temperature is flown over the condenser at that time a heat exchange takes place between the air and the refrigerant causing the air to heated up and also leads condensation of the refrigerant that liquefies after condensation, slight difference in temperature occurs between the inlet and outlet of the condenser in practical scenario as it is a constant temperature process.
2) From the condenser outlet the liquid refrigerant is passed through the capillary tubes that act as an expansion valve where the drop in temperature of the refrigerant occurs due to expansion as it is a constant enthalpy process.
3) The cooled refrigerant is now passed to the evaporator where in when air at room-temperature is passed over a heat exchange takes place leading to evaporation of the refrigerant and thus the air is cooled which is passed to the outlet terminals.
4) The refrigerant is again directed back to compressor where the compression takes place at constant entropy.
5) Finally the cycle of air- conditioning is completed.

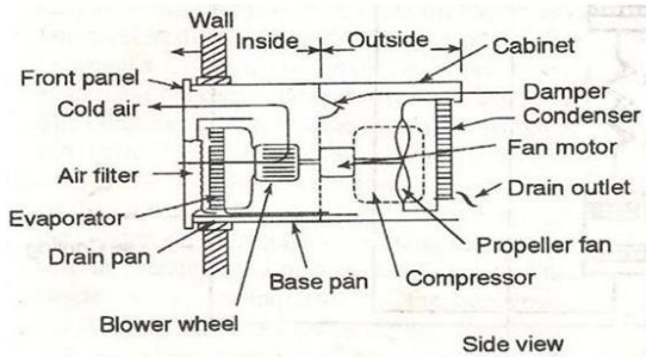
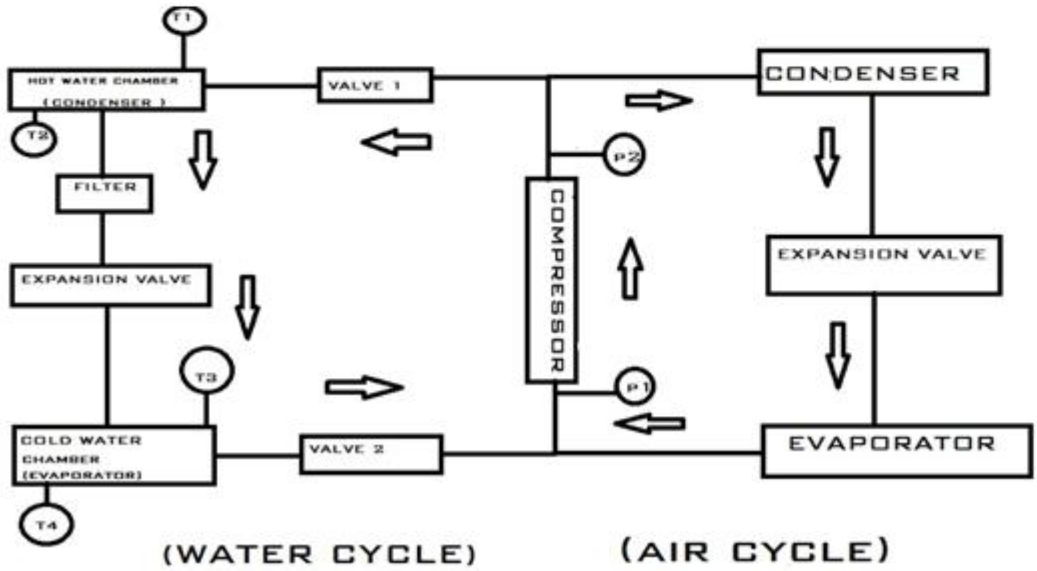


Figure 1.3: Side view of air-conditioning system

1.4 Design of Air-Conditioning Cum Water Dispenser System



Here,
P1- compressor inlet pressure P2- compressor outlet pressure
T1- condenser inlet temperature
T2- condenser outlet temperature T3- evaporator inlet temperature T4- evaporator outlet temperature T5- hot water temperature
T6- cold water temperature
Valves- for regulation of refrigerant into the water-cycle

1.5 Working of Air-Conditioning Cum Water Dispenser System

1) Working of air-conditioning cum water dispenser system is similar to that of the air-conditioning system with an additional water cycle associated with it.
2) Initially R22 refrigerant of 1.75 kg is inserted into the compressor pinvalve.
3) Copper coils of 40turns are made and inserted in the drum that acts as an condenser for the water cycleandcoppercoilsof20turnsare made for the evaporator in order to get maximum efficiency.
4) The condenser and evaporator of the water cycle are connected to the outlet and the inlet of the compressor.
5) A filter is placed between condenser and capillary tube in order to prevent clogging of impurities in thesetup.
6) Capillary tubes are used in order to enable expansion under constant enthalpy process
7) Valves are here used in order to regulate and control the air and water cycles independently
8) When the system is started the refrigerant flows to both air cycle and the water cycle
9) The compressed refrigerant flows through the condenser coils where condensation of the refrigerant occurs causing heating of the water in the hot water chamber and then it is passed through the expansion valve leading to a drop of temperature of the refrigerant and then it is passed to the evaporator in the form of liquid at a very low temperature where heat exchange occurs between water at room temperature and the refrigerant leading to cooling of the water and heating of the refrigerant thus cold water is obtained from cold water chamber.
10) The refrigerant from the evaporator enters the compressor and thus the cycle continues.
11) Temperatures at the inlet and outlet of the condenser, inlet outlet temperatures of evaporator , pressures at the inlet and outlet of compressor is noted down and calculations related to COP , mass-flow rates, efficiencies are determined.
12) Finally a combined system of air cycle and water cycle is obtained with increased efficiency is thus obtained

Figure 1.4: Air conditioning cum Water Dispenser System

2. Calculations

2.1 For Water cycle

2.1.1 Design of Hot Chamber (Condenser)

The refrigerant flows from the compressor in a chamber consisting of 40 turns which acts as a condenser. The chamber acts as Shell and tube heat exchanger wherein the condensation of the refrigerant takes place. The calculations are done taking the hot chamber as a heat exchanger.

Heat transferred by condenser:
$Q = K \times \pi d \times (T_{hi}-T_{ho})$
where, Q= heat transferred by condenser in W
K= Thermal conductivity of copper = 386W/m^{2}k
D = Diameter of tube= 6.35 x 10^{-3}m
T_{hi}= Condenser inlet temperature = 79.3 ^{0}C
T_{ho}= Condenser outlet temperature = 36.7 ^{0}C Q= 386 x π x 6.35 x 10^{-3}x (79.3-36.7)
Q= 328.035 W

Mass flow rate of refrigerant:
$Q= m \times C_p \times (T_{hi}-T_{ho})$
where, Q= heat transferred by condenser in W m= mass flow rate in Kg/sec
C_p= Specific heat at constant pressure = 1.022KJ/KgK
T_{hi}= Condenser inlet temperature in ^{0}C
T_{ho}= Condenser outlet temperature in ^{0}C
m= 328.035/ (1022 x (79.3-36.7)
m= 7.35 x 10^{-3} Kg/sec

Velocity of refrigerant:
m = ρ x A xv
Where, m= mass flow rate in Kg/sec
ρ = density of Refrigerant = 1216Kg/m^3
A = Area of tube, m^2
v = velocity of refrigerant, m/s
A= π x d x L Where, L= length of condenser tube= 10.884 m
A= 3.14 x 6.35 x10^{-3} x 10.884
A = 0.2171 m^2

V = (7.35 x 10^{-3})/(1216 x 0.2171)
V = 2.8523 x 10^{-5} m/s

Logarithmic mean temperature difference (LMTD):
$LMTD= ((T_{hi}-T_{sat})-(T_{sat}-T_{ho}))/\ln((T_{hi}-T_{sat})/(T_{sat}-T_{hi}))$
Where, T_{hi}= Condenser inlet temperature in ^{0}C
T_{ho}= Condenser outlet temperature in ^{0}C
T_{sat} = Saturation temperature = 50^{0}C
LMTD= ((79.3-50)-(50-36.7))/ln((29.3/13.3))
LMTD = 20.25^{0}C

Effectiveness of condenser (ε):
$\varepsilon= ((m \times c_p \times (T_{hi}-T_{ho}))/(m \times c_p \times (T_{hi}-T_w))$
Where, m= mass flow rate of refrigerant in kg/sec
T_{hi}= Condenser inlet temperature in ^{0}C
T_{ho}= Condenser outlet temperature in ^{0}C
T_w = Temperature of water = 31.8 ^{0}C
C_p = Specific heat at constant pressure =1.022KJ/KgK
ε = ((79.3-36.7)/(79.3-31.8))
ε = 0.8968= 89.68%

2.1.2 Design of Evaporator
The refrigerant now passes through a receiver drier and then goes into the cold chamber which acts as an evaporator. This chamber also acts as a Shell and tube heat exchanger and the calculations are done taking this consideration. In the evaporator, the refrigerant changes its state from liquid to gaseous form and the heat transfer takes place through conduction to the water.

Heat transferred by evaporator:
$Q = K \times \pi d \times (T_{co}-T_{ci})$
Where, Q= heat transferred by condenser in W
K= Thermal conductivity of copper = 386W/m^{2}k
d= Diameter of tube= 6.35 x 10^{-3}m
T_{ci}= Evaporator inlet temperature = 36.7 ^{0}C
T_{co}= Evaporator outlet temperature = 27.1 ^{0}C
Q= 386 x π x 6.35 x 10^{-3}x (36.7-27.1)
Q= 73.923W

Mass flow rate of refrigerant:
$Q= m \times C_p \times (T_{hi}-T_{ho})$
Where, Q= heat transferred by condenser in W m= mass flow rate in Kg/sec
C_p= Specific heat at constant pressure = 0.966KJ/KgK
T_{ci}= Evaporator inlet temperature = 36.7^{0}C
T_{co}= Evaporator outlet temperature = 27.1^{0}C
m= 73.923/ (966 x (36.7-27.1)
m= 7.971 x 10^{-3} Kg/sec

Velocity of refrigerant:
m = ρ x A x v
Where m= mass flow rate in Kg/sec
ρ = density of Refrigerant R22 = 1330Kg/m^3
A = area of tube, m^2
v = velocity of refrigerant, m/s
A= π x d x L
Where L= length of evaporator tube= 5.422 m
A= 3.14 x 6.35 x10^{-3}x 5.422
A= 0.1081 m^2
v = (7.35 x 10^{-3})/(1330 x 0.1081)
v= 5.524 x 10^{-5} m/s

Logarithmic mean temperature difference (LMTD):

$LMTD= ((T_{ci}-T_{sat})-(T_{co}-T_{sat}))/\ln((T_{ci}-T_{sat})/(T_{co}-T_{sat}))$
Where T_{ci}= Evaporator inlet temperature = 36.7 ^{0}C
T_{co}= Evaporator outlet temperature = 27.1^{0}C
T_{sat} = Saturation temperature = 23.1^{0}C
LMTD= ((36.7-23.1)-(27.1-23.1))/ln((13.6/4))
LMTD = 7.844^{0}C

Effectiveness of evaporator (ε):
ε= ((m x cp x (Tci-Tco))/(m x cp x (Tci-Tw))
Where m= mass flow rate of refrigerant in kg/sec
T_{ci}= Evaporator inlet temperature in 36.7 ^{0}C
T_{co}= Evaporator outlet temperature in 27.1^{0}C
T_w = Temperature of water = 23.1^{0}C
C_p = Specific heat at constant pressure =0.966KJ/Kg
K_ε = ((36.7-27.1)/(36.7-23.1))
ε = 0.7058 = 70.58%

2.1.3 Design of Capillary Tube
The capillary tube has been taken into consideration according to the capacity of the heat exchanger and the volume of the chambers respectively.
F=L/D
Where F= friction factor of capillary tube
L= length of capillary tube=304.8mm D= diameter of capillary tube = 0.6mm
F= 304.8/0.6= 508

2.1.4 Theoretical C.O.P:

The theoretical C.O.P is the coefficient of performance which is calculated from the pyscometric chart and the respective temperatures and pressures.

C.O.P = $(h_1-h_4)/(h_2-h_1)$

Where h_1 = Enthalpy at inlet of compressor in KJ/Kg

h_2 = Enthalpy at outlet of compressor in KJ/Kg

h_4 = Enthalpy at outlet of evaporator in KJ/Kg

From Psychometric chart of R-22,

p_1= pressure at compressor inlet = 3.2psi

p_1= (3.2 x 0.06894) + 1.013= 1.2336 bar

p_2 = pressure at compressor outlet = 15.8psi

p_2= (15.8 x 0.06894) + 1.013= 2.1 bar

h_1 = Enthalpy at p=1.2336 bar and T=27.1^{0}C = 320 KJ/Kg

h_2 = Enthalpy at p=2.1 bar and T=79.3^{0}C = 360 KJ/Kg

h_3= Enthalpy at p=1.2336 bar and T=23.1^{0}C = 260KJ/Kg

C.O.P=(320-260)/(360-320)

C.O.P = 60/40

C.O.P = 1.5

2.1.5 Actual C.O.P:

The actual C.O.P is defined as the ratio of refrigeration effect to the compressor work. This C.O.P is the actual coefficient of performance which corresponds to the experimental value.

C.O.P = Refrigeration Effect / Compressor Work

Refrigeration Effect:

For 1 ton A/C, refrigeration effect = 3.5 KW

For 1.5 ton A/C, refrigeration effect = 3.5 x 1.5= 5.25 KW

Compressor work:

I = current input to compressor = 20A

V = Voltage across the compressor = 240v

Compressor work = V x I = 20 x 240 = 4800W = 4.8KW

C.O.P = 5.25/4.8

C.O.P = 1.1

2.2 Calculations for Aircycle

2.2.1 Theoretical C.O.P:

This C.O.P is the coefficient of performance that is calculated for the air cycle

C.O.P = $(h_1-h_4)/(h_2-h_1)$

h_1 = Enthalpy at inlet of compressor in KJ/Kg

h_2 = Enthalpy at outlet of compressor in KJ/Kg

From Psychometric chart of R-22,

p_1= pressure at compressor inlet = 3.2psi

p_1= (3.2 x 0.06894) + 1.013= 1.2336 bar

p_2 = pressure at compressor outlet = 15.8psi

p_2= (15.8 x 0.06894) + 1.013= 2.1 bar

h_1 = Enthalpy at p=1.2336 bar and T=27.1^{0}C = 320 KJ/Kg

h_2 = Enthalpy at p=2.1 bar and T=79.3^{0}C = 360 KJ/Kg

h_4= Enthalpy at outlet of evaporator =180KJ/Kg

C.O.P = (320-180)/(360-320)

C.O.P= 140/40= 3.5

2.2.2 Actual C.O.P:

C.O.P = Refrigeration effect/energy input Refrigeration effect produced by 1.5 ton A/C:

1 ton of refrigeration = (2000lb/day) (144BTU/lb)/(24h/day)(60min/h)

=300BTU/min Where 2000lb/day ➔ 1ton of ice

144BTU/lb ➔ Enthalpy of solidification at 32^{0}F So for 1.5 ton, it is 300BTU/min

In S.I units 1ton= 210KJ/min

1.5 ton=210*1.5=315KJ/min.

Energy input for 1.5ton A/C = 1.5KW = 1500Watts

C.O.P = Refrigeration effect/energy input C.O.P = (315*1000/60)/(1500)

C.O.P = 3.5

3. Testing

The testing of the equipment has been carried out under certain crucial conditions where in the values are tabulated and the corresponding data is tabulated and the graphs are plotted as per calculations. These values are then matched with that of the theoretical values and the corresponding data are calculated.

3.1 Tabulation

S.no	Time (t) in min	Evaporator temperature in (^{0}C)		Condenser temperature in (^{0}C)		Compressor pressure in (psi)		Cold water temperature (^{0}C)	Hot water temperature (^{0}C)
		Inlet (T_{ci})	Outlet (T_{co})	Inlet (T_{hi})	Outlet (T_{ho})	Inlet (p_1)	Outlet (p_2)		
1	0	29.9	29.9	32	29.9	1.7	12.2	31.8	31.3
2	30	31.7	28.5	35.5	31.7	2.1	13.1	28.3	33.7
3	60	33.5	27.2	38.9	33.5	2.5	14	24.9	36.2
4	90	34.1	27.2	50	34.1	2.75	14.5	24.6	42
5	120	34.7	27.1	60.9	34.7	3	15	24.3	47.8
6	150	35.7	27.1	70.4	35.7	3.1	15.4	23.7	53
7	180	36.7	27.1	79.3	36.7	3.2	15.8	23.1	58

The general p-h chart for air conditioning system is given by-

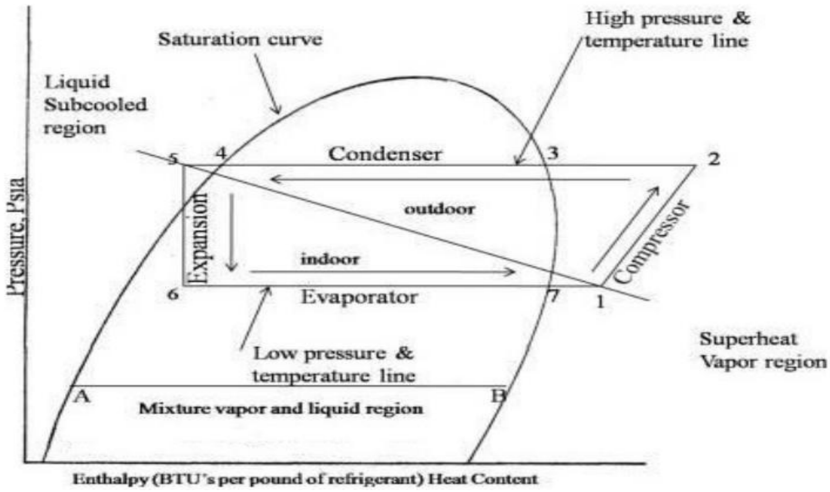


Figure 3.1: p-h chart

The graphs are drawn according to the respective values in the table for cold chamber, hot chamber, pressure and comparison of C.O.P of air and water.

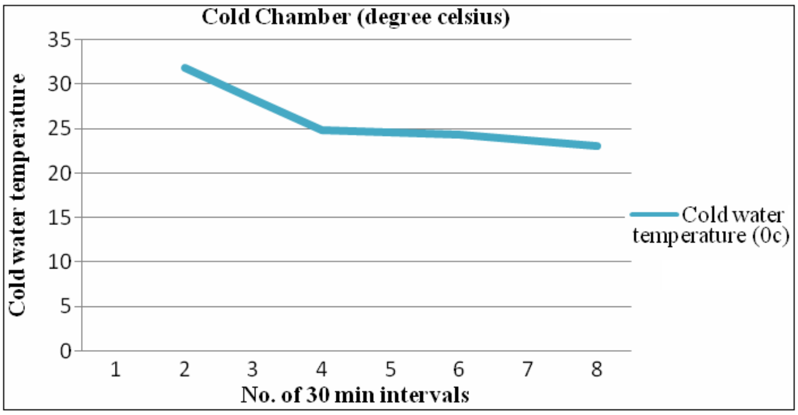


Figure 3.2: Cold chamber graph

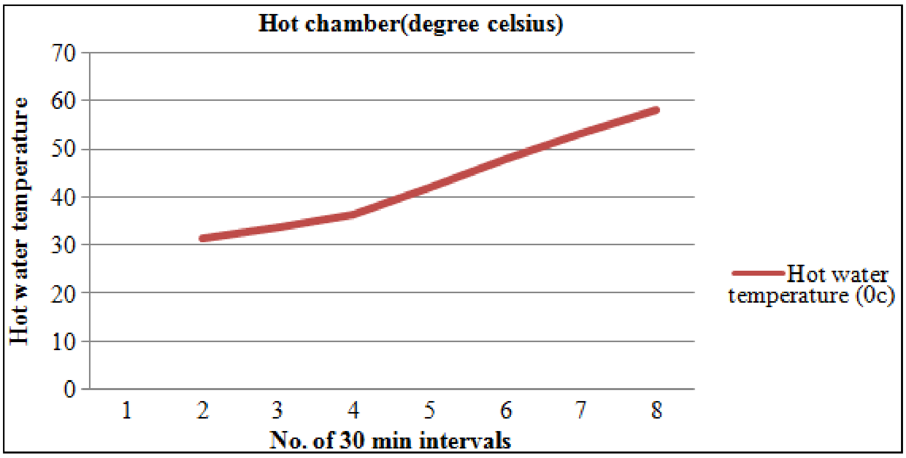


Figure 3.3: Hot Chamber Graph

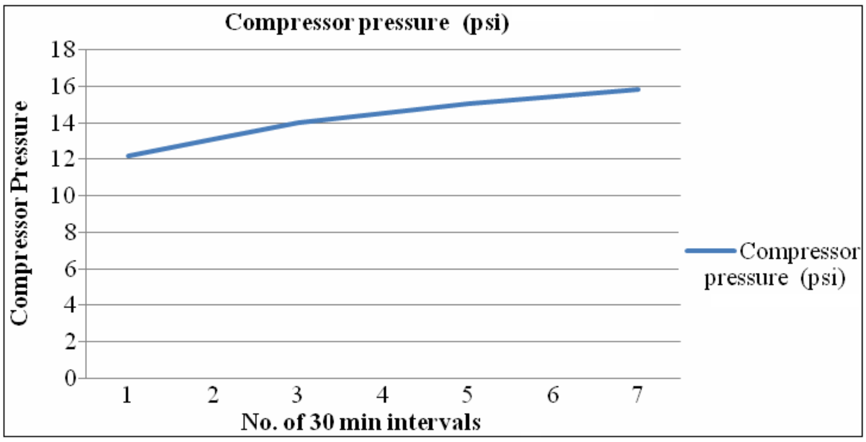


Figure 3.4: Compressor Pressure graph

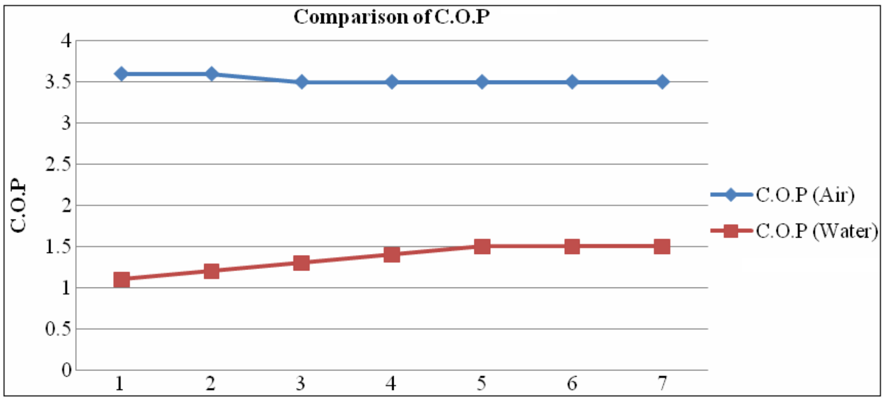


Figure 3.5: C.O.P graph

4. Final Assembly

5. Conclusion

The air conditioner cum water dispenser system was manufactured for air, water & air-water cycle combined. The air cycle provides good results with conventional optimum efficiency. The water cycle also predicts better results but then water cycle alone is not useful. Hence the combined air conditioner cum dispenser by utilizing conventional air-conditioning. The dispenser gives required efficiency in terms of co- efficient of performance. Air conditioning can also be provided by a process called free cooling which uses pumps to circulate a coolant (typically water or a glycol mix) from a cold source, which in turn acts as a heatsink for the energy that is removed from the cooled space. Common storage media are deep aquifers or a natural underground rock mass accessed via a cluster of small-diameter boreholes, equipped with heat exchanger. Some systems with small storage capacity are hybrid systems, using free cooling early in the cooling season, and later employing a heat pump to chill the circulation coming from the storage. The heat pump is added because the temperature of the storage gradually increases during the cooling season, thereby declining its effectiveness.

The greatest supporting advantage to our project is that Air Conditioning Systems are very common and are now used in almost all the areas viz

i. Public Commercial Malls
ii. Office Buildings
iii. Residential Houses
iv. Public Transport like Train, Bus etc.,
v. Hospitals; and many more.

This increases the area of application of our project. On one hand where Air Conditioners are basic features of any infrastructure or locomotive, providing hot and cold water for various purposes is one of the common features.

1) In huge commercial malls, there are large numbers of air conditioners used to comfort the public. Also they have to provide hot and cold water for various applications. This can be economically achieved by application of our Air Conditioning cum Water Dispensing system, and hence hot and cold water demands can be economically met using our experimental setup.
2) In residential infrastructure, air conditioning systems are widely used and now become a cheap luxury. By applying the project apparatus, hot water demands for drinking, cooking, bathing etc. and cold water for other miscellaneous purposes can be economically met using the apparatus. A proper filtration unit has to be installed before consuming it.
3) In official building, there are large numbers of air condition system used. The demand for hot and cold water can be hence met economically with the use of our project.
4) Public transport like buses are now being updated to air conditioned for improving the service and the travellers journey. With our project apparatus, now hot and cold water can be provided for various purposes.

Water is a primary requirement which is found almost everywhere. Now with the application of our project, hot and cold water can be easily obtained without using different apparatus for controlling the temperature of water. Hot or cold water can be consumed for drinking with proper filtration unit obtained before water disposal. Apart from using the air conditioning system cum water dispenser you can also save electricity. The electricity consumption amount of heating or cooling of water when you switch on the Ac switch is equal to amount of electricity used by a single Ac. Hence we can save electricity.

6. Acknowledgement

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