ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANIZATION OF ISLAMIC CONFERENECE (OIC)

Project Name:

DESIGN, CONSTRUCTION & TESTING OF A ½ TR R-12 BARE-TUBE FORCED CONVECTION EVAPORATOR FOR COOLING AIR

SUPERVISED BY

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Abstract

The title of my project is **DESIGN, CONSTRUCTION & TESTING OF A ½ TR R-12 BARE-TUBE FORCED CONVECTION EVAPORATOR FOR COOLING AIR.**

The goal of this presentation is to design and construct a bare tube forced convection evaporator and testing with half TR R-12 refrigerator for cooling air.

The procedure involves by designing an evaporator and set the evaporator to the refrigeration system and take the data.

By experimental analysis we found C.O.P which is satisfactory. So our project work is successful.

Keywords: Refrigerant, C.O.P, HRR, tonn, Bare tube, Overall Heat transfer co- efficient.

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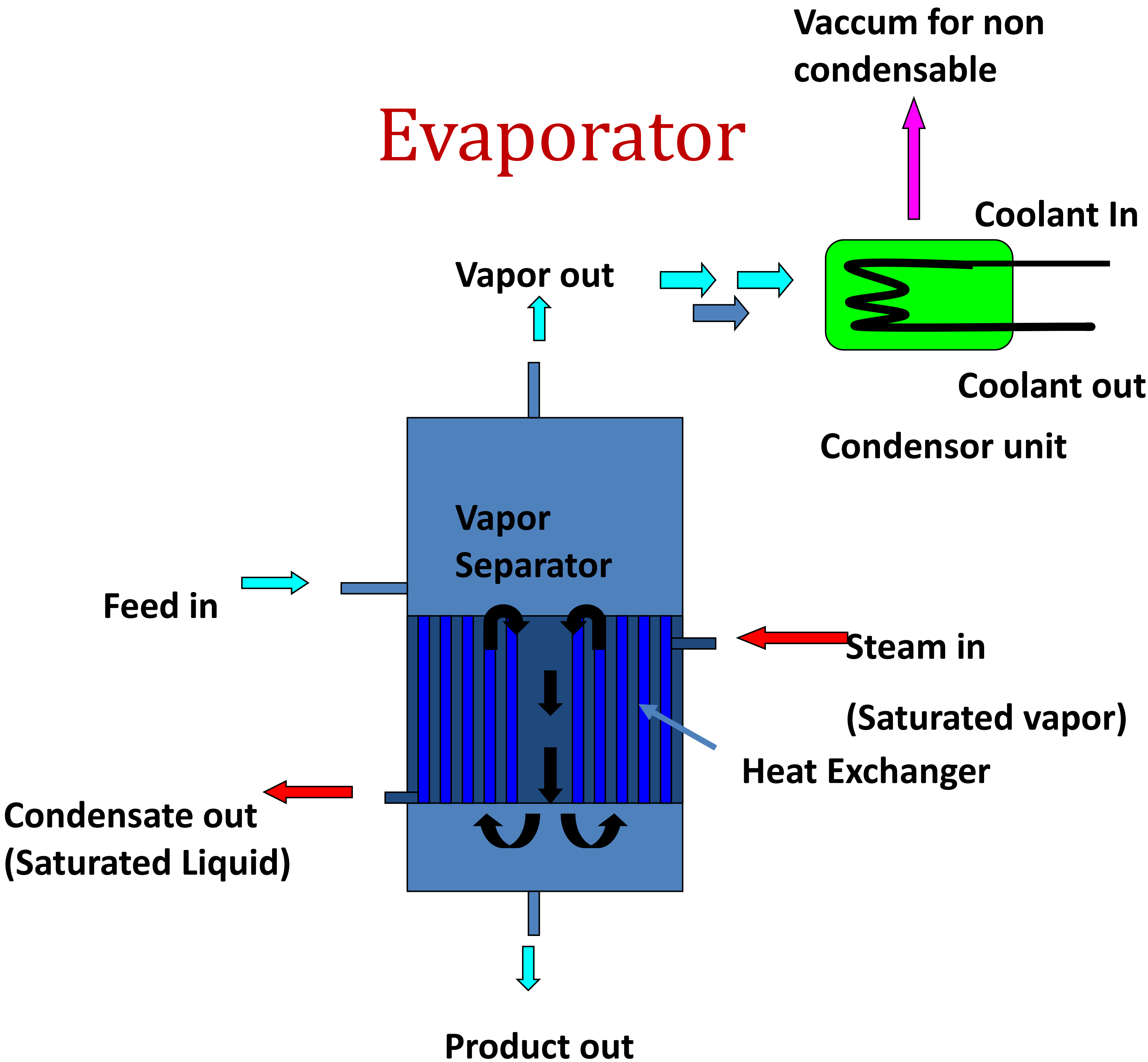
Introduction

Refrigeration is a process by which a system pumps out heat from within the system by employing a cycle by doing work. The construction of a refrigeration system involves lab activities such as fabrication, filling, welding, drilling etc. Initially the required material, machinery and devices had been listed and purchased. Then a spacious and secure open space was selected where the system is to be constructed. Next the system components were assembled together and they were all connected and joined to form the complete and working refrigeration system. The system needed to be sealed and made leak proof. Then the refrigerant was to be charged into the system. And finally the test run was made and the system was found to be working well. The system data was recorded and analyzed.

The refrigeration system had the following main components which had to be connected together:

1. Compressor
2. Condenser
3. Capillary tube
4. Evaporator

There were other important external components which were to be fitted to the system arrangement separately and they will be discussed later accordingly.


Vaccum for non condensable
Evaporator
Coolant In
Vapor out
Coolant out
Condensor unit
Vapor Separator
Feed in
Steam in
(Saturated vapor)
Heat Exchanger
Condensate out
(Saturated Liquid)
Product out

An evaporator is essentially a heat exchanger in Refrigeration system which a liquid is boiled to give a vapour, which also acts as a low pressure steam generator.

In Bangladesh and worldwide, refrigeration systems of capacities below 1 ton use only R-12 refrigerants.

The evaporator is very similar in construction to a condenser. An evaporator will have a serpentine, tube and fin or parallel type construction. The function of an evaporator is to provide a large surface area to allow the warm often humid air to flow through it releasing its heat energy to the refrigerant inside. The refrigerant by this time will have just had a large pressure and temperature (Fig.) drop coming through the expansion/fixed orifice valve causing it to want to boil and just requiring the heat energy to do so. The evaporator absorbs the heat energy from the air flowing over its surface. The energy is transferred and the refrigerant reaches saturation point. At this point the refrigerant can still absorb a small amount of heat energy. The refrigerant will do so and become superheated. The superheated refrigerant will then flow to the compressor.

The evaporator is extremely cold at this stage and any moisture in the air flowing through the evaporator will adhere to the evaporator's surface. The water droplets on the surface help clean the incoming air by trapping dirt and foreign particles.

Working Base

This project derives from a previous project named “Design and Construction of a 500 Watt Refrigeration System” by Md. Mustafizur Rahman and Saiham Siraj of Islamic University of Technology in 2011.

Rahman and Siraj’s project sought to develop a refrigeration system that employed R-22 fluid as refrigerant to produce a cooling effect of 0.5 kW cooling capacity using a R-12 compressor. After building the system, they analyzed it and obtained desired satisfactory results within expectation.

We are using their system as standard and making a new evaporator and testing with ½ tonn cooling effect using a R-12 compressor.

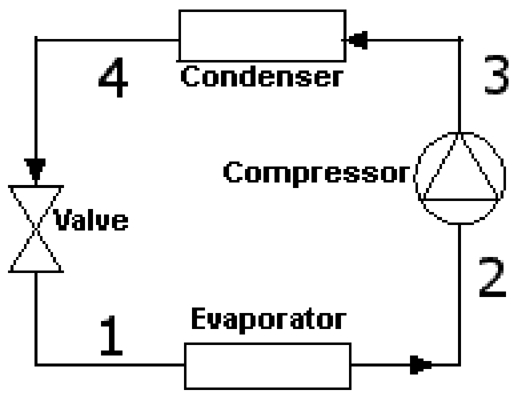
Purpose of achievement

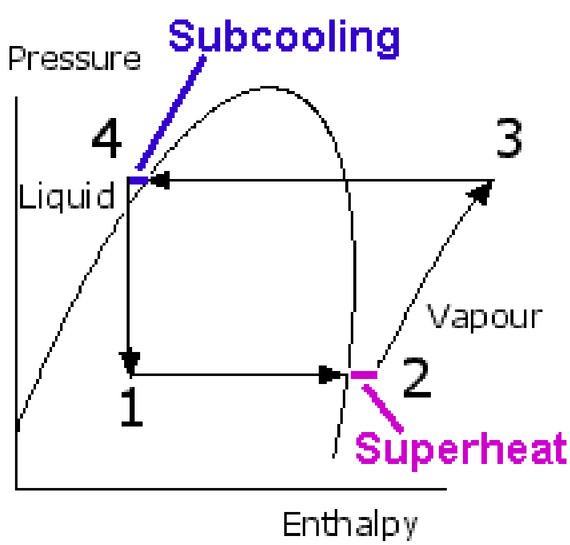
The procedure will consist of:

- Design a bare tube forced convection evaporator
- And then construct it
- Running the system with R-12 refrigerant
- Recording observations and calculating performance parameters for R-12 refrigerant

Working Principle

The vapour compression system is the most important refrigeration system. A schematic diagram of the vapour compression refrigeration system and corresponding pressure- enthalpy diagram is shown below:





The system consists of 4 components and the cycle consists of 4 different processes. As illustrated above.

The system components are:

- Compressor
- Condenser
- Expansion Device
- Evaporator

The cycle processes consist of:

- Process 1-2: Heat Absorption at Constant Pressure
- Process 2-3: Isentropic Compression
- Process 3-4: Heat Rejection at Constant Pressure
- Process 4-1: Isenthalpic Expansion

The refrigerant gas coming from the evaporator is compressed by the compressor to a high pressure. By being compressed the gas gets superheated and then the gas is cooled and condensed in a condenser with the help of cooling water or atmospheric air. The magnitude of high pressure required in the condenser depends on the properties of particular refrigerant and thus it is different for different refrigerants. After being condensed at high pressure, the condensate becomes a saturated liquid at that pressure. In this process the liquid gets practically evaporated and becomes a wet vapour at low pressure. The low pressure wet vapour then enters an evaporator where it further evaporates by absorbing heat from the surroundings. Absorption of heat from the surroundings takes place at low temperature which corresponds to saturation temperature at the evaporator is the refrigeration effect of the plant. After evaporation the dry saturated vapour is again sucked by the compressor. Thus the cycle goes on.

The compressor has to be driven either by electric motor or an engine, requiring work input to the system. The condenser rejects heat from the system to the surroundings through the cooling medium. Heat is received by the system, to the surroundings in the evaporator.

DESIGN

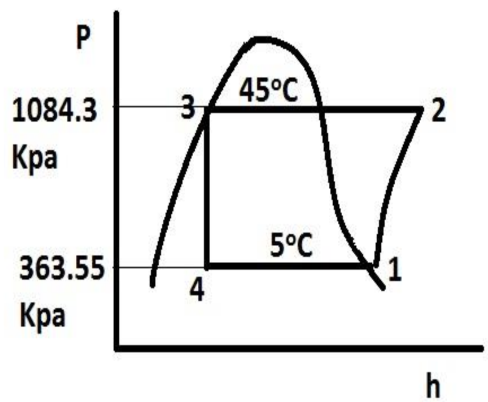
Design Steps:

- First we have to calculate heat transfer co-efficient h
- Then we have to calculate overall heat transfer co-efficient U_o
- Then we have to calculate area of evaporator A_e
- Finally we have to calculate length of tubes and no. of tubes.

Design Calculation

We know, 1 tonn = 3.517 KW

Q_e = ½ ton = 1.76 KW



For R-12,

h_1= 353.60 KJ/Kg

$h_3 = h_4$ = 243.659 KJ/kg

For 5^o C,

$h_{fg} = h_1 - h_4$= 109.941KJ/kg = 109941KJ/Kg

From Moliar diagram, h_2=373KJ/Kg

Density, ρ= 1/v_f = 1/.72438=1.3805Kg/l=1380.3Kg/m^3

The conductivity k and viscosity μ of R-12 liquid at 5^{o}C,

K=.0766 W/m.K

μ= .0002565 Pa.S

We know,

h_o= .725$(g\rho^2 h_{fg} k^3/\mu \Delta tND)^{1/4}$

= 1648.156W/m^2.K

The conductivity of copper is 390W/m.K and the resistance of tube is,

xA_o/KA_m=.000002913m^2K/W

Fouling factor, $1/h_{ff}$=0.000176m^2K/W

The velocity of water through the tube is 2m/s (assumed)

For 10^{o}C water,

μ=0.00131 Pa.S

ρ= 1000Kg/m^3

K=0.573W/m.K

C_p=4190J/Kg.K

The Reynolds number is,

R_e= 2(6.35E^{-3})(1000)/0.00131=9694.66

The Prandtl number is

P_r=4190X.00131/.573=9.6

The Nusselt number is

N_u=0.023($9694.66^{0.8}$)($9.6^{0.4}$)

=87.87

Heat transfer co-efficient on inside of tube,

h_i=(.573/6.35E^{-3})X87.87

=7929.45W/m^2.K

Now overall heat transfer co-efficient,

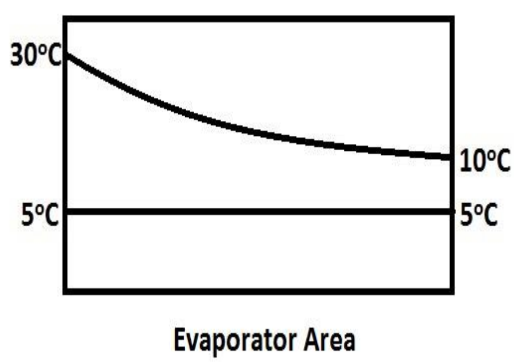
$1/u_o=1/h_o+xA_o/kA_m+A_o/h_{ff}A_i+A_o/h_iA_i$

U_o=993.195W/m^2.K

$(\Delta t)_{ln}$=(30-5)-(10-5)/ln(30-5)/(10-5)

=12.4^{o}C

Tube dia=3/4$''$ Nominal



ID=0.423 inches=1.074cm

OD=0.675 inches=1.715cm

$Q_e=A_e x U_e X(\Delta t)_{ln}$

1.76X1000=A_eX993.2X12.4

$A_e = n\pi D_o L$

=17.6X1000/993.2X12.4

= $14.29m^2$

L=14.29/36X0.01715X3.14

=11.06m

1 pass length = 30cm

Let,

Evaporator area=30cmX30cm

With 4 pass

Let, Spacing between tubes=3.4cm

No. of tubes, n=3X30/2.5

=35.5=36

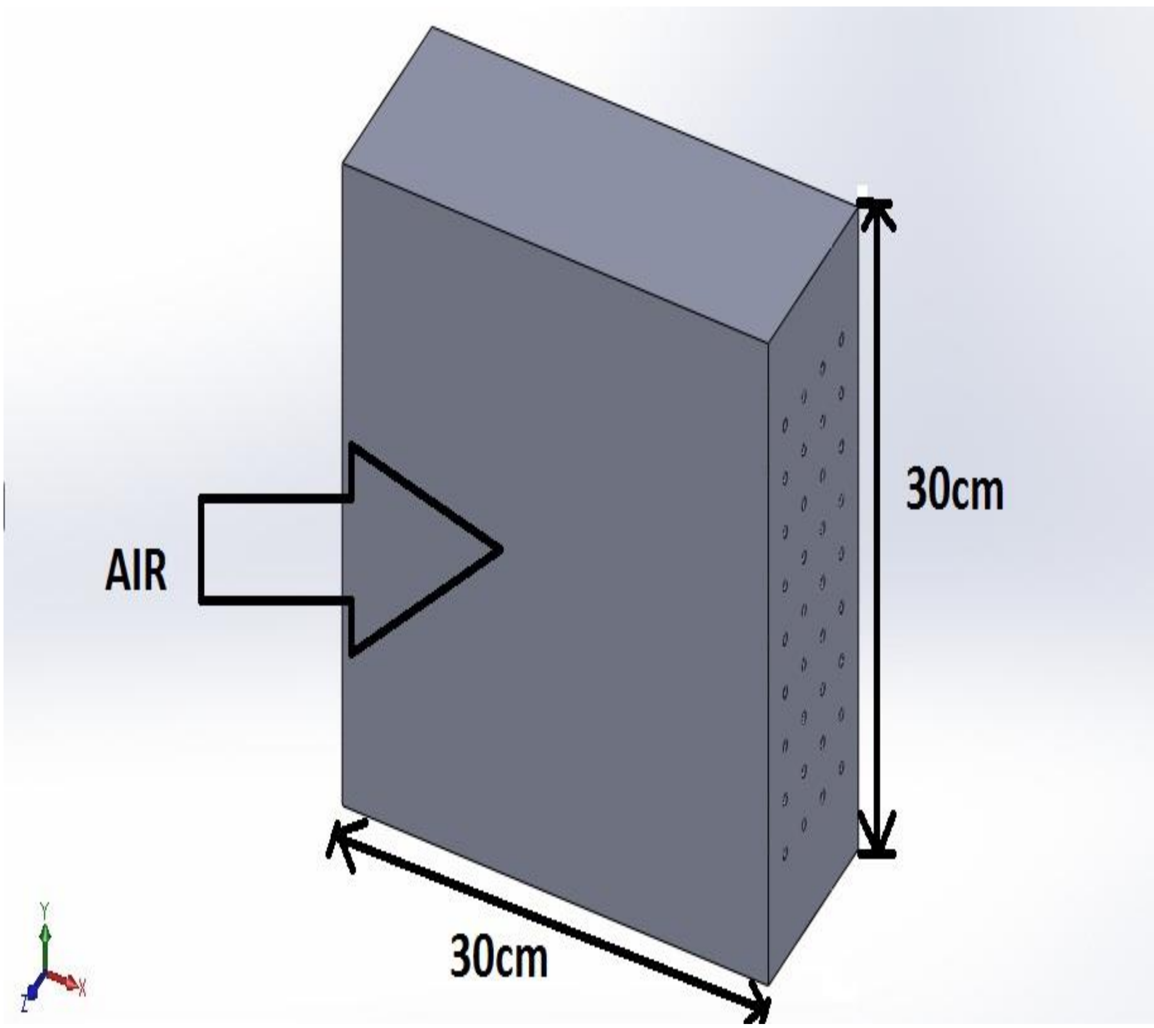
Length of 36 tubes = 30X36=1080cm

=10.8m

Total length=11.06X1.50

=16.5m

SOLID WORK DESIGN



Budgeting & Purchase

From the design and calculation that we concluded in the previous semester, and as we know the required dimensions and parameters for the system to be constructed, we estimated the materials and machinery requirements as:

- Copper tube 3/8’’
- U-Bend 180
- Refrigerant R-12 - 3 kg
- Fittings
- Brazing Rod
- Miscellaneous

Items already available at the lab were identified, and hence a budget was estimated from the above list for the items that needed to be purchased, and we went ahead with the purchase of those items from the nearest shop. Thus with all the above items at hand we were ready for the construction work.

Assumption & Facts

We assumed the following parameters and conditions for our design purpose:

- Compressor Isentropic efficiency 85%

  As the compression process is not actually isentropic due to various losses, we assumed the common isentropic efficiency of compression i.e. 85%

- Motor efficiency 75%

  As the conversion of electrical energy to mechanical energy by a motor is not 100% efficient we assumed a common motor efficiency of 75%.

- Forced Air cooled Evaporator & Condenser

  Our system is not so big that water cooled condenser is required, thus we chose air cooled one. Also we chose forced convection for both components because otherwise the length of the condenser and evaporator tubes will be too long and thus the sizes will be very big.

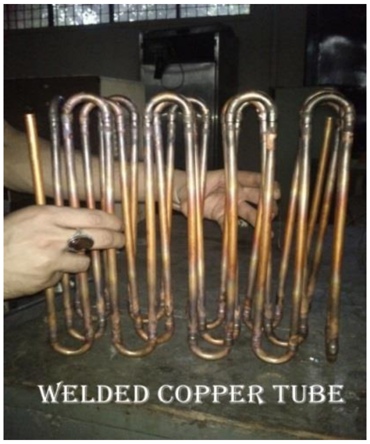
- Air density is assumed to be 1.22kg/m^3

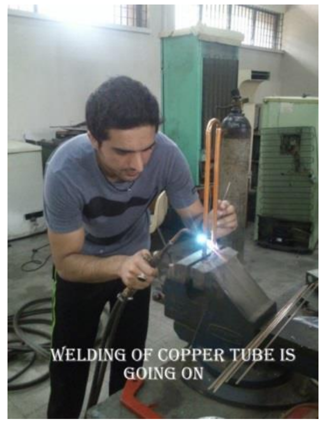
Construction Procedure

At first we accommodate a spacious table where the evaporator to be established. It is made sure that the table is near an electric socket and is safe and secure. According to requirements, for making an evaporator of 16.5m, we had to cut 30 pieces of copper tube each 30cm length. Then we joined together by u-bends and brazing them together to make the evaporator. Then they were fixed in certain patterns by welding thin wires between tube lines. Now that the evaporator have been finished they are fitted in their own frame, which have been fabricated from separate metal sheets and are held vertically erect on the table setup and the frame is firmly screwed to the table. Next the fan blades and motor are assembled to form the two external cooling fans for forced convection evaporator and they are placed at a distance from the evaporator and screwed to the table base.

Then join the evaporator with the compressor and complete the system. A charging line is drawn from the compressor to facilitate refrigerant charging. Two pressure gauges are connected, one in the suction line and the other in the discharge line. We tested the circuit for leaks and fortunately there was none. Finally the electric power wires of the fans and the compressor were connected together to form the main power line and it was made ready to be connected to the power mains.

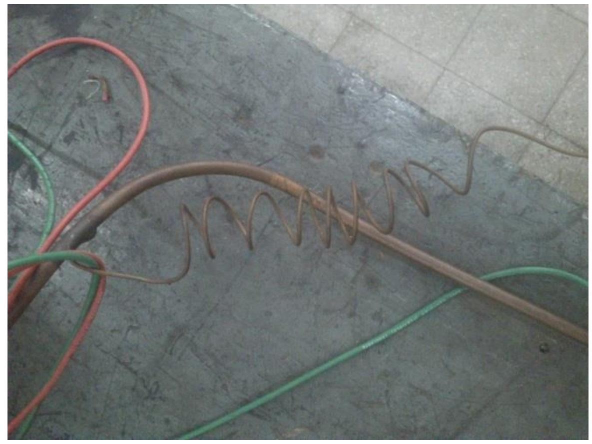
Project Outlook





Evaporator

Condenser



Compressor **Capillary Tube**

The Complete System

Operation & Data Collection

Using a pump we produced vaccum inside the system to suck out any unwanted substances and air, and to make it ready to be charged with refrigerant. R-12 refrigerant was charged. The system was started and the test run was commenced. After some time the condensing and evaporating pressure became stable and they were found to be within the safe range, also cooling was obtained. Thus we concluded that the system was stable, safe and ready to operate.

Next we began with the system operating with the R-12 refrigerant, and some time was allowed till the system reached steady state. Then the following observations of data were made using thermometers, thermocouples, pressure gauge and anemometers from the relevant points and recorded as:

- Mean Air Velocity over the condenser, v=2.74m/s
- Entering Air Temperature, t_{a1} =31.5^oC
- Leaving Air temperature, t_{a2} =32.2^oC
- Fan Diameter, d=0.3048m
- Temperature at suction to compressor, t_2 =27.3^oC
- Temperature at compressor exit, t_3 =85.5^oC
- Temperature at condenser outlet, t_4 =34.3^oC
- Evaporator pressure, P_1 =15 PSI =103.425Kpa
- Condenser Pressure, P_2 =185 PSI=1275.575Kpa
- Temperature of Evaporator outlet =27.5^oC
- Temperature of Evaporator inlet =29.5^oC

Calculation

From the observation data obtained during the operations of the R-12 system. Thus we can calculate:

- **FOR R-12**

Mean Air Velocity over the condenser, v=2.74m/s

Entering Air Temperature, t_{a1} =31.5^oC

Leaving Air temperature, t_{a2} =32.2^oC

Fan Diameter, d=0.3048m

Fan Area, A= $\pi/4\ d^2 = \pi/4(.03048)^2 = 0.073m^2$

Temperature at suction to compressor, t_2 =27.3^oC

Temperature at compressor exit, t_3 =85.5^oC

Temperature at condenser outlet, t_4 =34.3^oC

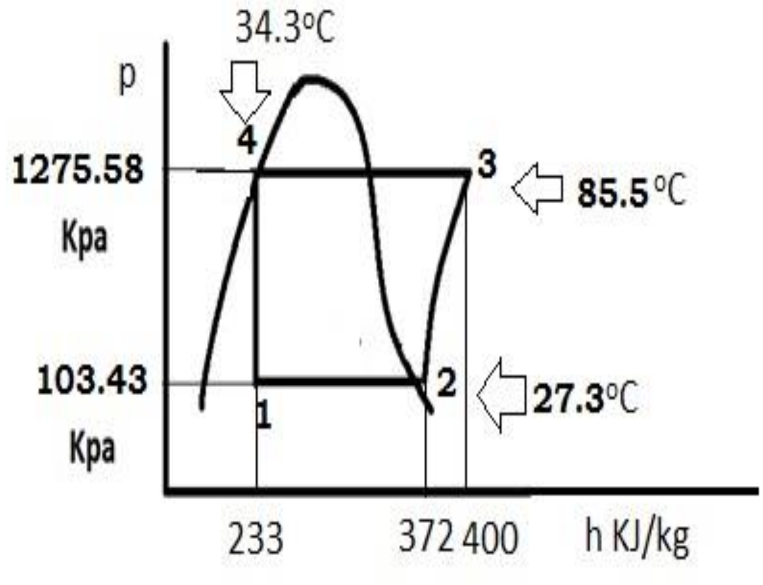
Evaporator pressure, P_1 =15 PSI =103.425Kpa

Condenser Pressure, P_2 =185 PSI=1275.575Kpa

Temperature of Evaporator outlet =27.5^oC

Temperature of Evaporator inlet =29.5^oC

From the observed data we can draw the following P-h diagram,



From the p-h diagram and table for R-12 the following values of enthalpy are moted down:

- $h_1 = h_4 = 233$ KJ/kg
- $h_2 = 372$ KJ/kg
- $h_3 = 400$ KJ/kg

As heat rejected in the condenser must be equal to the heat absorbed by the air passing over it,

$$m_a \Delta t_a C_{pa} = m_r (h_3 - h_4)$$

Refrigerant Mass flow Rate,

$m_r = 0.24X1.005X0.7/(400-233)$

$=1.01X10^{-03}$ kg/s

Cooling Effect,

$Q_e = m_r(h_2 - h_1) = 1.01X10^{-03} (372-233)$

= 0.14 KW

Heat Rejected in the Condeser,

$Q_c = m_r(h_3 - h_4) = 1.01X10^{-03}(400-233)$

=0.17 KW

Compressor Work,

$W_c = m_r (h_3 - h_2) = 1.01X10^{-03}(400-372)$

=0.028 KW

Coefficient of Performance,

COP = Heat Absorbed/ Compressor Work

$= Q_e / W_c = 0.14 / 0.028 = 5$

Heat rejection ratio,

HRR= Heat Rejected/Heat absorbed

$= Q_c / Q_e = 0.17 / 0.14 = 1.21$

From the calculated results we tabulate the following parameters:

Refrigerant	Mass Flow Rate of Air, m_{a}, kg/s	Mass flow rate of Refrigerant, m_{r}, kg/s
R-12	0.24	$1.01X10^{-03}$

Refrigerant	Condensing Pressure, KPa	Evaporating Pressure, Kpa	Condensing Temp., ^{o}C	Evaporation Temp., ^{o}C
R-12	1275.575	103.425	50	27.5

Refrigerant	Ref. Capacity Q_{e}, KW	Heat Rejected, Q_{c}, KW	Work of Compression W_{c}, KW	C.O.P	HRR
R-12	0.14	0.17	0.028	5	1.21

Results

By using energy balance in the condenser mass flow rate of refrigerant was found. There may be little error but acceptable. Work of compression is less for refrigerant R-12. Refrigerant capacity is 0.14 KW for refrigerant R-12 and C.O.P. value is 5 for R-12.

Conclusion

A BARE-TUBE FORCED CONVECTION EVAPORATOR FOR COOLING AIR using ½ tonn R-12 as the refrigerant was designed, built and tested. A commercially available small-scale compressor was installed in the system. After an extensive experimental investigation we found satisfactory cooling and coefficient of performance. After the experiment it can be said that in household refrigeration R-12 can be used. As we get sufficient cooling with good coefficient of performance we can say that our design was satisfactory.

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