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DESIGN AND CONSTRUCTION OF LITHIUM BROMIDE - WATER BASED SINGLE EFFECT SOLAR VAPOR ABSORPTION AIR CONDITIONING SYSTEM

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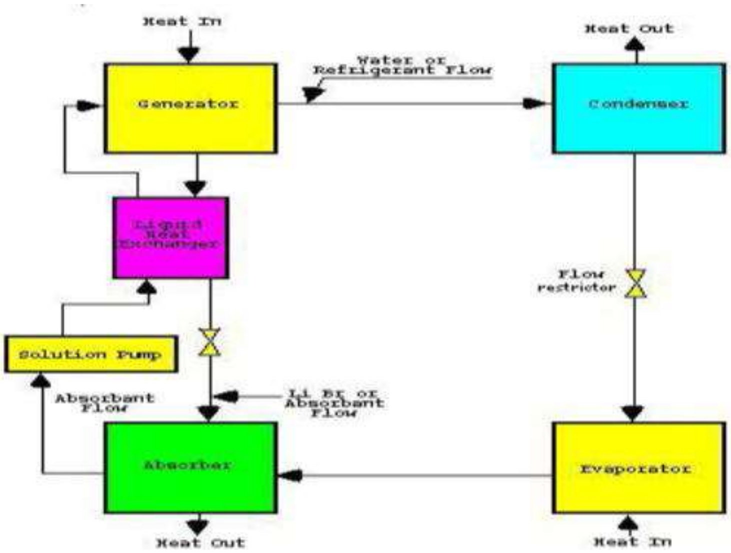
ABSTRACT

The objective of this work is to design and construct a lithium bromide–water ($LiBr-H_2O$) based single effect solar vapor absorption air conditioning system up to 1TR capacity**.** Absorption air conditioners are machines which produce cooling by using heat energy and have no moving parts. The various stages of design are presented including the design of the evaporator, absorber, solution heat exchanger, generator and condenser. The major problem faced during the design stage was the calculation of the heat transfer coefficient (U-value) of the various components. Single-pass vertical-tube heat exchangers have been used for the absorber and for the evaporator. The solution heat exchanger was designed as a single-pass annulus heat exchanger. The condenser and the generator were designed using horizontal tube heat exchangers. The condenser handles pure water vapor and adequate equations exist for the determination of the U-value. In design the area of all the major components of the system is calculated on the basis of enthalpy parameters at different points in the system. Water is used as the refrigerant in the system and Lithium bromide as absorbent in the physic-chemical process. The various stages of refrigeration system are presented including the design of the evaporator, absorber, solution heat exchanger, generator and condenser and finally COP is calculated.

KEYWORDS: Single effect, solar, vapor absorption, component design, LiBr-water, C.O.P..

INTRODUCTION

Absorption machines are thermally activated and for this reason large amount of input (shaft) power is not required. In this way where power is expensive or unavailable or where there is waste, gas, geothermal or solar heat available, absorption machines provide reliable and quiet cooling .A number of refrigerant-absorbent pairs are used for which the most common is water-lithium bromide . Lithium bromide-water chillers are available in two types, the single and the double effect. The single effect absorption chiller is mainly used for building cooling loads, where chilled water is required at 6-7 ^{0}C. The coefficient of performance (COP) varies to a small extent (0.65-0.75) with the heat source and the cooling water temperatures. Single effect chillers can operate with hot water temperature ranging from about 80^{0}C to 120 C when water is pressurized In a basic absorption cycle low pressure refrigerant vapor is converted to a liquid phase (solution) at same pressure. This conversion is made possible by the vapor being absorbed by a secondary fluid called absorbent. In the cycle shown in figure water vapor evaporates and separates from aqueous LiBr solution in generator, and increases the concentration of LiBr in solution. For this process heat is supplied from external source. At the same pressure, the water vapors from generator are condensed in condenser and this condensed water is throttled to the evaporator at low pressure. Due to reduced pressure, the water change phase and evaporate by taking latent heat of vaporization in the evaporator at chiller temperature and generates the cooling effect. At same pressure, the vapors from evaporator are absorbed by LiBr-aqueous solution supplied form generator having higher concentration of LiBr. The absorption of water vapor reduces the concentration of LiBr in aqueous solution; this solution is then passed to generator through pump at higher pressure. A solution heat exchanger is used between absorber and generator to increase the efficiency of system. This low grade energy can be obtained from solar panel. The cooling water is circulated in the condenser to change the phase of water from vapor to liquid. The papers discuss about the complete theoretical calculations and design the system as per the theoretical calculations and experimentally validate the system with reducing the temperature.



METHDOLOGY

Design of the vapor absorption system is carried out as per the following steps. The steps includes –

1. Selection of the Li-Br vapor absorption system component parameters.
2. Determination of Generator and absorber LiBr- Water solution concentration to avoid crystallization.
3. Determination of enthalpy values corresponding to generator & evaporator pressure from Pressure – Enthalpy chart of LiBr .
4. Calculation of mass flow rates of strong and weak solutions.
5. Determination of heating and cooling load on generator and evaporator.
6. Determination of work required for solution pump.
7. Determination of the mass flow rate of cooling water circulation.
8. Carrying out design of the different components of vapor absorption system such as Generator, condenser, absorber, evaporator, heat exchanger and solar collector as per the values obtained during steady flow analysis.
9. Preparation of the component drawings as per the specifications.
10. Selection of the material as per the requirement of the thermal and chemical properties of the vapor absorption system & need of a system.
11. Manufacturing of the different system components as per working drawings.
12. Assembling of the different system components.

DESIGN OF A SINGLE-EFFECT LITHIUM BROMIDE – WATER SYSTEM

Design of Generator

Generators of absorption refrigeration machines are usually of the flooded type where the tubes carrying the hot fluid are totally immersed in the cycle working solution.

The design data are

Qg = l.21 kW, Tg = 75°C,Mws=13.32 kg/h, Tss = 75°C, Xss= 59.6%,Mss=11.82 kg/h, Tws=51.5°C, Xws = 52.9%, T_{hwin} = T_g+ 5°C = 80°C, $T_{hw\ out}$ = T_g+ 3°C = 78°C, $T_{chw\ avg}$ = 79°C,

The properties of hot water at 79°C are

€w= 971.6 kg/m3,µw=0.354 $\times 10^{-3}$ kg/m-s,kw= 0.666 W/m-°C,Cpw=4.195 kJ/kg-°C, Prw =2.22

The properties of Li-Br-water solution at 75°C and 59.9% are

€ss= 1670 kg/m^3, µss =2. 95$\times 10^{-3}$ kg/m-s, Cpss =1.905 kJ/kg-°C, kss =0.419 W/m-°C

Specifications for Generator

Sr.No.	Parameter	Dimensions
1	Inner diameter of tube	11.96 mm
2	Outer diameter of tube	13.96 mm
3	Material of tubes	Copper
4	Number of tubes	12
5	Tube orientation	Horizontal
6	Length of tubes	0.5 m
7	Length of shell	0.6 m
8	Thickness of shell	1.2 mm
9	Diameter of shell	40 cm
10	Material of shell	Stainless steel
11	Insulation of shell	Armaflux
12	Heating water in temp	80^0 C
13	Heating water out temp	78^0 C
14	Type	Single pass horizontal tubes. Strong solution flows over tubes & hot water inside tubes.

Design of Condenser

A shell and coil condenser is used where water vapor is condensing in the shell and cooling water inside the coil tubes. The design data are

Qc = l.058 kW, Tc = 32°C, Mw= 1.50 kg/hr Tcw in = 30^0 C, Tcw exit = 28^0 C, Tcw avg = 32^0 C

The properties of cooling water at 30 °C are

€w= 996.02 kg/m3,µw=0.815 $\times 10^{-3}$ kg/m-s,kw= 0.607 W/m-°C,Cpw=4.184 kJ/kg-°C Prw =5.61

The properties of saturated water refrigerant at 32 ^{0} C

€wr= 995.09 kg/m3, €vapor ref= 0.0272 kg/m3 µwr =0.765×10^{-3} kg/m-s Cp_{ss} =1.905 kJ/kg °C
kwr =0.622 W/m-°C. Hfg = 2435.2 KJ/kg

Specifications for Condenser

Sr.No.	Parameter	Dimmensions
1	Inner diameter of tube	11.96 mm
2	Outer diameter of tube	13.96 mm
3	Material of tubes	Copper
4	Number of tubes	12
5	Tube orientation	Horizantal
6	Length of tubes	0.334 m
7	Length of shell	0.6 m
8	Thickness of shell	1.2 mm
9	Diameter of shell	40 cm
10	Material of shell	Stainless steel
11	Insulation of shell	Armaflux
12	Heating water in temp	28^0 C
13	Heating water out temp	30^0 C
14	Type	Single pass horizontal tubes.

Design of Absorber

A shell and coil absorber of the falling film type is used in which the solution flows over the tubes and the cooling water inside tubes..

The design data are

Qa = l.094 kW, Ta = 37°C,Mss=11.82 kg/h, Tss = 51.5°C, Xss= 59.6%,Mws=13.32 kg/h, Tws=37°C, *Xws* = 52.9%

The cooling water properties at 34^{0}C are

€cw= 994.43 kg/m^3, µcw=0.706 ×10^{-3} kg/m-s, kcw= 0.623 W/m-°C, Cpcw=4.178 kJ/kg-°C
Prw =4.95

Solution properties at mean temperature of 44.25^{0}C & mean concentration of 57.4% are

€ss= 1650 kg/m3, µss =3.7×10^{-3} kg/m-s ,Cp$_{ss}$ =1.97 kJ/kg-°C ,k ss =0.426 W/m-°C.

Specifications for Absorber

Sr.No.	Parameter	Dimmensions
1	Inner diameter of tube	11.96 mm
2	Outer diameter of tube	13.96 mm
3	Material of tubes	Copper
4	Number of tubes	12
5	Tube orientation	Horizantal
6	Length of tubes	0.5 m
7	Lenth of shell	0.6 m
8	Thickness of shell	1.2 mm
9	Diammeter of shell	40 cm
10	Material of shell	Stainless steel
11	Insulation of shell	Armaflux
12	Heating water in temp	33^0 C
13	Heating water out temp	35^0 C
14	Quanity	1
15	Type	Single pass vertival tubes. Cooling water in tubes & solution over the tubes.

Design of Evaporator

A shell and coil evaporator of the falling-film type is used where water is chilled inside tubes and water liquid refrigerant evaporated outside tubes. The design data are

1. Qe = l kW, Te = 10°C, Mw= 1.50 kg/hr
2. Tchwin = 15^0 C, Tchw exit = 12^0 C, Tchw avg = 12.5^0 C

The properties of chilled water at 13.5°C are

€w= 999.35 kg/m3,µw= 1.185 ×10^{-3} kg/m-s, kw= 0.592 W/m-°C, Cpw=4.195 kJ/kg-°C Prw =8.4

The properties of water refrigerant at 10^0 C

€wr= 999.6 kg/m3, €vapor ref= 9.4×10^{-3} kg/m3 µwr =1.28×10^{-3} kg/m-s Cp$_r$ =4.199 kJ/kg-°C
kwr =0.587 W/m-°C.

Specifications for Evaporator

Sr.No.	Parameter	Dimmensions
1	Inner diameter of tube	11.96 mm
2	Outer diameter of tube	13.96 mm
3	Material of tubes	Copper
4	Number of tubes	12
5	Tube orientation	Horizantal
6	Length of tubes	0.5 m
7	Length of shell	0.6 m
8	Thickness of shell	1.2 mm
9	Diameter of shell	40 cm
10	Material of shell	Stainless steel
11	Insulation of shell	Armaflux
12	Heating water in temp	15^0 C
13	Heating water out temp	12^0 C

14	Quantity	1
15	Type	Single pass vertical tubes. Chilled water in tubes & Refrigerant over the tubes.

Design of Solution Heat Exchanger

For small capacity lithium bromide-water refrigeration units, solution heat exchangers are usually formed of closely spaced steel plates to combine low pressure drop and good heat transfer.

The design data are:
1. Qhe = 0.328 kW, Te = 10°C, Mw= 1.50 kg/hr
2. Tchwin = 15^0 C, Tchw exit = 12^0 C, Tchw avg = 12.5^0 C
3 Mws = 13.33 kg/hr, Xss = 59.9 % Tssin= 75 Tsse=57.5 Tss= 66.25
4 Mss =11.82 kg/hr Xws = 52.9% Twsin= 37 Twse= 51.03 Tws= 44.01

The properties of LiBr-water solution at 66.25°C and 59.9% are

ρ = 1670 kg/m3, μ =2. 95×10^{-3} kg/m-s,Cp =1.905 kJ/kg-°C, k =0.419 W/m-°C.

The solution properties at mean temperature of 44 ^{0}C & mean concentration of 52.9% are

ρ = 1650 kg/m3, μ =3.7*10^{-3} kg/m-s Cp =1.97 kJ/kg-°C k =0.

Design of Flat plate solar collector

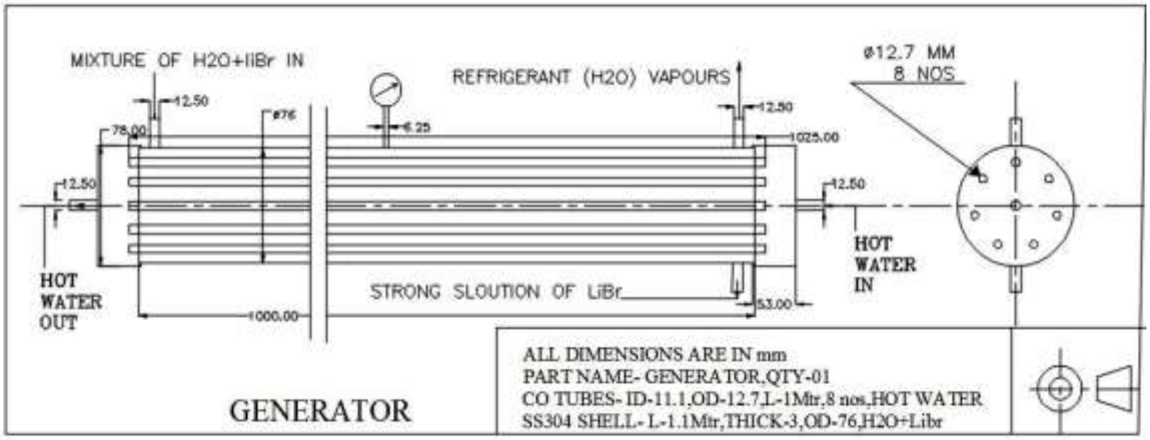
Flat plate collector is an insulated weather proofed box containing a dark absorber plate under one or more transparent or translucent covers.

Calculations of solar water heater,

Energy absorbed by the collector plate is given by Qu= K × S × A
Where,
K=efficiency of collector plate (assume k=0.70)
S=average solar radiation falling on Kolhapur=516 W/m2
A=Area of collector plates
Qg = 1.21 KJ/ sec = 1210 J/s
Hence approximate area of the collector plates required for providing this much amount of energy
= 1210 / (750× K)
= 1210 / (750 ×0 .7)
= 2.30 m^2 (approx)
Total Area of collector plates
A = 2.30 m^2
Solar collector area = 2.30 m^2
The projected area = A * cosϕ = 2.30 * cos(40) = 1.76 m^2

CONSTRUCTION OF THE UNIT

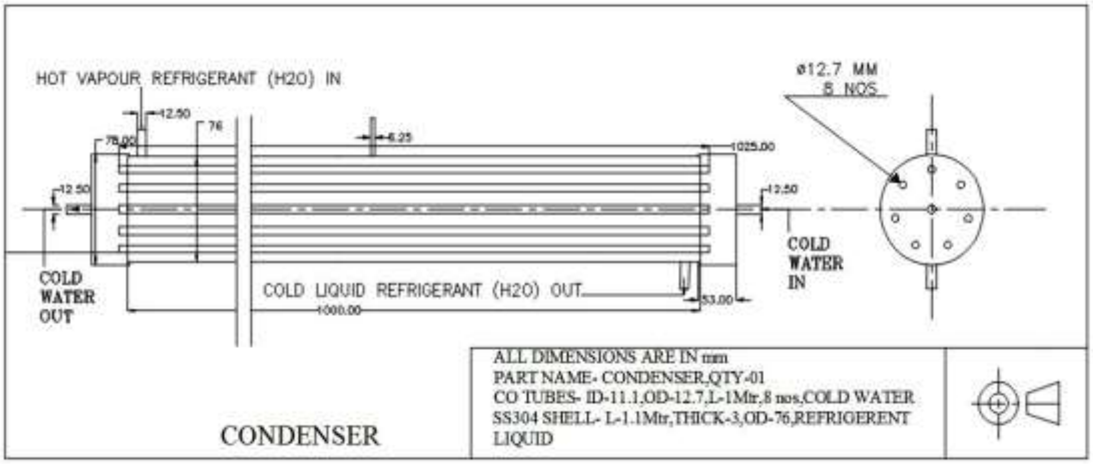
Manufacturing of Generator



As shown in above fig. the hot water will come inside from right side of the generator, and will pass through 8 copper tubes towards left said. Mean while the liquid mixture of LiBr-H_2O, will enter in the shell from top side, and will leave the shell at right side. In which the refrigerant will be converted in the vapors and will send to the condenser for condensation process, from top right side of shell. The hot LiBr will send out as a strong solution, at the bottom right side of the shell, towards absorber through heat exchanger. Bellow, actual image is shown of generator during manufacturing.

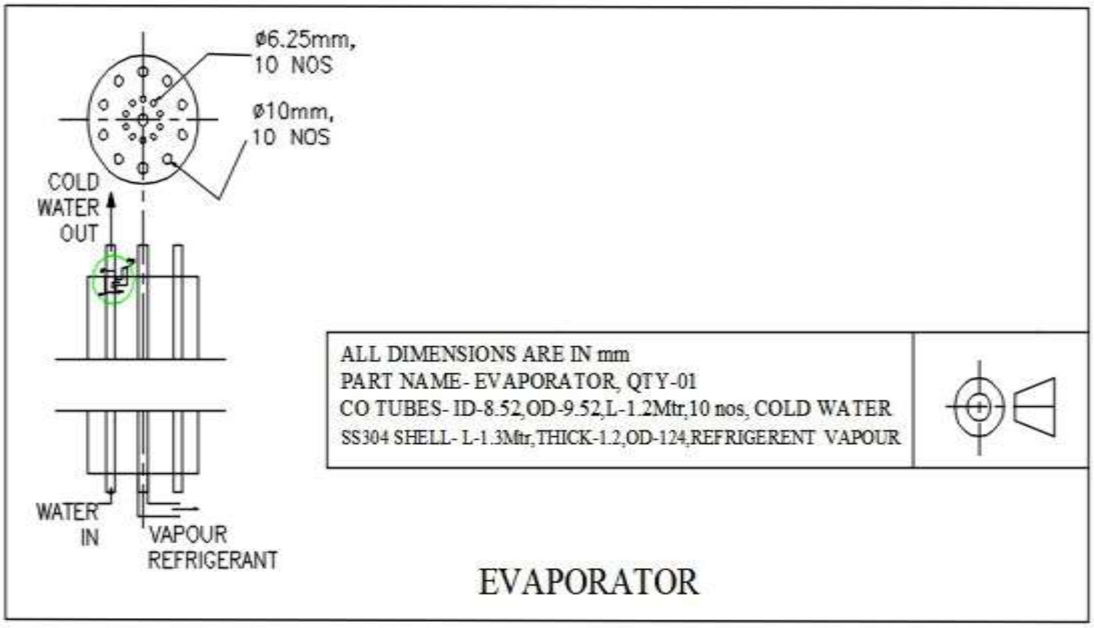
Manufacturing of Condenser

As shown in above fig. the normal water will come inside from right side of the condenser, and will pass through 8 copper tubes towards left side. Mean while the refrigerant vapors, will enter in the shell from top side, and will leave the shell at right side. In which the refrigerant will be converted in the condensate and will send to the capillary tubes for reduction in pressure, from bottom right side of shell. Condensate before passing towards capillary tube, it is passed through flow meter for flow measurement. Bellow, actual image is shown of condenser during manufacturing. Side view of condenser is also shown above which contains 8 numbers of copper tube, through which normal water will pass and will take heat from vapors refrigerant, and will increase its own temperature.



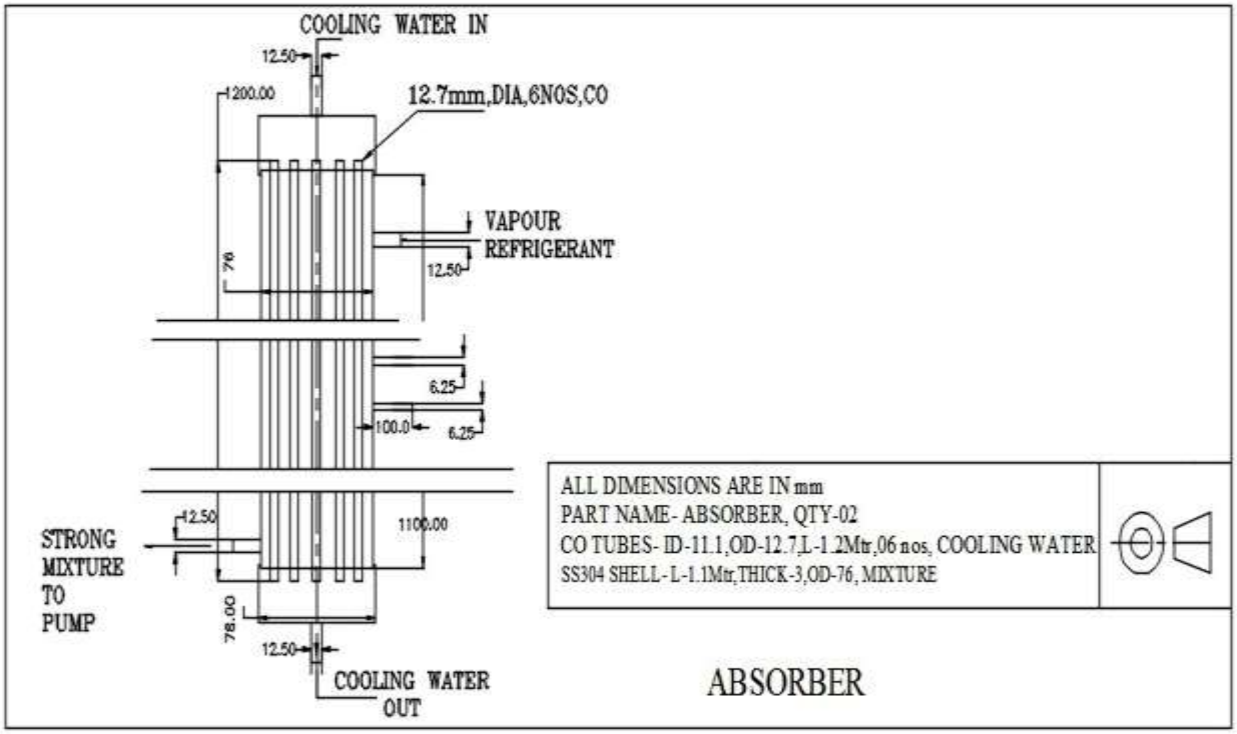
Manufacturing of evaporator

As shown in above fig. the normal water will come inside from top side of the evaporator, and will pass through 10 copper tubes towards bottom side. Mean while the cold refrigerant liquid, will enter in the shell from top side, through capillary tubes, and will leave the shell at bottom side, but during this process the cold vapours of refrigerant will be absorbed by the absorber. Bellow, actual image is shown of details section of top part evaporator and evaporator during manufacturing.



Manufacturing of absorber

As shown in above fig. the normal water will come inside from bottom side of the absorber, and will pass through 06 copper tubes towards top side, by increasing its own temperature. Mean while the cold refrigerant vapors will be absorbed, through evaporator. That vapors will be converted into the liquid and will be added into the LiBr. This mixture will be send to the generator through heat exchanger. Bellow, actual image is shown of absorber during manufacturing. Here we are using two absorbers of same size and same dimensions to match designed dimensions of the absorber.



ALL DIMENSIONS ARE IN mm
PART NAME- ABSORBER, QTY-02
CO TUBES- ID-11.1,OD-12.7,L-1.2Mtr,06 nos, COOLING WATER
SS304 SHELL- L-1.1Mtr,THICK-3,OD-76, MIXTURE

ABSORBER

CONCLUSIONS

Above calculated specification gives a platform to design for manufacturing of a 1 kw absorption system, driven by low grade energy source i.e. solar panel. Shell and tube type heat exchangers are analyzed due to their efficiency and ease in manufacturing. Among the components, absorber and evaporator dimensions are highest and required further design modifications to make the system more compact. The design procedure used can be applied to scale up the capacity. This paper assists the economic analysis for manufacturing of absorption chillers. The current calculations has used some assumptions which need more analysis i.e. no jacket heat loss. Other fields of investigation are creating and sustaining vacuum, throttling process and optimum size of pump. The unit designed is constructed and each heat exchanger is adjusted to the required output. In this way the designed COP is ensured. The present cost of the absorption unit together with its running cost is economically viable. Considering also the destruction of the ozone layer caused by the use of electric chillers, absorption units will offer a better environment, especially if some form of renewable or waste energy is used for their operation.

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