ABSORPTION CHILLR- DESIGN AND OPTIMIZATION OF GENERATOR AND CONDENSER

SEYEDAHMAD TOHIDI

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To my father, mother, sister and brother for their enormous financial and emotional supports

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ABSTRACT

Since absorption chillers are more commodiouse than compression chillers, the usage of them increases these days. In comparison with compression chillers these type of chillers have lower coefficient of performance (COP). By improving the performance of each component of these chillers such as generator, condenser, heat exchanger and absorber the COP will increase. In this study , after designing generator and condenser an optimization was done on these two components by using genetic algorithm(GA). The parameters which consider for optimization were tube diameter, shell diameter and baffle spacing.The main purpose is to find the optimum amount of these three parameters so that the COP can be increased and the cost of absorption chillers is decreased simultaneously. After optimization the COP of the chiller increases from 0.62 to 0.66 and the price of chiller is reduced. These results indicate that GA is a successful optimization technique for the optimization of generator and condenser in absorption chillers.

ABSTRAK

Sejak pendingin penyerapan commodiouse lebih daripada pendingin mampatan, penggunaan mereka meningkat ini hari perbandingan.in dengan pendingin pemampatan-jenis penyejuk mempunyai pekali prestasi yang lebih rendah (COP). Dengan meningkatkan prestasi setiap komponen ini penyejuk seperti penjana, pemeluwap, penukar haba dan penyerap COP akan meningkat. Dalam kajian ini, selepas mereka bentuk penjana dan pemeluwap pengoptimuman yang dilakukan ke atas komponen kedua-dua dengan menggunakan algorythm genetik. Parameter yang mempertimbangkan untuk aptimization diameter tiub, diameter shell dan maksud sesekat spacing.the utama adalah untuk mencari jumlah optimum thease tiga parameter supaya kenaikan COP dan kos pendingin penyerapan berkurangan simoltaneously. Selepas pengoptimuman COP kenaikan pendingin 0.62-0.66 dan harga pendingin mengurangkan. Keputusan ini menunjukkan bahawa GA teknik pengoptimuman yang berjaya untuk pengoptimuman penjana dan pemeluwap dalam pendingin penyerapan.

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Re	-	Reynolds number
Pr	-	Prandtl number
Nu	-	Dimensionless coefficient of heat transfer
$\dot{m}$	-	Mass flow rate
G	-	Mass flux
S	-	Flow surface
N_p	-	Tube pass
N_t	-	Tube numbers
L	-	Length
D	-	Diameter
Q	-	Heat load
w	-	Per unit mass work
$\dot{w}$	-	Power
W	-	Work
COP	-	Coefficient of performance
q”	-	Heat flux of per unit surface
R	-	Heat resistance

R”	-	Heat resistance per unit surface
U	-	Total heat transfer coefficient
e	-	Error
h	-	Enthalpy
μ	-	Viscosity
ρ	-	Density
v	-	Specific volume
K	-	Conduction heat transfer coefficient
T	-	Temperature
X	-	Concentration
P	-	Pressure
α	-	Convection heat transfer coefficient
x	-	Vapor quality
L_{bb}	-	Baffle spacing
P_T	-	Pitch
θ_T	-	Tube angle
BC	-	Cuts of baffle
f	-	Coefficient of friction
LMTD	-	Logarithmic mean temperature difference
F	-	Coefficient of correction for LMTD
δ_r	-	Characteristic thickness of falling film
D_e	-	Equivalent diameter
σ	-	Surface tension
A	-	Required heat transfer surface
$A_{p,o}$	-	External surface of the tube per unit length

$A_{p,i}$ - Inner surface of the tube per unit length

L_{eff} - Effective length

CHAPTER 1

INTRODUCTION

1.1 History of refrigeration

Before 19th century AD refrigeration was just limited to transfer ice from cold region to warm areas and keep it in specific boxes for using in hot seasons. In 1834 the first manually refrigeration machine in England caused a change in the refrigeration industry. Before that in 1824 a series of tests done by Michele faraday to convert some stabilized gas to the liquid. Although faraday could not use those experiences for cooling, they became a prelude for the future. In 1851 an American made a machine which produced ice it was using air as refrigerant. In 1859 an absorption cycle was used by Ferdinand Carre with ammonia as refrigerant and water as absorbent. Americans used this system for the first time to made absorption chillers. In 1860 the first ether sulfuric machine made for refrigeration in beverage industry in Australia. Later on in 1880 the first company for making ice established.

In 1890 compression refrigeration and absorption refrigeration became really common but they were very bulky and expensive. One of the reasons that mechanical refrigeration did not develop in the early decades was the usage of steam to spin a compressor. By inventing electric motors and improvement in non dangerous refrigerant, refrigeration industry reached its peak. small Air refrigerators and household freezers produced widely and still continue to evolve and progress. The operation of absorption chillers is based on Michael faraday experiment in 1842. In that time scientist thought that ammonia is just exists as vapor, faraday did some experiment to make it liquid. During the experiment he understood that ammonia absorb the ambient heat when it convert from vapor to liquid and cause refrigeration. That was the start point for appearance of absorption refrigeration systems. For the first time absorption refrigeration systems was invented by Ferdinand Carre in 1860.

1.2 Why absorption chillers

Refrigeration and cooling cycles are mostly based on mechanical vapor compression. In Warm climate countries, where cooling needs a large amount of electricity, the usage of alternative technologies could be preferred. Absorption chillers get their energy from sun or waste heat of other devices such as turbine in power plant to drive Cooling system. Absorption chillers are a good alternative for compressor chillers when electricity is unavailable, expensive or unreliable, or where compressor noise is a problem. Since absorption chillers have a lot of advantages in comparison

with mechanical chillers, usage of them is more economical and environmental friendly. Absorption chillers are a good choice these days, hence optimizing them will be an important issue. In this study it is tried to design the generator and condenser and optimizing generator in a single effect LiBr/H_2o indirect fired absorption chillers. The waste energy from a gas power plant is used to drive the generator. This heat will be obtained from the hot gas which is expelling to ambient from turbine in power plant. Let's know more about absorption chillers.

1.3 What is Absorption Refrigeration

These kinds of chillers use heat instead of mechanical energy to provide cooling. A thermal compressor includes an absorber, a generator, a pump and a throttling device, and replace mechanical vapor compressor. In these chiller the vapor that comes from evaporator absorb by solution in absorber, mix with solution and become liquid, then the solution pump to generator. In generator solution will be heated by the waste heat or solar source or other sources then re-vaporize so the refrigerant separate from absorbent then this vapor will go to the condenser and the refrigerant-depleted solution will go back to the absorber through a throttling device.

Two solution mostly use in absorption chillers, water/lithium bromide and ammonia/water. The first solution mostly use for air conditioning and the second one use for refrigeration purposes. Pair of lithium bromide /water is more common due to high volatility, stability and relatively high latent heat, high safety factor of water and the higher COP in the cycle. Since water freezes at zero degree centigrade this solution cannot be used in low temperatures hence the temperature of exited water from chiller cannot be less 7 degree of centigrade but this temperature is enough for air conditioning. For obtaining lower temperature it is needed to use NH_3/H_2o as the solution in the cycle.

Cop is coefficient of performance (chiller load/heat input). High amount of cop indicate the optimized consumption of energy.

Crystallization: in the solution, LiBr is liquid in the common density but if it is over concentrated in generator by giving heat to it, the inside crystals will increase in size and block the way of solution. This is called crystallization.

1.4 Some factors that should be conceder for choosing the refrigerant

1-safety

2- toxic

3- ability of ignition or explosion

Table 1-1 : A comparison of two solutions that can be used in refrigeration cycle.

Refrigerant/absorbent	H_2o/LiBr	Nh_3/H_2o
Operation pressure	low	high
COP	From 0.6 to 0.8	From 0.6 to 0.7
Limitation	-Freezing -Crystallization	-need rectifier -does not freeze -toxic
Application	Air conditioning	Refrigeration

1.5 A comparison of the mechanical coolers and absorption chiller

i - Cost effective and more economical than electric cooler. Vapor compression chillers use mechanical compressor which need a lot of electricity but absorption chillers use heat.
ii - Since absorption chillers do not have mechanical parts so they are less noisy and they have less vibration.

iii -For a facility that needs high system reliability, the absorption chiller will reduce emergency generator load requirements since they use lower electricity.

iv - Compression chillers are harmful for environment since they use CFC and HCFC but absorption chillers use natural refrigerant like water which is environmental friendly.

v - Absorption chillers have lower coefficient of performance (COP = chiller load / heat input)

1.6 Absorption chiller disadvantages

Although absorption chillers are really good but they have some disadvantages. Their COP is less than compression chillers since they use water which is less efficient refrigerant in comparison with fluorocarbon based refrigerants that use in compression chillers. They have higher first cost than compression chillers and they are larger than electric chiller with the same capacity.

Using absorption chillers for cooling the site is good when at least one of the fallowing conditions applies

i -A combined heat and power CHP) unit exists, and you cannot use all the available heat, or considering a new CHP plant.

ii - you have a large amount of Waste heat.

iii -When a low cost fuel source is available.

iv - When the efficiency of boiler is low due to a poor load.

v - when electrical load of the site is limit and expensive to upgrade.

vi - When your site needs more cooling, but it is expensive to overcome the electrical and there is an adequate heat supply.

-In short, absorption chillers use when a free or low-cost heat source is available.

1.7 Absorption Chiller Refrigeration Cycle

A basic absorption cycle consists of two fluids, refrigerant and absorbent. Commonly water is used as refrigerant and lithium bromide used as absorbent. These fluids are separated and mixed in absorption cycle. In this cycle the low pressure vapor (refrigerant) that comes from evaporator, absorbed by absorbent and release a large amount of heat in absorber then this solution is pumped to the high operating pressure generator and use lower electricity in comparison with mechanical chillers. In generator heat is added to the solution and it is caused that refrigerant desorbs from absorbent and vaporize.

The heat in generator is obtained from hot water, hot gases, steam or gas burner. The high pressure refrigerant vapor then goes to the condenser, reject some heat and convert to high pressure liquid. After that this liquid passes through an expansion valve and looses the pressure to enter the evaporator. In the evaporator this liquid refrigerant absorbs heat to become vapor and cause a useful cooling. The remained liquid absorbent in generator pass through an expansion valve to reduce the pressure then go to the absorber. In the way back, it gives some heat to the solution which is comes from absorber in an heat exchanger. This will increase the efficiency. This cycle will be repeated.

1.8 "Indirect fire" and "direct fire" absorption chillers

Indirect fire chillers use hot gases, hot water or steam as an input. These inputs can come from a turbine, boiler or engine generator or other devices that have waste energy. These chillers are good for CHP (combine heat and power) system for buildings. The rejected heat from electric generator is used as an input for chiller hence by using the waste energy the operating efficiency will increase.

Direct fired systems have natural gas burners so the rejected heat from these chillers can provide the hot water or can be used to regenerate desiccant dehumidifiers.

1.9 Commercially division of absorption chillers

There are two kinds of absorption chillers, single effect and multiple effects. In single effect chillers all the heat that produced by absorbing the refrigerant in absorber release to the environment but in multiple effect chillers this heat is also used to provide refrigerant vapor in generator. More vapor generated from per unit of input heat cause higher cooling capacity and better efficiency.

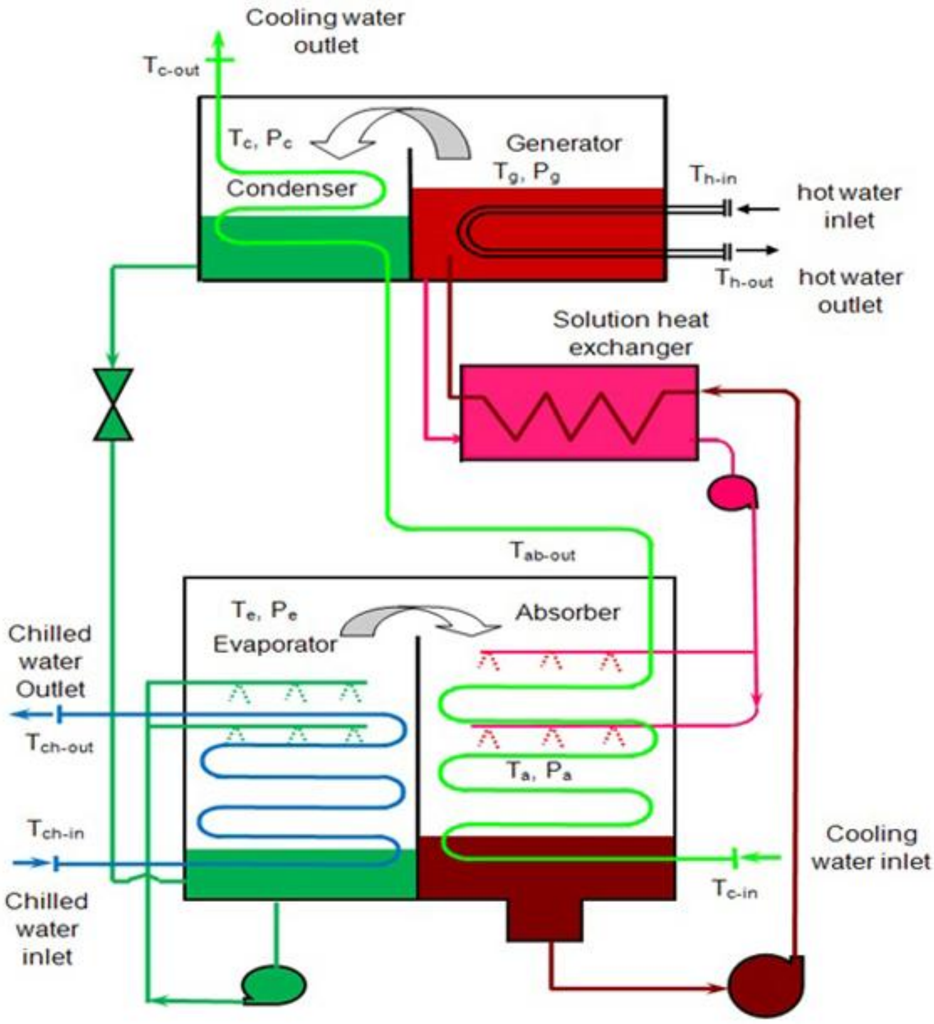

Figure 1-1 Single effect absorption cycle

Double effect absorption chillers have two generators that paired to a condenser, evaporator and absorber. Since they need a high temperature for the heat input they can be used in a CHP system and can pair to electrical generation equipment, so their usage is limited.

Triple effected chillers have higher efficiency in comparison with double effect chillers but they need also the higher temperature heat input so choosing the material in these chillers is an issue and even choosing refrigerant/absorbent solution is also important and harder. Researchers are still working on this kind of chillers so these chillers are still under development.

Table 1-2 : Comparison of COP and heat source temperature in single, double and triple effect absorption chillers

Type	COP	Heat source temperature[c]
Single effect	0.7	85(60-110)
Double effect	1.2	130(130-165)
Triple effect	1.7	220

Absorption refrigeration application

1-Use in air conditioning for this purpose the chilled water that comes out from evaporator goes through a coil or heat exchanger in any kind of thermal devices that making the air cool these coils transfer the sensible or latent heat of air to the child water and cause air cooling then this water will take back to the evaporator to be cool again and this cycle will be repeated. The capacity of common chillers is between 53 to 5300 KW (15 to 1500 tons) and the temperature of chilled water can be from1.5 to 7 degree of Celsius that is depending on the application requirement.

2-Use in industry for industry the chilled water that comes from the chiller is pumped through process or laboratory equipment. Chillers are used to cool the products, factory machinery, or mechanisms. They can be used mostly in hotels and campuses, X-ray diffraction, metal working, MRI machines and lasers, food and beverage processing, chemical processing, cutting oils, plastic industry, die-casting and machine tooling, welding equipment, paper and cement processing, power supplies and power generation stations, compressed air and gas cooling and a lot more.

1.10 Different type of water chillers

Water chillers can be air cooled, water cooled or evaporatively cooled. Water cooled chillers are mostly use for indoor installation and they use an outdoor cooling tower to reject the heat to the environment. Usage of cooling tower in these chillers increase their thermodynamic effectiveness in comparison with air cooled chillers. The reason is that heat rejection is happened near wet bulb temperature and the amount of this heat is higher than the heat which is rejected near dry bulb temperature.

Evaporatively cooled and air cooled chiller typically used for outside installation. Air cooled chillers are cooled directly by the environment air which is mechanically circulated around coils in condenser. Evaporatively cooled chillers are the same as air cooled chillers; just in this case a mist of water is used over the condenser coil which is helped better cooling so they are more efficient than air cooled chillers. For these two kinds there is no need of cooling tower.

Efficiency: water cooled chillers > evaporatively cooled chillers > air cooled chillers

1.11 Generator

Generator is one part of absorption cycle. In generator the solution that come from absorber will receive heat from the tubes which carry hot water or steam and then water will vaporize and go to the condenser. The remained solution will go back to the absorber. In fact generator is a special type of heat exchanger which is called kettle reboiler. There is a bundle of U shape tubes on the bottom of generator and the above space does not have any tube. This type of heat exchanger is used when some part of the solution is needed to be vaporized. This vapor will go to the condenser from the upper vessel.

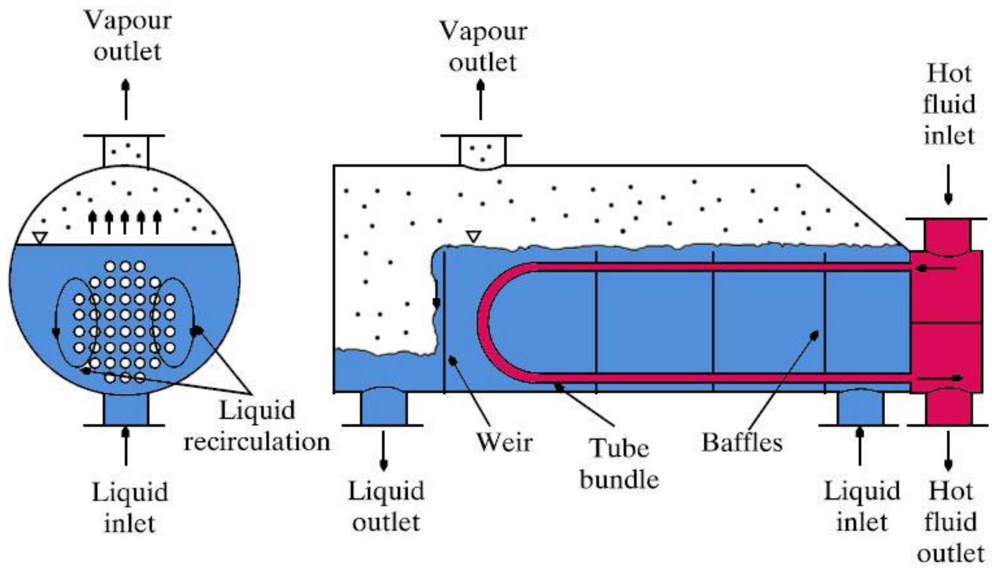

Figure 1-2 A two-dimensional model of the kettle reboiler shell side thermal-hydraulics.

There are different types of heat exchangers. One of them is shell and tube heat exchanger. Since generator that is used in absorption cycle is one of these exchangers it is worth to know more about this type of heat exchangers.

1.12 Condenser

In systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant.

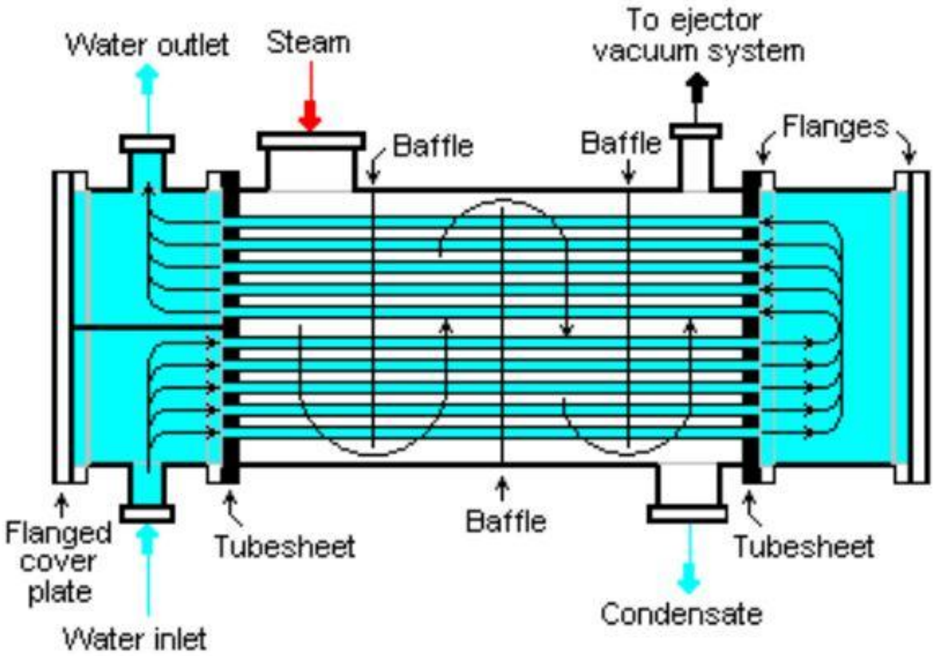

Figure 1-3 Diagram of a typical water-cooled surface condenser

1.13 Shell and tube heat exchangers

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications (with pressures greater than 30 bar and temperatures greater than 260°C). This is because the shell and tube heat exchangers are robust due to their shape.

There are several thermal design features that are to be taken into account when designing the tubes in the shell and tube heat exchangers. These include:

-Tube diameter

Using a small tube diameter makes the heat exchanger both economical and compact. However, it is more likely for the heat exchanger to foul up faster and the small size makes mechanical cleaning of the fouling difficult. To prevail over the fouling and cleaning problems, larger tube diameters can be used. Thus to determine the tube diameter, the available space, cost and the fouling nature of the fluids must be considered.

-Tube thickness

The thickness of the wall of the tubes is usually determined to ensure:

i- There is enough room for corrosion

ii- That flow-induced vibration has resistance

iii- Axial strength

iv- Availability of spare parts

v- Hoop strength (to withstand internal tube pressure)

vi- Buckling strength (to withstand overpressure in the shell)

-Tube length

heat exchangers are usually cheaper when they have a smaller shell diameter and a long tube length. Thus, typically there is an aim to make the heat exchanger as long as physically possible whilst not exceeding production capabilities. However, there are many limitations for this, including the space available at the site where it is going to be used and the need to ensure that there are tubes available in lengths that are twice the required length (so that the tubes can be withdrawn and replaced). Also, it has to be remembered that long, thin tubes are difficult to take out and replace.

-Tube pitch

when designing the tubes, it is practical to ensure that the tube pitch (i.e., the centre-centre distance of adjoining tubes) is not less than 1.25 times the tubes' outside diameter. A larger tube pitch leads to a larger overall shell diameter which leads to a more expensive heat exchanger.

-Tube corrugation

This type of tubes, mainly used for the inner tubes, increases the turbulence of the fluids and the effect is very important in the heat transfer giving a better performance.

-Tube Layout

refers to how tubes are positioned within the shell. There are four main types of tube layout, which are, triangular (30°), rotated triangular (60°), square (90°) and rotated square (45°). The triangular patterns are employed to give greater heat transfer as they force the fluid to flow in a more turbulent fashion around the piping. Square patterns are employed where high fouling is experienced and cleaning is more regular.

-Baffle Design

baffles are used in shell and tube heat exchangers to direct fluid across the tube bundle. They run perpendicularly to the shell and hold the bundle, preventing the tubes from sagging over a long length. They can also prevent the tubes from vibrating. The most common type of baffle is the segmental baffle. The semicircular segmental baffles are oriented at 180 degrees to the adjacent baffles forcing the fluid to flow upward and downwards between the tube bundles. Baffle spacing is of large thermodynamic concern when designing shell and tube heat exchangers. Baffles must be spaced with consideration for the conversion of pressure drop and heat transfer. For thermo economic optimization

It is suggested that the baffles be spaced no closer than 20% of the shell's inner diameter. Having baffles spaced too closely causes a greater pressure drop because of flow redirection. Consequently having the baffles spaced too far apart means that there may be cooler spots in the corners between baffles. It is also important to ensure the baffles are spaced close enough that the tubes do not sag. The other main type of baffle is the disc and donut baffle which consists of two concentric baffles, the outer wider baffle looks like a donut, whilst the inner baffle is shaped as a disk. This type of baffle forces the fluid to pass around each side of the disk then through the donut baffle generating a different type of fluid flow.

1.14 Combined Heat and Power (CHP)

CHP plays an important part in meeting energy requirements and reducing the environmental impact of power generation, providing numerous benefits to both the user and the environment. A CHP scheme will dramatically cut costs because it operates at much higher efficiencies than other forms of power generation. CHP, also known as cogeneration, is a simple concept which involves a cost-efficient means of generating both electrical and thermal energy from the same fuel source. The electricity generated by the gas turbine generator can be used as an "island" solution for stand-alone power supply in manufacturing plants and industrial facilities. However, the gas turbine exhaust is packed with thermal energy which, in a CHP solution, can be recovered in a heat exchanger to generate either steam or hot water

For further application. Municipal utilities can use the steam for district heating, and industrial users benefit from using it in production processes, e.g. for heating or drying. Alternatively steam can be used in absorption chillers to cool industrial processes or warehousing facilities. A CHP system is one of the most efficient ways of converting fuel into useful energy. You can expect a conversion efficiency of up to 95% from a well designed scheme

All thermal power plants produce waste heat energy as a byproduct of the useful electrical energy produced. The amount of waste heat energy equals or exceeds the amount of electrical energy produced. Gas-fired power plants can achieve 50% conversion efficiency while coal and oil plants achieve around 30-49%.

1.15 Problem statement

i) absorption chillers known to have low coefficient of performance (COP)

In comparison with compression chillers these kinds of absorbers have lower COP so trying to increase the COP is one of the issues that should be work on it.

ii) The big size of absorption chillers.

Since absorption chillers are big, installing them everywhere is not possible; by minimizing the size of absorption chillers this limitation will be eliminated.

iii) by increasing cop, cost will increase.

The cost of chiller is another factor that should be under consideration. The bigger size the chillers have, the higher cost they have. For increasing COP the surface of heat transfer in different component of chillers usually increase. The main issue is to bring up COP while the cost reduces.

1.16 Objectives

i. designing generator and condenser
ii. optimizing design of generator
iii. optimizing design of condenser
iv. compare the performance of optimized generator and condenser with the existing one.

1.17 scopes

i- litereture review on previous works for designing and optimizing heat exchangers.

ii- set the thermodynamic and physical properties based on exciting model for the cycle.

iii- study and understand about genetic algorithm for optimization.