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An Empirical Study on the Ways of improvement in Chiller Efficiency by Variation of Various Performance Parameters

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Abstract

As well known, A chiller is a refrigeration system that cools a process fluid typically water, which is further used in commercial and industrial ways for process cooling or air-conditioning. With the help of such systems water can be cooled to temperatures as low as 5°C (~40°F) and pumped through a hydraulic circuit to reach the process equipment or the air handling units. Rather than water some other suitable primary and secondary refrigerants are also be used for such refrigeration purposes. For still lower temperatures glycol or brine solution may be used (also known as secondary refrigerants). A chiller would use either a vapour compression or absorption cycle to cool. Once cooled or chilled water is used in air-conditioning applications for cooling/dehumidification and thus creating comfortable and productive environments. A large amount of power is required to operate these system. This paper represents the possible and suitable ways of improving the performance of such systems because of maximization in performance is the key requirement of current running refrigeration chillers for energy saving point of view.

Keywords : chiller, vapour compression chillers, improved performance of chiller, industrial chillers.

Introduction

A chiller is a machine that removes heat from a liquid via any suitable refrigeration method i.e vapour-compression or absorption refrigeration cycle. This low temperature liquid can then be circulated through a heat exchanger to cool air or equipment as required. As a necessary by product, refrigeration creates waste heat that must be exhausted to atmosphere or, recovered for heating purposes. The refrigeration cycle is a key differentiating characteristic between chiller types. The vapour compression and absorption refrigeration cycles are the two most common cycles used in commercial air conditioning. Given figure shows the cut sectional view of essential parts of an industrial chiller.

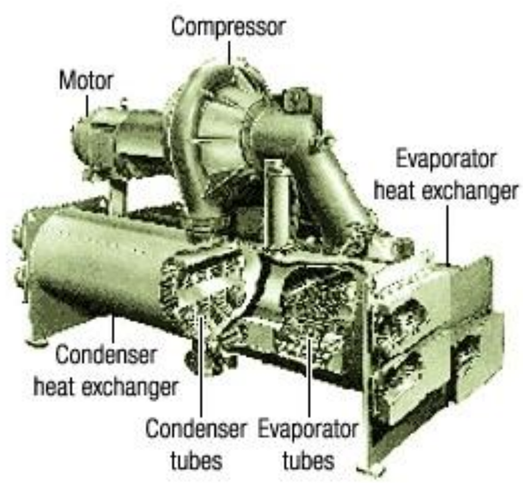

Fig. Sectional view of industrial chiller.

In recent years development, application of Variable Speed Drive (VSD) technology has increased performance of vapour compression chillers. The first Variable Speed Drive was applied to centrifugal compressor chillers in the late 1980s and has result as the cost of energy has increased. Now a days, VSDs are being applied to rotary screw

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and scroll technology compressors, which results an improved co-efficient of performance. {1} Water chillers using the vapour-compression refrigeration cycle vary by the type of compressor discussed above. Chillers use either a vapour-compression or absorption refrigeration cycle to cool a fluid for heat transfer. Both types of chiller rely on three basic principles.

- First - When a liquid is heated it converts into a gas by vaporization , and it get condensed into a liquid when a gas is cooled.
- Second - Lowering the pressure above a liquid reduces its boiling point and increasing the pressure raises it.
- Third - Heat always flows from hot to cold. {2}

A vapor-compression chiller uses a refrigerant internally as its working fluid with the help of which the transfer of heat takes place. Many refrigerants options are available; whenever selecting a chiller, the space cooling temperature requirements and refrigerant's cooling characteristics and chemical properties need to be matched. There are many environmental factors that concern refrigerants, along with the future availability for chiller applications. This is a main consideration in intermittent applications where a large chiller may last for 25 years or more. Ozone depletion potential (ODP) and global warming potential (GWP) of the refrigerant need to be considered. Such data for some of the more common vapor-compression refrigerants (noting that many of these refrigerants are highly flammable and/or toxic):{3}

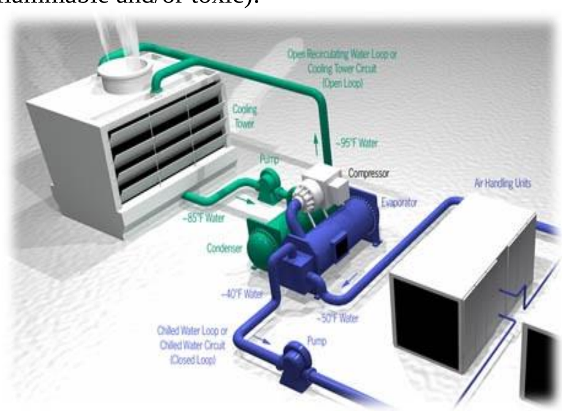

Fig : Arrangement of chiller parts.

The key goals of operation of vapour compression chillers are;

- ➢ Maintain desired temperature in a building
- ➢ Remove heat within a building and reject it to the ambient environment
- ➢ Heat sources
  - ➢ Internal gains: lights, people & equipment
  - ➢ External gains: solar, transmission
  - ➢ Infiltration

Working Cycle

The basic cooling cycle is the same for both vapor-compression and absorption chiller systems. Both systems utilize a refrigerant that changes phase from liquid to a gas within an **evaporator** which absorbs heat from the water to be cooled. The refrigerant gas is then compressed from a low pressure to higher pressure by a **compressor** or a **generator**, converted back into the liquid form by rejecting its latent heat through a **condenser** and then expanded to a low- pressure mixture of liquid and vapor (major part of liquid and a minor part of vapour) that goes back to the evaporator section. The cycle is repeated. A **vapor-compression chiller** consists of four primary components of the vapor-compression refrigeration cycle. They includes some major operating to complete the cycle i.e a **compressor**, **evaporator**, **condenser** and a expansion device.{4-5} Vapor-compression chillers typically utilize HCFC or CFC refrigerants to achieve a required cooling effect. Compressed refrigerant gas is sent from the compressor to a condenser unit that rejects the latent heat from the refrigerant to cooling water or air outside of the system.

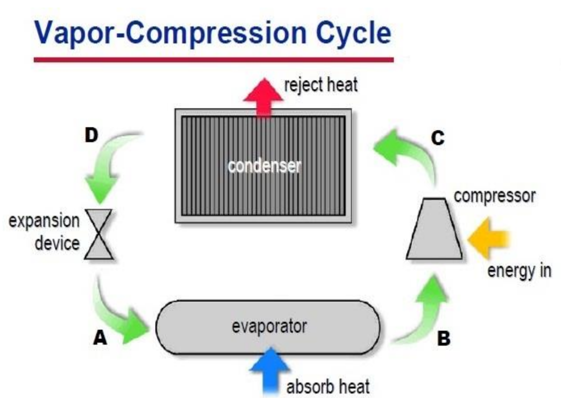

Fig : Basic chiller based on vapour compression cycle.

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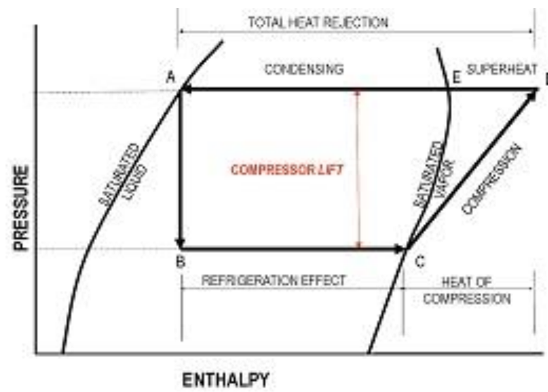

Fig : Diagram of same on pressure enthalpy curve.

This heat transfer allows the refrigerant gas to condense into a liquid which is then sent to a expansion device, which restricts the flow of liquid refrigerant which causes a drop in pressure. The pressure drop causes the warm refrigerant liquid to change phase from liquid to gas and in doing so absorbs heat from the water to be cooled due to adiabatic flash evaporation. The expansion device is positioned so that the expanding refrigerant gas is contained within the evaporator, heat transfer takes place from the water to be cooled into the refrigerant gas. [6]The refrigerant vapour is then sent back to the compressor to start the cycle over again and the newly chilled water in the separate loop can now be used for cooling. [7] When we focus on the working fluid, some desirable properties should have in a working fluid. These are:

- ✓ Thermodynamic/transport properties
- ✓ Efficiency
- ✓ Cost (refrigerant & equipment)
- ✓ Stability
- ✓ Likelihood of future availability
- ✓ Safety
  - ✓ Toxicity
  - ✓ Flammability
  - ✓ Environmental impacts

COP comparison of various refrigerants. When the working fluid is used rather then the water, the co-efficient of performance is varying due to their different chemical properties. Given table shows the comparison of performance of industrial chiller working on vapour compression refrigeration cycle, (literature survey).[8]

Refrigerant	COP	kW/ton
R-11	6.912	0.509
R-12	6.423	0.547
R-123	6.715	0.524
R-134a	6.294	0.559
R-22	6.329	0.556

Methods of Improving System Performance

There are certain suitable ways which could be applied for improving the performance of vapour compression chiller systems. Some of these possible ways are discussed below. [9] The performance of such systems could be increased by:

➢ **Minimizing chiller lift.** The work required by the compressor is referred to as the *lift*. Lift, also known as head pressure in positive displacement compressors, can best be described as the amount of work necessary to increase the refrigerant from a lower pressure to one that is much higher. Increased pressure differential translates into a greater amount of work necessary to compress the refrigerant. The work performed by the compressor is provided by the compressor motor, which uses electrical energy to drive the compressor shaft. **[10]** As a result, higher lift increases electrical demand and energy consumption. It's that simple. *Increased lift on the chiller increases chiller power consumption* and should be avoided. Therefore, the system designer should make every attempt to reduce the lift to minimize energy consumption. Figure shows the effect of lift minimization on pressure –enthalpy curve.

- ➢ Basic cycle : 1'-2'-3-4'-1'.
- ➢ Effective cycle : 1-2-3-4-1.

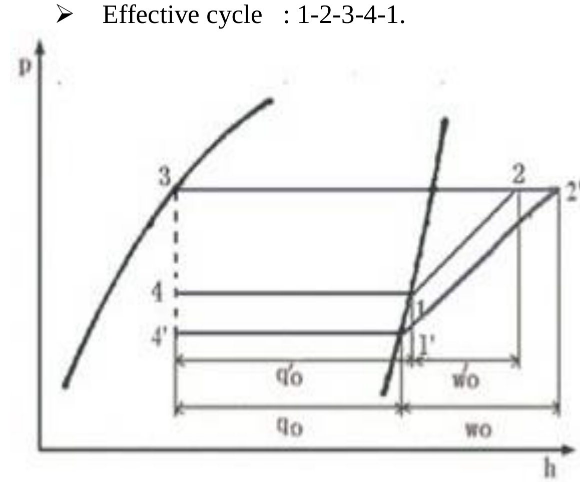

Fig : Effect of increased suction pressure.

Hence we can say that with increasing suction pressure, i.e, $(h_{1'} - h_{4'})$ increases to $(h_1 - h_4)$ and $(h_{2'} - h_{1'})$ decreases to $(h_2 - h_1)$, so that the coefficient of performance increases. Stated another way, *minimizing*

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lift maximizes energy savings. The multistage compression with inter cooling or without intercooler is another alternate option to minimize the compressor work or lift requirement.

➢ **Decreasing the condenser pressure.** Figure shows the change in the basic vapour compression cycle on the p-h diagram when the discharge pressure is decreased, with a constant evaporating pressure. It is clear from the sketch that the refrigeration effect increases (4'-1 instead of 4-1), the specific work of isentropic compression decreases (1-2' instead of 1-2).

Basic cycle : 1-2-3-4-1.
Effective cycle : 1-2'-3'-4'-1.

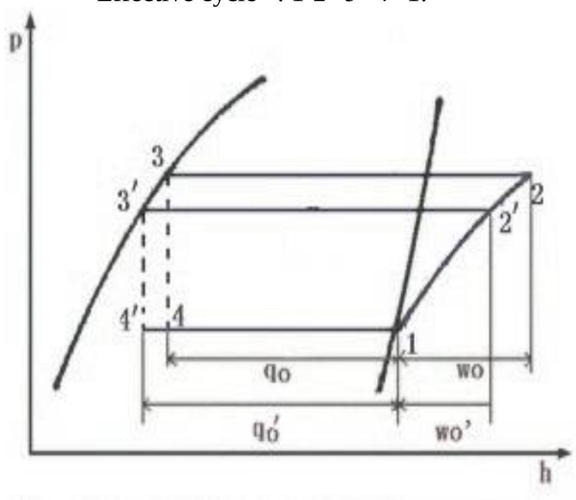

Fig : Effect of decrease in condenser pressure.

Following conclusions can be drawn from figure.

- With decreasing condenser pressure h_3 or h_4 decreases, so that the specific refrigerating effect increases with decreasing condenser pressure (h_4 to $h_{4'}$).
- The specific work of isentropic compression decreases with decreasing condenser pressure (w_o to $w_{o'}$).
- Decreasing condenser pressure can markedly decreases the volume work of isentropic compression and hence decrease the power required to drive a given machine.

Hence we can say that with decreasing discharge pressure,(h_1 - h_4) increases to (h_1 - $h_{4'}$) and (h_2 - h_1) decreases to ($h_{2'}$ - h_1), so that **the coefficient of performance increases.**

➢ **Sub-cooling of working fluid.** Sub-cooling is the process of cooling the liquid refrigerant below the condensing temperature for a given pressure. The effect of sub-cooling in p-h diagram is shown in figure. It is clear from figure that the refrigeration effect increases (4'-1 instead of 4-1), the specific work of isentropic compression is same.

Basic cycle : 1-2-3-4-1.
Effective cycle : 1-2-3'-4'-1.

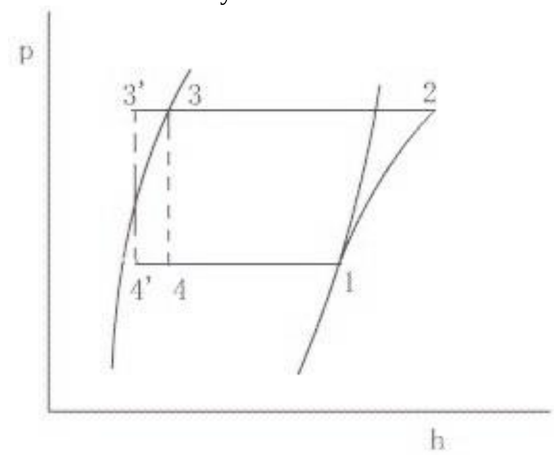

Fig : Effect of sub cooling of condensate.

- With decreasing condenser output temperature from T_3 to $T_{3'}$, the specific refrigeration effect increases as shown.
- The specific work of isentropic compression is remains same the both cycles.[11]

Result: The sub-cooling results in **increase of C.O.P.** provided that no further energy has to be required to obtain the extra cooling or refrigerating effect.[C]

The sub cooling might be obtained by any of the following methods:

a. By inserting a special cooling coil between the condenser and expansion device.
b. By circulating large quantity of cooling water in condenser.

Conclusion

From the above discussion it is concluded that there are several ways of improvement in co-efficient of performance of the chillers basically working of simple vapour compression refrigeration cycle. The performance could be increase by decreasing the lift, decreasing condenser working pressure, and sub cooling of working fluid in the condenser. These ways does not required and additional work input of any additional major modification or construction in the running system. Another advantage is that there are no negative environmental impacts associated with the technology. These devices are generally made of various suitable plastics and polymers, tubes are generally made of copper, and/or stainless steel, depending on the manufacturer. Also it has no active

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electronics and could be disposed off. For example, the conditions where it saves energy and increases the capacity of chillers, it provides secondary environmental benefits such as reduced electricity input, hence reduced the harmful flue gases at electricity generating plants. Just because of using water as a working medium in these systems there will reduction a huge amount of pollution created by chemical refrigerants which are responsible for Ozone layer depletion.

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