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# Estimation of Chilled Water Required for an Air-Cooled Chiller Plant

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**ABSTRACT:** The Heating, Ventilation and air conditioning (HVAC) system is arguably the, most complex system installed in the building and is responsible for a substantial component of the total building energy use. The calculated cooling capacity with appropriate buffer is then used to select the number and size of chiller in the system. This role is played by HVAC (Heating, Ventilation and air conditioning) systems. The layout is made by Autodesk REVIT software. A Complete air conditioning system was designed to control the temperature, relative humidity, air movement etc. Conditioning software after taking the plan and heating and cooling load calculations values were taken by the design department. The same values we will give in the Revit software at human comfort condition then we will get temperatures like DBT, WBT and MEAN RANGE VALUE.

## I. INTRODUCTION

### 1.1 HVAC

Most importantly, HVAC represents warming, ventilation, and cooling. This framework gives warming and cooling to private and business structures. You can find HVAC frameworks anyplace from single-family homes to submarines where they give the means to ecological solace. Turning out to be increasingly more well known in new development, these frameworks utilize outside air from outside to give high indoor air quality. The V in HVAC, or ventilation, is the most common way of supplanting or trading air inside a space. This gives a superior nature of air inside and includes the expulsion of dampness, smoke, scents, heat, dust, airborne microorganisms, carbon dioxide, and different gases just as temperature control and oxygen renewal.

### 1.1 How does an HVAC system works?

The three primary elements of a HVAC framework are interrelated, particularly while giving satisfactory indoor air quality and warm solace. Your warming and cooling framework is regularly one of the most confounded and broad frameworks in your home, however when it quits working, you'll know soon enough! There are nine sections to your HVAC framework that you ought to be acquainted with the air return, channel, exhaust outlets, conduits, electrical components, open air unit, blower, loops and blower.

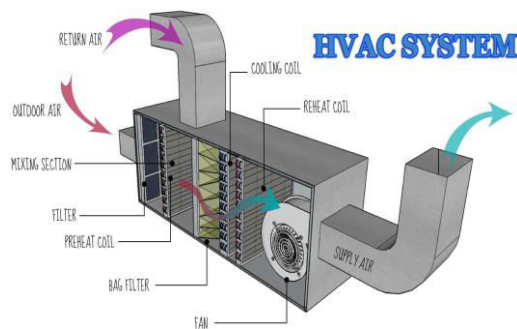
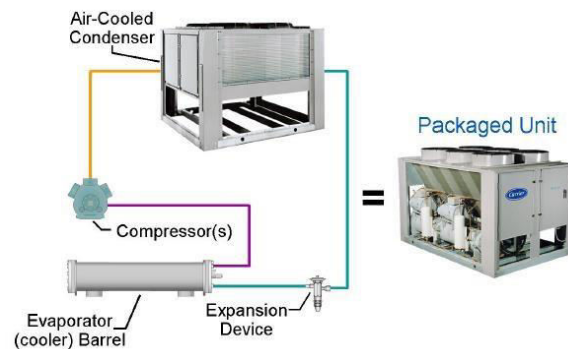


Fig. HVAC system

## 1.2 AIR COOLED CHILLER PLANT

Air-cooled chillers actively absorb heat from process water; they then transfer this heat into the air around the chiller unit. This type of unit is typically used in areas where additional heat discharge is not an issue, but instead works as a benefit. For instance, the additional heat can be used to warm a space during the winter for less money than traditional heating systems. The cycle starts with the evaporator, which has a liquid refrigerant that flows over the evaporator tube bundle where it evaporates. In the process, heat is absorbed from the chilled water circulating through the bundle. The compressor then pulls the refrigerant vapor from the evaporator. The compressor is then tasked with pumping the refrigerant vapor to the condenser, which increases temperature and pressure. The refrigerant condenses when it's in the condenser tubes, releasing its internal heat to the air or cooling water. The high-pressure liquid then moves through the expansion device and into the evaporator, in the process the refrigerant pressure is reduced along with the temperature.



*Fig. Air Cooled Chiller Plant*

To complete the continuous cycle, the refrigerant flows back over the chilled water coils and absorbs more heat. Air-cooled chillers utilize the mechanical refrigeration cycle to produce chilled water or a chilled water and antifreeze mixture. They reject the building heat to the ambient with an air-cooled condensing coil. Chillers are the heart of the chilled water air-conditioning system since they serve the pivotal function of creating the cooling effect required to maintain comfort conditions. Chillers are used in a variety of comfort air conditioning and process cooling applications. The chilled liquid is transported by pumps and pipes that can be connected to literally hundreds of room fan coils and terminals. This allows chillers to be applied on application requiring many zones of control. Air-cooled chillers are common in modern systems and have been growing in popularity since the 1980s, nearly doubling in the last ten years. Today, air-cooled chillers are applied on small to large commercial jobs and can be used in multiples to form systems reaching several thousand tons of installed capacity. The popularity is primarily due to the all-inclusive nature of air-cooled chillers and the reduction of costs associated with eliminating cooling tower. On some models, even the hydronic accessories, such as the pump and expansion tank, may be included, assembled, and tested from the factory ready to begin operation.

## II. LITERATURE SURVEY

'60s when the author was involved in the US government's projects to evaluate the thermal environment in fallout shelters by an hour simulation of heat and moisture transfer process between human occupants and shelter walls under limited ventilation conditions. General building thermal simulations based on calculations were started at that time by gas and electric industries. In the USA, full scale computer applications for HVAC related problems started in the early 1960s. This led to the formation of the ASHRAE Task Group on Energy Requirements to develop a comprehensive hourly energy performance simulation of buildings as well as the APEC (Automated Procedure for Engineering Consultants) activities for cooling load calculation. These activities were linked to the four successful international symposia (Gaithersburg, Banff, Paris, and Tokyo) on the use of computers for environmental engineering related to buildings, the forerunner of IBPSA. A considerable amount of effort went into the earlier thermal simulation programs to improve the physical and empirical modeling of air and moisture and heat transfer processes in and through a complex building structure under varying weather conditions and building use conditions. Although the thermal physics aspects of building environmental simulation have sufficiently been explored in recent years, the author contends that there are still several areas that need further improvements and developments. Although the use of computers for building thermal environmental calculations have been confined to universities and national laboratories where computers were readily accessible in the early 1960s, consulting engineers had begun to use computers for HVAC designs, the most notable was the APEC (Automated Procedures for Engineering Consultants) which developed a cooling load calculation program based on the TMTD method,

the time averaging of hourly heat gain over a designated time period. the development alongside opening and shutting of entryways. Nonetheless, present day development is making homes that are undeniably more firmly fixed so ventilation is turning into an inexorably significant part in home HVAC frameworks. When the air is acquired, it is brought into an air taking care of unit where the work starts. Here, air is attracted through channels to eliminate soil, residue, allergens, and different particles. Following up, is solace. Air is either shipped off be warmed or shipped off be cooled and have overabundance mugginess eliminated. When the air is spotless, new, and at an agreeable temperature, it is coordinated into the home. For focal frameworks, this implies traveling through an organization of conduits and registers to various rooms. For different frameworks, this generally implies being coordinated directly into the space.

### III. WORKING OF AIR-COOLED CHILLER

Air-cooled chillers actively absorb heat from process water; they then transfer this heat into the air around the chiller unit. This type of unit is typically used in areas where additional heat discharge is not an issue, but instead works as a benefit. For instance, the additional heat can be used to warm a space during the winter for less money than traditional heating systems. The cycle starts with the evaporator, which has a liquid refrigerant that flows over the evaporator tube bundle where it evaporates. In the process, heat is absorbed from the chilled water circulating through the bundle. The compressor then pulls the refrigerant vapor from the evaporator. The compressor is then tasked with pumping the refrigerant vapor to the condenser, which increases temperature and pressure. The refrigerant condenses when it's in the condenser tubes, releasing its internal heat to the air or cooling water.

#### 3.1 Basic Refrigeration Cycle for Air-Cooled Chillers

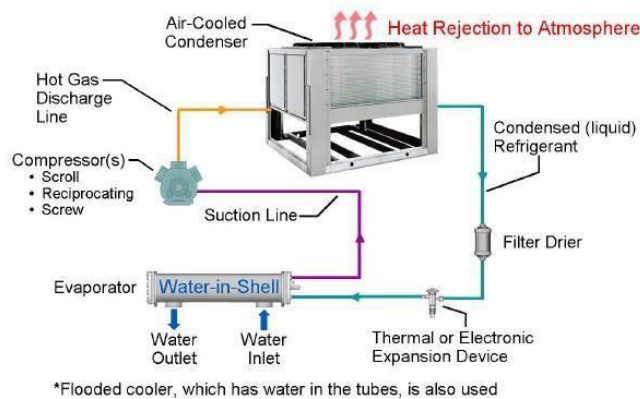


Fig. Refrigeration Cycle

The refrigeration cycle of an air-cooled chiller includes two important processes:

The evaporation of the liquid refrigerant in the evaporator, which absorbs heat and lowers the temperature of the chilled-water system.

- The condensation of the refrigerant vapor in the air-cooled condenser and rejection of heat to the atmosphere.

In the air-cooled chiller refrigeration cycle, water enters the evaporator (also known as the cooler) and is cooled by the colder refrigerant flowing through the other circuit inside the evaporator. The chilled water is pumped from the chiller to the building coils to provide cooling. In the evaporator, the chilled water cools the building or process load and the cycle is completed when warmer water flows back to the evaporator. A mixture of cold liquid refrigerant and flash gas passes through the evaporator circuit opposite the water to be chilled. The refrigerant in the evaporator absorbs heat from the warmer return water, evaporates to a vapor, and finally exits the evaporator as a superheated vapor. The superheated refrigerant vapor then enters the suction inlet of the compressor. In the compressor, the refrigerant is compressed, raising its pressure and temperature. High pressure and temperature refrigerant gas exits the compressor, passes through the discharge line and enters the condenser. While in the air-cooled condenser coil, the hot gas condenses to liquid inside the tubes as it gives up heat. The condensed liquid refrigerant then leaves the condenser and enters the expansion device. As the refrigerant passes through the expansion device, its pressure and temperature is decreased to the point that some of the liquid flashes to vapor.

The expansion device controls the amount of flashing in order to maintain a certain superheat to ensure no liquid droplets enter into the compressor suction. After leaving the expansion device, the refrigerant enters the evaporator and the cycle is repeated.



### Air-Cooled Chiller Components

All air-cooled chillers are comprised of the following components:

1. Evaporator (cooler)
2. Condenser
3. Compressor

Three types of evaporators are used in air-cooled chillers:

1. Brazed-plate, Direct expansion (DX) shell and-tube, Flooded shell-and-tube

The most common choice of evaporator design for larger screw and reciprocating chillers has been the shell-and-tube types while smaller chillers utilize brazed-plate.

Shell and-tube evaporators are widely used and they are larger and heavier than brazed-plate heat exchangers. The tubes for some evaporator types may utilize internal and/or external enhancements to promote turbulence and create increased heat transfer between the fluid and the refrigerant.

Turbulence actually increases the heat transfer process by keeping more of the fluid in contact with the heat exchanger surface area. On the refrigerant side and water side, more contact means greater heat transfer and a higher efficiency rating. Enhancement of tubes typically is achieved through a rifling or finning process during manufacturing.

### Braze-Plate

Braze-plate evaporators are used on chillers up to approximately 60 tons and consist of a series of plates brazed together with every second plate turned 180 degrees. This design creates two highly turbulent fluid channels that flow in opposite directions over a surface area with a high heat transfer coefficient and good performance characteristics. The plates are stacked so they form a multi-layered alternating path for each fluid to travel through. Each layer or circuit is linked to an inlet and outlet via a manifold at either end.

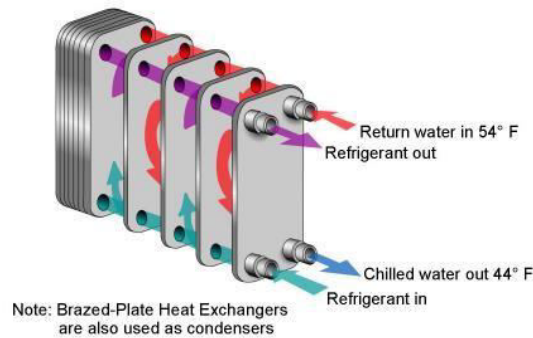
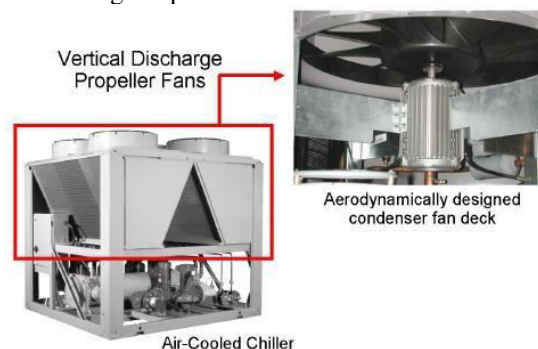


Fig .Braze Plate

### Condenser

The condenser in an air-cooled chiller is a heat exchanger that condenses the hot refrigerant gas by using cooler outside air passing over a coil. In a typical air-cooled chiller, propeller type fans are used to draw the outdoor air over the coil. The hot, high-pressure refrigerant vapor flows through the coil tubes and is condensed to a liquid. In the last portion of condenser tubing, the condensed liquid refrigerant is then sub cooled. A final portion of the condenser is used to lower the refrigerant temperature below the saturated condensing temperature.





**Compressor**

There are three types of compressors utilized for air-cooled chillers. They are reciprocating, scroll, screw

**Reciprocating**

Reciprocating compressors, like a reciprocating engine, have pistons, rods, and discharge and intake valves. The valves operate on suction and discharge pressure. Compression is achieved by trapping a fixed amount of refrigerant gas into a chamber. For this reason, reciprocating compressors are positive displacement type com as are scrolls and screws. Reciprocating compressors were the workhorse of the small chiller market for decades and are still used in many designs. Multiple reciprocating compressors were often installed in a single chiller to provide chiller capacities of up to 400 tons. The reciprocating compressor is available open, semihermetic, or hermetic. Open compressors extend the shaft through a seal in the crankcase for use with an external driver. Hermetic compressors have the motor and compressor contained in the same housing, typically welded and sealed. Semi-hermetic compressors utilize a bolted housing, instead of a welded one, to facilitate repair in the



Fig.reciprocating compressor

**IV. RESULT**

**Chiller flow rate calculation:**

condenser flow rate  
chilled water flow rate

**1.Condenser flow rate calculation:**

Q)150 TR chiller, compressor 66kw, condenser water inlet 90F, condenser water outlet 98F  
 Condenser water flow (GPM)=(THR\*24)/ Δt.  
 THR=Total Heat Rejection (refrigeration effect +work done).

**2.Condenser flow rate calculation:**

Given data:  
 Plant capacity=TR  
 Comp power input=KW  
 Condenser water inlet =90F  
 Condenser water outlet=98F  
 Convert work done by comp in TR  
 TR=KW/3.516=18.77 TR  
 GPM=(THR\*24)/Δt  
 = (150 + 18.67) \*24/8= (168.67\*24)/8  
 = 506 GPM  
 = 138 m3 /HR (1 m3/HR =3.67gpm).

**3.Chilled water flow calculation:**

Given data:  
 GPM=(TR\*24)/Δt  
 TR = 150  
 Chiller inlet temp = 54 F



Chiller outlet temp = 44F

T = 54-44 = 10 F

GPM = (TR\*24)/t

= (150\*24)/10

=360gpm

=98 m3/HR

(1m3/HR = 3.67 GPM)

Inlet and outlet temperatures at the chiller should be set based on the type of the chilled water system and in line with the standards.

Chilled water supply & return temperature of 5.55 & 12.22 °C i.e. Δt=6.67 °C

Condenser entering air temperature equal to the design ambient temperature (46°C)

**Flow rate calculations formulae**

Chilled water flows shall be established using the following formula:

$$Q = m \cdot C_p \cdot \Delta t$$

Where, Cp = specific heat of chilled water media which is 4.186 KJ/KG.°C

ΔT = temperature difference between supply & return chilled water in (°C) The above formula is further simplified for quick calculations

kw = cooling capacity

ΔT = chilled water temperature differential in deg C

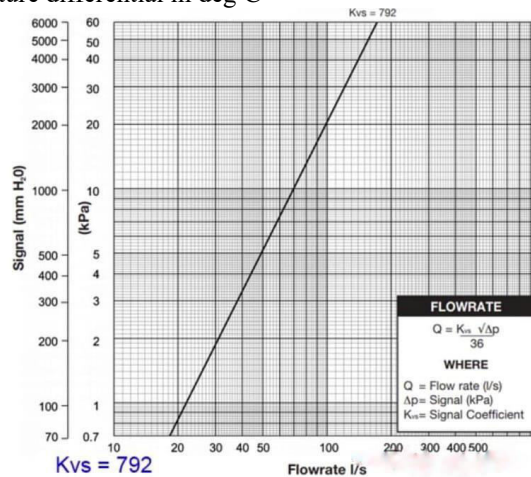


Fig. Flow Rate

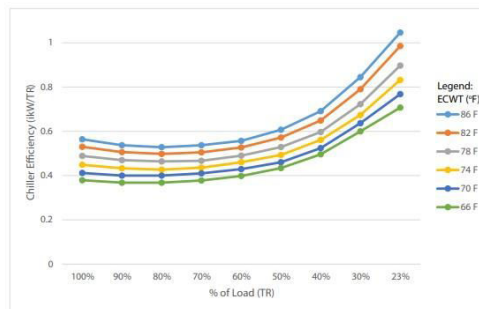


Fig. Chiller Performance Curve

**V. CONCLUSIONS**

Air conditioning systems account for nearly 40% of total energy consumption of a typical commercial building. Thus, it is essential to ensure proper operations and maintenance of chiller systems to prevent high energy consumption, equipment deterioration and poor quality of circulated air. By using real time operational and maintenance data from chillers, we identified the leading causes of poor chiller performance, these include improper temperature differences in entering chilled



water, leaving chilled water and condenser water. by calculating the flow rate of chilled water and flow rate of condenser, we can find the required chilled water for air cooled chiller plant.

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