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Impact Analysis of Cooling Systems in Polymer Industries

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I. OVERVIEW AND PROPERTIES OF POLYMERS

A polymer is a Greek word, combination of two terms poly and mer, the term 'poly' means many 'mer' means units, it is a large molecule, which consists of number of repeated subunits in the form of long chains. Because of the wide range of properties and advantages in day to day life the synthetic and natural polymers play an essential role in everyday life.

The polymers are processed by the following methods like molding, extrusion process mainly. Polymers are required to be cooled immediately to get the desired properties, otherwise the properties get change, and cooling time has to b minimized with homogeneous cooling. The melting point of the polymers is around 180 -220 degree Celsius. It must be cooled within a span of few seconds. If the cooling time increases the properties such as dimensions, surface finish, strength get changed and they get deformed. Therefore the effective cooling systems required for these polymer manufacturing purposes. A specially designed plastic process chillers are used as per requirements of the various type of manufacturing process, such as extrusion process, injection process etc.

II. IMPORTANCE OF COOLING SYSTEMS IN POLYMER PROCESSING INDUSTRIES

Cooling system is an important part in the various industries like textile, printing, food preservation and polymer processing etc, to obtain desirable properties, productivity and effective functioning of the plastic processing process. Air conditioning plays a very important role in all these industries for increasing the rate of production and quality of the product. The cooling or air conditioning requirements for each industry differs from other in terms of temperature and humidity of air.

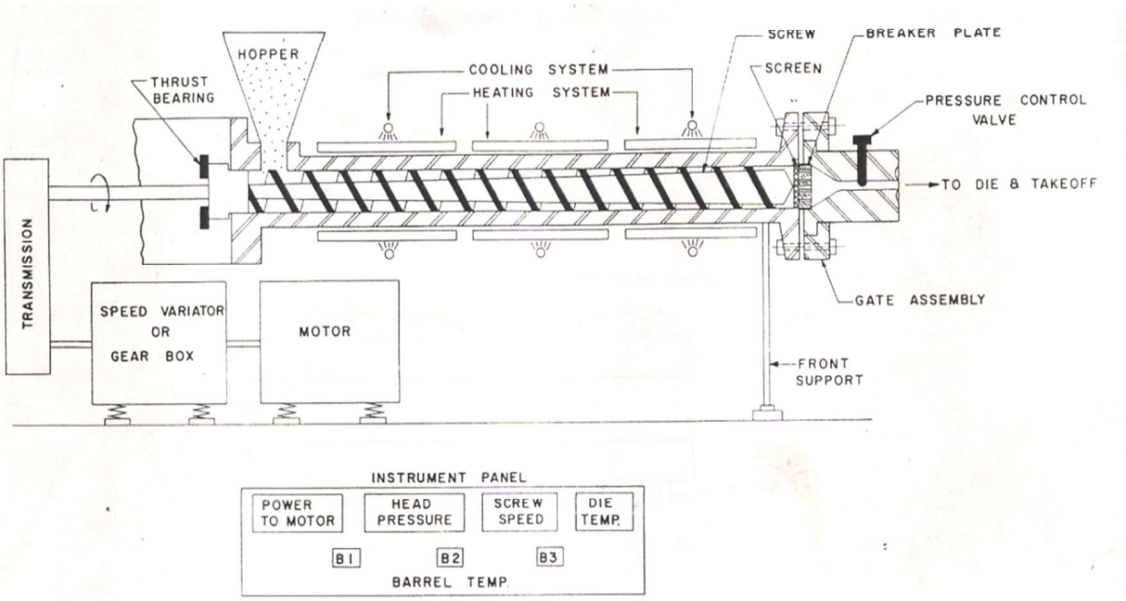
The entire plastic processing industry depends on the cooling systems or basically chill water systems. It is considered as the heart of the entire process in polymer industries. The Polymers are required to be cooled immediately to get the desired properties, otherwise the properties get changed, for this purpose efficient cooling system are used. This project includes the analysis of the cooling systems used in polymer manufacturing processes like extrusion process and injection molding process. Generally plastic processing chillers are used for this purpose, in the plastic processing industries the calculation of the tonnage or capacity of the chillers The main important objective of this paper, "Impact analysis of cooling systems in polymer industries" is to analyze effect of cooling systems on product quality, productivity and cost of production, and suggest the suitable measures to maintain the existing cooling systems i.e. process chillers and suggest best cooling system for the various polymer manufacturing processes

There are various types of polymer manufacturing processes, the most important are are discussed below

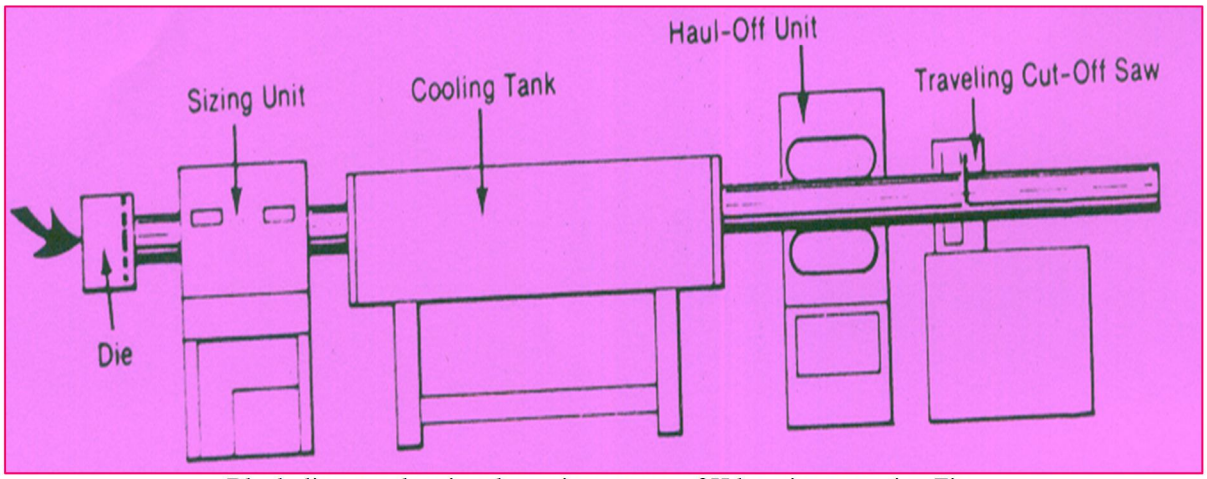
1) Manufacturing of HDPE pipes through extrusion process.
2) Making plastic articles using injection molding processing machines or process.

A. *Extrusion Process*

1) *Introduction of Extrusion Process:* Extrusion process is one of most important and versatile plastic processing process. It converts a plastic material into a product of specific shape and also dimensions by forcing the material through specially designed orifice shaped passage called die under specific controlled conditions. There are specific requirements that must be satisfied regarding both equipments and the raw materials. The equipment or the extruder must b capable of providing sufficient heat to soften the material into a form of semisolid state i.e. molten state, sufficient mixing is action required to homogenize melt and then sufficient pressure to force the melt through filter pad, or screen pack and die. The material in suitable conditions, like pressure and temperature will flow and will solidify when these conditions are removed.
2) *Extrusion process:* Extrusion process is the continuous process for production of pipes, sheets or films etc in a continuous fashion. An extruder is the main part in this process; it works just as volumetric pump. The plastic pellets or raw material are melted by heating it in the barrel and pumped out into desired shape and size. A especially designed screw is placed inside barrel which forces out plastic material from a die. The molten material comes out and takes shape similar to that of cross-section of die



Extruder



Block diagram showing the entire process of Hdpe pipe extrusion Fig

III. COOLING PROCESS FOR MANUFACTURING OF HDPE PIPE i.e. EXTRUSION PROCESS

A. Equipment's

Cooling systems for plastic processing units comprises of chiller as perrequired the capacity, the important equipments of the plastic processing chiller are discussed below, they are

1) Compressor
2) Condensers
3) Evaporators
4) Cooling Towers
5) Expansion Valve
6) Temperature sensors
7) Pressure sensors
8) Pressure relief valve
9) HMI
10) Solenoid valves
11) Refrigerant filter/Drier

B. Chilled water lines

To prevent unwanted condensation, insulate all chilled water pipes. If the water vapor forms on the pipes will become substantial load and it is an additional burden on the chiller. The pipes with low thermal conductivity are used for the chilled water piping, as Hdpe pipes can withstand high pressures and have low thermal conductivity, we have used Hdpe pipes for chilled water pipes. Suitable filters are arranged at all the inlets to arrest the unwanted particles as unwanted particles damage the system if they enter into it, the filter can be seen in the Fig. below

Design consideration for chilled water pipe lines are as follows:-

1) Keep the frictional losses in the pipes to the minimum.
2) Prevent the liquid refrigerant to enter into compressor during running or off cycle is must.
3) Avoid trapping of lubrication oil in the equipments such as evaporator to maintain the equipment efficiency.
4) Continuous and uniform circulation of oil to compressor crank case should be ensured.
5) In multi evaporators the piping should be such that the supply of refrigerant to all the evaporators under all load conditions must be assured.

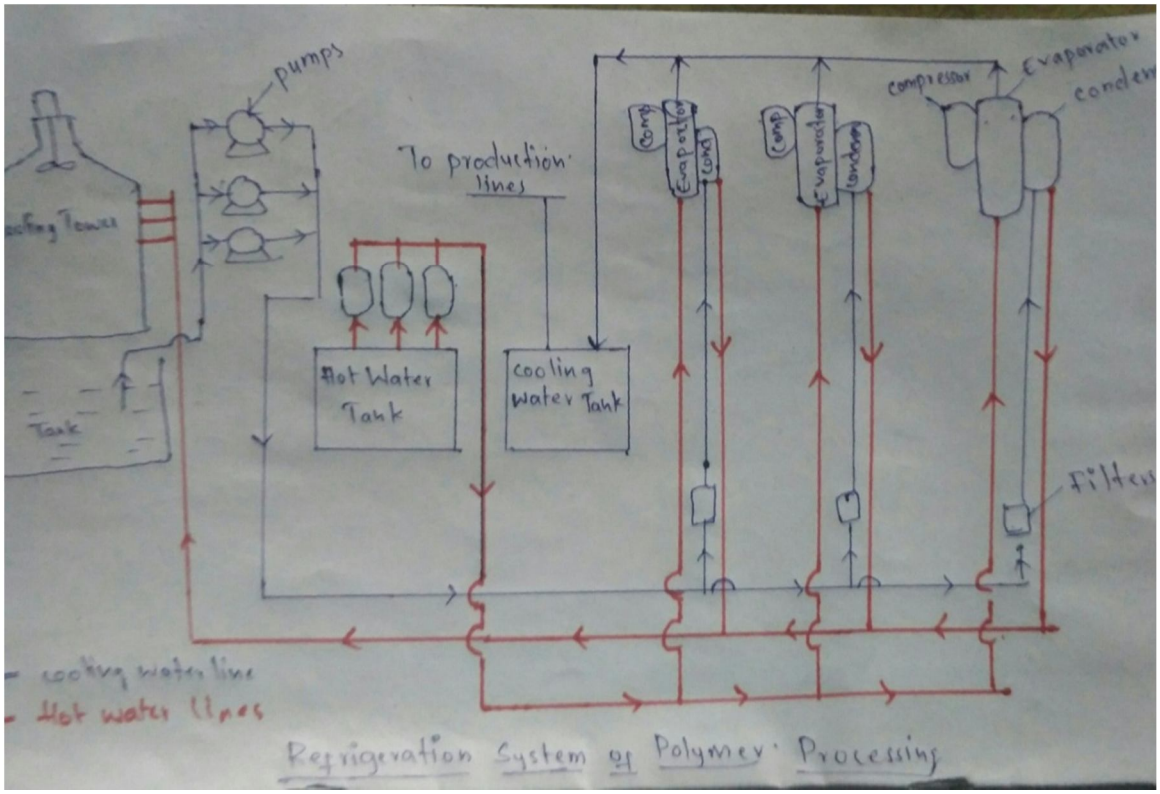


Fig 3.4 Figure showing chilled water lines.

C. Applications Of Extrusion Manufacturing Process

By using extrusion process the following things can be produced

1) Rods
2) Plates
3) Tubes and pipes
4) Wire coating
5) Coating of cables
6) Lining of hose
7) Sheet production
8) Multilayer film
9) Packaging medical items or accessories
10) Packaging items

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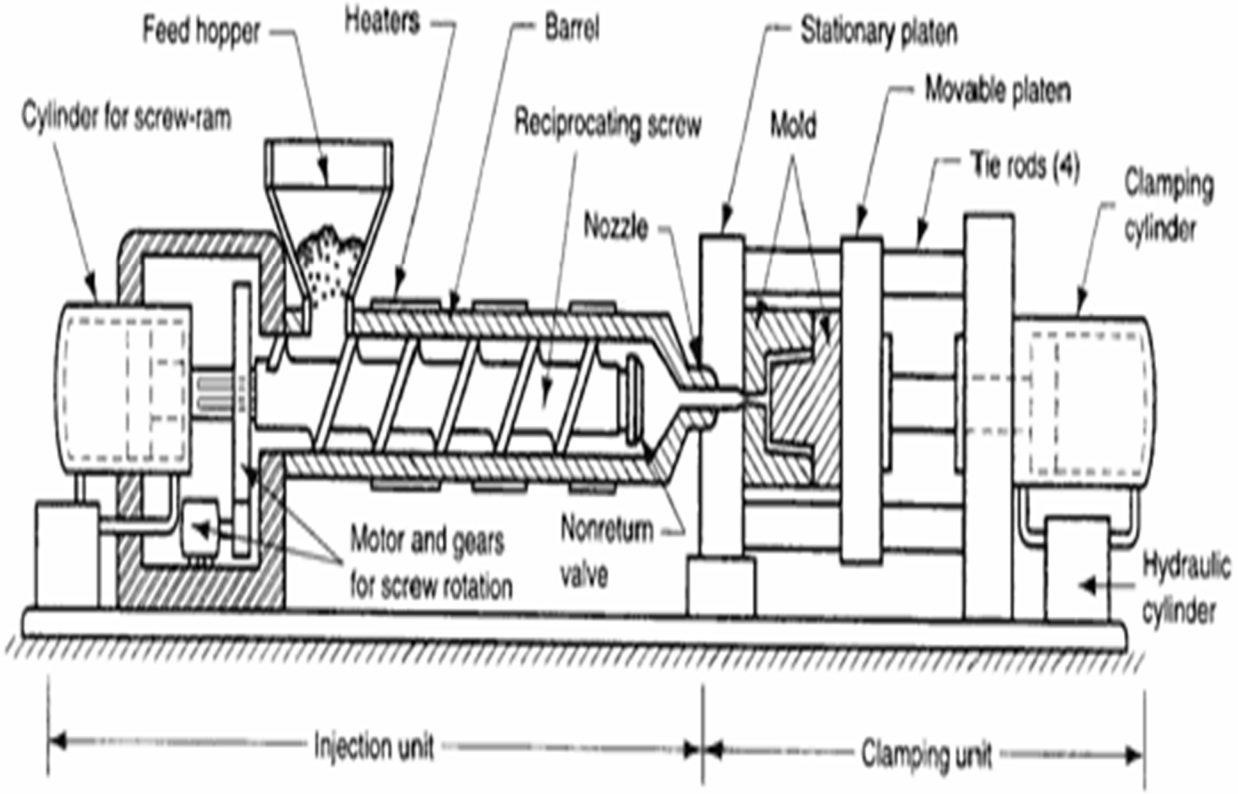
IV. INJECTION MOLDING PROCESS

A. *Description*

It is the plastic manufacturing machine, which uses for the bulk manufacturing plastic parts and plastic articles of one single dimension and shape at a time in its respective die. For ever different article or part there is specially designed die, which can be replaced as perproduction requirements. Injection molding machine are mainly of two types based on the injection type

1) *Reciprocating Screw Machine:* This type of machine is mostly used for the plastic processing. It is also known as single barrel or common barrel injection molding machine, as this machine uses the same barrel for melting and injection of plastics. It reciprocates into the barrel, rotating in one direction conveys the material ahead and gets emptied. And rotates in anti direction.
2) *Screw Plasticizer Injection Molding Machine:* It is also called as two stage screw machine, as it uses two separate barrels for plasticizing purpose and injection of a polymer respectively. Screw drives in one barrel in which the plastic raw material pellets gets feeded from the hopper, in this barrel the material gets melted. And in the second barrel a plunger is present, when the material is conveyed into the second barrel it is further injected into the cavity by this plunger, which pumps the material through nozzle into the mould cavity.



Plastic Injection molding machine

Plastic Injection molding machine can be described into two units, such as

B. *Injection Unit*

1) *Main Motor:* It is a three phase induction motor of required capacity which is connected to the transmission drive i.e. gear box. The rotating speed of main motor is controlled by using VFD or variable frequency drives.
2) *Gear Box:* It is a transmission drive, it helps to get required speed and power to screw. **Screw ram and cylinder:-** It controls the direction of the rotating screw.
3) *Reciprocating Screw:* It is similar to that of pump, the material from feed hopper enters through a throat into abarrel. The screw rotates into the barrel pumping the material forward, simultaneously the material becomes molten by gaining heat from the heaters present above the barrel and shear stress generated in the barrel as a result if rotation of the screw.
4) *Feed Hopper:* Material is gravity fed through this feed hopper, the material is fed continuously and uniformly throughout the process, fluctuated or discontinuous feeding results breakdown of the production process, and impacts the productivity.

5) *Heater:* These are the heating elements fixed over the surface of the barrel. Ceramic heaters can be used for the purpose of heating of barrel. During the start-ups these heater are started first, after barrel and die reaches the melt temperature the production is started. The heating time depends on the size of the barrel and at the same time dies.
6) *Barrel:* It is hollow cylindrical shaped equipment in which the screw is made to rotate. Though the barrel is in hollow cylindrical in shape the wall thickness is little bit higher, there large amount of heat is required to get this barrel heated up.
7) *Nozzle:* It is the mechanical device used to raise the pressure of the flowing element. The nozzle is present at the front part of the barrel, through which the molten material is injected into the cavity.

C. *Clamping Unit*

1) *Stationary Platen:* The molten material from the injecting unit is pumped into the cavity through the nozzle which is attached to the stationary platen.
2) *Movable platen:* this is a movable unit, it moves over the tie rods . Between stationary platen and movable pattern mold is present
3) *Mould:* It is a special tool , it prepare as perspecifications of the part to be produced using injection moulding machine. r are unique for each and every part. These are of various types like two plate moulds and three plate moulds.
4) *Tie Rods:* over these rods the movable platen moves to and fro
5) *Clamping cylinder:* It creates the pressure required for the movable platen to move over the tie rods.
6) *Hydraulic Cylinder:* It creates the pressure to open and closing of the die.

a) The Cooling Process Of Manufacturing Of Parts By Injection Molding Process Involves The Following Steps

i) First of all the pellets i.e. plastic raw material is fed into the hopper after making a suitable recipe i.e. combination of materials.
ii) These pellets move into the barrel which is heated using the heaters present over its external surface.
iii) A special type of screw rotates in this barrel.
iv) In the barrel zone the raw material or pellets get melted due to mechanical shear between the barrel and the screw and also gets compressed in the compression zone of screw.
v) The screw rotates forward injecting the melt or melted plastic material.
vi) This melted material moves forward to the screw and material getss injected into cavity, and the screw comes backward.
vii) From the cavity melted plastic moves into the moulds, there it takes shape of mould.
viii) In the mould the article cooled down immediately,
ix) After cooling the mould opens and ejection pins eject the processed plastic part.
x) The mould is closed after ejecting the part, and the cylcle begins again.

b) *The Cooling Requirements For Injection Molding Process Are*

i) A Process chiller of suitable capacity is required for cooling the processed plastic part.
ii) A ductable package unit of required capacity to maintain the temperature relatively lower than room temperature and also to maintain humidity at a required level as permachine requirements.

D. *A Process Chiller*

A process chiller is a special refrigeration or cooling system, which removes the heat from the processed plastics. Water is used as a medium of to absorb the heat from the processed plastics. This water is cooled by the chiller, again it is circulated into the cycle.

For injection molding machine we are using a 7.3 T.R chiller with built in water tank of storage capacity of 25 liters. This chiller is air cooled condenser type chiller. The makeup water is added from time to time as some amount of water is lost during the process due to sweating of pipes and evaporation.

This chiller capacity is calculated by using chiller capacity calculators. The chiller manufacturing companies have their own chiller capacity calculators. We are required to give the input parameters such as type of raw material, the output capacity of the machine and type of process, the chiller capacity calculator software will give the capacity of the chiller required. For further accuracy, the parameters like weather conditions of the area, type of condenser like water cooled or air cooled, entering and leaving temperatures of the water is given input parameters.

After the calculation of tonnage by using chiller capacity tonnage, the best suitable chiller is selected by using the brochures of the company. After that chilled water piping is done. The pipe sizes are determined by using Mc quay pipe sizer software.

E. Air Cooled Chiller

Chiller works on vapour compression cycle, if the condenser is cooled by axial fans then it is known as air cooled chiller. Similarly if the condenser is cooled by water then it is known as water cooled chiller.

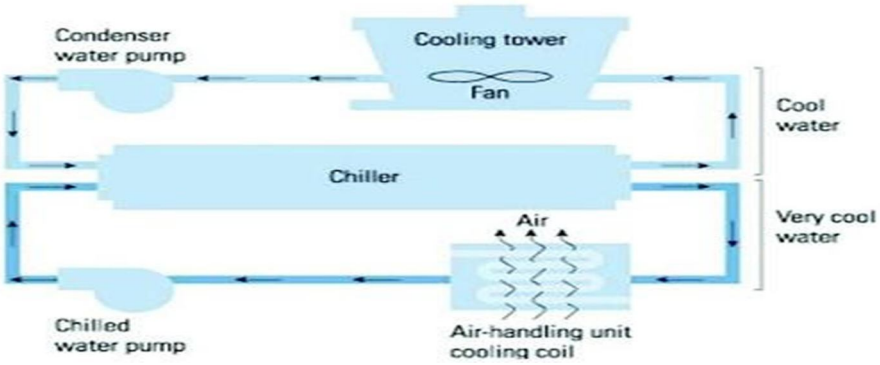
In the air cooled chillers there are two refrigerants one is primary refrigerant and the other is secondary refrigerant. Primary refrigerant works in vapour compression cycle where as secondary refrigerant is used to distribute the cooling effect from chillers to equipments like air handling unit, fan coil unit etc. The primary refrigerant collects heat from secondary refrigerant then it is compressed and condensed to get cooling effect which is carried by secondary refrigerant to the equipments.

Chillers are selected in such a way that it has one standby. For example, there is a load requirement is of 2-chillers, 3 chillers are designed so that two chillers are used keeping one in standby. Number of chillers is selected by the diversity factor. In this project report diversity factor is taken as 66% therefore 3-chillers are selected of each capacity 84TR.

F. Water Cooled Chiller

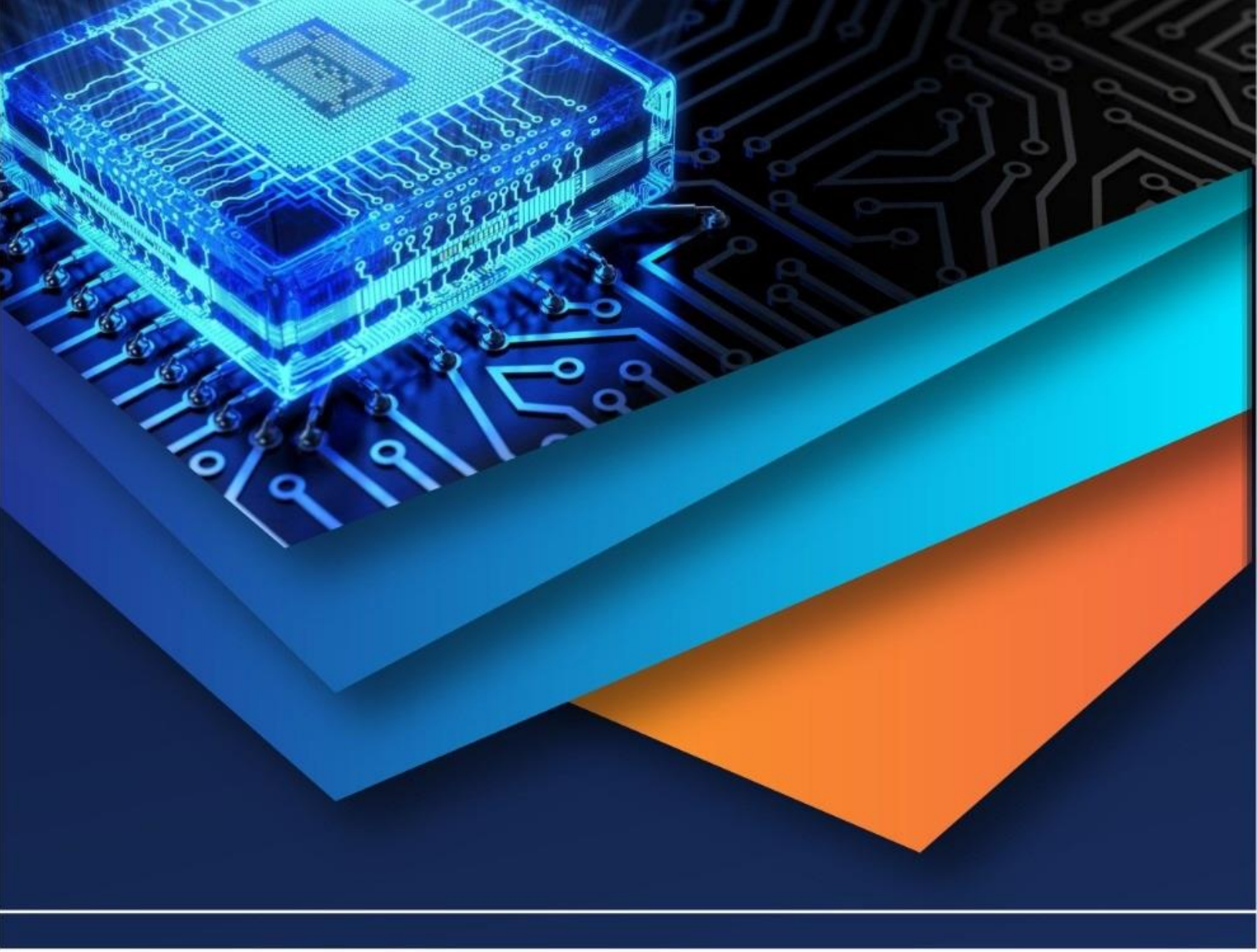
In this type of chillers the condenser is cooled by water. A cooling tower is used to reject the heat to the surroundings. Water cooled condenser are used where the water is available easily and there is enough space to accommodate these chillers, as water cooled chillers occupy a large space compared to air cooled chillers.

Water cooled chillers are usually used for higher capacity requirements, such as 25 T.R to 200 T.R.



If the cooling is not sufficient the following problems are encountered in the materials produced:-

1) Flow lines
2) Vacuum voids
3) Surface delamination
4) Weld lines
5) Short fills or short shots
6) Warping
7) Burn marks
8) jetting



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