UNIT-1

Lecture-1

VARIOUS PROCESS UTILITIES

The word “utilities” is used for the ancillary services needed in the operation of any production process. These services are normally supplied from a central site facility, and include:

1. Electricity

2. Fuel for fired heaters

3. Fluids for process heating
a. Steam
b. Hot oil or specialized heat transfer fluids

4. Fluids for process cooling
a. Cooling water
b. Chilled water
c. Refrigeration systems

5. Process water
a. Water for general use
b. De-mineralized water

6. Compressed air
7. Inert-gas supplies (usually nitrogen)

Role and importance in chemical plant

Most plants are located on sites where the utilities are provided by the site infrastructure. The price charged for a utility is mainly determined by the operating cost of generating and transmitting the utility stream. Some companies also include a capital recovery charge in the utility cost, but if this is done then the offsite (OSBL) capital cost of projects must be reduced to avoid double counting and biasing the project capital-energy trade-off, leading to poor use of capital.

Some smaller plants purchase utilities “over the fence” from a supplier such as a larger site or a utility company, in which case the utility prices are set by contract and are typically pegged to the price of natural gas, fuel oil, or electricity.

The utility consumption of a process cannot be estimated accurately without completing the material and energy balances and carrying out a pinch analysis, as described in Section 3.5.6. The pinch analysis gives targets for process heat recovery and hence for the minimum requirements of hot and cold utilities. More detailed optimization then translates these targets into expected demands for fired heat, steam, electricity, cooling water, and refrigeration. In addition to the utilities required for heating and cooling, the process may also need process water and air for applications such as washing,

Electricity

The electricity demand of the process is mainly determined by the work required for pumping, compression, air coolers, and solids-handling operations, but also includes the power needed for instruments, lights, and other small users. The power required may be generated on site, but will more usually be purchased from the local supply company. Some plants generate their own electricity using a gas-turbine cogeneration plant with a heat recovery steam generator (waste-heat boiler) to raise steam . The overall thermal efficiency of such systems can be in the range 70% to 80%; compared with the 30% to 40% obtained from a conventional power station, where the heat in the exhaust steam is wasted in the condenser. The cogeneration plant can be sized to meet or exceed the plant electricity requirement, depending on whether the export of electricity is an attractive use of capital.

Fired Heat

Fired heaters are used for process heating duties above the highest temperatures that can be reached using high pressure steam, typically about 250 ºC (482 ºF). Process streams may be heated directly in the furnace tubes, or indirectly using a hot oil circuit or heat transfer fluid.
The cost of fired heat can be calculated from the price of the fuel fired. Most fired process heaters use natural gas as fuel, as it is cleaner burning than fuel oil and therefore easier to fit NOx control systems and obtain permits.

Steam

Steam is the most widely-used heat source in most chemical plants. Steam has a number of advantages as a hot utility:

- The heat of condensation of steam is high, giving a high heat output per pound of utility at constant temperature (compared to other utilities such as hot oil and flue gas that release sensible heat over a broad temperature range).

- The temperature at which heat is released can be precisely controlled by controlling the pressure of the steam. This enables tight temperature control, which is important in many processes.

- Condensing steam has very high heat transfer coefficients, leading to cheaper heat exchangers.

- Steam is nontoxic, nonflammable, visible if it leaks externally, and inert to many (but not all) process fluids.

Water

The water required for general purposes on a site will usually be taken from the local mains supply, unless a cheaper source of suitable quality water is available from a river, lake, or well. Raw water is brought in to make up for losses in the steam and cooling water systems and is also treated to generate de-mineralized and de-ionized water for process use. Water is also used for process cleaning operations and to supply fire hydrants.

Demineralized Water

Demineralized water, from which all the minerals have been removed by ion-exchange, is used where pure water is needed for process use, and as boiler feed water. Mixed and multiple-bed ionexchange units are used; one resin converting the cations to hydrogen and the other removing the anions. Water with less than 1 part per million of dissolved solids can be produced. The design of ion exchange units is discussed in Section 16.5.5. Demineralized water typically costs about double the price of raw water, but this obviously varies strongly with the mineral content of the water and the disposal cost of blowdown from the demineralization system.

Compressed Air

Compressed air is needed for general use, for oxidation reactions, air strippers, aerobic fermentation processes, and for pneumatic control actuators that are used for plant control. Air is normally distributed at a mains pressure of 6 bar (100 psig), but large process air requirements are typically met with standalone air blowers or compressors. Rotary and reciprocating single-stage or two-stage compressors are used to supply utility and instrument air. Instrument air must be dry and clean (free from oil). Air is usually dried by passing it over a packed bed of molecular sieve adsorbent. For most applications, the adsorbent is periodically regenerated using a temperature-swing cyclc.

Cooling Air

Ambient air is used as a coolant in many process operations; for example, air cooled heat exchangers, cooling towers, solids coolers, and prilling towers. If the air flow is caused by natural draft then the cooling air is free, but the air velocity will generally be low, leading to high equipment cost. Fans or blowers are commonly used to ensure higher air velocities and reduce equipment costs. The cost of providing cooling air is then the cost of operating the fan, which can be determined from the fan power consumption. Cooling fans typically operate with very high flow rates and very low pressure drop, on the order of a few inches of water.

Nitrogen

Where a large quantity of inert gas is required for the inert blanketing of tanks and for purging this will usually be supplied from a central facility. Nitrogen is normally used, and can be manufactured on site in an air liquefaction plant, or purchased as liquid in tankers. Nitrogen and oxygen are usually purchased from one of the industrial gas companies via pipeline or a small dedicated "over-the-fence" plant. The price varies depending on local power costs, but is typically in the range $0.01 to $0.03 per lb for large facilities.

Waste-heat Boilers

If the process streams are at a sufficiently high temperature and there are no attractive options for process-to-process heat transfer, then the heat recovered can be used to generate steam. Waste-heat boilers are often used to recover heat from furnace flue gases and the process gas streams from high-temperature reactors. The pressure, and superheat temperature, of the steam generated depend on the temperature of the hot stream and the approach temperature permissible at the boiler exit. As with any heat-transfer equipment, the area required increases as the mean temperature driving force (log mean ΔT) is reduced.

Lecture-2

Water Sources of water and their characteristics

Water Resources

Water, a vital natural resource and precious commodity, is essential for multiplicity of purposes, viz., drinking, agriculture, power generation, transportation and waste disposal.

In chemical processes industrial water is used as a reaction medium, a solvent, a scrubbing medium and a heat transfer agent.

As a source of life for man, plants and animals, it is indispensable and cannot be replaced by any other solvent

Availability of Water:

The chief sources of water are rain water, sea water, ground and surface water. The World's total quantum of water is 140 x 10^{16} m^3.

Sea Water:

About 97% of earth's water supply is in the oceans which is unfit for human consumption or other uses due to high salt contents. Of the remaining 3%, 2.3% is locked in the polar ice caps and hence inaccessible. The remaining 0.7% is available as fresh water. If all the sea beds could be raised up and brought at the level of the earth surface, then the entire water in oceans would cover the whole earth's surface and make it 2.5 km deep water mass.

Ground Water:

Ground water, a gift of nature, is about 210×10^9 m^3 (0.66%) including recharge through infiltration, seepage and evapo-transpiration. Out of this nearly one-third is extracted for irrigation, industrial and domestic use, while most of the water is recycled into rivers. Of the fresh water below the surface about 90% satisfies the description of ground water that is, water which rests below the water table. About 2% water occurs as soil moisture in the unsaturated zone above the water table and is essential for plant growth.

The major portion of water (about 165 x10^{10} m^3) which goes to earth crust is retained as soil moisture. Only 500 x10^9 m^3 percolates down to the ground water deposits. About 120 x10^9 m^3 of water applied to agricultural fields moves down to ground water table and 50 x 10^9 m^3 of surface flow also end up as ground water. Thus a total of 670 x10^9 m^3 fresh water enters the ground annually.

Surface Water:

We have a very limited stock of usable water that is, 0 03% of the mass balance. The 115×10^{10} m^3 of surface water is increased by the addition of about 450 $x10^9$ m^3 of fresh water from ground water flow, 200 $x10^9$ m^3 from surface flow and 50 x 10^9 m^3 as run-off from irrigated areas. The surface loses almost 50×10^9 m^3 m of its water which percolates down to ground water deposits. The total surface flow per year is 185×10^9 m^3 which is distributed among river basins

Rain Water:

In India, the annual rainfall is about 400 $x10^{10}$ m^2. Out of this, 70 $x10^{10}m^2$ of water evaporates immediately, 115 $x10^{10}$ m^2 runs off into surface water bodies and the remaining percolates into the soil. The hydrological cycle in nature is, more or less, balanced in terms of charge (cloud formation) and discharge (rainfall). By 2010, the total water requirement was expected to thrice as much as we had in 1974. The waste water from these is extremely polluted and on mixing with rivers it is polluting the rivers also.

Lecture-3

BOILER FEED WATER

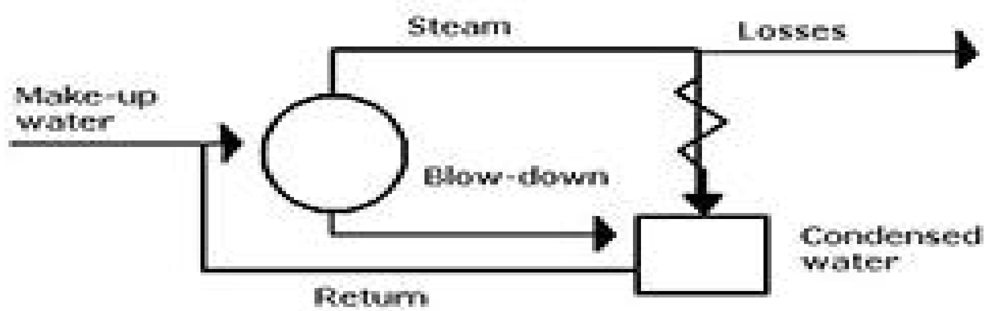
Water treatment for thermal power plant is conducted to prevent problems such as carry over to the turbine components, as well as corrosion and scale formation/deposition in the boiler and turbine system. Since 1959, water treatment methods have been improved to deal with equipment nonconformities. The improvement of water treatment method for aging plants, higher operational efficiency, and better environmental conservation has been high on the agenda in recent years. This technology aims to remove particles and dissolved impurities by evaporation and condensation. Distilled or row water is used for boiler make up, chemical treatment is necessary to counteract harmful substance which are present. Particularly the contaminates present in row water are inorganic sodium compound of chloride, sulphate and carbonate and the hardness (calcium and magnesium) compounds of this same material. Gases such as oxygen and carbon dioxide are present in feed water.

In the steam boiler industry, high purity feed water is required to ensure proper operation of steam generation systems. High purity feed water reduces the use of boiler chemicals due to less frequent blow down requirements. Lower blow down frequency also results in lower fuel costs. Scale buildup is reduced due to a smaller concentration of impurities in the boiler feed water. The lower level of impurities also reduces corrosion rates in the boiler. When boiler is used to run a steam turbine, turbine blade erosion is reduced due to higher purity steam generated.

Water treatment for thermal power plants is conducted to prevent problems such as carryover to the turbine components, as well as corrosion and scale formation/deposition in the boiler and turbine systems. In recent years, with increased focus on water treatment methods for aging plants, higher operational efficiency and better environmental conservation, we are developing a package of new products and technologies that address the following problems:

- Powdered scale deposition for oxygenated treatment (combined water treatment; CWT)-applied plants
- flow-accelerated corrosion (FAC) and the use of hydrazine
- Turbine contamination due to the leakage of sea water.
- The successful operation of boilers requires accurate analysis of the water that is used, proper treatment to remove corrosive minerals and gases, and careful attention to the controls and procedures for the taking of water samples, their testing, and all required inspections.
- The main purpose of boiler feed water treatment is to improve maintenance, efficiency, reliability, treatment, system life and safety of boiler systems.

A boiler is a device for generating steam, which consists of two principal parts: the furnace, which provides heat, usually by Burning a fuel, and the boiler proper, a device in which the heat changes water into steam. The steam or hot fluid is then re circulated out of the boiler for use in various processes in heating applications. The boiler receives the feed water, which has been purified in varying degrees (makeup water). The make-up water is usually natural water either in its raw state, or treated by some process before use .feed water composition therefore depends on the quality of the make-up water and the amount of condensate returned to the boiler. The water remaining in liquid form at the bottom of the boiler picks up all the foreign matter from the water that was converted to steam. The impurities must be blown down by the discharge of some of the water from the boiler to the drains. [5] Feed water purity is a matter both of quantity of impurities and nature of impurities: some impurities such as hardness, iron and silica are of more concern, for example, than sodium salts. The purity requirements for any feed-water depend on how much feed water is used as well as what the particular boiler design (pressure, heat transfer rate, etc.) can tolerate.



IMPURITIES IN BOILER FEED WATER

Impurities are substance inside a confined amount of liquid, gas or solid which differ from the chemical composition of the material or compound. Impurities are either naturally occurring or added during synthesis of a chemical product. During production impurities may be purposely, accidently or incidentally added into the substance. [10]

The following impurities are present in the boiler water are discussing in below:-

Calcium (Ca) scale A.

Calcium forms with sulfates and other compounds to form calcium sulfate, calcium bicarbonate, calcium carbonate, calcium chloride, and calcium nitrate. During evaporation, these chemicals adhere to boiler tube walls forming scale. Its formation increases with the rate of evaporation so these deposits will be heaviest where the gas temperatures are highest. Scale is a nonconductor of heat which leads to a decreased heat transfer of the boiler tubes, and can result in tube failure due to higher tube metal temperatures.

Iron (Fe) B.

High iron is not found in raw water but high concentrations can come from rusted piping and exfoliation of boiler tubes. Iron is found in condensate return in a particle form as it does not dissolve in water. The detrimental aspect of iron is called steam turbine solid particle erosion, which causes significant erosion of steam turbine steam path components.

Oil C.

Oil is an excellent heat insulator, and adherence of oil on tube surfaces exposed to high temperatures can cause overheating and tube damage.

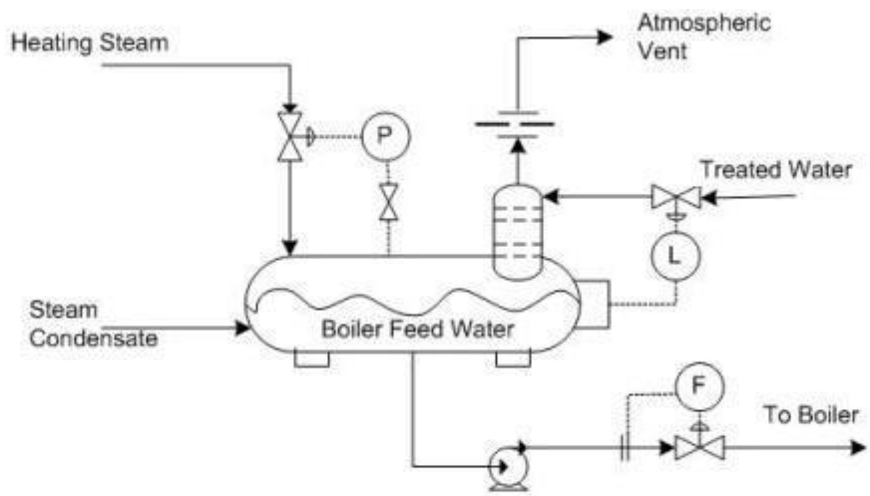
Carbon Dioxide (CO_2) D.

Carbon dioxide can react with water to form carbonic acid (H_2CO_3). Carbonic acid will cause corrosion in team and return lines. Carbon dioxide can originate from condenser air leakage or bicarbonate (HCO_3) alkalinity in the feed water.

Lecture-4

BOILER WATER TREATMENT PROCESS

Boiler water treatment is a type of industrial water treatment focused on removal or chemical modification of substances potentially damaging to the boiler. Varying types of treatment are used at different locations to avoid scale, corrosion, or foaming. External treatment of raw water supplies intended for use within a boiler is focused on removal of impurities before they reach the boiler. Internal treatment within the boiler is focused on limiting the tendency of water to dissolve the boiler, and maintaining impurities in forms least likely to cause trouble before they can be removed from the boiler in boiler blow down. Water treatment is used to improve the quality of water contacting the manufactured product e.g. semiconductors, and/or can be part of the product e.g. beverages, pharmaceuticals, etc. In these instances, poor water treatment can cause defective products. Domestic water can become unsafe to drink if proper hygiene measures are neglected.



The boiler feed water treatments are as follows:-

Coagulation and flocculation A.

Coagulation and Flocculation is a process where by adding aluminum sulfate to the raw water, settlement can be achieved in a considerably shorter time. In traditional water treatment, certain chemicals are added to raw water to remove impurities. While some particles will spontaneously settle out from water on standing (a process called sedimentation), others will not. To cause particles that are slow to settle or are non-settling to settle out more readily, a soluble chemical or mixture of chemicals is added to the water. Such a chemical is called a coagulant and the process is called coagulation.

Sedimentation B.

Some particles will spontaneously settle out from standing water (a process called sedimentation). Sedimentation is used to remove the majority of settle able solids from coagulated/flocculated raw water. The solids are removed before the water passes to the filter hence reducing the solids load on the filter and increasing the efficiency of the Treatment plant.

Flotation C.

The natural flotation process differs from the flotation with air. In the first case, the material particles lighter than the water (oils, greases) eventually associated with gas bubbles have the tendency to raise to the stationary liquid surface. In the flotation process with air, the material particles heavier than the water are transported to the liquid surface by attaching them with air bubbles. [18] It is process for removing suspended particles from liquid by bringing particles to the surface of the liquid. The influent feed liquid can be the row water, waste water or liquid sludge. The flotation system consists of four major components air supply, pressurizing and flotation chamber.

Filtration D.

Filtration is another important element of the treatment process. This process involves the water passing through a bed of fine particles, usually sand. This process is called sand filtration. Other materials are also used in the filtration process. Generally they are layered. Originally filtration was a slow process, however because the sand filtration processes become less effective at removing fine suspended particles at higher water flow rates. The water must be pretreated – coagulated and flocculated – before passing through the filter bed. Such high rate direct filtration processes are widely applied to raw water with low levels of suspended matte

Lecture-5

Reuse and conservation of water

What we can do for water conservation?

- Local communities should take an active part in planning and implementing water management schemes, if they are to be sustainable
- Look for appliances that reduce water use. Shower heads, dishwashers, washing machines, taps and toilets with excellent water efficiency.
- Turn the tap off when you brush your teeth
- Toilets are big water users. Use the full flush only when necessary
- Installing flow regulators on kitchen and bathroom taps
- Clean vegetables in a plugged sink rather than with the water running
- Pool covers help to reduce evaporation
- Use a bucket and not the pipes to wash your car.
- Use the water meter to check for hidden leaks

Water Conservation and Management

- How much water do we need and where do we get it?" Rather, it is "how much water is there and how can we best benefit from it?‟
- India as a whole is expected to enter the water-stress category by 2025.
- Proper domestic use
- Efficient agricultural use
- Water harvesting
- Desalination of marine water
- Forest conservation. Forests are important water regulators Their root structures act as nature's sponges, soaking up water and releasing it slowly throughout the

year, thus contributing to reliable river flow, replenishing groundwater supplies, reducing soil erosion, and releasing moisture into the atmosphere.

- Recycling of industrial water
- Waste water treatment to avoid water pollution & save the aquatic and our life.
- watershed or river-basin management especially in water-short regions
- Instituting a workable water infrastructure
- Enacting and enforcing water legislation and regulations
- Valuing freshwater resources
- Creating competent administrative and legal structures
- Making institutions more responsive and effective
- Training senior water managers
- Establishing closer ties to universities and research institutes
- Connecting water management to the needs of agriculture, industry, and municipalities, and meeting public health requirements for proper sanitation and disease prevention.

Lecture-6

Water resource management

DEFINITION-

1.” Water resource management is the control of water usage and also the quality of water. Many cities have departments that will test the quality of water at treatment plants.”

Water is a unique substance. It is one of the few materials on the Earth that exists naturally as a solid, liquid or gas. It is not possible for life on earth to exist without water. Scientists estimate that there are over one billion cubic kilometers of water on this earth, which covers nearly three fourth of the earth's surface. Though this seems an extremely huge amount, in actual fact, less than one percent is fresh and usable and is found in lakes, ponds, rivers and groundwater. Of the remaining, ninety seven percent is found in oceans and two percent is locked up in glaciers and ice-caps. From a global viewpoint, fresh water is abundant and the volume of fresh water renewed by the hydrological cycle between the oceans, the atmosphere, the sun and the land is more than enough to meet the needs of five to ten times existing world population.

Water quality monitoring is not yet developed in some countries, in other it is in decline. The quality of water available for drinking is posing a serious threat to the existence of life. Degradation of water quality is a consequence (result) of human activities, land use practices and economic development. Land use practices affect the quality of water in our streams, lakes, ground water and ultimately the marine environment. Experience has shown that it is within our ability to slow and reverse water quality degradation, to improve human health and ecosystem integrity by nations putting forward a concerted effort. To accomplish this, aggressive, positive and timely policies and actions are needed. The world has a moral obligation to ensure that future generations inherit a world with clean water and healthy environment. So there is a significant need for Water Resource Management.

Water Resources Management is a very important issue with regard to the conservation and the protection of water. Water demand management is meant to manage the available water resources wisely and to deliver the necessary amount for sustainable development. In these include environmental conservation with inter and intra generation equity in mind while any policy of conservation is formulated.

Water Resources Management is an international, multidisciplinary forum for the publication of original contributions and the exchange of knowledge and experience on the management of water resources. In particular, the journal publishes contributions on water resources assessment, development, conservation and control emphasizing policies and strategies. Contributions examine planning and design of water resource systems, and operation, maintenance and administration of water resource systems.

Coverage extends to these closely related topics: water demand and consumption; applied surface and groundwater hydrology; water management techniques; simulation and modeling of water resource systems; forecasting and control of quantity and quality of water; economic and social aspects of water use; legislation and water resources protection. Water Resources Management is supported scientifically by the European Water Resources Association, a scientific and technical nonprofit-making European association.

Treatment of Water

Cooling Water Treatment in India

Water due to its unique molecule and basic properties is ideal and widely used for cooling water applications. Water is easily available, safe to handle and inexpensive making it the most obvious choice for use in various industrial applications. Compared to air, water is the most efficient and effective medium for transferring heat and therefore widely used.

Which industries In India Need Cooling Water Systems and Why

Cooling water systems are required in many industries for efficient and proper functioning of industrial operations. Typically, refineries, steel mills, petrochemical plants, manufacturing industries, food plants, chemical processing plants and electrical utilities are heavily dependent on cooling water systems.

By transferring hest from hot process, fluids to the cooling water this system helps in controlling temperature and pressures of the entire facility or typical industrial operation. During this process often, water is heated and needs to be cooled for further use or replacement fresh water has to be used for next cooling water cycle.

Usually the entire sustainability and the value of production process will be maintained only if the cooling water system is able to keep precise temperature and pressure. Most of the times effectiveness and efficiency of the cooling system design entirely depends on the type of process being cooled, characteristics of water as well environmental considerations.

Why Cooling Water Treatment is Important

Until now, it is clear that cooling system operations have ability for directly affecting the reliability, efficiency and cost of industrial process. Therefore, it is important to monitor, maintain as well control the corrosion deposition, microbial growth in order to achieve efficiently working cooling water system.

What Problems Arise in Cooling Water System

Water is a universal solvent as it has the ability to dissolve many substances including gases like oxygen and carbon dioxide thereby easily subsidizing many unwanted side effects of industrial applications. Often this leads to corrosion of metals frequently used for cooling systems, furthermore as water concentration in cooling system the irons that are dissolved in water have tendency to exceed the solubility of few minerals forming scale.

Due to water, living up to its expectations of life giver bacterial growth is enhanced, eventually damaging system surface.

All these problems specifically arise in cooling water systems and therefore it is necessary to implement proper cooling water treatment so that the value of cooling water system in industrial processes can preserved. Remember in many industries cooling water system is an integral part of processes and functions so if you want to maintain the continuous productivity of your plant proper chemical treatment and preventive maintenance is very much necessary.

Accepted Cooling Water treatment In India

First thing, the choice of treatment used is always dependent on the type of cooling system used in industry.

In open re-circulating system chemical present are more in amount because every time, water evaporates its composition changes dramatically. More often, in this system, corrosive and scaling constituents are concentrated and so evaporation concentrates the chemicals used for treatment. Therefore, initial dose of chemicals used is pretty high whereas moderate dosage afterwards are used for maintaining the higher level of cooling water treatment needed in these plants.

In Once-Through system usually water composition does not change significantly while passing through the heat exchanger equipment so only few parts per million of chemicals are enough to treat cooling water. Care is taken while treating cooling water system based on this method because large volume of water is used in this system so even a small chemical dose means abundant presence of chemicals.

Cooling water treatment in Closed Recirculating System is easy because the water composition usually remains constant so there is almost negligible loss of water or chemical used for treatment. More often softened or demineralized water is used having significant high dosage of chemicals because system needs water only once and loss of water in this system is far less.