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Single-pressure and multi-pressure condenser in Industry

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ABSTRACT

The idea of using steam to produce mechanical work probably raised for the first time in relation to pumping water from coalmines. The first successful work in this case was a "Pump engine" made by Thomas Savory (1650-1715) in England. In the riding engine, steam directly applied with a pressure between 4.5 and 8 bar on the surface of the water located in a chamber and it raised in a pipe. In this engine, a one-way valve prevented the reverse flow of water. After the water emptied from the chamber, the flow of steam manually cut off and cold water entered the chamber so that more water would enter it by condensing the steam inside and creating a vacuum in the chamber. In this engine, because of direct contact between water and steam, the loss of steam due to condensation was high, and the lack of safety valves caused many explosions. Almost at the same time as Savory, Denis Papin (1647-1712), who was also the inventor of the safety valve, proposed the idea of separating steam and water by means of a piston, and Thomas Newcomen (1663-1729) designed and then built such a piston engine. In this engine, steam enters the vertical cylinder with low pressure and causes a piston to move upwards. Then, the steam that remains in the cylinder turned into a liquid from the outside by the direction of cold water, and thus a vacuum created in the cylinder.

Introduction

The pressure of the external atmosphere pushes the piston back during the working phase, for this reason it called "Atmospheric engine". The piston connected to one end of a rod that sometimes had a support in the middle. A piston also connected to the other end of the pump in a separate cylinder. The diameter of this pump piston was smaller than the steam piston and as a result, the water pressure was higher than the steam pressure. Many valves in the Newcomen engine operated manually at first. The idea of automating the valves initially presented by a teenager who hired to regulate the valves. According to the story, despite being smaller and lazier than others are, this teenager noticed the regular pattern of the rod and the valve and invented a rope mechanism that allowed the rod to regulate the valves.

The Newcomen engine used one third less coal than the Savori engine.

After 60 years, James Watt proposed the idea of a "Modern" reciprocating engine. As an equipment repairer, he called one day in 1764 to repair the Newcomen engine, and in this way, he realized the loss of liquefied steam in the cylinder. In 1765, he thought of a separate condenser, and then about the working stage due to the expansion of steam, the double-acting cylinder, the damping regulator with hanging weights, the conversion of reciprocating motion into rotary motion (in 1781), and ideas Importantly, he expressed other innovative opinions. Today, his famous engine considered as an invention that had an outstanding contribution in the industrial revolution.

The Watt engine used 60% less coal than the Newcomen engine and 75% less than the Savori engine. Corliss (1817-1888) made another important progress. He made inlet valves that closed quickly.

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These lions, which named after him, reduced his pain while being closed. The Corliss engine consumed half as much coal as a watt engine, but despite this, the consumption was four or five times the coal consumption of modern steam turbine power plants. The next step taken by Stumf (1863-?) and he also made the "Single flow engine". In the design of this engine, reduction of condensing loss considered even more.

The largest reciprocating steam engine was built at the beginning of the 20th century to run a 5-megawatt power generator, which was very large at the time. No larger engine ever built after that, although performance improvements continued, especially with the single-flow engine. Of course, at the same time, the need for larger power generators felt without the presence of large enough reciprocating engines to run them. Entering the steam turbine into the scene was not a new idea at all, but its need was predicted by many inventors in the late 1800s. Like many other important inventions, the steam turbine created when the world needed it. In fact, the first recorded steam turbine in history is the steam turbine that built by Hervasekandrani around the first century AD. This turbine consisted of a hollow sphere that was able to rotate around a horizontal axis, fixed in the distance between two tubes that connected the sphere to a steam boiler. The steam produced in the boiler entered the furnace and tangentially discharged into the atmosphere through two trumpets. Trumpets were located in a plane perpendicular to the axis of rotation and in two opposite directions. The steam coming out of the trumpets, like the water coming out of a rotating lawn sprinkler, caused the Korean era. Therefore, the turbine was working based on the reverse reaction principle. After a long period, around the year 1629, a steam turbine was built in which a jet of steam hitting the blades of a wheel was used to make it rotate. This turbine worked based on the impact principle. After that, in 1831, the American William Avery built the first steam turbine that was used commercially in sawmills. At least in one case, it tried to use in the locomotive. Similar turbines were used with approximately 0.75 meters, the arms were connected to the axis at a right angle, and at the end of each there was a small opening from which the steam exited in the opposite direction. The steam that entered the hollow shaft exited through the holes and caused the shaft to rotate. The steam that entered the hollow shaft exited through the holes and caused the shaft to rotate. Therefore, the turbine was a reaction turbine like any turbine. Although it claimed that the efficiency of these turbines is similar to the efficiency of their contemporary reciprocating steam engines, they were not used due to their high noise, difficulty in controlling and frequent breakdowns.

Anyway, the steam turbine that replaced the reciprocating steam engine came into being because of the efforts of several people in the late 19th century. The pioneers of these people were the Swedish Gustavo Delaval and the English Charles Parsons. At first, Delaval designed a small reaction turbine with high speed ($42000\frac{r}{min}$), but because he did not consider it a practical design, he turned his attention to the design of a single-stage impact turbine, this type of turbine is still named after him. Also, the use of converging-diverging trumpet in the turbine is attributed to him for the first time. This type of turbine still named after him today. This type of turbine was tested for the first time in 1890, and in 1891, a turbine with a power of 15 horsepower and two wheels was made for use in ships. One of the wheels was for moving the ship forward and the other for moving it backward. Parsons A Parsons turbine was built in 1884. The first ship that used a turbine as a propulsion engine launched in 1895, and it was natural to call it Turbinia. In this ship, two turbine wheels were used, one for forward movement and the other for backward movement. Later, many steam turbines used, both in factories, power plants.

In addition to Delaval and Parsons, the French Rato invented a multi-stage shock turbine (combined with pressure layers), the American Charles Curtis invented a shock turbine with a combination of velocity layers, and the American George Westinghouse also built the first Parsons turbine in America with a capacity of 400KW in the factory. Westinghouse built in Pennsylvania. A little after the beginning of this century, the use of steam turbines instead of reciprocating steam engines in power plants began. The rapid progress made in this field was the construction of a 12MW unit and its installation at the Fisk Power Plant in Chicago. The performance and efficiency of the steam turbine also surpassed the reciprocating engine and superheated steam was widely used in the turbines, which required the use of steel instead of cast iron in the turbines. The capacity of the turbines increased continuously. In 1929, a 208MW unit was built in New York. In 1937, electric generators $3600\frac{r}{min}$ cooled by hydrogen were used. In the late 1950s, the capacity of steam turbines reached 450MW.

In the post-World War II era, steam turbine capacity exceeded 1000MW, and high-speed high-pressure units $3600\frac{r}{min}$ became common in the United States, where the standard power frequency is 60Hz (in many other countries, $3000\frac{r}{min}$units operating at 50Hz were used). Low-pressure $1800\frac{r}{min}$units were also rapidly used in water-cooled nuclear power plants in the United States (and $1500\frac{r}{min}$units in other countries). Today, the steam turbine plays the main role in the production of electric energy and it is expected to maintain this role in the foreseeable future. Gas turbines are as old as windmills because a windmill can basically be considered as a gas (air) turbine. The first gas device designed by Leonardo da Vinci and later John Will Keynes, who was an English clergyman, described it in his book called Mathematical Magic in 1648. Other efforts were made, among them was the work of Englishman who registered his invention in 1871. In his device, the compressed air and the produced gas were burned in a cylinder and the mixture was directed to the turbine wheel through trumpets. The first important step in the field of gas turbine construction was taken by the German Stolts. His turbine consisted of parts similar to today's gas turbines, that is, a separate combustion chamber and a multi-stage compressor with an axial flow that was directly connected to a multi-stage reaction turbine. Despite this, the efficiency of the compressor and turbine and the temperature of the gases were so low that his device was not successful. The first successful gas turbine was built in 1903 in France. This turbine included a multi-stage reciprocating compressor, a combustion chamber, and a two-row impact turbine. The thermal efficiency of this turbine was about 3%. Later developments were made slowly. In the new era and during the Second World War, Swiss manufacturers, whose country was isolated due to the war, developed the technology of power generation with gas turbines. British Sir Frank Whittle was one of the people who recognized the possibility of using gas turbines for airplane propulsion. Such efforts finally led to the construction of fighter jet aircraft and later passenger jet aircraft in different countries. Now, gas turbines are mainly used in power plants to provide peak load (providing additional power when demand increases), to provide electric energy to remote areas and oil transmission lines, and recently in gas and steam combined cycle power plants.

The principle of impact

Before entering the discussion of impact turbine, it is not bad to examine the principle of impact. Consider a jet of fluid that hits a fixed vertical plane horizontally in the +x direction. The jet will spread on the screen and its speed will decrease to zero in the direction of the jet, and as a result, it will introduce a horizontal force in the +x direction to the screen. This force is called impact and its value is equal to the change in the size of the jet movement in the +x direction.

$$F = \dot{m}(V_s - 0) = \dot{m}V_s$$

where in:

F = force or impact, N

$\dot{m}$= Mass flow of the jet stream, $\frac{kg}{s}$

V_s= speed in the horizontal direction, $\frac{m}{s}$

Fluid friction

Flux friction is the most important factor of losses in the turbine. Friction exists throughout the turbine, including in the horns and moving blades. As explained earlier, the amount of friction can be reduced by reducing steam velocities through the method of "Combination" and so on. Also, when the vanes operate at loads other than the design load and the entrance angle is not suitable, when the vanes operate at loads other than the design load and the entrance angle is not suitable, turbulences occur in the vanes. There is friction between the steam and the rotating discs on which the vanes are located, and the rotating design is also important for this reason. In addition, there is a period of friction and the wheel design is also important for this reason. In addition, the rotation of the vane exerts a centrifugal force on the steam, which causes a part of it to flow radially and be pulled along the moving vanes. When the steam admission to the moving vanes is less than full admission, such as the shock floor, a rotating condition occurs in the moving vans, and the loss caused by it is called propeller loss. Losses caused by fluid friction can exceed 10% of the energy given to the turbine.

Leakage

Steam leakage occurs inside and outside the turbine. Inside the turbine, steam can leak from the gap between the tip of the moving blades and the shell if there is a pressure drop in the blade like a reaction blade. The higher the pressure drop and the ratio of the blade tip to blade height, the more steam leakage is, an example of which is the case of high-pressure floors. A steam that leaks due to suffocation causes a loss of ability to do work. In the composite pressure shock turbine, steam leakage occurs between the base of the fixed diaphragms on which the trumpets are located and the shaft. The steam leakage outside the turbine also takes place in the place of the different shaft bearings. This type of leakage can be minimized by using proper sealing, such as screw-in-screw cover. The loss caused by the leakage amounts to about 1% of the total energy given to the turbine.

Loss due to steam moisture

In addition to the losses that occur as a result of the super saturation phenomenon in the two-phase region, the presence of liquid particles also causes more energy loss. The size distribution and speed distribution of these particles is not similar to the distribution of liquid spray from a trumpet. The particles that have low speed are thrown on the moving vans, that is, they collide with the vanes at angles other than the designed angles and cause a decrease in the mechanical work of the wheel. The speed of other particles is also increased by the steam, and as a result of the exchange of movement, some of the energy of the steam is taken. As a result, the part of the turbine that works in the two-phase region is basically less efficient than the part that works in the superheated region. Usually, the turbines are designed so that the moisture content of

the output steam is not more than approximately 12% (minimum quality of 88%). High humidity (which is often accompanied by a high percentage of oxygen in boiling water reactors) as a result of the collision of liquid particles with the vanes causes wear of the vanes. High humidity also causes the surfaces to get wet and create very long strips of water that move quickly. In addition, oxygen also causes corrosion. If the expansion of steam leads to a moisture content of more than 12%, it becomes necessary to extract moisture from some turbine floors to keep the moisture content at a normal level. This is what is done, for example, in the turbines of nuclear power plants with boiling water reactors.
Extracting moisture means reducing the mass rate of the flow from the turbine and hence the loss of turbine work, although this effect can be minimized by combining it with the steam extracted from the turbine to heat the feed water. Moisture extraction is made possible by installing grooves behind the moving vans, which are the places where water droplets accumulate. In this case, as a result of the centrifugal force of the moving vans, the water droplets will flow down radially and collect in the chamber in the shell to collect them, and then the collected water will enter the feed water heater or condenser. From a practical point of view, non-oxygen pollutants in water vapor, such as suspended substances and chemicals such as sodium and chlorine, which enter the system during water treatment, because cracking caused by stress and corrosion. These issues require more precise chemical control, continuous monitoring and better water maintenance.

Loss due to steam exit

It was already mentioned the speed of steam exiting the turbine stages, both impact and reaction. The kinetic energy of the output steam is usually used in the next stages, except the kinetic energy of the steam when leaving the last stage of the turbine. The exit speed from this layer is considered a kind of energy loss due to the low steam pressure and the maximum specific volume of steam and due to the kinetic energy of the steam. This speed is almost perpendicular to the plane of rotation at nominal load but has a large horizontal component at lighter loads. The designer can change the output steam speed by choosing a suitable combination of the height of the fins of the last row, the speed and the area of the steam output channel to the condenser. Although high output speeds cause energy loss, the use of very low speeds also results in unusually high blade heights, large output channels, and increased investment costs. Common output speeds are between 270 and 300 $\frac{m}{s}$, which causes losses of about 2 to 3 percent. The cross-sectional area of the outlet channels that takes the steam to the condenser gradually increases like a spreader, and as a result, the speed of the steam when entering the condenser decreases and its pressure increases. These channels cause the turbine outlet pressure to be slightly lower than the condenser pressure (the condenser pressure is determined by the available cooling water temperature) and hence the turbine work increases. This is more common for 3000 and 3600 rpm turbines compared to 1500 and 1800 rpm turbines. Because the latest turbines have longer bladed and larger outlet channels.

Loss due to heat transfer

Energy loss caused by heat transfer usually occurs in three ways, conduction, convection and radiation. The conduction is done inside the turbine and between its floors and is strengthened by convection, which is mainly caused by high steam velocities. Conduction also takes place between the turbine shell and its base. The loss due to convection and radiation that reaches the surrounding environment or the turbine hall through the turbine shell is more noticeable in the case of high-pressure turbines because the steam temperature in Ana is higher. High pressure turbines have a smaller diameter and are usually well insulated. Low pressure turbines, where the steam temperature is not much higher than the ambient temperature, are usually not insulated. Although the turbine hall looks hot, but the total heat loss per unit mass of the current passing through the large turbines is very small and can be ignored. Despite this, in the case of small mechanical turbines, heat transfer losses usually account for a few percent of the turbine's energy.

Mechanical and electrical loss

The turbine transfers the production work to an electricity generator. During this work, we encounter frictional losses in bearings, control mechanism, reduction gear box (if any). Also, some of the work of the turbine is spent on providing the mechanical work of sub-components such as oil pumps and so on. Mechanical loss is practically constant and independent of the load, and hence its percentage increases with decreasing load. On the other hand, its percentage is lower for larger turbines. In general, the number of mechanical losses is relatively small and accounts for one percent of the turbine's energy or less. Because the output power of the power generator is usually used to introduce the power of the turbine, it is necessary to know the number of losses of the power generator. Modern and large generators cooled by hydrogen and well-designed have very good efficiency. Yields of around 98 to 99 percent are common for them. Their efficiency increases with a slight increase in load, and the efficiency of 1500 and 1800 rpm generators is slightly higher than 3000 and 3600 rpm generators.

Turbine efficiency

As we mentioned before, the single pressure lines on the Moyer diagram are divergent (this is true for gases as well), so the sum of isentropic enthalpy drops for the stages of a turbine is greater than the isentropic enthalpy drop of the whole turbine. As a result, the floor efficiency is smaller than the turbine efficiency. The ratio of the total isentropic enthalpy drops of a turbine to the isentropic enthalpy drop of a turbine part or the whole turbine is called R_h reheating coefficient. It is clear that Rh is greater than one and its value varies from slightly more than one to perhaps 1.065, depending on the pressure range. If the designer wants the work of the floors to be equal, this is not possible by dividing the isotropic enthalpy drop of the whole turbine into equal parts. Because due to the divergence of the pressure lines, the actual work in the floors will not be equal. In order for the real work between the floors to be equal to each other, the designer must consider the divergence of single pressure lines. We already mentioned that the classes of the turbine that operate in the superheated region are more efficient than the classes that work in the two-phase region. Without a doubt, the performance and efficiency of the floors or the whole steam turbine is a function of many variables. For example, in the analysis of the steam cycle that has a reheating turbine or a turbine with a steam drag, one should have the condition curve of the turbine, which is more affected by the efficiency of individual layers than the total efficiency of the turbine.

The methods used to predict the performance and efficiency of various types of steam turbines are often available to turbine manufacturers. Although some of them can be found in references. Using one of these methods, it is possible to predict the performance of large turbines that are used in modern nuclear power plants and work with low superheated steam or saturated steam.

Condensation System - Feed Water

In this chapter, we will follow the path of the worker's flow in the cycle of the power plant. In chapters 3 and 2, we examined the steam generator and combustion, and then in chapter 3, we introduced the turbine, and in this chapter, we will study the main components of the condensation-feed water system, which finally leads to the steam generator. The components of this system mainly include heat transfer devices such as condensers and feed water heaters, but it also includes some other important devices such as boiler compensation water devices and water purification devices. The existence of such devices is necessary for the reliable operation of the cycle. The heat removal system from the power plant that connects with the circulating cooling water in the condenser needs a special and separate investigation that will be discussed in the next chapter. The main task of the condenser is to liquefy the steam coming out of the turbine and in this way to recover high quality feed water for reuse in the cycle. In performing this task, the condenser actually performs another task which is even more useful than its main role. If the temperature of the cooling water is low enough, as is common, then a low pressure (relative vacuum) is established in the condenser to which the turbine discharges. This pressure is equal to the saturation pressure related to the temperature of the condensing steam, which in turn depends on the temperature of the cooling water. Now it is known that the enthalpy drops and as a result the work of the turbine per unit of pressure drop is much more in the low-pressure part of the turbine than in the high-pressure part of the turbine. By reducing the condenser pressure by only a few kilopascals, the turbine work and the power plant efficiency increase and the steam flow decreases for a certain power for the power plant. The lower the condenser pressure, the greater these effects. Therefore, from the thermodynamic point of view, the lower the temperature of the cooling water used, the better. Therefore, the efficiency of condensing power plants is much higher than non-condensing power plants. Condenser is used in all modern power plants, and the condenser is a main and very important device in the power plant. There are basically two types of condensers: Direct contact condensers and surface condensers. In most power plants, the second type of condenser is used. The main function of the feed water heaters is to increase the efficiency of the cycle by heating the feed water before returning it to the steam generator. The heating of feed water in fossil power plants leads to an increase in its temperature by 400 to 500^{of} (200 to 260^{oc}), but the amount of temperature increase in water-cooled nuclear power plants is less. There are two types of feed water heaters: Closed and surface or shell and tube type heaters, and open type heaters with direct contact with the aerator.

Direct contact condensers

Direct or open contact condensers are used in certain cases, such as in the case where dry cooling towers are used in geothermal power plants and in power plants that take advantage of the ocean water temperature difference (OTEC) new direct contact condensers of the spray type. Old designs were of barometric or jetty types.

Spray condenser

In direct contact condensers, as their name suggests, steam turns into liquid as a result of direct mixing with cooling water. In the spray condenser, this is done by spraying water into the steam. In this way, the exhaust steam of the turbine is mixed with the cooling water and the liquid is almost saturated, which reaches the state 4 with the pump. A part of the condensed steam, which is equivalent to the output steam flow of the turbine, returns to the power plant in the form of feed water. The rest is usually cooled in a dry (closed) cooling tower and exits the tower. The cooled water is sprayed into the turbine outlet steam and this process is repeated regularly. In this way, the cooling water is continuously circulating. Because the cooling water is mixed with steam, it must be kept pure, and for this reason, closed type dry cooling towers are used. The pipes were divided into two parts and in fact, the formation of a bunch of smaller pipes that were placed side by side was done. With this work, the shape of the condenser resembled the shape of a cross-section of scraps, which was a favorite design of many builders in the 1940s.

Even this solution was not enough for the larger units that were becoming common because the depth of the pipes was still too much for the effective penetration of steam. Therefore, a design in which four groups of pipes were used was used. With this plan, the condenser was also reduced and thus the problem of the low height of the power plant building was solved. Nowadays, the design philosophy is to make the tubes as much as possible in the form of a funnel and consider the maximum area for the steam flow path in the part where the steam is condensed from the unit turbine. The number of tubes in the part where the steam turns into liquid and its volume decreases is less and the steam passages are smaller. The steam enters the tube stack from all directions and flows towards the central air cooler for ventilation. In general, it should be arranged so that the steam pressure drop is low and balanced (to prevent cross flow). The pipes are widened at both ends to prevent the coolant from leaking into the steam. Because the amount of expansion between the pipes and the shell is different, therefore, an expansion washer is used. Tube plates are usually made of Montez metal, which is similar to brass. In steam distribution, apart from the issue of vertical penetration of steam, there is another issue that is raised in today's units that have long pipes. End-to-end distribution or horizontal distribution of steam. In today's condensers, it is common to use pipes with a length of 30 to 50 ft (9 to 15 meters). Multiple pressure condensers (discussed below) may even use 70 to 90 ft (21 to 27 m) of tubing. Long pipes cause more changes in the temperature of the water flowing inside the pipes, and as a result, the ability to condense steam will also have larger changes. Therefore, the tubes can be much closer to each other at the cold end of the condenser, i.e. where the condensation is good, and further apart at the hot end. Of course, choosing a suitable interface mode is necessary in terms of design. This work reduces the length of the circuit, which can be neutralized with the help of transverse plates. Another issue of steam distribution is caused by the uneven flow of steam from the turbine outlet channel to the condensing tubes, which is unavoidable. Therefore, special attention should be paid in the design of the connecting pipe between the turbine and the condenser (which is called the outlet neck). Among the measures that are used is adding a dome-shaped duct called steam dome above the pipes, which solves the above problem to a large extent. An expansion gasket is usually considered between the turbine outlet and the steam inlet pipe to the condenser. In this way, it becomes possible to place the condenser on the floor. In another method of installing the condenser, which is less common, the condenser is directly connected to the outlet channel of the turbine by bolts and nuts, and it is placed on springs that provide the power of vertical movement for it, and as a result, the strain on the turbine shell is reduced.

The number of divisions of water tanks is often more than the number required to have a certain number of cooling water paths in the condenser. For example, in a one-way condenser, the inlet and outlet water tanks located at the two ends of the condenser may be divided by plates. With this, half of the condenser can be working while the other half can be cleaned or repaired. In a two-way split condenser, the water tanks are divided into four parts. In divided water tanks, the number of inlet and outlet pipes is double and each part has its own cooling water path. By installing taps in the divided plates and by reversing the direction of the water flow, it is possible to perform the washing operation, which is important in terms of cleaning the condenser.

Single-pressure and multi-pressure condenser

As is common today, in large power plants there are usually one or more low pressure turbines that are placed in a row. The condenser may consist of several parts or shells according to the number of turbines, each of which is placed under a low-pressure turbine. If the output pressure of the turbine is the same in all parts, that is, if the output channels are not separate, then we will deal with a single-pressure condenser. If the exit channels are separated from each other, the pressure of individual condensing shells will increase because the temperature of the cooling water will be high while passing from one shell to another shell. In this case, we will deal with a multi-pressure condenser. The multi-pressure condenser increases the efficiency because in this type of condenser, the average pressure of the turbine is lower compared to the single-pressure condenser (so the pressure is determined by the highest temperature of the cooling water). Multi-pressure condensers are mostly used in nuclear power plants. These condensers are usually of the one-way type; whose pipes are parallel to the turbine axis. The length of the tubes is approximately equal to the total length of the low-pressure turbines, i.e. 70 to 90 ft (21.3 to 27.4 m). On the other hand, in single-pressure condensers, the length of the pipes is usually between 30 to 50 ft (9.1

to 15.2 meters) and often the pipes are placed vertically with respect to the turbine axis. Basically, the condenser is designed according to the customer's wishes to meet requirements such as the amount of steam flow, the amount and temperature of the available cooling water, the available space and some other factors. This condenser is of one path type. It is single-pressure and with radial flow, the steam enters from above, from the sides and below and flows towards the center of the network of pipes. At this point, most of the vapor liquefies and only air and other non-condensable gases remain, which will be cooled before being separated by the aeration system (discussed below).

Conclusion

It should be mentioned that the higher the characteristic number, the thinner and lighter the tubes. 5.8 in pipes (all values specify the size of the outer diameter of the pipe) are easily clogged and are used only in small and special units. In new condensers, usually 7.8 or 1in tubes are used with the characteristic number 18, which is sufficient for the water pressure in the condenser. Bronze metal has been used for a long time, although in some cases stainless steel type 304 has been used instead. Today, this steel is easily available at a reasonable price and shows very good resistance to corrosion and wear and remains immune to sulfide and ammonia attacks. This steel also does not have the risk of introducing copper ions into the feed water, while other metals have such a risk. Its disadvantages include low thermal conductivity, low resistance to chloride attacks, and dirtiness and sedimentation of biological materials. 90-10 copper-nickel alloy is another material that is suitable for fresh water. 10-90 copper-nickel alloy is considered the best material for working with sea water and salt water, whether the water is clean or polluted. 70-30 copper-nickel alloy is better for working with clean water; Because in this case, ammonia attacks in the shell are a problem.

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