

[54] **MULTISTAGE CONDENSERS**

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165/162

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[58] Field of Search..... 165/110-114,
165/162; 60/95 R

[56] **References Cited**

UNITED STATES PATENTS

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[57] **ABSTRACT**

An improvement for sealing a small space between each cooling tube and a tube hole for receiving and supporting the cooling tube formed through a partition wall which divides a shell into a plurality of stages or chambers, in which straight cooling tubes are inclined from a high-pressure chamber to a low-pressure chamber and received and supported in the tube holes with square edges and the condensate flowing along the inclined cooling tube fills the small space between the cooling tube and the tube hole thereby effecting the seal between the high- and low-pressure chambers.

6 Claims, 3 Drawing Figures

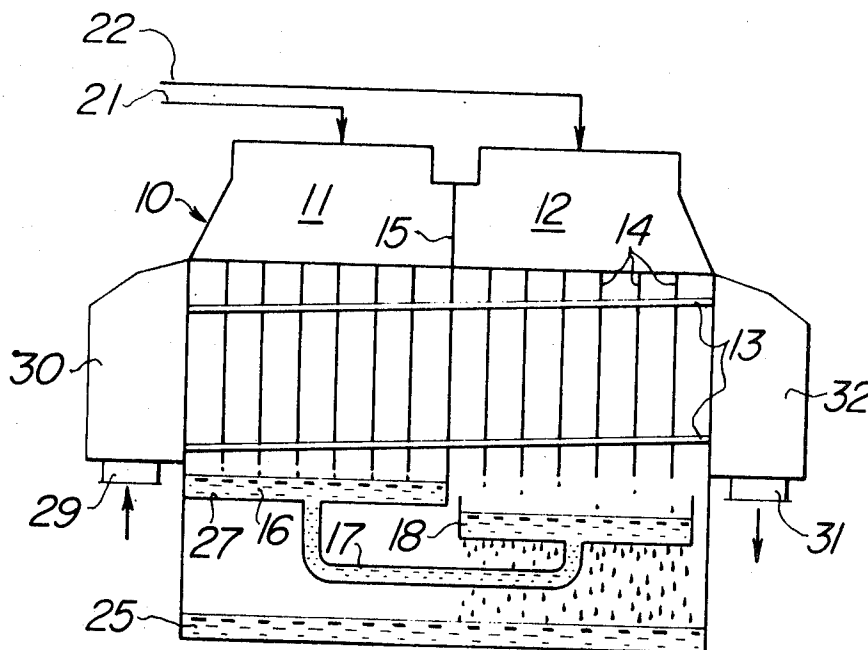


FIG. 1

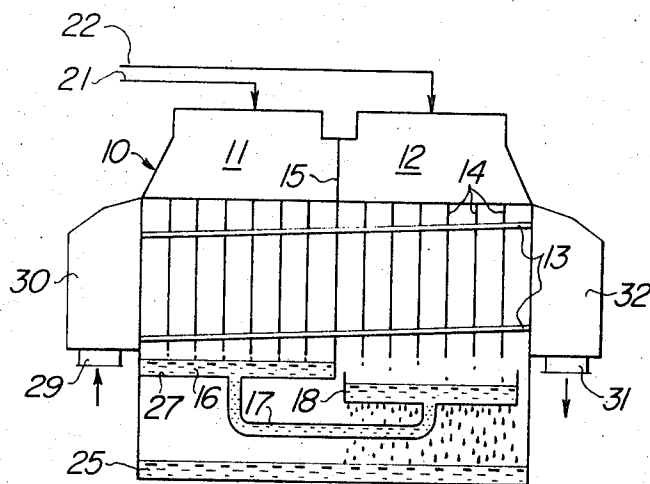


FIG. 2

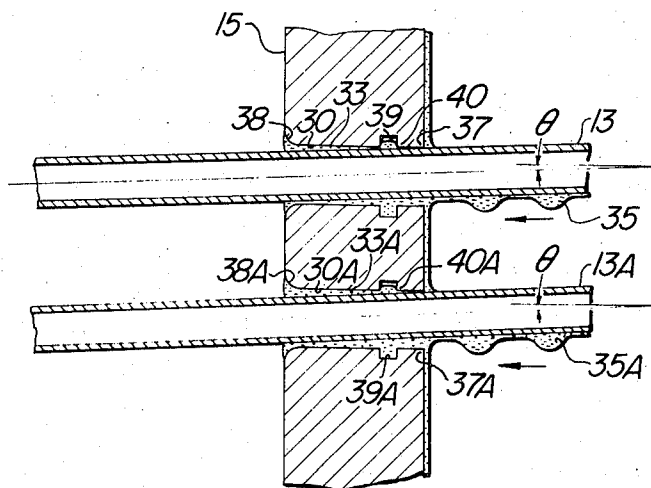
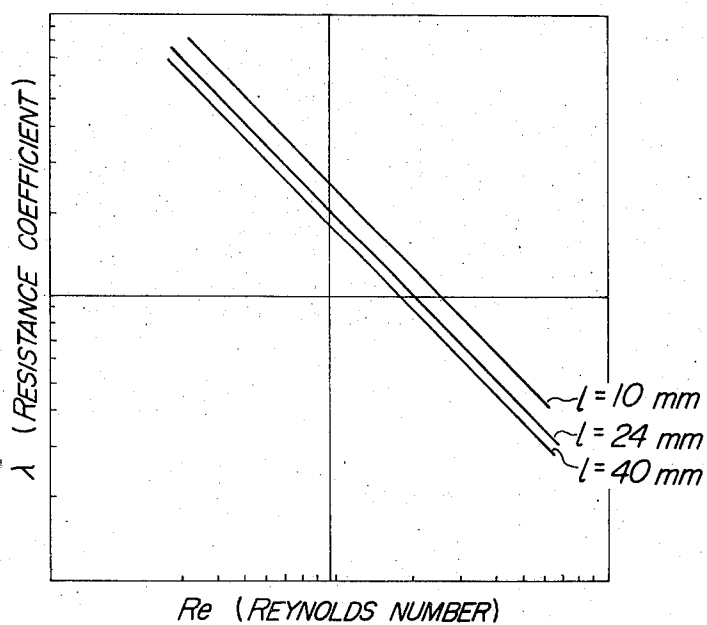


FIG. 3



MULTISTAGE CONDENSERS

The present invention generally relates to multistage condensers for use with steam turbines in thermal power plants, multiple-effect flash evaporators for use in saline water reclamation, and the like.

In a condenser for a steam turbine with a plurality of steam exhaust chambers, a shell is generally divided by partition walls into a plurality of chambers or stage equal in number to the exhaust chambers of the steam turbine in the direction of the flow of cooling water, exhaust steam is introduced into the chambers each of which is maintained at a different degree of vacuum, and steam or vapor is condensed by the cooling water flowing through the cooling tubes only in one direction. As compared with a single-stage condenser the multistage condenser has the advantages in (1) that the overall efficiency of the plant may be increased and (2) that the quantity of cooling water as well as the surface area of heat transfer may be reduced when the heat exchange quantity is same.

One of the problems of the multistage condensers and multiple-effect flash evaporators or the like is the leakage of steam through the small space or clearance between the cooling tubes and the through holes for receiving and supporting the cooling tubes formed through the partition wall which divides the shell into a plurality of chambers. In general one or two of some dozen tube supports in the shell are extended to be used as a partition wall in order to divide the shell into two or three chambers. The peripheral edges of the partition walls may be securely joined to the inner wall of the shell by welding so that no leakage or sealing problem arises, but the space or clearance between the cooling tubes and the tube holes of the partition walls presents serious problem in sealing between two chambers. In general the pressure difference between the high- and low- pressure chambers is of the order of 7-10 mm Hg in rated operation, and when the leakage of steam from the high-pressure steam chamber to the low-pressure steam chamber through the space or clearance between the cooling tube and the tube hole of the partition wall occurs the pressure in the low-pressure steam chamber would become equal to that in the high-pressure steam chamber in the worst case so that the multistage condenser will stop its operation. It is therefore imperative to effect the complete seal between the high- and low-pressure steam chambers so that they may be maintained at a predetermined degree of vacuum. Furthermore since the number of cooling tubes in a large-capacity condenser is generally of the order of tens of thousands, sealing means must be simple in construction easy to fabricate and reliable and dependable in operation.

Of the prior art sealing methods, there has been proposed a method in which the plastic bushings are snugly fitted over the cooling tubes and positioned in the space or clearance between the tubes and the tube holes which have a relatively large diameter. Even though this sealing method is very effective, it has still some defects. First of all the cost of cooling tube assembly is tremendously increased because the number of cooling tubes used in a large-capacity condenser is of the order of tens of thousands as already described above. Secondly the replacement of damaged, eroded and corroded cooling tubes becomes extremely difficult.

From the above description it is seen that there are distinct defects and problems in the sealing method in which the bushing is fitted into the space or clearance between the cooling tube and the tube hole with a relatively large diameter.

The present invention therefore has for its object to provide a sealing arrangement between the chambers in a shell of a multistage condenser or the like each of which must be maintained at a different degree of vacuum, and more particularly to provide means for preventing the steam or vapor leakage through the space or clearance between the cooling tubes and the tube holes of the partition walls which divide the shell into a plurality of chambers.

Another object of the present invention is to provide means which is simple in construction and very reliable and dependable in operation for preventing the leakage of steam through the space or clearance between a cooling tube and a cooling tube hole of a partition wall in a shell of a multistage condenser or the like.

Another object of the present invention is to utilize liquid, particularly the condensate in order to effect the seal between the chambers each of which is maintained at a different degree of vacuum.

Another object of the present invention is to facilitate the replacement or servicing of cooling tubes.

Another object of the present invention is to provide a novel arrangement for effecting the seal between the cooling tubes and partition walls.

Another object of the present invention is to provide a multistage condenser, multiple-effect evaporator and the like whose optimum operation may be ensured all the time.

In order to accomplish the recovered and other objects of the present invention, the condensate recovered is always made to flow into a small space or clearance between a cooling tube and a tube hole formed through a partition wall in a shell so as to fill the space or clearance so that the seal between the chambers at a different degree of vacuum may be effected by liquid. The present invention is therefore characterized by the construction of tube holes formed through the partition wall for receiving and supporting therein the cooling tubes in a multistage condenser. However it is well known in the art to assemble the cooling tubes in the shell in such a manner that they have a gradient of the order of 40 mm per 10 meters because all of water in the cooling tubes must be discharged when the steam turbine or the like is shut down.

In case of a two-path cooling tube in which the flow of cooling water is reversed in the same tube, the inlet and outlet of the cooling tube are positioned higher than the reversal point thereof at which are water flow in the cooling tube is reversed in direction. In case of a one-path cooling tube in which cooling water flows only in one direction either of the inlet or outlet of the cooling tube may be positioned higher than the other according to the design requirements independently of the direction of cooling water flow and of the positions of the expansion joints of the shell.

As described above the cooling tubes have been installed in inclined position in the prior art multistage condenser or the like, but according to the present invention the inclined cooling tubes are used in order effect the seal between two chambers, that is the seal of the small space or clearance between a cooling tube and a tube hole formed through a partition wall. Ac-

ording to the present invention the construction or configuration of the tube holes also serves to ensure the seal.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of one preferred embodiment thereof taken in conjunction with the accompanying drawing in which:

FIG. 1 is a sectional view of a multistage pressure condenser to which is applied the present invention;

FIG. 2 is a fragmentary sectional view thereof on enlarged scale; and

FIG. 3 is a graph used for the explanation of the relation between the Reynolds number and resistance coefficient of the liquid flow flowing through the space between a thorough hole of a partition wall of the condenser and a cooling pipe.

Referring to FIG. 1 a shell 10 of a two-stage condenser is divided by a partition wall 15 into two chambers, that is a high and low pressure chambers 12 and 11. The lower end of the partition wall 15 is joined to one end of a bottom plate 27 whose the other end is securely joined to the shell 10. The significant feature of the two-stage condenser is that the condensate collected in the lower portion 16 of the low pressure chamber 11 is made to flow through a pipe 17 or the like into a tray 18 located immediately below the tubes in the high pressure chamber 12 so that the condensate which drops through a large number of small holes in the bottom of the tray 18 may be made into contact with the steam in the high pressure chamber, heated and then stored in a reservoir at the bottom of the condenser.

Steam is condensated in the high and low pressure chambers 12 and 11 at different saturation temperatures so that there is a temperature difference between the condensates in the low and high pressure chambers 11 and 12 equal to the difference between the two saturation temperatures. Therefore when the condensate recovered in the low pressure chamber 11 is dropped and made into contact with the steam in the high pressure chamber 12 in the manner described above the heat energy of the steam may be sufficiently recovered by the condensate and the vacuum in the condenser may be increased.

A large number of cooling tubes 13, which are extended through and supported by a plurality of support plates 14 disposed in a parallel with the partition wall 15, are inclined from the high pressure chamber 12 toward the low pressure chamber 11, and the ends of the tubes 13 are communicated with an inlet and outlet headers 30 and 32.

The tubes 13 are extend through the partition wall 15 so that the liquid seal to be described in detail hereinafter must be provided.

The high pressure steam discharged from a turbine (not shown) is introduced through a high pressure line 22 into the high pressure chamber 12 (the steam may be directly introduced into the high pressure chamber 12 from the turbine) whereas the low pressure steam is introduced into the low pressure chamber 11 through a low pressure line.

Cooling water flows into the inlet header 30 through an inlet 29 and into the cooling tubes 13 so that the heat exchange between the cooling water and the steam occurs. Water is heated while steam is cooled and condensated so that a desired degree of vacuum in

the condenser shell may be maintained. Heated water flows into the outlet header 32 from which it is discharged through an outlet 31. The condensate is collected into the reservoir 25 from which it is fed into a boiler (not shown) by a pump (not shown).

A small amount of the condensate flows along the tubes 13, but is stopped by the partition wall 15 so that the condensate serves to seal the small space between the tube 13 and the tube hole in the partition wall 15. Thus the high and low pressure chambers 12 and 11 may be effectively sealed from each other.

Next referring to FIG. 2 the above sealing method will be described in more detail hereinafter. Cooling tubes 13 and 13A which are received and supported in tube holes 30 and 30a formed through the partition wall 15 are inclined by an angle θ with respect to the horizontal. The axes of the tube holes 30 and 30a are at right angles with respect to the partition wall, but they may be inclined also at an angle θ with respect to the horizontal as the need arises. Thus the very small spaces 33 and 33A are defined between the tubes 13 and 13A and the tube holes 30 and 30a, and these spaces 33 and 33A may be provided by the dimensional tolerances with which the tubes 13 are fitted into the tube hole 30. Thus not only the assembly of the tubes 13 is facilitated but also the condensate 35 and 35A flowing along the surfaces of the tubes 13 accumulates in the spaces 33 and 33A so as to provide the effective sealing. More particularly a part of the condensate flows into the small space 33 whereas the other flows upon the surface of the partition wall 15 on the side of the high pressure chamber 12. Since the condensate flowing down along the surface of the partition wall impinges upon the cooling tube 13A and enters the space 33A, sealing effect is further increased. The angle of inclination θ is of the order of downgrade of 40 mm per 10 meters.

The effect of sealing will be described in more detail hereinafter. Since the condensate in the spaces 33 and 33A flows from the high pressure chamber to the low pressure chamber due to the pressure difference therebetween, the condensate normally fills the spaces so that no leakage occurs, but when the condensate flows in large quantity out of the spaces there is a fear that the steam leakage occurs. Therefore it is very important to increase the resistance coefficient exhibited by the spaces. The relation among the pressure difference between the high and low pressure chambers, the resistance coefficient and the thickness of the partition wall is given by

$$\Delta p = \lambda l / 4m \quad \gamma / 2g \quad V^2 \quad 1$$

Hence,

$$\lambda = \Delta p l / 4m \quad \gamma / 2g \quad V^2 \quad 2$$

and

$$Re = 4mV/\gamma \quad 3$$

where

λ : resistance coefficient,

Δp : pressure difference between two chambers,

l : thickness of the partition wall,
 v : velocity of condensate flowing through space,
 γ : specific gravity of condensate,
 y : dynamic coefficient of viscosity of condensate,
 g : gravitational acceleration,
 m : mean depth of condensate, and
 Re : Reynolds number.

The resistance coefficients when $l = 10, 24$ and 40 mm were calculated and shown in FIG. 3, from which it is seen that the smaller the thickness l of the partition wall, the higher the resistance coefficient becomes. This means that the resistance encountered in the space consists largely of the friction loss at the inlet of the space on the side of the high pressure chamber and that since there exists the laminar flow in the space except the transition or turbulent flow at the inlet there is almost no resistance in the space except the inlet.

Therefore it follows that it is not advantageous to increase the thickness of the partition wall from the standpoint of the prevention of the leakage of steam and that it is more important to increase the loss at the inlet. It is therefore preferable not to bevel the end of the tube hole on the side of the high pressure chamber but to bevel only the end on the side of the low pressure chamber in order to facilitate the assembly. That is, referring back to FIG. 2, the ends 37 and 37A of the tube holes on the side of the high pressure chamber are right angles in cross section but the ends 38 and 38A on the side of the low pressure chamber are rounded so that the tubes may be easily inserted into the tube holes.

Furthermore annular grooves 39 and 39A with square rims or corners 40 and 40A may be formed within the tube holes 30 and 30A in order to increase the resistance coefficient.

Because of the arrangement of the present invention described hereinbefore the condensate itself may be advantageously used as very effective sealing means. Therefore when the present invention is applied to various apparatus such as multistage vacuum condensers, multistage flash evaporators and the like in which a large quantity of condensate is produced, the complete sealing between the chambers may be accomplished in a simple manner so that each chamber may be ensured to be maintained at a different pressure. Furthermore sealing means in accordance with the present invention is not only very simple in construction but also expedites the assembly, inspection and maintenance.

What is claimed is:

1. A multistage condenser of the type in which a shell is divided into a plurality of chambers with a different degree of vacuum by partition walls, a large number of cooling tubes which are communicated with a cooling liquid inlet and outlet are extended through said plurality of chambers and said partition walls, and steam or vapor to be condensed flows to contact with said large

number of cooling tubes to effect the heat transfer between said steam or vapor and the cooling liquid flowing through said large number of cooling tubes so that said steam or vapor may be condensed,

CHARACTERIZED IN THAT

said large number of cooling tubes are inclined from the high-pressure steam or vapor chambers toward the low-pressure steam or vapor chambers, and a small space is formed between each of said large number of cooling tubes and a tube hole which is formed through said partition wall for receiving and supporting said cooling tube therein, whereby the condensate flowing along the surface of said cooling tube may fill said small space thereby effecting the seal between said high- and low-pressure steam or vapor chambers.

2. A multistage condenser as defined in claim 1 wherein said tube holes on the side of said high-pressure steam or vapor chamber have square edges.

3. A multistage condenser as defined in claim 1 wherein an annular groove is formed in each of said tube holes.

4. A multistage condenser of the type in which a shell is divided into a plurality of chambers with a different degree of vacuum by partition walls, a large number of cooling tubes which are communicated with a cooling liquid inlet and outlet are extended through said plurality of chambers and said partition walls, and steam or vapor to be condensed flows to contact with said large number of cooling tubes to effect the heat transfer between said steam or vapor and the cooling liquid flowing through said large number of cooling tubes so that said steam or vapor may be condensed,

CHARACTERIZED IN THAT

said large number of cooling tubes are straightly inclined from the high-pressure steam or vapor chambers toward the low-pressure steam or vapor chambers,

each of tube holes formed through the partition wall for receiving and supporting the cooling tube therein is substantially at a right angle with respect to said partition wall, and

a small space is formed between each of said large number of cooling tubes and each of said tube holes, whereby the condensate flowing along the inclined cooling tube may fill said small space thereby effecting the seal between said high- and low-pressure steam or vapor chambers.

5. A multistage condenser as defined in claim 4 wherein said tube holes on the side of said high-pressure chamber have substantially square edges.

6. A multistage condenser as defined in claim 4 wherein an annular groove with square corners is formed in each of said tube holes.

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