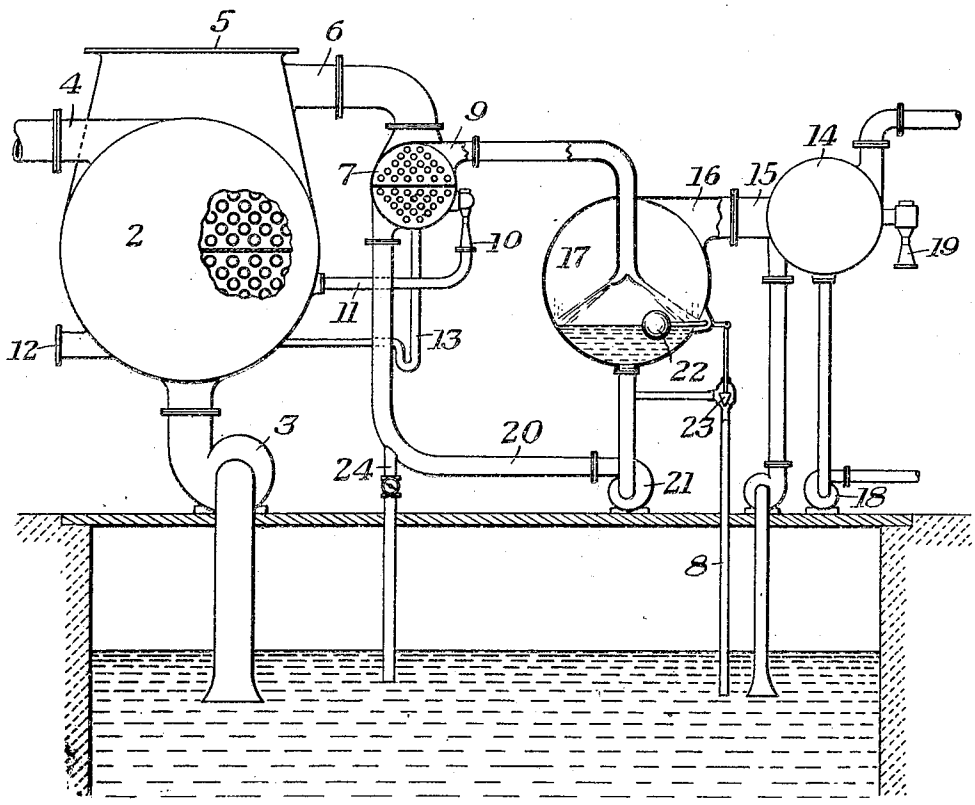
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APPARATUS FOR EVAPORATING LIQUIDS

Filed June 2, 1927



INVENTOR

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his attys.

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UNITED STATES PATENT OFFICE

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APPARATUS FOR EVAPORATING LIQUIDS

Application filed June 2, 1927. Serial No. 195,925.

The present invention relates broadly to the exchanging of heat in connection with the treatment of liquid, and more particularly to an improved apparatus by means of which such a heat exchange is effective for the evaporation of at least a portion of the liquid being treated.

In the art to which the present invention relates, it is customary practice to utilize high pressure steam for the development of energy in mechanical or other forms, the steam in passing through the particular apparatus provided for that purpose, giving up a certain portion of its thermal energy. This portion of the thermal energy so given up is in turn transformed by the apparatus provided into mechanical energy for example, capable of being conveniently utilized. In such cases, however, the greater portion of the thermal energy of the steam is not utilized by the apparatus with the result that the steam rejected thereby carries away with it a greater portion by far of its original thermal energy than was used in such apparatus. In other words, the thermal energy in the exhaust of standard apparatus, such, for example, as a steam engine, is many times that which has been utilized by the engine. The thermal energy content of exhaust steam in such cases is usually referred to as degraded or lower level heat.

In the operation of apparatus utilizing steam, it is necessary in order to obtain the maximum range in the utilization of heat, to insure exhausting of the apparatus into a region having the lowest practical pressure. Conveniently such a condition of low pressure is produced by means of a condenser, the temperatures maintained thereby usually being so low, however, that there is no way of utilizing all of the low level heat in the range as maintained by the condenser. It is, however, possible to reclaim small portions of the low level heat that would be ordinarily rejected to the condenser, and it is with this phase of the operation that the present invention deals.

One of the objects of the present invention, therefore, is to effect a practical utilization of a portion of the degraded heat for evaporating, and more particularly that portion which is ordinarily thrown away.

In my United States Patent No. 1,831,234 dated November 10, 1931, there is disclosed and claimed apparatus by means of which extremely desirable results in this connection may be obtained. I have found, however, that it is possible to further increase the efficiency of such apparatus, and the present application discloses a construction in which such improvements are embodied.

In the accompanying figure of the drawing, which figure is largely diagrammatic and representative of one embodiment of the invention, there is shown for purposes of illustration only, one system by means of which the invention may be carried out and a portion of the low-level heat effectively utilized.

In accordance with the present invention, there may be provided a condenser 2 of the two-surface type of any desired construction, and hereinafter referred to as the main condenser. Water may be circulated through the tubes of the condenser by a suitable pump 3 and discharged therefrom through an outlet 4, while steam may be delivered to the space around the tubes through the inlet 5, such steam obviously being led from the engine or other apparatus which the condenser serves. Usually, all of the heat in the exhaust steam delivered through the inlet 5 is communicated to the cooling water supplied to the condenser, which cooling water in turn goes to waste. By the utilization of the present invention, at least a portion of the heat which is thus normally wasted is diverted and utilized in a process of liquid evaporation effective for evaporating a sufficient quantity of raw water, for example, to make up the losses in distilled water incident to normal power plant operation. Such desirable results may be accomplished by providing relatively large and relatively small tube nests, suitably confined and by so utilizing the vapor as to cause that portion of the water passing through the relatively small tube nest to be raised above the temperature of the main body of cooling water passing through a relatively large tube nest. This may be accomplished by the provision of en-

tirely separate tube nests, each within its own confining casing, or as disclosed in my copending application Serial No. 195,924, filed June 2, 1927, may be accomplished by the provision of the relatively large and relatively small tube nests in a common casing.

In accordance with the embodiment of the invention illustrated herein, the main condenser is provided with an off-take connection 6 through which a portion of the exhaust steam led to the main condenser may be diverted to a second condenser 7, this condenser being hereinafter referred to as a heater condenser. The heater condenser provides the relatively small tube nest, it being materially smaller in size than the main condenser, but otherwise conveniently constructed in a manner generally similar thereto.

Cooling water for the heater condenser may be drawn from a suitable supply through a conduit 8 and discharged through a connection 9 hereinafter more fully referred to. Cooperating with the heater condenser is an air exhausting means 10 herein illustrated as discharging through a conduit 11 directly into the main condenser. As the pressure in the main condenser is not materially different from that in the heater condenser, it will be apparent that for but a small expenditure of steam in an exhausting means, such for example as an ejector, a relatively large exhausting capacity may be realized. By the use of a relatively large exhausting means, the efficiency of the heater condenser may be comparatively much greater than is possible for practical operating reasons with the main condenser.

For purposes of illustration only and not with the object in view of limiting the present invention, it may be pointed out that a main condenser requires such differences in heat head between the water and steam spaces that the water discharged is usually at a temperature at least ten degrees and not infrequently 15 degrees lower than the temperature of the steam which is being condensed thereby. Also, condensers with ejecting or exhausting means of the general character illustrated by the exhausting means 10 for the heater condenser, require a much less heat head. Again, by way of example only, a two-thousand square foot condenser receiving steam from the inlet of the main condenser will extract 18,000 pounds of steam per hour and the circulating water leaving such condenser will be heated to within a fraction of a degree of the temperature of the heating steam so extracted. I also find that such results are accomplished with a steam ejector which has a steam consumption of but 50 pounds an hour, such an operation being obtainable with an exhausting means of the general character herein illustrated for the heater condenser.

It not infrequently happens that condensers are of such design or are so operated that there is a very material pressure loss therethrough between the inlet and the point of gas off-take. If the main condenser disclosed herein possesses such characteristics, whereby the pressure adjacent the gas off-take 12 is materially lower than the pressure in the inlet 5, I may entirely eliminate the exhausting means 10 for the heater condenser and connect the pipe 11 directly with the gas off-take 12, as will be readily apparent. Ordinarily a main condenser is so much larger than the heater condenser that the normal pressure loss through it is much greater than that through the heater condenser for normal flows through each. The result, then, of connecting the two gas off-takes as shown, is equivalent generally in such cases to giving the heater condenser an oversized air exhausting means.

Condensate formed within the heater condenser may, if desired, be drained directly into the main condenser through a suitable connection 13.

In addition to the condensers already referred to, my invention contemplates the use of a third condenser 14 which will hereinafter be referred to as a high vacuum condenser, merely by way of definition. This condenser is similar in its general characteristics to the heater condenser, but whereas the heater condenser is operated to deliver water at as high a temperature compared to that of the steam as is feasible, the high vacuum condenser is proportioned and operated to maintain a vacuum as high as possible therein, and in all cases greater than the vacuum maintained in the main condenser. I have found that it is possible to so proportion the high vacuum condenser with respect to surface area, amount of circulating area and the like, that it is practically possible to continuously maintain a vacuum therein, the incident steam temperature of which is from ten to fifteen degrees lower than that in the main condenser.

The high vacuum condenser has its vapor space operatively connected as by a suitable conduit 15 with the vapor off-take 16 of a flash chamber 17. By reason of this relationship, there is continuously maintained in the vapor space of the flash chamber a high vacuum of the order which exists in the vapor space of the high vacuum condenser. The circulating water from the heater condenser passes through the outlet 9 directly to the flash chamber. By reason of the fact that the heater condenser maintains a high temperature in the portion of the water discharged thereby, while the condenser 14 maintains a high vacuum within the flash chamber, the water passing through a connection 9 to the flash chamber will be at a temperature higher than that at which it can exist as water in the flash chamber, so

that a portion thereof will immediately flash into steam. This flashing or violent boiling of the liquid is obviously accomplished at the expense of its contained heat. Under the conditions of operation referred to by way of example, there would be maintained a temperature gradient between the heater condenser and the high vacuum condenser of from ten to fifteen degrees.

The portion of the water from the heater condenser which flashes into steam in the flash chamber will leave the same and pass to the vapor space of the high vacuum condenser wherein it will be condensed and pumped and delivered to any desired location in the form of distilled water. This may be acomplished in any desired manner, as for example, by means of a water removal pump 18.

In accordance with the disclosure of my Patent No. 1,831,234 referred to, the water remaining in the flash chamber may be delivered to any desired point. It will be apparent to those skilled in the art that if there is a ten degree flash gradient in the evaporating chamber 17, approximately 100 times as much water is circulated through the evaporator as is evaporated therein. If the apparatus is of such construction as to effect the evaporation of 10,000 pounds of water per hour, there must obviously, under such conditions, be approximately a million pounds per hour of raw water circulated through the evaporator. This means that the amount of air incident to a million pounds of water is necessarily liberated in the flash chamber, and all of this air goes to and must be handled by the high vacuum condenser. This has heretofore necessarily so interfered with the efficiency of that condenser as to require the condenser to be abnormally large relative to the amount of steam condensed.

Inasmuch as the vacuum maintenance of the high vacuum condenser must be of a very high order, it has heretofore been necessary not only to make it larger than would normally be required for the steam load, but to supply it with a liberal amount of water and to equip it with gas exhausting means of great capacity as compared with either the main condenser or the heater condenser. Heretofore, multi-stage ejectors with intercondensers have been considered essential, the heat from the ejectors being absorbed by the water being treated, such water being passed by suitable connections through the inter and after condensers. In accordance with the present invention, multi-stage ejecting means may be utilized, although there is herein indicated a conventional ejecting means 19.

The increased efficiency herein contemplated is accomplished in accordance with the present invention, by a novel disposition of the water exhausted from the evaporating chamber which water, instead of being thrown away, is subjected to repeated recirculation through the heater condenser 7. This may be accomplished by the provision of a recirculating connection 20, provided with a recirculating pump 21 whereby the pump is effective for drawing the water from the flash chamber and redelivering it to the heater condenser. Such recirculation necessarily would result at least after a comparatively few number of cycles in the elimination of at least the major portion of all of the air, so that thereafter the surface of the condenser 14 could be greatly diminished as well as the size and consequent steam consumption of the ejector 19. It is obvious, however, that some make up must necessarily be supplied to the chamber 17 under such conditions, inasmuch as a certain amount is removed during each cycle in the form of vapor produced by the evaporation therein. In order to keep the system primed and to maintain a substantially constant amount of water, there would necessarily be supplied thereto an amount at least equivalent to that evaporated. In other words, if the apparatus was started into operation with a certain water level, and 10,000 pounds per hour was removed by way of evaporation, there would necessarily be supplied at least 10,000 pounds per hour as make-up, and when the outfit was in actual operation the only air to be removed would be that resulting from air infiltration plus the comparatively small amount coming in with the make-up water. Such an operation, however, presents another difficulty in the form of gradual concentration of the water with salt or other soluble solids. In order to obviate such a condition, I conveniently provide a float 22 cooperating with the water level in the flash chamber 17 and actuating a valve 23 in the water supply 8 whereby the amount of water admitted is automatically controlled by the level in the flash chamber. This float is originally adjusted in such manner as to continuously admit a greater amount of liquid than that evaporated, and preferably substantially twice as much liquid as is evaporated. In order to take care of such excess, there is provided an overflow 24 through which a portion continuously escapes and thereby keeps down objectionable concentration.

By the use of the present invention, it is possible to substantially cut the size of the high vacuum condenser 14 in half and to operate the ejector 19 with approximately 1/50 of the steam required for an operation in which none of the water from the flash chamber is recirculated, thereby materially decreasing the original installation cost as well as the cost of maintenance and operation.

I am aware that it has heretofore been proposed, as illustrated for example in the patent

to Forbes, No. 1,232,269, of July 3, 1917, to take water from the discharge of a main surface condenser and flash it to obtain distilled water. Installations of this character, however, have not been feasible or practical from a commercial standpoint for the reason that with such condensers there is very little rise in the temperature of the circulating water, and therefore, no opportunity for obtaining a sufficient heat head to insure satisfactory operation. In accordance with the present invention I not only overcome difficulties of the nature referred to, but provide means for increasing in a very effective manner the heat in a certain quantity of water and then flashing this water in a flash chamber having a vacuum maintained therein which is higher than the vacuum maintained in the main condenser. As a part of my installation I have also disclosed exhausting means for the high vacuum condenser capable of giving very efficient performance. It is so proportioned as to have the ability to withdraw gases and vapors from the high vacuum condenser with a vacuum existing therein of greater magnitude than is ordinarily encountered in condenser installations. As an example of this condition, it will be found that main condensers with water temperatures incident to the winter season will maintain vacua the temperatures of which are 70° or even lower. In such cases, if I wish to obtain flash gradients of 15°, there must be provided an ejector capable of handling fluid from the high vacuum condenser, the pressure of which fluid in inches of mercury is less than .4 of an inch absolute. While the invention is disclosed herein as embodying a main condenser of the surface type, the utility of the invention is not limited with respect thereto as the present invention will operate effectively with a main condenser of the jet type. I further realize that while the present embodiment of the invention illustrates utilizing heating steam from the main condenser for the heater condenser, low level steam for this purpose may be taken from other sources as for example from the low pressure stages of a steam turbine or from the intermediate receiver of a steam engine of the reciprocating type. The present drawing is illustrative only of a preferred embodiment of the invention for the purpose of setting forth the principles of operation thereof and do not define the limits of my invention as changes in the construction and operation may be made without departing either from the spirit of the invention or the scope of my broader claims.

Also, while I have herein referred to a flash temperature gradient of 10 to 15°, and while, for practical purposes it is desirable to have a flash temperature gradient as high as possible, I find that a 5° gradient will give fairly satisfactory operation. It is desirable, however, under the majority of conditions to maintain a temperature gradient for flashing purposes in excess of 5°.

It will be understood by those skilled in the art that where I have referred to the adjustment of the float control, such example is given by way of illustration only, it being possible to supply a relatively greater or less amount of water depending upon its salt or solid concentration.

Certain advantages of the present invention arise from the provision of an apparatus providing relatively large and relatively small tube nests subjected to vapor under such conditions that the raw water in the relatively small tube nest is raised to a temperature higher than the temperature of the water in the relatively large tube nest, and particularly where at least a portion of the raw water originally heated in the relatively small tube nest is circulated therethrough.

Still further advantages of the present invention arise from the method of treating liquids in such manner that the thermal energy of degraded or low-level heat may be effectively utilized for producing temperatures of such order that the evaporation of certain quantities of liquid may be obtained, and the energy of such steam thereby recovered, and more particularly where at least a portion of the unevaporated portion of such liquid is recirculated under such conditions as to reduce the amount of air which it is necessary for the apparatus to handle.

I claim:

1. In a heat exchange apparatus, a relatively large tube nest, a relatively small tube nest, means for supplying low-level vapor to said nests, a gas offtake from the relatively small nest to the relatively large nest, constructed to maintain a lower pressure in the relatively small tube nest than in the relatively large tube nest, a flash chamber, means for delivering water from said relatively small nest to said flash chamber, means maintaining a lower pressure in the flash chamber than the pressure in said relatively large nest, and means for recirculating at least a portion of the water from said flash chamber to said relatively small nest.

2. Evaporating apparatus, comprising a main surface condenser, a heater surface condenser, means interconnecting the vapor spaces of said condensers, said means being effective at least in part to maintain a lower absolute pressure in the heater condenser than in the main condenser, means for supplying steam from a common source to both of said condensers, means for supplying liquid to both of said condensers, a flash chamber, means for passing liquid from the heater condenser to said flash chamber, means other than said main condenser for maintaining in said flash chamber a pressure lower than the pressure in the vapor space of the main con-

denser, and means for recirculating from the flash chamber at least a portion of the unvaporized liquid.

3. Evaporating apparatus, comprising a main surface condenser, a heater surface condenser, means interconnecting the vapor spaces of said condensers, said means being effective at least in part to maintain a lower absolute pressure in the heater condenser than in the main condenser, means for supplying steam to both of said condensers, means for supplying liquid to both of said condensers, a flash chamber, means for passing liquid from the heater condenser to said flash chamber, means other than said main condenser for maintaining in said flash chamber a pressure lower than the pressure in the vapor space of the main condenser, and means for recirculating from the flash chamber at least a portion of the unvaporized liquid.

4. Evaporating apparatus, comprising a main surface condenser, a heater surface condenser, means interconnecting the vapor spaces of said condensers, said means being effective at least in part to maintain a lower absolute pressure in the heater condenser than in the main condenser, means for supplying steam to both of said condensers, means for supplying liquid to both of said condensers, a flash chamber, means for passing liquid from the heater condenser to said flash chamber, means other than said main condenser for maintaining in said flash chamber a pressure lower than the pressure in the vapor space of the main condenser, and means for recirculating from the flash chamber through the heater condenser at least a portion of the unvaporized liquid.

5. Evaporating apparatus, comprising a main surface condenser, a heater surface condenser, means interconnecting the vapor spaces of said condensers, said means being effective at least in part to maintain a lower absolute pressure in the heater condenser than in the main condenser, means for supplying steam to both of said condensers, means for supplying liquid to both of said condensers, a flash chamber, means for passing liquid from the heater condenser to said flash chamber, means other than said main condenser for maintaining in said flash chamber a pressure lower than the pressure in the vapor space of the main condenser, means for recirculating from the flash chamber through the heater condenser a portion only of the unvaporized liquid, means for discarding the remainder of such unvaporized liquid, and means for maintaining the quantity of recirculated liquid substantially constant.

6. Evaporating apparatus, comprising a main surface condenser, a heater surface condenser, means interconnecting the vapor spaces of said condensers, said means being effective at least in part to maintain a lower absolute pressure in the heater condenser than in the main condenser, means for supplying steam to both of said condensers, means for supplying liquid to both of said condensers, a flash chamber, means for passing liquid from the heater condenser to said flash chamber, means other than said main condenser for maintaining in said flash chamber a pressure lower than the pressure in the vapor space of the main condenser, means for recirculating from the flash chamber through the heater condenser a portion only of the unvaporized liquid, means for discarding the remainder of such unvaporized liquid, and means for maintaining the quantity of recirculated liquid substantially constant, said last mentioned means including a float operated valve controlled by the liquid in the flash chamber.

7. In a heat exchange apparatus, a main condenser and a heater condenser, means for supplying both steam and water to said condensers in parallel, means for maintaining a lower pressure in the heater condenser than in the main condenser, a flash chamber, means for conducting heated water from the heater condenser to the flash chamber, and means for recirculating from the flash chamber at least a portion of the unvaporized liquid and passing it through the heater condenser.

8. In a heat exchange apparatus, a main condenser and a heater condenser, means for supplying both steam and water to said condensers in parallel, means discharging into the main condenser for maintaining a lower pressure in the heater condenser than in the main condenser, a flash chamber receiving water from the heater condenser, and means for recirculating a portion of such water from the flash chamber through the heater condenser.

In testimony whereof I have hereunto set my hand.

RAYMOND N. EHRHART.