P. A. BANCEL.

METHOD AND APPARATUS FOR DEVAPORIZING AND COOLING.

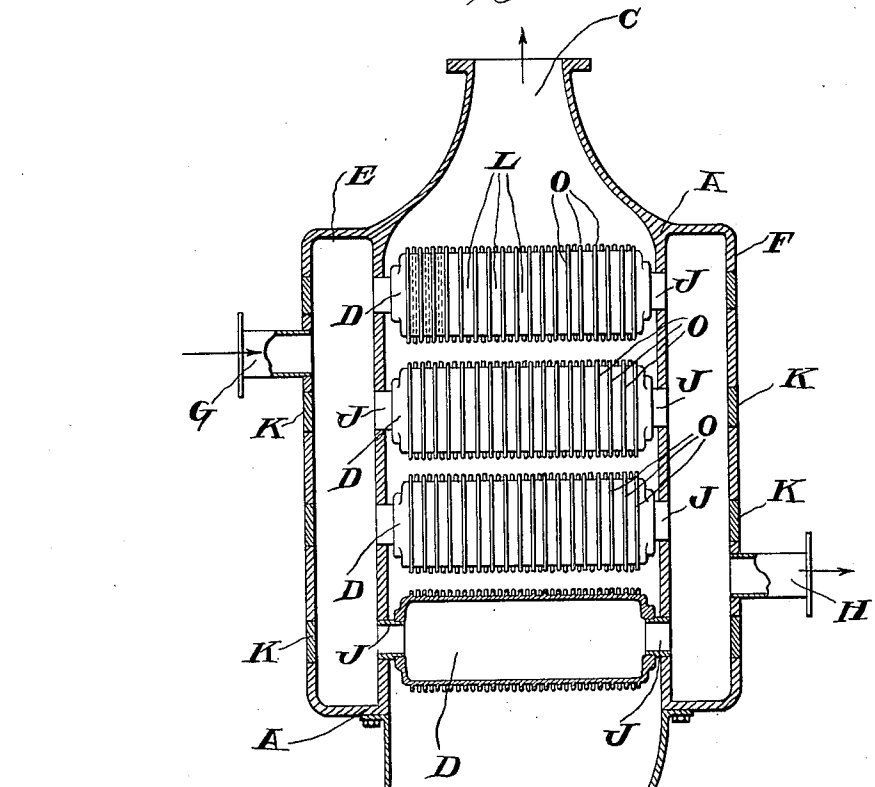
APPLICATION FILED JUNE 5, 1920.

1,380,460.

Patented June 7, 1921.

4 SHEETS—SHEET 1.

Fig. 1.



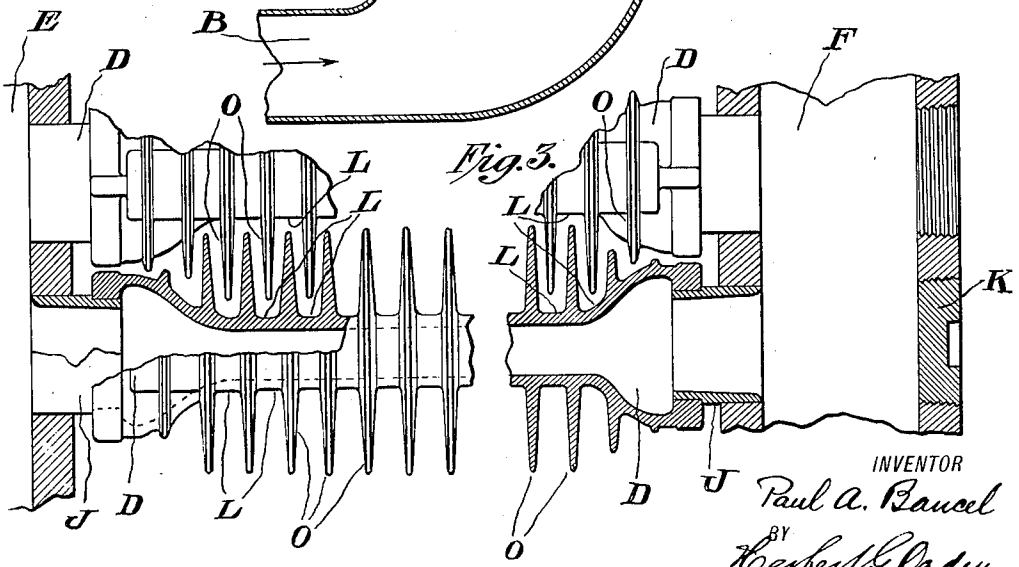


Fig. 3.

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4 SHEETS—SHEET 2.

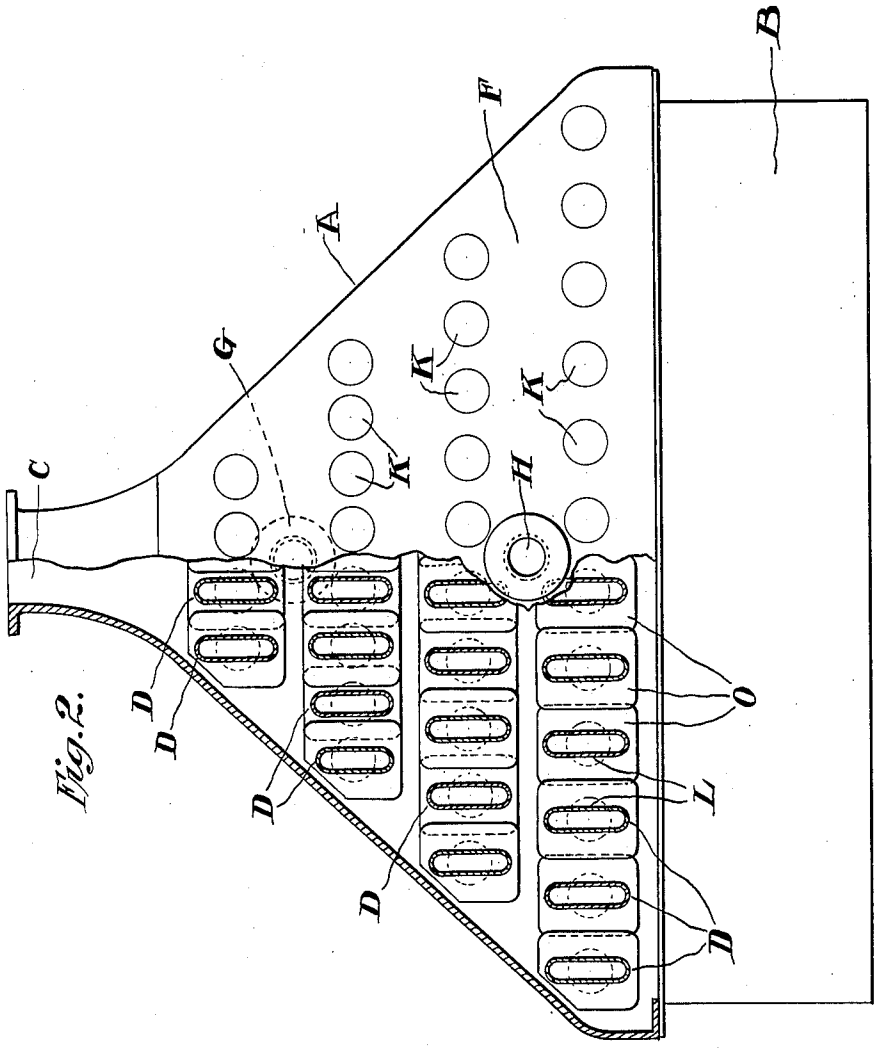


Fig. 2.

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4 SHEETS—SHEET 3.

Fig. 5.

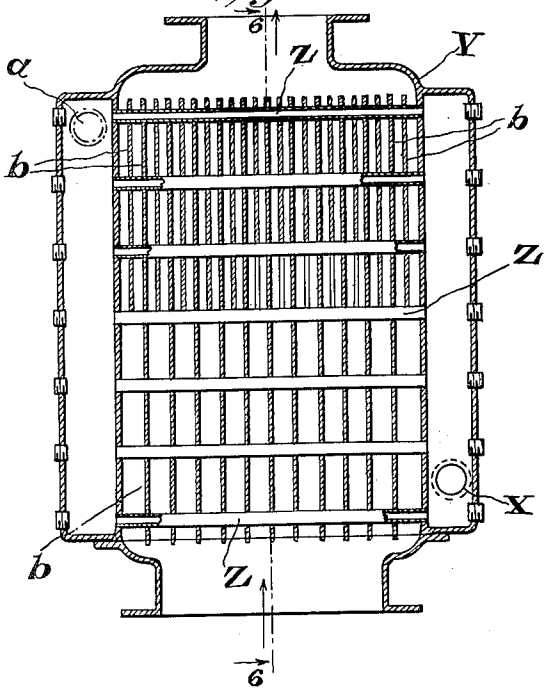


Fig. 6.

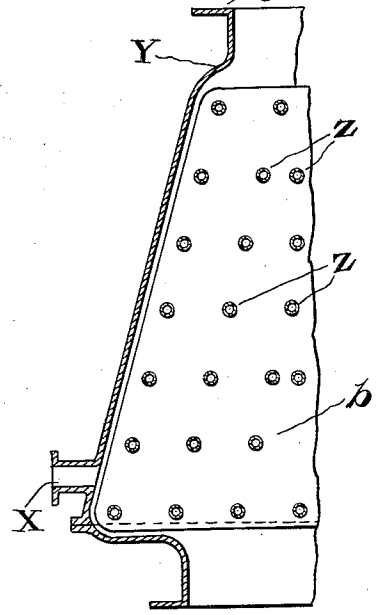
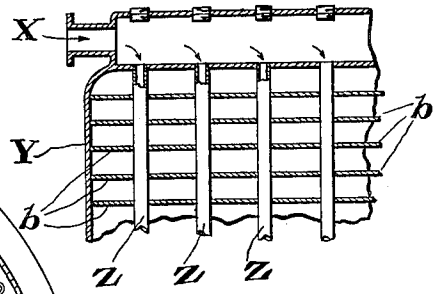


Fig. 7.



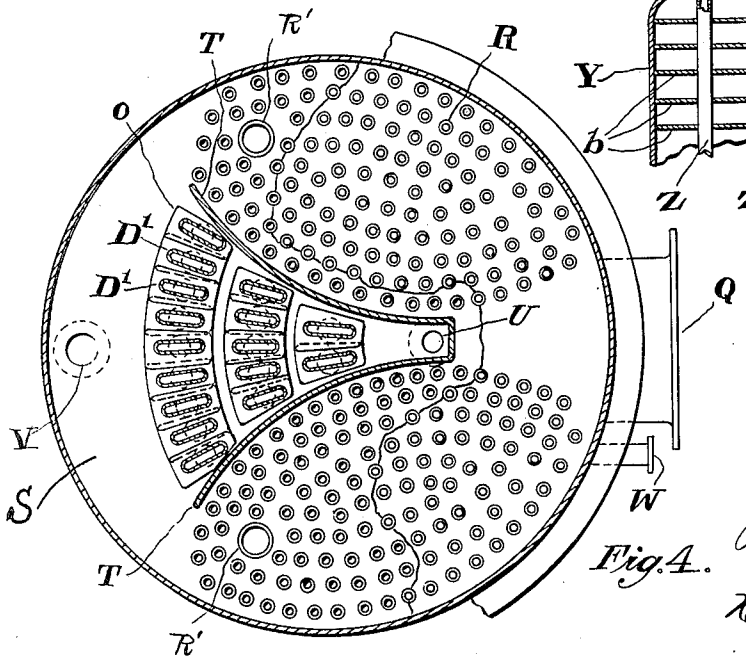


Fig. 4.

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4 SHEETS—SHEET 4.

Fig. 8.

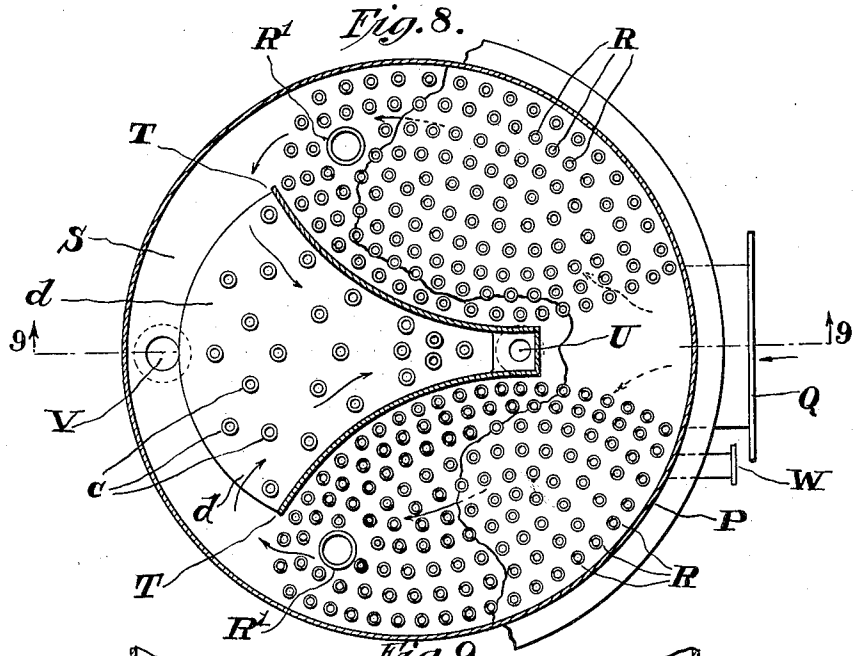
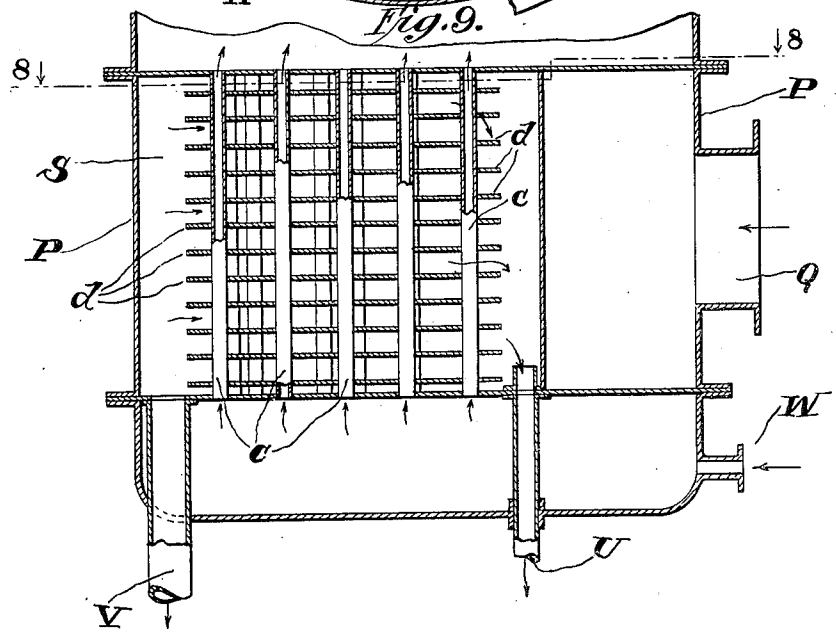


Fig. 9.



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METHOD AND APPARATUS FOR DEVAPORIZING AND COOLING.

1,380,460. Specification of Letters Patent. Patented June 7, 1921.

Application filed June 5, 1920. Serial No. 386,766.

To all whom it may concern:

Be it known that I, PAUL A. BANCEL, a citizen of the United States, residing at Nutley, in the county of Essex and State of New Jersey, have invented a certain new and useful Improvement in Methods and Apparatus for Devaporizing and Cooling, of which the following is a specification.

This invention relates to improvements in methods and apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, as steam and air, the invention being applicable more particularly to that portion of condensing apparatus in which the latter part of the total heat abstraction takes place.

The objects of the invention are to improve upon devaporizing and cooling methods and enable condensing and cooling apparatus to be constructed in which a mixture of condensable vapor and gas may be materially devaporized and to a higher degree than heretofore, and at the same time lowered in temperature with high efficiency of heat transfer.

In a surface condenser of any type, the mixture of steam and air flowing at any point is not homogeneous, as long as condensation occurs, because condensation on a cold surface immediately results in the formation of a compressed layer or film against the surface, having a higher air content compared to its steam content than that of the remainder of the body of fluid flowing.

When a fluid flows in a channel such as is formed, for example, between the outer surfaces of any two tubes in a condenser, those portions of the fluid contiguous to the walls of the channel have a lower velocity than those more remote from the walls. At small, but measurable distances from the walls, the velocity is found to be only a fraction of that in the center of the stream, and in the case of a condenser, the low velocity applies to the layer of air formed on the condensing surfaces forming the walls of the numerous flow channels. The velocity of these particles is further retarded because of their greater density compared to the fluid in the center of the stream, as air is denser than steam for the same conditions of pressure and temperature. There is, in fact, a pronounced difference in velocity between the air and steam mixture in the center of the path of flow at any point in the condenser, as compared with the denser air and steam mixture at the condensing surfaces.

The amount of air leaving any part of a channel containing the mixture of vapor and air must be as great as the amount entering, in order to maintain fixed vacuum. Thus, the slow moving denser steam and air must accumulate against the condensing surfaces to such an extent as to insure the necessary flow of air to maintain such equilibrium.

The extent to which the air accumulates is dependent, among other things, on the relative amount of air to steam in the flowing mixture. If the air content be increased, then the rapidity of condensation from a homogeneous mixture first presented to the surface is less, so that the surface is colder and the density of the layer of compressed air and steam against the surface is greater, which tends to more greatly retard the flow of such layer and increase the relative velocity in the center of the stream. There is thus a tendency to increase the accumulation of insulating air over a condensing surface, as the proportion of air to steam increases in the flowing mixture. The fact that the particles of steam and air in various parts of the stream have a velocity of turbulence as well as of translation does not change the fundamental phenomena outlined.

As the mixture passes from the steam inlet of a condenser over the succeeding rows of tubes, the condensation of the steam increases the ratio of the air to the steam in the mixture at each succeeding row of tubes, so that each row of tubes has a thicker and denser layer of slow moving insulating mixture of steam and air flowing over and around the tubes, the percentage of air in the mixture being relatively high. Each succeeding row of tubes would be expected to show a poorer heat transmission, which is actually found to be the case in practice, with commercial condensers. In fact the insulating effect of the air is so pronounced after 98% to 99% of the steam is condensed, that a large part of the total surface is

needed to condense the small amount of remaining steam.

I have discovered that, particularly with steam containing relatively large amounts of air, such as exist in a condenser after 98% to 99% of condensation has occurred, interference of the air to the process of condensation from a flowing stream can be largely eliminated by the proper disposition of skin resistance in the path of the flow.

In accordance with my preferred method of devaporizing and cooling, I retard the flow of the mixture at points between the relatively cold condensing surfaces, but remote from the surfaces themselves. I thus secure a higher proportionate condensation and prevent withdrawing a large proportion of uncondensed vapor. I am also enabled to withdraw gas with as little vapor as practically possible and I permit the vapor tension to fall approximately to the corresponding temperature of the cooling surfaces.

In carrying out my method in suitable apparatus, I preferably dispose surfaces presenting skin resistance in planes substantially normal to the condensing surfaces, which counteracts the tendency of the mixture remote from the said surfaces to move more rapidly than the mixture in contact with the cold condensing surface. There is perhaps a greater loss of pressure for the same flow, but this is expended to overcome skin friction resistance remote from the condensing surfaces, while the skin resistance at the surface itself is unaffected, and therefore the greater pressure drop causes a higher velocity of flow in that region. The accumulation of air which previously interfered with condensation is thus greatly reduced by my method.

My method of devaporizing and cooling is illustrated by means of suitable apparatus in the accompanying drawings, in which,

Figure 1, is an end elevation, partly in vertical section, of a cooler constructed in accordance with my invention. The cooler shown in this instance forms that portion of condensing apparatus in which the latter part of the total heat abstraction takes place.

Fig. 2, is a side elevation of the cooler shown in Fig. 1 with the shell partly broken away and some of the internal parts in vertical section.

Fig. 3, is an enlarged detail plan view of a plurality of the internal members of the cooler, partly broken away and partly in horizontal section.

Fig. 4, is a horizontal sectional plan view of an evaporator for carrying out my method, containing a cooler constructed in some respects like the cooler shown in Figs. 1, 2 and 3.

Fig. 5, is a sectional side elevation of a modified form of cooler,

Fig. 6, is a partial longitudinal sectional elevation of Fig. 5 on the line 6—6 looking in the direction of the arrows.

Fig. 7, is a horizontal sectional plan view of a portion of the cooler shown in Fig. 5.

Fig. 8, is a horizontal sectional plan view of a modified form of evaporator on the line 8—8 of Fig. 9, and

Fig. 9, is a vertical sectional view of Fig. 8 partly broken away on the line 9—9 looking in the direction of the arrows.

Before describing the drawings in detail, certain considerations underlying the invention may be referred to. In accordance with my researches, in which the inlet and outlet temperatures of water flowing through tubes in the various rows of a surface condenser were observed, I have confirmed the now well understood fact, that the efficiency of heat transfer becomes poorer, the greater the proportion of the steam condensed and therefore the greater the relative percentage of air mixed with the steam. I have further found that the decrease in efficiency is substantially small and in fact hardly perceptible, until the proportion of steam condensed has reached a relatively high percentage. Thus, the last rows of tubes in a surface condenser will show an efficiency of heat transmission almost as high as the first rows provided there is a sufficient outflow away from the tubes of steam and the air mixed with it. The condenser should be of the proper shape and the suction removing the steam and air after the last row of tubes should be exerted over approximately the whole length of the tubes. Unless approximately these conditions are maintained, a large percentage of the surface of the condenser located near the bottom, will be seriously decreased in efficiency perhaps to such an extent that the water flowing through the tubes will show no rise in temperature.

Consideration of the total quantities of steam exhausted into a condenser of moderately large size will show that even if only 1% of the steam is to be withdrawn from the last row of tubes, a vacuum pump capacity of about 10,000 to about 30,000 cubic feet a minute would be required. It is therefore highly desirable to condense a large part of the residual steam, thereby shrinking its volume and increasing the partial air pressure of the air, so that only a moderate pump displacement is needed to continuously remove it from the apparatus.

Referring more particularly to the drawings, and at first to Figs. 1, 2 and 3, A represents the casing of a cooler for cooling a mixture of air and steam. Such a mixture of air and vapor is encountered in connection with the condensation of steam in surface condensers, after the major portion of the steam has been condensed by the tubes

within the condenser proper. The function of the cooler A is to complete the condensation of the vapor as the mixture flows from the surface condenser through the cooler inlet B and from the cooler outlet C to the usual vacuum pump. The casing A is preferably constructed in pyramidal form indicated in Fig. 2, narrower at the top and wider at the bottom and cooling elements, in this instance in the form of hollow cores or grids D, are mounted transversely in rows in the casing A and communicate with the heads E and F, provided respectively with the upper water inlet G and lower water outlet H for cooling water. The grids D may be mounted in the tube sheets of the casing A in any suitable manner as by means of the nipples J. The handholes K are preferably provided for the casing A opposite each grid. The grids are preferably closer together in the top rows than in the bottom rows which decreases the widths of the streams the greater the relative amount of air in the mixture.

In order to retard the flow of the mixture of steam and air at points between the surfaces L of the grids D but remote from said surfaces, one device consists of transverse fins or flanges O which may be formed on the grids D and preferably lie in intermeshing relation in planes substantially normal to the core surfaces L. These fins or flanges O interpose numerous skin friction surfaces between the cooling surfaces and retard the flow in planes normal to said surfaces. At the condensing surfaces proper, indicated at L the skin resistance remains the same as before and as though the flanges O were absent.

The fins or flanges O may be of any suitable shape and conformation but I have obtained excellent and satisfactory results with flanges O of substantially the rectangular shape shown particularly in Fig. 2. In the present instance the flanges O are shown extending outwardly from the cores D substantial distances in horizontal planes but may extend a short distance only from the cores in vertical planes. I have found that it is desirable to provide flanges O of different dimensions and change the distance between condensing surfaces L to suit different conditions of vacuum and proportions of vapor and air in the mixture. With a certain difference in temperature between the vapor and the water passing through the grid bodies, I have found that flanges of a predetermined dimension and certain preferable distance between condensing surfaces is the more desirable in practice. The grids D may be of case iron and the fins or flanges O cast integral with them.

Of the total surface of a grid D exposed to the vapor and air, the main-body or hollow core comprises about 10% and the total exposed surface of the fins or flanges about 90%. In accordance with my method, the function of the grid is primarily to condense vapor; the heat to be abstracted from the small amount of air being negligible and the flange surface condenses a relatively small amount of the steam, its principal function being to present frictional surface in the path of flow of the vapor and air. In an actual commercial size condenser and cooler carrying a commercial load with the usual air leakage and vacuum pump displacement, I have found that the total heat transmission through a grid at one point in the cooler for one degree of difference in temperature between the vapor and the outside surface of the core may be represented by the figure 1,000. The total heat which could be conducted through the metal of the flanges based on the known conductivity of the metal, provided it was conducted to the surfaces of the flanges with a very small temperature difference, may be represented by the figure 100. This demonstrates that the fin or flange surface of a grid composing approximately 90% of the total surface, can conduct only about 10% of the total heat. Or on the basis of surface exposed, each unit of surface of the flanges condenses only about 1.1% of a unit of surface of the core body. At another location of the grid in the cooler these percentages would vary above and below these figures depending on whether the steam and air mixture contained more or less air. Accordingly if the fin surface were composed of a material, which is a poorer conductor of heat but still exposes the same rough surface to the flow, the efficiency of heat transmission of the entire structure would be only slightly reduced.

The efficiency of my method and the importance of the fins or flanges O is apparent when it is considered, that if no fins were used at all, the condensing surface would only have high efficiency and condense relatively large volumes of steam provided there was a large volume flowing away, as in the condenser proper. In accordance with my method, the skin friction surfaces presented by the fins delays the flow of those particles of steam and air remote from the cold condensing surfaces. If these frictional surfaces were not present, the devaporized mixture coming off the cold surfaces would be mixed with a relatively large volume of hot vapor, which had a free path of flow in between the condensing surfaces, thus resulting in a mixture having a much larger steam content, finally passing to the pump. The mixture in conact with the cold condensing surfaces is rich in air but by reason of its proximity to the surfaces, tends to move slowly while those particle farther away have less air

and more steam and tend to move faster. The action of the fins or flanges is therefore to counteract this difference in velocity of flow.

My method of devaporizing and cooling may be carried out in different forms of apparatus for a number of different purposes. For instance, the method may be applied to apparatus for evaporating sugar solutions, one form of evaporator being shown in Fig. 4, of that type in which the sugar solution rises vertically through a plurality of tubes around the outside of which steam is passing. Some of these vertical tubes may be in the form of grids D′ having the fins or flanges O as in Figs. 1, 2 and 3. Referring more in detail to Fig. 4, the mixture of steam and air enters the casing P at the inlet Q and first passes around the rows of main evaporating tubes R to the space S, and from there passes around the grids D′ suitably mounted in that portion of the apparatus bounded by the baffles T. Air passes out at the outlet U and the condensate is drawn off at the outlet V. The sugar solution, which corresponds in function to the circulating water of a surface condenser, enters the apparatus at the inlet W and circulates through the evaporating tubes and the hollow core bodies of the grids D′ and down-comer tubes R′ in the usual manner. It will be observed that the steam entering at Q is progressively condensed with increasing relative richness in air as the mixture passes through the apparatus toward the final air outlet U and the action of the fins or flanges O is the same as that described in connection with Figs. 1, 2 and 3.

Instead of providing grids having fins or flanges, cooling apparatus like that shown in Figs. 5, 6 and 7 may be utilized for carrying out my method of devaporizing and cooling. In this instance cooling water enters the lower inlet X in the casing Y and passes through the horizontal tubes Z to the upper outlet *a*. Vertically disposed plates *b* presenting skin friction to the flow of the mixture of steam and air are arranged in the casing dividing the spaces between the tubes Z into a plurality of channels. A greater number of more closely spaced plates *b* are preferably provided in the upper portion of the casing, thus increasing the resistance to flow in planes normal to the condensing surfaces at points nearer the outlet at which the relative amount of air is largest. The plates *b* may be of any suitable or desired material such as metal or wood.

In Figs. 8 and 9, a sugar evaporator is shown constructed substantially like Fig. 4, except that the grids D′ have been replaced by vertical tubes *c* preferably more widely spaced than the main tubes R through all of which the sugar solution circulates. The spaces between the tubes are divided by horizontal plates *d* presenting skin friction to the flow of the mixture of steam and air passing from the chamber S around the tubes *c* through the channels afforded by the plates *d* which plates may be of metal or wood.

I claim:

1. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas, which consists in passing said mixture over relatively cold surfaces and retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves, thereby securing a higher proportionate condensation and preventing the withdrawal of a large proportion of uncondensed vapor.

2. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas, which consists in passing said mixture over relatively cold surfaces and retarding the flow of the mixture in planes substantially normal to the said surfaces, in order to withdraw gas with as little vapor as possible and permit the vapor tension to fall approximately to the corresponding temperature of the said cooling surfaces.

3. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas, which consists in passing said mixture over relatively cold surfaces and increasing the resistance to flow in planes substantially normal to the said surfaces at points at which the relative amount of air is smaller, thereby compensating for high friction near the cold surfaces and securing a higher proportionate condensation.

4. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas, which consists in passing said mixture over relatively cold surfaces and affording greater resistance to flow in a direction normal to the said surfaces at points more remote from said surfaces than at points near the cooling surfaces.

5. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas, which consists in passing said mixture over relatively cold surfaces, decreasing the width of the streams or distance between said cold surfaces the greater the relative amount of air, and retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves, thereby causing a high proportionate condensation.

6. The method, substantially as herein described, of devaporizing and cooling a flowing mixture of condensable vapor and gas,

which consists in passing said mixture over relatively cold surfaces, decreasing the width of the streams or distance between said cold surfaces, the warmer the surface relative to the vapor and as the mixture grows colder in its flow, and retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves, thereby causing a high proportionate condensation.

7. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including means for retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves, thereby securing a higher proportionate condensation and preventing the withdrawal of a large proportion of uncondensed vapor.

8. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including means for retarding the flow of the mixture in planes substantially normal to the said surfaces, in order to withdraw gas with as little vapor as possible and permit the vapor tension to fall approximately to the corresponding temperature of the said cooling surfaces.

9. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including means for increasing the resistance to flow in planes substantially normal to the said surfaces at points at which the relative amount of air is smaller, thereby securing a higher proportionate condensation.

10. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including means affording greater resistance to flow in a direction normal to the said surfaces at points more remote from said surfaces than at points near the cooling surfaces.

11. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including means for retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves, the distance between said cold surfaces decreasing toward the outlet of the apparatus.

12. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising means for passing said mixture over relatively cold surfaces, including skin friction elements extending in planes normal to the said surfaces for retarding the flow of the mixture at points between said surfaces remote from the surfaces themselves.

13. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising a casing, a plurality of grids through which a cooling medium is adapted to flow, and over and around which the mixture of vapor and gas is adapted to flow, said grids being arranged within the casing and having body portions provided with skin friction surfaces extending substantially parallel to the flow of the mixture, for retarding the flow at points between the body portions and remote from the surfaces of said body portions.

14. Apparatus for devaporizing and cooling a flowing mixture of condensable vapor and gas, comprising a casing having an inlet at the bottom for the vapor and gas and an outlet at the top, a plurality of grids through which a cooling medium is adapted to flow, and over and around which the mixture of vapor and gas is adapted to flow, said grids being arranged within the casing and having body portions provided with surfaces extending in directions substantially normal to the surfaces of the body portions of the grids, for retarding the flow at points between the body portions and remote from the surfaces of said body portions.

In testimony whereof I have signed this specification.

PAUL A. BANCEL.