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D. ARONSON ET AL
MODULAR HEAT EXCHANGER

2,869,833

Filed April 3, 1957

3 Sheets-Sheet 1

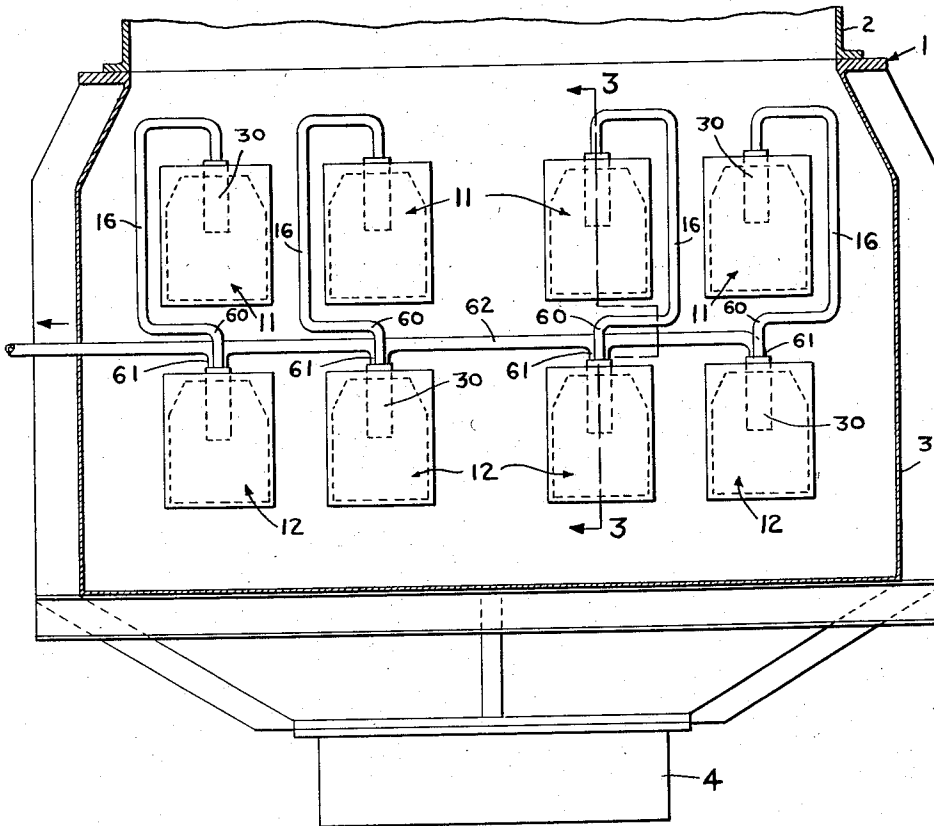
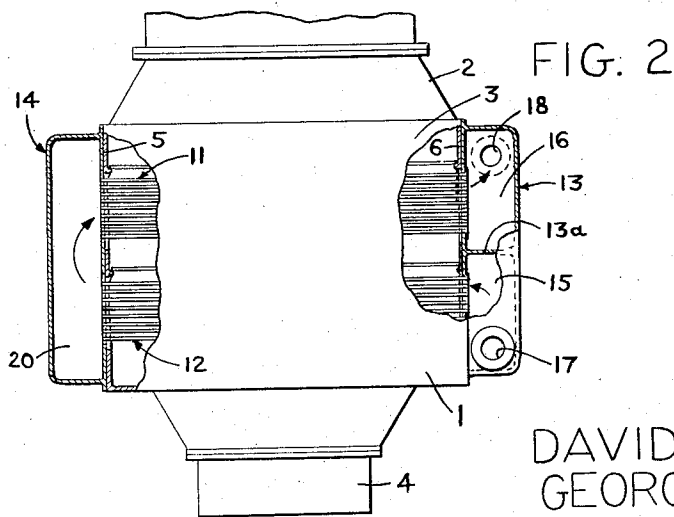


FIG. 1

FIG. 2
DAVID ARONSON
GEORGE F. MELICK
INVENTORS
BY *Daniel H. Bohls*
Attorney

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3 Sheets-Sheet 2

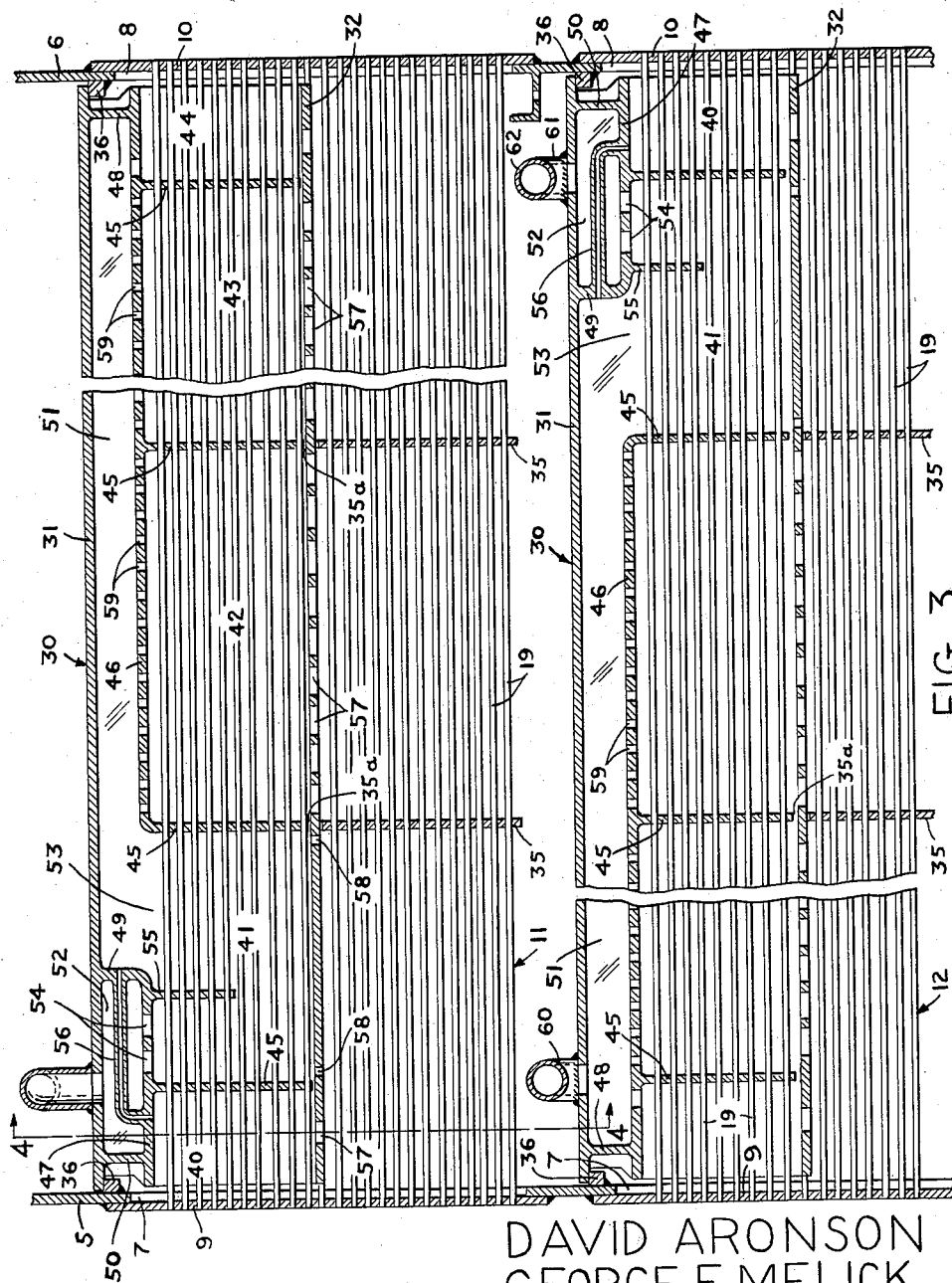


FIG. 3

DAVID ARONSON
GEORGE F. MELICK
INVENTORS

BY *Daniel H. Boerio*
att'y

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3 Sheets-Sheet 3

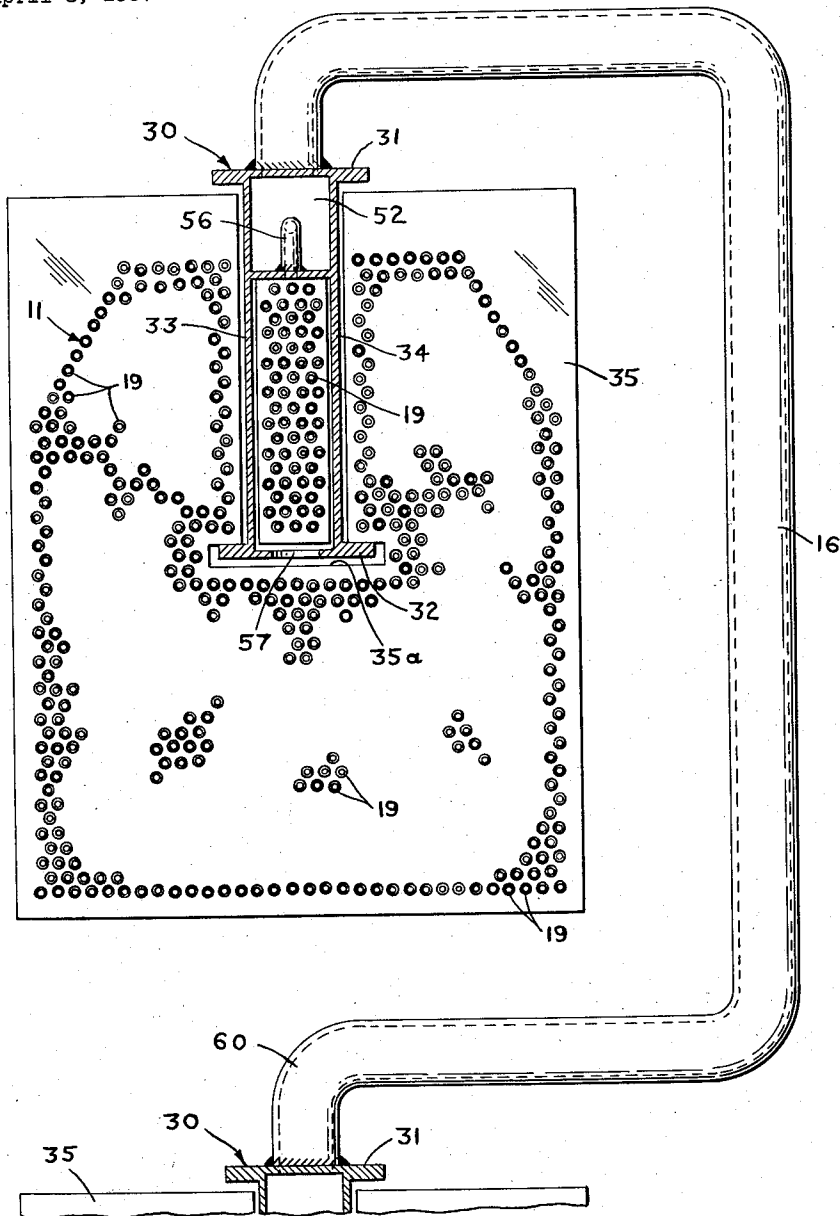


FIG. 4

DAVID ARONSON
GEORGE F. MELICK
INVENTORS

BY *Daniel A. Bobis*
Atty

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2,869,833

MODULAR HEAT EXCHANGER

David Aronson, Upper Montclair, and George F. Melick, Murray Hill, N. J., assignors to Worthington Corporation, Harrison, N. J., a corporation of Delaware

Application April 3, 1957, Serial No. 650,407

9 Claims. (Cl. 257-43)

This application is a continuation in part of an application for Letters Patent Serial No. 531,681 filed August 31, 1955, in the United States Patent Office, now abandoned.

This invention relates generally to heat exchangers and more particularly to a non-contacting type heat exchanger wherein the tube elements are split into units such that the condenser can be field assembled to obtain the desired capacity and conditions of operation.

The fundamental idea of splitting the tube elements of a non-contacting type heat exchanger into groups or even into discrete tube bundles to improve the performance characteristics is indicated in Patents 1,502,257 and 1,198,629, and described in an article entitled "Some Results of Condenser Operation," by Edward R. Ricketts, presented at the annual meeting at New York, December 6-9, 1926, of the American Society of Mechanical Engineers.

Little attention, however, has been given to the utilization of this type construction for two purposes. First, as a means of standardization of heat exchangers expressly in the larger type surface condensers and, second, as a means of reducing the size, weight and cost of manufacture of such larger heat exchangers.

The present invention covers a heat exchanger which utilizes the idea of discrete tube bundles or units which are constructed or designed with an independent support means and arranged relative to the tube heads or supports so that the tube bundle units may be independently assembled for the desired capacity without or substantially without any connections to the heat exchanger shell and wherein the independent support means is so constructed that it operates as an air cooler and as a mechanism for removing the non-condensable gases and non-condensed steam for efficient operation of the heat exchanger.

Accordingly, it is an object of the present invention to provide a modular condenser construction composed of a plurality of tube bundle units each having an independent support means which support means has a corollary function as an air cooler and means for removing non-condensable gases.

It is a further object of the present invention to provide an air cooler construction for the independent and discrete tube bundles in such modular condenser such that the need for sealing between the end of the air cooler and the tube sheet head is eliminated.

It is a still further object of the present invention to provide an air cooler so positioned for each independent and discrete tube bundle unit which it supports in the modular condenser that condensation of a substantial portion of the steam will be effected before the non-condensable gases and non-condensed steam reach the vacuum system which includes the passage means in the air cooler whereby the effective removal of non-condensable gases from the condenser will be increased and the efficiency of the condenser increased.

The invention will be better understood from the fol-

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lowing description when considered in connection with the accompanying drawings forming a part thereof and in which:

Figure 1 is a side elevational view of a condenser partly broken away, embodying the present invention.

Figure 2 is an end view of the tube bundle units disposed in a condenser with the tube sheet support head removed.

Figure 3 is an enlarged section taken on line 3-3 of Figure 2 illustrating the details of the air cooler embodied in the present invention.

Figure 4 is an enlarged section taken on line 4-4 of Figure 3.

Referring to the drawings, Figure 1 shows the invention as applied to a 2-pass surface condenser generally designated 1 having a steam inlet 2 for delivering steam from any suitable source such as a steam turbine (not shown) to the condenser shell 3 designed in the conventional manner of radial flow type condensing units, a condensate collecting means or hot well 4 being provided at the lowermost portion of the condenser for collecting condensed steam. This type condenser is well known in the art and it will be understood that while a 2-pass condenser is shown in the preferred form of the present invention that the invention is equally applicable to any single or multi-pass heat exchanger.

The condenser 1 includes support heads 5 and 6 at the respective ends which support heads are provided with a plurality of openings shown at 7 and 8 in Figure 3 of the drawings. As indicated in Figure 3, the openings on the respective support heads are in alignment with each other, and thus are adapted to receive spaced tube sheets 9 and 10 of tube bundles or units generally designated 11 for the upper pass units and 12 for the lower pass units. These tube sheets 9 and 10 can be mounted to the respective support heads 5 and 6 about such openings as by welding or any other suitable means to provide a fluid tight connection as is clearly shown in Figures 1 and 3 of the drawings. In addition, by so positioning or spacing the openings relative each other suitable steam lanes can be formed for optimum flow of steam through the condenser shell 3.

Water boxes 13 and 14 are also provided at the ends of the condenser 1 outwardly of the tube sheets 9 and 10 in the conventional manner for surface condensers. Water box 13 has a partition 13a thereacross to form an inlet chamber 15 and an outlet chamber 16 which chambers communicate with the respective fluid inlet 17 and fluid discharge outlet 18 as is shown in Figure 1 of the drawings. The tubes generally designated 19 for each of the independent and discrete tube bundle or units, 11 for the upper pass of the condenser and tube bundle or units 12 of the lower pass of the condenser communicate with chambers 15 and 16 and with a crossover passage 20 formed in the water box 14 so that fluid delivered to inlet chamber 15 will flow through the tubes 19 of the respective tube bundles 12 then through the crossover passage 20 to the tubes 19 of the tube bundle or units 11 and finally to the outlet chamber 16 and fluid discharge outlet 18 in a conventional flow path or pattern of a tube pass condenser.

While the partition 13a is shown disposed horizontally, it is believed clear that it could be vertically disposed or that additional partitions could be formed in the water box to increase the number of passes for the condenser as is well known in the art.

TUBE BUNDLES OR UNITS

The respective tube bundles are substantially identical in construction. They include the spaced tube sheets 9 and 10 which are substantially flat, plate-like elements rectangular in end view as is shown in Figure 2 of the

drawings, and also as indicated in Figure 3 of sufficient size to cover the openings 7 and 8 so that they may be connected to the support sheets 5 and 6.

Since the openings 7 and 8 are in alignment with each other the tube sheets 9 and 10 will also be in alignment, thus the respective ends of the tubes 19 can be mounted in such tube sheets as by rolling, or any other suitable means.

Figures 3 and 4 show that the tube bundles or units 11 and 12 will also include a substantially I-shaped member or element generally designated 30. Member 30 is disposed along the longitudinal line of each tube bundle or unit and although shown in Figures 3 and 4 disposed at the upper portion of each tube bundle, it will be understood that this element can be expanded or widened or disposed in other portions of the tube bundle without departing from the scope of the present invention and that such changes in the design of this member or element will be determined by its practical functions as a support member for the tube bundle, as an air cooler, and as a conduit for removing non-condensable gases and non-condensed steam from the condenser.

Each of the I-shaped members 30 includes an upper plate element 31 and a lower plate element 32 which plates extend substantially the full length of the tube bundle or units terminating just short of the support heads 5 and 6. These elements are joined to each other by spaced side plates 33 and 34 in the manner shown in Figure 4 of the drawing so that a space is delineated between the upper and lower plates 31 and 32 and the respective side plates 33 and 34 in each of the I-shaped members 30. The lower portion of this space will enclose a plurality of the condenser tubes 19 for each of the tube bundles or units 11 and 12, which tubes act as air coolers as is hereinafter described.

In assembled position the tube bundle units 11 and 12 are supported longitudinally by the upper plate element 31 of the I-shaped member 30. Thus the upper plate element 31 will engage at its respective ends horizontal brackets 36 formed on the inner surface of the support heads 5 and 6 adjacent the upper end of each of the openings 7 and 8.

The tubes 19 in each tube bundle unit 11 and 12, are supported laterally by a plurality of tube support plates 35 mounted transversely of the longitudinal line of each I-shaped member 30 in spaced relation to each other. The tube support plates 35 are perforated with a plurality of holes to receive the tubes 19 and are so shaped that they will engage and rest in the recesses formed in the I-shaped member 30 by spacing the side walls or side plates 33 inwardly of the ends or side edges of the upper plate 31 and lower plate 32, all of which is shown in Figure 3 of the drawings.

In order to utilize the tubed portion of the space formed by the upper plate 31, lower plate 32, and the side plates 33 and 34 as an air cooler and conduit for non-condensable gases and non-condensed steam, the space is divided into a plurality of chambers and a convoluted flow passage by suitable partitions as is hereinafter described.

Thus Figures 3 and 4 show that in the portion of the space having the tubes 19, the area is subdivided into air cooling chambers 40, 41, 42, 43 and 44 by transverse partitions 45 at spaced intervals therealong perpendicular to the longitudinal length of the tubes 19. The transverse partitions are connected at their lower ends to the inner aspect of the lower plate 32 and at their upper ends to medially disposed longitudinally extending plates 46 and 47.

The medially disposed longitudinally extending plate 46 and the medially disposed plate 47 are spaced vertically from the inner aspect of the upper plate 31 by vertical brackets 48, 49 and 50. They are also attached laterally to the inner walls of the side plates 33 and 34 to form the flow channel 51 extending substantially the entire length of each of the I-shaped members 30 and an

outlet chamber 52 which occupies a relatively small portion of the space formed in the I-shaped member 30 as is shown in Figures 3 and 4 of the drawings.

However, as is further shown in Figure 3 the outlet chamber 52 is on substantially the same plane as the flow channel 51 but is separated and enclosed by the vertical brackets 49 and 50. Accordingly, to provide communication between chambers 51 and 52 the medially disposed plates 46 and 47 are spaced horizontally from each other to form a passage or passageway 53 which opens one end of the flow channel 51 into the air-cooling chamber 41. Similarly spaced from the passage 53 a plurality of openings 54 in the medially disposed plate 47 connect the outlet chamber 52 with the air cooling chamber 41. Thus non-condensed steam and non-condensable gases collected in the flow channel 51 will pass through the passage 53 into the air cooling chamber 41 and then through openings 54 into the outlet chamber 52. In order to utilize the full advantage of the cooling capacity of the air cooling chamber 41 a vertical baffle 55 is further provided which is connected to the medially disposed plate 47 adjacent passage 53 and the openings 54 so as to force the flow of air downwardly from the passage 53 and upwardly to the openings 54 in convoluted flow across the tubes 19 which extend through the air-cooling chamber 41.

To pass the non-condensed steam and non-condensable gases into the air-cooling chambers 40, 41, 42, 43 and 44 formed in the I-shaped member 30 the lower plate 32 has a plurality of relatively large inlet openings 58 for the air cooling chamber 41. The openings into the chamber 41 differ from the size of the openings in the other air cooling chambers so as to obtain optimum steam flow conditions into and through the air cooling chambers and the flow channels formed in the air cooler. The medially disposed plate 46 enclosing the chambers 42, 43 and 44 and forming the flow channel 51 has relatively small outlet openings 59 so that non-condensed and non-condensable gases which remain after passing across the tubes in the air cooling chambers 42, 43 and 44 will be continually passed from these air cooling chambers to the flow channel 51 and thence to the outlet chamber 52 through the passageway 53, air cooling chamber 41 and openings 54. Condensate produced in the air cooling chambers 40, 41, 42, 43 and 44 will drop by gravity flow back through the openings 57 and 58.

One of the transverse partitions 45 inwardly of the end on each tube bundle or unit 11 or 12 will delineate the air cooling chamber 40. In order to maintain optimum operation of this air cooling chamber the non-condensable gases and non-condensed steam are continuously vented through a conduit or pipe 56 which connects the upper end of the air cooling chamber 40 with the passageway end of the flow channel 51. It is of course possible to place a suitably sized opening in the transverse partition 45 adjacent the openings 54 but the use of a conduit 56 coupled with the convoluted flow pattern through the passage 51 and passageway 53 provides full cooling treatment and full use of the available heat exchange capacity of the tubes 19 extending through the air cooling chambers 40 and 41.

Referring further to Figure 2, one system is shown for evacuating or removing the non-condensed steam and non-condensable gases collected in the respective outlet chambers 52 of each of the tube bundles or units 11 and 12.

Thus the outlet chambers 52 of the tube bundles 11 are provided with communicating or connecting conduits 60 which connect to the flow channels 51 of the tube bundle or units 12 at a point remote from their outlet chambers 52 as is shown in Figures 2, 3 and 4. The outlet chambers 52 of the tube bundle or units 12 in turn connect through discharge outlets 61 to a common vacuum or discharge duct 62 which is connected to any suitable type of evacuating means, not shown, such as a vacuum pump,

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steam ejector or the like which is utilized with this type of apparatus.

The construction and arrangement of the tube bundles or units 11 and 12 are substantially identical except that the outlet chambers 52 on each tube bundle will always be positioned adjacent the inlet end of the tubes 19 for reasons to be shown in connection with the description of the operation of this invention.

As indicated in the above description the I-shaped member operates as the means for supporting the tube bundles or units 11 and 12 longitudinally. Transversely, the tube support plates operate to support the tubes in the respective tube bundles or units 11 and 12 in the lateral direction. This is accomplished through the coaction of the tube support plates 35 with the I-shaped member, a T-shaped cutout portion 35a being provided on each of the tube support plates to enable it to fit or engage the I-shaped member as above described. This construction eliminates the need for supporting struts attached to the inner surface of the steam side of the condenser which would form restricted areas in the condenser which produce large pressure losses.

Since the tube bundles as above described are independent and discrete units it is obvious by so proportioning or arranging the number of tube bundles for a given size of shell that the desired capacity for a particular condenser can be selected or changed as is desired in the initial or subsequent construction of the condenser.

Operation

In operation, the cooling water is passed through the condenser as above described.

Steam is then passed from any suitable source such as a steam turbine, not shown, through the inlet 2 for the condenser shell 3 where it passes in heat exchange relation with the tubes 19 in the respective tube bundles 11 and 12. As the steam flows downwardly over the tubes 19 in each of the tube bundles 11 and 12 a substantial portion thereof will condense and the condensate will drop by gravity into the hot well 4 in the manner well known in the art.

However, there remains in the shell 3 a mixture of non-condensed steam and non-condensable gases which mixture must be further cooled to obtain the fullest possible utilization of the condensing capacity of the condenser and in addition the non-condensable gases must be continuously removed to prevent the build-up of back pressures which would affect the efficiency of the condenser and cause increased maintenance cost.

Accordingly, the non-condensed steam and the non-condensable gas mixture remaining in the shell will pass upwardly by differential pressure into the tube bundles and thence through the openings 57 and 58 into the air cooling chambers 40, 41, 42 and 43 formed in the I-shaped member 30. In the air cooling chambers 40, 41, 42, 43 and 44 the mixture passes in heat exchange relation with the tubes disposed in these chambers. Further condensation will then occur in these chambers, the condensate dropping by gravity back through the openings 57 and 58 and the residual steam gas mixture now predominantly non-condensed gases will be passed by differential pressure through the openings 59 and the pipe 56 in each of the tube bundles 11 and 12 to the flow channels 51 and thence through the air cooling chamber 41, outlet chamber 42 and common discharge duct 62 to the evacuating means or system (not shown).

In Figure 3 the clearance between the I-shaped member 30 and the tube sheets 9 and 10 at the respective ends is indicated as being comparatively small. Nonetheless, there is sufficient space therein so that steam can flow directly into this space formed by the air cooling chambers 40 and 44. However, by reason of the fact that the air cooling chambers 40 and 44 on the respective ends of each of the tube bundle units 11 and 12 do not connect or communicate directly with the outlet chambers 52 or the

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common discharge duct 62 it is unnecessary to effect a seal to prevent this direct steam flow through the ends of the respective I-shaped members into these chambers. If such direct flow occurs the flow joins with the residual non-condensed gases and non-condensed steam in these respective chambers and passes into the flow channel 51 and the pipe 56 to be further cooled in the manner above described and thus optimum use of the condensing capacity of the air cooler will be further utilized. This construction further avoids excessive load on the vacuum system which would otherwise reduce its efficiency.

The air cooling chambers in the tube bundle units 11 in the upper pass of the condenser will only cool the steam-gas mixture to within a degree or so of the temperature of the cooling water entering the inlet ends of the tubes 19 in these tube bundles from the crossover passage 20. Since this cooling water is at a temperature more than halfway between the initial inlet temperature and the final temperature at which it is discharged to the outlet chamber 16 the steam-gas mixture may be further cooled. This is accomplished by passing the steam-gas mixture from the outlet chambers 52 of the tube bundles or units through the connecting conduit 16 to the airflow channels 51 and outlet chambers 52 of the tube bundles or units 12 of the lower pass of the condenser where further cooling and optimum use of the capacity of the air cooling chambers in the condensing arrangement is effected.

It will be understood that the invention is not to be limited to the specific construction or arrangement of parts shown but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. In a non-contacting type heat exchanger including, a shell, support heads at each end of said shell forming a vapor flow space, and said support heads each having a number of openings in alignment with each other, the combination with said support heads of a plurality of discrete and independent tube bundle units each having spaced tube sheets at their respective ends adapted to be connected between said support heads in a pair of aligned openings, a plurality of tubes in said tube bundle units connected between said support heads, a longitudinal support means for each of said tube bundle units connected between said support heads, said longitudinal support means enclosing a portion of the tubes in said tube bundle units, means in said support means delineating air cooling chambers, said air cooling chambers having an inlet communicating with said vapor space to receive non-condensed steam and non-condensable gases, said air cooling chambers having outlet means, a flow channel in said support means communicating with said air cooling chambers to receive residual non-condensed steam and non-condensable gases, means providing communication between said flow channel and said outlet means, and vacuum means communicating with said outlet for continually removing residual non-condensed steam and non-condensable gases from said heat exchanger.

2. In a non-contacting type heat exchanger as claimed in claim 1 wherein said means providing communication between the flow channel and the outlet means includes a passageway connecting one end of said flow channel with one of said air cooling chambers, and openings communicating the outlet means with the same air cooling chamber, and a baffle between said passageway and said openings to cause residual non-condensed steam and non-condensable gases to flow downwardly and upwardly across the tubes in said air cooling chamber communicating with the passageways and the openings.

3. In a non-contacting type heat exchanger as claimed in claim 1 wherein each of said tube bundle units has a plurality of tube supports mounted transversely along said longitudinal support means in spaced relation to each other, and said longitudinal support means includes an upper plate, a lower plate, and side plates connected be-

tween and inwardly of the side edges of said upper plate and said lower plate, said tube supports on each of said support members having a slot shaped to fit about the side plates and to rest on the lower plate of the support means for supporting the tubes in said tube bundle units outwardly of said longitudinal support means.

4. In a non-contacting type heat exchanger including a shell, support heads at each end of said shell forming a vapor space, and said support heads each having a number of openings in alignment with each other, the combination with said support heads of a plurality of discrete and independent tube bundles each having spaced tube sheets at their respective ends adapted to be connected between said support heads in a pair of aligned openings, a plurality of tubes in said tube bundle units connected between said tube sheets, longitudinal support means for each of said tube bundles connected between said support heads, each of said support means terminating relatively close to said support heads to form a clearance space at the ends of said tube bundle units for a limited amount of steam leakage into said support means, each of said support means enclosing a portion of the tubes in its respective tube bundle, means in said support means transversely disposed with respect to said tubes to form air cooling chambers having inlets in communication with said vapor flow space to receive non-condensed steam and non-condensable gases, an outlet for said air cooling chambers, means connected to said outlet for continually removing residual non-condensed steam and non-condensable gases from said air cooling chambers, and the air cooling chambers adjacent the respective ends of said longitudinal support member communicating with the clearance spaces to receive the limited amount of steam leakage therein.

5. In a non-contacting type heat exchanger including a shell, support heads at each end of said shell forming a vapor space, and said support heads each having a number of openings in alignment with each other, the combination with said support heads of a plurality of discrete and independent tube bundles each having spaced tube sheets at their respective ends adapted to be connected between said support heads in a pair of aligned openings, a plurality of tubes in said tube bundle units connected between said tube sheets, longitudinal support means for each of said tube bundles connected between said support heads, each of said support means terminating relatively close to said support heads to form a clearance space at the ends of said tube bundle units for a limited amount of steam leakage into said support means, each of said support means enclosing a portion of the tubes in its respective tube bundle, means in said support means transversely disposed with respect to said tubes to form air cooling chambers having inlets in communication with said vapor flow space to receive non-condensed steam and non-condensable gases, means in said support means forming a flow channel to receive residual non-condensed steam and non-condensable gases from said air cooling chambers, an outlet chamber in said support means communicating with said flow channel, and vacuum means communicating with said outlet chamber for continually removing the residual non-condensed steam and non-condensable gases from said heat exchanger; and the air cooling chambers at the respective ends of said longitudinal support member communicating with the clearance spaces to receive the relatively small amount of leakage steam therein.

6. In a non-contacting type heat exchanger as claimed

in claim 5 wherein said flow channel and said outlet chamber have means to provide communication which includes a passageway connecting one end of said flow channel with one of said air cooling chambers and openings communicating the outlet chamber with the same air cooling chamber, and a baffle between said passageway and said openings to cause non-condensed steam and non-condensable gases to flow downwardly and upwardly across the tubes in said air cooling chamber.

7. In a non-contacting type heat exchanger including a shell, support heads at each end of said shell forming a vapor space, and said support heads each having a number of openings in alignment with each other, the combination with said support heads of a plurality of discrete and independent tube bundle units each having spaced tube sheets at their respective ends adapted to be connected between said support heads in a pair of aligned openings, a plurality of tubes in said tube bundle units connected between said tube sheets, a longitudinal support means for each of said tube bundle units connected between said support heads, each of said longitudinal support means including an upper plate, a lower plate, and side plates connected between said upper and lower plates in spaced relation, said plates enclosing a portion of the tubes in said tube bundle units, partition means transversely disposed in said support means to delineate a plurality of air cooling chambers, a pair of spaced medial plates in said support means intermediate the upper and lower plates to form a flow channel and an outlet chamber above said air cooling chambers, one of said air cooling chambers having passage means to provide communication between said flow channel and said outlet chamber, said air cooling chambers having inlet means communicating with said vapor flow space to deliver non-condensed steam and non-condensable gases to said air cooling chambers, said flow channel communicating with each of said air cooling chambers to receive residual non-condensed steam and non-condensable gases therefrom, and vacuum means communicating with said outlet chamber for continually removing non-condensed steam and non-condensable gases from said heat exchanger.

8. In the combination as claimed in claim 7 wherein said passage means includes an opening formed between the spaced medial plates at one end of said flow channel and openings between the communicating air cooling chamber and the outlet chamber, and a baffle disposed between the space formed between the medial plates and the openings to direct residual non-condensed steam and non-condensable gases downwardly and then upwardly through said air cooling chamber into the outlet chamber.

9. In a non-contacting heat exchanger as claimed in claim 7 wherein said longitudinal support means has its respective ends in relatively close clearance to the support heads, and the air cooling chambers adjacent the respective ends of each of said longitudinal support means adapted to communicate with said clearance space to receive limited steam flow from said clearance space.

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