United States Patent

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[72] Inventor **Dietrich Dohnt**
Berlin, Germany

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[73] Assignee **Borsig Gesellschaft mit beschrankter Haftung**
Berlin, Germany

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[33] **Germany**
[31] **P 17 76 130.7**

[54] **AIR-COOLED CONDENSER**
10 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** **165/111,** 165/174, 62/289, 62/290
[51] **Int. Cl.** **F28f 13/04**
[50] **Field of Search** ..... 165/111, 174, 175, 110; 159/28; 202/185, 185 B; 62/289, 290, DIG. 16

[56] **References Cited**

UNITED STATES PATENTS

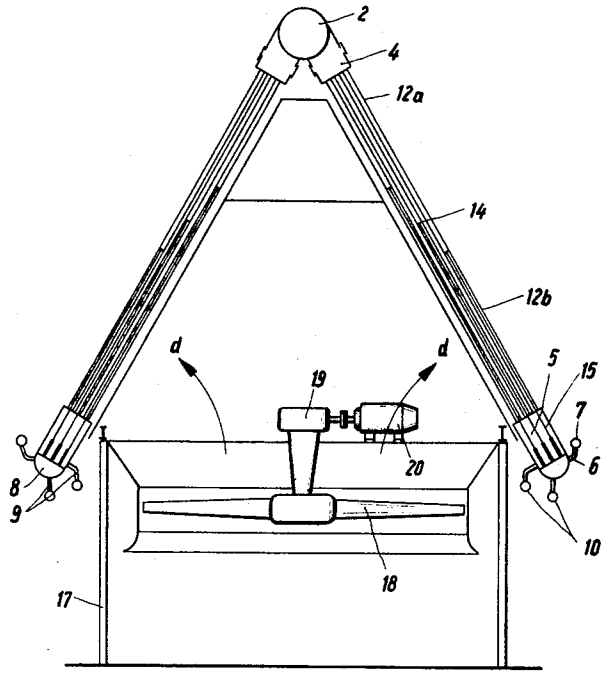
1,890,185	12/1932	Lucke	165/175 X
3,450,197	6/1969	Fieni	165/174 X

FOREIGN PATENTS

255,445	Germany	165/174
908,429	Great Britain	165/111

Primary Examiner—Frederick L. Matteson
Assistant Examiner—Theophil W. Streule
Attorney—Walter Becker

ABSTRACT: An air-cooled condenser in which pipes extending between an upper header and a lower header are divided into upper and lower axial sections by the upper ends of condensate tubes which lead downwardly to a condensate chamber. Steam is supplied through the headers to opposite ends of the pipes and condensate from the upper section of each pipe draining down the respective tube to the condensate chamber which condensate from the lower section of each pipe drains into the lower header. A fan causes cooling air to pass over the pipes which, for efficient heat transfer, may be finned.



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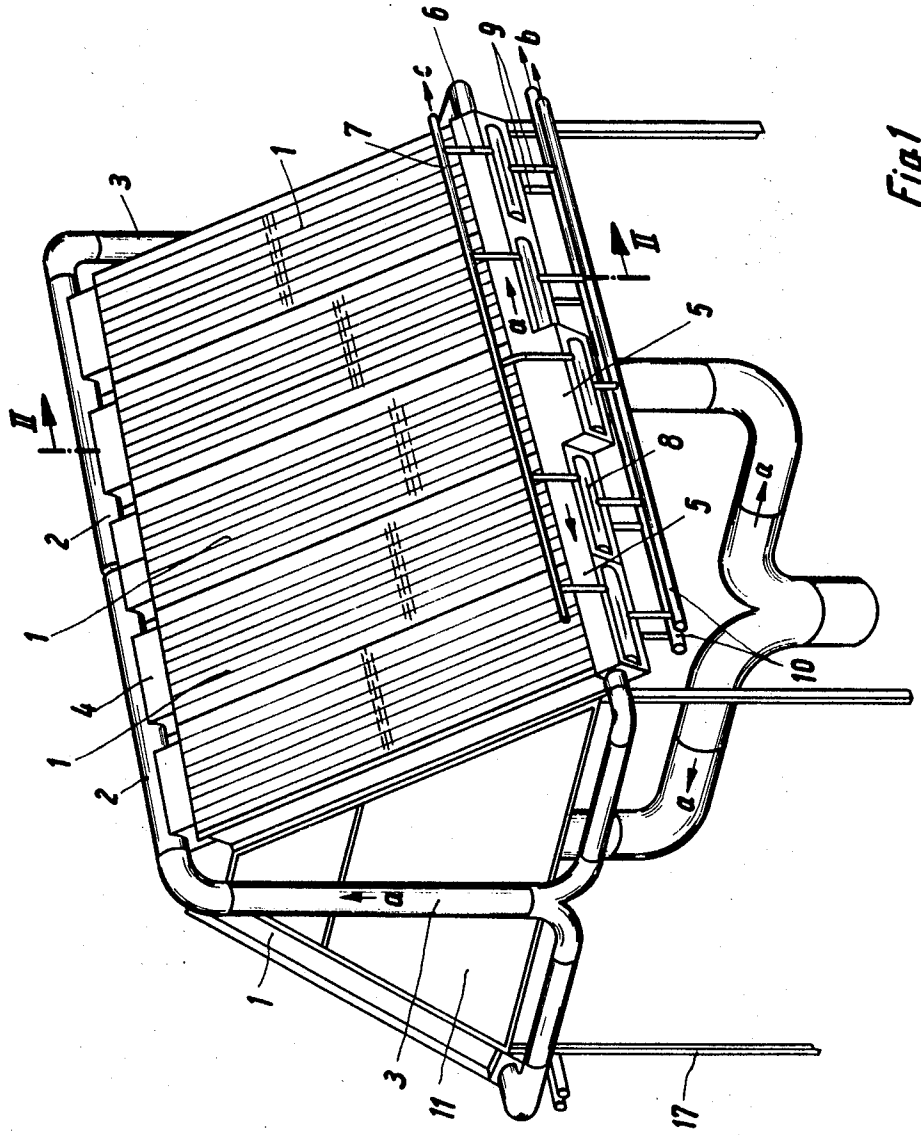
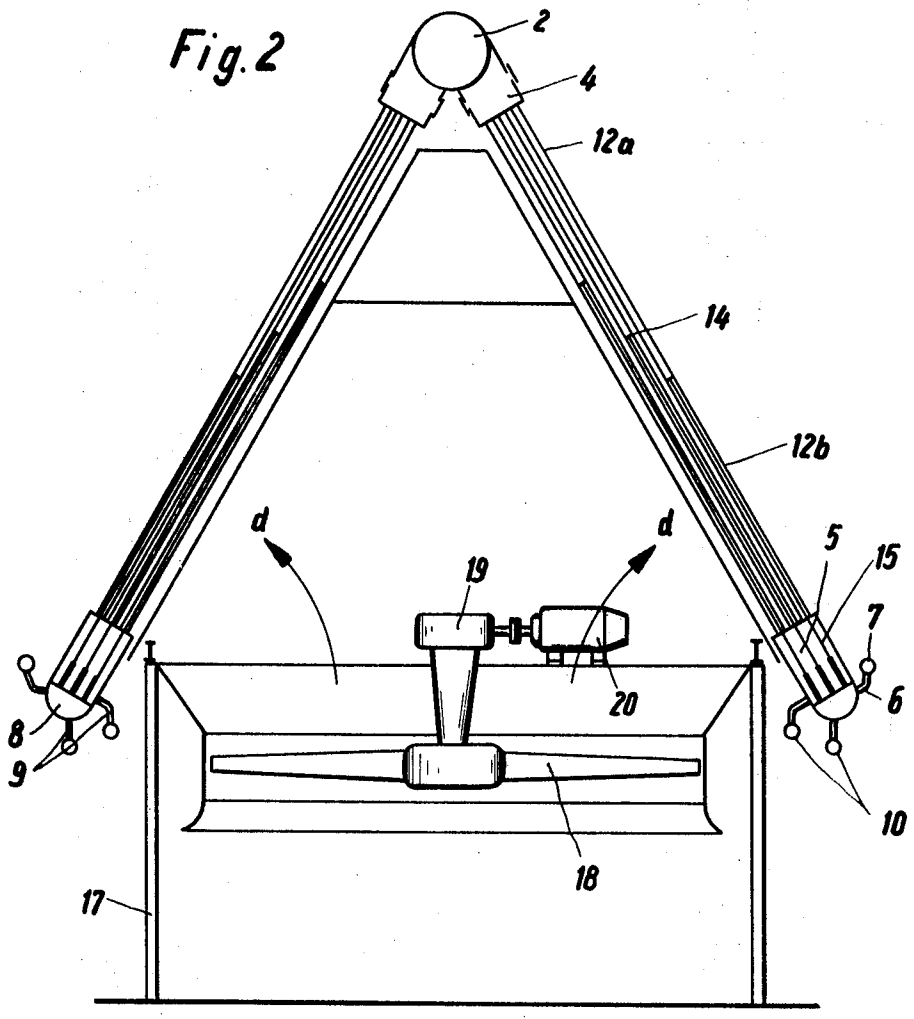


Fig 1

Inventor:
Dietrich Dohnt
By Walter Becker

Fig. 2



Inventor:
Dietrich Döhnt
By

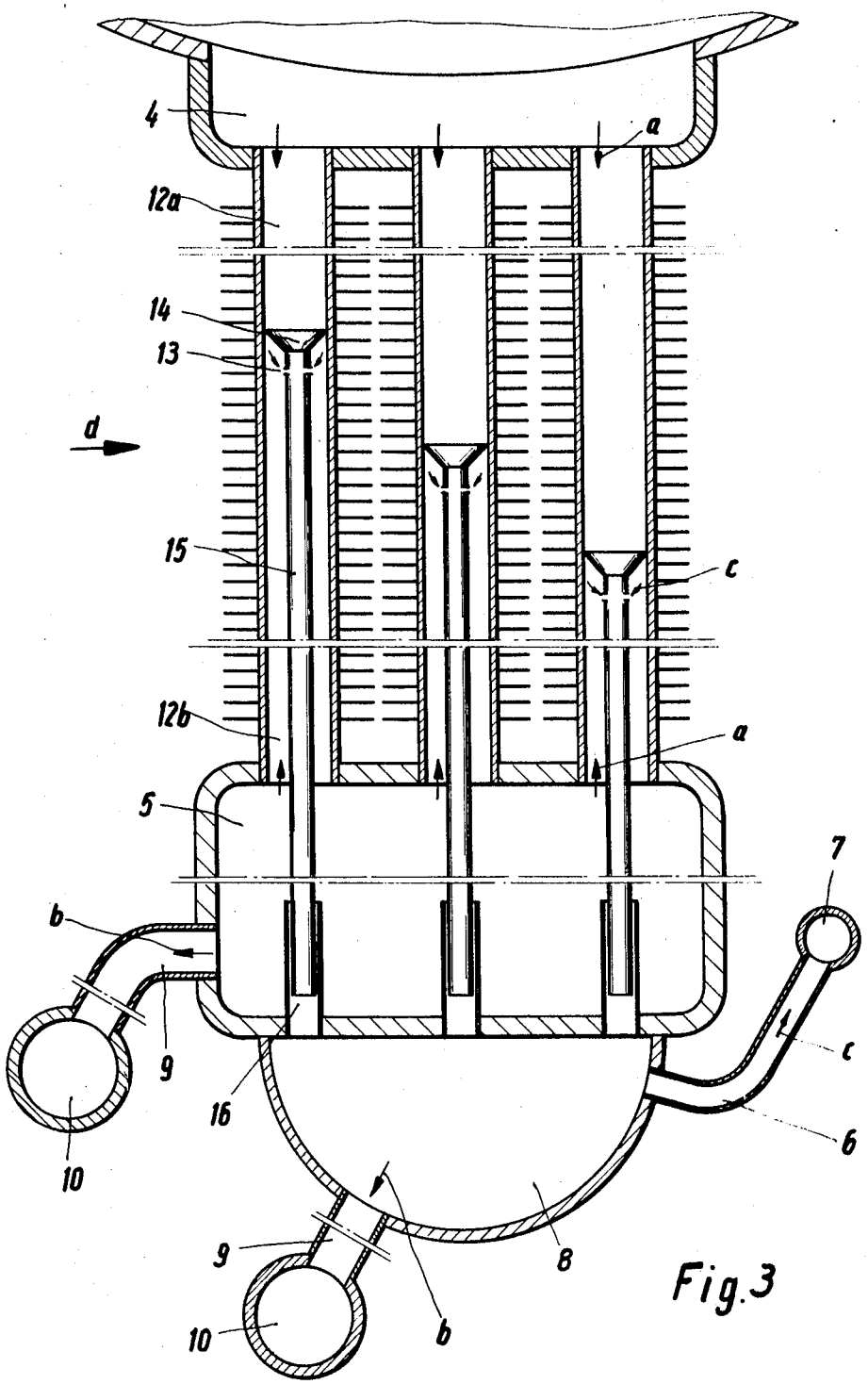


Fig.3

Inventor:
Dietrich Dohnt
By

AIR-COOLED CONDENSER

The present invention relates to a condenser which is cooled by an automatically moved airflow, and in which there are provided at least two rows of substantially parallel condenser pipes spaced from each other and located one behind the other when looking in the direction of flow of the cooling air. More specifically, the present invention concerns an air-cooled condenser of the above-mentioned type in which the rows of condenser pipes are in parallel arrangement connected to steam-distributing chambers common thereto and are in communication with condensate collecting chambers. The round or profiled condenser pipes, which are in most instances of the same design, are, as a rule, equipped with fins. On the outside, the condenser pipes are acted upon by a cool airflow which is drawn from the atmosphere and is automatically put into motion by a fan.

Generally, condensers are so operated that the stream to be condensed flows from the top into or about the pipes, and the condensate flows in the direction of the steam downwardly into the condensate collector.

Air-cooled condenser installations of the above-mentioned type, especially such for depositing turbine exhaust steam with finned pipe bundles which at the upper end are connected to a common steam-distributing pipe system so that the steam and the condensate in each pipe can flow in one direction only, namely, from the top downwardly, and with cooling air temperatures below the freezing point cause considerable disturbances in the operation for instance in the vacuum installation. With turbine exhaust steam, for instance, the condensation temperature is generally at 60° C. and in most instances even lower which means that the temperature distance between the water steam condensate and the freezing point thereof is relatively small. The condensate flows along the inner pipe wall downwardly to the mouth of the pipe into the condensate chamber. In view of the very unfavorable heat passage conditions between the condensate and the cooling air in the lower portion of the pipes, also air under certain conditions of operation, a steam condensation no longer occurs, with low outer air temperatures also a low temperature of the pipe wall occurs. On the other hand, with low outer air temperatures also the temperature distance between exhaust steam and cooling air is relatively great. This brings about that the condensation is completed at a greater distance from the lower pipe mouth than for instance at the point for which the installation was designed, whereas the condensate with a forming temperature of for instance 60° C. has to overcome this relatively long path along the cold inner pipe wall, which means that the condensate has a long staying time in the unfavorable cooling zone. In the lower pipe section, the condensate conveys its heat up to solidifying to the cold pipe wall.

It is a well-known fact that the icing danger is greatest in the first pipe row when looking in the direction of flow of the cooling air, because here the temperature drop between steam and cooling air is greater than in the pipe rows therebehind. This means that the condensate stays particularly long in the first pipe row in the unfavorable cooling zone. Similar remarks also apply to the partial load operation for instance of a condensation turbine. The condensation of the exhaust steam may in this instance be completed soon after the steam enters the upper pipe mouth because the excessive cooling surface will under partial load operation have such an effect that the major portion of the lower section of the cooling surface is not contacted by the excess steam. Also in this connection, the condensate has to pass over a larger under cool surface. A control of the quantity of cooling air or the turning off of cooling surfaces may at less low outer air temperatures result in a slight improvement, however, at surrounding temperatures approximately from −5° C. on, the less mentioned step is not effective against formation of ice in the pipes. Noncontrollable wind influences increase the icing danger in winter considerably.

Ice formation in the lower pipe mouth brings about an increase in pressure in the condenser and considerably reduces the vacuum.

Ice plugs which may form may even burst the pipes with the result that air will break in. Under certain circumstances, it may then be necessary to disassemble the installation.

Condensers have become known in which the exhaust steam line is so arranged that the steam can enter the mouth of the finned pipes only from below, and in which the condensate flows downwardly in countercurrent flow to the upwardly flowing steam, into the condensate collecting chambers. This arrangement of the exhaust steam line, which is also known as dephlegmatoric circuit, prevents the undercooling of the condensate by the fact that the upwardly flowing warm steam keeps warm the condensate which flows in opposite direction. However, this circuit can be employed only under certain conditions of operation, but wherever it can be employed, it will safely prevent ice formation in the pipes. This dephlegmatoric circuit, however, as already indicated, can be employed only under certain conditions when the proper function of the condenser installation is to be assured. In this connection, it has to be taken into consideration that the speed of the steam when flowing into the lower mouth of the pipes is not very high. Too high steam velocities bring about an accumulation of the downwardly flowing condensate in the mouths of the pipes. Variations in the pressure in the condenser and shockwise flowing off of the liquid and thereby an irregular operation for instance of a vacuum installation will result. Admissible inflow speeds require a relatively small specific volume of the steam to be condensed or a correspondingly high inlet cross section of all mouths of the pipes. Vacuum steam, especially turbine exhaust steam, however, has a relatively large specific steam volume so that the inlet cross section of all mouths or exits of the pipes must be very great in order to make possible a corresponding inlet speed of the steam during full load operation. Large inflow cross sections, however, require short pipes and a constant cooling surface. It is a well-known fact that devices and therefore air-cooled condensers with relatively short pipes have the drawback that for instance a considerable number of chambers, long pipelines and a plurality of fans increase the cost of the installation and make the same uneconomical.

On the other hand, the construction of a condenser with such short pipes is frequently not possible at all because with such short pipes an economic relationship with regard to the diameter of the fans cannot be realized. It is for this reason that the dephlegmatoric operation is frequently not possible at all.

There have also become known condenser installations with nozzles which are inserted into the pipe bottom of the steam distributing chamber or directly into the pipes. These nozzles, when looking in the direction of the cooling airflow have their cross-sectional passage for the steam decreasing successively so that a better distribution of the steam over the individual rows of pipes will be obtained and the pressure drop in the rear rows of pipes will be increased. For certain definite conditions of operation, it is possible by such an arrangement to bring about that in the rows of pipes which are first acted upon or passed through by the cooling air, the condensation of the steam is completed only shortly in front of those areas where the pipes lead into the condensate collecting chamber so that an undercooling of the condensate will be avoided. However, with such air-cooled condenser equipped with nozzles, it is not possible to adapt the arrangement to the respective conditions of operation in such a way that in particular at low-cooling temperatures and low steam loads, the icing danger will be eliminated, because in view of the excessive cooling surface, the condensation of the steam is completed far away from the lower mouth of the pipes. Furthermore, the nozzles bring about a considerable pressure loss at the steam side and thus create a poor vacuum. Furthermore, an air-cooled condenser installation has become known in which the condenser chambers provided at the lower end of the pipe bundle are in the direction of flow of the cooling air subdivided into individual subchambers. These finned pipe bundles, in which the steam flows from the top downwardly while condensing, have associated therewith dephlegmator bundles which on the air side

are parallel to each other and on the steam side are arranged one behind the other. These subchambers are individually and adjustably connected to the air suction devices. Such an arrangement is supposed to bring about that the underpressure in the succeeding subchambers decreases in the direction of the airflow whereby the steam distribution is, in conformity with the pipe rows, connected to the individual subchambers in conformity with the respective available temperature drop between steam and cooling air. The condensation is supposed in this way to be completed in all pipe rows at a slight distance from where the pipe ends lead into the pertaining subchambers. Such an arrangement has the drawback that the exhaust steam condenses first from the top in downward direction and only subsequently the residual steam passes into the dephlegmator. It will be evident therefrom that with partial load operation, for instance, a condenser turbine, and at low cooling temperatures, an excessive cooling surface is obtained in the condenser portion which with regard to the steam side is located in front. This cooling surface completes the condensation of the exhaust steam not at a short distance from where the pipe ends lead into the lower chambers but at a considerable distance therefrom . The controllable air suction device will definitely not remedy the situation because with said air suction devices it is possible only to maintain the condensation in the individual pipe rows approximately equal. Under no circumstances is it possible by means of the air suction device to displace the condensation downwardly which has been completed at a considerable distance from the lower pipe mouth. Consequently, also with the condenser equipped with these devices, the desired effect cannot be realized. A further drawback consists in that expensive and sensitive control devices are necessary for the air withdrawal.

It is, therefore, an object of the present invention to provide an air-cooled condenser which will overcome the above mentioned drawbacks.

It is another object of this invention to provide an air-cooled condenser, in which the condensation of the steam is effected in two spaced sections with clear flow relationship in the pipes in flow directions which are opposite to each other. The length of the pipe up to the condensate discharging means in the upper subsection of the finned pipe bundle is relatively short so that also the undercooling distance at very low cooling temperatures will be reduced to a minimum.

These and other objects and advantages of the invention will appear more clearly from the following specification in connection with the accompanying drawings, in which:

FIG. 1 diagrammatically illustrates a condenser.

FIG. 2 represents a section taken along the line II—II of FIG. 1.

FIG. 3 represents a cross section through a condenser element on a larger scale than that of FIG. 1.

The condenser according to the present invention is characterized primarily in that the steam-distributing chambers and pipelines at the upper end of the finned pipe bundle, and the steam distributor and condensate collecting chambers combined at the lower end are so connected to the bypass lines that the steam flows through the finned pipes in countercurrent direction while the finned pipes spaced at a certain distance from the upper and lower mouths of the pipes are subdivided transverse to the pipe axis into pipe sections by means of condensate withdrawing means which are connected to the central pipes which latter lead into the condensate collecting chamber. In this way, the condensation of the steam is effected in two separate subsections with clear flow conditions in the pipes in countercurrent flow direction. The pipe length up to the condensate withdrawing line in the upper partial section of the finned pipe bundle is relatively short so that also the undercooling distance will be reduced to a minimum at low-cooling air temperatures. The condensate is detached from the upper pipe section before it is undercooled and might ice. This detachment from the inner pipe wall is effected by the condensate withdrawal means, and the detached condensate passes through the central pipes countercurrent to the upwardly flowing warm steam in the dephlegmator part, and is here held warm by the steam, which is extremely advantageous.

A further advantage by subdividing the finned pipe in a direction transverse to the pipe axis in two separate subsections and by the bilateral steam action consists in that the steam has available a pipe section which is large (approximately twice as large) as is available with the heretofore known condenser designs. As a result thereof, the loss in pressure of the steam when flowing into the mouth of the pipes is reduced and thereby an economic vacuum is realized. Particularly during the summer season, the heretofore known condensers have a poor vacuum because they lack the abovementioned advantage.

It is further advantageous at reduced quantity of steam, to keep only the dephlegmator part in operation which is particularly suitable in this connection inasmuch as it prevents the freezing of the condensate. Also when in this instance, i.e. at a low steam quantity, still some steam should come in from above, the path through the pipe bundle part which is operated as a condenser is shorter than is the case with heretofore known designs requiring the entire or full-pipe length.

A further important advantage of the present invention over heretofore known structures consists in that not only the steam side is separated but also the condenser side. Due to the fact that a portion of the condensate is separated by the central pipes from the condensate flowing off from the dephlegmator part, an accumulation of condensate in the lower pipe mouth, i.e. at the steam inlet of the dephlegmator is avoided for all practical purposes.

With the present design, no control elements and shutoff devices are necessary which at temperatures below the freezing point are necessary with the heretofore known designs in order to prevent freezing.

A further development of the present invention consists in that the pipe sections, measured from the condensate withdrawal means to the respective pipe mouth in the lower as well as in the upper pipe sections prior to flowing into the pipe mouth are so designed that they become greater in steps. In view of this stepwise greater configuration, it will be assured that where the steam enters the finned pipe bundles, the shortest pipe length and thereby the smallest cooling surface is available to the incoming steam. The finned pipe bundles which are located farthest from the steam entry have, when viewing in the flow direction of the steam, the larger cooling surface. At full-load and relatively large inflow speed of the steam, the actuation on the steam side in the individual finned pipe bundles is distributed better due to the fact that between the inflowing steam and the finned pipe bundles remote therefrom, with the increasing cooling surfaces, an ever greater pressure drop will form. This brings about that the nonuniform flow conditions of the steam in the distributing chambers or pipelines and the different pressure losses in the pipe mouths are equalized with regard to each other.

With small quantities of steam, however, the steam is condensed only in the lower dephlegmator part. As a result thereof, it will be realized that a residue steam quantity will penetrate the connecting pipes and pass into the condenser operated pipe bundle part whereby the safety of operation will be increased.

If the inflow velocity of the steam, contrary to the just described instance, is relatively small, it will be understood that a stepping of the cooling surface also in the inverse direction may be effected in conformity with the present invention so that the fin pipe mouths which are the first when looking in the steam direction are actuated open to the same extent by the said operation as are the finned pipe mouths located therebehind.

According to a further feature of the invention, the bores are arranged slightly below the condensate withdrawal means in the central pipes so that from the lower condensate collecting chamber, the inert air is withdrawn from the upper subsection of the pipe through the pipe mouth of the central pipes in

the condensate withdrawing means, as well as from the lower subsection of the pipes through the bores, and the withdrawn inert air then passes through the central pipe. In view of this arrangement of the bores, the dephlegmator chamber or cooling surface is better taken advantage of so that the condensate withdrawing means will be kept warm at this area.

It is known that the condensation in the first row of pipes when viewing in the cooling airflow direction is completed at a larger distance from the lower pipe mouth than is the case with the pipe rows therebehind. According to a further development of the invention, the pipe sections measured from the condensate withdrawing means to the pipe mouth in the upper steam distributing chamber when seen in the flow direction of the cooling air is in each pipe row designed longer. By shortening the front pipe rows of the part operated as condenser, the condensate withdrawing means are closer to the end of the condensation, and the path of the condensate along the cold pipe inner wall is reduced and is earlier introduced into the central pipes in the warm dephlegmator part. In the last row of pipes when viewing the arrangement in the airflow direction, the cooling surface in the part operated as a condenser is so large that the steam does not penetrate the central pipes of the dephlegmator part but is already condensed. As a result thereof, optimum design of the installation will be assured.

In order to be able to equalize different temperature expansions of the individual pipes, the central pipe is, in conformity with the present invention, built up of two parts. The lower part with a larger diameter is connected to the combined steam distributor and condensate collecting chamber and overlaps the upper portion of the central pipe.

Referring now to the drawings in detail, the condenser illustrated in FIGS. **1** and **2** comprises a plurality of roof-shaped condenser elements which are formed of at least one or, as illustrated, of three rows of substantially parallel finned pipe bundles **1** which are spaced from each other or are arranged one behind the other when viewing in the flow direction *d* of the cooling air. Steam from below is conveyed to the finned pipe bundles **1** through the lower combined steam producing and condensate collecting chamber **5**. Through the conveying lines **3** and steam lines **2**, also steam from above is conveyed to the finned pipe bundles **1**. The pipe bundles are thus passed through by the steam in opposite direction. However, it is also obvious that, if desired, the exhaust steam conduits may be connected to the finned pipe bundles in such a way that a portion of the steam is condensed first in the upper pipe sections and the residual steam is condensed in the lower pipe sections. The supply of steam may also be effected (in a nonillustrated manner) from a gable side (FIG. **1**) through only one bypass line **3** in such a way that the steam acts upon the upper and lower pipe sections parallel or in series and passes therethrough in opposite direction in conformity with the invention. The pipes are, by a condensate withdrawing means **14**, subdivided on the inside transverse to the pipe axis into an upper section **12***a* and a lower section **12** *b*. The steam fed from above through the steam distributing chambers **4** will condense in the upper pipe section **12***a*, and the condensate will flow through the condensate withdrawing lines **14** and central pipes **15** into the condensate collecting chambers **8**.

The steam which flows from the combined steam distributor and condensate collecting chambers **5** upwardly will condense in the lower pipe sections **12***b*, and the condensate will flow back into the above-mentioned condensate collecting chambers **5**. The condensate is withdrawn from the condensate collecting chambers **5** and **8** through the pipes **9** and condensate lines **10**, respectively, in the direction of the arrow b. The inert air from the lower pipe sections **12***b* is, through bores **13**, located shortly below the condensate withdrawing lines **14** in the central pipes **15**, withdrawn together with the inert air from the upper pipe sections **12***a* through the central pipes **15**, the condensate collecting chambers **8**, and pipes **6** into the air lines **7** in the direction indicated by the arrow *c*. FIG. **1** further shows the bulkheads **11** of the air condensator which is supported by four supports **17** illustrated at the lower end.

FIG. **1** furthermore illustrates that the pipe sections, measured from the condensate withdrawing line **14** to the respective mouth of the pipes increase by steps or continuously not only in the upper but also in the lower pipe sections **12***a* and **12***b* when viewed in the flow direction "*a*" of the steam. The pipe sections measured from the condensate withdrawing means **14** to the respective pipe mouth not only in the upper but also in the lower pipe sections **12***a* and **12***b* when viewed in the flow direction "*a*" of the steam may be designed stepwise smaller (not illustrated).

FIG. **2** shows that the roof-shaped finned pipe bundles **1** have a cross section forming the sides of an approximately equilateral triangle the basis of which is formed by an axial fan **18**. The fin-equipped pipe bundles may also be so arranged that in the direction of the pipe axis they are perpendicular with regard to the horizontally arranged fan axis (not illustrated). Above the axial fan **18** there is provided a transmission **19** and a motor **20**. As indicated by the arrows *d*, the cooling air is, by at least one axial fan **18**, conveyed from the bottom in upward direction or in reverse direction (not illustrated) and passes by the outside of the smooth or fin-equipped bundle **1**.

FIG. **3** shows the subdivision of the upper pipe sections **12***a* which, when viewed in cooling airflow direction *d* are longer in each pipe row. The condensate withdrawing means **14** is thus arranged closer to the condensation end in the upper pipe section **12***a*, because the latter is displaced as is well known in downward direction when viewing the flow direction of the cooling air. Thus, the path of the condensate along the cold inner wall of the pipe section **12***a* is reduced in those pipe rows which, when viewing the direction of flow of the cooling air, are located in front. The central pipe **15** comprises two parts. The lower part **16** with a larger diameter is connected to the combined steam distributor and condensate collecting chamber **5**, and the upper part of the central pipe **15**, which has a smaller diameter, is covered up by said lower part **16** in such a way that therebetween a labyrinthlike sealing effect is obtained. This subdivision of the central pipe compensates for the temperature expansions of the individual pipes.

It is, of course, to be understood that the present invention is, by no means, limited to the particular showing in the drawings but also comprises any modifications within the scope of the appended claims.

What is claimed is:

1. A condenser having an upper header means and a lower header means, conduit means connected to said header means for supplying steam thereto, pipe bundle means connected to and extending between said header means, and fan means operable for causing cooling airflow through said pipe bundle means, a condensate discharge tube extending into each pipe of said pipe bundle means from the lower end of the respective pipe, the upper end of each discharge tube engaging the inside of the respective pipe and dividing the pipe into upper and lower axial sections whereby steam to be condensed flows in countercurrent direction simultaneously from said header means into both ends of said pipes, condensate chamber means connected to the lower ends of said tubes to receive from said tubes the condensate from the upper sections of said pipes, the condensate from the lower sections of said pipes drawing from said pipes into said lower header means, and means for withdrawing condensate from said condensate chamber means and from said lower header means.

2. A condenser according to claim **1** in which said steam flows axially in said header means and the length of said pipe sections varies in increasing direction in conformity with the length of travel of the steam prior to entry into pipes along said header means to the end of the respective section.

3. A condenser according to claim **1** in which said steam flows axially in said header means and the length of said pipe sections varies in decreasing direction in conformity with the length of travel of the steam prior to entry into pipes along said header means to the end of the respective section.

4. A condenser according to claim **1** in which steam is supplied to about the middle of the length of said lower header

means for flow outwardly therein toward the ends and flows from the ends thereof to the ends of said upper header means and then toward the middle of the length of said upper header means, the length of the said sections of said pipes into which steam flows progressively increasing in the direction of steam flow prior to entry into pipes through said header means.

5. A condenser according to claim 1 in which each said tube has aperture means therein immediately below the region of engagement of the upper end of the tube with the respective pipe whereby inert air from both collectively withdrawn axial sections of each pipe passes into the respective condensate discharge tube and downwardly therethrough to said condensate chamber means.

6. A condenser according to claim 1 in which said pipe bundle means comprise pipe sections longer in differing pipes displaced from each other in the direction of airflow through the bundle means, the upper sections of said pipes varying in length in the direction of said airflow.

7. A condenser according to claim 1 in which each of said tubes comprises a first upper portion which at its upper end engages a respective pipe and a second lower portion extending into said condensate chamber means, said respective portions being in slidable telescopic engagement and thereby compensating for differential thermal expansion of individual pipes in the condenser.

8. A condenser according to claim 1 in which said pipes individually are finned for each bundle means.

9. A condenser according to claim 1 in which said lower header interconnected also to bypass means is in the form of two laterally spaced lower headers, said pipes converging in the upward direction from said lower headers, said fan discharging air upwardly into the space confined between said pipes and flowing laterally over and between said pipes.

10. A condenser according to claim 6 in which said upper respectively sections of said pipes individually increase in length progressively in the direction of airflow through said pipe bundle means.