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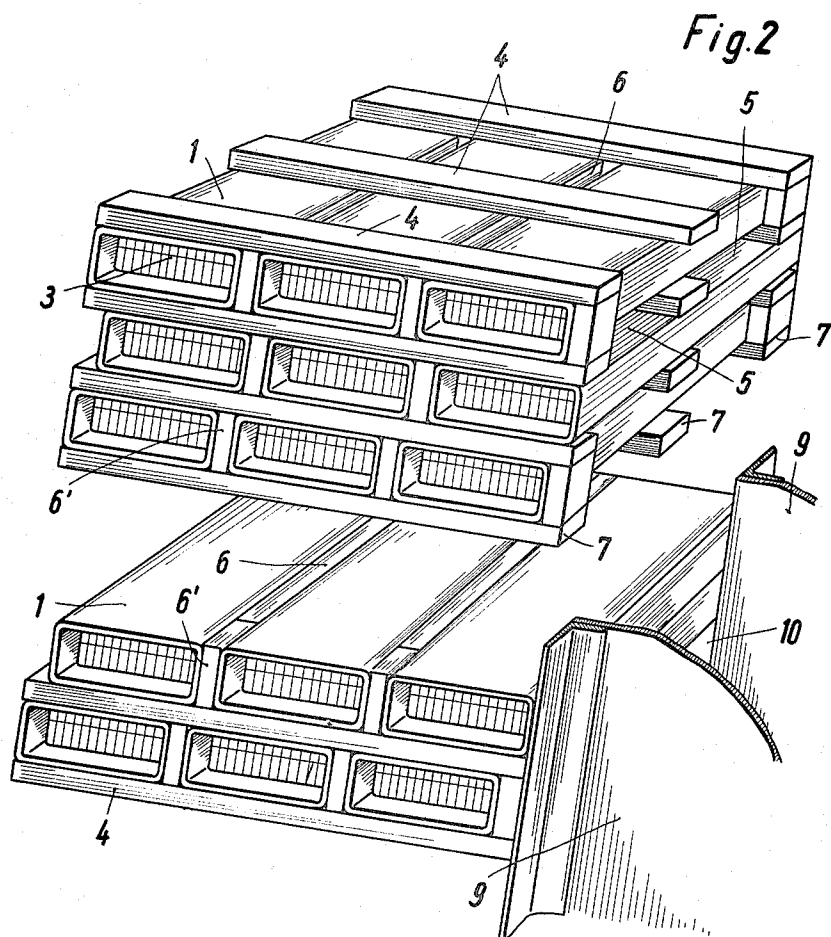
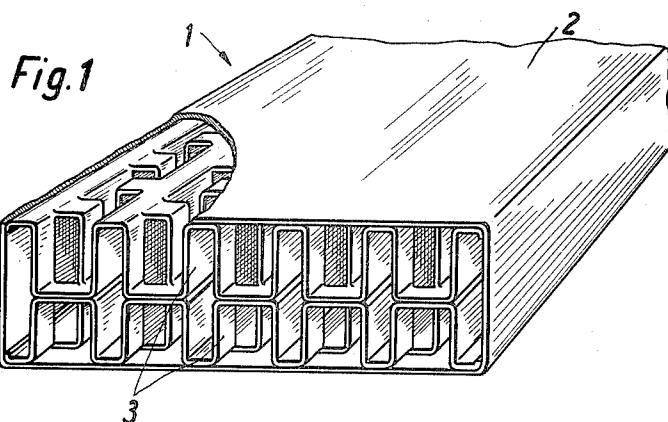
C. KÜHN

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AIR-COOLED STEAM-CONDENSER SYSTEM

Filed July 19, 1963

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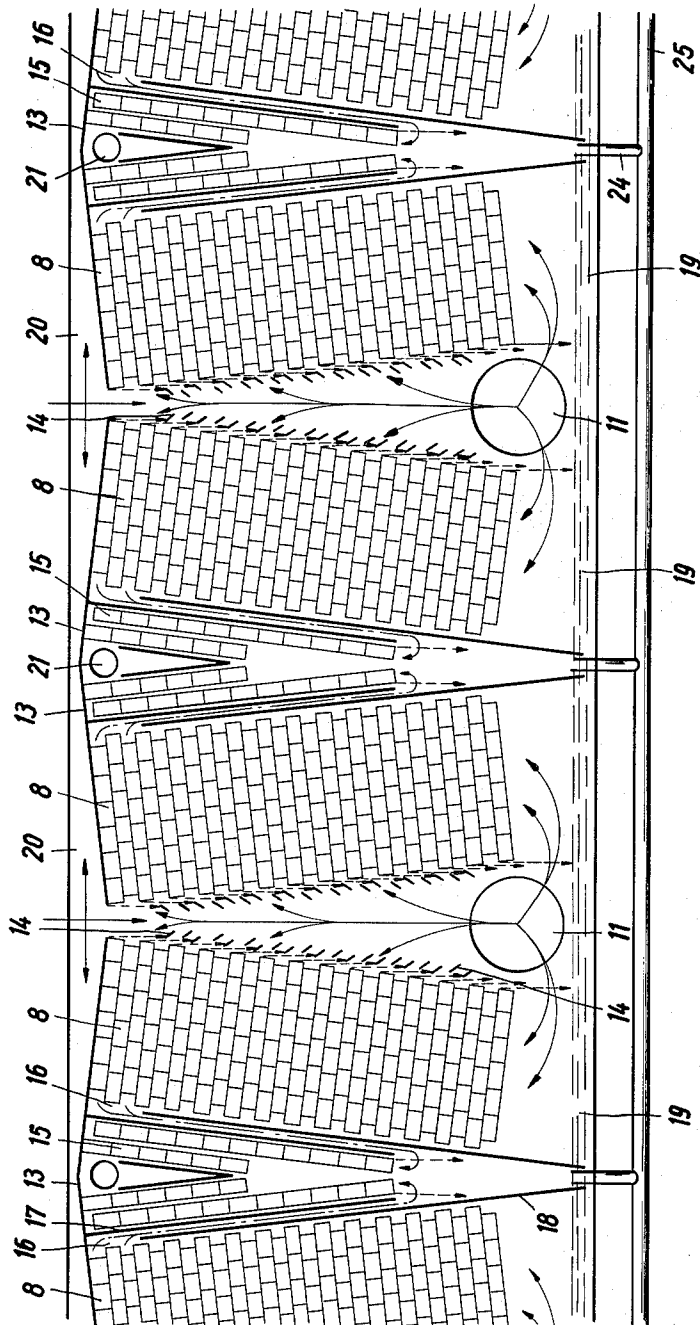
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AIR-COOLED STEAM-CONDENSER SYSTEM

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Fig. 3



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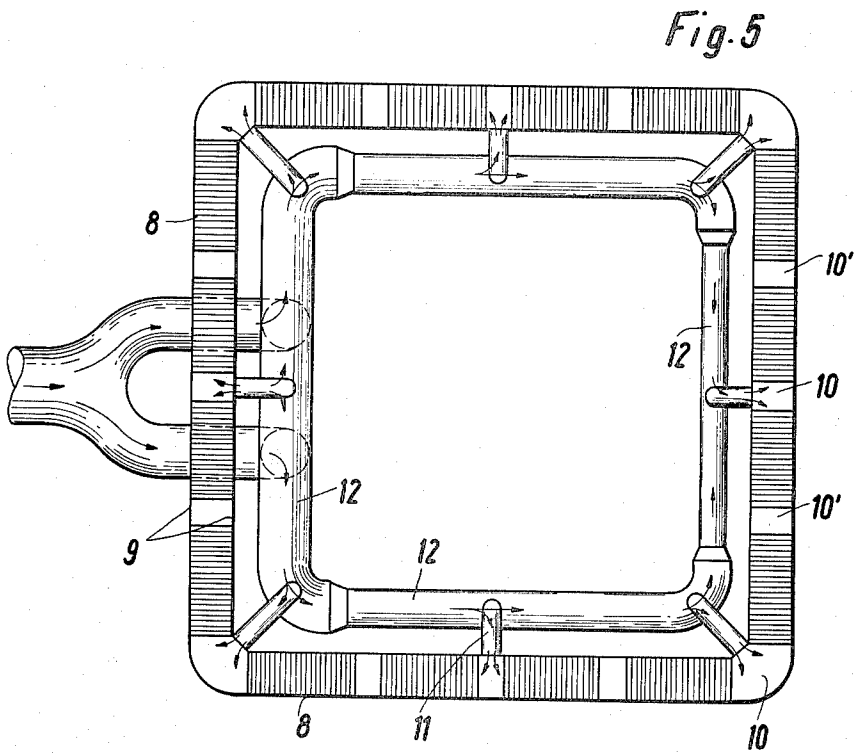
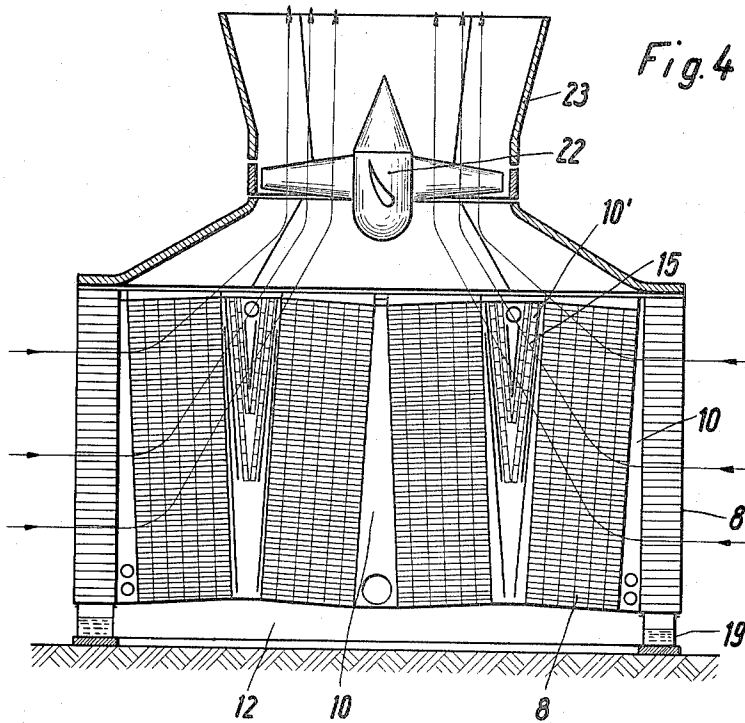
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AIR-COOLED STEAM-CONDENSER SYSTEM
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A 5,958/62
12 Claims. (Cl. 165—111)

The present invention relates to an air-cooled steam-condenser system. More specifically, this invention is described to an air-cooled steam condenser as utilized in stream power plants in connection with steam-operated power engines, wherein heat exchanger units are connected to a blower unit and are provided with internally finned tubes for air circulation.

It is a primary objective of the invention to make the steam passages through the heat exchangers as short as possible, at the same time passing the steam therethrough at a low velocity to reduce losses in pressure. In air-cooled condensers with tubes which are provided with external fins, such short steam passages are not economically obtainable. Similarly, in condensers with tubes having internal fins shorter steam passes have been obtained heretofore to a modest extent only.

It is another object of the invention to eliminate the formation of ice. In the past, this requirement has not been entirely satisfied.

It is a further object of this invention to provide an air-cooled condenser of simple construction.

Another object of the present invention is to provide a condenser in which the steam and the condensate flow in opposite directions, and wherein the steam-influx velocity at the inlet cross-sections of the condensation compartments does not exceed 65.5 feet per second (20 meters per second).

According to one feature of the present invention, the air-cooled condenser is composed of heat exchanger units consisting of a plurality of heat exchanging elements. These heat exchanging elements are arranged in a plurality of superposed rows, each row including a plurality of spaced tubes of substantially rectangular cross-section. The tubes are provided with internal fins and are arranged in such a manner that the lateral distance between adjacent tubes is smaller than the width of the tube cross-section.

According to another feature, the superjacent rows of tubes are arranged in staggered relationship, the amount of staggering between each two superjacent rows of tubes corresponding to part of the width of a tube.

According to another feature of this invention, the superjacent rows of tubes are spaced apart by flat spacer bars of substantially rectangular cross-section, the lengthwise dimension of each of the spacer bars being equal to the width of a row of tubes. In this manner, flat or narrow transversely extending channels are formed.

According to a further feature, the block-shaped heat exchanger units making up a condenser system are arranged side by side in inclined relationship in such a manner that at one side of each unit a substantially V-shaped first space is formed by the respective one of two lateral surfaces of the respective unit, which surfaces are square with the tube apertures in that respective unit, and by the opposite lateral surface of an adjacent unit, while at the other side of each unit a second space having the shape of a substantially inverted V is formed by the respective other of two lateral surfaces of the respective unit and by the opposite lateral surface of an adjacent unit. Each of the wedge-shaped spaces has wall members secured to its longitudinal edges, which wall members

interconnect the opposite edges of the heat exchanger units thereby defining wedge-shaped chambers.

Another object of the invention is to provide a condenser system in which a uniform operation is insured, irrespective of external factors such as ambient temperature, partial or full loads, etc.

Further objects and advantages of the invention will become apparent from the following specification, when read in conjunction with the appended drawings in which an embodiment of the invention is illustrated.

In the drawings:

FIGURE 1 is a perspective cross-sectional view, partly broken off, of the front end of a heat-exchanger element constituting the basic element of the heat exchanger units according to the invention;

FIGURE 2 is another perspective view showing the arrangement of a plurality of heat-exchanger elements of FIG. 1, with the upper part of the arrangement being lifted off for better illustration;

FIGURE 3 is a schematic view of the developed entire cooling surface of a condenser constructed according to the invention;

FIGURE 4 is a side elevation of the condenser system with a vacuum blower, with the front walls of the steam distributing chambers and the gas exhaust chambers being removed; and

FIGURE 5 is a plan view of the condenser system according to the invention, after removal of the blower and the upper end plate of the compartment common to the all steam distributing chambers.

Referring now more particularly to FIG. 1, there is shown at 1, a heat exchanger element or tube of substantially rectangular cross-section. Inside element 1, fin members 3 are provided which extend throughout the length of tube and are firmly secured to the inner side of a tube wall 2, to insure a proper thermal connection between the fin members and the tube wall.

As is shown in FIG. 2, elements 1 are combined to form heat-exchanger units in such a manner that each row of parallel tube elements arranged in one plane is spaced apart from the next row of parallel tube elements arranged in another plane by flat iron bar members 4 which, in turn, are arranged in spaced relationship along tube elements 1 thereby forming between superjacent rows of elements narrow channels 5 of substantially rectangular cross-section for steam passage and removal of the condensate.

The assembly of tube elements 1 to form heat exchanger units 8 (FIG. 3) is governed by the following three factors:

(a) The efficiency of the heat exchanging surface forming the transverse channels;

(b) The velocity at the inlet cross-sections of channels 5, which velocity should not exceed 65.5 feet per second (20 meters per second) to permit the steam and the condensate to flow in opposite directions;

(c) The length of steam passage through the heat exchanger unit, which length is determined by the width of the individual rows of tube elements, that is, the length of channels 5; this length of steam passage should not be greater than approximately 6.5 feet (2 meters), to eliminate the possibility of occurrence of uncontrollable minimum pressures in the heat exchanger unit.

Since the width of channels 5 is fixed by the length of tube elements 1, which length is based upon the temperature to which the heat exchanger may be heated, only the height of channels 5, that is, the thickness of spacer bars 4 may be varied for adaptation to specific conditions.

Thus the height of channels 5 is approximately 0.39 inch (1 cm.), assuming an efficiency of the heat exchanging surface of 138 to 158 B.t.u./1.20 sq. yd./hr. ° F. (35 through 40 kcal./m.²/h. ° C.), a permissible steam velocity

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of 65.5 feet (20 meters) per second, and a permissible length of steam passage through the heat exchanger unit of approximately 6.5 feet (2 meters).

Gaps 6 are formed between adjacent tube elements 1. Because of the staggered arrangement of the tube rows and the inclination of the rows, which will presently become apparent, condensate cascades through the gaps 6 and channels 5 to steam distributing chambers 10 to be described hereinafter. The length of the condensate path to chambers 10 is short. In no event will the condensate flow through the entire height of the heat exchanger unit. At the front and rear ends of heat exchanger units 8, the gaps 6 are sealed off by flat-iron bar members 6'. In addition, elastic spacer bars 7 of plastic material can be provided in heat exchanging unit 8 at suitable distances between rows of tube elements to prevent thermal stresses in the large tube surfaces exposed to the inlet and outlet streams. Such spacer bars 7 can be secured to tube elements 1 by cement.

As is seen in FIGS. 3 and 4, the air-cooled condenser system according to the invention is composed of a plurality of heat exchanger units 8 which are arranged in such a manner that a condenser of a polygonal, that is, square, configuration is formed. As is also seen in FIGS. 3 and 4, adjacent heat exchanger units 8 are arranged in inclined relationship relative to each other to form opposite walls of steam distributing chambers 10 and gas exhaust chambers 10'. As is shown in FIGS. 3 and 4, the steam distributing chambers 10 have substantially the shape of an inverted V, while the exhaust chambers 10' are substantially V-shaped. The rear and front sides of the steam distributing chambers 10 and gas exhaust chambers 10' are sealed off by transverse walls 9 which are respectively secured to the opposite edges of tube rows. Further, the gas exhaust chambers 10' are sealed off at their top sides by a suitable roof-like wall member 13.

Steam from a suitable steam engine (not shown) enters the steam-distributing chambers 10 through steam lines 11 which are connected with a steam distributing line 12. To insure a uniform distribution of steam, the cross-section of distributing line 12 decreases in a direction away from the feed line. From steam distributing chambers 10, the steam to be condensed is admitted to transverse channels 5 formed by superjacent rows of tubes 1. Due to the inclined arrangement of tube elements 1, the condensate formed is returned to steam distributing chambers 10. Baffle plates 14 are provided in the steam distributing chambers 10 beneath the lower orifices of the transverse channels 5 on appropriate levels so that the condensate impinges upon baffle plates 14 as it issues from channels 5 whereby it is reduced to fine particles which are sprayed into the chambers 10. The constituents of the steam which are not condensed, particularly the non-condensable gases, are released from the higher orifices of channels 5 into gas exhaust chambers 10', are guided through channels 16 to heat exchanging elements 15 for recooling. The channels 16 are defined by guide plate members 17 and 18 arranged in V configuration in each gas exhaust chamber 10'. The heat exchanging elements 15 consist of substantially rectangular tubes which are provided with internal fins and are arranged in V configuration. The recooling elements 15 prevent the formation of ice, when the condensate is obtained at cooling-air temperatures below 32° F. (0° C.). Due to the V configuration of the recooling elements 15, the gas-steam mixture upon entering channels between the recooling elements at their lower ends is uniformly distributed over the heat exchanging surfaces. Speaking in terms of flow, the V-shaped channels between the recooling elements can be compared to nozzles having a continuously increasing cross-section. Preferably, the smallest cross-sectional area is so dimensioned that under full load the velocity of the steam-gas mixture is 65.6 feet (20 meters) per second thereby insuring that even in partial-load operation no streams of different densities are formed in the

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vicinity of the smallest cross-sectional area, which at cooling temperatures of below the freezing point might cause the reflux condensate to come in contact with tube sections whose wall temperature is also less than 32° F. (0° C.), even though the steam and the condensate flow in opposite directions.

The lower ends of guide plates 18 are immersed in the condensate fluid in a tank 19 below the units 8 to prevent steam from passing directly from steam distributing chambers 10 into the recooling elements 15 through the tank 19. In this manner, a fluid barrier is formed in accordance with the difference in pressure.

Each steam distributing chamber 10 of the condenser system communicates with a common compartment 20 via its narrow top aperture thereby insuring an equal distribution of pressure in each of the condenser units, compartment 20 being disposed above the condenser system.

Unlike water-cooled condensers, in which the non-condensable gases can be relatively easily removed from the steam space because of the relatively small dimensions and the fact that the steam space is made up of a single compartment, air-cooled condensers must have a steam room subdivided into a plurality of sections, and each of these sections must communicate with a common exhaust channel. In such a case, the exhaust plant is designed to operate under predetermined conditions, that is, to handle a given amount of gas under a given absolute pressure at a given temperature, which is determined by the heat gradient desired to be obtained between the cooled gas and the steam. Further, the aerodynamic resistance in the steam lines to the various condenser batteries is not so adjustable that each section will receive an equal amount of steam. In addition, the condenser batteries are not equally efficient. Thus the efficiency of the batteries or sections located at the windward side is inherently greater than the efficiency of sections located leeward because of the great amount of air blast available at the windward side. Consequently, if a particular condenser section is simultaneously affected by such conditions as lower steam supply and increased efficiency caused by greater amounts of air blast, an absolute pressure will be obtained in that section which is smaller than the absolute pressure in other sections of the condenser system because of the smaller load in proportion to the efficiency. Due to the decreased pressure gradient up to the point where the exhaust lines are connected to the system, the flow of non-condensable gases is reduced so that the condenser space filled with gases can no longer be used for steam condensation. It is true that for this purpose another independent exhaust plant can be provided for the removal of gas, to which each condenser section is connected by means of a regulating valve, so that by proper regulation of the valves the pressure in each section can be maintained at the same level. However, it is well known that control devices connected into vacuum lines are frequently the cause of trouble. In addition, the amount of apparatus is considerably increased in condensers of the aforementioned type.

The present invention obviates such disadvantages by providing communication among all the condenser sections through a common compartment 20 whereby effective removal of the gas is insured, at the same time maintaining the absolute pressure in all condenser sections at the same level.

Connections 21 are provided for exhausting the air from the gas exhaust chambers near the wall 13. The non-condensable gases are drawn off from the heat exchanger units at points which are farthest away from the steam inlet, as seen in the main direction of steam flow.

Cooling air is passed through tube elements 1 and 15 of the heat exchanger units in a conventional manner and is discharged into the open air by a fan 22 through a diffuser 23. Overflow pipes 24 in the lower portions of

gas escape chambers 10' lead to a common condensate line 25.

The air-cooled condenser according to the invention insures uniform operation, irrespective of external conditions such as ambient temperature and air inflow under full or partial load. In the condenser of the invention, the steam is uniformly distributed over the entire heat exchanging surface without special equipment. In addition, supercooling of the condensate or the formation of ice is eliminated without special circuit requirements and apparatus to be installed in the heat exchangers, at the same time insuring effective removal of the non-condensable gases.

Furthermore, the air-cooled condenser according to the invention retains its heat exchanging capacity even when the exhaust steam enters the condenser in a superheated state. Due to the special design and the fact that the steam velocity at no point in the condenser is greater than 65.6 feet (20 meters) per second, the steam distributing chambers are capable of acting as a steam deheater by simply providing means which are adapted to sufficiently finely distribute the condensate leaving the transverse channels. This arrangement is considerably simpler than conventional means such as condensate injection apparatus or a jet condenser which is connected into the condenser system at the inlet side of the air-cooled condenser and to which the whole condensate obtained in the air-cooled condenser is fed back. In addition, the provision of such a condenser at the inlet side of the air-cooled condenser has the disadvantage that the cooled condensate is exposed to being possibly reheated.

While the novel features of the invention as applied to a preferred embodiment have been shown and described herein, it will be obvious that modifications of the condenser illustrated may be made without departing from the spirit and the scope of the invention. Accordingly, the scope of this invention is to be governed by the language of the following claims construed in the light of the foregoing description of this invention.

What is claimed is:

1. An air-cooled condenser comprising a plurality of heat exchangers connected to an exhaust system, tube elements disposed inside of each of said heat exchangers and adapted for passing cooling air therethrough, said tube elements having a substantially rectangular cross-section and being provided with internal fin members, said heat exchangers being assembled to form block-shaped inclined heat exchanger units, each of said heat exchanger units consisting of a plurality of said tube elements of substantially rectangular cross-section, said tube elements being arranged in a plurality of superposed rows, each of said rows being composed of a plurality of spaced, parallel tube elements, the distance between adjacent ones of said tube elements being smaller than the width of the cross-sectional area of each of said tube elements, said superjacent rows of said adjacent tube elements being arranged in staggered relationship, the amount of staggering between each two superjacent rows of tube elements being not greater than part of the cross-sectional area of each of said tube elements, flat spacer bar members of substantially rectangular cross-section interposed between said superjacent rows of adjacent tube elements, the lengthwise dimension of each of said spacer bar members being equal to the width of each of said rows of tube elements, whereby narrow transversely extending channels are defined by said spacer bar members and said tube elements, said heat exchanger units being arranged side by side in an inclined relationship in such a manner that at one side of each of said heat exchanger units a substantial V-shaped first space is formed by the respective one of two lateral surfaces of said unit and by the opposite lateral surface of an adjacent one of said units, said lateral surfaces being at right

angles to the tube apertures in the respective ones of said heat exchanger units, while at the other side of each of said units a second space having the shape of a substantially inverted V is formed by the respective other of said lateral surfaces of said unit and by the opposite lateral surface of another adjacent one of said units, each transversely extending channel having two orifices communicating with said spaces respectively, wall members respectively secured to the longitudinal edges of each of the so formed wedge-shaped spaces, said wall members connecting the opposite edges of said heat exchanger units thereby defining wedge-shaped chambers in conjunction with said lateral surfaces of said heat exchanger units, steam feed lines communicating with said spaces of substantially inverted V shape through the lower portions thereof to feed exhaust steam to be condensed into said spaces of substantially inverted V shape, and gas exhaust pipes communicating with said substantially V-shaped spaces through the upper portions thereof to remove gases from said substantially V-shaped spaces, said spaces of substantially inverted V shape and said substantially V-shaped spaces respectively serving as steam distributing and gas exhaust chambers.

2. An air-cooled condenser as set forth in claim 1, wherein the length of each of a plurality of said transversely extending channels is not greater than approximately 6.56 feet (2 meters).

3. An air-cooled condenser as set forth in claim 1, wherein the height of said spacer bar members between superjacent rows of tubes is approximately 0.39 in. (1 cm.).

4. An air-cooled condenser as set forth in claim 1, wherein some of said spacer bar members are made of plastic material.

5. An air-cooled condenser as set forth in claim 1, wherein said first spaces are provided with heat exchanger elements suitable for recooling.

6. An air-cooled condenser as set forth in claim 1, further comprising heat exchanger elements composed of internally finned cooling tubes of substantially rectangular cross-section for air circulation and arranged in said first spaces.

7. An air-cooled condenser as set forth in claim 6, wherein the heat exchanger elements in the first spaces are arranged to form V-shaped heat exchanger units.

8. An air-cooled condenser as set forth in claim 1, wherein said heat exchanger units are inclined, and at least two pairs of guide plates are arranged in each of said first spaces in such a manner that guide channels are formed, said guide channels extending each between a guide plate and a unit, and converging downwards in V relationship to define deflecting paths for the steam saturated gases leaving said heat exchanger units.

9. An air-cooled condenser as set forth in claim 1, further comprising a plurality of gas exhaust pipes in communication with the uppermost portions said first chambers respectively, and a common gas exhaust line leading away from said exhaust pipes.

10. An air-cooled condenser as set forth in claim 1, wherein said heat exchanger units constitute a polygon-shaped condenser section.

11. An air-cooled condenser as set forth in claim 1, further comprising a plurality of baffle plates in the said second spaces of each of said steam distributing chambers at such a distance from and beneath the orifices of transverse channels communicating with said second spaces that condensate issuing from said orifices of said transverse channels is dispersed by said baffle plates.

12. An air-cooled condenser as set forth in claim 1, further comprising a common compartment, each of said second spaces being in communication with said common compartment through the narrowed ends of said second spaces, each of said first spaces being arranged between

two adjacent ones of said second spaces and being sealed off at the upper ends thereof against said compartment.

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