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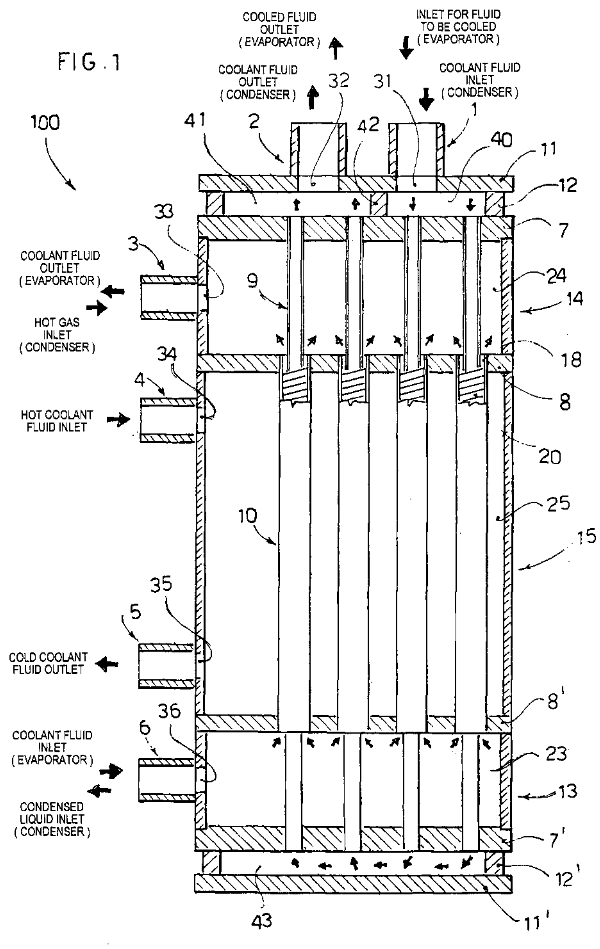
(54) **Heat exchanger**

(57) A heat exchanger comprising pair of coaxially disposed tubes (9, 10) and fixed to tube plates (7, 8, 8', 7') so as to form a top chamber (24), an intermediate chamber (25) and a bottom chamber (23), the heat exchanger being suitable to be employed in an evaporator, a condenser or an evaporative condenser.



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Description

[0001] The present invention refers to a heat exchanger, that is to say an apparatus in which transfer or exchange of heat occurs between fluids at different temperatures, separated by conducting walls. The present invention refers in particular to a tube bundle heat exchanger particularly suitable to be employed as an evaporating, condensing or evaporative condensing device.

[0002] Various types of heat exchangers are currently available on the market. Prior art heat exchangers have various drawbacks.

[0003] Widely used are heat exchangers with tube coils in which the fluid to be cooled or the coolant circulates. Said heat exchangers have the drawback that the tubes, besides being complex to make, are difficult to clean and inspect.

[0004] Moreover, prior art heat exchangers generally require a separate exchanger for subcooling the coolant fluid which from the heat exchanger must be recirculated in the refrigeration system for coolant supply. Said separate heat exchanger consequently involves greater complexity and additional costs.

[0005] Another drawback of known heat exchangers is that they lack versatility. In fact structurally different heat exchangers are generally used to act as condensers, evaporators and evaporative condensers.

[0006] An object of the present invention is to obviate the drawbacks of the prior art, providing a heat exchanger that is versatile, practical, economical and easy to make.

[0007] This object is achieved in accordance with the invention with the characteristics listed in appended independent claim 1.

[0008] Advantageous embodiments of the invention are apparent from the dependent claims.

[0009] The heat exchanger according to the invention provides a plurality of pairs of tubes, each pair consisting of an inner tube disposed coaxially to an outer tube so as to leave a space or gap within which a fluid can flow.

[0010] The inner tubes have their ends fixed to a first end tube plate and to a second end tube plate. The outer tubes have their ends fixed to a first intermediate tube plate and to a second intermediate tube plate. The pairs of tubes are disposed substantially parallel to each other and the tube plates are disposed substantially at right angles to the tubes and parallel to each other.

[0011] The tube plates are laterally surrounded by casings so as to create a first chamber between the first end tube plate and the first intermediate tube plate, an intermediate chamber between the two intermediate tube plates and a second chamber between the second intermediate tube plate and the second end tube plate.

[0012] In this manner, when the exchanger has to work as an evaporator, the fluid to be cooled passes within the inner tubes or ducts and the coolant enters the second chamber, passes in the gaps between the outer tubes or ducts and the inner ducts in which it evaporates and leaves the first chamber. The intermediate chamber, on the other hand, is used for subcooling the coolant fluid to be sent to the refrigeration system.

[0013] When the heat exchanger has to work as a condenser, a coolant fluid passes in the inner tubes or ducts, a hot gas enters the first chamber and passes into the gaps between the inner tubes and the outer tubes in which it condenses, the condensed liquid is collected in the second chamber and sent for use. The intermediate chamber is used for cooling the oil of the cooling compressor.

[0014] When the heat exchanger has to operate as an evaporative condenser, the tubes are advantageously disposed vertically and the tube plates horizontally. Thus, through gravity or by means of injection nozzles, a liquid is sent into the inner ducts and by means of a fan disposed above the first end tube plate air is sucked form the inner tubes. In this manner the water flows peripherally from top to bottom in the inner tubes or ducts and air flows axially in the inner ducts, in counter-current from bottom to top.

[0015] In this manner part of the water evaporates and the change of state from liquid to steam contributes to lowering of the temperature inside the inner duct. A hot gas enters the first chamber, passes in the gaps between inner tubes and outer tubes in which it condenses and the condensed fluid collects in the second chamber and is sent for use. In this case also the intermediate chamber is used as a cooling tank for the cooling compressor oil.

[0016] The advantages of the heat exchanger according to the invention are obvious from this description.

[0017] First of all, the particular arrangement of the inner tubes and the outer tubes allows complete inspection of said tubes and makes cleaning and descaling operations extremely simple.

[0018] Furthermore, this arrangement of the tubes does not involve excessive construction difficulties, with a consequent saving in construction costs, thus stronger and more expensive materials can be used for the tubes, such as stainless steel and titanium.

[0019] Moreover, in the heat exchanger according to the invention, provision of the intermediate chamber acting as a fluid cooling tank for the refrigeration system spares the use of an additional heat exchanger for cooling fluid to be sent to the refrigeration system.

[0020] Furthermore, the heat exchanger according to the invention is extremely versatile, since it can be applied to an evaporator, a condenser or an evaporative condenser.

[0021] Further characteristics of the invention will be made clearer by the detailed description that follows, referring to purely exemplary and therefore non-limiting embodiments thereof, illustrated in the appended drawings, in which:

[0022] Figure 1 is a part-sectional longitudinal view, illustrating a heat exchanger according to the invention in an evaporator and condenser configuration;

[0023] Figure 2 is a view, similar to Figure 1, illustrating a second embodiment of the heat exchanger according to the invention in an evaporative condenser configuration.

[0024] The heat exchanger according to the invention will now be described with the aid of the figures.

[0025] With reference to Figure 1, a first embodiment of a heat exchanger designated as a whole with reference numeral 100 will be described. The heat exchanger 100 comprises a plurality of inner tubes 9 fixed at their ends by expanding or welding respectively to a first top end tube plate 7 and a second bottom end tube plate 7'.

[0026] Externally and coaxially to the tubes 9 are disposed outer tubes 10, with a greater inside diameter than the outside diameter of the tubes 9, so as to leave a toroidal space or gap 18 inside which finning 20 can be contained to increase the turbulence of the fluid flow passing along the gap 18. The outer tubes 10 are fixed at their ends, by means of welding, to a first intermediate tube plate 8 disposed below the upper tube plate 7 and a second intermediate tube plate 8' disposed above the lower tube plate 7' and below the first intermediate tube plate 8.

[0027] Disposed between the upper tube plate 7 and the first intermediate tube plate 8 is a cylindrical upper casing 14 which defines an upper cylindrical chamber 24 within which the top parts of the inner tubes 9 are contained. In the casing 14 a through hole 33 is provided, communicating with a duct 3 which protrudes externally from the casing 14 for outlet/inlet of a fluid from/into the chamber 24.

[0028] Disposed between the first intermediate tube plate 8 and the second intermediate tube plate 8' is a cylindrical intermediate casing 15 which defines a cylindrical intermediate chamber 25 within which the outer tubes 10 coaxial to the inner tubes 9 are contained. In the intermediate casing 15 two through holes 34 and 35 are provided, communicating with the respective ducts 4 and 5 which protrude outward from the intermediate casing 15 for outlet/inlet of a liquid from/into the chamber 25.

[0029] Disposed between the second intermediate tube plate 8' and the bottom tube plate 7' is a cylindrical bottom casing 13 which defines a cylindrical bottom chamber 23 inside which the bottom parts of the inner tubes 9 are contained. In the bottom casing 13 a through hole 36 is provided, communicating with a duct 6 which protrudes outward from the bottom casing 13 for outlet/inlet of a fluid from/into the chamber 23.

[0030] Above the upper tube plate 7 an upper cylindrical wall 12 is provided above which a roof plate 11 is mounted, so as to delimit an upper end chamber. By means of a partition 42, the upper end chamber is divided into a first upper end chamber 40 and a second upper end chamber 41. The roof plate 11 has two through holes 31 and 32 which put two outer ducts 1 and 2 respectively in communication with the first upper end chamber 40 and the second upper end chamber 41. The ducts 1 and 2 protrude upward from the top plate 11 for inlet/outlet of fluid into/out of the upper end chambers 40 and 41.

[0031] Below the bottom plate 7' a cylindrical bottom wall 12' supported by a base plate 11' is disposed so as to define a lower end chamber 43.

[0032] With reference to Figure 1, operation of the heat exchanger 100 as an evaporator will now be described.

[0033] The fluid to be cooled, which for example can be a liquid, is introduced, through the inlet duct 1, into the first upper end chamber 40, from which it enters the inner tubes 9 in which it undergoes a first cooling. The fluid to be cooled then comes out of the inner tubes 9 in the lower end chamber 43 and, through pressure, enters other inner tubes 9, the top end of which opens into the second upper end chamber 41. In this manner the fluid to be cooled undergoes a second cooling and exits into the second top chamber 41. The cooled fluid leaves the second upper end chamber 41 through the outlet duct 2 and goes for use.

[0034] The coolant fluid, coming from a refrigeration system, passes through the inlet duct 6 and is let into the lower chamber 23. The coolant fluid passes from the lower chamber 23 into the gaps 18 between the inner tubes 9 and the outer tubes 10. By means of finnings 20 the flow of coolant fluid becomes turbulent and there is a greater heat exchange between the coolant fluid and the walls of the inner tubes which are heated by the fluid to be cooled which circulates inside the inner tubes 9. In this manner the coolant fluid begins to evaporate, removing heat from the walls of the inner tubes 9 and thus aiding cooling of the fluid to be cooled by means of thermal exchange with the walls of the inner tubes 9.

[0035] The evaporated coolant fluid leaving the spaces 18 goes into the upper chamber 24 which also serves to retain the liquid drops of the coolant fluid which has not evaporated. Steam leaves the chamber 24 through the outlet duct 3 and returns to the refrigeration compressor.

[0036] The intermediate chamber 25 can be used as a tank for coolant liquid coming from the condenser of the refrigeration system. The coolant liquid coming from the refrigeration system is introduced, by means of the duct 4, into the intermediate chamber 25, in which it is in contact with the outer surface of the outer tubes 10 which have a temperature equal to the lower evaporation temperature of the coolant fluid entering the space 18, thus the liquid inside the intermediate chamber 25 is cooled. The cooled liquid is made to leave the intermediate chamber 25 through the outlet duct 5 and is sent to the refrigeration system.

[0037] This cooling of the cooling liquid in the intermediate chamber 25 is very important, because it increases the enthalpy variation of the cooling liquid and consequently the efficiency of the refrigeration compressor.

[0038] To achieve this, prior art heat exchangers are connected to air condensation or evaporative condenser refrigeration systems in which a containment tank is installed for the coolant liquid. Said tank is connected to an additional heat exchanger on which a thermostatic control is also installed to cause part of the coolant to expand. This results in further structural complications and additional costs for the separate exchanger and the containment tank for the coolant liquid.

[0039] Operation of the heat exchanger 100 as a condenser will now be described. In this case a hot gas is introduced into the duct 3, entering the upper chamber 24 and entering the spaces 18, where it condenses on contact with the cooler tubes 9. The condensed liquid then collects in the lower chamber 23, from which it exits through the duct 6 to go for use.

[0040] In this case a coolant fluid enters the duct 1, for example cold water coming from the refrigeration system, which circulates inside the inner tubes 9, so as to cool the wall of the inner tubes. In this manner a heat exchange takes place between the hot gas circulating in the gaps or spaces 18 and the walls of the inner tubes 9, which causes condensation of the hot gas that circulates in the gaps 18.

[0041] In those systems in which a screw refrigeration compressor is used, there is a need to cool the oil used therein. In this case the oil can be cooled in the intermediate chamber 25. In fact the walls of the outer ducts 10 gradually grow increasingly cold toward the bottom, since the hot gas in the spaces 18 condenses as it flows downward.

[0042] In this case also the heat exchanger according to the invention avoids the use of an additional heat exchanger for cooling oil in the screw refrigeration compressor, required in prior art exchangers.

[0043] With reference to Figure 1, by way of example a heat exchanger 100 has been illustrated in which the tube bundle 9 and 10 is vertically disposed and the tube plates 7, 8, 8', 7' are horizontally disposed, however a heat exchanger can be provided in which the tube bundle 9 and 10 is horizontally disposed or inclined and the tube plates 7, 8, 8', 7' are vertically disposed or inclined, without thereby departing from the scope of the invention.

[0044] With reference to Figure 2, a second embodiment of the heat exchanger according to the invention will now be described. Said heat exchanger is designated as a whole by reference numeral 300 and is applied to an evaporative condenser, designated as a whole with reference numeral 200.

[0045] In this second embodiment of the heat exchanger, the same reference numerals are used to refer to like or similar parts to those already described in the first embodiment. The heat exchanger 300 is substantially similar to the heat exchanger 100 described in the first embodiment. In the heat exchanger 300 the upper wall 12, the dividing or partition wall 42, the roof plate 11, the lower wall 12' and the base plate 11' are eliminated.

[0046] In the evaporative condenser 200, a cylindrical casing 50 which defines a cylindrical chamber 51 is mounted above the top plate 7 of the heat exchanger 300. A helical or centrifugal ventilator 52 able to generate an air flow from the bottom upward in the chamber 51 is mounted inside the cylindrical chamber 51. The cylindrical casing 50 has a through hole 54 in communication with a duct 53 for entry of a fluid into the chamber 51.

[0047] Again in the cylindrical chamber 51, delivery nozzles 55 are provided in the vicinity of the entry mouths of the inner tubes 9, so that a fluid can be introduced uniformly into the tubes 9.

[0048] Below the bottom plate 7' of the heat exchanger 300 a containment tank 60 is provided for a fluid, preferably in liquid form and in particular water. The tank 60 is connected by means of a hydraulic duct 62 to the inlet duct 53 of the chamber 51. A pump 63 is provided to allow the flow of water in the hydraulic duct 62 from the bottom upward, that is to say from the tank 60 to the inlet duct 53 of the chamber 51. The hydraulic duct 62 can also be connected to the delivery nozzles 55.

[0049] Operation of the evaporating condenser 200 will now be described. Water coming from the tank 60 through the duct 62 is let into the inlet duct 53 and/or the delivery nozzles 55. Water from the inlet duct 53 enters the chamber 51 and falls by gravity into the inner tubes 9, or water from the delivery nozzles 55 is introduced and uniformly distributed into the tubes 9. Water from the tubes 9 runs into the tank 60 where it is again collected and circulated.

[0050] The fan 52 draws air from the bottom upward into the chamber 51, thus the air is also drawn inside the tube 9. Consequently a flow of water is produced that flows peripherally, from top to bottom, inside each inner tube 9 and a flow of air is produced which flows axially, counter-current, from bottom to top inside each inner tube 9. Air thus enters the tube 9 from beneath the bottom tube plate 7' and exits from the tubes 9 in the chamber 51, into which it is drawn by the fan 52.

[0051] Inside the tubes 9, the water, in direct contact with the air, in part evaporates, removing heat and cooling the walls of the tubes 9. Consequently the hot gas which is introduced from the duct 3 into the upper chamber 24, passing in the gaps 18 is cooled by thermal exchange with the inner tubes 9. Thus the hot gas in the gap 18 condenses and the condensed liquid collects in the bottom chamber 23, from which it exits through the duct 6 and is sent for use.

[0052] The intermediate chamber 25 of the evaporative condenser 200, as in the previous embodiment of the condenser, can be used as an oil tank and cooler for the screw compressor refrigeration system.

[0053] Numerous variations and modifications of detail within the reach of a person skilled in the art can be made to the present embodiments of the invention without thereby departing from the scope of the invention, set forth in the appended claims.

Claims

1. A heat exchanger **characterized in that** it comprises a plurality of pairs of tubes (9, 10), each pair consisting of an inner tube (9) disposed coaxially to an outer tube (10) so as to leave a gap (18) wherein a fluid can flow, the inner tubes (9) being fixed at their ends to a first end tube plate (7) and to a second end tube plate (7'), the outer tubes (10) being fixed at their ends to a first intermediate tube plate (8) and to a second intermediate tube plate (8) and to a second intermediate tube plate (8'), the tube plates being disposed substantially at right angles to the tubes, the tube plates (7, 8, 8', 7') being surrounded laterally by casings (14, 15, 13) so as to create a first chamber (24) between the first end tube plate (7) and the first intermediate tube plate (8), an intermediate chamber (25) between the two intermediate tube plates (8, 8') and a second chamber (23) between the second intermediate tube plate (8') and the second end tube plate (7').

2. An exchanger according to claim 1, **characterized in that** provided in said casings (14, 15, 13) are a duct (2) for inlet/outlet of fluid into/from said first chamber (24), a duct (4) for inlet of fluid into said intermediate chamber (25), a duct (5) for outlet of fluid from said intermediate chamber (25), and a duct (6) for inlet/outlet of fluid into/from said second chamber (23).

3. An exchanger according to claim 1 or 2 **characterized in that** in said spaces (18) fin arrangements (20) are provided to increase the turbulence of the flow flowing therein.

4. An exchanger according to any one of the preceding claims, **characterized in that** in contact with said first end tube plate (7) and in contact with said second end tube plate (7') are positioned a first wall (12) and a second wall (12') to which a first end plate (11) and a second end plate (11') are fixed respectively so as to form a third end chamber (40, 41) and a fourth end chamber (43) inside which the fluid circulates passing inside the inner ducts (9).

5. An exchanger according to claim 4, **characterized in that** in contact with said first end tube plate (7) at least one partition wall (42) is provided to divide said third end chamber into at least two chambers (40, 41).

6. An exchanger according to claim 5, **characterized in that** on said first end plate (11) at least two fluid inlet/outlet ducts (1, 2) are provided, communicating respectively with said at least two chambers (40, 41).

7. An evaporator, **characterized in that** it comprises a heat exchanger according to any one of the preceding claims.

8. An evaporator according to claim 7, **characterized in that** a fluid to be cooled passes within said inner tubes (9), a coolant fluid which evaporates causing a lowering in temperature passes within said gaps (18) and a coolant fluid which is cooled to be sent to a refrigeration system is contained in said intermediate chamber (25).

9. A condenser, **characterized in that** it comprises a heat exchanger according to any one of claims 1 to 6.

10. A condenser according to claim 9, **characterized in that** a coolant fluid circulates within said inner tubes (9), a hot vapour that is condensed circulates within said gaps (18), and a coolant fluid which is cooled to be sent to a refrigeration system is contained in said intermediate chamber (25).

11. An evaporative condenser, **characterized in that** it comprises a heat exchanger according to any one of claims 1 to 3.

12. An evaporative condenser according to claim 11, **characterized in that** above said first end tube plate (7) suction means (52) to suck air from said inner ducts (9) and inlet means (55, 53) to send fluid into said inner ducts (9) are provided.

13. An evaporative condenser according to claim 12, **characterized in that** said suction means is a helical or centrifugal fan (52).

14. An evaporative condenser according to claim 12 or 13, **characterized in that** said inlet means is a duct (53) to introduce a liquid fluid which falls by gravity into the inner tubes (9).

15. An evaporative condenser according to any one of claims 12 to 14, **characterized in that** said inlet means are delivery nozzles (55) able to deliver a liquid fluid in a uniform manner into said inner tubes (9).

16. An evaporative condenser according to any one of claims 11 to 15, **characterized in that** positioned beneath said second end tube plate (7') is a tank (60) for collection of the liquid fluid leaving said inner tubes (9).

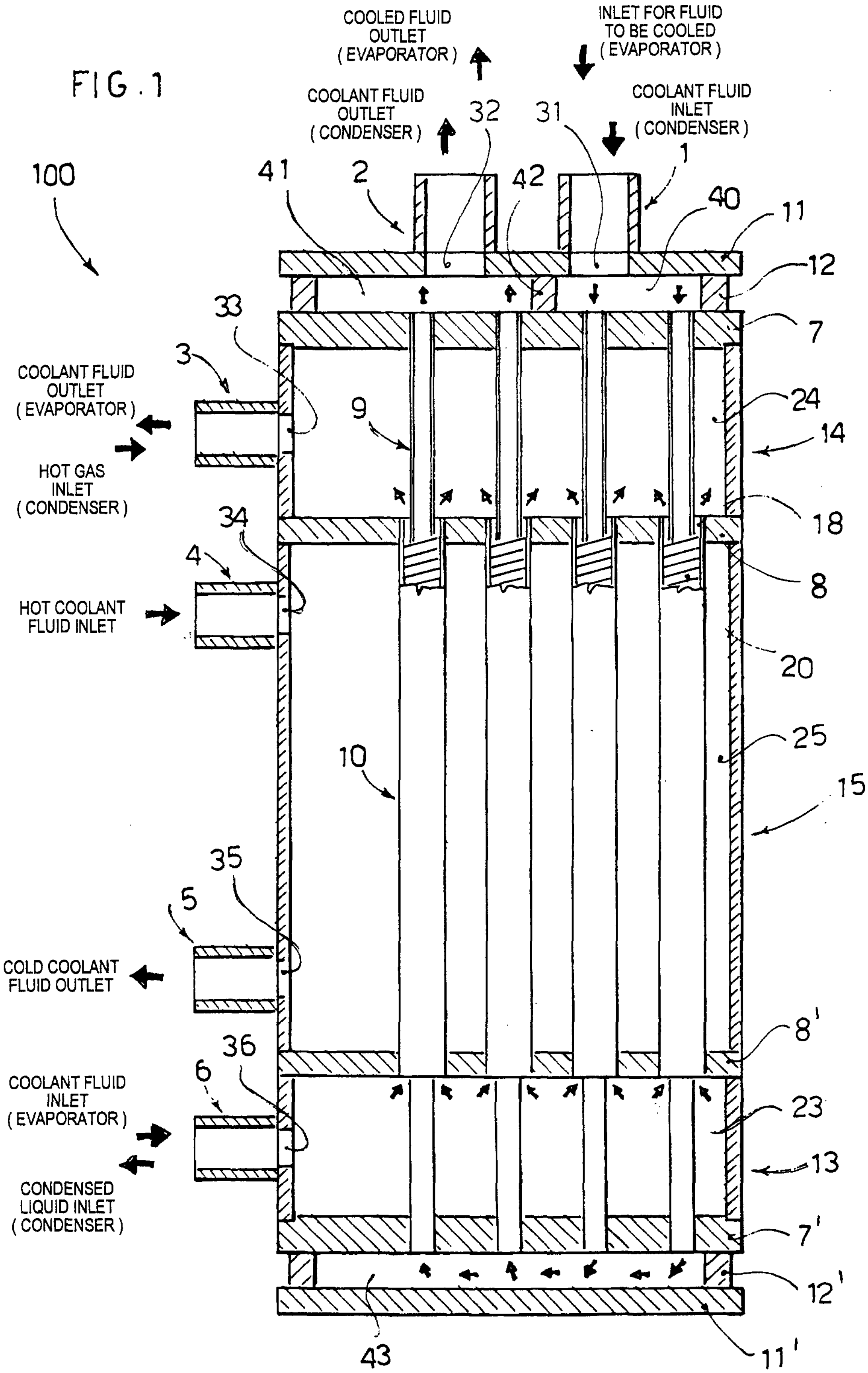
17. An evaporative condenser according to claim 16,

characterized in that said collection tank (60) is connected by means of a hydraulic system (62) to said inlet means (53, 55).

18. An evaporative condenser according to claim 17, **characterized in that** said hydraulic system (62) comprises a pump (63) to send the fluid from said tank (60) to said inlet means (53, 55).

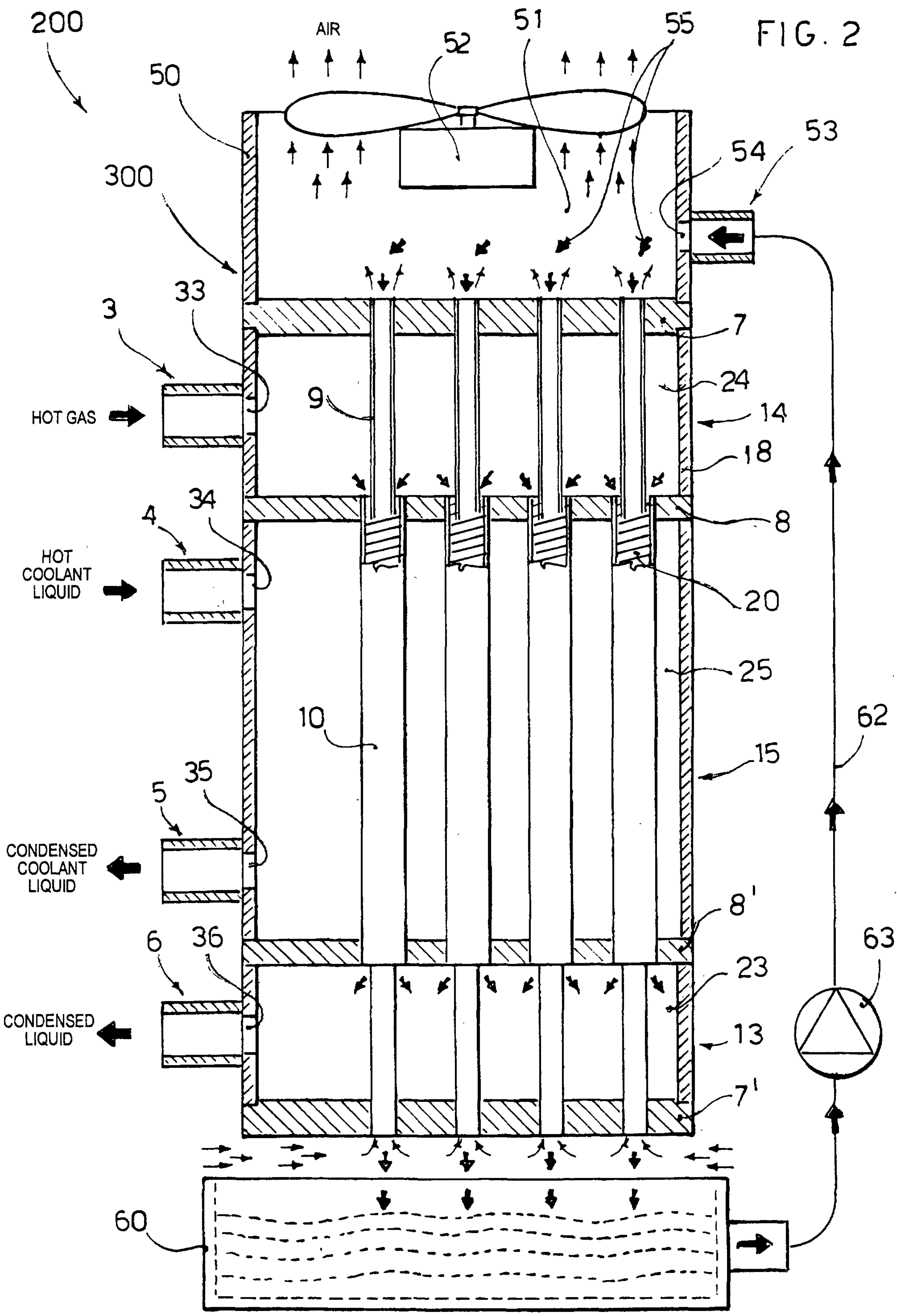
19. An evaporative condenser according to any one of claims 11 to 18, **characterized in that** inside said inner tubes (9) a liquid fluid flows peripherally from top to bottom and air flows axially, counter-current, from bottom to top, a hot gas that condenses flows inside said gaps (18) and a coolant fluid which is cooled to be sent to a refrigeration system is contained in said intermediate chamber (25).

FIG. 1



COOLED FLUID OUTLET (EVAPORATOR)
INLET FOR FLUID TO BE COOLED (EVAPORATOR)
COOLANT FLUID OUTLET (CONDENSER)
COOLANT FLUID INLET (CONDENSER)
100
41
2
32
42
31
1
40
11
12
33
7
3
COOLANT FLUID OUTLET (EVAPORATOR)
HOT GAS INLET (CONDENSER)
9
24
14
18
34
4
8
HOT COOLANT FLUID INLET
20
25
10
15
35
5
COLD COOLANT FLUID OUTLET
8'
36
6
COOLANT FLUID INLET (EVAPORATOR)
CONDENSED LIQUID INLET (CONDENSER)
23
13
7'
12'
43
11'

FIG. 2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HOT
COOLANT
LIQUID
20
25
10
62
15
35
5
CONDENSED
COOLANT
LIQUID
8'
6
36
63
23
CONDENSED
LIQUID
13
7'
60