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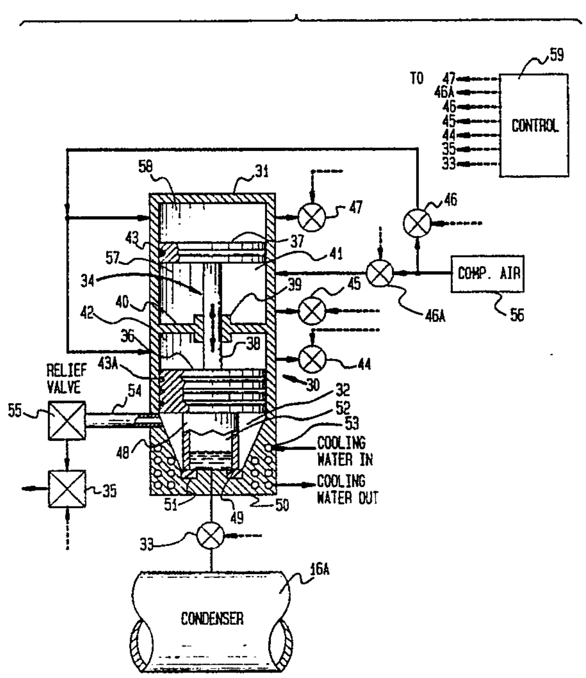
(54) **Method of and means for purging noncondensable gases from condensers or the like.**

(57) Condenser fluid, comprising vaporized working fluid and non-condensable gases, is treated by extracting fluid from the condenser (16A) and pressuring the fluid to liquefy the vaporized working fluid therein in such a way that the non-condensable gases are separated from the working fluid and can be vented from the extracted fluid. A piston (36) draws the vaporized fluid into a chamber (32) through an open valve (33). The valve is then closed and the fluid is compressed by the piston (36), the fluid being cooled by a cooling coil (53), so that working fluid condenses, whereupon the non-condensed gases are vented (valve 39). The valve (33) is then opened so that the working fluid can flow back into the condenser (16A).

FIG. 2



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METHOD OF AND MEANS FOR PURGING NONCONDENSABLE GASES FROM CONDENSERS OR THE LIKE

This invention relates to a method of and means for purging non-condensable gases from a condenser or the like.

Non-condensable gases almost always cause problems in Rankine cycle power plants, in air conditioning systems, and in other arrangements that utilize condensers. A major problem caused by the presence of non-condensable gases is a reduction in the heat transfer efficiency of various components in a system. That is to say, the presence of non-condensable gases in the working fluid of the system reduces the rate at which heat can be transferred from a heat source to the working fluid in a vaporizer of a Rankine cycle power plant, as well as the rate at which heat can be transferred from vapor to a cooling fluid in a condenser of a Rankine cycle power plant. The deleterious effect non-condensable gases have on the operation of a power plant is illustrated by the example described below of an actual operational system.

Waste heat is applied to a vaporizer of a Rankine cycle power plant utilizing isopentane as the working fluid. The vaporizer vaporizes the working fluid and supplies it to an organic vapor turbine designed to produce 1.5 MW by driving an electric generator. In the turbine, the vapor expands producing work and heat-depleted working fluid which is supplied to a condenser. In the condenser, the heat. depleted working fluid is condensed into a liquid which is pumped back into the vaporizer to repeat the cycle.

Except during very cold periods of time, the internal pressure at various locations in the power plant described above, including the condenser, will exceed atmospheric pressure. Nevertheless, even under these conditions, experience proves that ambient air leaks into the working fluid through the metal piping, flanges, joints, etc. Apparently, air diffuses through the metal piping and seals even when the pressure inside the system exceeds ambient pressure.

The effect on the power output of a power plant having non-condensable gases in the working fluid is significant. For example, in relatively small systems designed to produce about 1.5 MW, experience has shown more than a 10% decrease in power may result if a constant program of purging non-condensable gases from the system is not carried out, an amount that is significant in terms of the total power output.

The conventional approach to purging non-condensable gases from the condenser of a power plant of the type described is to utilize a vacuum pump arrangement by which fluid (vaporized working fluid and non-condensable gases) in the condenser is admitted to a cooled chamber. The result is a miniature condenser wherein the working fluid condenses and is thus separated from the non-condensable gases which are vented from the chamber before the condensed working fluid is returned to the system.

While this approach is satisfactory in some instances, it is unsatisfactory in many instances because of the power consumption involved, and because of the complex equipment needed to establish and maintain a vacuum. Furthermore, the conventional approach is insensitive to the amount of non-condensable gases in the power plant system requiring continuous operation that, itself, is a disadvantage in many cases. Furthermore, experience proves that extraction of non-condensable gases requires operation of the purging system over long periods of time because the non-condensable gases often are dissolved in the working fluid, and only slowly are released and extracted in the purging system associated with the condenser. Thus, constant operation is often required to ensure removal of these gases. Also, during cooling of the fluid in the cooled chamber, even though a substantial portion of the working fluid is condensed and returned to the system, a large portion of working fluid remains in vapor form and is extracted together with the non-condensable gases during the operation of the vacuum pump. This portion is lost to the system.

What is therefore desired is a way of purging non-condensable gases from a condenser which is more efficient than other systems previously known, simpler to maintain control and operate, more sensitive to the actual amount of non-condensable gases in the system, and effective in substantially minimizing the amount of working fluid lost from the system.

Apparatus in accordance with the present invention for purging non-condensable gases from a condenser or the like containing vaporized working fluid includes a chamber, and a valve having an open state for connecting the condenser to the chamber, and having a closed state for disconnecting the condenser from the chamber. Associated with the chamber is an element, made effective when the valve is in its closed state, to condense working fluid in the chamber thereby separating the same from non-condensable gases in a chamber. A selectively operable vent connected to the chamber permits the latter to be vented when the valve is in its closed state. A relief valve connected to the vent substantially prevents extraction of working fluid from the system when no non-condensable gases are present in the chamber.

The apparatus according to the invention thus provides for the extraction of fluid from the condenser, the fluid containing both vaporized working fluid and non-condensable gases. The fluid so extracted from the condenser is pressurized in such a way that the working fluid is liquefied and separated from the non-condensable gases. Loss of working fluid from the system being purged is substantially prevented or minimized.

The invention also provides a method as claimed in claim 14.

Embodiments of the present invention are shown in the accompanying drawings wherein:

Fig. 1 is a block diagram of a Rankine cycle power plant utilizing an organic working fluid showing, in general form, the application of the present invention to the power plant;

Fig. 2 is a schematic diagram, partly in section, and showing parts partly broken away, illustrating one embodiment of the present invention; and

Fig. 3 is a second embodiment of the present invention.

Turning now to the drawings, reference numeral 10 designates a Rankine cycle power plant according to the present invention wherein the purging of non-condensable gases from the condenser of the power plant is achieved by using purging system 22. Power plant 10 comprises vaporizer 12 to which heat is applied for evaporating a working fluid such as an organic liquid (e.g., isopentane, or other hydrocarbon, or halogenated hydrocarbon). The heat may be waste heat from an industrial process, heat contained in natural sources such as geothermal fluid, or may be from the burning of natural or manufactured fuel.

Vaporized working fluid produced by vaporizer 12 is applied to organic vapor turbine 14 in which the vaporized working fluid expands and produces work and heat-depleted working fluid which is supplied to condenser 16. Work produced by the turbine drives electrical generator 18 which supplies power to an electrical grid (not shown). A typical system would require turbo-generator 14/18 to produce maximum rated power over long periods of time with a minimum of maintenance. Heat-depleted working fluid in condenser 16 is cooled, by air or cooling water; and the working fluid condenses into a liquid that is returned to vaporizer 12 by pump 20, where the cycle repeats.

From experience, it has been found that one of the causes of a power reduction, under conditions of fixed heat input and ambient temperatures, is a build-up of non-condensable gases in the condenser and elsewhere in the system. Such build-up reduces the heat transfer coefficients in the various heat exchangers in the power plant to a point where the power produced drops below its expected value.

In order to maintain the power produced by power plant 10 at substantially its expected value, purging system 22, according to the present invention, operates in the manner described below by extracting fluid from the condenser. Such fluid is a mixture of heat-depleted vaporized working fluid and non-condensable gases; and the fluid is externally compressed in such a way that the working fluid is liquefied and separated from the non-condensable gases.

The liquefied working fluid is returned to the condenser, and the non-condensable gases are vented. This operation is carried out periodically, preferably in accordance with a series of control signals, e.g., every 20 minutes, to substantially purge the non-condensable gases and thus substantially maintain the power level of the power plant. Alternatively, such operation can be carried out until a monitor (not shown) monitoring the power level of generator 18 determines that the power output thereof returns to its set level, i.e., until the amount of non-condensable gases in the system is reduced to a level at which minimal effect is exerted by the gases on the efficiency of the power plant.

An embodiment of a purging system according to the present invention is shown in Fig. 2 and designated by reference numeral 30. System 30 comprises housing 31 defining variable volume chamber 32, valve 33 having an open state for connecting condenser 16A to chamber 32, and having a closed state for disconnecting the condenser from the chamber, and control unit 59 for controlling the operation of the purging system. The state of the valve is determined in accordance with the nature of the control signal applied thereto.

System 30 further comprises means associated with the chamber, namely piston assembly 34, made effective in the manner described below when valve 33 is in its closed state to condense working fluid in the chamber in a way that separates the working fluid from the noncondensable gases in the chamber. Once separation is effected, valve 35 is tripped by a control signal, and the non-condensable gases are vented. During the interval that the gases are vented, valve 33 remains closed.

Assembly 34 is in the form of a double-ended piston, and comprises lower piston 36 connected to upper piston 37 by piston rod 38 passing through sealing sleeve 39 in transverse wall 40 which divides the interior of housing 31 into upper cylinder 41 and lower cylinder 42. Piston 37, carrying O-ring seal 43 on its periphery, slideably moves in upper cylinder 41, and piston 36, carrying O-ring seals 43A on its periphery, slideably moves in a lower cylinder 42 which includes variable chamber 32 whose volume is established by the movement of piston 36 in response to controlled operation of air valves 45, 46 or valves 44, 46A, and 47 as described below.

The lower, free end of piston 36 is provided with a cup-like extension in the form of sleeve 48 whose free edge 49 faces closed bottom end 50 of housing 31. Edge 49 engages annular seal 51 embedded in end 50 when piston 36 approaches the limit of its travel thereby sealing region 52 defined by sleeve 48 from the balance of chamber 32 for the reason explained below.

The interior wall defining chamber 32 is tapered, meeting end 50 in the vicinity of seal 51. This portion of the wall is also provided with means for cooling the contents of chamber 32; and the preferred way to achieve this end is embedded cooling coil 53 to which cooling water is supplied. Finally, exit tube 54 connects chamber 32 to the exterior of the housing through relief valve 44 and controlled valve 35.

In operation, control unit 59 produces a programmed series of control signals that are applied to valves 33, 35 and 44-47 in their quiescent state wherein valve 33 is closed, as are valves 46, 46A; and assembly 34 is in the position shown in Fig. 2. Such control signals are effective to first raise the piston assembly in the housing for drawing fluid in the condenser into chamber 32, and subsequently permit further fluid in the condenser to flow into this chamber, to trap the fluid in the chamber, and then to lower the piston to compress the trapped fluid such that vaporized working fluid present in chamber 32 is condensed and separated from non-condensable gases that are then vented from the chamber.

To this end, the control signals cause valve 33 to open and valve 35 to close thereby connecting the interior of condenser 16A to chamber 32, which at this time has a minimum volume. Valve 46 is then opened allowing compressed air from supply 56 to enter chamber 57, defined by the space between piston 37 and wall 40. At the same time, valves 44 and 47 are opened. As a result, the compressed air imparts upward displacement to pistons 36 and 37; and the resultant enlargement of chamber 32 reduces the pressure in the chamber and draws in fluid from the condenser through open valve 33. Such fluid is a mixture of heat-depleted working fluid in the condenser and non-condensable gases in the condenser.

When the piston assembly at its upper dead-center position, the volume of chamber 32 is a maximum, and fluid from the condenser continues to flow into this chamber. Due to the presence of cooling water in cooling coil 53, vaporized working fluid present in the chamber condenses. The resultant condensate drips back into condenser 16A while non-condensable gases from condenser 16A continue to collect in chamber 32 because the non-condensable gases are lighter than the vaporized working fluid. Subsequently, valves 33 and 46A are closed, as are valves 44 and 47, thus trapping the fluid present in chamber 32. The control signals from control unit 59 are then effective to impart downward movement to the piston assembly. Valve 46 is opened, allowing compressed air from supply 56 to enter chambers 42 and 58. Simultaneously, valve 45 is opened. Thus, fluid trapped in chamber 32 is compressed: the volume of the chamber decreases toward its minimum value. As a consequence, and also due to cooling by the cooling water flowing in coils 53, working fluid present in chamber 32 condenses into a liquid.

Seal 51, in cooperation with free edge 49 on sleeve 48, serves to trap the condensed working fluid as shown in Fig. 2 in the cup-like extension on piston 36, the non-condensable gases being separated from the condensed working fluid and being trapped in the annular region surrounding sleeve 48. At this point, the control signals are effective to open valve 35 to vent the annular region surrounding sleeve 48, thereby venting non-condensable gases and any vaporized working fluid remaining in chamber 32, and to open valve 33 to effect return of liquefied working fluid to the condenser. Thereafter, valves 35 and 33 are closed; and the cycle is repeated periodically. In the case where no non-condensable gases accumulate or are present in chamber 32, no pressure will build up as piston 36 travels downwardly. Relief valve 55, which is adjusted to operate at a pressure slightly above that of the condenser, will not open; and consequently, extraction of working fluid from the system is prevented. The cycle is repeated as many times as needed.

The preferred embodiment of the invention is designated by reference numeral 60 in Fig. 3. System 60 differs from system 30 essentially in the elimination of sleeve 48 and its seal 51 in favor of tank 61 interposed between valve 33 and the system. In system 60, normally open valve 62 is located between tank 61 and system 60.

The operation of system 60 is essentially the same as the operation of system 30, except that in the case of system 60, tank 61 serves to separate condensed working fluid from non-condensable gases in chamber 32. That is to say, upon downward movement of assembly 34A in system 60, the cooled and liquefied working fluid that results drains into tank 61 because valve 62 is open during the compression stroke of the assembly. At the end of the compression stroke, valve 62 is closed as valve 33 is opened to effect drainage of the working fluid in tank 61 into the condenser.

The orientation of the purging apparatus according to the invention is preferably as indicated in Figure 2, with the apparatus being located physically above the condenser to effect a gravitational return of the condensed working fluid into the condenser, and also to permit the lighter non-condensable gases to flow up into the purging apparatus. The non-condensable gases will be lighter than the working fluid when the latter is an organic working fluid. However, the apparatus could be located below the condenser if a pump were available to return the condensed working fluid to the condenser. Furthermore, the present invention is also applicable for purging systems where the non-condensable gases are heavier than the working fluid, e.g., where water or steam is the working fluid.

Even though the embodiment shown in Fig. 2 shows the presence of five separate air operated valves (i.e., valves 44-47), these valves may be replaced by one four-way, three position (up-down-neutral), double operation (two solenoid, spring, neutral return) valve.

While the above description of the present invention is associated with a Rankine cycle power plant, the invention is applicable to any system having a condenser in which non-condensable gases are a problem. Examples of other systems to which the present invention is applicable are air conditioning systems and refrigeration systems.

In an example of the use of the present invention, a ratio of about 7:1 of the maximum volume of chamber 32 to the minimum volume has been used when the air pressure of supply 56 was about 7 atmospheres (above atmospheric pressure) to vent non-condensable gases from a condenser operating at about 1.5 atmospheres above atmospheric pressure. It was found that the purging apparatus maintained the condenser operating pressure when the purging apparatus was operated at ten minute intervals.

The advantages and improved results furnished by the method and apparatus of the present invention are apparent from the foregoing description of the preferred embodiment of the invention. Various changes and modifications may be made without departing from the scope of the invention as described in the appended claims.

Claims

1. Apparatus for purging non-condensable gases from a condenser or the like (16A) containing vaporized working fluid, e.g. organic fluid, the apparatus comprising:

a) a chamber (32);

b) a valve (33) having an open state for connecting the chamber (32) to the condenser or the like (16A) and having a closed state for disconnecting the chamber (32) therefrom;

c) means associated with the chamber (32) and made effective when the valve (33) is in its closed state to condense working fluid in the chamber (32), thereby separating working fluid from non-condensable gases in the chamber (32); and

d) means to vent the chamber while the valve (33) is in its closed state.

2. Apparatus according to claim 1, wherein the said means associated with the chamber (32) comprises operating means for effecting the flow of fluid from the condenser or the like (16A) into the chamber (32) when the valve (33) is in its open state, and for compressing fluid in the chamber (32) when the valve (33) is in its closed state.

3. Apparatus according to claim 2, including cooling means (53) for cooling fluid.

4. Apparatus according to claim 2 or 3, wherein the operating means comprises a piston (36) in the chamber (32) movable between two axial positions that define a maximum volume and a minimum volume respectively, a piston operator for moving the piston (36) between its said two axial positions, and a control system (59) for causing the piston operator to move the piston (36) to the axial position defining a maximum volume when the valve (33) is open, and to move the piston (36) to the axial position defining a minimum volume when the valve (33) is closed, thereby effecting compression of working fluid and non-condensable gases in the minimum volume and causing working fluid to liquefy.

5. Apparatus according to claim 4, wherein the ratio of the maximum to the minimum volume is about 7:1.

6. Apparatus according to claim 4, wherein the piston operator comprises a second piston (37) rigidly connected to the first-mentioned piston (36), and means for effecting movement of the pistons (36,37) by compressed air.

7. Apparatus according to any of claims 4 to 6, including a cup-like member (48) on the piston (36), the member (48) having a free end which is open toward a closed end (50) of the chamber (32) and forming a region within which liquefied working fluid collects when the piston (36) moves to its axial position defining a minimum volume of the chamber (32).

8. Apparatus according to claim 7, wherein the closed end (50) of the chamber includes a seal (51) that engages and cooperates with the free end of the member (48) when the piston (36) moves to its axial position defining a minimum volume of the chamber, thereby separating the said region from the remainder of the minimum volume of the chamber (32).

9. Apparatus according to any of claims 1 to 5,

including means for separating condensed working fluid from non-condensable gases.

10. Apparatus according to claim 9, wherein the separating means comprises a tank (61) interposed between the valve (33) and the chamber (32), and a normally opened valve (52) connecting the tank (61) to the chamber (32).

11. Apparatus according to any preceding claim, wherein the chamber (32) is located physically above the condenser or the like (16A) to effect the return of liquid working fluid to the condenser or the like when the valve (33) is open.

12. Apparatus according to any preceding claim, including venting means (54) for venting non-condensable gases, and a relief valve (55) connected to the venting means (55) for substantially preventing the venting of working fluid.

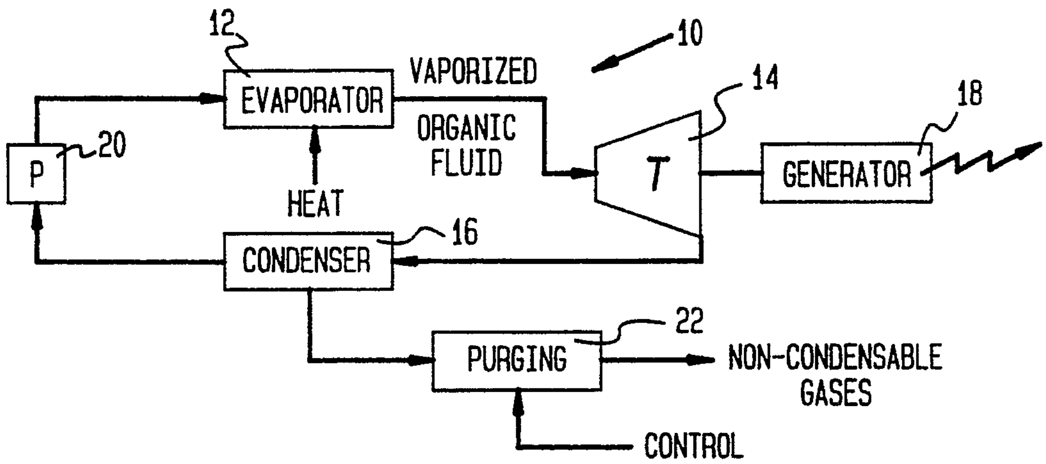
13. A Rankine cycle power plant comprising: a vaporizer (12) for vaporizing an organic working fluid and producing vaporized working fluid; a turbine (14) responsive to vaporized working fluid produced by the vaporizer (12) for producing work and heat-depleted working fluid; a condenser (16) responsive to heat depleted working fluid for condensing the same into a liquid which is returned to the vaporizer (12); and apparatus (22) for purging non-condensable gases from the condenser, the said apparatus (22) being as claimed in any preceding claim.

14. A method for treating fluid in a condenser, which fluid comprises vaporized working fluid and non-condensable gases, the method comprising the steps of:

a) extracting fluid from the condenser; and

b) pressuring the fluid to liquefy working fluid therein, thereby separating working fluid from non-condensable gases.

FIG. 1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GASES
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FIG. 3

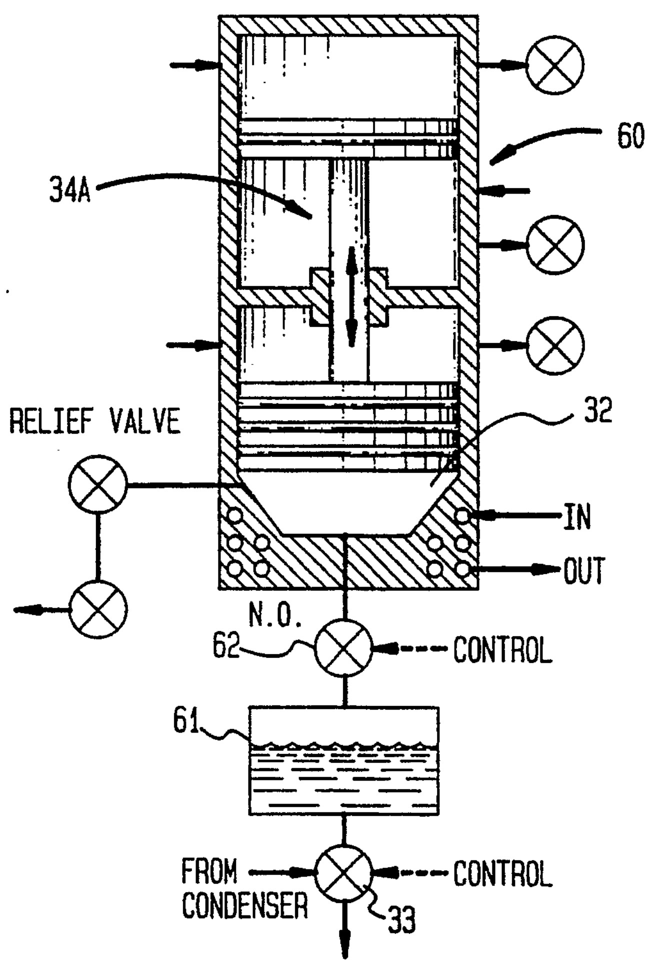
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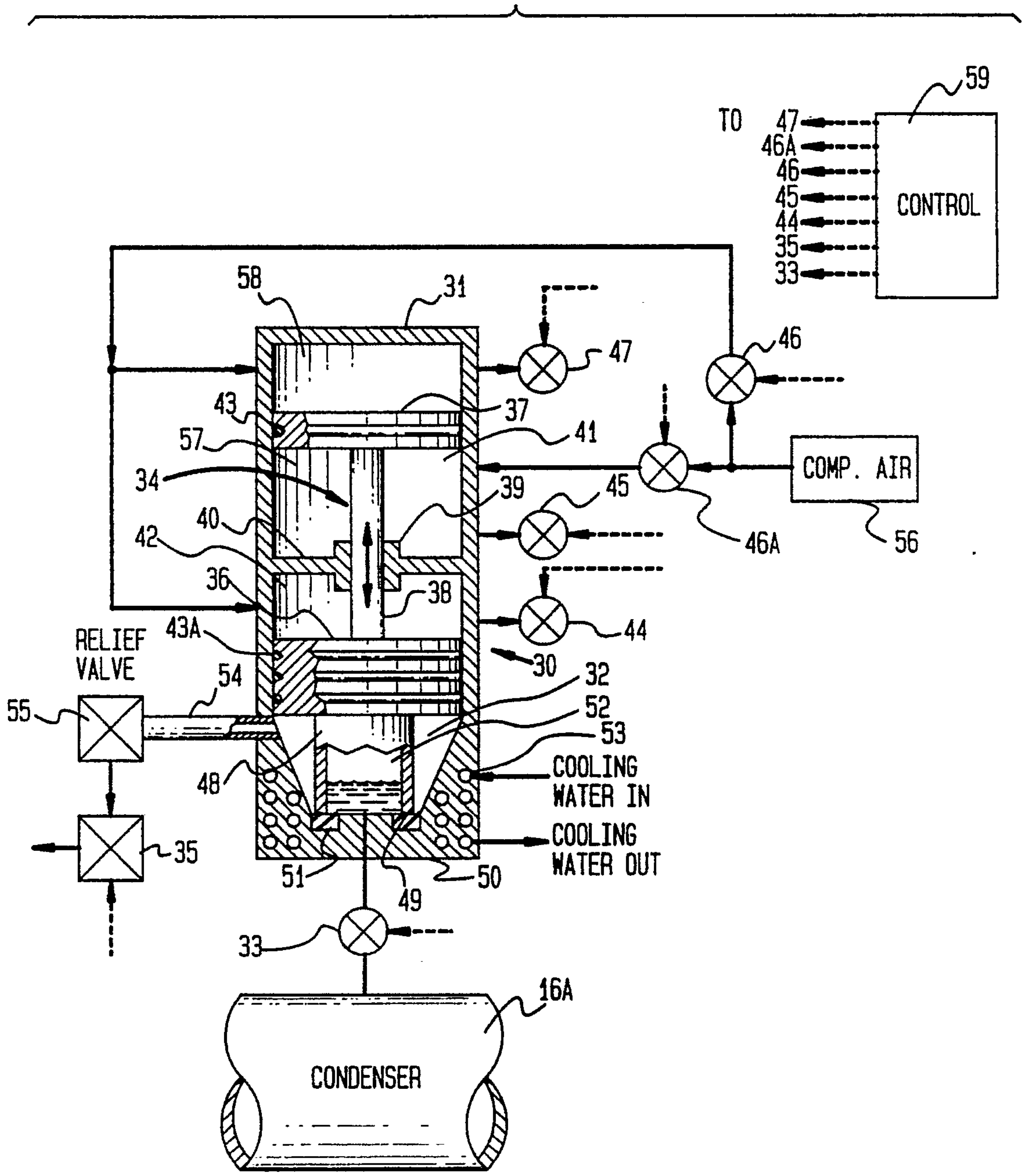
FIG. 2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COOLING
WATER IN
COOLING
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16A
CONDENSER

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EUROPEAN SEARCH REPORT

Application Number

EP 90 30 7065

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	US-A-3 230 729 (EBER) * Column 2, line 60 - column 3, line 17; figure 1 * ---	1,14	F 28 B 9/10
A	US-A-2 598 799 (KIENE) * Column 4, lines 25-62; column 5, lines 16-37; column 6, lines 27-36; figure 1 * ---	1,14	
A	FR-A-2 095 320 (BORG-WARNER CORP.) * Page 3, line 8 - page 5, line 24; figure 1 * ---	1,14	
A	EP-A-0 038 958 (CARRIER CORP.) * Page 3, line 1 - page 6, line 24; figure 1 * ---	1,14	
A	DE-A-1 926 395 (KUNZE) * Page 6, line 20 - page 8, line 28; fig. * -----	1,14	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F 28 B
F 25 B
F 25 B
F 01 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26-09-1990	BELTZUNG F.C.

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