# United States Patent [19]

**Dobney**

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[54] **COMPRESSOR, CONDENSER, EVAPORATOR STRUCTURE**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ........................................ **62/506,** 62/510

[51] **Int. Cl.** ................................................ **F25b 39/04**

[58] **Field of Search** ............. 62/506, 507, 508, 510, 62/115, 218, 219

[56] **References Cited**

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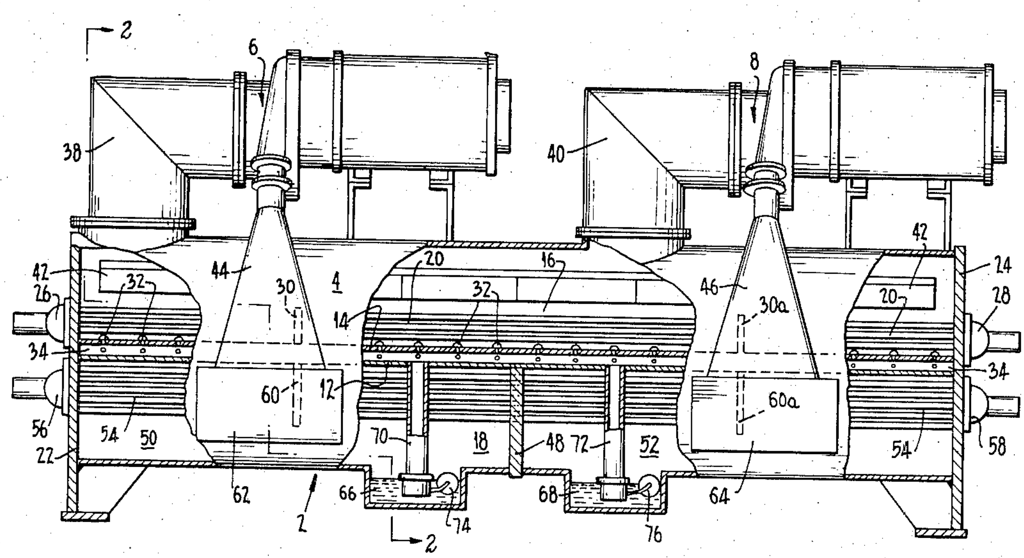
[57] **ABSTRACT**

A refrigeration machine comprising an evaporator and condenser, the condenser being divided into at least two condenser chambers, a separate compressor for each condenser chamber, the inputs of the compressors being in communication with the evaporator and the output of each being in communication with its associated condenser chamber, the division of the condenser affording the advantages of a two condenser machine without the cost of a separate condenser construction.

**10 Claims, 2 Drawing Figures**



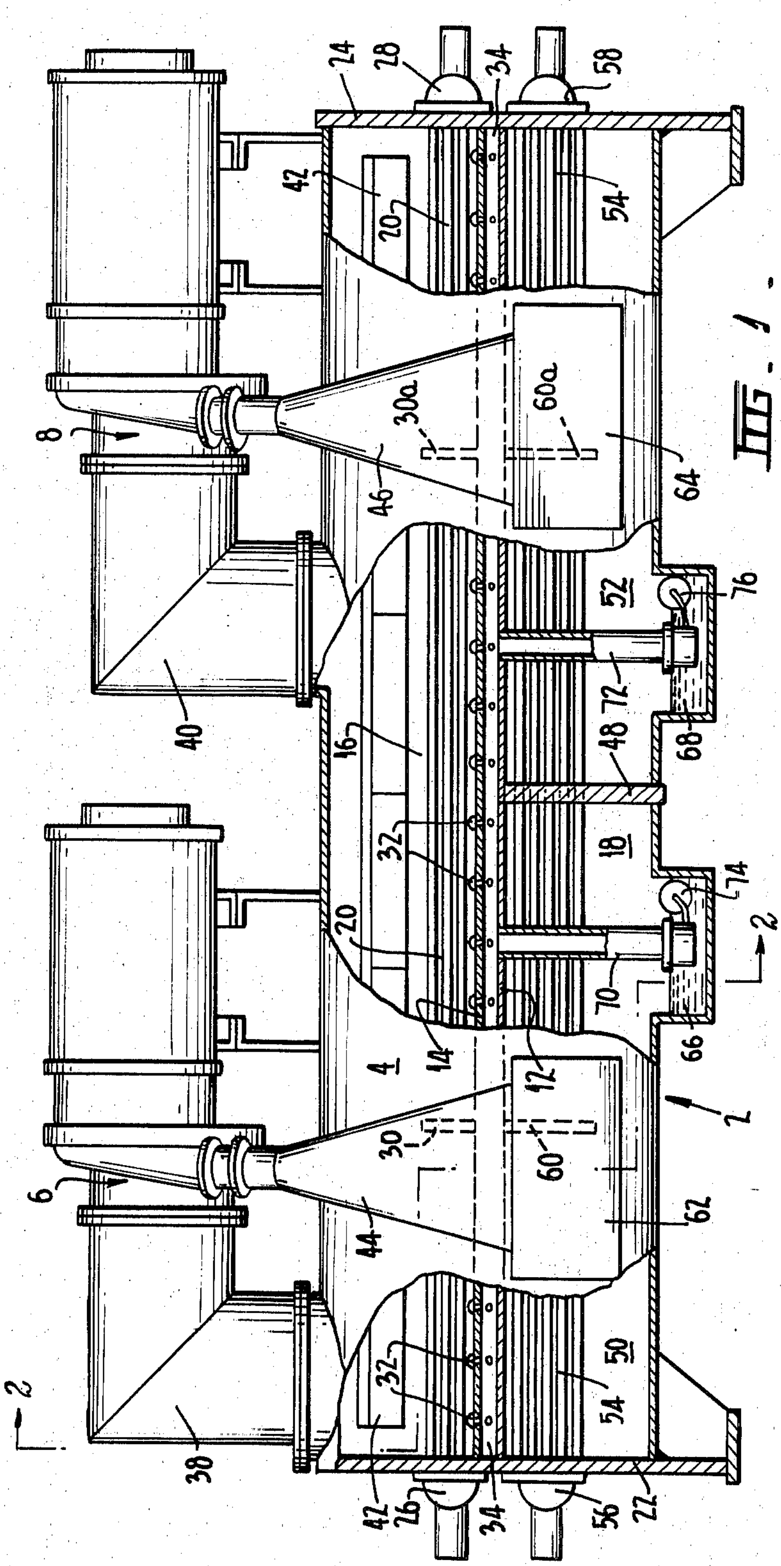


FIG. 1

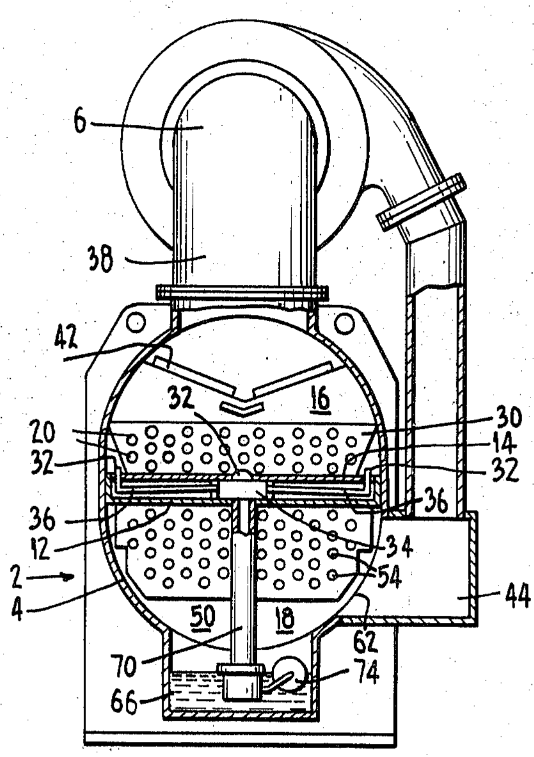



FIG. 2.

# COMPRESSOR, CONDENSER, EVAPORATOR STRUCTURE

## BACKGROUND

This invention relates to refrigeration machines, and in particular to refrigeration machines of the "tube-shell" type. Tube-shell type machines are those wherein the evaporator and condenser compartments are constructed in the form of elongated hollow shell structures with heat transfer tubes extending longitudinally therethrough. The evaporator and condenser compartments may comprise separate shell structures or alternatively the evaporator and condenser compartments may be defined by an insulated dividing wall within a single shell structure.

To increase the capacity of refrigeration machines of the type mentioned above, two compressors may be used in the parallel to enable larger flows of refrigerant gas in the system.

Apart from the advantage of providing greater capacity, the use of two compressors enables controlled load sharing of the compressors to provide for more stable and efficient operation of the machines. Where the proportion of load is low, it is preferable to use a single compressor operating at a relatively high level of load than to use both compressors operating at relatively low load levels because the characteristics of the compressors are poorer at low load levels.

The compressors which are normally used in this type of refrigeration machine are centrifugal compressors which are normally fitted with automatic control means to reduce the gas flow therethrough so that the overall performance of the refrigeration machine may be controlled to meet the load requirements of the machine. It is clear that where the refrigeration machine is used for airconditioning purposes the load requirements will vary according to the prevailing climatic conditions. Therefore in normal use considerable variation in load is to be expected. Unfortunately, the performance curves of the centrifugal compressors is such that when the gas flow is reduced below about 90 percent of the maximum, there is a tendency for the pressure head available from the compressor to be reduced. Thus, when two centrifugal compressors are used in parallel in a refrigeration machine, problems are frequently encountered in operation because the two apparently identical compressors do not have exactly the same characteristics under all conditions of load. In particular, if one compressor is operating at a lower proportion of its capacity then its output pressure head may not equal that of the other compressor, and consequently it it likely to enter a stalled condition. This condition is well known and easily recognised by practitioners in the field and is accompanied by "surge" operation of the stalled compressor which is characterised by intermittent or pulsating operation or complete cessation of refrigerant gas flow. The most serious affect of the pulsating surge condition is a loud rumbling noise which is most undesirable in an air-conditioning application. Other disadvantages in surge operation are peaked loading of the electric supply system if the compressors are electrically powered and the possibility of damage to the impeller blades if the surge conditions are sustained for any significant time. If the compressor becomes completely stalled there is danger of overheating.



To overcome the problems mentioned above it has been proposed to provide separate condenser constructions with associated compressors but this arrangement significantly increases the cost of the apparatus because of the need for two or more separate condenser structures.

## SUMMARY

The main object of this invention is to provide a refrigeration machine of the type referred to having the advantages of two compressors, the construction being such that problem of surge is substantially reduced, and yet the need for separate condenser structures is avoided.

According to the present invention there is provided a refrigeration machine comprising an evaporator and condenser, the condenser being divided into at least two condenser chambers, a separate compressor for each condenser chamber, the inputs of the compressors being in communication with the evaporator and the output of each being in communication with its associated condenser chamber. There may, of course, be two or more condenser compartments with associated compressors, but for most applications two is optimum.

The evaporator and condenser may comprise separate structures, or alternatively comprise a single divided structure, the latter being preferred because of its cheaper construction. The condenser is preferably divided into separate condenser chambers by a baffle or baffles which extend transversely of heat transfer tubes which pass through the condenser. The condenser may be divided by a baffle or baffles which extend in the direction of the heat transfer tubes but in most cases the former arrangement is preferred because normally a two-pass arrangement of tubes is employed and tends to give more equal average temperatures in the condenser chambers and thus more even loading of the compressors when operating in parallel. A similar temperature averaging effect can be achieved in the arrangement where the condenser is divided by a baffle extending in the direction of the heat transfer tubes by having both passes of the two pass tubes within one of the condenser chambers.

In a particularly advantageous form the invention comprises refrigeration apparatus comprising:

an elongated hollow structure divided longitudinally to define evaporator and condenser compartments, first and second heat transfer tubes extending through the evaporator and condenser compartments respectively, two compressors, the inputs of which are in communication with the evaporator compartments and the outputs of which are in communication respectively with separate ones of two separate condenser chambers within the condenser compartment, the chambers being defined by a baffle extending transversely across the condenser compartment to provide substantially gas tight divisions between the chambers, and return means to return condensed refrigerant fluid from each chamber of the condenser compartment to the evaporation compartment.

Preferably, the elongated hollow structure is substantially elliptical in cross-section, and in normal use of the machine, a major axis of the ellipse will be vertical. The evaporator and condenser compartments may be defined by a pair of spaced plates which are located near and parallel to the minor axis of the ellipse at any cross-section along the length of the hollow structure.

Preferably, the two compressors are mounted on the hollow structure and are spaced longitudinally thereon. The compressors may have impellers which rotate about horizontal axes, the inputs of which are in communication with the evaporator compartment through input ports provided in the upper part of the hollow structure, and the first heat transfer tubes are located near the lower part of the evaporator compartment. The outputs of the compressors are preferably in communication with the separate chambers through outlet ports provided in the side of the hollow structure, and the second heat transfer tubes are located in the upper part of the separate chambers. There may be more than two compressors and in this case an equal number of baffles would be required to define separate chambers for the compressors.

## DRAWINGS

A preferred construction of the invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is a fragmentary elevation view of a refrigeration machine in accordance with the present invention, and

FIG. 2 is a fragmentary cross-sectional view taken along the line 2—2 in FIG. 1.

## DESCRIPTION

The refrigeration machine, shown generally by the reference numeral 2, comprises an elongated hollow shell structure 4 and two centrifugal compressors 6 and 8 mounted on the shell structure 4. The shell structure 4 is formed from steel plate and is substantially elliptical in cross-section with the major axis vertical.

The shell structure 4 is divided longitudinally by a pair of spaced parallel plates 12 and 14 to define evaporator and condenser compartments 16 and 18, respectively. The spacing between the plates 12 and 14 provides thermal insulation between the evaporator and condenser compartments 16 and 18. An insulating jacket not shown in the drawings would normally be provided around part of the outer periphery of the shell structure 4 to provide thermal insulation for the evaporator compartment 16. In the illustrated machine, the evaporator compartment 16 is located above the condenser compartment 18 but this is not absolutely necessary. A plurality of spaced, parallel heat transfer tubes 20 extend through the evaporator compartment 16 in a regular array but are located near the lower part of the evaporator compartment 16. The tubes comprise finned or unfinned copper tubing supported at the end walls 22 and 24 of the structure 4. When the refrigeration machine 2 is installed, the heat transfer tubes 20 would form part of a primary heat transfer circuit in which a heat transfer fluid (normally water) is used as a cooling medium. In a typical installation the refrigeration machine 2 would be employed to cool the water which circulates in an air conditioning system. Water is arranged to enter the tubes 20 by means of an inlet manifold 26 and leave by an outlet manifold 28 located adjacent the end walls 22 and 24 of the shell structure 4 respectively. In some circumstances, the heat transfer fluid may be arranged to pass through a number of the tubes 20 before passing through the outlet manifold 28 to return the rest of the primary heat transfer circuit.

It will be appreciated that the tubes 20 when filled with water are quite heavy and additional support may be required at intermediate portions along their length. In the illustrated machine 2, such support is provided by a pair of perforated plates 30 and 30*a* which are mounted upon the plate 14. The tubes 20 pass through an array of perforations provided in the plates 30 and 30*a*.

The heat transfer fluid in the tubes 20 is arranged to be cooled by the agency of evaporating and expanding refrigerant fluid which issues from a plurality of nozzles 32. The nozzles 32 extend longitudinally in three rows along the evaporator compartment 16 adjacent to the plate 16. The refrigerant fluid, in liquid form, is supplied to the nozzles 32 by a supply channel 34 located centrally of and between the plates 12 and 14. One row of nozzles is directly above the supply channel 34 and the other rows are disposed to either side and are supplied with liquid refrigerant by a plurality of tubes 36 which extend laterally from the supply channel 34. The nozzles 32 are arranged to issue the evaporating and expanding refrigerant fluid in a direction generally parallel to the plate 14 to provide better circulation of the refrigerant gas about the heat transfer tubes 20 so that heat can be extracted more effectively from the heat transfer liquid therein. It will be appreciated that a greater volume flow of evaporating and expanding refrigerant fluid in the evaporator compartment will mean that a greater amount of heat will be extracted from the heat transfer fluid in the tubes 20. Therefore the output capacity of the machine can be controlled by controlling the flow of refrigerant fluid to meet the capacity required by the compressors. As mentioned previously, undesirable modes of operation would be encountered if the flow of refrigerant fluid were to be controlled by adjusting the two compressors 6 and 8 independently without the incorporation of a special feature into the condenser compartment to be described later.

The evaporated refrigerant fluid is collected from the evaporator compartment 16 by means of input ducts 38 and 40 to the centrifugal compressors 6 and 8 respectively. In accordance with known practice, an array of eliminator plates 42 is provided to ensure that only refrigerant fluid in the gaseous state and not droplets of refrigerant fluid is allowed to reach the compressor input.

The refrigerant fluid leaving the centrifugal compressors 6 and 8 is discharged into the compressor compartment 18 by means of discharge ducts 44 and 46. An important feature of the present invention is the provision of a partition 48 to effectively divide the condenser compartment 18 into two chambers 50 and 52.

The partition 48 is provided with an array of perforations which correspond with an array of heat conducting tubes 54 which pass through the perforations and are sealed at their peripheries to the partition 48. The discharge ducts 44 and 46 are in communication with the chambers 50 and 52 of the condenser compartment 18 respectively.

The heat conducting tubes 54 are provided in the upper part of the condenser chamber compartment 18 and extend between the end walls 22 and 24 of the shell structure 4. The tubes 54 form part of a secondary heat transfer conduit in which the heat transfer medium is arranged to enter the tubes 54 through an inlet manifold 56 located adjacent the end wall 22 and leave via an outlet manifold 58 located adjacent to the end wall 24. The tubes 54 may comprise finned or unfinned copper tubing supported along their lengths by the end wall 22, a pair of perforated support plates 60, 60*a*, the partition 48, and the end wall 24.

As is best seen in FIG. 2, the discharge ducts 44 and 46 are in communication with the respective chambers 50 and 52 of the condenser 18 by means of openings 62 and 64 in the side of the shell structure 4. The refrigerant fluid discharged from the discharge ducts 44 and 46 is at a relatively higher temperature because of the compression process and is arranged to circulate about the tubes 54 so that the heat transfer fluid in the secondary circuit absorbs heat from the refrigerant gas. The secondary circuit usually includes an atmospheric heat sink for dissipating unwanted heat. The refrigerant fluid after losing sufficient heat, will then condense on the tubes 54 or on the inside of the peripheral walls of the chambers 50 and 52. The condensed refrigerant fluid is then allowed to drain into refrigerant sumps 66 and 68. Supply tubes 70 and 72 are provided to allow liquid refrigerant fluid to pass therethrough from the sumps to the supply channel 34 from where it is free to issue from the rows of nozzles 32. The flow of refrigerant through the supply tubes 70, 72 is controlled respectively by float valves 74, 76, the operation of which is controlled by the level of refrigerant fluid in the sumps.

It is not essential that the partition 48 affords an absolutely gas tight seal between the two chambers 50 and 52. Thus, if the seal between the compartments 50 and 52 is imperfect, and compressors 6 and 8 are operating under different load conditions, then it is quite probable that the pressure in the chambers 50 and 52 will differ and consequently there will be some flow of refrigerant fluid between the chambers. But the amount of refrigerant fluid flow between the two chambers will, in practice, be insignificant compared to the amount of refrigerant fluid in the refrigeration machine which is likely to be very large, and, in addition, the pressures attained (depending on the refrigerant gas used) in the condenser chambers are only of the order of about 9 or 10 lbs. per sq. inch (gauge pressure) and thus a large pressure differential is unlikely. Where the two compressors 6 and 8 are set to operate to share equally the load, the existence of a small refrigerant fluid flow from one chamber to the other can be considered advantageous because this will have a tendency to more evenly distribute the loading between the two condensers. It would be difficult, in practice, to ensure perfectly gas tight sealing at the places where the tubes 54 pass through the baffle 48 but as mentioned previously some gas leakage can be tolerated. The main effect of providing the baffle 48 to divide the condenser compartment 18 into two separate chambers is that the pressure in one chamber is essentially independent from the pressure in the other chamber, and therefore operation of one compressor is substantially independent from the operation of the other. Thus, the likelihood of one of the compressors stalling is substantially reduced.

Although the invention has been described with reference to a single embodiment only, it will be understood that the scope of the invention is not limited thereto. Many modifications will be apparent to those skilled in the field without substantially departing from the spirit and scope of the invention. For instance, in the embodiment described, the primary and secondary heat transfer circuits are only "single pass," i.e. the heat transfer fluid travels the length of the evaporation and condenser compartments once respectively and clearly they could be arranged to make multiple passes in accordance with known practice.

We claim:

**1.** A refrigeration machine comprising evaporator and condenser compartments; first and second heat transfer tubes extending through the evaporator and condenser compartments, respectively; baffle means extending transversely across the condenser compartment and sealed to the second heat transfer tubes to form substantially gas-tight divisions defining separate condenser chambers within the condenser compartment; two compressors each having an input and an output, the respective inputs of the two compressors being in communication with the evaporator compartment, the outputs of the two compressors being in communication, respectively, with separate ones of the two separate condenser chambers; and return means for returning condensed refrigerant fluid from each condenser chamber to the evaporator compartment.

**2.** A machine as claimed in claim 1 wherein the evaporator compartment is above the condenser compartment.

**3.** A machine according to claim 1 including an elongated structure having a hollow interior, and means for dividing the hollow interior longitudinally to define evaporator and condenser compartments within the hollow structure.

**4.** A machine as claimed in claim 3 wherein the hollow structure is substantially elliptical in cross-section with the major axis vertical, the means for dividing the hollow structure being in a horizontal plane which includes the minor axis of the hollow structure.

**5.** A machine as claimed in claim 4 including spaced apart, generally parallel upper and lower longitudinal plates for dividing the hollow structure into the evaporator and condenser compartments, the space above the upper plate being the evaporator compartment and the space beneath the lower plate being the condenser compartment, the area between the upper and lower plates being a hollow space for serving as a duct for condensed refrigerant fluid being returned to the evaporator compartment by the return means.

**6.** A machine as claimed in claim 5 including separate means to return condensed refrigerant fluid from the separate condenser chambers to the evaporator compartment.

**7.** A machine as claimed in claim 6 in which each separate return means delivers condensed refrigerant fluid to the hollow spapce between the plates.

**8.** A machine as claimed in claim 7 a series of tubes which, on the upper side of the plate, are terminated with a series of nozzles to discharge condensed refrigerant fluid to the evaporator compartment.

**9.** A machine as claimed in claim 1 wherein the two compressors are of substantially equal capacity and the baffle means extends through a medial plane of the condenser compartment, whereby the two separate condenser chambers are substantially equal in volume, and including an equal number of second heat transfer tubes extending through each of the two separate condenser chambers.

**10.** A machine according to claim 1 in which the baffle means divides the condenser compartment into condenser chambers of substantially equal size.

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# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,859,820 Dated January 14, 1975

Inventor(s) WILLIAM EDWIN DOBNEY

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 6, line 6 (Claim 1, line 1) after "comprising" insert -- separate --.

Col. 6, line 51 (Claim 7, line 3) "spapce" should read -- space --.

**Signed and Sealed this**

*fourth* **Day of** *May 1976*

[SEAL]

*Attest:*

**RUTH C. MASON**
*Attesting Officer*

**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*