May 8, 1962 S. RUPPRIGHT 3,033,440

COOLING DEVICE FOR ELECTRONIC APPARATUS

Filed June 25, 1958 2 Sheets-Sheet 1

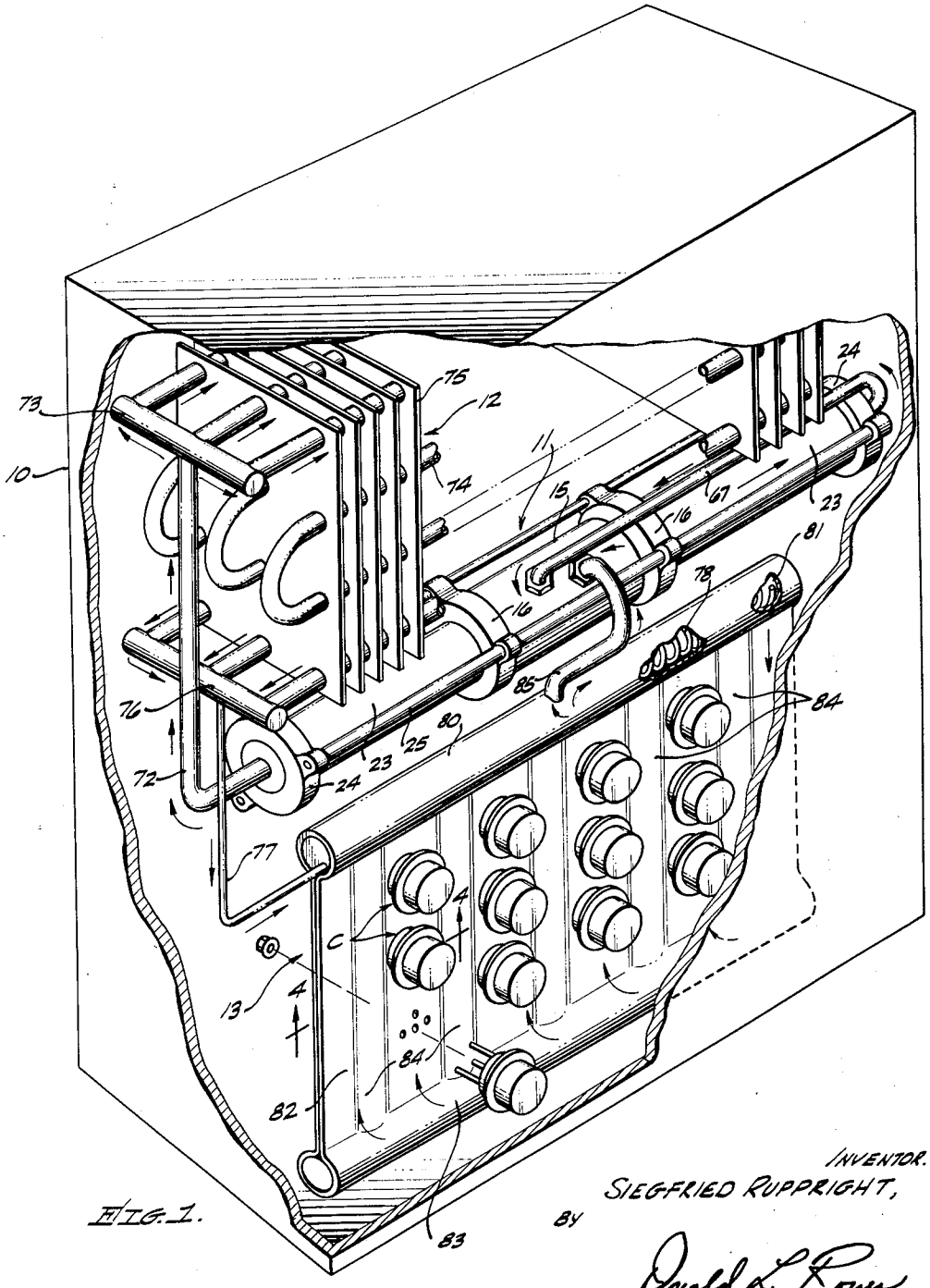


FIG. 1.

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COOLING DEVICE FOR ELECTRONIC APPARATUS

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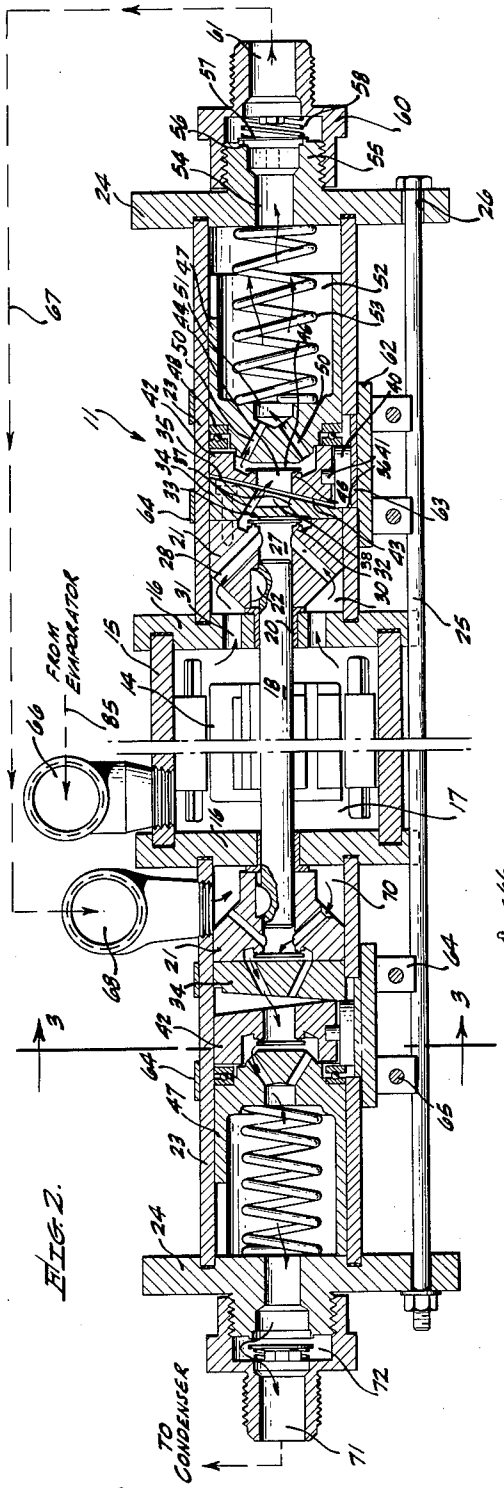


FIG. 2.

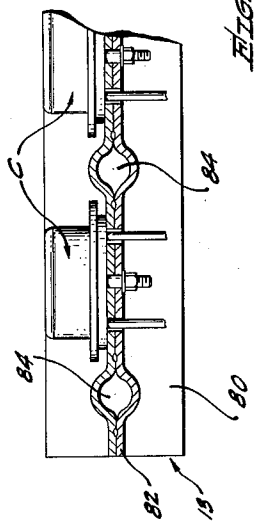


FIG. 4.

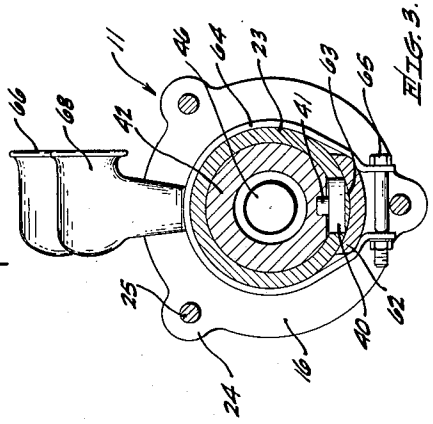


FIG. 3.

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United States Patent Office 3,033,440 Patented May 8, 1962

3,033,440 COOLING DEVICE FOR ELECTRONIC APPARATUS

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Filed June 25, 1958, Ser. No. 745,800
6 Claims. (Cl. 230—45)

The present invention relates to a cooling device for an electronic apparatus and relates more particularly to a refrigerating mechanism and system including improved compressor means in combination and cooperation with a cold plate type evaporator. The present refrigeration system or cooling device is of the vapor cycle type, employing relatively standard over-all system characteristics with substantial improvements therein.

For proper operation of certain electronic devices such as, for example, transistors and the like, it is necessary that waste heat be removed to maintain such devices at a temperature of approximately 50° F. Such cooling of these electronic devices may be accomplished in a variety of ways including the use of both air and vapor cycles refrigeration equipment. However, air cycle types of refrigeration equipment are cumbersome and require not only a source of high pressure air but also a large space to enclose the equipment and the driving means therefor. In vapor cycle systems such as those used in household refrigerators and the like, greater efficiency is available coupled with reduced space requirements. However, contemporary vapor cycle refrigeration systems are still relatively large and cannot normally be disposed and operated within the space to be cooled.

It has been found that the most efficient type of cooling for electronic structures resides in the use of a heat sink type plate wherein electronic components are mounted directly on the plate, the waste heat therefrom being conducted through the plate and away through a suitable refrigerant. In order that the refrigeration unit and system may be as small as possible to accomplish the desired cooling, it is necessary that increased efficiency be obtained not only in the system but in all of the component parts thereof. For example, the compressor and the evaporator, together with the condenser, must be such as to operate efficiently and enable disposition within limited available space; must operate in any position; and must operate with low power consumption to provide the desired spot cooling for parts of an electronic equipment assembly, as a package within a larger assembly.

Accordingly, not only are the size and weight factors important considerations but also power consumption and unit efficiency must be considered. For these purposes the present invention includes a compressor that is internally cooled and thus thermally insulated to enable location at any desired position and even within the refrigerated space. The particular compressor employed herewith employs a construction which disposes both the cylinder and motor axes in continuous alignment and with a liquid refrigerant flowing from one end to the other without a change of direction within the compressor. Furthermore, the compressor hereof employs multiple compression stage mechanism wherein a piston is directly operated by a wobble plate and in a free flowing manner to eliminate dangers heretofore encountered and damage to compressor units from entrained liquids. The actual amount of stroke of the compressor can be altered by merely exchanging a small number of internal parts thereof and the rate of this stroke and thus the power consumption within the stroke of the piston is controlled in such a manner as to reduce or eliminate liquid fluctuations, thus avoiding a disturbing reaction in the power supply. Smooth operation is therefore obtained that has not heretofore been possible with reciprocating type compressors.

It is accordingly one object of the present invention to provide an improved refrigerating system.

It is another object of the invention to provide a cooling apparatus for electronic components that includes an efficiently operable compressor in conjunction with an improved system for use therewith.

It is still another object of the invention to provide a refrigerating system, including an inline, multiple stage, common axis type compressor.

A further object of the invention is to provide a cooling apparatus for electronic components employing a cold plate type evaporator and improved means for delivering a refrigerant to the evaporator.

It is a still further object of the invention to provide a cooling apparatus for electronic components wherein a refrigerant is reliquified for delivery to elements of an evaporator and is thereafter used as not only a cooling medium within the evaporator but also regeneratively as a means for maintaining the liquid-gas position within passage means extending between the condenser and the evaporator.

Other and further important objects of the invention will become apparent from the disclosures of the following detailed specification, appended claims and accompanying drawings, wherein:

FIGURE 1 is a perspective view showing the present refrigerating system as enclosed within a suitable container and including the electronic components to be cooled;

FIG. 2 is a longitudinal sectional view through the compressor employed herewith;

FIG. 3 is a transverse sectional view through a portion of the compressor and taken substantially as indicated by line 3—3, FIG. 2; and

FIG. 4 is an enlarged fragmentary sectional view through a portion of the evaporator and taken substantially as indicated by line 4—4, FIG. 1.

With reference to the drawings, the refrigeration device, including the cold plate type evaporator and electronic components mounted thereon, is adapted for disposition in a suitable container or housing **10**. The housing **10** may be of any desired configuration to accommodate both the elements of the refrigeration system and establish the space requirements necessary for the system and the container in the place desired. In actual practice, it is common to employ large frame structures or consoles for containing electronic assemblies of mechanisms such as computers and the like, with these assemblies being positioned in drawers or removable panels. In such an instance it is advantageous to locate the present refrigeration system in one of such drawers or containers.

In general, the refrigeration system hereof includes a compressor **11**, a condenser **12** and an evaporator **13**, together with suitable passage means and conduits interconnecting such units.

The compressor **11** is shown in detail in FIGS. 2 and 3 and is of the multiple stage, double acting type. Each of the end portions thereof is substantially identical, with components thereof being shown in different operating positions. Accordingly, only one end portion, comprising two stages of the compressor, will be described in detail with the other portions being similar in construction although positioned in such a manner as to permit progressive compression of a refrigerant.

As shown, the compressor **11** is of an axial type deriving motive power from an electric motor **14**. The motor **14** is disposed within an annular housing **15** having end plates **16**. The housing **15** and end plates **16** de-

fine a chamber 17 about the motor 14. The motor 14 has an axial shaft 18 that extends laterally from each side thereof and through bearings 20 in the end plate 16. Each end of the shaft 18 is adapted to drive compressor elements located respectively in each longitudinal end of the compressor 11. As stated hereinbefore, inasmuch as the compressor elements are substantially identical on each end of the compressor 11, only one end thereof will be described with reference being made to single elements, it being understood that such reference includes the similar structures at each end of the device. In this connection it is to be understood that, in the present refrigerating system, a compressor embodying components contained in only one end portion thereof may be utilized without departing from the spirit and scope hereof.

The end of the shaft 18 is connected to a rotary cylinder head 21 and secured thereto by means of a key 22. This cylinder head 21 is adapted for disposition and rotation within a cylinder 23 that is, in turn, disposed between one of the end plates 16 and an end plate 24. The end plates 24, together with the cylinders 23, end plate 16 and annular housing 15, are secured together by means of longitudinally extending rods 25 which are disposed through suitable openings 26 in the end plates 24 and engage outer surfaces thereof. The rotary cylinder head 21 has an axial passage 27 therein and lateral passages 28 which communicate with a space 30 between one end of the head 21 and an inner surface of the cylinder 23. Communication is provided between the chamber 17 in the space 30 by means of passages 31 through one of the end walls 16. The cylinder head 21 also has an annular valve seat 32 formed thereon that is of magnetic material and cooperates with a valve disc 33 to bias the disc toward the seat. In the compressor 11 of this invention, there are several magnetic type check valves, of the type defined by the seat 32 and disc 33, that are employed herein. These check valves are of the type defined in my copending application, Serial Number 711,997, filed January 29, 1958, now Patent No. 2,949,931. This type of check valve is such as to bias a valve disc toward a valve seat through magnetic attraction.

The rotary cylinder head 21 has a wobble plate 34 secured thereto. One side of the wobble plate 34 provides a backup for the valve disc 33 and is further beveled as at 35 for a purpose to be hereinafter more fully described. The wobble plate 34 is further provided with an annular race 36 located on an axially directed surface thereof and adjacent the periphery of the wobble plate 34. The wobble plate 34 is further provided with lateral passages 37 that communicate with an axial passage 38 therein. Other ends of the passages 37 communicate with an annular passage surrounding the valve seat 32 in the cylinder head 21.

It is to be noted that the race 36 may be defined as a cam surface that is adapted for engagement by a thrust roller 40. The roller 40 has a shaft 41 that is rotatably journalled in a head 42 of a piston. The axis of the roller 40 and shaft 41 is disposed normal to the axis of the shaft 18. The head 42 has a beveled surface 43 that is adapted for cooperation with the surface 35 of the wobble plate 34. The head 42 is also provided with an axial passage 44 and carries a valve seat 45 which magnetically cooperates with a valve disc 46. The magnetic attraction of the valve seat 45 serves to bias the disc 46 towards a closed position.

A piston 47 is positioned adjacent the head 42 and carries a thrust bearing 48 that is adapted for engagement and cooperation with the thrust roller 40. The transverse head of the piston 47 has a plurality of lateral passages 50 therein which communicate with an axial passage 51 and with a chamber 52 within the confines of the piston 47 and end of the cylinder 23. The piston 47 and the head 42 are retained in cooperative relationship with each other by means of a compression spring 53 that is disposed between an inner surface of one end of the piston 47 and an inner surface of the end wall 24.

As shown, the end wall 24 is provided with an axial opening 54 therein which communicates with the chamber 52 and extends through a threaded boss 55 which in in turn carries a valve seat 56 that has a valve disc 57 positioned in cooperation therewith and biased toward the seat 56 by means of a compression spring 58. A fitting 60 threadably engages the boss 55 and supports one end of the compression spring 58 to provide an outlet 61 from the compressor.

It is to be noted that the thrust roller 40 is covered by a cover member 62 and an insert plate 63. A pair of straps 64, that are secured together by means of bolt and nut combinations 65, serve to retain the cover member 62 and insert plate 63 in position.

In operation of the compressor 11, the refrigerant is delivered thereto through a port 66 and into the chamber 17. As the motor 14 rotates the shaft 18, the cylinder head 21 and wobble plate 34 will be rotated, thus to move the piston 47 and head 42 axially against the compression of the spring 53 and through interaction between the race 36, thrust roller 40 and thrust bearing 48. Thus, a resulting variable space will be established between the surface 35 of the wobble plate 34 and the surface 43 of the head 42 to produce a normally evacuated area which serves to draw the refrigerant from the chamber 17 through the openings 31 and passages 28, through the check valve disc 33, through the passages 37 and into the space defined between the surfaces 35 and 43. Additionally, as the piston 47 is moved axially, the chamber 52 within the confines of the piston 47 and an end of the cylinder 23 is reduced in volume, whereby to force the refrigerant contained in the chamber 52 outwardly through the check valve, defined by the valve disc 57, and outwardly from the compressor. The piston 47 therefore acts as a second stage for compression of the refrigerant and, upon rotation of the cylinder head 21 and wobble plate 34 to the position shown in the rightward end of FIG. 2, a reduced pressure will be established in the chamber 52, whereby to permit acceptance of the refrigerant contained between the surfaces 35 and 43 as this refrigerant is forced outwardly therefrom, past the valve disc 46 and through the passages 50 and 51. The fact that the chamber 52 is expanding as the area between the surfaces 35 and 43 is decreasing, serves to facilitate discharge of the refrigerant from between the wobble plate 35 and head 42. Thus, the spring 53 need be only a lighter spring than would seem to be necessary and reduced torque of the motor 14 may be used together with less energy requirement for driving the compressor. This energy requirement is particularly reduced during the first one half stroke rotation of the cylinder head 21, there being less possible energy return during the second one half stroke, thus resulting in a smooth electrical load on a power source.

From the discharge or outlet port 61 of the compressor 11, the refrigerant is carried by means of a conduit 67 to an inlet fitting 68 of the two stage compressor portion shown in the leftward end of the compressor illustrated in FIG. 2. The refrigerant is delivered to an annular space 70 about the leftward cylinder head 21 and passes through the leftward wobble plate 34, head 42 and piston 47, thereafter to be delivered outwardly through a port 71 and past a suitable check valve 72. From the port 71, the compressed refrigerant is delivered by way of a conduit 72 to a suitable manifold 73 forming a portion of the condenser 12. It is to be understood that the refrigerant may be delivered directly to the manifold 73 from the outlet port 61.

The condenser 12 is of the multiple fin type having coiled tubing 74 and fins 75. The coiled tubing 74 terminates in an exit manifold 76 from which a capillary tube 77 extends. The capillary tube 77 has a terminal portion that is tightly coiled as at 78 and disposed within

a manifold **80** forming an upper edge portion of the evaporator **13**. An end **81** of the coiled portion **78** of the capillary tube **77** is disposed within the manifold **80** adjacent one end thereof.

The evaporator **13** is in the form of a cold plate on which a plurality of electronic components C may be mounted. Components C may be in the form of transistors or the like that are adapted to be cooled and are connected to any suitable electrical system as desired. The evaporator **13** includes a plate portion **82** that may be made from substantially identical side elements that are joined to or formed in conjunction with the manifold **80**. A second manifold **83** forms a lower gravitational portion of the evaporator **13**, there being a plurality of passageways **84** within the plate portion **82** that communicate between the manifolds **80** and **83**. The manifold **80** is connected to the inlet **66** of the compressor **11** by means of a conduit **85**.

It is to be noted that the coiled portion **78** of the capillary tube **77** is disposed in heat exchange relationship with the refrigerant in the evaporator **13**. This refrigerant passes from the end **81** of the coiled portion **78**, downwardly through the plate portion **82** through an end passage therein, into the manifold **83** and upwardly through the balance of the passages **84** into the manifold **80**.

The refrigerant employed herein may be that commonly known as Freon having a relatively low boiling point and is adapted to leave the compressor and reside in the condenser at a pressure of approximately 108 p.s.i. wherein the boiling point will be approximately 95° F. In the evaporator, the refrigerant will be at approximately 46 p.s.i. and a boiling point of approximately 50° F., there being the pressure drop in the capillary tube **77** and coiled portion **78** thereof. The capillary tube **77** acts as a metering device to meter the refrigerant in an amount that is equivalent to that removed from the evaporator to the compressor. The refrigerant is maintained as a liquid within the capillary tube **77** and coiled portion **78**, evaporation thereof taking place within the evaporator **13** and outside of the coiled portion **78** of the capillary tube **77**, rather than within the capillary tube as is normally experienced in similar prior structures. The particular length of the capillary tube, its diameter, together with the shape of the coiled portion **78** are all variables that are available to designers of equipment of this type to enable the desired performance. By disposition of the coiled portion **78** within the manifold **80** and in the particular relationship with the evaporator **13**, the liquid state of the refrigerant is maintained and the proportion of liquid and gas that may otherwise be present in the capillary tube does not present a problem herein. Thus efficient operation of the present refrigerating device may be maintained and efficient removal of heat from the components C may be accomplished through use of a minimum amount of equipment that is efficiently operating and which requires a relatively low amount of energy in the total operation thereof. Since the particular compressor requires neither a crank nor connecting rods, as in other similar reciprocating devices, it may be seen that this device may be inexpensively manufactured and inexpensively operated.

With further reference to the capillary tube **77**, in view of the fact that the condenser of this system may be cooled by air at different temperatures depending upon the time of day, source and other factors, and further due to the fact that at the same time the electric load on the cold plate portion of the evaporator may operate over a wide range, such a capillary tube, even if placed in heat exchange relationship with the conduit **85** will still be unsatisfactory during a portion of these conditions. Thus, this invention overcomes any disadvantage that may be encountered through use of the capillary tube **77** with the amount of liquid passing through the capillary tube being a function of the differences existing at the time between the condenser and evaporator pressures and the resistance encountered in the capillary tube. This capillary tube resistance to flow varies widely when flash gas appears therein. When the condenser is at an elevated temperature, the first amount of gas would normally appear near the condenser end of the capillary tube which would result in a high resistance to flow and thus a low quantity feed of liquid in spite of a high pressure differential. This condition causes a collection of liquid in the condenser and a low level of liquid in the evaporator and, accordingly a requirement for larger refrigerating equipment than is needed through use of the present device and capillary tube arrangement. The present device therefore utilizes a very short length of straight capillary tube and in the event a longer tube is required, the capillary portion of the tube would be limited to the area of the coiled portion.

The placement of a portion of the capillary tube within the evaporator serves to eliminate the formation of flash gas within the capillary tube and thus eliminates the principal variable that would otherwise adversely influence the function of the capillary tube. In other words, the present improved system serves to extend the operational range thereof and/or enables use of a reduced size for the mechanism.

It has been stated that a capillary tube arrangement of the present type removes other advantages of prior systems. In the prior known methods of eliminating the before-mentioned problems, the capillary tube is disposed in heat exchange relationship with the suction tube **85** to warm this suction tube and to eliminate droplets of liquid that may be entrained in the suction gas and which are capable of damaging conventional compressors. The particular compressor set forth herein and the present method of driving the piston during the compression-discharge stroke by a spring, rather than a rigid member, provides a mechanism that is not subject to liquid damage and therefore enables the present composite system including the capillary tube arrangement hereof.

Having thus described the invention and the present embodiment thereof, it is desired to emphasize the fact that many modifications may be resorted to in a manner limited only by a just interpretation of the following claims.

I claim:

1. A compressor comprising, in combination: a housing; a driving motor for said compressor; axially disposed shaft means extending from said driving motor; a wobble plate first stage refrigerant compressing means positioned in said housing and driven by said motor through said shaft means; a second stage piston operated compressing means disposed in said housing, in operative cooperation with said first stage compressing means; said second stage compressing means having a piston and deriving axial motive force by engagement with said first stage compressing means; valve means positioned between said first and second stage compressing means; spring means positioned between said housing and said piston for mechanically biasing said piston operated compressing means into said operative cooperation with said first stage compressing means; and refrigerant inlet and outlet means for said compressor and connected to said housing.

2. A compressor comprising, in combination: a housing; a driving motor for said compressor; axially disposed shaft means extending from said driving motor; a wobble plate first stage refrigerant compressing means positioned in said housing and driven by said motor through said shaft means; a second stage piston operated compressing means disposed in said housing, in operative cooperation with said first stage compressing means, said second stage compressing means having a piston and deriving axial motive force by engagement with said first stage compressing means; valve means positioned between said first and second stage compressing means; spring means positioned between said housing and said piston for mechanically biasing said piston operated compressing means into

said operative cooperation with said first stage compressing means; refrigerant inlet and outlet means for said compressor and connected to said housing; and passage means in said housing and about said driving motor for conducting refrigerant from said inlet of said compressor in heat exchange relationship with said driving motor.

3. A compressor comprising, in combination: a housing; a driving motor for said compressor; axially disposed shaft means extending from said driving motor; a wobble plate first stage refrigerant compressing means positioned in said housing and driven by said motor through said shaft means; a second stage piston operated compressing means disposed in said housing, in operative cooperation with said first stage compressing means, said second stage compressing means having a piston and deriving axial motive force by engagement with said first stage compressing means; magnetically operated check valve means positioned between said first and second stage compressing means; spring means positioned between said housing and said piston for mechanically biasing said piston operated compressing means into said operative cooperation with said first stage compressing means; and refrigerant inlet and outlet means for said compressor and connected to said housing.

4. A compressor comprising, in combination: a housing; a driving motor for said compressor; axially disposed shaft means extending from said driving motor; a rotatable wobble plate first stage refrigerant compressing means positioned in said housing and driven by said motor through said shaft means; a second stage piston operated compressing means disposed in said housing in axially aligned operative cooperation with said first stage compressing means, said second stage compressing means having a piston and deriving reciprocating axial motive force by engagement with said first stage compressing means; magnetically operated check valve means positioned before and between said first and second stage compressing means as oriented by direction of refrigerant flow therethrough; spring means positioned between said housing and said piston for mechanically biasing said piston operated compressing means into said operative cooperation with said first stage compressing means; refrigerant inlet and outlet means for said compressor and connected to said housing; and passage means in said housing and about said driving motor for conducting refrigerant from said inlet of said compressor in heat exchange relationship with said driving motor.

5. A refrigerant compressor comprising, in combination: an elongated casing; a driving motor; a shaft extended from said motor and into said casing; an axially

stable wobble plate secured to said shaft and adapted to be rotated thereby and within said casing; an axially movable, rotationally stable beveled surface plate adapted for contact with said wobble plate; passage means in said wobble plate for conducting a refrigerant to an area between said plates; a piston slidably disposed in said casing and having one end disposed in contact with said beveled surface plate and deriving axial reciprocal movement therefrom; spring means positioned between said casing and said piston for biasing said piston into said contact with said beveled surface plate; passage means in said piston for conducting said refrigerant from said area to a downstream side of said piston; and check valve means carried by said wobble and beveled surface plates and disposed upstream and downstream from said area and in said refrigerant conducting passage means extending to and from said area.

6. A refrigerant compressor comprising, in combination: an elongated casing; a driving motor; a shaft extended from said motor and into said casing; an axially stable wobble plate secured to said shaft and adapted to be rotated thereby and within said casing; an axially movable, rotationally stable beveled surface plate adapted for contact with said wobble plate; passage means in said wobble plate for conducting a refrigerant to an area between said plates; a thrust roller carried by said beveled surface plate; a piston slidably disposed in said casing and having one end disposed in contact with said roller carried by said beveled surface plate and deriving axial reciprocal movement therefrom; spring means positioned between said casing and said piston for biasing said piston into said contact with said beveled surface plate; passage means in said piston for conducting said refrigerant from said area to a downstream side of said piston; and magnetically operated check valve means carried by said wobble and beveled surface plates and disposed upstream and downstream from said area and in said refrigerant conducting passage means extending to and from said area.

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