Nov. 21, 1939. E. R. WOLFERT 2,180,493

REFRIGERATION APPARATUS AND METHOD

Filed April 30, 1938 3 Sheets-Sheet 1

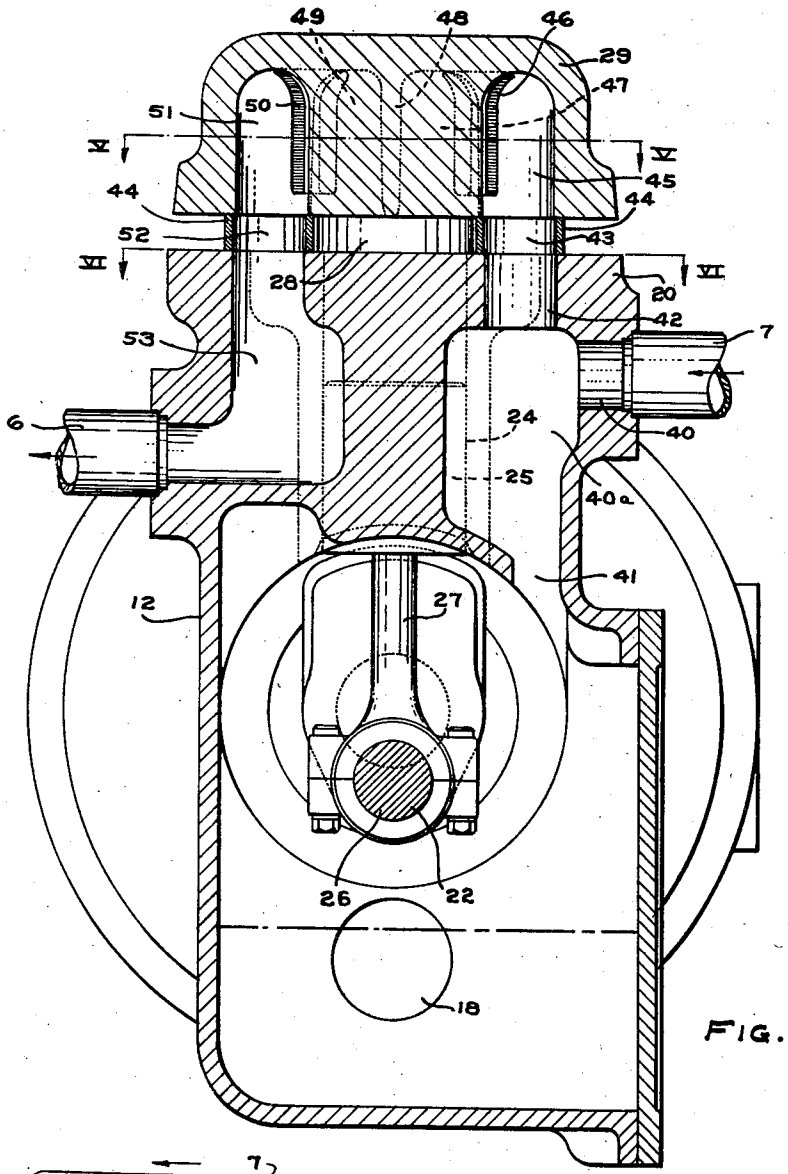


FIG. 2.

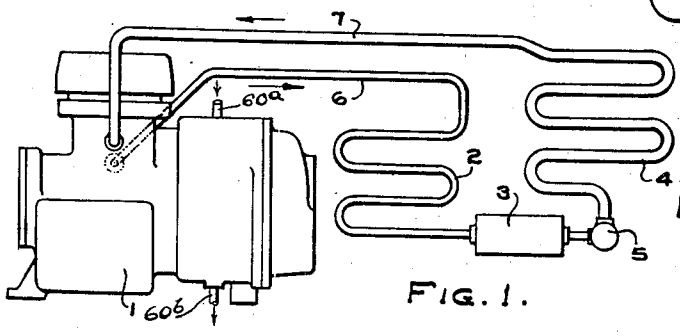


FIG. 1.

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REFRIGERATION APPARATUS AND METHOD

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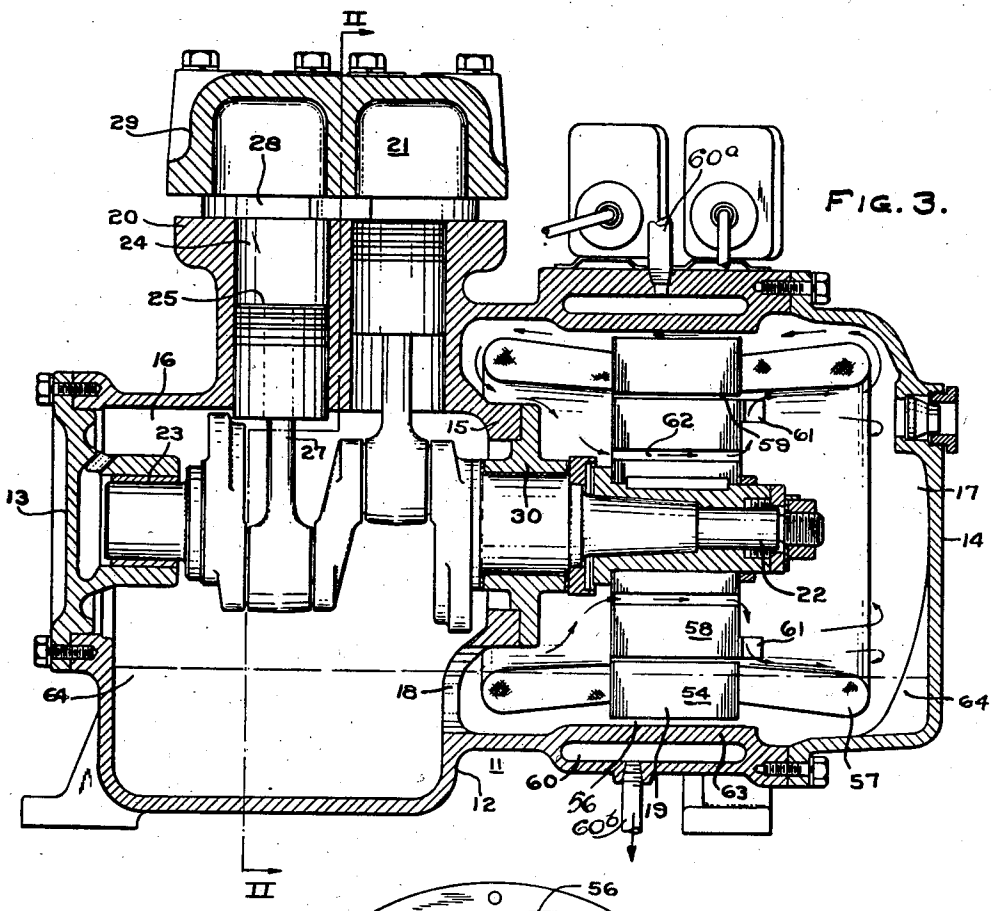


FIG. 3.

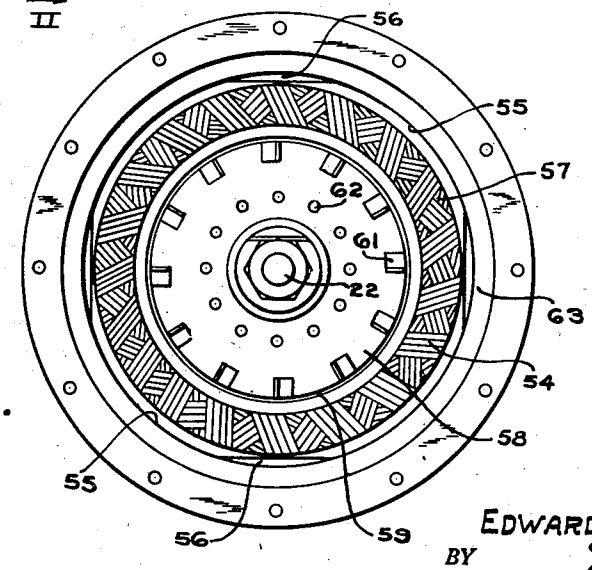


FIG. 4.

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REFRIGERATION APPARATUS AND METHOD

Filed April 30, 1938 3 Sheets-Sheet 3

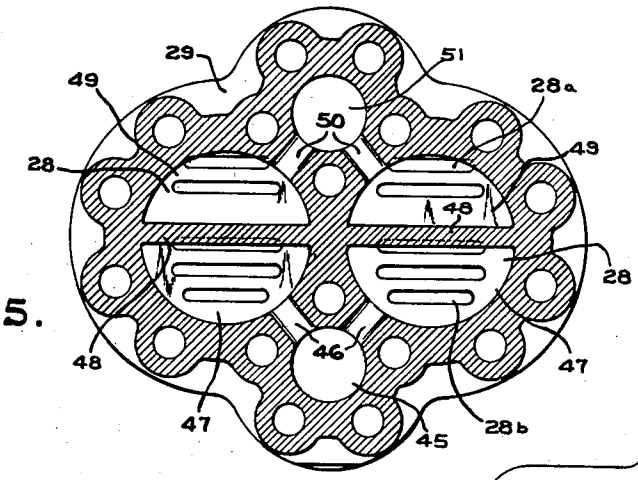


FIG. 5.

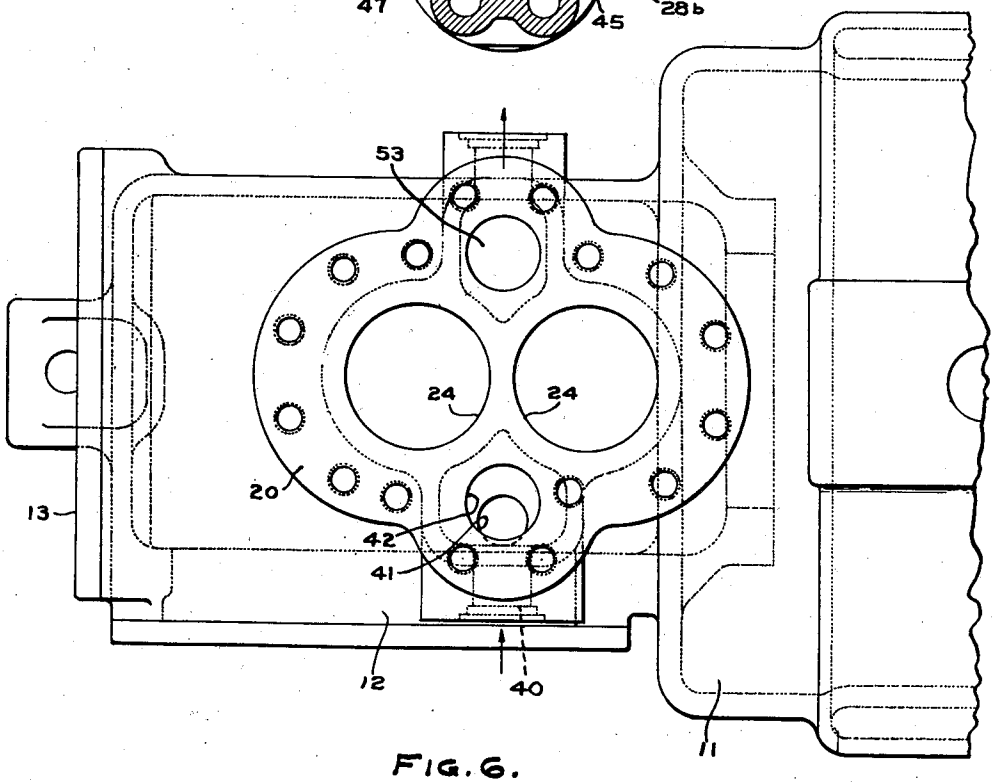


FIG. 6.

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UNITED STATES PATENT OFFICE

2,180,493

REFRIGERATION APPARATUS AND METHOD

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Application April 30, 1938, Serial No. 205,350

15 Claims. (Cl. 62—115)

My invention relates to refrigerating systems and method, and particularly to refrigerating systems wherein the refrigerant compressor and motor for driving the same are enclosed in a fluid-tight casing. This application is a continuation in part of subject-matter divided from my application, Serial No. 98,742, filed August 31, 1936.

It is an object of my invention to provide an improved cooling system for a motor-compressor unit of this type wherein the refrigerant fluid of the refrigerating system is employed as a heat transfer agent for dissipating the heat of the motor.

It is another object of my invention to cool a sealed motor-compressor unit by effecting a forced circulation of cool refrigerant gas over heated portions of the unit.

It is still another object of my invention to convey refrigerant suction gas from the low pressure side of the refrigerating system directly to the compressor and at the same time to maintain an atmosphere of low pressure refrigerant gas in the fluid-tight casing enclosing the motor and compressor.

It is a further object of my invention to vary the cooling effect of the low pressure refrigerant gas which is forcibly circulated in the sealed casing of a motor-compressor unit in proportion to the refrigeration load on the unit, and to also decrease the power required for circulating the gas when the motor-compressor unit is lightly loaded.

These and other objects are effected by my invention, as will be apparent from the following description and claims taken in connection with the accompanying drawings, and forming a part of this application, in which:

Fig. 1 is a diagrammatic view of a closed refrigerating system embodying a sealed motor-compressor unit;

Fig. 2 is a sectional view of the sealed motor-compressor unit taken on line II—II of Fig. 3;

Fig. 3 is a longitudinal sectional view of the motor-compressor unit;

Fig. 4 is a view of the motor end of the motor-compressor unit shown in Figs. 2 and 3, with the end cover plate removed;

Fig. 5 is a sectional view of the cylinder head taken on V—V of Fig. 2; and

Fig. 6 is a top elevational view of a portion of the main casing showing the cylinders and the suction and discharge passages in the crank case.

Referring specifically to the drawings for a detailed description of my invention, in Fig. 1, numeral 1 designates generally a motor-compressor unit which is a part of a closed refrigerating system embodying a condenser 2, a liquid receiver 3 and an evaporator or low pressure side 4, with an expansion valve 5 disposed between the receiver 3 and evaporator 4. A discharge conduit 6 for compressed refrigerant gas and a suction conduit 7 for vaporized refrigerant gas are connected to the condenser 2 and evaporator 4, respectively, and are connected to the motor-compressor unit 1 in a manner hereinafter described in detail. The operation of the refrigerating system is as follows: Refrigerant gas is compressed in the motor-compressor unit 1 and is directed to a condenser 2 through discharge conduit 6. The compressed gas is condensed in the condenser 2 and drains to the liquid receiver 3. Liquid refrigerant passes through the expansion valve 5 and evaporates in the evaporator 4 thus abstracting heat and the vaporized low pressure, low temperature refrigerant gas is then returned to the motor-compressor unit 1 through suction conduit 7, whereupon the cycle is repeated. The system shown is primarily designed for operation at variable refrigeration loads, so that the suction pressure varies considerably, which in turn increases and decreases the amount of work which must be performed by the motor and the compressor.

Referring now to Figs. 2 to 6, numeral 11 designates generally a sealed casing embodying a main frame member 12 and a pair of end closure members 13 and 14. A partition 15 divides the casing into a compressor chamber 16 and a motor chamber 17, which chambers are in free and open communication through a passage 18 in the partition.

A motor, generally indicated at 19, is contained in the motor chamber 17, and a compressor generally designated at 21 is contained in the compressor chamber 16. A drive shaft 22 connects the motor 19 and compressor 21, and bearings 23 and 30 provided in the end cover member 13 and in the partition 15, respectively, support the drive shaft 22.

The compressor 21 comprises a pair of cylinders 24 formed in a cylinder casting 20 cast integrally with the main frame member 12. A pair of pistons 25 are reciprocated in the cylinders 24 by means of crank portions 26 of the shaft 22 and connecting rods 27 which connect the pistons with their respective crank portions of the drive shaft 22. A pair of valve plates, generally indicated at 28 are clamped between the cylinders 24 and a cylinder head 29.

As shown in Fig. 5, the valve plates 28 each

comprises a metal disc having discharge ports 28a and suction ports 28b extending through the disc, which ports are controlled by strips of metal (not shown) retained in the valve plate. The discharge and suction ports are disposed on opposite sides of the vertical center line of the disc for a purpose hereinafter described. The valves used are of the flexible metal strip type and a complete description of the construction and operation of the valves will be found in the patent to Meyer, No. 1,341,145.

As best shown in Figs. 2 and 6, the cylinder casting 20 is provided with an inlet gas passage 40 which is connected to the suction conduit 7 from the evaporator 4. The inlet passage 40 communicates with an oil separating chamber or manifold 40a which in turn communicates with the compressor chamber 16 through a passage 41, and with the cylinder head 29 through a passage 42 in the cylinder casting 20 and through a passage 43 formed by a gasketed ring 44 clamped between the head 29 and the cylinder casting 20. The passage 42 constitutes the refrigerant gas inlet of the compressor referred to in the appended claims. Lubricant separated from the suction gas in chamber 40a drains through passage 41 to a lubricant reservoir 64. The suction gas then passes through a passage 45 in the cylinder head and through passages 46 to the suction chambers 47 of the cylinder head. When the pistons 25 move downwardly, the suction gas passes through the valve plate 26 into the cylinders 24, the discharge ports 28a being closed at this time, and the suction ports 28b being open. The cylinder head 29 is provided with a partition 48 which seats tightly on the valve plate 26 dividing the cylinder head into compression chambers 49 and suction chambers 47, and separating the discharge ports 28a from the suction ports 28b. When the piston 25 moves upwardly in the cylinders 24, the suction ports 28b are closed and the discharge port 28a are open, admitting compressed gas to the compression chamber 49. Discharge gas is then conveyed through passages 50 and 51 in the cylinder head and through a passage 52 also formed by a gasketed ring 44 to a passage 53 in the cylinder casting 20, and thence through the discharge conduit 6 to the condenser 2.

On each compression stroke of the pistons 25, some refrigerant gas may leak past the pistons into the sealed casing 11. However, as the casing is in communication with the suction side of the system through the passage 41, it will be apparent that an atmosphere of gas at substantially suction pressure in the evaporator 4 will prevail throughout the sealed casing 11 since the motor chamber 17 and the compressor chamber 16 are in free and open communication with each other through the passage 18 in the partition 15, as best shown in Fig. 3.

It will be apparent, therefore, that the refrigerant gas present in the sealed casing 11 is supplied thereto from the closed refrigerating system, and is being constantly circulated through the sealed casing. Furthermore, the density of the low pressure gas in the sealed casing always corresponds to the density of the gas in the low pressure side of the system, which is dependent on refrigeration load or suction pressure. However, most of the refrigerant gas returning from the evaporator 4 is conveyed directly to the inlet of the compressor 21 and does not enter the remainder of the sealed casing 11. Therefore, the majority of the suction gas does not come into contact with the hot portions of the motor 19 and compressor 21 which are within the sealed casing. As a result, the suction gas is not superheated and the efficiency of the refrigerating system is materially increased.

Many advantages are gained by maintaining low pressure refrigerant gas in the sealed casing, especially in apparatus of the type disclosed which are usually quite large, from two tons of ice melting equivalent per day, up. For example, less strength is needed for the casing construction. There is less windage loss from the rotor and refrigeration contamination of lubricant in the sealed casing is reduced. Furthermore, with high pressure refrigerant in the sealed casing, the motor temperature must always be above the condensing temperature at that pressure so that refrigerant will not condense in the sealed casing, resulting in contamination of lubricant and possible starving of the evaporator of refrigerant. With low pressure refrigerant gas in the sealed casing, a cooling fluid, such as water, may cool parts of the apparatus to temperatures, for example, below room temperature, in a system utilizing an air cooled condenser, without condensing refrigerant in the sealed casing. It is possible, therefore, to produce more cooling of the apparatus contained in the sealed casing than could be achieved with high pressure gas therein.

The motor 19 comprises a generally polygonally shaped stator 54 which is pressed into the cylindrical motor portion of the main frame 12. As shown in Fig. 4, the stator stampings preferably contact the main frame 12 at four points 55, leaving passages 56 between the stator and the rotor. As will be apparent, any generally polygonally shaped stator will provide the passages 56. Field windings 57 extend from both ends of the stator and are out of contact with the sealed casing 11. The motor is also provided with a rotor 58 which is connected to the drive shaft 22 in any convenient manner. A gap 59 is present between the stator 54 and the rotor 58.

As best shown in Fig. 3, the motor portion of the main frame member is provided with a passage or jacket 60 for cooling water for cooling the motor 19. Cooling water is circulated through the jacket 60 in any suitable manner well understood in the art through water inlet conduit 60a and water outlet conduit 60b.

A large portion of the heat of the motor 19 is transmitted directly to the cooling water in the jacket 60 by conduction through the points of contact 55 of the polygonal stator with the sealed casing 11. However, in machines of this type, it has been found that insufficient cooling of the motor is effected when the above heat transmittal is alone relied upon, as the rotor and the field windings of the stator are remote from the points of contact 55 of the stator 54.

In order to assist in removing heat from the remote portions of the stator 54 and from the rotor 58, the rotor is provided with a fan 61 preferably on one side thereof, and with passages 62 extending through the rotor 58. The fan 61, as shown in Figs. 3 and 4, is formed of a plurality of blades on the end of the rotor 58. The refrigerant gas present in the sealed casing which is derived from the crank case of the compressor is circulated by the fan 61, the arrows in Fig. 1 showing the gas circulation first through the passages 56 between the stator 54 and the inner wall 63 of the sealed casing 11 opposite the water jacket 60, where heat is absorbed from the gas by the cool water in the jacket 60. The cooled

refrigerant gas is then forced over the field windings 57 at the compressor end of the motor, in a parallel path through the passages 62 in the rotor 58 and through the air gap 59, through the fan 61 and over the field windings 57 at the outboard end of the motor 19, thus cooling portions of the stator and rotor. It has been found that, by circulating refrigerant gas, which is substantially at suction pressure, in the above described manner, the motor 19 may be heavily loaded without overheating, since the cooled gas passing over the field windings, through the passages in the rotor and through the air gap absorbs heat from portions of the motor remote from points of contact of the motor and the water-jacketed casing.

As stated hereinbefore, it is an important feature of my invention to proportion the power required by the fan 61, and the cooling effect thereof to the refrigeration load. This may be accomplished by circulating, interiorly of the sealed casing, low pressure gas which varies in pressure with refrigeration load.

The following facts are first pointed out: First, the power input to the fan 61 is proportional to gas density and the gas density of the low pressure gas depends on suction pressure, or refrigeration load. Secondly, the cooling effect or heat transfer rate of the moving stream of gas varies approximately as the .7 power of gas density. Thirdly, the losses taken care of by the fan are largely copper losses, because of the relative isolation of the field windings from the cooled portions of the sealed casing, although this factor is not essential to the premise. If high pressure gas is circulated by the fan 61, particularly in a water-cooled machine, the gas pressure will vary in a ratio of not more than 2 to 1. Furthermore, as the discharge gas pressure varies, the electrical input to the motor 19 changes but little. However, as the suction pressure changes, the electrical input to the motor 19 changes in a ratio of more than 2 to 1, and the copper loss in a typical calculated case varied in a ratio of nearly 4 to 1. Therefore, it is clear, with the fan 61 circulating high pressure refrigerant gas, that it is not responsive to changes in load; rather the fan 61 must be so constructed that with the lowest discharge pressure, and, therefore, with the lowest cooling effect on the motor 19, and with the highest suction pressure, and, therefore, with the highest load on the motor, it must circulate sufficient gas for adequate cooling. Then when load decreases due to reduction in suction pressure, the fan will continue to take substantially as much power as before, because the discharge pressure changes but little, and the power input to the fan is, as stated above, proportional to gas density.

If, however, the fan 61 circulates low pressure refrigerant gas, the pressure of which varies with suction pressure, both the cooling effect and the power input to the fan will increase and decrease with increases and decreases in suction pressure and, therefore, motor load, because the density of the gas and, therefore, the amount of gas by weight circulated varies with suction pressure. In the typical calculated example referred to above, over a range of 5 to 1 change in suction pressure, and, therefore, in cooling effect and power input, the copper losses varied in the aforesaid ratio of about 4 to 1, which clearly illustrates that the fan 61 automatically takes substantially the exact power necessary to do the work required of it. In normal operation after pull-down during starting of the system, the suction pressure varies in about a ratio of 2 to 1. During pull-down it may vary in a ratio of 4 to 1. In either case, however, the copper losses vary in proportion to the suction pressure. For example, the increase in copper losses in one machine operating between suction pressures of 25 pounds per square inch gauge and 47 pounds per square inch gauge, was 44 per cent. Over the same range of suction pressures, the heat transfer rate varies about 55 per cent. It is obvious, therefore, that as the copper losses increase, the cooling effect increases almost in direct proportion thereto.

The lubrication system for the motor-compressor unit is fully described in my copending application, Serial No. 81,032, filed May 21, 1936, for Compression apparatus, and assigned to the Westinghouse Electric & Manufacturing Company.

From the foregoing, it will be apparent that I have provided for an improved cooling system for the heat generating parts of a motor, and particularly for the heat generating parts of a sealed motor-compressor unit for refrigeration applications by circulating refrigerant gas which has been cooled by contact with the cooled casing of the apparatus over the heat generating portions of the apparatus, to cool the latter.

While I have shown my invention in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:

1. In a refrigerating system for variable refrigeration loads, the combination of a compressor, a motor for driving the compressor, said compressor and motor being provided with a fluid-tight enclosing casing, a condenser, an evaporator, means for conveying refrigerant from the compressor to the condenser, means for conveying refrigerant vapor from the evaporator to the compressor, said last-mentioned conveying means communicating with the motor-enclosing portion of said casing, whereby low pressure refrigerant gas at variable pressures dependent upon refrigeration load prevails in the motor-enclosing portion of said casing, and means disposed within said casing and driven by the motor for effecting forced circulation of the low pressure refrigerant gas between the motor and the wall portions of the casing, so that as the motive power to drive said motor increases due to refrigeration load and more heat is present to be dissipated, the cooling effect produced by said circulating means also increases, and vice versa.

2. In a refrigerating system for variable refrigeration loads, the combination of a compressor, a motor for driving the compressor, said compressor and motor being provided with a fluid-tight enclosing casing, a condenser, an evaporator, means for conveying refrigerant from the compressor to the condenser, means for conveying refrigerant vapor from the evaporator to the compressor, said last-mentioned conveying means communicating with the motor-enclosing portion of said casing, means driven by the motor for effecting forced circulation of refrigerant gas at substantially evaporator pressure between the motor and wall portions of the casing, the density of said gas being controlled by refrigera-

tion load, so that the motive power to drive said circulating means and the cooling effect produced by said circulating means both increase with increases in refrigeration load and decrease with decreases in refrigeration load.

3. In a refrigerating machine for variable refrigeration loads, the combination of a compressor, a motor for driving the compressor, a fluid-tight enclosing casing for the motor and compressor, means for conveying a liquid cooling agent in heat-exchange relation with the walls of the sealed casing, a condenser, an evaporator, means for conveying refrigerant from the compressor to the condenser, means for conveying refrigerant vapor from the evaporator to the compressor, said last-mentioned conveying means communicating with the motor-enclosing portion of said casing, whereby low pressure refrigerant gas at variable pressures dependent upon refrigeration load prevails in the motor-enclosing portion of said casing, and means disposed within said casing and driven by the motor for effecting forced circulation of the low pressure refrigerant gas between the motor and the wall portions of the casing, so that as the motive power to drive said motor increases or decreases with changes in refrigeration load, the cooling effect produced by said circulating means also increases or decreases and the power consumed by the circulating means increases or decreases.

4. The method of cooling the motor of a motor-compressor unit contained in a sealed casing in communication with the low pressure side of a refrigerating system operating at variable refrigeration loads, which method comprises circulating, with a circulating device, low pressure refrigerant gas in contact with the motor, and increasing and decreasing the cooling effect of the circulated low pressure refrigerant gas in response to increases and decreases in refrigeration load.

5. The method of cooling the motor of a motor-compressor unit contained in a sealed casing which is in communication with the low pressure side of a refrigerating system operating at variable refrigeration loads, which method comprises circulating, with a circulating device, low pressure refrigerant gas in contact with the motor, and increasing and decreasing the amount by weight of gas circulated and, therefore, its cooling effect in response to increases and decreases in refrigeration load and, therefore, motor load.

6. The method of cooling the motor of a motor-compressor unit contained in a sealed casing which casing is in communication with the low pressure side of a refrigerating system subjected to varying loads and, therefore, varying suction pressures, which method comprises circulating, with a circulating device, low pressure refrigerant gas in contact with heated portions of the motor, and increasing and decreasing the amount of low pressure gas which is circulated in response to changes in suction pressure.

7. The method of cooling the motor of a motor-compressor unit contained in a gas-tight casing, which motor-compressor unit is part of a refrigerating system operating at variable refrigeration loads, which method comprises circulating, with a circulating device, refrigerant gas at substantially the pressure of the low pressure side of the refrigerating system in contact with the motor, whereby the cooling effect of the circulated gas and the power required by the motor vary with the refrigeration load of the refrigerating system.

8. The method of cooling the motor of a motor-compressor unit contained in a gas-tight casing, which motor-compressor unit is a part of a refrigerating system operating at variable refrigeration loads, which method comprises circulating a liquid cooling agent in contact with a wall of the gas-tight casing, and circulating, with a circulating device, refrigerant gas substantially at the pressure of the low pressure side of the refrigerating system in contact with the motor and with said liquid-cooled wall of the sealed casing, whereby the cooling effect of the circulated gas and the power required by the circulating device vary with the refrigeration load of the refrigerating system.

9. The method of cooling the motor of a motor-compressor unit contained in a gas-tight casing, which motor-compressor unit is a part of the refrigerating system operating at variable refrigeration loads, which method comprises circulating a cooling fluid in heat exchange relation with the motor-compressor unit, and circulating, with a circulating device, refrigerant gas substantially at the pressure of the low pressure side of the refrigerating system in heat exchange relation with both the motor and the cooling fluid, whereby the cooling effect of the circulated gas varies with the refrigeration load of the refrigerating system.

10. In a refrigerating system, the combination of an evaporator, a condenser, a compressor for circulating refrigerant gas from the evaporator to the condenser, a motor for driving the compressor, a fluid-tight casing enclosing the motor and the compressor, means for admitting refrigerant gas circulated by the compressor to the motor containing portion of the casing, means for circulating a cooling medium in heat exchanging relation with the motor containing portion of the casing, and means driven by the motor for forcibly circulating refrigerant gas in the casing in heat exchanging relation with said cooling medium and with heated portions of the motor to abstract heat from the latter.

11. In a refrigerating system, the combination of an evaporator, a condenser, a compressor for circulating refrigerant gas from the evaporator to the condenser, a motor for driving the compressor embodying a stator and a rotor with a gap therebetween, a fluid-tight casing enclosing the motor and compressor, means for admitting refrigerant gas circulated by the compressor to the motor-containing portion of the casing, and means driven by the motor for forcing the gas present in said casing through said gap of the motor to absorb heat from the latter.

12. In a refrigerating system, the combination of an evaporator, a condenser, a compressor for circulating refrigerant gas from the evaporator to the condenser, a motor for driving the compressor, a sealed casing for totally enclosing the motor and compressor, a motor compartment in which the motor is disposed and a compressor compartment in which portions of the compressor are disposed, said motor embodying a stator and a rotor, said stator being pressed into the motor portion of the sealed casing and directly contacting portions of the interior surface thereof, said stator being spaced from other portions of the sealed casing to provide for passages extending longitudinally of the stator, said rotor being provided with passages extending longitudinally thereof, means for admitting refrigerant gas circulated by said com-

pressor to the motor compartment of said casing, means for circulating cooling medium in heat exchange relation with the casing, and means driven by the rotor for circulating the refrigerant gas in the casing in heat exchange relation with said cooling medium and through the passages between the stator and the casing and the passages in the rotor to absorb heat from the stator and the rotor.

13. The combination as claimed in claim 12 wherein the sealed casing is in open communication with the evaporator of the refrigerating system whereby refrigerant gas at substantially suction pressure prevails within the sealed casing.

14. In a refrigerating system, the combination of an evaporator, a condenser, a compressor for circulating refrigerant gas from the evaporator to the condenser, a motor comprising a stator and a rotor for driving the compressor, a fluid-tight casing enclosing the motor and the compressor, means providing communication between the inlet of the compressor and the motor-containing portion of said casing, a fluid impelling element carried by said rotor and effecting flow of refrigerant gas from one end of said motor to the other in contact with said stator and back to said one end in contact with said rotor.

15. In a refrigerating system, the combination of an evaporator, a condenser, a compressor for circulating refrigerant gas from the evaporator to the condenser, a motor for driving the compressor, a fluid-tight casing enclosing the motor and the compressor, said motor embodying a stator and a rotor, portions of said stator being disposed in contact with the inner surface of said casing and other portions being spaced from said inner surface to provide refrigerant gas, the portion of said casing adjacent said first-mentioned stator portions and said passages being provided with a cooling water jacket for cooling the motor, means for admitting refrigerant gas circulated by said compressor to the motor containing portion of the casing, and means driven by the rotor for circulating the refrigerant gas in the motor containing portion of the casing through the passages between the casing and the stator to cool the gas and in contact with heated portions of the motor to abstract heat therefrom.

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