Jan. 11, 1949. A. I. PONOMAREFF 2,458,730

REFRIGERANT COMPRESSOR

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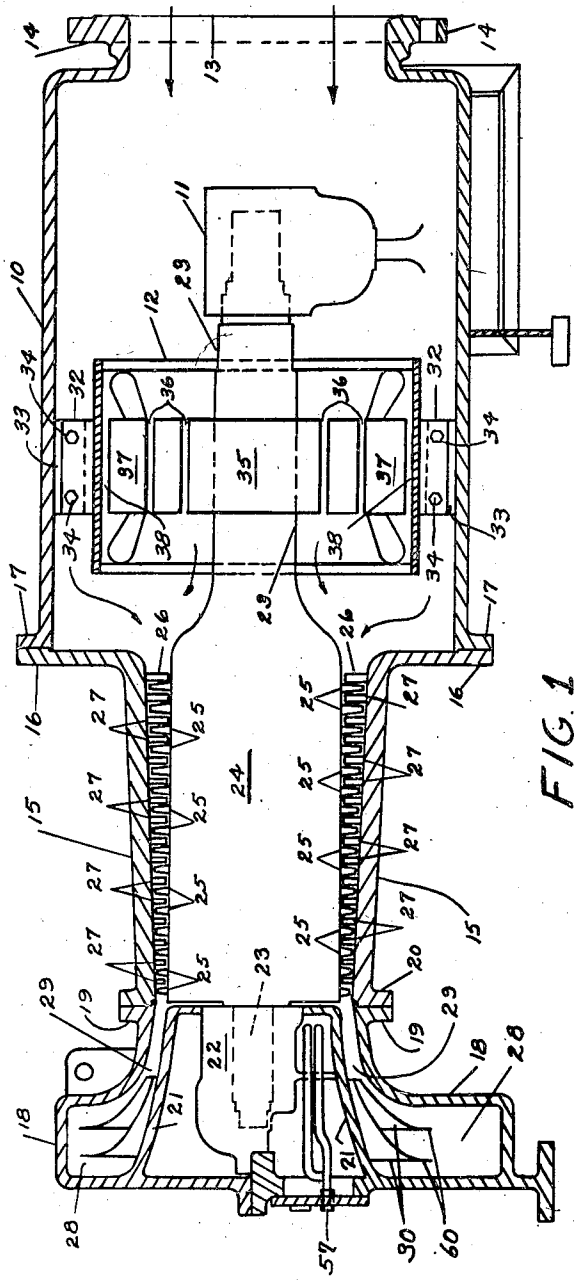


FIG. 1

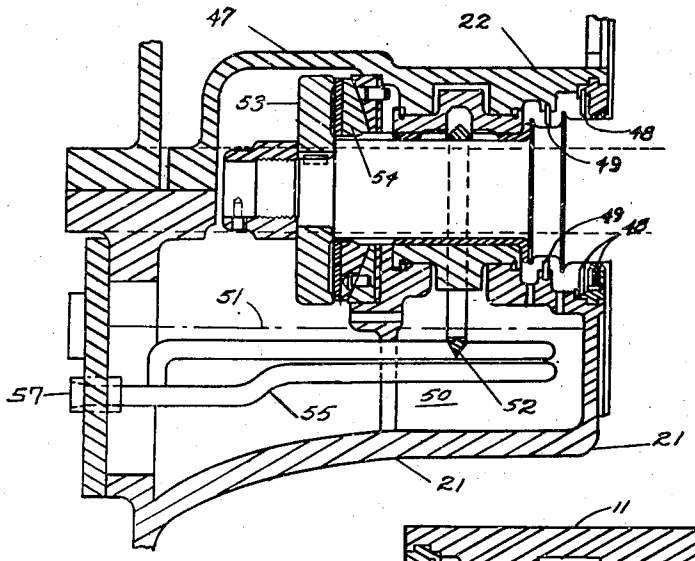
INVENTOR.
ALEXANDER I. PONOMAREFF
BY Robert J. Palmer
Attorney

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FIG. 2



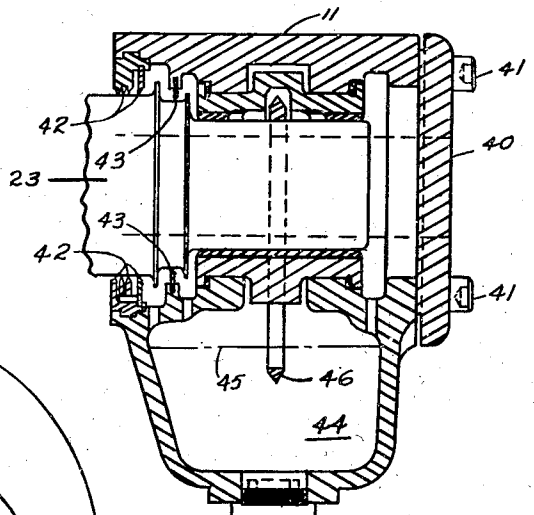
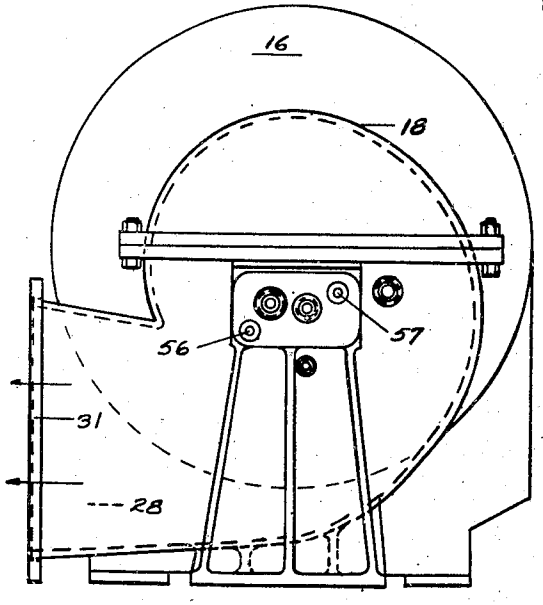


FIG. 3

FIG. 4



INVENTOR.
ALEXANDER I. PONOMAREFF
By Robert J. Palmer
Attorney

Jan. 11, 1949. A. I. PONOMAREFF 2,458,730

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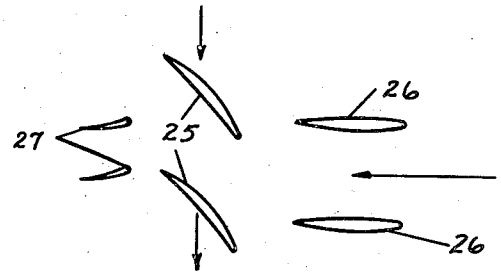


FIG. 5

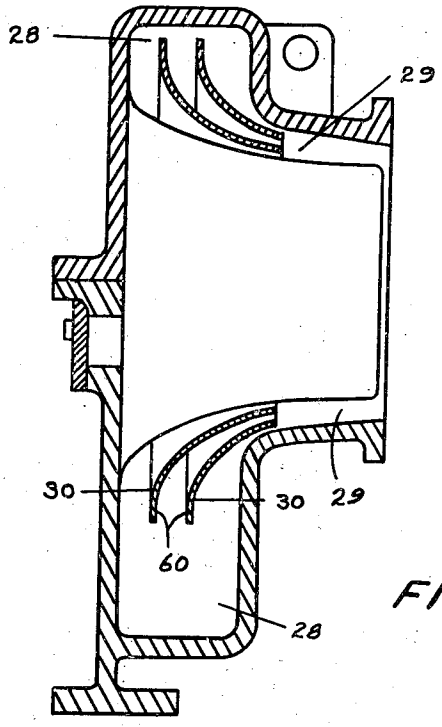


FIG. 6

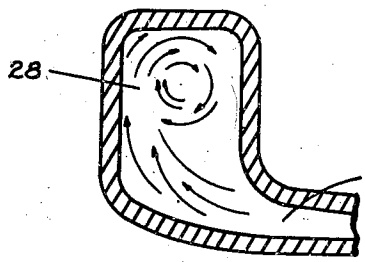


FIG. 7

INVENTOR.
ALEXANDER I. PONOMAREFF
BY Robert T. Palmer
Attorney

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REFRIGERANT COMPRESSOR

Alexander I. Ponomareff, Havertown, Pa., assignor, by mesne assignments, to Westinghouse Electric Corporation, a corporation of Pennsylvania

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11 Claims. (Cl. 230—117)

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This invention relates to refrigerant compressors, and relates more particularly to motor-driven refrigerant compressors in which the compressor rotors and the motors driving same are enclosed in common, fluid-tight casings.

A feature of this invention is that it provides a multiple-stage, axial-flow compressor having many advantages such as high efficiency and small over-all dimensions due to high velocities. As compared to a conventional centrifugal compressor, the axial-flow type, of the same capacity, has the advantage of less over-all diameter. Also, the axial-flow compressor is compact and adaptable for sealing due to the flow of the refrigerant in a general direction coaxial with the driving shaft.

Another feature of the invention is that the compressor is driven by an electric motor arranged in a suction passage in axial alignment with the compressor rotor, the motor being cooled by the expanded refrigerant vapor entering the compressor rotor.

Another feature of this invention is that the compressor driving spindle is used to mount the driving motor rotor, and two end bearings support the entire rotary assembly. This feature eliminates the need for the conventional coupling and bearing between the motor and the compressor rotor.

Another feature of this invention is that the end bearings used, are so enclosed that each has but one end to be sealed from lubricating oil leakage into the compressor casing.

Another feature of the invention is the use of stationary guide vanes in the entrance to the compressor rotor, for straightening out the turbulence in the refrigerant vapor caused by the motor in the suction passage.

Another feature of the invention is the use of a diffusion passage at the outlet of the compressor rotor, which includes a volute outlet passage, and which includes an annular passage between the compressor rotor and the volute passage, the annular passage diverging into the volute passage for converting velocity energy into pressure energy so as to minimize losses in the change of direction from axial flow from the compressor blading into spiral flow in the volute passage.

Another feature of the invention is the use of curved guide vanes in the diffusion passage for aiding in the change of direction from axial flow from the compressor rotor to spiral flow in the volute passage.

Another feature of the invention is that the

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wall defining the inner surface of the annular passage forms an enclosure around the downstream bearing of the compressor, the enclosure accommodating means for lubricating the bearing.

Another feature of the invention is that the downstream blades of the compressor rotor discharge directly into the inlet of the diffusion passage thereby providing spin in the vapor entering the diffusion passage, and aiding in the change of direction from axial from the compressor rotor into spiral in the volute outlet passage.

Another feature of the invention is the use of a combined radial and thrust bearing at the downstream end of the compressor driving spindle which is supplied with lubricating oil by an oil ring and the pumping action of the thrust members whereby no pressure is exerted on the lubricating oil tending to force it into the refrigerant vapor.

An object of the invention is to provide a refrigerant compressor in which a refrigerant vapor is compressed in a plurality of axial flow stages.

Another object of the invention is to combine an axial flow refrigerant compressor and a driving motor therefor in a common casing sealed from the atmosphere.

Another object of the invention is to compress a refrigerant vapor in a plurality of axial flow stages, and to discharge the compressed vapor through a volute outlet passage.

Another object of the invention is to compress a refrigerant vapor in a plurality of axial flow stages, and to discharge the compressed vapor through a diverging annular passage into a volute outlet passage.

Other objects of the invention are to reduce the dimensions of, and to improve the efficiencies of, refrigerant compressors.

The invention will now be described with reference to the drawing, of which:

Fig. 1 is a side elevation, partially in section, of a refrigerant compressor embodying this invention;

Fig. 2 is an enlarged sectional view of the bearing at the pressure end of the compressor;

Fig. 3 is an enlarged sectional view of the bearing at the suction end of the compressor;

Fig. 4 is an end view, in reduced scale, of the discharge end of the compressor;

Fig. 5 is a diagrammatic view illustrating the relation between the stationary and rotary blades of the compressor;

Fig. 6 is an enlarged cross-section through the annular diffusion passage and the volute outlet passage of Fig. 1 and illustrates the curved guide vanes in more detail;

Fig. 7 is a detail sectional view showing undesired rotational motion of the refrigerant vapor which occurs in the volute outlet passage when the curved guide vanes illustrated by Figs. 1 and 6, are not used.

The compressor illustrated has the cylindrical casing portion 10 forming a suction passage extending around the bearing 11 and the electric, driving motor 12. The casing portion 10 has an axial circular inlet opening 13 of reduced diameter, and has the flange 14 adapted to be connected to the suction side of a refrigerant evaporator. The casing portion 15 has the flange 16 at its inlet end, which is connected, as by being bolted, to the flange 17 at the outlet end of the casing portion 10, and extends around the blades of the refrigerant compressor stages as will be described.

The scroll shaped outlet portion 18 of the casing has the flange 19 on its inlet end, which is connected, as by being welded, to the flange 20 at the outlet end of the casing portion 15. The outlet portion 18 of the casing has a wall 21 which extends inwardly around the bearing 22 at the pressure end of the unit, and forms an enclosure around the bearing as will be described in detail with reference to Fig. 2.

The driving spindle 23 is journalled at its ends in the bearings 11 and 22, and has a hub portion 24 of increased diameter, within the casing portion 15, and which supports the axial flow, compressor blades 25 which extend substantially radially therefrom, there being sixteen compressor stages in the embodiment illustrated.

The density of the vapor increases in the downstream stages due to temperature and pressure increases, and as the density increases the volume decreases. For providing that each stage handle the same mass of vapor, the lengths of the blades in the downstream stages are progressively reduced, and the casing portion 15 around the blades, converges correspondingly for providing a converging flow passage through the compressor blading whereby, for continuity of flow, the downstream stages handle progressively reduced vapor volumes.

The stationary vanes 26 and 27 carried by the casing portion 15 are designed to impart to discharging vapor angularity suitable to the design of the rotor blades 25. Also, the vanes 26 serve to remove turbulence in the vapor caused by its flow over the motor 12.

As illustrated in Fig. 5, the vanes 26 are straight, having airfoil sections, and are arranged to provide axial flow in the vapor entering the compressor rotor; and the vanes 27 have inlet portions curved to suit the angle of approach of the vapor delivered thereto by the preceding row of moving blades, and have straight portions followed by the inlet portions for straightening out the spin imparted by the moving blades to the vapor.

The spin-neutralizing vanes are omitted downstream of the last row of rotary blades for the reason it is desired for the vapor leaving the compressor rotor to have some spin for aiding in the conversion of axial flow into spiral flow in the volute outlet passage 28 in the scroll shaped casing portion 18.

The outer surface of the inner wall 21 has an inner diameter adjacent the hub portion 24 of

the spindle, equal to that of the hub portion, and progressively increasing diameters between same and its outer end, and forms with the inner surface of the casing outlet portion 18 thereabout, an annular passage 29 which conducts the vapor from the final stage of the compressor into the volute outlet passage 28, and which diverges, as illustrated by Fig. 1, towards the passage 28 for changing the velocity energy in the vapor into pressure energy. This aids in the conversion of the vapor from axial flow into spiral flow since the turning force required is reduced due to the reduced velocity.

The volute outlet passage 28 has a tangential outlet 31 (Fig. 4) and increases in radius and in area in the direction of the spin of the fluid, towards the outlet 31. The outlet 31 is adapted to be connected by the flange 32 to a refrigerant condenser.

The annular passage 29 and the volute outlet passage 28 form a diffusion passage which diverges gradually from its inlet at the downstream end of the compressor rotor, to the outlet 31 thus providing for effective conversion of the velocity energy in the compressed vapor into the desired pressure energy.

The guide vanes 30 have curved conical portions extending into the outlet of the annular passage 29 and into the volute passage 28, nd end portions 30 of the vanes in the passage 28 extending along straight, radial lines for providing radial velocity components in the vapor, which components tend to prevent the development of undesired rotational movement of the vapor in the volute passage along planes transverse same. Without the use of the vanes 30, the deflection of the vapor by the inner wall 21 would result in the crowding of the vapor towards the latter with the result that the higher pressure and velocity of the vapor adjacent thereto would be effective to produce rotational movement of the vapor as illustrated by Fig. 7. The guide vanes 30 thus not only aid in turning the vapor into the volute outlet passage and prevent turbulence therein, but act to distribute the vapor more uniformly across the outlet passage.

The volute outlet passage 28 is desirable for conveying the vapor from the unit, smoothly and efficiently around the downstream bearing 22. The vapors of commercial refrigerant are relatively dense, as compared, for example, with air, and it is, therefore, relatively difficult to convert their high velocity, axial movement from the compressor stages into smooth spiral movement through the volute outlet passage. However by omitting the usual spin-neutralizing vanes from the downstream side of the last stage of the compressor, the vapor entering the annular passage 29 has some spin in the direction of flow conversion desired and enters the passage 29 with that spin. The divergence of the passage 29 in the direction of flow causes a reduced vapor velocity making the resistance of the vapor to change of direction, less. The curved guide vanes 30 then deflect the vapor in the desired direction, and finally the provision of the volute passage 28 with increasing diameter and area in the direction of the spin of the vapor entering it, completes the change of direction of vapor flow with minimum turbulence and minimum pressure loss.

The housing of the electric motor 12 has the spaced, outwardly extending flange 32 which are secured by the bolts 34 to the spaced inwardly extending flanges 33 of the compressor casing.

The rotor 35 of the motor, is mounted on the spindle 23, and has the axially extending passage 36 for the flow of the refrigerant vapor therethrough to cool the rotor. The stator 37 of the motor is formed to have the passages 38 between same and the motor housing for the cooling of the stator with its windings. The refrigerant vapor thus flows through and about the electric motor. This motor cooling construction is described in more detail in the E. R. Wolfert Patent No. 2,283,024. The motor 12 causes turbulent flow in the vapor passing its surfaces, the vanes 26 straightening out the turbulent flow as described in the foregoing.

By supporting the rotor of the motor directly from the spindle 23, no motor coupling and no motor bearings are necessary, the two end bearings 11 and 22 supporting the entire rotary structure of the compressor unit. Therefore, no only is it possible to locate the motor as close to the inlet of the compressor rotor as good flow conditions will permit, but the absence of bearing or coupling structures between the motor rotor and the compressor rotor avoids any interference with smooth vapor flow that would be caused thereby. Furthermore, as above pointed out in the foregoing, the vanes 26 serve to straighten the flow rendered turbulent by the motor before such flow enters the compressor rotor.

The two bearings 11 and 22, in which the ends of the compressor spindle are journalled, are enclosed within the casing of the compressor and are therefore completely isolated from the atmosphere. Each bearing is enclosed at one end, and has therefore, but one end to be sealed from lubricating oil leakage into the compressor casing.

The bearing 11 as illustrated by Fig. 3 has its upstream end closed off by the end plate 40 attached by the machine screws 41 to the casing of the bearing, whereby no oil seal is necessary at that end of the bearing. The bearing has the conventional oil seals 42 and 43 contacting the spindle 23 at the downstream end of the bearing. The lower portion of the bearing casing has an oil sump 44 therein, the oil level being shown by the dash-dot line 45. The oil ring 46 dips into the oil in the sump and lubricates the bearing.

The bearing 22 is enclosed at its downstream end by the wall 21, the end wall of the outlet portion 18 of the casing and the bearing wall 47, whereby no oil seal is necessary at that end of the bearing. The upstream end of the bearing has the conventional oil seals 48 and 49 in contact with the spindle 23.

The oil sump 50 is formed above the lower portion of the wall 21, the oil level therein being shown by the dash-dot line 51. The oil ring 52 dips into the oil in the sump and lubricates the bearing portion around the journal of the spindle. The bearing 22 is a combined radial bearing for the downstream journal portion of the spindle, and a thrust bearing, comprising the thrust members 53 and 54, the details of which are disclosed in the H. F. Schmidt Patent No. 2,362,667; and, as this particular type of thrust bearing functions as a pump to provide its required pressure, a force-feed supply is unnecessary. Hence, oil escaping from the adjacent end of the journal portion of the bearing 11, and subject to pump action of the thrust members of the bearing is adequate to supply the latter, and the ring 52 suffices to supply both the journal bearing and the thrust bearing. Therefore, as the lubricating requirements are met without exerting pressure on the oil, the pressures at opposite sides of the oil seal are in equilibrium, in consequence of which there is no tendency for oil to be forced from the lubricating space through the seal into the refrigerant passages to contaminate the refrigerant vapor.

The oil cooling coil 55 is immersed in the oil in the sump 50, and its inlet 56 and outlet 57 are adapted to be connected to a source of circulating cold water or other cooling fluid, for reducing the temperature of the oil as it is heated by the bearing. Cooling of the oil in the sump 50 is desirable for two reasons, first, to assure of satisfactory viscosity of oil for the bearings supplied therefrom, particularly the thrust bearing, and, second, on account of the increased heating of the oil because of passage of the latter through the bearings in series, as well as location of such bearings at the high temperature region of the compressor in which the refrigerant vapor has heat absorbed from the motor as well as compression heat.

The wall 21 extending inwardly within the volute outlet passage 28 is seen not only to form an enclosing wall around the bearing 22, and an oil sump therefor, but to form the inner wall of the diffusion passage 29.

The annular diffusion passage 29 and the volute passage are seen to merge together and to form an outlet passage for the fluid from the final stage of the compressor, which outlet passage increases progressively in diameter and in area towards the outlet 31 of the unit whereby the velocity energy in the fluid leaving the final stage of the compressor, is converted into pressure energy.

The fluid flow through the suction passage enclosed by the casing portion 10, the cooling passages in the motor 12, and the blades of the compressor, is seen to be generally axial thereby avoiding the turbulence of flow and loss in efficiency resulting from the fluid flow direction changes in a centrifugal compressor, particularly a multi-stage compressor.

By sealing the compressor and its driving motor from the atmospheric air in a common casing, and by mounting the rotor of the driving motor on the spindle of the unit, the necessity for make-up refrigerant and purification of the refrigerant is eliminated, and the over-all dimensions and the manufacturing cost are reduced. Sealing of the compressor and its driving motor entails the provision of enclosed bearings and lubricating means therefor. These requirements are conducive, not only to the maintenance of minimum axial length, but to good flow conditions, with the motor arranged in the suction passage so that it may be cooled by entering refrigerant vapor. Axial shortening of the structure is made possible by a fluid flow path including an annular passage which curves outwardly to provide an outlet directed transversely of the compressor axis, the annular portion opening into a volute passage having a tangential outlet, the annular passage portion encompassing the downstream journal and thrust bearing and the lubricating means therefor, this nested relationship of the downstream journal and thrust bearing and the diffuser passage providing both for reduction in axial length of the compressor and the span distance between the bearings at the upstream and downstream ends thereof. By having the bearings at the ends of the spindle, the motor rotor may be placed as close as practicable to the rotor without

any intervening bearing structure being in the way to interfere with fluid flow; and, by the incorporation of suction guide vanes, the effects of turbulence introduced by the motor are reduced, such guide vanes straightening the stream entering the compressor rotor. The necessary thrust bearing is arranged at the downstream end, not only to locate it out of the way so far as the flow passage is concerned, but to facilitate the provision, construction and assembly of the sump oil cooler which is desirable. Furthermore, as the thrust bearing is of the self-pumping and self-oil-entraining type, it is merely necessary to convey oil to the entrance thereof without imposing pressure on the oil, in consequence of which pressures at opposite sides of the seal are kept in equilibrium and contamination of the refrigerant with oil is minimized.

While one embodiment of the invention has been described for the purpose of illustration, it should be understood that the invention is not limited to the exact apparatus and arrangement of apparatus illustrated, as modifications thereof may be suggested by those skilled in the art without departure from the essence of the invention.

What is claimed is:

1. A refrigerant compressor comprising a casing having a suction passage for refrigerant vapor, and a diffusion passage including an annular passage curving outwardly to provide a compressed refrigerant vapor outlet directed transversely of the compressor axis; a rotary spindle within the casing having journal portions at its upstream and downstream ends, and a hub adjacent the downstream journal portion, said hub cooperating with the casing to provide a blade passage connecting the suction and diffusion passages, said blade passage being axially aligned with the suction passage and converging toward the diffusion passage; axial-flow blading in the blade passage and including a plurality of rows of rotary blades carried by the hub and guide vanes carried by the casing; bearings carried interiorly by the casing for said journal portions, and an electric motor for driving the spindle and arranged in the suction passage so that the stream of refrigerant vapor flowing in the latter passes through and about the motor, said motor including a rotor mounted on the spindle between the hub and said upstream journal portion.

2. A refrigerant compressor as claimed in claim 1 in which the annular passage diverges in the direction of vapor flow.

3. A refrigerant compressor comprising an elongated casing having suction passage for refrigerant vapor at one end, having a volute outlet passage at the other end, and having an annular passage diverging towards, and opening into, said volute passage; a rotary spindle having journal end portions, and having a hub within the casing, said casing cooperating with the hub to provide a blade passage connecting the suction and annular passages; a plurality of axial flow blades carried by the hub in the blade passage, said blade and annular passages being axially aligned with said suction passage; bearings carried interiorly of said casing for said journal portions, and an electric motor for driving the compressor arranged in said suction passage so that the refrigerant vapor flowing therein passes through and about the motor, said motor including a rotor mounted on the spindle between the hub and the upstream journal portion.

4. A refrigerant compressor as claimed in claim 3 in which curved conical guide vanes extend from the outlet of the annular passage into the volute passage for imparting radial components of velocity to the vapor entering the volute passage.

5. A refrigerant compressor comprising a casing having a suction passage for refrigerant vapor, and a diffusion passage including an annular portion curving outwardly from the compressor axis to provide a compressed refrigerant vapor outlet directed transversely of such axis; a rotary spindle within the casing and having journal portions at its upstream and downstream ends and a hub adjacent to the downstream journal portion, said hub cooperating with the casing to provide a blade passage connecting the suction and diffusion passages, said blade passage being axially aligned with the suction passage and converging toward the diffusion passage, axial-flow blading in the blade passage and including a plurality of rows of rotary blades carried by the hub, and guide vanes carried by the casing; bearings carried interiorly by the casing for said journal portions, and an electric motor for driving the shaft and arranged in the suction passage so that the stream of refrigerant vapor flowing in the latter passes through and about the motor, said motor including a rotor mounted on the shaft between the hub and the upstream journal portion; said guide vanes including an initial row preceding the first row of moving blades and plurality of other rows arranged between successive moving rows of blades, said guide vanes being arranged to discharge vapor with angularity suitable for the design of succeeding moving blades and the initial row to guide vanes serving also to remove turbulence in the flow of refrigerant vapor leaving the motor and entering the first row of moving blades.

6. A refrigerant compressor as claimed in claim 5 in which the guide vanes of said initial row are straight and the guide vanes of said other rows have curved inlet edges.

7. A refrigerant compressor comprising a casing having a suction passage for refrigerant vapor, and a diffusion passage including an annular portion opening into an encompassing volute portion terminating in a tangential outlet for compressed refrigerant vapor; a rotary spindle within the casing and having journal portions at its upstream and downstream ends and a hub adjacent to the downstream journal portion, said hub cooperating with the casing to provide a blade passage connecting the suction and diffusion passages, said blade passage being axially aligned with the suction passage and converging toward the diffusion passage; axial-flow blading in the blade passage and including a plurality of rows of vanes carried by the casing and a plurality of rows of blades carried by the rotor; journal bearings carried interiorly by the casing for the journal portions, a thrust bearing between the downstream journal portion and the downstream end of the casing, and an electric motor for driving the compressor and arranged in the suction passage so that the stream of refrigerant vapor flowing in the latter passes through and about the motor, said motor including a rotor mounted on the spindle between the hub and the upstream journal portion.

8. A refrigerant compressor comprising a casing having a suction passage for refrigerant vapor and a diffusion passage of increasing flow area throughout its length and including an annular passage opening into an encompassing volute passage terminating in a tangential outlet for compressed refrigerant vapor; a rotary spindle

within the casing and having journal portions at its upstream and downstream ends and a hub adjacent to the downstream journal portion, said hub cooperating with the casing to provide a blade passage connecting the suction and diffusion passages, said blade passage being axially aligned with the suction passage and converging toward the diffusion passage, axial-flow blading in the blade passage and including a plurality of rows of blades carried by the hub and fixed guide vanes carried by the casing, said blading being arranged to discharge refrigerant vapor into the annular passage with a component of rotational motion in the direction of increasing radius of the volute portion, said annular passage having a discharge section which is curved outwardly to effect transition of flow from an axial to a radial direction; bearings carried interiorly by the casing for the journal portions, and an electric motor driving the spindle and arranged in the suction passage so that the stream of refrigerant vapor flowing in the latter passes through and about the motor, said motor including a rotor mounted on the spindle between the hub and the upstream journal portion.

9. A refrigerant compressor as claimed in claim 8 in which the fixed guide vanes include an initial row preceding the first row of rotor blades and serving to straighten the flow between the motor and such blades and wherein the last row of rotary blades discharges directly into the diffusion passage, with the direction of rotation of the rotor and the arrangement of blading such that such last row of rotor blades discharges vapor into the diffusion passage with a rotational component in the same direction as the direction of increasing radius of the volute passage.

10. A refrigerant compressor comprising a casing having an axial inlet for refrigerant vapor at one end, a volute outlet passage for the compressed refrigerant vapor at the other end, having an annular passage having a curved portion opening into said volute passage, and having a suction passage extending inwardly from said inlet; a rotary spindle for driving said compressor having an upstream journal end portion in said suction passage adjacent said inlet, and having a downstream journal portion encompassed by said annular and volute passages; bearings carried inwardly of said casing for said journal portions; said spindle having a hub between said suction and annular passages, said casing and said hub forming a blade passage which converges towards the annular passage, said inlet, said suction passage and said blade passage being in axial alignment; a plurality of rows of rotary, axial flow

blades carried by said hub; a plurality of rows of fixed, vanes between said rows of rotary blades, and an electric motor carried inwardly by said casing in said suction passage for driving the spindle, and arranged in the suction passage so that the refrigerant vapor flowing through same passes through and about the motor, said motor including a rotor mounted on the spindle between said upstream journal portion and said hub.

11. A refrigerant compressor comprising a casing having a substantially barrel shaped portion with an axial inlet at one end of the casing, and an axial outlet intermediate the casing ends, and forming a suction passage for refrigerant vapor, said casing having a scroll shaped portion at the other end forming a volute outlet passage having a tangential outlet, and having an intermediate substantially barrel shaped portion having a substantially smaller diameter than that of said first mentioned barrel portion, forming the outer surfaces of an annular passage opening into said outlet passage, and of a blade passage connecting the outlet of the suction chamber with said annular passage, said suction, blade and annular passages extending in axial alignment, a rotary spindle for driving said compressor, said spindle having a journal end portion in said sucton passage adjacent said inlet, and having another journal portion downstream of said blade passage, bearings carried inwardly of said casing for said journal portions, said spindle having a hub in said blade passage and forming the inner surface thereof, rows of axial flow blades on said hub, rows of fixed vanes carried by said casing between the rows of blades, and an electric motor carried inwardly of said casing in said suction passage and arranged so that the refrigerant vapor flowing therethrough passes through and about the motor, said motor having a rotor mounted on the spindle between the upstream journal portion and the hub.

ALEXANDER I. PONOMAREFF.

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