Feb. 12, 1946. R. W. WATERFILL 2,394,953

MECHANICAL REFRIGERATING SYSTEM

Original Filed Aug. 3, 1940 2 Sheets-Sheet 1

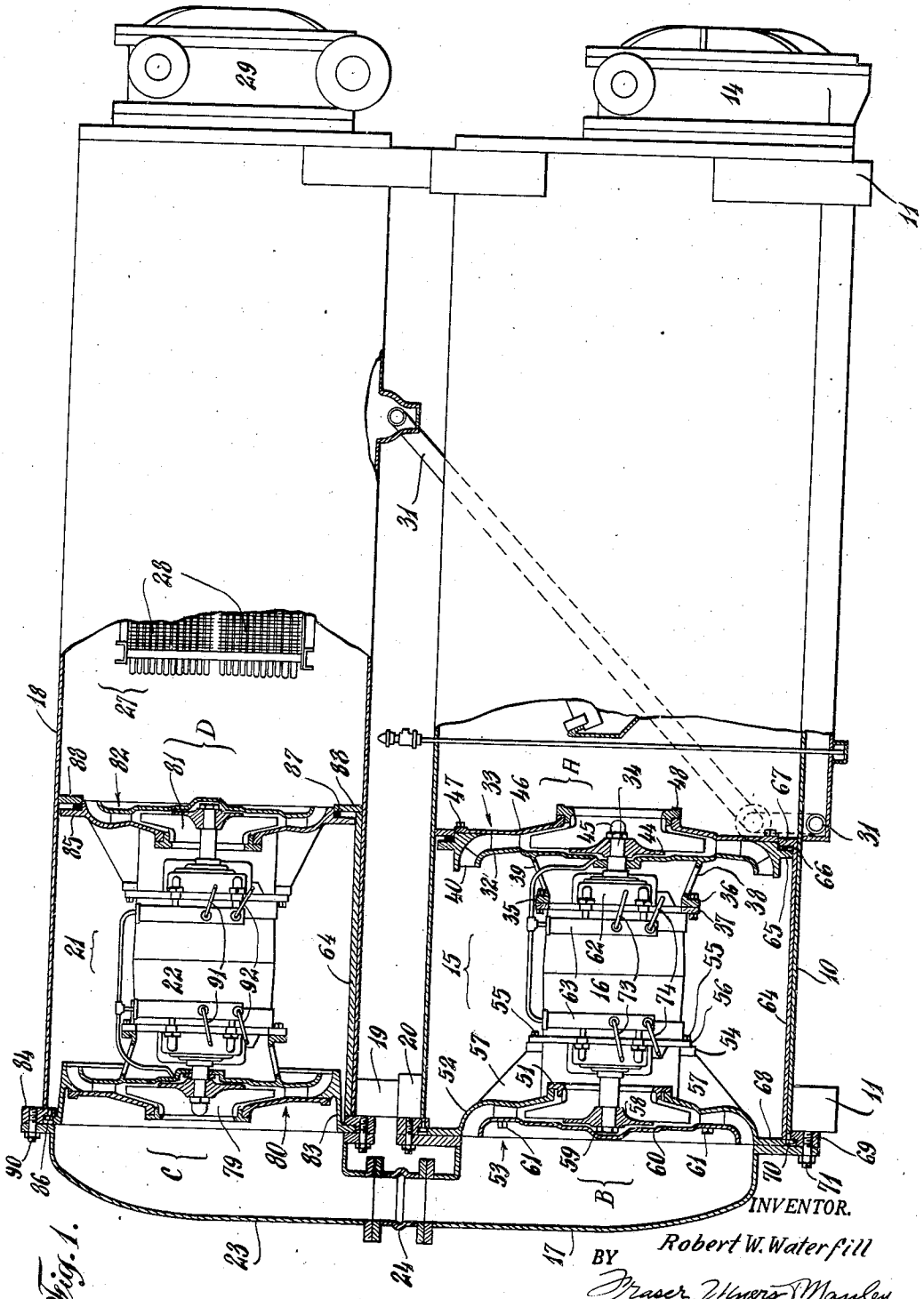


Fig. 1.

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Fig. 2.

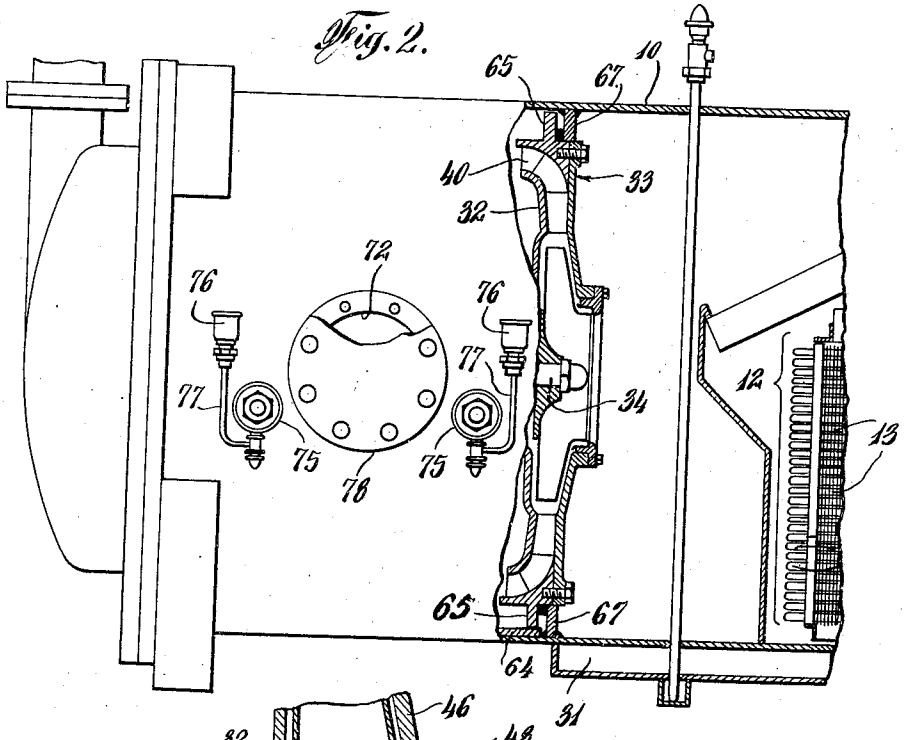
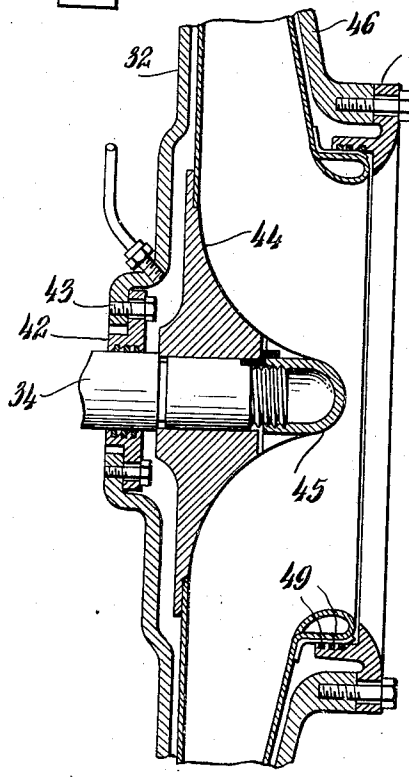


Fig. 3.



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MECHANICAL REFRIGERATING SYSTEM

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Original application August 3, 1940, Serial No. 350,785. Divided and this application July 24, 1943, Serial No. 496,039

7 Claims. (Cl. 62—115)

This invention relates to improvements in mechanical refrigerating equipment, the present application being a division of prior application Serial No. 350,785, filed August 3, 1940, upon which Patent No. 2,341,132 issued February 8, 1944.

The principal object of the invention is to simplify the construction and operation of mechanical refrigerating systems, particularly those of the low-pressure class; to render such systems more compact and of lesser weight as compared with prior structures of equal refrigerating capacity; to arrange the components of such systems in a way which will facilitate manufacture as well as servicing of the equipment after it has been installed; and, generally, to improve and lessen the cost of manufacture and of operation of mechanical refrigerating equipment.

It is another object of the invention to provide a refrigerating system including a compressor unit comprising one or more stages of centrifugal compression, and a driving motor, which is adapted to be housed in one end of a casing which also serves as the shell of the evaporator of the system; and, more specifically, to provide a system in which the compressor is divided into two units each including two stages of centrifugal compression, a driving motor and accessories, and to house one of these units in one end of a casing which serves as the shell of a shell-and-tube evaporator for the system, and the other in a casing which serves as a part of the condenser of the system.

The foregoing and other objects, as well as various features of the invention, will be more fully understood from a consideration of the following description when read in the light of the accompanying drawings, in which:

Figure 1 is an elevational view of the complete mechanical refrigerating system of the present invention, certain parts thereof being broken away better to show underlying ones;

Fig. 2 is an elevational view, partly in section and on an enlarged scale, of a portion of the compressor-evaporator unit of Fig. 1; and

Fig. 3 is a sectional view, on an enlarged scale, of a fragment of the first stage of the first compressor unit of Fig. 1.

In the drawings, and referring first to Fig. 1, numeral 10 designates a casing which preferably is of cylindrical form having legs 11 adapted to rest upon any appropriate foundation so that the casing may serve as the effective base of the machine. A major portion of this casing (Fig. 2) houses a bank of tubes 12 which, as may be seen, are provided with a large number of surface extending fins 13, and are interconnected with a water-box 14 covering the right-hand end of the casing as viewed in Fig. 2. This portion of casing 10 accordingly serves as the shell of the evaporator of the system in which refrigerant liquid may be vaporized to abstract heat from water or any other desired medium circulated through the tube bank. At this point it will be noted that water-box 14 is of conventional design and provides both supply and discharge connections between the ends of tubes 12 and circulating lines (not shown) for a liquid to be cooled.

The first compressor unit 15, comprising compressor stages A and B, their common driving motor 16 and accessories, is housed in the left-hand end portion of the casing 10 (Fig. 2) and in direct communication with the evaporator. In the operation of the system, stage A serves to withdraw refrigerant vapor from the evaporator portion of the casing, to compress the vapor to a certain extent, and to discharge it over and through the motor 16 to cool that element. The second stage, B, withdraws the partially compressed vapor from that part of casing 10 which serves as the compressor housing, further compresses the vapor, and discharges it into a manifold 17 which is bolted to the end of the casing.

In the preferred construction, a second casing 18, again of cylindrical form, is mounted atop the combination evaporator-compressor unit, the second casing having legs 19 welded or otherwise secured to its underside and resting upon similar legs 20 affixed to the upper part of casing 10. The second compressor unit 21 of the system, including compressor stages C and D, their common driving motor 22 and accessories, is housed in an end of casing 18 immediately above the first compressor unit 15 in casing 10; and the end of casing 18 is covered by a manifold 23. When the system is operating, the partially compressed refrigerant vapor discharged from stage B of the first compressor unit passes through manifold 17, fitting 24, and manifold 23 into stage C, is further compressed therein, and is then discharged over and through the motor 22 to cool that element. The last stage, D, withdraws partially compressed vapor from that part of casing 18 which serves as a housing for the second compressor unit, raises the pressure of the vapor to a desired final value, and discharges it into the remaining portion of casing 18.

The last-mentioned casing portion is adapted to serve as the shell of the condenser of the system, and in it is housed a bank of tubes 27

which carry a large number of surface extending fins 28, and which have their ends interconnected with the water-box 29. Here again the water-box serves its conventional function of providing both supply and discharge connections between the ends of tubes 27 and circulating lines (not shown) for condenser cooling water. Accordingly, the compressed vapor discharged from stage D passes over the bank of tubes, gives up its heat to water circulating through the bank, and is condensed, the resulting refrigerant collecting in the base of the shell (casing 10), whence it may be returned to the evaporator through conduit 31 for re-use.

The refrigerating machine which has been generally described above is primarily designed to operate with one of the so-called low-pressure refrigerants, such as trichloro-trifluro-ethane or the like. These substances, as is well recognized in the art, are almost ideally suited to centrifugal compression. Accordingly, each of the compressor units 15 and 21 includes two stages of centrifugal compression each comprising an impeller adapted to be driven directly by the motor of the unit, and a diffuser surrounding the impeller, the latter element serving in the well-understood manner to convert the velocity pressure of vapor issuing from the impeller into a static head. These two units are so nearly identical in basic design that a consideration of one of them will suffice to bring out the features of both and the manner in which they are mounted in their respective casings. For this purpose the first compressor unit 15 and its mounting in the evaporator casing 10 will be described in detail.

In assembling the unit 15, and starting with stage A, the inner half 32 of the diffuser (generally designated 33) is slipped over the shaft 34 of motor 16, and its flange 35 is bolted at 36 to a flange 37 of the motor housing. It will be seen that the flange 35 is formed at the rear end of a spider 38 which comprises an integral part of the diffuser element 32, and that this spider has a series of openings 39 through which some vapor may pass from the outlet 40 of the diffuser through and over the windings of the motor 16 to cool those parts. If it has not already been set in place, the gland 42 (Fig. 3) is slipped over the shaft 34 and is bolted at 43 to the diffuser element 32 to provide a labyrinth packing around the shaft at this point.

The impeller 44 is next fitted and keyed to the shaft, and a spanner nut 45 is applied to the end of the shaft to hold the impeller in place. It will be noted (Fig. 3) that this nut has smoothly rounded surfaces which complement those of the impeller, whereby friction between the refrigerant vapor and the impeller may be minimized. After the impeller has been mounted, the outer half 46 of the diffuser 33 can be fitted in place, and bolted to the inner half 32 at 47. Finally, the inlet guard 48 is bolted or otherwise secured to the diffuser element 46. It will be noted at this point (Fig. 3) that the surface of the inlet guard is smoothly rounded, and is so designed as to complement the adjacent surfaces of the inlet of the impeller, all to the end that friction between the refrigerant vapor and the parts of the machine may be kept as low as possible. While the inlet guard must not touch the impeller, the clearance between these parts is small, and the guard is provided with a series of labyrinths 49 which effectively prevent the short-circuiting of any substantial volume of vapor from the discharge of the impeller 44 around the inlet guard to its inlet.

The assembly of stage B of the unit is quite similar to that of stage A. Specifically, and referring to Fig. 1, the inlet guard 51 is first applied to the inner half 52 of the diffuser (generally designated 53), that inner half is slipped over the motor shaft 34, and its flange 54 is bolted at 55 to the flange 56 of the motor housing. Here, again, it will be noted that the flange 54 is spaced from the main body of the diffuser by a spider, the spaces between the arms 57 of the spider again allowing for the flow of vapor through the motor windings and into the second stage impeller. The impeller 58 is then fitted and keyed to the shaft 34, and a nut 59 is applied to secure the impeller in place. When this has been done, some adjustment of the inlet guard 51 may be needed to insure that the guard and the impeller do not touch. Here, again, the outer surface of the guard is smoothly rounded to complement the surface of the impeller inlet; and the guard is provided with labyrinths to restrict the flow of vapor between that guard and the adjacent surface of the impeller. The assembly of the compressor unit 15 is completed by the application of the outer half 60 of the diffuser, this element being bolted at 61 to the inner half 52 (Fig. 1).

It is evident that the first compressor stage A must handle a larger volume of refrigerant vapor than the second stage B, the volumetric difference being accounted for by the fact that the vapor is partially compressed in the first stage before it is delivered to the second stage. Accordingly, and as is shown in Fig. 1, the diffuser 33 and the impeller 44 of stage A are somewhat larger than the like parts of stage B.

It will be noted that the two impellers are mounted directly upon the motor shaft and are supported by the bearings for that shaft (not shown). Each of these bearings is provided with an independent lubricating system 62, which may be constructed in accordance with the disclosure of Patent No. 2,266,107, dated December 16, 1941. Reference may be had to that patent for more complete details of the lubricating system and its manner of operation. The prime difference between the system there disclosed and the one here shown lies in the fact that the oil-settling chambers 63 are mounted directly upon the frame of the motor 16, rather than upon the casing of the unit.

The assembled compressor unit 15 is of such size and shape that it may readily be passed through the open end of casing 10, and be slipped along rails 64 which serve both to guide and to support it until the marginal flange 65 of the diffuser element 32 of stage A (Fig. 3) forces a packing ring 66 into engagement with an annular flange 67 formed on the inside of casing 10. The flange 68 of the diffuser element 52 of stage B may then be bolted to the flange 69 of the casing, the bolts 70 serving to force the entire unit endwise into the casing and to squeeze the packing ring 66 between the flanges 65 and 67 whereby to form a leak-tight joint between the compressor unit and that part of casing 10 which serves as the shell of the evaporator of the system. Finally, the manifold 17 may be bolted in place, as indicated at 71, to cover the end of the casing.

The manhole 72 (Fig. 2) gives access to the inside of the casing 10 after the compressor unit has been inserted for making the necessary elec-

trical connections of the motor 16, and for connecting pipes 73 and 74 leading from the settling chambers 63 of the oiling systems to the bull's-eyes 75 which are mounted on casing 10. These bull's-eyes give a visual indication of the quantity of oil in the lubricating systems. This oil may be supplied in the first instance, or more may be added, through filling cups 76 which are connected with the bull's-eyes through pipes 77, and, accordingly, with the lubricating systems through the above-mentioned pipes 74. When all of the internal connections have been made, the cover 78 may be applied to the casing over the manhole 72 to seal the unit at this point.

The basic design of the second compressor unit 21 is quite similar to that of the first unit 15, as has already been pointed out. These differences, however, should be noted. Stage C of the second unit is assembled in substantially the same manner as stage A of the first unit; and the assembly of stage D follows that of stage B. Here, again, it will be evident that the stages are of progressively decreasing volumetric capacity, the impeller 79 and the diffuser 80 of the third stage C being of somewhat lesser diameter than the comparable parts of the second stage B, and the impeller 81 and the diffuser 82 of the fourth stage D being of lesser diameter than the comparable parts of the third stage C.

The completely assembled unit 21 may be inserted through the open end of casing 18, and the procedure is much like that followed in mounting the first compressor unit 15 in the evaporator casing 10. The diffuser 80 of stage C has a flange 83, which is comparable in function to the flange 68 of stage B, whereby it may be bolted to an end flange 84 of the casing 18, and the diffuser 82 of stage D has a right-angle flange 85 at its edge which is comparable to the flange 65 of diffuser element 32 of stage A. Accordingly, the bolts 86 serve to drive the entire unit into the casing, and to cause flange 85 to compress a gasket 87 against an annular internal flange 88 formed on the casing 18 to form a leak-tight joint at that point. The manifold 23 may then be bolted at 90 to the end of casing 18.

When the foregoing steps have been completed, the electrical connections may be made to the motor 22, and the oil lines 91 and 92 may be connected to bull's-eyes mounted on the casing 18, these operations being accomplished through a manhole which may later be covered to seal the unit. Neither these last-mentioned bull's-eyes nor the manhole and its cover are shown in the drawings, but these parts may be identical with the comparable ones shown in Fig. 2, and further illustration and description are unnecessary.

The various constructional differences between the two compressor units and their individual stages are well illustrated in the drawings and need not be further described.

It is the usual practice in assembling a refrigerating machine of this kind to form two casings and to mount the small one 18 atop the large one 10. The compressor units are then assembled and inserted in their respective casings, after which the manifolds 17 and 23 are bolted in place. The manifolds may then be connected by the fitting 24, which preferably comprises a section of copper or brass tubing having flanges at its ends for connection to the flanges of the caps 17 and 23, and a peripheral fold at some point between its ends. The fitting is thus adapted to serve as an expansion point between the two compressor units, the fold collapsing or extending to take up an expansion or contraction of the various parts.

The constructional details of the tube banks 12 and 27 of the evaporator and condenser, respectively, are fully disclosed in the above-identified parent application, and need not be repeated here. It suffices to say that the completed banks are so constructed and arranged that they may be inserted endwise into the casings 10 and 18, respectively, opposite the compressor units, and may be secured in place by the application of the water-boxes 14 and 28.

The operation of the compressor units to withdraw vapor from the evaporator portion of the shell 10, and to discharge it at a higher pressure and temperature into the condenser portion of shell 18, will be readily apparent to those familiar with the art. Further details as to the operation of the completed refrigerating unit may be had by reference to the aforementioned parent application.

Since certain changes may be made in the construction of the compressor units, and the arrangement of their constituent parts in the casings, it is intended that the foregoing shall be construed in a descriptive rather than in a limiting sense.

What I claim is:

1. A refrigerating system comprising a tubular casing, a bank of tubes housed in one portion of said casing with the ends of such tubes disposed adjacent one end of the casing, a water-box covering that end of said casing and providing supply and discharge connections to said bank for a liquid to be cooled, said portion of said casing and said bank being adapted to serve as the evaporator of said system; a compressor and its driving motor housed in said casing, said compressor being adapted to withdraw refrigerant vapor from the evaporator portion and to discharge it through the other end of said casing; a second tubular casing, a bank of tubes in said second casing with the ends of such tubes disposed adjacent an end of said second casing, a water-box closing that end of said second casing and providing connections for circulating a cooling medium through said last-mentioned tube bank, said second-mentioned casing and tube bank being adapted to serve as the condenser of the system; means for conveying compressed refrigerant vapor from the discharge of said compressor unit to said second casing; and means for returning condensed refrigerant from said condenser to the evaporator portion of said first-mentioned casing.

2. A refrigerating system comprising a tubular casing, a bank of tubes housed in said casing with their ends lying adjacent one end of such casing, means covering that end of said casing and providing supply and discharge connections to said bank for a liquid to be cooled, said bank and the adjacent portion of said casing being adapted to serve as the evaporator of said system; a first compressor unit including a driving motor housed in said casing, said compressor unit having its inlet arranged to withdraw refrigerant vapor from the evaporator portion of said casing and its outlet arranged to discharge partially compressed vapor from the other end of said casing; a second tubular casing, a second compressor unit including a driving motor housed in said second casing adjacent the first compressor

unit, said second compressor being arranged to draw vapor through one end of said second casing and discharge it within such second casing; a bank of tubes housed in said second casing with their ends disposed adjacent the other end of such second casing, means covering that other end of said second casing and providing connections for circulating a cooling medium through said second tube bank, said second tube bank and the portion of said second casing in which it is housed being adapted to serve as the condenser of said system; means for conveying partially compressed refrigerant vapor from the discharge of said first-mentioned compressor unit to the inlet of said second-mentioned compressor unit; and means for returning the condensed refrigerant from the condenser portion of said second casing to the evaporator portion of said first casing.

3. A refrigerating system according to claim 2, wherein each of said compressor units comprises a pair of centrifugal impellers, one mounted upon each end of the shaft of its motor; and a diffuser surrounding each of said impellers, the first of said diffusers having its outlet arranged to discharge partially compressed refrigerant vapor into the portion of the casing in which the unit is mounted and over and through said motor, and the second of said impellers being adapted to withdraw refrigerant vapor passing over and through said motor from the portion of the casing in which said unit is mounted.

4. A refrigerating system according to claim 2, wherein each compressor unit comprises a pair of centrifugal impellers, one mounted upon each end of the shaft of said motor; and a diffuser secured to said motor and surrounding each of said impellers, each of said units being of such size and shape that it may be passed endwise into the casing in which it is housed, one of said diffusers being adapted to be secured to an end of such casing and the other of said diffusers being disposed in leak-tight relation with a portion of said casing to prevent a back flow of compressed vapor from the discharge side of such diffuser.

5. A combination refrigerant compressor-heat exchanger unit comprising a tubular casing, a bank of heat exchange tubes adapted to be passed through one end of said casing and to be disposed with open ends of such tubes lying adjacent that end of said casing, a water-box secured to that end of said casing and providing supply and discharge connections to said tubes for a liquid medium, said bank and the portion of said casing in which it is housed being adapted to serve as a refrigerant heat-exchanger, and a compressor unit housed in said casing, said compressor unit comprising an electric motor, a plurality of centrifugal impellers mounted on the shaft of said motor, a diffuser surrounding each of said impellers, said compressor unit being adapted to be passed through the other end of said casing, one of said diffusers having means whereby it may be secured to such other end of said casing, and another of said diffusers having a peripheral flange; a packing ring adjoining the flange of the last-mentioned diffuser; and means on the inside of said casing also engaging said packing ring to form a leak-tight joint around the last-mentioned diffuser; said compressor unit being adapted to maintain a flow of refrigerant vapor through the heat-exchanger portion of said casing.

6. A compressor unit comprising a tubular casing having a peripheral flange formed on its inside between its ends; an electric motor; a pair of centrifugal impellers, one mounted upon each end of the shaft of said motor; a pair of diffusers, each secured to an end of the housing of said motor and each surrounding one of said impellers; said motor, said impellers and said diffusers comprising a unit which is adapted to be inserted into said casing through one of its ends; one of said diffusers having a peripheral flange adapted to be secured to an end of said casing; the other of said diffusers having a peripheral flange adapted to oppose the flange on the inside of said casing; and a packing ring adapted to be compressed between the flange of the last-mentioned diffuser and the flange on the inside of said casing when said first-mentioned diffuser is secured to said casing.

7. A refrigerant compressor comprising a tubular casing having an upstanding flange formed on its inner surface between its ends; an electric motor; a plurality of centrifugal impellers mounted on the shaft of said motor; a plurality of diffusers each surrounding one of said impellers; said motor, impellers and diffusers comprising a unit which is adapted to be inserted into said casing through one of its ends; one of said diffusers having a peripheral flange which is adapted to oppose the flange on the inside of said casing; a packing ring between said flanges; the other of said diffusers having a peripheral flange adapted to engage said casing; and means for securing the last-mentioned flange to said casing and for simultaneously causing the flange of the first-mentioned diffuser to compress said packing ring against the flange on the inside of said casing to form a seal therebetween.

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