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REFRIGERATION SYSTEM AND SYSTEM FOR SEPARATING OIL FROM COMPRESSED GAS

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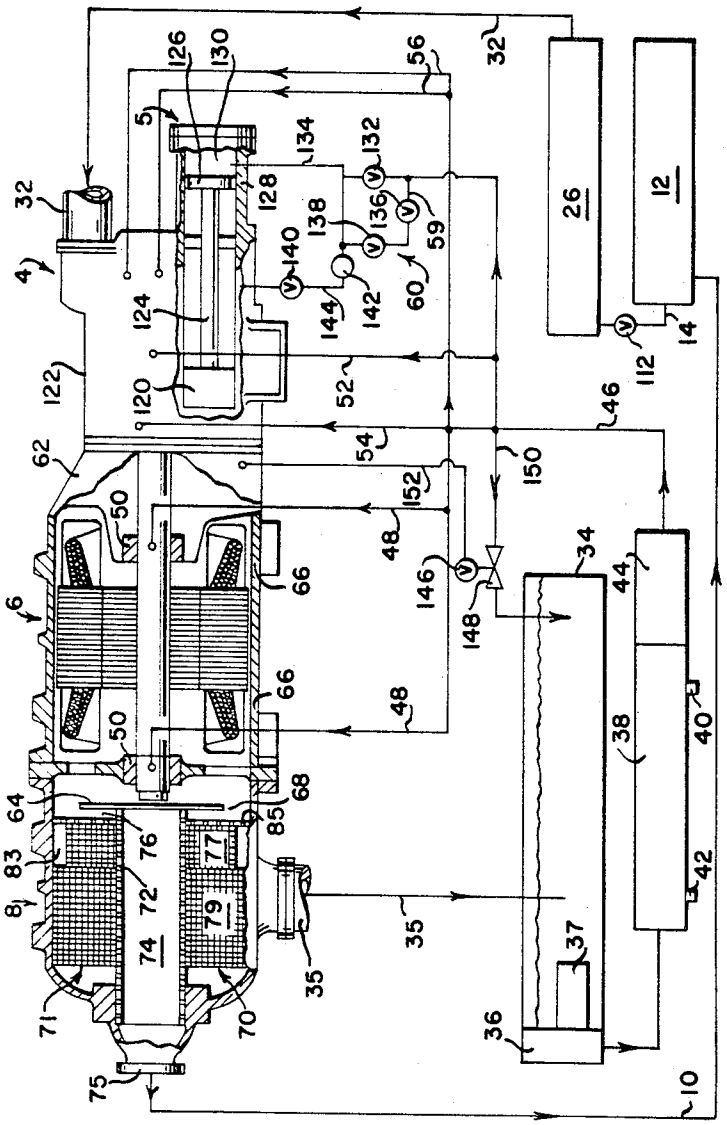


Fig. 1

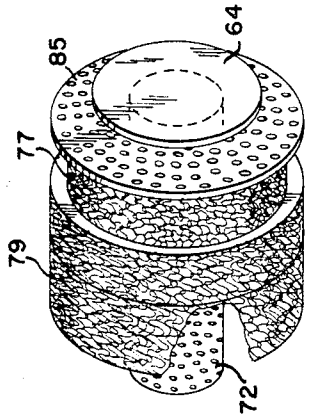


Fig. 2

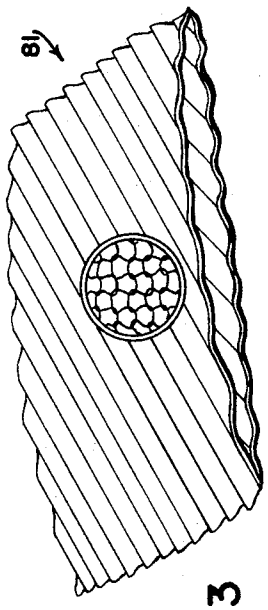


Fig. 3

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REFRIGERATION SYSTEM AND SYSTEM FOR SEPARATING OIL FROM COMPRESSED GAS

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5 Claims. (Cl. 62—470)

ABSTRACT OF THE DISCLOSURE

A refrigeration system is disclosed having a compressor of the screw type, and a stream of compressed gas and oil mist is used to cool the compressor and the motor. The oil is separated by passing the stream of refrigerant gas and oil through a unit which subjects the oil-laden gas to a thorough oil-separating treatment without restricting the flow of the oil-free gas.

This application is a continuation-in-part of application Ser. No. 612,222, filed Jan. 27, 1967, and covering the refrigeration system of the illustrative embodiment of the present invention. The present invention is directed to the details of structure and mode of operation involved in the separation of the oil which is entrained in the stream of compressed refrigerant gas.

This invention relates to refrigeration, and more in particular to a refrigeration system and method wherein the compressor is of the screw type and the stream of compressed gas and oil passes through a special oil separator.

An object of this invention is to provide an improved refrigeration system of the type having a compressor from which a stream of compressed refrigerant gas contains oil which must be separated from the gas. Another object is to provide an improved method and means for separating oil from compressed gas. A further object is to provide for the above with compressors of the screw type. Another object is to provide means for maintaining desirable operating conditions in a screw compressor under varying loads and extreme conditions of use. A further object is to provide for the above in a manner which avoids the difficulties which have been encountered in the past with similar constructions. These and other objects will be in part obvious and in part pointed out below.

In the drawings:

FIGURE 1 is a schematic representation of one embodiment of the invention;

FIGURE 2 is a fragmentary perspective view of the oil separator unit of FIGURE 1, with parts broken away; and,

FIGURE 3 is an enlarged view of the wire mesh which is in the oil separator unit of FIGURE 1.

Referring to FIGURE 1 of the drawings, a refrigeration system **2** includes: a screw compressor **4** having an unloader **5** and driven by an electric motor **6**; an oil separator **8**; a refrigerant discharge line **10**; a water-cooled condenser **12**; a liquid refrigerant line **14** extending to a refrigerant control and restrictor assembly **112** from which the refrigerant flows to an evaporator **26**; and, a gas refrigerant return line **32** through which the gas refrigerant returns to compressor **4**.

The system also includes an oil circulating system including the following in series: an oil sump **34**; an oil pump **36** driven by an electric motor **37**; an oil cooler **38** through which water flows from a water inlet **40** to a water outlet **42** and which cools the oil flowing from the pump and, an oil filter **44**. An oil supply line **46** delivers oil under controlled pressure through distributor lines **48** to the motor bearings **50** and through lines **52** and **54** and **56** to compressor **4**. Oil is also delivered from line **46** through a line **58** to the unloader **5**, and through a line **59** to a load control unit **60**.

During operation, the dense high-pressure oil-gas mixture is discharged from compressor **4** into a chamber **62** and thence through the motor where it is discharged axially against a baffle **64**. This gas-oil mixture uniformly blankets and cools the stator and rotor of the motor, and the motor also serves as a first-stage oil separator and removes, by centrifugal action, the bulk of the oil entrained in the gas. It has been found that something of the order of 95% of the oil is removed by the motor, and the oil accumulates at **66** in the bottom of the housing from which it flows through a line **35** to oil sump **34**. The remaining fine oil mist is then separated from the gas by the action of baffle **64** and oil separator **8**.

The disk-like baffle **64** deflects the stream of gas radially outwardly toward the outer wall and the oil then flows axially past the edge of the baffle through an annular passageway **68**. Positioned in axial alignment with passageway **68** is an annular separator unit **70** which effectively removes the oil from the gas passing through it. Separator unit **70** includes (see also FIGURE 2) a loosely-formed ring or annular separator **71** of knitted wire mesh which is wound upon a perforated tubular mandril **72**. Mandril **72** forms a central gas discharge passageway **74** through which the gas flows to a gas discharge tube **73**, and thence past a check valve **75** to line **10**.

Separator **71** is in the form of two rolls **77** and **79**, each of which is formed by a two-ply strip **81** (see FIGURE 3) of knitted wire mesh. Roll **79** is twice the axial dimension of roll **77**, and is formed by two strips **81** side-by-side. In this embodiment strip **81** is illustratively 7 inches wide and is formed by first knitting a wire-mesh tube having 60 openings per square inch and using steel of .011 inch in diameter. The mesh tube is then flattened to form the two-ply strip **81**, and it is crimped diagonally of the strip to form ridges, with the crimping being ¼ inch deep, and with the ridges being $\frac{9}{32}$ inch wide from ridge to ridge. A strip **81** is wound loosely on mandril **72** to form roll **77**, and two strips **81** are wound loosely side-by-side to form roll **79**. A perforated support plate **85** is assembled on mandril **72** at the side of roll **77**. The radius of roll **77** is less than that of roll **79**, so that there is an annular passageway **83** between roll **77** and shell **61**. Ilustratively, the radius of the inner surface of shell **61** is of the order of 10 inches, and the radius of roll **77** is 8½ inches. Therefore, a portion of the annular stream of gas with entrained oil flowing axially from passageway **68** may continue its axial flow through the perforations in plate **85** and along passageway **83**.

The portion of the stream adjacent the periphery of baffle **64** impinges against plate **85** at the periphery of roll **77**, and may pass through the perforations in the plate and into the roll. However, support plate **85** is spaced axially from baffle **64**, so as to provide a radial passageway **76** through which the gas may flow radially inwardly to passageway **74**, without passing through separator **71**. Therefore, it might be expected that some of the gas with entrained oil will pass radially inwardly through passageway **76** and enter passageway **74** without giving up its oil. However, it has been found that with the arrangement herein disclosed, there is a tendency for "two-phase fluid flow" axially through passageway **76** with gas having the oil mist therein flowing along the casing wall and through the perforations in plate **85** and along passageway **83**, while oil-free gas flows adjacent baffle **64** and thence radially inwardly through passageway **76**. The oil-laden gas in passageway **83** impinges against the rolls **77**

and 79, and there is a very substantial increase in the cross-sectional area of the flow path which causes a substantial reduction in the rate of flow. Hence, from passageway 83 the gas flows or migrates radially inwardly at a very slow flow rate toward the central mandril 72. Mandril 72 and plate 85 are sheet metal of sufficient rigidity to provide the desired support, and yet the perforations are of sufficient size and number to permit the relatively free flow of the gas through the plate and through the mandril wall. Hence, at the outer periphery of roll 77, some of the gas passes through plate 85 directly into roll 77.

During the flow through rolls 77 and 79, the oil adheres to the exposed surfaces of the wire mesh and flows downwardly and collects at the bottom of the casing 61 in the body of oil 66. There may be a tendency for the oil to bridge some of the passageways or perforations between the adjacent portions of the wire mesh in rolls 77 and 79. Such bridging of the passageways could be expected to cause the oil to be re-entrained in the gas so as to reduce the effectiveness of the oil separator. However, such re-entrainment does not occur, apparently because of the reduced velocity of the gas flow through the wire mesh. It has been found that the arrangement of the illustrative embodiment is effective to separate substantially all of the oil from the refrigerant gas throughout the entire range of loading from minimum to full load. At light loads there is a tendency for a high percentage of the refrigerant gas to flow through rolls 77 and 79, whereas at increased loads the tendency toward the "two-phase fluid flow" causes an increased amount of the refrigerant gas to be free of oil and to pass radially inwardly through passageway 68 without passing through rolls 77 and 79.

Certain details of the construction of the illustrative embodiment are set forth above, and it has been explained that very satisfactory results are obtained within the full range of variations in load on the compressor. In general the winding tension on the wire mesh must not be high enough to prevent the free flow of the refrigerant gas at a slow rate toward the central passageway 74 formed by mandril 72. In the illustrative embodiment mandril 72 has a diameter of the order of 7 inches, and baffle 64 has a diameter of 14 inches and is spaced 1⅜ inches from plate 85. The wire mesh forming rolls 77 and 79 is of substantially uniform density of the order of 15.5 pounds per cubic foot. It must be understood that these specific dimensions and other physical characteristics are illustrative.

As indicated above, unloader 5 controls the operation of the compressor so that it compresses the amount of refrigerant required for the load at all times. Accordingly, compressor 4 has a capacity control slide valve 120 which is shown in the full-load position wherein it forms a portion of the compressor-rotor casing 122. Slide valve 120 is mounted to slide to the left from the position shown to thereby expose an opening in the bottom of the rotor casing through which the suction gas can pass back from the central portion of the compressor to the suction inlet. In this way the amount of gas pumped is reduced.

Sliding valve 120 is connected through an operated spindle 124 to a piston 126 which is slidable in a cylinder 128. Piston 126 is moved to the left from the position shown by supplying oil at a controlled pressure to the chamber 130 in the cylinder at the right of the piston. Cylinder 128 is open at its left-hand end to the suction pressure of the compressor. Hence, when oil is supplied to chamber 130 at a pressure greater than the discharge pressure, piston 126 is moved to the left; and, when the pressure of the oil in chamber 130 is less than the discharge pressure, piston 126 moves to the right. Oil supply line 58 is connected to chamber 130 through a shut-off valve 132 and a line 134. Hence, when valve 132 is open the oil at the full pressure in lines 46 and 58 is supplied at once to chamber 130. Also, a flow circuit is provided in parallel with valve 132 by line 59 and a restrictor valve 136 and a shut-off valve 138. Hence, when valve 132 is closed and valve 138 is opened, the oil at the pressure of line 46 flows through line 59 restrictor 136, valve 138 and line 134 to chamber 130. However, restrictor 136 limits the rate of flow so that piston 126 is moved at a reduced but controlled rate, whereas when valve 132 is open the piston moves at a rapid rate. This permits unloading rapidly by opening valve 132, or unloading at a slower rate by opening valve 138.

An additional control circut is provided by a shut-off valve 140 and a restrictor 142 in a line 144 which extends between the suction inlet of the compressor housing and chamber 130. Hence, when valve 140 is open the oil in chamber 130 is free to flow through line 134, restrictor 142, line 144, and valve 140 to the compressor casing. As indicated above, when the compressor is operating, the pressure of the compressed gas at the discharge side of the compressor urges sliding valve 120 toward its full-load position. Hence, when valve 140 is open, the pressure equalizes on the two sides of the piston because of the flow of oil from chamber 130, and the discharge pressure acting on slide valve 120 moves the slide and piston 126 back to the position shown. Restrictor 142 controls the rate of flow of oil from chamber 130 and therefore controls the rate of movement of the piston from a partial-load position to the full-load position.

The oil pressure in line 46 is controlled by a control unit 146 which has a valve 148 in a line 150 extending from line 46 to sump 34. A control line 152 extends from unit 146 to the discharge chamber 62 of the compressor so that unit 146 is responsive to the compressor discharge pressure. Unit 146 and its valve 148 act as a relief valve to maintain a pressure in line 46 which is a predetermined amount above the pressure in chamber 62. Illustratively, when the compressed gas pressure in chamber 62 is 200 pounds per square inch, the pressure in line 46 is 240 pounds per square inch. Hence, the oil delivered to the compressor through the various lines 48, 52, 54 and 56, and through lines 58 and 59 to the unloader is maintained at a predetermined value above the compressor discharge pressure. This insures a proper and adequate supply of oil to the motor bearings and to the compressor. It also insures that the unloader will operate properly. The opening of valve 132 when the compressor is partially or fully loaded will unload it at a rapid rate. The opening of valve 140 when the compressor is partially or completely unloaded will fully load it at a controlled rate.

It has been pointed out above that the heavy mixture of compressed gas and oil mist provides a very satisfactory cooling of the motor. The oil mist produces a scrubbing action which improves the heat exchange factor and increases the cooling of the motor. The oil which is supplied to the compressor may contain some refrigerant and that refrigerant tends to flash and to aid in the cooling effect of the oil. It is thus seen that the refrigerant and the oil are circulated through separate cycles, but that inter-relationship is maintained which provides an improved mode of operation. Pump 36 is started prior to the starting of motor 6 so that the oil pressure builds up and provides oil for the motor and compressor, and the desired oil pressure is provided for the unloader. The controls also provide automatic unloading at start-up.

The system of FIGURE 1 includes standard components and controls. It is also understood that the embodiment herein disclosed is illustrative, and it is contemplated that changes and modifications may be made within the scope of the invention. Reference may be had to the above-identified co-pending application, which is incorporated herein by reference.

What is claimed is:

1. In a refrigeration system of the type having a motor-compressor of the type wherein a stream of compressed refrigerant gas containing a substantial amount of oil is delivered for passage to a refrigerant condenser, an oil separator to separate the oil from the refrigerant gas comprising, means including an enclosure wall forming a

flow path in a general direction which is along and parallel to an oil-separating axis, baffle means extending transversely of said axis positioned to divert the stream of gas radially outwardly from said axis and forming with said enclosure wall an axial passageway path parallel to said axis, a body of mesh positioned along said flow path upon the downstream side of said baffle means and spaced axially downstream and thereby providing a free passageway extending radially inwardly from said axial passageway.

2. Apparatus as described in claim **1** wherein said enclosure wall is a substantially cylindrical wall having its axis substantially parallel to the axis of the motor and which includes a perforated mandril forming an axial gas discharge passageway, and wherein said body of mesh is an annular body of knitted wire surrounding said mandril.

3. Apparatus as described in claim **2** wherein said knitted mesh is formed of steel wire which has been knitted into a mesh tube and then flattened to form a strip and the strip has been wound into a spiral.

4. Apparatus as described in claim **2** wherein said knitted mesh is formed by spiral layers of knitted mesh and the density in terms of weight of metal per cubic foot is of the order of 15.5 pounds.

5. Apparatus as described in claim **1** wherein said enclosure wall presents a substantially cylindrical inner surface and said baffle means is centrally positioned with respect to said inner surface and is positioned to make said axial passageway annular, and wherein said body of mesh is an annular body of wire mesh, and a perforated gas discharge conduit positioned within said annular body, said annular body being of such density as to permit the flow of refrigerant gas therethrough at a rate which is insufficient to cause re-entrainment of oil which is separated from the gas.

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