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Eber

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[54] **REFRIGERATION MACHINE WITH LIQUID REFRIGERANT COOLED MOTOR**

[75] Inventor: **David H. Eber,** La Crosse, Wis.

[73] Assignee: **The Trane Company,** La Crosse, Wis.

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[52] **U.S. Cl.** **62/505,** 310/54
[51] **Int. Cl.** **F25b 31/00**
[58] **Field of Search** 310/54; 62/505

[56] **References Cited**

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Primary Examiner—Meyer Perlin

[57] **ABSTRACT**

A centrifugal compressor type refrigeration machine is shown with a liquid refrigerant cooled electric motor for driving the compressor. The liquid refrigerant for motor cooling is derived from the refrigeration machine refrigerant circuit at refrigerant circuit pressure but is applied directly to the stator-rotor gap of the motor at a relatively uniform elevationally controlled hydrostatic pressure. Prior to entering the stator-rotor gap, liquid refrigerant is separated from refrigerant vaporized by heat exchange with the stator.

9 Claims, 2 Drawing Figures

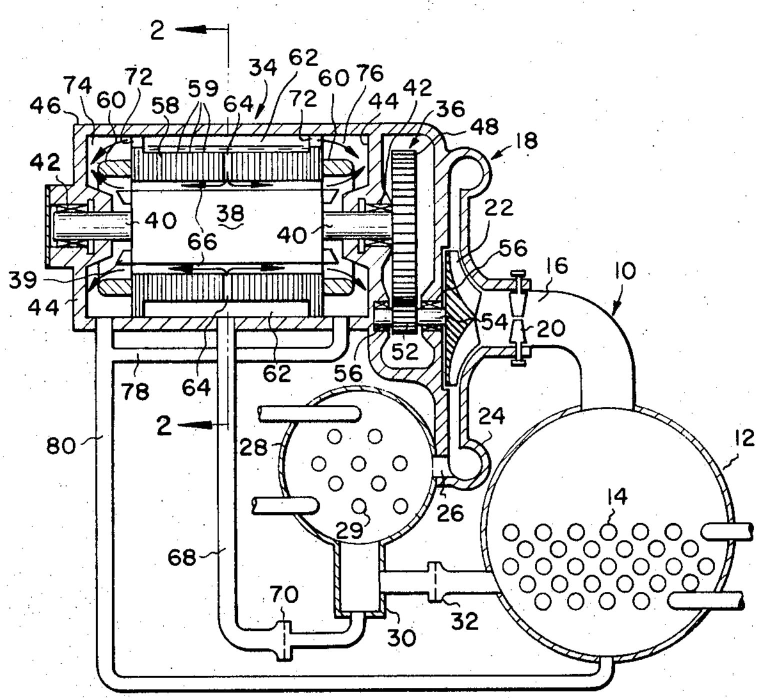

FIG. 1

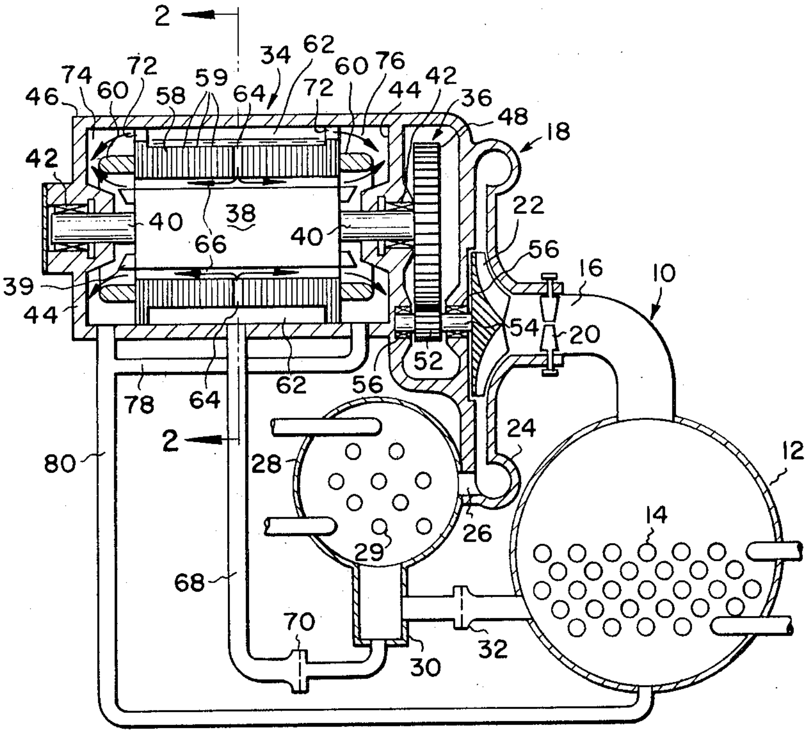
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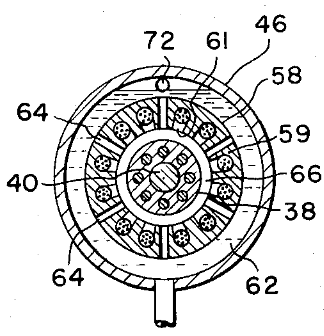
FIG. 2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REFRIGERATION MACHINE WITH LIQUID REFRIGERANT COOLED MOTOR

BACKGROUND OF THE INVENTION

Heretofor many advancements have been made in the art of cooling compressor motors for refrigeration machines to thereby reduce their size, weight, cost and increase their reliability. The art has advanced from a state of using solely refrigerant gas for cooling to using liquid sprays directed at both the moving and fixed parts of the ends of the motor.

SUMMARY OF THE INVENTION

This invention pertains to refrigeration machines of the compression type wherein a refrigerant is advanced through a closed circuit of widely varying pressures and temperatures to effect changes in state of the refrigerant medium.

More particularly this invention pertains to the method of utilizing the refrigeration effect of the refrigerating medium of the circuit to effectively cool the compressor motor. In this invention refrigerant liquid is derived from the closed refrigerant circuit under circuit pressure. The liquid refrigerant is then delivered across the stator-rotor gap of the motor via an annular stator cooling chamber at a relatively low pressure of substantially fixed elevational head. The stator cooling chamber also functions as a separator to remove substantial quantities of vaporized refrigerant from the refrigerant liquid prior to the refrigerant passing to the stator-rotor gap. The refrigerant then passes axially outwardly from the stator-rotor gap and with some tangential velocity imparted thereto by the rotor is impelled over the motor end turns and finally is returned to the closed refrigerant circuit at a second lower circuit pressure.

The invention eliminates small internal jets and orifices commonly used in liquid spray cooled refrigerant compressor motors.

It eliminates the hazards of clogged motor cooling passages in the motor.

It further reduces the likelihood of erosion due to high velocity refrigerant impingement.

Other objects and advantages will become apparent as this specification describes the invention with reference to the accompanying drawings in which:

FIG. 1 is a semi-schematic vertical section of a refrigeration machine employing the invention; and

FIG. 2 is a section of the compressor motor taken at line 2—2 of FIG. 1.

Now referring to the drawing it will be seen that the refrigeration machine **10** has a shell-and-tube type evaporator **12** for cooling water, such as from a building chilled water system, which water is passed through a series of interconnected tubes **14**. By indirect heat exchange with the water in tubes **14**, refrigerant liquid within the shell of the evaporator **12** is vaporized and passes to the inlet **16** of centrifugal compressor **18** which may be provided with capacity control adjustable inlet vanes **20**. The refrigerant gas is centrifugally impelled by rotation of compressor impeller **22** to a high pressure and collected in the compressor volute **24** for discharge at **26** to the shell-and-tube condenser **28**.

In the condenser the refrigerant gas under high pressure is cooled by indirect heat exchange with cooling water passed through the tubes **29** thereof. The condensed refrigerant falls to and collects in the condenser well **30** where upon it returns to the evaporator **12** through a refrigerant throttling means such as pressure reducing valve **32** which may be constructed in accordance with the teachings of U.S. Pat. No. 3,260,067 regarding valve **52** thereof.

The refrigerant is thus conducted through a closed refrigerant circuit or loop including evaporator **12**, compressor **18**, condenser **28**, and refrigerant throttling means **32**.

The compressor impeller **22** is rotatably driven by an electric motor **34** via a speed increasing gear drive assembly **36**. The compressor **18**, gear drive assembly **36** and motor **34** are preferably hermetically constructed, i.e., with no sliding or rotating seals in the exterior walls.

The motor has a rotor **38**, the shaft **40** of which is journaled in suitable bearings **42** carried by the ends **44** of motor housing **46**. One end of shaft **40** extends into the casing of the gear drive assembly **36** and has mounted thereon for rotation therewith a large bull gear **48** which is disposed in driving mesh with a small pinion gear **52** mounted on and in driving relationship with the impeller shaft **54** of the impeller **22** which is journaled in bearings **56**. The gears **52** and **48** are provided with a suitable lubrication system which is not shown for purposes of simplicity.

The motor has an annular stator **58** disposed about rotor **38** which stator is comprised of a stack of annular plates **59** provided in the conventional manner with axially extending interior grooves or slots **61** for receiving the stator windings the end turns **60** of which extend axially therefrom at each end. The axially inner laminations or plates are constructed so as to provide a substantially annular chamber **62** between their radial outer edge and the inner surface of the motor housing **46**. The stator **58** has a plurality of circumferentially spaced radially extending passages or bores **64** disposed intermediate the ends of the stator which communicate chamber **62** with the stator-rotor radial gap **66**. A conduit **68** is provided to communicate the lower portion of the condenser well **30** through a fixed orifice valve **70** to chamber **62**. Valve **70** may be similar to valve **32**. Axially extending bores **72** extend through the ends of the stator **58** adjacent the top to communicate chamber **62** with the motor end chambers **74** and **76** which are located between the stator ends and the motor housing end walls **44**. The motor end chambers **74** and **76** are connected at their bottoms by conduits **78** and **80** to evaporator **12**.

During operation of the refrigeration machine refrigerant is circulated through the closed refrigerant circuit afore described. During this operation liquid refrigerant also passes from the condenser well **30** at a relatively high condenser pressure through pressure reducing valve **70** into the motor **34** to chamber **62** at a rate in excess of that required to adequately cool the motor. Except for bores **64**, **72** and inlet conduit **68**, chamber **72** is sealed and is maintained during operation full to the level of bores **72** so liquid refrigerant is circumferentially distributed under hydrostatic pressure within the motor housing completely around the outside of stator **58** and to radial passages **64**. During operation sufficient heat passes from stator **58** to chamber **62** to vaporize a portion of the refrigerant therein. A substantial portion of refrigerant liquid which may have vaporized in chamber **62** or by reason of the reduction in pressure at valve **70** will separate by rising to the top of chamber **62** whereby predominately liquid refrigerant enters passages **64.** Excess liquid refrigerant in chamber **62** rising above apertures **72** passes into end chambers **74** and **76** along with the vaporized refrigerant collected at the top of chamber **62.**

Liquid refrigerant entering passages **64** passes directly to the center of the stator-rotor gap **66** where it impinges upon the rotor. The elevational hydrostatic head impelling the refrigerant through passages **64** is limited by the elevation of the refrigerant in chamber **62** as determined by the position of apertures **72.** Sufficient heat is passed from the rotor **38** and stator **58** to at least partially vaporize the refrigerant in the stator-rotor gap to cool the rotor and internal surface of the stator. Vaporized and any unvaporized refrigerant passes axially from each end of the stator-rotor gap **66** from whence it passes along with refrigerant passing through apertures **72** over the motor winding end turns **60** in the motor end chambers **74** and **76.** The rotational or tangential velocities imparted to the vapors by the rotor in passing axially outwardly through the stator-rotor gap **66** and by the rotor fan blades **39** causes the refrigerant to pass radially outwardly in intimate heat exchange relationship with the motor end turns for improved cooling thereof.

Refrigerant gas and any unvaporized refrigerant liquid is withdrawn from motor end chambers **74** and **76** and passes through conduits **78** and **80** to evaporator **12** thereby maintaining chambers **62, 74** and **76** close to relatively low evaporator pressure. However, it should be appreciated that where a two stage compressor is employed conduit **80** could be connected to the interstage such as by an interstage economizer rather than to the evaporator. In such case chambers **62, 74** and **76** would be maintained at relatively low economizer pressure.

Thus it will be seen that while refrigerant for motor cooling is taken from and returned to the closed refrigerant circuit at variable system pressures which exist within such circuit, the differential pressure forcing the liquid refrigerant through the stator passages **64** is substantially fixed by the hydrostatic gravitational or elevational pressure head of the liquid refrigerant in chamber **62,** it being appreciated that excess liquid exceeding the predetermined level established by apertures **72** overflows into chambers **74** and **76.** Since this pressure differential is relatively small and constant during operation, the orifices defined by passages **64** may be made relatively large whereby they cannot easily become clogged. The system operates in a simple reliable manner with minimum structure to provide direct liquid cooling to both the outside of the stator and the surfaces defining the stator-rotor gap.

Having now described the preferred embodiment of the invention, it is contemplated that any changes may be made without departing from the scope or spirit of the invention as limited only by the claims.

What is claimed is:

1. In a refrigeration machine having a refrigerant compressor, a refrigerant condenser, and a refrigerant evaporator respectively serially connected in a closed refrigerant circuit, and an electric motor drivingly connected to the compressor and having a stator formed of a stack of plates and a rotor spaced by a stator-rotor radial gap, the improved method of cooling said motor comprising the steps of:

A. passing a refrigerant liquid from said refrigerant circuit and delivering it into said motor;

B. passing the refrigerant liquid thus entering said motor in intimate heat exchange relationship with a major portion of the radial outside of said stack of plates of said stator;

C. passing sufficient heat from said radial outside of said stack of plates of said stator to the liquid refrigerant in heat exchange relation therewith to thereby vaporize a first portion of the liquid refrigerant;

D. separating therefrom at least a portion of the thus vaporized refrigerant thereby leaving a remaining predominantely liquid portion of refrigerant;

E. passing at least a part of said remaining predominantely liquid portion of refrigerant radially inwardly through said stack of plates of said stator to the stator-rotor gap;

F. passing sufficient heat from said rotor to the liquid portion of refrigerant in said stator-rotor gap to thereby vaporize a second portion thereof; and

G. returning said first and second vaporized portions of refrigerant to said closed refrigerant circuit.

2. The method as defined by claim **1** wherein step A includes passing refrigerant liquid from said refrigerant circuit at a first pressure and step G includes returning at least one of said vaporized portions of refrigerant to said closed refrigerant circuit at a second substantially lower pressure.

3. The method as defined by claim **2** including the step of maintaining the pressure in said motor substantially closer to said second pressure than said first pressure.

4. The method as defined by claim **3** wherein said last named step includes the step substantially reducing the pressure of the refrigerant in route from said refrigerant circuit to said motor.

5. In a refrigeration machine having a refrigerant compressor, a refrigerant condenser, and a refrigerant evaporator respectively serially connected in a closed refrigerant circuit, and an electric motor drivingly connected to the compressor and having a stator and a rotor spaced by a stator-rotor radial gap, the improved method of cooling said motor comprising the steps of:

A. passing a refrigerant liquid from said refrigerant circuit and delivering it into said motor;

B. passing the refrigerant liquid thus entering said motor circumferentially about said stator within a substantially annular chamber in intimate heat exchange relationship with the outside of said stator;

C. passing sufficient heat from said outside of said stator to the liquid refrigerant in heat exchange relation therewith to thereby vaporize a first portion of the liquid refrigerant;

D. separating therefrom at least a portion of the thus vaporized refrigerant thereby leaving a remaining predominantely liquid portion of refrigerant;

E. passing at least a part of said remaining predominantely liquid portion of refrigerant radially inwardly through said stator to the stator-rotor gap;

F. passing sufficient heat from said rotor to the liquid portion of refrigerant in said stator-rotor gap to thereby vaporize a second portion thereof; and

G. returning said first and second vaporized portions of refrigerant to said closed refrigerant circuit.

6. The method as defined by claim **5** further including the step of limiting the pressure differential on said refrigerant in passing through said stator.

7. The method as defined by claim **6** wherein the step of limiting the pressure differential includes the step of limiting the hydrostatic elevational head pressure applied to the refrigerant passing about said stator.

8. The method defined by claim **7** wherein step A includes the step of delivering refrigerant liquid into said motor at a rate in excess of that required to adequately cool said motor and wherein said step of limiting the hydrostatic elevational head pressure includes the step of passing an overflow portion of liquid refrigerant exceeding a predetermined height relative to said chamber from said chamber.

9. The method as defined by claim **8** including the steps of passing said first and second vaporized portions and said liquid overflow portion of refrigerant simultaneously in heat exchange relation with the end turns of said stator.

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