March 22, 1966 J. W. ENDRESS ETAL 3,241,331

APPARATUS FOR AND METHOD OF MOTOR COOLING

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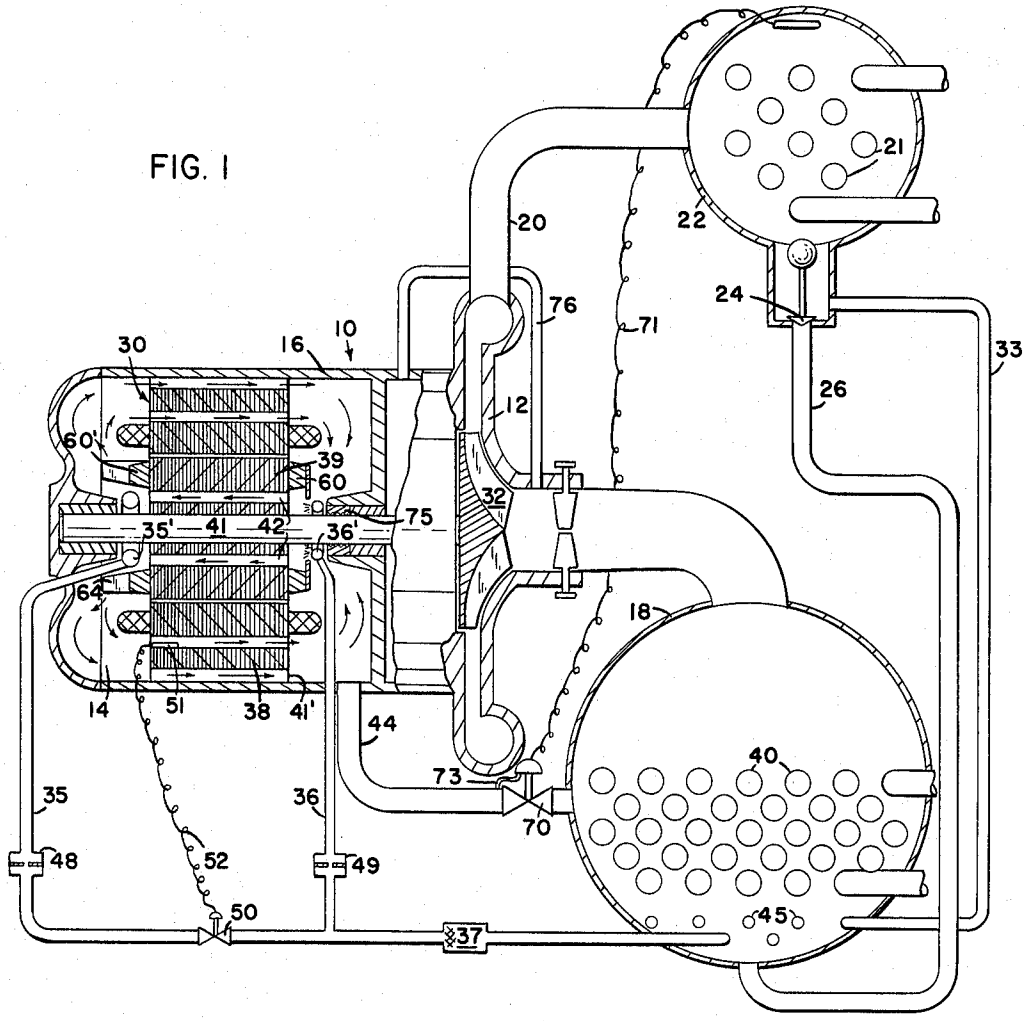
FIG. 1



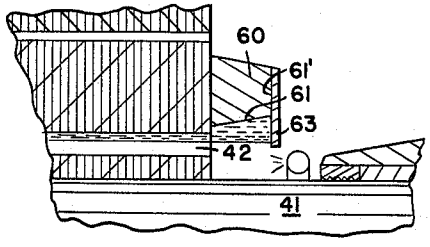


FIG. 2

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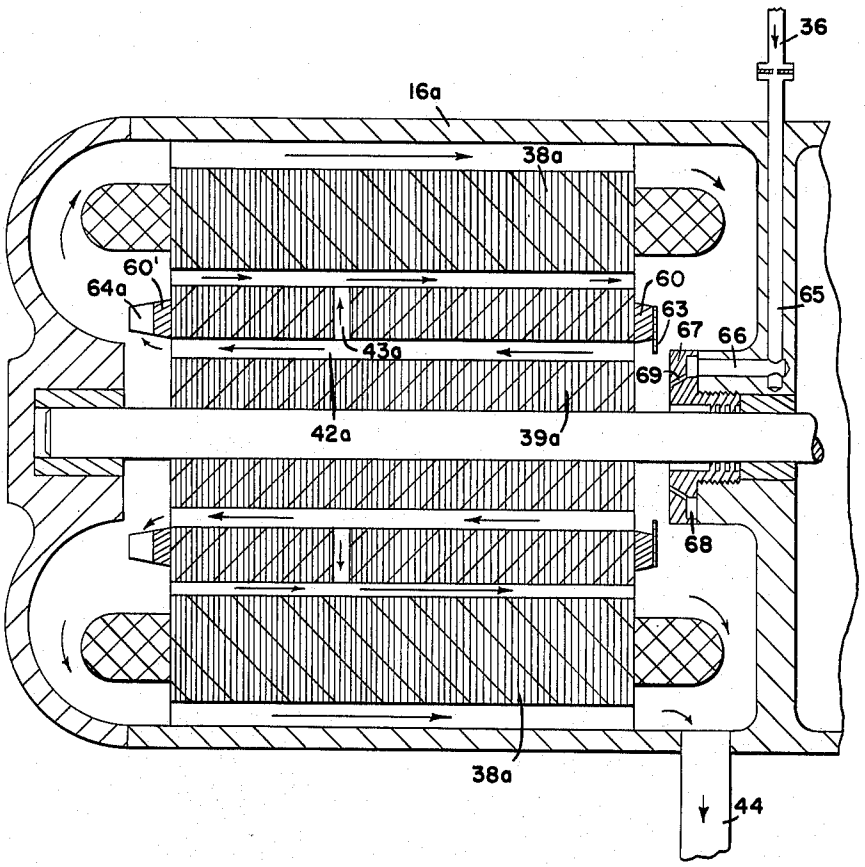
FIG. 3



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APPARATUS FOR AND METHOD OF MOTOR COOLING

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21 Claims. (Cl. 62—117)

This application is a continuation-in-part of our copending application Serial No. 114,359, filed June 2, 1961, now abandoned.

This invention relates broadly to the art of cooling motors employed to drive rotating power consuming apparatus. More particularly, this invention relates to a method of an apparatus for cooling the motor employed to drive a compressor in a compression refrigeration machine.

Various arrangements have been proposed for the purpose of cooling the motor used to provide rotational movement to a compressor in a refrigeration system. One of the arrangements suggested includes the use of refrigerant either in the liquid or gaseous state from the refrigeration machine as a coolant or cooling medium for the motor. For instance, gaseous refrigerant formed in the evaporator has been proposed as a cooling medium. However, its use introduces into the system an additional power requirement to circulate gaseous refrigerant at high velocity, due to its low specific heat and density, which, in turn, affects the efficiency of the refrigeration machine.

This invention contemplates the use of liquid refrigerant from the refrigeration system as the cooling medium for the motor employed to drive the compressor in the machine. Liquid refrigerant is introduced into the housing accommodating the motor components where it flows in heat transfer relation with the components. A preferred source of liquid refrigerant from the refrigeration machine is in the high pressure side of the machine, more precisely, liquid from the condenser. In equipment of the kind under consideration, the interior of the motor housing is in communication with the inlet of the compressor so as to be under a relatively low pressure. The high pressure liquid refrigerant is introduced into the interior of the motor casing where a certain amount of flashing-off of the liquid refrigerant occurs. This action results in the cooling of the portion of the unvaporized liquid refrigerant remaining in the mixture of vaporous and liquid refrigerant for flow in heat transfer relation with the heat producing motor components. After passing through the components of the motor to be cooled, substantially all of the liquid refrigerant in the mixture is converted to the gaseous state and introduced into the inlet of the compressor.

The chief object of this invention is the provision of an improved arrangement for cooling the motor of a hermetic motor-compressor unit in a refrigeration machine wherein liquid refrigerant from the refrigeration machine is employed as a cooling medium.

Another object of the invention is the provision of an improved arrangement for cooling the motor of a motor-compressor unit of the kind under consideration wherein liquid refrigerant from the high pressure side of the machine is employed as a cooling medium.

A still further object of the invention is the provision of improved motor cooling apparatus of the kind under consideration wherein the relatively warm high pressure liquid refrigerant is subcooled in the low pressure portion of the machine prior to its use as a cooling medium for the motor.

A still further object of the invention is the provision

of an arrangement for cooling the motor of a motor-compressor unit wherein novel arrangement is employed for distributing the liquid refrigerant throughout the housing of the motor.

Another object of the invention is the provision of a novel method of cooling the motor driving a compressor in a refrigeration machine.

Another object of the invention is the provision of a novel method of cooling a motor employed in a facility or plant including a working fluid as the cooling medium for the motor.

These and other objects of the invention will be apparent upon a consideration of the ensuing specification and drawings in which:

FIGURE 1 is a diagrammatic view of a refrigeration machine employing a motor compressor unit as a compressor thereof wherein the novel cooling means forming the subject of this invention are illustrated.

FIGURE 2 is a fragmentary view of a portion of the motor assembly illustrating a part of the arrangement for promoting flow of cooling medium through the motor.

FIGURE 3 is a partial diagrammatic view, similar to FIGURE 1 of a modification of the invention.

Referring more particularly to the drawing for an illustration of a refrigeration machine of the type to which this invention applies, motor-compressor unit **10** includes a compressor section or compartment **12** and a separate motor section or compartment **14** arranged within a housing **16**. The compressor is arranged so as to extract gaseous refrigerant from evaporator **18** and discharge it at relatively high pressure through line **20** to a condenser **22**. In the condenser the gaseous refrigerant is converted to the liquid phase through heat transfer with a cooling medium such as a source of relatively cool water supplied through coil **21**. From the condenser **22** liquid refrigerant flows through an opening controlled by a float valve **24** and line **26** to evaporator **18** where it is converted to the gaseous state through heat transfer with a medium such as water flowing in a circuit including coil **40**, separate from the circuit supplying the water to the condenser. The circuit including coil **40** supplies cool water to an air conditioning plant, not shown.

In order that the motor **30**, employed to drive the compressor impeller **32**, be suitably cooled, there is provided a line **33** connected to the portion of the condenser **22** wherein liquid refrigerant collects and to branch lines **35** and **36** connected in turn to apertured headers **35'** and **36'** in the casing forming the housing for the motor assembly.

In the motor compartment **14** there is provided the usual stator member **38** and rotor member **39**. The rotor is assembled in the usual manner with the drive shaft **41** and is provided with a number of openings **42** extending axially through the laminations thereof for the purpose of providing passages for the flow of cooling medium in a manner to be later described. The stator is likewise provided with openings similar to those formed in the rotor to provide passages for the flow of cooling medium. Circumferentially oriented spacer bars **41'** connect the stator to the inner surface of casing **16** and form passages between the stator and housing structure. Line **44** is provided for the purpose of returning gaseous refrigerant formed in the motor compartment to the inlet of the compressor. Thus it will be apparent that the gaseous refrigerant warmed by passage in heat transfer relation to the motor components is re-introduced into the refrigeration machine.

One of the features of this invention involves providing a portion **45** of the line **33** in heat transfer relation with the liquid refrigerant supplied to the evaporator. Thus the relatively warm high pressure liquid refrigerant from

the condenser is cooled prior to its introduction into the motor compartment. Restrictions **48** and **49** are shown provided in branch lines **35** and **36** for the purpose of maintaining a pressure difference between the high pressure side of the machine and the low pressure side of the machine as well as to meter refrigerant flow in lines **35** and **36**. Strainer **37** is provided in line **33** to filter foreign material that may clog the apertures in headers **35'** and **36'**. Also located in branch line **35** for a purpose to be later described is a valve member **50** of the well known thermal expansion type. The valve **50** includes a bulb **51** disposed in heat transfer relation with the refrigerant passing through the stator and a capillary **52** providing communication between the bulb and the valve. The valve assembly described is charged with a thermal responsive fill such that the valve is opened in response to a refrigerant or stator temperature of a predetermined value.

Thus with the arrangement provided, liquid refrigerant is continuously supplied to the interior of the casing through branch line **36**. Under circumstances where the cooling requirement remains unsatisfied, valve **50** opens and permits the supply of additional liquid refrigerant to the interior of the motor casing. It will be observed that the lines **35** and **36** terminate in the headers located adjacent the ends of the rotor in the area between the end rings **60** and **60'** and the rotor. Upon delivery of liquid refrigerant the rotary motion of the rotor imparts centrifugal forces to the refrigerant draining through the header apertures to cause the liquid refrigerant to collect against surface **61** of the motor rotor end ring **60**, note FIGURE 2, by action similar to a centrifuge.

In order to effectively feed the liquid refrigerant emanating from header **36'** to the passages **42** in the rotor **39**, a flat ring member **63** is secured to the surface **61'** of end ring **60** to form a confining pocket with the end ring for receiving liquid refrigerant flung there by centrifugal forces generated by the shaft **41**. A particular feature of the invention is the utilization of the construction described to assure flow of liquid refrigerant through the rotor passage **42**. To this end, the flat ring **63** is arranged to overlie a portion of the end of the passage **42** so that a head of liquid is available for flow through the passage.

To assist in the flow of refrigerant through passage **42**, end ring **60'** has secured thereto a plurality of axially extending, circumferentially spaced blades **64**, operable to create a suction within the end of the passage adjacent the blades. Flow of liquid refrigerant through rotor passage **42** is thus assured and delivery of the refrigerant through stator passages **42** or in the space between the stator and housing under the influence of the blades **64** is promoted through a path as indicated by the arrows.

The end ring **60'** is not equipped with a restricting ring similar to ring **63**. However, upon delivery of liquid refrigerant through header **35'** the blades **64** and ring **60'** are effective to atomize the refrigerant and force it through the path shown by the arrows.

FIGURE 3 represents a modification of the invention wherein radial passages **43***a* are provided in the rotor for the purpose of assuring flow of coolant to the space between the rotor **39***a* and the stator **38***a*. The passages **43***a* connect with passages **42***a* and coolant flow occurs in the manner indicated by the arrows because the fan, represented by blades **64***a* imposes a slight pressure in the space between the rotor and stator.

Another feature of the modification shown in FIGURE 3 involves the supply of liquid refrigerant to the interior of the casing. A passage **65** and a passage **66** are provided in the wall structure of casing **16***a*. Fitting **67** having an annular space **68** in communication with passage **66** is provided with small passageways **69** serving as nozzles for delivering liquid coolant to the interior of the casing.

An additional feature of the invention involves the inclusion of valve **70** in line **44** connecting the motor casing and the evaporator. Valve **70** is connected, through capillary **71**, with condenser **22**. Line **73** serves to connect the operating mechanism of the valve with the motor compartment. Thus the valve responds to a relationship between condenser and motor compartment pressure. Valve **70** is provided to maintain a suitable pressure difference between the interior of compartment **14** and the condenser. In this manner, refrigerant leakage across labyrinth seal **75** to the compartment **12** is assured, while lubricant flow in the opposite direction across the labyrinth is prevented. Vent line **76** provides a path for the return of the refrigerant escaping from compartment **14** to the suction of the impeller. Valve **70** is constructed so that restricted communication between the evaporator and compartment **14**, through line **44**, is always assured. To this end, a stop element preventing closure of the valve may be employed in the valve construction. At machine startup, pressure throughout the machine is substantially constant. Valve **70** is arranged so as to be in its open position permitting communication between the evaporator and compartment **14** through line **44**. As the pressure in the high pressure side of the machine increases, relative to the pressure in the low pressure side of the machine, the valve closes to maintain a pressure in the compartment **14** intermediate the high and low pressures in the machine. Preferably, the valve is designed to maintain a pressure within compartment **14** below the condenser pressure by a predetermined value and to function to maintain the pressure differential constant over a wide range of condenser pressures. With the valve operable in the manner described, efficient heat transfer action is accomplished due to the character of the gaseous refrigerant circulating in compartment **14**. It is well known that gaseous refrigerant of relatively high temperature has more favorable specific heat and specific density properties than lower temperature gaseous refrigerant making it more desirable for some heat transfer applications.

Considering the operation of the invention illustrated, liquid refrigerant formed in the condenser flows through line **33** via portion **45** and branch **36** to the interior of the casing housing the motor. The refrigerant, upon introduction into the motor housing, has portions thereof flash-off or vaporize to combine with the remaining liquid portions to form a cooling medium for flow through the passages formed in the rotor and stator members in the manner described. If desired, suitable baffling may be incorporated within the housing in the interest of promoting flow in any given direction.

After the refrigerant has passed through the passages formed in the rotor and stator, it is substantially completely vaporized as it absorbs heat radiating from the motor components. With the arrangement described, the vaporized refrigerant is withdrawn through the line **44**. It is also possible with the arrangement shown to calculate the rate of liquid flow such that the gas flowing in line **44** is not superheated beyond a desirable minimum value. Under certain circumstances where the condensing temperature drops, as for example, when the outdoor temperature falls and an air cooled condenser is employed, it is desirable that additional flow of refrigerant to the motor casing be provided. The need for additional flow will be reflected in the temperature of the stator which, in turn, will be sensed by valve **50**, the valve opening under these circumstances to supply liquid refrigerant through branch line **35**.

It will thus be appreciated that an improved method of and apparatus for cooling a motor with liquid refrigerant is provided. The method and apparatus involved enable cooling of the motor to be conducted under circumstances where power loss and performance loss are held to a minimum.

While we have described preferred embodiments of the invention, it will be understood that the invention is not

limited thereto since it may be otherwise embodied within the scope of the following claims.

We claim:

1. Refrigeration apparatus comprising a compressor; a motor including a drive shaft coupled to the compressor, a rotor assembled about the drive shaft, end rings secured to and extending axially from the terminal portions of the rotor, a stator assembled about the rotor and a housing enclosing the drive shaft, rotor and stator, said rotor and stator being provided with passages extending therethrough; a condenser; an evaporator; a refrigerant flow control member interposed between the condenser and the evaporator; and lines connecting the compressor, condenser and evaporator to form a closed circuit for the flow of refrigerant; conduit means connecting a portion of the circuit accommodating liquid refrigerant and the housing, said conduit means terminating in said housing adjacent said rotor so that refrigerant delivered to the housing through said conduit means is subjected to flow under the influence of centrifugal forces developed by the rotating drive shaft and rotor, means forming with one of said end rings a pocket, having communication with at least one of the rotor passages, accumulating refrigerant flowing under the influence of the said centrifugal forces and means providing a passage for return of refrigerant from the housing to the circuit.

2. The invention set forth in claim 1 including means for inducing flow of refrigerant from the pocket through the passage.

3. The invention set forth in claim 2 wherein said last-mentioned means are connected to the end ring remote from the end ring forming the refrigerant accommodating pocket.

4. The invention set forth in claim 3 wherein said last-mentioned means are circumferentially spaced axially extending blades arranged to induce refrigerant flow through said rotor passage and upwardly through said stator passages so as to pass in heat transfer relation therewith.

5. The invention set forth in claim 1 wherein said conduit means includes branch portions providing paths of flow to spaced locations within said housing.

6. The invention set forth in claim 5 wherein said branch portions terminate adjacent the opposed end rings on the rotor.

7. The invention set forth in claim 6 wherein thermally responsive control means are provided in at least one of said branches for regulating flow of refrigerant therein.

8. Refrigeration apparatus comprising a compressor; a motor including a drive shaft coupled to the compressor, a rotor assembled about the drive shaft, end rings secured to and extending axially from the terminal portions of the rotor, a stator assembled about the rotor and a housing enclosing the drive shaft, rotor and stator, said rotor and stator being provided with passages extending therethrough; a condenser; an evaporator; a refrigerant flow control member interposed between the condenser and the evaporator; and lines connecting the compressor, condenser and evaporator to form a closed circuit for the flow of refrigerant; conduit means connecting the condenser and the housing, said conduit means terminating in said housing adjacent said rotor so that refrigerant delivered to the housing through said conduit means is subjected to flow under the influence of centrifugal forces developed by the rotating drive shaft and rotor, means forming with one of said end rings a pocket, having communication with at least one of the rotor passages, for the accumulation of refrigerant flowing under the influence of the said centrifugal forces and means providing a passage for return of refrigerant from the housing to the circuit.

9. The invention set forth in claim 8 wherein means are provided for inducing flow of refrigerant through the passage from the pocket.

10. The invention set forth in claim 9 wherein said last-mentioned means are connected to the end ring remote from the end ring forming the refrigerant accommodating pocket.

11. The invention set forth in claim 10 wherein thermally responsive control means are provided in at least one of said branches for regulating flow of refrigerant therein.

12. Apparatus for cooling a motor having a drive shaft for connection with a rotatably driven component of a facility incorporating a working fluid suitable as a coolant for the motor, a rotor having passages extending therethrough and end rings secured to the opposite ends thereof, a stator having at least one passage therethrough; conduit means for supplying coolant from the facility to a location adjacent the area defined by the end ring and shaft; means including a relatively flat, thin ring assembled with one of said end rings so as to form an inwardly extending flange and present a pocket in communication with said rotor passage for the accommodation of coolant propelled radially outwardly relative to said drive shaft under the influence of centrifugal forces developed thereby; and means operatively associated with said other end ring for inducing flow of coolant first through said rotor passage and then through said stator passage.

13. Refrigeration apparatus comprising a compressor; a motor for driving said compressor, said motor including a housing, a stator, a rotor and a drive shaft assembled within said rotor and operatively connected to said compressor; a condenser for receiving gaseous refrigerant discharged from said compressor and converting it to the liquid phase, an evaporator for receiving liquid refrigerant from the condenser and converting it to gaseous refrigerant; refrigerant flow control means interposed between the condenser and the evaporator; means forming a path for the flow of a portion of the liquid refrigerant formed in the condenser to the motor housing, said means including a line having a portion in heat transfer relation with the liquid refrigerant flowing in the low pressure side of the apparatus; means forming passages for the flow of refrigerant delivered to said housing through said line in heat transfer relation with said rotor and stator members and a line connecting the motor housing and the apparatus providing a path for the flow of gas heated by flow through the motor housing to the refrigeration system.

14. The invention set forth in claim 13 wherein means are provided in said last-mentioned line for controlling flow of refrigerant therein.

15. The invention set forth in claim 14 wherein said means includes a valve operable in response to a predetermined relationship between condenser pressure and motor housing pressure.

16. The invention set forth in claim 15 wherein said valve is operative to provide at least restricted communication between the evaporator and motor housing independently of condenser and motor housing pressure.

17. The method of cooling a motor including a drive shaft, a rotor having at least one passage formed therein, end rings secured to opposite ends of said rotor, a stator having at least one passage and a housing surrounding said drive shaft, rotor and stator; which comprises the steps of delivering a cooling medium within the housing adjacent the rotatably driven drive shaft, collecting cooling medium flowing radially outwardly under the influence of centrifugal forces developed by the drive shaft, confining the collected cooling medium in a space having communication with the rotor passage so as to provide a liquid head for the flow of collected cooling medium through the passage.

18. The method of cooling a motor, having heat generating components positioned within a housing, employed to drive a compressor in a refrigeration machine including a condenser, evaporator and refrigerant flow metering means connected to form a closed circuit for the flow of refrigerant which comprises the steps of forwarding liquid refrigerant formed in the circuit to the housing, supplying the liquid refrigerant to the motor components so that at

least a portion is subject to centrifugal force developed by the rotation of the motor components, collecting the refrigerant flowing under the influence of the centrifugal force, feeding the refrigerant through a path including the heat generating components of the motor to cool same, extracting the refrigerant heated by flow through said housing and controlling the pressure within said housing by regulating the extraction of refrigerant from the housing.

19. The method set forth in claim **18** wherein said last step includes controlling the extraction of refrigerant in response to a relation between the condenser and motor housing pressure.

20. The method of cooling a motor, having heat generating components positioned within a housing, employed to drive a compressor in a refrigeration machine including a condenser, evaporator and refrigerant flow metering means connected to form a closed circuit for the flow of refrigerant which comprises the steps of forwarding liquid refrigerant formed in the circuit to the housing, supplying the liquid refrigerant to the motor components so that at least a portion is subject to centrifugal force developed by the rotation of the motor components, feeding the refrigerant through a path including the heat generating components of the motor to cool same, extracting the refrigerant heated by flow through said housing and controlling the pressure within said housing by regulating the extraction of refrigerant from the housing, downstream of the housing, and controlling the extraction of refrigerant in response to a relation between an operating characteristic of the condenser and motor housing pressure.

21. Apparatus comprising a motor having a drive shaft

connected with a rotatably driven component of a facility means incorporating a working fluid suitable as a coolant for the motor, a rotor on the drive shaft having passages extending axially therethrough with branches extending radially therefrom to the periphery of the rotor, end rings secured to the opposite ends thereof, a stator having at least one passage therethrough; conduit means for supplying coolant from the facility means to a location adjacent the area defined by one end ring and shaft; means including a relatively flat, thin ring assembled with one of said end rings so as to form an inwardly extending flange and present a pocket in communication with said rotor passage for the accommodation of coolant propelled radially outwardly relative to said drive shaft under the influence of centrifugal forces developed thereby; and means operatively associated with said other end ring for inducing flow of coolant first through said rotor passage and then through said stator passage.

References Cited by the Examiner

UNITED STATES PATENTS

2,746,269	5/1956	Moody	62—505
2,768,511	10/1956	Moody	62—505
3,088,042	4/1963	Robinson	62—505

FOREIGN PATENTS

1,232,820	4/1960	France.

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