

## Description

This invention relates generally to centrifugal chiller systems and, more particularly, to a method and apparatus for reclaiming oil from a cooler to the transmission of a centrifugal compressor.

In centrifugal compressors of the type which are used in large chiller type air conditioning systems such as disclosed in the document US-A-4 938 664, there is an inherent tendency for oil to migrate from the transmission to other parts of the system. In particular, during start-up and surge conditions, oil tends to migrate from the transmission into the motor, and hence to the evaporator or cooler. It was therefore necessary in such systems to provide the capability of reclaiming this lost oil and returning it to the transmission so as to allow continuous operation of the machine and to avoid degradation of the heat exchanger performance brought on by oil contamination.

The most common approach is to provide a stagnant cavity just downstream of the guide vanes in the compressor where oil may accumulate after being carried over with the main flow from the cooler. Some of the oil/refrigerant mixture may also be caused to flow directly from the cooler to the cavity because of the pressure difference between the two. An ejector, which is preferably driven by a source of gas from a compressor discharge, then functions to pump the oil from the cavity into the transmission of the compressor. This approach works fine for full load and part load operating conditions, but is unsatisfactory during operation in low load conditions. That is, when the guide vanes are closed down to accommodate low load operating conditions, the effectiveness of the ejector is substantially reduced. The reasons are twofold: first, the pressure at the compressor suction just downstream of the guide vanes is substantially reduced such that it is difficult to overcome the larger pressure difference between the low pressure cavity and the higher pressure transmission; and secondly, since the compressor discharge pressure is also reduced, the motive power of the ejector is substantially reduced. The result is that under low load operating conditions, the amount of oil that is pumped from the cavity into the transmission is substantially reduced, possibly to the point of inadequacy.

It is therefore an object of the present invention to provide an improved oil reclaim system.

This object is achieved in a method and apparatus according to the preambles of the claims and by the features of the characterizing parts thereof.

Briefly, in accordance with one aspect of the invention, valve means is provided to direct the flow of reclaimed oil along either of two channels,

depending on whether the centrifugal compressor is operating under high or low load conditions. Under low load conditions, when the compressor discharge pressure is too low to provide an adequate flow of reclaimed oil from the suction housing, the reclaimed oil is made to flow directly from the cooler to the transmission of the compressor. Under higher load operating conditions, the valving is switched to provide for the flow of reclaimed oil to and from the suction housing.

In the drawings as hereinafter described, a preferred and modified embodiments are depicted; however, various other modifications and alternate constructions can be made thereto without departing from the scope of the invention.

Figure 1 is a schematic illustration of the oil reclaim system in accordance with one embodiment of the invention.

Figure 2 is a partial front end view of a portion of the compressor with the present invention embodied therein.

Figure 3 is a bottom view thereof.

Figure 4 is a rear end view thereof.

Figure 5 is a schematic illustration of the sensor and valve portions thereof.

Figure 6 is a schematic illustration of the oil reclaim system in accordance with another embodiment of the invention.

Referring now to Figure 1 the invention is shown as being incorporated into a chiller type air conditioning system having a cooler 12, a condenser (not shown) and a centrifugal compressor 13. These components are installed in a conventional manner to form a part of a refrigeration circuit which includes an expansion device (not shown) for an introducing refrigerant vapor into the cooler 12, with the centrifugal compressor 13 then compressing the heated vapor coming from the cooler 12 before it passes on to the condenser.

The centrifugal compressor 13 is of a conventional type and includes a motor 14, a transmission 16, a compressor discharge section 17, and a suction housing 18. The motor 14 drives the compressor impeller through the transmission 16, with the impeller acting to compress the refrigerant passing into the suction housing 18 by way of an inlet 19, after which the compressed refrigerant passes into the compressor discharge section 17 to then flow to the condenser.

In order to reclaim the oil that has been transferred to the cooler 12, an oil/refrigerant mixture is drawn from the cooler 12, from a point just beneath the top of the cooler bundle, through a filter 20 and along the oil reclaim line 21. A check valve 22 is provided to ensure that there is no reverse flow into the cooler 12. As will be seen in Figures 1-3, a "T" connector 23 provides for the flow of oil/refrigerant in either of two lines, the primary line 24 or the

secondary line 26, depending on whether the primary solenoid valve 27 or the secondary solenoid valve 28 is open. Those, in turn, will depend on the operating conditions of the centrifugal compressor 13 as will be described hereinafter.

Under normal full load and part load operating conditions of the centrifugal compressor 13, the solenoid valve 27 will be open and the solenoid valve 28 will be closed. The oil refrigerant mixture then passes along the inlet line 29 to the suction housing 18. Fluid communication is then provided from the suction housing 18 by way of suction tube 31, a filter 32, a check valve 33, a line 34, (see also Figure 4), a line 35, an ejector 40, and a ejector discharge line 36, to the transmission 16. The ejector 40 is driven by high pressure fluid from the compressor discharge section 17 passing along line 37, a filter 38, and a line 39 to the ejector 40. Thus, in normal operations, the ejector takes a suction on line 35, and hence to line 21, such that the oil/refrigerant mixture is drawn from the suction housing 18 and pumped into the transmission 16.

When operating under low load conditions, wherein the inlet guide vanes are closed down to the point where the compressor discharge pressure is reduced such that the normal flow as described hereinabove is not satisfactory, the position of the solenoid valves 27 and 28 are reversed such that solenoid valve 27 is closed and solenoid valve 28 is open. In such case, the oil/refrigerant mixture is pumped from the cooler 12, to the filter 20, the check valve 22, the oil reclaim line 21, the secondary line 26, the solenoid valve 28, the line 35, the ejector 40, the ejector discharge line 36, and finally to the transmission 16. During this operation, none of the mixture passes along line 29 and line 31 into the suction housing 18.

The operation of the solenoid valves 27 and 28 can be controlled by any of various means. A preferred approach as shown in Figure 1 is the use of a differential pressure switch 41 which is connected by lines 42 and 43 to the suction housing 18 and the cooler 12, respectively. In normal operation, the pressure at the suction housing 18 and in the cooler 12 is close to being equal. As the load is reduced, however, the pressure in the suction housing 18 is reduced. Thus, when the pressure differential reaches a predetermined limit, the differential pressure switch 41 transmits a signal to the relay 44 to cause the relay 44 to close the solenoid valve 27 and open the solenoid valve 28.

Typical absolute operating pressures for a system are 5.71 bar (80 psia) in the cooler and 5.84 bar (79 psia) in the suction housing 18 (i.e. downstream of the guide vanes), under full load conditions. The typical pressure differential required to switch to the alternative reclaim system would thus be 0.57 to 0.71 bar (8 to 10 psia).

As an alternative to the pressure differential basis for switching between the valves 27 and 28 for the oil reclaim system, the position of the guide vanes may be used for this purpose. As is shown on Figure 5, the guide vane actuator 46, which is indicative of the actual position of the guide vanes, passes a representative signal along line 47 to the primary solenoid valve 27, and along line 48 to the secondary solenoid valve 28. Power is supplied to the circuit by way of the line 49 from the power panel. Thus, depending on the load, which in turn is dependent on the guide vane position, either the primary solenoid valve 27 is open to pass the reclaimed oil/refrigerant from the cooler to the suction housing 18 and the ejector 40, or the secondary solenoid valve 28 is open to pass the oil/refrigerant mixture directly from the cooler 12 to the ejector 40. Thus, the primary solenoid valve 27 will be open until the inlet guide vanes are moved to a predetermined threshold position (e.g. 30°) towards the closed position, whereupon a signal will be transmitted to cause the primary solenoid 27 to be closed and the secondary valve 28 to be opened. When the guide vanes are later opened beyond the threshold point the valve positions are reversed.

As an alternative to the changing of the oil/refrigerant flow path by way of solenoid valves and a relay, a single 4-way reversing valve as shown at 51 in Figure 6 may be employed. Operation of the 4-way reversing valve 51 is brought about by a pilot valve 52 in response to the above described differential pressure or guide vane position signals as received along line 53.

Operation of the 4-way reversing valve 51 is as follows. During operation at higher load conditions, the reversing valve 51 interconnects line 21 to line 29 and likewise interconnects line 31 to line 35. During lower load operating conditions, the reversing valve 51 interconnects line 21 directly to line 35, while interconnecting lines 29 and 31 to effectively isolate that portion of the system.

### Claims

1. An oil reclaim system for a centrifugal compressor of the type having a suction housing (18) with an inlet (29) for receiving an oil refrigerant mixture from a cooler (12) and with a cavity for accumulating oil from the mixture, a transmission (16), and an ejector (40) for pumping accumulated oil from the cavity to the transmission (16), wherein the improvement is characterized by:

first valve means (27) fluidly interconnected between the cooler (12) and the inlet (29);

second valve means (28) fluidly intercon-



secondary line 26, depending on whether the primary solenoid valve 27 or the secondary solenoid valve 28 is open. Those, in turn, will depend on the operating conditions of the centrifugal compressor 13 as will be described hereinafter.

Under normal full load and part load operating conditions of the centrifugal compressor 13, the solenoid valve 27 will be open and the solenoid valve 28 will be closed. The oil refrigerant mixture then passes along the inlet line 29 to the suction housing 18. Fluid communication is then provided from the suction housing 18 by way of suction tube 31, a filter 32, a check valve 33, a line 34, (see also Figure 4), a line 35, an ejector 40, and a ejector discharge line 36, to the transmission 16. The ejector 40 is driven by high pressure fluid from the compressor discharge section 17 passing along line 37, a filter 38, and a line 39 to the ejector 40. Thus, in normal operations, the ejector takes a suction on line 35, and hence to line 21, such that the oil/refrigerant mixture is drawn from the suction housing 18 and pumped into the transmission 16.

When operating under low load conditions, wherein the inlet guide vanes are closed down to the point where the compressor discharge pressure is reduced such that the normal flow as described hereinabove is not satisfactory, the position of the solenoid valves 27 and 28 are reversed such that solenoid valve 27 is closed and solenoid valve 28 is open. In such case, the oil/refrigerant mixture is pumped from the cooler 12, to the filter 20, the check valve 22, the oil reclaim line 21, the secondary line 26, the solenoid valve 28, the line 35, the ejector 40, the ejector discharge line 36, and finally to the transmission 16. During this operation, none of the mixture passes along line 29 and line 31 into the suction housing 18.

The operation of the solenoid valves 27 and 28 can be controlled by any of various means. A preferred approach as shown in Figure 1 is the use of a differential pressure switch 41 which is connected by lines 42 and 43 to the suction housing 18 and the cooler 12, respectively. In normal operation, the pressure at the suction housing 18 and in the cooler 12 is close to being equal. As the load is reduced, however, the pressure in the suction housing 18 is reduced. Thus, when the pressure differential reaches a predetermined limit, the differential pressure switch 41 transmits a signal to the relay 44 to cause the relay 44 to close the solenoid valve 27 and open the solenoid valve 28.

Typical absolute operating pressures for a system are 5.71 bar (80 psia) in the cooler and 5.64 bar (79 psia) in the suction housing 18 (i.e. downstream of the guide vanes), under full load conditions. The typical pressure differential required to switch to the alternative reclaim system would thus be 0.57 to 0.71 bar (8 to 10 psia).

As an alternative to the pressure differential basis for switching between the valves 27 and 28 for the oil reclaim system, the position of the guide vanes may be used for this purpose. As is shown on Figure 5, the guide vane actuator 46, which is indicative of the actual position of the guide vanes, passes a representative signal along line 47 to the primary solenoid valve 27, and along line 48 to the secondary solenoid valve 28. Power is supplied to the circuit by way of the line 49 from the power panel. Thus, depending on the load, which in turn is dependent on the guide vane position, either the primary solenoid valve 27 is open to pass the reclaimed oil/refrigerant from the cooler to the suction housing 18 and the ejector 40, or the secondary solenoid valve 28 is open to pass the oil/refrigerant mixture directly from the cooler 12 to the ejector 40. Thus, the primary solenoid valve 27 will be open until the inlet guide vanes are moved to a predetermined threshold position (e.g. 30°) towards the closed position, whereupon a signal will be transmitted to cause the primary solenoid 27 to be closed and the secondary valve 28 to be opened. When the guide vanes are later opened beyond the threshold point the valve positions are reversed.

As an alternative to the changing of the oil/refrigerant flow path by way of solenoid valves and a relay, a single 4-way reversing valve as shown at 51 in Figure 6 may be employed. Operation of the 4-way reversing valve 51 is brought about by a pilot valve 52 in response to the above described differential pressure or guide vane position signals as received along line 53.

Operation of the 4-way reversing valve 51 is as follows. During operation at higher load conditions, the reversing valve 51 interconnects line 21 to line 29 and likewise interconnects line 31 to line 35. During lower load operating conditions, the reversing valve 51 interconnects line 21 directly to line 35, while interconnecting lines 29 and 31 to effectively isolate that portion of the system.

### Claims

1. An oil reclaim system for a centrifugal compressor of the type having a suction housing (18) with an inlet (29) for receiving an oil refrigerant mixture from a cooler (12) and with a cavity for accumulating oil from the mixture, a transmission (16), and an ejector (40) for pumping accumulated oil from the cavity to the transmission (16), wherein the improvement is characterized by:

first valve means (27) fluidly interconnected between the cooler (12) and the inlet (29);

second valve means (28) fluidly intercon-



nected between the cooler (12) and the ejector (40);

means (41) for determining when the compressor is operating under low load conditions; and

control means (44) for responsively closing the first valve means (17) and opening said second valve means (28) such that the refrigerant oil mixture flows directly from the cooler (12) through the ejector (40) to the transmission (16).

2. An oil reclaim system as set forth in Claim 1 and including variable position guide vanes, and further wherein said determining means comprises means (46) for determining the position of the guide vanes.
3. An oil reclaim system as set forth in Claim 1 or in said determining means comprises a pressure switch (41) which is responsive to the pressure between the cooler and the suction housing.
4. An oil reclaim system as set forth in Claim 2 wherein the position of the guide vanes that indicates a low load condition is 30°.
5. An oil reclaim system as set forth in Claim 3 wherein said determining means (41) is responsive to a pressure differential of 0.57-0.71 bar (8-10 psia) to indicate a load low condition.
6. An oil reclaim system as set forth in Claim 1 wherein said first valve means (27) comprises a solenoid valve.
7. An oil reclaim system as set forth in Claim 1 wherein said second valve means (28) comprises a solenoid valve.
8. An oil reclaim system as set forth in Claim 1 wherein said first and second valve means is combined as a single four way valve (51).
9. A method of reclaiming oil in a centrifugal compressor of the type having a suction housing (18) with an inlet (29) for receiving an oil/refrigerant mixture from a cooler (12) and with a cavity for accumulating oil from the mixture, a transmission (16), and an ejector (40) for pumping accumulated oil from the cavity to the transmission (16), characterized by the steps of:
 

determining when the compressor is operating under low load conditions; and

responsively routing the flow of oil/refrigerant mixture flow directly from the

cooler (12), through the ejector (40) to the transmission (16).

10. An oil reclaim process as set forth in Claim 9 and including the additional step of responsively preventing the flow of the oil/refrigerant mixture from the cooler (12) to the inlet (29).

#### Patentansprüche

1. Rückgewinnungssystem für Öl für einen radialen Turbokompressor des Typs, der ein Ansauggehäuse (18) mit einem Einlass (29) zum Einfüllen einer Mischung aus Öl und Kühlmittel aus einer Kühlvorrichtung (12) hat, und der einen Hohlraum zum Abscheiden von Öl aus der Mischung, ein Getriebe (16) und eine Saugstrahlpumpe (40), um das abgeschiedene Öl vom Hohlraum zum Getriebe (16) zu pumpen, aufweist, wobei die Verbesserung gekennzeichnet ist durch:

eine erste Ventileinrichtung (27), die fluidleitend zwischen die Kühlvorrichtung (12) und den Einlass (29) geschaltet ist;

eine zweite Ventileinrichtung (28), die fluidleitend zwischen die Kühlvorrichtung (12) und die Saugstrahlpumpe (40) geschaltet ist;

eine Einrichtung (41) zur Bestimmung, wann der Kompressor unter Bedingungen mit kleiner Last betrieben wird; und

eine Steuereinrichtung (44), um auf Befehl die erste Ventileinrichtung (27) zu schliessen und die zweite Ventileinrichtung (28) zu öffnen, so dass die Mischung aus Kühlmittel und Öl direkt von der Kühleinrichtung (12) durch die Saugstrahlpumpe (40) zum Getriebe (16) strömt.

2. Rückgewinnungssystem für Öl nach Anspruch 1, das zusätzlich in der Lage verstellbare Leitschaufeln enthält und bei dem weiter die Einrichtung zur Bestimmung eine Einrichtung zur Bestimmung der Lage der Leitschaufeln umfasst.

3. Rückgewinnungssystem für Öl nach Anspruch 1, dessen Einrichtung zur Bestimmung einen Druckschalter (41) umfasst, der auf den Druck zwischen der Kühlvorrichtung und dem Ansauggehäuse reagiert.

4. Rückgewinnungssystem für Öl nach Anspruch 2, bei dem die Lage der Leitschaufeln, die eine Bedingung mit kleiner Last anzeigt, 30° ist.

5. Rückgewinnungssystem für Öl nach Anspruch 3, bei dem die Einrichtung (41) zur Bestimmung auf einen Druckunterschied von 0.57-



0.71 Bar (8-10 psia) reagiert, um eine Bedingung mit kleiner Last anzuzeigen.

6. Rückgewinnungssystem für Öl nach Anspruch 1, bei dem die erste Ventileinrichtung (27) ein elektromagnetisches Ventil umfasst. 5
7. Rückgewinnungssystem für Öl nach Anspruch 1, bei dem die zweite Ventileinrichtung (28) ein elektromagnetisches Ventil umfasst. 10
8. Rückgewinnungssystem für Öl nach Anspruch 1, bei dem die erste und zweite Ventileinrichtung in einem einzelnen Vierwegventil (51) vereinigt sind. 15
9. Verfahren zum Rückgewinnen von Öl in einem radialen Turbokompressor des Typs, der ein Ansauggehäuse (18) mit einem Einlass (29) zum Einfüllen einer Mischung aus Öl und Kühlmittel von einer Kühlvorrichtung (12) hat, und der einen Hohlraum zum Abscheiden von Öl aus der Mischung, ein Getriebe (16) und eine Saugstrahlpumpe (40), um das abgeschiedene Öl vom Hohlraum zum Getriebe (16) zu pumpen, aufweist, gekennzeichnet durch die Schritte:
  - zu bestimmen, wann der Kompressor unter Bedingungen mit kleiner Last betrieben wird; und
  - auf Befehl den Fluss der Öl/Kühlmittel Mischung direkt von der Kühleinrichtung (12) durch die Saugstrahlpumpe (40) zum Getriebe (16) zu leiten. 20
10. Verfahren zum Rückgewinnen von Öl nach Anspruch 9, welches den zusätzlichen Schritt umfasst, auf Befehl den Fluss der Öl/Kühlmittel Mischung von der Kühlvorrichtung (12) zum Einlass (29) zu verhindern. 25

#### Revendications

1. Un système de récupération d'huile pour un compresseur centrifuge du type ayant un logement d'aspiration (18) avec une entrée (29) pour recevoir un mélange huile/réfrigérant provenant d'un appareil réfrigérant (12) et ayant une cavité pour une accumulation de l'huile à partir du mélange, une transmission (16) et un éjecteur (40) pour pomper l'huile accumulée de la cavité jusqu'à la transmission (16), dans lequel l'amélioration est caractérisée par:
  - un premier moyen de vanne (27) interconnecté par voie fluide entre l'appareil réfrigérant (12) et l'entrée (29),
  - un second moyen de vanne (28) interconnecté par voie fluide entre l'appareil réfrigérant

(12) et l'éjecteur (40);

un moyen (41) pour déterminer quand le compresseur fonctionne dans des conditions de charge faible; et

un moyen de contrôle (44) pour fermer, en réaction, le premier moyen de vanne (27) et ouvrir ledit second moyen de vanne (28), de sorte que le mélange réfrigérant/huile s'écoule directement de l'appareil réfrigérant (12) à travers l'éjecteur (40) jusqu'à la transmission (16).

2. Un système de récupération d'huile tel qu'exposé dans la revendication 1 et comprenant des pales de guidage à position variable et en outre, dans lequel ledit moyen de détermination comprend un moyen (46) pour déterminer la position des pales de guidage. 15
3. Un système de récupération d'huile tel qu'exposé dans la revendication 1 et dans lequel ledit moyen de détermination comprend un interrupteur de pression (41) qui est sensible à la pression entre l'appareil réfrigérant et le logement d'aspiration. 20
4. Un système de récupération d'huile tel qu'exposé dans la revendication 2, dans lequel la position des pales de guidage qui indique une condition de charge faible est 30° . 25
5. Un système de récupération d'huile tel qu'exposé dans la revendication 3, dans lequel ledit moyen de détermination (41) est sensible à un différentiel de pression de 0,57-0,71 bars (8-10 psia) pour indiquer une condition de charge faible. 30
6. Un système de récupération d'huile tel qu'exposé dans la revendication 1, dans lequel ledit premier moyen de vanne (27) comprend une électrovanne. 35
7. Un système de récupération d'huile tel qu'exposé dans la revendication 1, dans lequel ledit second moyen de vanne (28) comprend une électrovanne. 40
8. Un système de récupération d'huile tel qu'exposé dans la revendication 1, dans lequel lesdits premier et second moyens de vanne sont combinés en une vanne unique à quatre voies (51). 45
9. Une méthode de récupération d'huile, dans un compresseur centrifuge du type ayant un logement d'aspiration (18) avec une entrée (29) pour recevoir un mélange huile/réfrigérant pro-



venant d'un appareil réfrigérant (12) et avec une cavité pour une accumulation de l'huile provenant du mélange, une transmission (16) et un éjecteur (40) pour pomper l'huile accumulée de la cavité jusqu'à la transmission (16), caractérisée par les étapes de:

déterminer quand le compresseur fonctionne dans des conditions de charge faible; et

détourner, en réaction, l'écoulement du mélange huile/réfrigérant directement à partir de l'appareil réfrigérant (12), à travers l'éjecteur (40) jusqu'à la transmission (16).

10. Un procédé de récupération d'huile tel qu'exposé dans la revendication 9 et comprenant l'étape supplémentaire d'empêcher, en réaction, l'écoulement du mélange huile/réfrigérant à partir de l'appareil réfrigérant (12) jusqu'à l'entrée (29).

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