



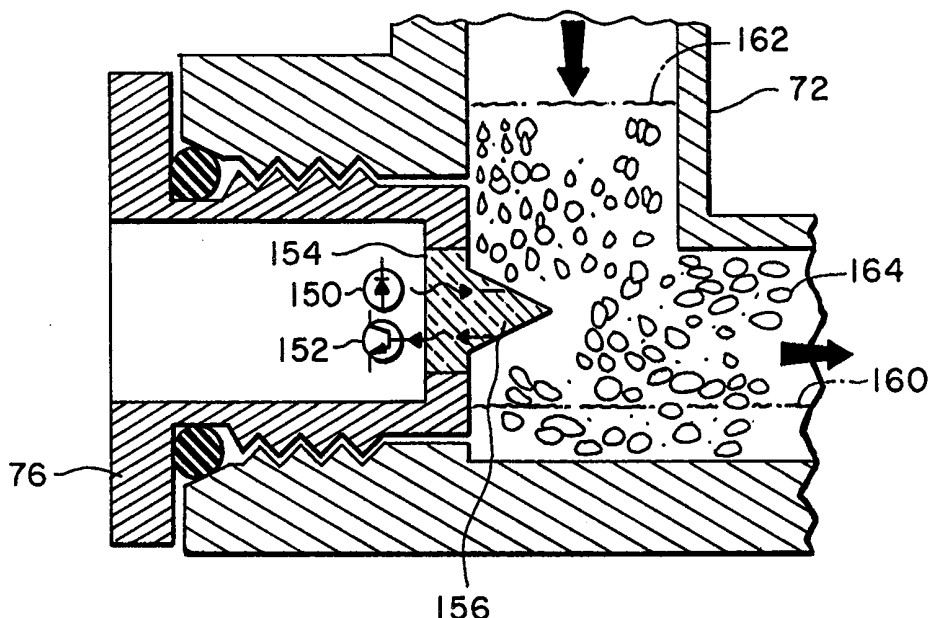
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification <sup>6</sup> : <b>F04C 29/10, 29/02</b></p>	<p><b>A1</b></p>	<p>(11) International Publication Number: <b>WO 99/13225</b> (43) International Publication Date: 18 March 1999 (18.03.99)</p>
<p>(21) International Application Number: PCT/US98/14695 (22) International Filing Date: 16 July 1998 (16.07.98) (30) Priority Data: 08/924,229 5 September 1997 (05.09.97) US (71) Applicant: AMERICAN STANDARD INC. [US/US]; One Centennial Avenue, P.O. Box 261, Piscataway, NJ 08855-6820 (US). (72) Inventors: OKOREN, Ronald, W.; 713 Evergreen Drive, Holmen, WI 54636 (US). SMITH, Sean, A.; 2110 Madison Street, La Crosse, WI 54601 (US). LEAVER, Daniel, C.; N1658 Hagen Road, La Crosse, WI 54601 (US). MOILANEN, John, R.; Route 1, Box 128, La Crescent, MN 55947 (US). ULLAND, Paul, D.; 562 Hickory Lane, La Crescent, MN 55947 (US). CAREY, Michael, D.; 603 Hillcrest Drive, Holmen, WI 54636 (US). (74) Agent: O'DRISCOLL, William; The Trane Company, 3600 Pammel Creek Road, La Crosse, WI 54601-7599 (US).</p>	<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: OIL FLOW PROTECTION SCHEME

(57) Abstract

A protection system for a compressor. The system comprises a compressor having a discharge and including at least one rotor and at least one bearing; a lubrication system including at least one oil recovery device for recovering oil from the compressor, and further including bearing conduit connecting the oil recovery device to the compressor bearing and including rotor conduit for connecting the oil recovery device to the compressor rotors; and an oil protection system. The oil protection system includes a compressor discharge temperature sensor located in the discharge for sensing the temperature of a lubricant/refrigerant mixture discharged by the compressor, a differential pressure sensor located in the bearing conduit for measuring a differential pressure in the bearing conduit, and an oil detector located in the rotor conduit for detecting the presence of oil in the rotor conduit.



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D E S C R I P T I O NTitle

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**OIL FLOW PROTECTION SCHEME**Background of the Invention

10 This application is related to commonly assigned U.S. Patent Application \_\_\_\_\_, entitled "Liquid Level Sensor" as invented by Ronald W. Okoren, Ali Ameen and Matthew A. Shepeck and filed on even date hereof.

15 The present invention is directed to an oil flow protection system for an air conditioning or refrigeration system. The system is an active and robust system which avoids compressor failure by stopping compressor operation upon failure of the oil circulation or return system.

20 The present invention is discussed in terms of screw compressors for air conditioning systems, but is contemplated to apply to all compressors whatever the application. Like many other compressors, screw compressors require oil flow to the compressor so as to lubricate bearings and prevent long term degradation's of the bearings. Additionally, oil flow is needed to seal the rotors in a screw compressor to avoid reduced performance and to cool the rotors  
25 to prevent frictional heating.

30 Oil flow is needed by a compressor to lubricate the bearings and enhance their life. Additionally, in screw and scroll compressors, oil is used to seal the rotors, the absence of such a seal resulting in reduced compressor performance. Also, the lubrication of rotors can prevent frictional heating

while cooling the rotors, and can prevent the radial growth and interference of rotors with adjacent compressor components. If the oil circulation system fails and compressor operation is allowed to continue, compressor failure and damage will ultimately result.

U.S. Patents 5,431,025 and 5,347,825, both to Oltman et al., are directed to an oil charge loss protection arrangement for a compressor. Essentially both patents disclose comparing the temperature of a liquid in the oil system with the temperature of saturated refrigerant, and generating a signal to shutdown the compressor when the comparison indicates that the differential is off range. These patents are commonly assigned with the present invention and are incorporated herein by reference.

An oil protection system is desired which proves that there is oil in the compressor or that there is an immediately available supply of oil trapped in lines feeding the compressor prior to any starting of the compressor. Additionally, a perfect oil protection system would prove flow in the oil line during compressor operation and prove that the flow is a liquid rather than a vapor or at least is a liquid foam. Additionally, the desired oil protection system should prove that the flow is high in oil quantity (i.e., less than 30% refrigerant by weight).

#### Summary of the Invention

It is an object, feature and advantage of the present invention to solve the problems in prior oil protection systems.

It is an object, feature and advantage of the present invention to provide an oil protection system which verifies both the quantity and quality of lubricant flow to the compressor.

5 It is a further object, feature and advantage of the present invention to provide a compressor discharge temperature sensor to verify oil concentration, to provide a differential pressure sensor in one of the compressor lubricant feed lines to verify oil flow, to provide a liquid level sensor  
10 in one of the compressor lubricant feed lines to verify oil presence at start-up, and to further use the liquid level sensor to verify oil quality during compressor operation.

It is an object, feature and advantage of the present invention to provide a liquid level sensor, which is  
15 normally used only at start-up to verify the presence or absence of liquid at a certain height, in a dynamic environment to determine the quality of a liquid vapor mixture.

It is an object, feature and advantage of the present invention to prove that there is either already  
20 lubricant in a compressor at start-up or that there is an immediately available lubricant supply trapped in the lines feeding the compressor prior to compressor start-up.

It is an object, feature and advantage of the present invention to prove lubricant flow in the compressor  
25 lubricant feed lines during compressor operation within predetermined time periods.

It is an object, feature and advantage of the present invention to prove that the flow in a lubricant feed line to a compressor is a liquid rather than a vapor.

It is a further object, feature and advantage of the present invention to prove that flow of liquid even in the presence of some normal amount of foam.

5 It is an object, feature and advantage of the present invention to prove that flow in a lubricant feed line is high in oil quality.

It is a further object, feature and advantage of the present invention to prove that that high quality oil flow is less than 30% refrigerant by weight.

10 It is an object, feature and advantage of the present invention to provide an oil protection system which allows for inverted start or other normal transient conditions.

15 It is an object, feature and advantage of the present invention to provide checks where possible in the operation of the components involved in an oil protection system for a compressor and to verify that no flow occurs when there clearly should be no flow.

20 The present invention provides a control arrangement using a sensor having a binary output to monitor a fluid having three states. The arrangement comprises a controller, and a sensor measuring the presence or absence of a fluid and providing a binary signal to the controller. The controller is responsive to the binary signal indicating the presence or absence of the fluid and the controller determines  
25 an intermediate fluid state by monitoring the rate of binary transitions in the binary signal.

30 The present invention further provides an oil protection system for a compressor. The system comprises a compressor operable to compress a compressible fluid and having a discharge, a rotor and a bearing; an oil supply system including a first oil line operably connected to and providing

lubricant to the rotor and a second oil line operably connected to and providing lubricant to the bearing; and an orifice located in either of the first or second oil lines and controlling flow therethrough. The system also includes a  
5 first sensor located in the discharge so as to measure a condition representative of the temperature of the compressible fluid discharged by the compressor and provide a representative signal to the controller; a second sensor located proximal the orifice so as to measure a differential pressure across the  
10 orifice and provide a representative signal to the controller; a third sensor located proximal the oil line lacking the orifice, the third sensor measuring the presence or absence of liquid and providing a representative binary signal to the controller. The system further includes a controller operably  
15 connected to and receiving the signals from the first, second, and third sensors. The controller is operable to control the operation of the compressor and in response thereto. The controller uses the first sensor signal to determine the quality of lubricating fluid, the second sensor signal to  
20 verify actual flow of the lubricating fluid, and the third sensor signal to distinguish between a liquid state of the lubricant and a vaporous state of the compressible fluid.

The present invention still further provides a protection system for a compressor. The protection system  
25 comprises a compressor having a discharge and including at least one rotor and at least one bearing; and a lubrication system including at least one oil recovery device for recovering oil from the compressor, bearing conduit connecting the oil recovery device to the compressor bearing and rotor  
30 conduit for connecting the oil recovery device to the compressor rotors. The system also includes an oil protection

system including a compressor discharge temperature sensor located in the discharge for sensing the temperature of a lubricant/refrigerant mixture discharged by the compressor, a differential pressure sensor located in the bearing conduit for measuring a differential pressure in the bearing conduit, and an oil detector located in the rotor conduit for detecting the presence of oil in the rotor conduit.

The present invention yet further provides a method of ensuring the operation of a compressor. The method comprises the steps of: measuring a compressor discharge temperature; verifying, from the measured discharge temperature, the presence of an adequate superheat; measuring a differential pressure associated with a compressor lubrication line; verifying, from the measured differential pressure, the adequacy of lubricant flow through that line; measuring an oil quality in a compressor rotor lubrication line; and verifying, from the measured oil quality signal, an appropriate lubrication quality.

The present invention additionally provides a method of providing oil protection for a compressor. The method comprises the steps of: using a liquid level sensor to verify the presence of lubricant in a rotor feed line prior to compressor operation; and using the same liquid level sensor to verify the quality of the lubricant in the rotor feed line during compressor operation.

The present invention still further provides the method of protecting a compressor lubrication system. The method comprises the steps of: sensing differential pressure in a compressor lubrication line to verify lubricant flow;



sensing the discharge temperature of the compressor to verify lubricant concentration; and sensing the level of foaminess in a lubrication feed line to the compressor to verify lubricant quality.

5                   The present invention yet further provides the method of protecting an oil lubrication system for a compressor. The method comprises the steps of: providing a compressor discharge temperature sensor located in a compressor discharge; sensing, using the compressor discharge temperature  
10                   sensor, the discharge temperature of a lubricant/refrigerant mixture being discharged by a compressor; providing a differential pressure sensor; sensing, using the differential pressure sensor the differential pressure across a compressor lubricant feed line; providing a liquid level detector in a  
15                   compressor lubricant feed line; monitoring, using the liquid level detector, either the presence or absence of liquid in the lubricant feed line or the quality of foam in the lubricant feed line; and comparing the sensed discharge temperature, the sensed differential pressure, the sensed signal from the liquid  
20                   level detector to respective setpoints and terminating compressor operation if any of the signals result in an unfavorable comparison.

                  The present invention still further provides a method of operating an oil protection system for a compressor.  
25                   The method comprises the steps of monitoring compressor discharge temperature; comparing the monitored discharge temperature versus the saturated condenser temperature to determine a discharge superheat; terminating operation if the discharge superheat is less than a predetermined minimum  
30                   superheat; sensing pressure in a compressor lubricant feed line; terminating operation if the sensed differential pressure

is less than a desired minimum lubricant flow rate; monitoring the presence or absence of lubricant in a compressor lubricant feed line prior to compressor operation using a liquid level sensor; using the liquid level sensor during compressor operation to verify a quality of lubricant in the lubricant feed line; and terminating operation of the compressor if the lubricant quality does not exceed a desired quality.

#### Brief Description of the Drawings

10

Figure 1 is a diagram of an air conditioning or refrigeration system including a temperature conditioning subsystem, a lubrication subsystem, and a controls subsystem and which also includes the oil protection system of the present invention.

15

Figure 2 is a cutaway diagram of a liquid level sensor in accordance with the present invention.

Figure 3 depicts a block diagram for processing a signal from the liquid level sensor of Figure 2.

20

#### Detailed Description of the Invention

Figure 1 shows an air conditioning or refrigeration system 10. The system 10 includes three subsystems: a temperature conditioning system 12 (illustrated by wide double lines) which conditions the temperature of a fluid, a lubrication system 16 (illustrated by narrow double lines) which lubricates the mechanical components of the conditioning system 12, and a control system 18 (illustrated by single lines) which coordinates and controls the operation of the conditioning system 12 and the lubrication system 16.

30

The conditioning system 12 includes a compressor 20 which compresses a refrigerant and directs the compressed refrigerant and lubricant from a compressor rotor 21 and a compressor bearing 23 through a compressor discharge 22 to one or more oil separators 24. Exemplary compressors are shown in U.S. Patents 5,341,658 to Roach et al., 5,201,648 to Lakowske and 5,203,685 to Andersen et al. and exemplary oil separators are shown in U.S. Patents 5,502,984 to Boehde et al. and 5,029,448 to Carey, all of which are commonly assigned with the present invention and all of which are incorporated herein by reference.

In the oil separators 24, the lubricant and the refrigerant are separated into a primarily lubricant mixture and a primarily refrigerant mixture. The primarily refrigerant mixture (with some entrained lubricant) is directed by conduit 26 to a condenser 28 where the refrigerant is condensed from a hot vapor to a hot liquid. The hot liquid refrigerant passes through conduit 30 to an expansion valve 32. The expansion valve 32 meters the operation of the conditioning system by controlling the flow of the hot liquid refrigerant from the condenser 28. The hot liquid refrigerant leaving the expansion valve 32 enters conduit 34 where some of the liquid refrigerant flashes into a hot vapor leaving a cooler liquid refrigerant. The mixture of vapor and liquid refrigerant enters a liquid vapor separator 36 where the hot vapor is separated out and preferably directed to the compressor 20. The cooled liquid mixture leaves the liquid vapor separator 36 by means of conduit 38 and enters an evaporator 40 where the refrigerant cools the fluid, the refrigerant vaporizing in the process. Lubricant entrained in the primarily refrigerant mixture

remains and pools in the bottom 44 of the evaporator 40. A conduit 42 directs the hot vaporous refrigerant from the evaporator 40 back to the compressor 20 to continue the temperature conditioning cycle.

5                   The lubrication system 16 includes the compressor 20 where a lubricant is injected or provided to the compressor rotor or rotors 21 and to the compressor bearing or bearings 23. The lubricant mixes with the refrigerant and the lubricant/refrigerant mixture exits through the compressor  
10 discharge 22 to the oil separator 24. The oil separator 24 separates the lubricant/refrigerant mixture into a primarily lubricant mixture and a primarily refrigerant mixture. The primarily lubricant is directed by conduit 50 to an oil sump 52. The oil sump 52 includes a vent 54 and an oil heater 56.  
15 From the oil sump 52 the primarily lubricant mixture travels through conduit 58, oil filter 60, an optional oil cooler 62, and a check valve 64 provided in the conduit 58 to prevent backflow. The conduit 58 also includes a master oil line solenoid 66 for automatic control of flow of lubricant through  
20 the conduit 58 and includes a manual service valve 68. The conduit 58 ultimately directs the primarily lubricant mixture to a large capacity, vertical line 70 which acts as a trap during compressor shutdown. The vertical line 70 feeds a rotor feed line 72 providing lubricant to the compressor rotor or  
25 rotors 21 and feeds a bearing feed line 74 providing lubricant to the compressor bearing or bearings 23. The rotor feed line 72 includes an optical oil detector 76 such as the S-9400 series level switch sold by AC&R Components of Chatham, IL and also includes an oil charging service port 78 for adding or  
30 removing oil lubricant. The bearing feed line 74 includes a

check valve 80 and a restrictor orifice 82. A differential pressure switch 84 is provided and arranged about the restrictor orifice so as to measure a differential pressure across that orifice 82.

5                   The lubrication system 16 also includes an oil return gas pump 86 for returning pooled lubricant from the bottom 44 of the evaporator 40. The oil return gas pump 86 returns the lubricant that accumulates from the refrigerant mixture as the refrigerant vaporizes in the evaporator 40. The  
10 accumulated lubricant passes through conduit 96 and a filter 98 and is returned to the compressor 20. Associated with the oil return gas pump is a vent line 88 whose operation is controlled by a fill solenoid 90, and a condenser pressure conduit 92 whose operation is controlled by a drain solenoid valve 94.  
15 This is more fully described in commonly assigned U.S. Patent Application Serial Number 08/801,545, entitled "Oil Return from Evaporator to Compressor in a Refrigeration System", filed on February 18, 1997, and incorporated herein by reference.

                  The control system 18 includes a controller 100  
20 which may be implemented as a single controller or a plurality of controllers working in concert. The controller 100 is operably connected to the compressor 20 by an electrical line 102 so as to control the operation and capacity of the compressor 20. The controller 100 also controls the operation  
25 of the expansion valve by means of an electrical line 104 and controls the operation of the oil heater 56, the master oil line solenoid 66, and the solenoid valves 90 and 94 by means of an electrical lines 106. The controller 100 also includes an electrical line 108 connecting the controller 100 to a  
30 compressor discharge temperature sensor 110 located in the compressor discharge 22 so as to sense the discharge

temperature of the lubricant/refrigerant mixture, and an electrical line 132 connecting the controller 100 to a saturated condenser temperature sensor 130 so as to sense the saturated condenser temperature. The controller 100 is also  
5 connected by an electrical line 112 to the differential pressure sensor 84 so as to receive a signal representative of a differential pressure from the sensor 84. The controller 100 is also connected to the optical oil detector 76 by an electrical line 114 so as to receive a signal from the optical  
10 oil detector 76 representative of the presence of oil, refrigerant or foam. The controller 100 also includes a variety of other sensors including sensors 120 associated with the evaporator and connected to the controller 100 by electrical lines 122 so as to sense the delta T across the  
15 evaporator 40 in any conventional manner.

The large capacity vertical line 70 is arranged to trap oil very near the compressor 20 at shutdown. Compressor start will not be allowed by the control system 18 until oil is detected by the oil detector sensor 76 thus guaranteeing a  
20 minimum volume of oil available at compressor start. The oil flow differential pressure sensor 84 is also checked in the off cycle to guard against a failed switch or a wiring fault.

During compressor operation, all three key components of an oil protection system are required for optimal  
25 operation. These key components are: the differential pressure sensor 84, the oil detector sensor 76, and the discharge temperature sensor 110.

The discharge temperature sensor 110 is constantly monitored and compared against the saturated condenser  
30 temperature as determined by the sensor 130. The comparison of the saturated condenser temperature with the discharge

temperature determines a discharge superheat. A low superheat condition suggests that the oil separator 24 will begin to separate liquid refrigerant along with the lubricant and thus the primarily lubricant mixture will become too dilute. The controller 100 has a "time to trip" integral so that, if the superheat is deemed to be too low for too long, the system 10 will safely shutdown. The superheat value below which indefinite operation is not allowed and the total integral trip point are each determined from empirical tests on an actual system.

The differential pressure sensor 84 senses pressure across the orifice 82 and the check valve 80 in the bearing feed line 74. The differential pressure sensor 84 is calibrated for a switch point relating to a desired minimum oil flow rate and the sensor 84 basically indicates the presence or absence of that minimum oil flow rate. The orifice 82 serves to provide pressure drop to indicate actual flow, while balancing oil flow to the bearing 23 as compared to the oil flow to the rotor 21. Since previous compressors 20 had orifices located within the compressor, the removal of the orifice 82 outside the compressor 20 improves oil quality by extending the dwell time that the oil is at a lower pressure to thereby release more refrigerant to vapor before the lubricant enters the compressor 20 to lubricate the bearings 23. The longer dwell time helps vaporize any liquid refrigerant still entrained in the lubricant to ensure that a liquid comprising highly concentrated lubricant is used to lubricate the compressor 20. The pressure sensor 84 is constantly monitored in normal operation and will shutdown the system 10 if flow is lost for more than a predetermined time period such as two seconds.

The oil detector sensor 76 was previously used only as a binary level switch but is used in the present invention additionally as an analog sensor for foam quality. This is described as follows.

5 Under most normal operating conditions, the oil flow in the rotor feed line 72 has only a small amount of vapor and the flow is generally clear with only a small amount of bubbles or foaming present. In certain operating conditions foaming in the line 72 is normal and must be differentiated  
10 from the very dry foam condition which occurs as oil is lost from the primary lubrication system 16 and the level of oil in the oil sump 52 falls.

Referring to Figure 2, the sensor 76 uses an infrared LED 150 and a matching infrared detector 152 in  
15 conjunction with a conical glass prism 154 having an interface 156 exposed to the rotor feed line 72. Owing to the properties associated with the index of refraction of light as light passes through a glass to vapor interface as opposed to a glass to liquid interface, the light from the LED 150 is either  
20 reflected back to the detector 152 when vapor is present within the rotor feed line 72 or is only marginally reflected when oil is present within the rotor feed line 72. The detector 152 then controls an open collector transistor for a discrete binary output. The off state (or high output) implies dry as  
25 illustrated by a liquid level at line 160, while the on state (or low output) implies wet as illustrated by a liquid level at line 162. This concept has previously been patented by others as evidenced by U.S. Patent 5,278,426 to Barbier, the disclosure of which is hereby incorporated by reference. In  
30 these previous uses, the sensor was used solely at start-up when the liquid level had already stabilized so the liquid



level could be sensed relative to the interface 156 such as shown by the liquid level lines 160 and 162. However, once the compressor 20 commences operation, the interior of the large capacity vertical line 70 and the rotor feed line 72 represents a dynamic mix of liquid lubricant and refrigerant as well as vaporous refrigerant resulting in a foamy mix indicated by the bubbles 164. Conventionally, the sensor 76 can no longer be used because there is no stable liquid level to sense. The present invention enables the conventional sensor to be used in a dynamic environment to sense the quality of the foam, enabling the verification that enough lubricant is present in the foam to ensure proper compressor operation.

With minor modifications to the internal components of the sensor 76 to control the sensitivity of the detector 152 and a calibration process to adjust the LED light output from the LED 150, the sensor 76 is used for foam determination. The internal components of the sensor 76 are selected so that the detector 152 has a gain lying within a desired range. The desired gain and the desired range are empirically determined based on the environment to be sensed and will vary with any particular lubricant and refrigerant combination. Only detectors 152 which meet the desired gain and range criteria are used in the sensor 76. The intensity of the LED 150 is then calibrated to get the correct output for the desired criteria. This calibrated intensity will vary with the environment being sensed specifically including the lubricant and the refrigerant combinations being sensed.

When such a calibrated sensor 76 is used in the oil protection system of the present invention, the calibrated sensor 76 creates a very "noisy" signal due to the random nature of foamy flow, reacting very quickly to the small vapor

bubbles 164 moving over the prism 154 and reflecting light back to the detector 152. As the vapor content of the foam 158 in the rotor feed line 72 increases, so does the DC level of the signal from the sensor 76.

5                   Figure 3 depicts a block diagram 200 for processing the signal from the sensor 76 in the controller 100. This signal is processed by the controller 100 using special filtering to create an analog value representative of the foam content. A time to trip function is implemented in the  
10 software in the controller 100 to define a foam content level beyond which a time integral is begun and the ultimate trip value for the integral at which compressor operation is terminated. The values for the protection level were empirically determined.

15                   The signal from the sensor 76 is provided on an electrical line 202 and passes through a first order filter and voltage divider 204 which roughly filters the signal and converts the 24 VDC signal to a 5 VDC signal. As depicted in  
20 Figure 3, the filter and voltage divider 204 includes a pull-up resistor 206, a 200 k ohm resistor 208, a 30.1 k ohm resistor 210, a 0.1 microfarad capacitor 212, diodes 214 and 216, a 100 k ohm resistor 218 and a 15 microfarad capacitor 220. Of course, these values are dependent upon the application and will vary accordingly.

25                   After leaving the filter and voltage divider 204, the signal is sampled at a rate of 200 milliseconds by a sampler 222 and then the signal is converted to a 10 bit digital signal by the analog to digital converter 224. The resultant digital signal enters a infinite impulse response

filter 226 having a time constant of 6.4 seconds. This filter 226 smoothes out the resultant digital signal by taking a running historical sample of the last 32 samples and averaging them according to the following formula:

5

Filtered signal =  $1/32$  of the latest signal +  $31/32$  of the old average.

10 The filtered signal from the filter 226 is provided to a 24 volt compensator 228 which compensates for variations in the sensor supply voltage to avoid errors resulting from variations in the 24 VDC supply voltage, these errors typically ranging between 19 and 26 VDC.

15 The compensated signal is passed to an integrator control 240, an offset and time scaling block 242 and an integrator 244. The integrated control 240 specifies a must integrate level of 778 bit counts, this level being an empirically determined level differentiating dry foam from lubricant laden foam and corresponding to 3.8 VDC. The  
20 integrate level 778 is empirically selected to avoid transient levels which might occur at start-up as well as any other transient fluctuations in the line level. Integration is enabled above this level and the integrator 242 will integrate the product of bit count times time accumulation above 778.  
25 This integrated amount will be accumulated unless the bit count level in the compensated signal drops below 573, this bit count being the equivalent of 2.8 VDC. When the bit count measure drops below 573 bit counts, the accumulated integral in the integrator 244 will be cleared. Between 573 and 778 bit  
30 counts, the accumulated integral will be held but no new integral values will be added. Only above 778 bit counts will

the integrator control 240 allow the accumulation of bit counts. The summed integral will be provided to a comparator 246 which trips whenever the integrated bit count exceeds 3,200 bit count seconds. This trip count is empirically determined and will vary for any particular system or application.

Essentially, the foam causes a high number of transitions between the high and low states, and the high number of transitions caused by such foam is treated as "chatter" and measured to determine a third state of the fluid in the conduit 72. Thus, a binary sensor 76 provides an analog output representative of the quality of the bubbles 164. As discussed above, the measurements relating to conventional use apply to start-up whereas the new use applies to dynamic operation.

What has been described is a oil protection system for a compressor which ensures oil flow concentration and quality. A person of ordinary skill in the art will recognize that many modifications of the oil protection system will be apparent including the application of the invention to various other compressors and the use of various other lubricant and refrigerant combinations. Additionally, the invention can be generalized with regard to the liquid level sensor to apply to other environments where the presence of a certain quality of foam in a conduit is desired to be measured. Other modifications and alterations are also evident. All such modifications and alterations are contemplated to fall within the spirit and scope of the attached claims.

What is desired to secured as Letters Patent of the United States is as follows.

C L A I M S

5 1. A protection system for a compressor comprising:

a compressor having a discharge and including at least one rotor and at least one bearing;

10 a lubrication system including at least one oil recovery device for recovering oil from the compressor, and further including bearing conduit connecting the oil recovery device to the compressor bearing and including rotor conduit for connecting the oil recovery device to the compressor rotors; and

15 an oil protection system including a compressor discharge temperature sensor located in the discharge for sensing the temperature of a lubricant/refrigerant mixture discharged by the compressor, a differential pressure sensor located in the bearing conduit for measuring a differential pressure in the bearing conduit, and  
20 an oil detector located in the rotor conduit for detecting the presence of oil in the rotor conduit.

25 2. The protection system of claim 1 wherein the oil detector is operable to detect liquid level when the compressor is not operating and wherein the oil detector is operable to detect foam quality when the compressor is operable.

3. The protection system of claim 2 wherein the measured differential pressure is compared to a desired differential pressure, and compressor operation is not allowed if the measured differential pressure is less than the desired differential pressure.

4. The oil protection system of claim 3 wherein the measured discharge temperature is compared to a measured condenser temperature and compressor operation is not allowed if the difference between the measured discharge temperature and the measured condenser temperature are outside of a desired range.

5. The protection system of claim 4 wherein the lubrication protection system includes a lubricant trap disposed in a conduit portion common to the bearing conduit and the rotor conduit.

6. The protection system of claim 5 wherein the oil detector is located in the lubricant trap.

7. The oil protection system of claim 2 wherein the liquid level detected by the oil detector is compared to a desired level and compressor operation is not allowed if the detected liquid level is less than the desired liquid level.

8. The oil protection system of claim 2 wherein the foam quality detected by the oil detector is compared to a desired foam quality and compressor operation is terminated if the desired foam quality level is greater than the detected foam quality level.

9. The oil protection system of claim 8 wherein the desired foam quality level includes less than 30% refrigerant by weight.

10. An oil protection system for a compressor comprising:

- 15 a compressor operable to compress a compressible fluid and having a discharge, a rotor and a bearing;
- an oil supply system including a first oil line operably connected to and providing lubricant to the rotor
- 20 and a second oil line operably connected to and providing lubricant to the bearing;
- an orifice located in either of the first or second oil lines and controlling flow therethrough;
- 25 a first sensor located in the discharge so as to measure a condition representative of the temperature of the compressible fluid discharged by the compressor and provide a representative signal to the controller;

a second sensor located proximal the orifice so as to measure a differential pressure across the orifice and provide a representative signal to the controller;

5 a third sensor located proximal the oil line lacking the orifice, the third sensor measuring the presence or absence of liquid and providing a representative binary signal to the controller; and

10 a controller operably connected to and receiving the signals from the first, second, and third sensors and operable to control the operation of the compressor and in response thereto, the controller using the first sensor signal to determine the quality of lubricating fluid, the second sensor signal to verify actual flow of the lubricating fluid, and the third sensor signal to distinguish between a liquid state of the lubricant and a vaporous state of the compressible  
15 fluid.

11. The system of claim 10 wherein the controller  
20 receives a signal representative of quality from the third sensor to determine the foaminess of a fluid.

12. The system of claim 10 further including an  
25 oil trap in the oil supply system proximal the first and second oil lines.



13. A method of protecting a compressor lubrication system comprising the steps of:

sensing differential pressure in a compressor lubrication line to verify lubricant flow;

5 sensing the discharge temperature of the compressor to verify lubricant concentration; and

sensing the level of foaminess in a lubrication feed line to the compressor to verify lubricant quality.

10

14. The method of claim 13 including the further steps of:

15 verifying, from the sensed discharge temperature, the presence of an adequate superheat;

verifying, from the sensed differential pressure, the adequacy of lubricant flow through that line; and

verifying, from the sensed lubricant quality, an appropriate lubrication quality.

20

15. The method of claim 14 including the further step of sensing liquid level at start-up in a compressor lubricant feed line.

25

16. The method of claim 15 further including the steps of:

30 providing a compressor discharge temperature sensor located in a compressor discharge;

sensing, using the compressor discharge temperature sensor, the discharge temperature of a lubricant/refrigerant mixture being discharged by a compressor;

providing a differential pressure sensor;

5 sensing, using the differential pressure sensor, the differential pressure across a compressor lubricant feed line;

providing a liquid level detector in a compressor lubricant feed line;

10 monitoring, using the liquid level detector, either the presence or absence of liquid in the lubricant feed line or the quality of foam in the lubricant feed line; and

15 comparing the sensed discharge temperature, the sensed differential pressure, the sensed signal from the liquid level detector to respective setpoints and terminating compressor operation if any of the signals result in an unfavorable comparison.

20 17. The method of claim 16 including the steps of:

monitoring saturated condenser temperature;

25 comparing the discharge temperature with the saturated condenser temperature to determine a discharge superheat; and

terminating operation if the discharge superheat is less than a predetermined minimum superheat.

18. The method of claim 16 including the steps  
of:

sensing pressure in a compressor lubricant  
feed line; and

5 terminating operation if the sensed  
differential pressure is less than a desired minimum lubricant  
flow rate.

10 19. The method of claim 16 including the steps  
of:

monitoring the presence or absence of  
lubricant in a compressor lubricant feed line prior to  
compressor operation using a liquid level sensor;

15 using the liquid level sensor during  
compressor operation to verify a quality of lubricant in the  
lubricant feed line; and

terminating operation of the compressor if  
the lubricant quality does not exceed a desired quality.

20

20. A method of providing oil protection for a  
compressor comprising the steps of:

25 using a liquid level sensor to verify the  
presence of lubricant in a rotor feed line prior to compressor  
operation; and

using the same liquid level sensor to verify  
the quality of the lubricant in the rotor feed line during  
compressor operation.

30



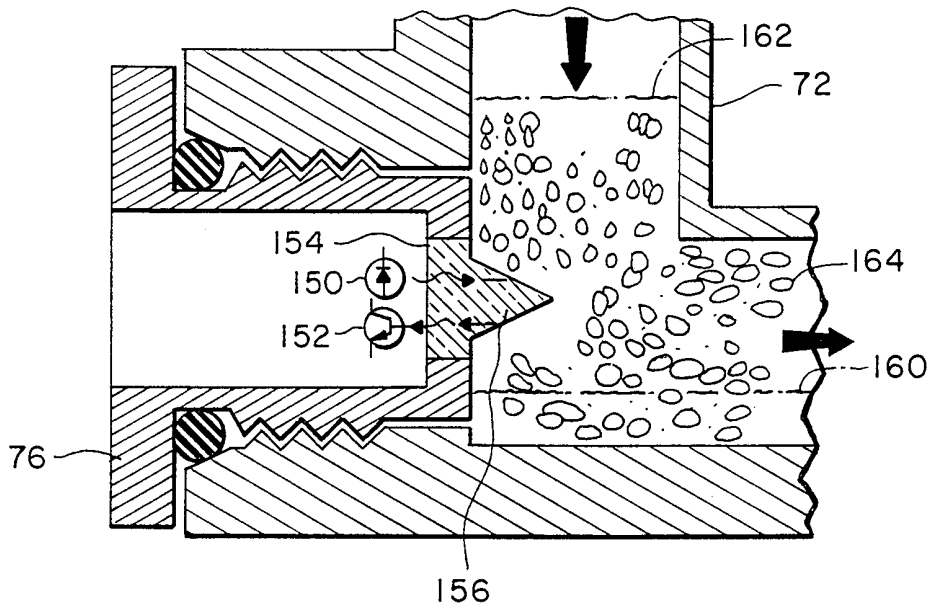


FIG. 2

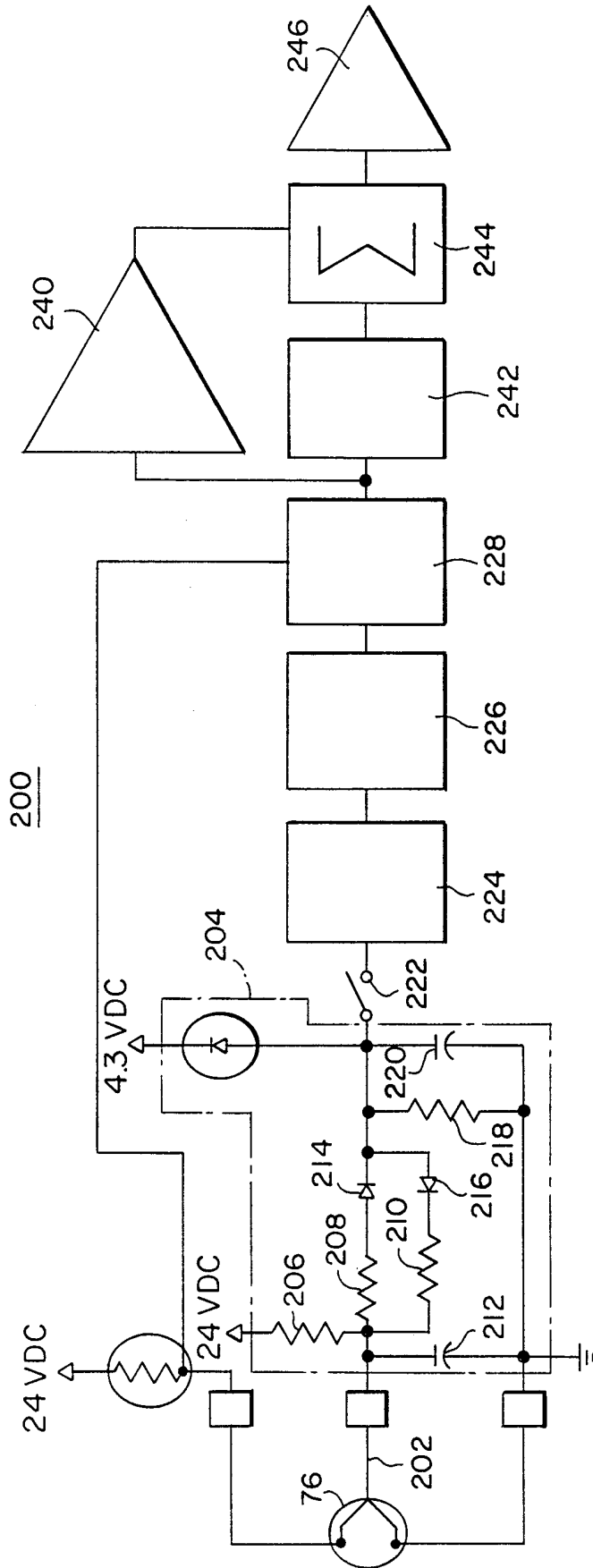


FIG. 3

# INTERNATIONAL SEARCH REPORT

International Classification No  
PCT/US 98/14695

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 F04C29/10 F04C29/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 F04C F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 96 39601 A (ALTECH CONTROLS CORP) 12 December 1996 see page 1, line 10 - page 12, line 2; figures 1-3 ---	1,10,13
A	US 5 318 151 A (HOOD JAMES A ET AL) 7 June 1994 see column 1, line 6 - column 4, line 28; figures 1,2 ---	1,10,13
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 019 (M-919), 16 January 1990 & JP 01 262216 A (NIPPON DENSO CO LTD), 19 October 1989 see abstract ---	1,10,13
	-/--	

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

\* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*Z\* document member of the same patent family

Date of the actual completion of the international search

12 October 1998

Date of mailing of the international search report

02.02.99

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INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/14695

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 243 (P-1364), 4 June 1992 & JP 04 054417 A (TOSHIBA CORP), 21 February 1992 see abstract ---	1,10,13
A	US 5 209 076 A (KAUFFMAN GARY O ET AL) 11 May 1993 see column 3, line 21 - column 6, line 9; figures 1,2 ---	1,10,13
A	GB 2 054 101 A (PRESTCOLD LTD) 11 February 1981 see abstract; figure 3 ---	1,10,13
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 347 (M-743), 19 September 1988 & JP 63 106392 A (MATSUSHITA ELECTRIC IND CO LTD), 11 May 1988 see abstract ---	1,10,13
A	PATENT ABSTRACTS OF JAPAN vol. 015, no. 407 (M-1169), 17 October 1991 & JP 03 168376 A (HITACHI LTD), 22 July 1991 see abstract -----	1,10,13



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 98/14695

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-19

### Remark on Protest

- The additional search fees were accompanied by the applicant's protest.
- No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/US 98/14695

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

1. Claims: 1-19

Oil protection system further comprising differential pressure sensor in bearing conduit and oil detector in rotor conduit

2. Claim : 20

Method of providing oil protection for a compressor using liquid level sensor to verify presence of lubricant prior to operation, and quality of lubricant during operation

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/14695

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