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(54) COMPRESSOR ARRANGEMENT INCLUDING AN OIL-INJECTION-TYPE ROTARY COMPRESSOR HAVING A CENTRIFUGAL WATER SEPARATOR

(71) We, HOKUETSU KOGYO CO. LTD., a Japanese Corporation of No. 113-1 Ohtakeshinden, Oaza, Bunsui-cho, Nishikanbara-gun, Niigata-ken, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a compressor arrangement including an oil-injection-type rotary compressor. Widely employed at present are compressors of the slide vane type, the screw type, and the worm type, in which cooling and lubricating oil is directly injected into the compressed gas in order to enhance the cooling effect and to obtain a higher compression efficiency of the compressor. Moreover, the machinery of these types, as compared with any conventional one of the reciprocating type, has the advantage that it will cause less public nuisance and produces less vibration, noise and the like, and therefore it is outstandingly superior thereto.

However, the oil-injection-type rotary compressor in which cooling and lubricating oil is directly injected into the compressed gas has one defect. During its operation with highly humid suction gas, the sucked water vapour contained therein reaches its dew point in relation to the temperature, and thus condensed water particles are mixed with the cooling and lubricating oil causing the oil to become emulsified.

In the case where the ambient air is sucked into the oil-injection-type rotary compressor, if the ambient air is highly heated and humid, the dew point of the vapour is raised as the compression pressure is increased, and even though both the temperatures of the cooling and lubricating oil itself and of the air contained in the compressed air circulating system are very high, the water vapour is condensed to form a lot of water drops suspended in the cooling and lubricating oil. The oil and water drops

are agitated and combined into mineral particles mixing with each other, in the compression chamber of the compressor and in the oil pump for the compressor, until the mixed oil water particles are entirely converted to a colloidal phase, so as to form a kind of petroleum emulsion, thus resulting in that the oiliness is lost and failure of the compressor is possibly caused thereby. In addition, a phenol resin vane used in slide-vane type compressor and phenol resin pinion used in worm type compressor absorb the water particles contained in lubricating oil and expand, resulting in the compressing function of the vane being impaired, or otherwise, the vane and pinion may fail.

Heretofore, a generally adopted method to prevent emulsification as described above was to maintain the temperature of the cooling and lubricating oil supplied to the compressor above a definite temperature while the compressor was operated, the water vapour contained in the sucked air being discharged, in vapour form, out of a discharge port of the compressor.

Therefore, the temperature of the cooling and lubricating oil could not be lowered below a definite temperature and was kept at a high temperature at which the lubricating oil was quickly oxidized, thereby accelerating the deterioration of the lubricating oil, resulting in a short effective life of the oil such as 1,000 hours at the most. Furthermore, the suction efficiency of the compressor was also impaired due to the high temperature of the air sucked into the compressor, caused by a higher level of the temperature of the cooling and lubricating supplied to the compressor.

Moreover, for the purpose of maintaining the operating temperature of the cooling and lubricating oil above the definite temperature level, even if the temperature of the oil is regulated by means of a temperature regulating device, for example an element such as a thermostat, in such a case where the amount of the discharged compressed air

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being put to use is limited, the heat energy generated by the compression is substantially decreased so that it is difficult to keep both the temperature of the discharged air and the temperature of the lubricating oil to respective appropriate levels. Consequently, condensed water particles are increasingly contained in and mixed with the cooling and lubricating oil within its circulating system. Therefore, it was a customary practice to discharge, at least once a day, the gathered water in a lubricating oil reservoir in the circulating system by opening a drain cock at the bottom of the reservoir when the temperature of the cooling and lubricating oil in the reservoir had fallen, i.e. when the operation of the compressor was interrupted or terminated.

However, this method cannot be put into practical use where the compressor is operated through 24 hours continuously for many days, and therefore the cooling and lubricating oil would inevitably soon deteriorate.

Recently, 24 hour continuous operation lasting a great many weeks, working with a high pressure and with continuous non-attendant operation, are frequently called for. Therefore if the contaminated water particles in the cooling and lubricating oil are not automatically separated and discharged therefrom during the operation, the performance of the oil injection type rotary compressor will deteriorate, becoming a public nuisance and producing trouble such as vibration, noise and the like. It will also not be reliable and its use may be discontinued in some cases.

The object of the present invention is to provide a compressor arrangement including an oil-injection-type rotary compressor in which the suction efficiency of the compressor is improved and the deterioration of the cooling and lubricating oil due to oxidation thereof is prevented by lowering the temperature of the cooling and lubricating oil which is being supplied to the compressor. In addition, the water particles mixed with the cooling and lubricating oil are automatically removed from the compressor, either continuously or intermittently and discharged to the exterior thereof by means of a centrifugal water separator inserted in the path of the cooling and lubricating oil. This process extends the effective life of the cooling and lubricating oil by over 10,000 hours and it also makes continuous operation of the compressor possible over a period of many weeks.

In an oil-injection-type rotary compressor working at a high pressure, as the dew point under the high pressure becomes higher than the oxidation temperature for the cooling and lubricating oil, emulsification of the cooling and lubricating oil is rapidly accelerated. Therefore, it has been found that the oil injection type rotary compressor cannot be

used under such a high pressure. However, according to the present invention, this problem is also solved so that the range of the available pressures of the oil injection type rotary compressor can be further extended.

It is generally considered that it is difficult to mix water and oil with each other, but actually, water and oil mix easily and well, to make up a mixture thereof. When water is merely added into oil, the water is kept completely separated from the oil. However, if they are either agitated violently or broken into mineral particles by passing them through a gear pump, the oil and water are fully mixed together and, in mixing, produce a turbid white emulsion. Once this state of emulsion is produced, any attempt to separate the oil from the water by any means will never succeed therein, under the ambient temperature.

Now, it was found by experiments that even the oil and water mixed to form an emulsified phase can be separated gradually in response to raising its temperature above the normal temperature. In the passage of the cooling and lubricating oil having a high temperature, before the cooling and lubricating oil was cooled by a cooler, a centrifugal water separator was inserted, by means of which it has become possible to completely separate oil from the mixed water.

As a result of various experiments, in separating emulsified water in cooling and lubricating oil by means of a centrifugal separator, it is found that oil and water are different in the rate of variation of viscosity to that of temperature and in the rate of variation of surface tension to that of temperature, so that it is difficult to separate them from each other. It is found however, that it is possible to separate them by raising the temperature of the oil, and if a suitable peripheral speed is given to the centrifugal separator corresponding to the temperature of oil and water, it is possible to separate oil from water with ease. Namely, it is found that if the peripheral speed N m/sec of the centrifugal separator and oil temperature $T^\circ\text{C}$ are defined within the range where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

oil and water can be perfectly and easily separated from each other under any condition.

According to the present invention, there is provided a compressor arrangement comprising an oil injection type rotary com-

pressor, a cooling and lubricating oil system for said rotary compressor, and a centrifugal water separator disposed in said oil system, said water separator being operable such that water particles contained in the cooling and lubricating oil are automatically separated either continuously or intermittently from the oil and are discharged from the oil system to the exterior thereof.

Preferably, the cooling and lubricating oil itself is used in the centrifugal water separator as the power source thereof and the centrifugal water separator is disposed within the cooling and lubricating oil system in such a way that the pressure difference between the inlet and the outlet thereof is higher than 1 kg/cm², whereby the centrifugal water separator is driven by the flow of the cooling and lubricating oil itself.

Conveniently, the centrifugal water separator is driven by the flow of a pressurised gas leaving said rotary compressor on its way to a point of use.

Advantageously, the centrifugal water separator is driven by making use of a part of the pressurised gas discharged from said rotary compressor, said part being discharged to the atmosphere after driving the separator.

Preferably, the centrifugal water separator is operated under the condition where peripheral speed N m/sec of the centrifugal separator and temperature T°C of the cooling and lubricating oil are defined within the range where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

Several embodiments of the present invention will be described hereinbelow by way of example with reference to the accompanying drawings.

Figure 1 is a circulating system diagram of cooling and lubricating oil in a compressor arrangement including an oil injection type rotary compressor in accordance with one embodiment of the present invention.

Figure 2 is a sectional elevation view showing a water separator of the compressor arrangement of Figure 1.

Figure 3 is a fragmentary enlarged view in section taken along the line A-A in Figure 2.

Figure 4 is a circulating system diagram of cooling and lubricating oil in a compressor arrangement including an oil injection type rotary compressor in accordance with a second embodiment of the present invention.

Figure 5 is a circulating system diagram

of cooling and lubricating oil in a compressor arrangement including an oil injection type rotary compressor in accordance with a third embodiment of the present invention.

Figure 6 is a sectional elevation view showing a water separator for use in either of the embodiments of Figure 4 and Figure 5.

Figure 7 is a side view showing modification of the water separator in the compressor arrangement of Figures 1, 2 and 3.

Figure 8 is a sectional elevation view showing a modified form of water separator for use in either of the embodiments of Figure 4 and Figure 5, and

Figure 9 is a graph showing the relation between peripheral speed N of the centrifugal water separator and temperature T of lubricating oil in an embodiment of the present invention.

Describing now the present invention with reference to the drawings, Figure 1 is a circulating system diagram of the cooling and lubricating oil in a compressor arrangement including an oil injection type rotary compressor in accordance with an embodiment of the present invention, said compressor being an air compressor in this case. An oil injection type rotary compressor of the slide vane type will be hereinafter described, but the description can be similarly adapted to the screw type and worm type, which is therefore to be included in the present invention.

Referring to Figure 1, the reference numeral 1 denotes a rotary compressor in section, the compressor 1 being provided with an air suction port 3 and an air discharge port 4. A pressure vessel and oil separator 2 is connected at its one side portion with the discharge port 4 via an outlet pipe 5, and a service header 6 is connected to the top portion of the oil separator 2.

Connected in sequence to a conduit 7 which communicates with the bottom of the oil separator 2 are a temperature regulating device 8, a conduit 9, a cooler 10, and a conduit 11, which is in turn connected to the compression chamber in the compressor 1. The temperature regulating device 8 is directly interconnected with the conduit 11 through a by-pass conduit 12.

Moreover, connected in sequence to a conduit 13 which also communicates with the bottom of the oil separator 2 are a centrifugal water separator 14, a conduit 15, a pump 16, and a conduit 17, which is in turn interconnected with the conduit 7.

Referring next to Figure 2 in which is shown a sectional elevation view of the centrifugal water separator 14. The centrifugal water separator 14 comprises a hollow body 14' and a cover 14'' sealed to the top periphery of the body 14'. The interior of the body 14' constitutes a low pressure chamber 32, and an entrance chamber 18

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which is located underneath the low pressure chamber 32. The entrance chamber 18 is connected to the conduit 13; whereas, the low pressure chamber 32 is connected to the conduit 15. A shaft 19 is disposed along the vertical centre axis of the body 14', and the upper and lower ends of the shaft 19 are respectively secured to the cover 14'' and the body 14'. The shaft 19 is provided at its lower half section with an elongated axial passage 20 which communicates with the exterior of the shaft 19 through a radial bore 21 disposed at the upper end of the axial passage 20. The lower end of the axial passage 20 communicates with the entrance chamber 18.

A rotary unit 22 is journaled at its hub 22' by bearings 26 and 27 which are provided at the upper and lower ends of the shaft 19 so as to be rotatable about the shaft 19. Between the hub 22' of the rotary unit 22 and the shaft 19 is a space 23, said space 23 communicating with the axial passage 20 communicates with the entrance bore 21.

The rotary unit 22 comprises a drum-like outer wall 28 which is integrally connected to the lower part of the hub 22' and extended outward therefrom to constitute a rotary chamber 25 between the outer wall 28 and the peripheral surface of the hub 22'. Disposed within the rotary chamber 25 is a drum-shaped filter 29 by means of which the rotary chamber 25 is divided into the chambers, an outer chamber 25' and an inner chamber 25''. Provided at the upper part of the hub 22' of the rotary unit 22 are several holes 24 through which the aforesaid space 23 communicates with the outer chamber 25'.

A number of dependent chambers 30, which project downwardly from the bottom of the outer wall 28 of the rotary unit 22 into the low pressure chamber 32, communicate with the inner chamber 25'' through top openings thereof, and each dependent chamber 30 is provided at its side wall with an ejection nozzle 31 from which the ejected fluid is tangentially directed with respect to the rotary unit 22. (Refer to Figure 3.)

The outer wall 28 is provided at one lower side portion thereof with an aperture 28' which, when the rotary unit 22 is in a predetermined angular position, coincides with an aperture 28'' which is provided in the body 14' and which is connected to a conduit 63 having a valve 34 fitted therein.

With the rotary compressor so far constituted, air at atmospheric pressure is sucked through the suction port 3 into the compressor 1, the compressed gas being discharged from the discharge port 4, and fed through the outlet pipe 5 into the pressure vessel and oil separator 2. The pressurized gas is sent out from the compressor arrange-

ment through the service header 6 for any service required.

The cooling and lubricating oil stored in the bottom of the pressure vessel and oil separator 2 is, by the pressure of the pressurized gas, ejected into the compression chamber in the compressor 1 through the conduit 7, the temperature regulating device 8, the conduit 9, the cooler 10 and the conduit 11.

So long as the temperature of the cooling and lubricating oil passing through the conduit 7 is pretty low, some of the cooling and lubricating oil is directly sent from the temperature regulating device 8 to the conduit 11 via the by-pass conduit 12 without passing through the cooler 10. This quickly brings the temperature of the cooling and lubricating oil ejected into the compression chamber of the compressor 1 to a definite value which is to be maintained at all times.

On the other hand, when the compressor 1 is continuously operated for a long time, the water vapour contained in the atmosphere is condensed to become water particles in the pressure vessel and oil separator 2. The water particles mix with the cooling and lubricating oil in the bottom part of the pressure vessel and oil separator 2, resulting in the emulsification of the oil. The cooling and lubricating oil thus emulsified flows into the conduit 7 through the conduit 13, the centrifugal water separator 14, the conduit 15, the pump 16, and the conduit 17.

The pump 16 is provided to create a pressure difference between the inlet and the outlet of the cooling and lubricating oil flowing into and from the centrifugal water separator 14, that is, the function of the pump 16 is to set up a pressure difference between the pressure in the conduit 13 and that in the conduit 15. Therefore, this pump may alternatively be disposed in the conduit 13. Where an appropriate pressure difference is created between the inlet and the outlet of the cooling and lubricating oil flowing through the centrifugal water separator 14, it is not normally required to provide the pump 16, as shown in the drawing. It is necessary for the pressure difference between the inlet and the outlet to be higher than 1 kg/cm² if, as hereinafter explained, the centrifugal separator is to be successfully driven by the flow of cooling and lubricating oil.

In the centrifugal water separator 14, as shown in Figure 2, the cooling and lubricating oil in the state of the turbid white emulsion first enters the axial passage 20 in the shaft 19 from the conduit 13 via the entrance chamber 18. It then flows into the space 23 between the peripheral surface of the shaft 19 and the inner surface of the hub 22' of the rotary unit 22 via the radial

bore 21 in the shaft 19, and finally into the rotary chamber 25 of the rotary unit 22 through the holes 24 thereof. Since the rotary unit 22 is being rotated, at a high speed, about the axes of bearings 26 and 27, the cooling and lubricating oil in the state of the turbid white emulsion in the rotary chamber 25 rotates at a high speed at a temperature much higher than the atmospheric temperature, so that the water particles in the emulsion are collected on the outer wall 28 of the rotational chamber 25. Only the oil passes through the drum like filter 29 disposed in the rotary chamber 25 and is then ejected from the ejection nozzles 31 in the dependent chambers 30 at the bottom of the rotary chamber 25, into the low pressure chamber 32. The cooling and lubricating oil which is ejected into the low pressure chamber 32, having been fully separated from water particles, is collected in the bottom chamber 33 and flows into the conduit 15.

Owing to the action of the cooling and lubricating oil ejected from the ejection nozzles 31 into the low pressure chamber 32, the rotary unit 22 is automatically rotated at a high speed merely by making use of the flow of fluid through the nozzles 31 without being assisted by any external power source.

One of the ejection nozzles 31 is shown in detail in Figure 3, and the configuration and the dimensions thereof can be modified as desired so as to obtain any desirable number of rotations of the rotary unit 22, as well as desirably to regulate the amount of the cooling and lubricating oil flowing through the centrifugal water separator 14. As seen in Figure 2, the water particles separated out of the emulsion and collected on the outer wall 28 of the rotary chamber 25 are discharged to the exterior thereof through the valve 34 which is automatically operated by detecting the amount of water gathered thereonto. The valve 34 may be substituted by a valve of the manual type or by an automatic valve, which is automatically opened on the basis of a predetermined interval.

Referring again to Figure 1, it is possible that the arrangement shown in Figure 1 can be modified such that the conduit 17 on the outlet side of the centrifugal water separator 14 is connected to the bottom of the pressure vessel and oil separator 2, and that the conduit 13 on the inlet side of the centrifugal water separator 14 is connected to the conduit 7. In a further modification, the centrifugal water separator 14 is disposed in the circulating system of the cooling and lubricating oil flowing from the pressure vessel and oil separator 2 to the compression chamber in the compressor 1, and the cooling and lubricating oil in the bottom of the pressure vessel and oil separator 2

is led into the centrifugal water separator 14 and the same oil is then returned to the bottom of the pressure vessel and oil separator 2. These modifications of the arrangement would be included as a matter of course in the scope of the present invention.

Figure 4 shows another embodiment of the present invention, in which the flow of compressed gas leaving a compressor on its way to a point of use is used as the power source for its centrifugal water separator.

The essential components of the arrangement shown in Figure 4 are identical with those shown in Figure 1; but, in Figure 4, connected to the bottom of the pressure vessel and oil separator 2, is a conduit 34 to which are connected a centrifugal water separator 35 and a conduit 36, the conduit 36 being further interconnected with the conduit 7 which allows the bottom of the pressure vessel and oil separator 2 to communicate with the temperature regulating device 8.

The outlet pipe 5 is provided therein with an orifice 5', and the respective one end of an introducing pipe 37 and a discharging pipe 38 are connected to the outlet pipe 5 respectively at the upstream and the downstream sides of the orifice 5', whereas, the respective other ends of the introducing pipe 37 and the discharging pipe 38 are connected with the centrifugal water separator 35.

The essential components of the arrangement shown in Figure 5 are identical with those in Figure 4, but, in Figure 5 the introducing pipe 37 is connected to an outlet pipe 39 which allows the pressure vessel and oil separator 2 to communicate with the service header 6, and the discharging pipe 38 is opened to the atmosphere.

Air is sucked from the suction port 3 into the compressor 1, and the gas compressed therein is discharged from the outlet port 4, then it flows into the pressure vessel and oil separator 2 through the outlet pipe 5. The pressurized gas flows to the exterior thereof through the service header 6.

The cooling and lubricating oil is stored in the bottom part of the pressure vessel and oil separator 2, and the stored oil is thereafter ejected on account of the pressure of the pressurized gas into the compression chamber of the compressor 1 through a conduit 7, a temperature regulating device 8, a conduit 9, a cooler 10, and a conduit 11. However, in such a case where the temperature of the cooling and lubricating oil in the conduit 7 is low, some of the cooling and lubricating oil is directly sent from the temperature regulating device 8 to the conduit 11 through a by-pass conduit 12, without passing through the cooler 10. Accordingly, the temperature of the cooling and lubricating oil ejected into the compression

chamber of the compressor 1 is quickly brought to a definite value which is to be maintained at all times.

When the compressor 1 is continuously operated for a long time, the water vapour contained in the atmosphere is condensed to become water particles, and the water particles are mixed with the cooling and lubricating oil so as to emulsify them. The cooling and lubricating oil in the state of an emulsion is separated from the water particles by means of a centrifugal water separator 35 which is rotated at a high speed by the fluid pressurized by the compressor and supplied thereto; thereafter, the clean oil flows into the conduit 7 via the conduit 36.

In the embodiment shown in Figure 4 the flow of the pressurized gas from the compressor 1 is used as the power source of the centrifugal water separator 35. The pressure of the gas introduced into the introducing pipe 37 from the upstream side of the outlet pipe 5 is made higher by 1 kg/cm² or more, than the same discharged from the discharging pipe 38 into the downstream side of the outlet pipe 5 on account of the orifice 5' or a venturi tube or like pressure difference-producing device disposed in the outlet pipe 5. The centrifugal water separator 35 is accordingly rotated by virtue of this pressure difference higher than 1 kg/cm².

In the embodiment shown in Figure 5 the compressed gas supplied from the compressor 1 to the exterior of the compressor arrangement is used as the power source to force the centrifugal water separator 35 to rotate. The compressed gas flowing towards the outlet pipe 39 is introduced into the introducing pipe 37. After driving the water separator, the used gas is discharged to the atmosphere through the discharging pipe 38. Thus the pressurized gas delivered by the oil injection type rotary compressor is introduced into the centrifugal water separator 35 for the purpose of forcing the latter to rotate at a high speed.

This embodiment can be further modified in such a way that the air flow into or the gas flow discharged from the internal combustion engine driving the compressor, is introduced into the centrifugal water separator 35 as the power source thereof, the air or gas leaving the water separator being discharged into the atmosphere.

In addition, the centrifugal water separator 35 in Figure 4 and Figure 5 is arranged so as to be connected to the bottom part of the pressure vessel and oil separator 2 and to be interposed within the circulating system of the cooling and lubricating oil. However, the arrangement can be modified in a similar way to that of Figure 1, such that the centrifugal water separator 35 is disposed in the circulating system of the cooling and lubri-

cating oil flowing from the pressure vessel and oil separator 2 to the compression chamber of the compressor 1, in such a manner that the cooling and lubricating oil in the bottom part of the pressure vessel and oil separator 2 is introduced into the centrifugal water separator 35 and the cooling and lubricating oil discharged therefrom is returned into the bottom part of the pressure vessel and oil separator 2.

Figure 6 shows the centrifugal water separator 35 in detail. The separator 35 comprises a vane chamber 40 and a hollow body 47 disposed underneath the vane chamber 40, the introducing pipe 37 being connected to one side of the vane chamber 40 and the discharging pipe 38 being connected to the other side thereof. A vertical shaft 43 is provided on the vertical centre axis of the vane chamber 40 and the hollow body 47, and the vertical shaft 43 is rotatably journaled in the separator 35 in two bearings 45 and 46.

Within the vane chamber 40, a hub 42 carrying vanes 41 is fixed onto the upper end of the shaft 43 by a nut 44. Within the hollow body 47, the shaft 43 is provided in its lower part with an elongated axial passage 48 which communicates with a conduit 34 at its lower end and with a centrifugal chamber 52 through a radial bore 49 which communicates with the upper end of the axial passage 48. Further within the hollow body 47, a rotor 50 and a cover 51 thereof are rigidly fixed onto the shaft 43, and the centrifugal chamber 52 is constituted by the enclosure defined by both the rotor 50 and the cover 51 thereof. An oil chamber 53 is provided under the centrifugal chamber 52 within the hollow body 47. The bottom plate of the rotor 50 is provided with a tubular passage 62 which is upwardly projected therefrom into the centrifugal chamber 52 and through which the centrifugal chamber 52 communicates with the oil chamber 53.

The rotor 50 is provided on one side with an aperture 50' which, when the rotor 50 is in a predetermined angular position, coincides with an aperture 50'' provided on one side of the body 47. A pipe 63' is connected to the aperture 50'' of the body 47 and is provided therein with a valve 54.

The pressurized fluid which is to function as the power source of the centrifugal water separator 35 while the compressor is operated, is introduced through the introducing pipe 37 into the vane chamber 40 so as to force the vanes 41 to rotate at a high speed. Thereafter it is discharged from the vane chamber 40 through the discharging pipe 38. The vanes 41 are constructed integrally with the hub 42 and fixed onto the shaft 43 by means of the nut 44. The shaft 43, rotatably supported in the bearings 45 and 46, is therefore rotated together with the vanes 41.

The cooling and lubricating oil flows through the conduit 34 into the axial passage 48 within the shaft 43 via the central hole at the bottom of the body 47 of the centrifugal water separator 35 and then flows through the radial bore 49 into the centrifugal chamber 52 which is formed by the enclosure defined by both the rotor 50 and the cover 51 thereof.

The rotor 50 and the rotor cover 51 are constructed integrally with the shaft 43 so as to be rotated together therewith. Therefore, the cooling and lubricating oil, in the state of the turbid white emulsion which entered the centrifugal chamber 52, is rotated at a high speed under a temperature much higher than the atmospheric temperature. Consequently, water particles collected on the inner peripheral surface of the outer wall of the centrifugal chamber 52, and the clean cooling and lubricating oil, having no water particles, which have been separated out therefrom, is expelled into the conduit 36 through the tubular passage 62 and the oil chamber 53. In addition, the water particles collected on the inner peripheral surface of the outer wall of the centrifugal chamber 52 are discharged therefrom to the exterior of the separator through the valve 54 which is automatically operated when the gathered water particles are detected thereby. This valve 54 may be replaced by any one of the manual types or such a device which is automatically opened for a predetermined interval.

The vanes 41 are illustrated in Figure 6 as the drive means of the centrifugal water separator 35. However, other drive means may be used so long as it is rotatable by pressurized fluid.

Moreover, if it is necessary to provide a power source to rotate the centrifugal water separator 35 at high speed, a DC or AC electric motor is used, although such a power source is not shown in the drawings. Alternatively an air motor or another electrical or mechanical means may be used.

Furthermore, as shown in Figure 7, the present invention can be applied so that an introducing conduit 13 of the centrifugal water separator 14 for the cooling and lubricating oil is provided with a valve 55. A discharging conduit 15 for the cooling and lubricating oil is also provided with a valve 56, a further conduit 57 being provided and in order to be able to communicate with the cooling and lubricating oil within the centrifugal water separator 14, one side of a valve 58 is connected to the conduit 57. The other side thereof is connected to a conduit 59 which is in turn connected to the suction port 3 (refer to Figure 1) of the compressor 1. When the water particles contained in the cooling and lubricating oil within the centrifugal water separator 14

are separated therefrom, both valves 55 and 56 are first closed. After several seconds have passed the valve 58 is opened to release the internal pressure within the centrifugal water separator 14 and thereafter, the valve 34 is opened to discharge water gathered in the centrifugal water separator 14. The valves 34 and 58 are immediately closed, and after several seconds the valve 55 and 56 are opened so as again to introduce the cooling and lubricating oil into the centrifugal water separator 14 and to allow the water particles therein to be separated therefrom. When the water particles are separated, the operation of the valves, as described above, is repeatedly carried out so as to allow the water particles in the cooling and lubricating oils to be entirely and surely removed therefrom.

The aforesaid operations of such valves as shown in Figure 7 can be carried out manually, or all of the valves can be automatically operated by detecting the water collected in the centrifugal water separator. By making use of an appropriate time interval, and otherwise, the operations can be automatically carried into effect by the use of any prepared programme in which any appropriate time interval is set up between respective operations of the individual valves.

Furthermore, as shown in Figure 8, the introducing pipe 37 for introducing the pressurized fluid which causes the centrifugal water separator 35 to rotate, is provided with a valve 60, and if necessary, the discharging pipe 38 is provided with a valve 61, whereby the centrifugal water separator 35 can be economically operated in several ways, one way is that the valves 60 and 61 are automatically opened to allow the centrifugal water separator 35 to be operated by automatically detecting the collected water only at the time when the cooling and lubricating oil in the bottom of the pressure vessel and oil separator 2 is emulsified by the water particles. The valves 60 and 61 are manually opened to allow the centrifugal water separator 35 to be operated, and by making use of any prepared program according to which the valves 60 and 61 are automatically operated intermittently in response to the degree of the emulsification within the compressor 1, the centrifugal water separator 35 is operated so as to have the water particles separated completely and to minimize the power loss in dependence on the separator operation.

Where the centrifugal water separator 35 is rotated by electrical or mechanical means, it is possible, as in the aforementioned cases, to have the separator 35 intermittently operated under manual control or to have it intermittently operated automatically by the detection of the emulsified state of the oil and

water, or to have it intermittently operated in accordance with the prepared program.

As described hereinabove, according to the present invention it becomes possible for the water particles, contained in the cooling and lubricating oil in the state of the turbid white emulsion, to be easily separated therefrom and discharged to the exterior of the compressor while it is being operated, by means of the centrifugal water separator which is disposed in the flow path of the cooling and lubricating oil under a temperature much higher than the atmospheric temperature. Therefore, the temperature of the cooling and lubricating oil supplied to the compressor can be lowered so as to enable the suction and the cooling efficiencies to be remarkably improved.

In all of the above embodiments, if the peripheral speed N m/sec of the centrifugal water separator and the temperature $T^{\circ}\text{C}$ of the lubricating oil are defined within the range of the shaded portion in Figure 9 where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

then oil and water can be perfectly and easily separated from each other under any condition and the water can thus be removed. As a result, the pressure of the compressor can be further raised so as to enable the range of the working pressure of the oil injection type rotary compressor to be extended. In addition, the compressor can be continuously operated without trouble for a long time.

Moreover, due to the process in which the cooling and lubricating oil is centrifugally rotated, not only are the water particles in the cooling and lubricating oil removed but also the minimal dusts, carbons, and the like contained in the oil together with the water particles. Accordingly, the compressor is operated at low temperatures without any worry about the emulsification, and therefore, it becomes unnecessary to worry about the oxidation of the oil. In addition, the working life of the oil is extended as much as ten times in comparison with that used in any conventional compressor. Therefore, it is noted that great improvements are brought into the rotary compressor by the present invention.

WHAT WE CLAIM IS:—

1. A compressor arrangement comprising an oil injection type rotary compressor, a cooling and lubricating oil system for said rotary compressor, and a centrifugal water separator disposed in said oil system, said water separator being operable such that water particles contained in the cooling and lubricating oil are automatically separated either continuously or intermittently from the oil and are discharged from the oil system to the exterior thereof.

2. A compressor arrangement as claimed in claim 1, wherein the cooling and lubricating oil itself is used in the centrifugal water separator as the power source thereof and the centrifugal water separator is disposed within the cooling and lubricating oil system in such a way that the pressure difference between the inlet and the outlet thereof is higher than 1 kg/cm^2 , whereby the centrifugal water separator is driven by the flow of the cooling and lubricating oil itself.

3. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is driven by the flow of a pressurised gas leaving said rotary compressor on its way to a point of use.

4. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is driven by making use of a part of the pressurised gas discharged from said rotary compressor, said part being discharged to the atmosphere after driving the separator.

5. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is operated under the condition where peripheral speed N m/sec of the centrifugal water separator and temperature $T^{\circ}\text{C}$ of the cooling and lubricating oil are defined within the range where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

6. A compressor arrangement substantially as hereinbefore described with reference to and as shown in Figures 1, 2 and 3 or Figures 1, 2 and 3 as modified by Figure 7 of the accompanying drawings.

7. A compressor arrangement substantially as hereinbefore described with reference to

water, or to have it intermittently operated in accordance with the prepared program.

As described hereinabove, according to the present invention it becomes possible for the water particles, contained in the cooling and lubricating oil in the state of the turbid white emulsion, to be easily separated therefrom and discharged to the exterior of the compressor while it is being operated, by means of the centrifugal water separator which is disposed in the flow path of the cooling and lubricating oil under a temperature much higher than the atmospheric temperature. Therefore, the temperature of the cooling and lubricating oil supplied to the compressor can be lowered so as to enable the suction and the cooling efficiencies to be remarkably improved.

In all of the above embodiments, if the peripheral speed N m/sec of the centrifugal water separator and the temperature $T^{\circ}\text{C}$ of the lubricating oil are defined within the range of the shaded portion in Figure 9 where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

then oil and water can be perfectly and easily separated from each other under any condition and the water can thus be removed. As a result, the pressure of the compressor can be further raised so as to enable the range of the working pressure of the oil injection type rotary compressor to be extended. In addition, the compressor can be continuously operated without trouble for a long time.

Moreover, due to the process in which the cooling and lubricating oil is centrifugally rotated, not only are the water particles in the cooling and lubricating oil removed but also the minimal dusts, carbons, and the like contained in the oil together with the water particles. Accordingly, the compressor is operated at low temperatures without any worry about the emulsification, and therefore, it becomes unnecessary to worry about the oxidation of the oil. In addition, the working life of the oil is extended as much as ten times in comparison with that used in any conventional compressor. Therefore, it is noted that great improvements are brought into the rotary compressor by the present invention.

WHAT WE CLAIM IS:—

1. A compressor arrangement comprising an oil injection type rotary compressor, a cooling and lubricating oil system for said rotary compressor, and a centrifugal water separator disposed in said oil system, said water separator being operable such that water particles contained in the cooling and lubricating oil are automatically separated either continuously or intermittently from the oil and are discharged from the oil system to the exterior thereof.

2. A compressor arrangement as claimed in claim 1, wherein the cooling and lubricating oil itself is used in the centrifugal water separator as the power source thereof and the centrifugal water separator is disposed within the cooling and lubricating oil system in such a way that the pressure difference between the inlet and the outlet thereof is higher than 1 kg/cm^2 , whereby the centrifugal water separator is driven by the flow of the cooling and lubricating oil itself.

3. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is driven by the flow of a pressurised gas leaving said rotary compressor on its way to a point of use.

4. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is driven by making use of a part of the pressurised gas discharged from said rotary compressor, said part being discharged to the atmosphere after driving the separator.

5. A compressor arrangement as claimed in claim 1, wherein the centrifugal water separator is operated under the condition where peripheral speed N m/sec of the centrifugal water separator and temperature $T^{\circ}\text{C}$ of the cooling and lubricating oil are defined within the range where the upper limit is expressed by

$$\frac{N^2}{150^2} + \frac{T^2}{155^2} = 1$$

and the lower limit is expressed by

$$0.049 N^2 + 0.605 N + T = 55$$

6. A compressor arrangement substantially as hereinbefore described with reference to and as shown in Figures 1, 2 and 3 or Figures 1, 2 and 3 as modified by Figure 7 of the accompanying drawings.

7. A compressor arrangement substantially as hereinbefore described with reference to



and as shown in Figures 4 and 6 or Figures 4 and 8 of the accompanying drawings.

- 5 8. A compressor arrangement substantially as hereinbefore described with reference to and as shown in Figures 5 and 6 or Figures 5 and 8 of the accompanying drawings.

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