

[54] **ROTARY COMPRESSORS WITH
INJECTION OF LIQUID**

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417/228; 62/192, 470; 184/6.16

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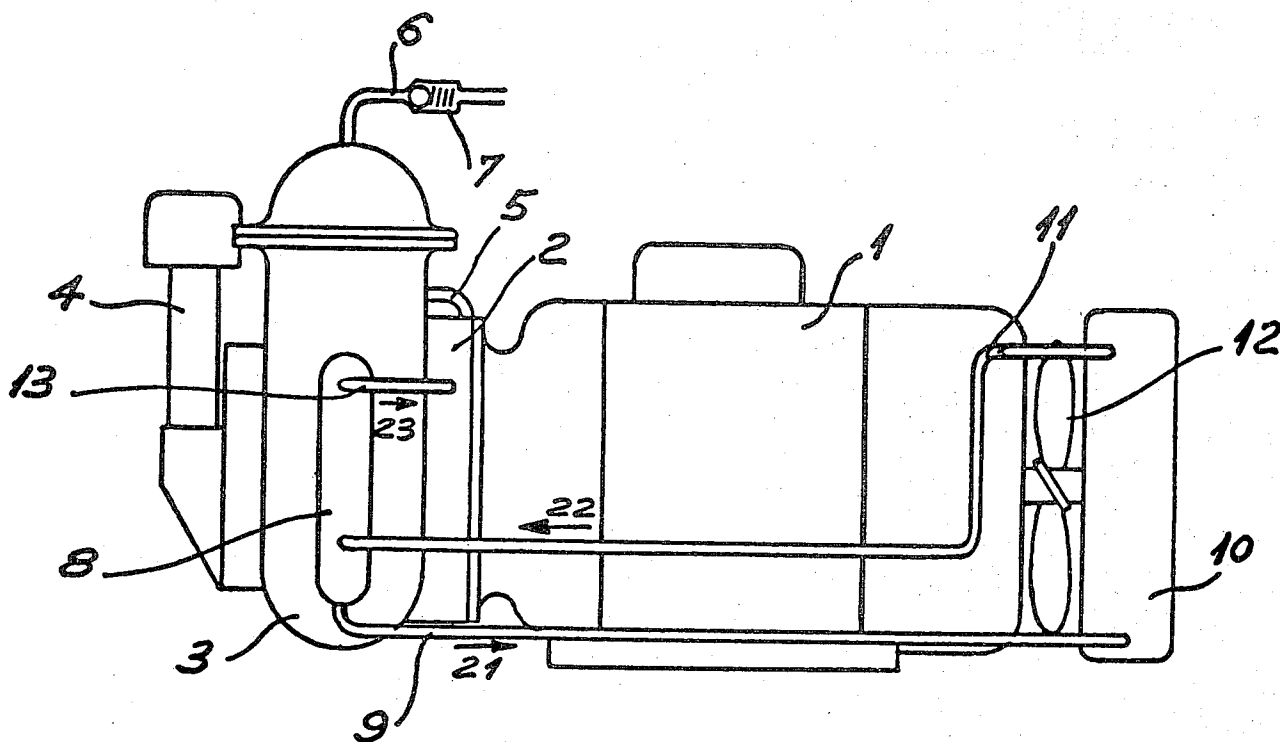
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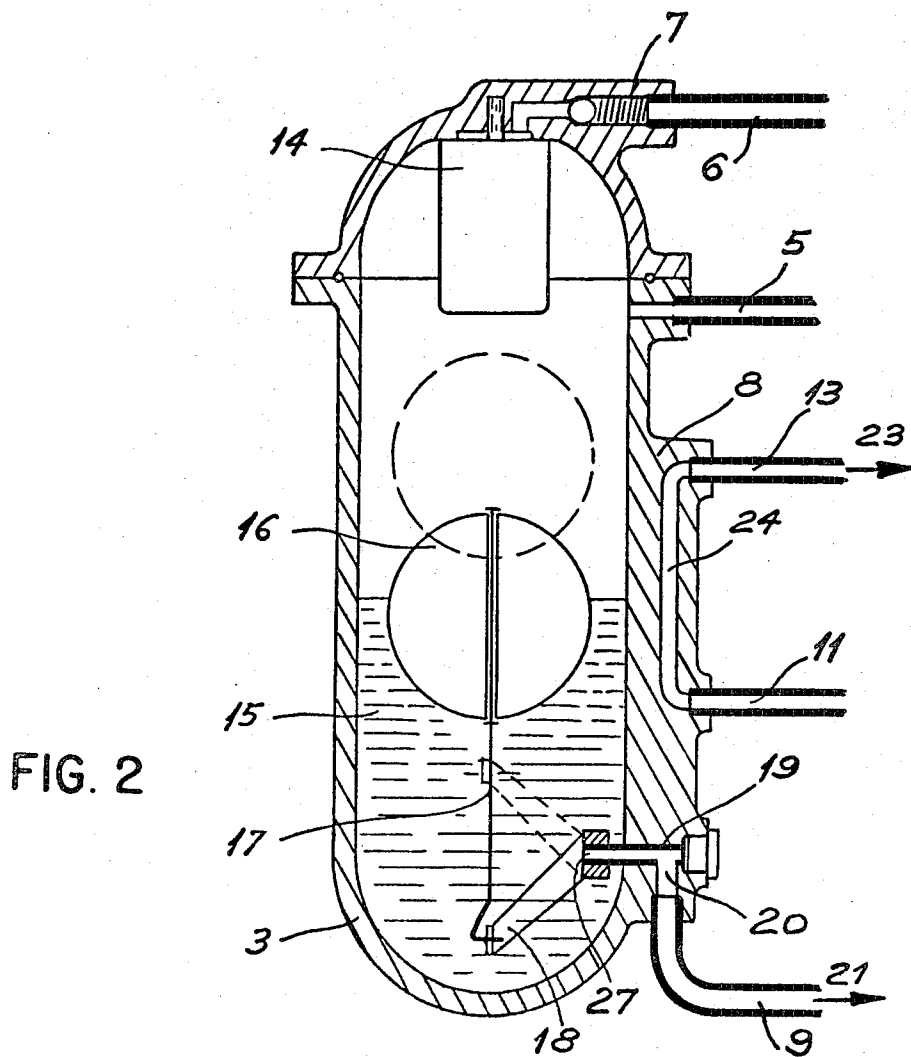
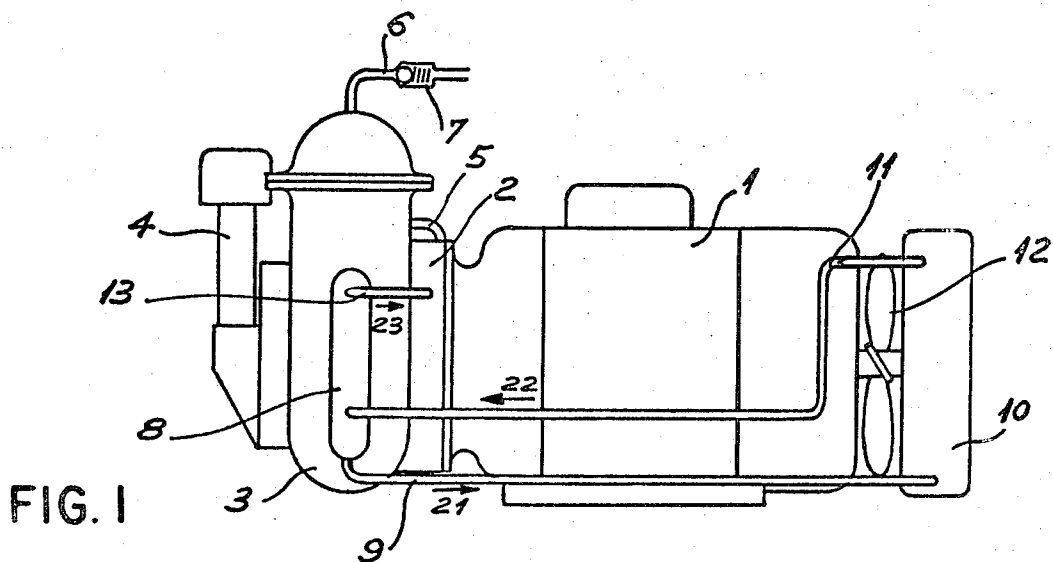
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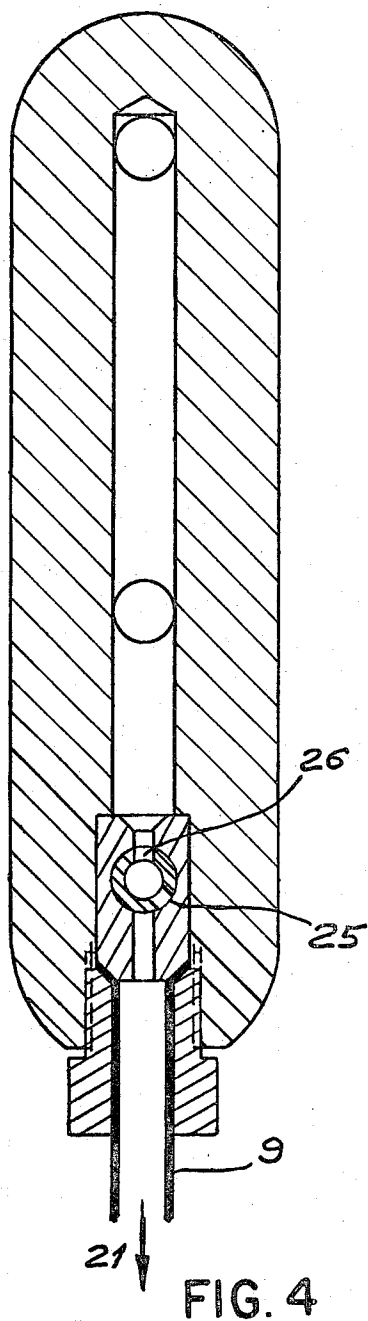
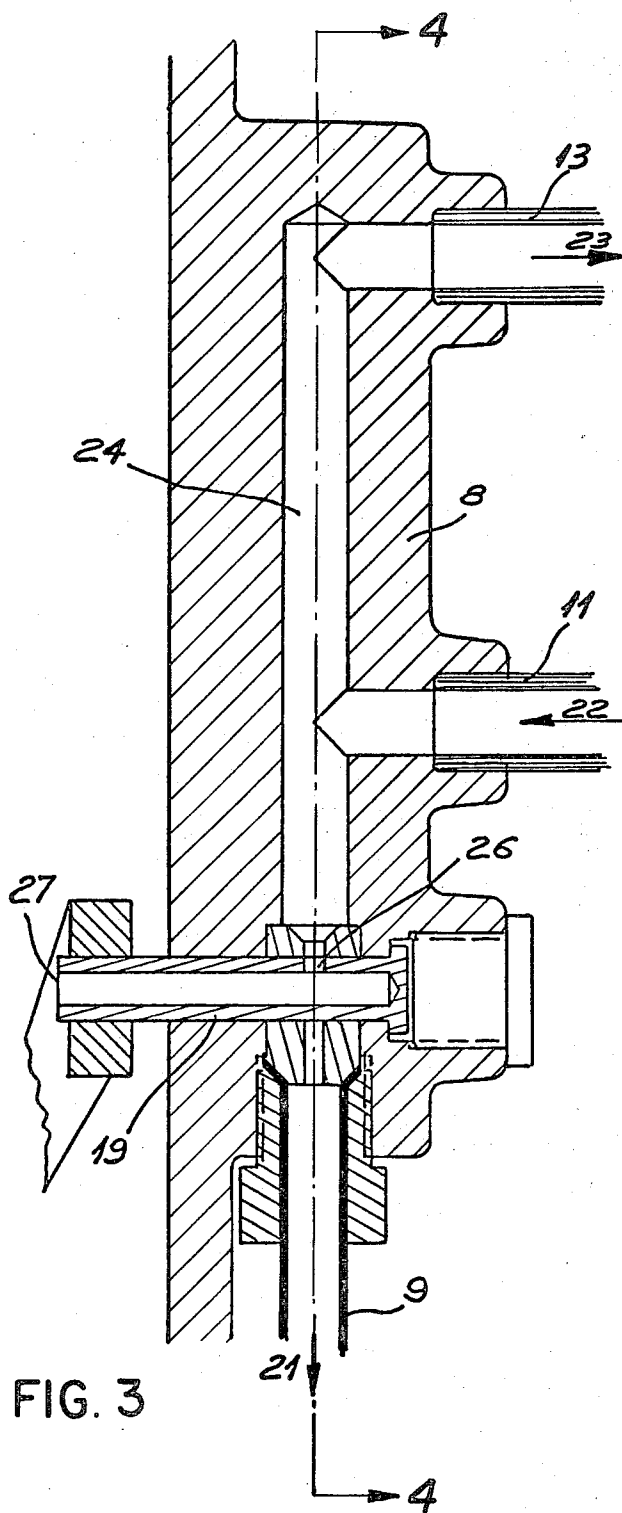
ABSTRACT

An air compressor set comprising a rotary compressor, a motor for driving said compressor, a reservoir connected to the high-pressure outlet of the compressor and partially filled with at least water, a water circulation system connecting said reservoir to at least one injection inlet provided in the compressor and comprising at least one cooling heat-exchanger, characterized in that, in combination the heat exchanger is cooled by the surrounding air and is designed to ensure a temperature difference within the range of 16° to 40° centigrade between the surrounding air and the water at the inlet of the heat exchanger when the entire maximum flow of water passes into the heat exchanger, and that the compressor set comprises means for adjusting the air delivery pressure to an effective value at least equal to 6 bars and for establishing substantially a thermal equilibrium between the compressed air at the outlet of the compressor and the water contained therein.

5 Claims, 4 Drawing Figures







ROTARY COMPRESSORS WITH INJECTION OF LIQUID

BACKGROUND OF THE INVENTION

This invention relates to rotary compressors in which leak-tightness between the rotor and the casing is ensured by injection of liquid.

As disclosed in particular in French Pat. Nos. 1,331,998 and 1,586,832, it is known to construct rotary air compressors which operate with oil injection, the oil being intended to perform at the same time the functions of sealing, cooling and lubrication of said compressor.

Oil is nevertheless attended by numerous disadvantages, especially in the case of air compressors, by reason of the fact that, unless provision is made for the addition of very costly purification installations, the air produced cannot be utilized in a large number of applications which call for clean air such as compressed air for paint, for the food industry, and for pressurization of enclosures in which the air is intended to be breathed by human occupants.

In point of fact, the mechanical characteristics of the compressors mentioned above do not entail the need to employ a liquid having lubricating properties and it is wholly possible to make use of a liquid such as water which does not contaminate the compressed air since this water is already present in the indrawn air in the form of water vapour.

Water is subject to a major disadvantage, however, in that it is entrained by compressed air in the form of vapour. This entails the need for frequent renewals and, if the requisite precautions are not taken is thus liable to result in progressive removal of the entire liquid content of the circulation system and in ultimate destruction of the compressor.

The object of the present invention is to permit the construction of a rotary air compressor which makes use of water as a sealing liquid.

In accordance with the invention, the air compressor set which comprises a rotary compressor, a motor for driving said compressor, a reservoir connected to the high-pressure outlet of the compressor and partially filled with at least water, a water circulation system connecting said reservoir to at least one injection inlet provided in the compressor and comprising at least one cooling heat-exchanger, is characterized in that, in combination, the heat exchanger is cooled by the surrounding air and is designed to ensure a temperature difference within the range of 16° to 40° centigrade between the surrounding air and the water at the inlet of said heat exchanger when the entire maximum flow of water passes into the heat exchanger, and that the compressor set comprises means for adjusting the air delivery pressure to an effective value at least equal to six bars and for establishing substantially a thermal equilibrium between the compressed air at the outlet of the compressor and the water contained therein.

It has in fact been found that, under the conditions of relative humidity which prevail in most regions of the world, that is to say a degree of relative humidity which is higher than 40 percent, it can be ensured that the quantity of water vapour entrained in the compressed air does not exceed the quantity of water vapour drawn in as this would eventually result in disappearance of the water and destruction of the compressor.

This is largely attributable to the fact that the compressed air should theoretically attain temperatures of several hundred degrees during compression and entrain considerable quantities of water but in fact achieves a state of thermal equilibrium with the injected water almost immediately as it passes out of the compressor and transfers its heat to the water without thereby causing any substantial increase in the temperature of this latter by reason of the relative quantities of air and water (which are in any case necessary for the mechanical operation of these machines) and of the high specific heat of water with respect to air.

In consequence, the compressed air is substantially at the temperature of the water after having passed over a distance of only a few tens of centimeters within the outlet ducts of the compressor and the quantity of saturated water vapour which is liable to be entrained by the air is of a low order.

A further advantage lies in the fact that the temperature difference between the air — or the water — after compression and the ambient temperature remains sufficiently high in the case of the design pressure ratios to permit removal of compression heat through a heat exchanger having dimensions which remain reasonable and, at a maximum, are double those usually encountered in compressors which operate with oil.

Another advantage arises from the fact that, by employing a heat-exchanger consisting of a radiator which is cooled by the ambient air, it is possible to cause the temperature of the compressed air to increase automatically with the ambient temperature and therefore to increase the quantity of water vapour entrained; at the same time, however, the quantity of water vapour drawn in at constant relative humidity increases and it will be seen that, by this method of cooling, there is a self-adjustment of the absolute relative humidity of the compressed air to the absolute relative humidity of the indrawn air which ensures a constant volume of circulating water without involving the need to carry out any addition or withdrawal of water.

Yet another advantage is that said constant volume can be maintained by simple means such as a float-valve, even when variations occur in the conditions of delivery pressure or of relative humidity.

BRIEF DESCRIPTION OF THE DRAWING

A better understanding of the invention will be gained from the following description, reference being made to the accompanying drawings, wherein:

FIG. 1 illustrates a complete compressor set in accordance with the invention;

FIG. 2 is a sectional view of a first embodiment of the reservoir which is incorporated in the compressor set of FIG. 1 and provides a reserve supply of liquid;

FIG. 3 is a sectional view of a second embodiment of the reservoir of FIG. 2;

FIG. 4 is a sectional view taken along line X—X' of FIG. 3.

DESCRIPTION OF PREFERRED EMBODIMENT

There is shown in FIG. 1 a motor 1 which is an electric motor in this example but could be of any other type such as a petrol engine, diesel engine and the like. A rotary compressor 2 is coupled with said motor and partly concealed by a reservoir consisting of a drum-type tank 3 mounted on one side of the compressor and in front with respect to the plane of the figure. The

compressor 2 can be of the vane type, of the so-called Lysholm type with parallel lobed rotors or of the single globoid-worm type in accordance with French Pat. Nos. 1,331,998 or 1,586,832.

Said compressor draws air through an inlet 4 fitted with a filter and the compressed air is discharged through a pipe 5 which is connected to the drum 3. The drum 3 is fitted with an air delivery pipe 6 and a valve 7 which is intended to establish a minimum pressure within the drum. There extends from a boss 8 formed on said drum a pipe 9 which is connected to the inlet of a heat exchanger constituted by a radiator 10, the outlet of which is connected to said boss 8 by means of another pipe 11, said radiator being cooled by a fan 12 which is fixed on the shaft of the motor 1.

Said boss is also adapted to carry a pipe 13 which is connected on the one hand to the injection inlet of the compressor and on the other hand to the pipe 11 by means of a duct 24 formed in the boss 8.

The enlarged sectional view of FIG. 2 shows said drum 3 and its boss 8 as well as the pipes 5, 9, 11 and 13. The drum comprises a filter 14 for retaining the droplets of liquid in suspension in the discharged air, a certain volume of water 15 which can contain selected additives such as antifreeze compounds or solid lubricants such as molybdenum bisulphide in suspension, a float 16 actuating by means of a link-rod 17 a crank lever 18 which in turn controls turning of a valve 19 in which is placed a nozzle 20. Valve 19 is turnable by the crank lever accordingly as the float 16 moves from its top (broken line) position down to its bottom (full line) position to completely open the nozzle 20 to pipe 9, the nozzle 20 being partially closed off from pipe 9 in the top position of the float.

The device operates as follows:

The compressed air which passes into the drum through the pipe 5 puts the water 15 under pressure; the water penetrates into the valve 19 through the hollow pintle of this latter, is discharged through the nozzle 20, passes along the pipe 9 in the direction of the arrow 21 up to the radiator 10, then returns along the pipe 11 in the direction of the arrow 22 to the boss 8 in which the duct 24 conveys the water to the pipe 13, then reaches the injection inlet or inlets of the compressor. Within the compressor, said water is entrained with the indrawn air and discharged through the pipe 5, then separated from the compressed air, largely under the sole action of gravity and partly by means of the filter 14.

When the float 16 is in the bottom position as shown in full lines in the drawing, the nozzle 20 is located opposite to the inlet of the pipe 21 and the flow rate of water is not slowed-down by the valve 19.

On the contrary, if the float is in the top position as shown in dashed lines, the valve has rotated and the nozzle 20 is partially closed-off by the bore in which it is pivotally mounted; the rate of flow of water through the pipe 21 is consequently reduced to a very appreciable extent.

The minimum-pressure valve 7 is adjusted so as to allow air to pass only above an effective pressure of 6 bars. It is readily apparent that conventional devices other than that shown in the drawing can be employed for the purpose of ensuring said minimum pressure.

The heat exchanger 10 is designed as a function of the dimension of the compressor so as to dissipate the power employed by the compressor with a temperature

difference between the water at the point of admission to the heat exchanger and the ambient air within the range of 16° to 40° centigrade and preferentially 20° to 25° C, when the float 16 is located at its bottom point and the nozzle 20 is completely open.

It will finally be noted that the flow rate of liquid injected into the compressor under these conditions is equal to or higher than 1 percent of the volume produced by the compressor. This flow rate can be obtained by conventional methods for example either by dimensioning the injection inlets for a pressure of six bars or by means of a positive displacement pump driven by the compressor shaft.

When the nozzle 20 is open, the flow rate is clearly of maximum value.

Under the conditions of temperature and relative humidity which prevail in most countries, the volume of water contained in the drum is accordingly not liable to decrease or fall to zero as a result of entrainment in the discharged air. In consequence, there is no potential danger of destruction of the compressor as a result of any failure of liquid injection.

In fact, the pipe 5 is so dimensioned that the air discharged by the compressor takes substantially the same temperature as the liquid within said pipe 5 while transferring its heat thereto.

In the case of flow rates of liquid representing 1 volume % or more of the volume swept by the compressor, the increase in temperature of the water as a result of its high specific heat remains of low value and less than 10° C, the effect of the heat exchanger being subsequently to reduce the water temperature to the same extent.

By way of example, in the case of air drawn in at 0° C and having a relative humidity of 50 percent, this air contains 2.4 grammes of water vapour per cubic metre of air at atmospheric pressure.

If a heat exchanger has been chosen so that the water delivered at the outlet of the compressor exhibits a temperature difference of 20° C with respect to the surrounding atmosphere, the discharged compressed air at the reservoir inlet is at the temperature of the liquid after compression which accordingly has the value of 20° C. This air is saturated with moisture and contains between 17 and 19 grammes of water per cubic metre but at an effective pressure of at least six bars; in other words, if the air were to undergo expansion, it would entrain a maximum of seven times less water per cubic metre, namely 2.4 grammes.

It is apparent that, under these conditions, equilibrium is established between the water vapour which is admitted into the device and the water vapour which is discharged therefrom.

It must be pointed out that, in the case of pressures below six bars, the above-mentioned equilibrium is practically no longer feasible. In fact, at a pressure of three bars, for example, it would be necessary for the water to penetrate into the radiator at a temperature which exceeds the ambient temperature by only 10°, which is impossible by reason of the temperature rise of the water within the compressor and would call for a heat exchanger of almost infinitely large size.

It is also worthy of note that, if the external temperature increases in respect of a constant discharge pressure and a constant relative humidity, the aforesaid equilibrium continues to be maintained.

Since the radiator is air-cooled, the difference between the water temperature and the ambient air temperature in fact remains constant and the temperature of the water, and therefore of the compressed air, increases at the same time.

Thus, in the case of a relative humidity of 50 percent, a pressure of six bars at effective value but an ambient air at 30° C, the quantity of vapour drawn-in is 15 grammes per cubic metre of air at atmospheric pressure; but the compressed air is at 50° C and contains 83 grammes per cubic metre of air at the pressure of six bars, namely 12 grammes per cubic metre when expanded air is considered.

There is therefore a differential condensation of only 3 grammes, that is to say a negligible quantity.

If the relative humidity of the air at 0° drops to 40 percent, it is similarly observed that a state of equilibrium is established if the temperature of the water at the heat-exchanger inlet is 16° C.

Assuming under these conditions that the float device does not exist and that the valve 19 remains permanently open, it can be stated with certainty that no water will ever be entrained but that, on the contrary, it will be condensed since the relative humidity of the air is practically always higher than 40%. In such a case, provision could readily be made if so desired for the incorporation of conventional automatic draining devices for removing the condensed water in excess and preventing any risk of choking the filter 14.

Depending on the local climatic conditions and on the compression ratio employed, it is possible in some cases to operate with higher water temperatures at the heat-exchanger inlet and therefore with a heat exchanger having smaller dimensions. Thus, in the case of a discharge pressure of 12 bars, a relative humidity which always remains higher than 60 percent, and an ambient temperature which is higher than 20° C as is the case in tropical regions, equilibrium is established at a water temperature of 60° at the heat-exchanger inlet, namely 40° above the ambient temperature.

By providing the heat exchanger with dimensions such that the water temperature at the heat-exchanger inlet is maintained between 16° and 40° C above the ambient temperature according to the climatic conditions and discharge pressures employed, it can be guaranteed that equilibrium or condensation is obtained and that any escape of water which would cause dewatering of the drum is accordingly prevented.

In the preferential arrangement of the invention as described above, the aforementioned auxiliary draining or purge devices are also dispensed with; in fact, if condensation occurs either because the discharge pressure rises above the value of six bars over a long period of time or because the relative humidity increases and even attains 100 percent, the water level rises within the drum 3 and lifts the float which partially closes the valve 19.

The flow rate of water within the compressor decreases and the temperature of the water at the outlet of the compressor increases.

It is acknowledged that there is a certain compensating effect due to the fact that the flow rate decreases through the heat exchanger and that the temperature drop within the radiator accordingly increases.

However, the temperature of the water at the outlet of the compressor nevertheless increases. Thus in the case of the same radiator as before, by reducing the

flow rate to one-third of its initial value, namely 0.33 percent of the flow generated by the compressor, the difference between the water temperature at the heat-exchanger inlet and the ambient air is established at approximately 35° C.

The difference aforesaid is sufficient to ensure that the compressed air entrains a quantity of saturated vapour equal to the inlet vapour when the ambient air has a relative humidity of 100 percent between 0° and 30° C and when compression takes place at an effective pressure within the range of six to seven bars.

Another embodiment of this invention is illustrated in FIGS. 3 and 4. There is shown in these figures a sectional view of the boss 8 of the drum 3. The lever 18 actuates the valve 19 but this latter is a two-way valve in which the inlet 27 is capable of communicating with the ducts 9 and 24 by means of the nozzles 25 and 26.

It is apparent from FIG. 4 that said nozzles are angularly displaced so that, when the nozzle 26 is positioned opposite to the duct 24, the nozzle 25 is closed at least to a partial extent; this position corresponds to the top position of the float. When the float moves downwards, it causes rotation of the two-way valve which progressively closes the nozzle 26 and progressively opens the nozzle 25.

This has the effect of distributing the flow of water discharged from the drum within the two portions of the circulation system formed in one case by the direct passage from 27 to 24 and in the other case by the pipes 9 and 11 and the heat exchanger. As the position of the float is higher, so the quantity of liquid permitted to pass into the heat exchanger is smaller and the quantity of uncooled liquid permitted to pass directly to the injection inlet is larger.

This automatically results in a rise in temperature of the water and the compressed air and therefore in increased entrainment of the saturated water vapour.

If the apparatus has a tendency to condense as a result of any change in conditions of pressure or delivery, the above-mentioned device automatically increases the temperature of the circulation system and stops the condensation.

Automatic stabilization of the level between the end positions of the float accordingly takes place.

These devices are of particular interest if the water contains additives such as antifreeze products which must be maintained at a constant concentration and cannot permit purges which would have the effect of reducing the concentration of said products or of entailing the need to make periodic additions.

It is clearly possible to dispose the nozzles 25 and 26 in such a manner that, during rotation, the rate of flow through the element which comprises the radiator should be reduced to one-half or to one-third before the nozzle 26 begins to open, thereby adding the advantages of the device of FIG. 2 to those of the device of FIG. 3.

Further equivalent arrangements are also possible. For example, the two-way valve can be placed between the drum, the duct 24 and the pipe 11, in which case the pipe 9 is permanently connected to the drum.

What is claimed is:

1. An air compressor set comprising a motor driven rotary compressor, a reservoir partially filled with water connected to the high pressure outlet of the compressor, an injection inlet in the compressor, a water

circulation system including a cooling heat exchanger having an inlet connection with a water outlet of the reservoir and having an outlet connection with the injection inlet of the compressor, and means controlling flow of water from the water outlet of the reservoir to the heat exchanger comprising a control valve, and a float in the reservoir connected for actuating the valve, the valve having a partially open condition in a top position of the float and a fully open condition in a bottom position of the float.

2. An air compressor set as in claim 1, including a compressed air delivery outlet from the reservoir, and a check valve in the delivery outlet normally closing the latter responsive to a predetermined rise in reservoir pressure to open the delivery outlet.

3. An air compressor set as in claim 1, wherein the valve is pivotable from its partially open condition to its fully open condition, and the float has a crank connection with the valve for pivoting the valve from one condition to the other.

4. An air compressor set comprising a motor driven rotary compressor, a reservoir connected to the high pressure outlet of the compressor and partially filled with water, an injection inlet in the compressor, a water circulation system connecting the reservoir to the injection inlet including a cooling heat exchanger and means in the reservoir controlling the flow of water out of the reservoir, characterized in that the water circulation system comprises a first portion which provides a direct connection between the reservoir and the injection inlet of the compressor, a second portion mounted in parallel with the first and comprising the heat exchanger and a two-way valve in which the first valve passageway connects the reservoir to the first portion of the circulation system and in which the second valve passageway connects the reservoir to the second portion of the circulation system, and that the reservoir comprises an internal float arranged so as to actuate the two-way valve in such a manner as to ensure that the second valve passageway is at least partly closed

when the float is in the top position and that said second valve passageway is completely open when said float is in the bottom position.

5. An air compressor set comprising a rotary compressor, a motor for driving said compressor, a reservoir connected to the high-pressure outlet of the compressor and partially filled with at least water, an injection inlet in the compressor, a water circulation system connecting said reservoir to the injection inlet and comprising at least one cooling heat-exchanger, and means in said reservoir controlling the flow of water out of said reservoir, characterized in that, in combination, the heat exchanger is cooled by the ambient air and is designed to ensure a temperature difference within the range of 16° to 40° centigrade between the ambient air and the water at the inlet of the heat exchanger when the entire maximum flow of water passes into said heat exchanger, and that the compressor set comprises means for adjusting the air delivery pressure to an effective value at least equal to six bars and for establishing substantially a thermal equilibrium between the compressed air at the outlet of said compressor and the water contained therein, characterized in that the water circulation system comprises a first portion which provides a direct connection between the reservoir and the injection inlet of the compressor, a second portion mounted in parallel with the first and comprising the heat exchanger and a two-way valve in which the first valve passageway connects the reservoir to the first portion of the circulation system and in which the second valve passageway connects the reservoir to the second portion of the circulation system, and that the reservoir comprises an internal float arranged so as to actuate the two-way valve in such a manner as to ensure that the second valve passageway is at least partly closed when the float is in the top position and that said second valve passageway is completely open when said float is in the bottom position.

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