An oil sealed mechanical vacuum pump having stages has means for supplying oil to the pump through a duct that presents an impedance which is a function of the mean inlet pressure of the pumped gas except the first stage.

10 Claims, 5 Drawing Figures
VACUUMPUMPS

This invention relates to vacuum pumps, and particularly to oil-sealed mechanical vacuum pumps.

Conventional oil-sealed mechanical vacuum pumps are supplied continuously with oil which enters the pump through oil-ways leading from an oil reservoir, and which is ejected back to the oil reservoir through the main pump outlet valve after circulating through the pump. Within the pump the oil performs three main functions: its first function is to lubricate the relatively moving parts; its second function is to seal the small clearances between such parts, so that gas which is being compressed in the pump is prevented from leaking back through these clearances to the high vacuum or inlet side of the pump, and its third function is to provide a liquid piston. Some oil accumulates on the front of the moving compression member of the pump and is swept along by it towards the outlet passage of the pump as rotation and compression proceed. When the compression member approaches the end of the outlet passage the oil is forced into the passage and travels towards the main outlet valve, sweeping with it any gas which is being compressed in the compression chamber of the pump. When the pump is operating at or near its ultimate vacuum, the gas load may be very small, and it is only the action of the oil in travelling up the outlet passage which sweeps the gas to the outlet valve and provides the force necessary to open the outlet valve to expel the oil-entrained gas.

The relative importance of the functions carried out by the oil varies with pumping conditions, as does the quantity of oil necessary to perform these functions. The flow of oil required for lubrication is small and is usually less than that required for sealing except, perhaps, in the high vacuum stage of a two-stage rotary vacuum pump. The flow of oil necessary for sealing depends on the average pressure difference between the inlet and outlet of the pump, i.e. between the vacuum and compression chambers, being high when the pressure difference is high.

When a pump first starts to operate from atmospheric pressure the pressure differential across the pump is low and the amount of oil required is small. As the pressure in the inlet is lowered the pressure differential across the pump increases, as does the pump's requirement for sealing oil. It is normal to supply oil to an oil-sealed mechanical vacuum pump at a rate which is a function of the pressure difference between an oil reservoir and the average pressure in the pump. Therefore as this average pressure starts to reduce the flow of oil increases. However this has the disadvantage that when the pump is operating at or near its ultimate vacuum then the rate of oil feed is at a maximum and may exceed the needs of the pump. The presence of this excess oil aggravates what is known as 'hydraulic knock'.

When the pump is operating near to its ultimate vacuum the gas load is extremely small, so that only a minute quantity of gas is present in the compression chamber. As the compression member nears the end of its compression stroke oil fills all the space between the compression member and the main outlet valve, to produce a so-called 'liquid piston'. As the amount of gas present in the oil is so minute it has a negligible buffering or cushioning effect, so that the liquid piston is effectively incompressible. As the compression member nears the end of its compression stroke this incompressibility of the liquid piston, together with the inertia of the valve closure member and any oil behind it, cause the pressure of the oil in the liquid piston to reach very high values before the main outlet valve has time to open and permit a quantity of the oil to be ejected from the pump. These high and sudden pressure rises, and the consequent pulsating operation of the outlet valve, give rise to the characteristic and annoying knock associated with high vacuum oil-sealed mechanical pumps.

The present invention aims at reducing or eliminating hydraulic knock in an oil-sealed mechanical vacuum pump irrespective of the degree of vacuum under which it is operating.

Accordingly the present invention provides an oil-sealed mechanical vacuum pump which is as claimed in the appended claims.

The present invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic view of a known vacuum pump of the sliding-vane type;

FIG. 2 is a sectional view of a vacuum pump of the present invention having a gas pumping stage, a scavenger stage and an oil control device and

FIGS. 3, 4 and 5 are views of alternative forms of oil-feed control devices.

Although pumps of the sliding-vane type are illustrated, it is to be understood that the present invention is applicable to any type of oil-sealed multi-stage mechanical vacuum pump having an inlet adapted to be placed in communication with the equipment to be evacuated, and having an outlet through which is ejected the gas being pumped.

By 'multi-stage' in this specification is meant —having two or more stages—.

In the pump shown in FIG. 1 a rotor 2 has two sliding vanes 4 which cooperate with the cylindrical wall of a housing 6. The housing has an inlet passage 8 and an outlet passage 10, the latter being closed by a main outlet valve 12 which is illustrated as being of the flap type but which can be of any suitable alternative construction. The passages by which oil is introduced into the interior of the pump are not illustrated.

In operation, the oil tends to be swept up by the vanes 4, as indicated at 14. As the compression stroke continues the volume of gas in the compression chamber 16 reduces, but not that of the oil, so that a stage is reached (as indicated at 18) in which the oil completely fills the space in front of the vane 4 and the outlet passage 10, the gas originally present in the compression chamber being either dissolved or entrained in the oil. This applies only when the pump is operating at or near its ultimate vacuum: at lower degrees of vacuum there is still a significant proportion of gas present in the region 18.

As the vane 4 continues to rotate the column of liquid in front of it and in the outlet passage 10 is rapidly compressed and lifts the flap valve 12 to enable a proportion of the oil (and with it the entrained gas) to escape to the overlying oil reservoir. The gas is then free to separate itself from the oil which is recirculated to the pump.
In that pump of the present invention shown in FIG. 2, those parts identical with the pump shown in FIG. 1 are given the same references.

As shown, the compression chamber 16 of the pump is in communication with a chamber 54 by means of a non-return valve 56. The chamber 54 is connected by a conduit 20 to the interior of an oilfeed control device 22 including an open-ended cylinder 24 having its open end closed by a diaphragm 26 which abuts the head 28 of a plunger 30. The head 28 is biased into contact with the diaphragm 26 by means of a compression spring 32 encircling the plunger 30.

The plunger 30 is a sliding fit in the end wall of the cylinder 24, and its outer end 34 is shaped to function as a valve member cooperating with a seat 36 formed in one end of a conduit 38 upon which oil is fed under pressure (which may be atmospheric) to a chamber 40. Oil entering the chamber 40 through the annular space between the valve member 34 and valve seat 36 escapes through a conduit 42 from which it flows to the usual oil-ways (not shown) in the housing 6.

The device operates as follows:

When the pressure in the inlet 8 is high, the pressure in the chamber 54, and hence in the interior of the cylinder 24 is also high. The conduit 20 may have an appreciable impedance to the flow of fluid along it, whereby transient fluctuations in the pressure in the chamber 54 are damped out to some extent. The pressure in the cylinder 24 closely approximates to the average pressure.

As the pressure in cylinder 24 is relatively high, it assists the spring 32 in keeping the valve member 34 spaced from the valve seat 36, so that oil is able to flow freely to the pump.

As the pressure in inlet 8 approaches the ultimate vacuum the average pressure in the chamber 54 will be substantially lower than before. This leads to an increase in the pressure differential across the diaphragm 26, which eventually reaches such a value that it is able to overcome the biasing effect of spring 32 and force the valve member 34 towards the valve seat until it blocks conduit 38 at least partially. If it is arranged to block the conduit completely, then a bleed passage (not shown) is provided to ensure that there is always a desired minimum flow of oil.

The characteristics of the different components in the device 22 are chosen so that the flow of oil to the pump is restricted as the pump is approaching its ultimate vacuum. This restriction in supply reduces the amount of oil in the pump to a level such that hydraulic knock is at least reduced if not eliminated.

The oil supply to the pump may be greatly reduced because the scavenger stage replaces the "liquid piston" (discussed with reference to FIG. 1) as the means for extracting the effluent oil together with residual traces of gas from the outlet of the main stage, and for compressing these for discharge into the oil reservoir at atmospheric pressure. The amount of air which enters the pump entrained with the oil is proportional to the amount of oil feed, so that reducing the amount of oil results in an improvement of the ultimate vacuum attainable by the pump. Also, as the amount of work done on ejecting the oil (and its gas content) back to the reservoir is reduced, the power requirements of the pump are reduced and the pump runs cooler compared with conventional pumps of the same capacity.

Should fresh gas enter the inlet 8 from the equipment being evacuated then the mean pressure in chamber 54 will rise and the flow of oil will be increased correspondingly.

A conduit (not shown in the drawing) is connected to the compression chamber of the pump and to a valve (not shown) by means of which a controlled bleed of gas may be introduced into the compression chamber 16 to gas ballast the pump. When the gas ballast is used the mean pressure in the chamber 54 will rise and the supply of oil increased.

The chamber 54 functions as the inlet chamber to the outlet stage 50 of the pump. The outlet stage is intended to act primarily as an oil-scavenger pump, but obviously assists in pumping gas. The outlet of stage 50 is exhausted into the overlying oil reservoir 58 through an outlet valve 60, which is shown composite with outlet valve 12 from chamber 54.

The displacement ratio of the two stages is large, about 20:1. This ensures that there is an appreciable inter-stage pressure, except when the gas load is very small.

When the pump has three or more stages, then it is arranged that the oilfeed control device is responsive to the pressure in the inlet of the last or outlet stage.

By ensuring that the control pressure is that in the inlet to the outlet stage, as opposed to that in the compression chamber or outlet passage of the first stage, the oilfeed device is buffered from the transient pressure fluctuations produced there, so that it has characteristics closer to the desired values than would otherwise be the case.

In the three alternative forms of oilfeed control device 22 shown in FIGS. 3 to 5 those parts common to the device described in connection to FIG. 2 are given the same references.

The principal difference in the FIG. 3 embodiment is that the head 28 of the plunger 30 is exposed directly to the reference pressure, being in fluid-tight engagement with an annular seal 61. The seal may be in sliding contact with the head 28 or it may be axially resilient or.invertible. Apart from this difference the device 22 functions as described above.

In the device shown in FIG. 4, a resilient diaphragm 62 carries a stem 64 connected to a valve member 66 which is adapted to cooperate with a passage 68 in a partition in a housing 70. Seated in a chamber 72 to which the passage of conduit 20 leads is a compression spring 74 which biases the valve member 66 out of engagement with the seat provided by the passage 68.

In operation, a high pressure in chamber 72 cooperates with the spring 74 in keeping the passageway open so that oil is able to pass freely between the conduits 38 and 42. As the associated oil-sealed mechanical vacuum pump nears its ultimate vacuum, the reduction in pressure in the chamber 72 allows the oil pressure on the upstream side of the partition 69 to flex the diaphragm 62 to bring the valve member 66 into sealing engagement with the passage 58 so that the flow of oil is reduced as required.

In that form of device shown in FIG. 5, the reference pressure is provided by a sealed aneroid capsule 80 having one wall in contact with a fixed wall of a housing 82 and having its other wall in contact with the head 28 of the plunger 30. As the pressure in the interior of the
housing 82 increases, the volume occupied by the capsule 80 decreases to allow the thickness of the capsule 80 to reduce to permit the valve member 34 to move away from the seat 36. As the pressure reduces (which happens as the pump nears its ultimate vacuum) the capsule 80 expands to move the plunger 30 to restrict or reduce to a minimum the flow of oil to the pump.

Although four different types of oilfeed control device 22 have been illustrated, these are only by way of example: numerous equivalent devices could be used.

Although the device has been described with particular reference to its use in conjunction with a multi-stage pump having a final scavenging stage (as described in our copending patent application Ser. No. 45,880, filed June 12, 1970) it may also be applied to a multi-stage pump when no oil scavenger stage is provided. An example of such an application is the use of the device to control the supply of oil to the inlet stage of a multi-stage pump by responding to the inlet pressure of the subsequent stage. The advantage sought in this case is a generous supply for lubrication of the inlet stage under arduous duties when a high gas load is being pumped, and a reduced supply of oil when the pump is used on high vacuum duties such that the release of dissolved air from an over-generous oil supply would degrade the vacuum.

I claim:

1. An oil-sealed mechanical vacuum pump having two or more stages comprising means for supplying oil to the pump including a duct, a fluid flow control valve in the duct, a pressure-responsive movable member in the control valve which presents an impedance to the flow of oil that is a function of the mean inlet pressure of the pumped gas to any one of the stages except the first, the impedance being variable by the action of this pressure on the movable member of the fluid control valve.

2. An oil-sealed mechanical vacuum pump having two or more stages as claimed in claim 1, the last stage including an inlet and a final outlet, in which the impedance of the said duct to the flow of oil is a function of the mean pumped gas pressure in the inlet of said last stage of the pump.

3. A pump as claimed in claim 1, one stage being a control stage for the oil supply means, the inlet of the oil supply controlling stage being isolated from the outlet of the immediately-preceding stage by means of a non-return valve.

4. In a pump as claimed in claim 3, an oil reservoir, said fluid flow control valve including a seat for its pressure-responsive movable member, spring means biasing the movable member away from its seat, a conduit through which oil is supplied through the space between the valve seat and the movable member continuously while the pump is working, a conduit establishing communication between the outlet side of the seat and the reservoir, and said pressure-responsive movable member being biased towards valve closing position on the seat by a control pressure of the pumped gas which is variable as a function of the pressure in the inlet to the oil supply control stage.

5. A pump as claimed in claim 3 in which the displacement of the oil supply controlling stage is appreciably smaller than that of the immediately preceding stage.

6. A pump as claimed in claim 2, in which the displacement of the last stage is of the order of one-twentieth of that of the immediately-preceding stage.

7. A pump as claimed in claim 6, in which the valve member is movable with a flexible diaphragm of which one side is exposed to a reference pressure and of which the other side is exposed to the control pressure of the pumped gas.

8. A pump as claimed in claim 6, in which the valve member is movable with a plunger defining a movable wall of a chamber having its interior in communication with the inlet to the outlet stage, the plunger being sealed to the chamber in a fluid-tight manner and having its outer surface exposed to a reference pressure.

9. A pump as claimed in claim 6, in which the valve member is movable with a flexible diaphragm of which one side is exposed to the oil inlet pressure, and in which the other side is exposed to the control pressure.

10. A pump as claimed in claim 6, in which the valve member is biassed into contact with an aneroid capsule having its external surfaces exposed to the control pressure.

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