

[54] **ROTARY MECHANICAL PUMPS OF THE SCREW TYPE**

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[58] Field of Search.....418/9, 97, 99, 200, 201, 15, 418/98; 417/310

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Primary Examiner—Carlton R. Croyle

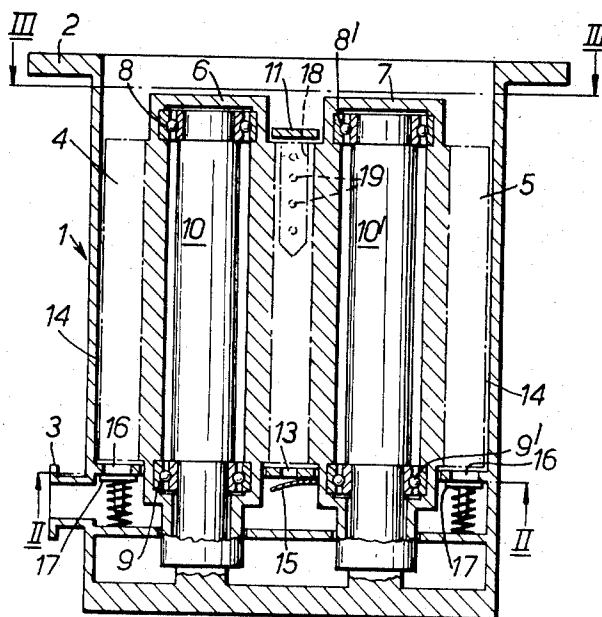
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[57] **ABSTRACT**

An oil-sealed screw rotor mechanical vacuum pump which may be used as a backing pump, together with a rotary dry-running fine pump, in a high vacuum pumping unit. The screw rotor pump has one or more non-return valves between the chambers being limited by the screw rotor action and the atmosphere. The sealing oil also acts as a "liquid piston" to sweep pumped medium out of the chambers via the non-return valve(s).

6 Claims, 4 Drawing Figures



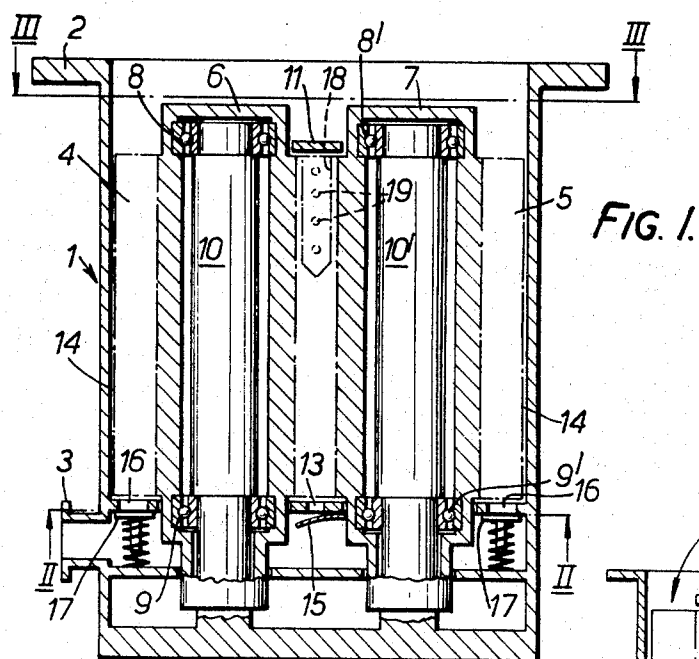


FIG. 1.

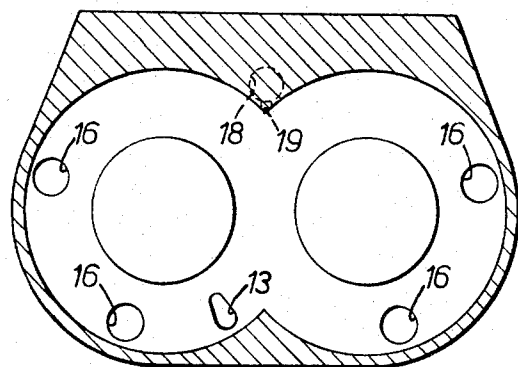


FIG. 2.

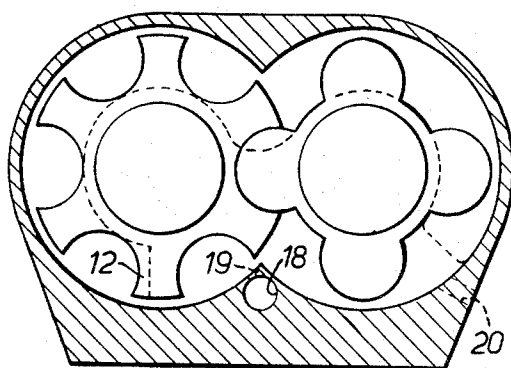


FIG. 3.

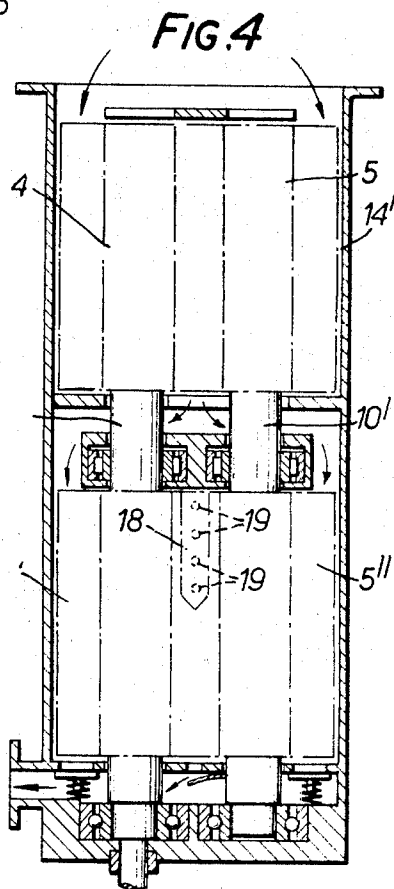


FIG. 4.

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ROTARY MECHANICAL PUMPS OF THE SCREW TYPE

This application is a continuation of our prior application Ser. No. 759,952, filed Sept. 16, 1968, and now abandoned, and relates back thereto for all dates and rights incident to the filing thereof and of our corresponding British Application No. 42965/67, filed Sept. 21, 1967, and from which priority is claimed.

This invention relates to rotary mechanical pumps of the screw type.

The screw rotor compressor or vacuum pump conventionally consists of a housing structure containing two cylindrical and intersecting bores wherein is supported a pair of co-operating male and female rotors which have helical lands and intervening grooves and are arranged to turn synchronously in opposite directions. Flat end covers are provided at both ends of the housing structure, and these are perforated by ports for the admission and expulsion of the gas to be pumped. Working chambers are formed bounded by parts of the surfaces of the two rotors and by part of the cylindrical inner wall of the housing and usually also by part of the end cover surface. During rotation the working chambers thus confined travel axially along the pump and are progressively limited in volume as the outlet end of the pump is approached so that a continuing pumping action is obtained.

Screw rotor compressors or vacuum pumps have been described with various different geometries of design which may affect the form or number of the lands or grooves on the rotors, the pitch of these lands and grooves and the number of chambers in series defined by a particular land and groove at any one instant. Pumps have been built having the lands and grooves reducing in depth towards the high pressure end of the pump. Two stage pumps have been built having two male and female rotor pairs mounted on a single shaft, separated by a partition and connected to pump in series. Screw rotor compressors and vacuum pumps are usually designed to operate with small clearances between the relatively moving parts and usually employ synchronizing gears at one end of the shafts to maintain the clearances between the rotors which are not themselves normally lubricated. Pumps have been built, however, where the rotors are supplied with oil for lubricating or sealing purposes and in some cases it has proved possible to dispense with the synchronizing gears. Pumps have not normally been built for high vacuum purposes although the use of pumps to produce pressures of several torr absolute has been described.

It is an object of this invention to provide a pump which is capable of producing higher vacua than has normally been available with screw rotor pumps, the invention being concerned both with primary pumps capable of producing a vacuum of, say, 10^{-3} torr whilst delivering directly to the atmosphere and with higher vacuum pumps capable of very high compression ratios whilst delivering gas to a pressure readily capable of attainment by a primary pump. The invention is also concerned with complete higher vacuum pumping units capable of delivering directly at atmospheric pressure.

The invention will not be described in greater detail, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 shows diagrammatically an oil-sealed screw rotor vacuum pump;

FIG. 2 is a cross-section taken on the line II—II of FIG. 1;

FIG. 3 is a cross-section taken on the line III—III of FIG. 1; and

FIG. 4 is a diagrammatic representation of a composite high vacuum pumping unit comprising a dry-running screw rotor vacuum pump and an oil-sealed screw rotor backing pump.

Referring to FIG. 1 of the drawing, a screw rotor medium vacuum pump has a housing 1 provided with a flange 2 for connection to a system to be pumped and a port 3 for discharge of the pumping medium. Within the housing 1 are two rotors 4 and 5 which are of the screw type and have central bores closed at the ends as at 6 and 7. These rotors are rotatably mounted on upper bearings 8 and 8' and lower

bearings 9 and 9' so they may rotate about cantilever shafts 10 and 10' which are fixed at their lower ends to the housing. A drive gear (not shown) on one of the rotor shafts transmits power to the other rotor shaft.

A top cover plate 11 partially covers the top end of the rotors, their non-covered or exposed areas defining an inlet port (shown at 12 in dotted lines in FIG. 3) which allows flow of the pumping medium into the spaces between the rotors and the housing. When the rotors 4 and 5 rotate in opposite directions, the pumping medium is enclosed within these spaces which move axially along the rotors towards an outlet port 13 (see FIG. 2) in a lower end cover. The port 13 is shown centrally in FIG. 1 for the purpose of clarity. As each space, or working chamber, approaches the outlet port the interaction of the rotors reduces its volume, the only leakage path upwards towards the inlet or high vacuum end being along the working clearances 14 and also between the rotors 4 and 5. The outlet 13 is provided with a non-return outlet valve 15. During initial evacuation of the system to be pumped the volume of gas contained within each working chamber will tend to be compressed until its pressure considerably exceeds that existing at the outlet 3. This would require undesirably large amounts of power and probably cause rough working of the pump. Thus, in accordance with the invention, there is provided, in addition to the outlet port 13, one or more additional outlet ports 16 which communicate with the working chambers at various stages of their reduction in volume. These additional ports 16 are provided with spring loaded one-way (non-return) pressure relief valves 17 arranged in the lower (outlet) end cover, which only open when the pressure in the working chamber exceeds that in the region of port 3 by a predetermined amount, say 3 psi. Thus, while these valves 17 will be in use during the initial stages of pumping, they will not necessarily be used when high vacuum is reached. The ports 16 and valves 17 could alternatively be arranged in the wall of the housing 1.

When pumping a vacuum system from atmospheric pressure the pumping medium is ejected, on the first compression stroke, through the nearest valve 17. As the rotors continue to mesh the medium is ejected successively through the remainder of the valves 17 and finally through the valve 15. As the process is continuous, subsequent compression strokes are started before the first stroke has finished. Thus, when pumping from atmosphere the pumping medium is ejected, to begin with, through all the valves 17 as well as through the valve 15. As the pressure falls, however, the valve 17 which is furthest away from the point of intermeshing of the rotors 4 and 5 (in the opposite direction to that of the rotation) will become inactive. As pumping progresses this will happen to each of the valves 17 in turn until when only a very little pumping medium is being handled, only the valve 15 will remain open. As the rotors 4 and 5 revolve rapidly, e.g. about 3,000 r.p.m. this results in a correspondingly high rate of compression strokes, e.g. of 12,000 per minute. In such condition, the valve 15 never closes entirely but "vibrates" in a position intermediate its fully open and fully closed positions. This position is determined by the pressure conditions acting on each side of the valve plate which are such as to prevent re-entry of pumped medium into the interlobal space.

The oil for sealing the pump is introduced in metered amounts into its working chambers via a passage 18 having a number of oil injection holes 19. The oil is metered into the working chambers in amounts in excess of that necessary for sealing purposes. This ensures that, in the final stage of delivery the working chambers are almost completely filled with oil, any pumped gas being compressed to a very small volume, and when the outlet valve 15 (or valves 15 and 17) are lifted the oil is caused to flow through the port 13 (or ports 13 and 16) in the manner of a hydraulic piston ensuring very complete elimination of gas at the end of each compression cycle.

The pump described above is particularly useful as a backing pump in a two stage high vacuum pumping unit, in

which case it is desirable to maintain as low an oil contamination as possible at its inlet end, namely the high pressure end of the fine pump. The oil is therefore introduced to a working chamber of the backing pump only after the chamber is sealed from the pump inlet so that there is at least one working clearance restriction 14 to limit leak back, the oil being introduced at a number of points 19 (FIG. 1). Thus, in the pump of FIG. 1, the first point of oil introduction should be sufficiently far down the rotor so as to give a single clearance restriction 14 between this point and the inlet end.

The oil introduced into the pump also provides a means of lubrication so that rubbing between the rotors can be permitted. However, in these circumstances lubrication would be required along the whole length of the rotors where rubbing occurs. Thus, in order to keep as low as possible oil contamination at the input, when the oil-sealed pump is used as a backing pump, the top portions of the rotors may be arranged not to rub so that there is no need for lubrication in these regions. This can be obtained, for example, by altering the form of the rotors slightly and slightly increasing the section of the rotor containing bores in the housing 1 in this region.

A particular advantageous feature of the oil-sealed pump of FIGS. 1-3 is the use of the arrangement of outlet valves 17 co-operating with the outlet end cover which closely abuts the end faces of the rotor pair and the housing so as to have a very small clearance or to rub in lubricating contact with the rotors.

All the outlet valves 17 of the oil sealed pump may be oil immersed so as to prevent any back flow of gas into the working chamber if the latter should be at a lower pressure than the discharge pressure. Again they may be arranged in the lower end cover or in the wall of the housing 1.

The oil sealed rotary screw pump is subject to many of the modifications already known or proposed with respect to other mechanical rotary pumps, such as the vane pump. Then the use of energy absorbers, as described in U.S. Pat. No. 3,421,688, may be used to reduce or prevent "oil knock" at the final outlet valve or valves during pumping at high vacuum. The absorbers may be of the type which communicate with gas or air at the discharge pressure or of the hermetically sealed type. Use may also be made of a gas ballast arrangement for permitting the pumping of condensable vapors with reduced risk of condensation within the pump. The ballast gas may be introduced into the working chambers once they are sealed from the inlet end, the ballast gas providing some of the pressure necessary to open the outlet valve or valves. A gas ballast entry conduit is shown at 20 in FIG. 3.

A problem associated with oil sealed vacuum pumps in general is suck back of oil if the pump stops under vacuum. British Pat. No. 875,444 describes one method of preventing this and this, or any other suitable methods, may be used with the oil sealed screw rotor pump.

A torque limiting hydraulic drive may be incorporated as an integral part of the pump, generally the same in manner as is disclosed in U.S. Pat. No. 3,401,808.

FIG. 4 diagrammatically illustrates a particularly suitable composite pump unit for pumping from atmosphere to high vacuum, say 10^{-5} torr (in principle, very much lower pressures than this should be possible). This unit comprises an oil-sealed backing pump, similar to that shown in FIGS. 1-3 having rotors 4'' and 5'' in series with a dry-running screw type pump having rotors 4 and 5. The rotors 4 and 4'' are both mounted on or are integral with a shaft 10 and the rotors 5 and 5'' on a shaft 10'. It will be noted that the portions of the shafts carrying the rotors 4 and 5 are cantilever portions so as to prevent the bearing lubricant reaching the high vacuum side of the

unit. Each shaft has two bearings located at either end of the backing pump rotors 4'' and 5''. The oil-sealed pump is substantially the same as has been discussed in the foregoing description with reference to FIGS. 1-3. The dry-running pump is very similar to the oil-sealed pump except that it does not have an oil introduction passage 18 and oil injection holes 19. As the dry-running pump is provided with no lubrication or oil sealing between the rotors or between the rotors and the housing it is necessary to have the working clearances 14' of the order of 0.005 inches. While such clearances are smaller than the mean free path of gas molecules at high vacuum, it is desirable in order to reduce the "leak back rate" from the higher pressure end of the pump to ensure that they are also comparable or less than the mean free path of the pumped gas molecules in the region of the discharge port of the dry-running pump.

What is claimed is:

1. A rotary mechanical vacuum pump apparatus of the screw type comprising in combination:

- a. a housing;
- b. a low pressure inlet region in said housing;
- c. a high pressure outlet region in said housing;
- d. two intermeshing screw rotors accommodated in said housing, said rotors being rotatable in opposite directions to produce a pumping and compressing action between said low pressure inlet region and said high pressure outlet region by limiting working chambers formed between said rotors and said housing;
- e. an outlet port, provided with a non-return outlet valve, in said outlet region;
- f. a plurality of additional ports communicating directly with said working chambers and the said outlet region, each of said additional ports being provided with a pressure relief valve whereby said working chambers are vented to said outlet region when a predetermined excess pressure exists between said working chambers and said outlet region; and
- g. means for introducing a sealing liquid into said working chambers, said sealing liquid providing a "liquid piston" which sweeps pumped medium out of said working chambers via said non-return outlet valve.

2. A pump apparatus according to claim 1, in which said sealing liquid introduction means introduces sealing liquid into said working chambers when said working chambers are no longer in communication with said low pressure inlet region.

3. A pump apparatus according to claim 1, further including gas introduction means whereby gas ballast is introduced into said working chambers when said working chambers are no longer in communication with said low pressure inlet region.

4. A pump apparatus according to claim 1, in which each of said rotors is formed with a central bore which is closed at said low pressure inlet region and is rotatably mounted on a cantilever shaft supported at said high pressure outlet region.

5. A pump apparatus comprising an oil sealed pump according to claim 1 further including a dry running high vacuum screw type pump in flow series therewith.

6. A pump apparatus according to claim 5, in which said dry running pump and said oil sealed pump have a common housing with two axially displaced pairs of dry and oil sealed rotors therein,

- e. the corresponding rotors of said two pairs are provided with a common shaft, and
- f. said common shafts have and are rotatably mounted in bearings located at the respective ends of said oil-sealed rotor.

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