(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 055 084 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 81305927.6

(51) Int. Cl.³: F 04 C 29/10

(22) Date of filing: 17.12.81

(30) Priority: 23.12.80 GB 8041245

(43) Date of publication of application: 30.06.82 Bulletin 82/26

(84) Designated Contracting States: AT BE CH DE FR IT LI NL SE

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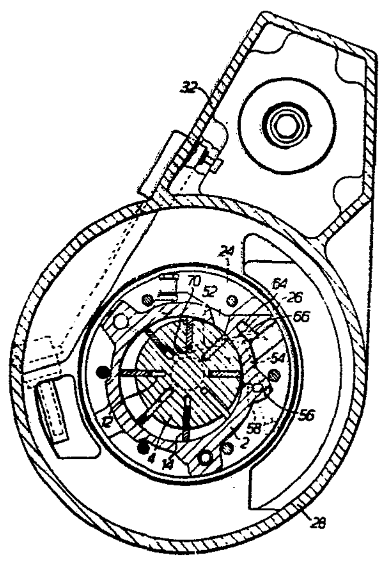
(54) **Rotary compressors of sliding vane eccentric rotor type.**

(57) A rotary compressor of sliding vane eccentric rotor type includes a stator 2, within which a rotor 4 is eccentrically mounted for rotation which defines together with the stator a crescent shaped working space. The rotor affords a plurality of radial slots 12 each of which slidably receives a vane 14 which contact the stator and thereby divide the working space into a plurality of compression cells. An unloader valve 20 is arranged to restrict or close the compressor inlet 18 when the compressor pressure rises above its normal working value and a vacuum relief valve 36 responsive to the unloaded condition of the compressor controls a vacuum relief passage 50 so as to bleed high pressure air into the working space through a plurality of passages 58 spaced along the length of the stator when the compressor is in the unloaded condition. The high pressure air is thus bled to precisely the position where it is required which permits less air to be recirculated by the vacuum relief valve than was previously possible resulting in a decrease of the power consumption of the compressor when offloaded.



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ROTARY COMPRESSORS OF SLIDING VANE ECCENTRIC ROTOR TYPE

The present invention relates to rotary compressors of the sliding vane eccentric rotor type. Such compressors include a stator within which a rotor is eccentrically mounted for rotation, the rotor and stator together defining a crescent shaped working space. A plurality of equispaced radial slots are formed in the rotor and these accommodate freely movable vanes which divide the working space into a number of cells. The stator is provided with appropriately positioned inlet and outlet ports and as the rotor is rotated each cell gradually increases in volume thereby drawing in air through the inlet and thereafter decreases in volume until its volume is virtually zero at which point it communicates with the outlet port or ports through which the air which has been compressed within the cell is discharged. Such compressors are generally "oil sealed", that is to say oil is circulated within the compressor by differential pressures within it and injected into the compression cells to ensure an adequate seal between the vanes and the stator and the end plates by which the stator is closed. The oil is entrained in the compressed air in the form of droplets and is subsequently removed, generally by two oil separation stages, and returned to the compressor sump.

Compressors of this type conventionally incorporate an unloader valve arranged to restrict or close the compressor inlet and controlled by a servo valve which is responsive to the compressor delivery pressure. If the demand for compressed air should fall substantially or stop altogether the compressor delivery pressure rises above its normal working value and the unloader valve restricts or closes the inlet so that a reduced amount of air, or no air at all, is compressed so that the compressor pressure stops rising and the power consumption of the compressor drops. In this unloaded condition not only is the compressor pressure higher than usual but the pressure at the inlet drops to below atmospheric pressure. This results in the pressure differential across the blade immediately upstream of the outlets in the stator being higher than usual with the result that this blade can become unstable and repeatedly lose contact with the inner surface of the stator thus producing a rattling or chattering sound and increased wear of the blade. In addition it is found that one or more other blades can also tend to chatter when the compressor is offloaded though the precise reasons for this are not fully understood.

To overcome this problem such compressors are provided with a vacuum relief valve responsive to the compressor inlet pressure which bleeds high pressure air from the compressor casing or secondary oil separation unit to the compressor inlet when the compressor is off-loaded. This air is drawn into the rotor stator unit through the normal inlet so that when even totally off-loaded the compressor is continually compressing a small volume of air. This constant circulation of air around the compressor when it is offloaded improves the force distribution acting on the vanes and largely overcomes the problem of their instability. Although the amount of air circulated is relatively small it does have the effect of increasing the power consumed by the compressor when it is running off-load.

Compressors of this type are commonly used for powering tools and machines of various kinds, such as pneumatic drills, and generally have a rated output pressure of about 7 bar (100 psi). As mentioned above, the volume of air that must be circulated when the compressor is offloaded to avoid blade chatter leads to an increase in power consumption. However, there is an increasing need for compressors having a higher output pressure of e.g. 10 bar (150 psi). With such compressors the volume of air that must be circulated using a conventional vacuum relief valve to prevent blade chatter when the compressor is offloaded is considerably greater and the power consumption of such higher pressure compressors when offloaded can be unacceptably high.

Accordingly, it is an object of the present invention to devise a rotary compressor of sliding vane eccentric rotor type having a vacuum relief system which adequately avoids the problem of blade chatter when the compressor is offloaded whilst maintaining the power consumption within acceptable levels even for compressors having a higher rated output pressure of e.g. 8 to 10 bar or even more.

According to the present invention there is provided a rotary compressor of sliding vane eccentric rotor type including a stator, a rotor eccentrically mounted for rotation within the stator and defining together with the stator a crescent shaped working space, a plurality of vanes slidably received in radial slots in the rotor and, in use, contacting the stator thereby dividing the crescent shaped working space into a plurality of compression cells, an unloader valve arranged to restrict or close the compressor inlet when the compressor pressure rises above its normal working value, a vacuum relief valve responsive to the unloaded condition of the compressor and a vacuum relief passage controlled by the vacuum relief valve, communicating with a space which, in use, is substantially at the compressor delivery pressure, and passing through the stator and communicating with the crescent shaped working space whereby, in use, when the compressor enters the unloaded condition high pressure air is bled directly into one of the compression cells.

When the compressor enters the offloaded condition the compressor pressure is higher than normal and the inlet pressure is lower than usual so the vacuum relief valve may be responsive to the change in either of these pressures. However in the preferred embodiment the vacuum relief valve is acted on by the inlet pressure opposed by atmospheric pressure.

Similarly, there are several places in the compressor which are normally at compressor pressure, that is to say its normal delivery pressure, but in the preferred embodiment the vacuum relief passage communicates with the space between the stator and the compressor casing. The compressor rotor rotates at a relatively high speed, and it is therefore desirable that the vacuum relief passage communicates with the crescent shaped working space at two or more points along its length. Thus according to a preferred aspect of the present invention the vacuum relief passage includes a passage extending along the length of the stator wall communicating with the crescent shaped working space through a plurality of spaced transverse passages.

In the compressor according to the present invention the vacuum relief valve bleeds high pressure air to the point in the rotor stator unit where it is most needed rather than into the inlet passage as before. This has the result that the volume of bleed air which is required to produce the desired result is considerably less than previously and the power consumed by the compressor when it is offloaded is therefore also considerably less. The vacuum relief passage preferably communicates with the crescent shaped working space at a point or points positioned between 35° and 100° from the outlet in the stator in the direction of rotation of the rotor and more preferably immediately downstream of the point where the compressor inlet begins to communicate with the crescent shaped space, i.e. at that point at which the blades start to move out of their slots. In compressors of this type the inlet passage generally communicates with the crescent shaped working space via a generally kidney-shaped recess formed in one of the compressor end plates. This recess extends around the end plate for about 135°, that is to say for as many degrees as each compression cell expands in volume before it starts to contract again thereby compressing the air.

It might be thought that bleeding high pressure air into the working space at a point or points very close to the beginning of the kidney shaped recess in the end plate would have a very similar effect to merely bleeding it in through the inlet passage as is conventional, but surprisingly this is found not to be the case. Blade chatter is caused by the effect of transient forces and differential pressures and even if these are reduced at one end of each compression cell by bleeding in air through the inlet they may still be a serious problem at the other end of the cell since the rotor may be rotating so fast that in the very short time available the pressure can not become fully uniform within the cells. With the present invention it is possible to bleed air into the compression cells at a number of points along their length thus leading to a more even pressure distribution.

As mentioned above, blade chatter is caused by transient forces and differential pressures, and one such force is that acting on the blades tending to pull them radially inwards, i.e. out of contact with the stator, due to the vacuum produced in the slots behind the blades as they move radially outwards under the action of centrifugal force. Thus a preferred embodiment of the present invention includes a further passage arranged to bleed high pressure air into each radial slot during at least a part of each revolution of the rotor. This may be achieved in a number of ways, but in one embodiment the further passage extends transverse to the rotor axis through one of the compressor end plates and communicates both with the vacuum relief passage and with the space within ______________________ the stator at a point which will communicate with the space behind each blade sequentially as the rotor rotates. It is found experimentally that the blades tend to reach their position of maximum instability at 25° to 65°, especially 45° before the outlet in the stator and thus in the preferred embodiment the further passage communicates with the space within the stator at a point spaced between 25° and 65° before the outlet in the stator in the direction of rotation of the stator. Thus, just as each blade is reaching its point of maximum instability high pressure air is briefly bled into the space behind it which reduces the force tending to pull it out of contact with the stator or even produces a force urging it against the stator.

Further features and details of the invention will be apparent from the following description of one specific embodiment which is given by way of example only with reference to the accompanying drawings in which:-

Figure 1 is a longitudinal sectional elevation of a compressor in accordance with the invention; and

Figure 2 is an axial sectional elevation through the compressor shown in Figure 1 viewed in a number of different planes.

The general construction of the compressor is largely conventional and will therefore only be described breifly. A stator 2 includes an eccentric bore within which is a rotor 4 mounted on a shaft 6 which is supported in bearings in two end plates 8 and 10 at respective ends of the stator. The rotor 4 has eight equispaced radial slots 12 formed in it each of which contains a freely movable vane 14. The rotor and stator together define a crescent shaped working space which is divided into compression cells by the vanes 14. The shaft 6 is coupled via a drive coupling, generally designated 16, to a drive motor (not shown). The end plate 8 remote from the drive end is provided with a generally kidney shaped recess (not shown) extending on its inner surface over about 135^{o} which communicates with an inlet passage 18. The inlet passage 18 is controlled by an unloader piston 20 forming part of an unloader valve 22 which is actuated by a servo valve 23 which is responsive to the compressor supply pressure. The stator is provided with a plurality of outlet ports 24 extending along its length, and extending around the stator is an impingement shield 26 connected to the drive end plate 10.

In use, the rotor is rotated clockwise, as seen in Figure 2, and the vanes are maintained in contact with the inner wall of the stator by virtue of centrifugal force. As each compression cell passes the inlet it is increasing in volume and thus draws air in. Subsequently its volume decreases to nearly zero thereby compressing the air which is discharged through the ports 24. Oil is injected into the compression cells by means which are not shown to lubricate the vanes and ensure an adequate seal between them and the stator and the end plates and the compressed air is therefore charged with oil droplets. The compressed air impinges with high velocity against the impingement shield and the majority of the oil droplets coalesce against it and drop down to the bottom of the outer compressor casing 28 which constitutes a sump and from which oil is withdrawn and reinjected into the stator under the action of pressure differentials within the compressor as is conventional. The compressed air flows to the left, as seen in Figure 1, between the impingement shield and the stator and then to the right and thence through a passageway 30 connecting the compressor casing 28 with a secondary separator casing 32 secured to it. The air then passes through a tubular secondary separation element 34 made of e.g. ceramic material and thence out of the compressor to its point of use. Any remaining oil droplets are coalesced and removed from the air by the element 34 and drip down to the bottom of the casing 32 whence it is returned to the compressor inlet by a passageway, not shown, under the action of the pressure differential.

The normal working pressure of the compressor is 10 bar. If the demand for compressed air should drop substantially the compressor pressure, i.e. the delivery pressure which is substantially equal to the pressure within the casings 28 and 32, will rise and this increase in pressure is sensed by the servo valve which progressively closes the unloader valve which restricts the inlet 18 and therefore reduces the volume of air being compressed. The servo valve and unloader valve are so arranged that when the demand for compressed air falls to substantially zero the unloader valve completely closes the inlet 18. To prevent the rattle and wear of the blades 14 that would otherwise occur in this no load condition there is provided a vacuum relief valve, generally designated 36, which is responsive to the reduced pressure which occurs in the inlet 18 when the compressor is on no-load to bleed a small volume of high pressure air back into the compressor.

The vacuum relief valve comprises a valve member 38 carrying an O ring 40 and connected to a piston 42 which is acted on by a return spring 44 and on one side (the right hand side as seen in Figure 1) by compressor inlet pressure via a passage 46 which communicates with the inlet 18 and on the other side by atmospheric pressure via a passage 48 which communicates with the atmosphere. In its normal position, that is to say the position shown in Figure 1 with the compressor in normal operation, the O ring 40 completely seals a longitudinal bore 50 in the end plate 8. The bore 50 communicates with a transverse bore 52 which communicates with a further transverse bore 54 which in turn communicates with a bore 56 extending along the length of the stator wall. The bore 56 communicates with the interior of the stator at a point immediately downstream of the upstream end of the inlet recess through a plurality of transverse bores 58 spaced along the length of the stator.

In the end plate 8 there is also a transverse bore 60 which terminates adjacent the side of the valve member 38 and which communicates with a longitudinal bore 62 which communicates with a longitudinal bore 64 in the stator which in turn communicates with a transverse bore 66 in the stator which terminates at the surface of the stator.

Thus, in use, when the compressor is operating normally the valve member 38 is in the position illustrated in Figure 1 and the bores 50 and 60 do not communicate. However, if the compressor should go off-load and the unloader valve piston closes the inlet 18, the reduced inlet pressure permits atmospheric pressure to exert a force on the vacuum relief valve piston 42 sufficient to overcome the force of the spring 44 thus moving the valve member 38 to the left and bringing the bores 50 and 60 into communication. A volume of air determined by the distance moved by the piston 42 which is limited by the position of an adjustable stop 68 will therefore flow from the high pressure space between the stator and the outer casing 28 into the interior of the stator through the bores 58. Due to the fact that this air is supplied to where it is needed, i.e. at points distributed along the length of the stator rather than being drawn into the working space at one end only, i.e. through the normal inlet passage the volume of air which is necessary to prevent blade chatter is found to be very much less than that which would be required if the air were drawn in through the inlet as is conventional. This represents a considerable saving when the compressor is running in the no-load condition since less energy must be expended in continuously circulating and compressing a proportion of the air within the compressor.

Although this construction considerably reduces the power consumption when the compressor is in the no-load condition it may be desirable or beneficial to provide yet a further means of inhibiting the vanes from losing contact with the inner surface of the stator. Thus in the preferred embodiment the passage 52 in the end plate 8 communicates with a single longitudinal bore 70 which communicates with the working space at a point about 45° upstream of the outlets 24 in the direction of rotation of the rotor and radially positioned that it communicates with the interior of each slot 12 behind the blades as they pass. It is found that it is approximately at this 45° position that maximum instability of the blades occurs when the compressor is off-loaded. Thus when the vacuum relief valve is passing air through the bores 58 a brief pulse of air at substantially delivery pressure will be injected behind each blade through the bore 70 thus reducing the vacuum in this space or even producing a superatmospheric pressure and thereby reducing the force which tends to pull the blade out of contact with the stator. Thus the provision of the bore 70 may reduce the volume of air that needs to be passed through the bores 58 to eliminate blade rattle and therefore also further reduce the power consumed when the compressor is offloaded.

CLAIMS

1. A rotary compressor of sliding vane eccentric rotor type including a stator (2), a rotor (4) eccentrically mounted for rotation within the stator (2) and defining together with the stator (2) a crescent shaped working space, a plurality of vanes (14) slidably received in radial slots (12) in the rotor (4) and, in use, contacting the stator (2) thereby dividing the crescent shaped working space into a plurality of compression cells, an unloader valve (22) arranged to restrict or close the compressor inlet (18) when the compressor pressure rises above its normal working value, a vacuum relief valve (36) responsive to the unloaded condition of the compressor and a vacuum relief passage (50, 52, 54, 56, 58) controlled by the vacuum relief valve (36), communicating with a space which, in use, is substantially at the compressor delivery pressure and with the crescent shaped working space, characterised in that the vacuum relief passage (56, 58) passes through the stator (2) and communicates directly with one of the compression cells, whereby, in use, when the compressor enters the unloaded condition high pressure air is bled directly into the said one of the compression cells.

2. A compressor as claimed in Claim 1 characterised in that the vacuum relief valve (36) is acted on by the compressor inlet pressure opposed by atmospheric pressure.

3. A compressor as claimed in Claim 1 or Claim 2 characterised in that the vacuum relief passage (50, 52, 54, 56, 58) communicates with the space between the stator (2) and the compressor casing (28) via a passage (60, 62, 64, 66).

4. A compressor as claimed in any one of the preceding claims characterised in that the vacuum relief passage (50, 52, 54, 56, 58) includes a passage (56) extending along the length of the stator wall (2) and communicating with the crescent shaped working space through a plurality of spaced transverse passages (58).

5. A compressor as claimed in any one of the preceding claims characterised in that the vacuum relief passage communicates with the crescent shaped working space at a point or points positioned between 35° and 100° from the outlet (24) in the stator (2) in the direction of rotation of the rotor (4).

6. A compressor as claimed in Claim 5 characterised in that the said point or points are positioned immediately downstream of the point where the compressor inlet (18) begins to communicate with the crescent shaped working space.

7. A compressor as claimed in any one of the preceding claims characterised by a further passage (70) arranged to bleed high pressure air into each radial slot (12) during at least a part of each revolution of the rotor (4).

8. A compressor as claimed in Claim 7 characterised in that the further passage (70) extends transverse to the axis of the rotor (4) through one of the compressor end plates (8) and communicates both with the vacuum relief passage (50, 52, 54, 56, 58) and with the space within the stator (2) at a point which will communicate with the space (12) behind each blade sequentially as a rotor rotates.

9. A compressor as claimed in Claim 8 characterised in that the further passage (70) communicates with the space within the stator (2) at a point spaced between 25^{o} and 65^{o} before the outlet (24) in the stator (2) in the direction of rotation of the rotor (4).

10. A compressor as claimed in any one of Claims 7 to 9 characterised in that the further passage (70) is also controlled by the vacuum relief valve (36).

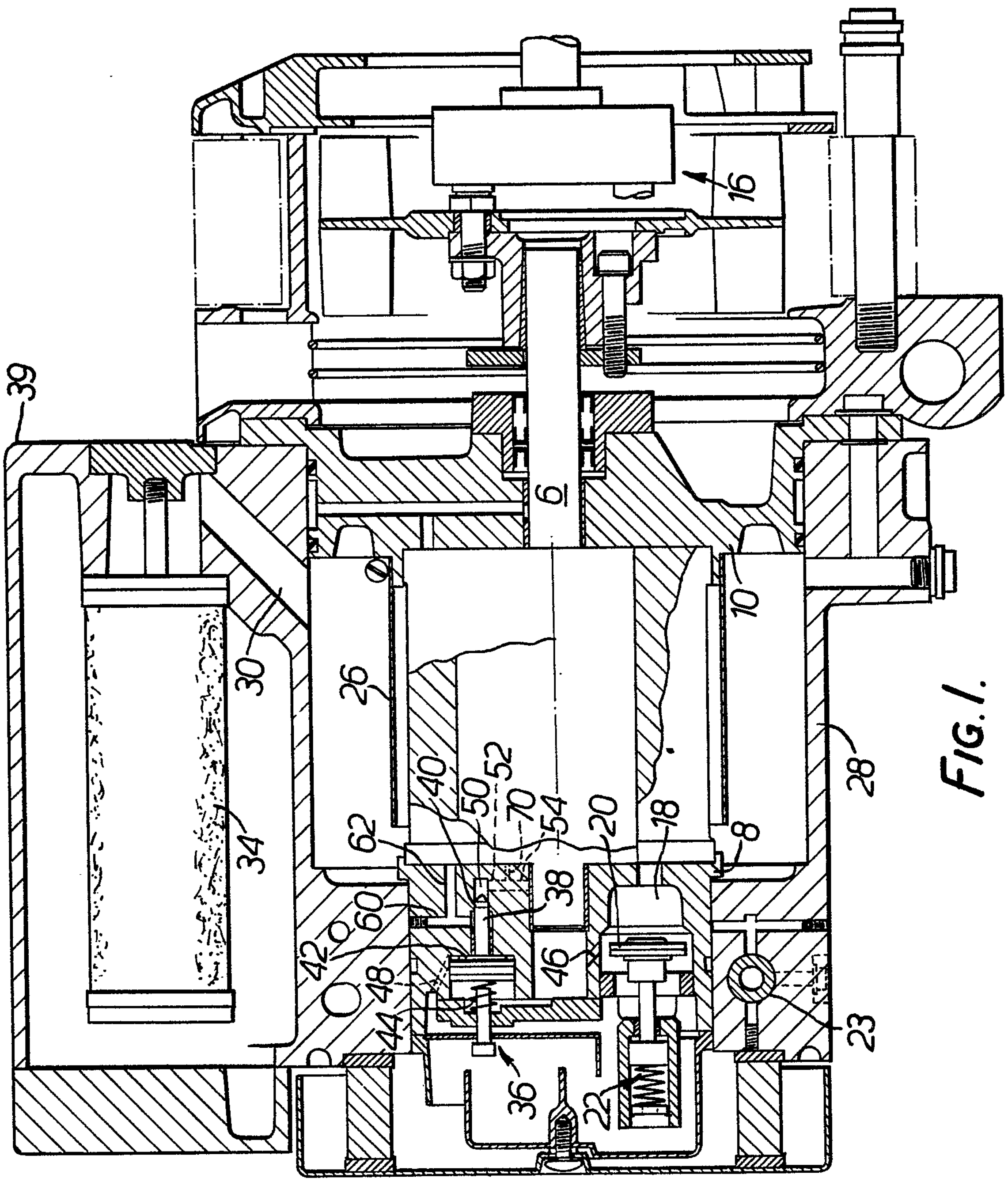
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FIG. 1.

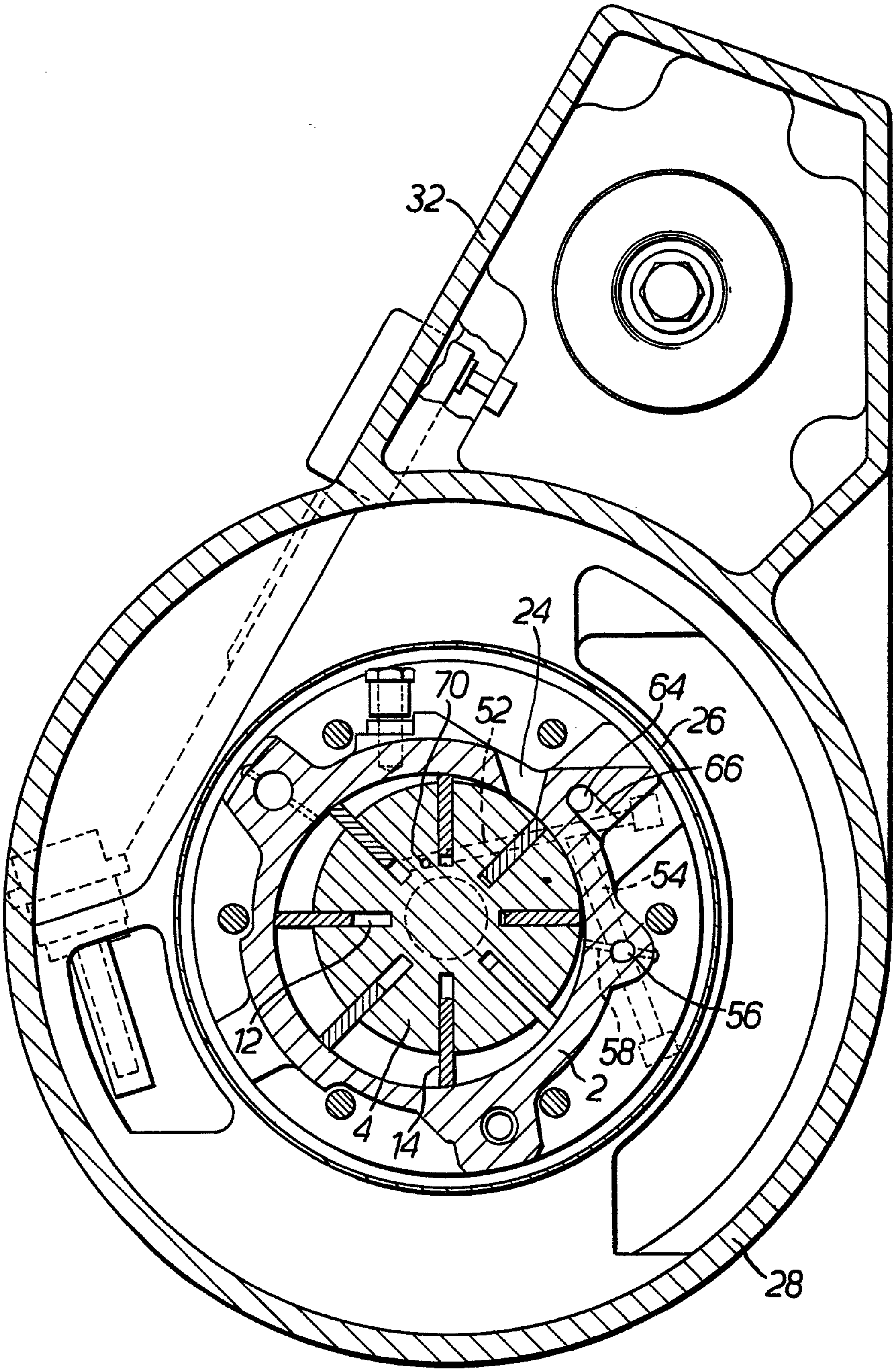

FIG. 2.

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Application number

European Patent Office

EUROPEAN SEARCH REPORT

EP 81 30 5927

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
Y	GB - A - 2 020 363 (IMI FLUIDAIR)	
	* page 8, line 65 to the end; page 9, lines 1-26; figures 7,8,9 *	1,2

Y	US - A - 4 295 804 (PEZZOT)	
	* column 1, lines 7-10; column 2, lines 24-35; column 3, line 53 - column 4, line 25; figure 3 *	1

A	CH - A - 152 328 (SULZER)	
	* page 1, ten last lines; page 2, first paragraph; figure *	1,4

A	US - A - 3 399 826 (ANDRIULIS)	
	* column 9, lines 25-54; figures 3,4,5; column 10, lines 39-61 *	7,8

CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)

F 04 C 29/10

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

F 04 C

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
Y: particularly relevant if combined with another document of the same category
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: earlier patent document, but published on, or after the filing date
D: document cited in the application
L: document cited for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	15-04-1982	KAPOULAS

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