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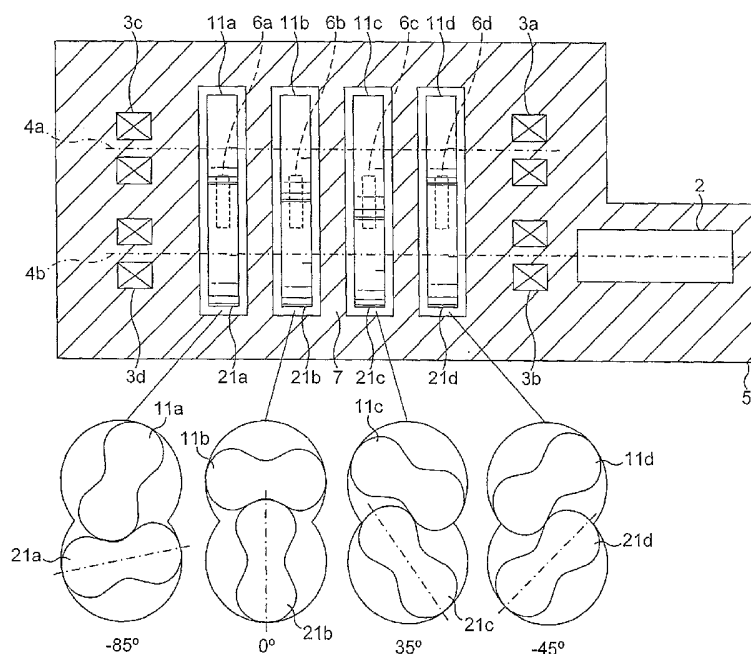
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(54) Title: LOW PULSATION BOOSTER PUMP



(57) Abstract: A booster pump comprises rotors which are made up of a number of multi-lobed rotor elements (11a), (11b), (11c), (11d), (21a), (21b), (21c), (21d), the rotor elements being carried by a common rotary shaft (4a, 4b) passing through a common axis of rotation, each rotor element (11a), (11b), (11c), (11d), (21a), (21b), (21c), (21d) being rotationally angularly displaced with respect to the or each adjacent rotor element.



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LOW PULSATION BOOSTER PUMP

This invention relates to the reduction of pulsation in positive displacement vacuum pumps, including but not strictly limited to Roots pumps used as
5 mechanical booster pumps.

Roots pumps (and in particular mechanical booster pumps) are used in a variety of applications including; semi-conductor processing, vacuum packaging, pharmaceutical freeze drying and metallurgical processes. Their purpose is to
10 provide compression of gases exhausting from a process chamber. The Roots mechanism conventionally comprises a stator housing a pair of rotary shafts arranged in parallel, each shaft carrying a rotor which, in a typical example, has, in cross-section perpendicular to the axis of rotation of the shaft, a generally figure 8 shape. Thus, in this example each rotor has two substantially similarly shaped
15 and sized lobes, each lobe extending radially from the axis of rotation of the rotary shaft and arranged at a 180 degrees angular separation from the other. The rotors are arranged in close contact to each other but not touching. Each rotor is arranged at an angle to the other such that, when the two rotary shafts rotate in opposite directions, the rotors intermesh such that the lobes from one rotor co-
20 operate with the spaces between the lobes of the other rotor.

During use, the Roots mechanism traps slugs of gas between the walls of the rotor and stator, and exhausts some of the gas to the pump outlet. This occurs twice per shaft revolution, for each rotor. As the two rotors rotate at a steady frequency
25 of rotation, periodic pressure pulses are thus generated at a period of 4 times rotational speed.

It is also known for Roots rotors to have more than two lobes. This affects the frequency of pulsation, for example a 3 lobed rotor will produce pulsation periods
30 of 6 times rotational speed, a four lobed rotor 8 and so on.

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This periodic pulsation can be transmitted through connecting pipes between the pump and the process chamber under evacuation. Such pulsation can cause particle movement backwards and forwards within the foreline of the pump and other equipment in the proximity, for example, the process chamber. The
5 presence of such particulate matter in the process chamber can have a seriously detrimental effect on the quality of components manufactured in that environment.

Throttle valves are often used to control the pressure within a process chamber. As a moving part of the system, these can further contribute to the problems of
10 particulate formation and particle migration mentioned above.

The present invention aims to reduce pressure pulsation in controlled pressure environments and to reduce the occurrence of particulate formation and contamination associated with such pressure pulsation.

15 In accordance with the present invention there is provided a rotor for a positive displacement pump, the rotor comprising at least two, preferably at least three, plural-lobed rotor elements located on a rotary shaft passing through a common axis of rotation of the rotor elements, wherein each rotor element is rotationally
20 angularly displaced with respect to each adjacent rotor element such that the angular displacement between each pair of adjacent rotor elements is different to that between each other pair of adjacent rotor elements.

The differences between the rotational angles may be randomly or sequentially
25 selected.

Preferably there are between two and eight rotor elements inclusive. For example, in the preferred embodiments there are four rotor elements. Whilst there will be practical limits as to how many rotor elements may usefully be
30 incorporated into the rotor, it is to be understood that the total number does not materially affect the mode of operation of the rotor.

The rotor elements on any rotor may each comprise the same number of lobes as those of other rotor elements or may comprise different numbers of lobes. For example, in one embodiment the rotor comprises four rotor elements, of which two of the rotor elements have two lobes and two of the rotor elements have three
5 lobes. The numbers of lobes of a rotor element is preferably in the range two to seven, for example the rotor elements may comprise two, three or four lobes.

In use, pairs of the aforementioned rotors are arranged in parallel such that the rotor elements of one rotor intermesh with the rotor elements of the other rotor,
10 with the intermeshing rotor elements preferably having the same number of lobes. Each cooperating or intermeshing pair of rotor elements is referred to as a stage. As the two rotors rotate, each stage follows a rotation cycle that is out of phase with that of adjacent stages. Consequently, rather than a periodic pulse which is exhibited when a pair of conventional single-phase rotors is used, a series of much
15 lower amplitude, irregular "pulses" occur. Practical consequences of this are reduced noise levels and reduced occurrence of particulate formation and the consequent contamination of the process environment in the process chamber.

Rotations of the multiple stages may be timed in such a manner as to avoid
20 regular pulsation in the process chamber. Thus, energy from any pulsation is spread over a broader range of frequencies than is exhibited by a conventional, single stage rotor assembly. This spreading of pulse frequencies disrupts any rhythmic gas motion which might otherwise cause particle migration into the process chamber.

25

In a further aspect, the invention provides a positive displacement pump comprising a pair of rotors arranged in parallel alignment and housed within a stator, the rotors each comprising a plurality of plural-lobed rotor elements, the rotor elements being carried by a common rotary shaft passing through a common
30 axis of rotation, each rotor element being rotationally angularly displaced with respect to each adjacent rotor element. The pump may be a mechanical booster pump.

In conventional systems for providing a vacuum environment, throttle valves are placed adjacent to the process chamber to control pressure in the process environment. "Booster" pumps (typically Roots pumps) communicate with the process chamber through the throttle valve via a long tube. The latter serves to dampen vibrations caused by periodic pulsation in the pump.

Pumps in accordance with the invention can remove the need for the throttle valve and dampening tube. The pumps can be positioned much closer to the process tools and chamber resulting in improved vacuum efficiency, repeatability and accuracy.

Variable valve control functions previously provided by the throttle valves can be provided by adjustment of the speed of rotation of the rotors of the invention or by other means downstream of the booster. This facilitates the removal of throttle valves thereby further reducing the occurrence of particle migration.

For the purpose of exemplification embodiments of the invention will now be further described with reference to the Figures in which:

Figure 1(a) illustrates a Roots pump including a single stage rotor assembly as known from the prior art, and Figure 1(b) illustrates an end view of the rotors of the pump of Figure 1(a);

Figure 2 illustrates a first embodiment of a positive displacement pump including a multi-stage rotor assembly;

Figure 3 illustrates a second embodiment of a positive displacement pump including a multi-stage rotor assembly; and

Figure 4 illustrates a third embodiment of a positive displacement pump including a multi-stage rotor assembly.

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Figure 1(a) shows schematically a top view of the Roots mechanism of a pump in accordance with the prior art. The mechanism comprises a pair of parallel-aligned shafts 4a, 4b represented by the broken lines, mounted in bearings 3a, 3b, 3c, 3d. The lower shaft 4b is driven by a drive mechanism 2 associated with the shaft, a timing gear arrangement (not shown) connecting the two shafts 4a, 4b to ensure that the two shafts counter-rotate in synchronisation. Fixedly mounted to each shaft 4a, 4b is a rotor, 1a and 1b respectively. The shafts 4a, 4b are arranged to be separated by a distance which is less than twice the maximum radius of rotors 1a, 1b so that the rotors intermesh as they rotate in opposite directions. Figure 1(b) shows schematically an end view of the two rotors 1a, 1b viewed in a plane perpendicular to the longitudinal axes of the parallel shafts.

Figure 2 illustrates schematically an embodiment of a rotor of the invention as it might be configured in a pump. In common with the prior art described with reference to Figure 1, the arrangement comprises a pair of parallel-aligned rotary shafts 4a, 4b mounted in bearings 3a, 3b, 3c and 3d. The bottom shaft 4b is driven by a drive mechanism 2 associated with the shaft 4b a timing gear arrangement (not shown) connecting the two shafts 4a, 4b to ensure that the two shafts counter-rotate in synchronisation. Each of these components are much the same in form and structure as their equivalents in the prior art.

The rotor is distinguished from the prior art by the alignment of the rotor elements of the rotor. Rotor elements 11a, 11b, 11c, 11d are mounted on the top (as illustrated) shaft 4a and rotor elements 21a, 21b, 21c, 21d are mounted on the bottom shaft 4b such that the rotor elements on the bottom shaft 4b intermesh with the rotor elements on the top shaft 4a. The rotors are housed within housing unit 5, which defines a stator element comprising a series of chambers each housing a respective pair of rotor elements, each pair being separated from the adjacent pair by partition 7. This provides a pump having a plurality (four in Figure 2) of pumping stages. Channels (indicated partially at 6) are provided between adjacent stages, that is, between the chambers housing the pairs of intermeshing

rotor elements, to direct pumped gas entering the pump inlet (not illustrated) from the outlet of one stage to the inlet of the next as it is pumped towards the pump outlet (not illustrated).

5 As shown in the lower part of Figure 2, each of the rotor elements 11a, 11b, 11c, 11d on the top shaft and each of rotor elements 21a, 21b, 21c, 21d on the bottom shaft are arranged with their reference axis of symmetry (represented by the broken line shown passing through rotor elements 21a, 21b, 21c and 21d) oriented at a different angle to those in the adjacent stage. The angle sizes given at the
10 bottom of Figure 2 refer to the angular displacement of the reference axis of the respective stages with respect to the vertical. Positive numbers indicate angles taken anti-clockwise from the vertical zero line and negative numbers to angles taken clockwise from the vertical zero line. As a consequence each stage (11a, 21a; 11b, 21b; 11c, 21c; 11d, 21d) is out of phase with each of the other stages

15

Figure 3 shows a slightly different configuration of the stages than that shown in the Figure 2 embodiment, in that the rotor elements are sequentially rotated such that the rotor assembly approximates that of a screw type booster. In other words, rotor elements 21a', 21b', 21c' and 21d' are each rotated about their axis of
20 rotation a little more than the previous, adjacent rotor element. The difference in rotation angle between each adjacent stage may be the same, it may be gradually changing or it could be entirely random. The housing unit 5' in this case encloses the rotors without the use of partitions 7 such that the stages are directly adjacent to and come into contact with each other. Figure 3b illustrates that such a pump
25 will require a single inlet 8' located in the region of the first stage and a single outlet 6' located adjacent to the final stage of the booster pump.

Figure 4 shows schematically an arrangement broadly similar to that shown in Figure 2 but which differs in that the stages comprise a mix of two lobed (31a, 41a, 31c, 41c) and three lobed (31b, 41b, 31d, 41d) stages. As with the embodiment
30 of Figure 2, each stage is rotationally angularly displaced with respect to the others.

Whilst all embodiments are specifically directed to Roots pumps, it is to be appreciated that a similar principle may be applied to multi-stage rotor assemblies of other types, eg claw or ball and socket arrangements.

5

It is to be understood the foregoing description describes just one embodiment of the invention and is not intended to be restrictive of the true scope of the invention as defined by the appended claims. In particular, it should be noted that the number of stages and/or rotors may be changed and the configuration of the shafts, in use, need not necessarily be in vertical alignment one above the other. Equally, the shafts need not be arranged horizontally with respect to ground.

10

CLAIMS

1. A rotor for a positive displacement pump, the rotor comprising at
5 least two plural-lobed rotor elements located on a rotary shaft
passing through a common axis of rotation of the rotor elements,
wherein each rotor element is rotationally angularly displaced with
respect to each adjacent rotor element such that the angular
displacement between each pair of adjacent rotor elements is
10 different to that between each other pair of adjacent rotor elements.
2. A rotor according to Claim 1, wherein the angular displacements are
randomly selected.
- 15 3. A rotor according to Claim 1, wherein the angular displacements are
sequentially selected.
4. A rotor according to any preceding claim, wherein the rotor elements
each comprise the same number of lobes.
20
5. A rotor according to any of Claims 1 to 3, wherein the rotor elements
comprise varied numbers of lobes.
6. A rotor according to Claim 5, comprising four rotor elements, of which
25 two of the rotor elements have two lobes and two of the rotor
elements have three lobes.
7. A rotor according to any of Claims 1 to 5, wherein the number of
lobes on a rotor element is in the range from 2 to 7.
30
8. A rotor according to Claim 7, wherein the number of lobes on a rotor
element is 2, 3 or 4.

9. A rotor according to any preceding claim, wherein the rotor comprises between two and eight rotor elements inclusive.

5 10. A rotor according to Claim 9, wherein the rotor has four rotor elements.

11. A positive displacement pump comprising a pair of rotors according to any preceding claim arranged in parallel alignment such that the
10 rotor elements of one rotor intermesh with the rotor elements of the other rotor.

12. A pump according to Claim 11, comprising a stator housing the rotors and defining a respective chamber for each intermeshing pair of rotor
15 elements.

13. A pump according to Claim 11 or Claim 12, which is a mechanical booster pump.

20

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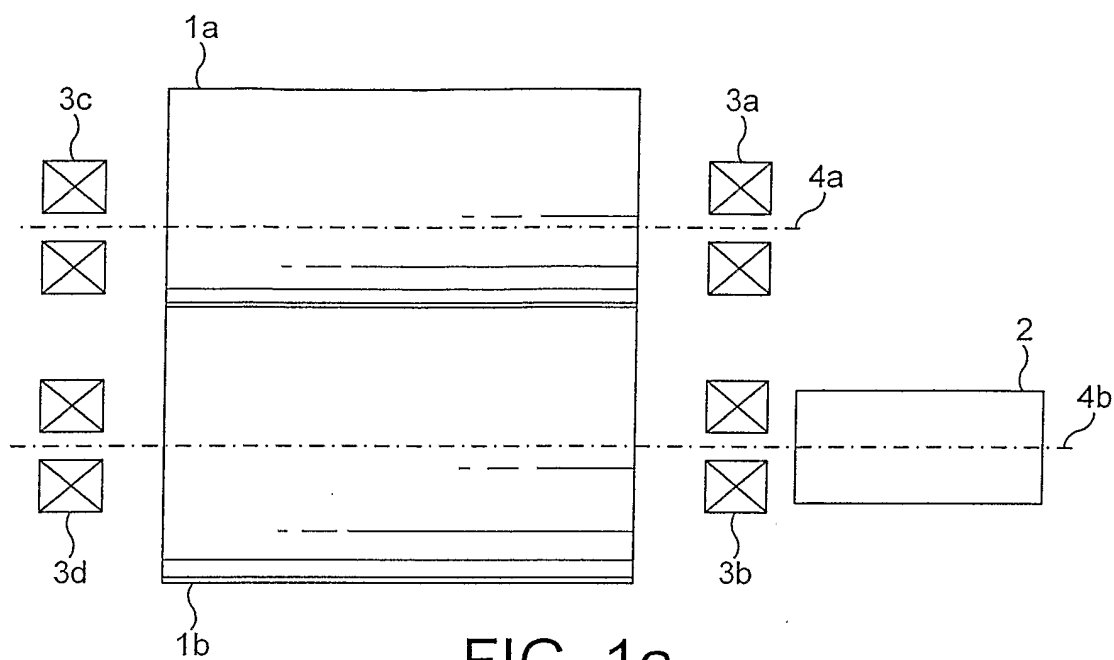


FIG. 1a

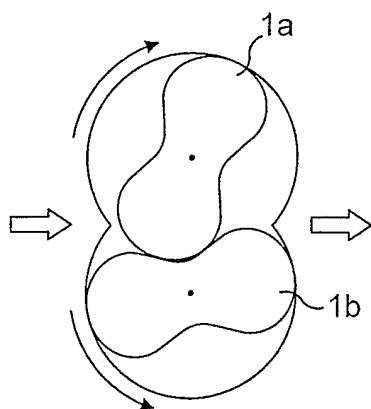


FIG. 1b

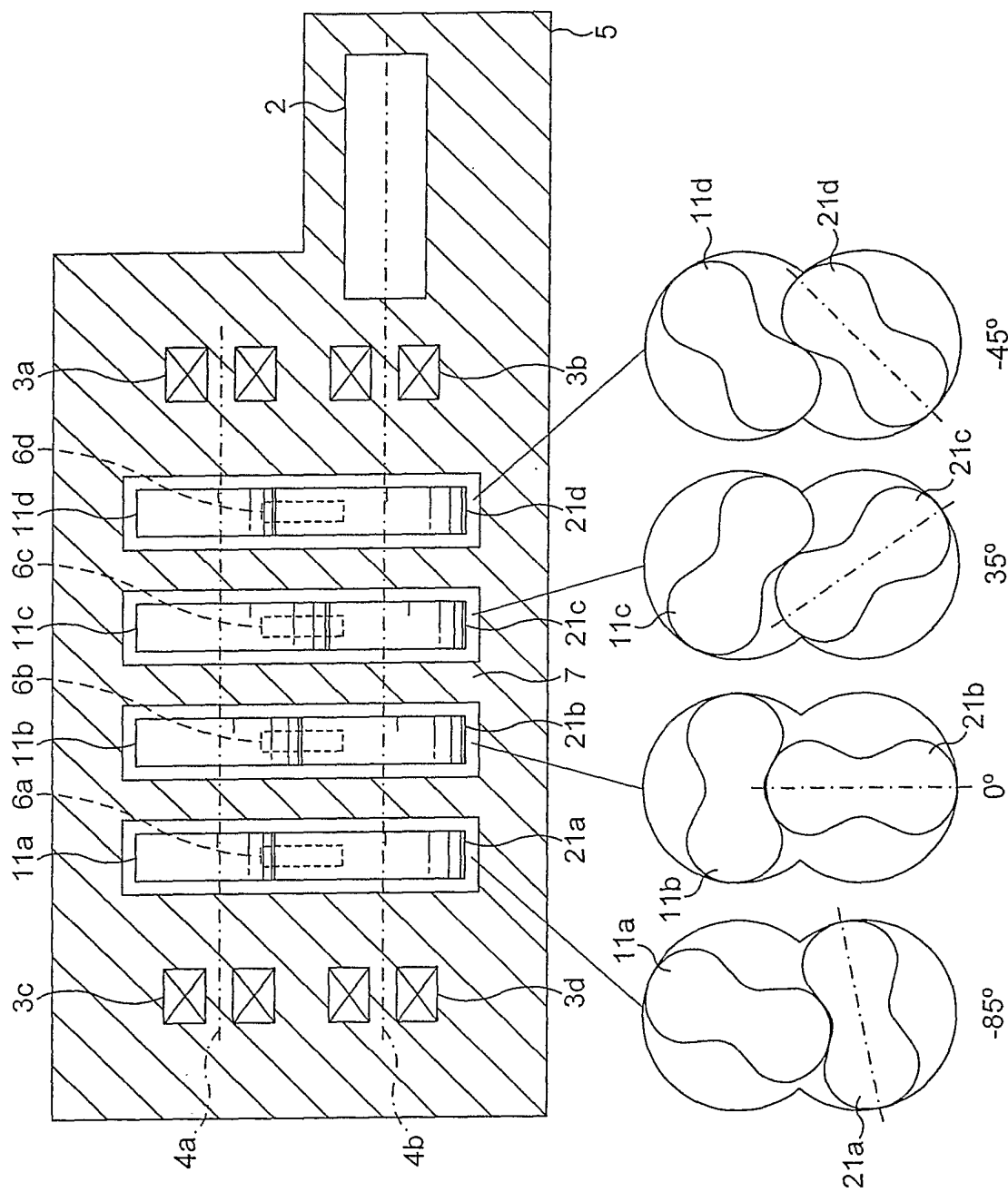


FIG. 2

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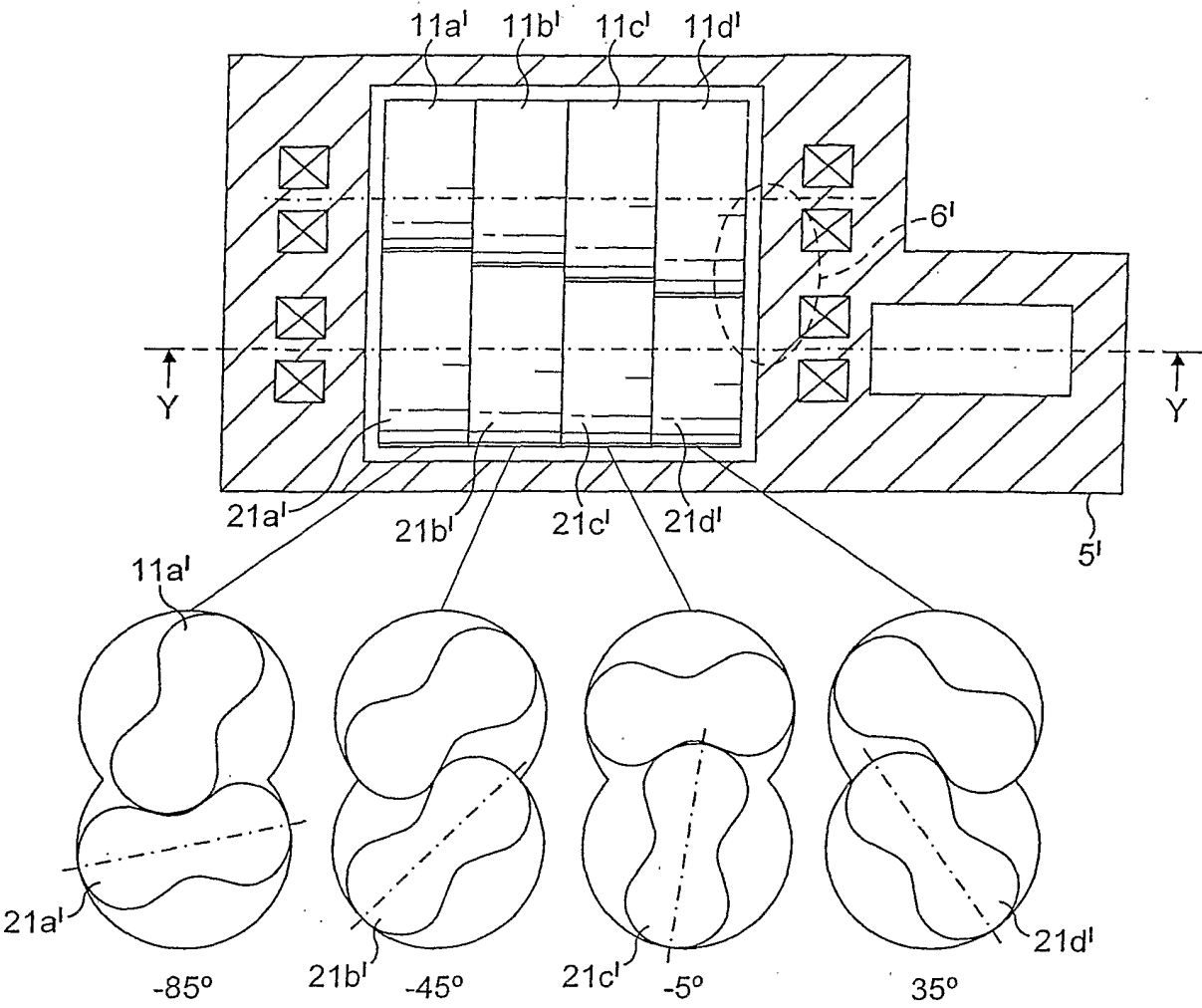


FIG. 3a

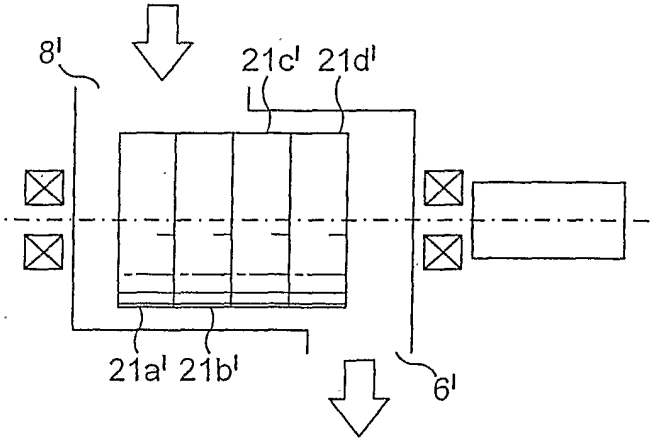


FIG. 3b

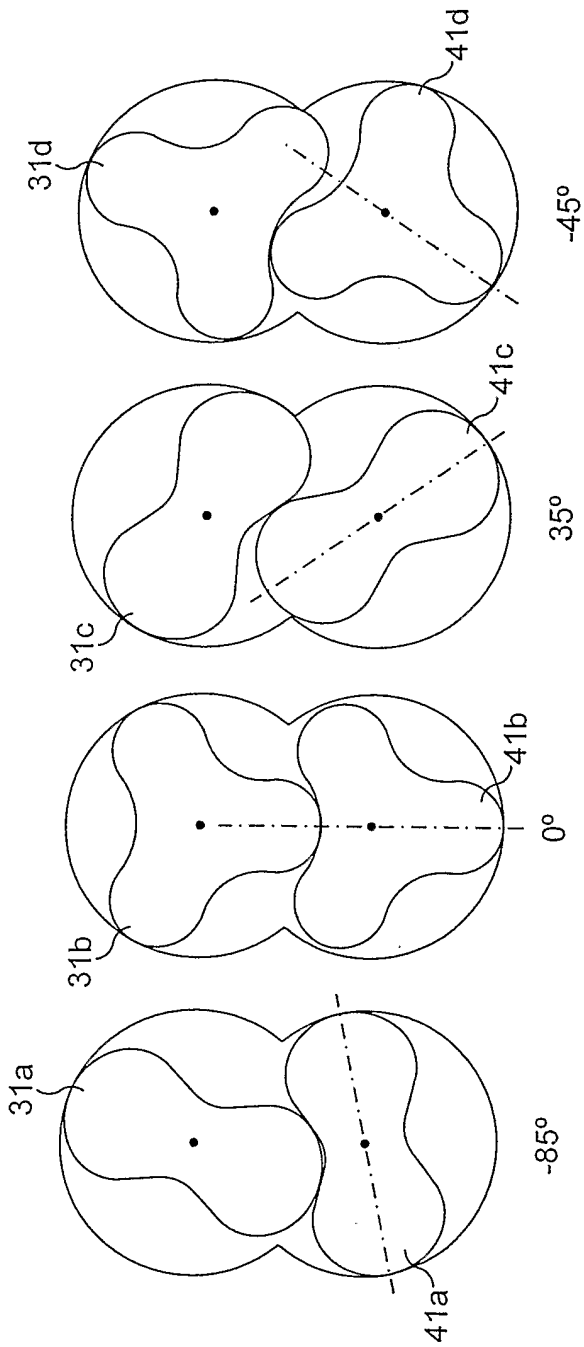


FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F04C23/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 667 874 A (WEATHERSTON ROGER C ET AL) 6 June 1972 (1972-06-06) page 1, column 2, line 55 - page 2, column 1, line 36	1,3-5, 7-13
X	GB 2 111 126 A (BRITISH OXYGEN CO LTD) 29 June 1983 (1983-06-29) abstract; figure 8	1,3,5-13
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A	EP 1 006 281 A (TOYODA AUTOMATIC LOOM WORKS) 7 June 2000 (2000-06-07) abstract; figures 1,2,4,5,7	1-13



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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