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VACUUM PUMP

The invention relates to a vacuum pump, in particular a multi-stage vacuum pump and a stator of such a pump.

A vacuum pump may be formed by positive displacement pumps such as roots or
5 claw pumps, having one or more pumping stages connected in series. Multi-stage pumps are desirable because they involve less manufacturing cost and assembly time compared to multiple single stage pumps in series.

Multi-stage roots or claw pumps may be manufactured and assembled in the form of a clamshell. As shown in Figure 1, the stator 100 of such a pump comprises first and
10 second half-shell stator components 102, 104 which together define a plurality of pumping chambers 106, 108, 110, 112, 114, 116. Each of the half-shells has first and second longitudinally extending faces which mutually engage with the respective longitudinally extending faces of the other half-shell when the half-shells are fitted together. Only the two longitudinally extending faces 118, 120 of half-shell 102 are
15 visible in the Figure. During assembly the two half shells are brought together in a generally radial direction shown by the arrows R.

The stator 100 further comprises first and second end stator components 122, 124. When the half-shells have been fitted together, the first and second end components are fitted to respective end faces 126, 128 of the joined half-shells in a generally axial, or
20 longitudinal, direction shown by arrows L. The inner faces 130, 132 of the end components mutually engage with respective end faces 126, 128 of the half-shells.

Each of the pumping chambers 106-116 is formed between transverse walls 134 of the half-shells. Only the transverse walls of half-shell 102 can be seen in Figure 1. When the half-shells are assembled the transverse walls provide axial separation between

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one pumping chamber and an adjacent pumping chamber, or between the end pumping chambers 106, 116 and the end stator components. The present example shows a typical stator arrangement for a roots or claw pump having two longitudinally extending shafts (not shown) which are located in the apertures 136 formed in the transverse walls 134
5 when the half-shells are fitted together. Prior to assembly, rotors (not shown) are fitted to the shafts so that two rotors are located in each pumping chamber. Although not shown in this simplified drawing, the end components each have two apertures through which the shafts extend. The shafts are supported by bearings in the end components and driven by a motor and gear mechanism.

10 The multi-stage vacuum pump operates at pressures within the pumping chamber less than atmosphere and potentially as low as 10^{-3} mbar. Accordingly, there will be a pressure differential between atmosphere and the inside of the pump. Leakage of surrounding gas into the pump must therefore be prevented at the joints between the stator components, which are formed between the longitudinally extending surfaces 118, 120 of
15 the half-shells and between the end faces 126, 128 of the half-shells and the inner faces 130, 132 of the end components. An adhesive is typically used to seal between the half-shells and between the half-shells and the end components, but the adhesive is particularly susceptible to damage by corrosive pumped gases, and is difficult and time consuming to apply consistently. It can also inhibit disassembly and maintenance.

20 A known alternative sealing arrangement is disclosed in US2002155014 providing a one piece sealing member comprising two longitudinal portions and two annular portions. The sealing member is however generally quite intricate to fit in place and expensive to manufacture.

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The present invention provides an improved seal arrangement for sealing a clam shell pump.

The present invention provides a multi-stage vacuum pump comprising: first and second half-shell stator components defining a plurality of pumping chambers for assembly together along respective longitudinal faces; first and second end stator components for assembly at respective end faces of the first and second half-shell stator components; gaskets for location in a longitudinal recess of respective longitudinal faces for sealing between the first and second half-shell stator components when assembled together; and O-rings for location in annular channels counter-sunk in respective end faces for sealing between the first and second end stator components and the first and second half-shell stator components when assembled; wherein the annular channels intersect the longitudinal recesses and each longitudinal recess comprises a stop fixed relative to the intersection, and the gasket and the longitudinal recess are configured that when the gasket is located in the recess during assembly the gasket is biased against the stop for locating an end portion of the gasket relative to the intersection.

The present invention also provides apparatus for assembling a multi-stage vacuum pump comprising a tool and the parts of such a multi-stage vacuum pump, wherein the tool is arranged for aligning the shaped end portions of the gaskets with the correspondingly shaped intersections between the annular channels and the longitudinal recesses when the gaskets have been fitted in the longitudinal recesses and prior to compression of the gasket between the half-shell stator portions.

The present invention also provides a method of assembling a multi-stage vacuum pump, the vacuum pump comprising: first and second half-shell stator components defining a plurality of pumping chambers for assembly together along respective

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longitudinal faces; first and second end stator components for assembly at respective end faces of the first and second half-shell stator components; gaskets for location in a longitudinal recess of respective longitudinal faces for sealing between the first and second half-shell stator components when assembled together; and O-rings for location in
5 annular channels counter-sunk in respective end faces for sealing between the first and second end stator components and the first and second half-shell stator components when assembled, the annular channels intersecting the longitudinal recesses at respective intersections, wherein the method comprises: fitting each gasket in a said longitudinal recess; biasing the gasket against a stop fixed relative to the intersection for locating an
10 end portion of the gasket relative to the intersection such that the end portion sits proud of the intersection; pressing the end portion of the gasket with a tool generally to align the end portion with the intersection during compression of the gasket as the half-shell components are assembled together along the longitudinal faces; fitting the O-rings in the annular channels; assembling the end stator components to the half-shell stator
15 components.

Other preferred and/or optional features of the invention are defined in the accompanying claims.

In order that the present invention may be well understood, an embodiment thereof, which is given by way of example only, will now be described in more detail,
20 with reference to the accompanying drawings, in which:

Figure 1 shows generally the components of a clam shell stator;

Figure 2 shows a theoretically possible but undesirable sealing arrangement for the half-shell stator components and two stator end components provided for explanatory purposes only;

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Figure 3 shows a half-shell having the sealing arrangement of Figure 2;

Figure 4 shows an end component having the sealing arrangement of Figure 2;

Figure 5 shows a part of one half-shell stator component according to an embodiment of the invention;

5 Figure 6 shows arrangement gasket fitted in the half-shell component shown in Figure 5;

Figure 7 shows additionally a tool for aligning the gasket prior to alignment;

Figure 8 shows the arrangement subsequent to alignment;

Figure 9 shows the fitted gasket after compression between half-shells and
10 removal of the tool; and

Figure 10 shows additionally an O-ring and end plate fitted to the half-shell components.

By way of background to the invention, US2002155014 discusses the problem of sealing a clam shell stator. In particular, it indicates that leakage lines exist between a
15 longitudinal gasket providing peripheral radial sealing and O-rings providing axial sealing at the ends which results in unsatisfactory sealing. As a consequence the patent proposes a one-piece sealing member as discussed above.

Looking in more detail now at this problem, Figure 2 shows a plan view of the half-shell 102 and sections taken through end components 122, 124. Figure 3 shows a
20 view of one end face 126 of the joined half-shells 102, 104. Figure 4 shows a view of an inner face 132 of an end component 124.

Referring to Figures 2 to 4, two longitudinal seal members 138 are located in channels 140 formed in the longitudinally extending faces 118, 120 and 142, 144 of the

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first and second half-shells 102, 104. The longitudinal seal members 138 resist leakage of ambient gases into the pump as shown by the arrows G1 over the length of the half-shells.

Two generally annular seal members 146 are located in respective generally annular channels 148 of the inner faces 130, 132 of the end components 122, 124. The seal members 146 resist leakage of ambient gases into the pump as shown by the arrows G2 over the periphery of the joint between the end components and the half-shells. Accordingly, the leakage of gases through the apertures 150 in the end components or the apertures 134 in the end of the joined half-shells is generally prevented.

A problem with this sealing arrangement is that an inconsistent seal is provided between the longitudinal seal members 138 and the annular seal members 146 as indicated by a space S shown in Figure 2. The inconsistent seal allows leakage of gases between the two seal members 138, 146. The longitudinal seal members 138 are configured to be compressed between the two half-shells when they are assembled together to provide a tight fit. However, when compressed there is a tendency for some movement of the seal members 138 in the channels 140 whereby the space S may be created or increased. The longitudinal seal members can be manufactured with a longer length than the length of the channels 140, however, in this case compression between the half-shells may lead to kinking in the seal members causing leakage.

Figures 5 to 10 show an embodiment of the invention illustrating an end of a longitudinal face of one half-shell stator component. The half-shells are generally similar to the clam-shell pump discussed in detail in relation to Figures 1 to 4, except that the sealing arrangement is different. The embodiment comprises a multi-stage vacuum pump comprising first and second half-shell stator components defining a plurality of pumping chambers for assembly together along respective longitudinal faces. First and second end

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stator components are arranged for assembly at respective end faces of the first and second half-shell stator components. Gaskets are arranged for location in a longitudinal recess of respective longitudinal faces for sealing between the first and second half-shell stator components when assembled together and O-rings are located in annular channels counter-sunk in respective end faces for sealing between the first and second end stator components and the first and second half-shell stator components when assembled. In the arrangement, the annular channels intersect the longitudinal recesses.

In more detail, Figure 5 shows an end of one longitudinal face 10 of a half-shell 12. The other end of the longitudinal face may have a similar configuration and the ends of other longitudinal faces may have similar configurations.

The longitudinally face 10 has countersunk into its surface a longitudinal recess, or channel, 14 for locating a gasket (shown in Figures 6 to 10). Upstanding generally orthogonally from the recess are two walls 16, 18 having upper surfaces which are flush with the face 10. In another arrangement the wall may extend into the recess of the opposing half-shell if the opposing face comprises a recess. The end face 20 of the half-shell has countersunk therein a generally annular channel 22 for receiving an annular seal member (shown in Figure 10). Only a cross-section of the annular channel 22 is shown in Figures 5 to 10 at the intersection with the longitudinal recess 14 at which the channel is extending generally perpendicular to the recess 14. The annular channel 22 is formed in the recess 14 at the intersection and has a generally semi-circular cross-section.

The longitudinal recess comprises upstanding end portions 24 for forming a stop to constrain movement of a gasket in a longitudinal dimension as described below. A cross-channel 26 extends between the upstanding walls 16, 18 and is arranged to allow a

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biasing force to be generated for urging the gasket against the stop, again as described below.

Referring to Figure 6, the gasket 28 is shown shaded to aid differentiation from the face 10. The gasket is generally similar in shape to the recess 14 and has a thickness
5 which causes its upper face to sit proud of the face 10 when fitted in the recess, for example by about a few fractions of a millimetre (e.g. 0.2 mm), for compression by an opposing longitudinal face of the second half-shell during assembly. The gasket comprises two generally parallel longitudinal portions 30 for sealing along the length of the face 10 when the pump is assembled. The longitudinal portions 30 terminate in
10 shoulders 32 for abutting against the end portions 24 of the recess 14. An end portion of the gasket comprises a generally semi-circular sealing surface 34 which is shaped to correspond with the intersection 22 (shown in broken lines) between the annular groove and the recess 14 for sealing between the gasket and the O-ring when the O-ring is received in the channel. As shown, the sealing surface extends through more than 180
15 degrees and terminates at points 23.

The gasket 28 and the longitudinal recess 14 are configured that when the gasket is located in the recess during assembly the gasket is biased against the stop 24 for locating the end portion of the gasket and sealing surface 34 relative to the intersection. In this example, the gasket 18 comprises a biasing member 36 which when inserted into
20 the longitudinal recess 14 acts against the upstanding wall 18 to bias the shoulders 32 of the gasket against the stops 24. The biasing member comprises a laterally extending cross-member received in cross-channel 26 having a protrusion 38 for bearing against the upstanding wall and which causes elastic deformation of the cross-member when the

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gasket is inserted in the longitudinal recess. The protrusion in the illustrated example comprises a bulbous portion of the cross-member which causes the required deformation.

The biasing force of the cross-member 36 causes the gasket to butt against the stops which constrain movement of the gasket in a longitudinal dimension. The fixed
5 relative positioning between the stops and the intersection 22 means that the sealing surface 34 of the gasket is reliably located relative to the intersection. As illustrated, the end portion extends to a small extent proud of the end face 20 and the intersection 22.

The upstanding end portions 24 of the longitudinal recess are proximate the intersection which is preferable for locating the end portion of the gasket relative to the
10 intersection. In an alternative the stops may comprise a second upstanding wall of the longitudinal recess against which a second cross-member of the gasket is biased for locating the end portion of the gasket relative to the intersection.

The upstanding walls 16, 18 also serve to locate the gasket in the lateral dimension when fitted in the recess. In this regard, longitudinally extending surfaces 40
15 of the upstanding walls engage longitudinally extending surfaces 42 of the gasket. The upstanding wall 16 comprises a laterally extending surface 44 which is spaced away from the laterally extending surface 46 of the gasket during this stage of assembly. When the gasket is compressed by assembling the half-shells together the gasket extends laterally into the space between surfaces 44, 46 but leaves sufficient space to allow for thermal
20 expansion during use of the pump.

When the gasket 28 has been fitted in the recess 14, the sealing surface 34 is aligned with the intersection by a tool 48, as shown in Figure 7 in an unaligned condition and Figure 8 in an aligned condition. The tool comprises a spring loaded member 50 biased by a spring 52 for causing compression of the end portion of the gasket in the

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longitudinal dimension as shown by the arrow in the Figures. The spring loaded member 50 has a rounded end to correspond with the shape of the sealing surface and intersection. The spring 52 and member 50 are supported by a jig 54 which is fixed relative to the stator half-shell.

5 When the end portion of the gasket has been aligned with the stator intersection the tool is maintained in position during assembly of the opposing half-shell with the illustrated half-shell. When assembled the gasket is compressed and undergoes expansion however the tool 48 maintains the sealing surface 34 in alignment with the intersection 22. Once the half-shells have been fastened together the tool is removed. The
10 compression between the half-shells maintains the gasket in position and preserves the alignment, as shown in Figure 9 with the tool removed. During the compression, the gasket undergoes longitudinal expansion into the space between laterally extending surfaces 44, 46.

 In a next stage of assembly, the O-ring 56 is located in the annular channel and a
15 head plate 58 secured in position. It will be seen that the O-ring deforms when compressed between end faces to take up the shape of the sealing surface 34 and the intersection thereby creating an extended sealing surface through substantially 180 degrees for resisting the leakage of ambient gas into the pump.

 Therefore, the present embodiment provides a method of assembling a multi-stage
20 vacuum pump, comprising fitting a gasket 28 in a longitudinal recess 14 as shown in Figure 6. The subsequent stage involves biasing the gasket against a stop fixed relative to the intersection for locating an end portion of the gasket relative to the intersection such that the end portion sits proud of the intersection. The next method step comprises pressing the end portion of the gasket with a tool generally to align the end portion with

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the intersection during compression of the gasket as the half-shell components are assembled together along the longitudinal faces, as shown in Figures 7 and 8. The following steps involve fitting the O-rings 56 in the annular channels 22 and assembling the end stator components 58 to the half-shell stator components.

- 5 The gaskets may be formed from a relatively hard material such as a metal or hard elastomer. In this case, it is important to control the sealing force between the gasket and the annular seal member so that the gasket does not damage the annular seal member when they are compressed together.

CLAIMS

1. A multi-stage vacuum pump comprising:

first and second half-shell stator components (102, 104) defining a plurality of
5 pumping chambers (106 – 116) for assembly together along respective longitudinal faces
(118, 120);

first and second end stator components (122, 124) for assembly at respective end
faces (126, 128) of the first and second half-shell stator components;

gaskets (138) for location in a longitudinal recess (140) of respective longitudinal
10 faces (118, 120) for sealing between the first and second half-shell stator components
(102, 104) when assembled together; and

O-rings (146) for location in annular channels (148) counter-sunk in respective
end faces (132) for sealing between the first and second end stator components and the
first and second half-shell stator components when assembled;

15 Characterised in that the annular channels intersect the longitudinal recesses and
each longitudinal recess comprises a stop (24) fixed relative to the intersection, and the
gasket and the longitudinal recess are configured that when the gasket is located in the
recess during assembly the gasket is biased against the stop (24) for locating an end
portion of the gasket relative to the intersection.

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2. A multi-stage vacuum pump as claimed in claim 1, wherein and an end portion of
each gasket is shaped to correspond with the intersection for sealing between the gasket
and the O-ring when the O-ring is received in the channel.

3. A multi-stage vacuum pump as claimed in claim 1 or 2, wherein the longitudinal recess comprises an upstanding wall (18) and each gasket comprises a biasing member (36) which when inserted into the longitudinal recess acts against the upstanding wall to bias the gasket against the stop.

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4. A multi-stage vacuum pump as claimed in claim 2, wherein the biasing member comprises a laterally extending cross-member having a protrusion for bearing against the upstanding wall and which causes elastic deformation of the cross-member when the gasket is inserted in the longitudinal recess.

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5. A multi-stage vacuum pump as claimed in any of the preceding claims, wherein the stop is arranged to constrain movement of the gasket in a longitudinal dimension.

6. A multi-stage vacuum pump as claimed in claim 4, wherein the stop comprises an upstanding end portion of the longitudinal recess proximate the intersection against which a shoulder of the gasket is biased for locating the end portion of the gasket relative to the intersection.

7. A multi-stage vacuum pump as claimed in claim 4, wherein the stop comprises a second upstanding wall (16) of the longitudinal recess against which a second cross-member (44) of the gasket is biased for locating the end portion of the gasket relative to the intersection.

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8. A multi-stage vacuum pump as claimed in any of the preceding claims, wherein the longitudinal recess comprises a longitudinally extending upstanding wall for constraining lateral movement of the end portion of the gasket relative to the intersection when the gasket is fitted in the longitudinal recess.

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9. Apparatus for assembling a multi-stage vacuum pump comprising a tool (48) and a multi-stage vacuum pump as claimed in any of the preceding claims, wherein the tool is arranged for aligning the shaped end portions of the gaskets with the correspondingly shaped intersections between the annular channels and the longitudinal recesses when the
10 gaskets have been fitted in the longitudinal recesses and prior to compression of the gasket between the half-shell stator portions.

10. Apparatus as claimed in claim 9, wherein the tool (48) comprises a biasing member (50) configured to be received in the intersection for biasing the shaped end
15 portion of the gasket into alignment with the intersection.

11. Apparatus as claimed in claim 10, wherein the biasing member (50) has a rounded end shaped to complement the corresponding shape of the intersection and end portion of the gasket.

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12. A method of assembling a multi-stage vacuum pump, the vacuum pump comprising:

first and second half-shell stator components (102, 104) defining a plurality of pumping chambers (106 – 116) for assembly together along respective longitudinal faces (118, 120),

first and second end stator components (122, 124) for assembly at respective end
5 faces (126, 128) of the first and second half-shell stator components;

gaskets (138) for location in a longitudinal recess (140) of respective longitudinal faces (118, 120) for sealing between the first and second half-shell stator components when assembled together; and

O-rings (146) for location in annular channels (148) counter-sunk in respective
10 end faces (132) for sealing between the first and second end stator components and the first and second half-shell stator components when assembled, the annular channels intersecting the longitudinal recesses at respective intersections,

Characterised in that the method comprises:

fitting each gasket in a said longitudinal recess;

15 biasing the gasket against a stop fixed relative to the intersection for locating an end portion of the gasket relative to the intersection such that the end portion sits proud of the intersection;

pressing the end portion of the gasket with a tool generally to align the end portion with the intersection during compression of the gasket as the half-shell components are
20 assembled together along the longitudinal faces;

fitting the O-rings in the annular channels;

assembling the end stator components to the half-shell stator components.