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(54) Title: SEAL ASSEMBLY FOR A ROTATABLE SHAFT

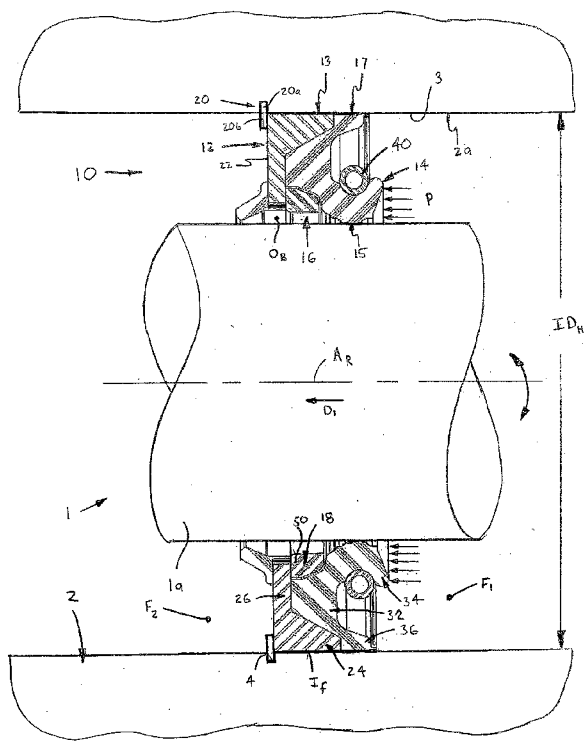

FIG. 1

(57) Abstract: A seal assembly is for a shaft rotatable about an axis, having an outer circumferential surface and being disposed within a housing having an inner circumferential surface defining a bore. The seal assembly includes an annular base member having an outer circumferential surface and a central opening for receiving the shaft with clearance, the base member being sized such that the base outer surface is engageable with the housing inner surface to form an interference fit to retain the seal assembly. An annular seal member is disposed on the base member and has an inner circumferential sealing surface for sealing against the shaft outer surface and an outer circumferential sealing surface for sealing against the housing inner surface. A support member includes a one-piece annular body, is disposed generally between the seal member sealing surface and a portion of the base member, and prevents axial deflection of the sealing member.

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TITLE OF THE INVENTION

Seal Assembly for a Rotatable Shaft

The present invention relates to seals, and more particularly to seals for sealing the space about a rotatable shaft.

One known type of seal for sealing the space about a shaft is typically referred to as a "lip seal" and includes an annular polymeric seal body having an inner surface that seals against the outer surface of the shaft. A metallic base member is generally provided to retain the seal body about the shaft, typically within a housing.

Although such seals are generally satisfactory for performing their intended sealing function, problems may arise in certain applications, particularly in sealing a high pressure fluid. Specifically, such seals may be forced by the high pressure to axially deflect in a direction away from the pressurized fluid so as to become extruded between the shaft and the base member, thus causing a failure of the seal.

SUMMARY OF THE INVENTION

In one aspect, the present invention is a seal assembly for a shaft rotatable about an axis, the shaft having an outer circumferential surface and being at least partially disposed within a housing having an inner circumferential surface defining a bore. The seal assembly comprises a generally annular base member having an outer circumferential surface and a central opening, the central opening being configured to receive the shaft with clearance, the base member being sized such that the base outer surface is engageable with the housing inner surface so as to form an interference fit to fixedly retain the seal assembly with respect to the axis. A generally annular seal member is disposed on the base member and having an inner circumferential sealing surface configured to seal against the shaft outer surface and an outer circumferential sealing surface configured to seal against the housing inner surface. Further, a support member includes a one-piece, generally annular body disposed generally between the seal member sealing surface and a portion of the base member, the support member being configured to at least reduce axial deflection of the sealing member.

In another aspect, the present invention is a method of forming a seal assembly comprising the steps of: providing a base member, the base member having an inner circumferential surface defining a central opening, and a support member including a one-piece, generally annular body; molding a seal member onto the base member so as to form a radial lip sealing engageable with a shaft and a generally annular groove located between the lip and the base member; inserting the support member through the base member central opening; and positioning the support member into the seal member groove.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The foregoing summary, as well as the detailed description of the preferred embodiments of the present invention, will be better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings, which are diagrammatic, embodiments that are presently preferred. It should be understood, however, that the present invention is not limited to the precise arrangements and instrumentalities shown. In the drawings:

Fig. 1 is an axial cross-section of a seal assembly of the present invention, shown in a horizontal orientation and installed about a shaft in a housing;

Fig. 2 is another cross-sectional view of the seal assembly, shown in a horizontal orientation and with a seal member in an uncompressed state;

Fig. 3 is an enlarged, broken-away axial cross-sectional view of a portion of Fig. 1, shown in a vertical orientation;

Fig. 4 is an enlarged, broken-away axial cross-sectional view of a portion of Fig. 2, shown in a vertical orientation;

Fig. 5 is an axial cross-sectional view of a base member;

Fig. 6 is an enlarged, broken-away view of a portion of Fig. 5;

Fig. 7 is an axial cross-sectional view of a seal member;

Fig. 8 is an enlarged, broken-away view of a portion of Fig. 7;

Fig. 9 is another axial cross-sectional view of the seal assembly in an unassembled state, showing a support member during installation into the seal assembly; and

Fig. 10 is a more diagrammatic view of the seal assembly installed on a steering input shaft.

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DETAILED DESCRIPTION OF THE INVENTION

Certain terminology is used in the following description for convenience only and is not limiting. The words "inner", "inwardly" and "outer", "outwardly" refer to directions toward and away from, respectively, a designated axis, a centerline or a geometric center of an element being described, the particular meaning being readily apparent from the context of the description. Further, as used herein, the word "connected" is intended to include direct connections between two members without any other members interposed therebetween and indirect connections between members in which one or more other members are interposed therebetween. The terminology includes the words specifically mentioned above, derivatives thereof, and words of similar import.

Referring now to the drawings in detail, wherein like numbers are used to indicate like elements throughout, there is shown in Figs. 1-10 a seal assembly 10 for a shaft 1, preferably a steering input shaft (see Fig. 10). The shaft 1 is rotatable about a central axis A_R, has an outer circumferential surface 1a, and is at least partially disposed within a housing 2 having an inner circumferential surface 2a defining a bore 3. The seal assembly 10 basically comprises a generally annular base member 12, a generally annular seal member 14 disposed on the base member 12, and a support member 16. The base member 12 has an outer circumferential surface 13 and a central opening O_B, the central opening O_B being configured to receive the shaft 1 with clearance. The base member 12 is sized such that the base member outer surface 13 is engageable with the housing inner surface so as to form an interference fit I_f to fixedly retain the seal assembly 10 with respect to the axis A_R. The seal member 14 has an inner circumferential sealing surface 15 configured to seal against the shaft outer surface 1a and an outer circumferential sealing surface 17 configured to seal against the housing inner surface 2a. Further, the support member 16 includes a one-piece, generally annular body 18 disposed generally between the seal member inner sealing surface 15 and a portion of the base member 12. The support member 16 is configured to at least reduce, and preferably substantially prevent, axial deflection of the sealing member 14, as described in further detail below.

Preferably, the base member 12 is configured to generally axially retain the seal member 14, and the support member 16, when a fluid F_l exerts pressure P greater than two thousand pounds per square inch (2000 psi) on the seal member 14, as depicted in Fig. 1 and described further below. To achieve such retention capability, the base member 12 is formed with a substantial thickness, preferably having a radial thickness t_R (Fig. 6) of sufficient magnitude such that the base member outer surface 13 is configured to engage with the housing inner surface 2a in a "heavy interference fit" without buckling or shearing of the base member 12. Specifically, the preferred interference fit I_f involves a difference in the base member outer diameter OD_B (Fig. 3) and the housing inner diameter ID_H (Fig. 1) in a range of about one thousandth of an inch (0.001") and about seven thousands of an inch (0.007"). Such a substantial interference fit I_f generates relatively high stresses in the base member 12, particularly hoop shear stresses and radial compressive stresses. Therefore, the base member radial thickness t_R must be sufficient to withstand such stresses, as discussed below. Further, the base member 12 preferably has an axial thickness t_A (Fig. 6) of sufficient magnitude so as to substantially prevent cantilever bending of a radial portion 26 of the base member 12 in a high pressure environment, which is also described in detail below.

Most preferably, to additionally ensure axial retention of the seal assembly 10 in a high pressure environment, the seal assembly 12 preferably further comprises an annular retainer 20, preferably a "snap ring", engageable with the housing 2 and disposeable against a generally radial end surface 22 of the base member 12. As such, the snap ring 20 prevents displacement of the seal assembly 10 in a first direction D_1 along the axis A_R. More specifically, the housing 2 includes an annular groove 4 extending radially outwardly into the inner surface 2a and the snap ring 20 has an outer portion 20a disposed within the groove 4 and an inner portion 20b disposed against the base member 12. Preferably, the base member 12 has an edge surface 23 (Fig. 6) extending between the outer circumferential surface 13 and the radial surface 22 that is formed with a minimal radius (i.e., a "sharp" edge), so as to increase the amount of surface area of the ring inner portion 20b disposed against the base member radial surface 22.

Referring now to Figs. 1-6, the base member 12 is preferably formed of a metallic material and includes a generally axial portion 24 and a generally radial portion 26 extending inwardly from the axial portion 24, the radial and axial portions 24, 26 bounding an open cavity C_B (see Fig. 5) configured to receive at least a portion of the seal member 14. More specifically, the base member axial portion 24 has first and second axial ends 24a, 24b, respectively, and an inner circumferential, axial retention surface 25 extending between the first end and the base member radial portion 26. The base member radial portion 26 is disposed generally adjacent to the axial portion second axial end 24b and has an outer end 26a connected with the axial portion

24, an opposing, free inner end 26b, and a radial retention surface 27 extending between the axial portion 24 and the radial portion inner end 26b. With this structure, the axial and radial retention surfaces 25, 27, respectively, at least partially bound or define the base member cavity C_B for receiving the seal member 14 and the support member 16 is disposed generally against the radial retention surface 27 of the base member 12, as described in further detail below. Also, the base member radial portion 26 has an inner circumferential surface 28 on the inner end 26b that defines the base member central opening O_B (Fig. 5), as discussed above and in further detail below.

Further, as mentioned above, the base member radial portion 26 has an axial thickness t_A of sufficient magnitude so as to substantially prevent bending of the radial portion 26 with respect to the axial portion 24 when a fluid F_l exerts pressure P greater than two thousand pounds per square inch (2000 psi) on the seal member 14. In other words, when the seal member 14 is subjected to a relatively high fluid pressure, the resultant force f_R (Fig. 4) exerted on the base member 12 (i.e., through the seal member 14 and support member 16) causes the radial portion 26 to behave as a cantilever beam. As such, a sufficient axial thickness t_A prevents the force f_R from bending or deflecting the radial portion 26 axially away in a direction D_1 generally away from the high pressure fluid F_l. Most preferably, the axial thickness t_A of the base member radial portion 26 has a magnitude or value of at least about thirty-four thousands of an inch (0.036"), but such a thickness t_A will vary depending on the specific application of the seal assembly 10.

Furthermore, the base member axial portion 24 has a radial thickness t_R varying from a minimum value t_{Rmin} proximal to the first axial end 24a and a maximum value t_{Rmax} proximal to the second axial end 24b, as indicated in Fig. 6. Preferably, the radial thickness t_R has a minimum value of about one hundred ten thousands of an inch (0.110") and a maximum value of about two-hundred forty-five thousands of an inch (0.245"), but the particular thickness ranges will depend on the specific seal application. Such a varying radial thickness t_R provides a cavity C_B with sufficient space for containing the seal member 14 and reinforces the cantilever-like radial portion 26, while also providing sufficient structural integrity to engage in a heavy interference fit I_f without failure, as discussed above. Also, with this varying radial thickness t_A, the axial retention surface 25 is generally angled and faces generally in a second axial direction

D_2 toward the first axial end 24a, and the axial portion 24 has generally wedge-shaped axial cross-sections S_C (see Fig. 6).

Referring now to Figs. 1-4 and 7-9, the seal member 14 has first and second axial ends 14a, 14b and is located within the base member cavity C_B such that at least a portion of the seal member second axial end 14b is disposed against the base member 12, specifically against the radial retention surface 27. The inner circumferential sealing surface 15 is configured to substantially prevent fluid flow between the seal member 14 and the outer surface 1a of the rotating shaft 1 when the seal member first end 14a is exposed to a high pressure fluid F_1. Preferably, the seal assembly 10 is utilized in an application in which the seal member first end 14a is exposeable to a high pressure fluid F_1, e.g., pressurized oil, while the seal member second end 14b is exposeable to a low pressure fluid F_2, such as atmospheric air. With such an application, the seal member 14 preferably further includes a generally radially-inwardly extending dust lip 30 spaced axially from the inner circumferential sealing surface 15 and having an inner end 30a, the dust lip inner end 30a being either engageable with the shaft outer surface 1a or disposeable generally adjacent to the shaft outer surface 1a. Such a dust lip 30 functions to prevent entry of dust or other contaminants within the low pressure fluid F_2 from entering the interface between the inner sealing surface 15 and the rotating shaft 1.

Preferably, seal member 14 is formed as a complex-shaped, generally annular body fabricated of an elastomeric material and including a central portion 32 disposed on the base 12 and inner and outer sealing arms 34, 36, respectively. The central portion 32 is substantially contained within the base member open cavity C_B and is disposed against the base member retention surfaces 25, 27. The dust lip 30 is preferably connected with the central portion 32 by a relatively thin, L-shaped connective portion 31 extending along the base member inner circumferential surface 28 and radial surface 27. Further, the inner sealing arm 34 extends both axially and radially inwardly from the central portion 32 and provides the inner circumferential sealing surface 15. Furthermore, the outer sealing arm 36 extends axially and radially outwardly from the central portion 32, provides the outer sealing surface 17, and is spaced radially outwardly from the inner arm 34, i.e., the outer sealing arm 36 extends generally coaxially about the inner arm 34. The outer arm 36 preferably has a radial surface 37 disposed against the base member first axial end 24a and is preferably formed such that the outer circumferential surface 17 is generally radially aligned with, and axially spaced from, the base member outer circumferential surface 13 when the seal assembly 10 is mounted within the housing 2 (see, e.g., Figs. 1 and 4).

Still referring to Figs. 1-4 and 7-9, each of the inner and outer sealing arms 34, 36 is deflectable in radial directions with respect the central portion, and are both generally angled generally away from each other so as to respectively engage with the shaft 1 and the housing 2. Preferably, the seal assembly 10 further comprises an annular "garter" spring 40 disposed about the inner sealing arm 34 and configured to bias the inner arm 34 radially inwardly against the shaft inner surface 1a so as to increase the sealing pressure on the shaft 1. Further, the inner sealing arm 34 preferably includes at least one and preferably a plurality of annular projections or "beads" 42 each extending radially inwardly from a remainder of the inner sealing arm 24 and providing, either singly if one bead or collectively if multiple beads, the inner circumferential sealing surface 15. Most preferably, the inner sealing arm 34 includes a primary sealing bead 44 and multiple secondary sealing beads 45, the primary bead 44 extending radially inwardly a greater distance in an unassembled state, as shown in Figs. 2, 3, 5 and 6, so as to generate a greater sealing pressure (in comparison with the secondary beads 45) when the seal assembly 10 is mounted on the shaft 1.

Furthermore, the seal member 14 also preferably includes an annular groove 46 configured to receive the support member 16; specifically, the groove 46 is preferably defined between the seal member central portion 32 and the inner sealing arm 32 and is partially bounded by the radial portion 26 of the base member 12. The support member 16 is located at least partially within the seal member groove 46 so as to be disposed axially adjacent to and generally against the inner sealing arm 34, so as to thereby "reinforce" the sealing arm 34 against deflection in the first axial direction D_1, and is discussed in greater detail below.

Referring to Figs. 1-4 and 9, the annular body 18 of the support member 16 is preferably formed as a solid, generally circular ring 50 that is unbroken or continuous about its circumference and having first and second axial ends 50a, 50b. The support member first axial end 50a is preferably disposed generally axially adjacent to and against the inner sealing arm 34 and the support member second axial end 50b is disposed generally against the base member 12, specifically against the base member radial portion 26 through mutual contact with the thin seal member connective portion 31, as best shown in Fig. 3. As such, the support member 16 is configured to prevent, or at least substantially reduce, deflection of the inner sealing arm 34 in the first axial direction D_1, i.e., generally toward the base member 12. Specifically, the support member 16 is preferably fabricated of a polymeric material, most preferably Nylon, and as such has a higher stiffness than the elastomeric seal member 14. Thus, when a relatively high pressure P is applied to the inner sealing arm 34, any tendency to deflect axially so as to be "extruded" into the clearance between the base member 12 and the shaft 1, is resisted by the "stiff" support member 16, which is in turn supported or "backed" by a section of the base member radial portion 26.

Referring particularly to Fig. 9, the seal member 16 is preferably at least partially radially-inwardly deflectable or collapsible so as to be insertable through the base member central opening O_B during assembly into the seal member 14. More specifically, the seal assembly 10 is preferably fabricated by forming the base member 12 of a metallic material by any appropriate means (e.g., forging, casting, stamping, etc.) and then molding the elastomeric seal member 14 to the metallic base member 12. The polymeric support member 16 is formed in a separate process (e.g., injection molding) and is then assembled into the molded seal member 14, as follows. The solid or one-piece support member ring 50 is deflected inwardly or partially collapsed and inserted through the base member opening O_B (Fig. 6) in separate, integral sections until the entire ring 50 has passed axially through the opening O_B. Then the support member ring 50 deflects or "snaps back" radially outwardly into the annular seal member groove 46, so as to be positioned as described above.

By forming the support member 16 as a one-piece, continuous deflectable/collapsible ring 50, the seal assembly of the present invention has a number of advantages over prior art seal assemblies that included a "split" support ring having an axially-extending gap (not shown), as has been used in seal assemblies for axially or linearly displacing shafts. Such prior art rings have the tendency to become dislodged from a desired location (e.g., a groove) during shipping, handling or final assembly onto a shaft and also enable extrusion of portions of the seal into the ring axial gap during use. With the support member 16 of the present seal assembly 10, the ring 50 has no tendency to dislodge from the annular groove 46 and has no gap for promoting extrusion of the seal member 14.

It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but it is intended to cover modifications within the spirit and scope of the present invention as generally defined generally herein and in the appended claims.

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I claim:

1. A seal assembly for a shaft rotatable about an axis, the shaft having an outer circumferential surface and being at least partially disposed within a housing having an inner circumferential surface defining a bore, the seal assembly comprising:

a generally annular base member having an outer circumferential surface and a central opening, the central opening being configured to receive the shaft with clearance, the base member being sized such that the base outer surface is engageable with the housing inner surface so as to form an interference fit to fixedly retain the seal assembly with respect to the axis;

a generally annular seal member disposed on the base member and having an inner circumferential sealing surface configured to seal against the shaft outer surface and an outer circumferential sealing surface configured to seal against the housing inner surface; and

a support member including a one-piece, generally annular body disposed generally between the seal member sealing surface and a portion of the base member, the support member being configured to at least reduce axial deflection of the sealing member.

2. The seal assembly as recited in claim 1 wherein the base member includes a generally axial portion and a generally radial portion extending inwardly from the axial portion, the radial and axial portions bounding an open cavity configured to receive the seal member, the radial portion having an axial thickness of sufficient magnitude so as to substantially prevent bending of the radial portion with respect to the axial portion when a fluid exerts pressure greater than two thousand pounds per square inch on the seal member.

3. The seal assembly as recited in claim 2 wherein base member axial portion has first and second axial ends and an inner circumferential, axial retention surface extending between the first end and the base member radial portion, the base member radial portion is disposed generally adjacent to the axial portion second axial end and has an outer end connected with the axial portion, an opposing, free inner end, and a radial retention surface extending between the axial portion and the radial portion inner end, the axial and radial retention surfaces bounding the base member cavity and the support member being disposed generally against the radial retention surface.

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4. The seal assembly as recited in claim 3 wherein the base member axial portion has a radial thickness varying from a minimum value proximal to the first axial end and a maximum value proximal to the second axial end such that the axial retention surface is generally angled and faces generally toward the first axial end.

5. The seal assembly as recited in claim 1 wherein the inner end of the base member radial portion defines the base member central bore and the support member is at least partially radially-inwardly deflectable so as to be insertable through the base member central bore during assembly into the seal member.

6. The seal assembly as recited in claim 1 wherein the base member is configured to generally axially retain the support member and the seal member when a fluid exerts pressure greater than two thousand pounds per square inch on the seal member.

7. The seal assembly as recited in claim 6 further comprising a snap ring engageable with the housing and disposeable against a generally radial surface of the base member so as to prevent displacement of the seal assembly in a first direction along the axis.

8. The seal assembly as recited in claim 1 further comprising a snap ring engageable with the housing and disposeable against a generally radial surface of the base member so as to prevent displacement of the seal assembly in a first direction along the axis.

9. The seal assembly as recited in claim 1 wherein the base member has a radial thickness of sufficient magnitude such that the base member outer surface is configured to engage with the housing inner surface in a heavy interference fit without buckling of the base member.

10. The seal assembly as recited in claim 1 wherein the seal member is molded to the base member and the support member is assembled into the molded seal member.

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11. The seal assembly as recited in claim 10 wherein the base member has a central opening and the seal member is at least partially radially-inwardly deflectable so as to be insertable through the base member central opening during assembly into the seal member.

12. The seal assembly as recited in claim 1 wherein the seal member further includes a radially-inwardly extending dust lip spaced axially from the inner circumferential sealing surface and having an inner end, the dust lip inner end being one of engageable with the shaft outer surface and disposeable adjacent to the shaft outer surface.

13. The seal assembly as recited in claim 1 wherein the seal member has first and second axial ends, the seal member second axial end being disposed against the base member, the inner circumferential sealing surface being configured to substantially prevent fluid flow between the seal member and the shaft outer surface when the seal member first end is exposed to a high pressure fluid.

14. The seal assembly as recited in claim 1 wherein the seal member includes a central portion disposed on the base, an inner sealing arm extending axially and radially inwardly from the central portion and providing the inner circumferential sealing surface, and an outer sealing arm extending axially and radially outwardly from the central portion, providing the outer sealing surface and being spaced radially outwardly from the inner arm portion, each of the inner and outer sealing arms being deflectable in radial directions with respect the central portion.

15. The seal assembly as recited in claim 14 wherein the inner sealing arm includes at least one annular bead extending radially inwardly from a remainder of the inner sealing arm and providing the inner circumferential sealing surface.

16. The seal assembly as recited in claim 14 wherein the seal member includes an annular groove defined between the central portion and the inner sealing arm and partially bounded by the base member, the support member being located at least partially within the seal member groove so as to be disposed axially adjacent to and generally against the inner sealing arm.

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17. The seal assembly as recited in claim 16 wherein the support member has first and second axial ends, the support member first axial end being disposed generally against the sealing arm and the support member second axial end being disposed generally against the base member such that the support member is configured to prevent deflection of the inner sealing arm in an axial direction generally toward the base member.

18. The seal assembly as recited in claim 14 wherein the seal assembly further comprises a circular spring disposed about the inner sealing arm and configured to bias the inner arm radially inwardly against the shaft.

19. The seal assembly as recited in claim 1 wherein the seal member includes a sealing arm providing the inner circumferential sealing surface and a generally annular groove defined between the sealing arm and the base member, the support member being located at least partially within the seal member groove so as to be disposed axially adjacent to and generally against the inner sealing arm such that the support member is configured to prevent axial displacement of the sealing arm in a direction generally toward the base member.

20. The seal assembly as recited in claim 19 wherein the support member has first and second axial ends, the support member first axial end being disposed generally against the sealing arm and the support member second axial end being disposed generally against the base member.

21. The seal assembly as recited in claim 1 wherein the base member is formed of a metallic material, the seal member is formed of an elastomeric material and the support member is formed of a polymeric material.

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22. A method of forming a seal assembly comprising the steps of:

providing a base member, the base member having an inner circumferential surface defining a central opening, and a support member including a one-piece, generally annular body;

molding a seal member onto the base member so as to form a radial lip sealing engageable with a shaft and a generally annular groove located between the lip and the base member; and

inserting the support member through the base member central opening; and

positioning the support member into the seal member groove.

23. The method of claim 20 wherein the step of inserting the support member into the base opening includes at least partially collapsing the support member annular body.

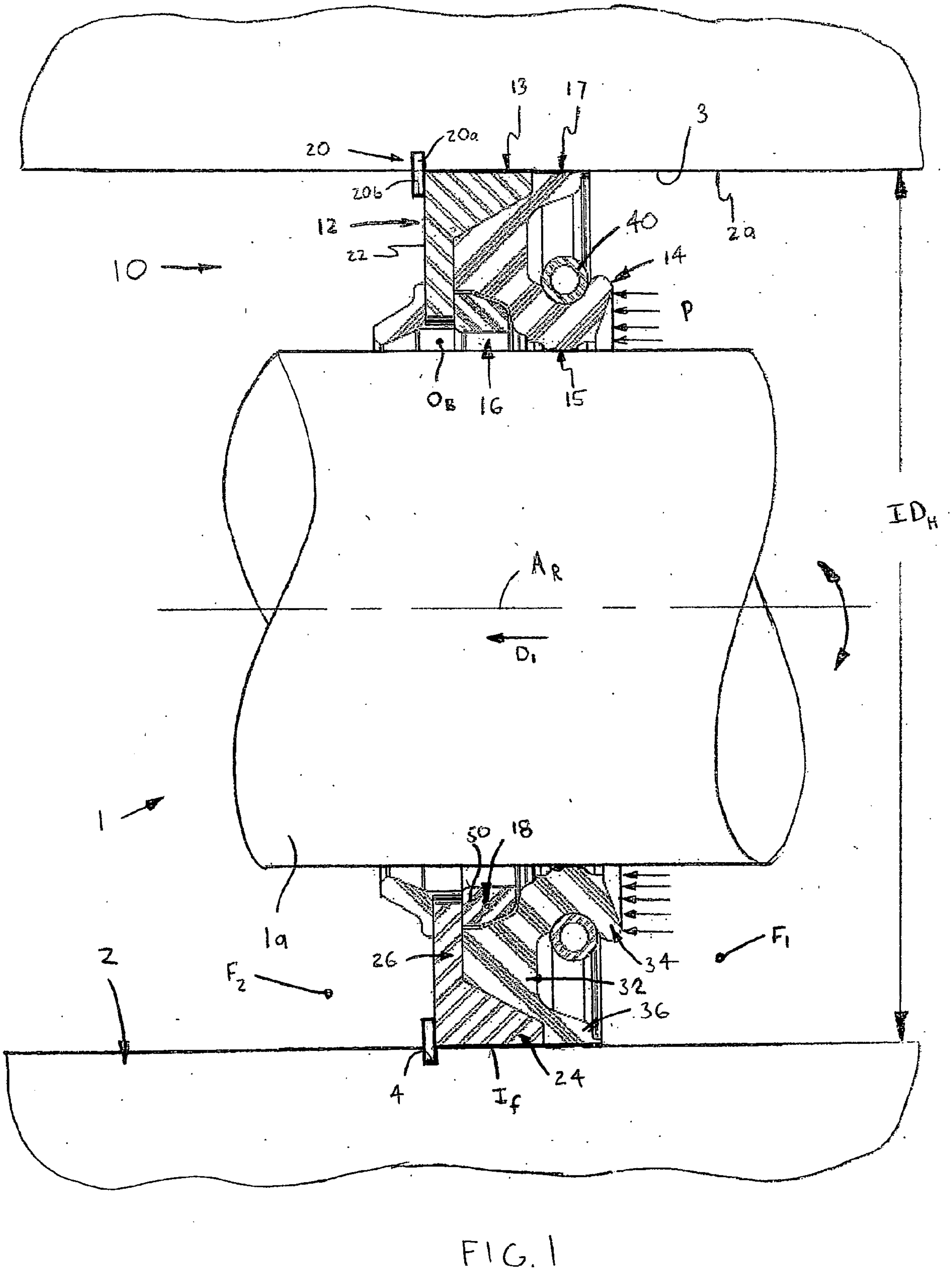
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FIG. 1

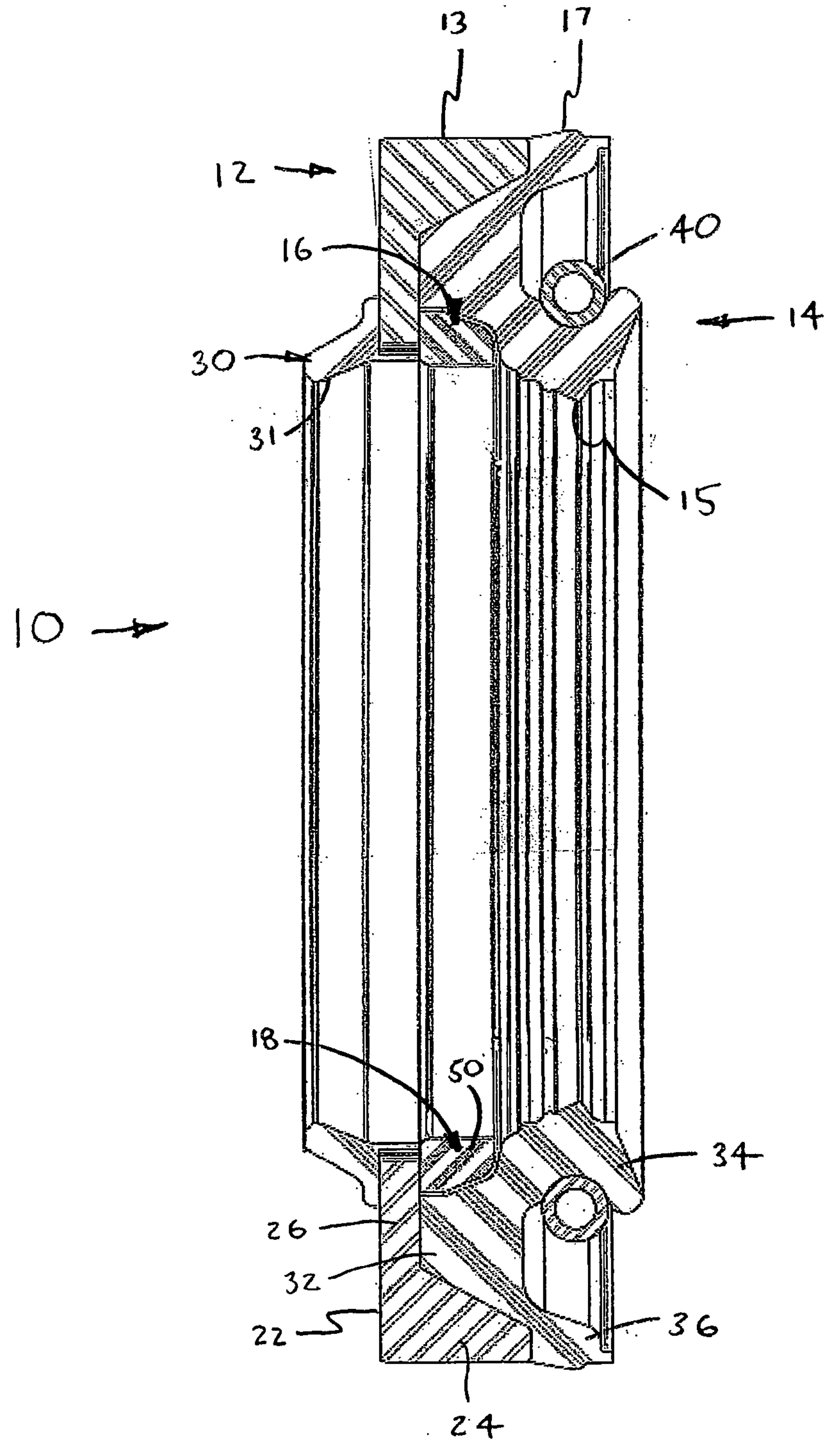

FIG. 2

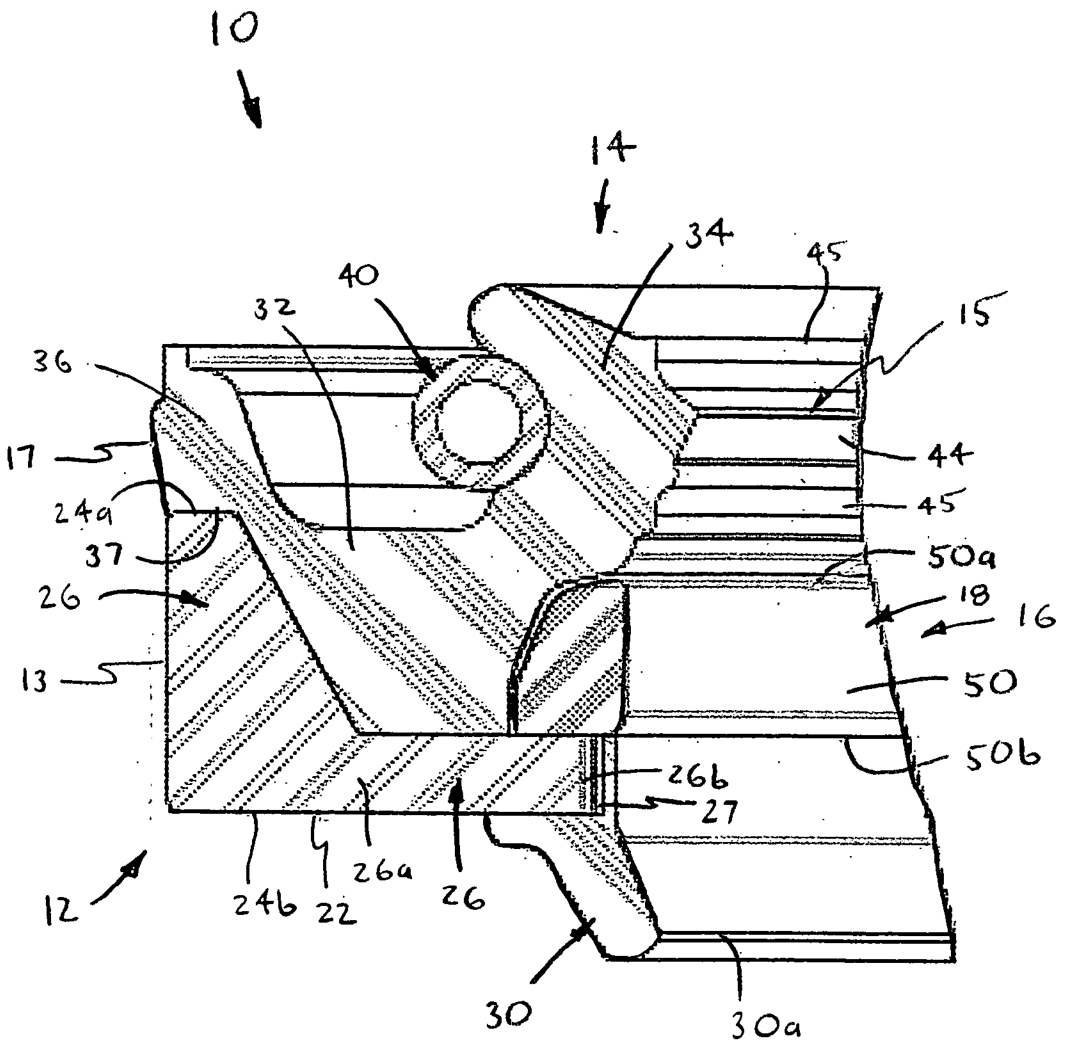
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FIG. 3

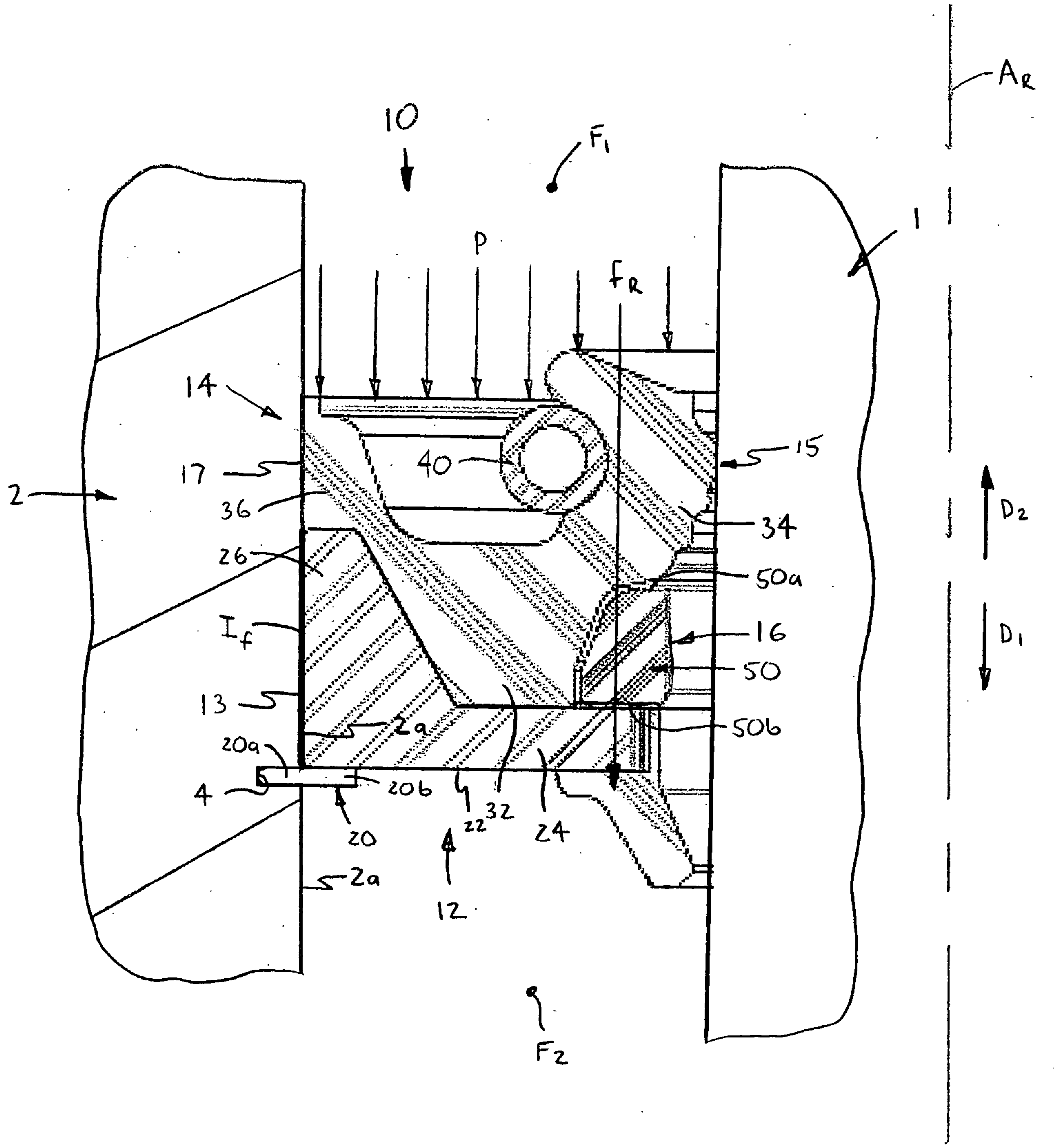
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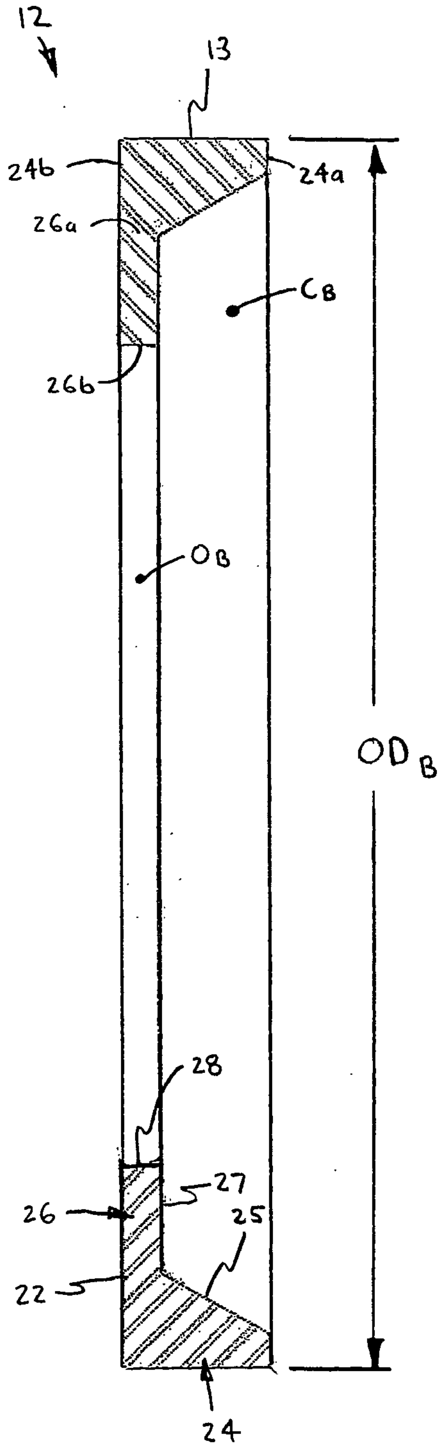
FIG. 4,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24

FIG. 5

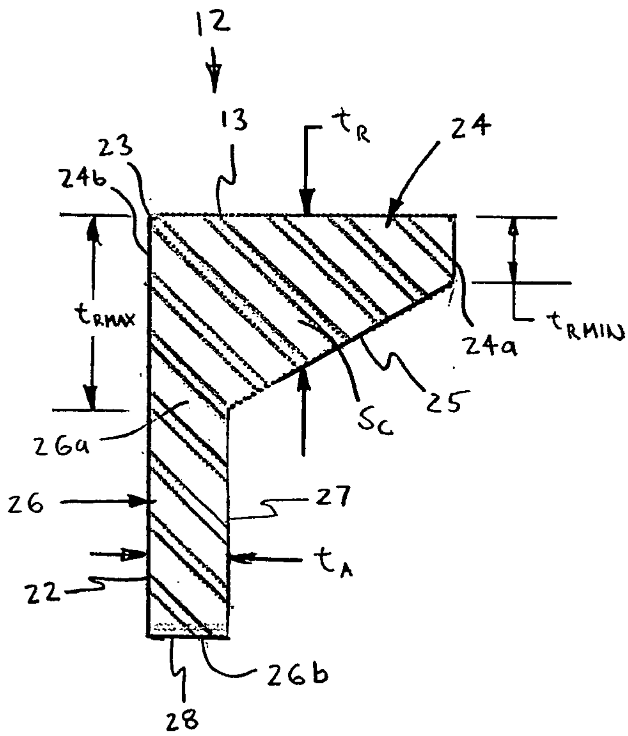
12
13
t_R
24
23
24b
t_RMAX
t_RMIN
24a
25
S_C
26a
26
27
t_A
22
26b
28

FIG. 6

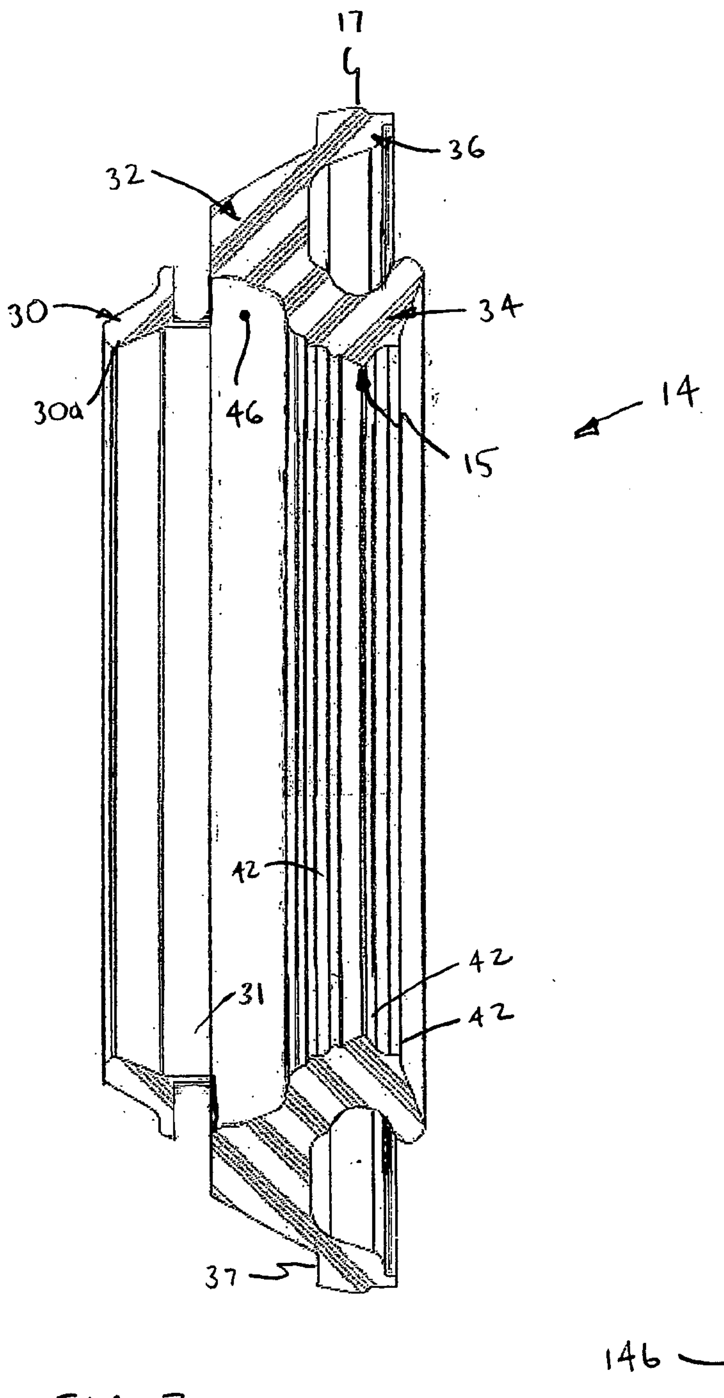
17
36
32
30
34
30a
46
14
15
42
42
42
31
37

FIG. 7

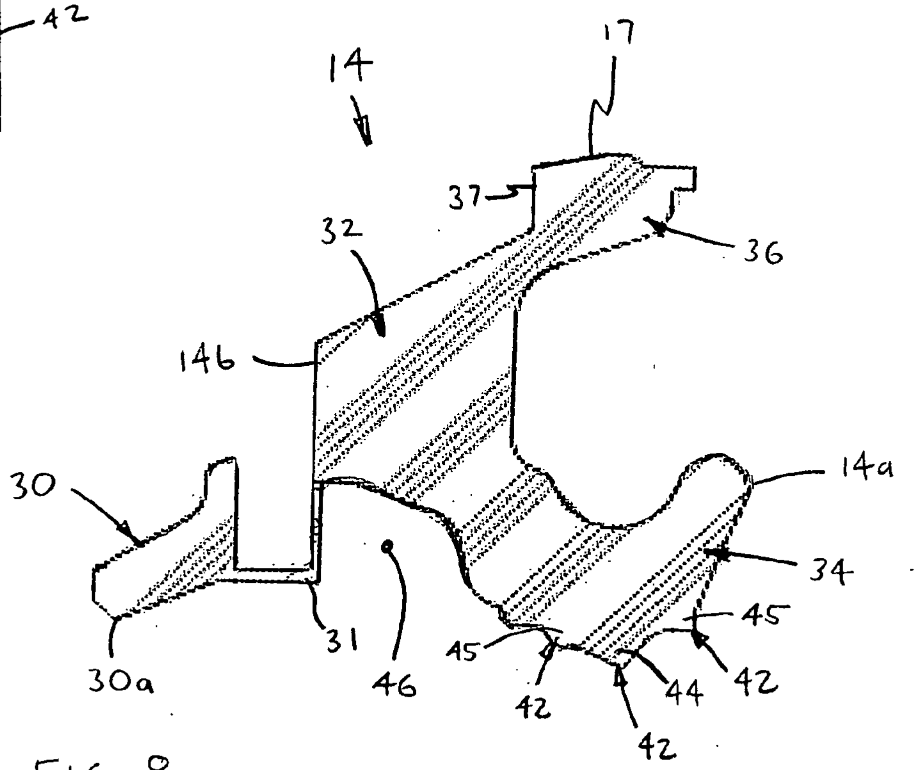
17
14
37
32
36
14b
30
14a
34
45
45
31
46
30a
42
44
42
42
42

FIG. 8

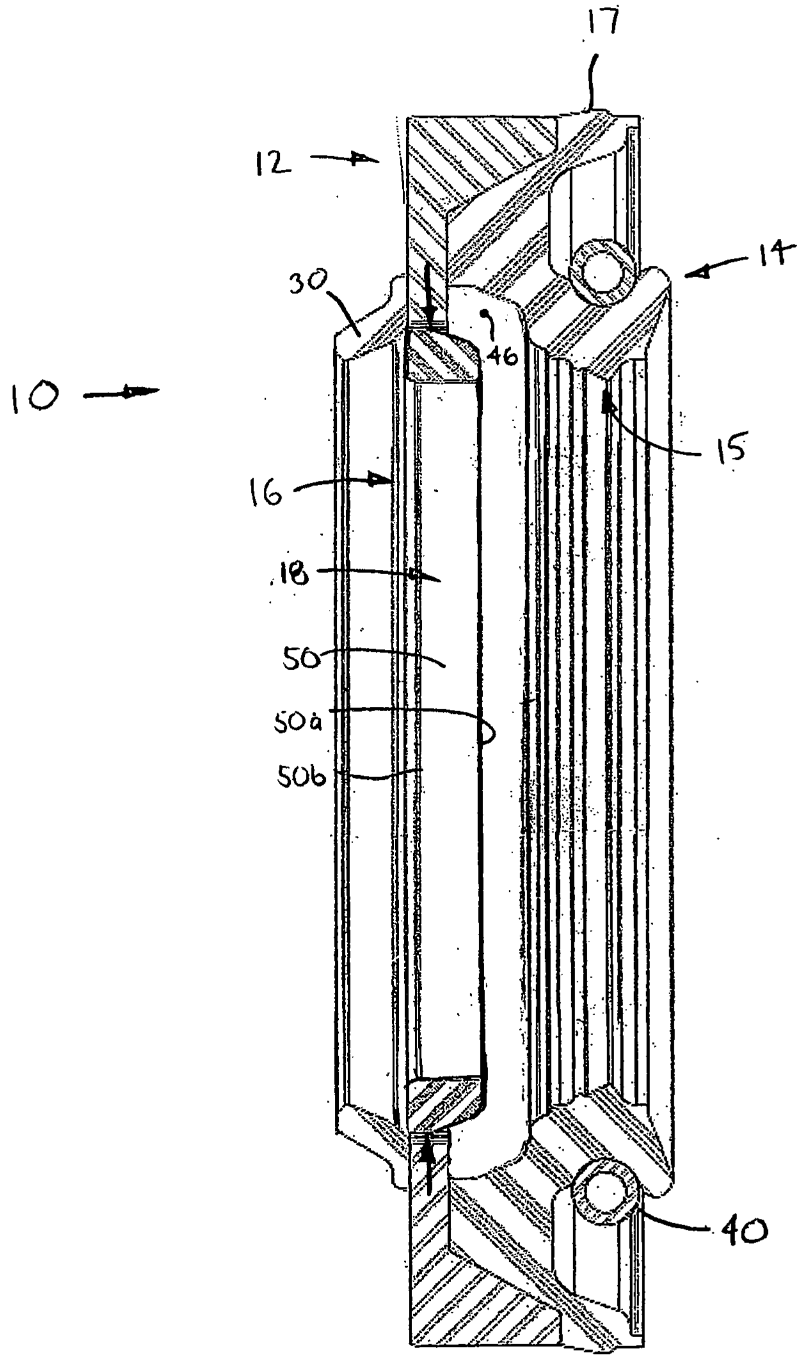

FIG.9

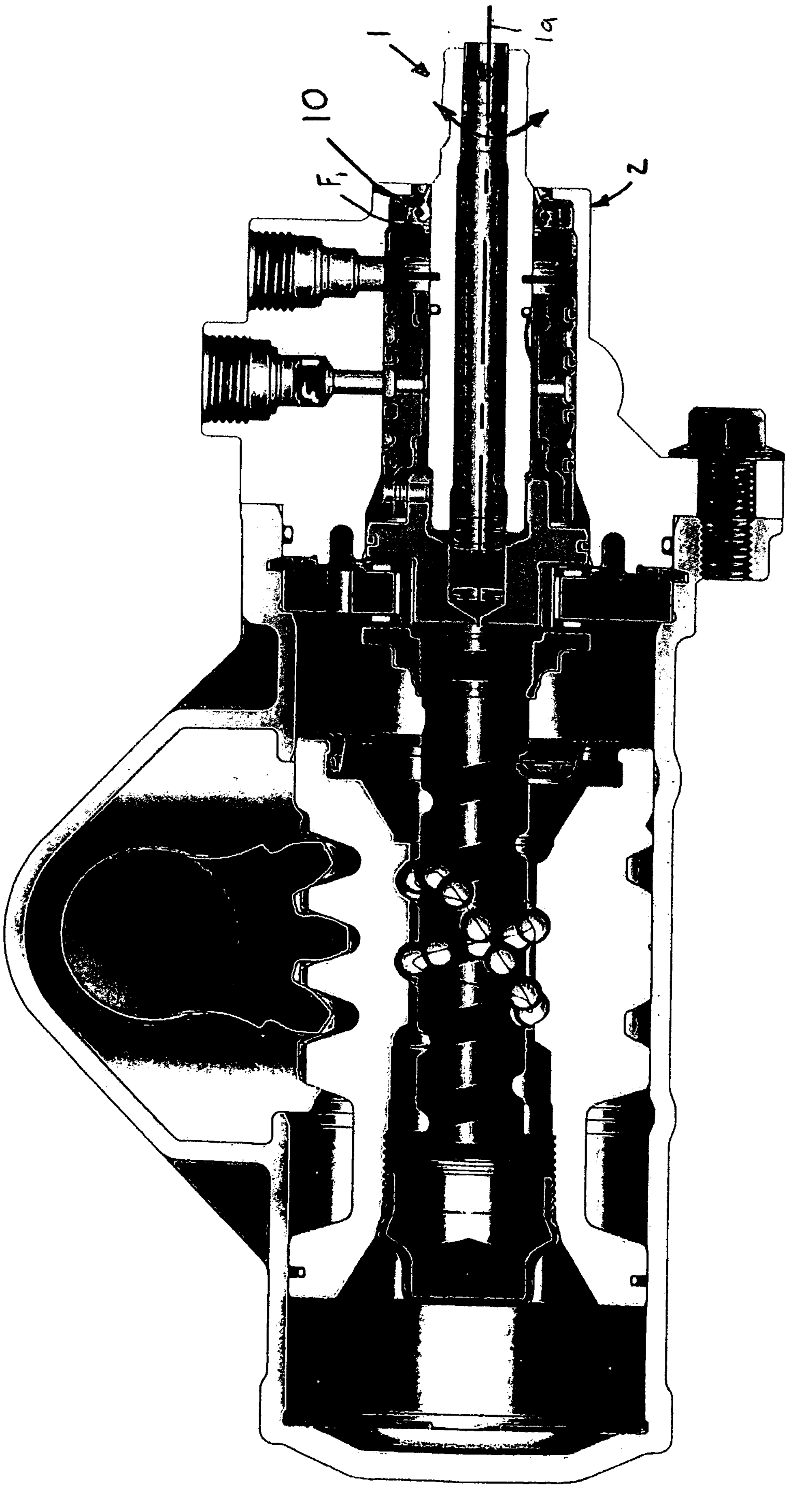

FIG. 10