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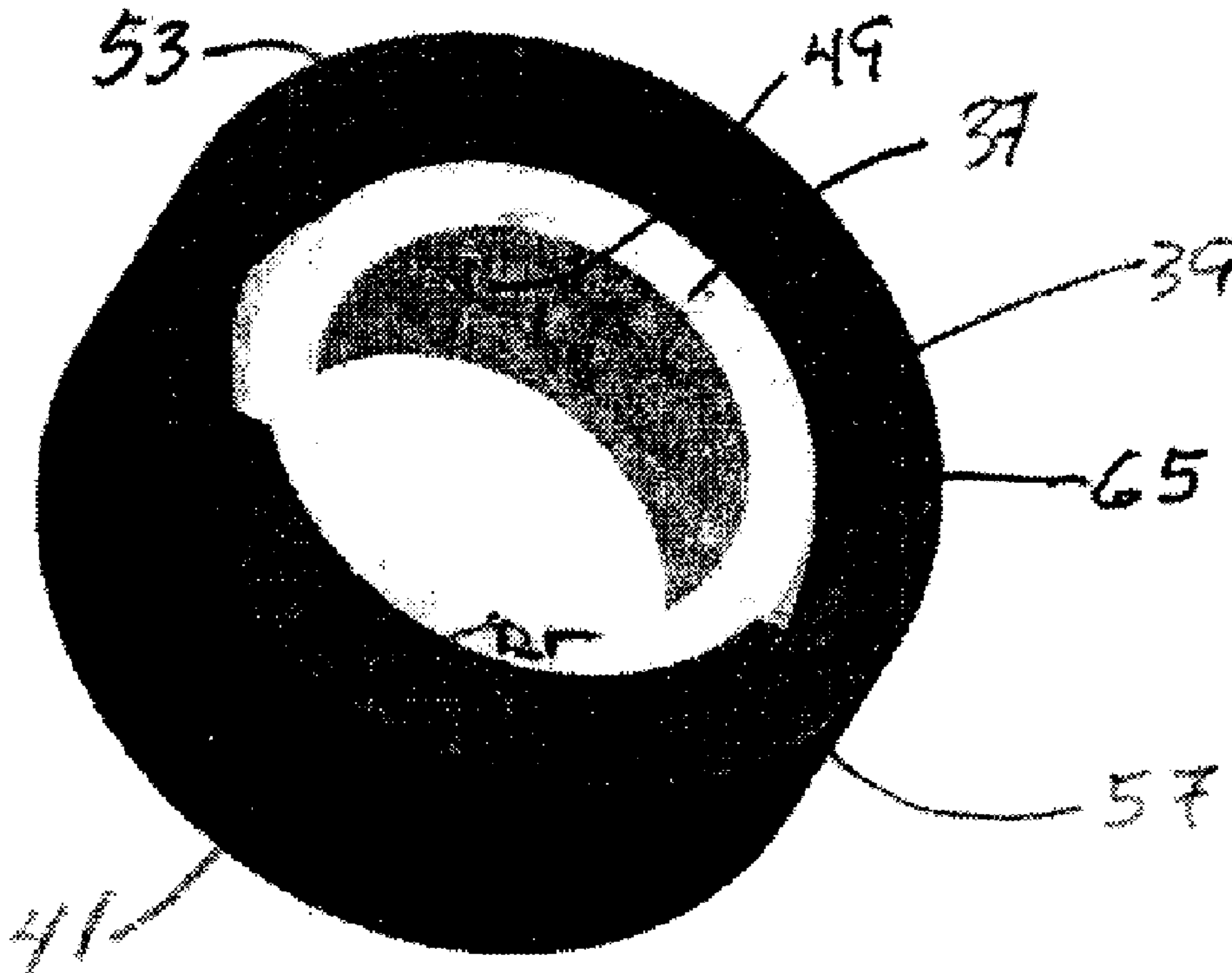
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(54) Titre : PALIER A BAGUE ET MANCHON SPHERIQUE POUR ETAGE DE POMPE CENTRIFUGE

(54) Title: SPHERICAL SLEEVE AND BUSHING BEARING FOR CENTRIFUGAL PUMP STAGE



(57) Abrégé/Abstract:

A centrifugal pump has a number of stages, each of the stages having an impeller and a diffuser. The impellers are mounted to the pump drive shaft for rotation. A bearing in at least one of the stages includes a sleeve coupled to the drive shaft for rotation. The sleeve has upper and lower ends and an outer side wall facing radially outward that is convex and spherical. A bushing is mounted in the diffuser and has a bore with an inner side wall facing radially inward that is concave and spherical. A pair of slots is formed in the inner side wall of the bushing 180 degrees apart from each other and extending axially. The slots enable the sleeve to be inserted into the bore with the sleeve axis and bore axis perpendicular to each other, then tilted 90 degrees to coincide the sleeve axis with the bore axis.

Abstract

A centrifugal pump has a number of stages, each of the stages having an impeller and a diffuser. The impellers are mounted to the pump drive shaft for rotation. A bearing in at least one of the stages includes a sleeve coupled to the drive shaft for rotation. The sleeve has upper and lower ends and an outer side wall facing radially outward that is convex and spherical. A bushing is mounted in the diffuser and has a bore with an inner side wall facing radially inward that is concave and spherical. A pair of slots is formed in the inner side wall of the bushing 180 degrees apart from each other and extending axially. The slots enable the sleeve to be inserted into the bore with the sleeve axis and bore axis perpendicular to each other, then tilted 90 degrees to coincide the sleeve axis with the bore axis.

SPHERICAL SLEEVE AND BUSHING BEARING FOR
CENTRIFUGAL PUMP STAGE

5 **Cross-Reference to Related Application:**

This application claims priority to S.N. 61/914,023, filed December 10, 2013.

Field of the Disclosure:

This disclosure relates in general to centrifugal well pumps and in particular to an
10 pump stage bearing having a rotating sleeve that fits within a stationary bushing, with a
spherical interface between the sleeve and bushing.

Background

Centrifugal well pumps are commonly used for pumping oil and water from oil
wells. The pumps have a large number of stages, each stage having a stationary diffuser and
15 a rotating impeller. The rotating impellers exert a downward thrust as the fluid moves
upward. Also, particularly at startup and when the fluid flow is non uniform, the impellers
may exert upward thrust. In a common pump design, the impellers float freely on the shaft so
that each impeller transfers downward thrust to one of the diffusers. A thrust washer, sleeve,
or bearing is located between a portion of each impeller and the upstream diffuser to
20 accommodate the downward thrust. Another thrust washer transfers upward thrust.

Some wells produce abrasive materials, such as sand, along with the oil and water.
The abrasive material causes wear of the pump components, particularly in the areas where
downward thrust and upward thrust are transferred. Tungsten carbide thrust bearings and
bearing sleeves along with shaping of components may be employed in these pumps to
25 reduce wear. A number of designs for these components exist, but improvements are
desirable.

Summary

The centrifugal pump of this disclosure has a drive shaft and a plurality of stages, each of the stages having an impeller and a diffuser. The impellers are mounted to the drive shaft for rotation therewith. The diffusers are mounted in a housing of the pump for non
5 rotation. A motor is operatively coupled to the pump for rotating the drive shaft.

A bearing in at least one of the stages includes a sleeve having a cylindrical opening coupled to the drive shaft for rotation therewith. The sleeve has upper and lower ends and an outer side wall facing radially outward. The outer side wall curves outward when viewed in a sleeve axis plane, defining upper and lower outer diameters at the upper and lower ends of
10 the sleeve that are smaller than an intermediate outer diameter halfway between the upper and lower ends.

A bushing is mounted in the diffuser of at least one of the stages for non rotation. The bushing has a bore with an inner side wall curving inward when viewed in a bore axis sectional plane. The curved inner side wall defines upper and lower inner diameters at upper
15 and lower ends of the bushing that are smaller than an intermediate inner diameter halfway between the upper and lower ends of the bushing. The sleeve locates in the bore with the outer side wall in rotational sliding contact with the inner side wall of the bore about the bore axis.

An upper hub member of the impeller of one of the stages located above the sleeve is
20 in engagement with the upper end of the sleeve. The upper hub member applies a downward directed force to the sleeve and from the sleeve to the bushing during down-thrust of the pump.

A lower hub member of the impeller of one of the stages located below the sleeve is in engagement with the lower end of the sleeve. The lower hub member applies an upward directed force to the sleeve and from the sleeve to the bushing during up-thrust of the pump.

5 A pair of slots is formed in the bore of the bushing 180 degrees apart from each other and extending into the bore of the bushing from one of the ends of the bushing. Each of the slots has a circumferential width at least equal to a height of the sleeve from the lower end to the upper end of the sleeve. The slots are radially spaced apart from each other a distance greater than the maximum outer diameter of the sleeve. The slots enable the sleeve to be inserted into the bore of the bushing while the sleeve axis is perpendicular to the bore axis,
10 then tilted so that the sleeve axis coincides with the bore axis.

Preferably, the sleeve and the bushing are formed of materials harder than the impeller and diffuser. In the embodiment shown, the slots extend axially from one of the ends of the bushing to a termination point at the intermediate inner diameter of the inner side wall of the bushing.

15 An upper portion of the outer side wall of the sleeve is in rotational sliding engagement with an upper portion of the inner side wall of the bushing. A lower portion of the outer side wall of the sleeve is in rotational sliding engagement with a lower portion of the inner side wall of the bushing. An intermediate portion of the outer side wall of the sleeve is in rotational sliding engagement with an intermediate portion of the inner side wall
20 of the bushing.

In the embodiment shown, the upper and lower outer diameters of the sleeve equal each other. The upper and lower inner diameters of the inner side wall of the bushing equal each other.

Brief Description of the Drawings:

So that the manner in which the features, advantages and objects of the disclosure, as well as others which will become apparent, are attained and can be understood in more detail, more particular description of the disclosure briefly summarized above may be had by
5 reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the disclosure and is therefore not to be considered limiting of its scope as the disclosure may admit to other equally effective embodiments.

Figure 1 is a side view of an electrical submersible pump assembly in accordance with
10 this disclosure and installed in a well.

Figure 2 is a sectional view of a portion of the pump of Figure 1, showing one of the sleeve and bushing bearings of one of the pump stages.

Figure 3 is a perspective, partially sectional view of the sleeve and bushing bearing of Figure 2.

15 Figure 4 is a perspective view from a different angle of the sleeve and bushing bearing of Figure 3.

Figure 5 is a top view of the bushing of Figure 3 with the sleeve removed.

Figure 6 is a sectional view of the bushing of Figure 5, taken along the line 6 -6 of Figure 5.

20 Figure 7 is a side view of the sleeve of Figure 3 apart from the bushing.

Figure 8 is a perspective view of the sleeve and bushing of Figure 3 with the sleeve partially inserted into the bushing.

Detailed Description of the Disclosure:

The methods and systems of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown.

The methods and systems of the present disclosure may be in many different forms and

5 should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout.

10 It is to be further understood that the scope of the present disclosure is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation.

15 Referring to Figure 1, electrical submersible pump assembly (ESP) 11 is illustrated as being supported on production tubing 13 extending into a well. Alternately, ESP 11 could be supported by other structure, such as coiled tubing. ESP 11 includes several modules, one of which is a centrifugal pump 15 that has an intake 16 for drawing in well fluid. Another module is an electrical motor 17, which drives pump 15 and is normally a three-phase AC
20 motor. A third module comprises a protective member or seal section 19 coupled between pump 15 and motor 17. Seal section 19 has components, such a bellows or bag, to reduce a pressure differential between dielectric lubricant contained in motor 17 and the pressure of the well fluid on the exterior of ESP 11. Intake 16 may be located in an upper portion of seal

section 19 or on a lower end of pump 15. A thrust bearing 21 for motor 17 may be in a separate module or located in seal section 19 or motor 17.

ESP 11 may also include other modules, such as a gas separator for separating gas from the well fluid prior to the well fluid flowing into pump 15. The various modules may be
5 shipped to a well site apart from each other, then assembled with bolts or other types of fasteners.

Referring to Figure 2, pump 15 includes a housing 23 that is cylindrical and much longer than its diameter. A drive shaft 25 extends along longitudinal pump axis 26 through housing 23 and is rotated by motor 17. Shaft 25 is normally made up of a different section
10 for each module connected together with splined ends. A large number of stages are normally within housing 23, each stage including a stationary diffuser 27. Diffusers 27 are stacked on one another and secured against rotation in housing 23. Diffusers 27 have flow passages 29 leading upward and inward toward axis 26. Each stage has an impeller 31 located above the diffuser 27. Impellers 31 have flow passages 33 that lead from a central
15 area upward and outward from axis 26. The terms “downward” and “upward” are used only for convenience, since pump 15 is not always oriented vertically as shown. The example of Figure 2 is a mixed flow type, wherein the flow passages 29, 33 extend both axially as well as radially. Alternately, pump 15 could be a radial flow type wherein the flow passages extend primarily radially and not axially.

20 Figure 2 illustrates how thrust imposed on each impeller 31 is transferred to one of the diffusers 27. Downward directed thrust is considered to be in a direction away from the direction the fluid is being pumped. Upward directed thrust can also occur, such as during startup or other conditions. Upward directed thrust is in an opposite direction to downward directed thrust. Each impeller 31 has a hub 35, which is a cylindrical member having a bore

through which shaft 25 passes. In this example, a thrust runner or sleeve 37 is located below hub 35. The lower end of hub 35 abuts an upper end of sleeve 37 to transmit down-thrust from the upper impeller 31 shown to sleeve 37. Alternately, a tubular spacer (not shown), which can be considered to be a part of hub 35, may be located between the lower end of hub 5 35 and the upper end of sleeve 37.

A tubular spacer 38 is shown between the upper side of a next lower impeller 31 and the lower end of sleeve 37 for transmitting up-thrust from the next lower impeller to sleeve 37. Spacer 38 may also be considered to be a hub member. Sleeve 37 could be employed with only some of the pump stages or in all of the pump stages. That is, if sleeve 37 is only 10 in some of the stages, hubs 35 could transfer thrust from one impeller 31 to another impeller 31 and eventually to sleeve 37. Sleeve 37 is a single-piece member and may be of a harder material than the material of impellers 31 and diffusers 27, such as tungsten carbide.

Sleeve 37 seats in a thrust bushing 39, which in turn is nonrotatably supported in a diffuser receptacle 40. Bushing 39 may be press-fit in diffuser receptacle 40 or secured 15 otherwise, such as by a retaining ring. Bushing 39 is also a single-piece member and may also be of a harder material, such as tungsten carbide, than the material of impellers 31 and diffusers 27. Sleeve 37 is secured to shaft 25 for rotation but is free to move a limited amount axially relative to shaft 25. Typically a key (not shown) engages mating axially extending grooves 41 (Fig. 3) in sleeve 37 and shaft 25.

20 Referring to Figures 3-7, sleeve 37 has an upper end 43, a lower end 45 and an external or outer side wall 47 extending from upper end 43 to lower end 45. A sleeve bore 49 that is cylindrical extends through sleeve 37 from upper end 43 to lower end 45. Sleeve bore 49 has a sleeve axis 51. External side wall 47 is convex and spherical from upper end 43 to lower end 45. The center point of the radius of curvature for side wall 47 could

coincide with sleeve axis 51 or it could be smaller. External side wall 47 has a maximum outer diameter halfway between sleeve upper end 43 and sleeve lower end 45. The outer diameters at upper end 43 and lower end 45 may be the same and are smaller than the outer diameter halfway between sleeve upper end 43 and sleeve lower end 45. Key groove 41 is
5 formed in sleeve bore 49 and extends parallel to sleeve axis 51 from upper end 43 to lower end 45.

Bushing 39 has an upper end 53, a lower end 55 and a cylindrical exterior 57.

Bushing has a bore 59 with a bushing bore axis 61. Bore 59 has an inner or internal side wall 63 that is concave, spherical, and has slightly greater radius of curvature than sleeve external
10 side wall 47. Bushing internal side wall 63 extends from bushing upper end 53 to bushing lower end 55. Internal side wall 63 has a maximum inner diameter 69 halfway between bushing upper end 53 and bushing lower end 55. The inner diameter of internal side wall 63 at upper end 53 and lower end 55 may be the same and are smaller than the maximum inner diameter 69 of internal side wall 63. The inner diameters of internal side wall 63 at any point
15 from bushing upper end 53 to lower end 55 are slightly greater than the outer diameters of sleeve external side wall 47 at the same places so as to closely receive sleeve 37 in rotating sliding contact.

Two slots 65 spaced 180 degrees apart from each other relative to bushing axis 61 are formed in internal side wall 63. Each slot 65 extends from upper end 53 to approximately
20 one-half the distance between bushing upper end 53 and bushing lower end 55, which is at the maximum inner diameter. Slots 65 thus do not extend all the way to bushing lower end 55 in this embodiment. Alternately, slots 65 could extend upward from bushing lower end 55 half the distance to bushing upper end 53. Each slot 65 has a base 67 with two side edges spaced circumferentially apart from each other the width of slot 65. When viewed in the

cross-section of Figure 6, base 67 of each slot 65 appears to be generally flat. However, base 67 has a circumferential curvature when viewed in a plane perpendicular to bushing axis 61 that has a radius equal to the radius of the maximum inner diameter 69 of bushing bore 59, as shown by the dotted lines in Figure 5.

5 The height or axial dimension of sleeve 37 along sleeve axis 51 from upper end 43 to lower end 45 is shown to be slightly less than the height or axial dimension of bushing 39 along bushing axis 61 from upper end 53 to lower end 55. The axial dimension along sleeve axis 51 of sleeve 37 is slightly less than the circumferential width of each bushing slot 65. The maximum outer diameter of sleeve external side wall 47 is slightly less than the radial
10 distance from base 67 of one slot 65 to base 67 of the other slot 65. The inner diameter of bushing bore 59 at upper end 53 and lower end 55 is smaller than the maximum outer diameter of sleeve external side wall 47.

To assemble sleeve 37 in bushing 39, an assembler will tilt sleeve 37 so that sleeve axis 51 is perpendicular to bushing axis 61. The assembler then aligns the tilted sleeve 37
15 with slots 65 and inserts sleeve 37 into bushing bore 59, as shown in Figure 8. Sleeve 37 is inserted until its maximum outer diameter portion contacts the lower end of each slot 65. While still inserted, the assembler tilts sleeve 37 to a position with sleeve axis 51 coinciding with bushing axis 61. Once axes 51, 61 coincide, sleeve 37 will be trapped in bushing 39. That is, unless one reverses the installation procedure, sleeve 37 cannot be lifted relative to
20 bushing 39 because the maximum outer diameter of sleeve external side wall 47 is greater than the inner diameter of bushing bore 59 at bushing upper end 53. Similarly, sleeve 37 will not drop downward from bushing 39 because the maximum outer diameter of sleeve external side wall 47 is greater than the inner diameter of bushing bore 59 at bushing lower end 55. Once assembled, sleeve 37 is free to rotate in bushing 39 about the common axes 51, 61.

After assembling sleeve 37 in bushing 39 as shown in Figure 4, the assembler slides the assembly onto pump shaft 25 (Fig. 2) into abutment with the impeller hub 35 directly above. A key (not shown) will insert in sleeve groove 41 to lock sleeve 37 to shaft 25 for rotation therewith. The operator slides the adjacent diffuser 27 over shaft 25 and installs bushing 39 in receptacle 40, such as by an interference fit or a retainer ring (not shown). If by a retainer ring, some mechanism, such a key, will be used to prevent rotation of bushing 39 in receptacle 40. Bushing 39 will be axially fixed to diffuser 27 in the case of an interference fit, or optionally free to move axially a slight amount in the event a retainer ring is used.

During operation, impellers 31 and sleeves 37 rotate with shaft 25. Down-thrust from the impeller 31 above sleeve 37 transfers through impeller hub 35 to sleeve 37. The load path for the down-thrust passes through sleeve 37 and bushing 39 to diffuser 27 and housing 23. The downward force passes from the lower portion of sleeve external side wall 47 to a lower portion of bushing internal side wall 63. Similarly, during up-thrust, spacer 38 transfers the up-thrust from the next lower impeller 31 to sleeve 37. The upthrust load path transfers through sleeve 37 and bushing 39 to diffuser 26. The upward directed force passes through an upper portion of sleeve external side wall 47 into an upper portion of internal side wall 63 of bushing 39. Sleeve 37 and bushing 39 serve as a radial bearing for shaft 25, as well as a thrust bearing for upward and downward directed thrust.

While, the disclosure has been shown in only one of its forms, it should be apparent to those skilled in the art that is susceptible to changes.

Claim:

1. A submersible pump assembly, comprising:

a centrifugal pump having a drive shaft and a plurality of stages, each of the stages having an impeller and a diffuser, the impellers being mounted to the drive shaft for rotation therewith, the diffusers being mounted in a housing of the pump for non rotation;

a motor operatively coupled to the pump for rotating the drive shaft;

a bearing in at least one of the stages, comprising:

a sleeve having a cylindrical opening coupled to the drive shaft for rotation therewith, the sleeve having upper and lower ends and an outer side wall facing radially outward relative to a sleeve axis, the outer side wall curving outward when viewed in a sleeve axis plane, defining upper and lower outer diameters at the upper and lower ends of the sleeve that are smaller than an intermediate outer diameter halfway between the upper and lower ends;

a bushing mounted in the diffuser of said at least one of the stages for non rotation, the bushing having a bore with a bore axis, the bore having an inner side wall curving inward when viewed in a bore axis sectional plane, defining upper and lower inner diameters at upper and lower ends of the bushing that are smaller than an intermediate inner diameter halfway between the upper and lower ends of the bushing;

the sleeve locating in the bore with the outer side wall in rotational sliding contact with the inner side wall of the bore about the bore axis;

an upper hub member of the impeller of one of the stages located above the sleeve in engagement with the upper end of the sleeve, the upper hub member applying a downward

directed force to the sleeve and from the sleeve to the bushing during down-thrust of the pump; and

a lower hub member of the impeller of one of the stages located below the sleeve in engagement with the lower end of the sleeve, the lower hub member applying an upward
5 directed force to the sleeve and from the sleeve to the bushing during up-thrust of the pump.

2. The assembly according to claim 1, further comprising:

a pair of slots formed in the bore of the bushing 180 degrees apart from each other and extending into the bore of the bushing from one of the ends of the bushing, each of the slots having a circumferential width at least equal to a height of the sleeve from the lower end
10 to the upper end of the sleeve, the slots being radially spaced apart from each other a distance greater than the intermediate outer diameter of the sleeve; and wherein,

the slots enable the sleeve to be inserted into the bore of the bushing while the sleeve axis is perpendicular to the bore axis, then tilted so that the sleeve axis coincides with the bore axis.

15 3. The assembly according to claim 1, wherein:

the sleeve and the bushing are formed of materials harder than the diffuser.

4. The assembly according to claim 1, further comprising:

a pair of slots formed in the bore of the bushing 180 degrees apart from each other and extending into the bore of the bushing from one of the ends of the bushing to a
20 termination point at the intermediate inner diameter of the inner side wall of the bushing, each of the slots having a circumferential width at least equal to a height of the sleeve from

the lower end to the upper end of the sleeve, the slots being radially spaced apart from each other a distance greater than the intermediate outer diameter of the sleeve; and wherein,

the slots enable the sleeve to be inserted into the bore of the bushing while the sleeve axis is perpendicular to the bore axis, then tilted so that the sleeve axis coincides with the
5 bore axis.

5. The assembly according to claim 1, wherein:

an upper portion of the outer side wall of the sleeve is in rotational sliding engagement with an upper portion of the inner side wall of the bushing;

a lower portion of the outer side wall of the sleeve is in rotational sliding engagement
10 with a lower portion of the inner side wall of the bushing; and

an intermediate portion of the outer side wall of the sleeve is in rotational sliding engagement with an intermediate portion of the inner side wall of the bushing.

6. The assembly according to claim 1, wherein:

the upper and lower outer diameters of the sleeve equal each other; and

15 the upper and lower inner diameters of the inner side wall of the bushing equal each other.

7. A submersible pump assembly, comprising:

a centrifugal pump having a drive shaft and a plurality of stages, each of the stages having an impeller and a diffuser, the impellers being mounted to the drive shaft for rotation
20 therewith;

a motor operatively coupled to the pump for rotating the drive shaft;

a bearing in at least one of the stages, comprising:

a sleeve coupled to the drive shaft for rotation therewith, the sleeve having upper and lower ends and an outer side wall facing radially outward, relative to a sleeve axis, that is convex and spherical;

5 a bushing mounted in the diffuser of said at least one of the stages for non rotation, the bushing having a bore with a bore axis, the bore having an inner side wall facing radially inward, relative to the bore axis, that is concave and spherical; and

a pair of slots formed in the inner side wall of the bushing 180 degrees apart from each other and extending axially relative to the bore axis, each of the slots having a
10 circumferential width greater than a height of the sleeve between the upper and lower ends of the sleeve, enabling the sleeve to be inserted into the bore through the slots with the sleeve axis and bore axis perpendicular to each other, then tilted 90 degrees to coincide the sleeve axis with the bore axis and position the outer side wall of the sleeve in contact with the inner side wall of the bushing.

15 8. The assembly according to claim 7, wherein each of the slots extends axially relative to the bore axis a distance that is less than a distance from an upper end to a lower end of the bushing.

9. The assembly according to claim 7, wherein each of the slots extends axially relative to the bore axis one-half a distance from an upper end to a lower end of the bushing.

20 10. The assembly according to claim 7, wherein each of the slots has a base wall and two circumferentially spaced-apart side edges extending radially from the base wall.

11. The assembly according to claim 7, wherein:

the inner side wall of the bushing has an upper inner diameter at an upper end of the bushing, a lower inner diameter at a lower end of the bushing, and an intermediate inner diameter halfway between the upper and lower ends of the bushing; and

5 wherein the intermediate inner diameter is greater than the upper inner diameter and greater than the lower inner diameter.

12. The assembly according to claim 7, wherein:

the inner side wall of the bushing has an upper inner diameter at an upper end of the bushing, a lower inner diameter at the lower end of the bushing, and an intermediate inner
10 diameter halfway between the upper and lower ends of the bushing;

wherein the intermediate inner diameter is greater than the upper inner diameter and greater than the lower inner diameter;

each of the slots has a base wall and two side edges circumferentially spaced apart from each other; and

15 the base wall has a circumferential curvature with a radius from the bore axis that is equal to a radius of the intermediate inner diameter of the inner side wall from the bore axis.

13. The assembly according to claim 7, wherein:

the inner side wall of the bushing has an upper inner diameter at an upper end of the bushing, a lower inner diameter at a lower end of the bushing, and an intermediate inner
20 diameter halfway between the upper and lower ends of the bushing;

the upper and lower inner diameters equal each other and the intermediate inner diameter is greater than the upper inner diameter and the lower inner diameter;

each of the slots has an axial length, relative to the bore axis, extending from one of the ends of the bushing halfway to the other end of the bushing; and

5 a distance from one of the slots to the other of the slots throughout the lengths of the slots is at least equal to the intermediate inner diameter.

14. The assembly according to claim 7, wherein:

the sleeve and the bushing are of harder materials than the impeller and the diffuser.

15. The assembly according to claim 7, wherein:

10 the sleeve is a single piece member formed entirely of tungsten carbide; and

the bushing is a single piece member formed entirely of tungsten carbide.

16. A method of pumping well fluid, comprising:

(a) providing a centrifugal pump with a drive shaft and a plurality of stages, each of the stages having an impeller and a diffuser;

15 (b) providing at least one of the stages with a sleeve having upper and lower ends and an outer side wall facing outward, relative to a sleeve axis, the outer side wall curving outward when viewed in a sleeve axis plane, defining upper and lower outer diameters at the upper and lower ends of the sleeve that are smaller than an intermediate outer diameter halfway between the upper and lower ends;

20 (c) providing a bushing in the diffuser of at least one of the stages, the bushing having a bore with a bore axis, the bore having an inner side wall curving inward when viewed in a

bore axis sectional plane, defining upper and lower inner diameters at upper and lower ends of the bushing that are smaller than an intermediate inner diameter halfway between the upper and lower ends of the bushing;

(d) installing the sleeve in the bore of the bushing;

5 (e) coupling a motor to the pump, lowering the pump and the motor into the well and operating the motor to rotate the drive shaft, the impellers, and the sleeve, causing the outer side wall of sleeve to slidably engage the inner side wall of the bushing ;

(f) applying a downward directed force from at least one the impellers above the sleeve to the sleeve and from the sleeve to the bushing during down-thrust of the pump; and

10 (g) applying an upward directed force from at least one of the impellers below the sleeve to the sleeve and from the sleeve to the bushing during up-thrust of the pump.

17. The method according to claim 16, wherein:

step (c) comprises providing a pair of slots in the bore of the bushing 180 degrees apart from each other and extending into the bore of the bushing from one of the ends of the
15 bushing; and

step (d) comprises inserting the sleeve into the bore of the bushing while the sleeve axis is perpendicular to the bore axis, then tilting the sleeve so that the sleeve axis coincides with the bore axis.

18. The method according to claim 16, wherein steps (b) and (c) comprise forming the sleeve
20 and the bushing of materials harder than the diffuser.

19. The assembly according to claim 16, wherein step (f) comprises:

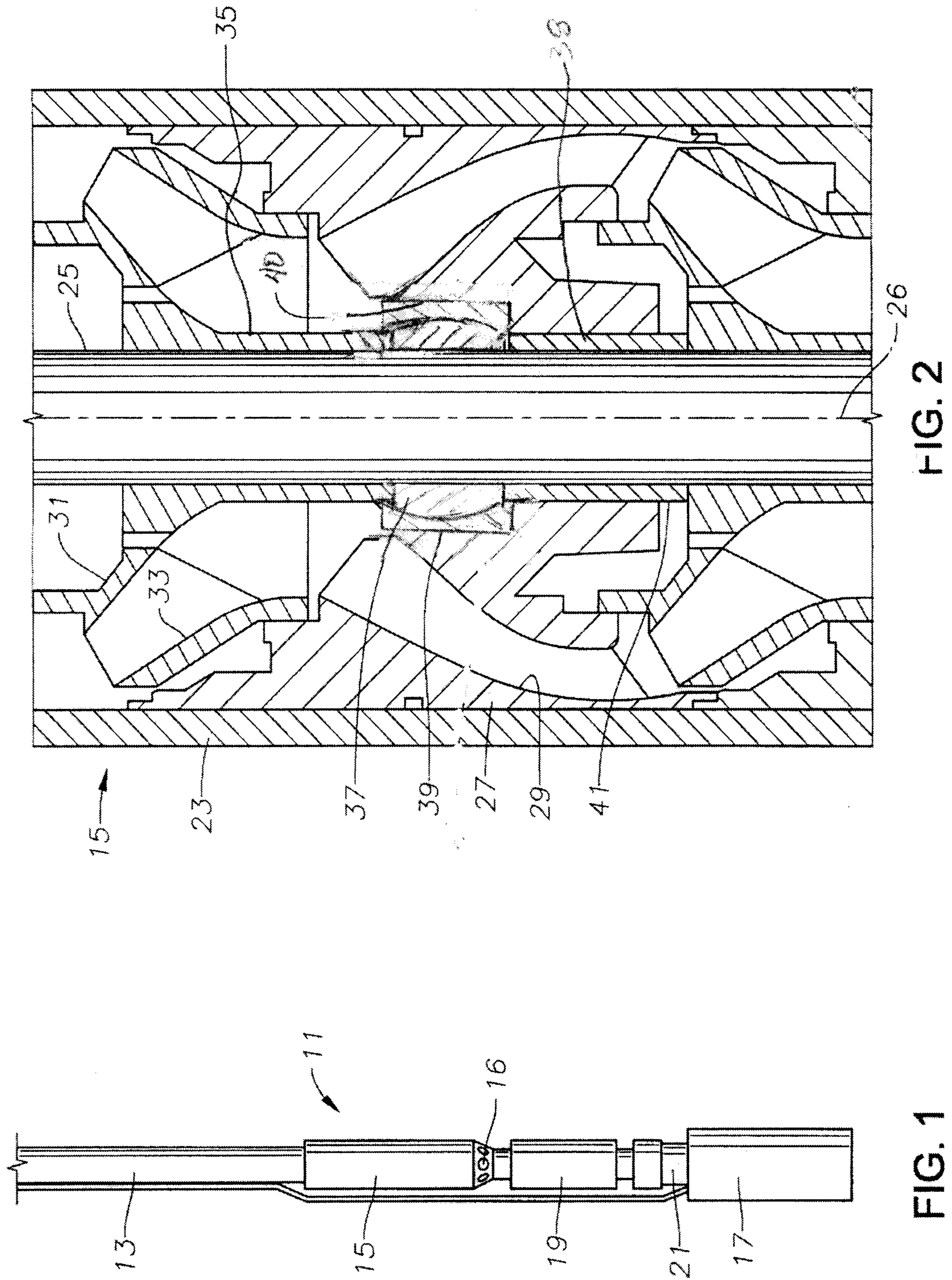
transferring the downward directed force through a lower portion of the outer side wall of the sleeve to a lower portion of the inner side wall of the bushing.

20. The assembly according to claim 16, wherein step (g) comprises:

transferring the upward directed force through an upper portion of the outer side wall
5 of the sleeve to an upper portion of the inner side wall of the bushing.

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