March 8, 1966 K. L. SHALLENBERG 3,238,879

SUBMERSIBLE PUMP WITH MODULAR CONSTRUCTION

Filed March 30, 1964 3 Sheets-Sheet 1

FIG. 1

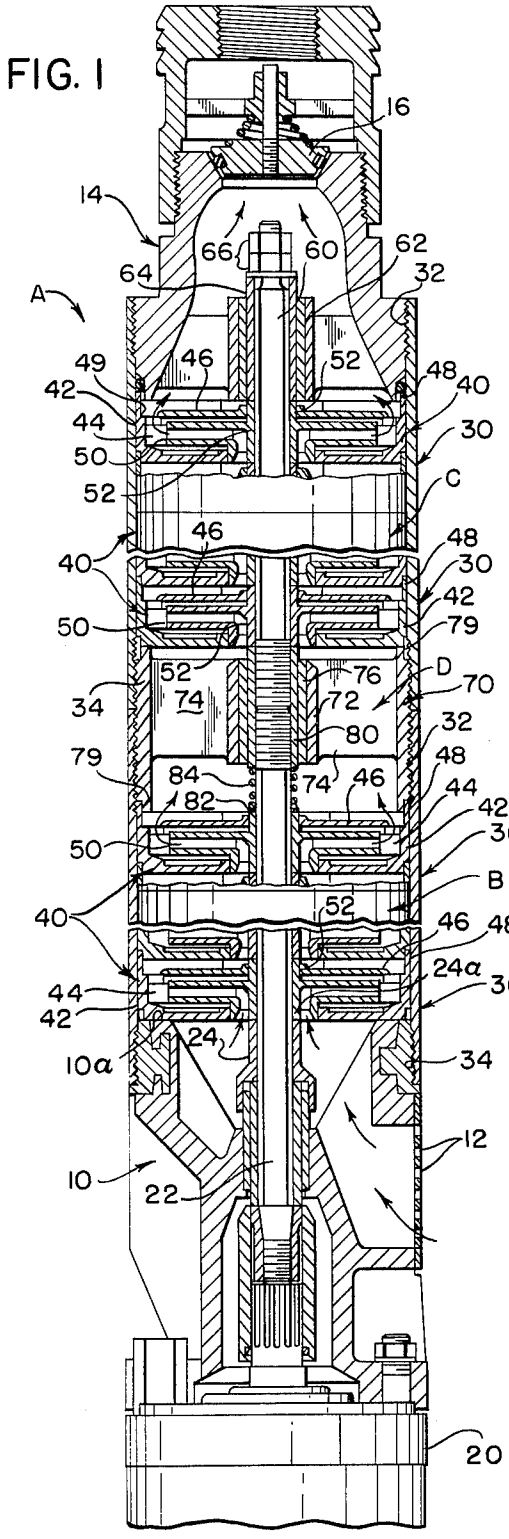


FIG. 2

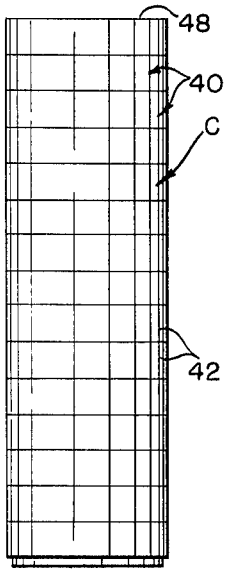


FIG. 3

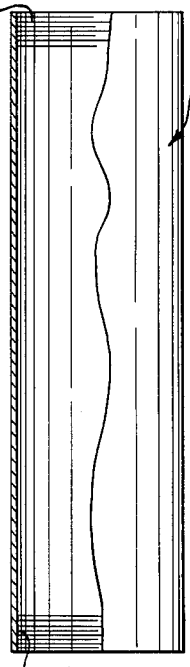
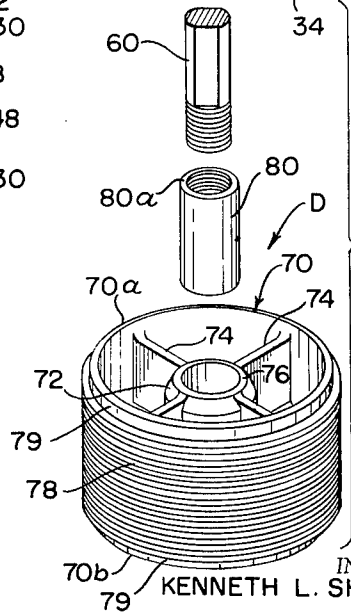


FIG. 4



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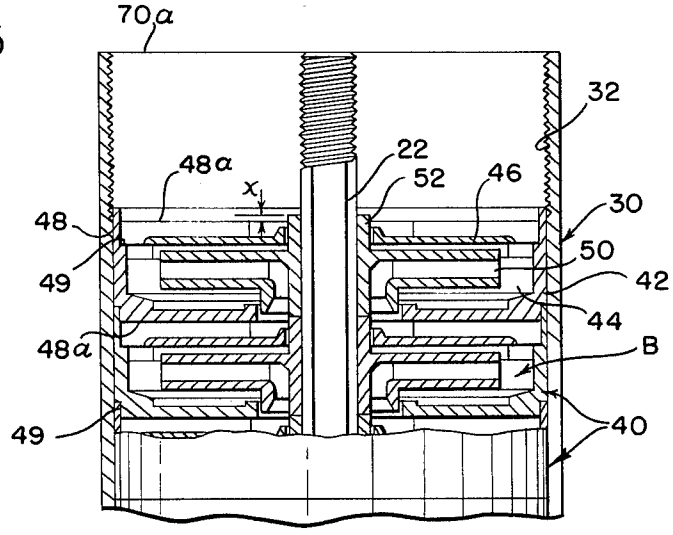
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SUBMERSIBLE PUMP WITH MODULAR CONSTRUCTION

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FIG. 5



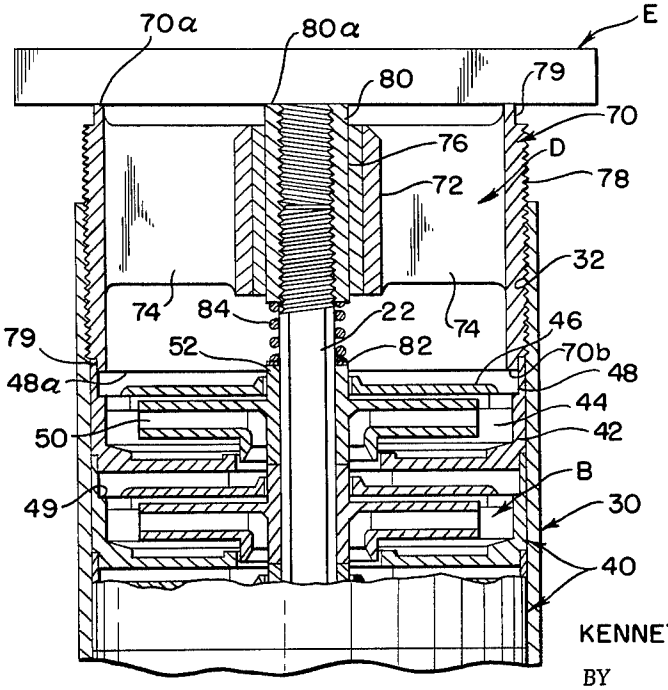


FIG. 6

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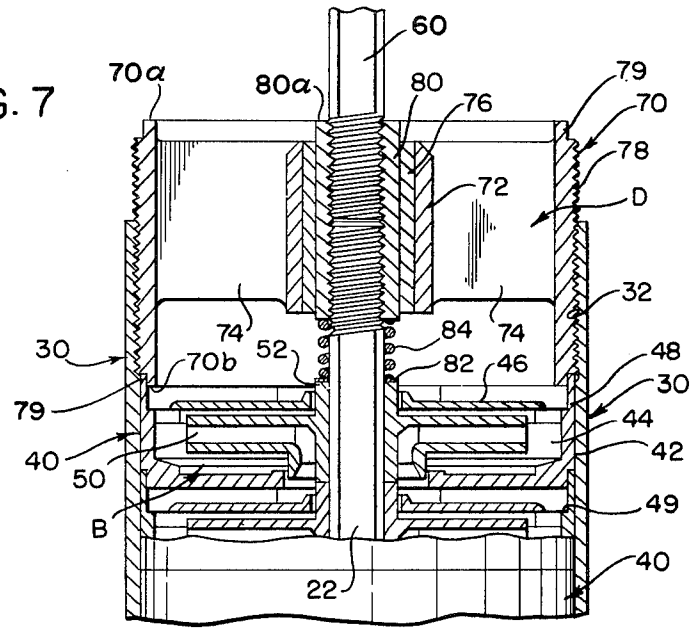
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SUBMERSIBLE PUMP WITH MODULAR CONSTRUCTION

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FIG. 7



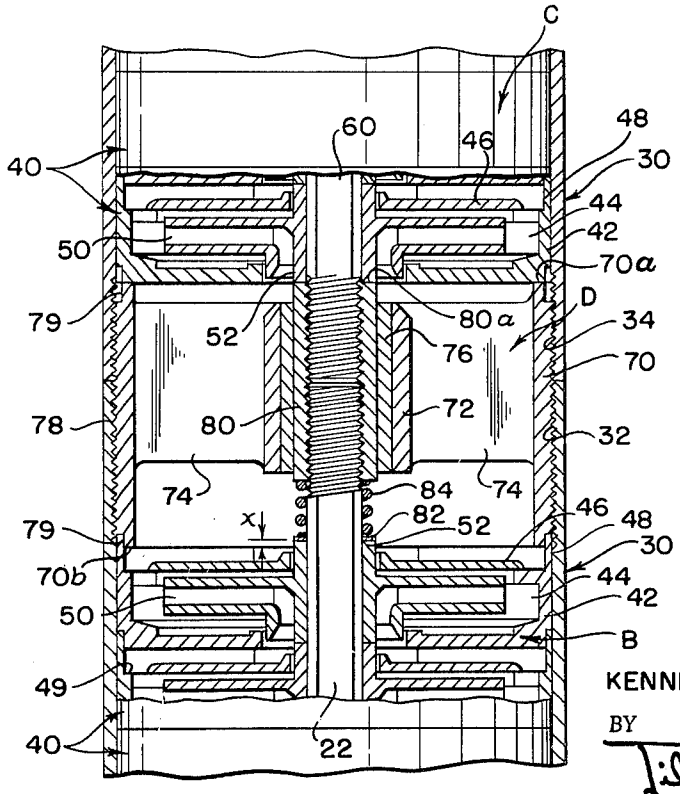


FIG. 8

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United States Patent Office

3,238,879
Patented Mar. 8, 1966

3,238,879

SUBMERSIBLE PUMP WITH MODULAR CONSTRUCTION

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Filed Mar. 30, 1964, Ser. No. 355,795
13 Claims. (Cl. 103—102)

The present invention pertains to the art of submersible pumps and more particularly to a submersible pump with a modular construction.

This invention is particularly applicable to a submersible pump of the type having a linear stack of axially mounted pumping units, each unit comprising a diffuser with an inner pumping chamber and an impeller rotatable within this chamber, and it will be described with particular reference thereto; however, it will be appreciated that the invention has much broader applications and may be used in a submersible pump having other types of lineally stacked pumping units.

It has become common practice to construct a submersible pump with a plurality of lineally stacked pumping units, each pumping unit having a stationary diffuser with an inner pumping chamber and an impeller rotatably mounted within the pumping chamber. These individual pumping units are stacked on a common, motor driven shaft and within a cylindrical metal casing or cover so that the separate diffusers form axially spaced pumping chambers along the shaft and the impellers are positioned, one on top of the other, to rotate within these spaced pumping chambers. This pump construction produces an economical and efficient pump for doing work at great depths, primarily in oil or water wells. The separate diffusers and impellers can be mass produced by molding or casting these primary members to their final dimensions.

In operation, each of the stacked pumping units, including a diffuser and an impeller, forms a separate pumping stage within the casing and the pumping unit receives liquid from a lower level and pumps it to an upper level where it is directed into the next upper pumping unit. The liquid progresses from one pumping unit to the next higher unit until it reaches the top of the submersible pump where it is forced by appropriate plumbing to a pump discharge positioned substantially above the pump itself.

As the depth or pressure head, against which the submersible pump forces the liquid, increases, it becomes necessary to increase the pump capacity by stacking more of these individual pumping units in the cylindrical casing. Also, the size of the motor driving the shaft must be increased to drive the increased number of individual pumping units. The general operation of the pumping units is not changed as more units are stacked within the casing.

In assembling a submersible pump of the construction described, an impeller is positioned within the pumping chamber of a diffuser to form an individual pumping unit and the pumping unit is positioned within the casing with the impeller being mounted over the drive shaft. The inner diameter of the casing locates the separate diffusers and the drive shaft centers the individual impellers with respect to the diffusers so that the impellers and diffusers within the pump casing are concentric with respect to each other. When positioned within the pump casing, the diffusers are stacked upon each other and the rotatable impellers are stacked upon each other so that

the location of the upper impellers, within their respective diffuser chambers, is determined by the axial dimensions of all lower impellers. Since the impellers are usually cast or molded and require at least a slight amount of dimensional tolerance, it has been found that the number of pumping units which can be practically stacked, one upon the other, is limited.

If a large number of pumping units were stacked within the cylindrical pump casing, the upper impellers are not accurately positioned within their diffuser chambers. In fact, these upper impellers often rub or drag on the upper or lower surface of the pumping chamber within the diffusers according to the dimensional stacking of the lower impellers on which the upper impellers are positioned. This mislocation of the upper impellers increases the frictional forces in the pump and, thereby, decreases the efficiency of the pump. In some instances this mislocation of the upper impellers completely incapacitates the pump. This problem is accentuated by the dimensional variations of the diffusers themselves. Consequently, the number of pumping units and, thus, the capacity of this type of submersible pump has heretofore been limited. In practice, it has been found that only thirty individual pumping units could be assembled into a single pump casing without experiencing assembly and operational difficulties. These thirty pumping units approximately correspond to a two horsepower pump capacity; therefore, a submersible pump of the type described was limited in practice to approximately two horsepower.

There is a great demand for a submersible pump having a capacity in the range of 3–5 horsepower. For the reasons stated above, this horsepower range could not be, heretofore, met economically by a submersible pump of the type having lineally stacked pumping units. To produce a five horsepower pump having the stacked pumping units, as described, 75–80 individual pumping units must be stacked within the pump casing. It is obvious that only a slight variation in the manufacturing tolerances of the impellers or diffusers, when magnified 75–80 times, would cause the upper impellers to drag or rub on the corresponding diffusers.

One obvious solution of this problem would be to manufacture the impellers and diffusers with no dimensional variation in the axial direction; however, in practice this is impossible. Even if this could be done, the thermal expansion of the parts, when magnified many times, could cause assembly and operational difficulties with a submersible pump requiring a large number of individual stacked pumping units. Thus, this obvious solution to the problem is not practical and, heretofore, submersible pumps of the type described were not produced for operation in an environment requiring substantially more than two horsepower pumping capacity per pump.

The capacity of each pumping unit generally cannot be increased because the diameter of the casing is somewhat limited if the pump is to be positioned within the casing of an oil well. Also, it is not practical to increase the capacity of the pumping units because this would require separate pumping units for all sizes of pumps and a large parts inventory would be required. Also, many separate molds would be required for the various parts in the pumping units of different capacity ratings.

The present invention is directed toward a device for use in assembly of a submersible pump having a plurality of lineally stacked pumping units as described which device eliminates the problem discussed above,

even when 75 or more individual pumping units are stacked within the pump casing to produce a high capacity pump.

In accordance with the present invention there is provided a submersible pump including at least first and second pumping modules, each of the modules comprising a number of lineally stacked pumping units, each unit having a first pumping member with a pumping chamber and a second pumping member within the pumping chamber and axially movable with respect to the first member, each module having an initial and final pumping unit at opposite ends thereof, means for causing relative rotational movement between the pumping members to cause a pumping action with the output of one pumping unit communicated with the input of the next higher pumping unit, and a device between the first and second modules to compensate for error in the axial location of the first member with respect to the second member in the final pumping unit of the first module so that the error is not transmitted to the second module, this device comprises a cylindrical body portion resting on the first member of the final pumping unit in the first module, and an upper aligned surface for supporting both the first and second members of the initial pumping unit of the second module.

By utilizing the device as defined above, the dimensional error caused by the lower pumping impellers is intermittently compensated for in the stack of pumping units so that the error never builds up to a prohibitive level. In practice, each module includes 15 pumping units which number has been found to be compatible with manufacturing tolerances so that the upper impeller freely rotates within its diffuser without dragging or rubbing on the upper or lower surfaces of the pumping chamber within the diffuser.

The primary object of the present invention is the provision of a submersible pump of the type having stacked pumping units, each comprising a diffuser and an impeller which submersible pump has a higher pumping capacity than heretofore practical.

Another object of the present invention is the provision of a submersible pump of the type having stacked pumping units, each comprising a diffuser and an impeller which submersible pump is economical to produce with a higher pumping capacity than heretofore practical.

Still another object of the present invention is the provision of a submersible pump of the type having stacked pumping units, each comprising a diffuser and an impeller which submersible pump can include over 75 individual pumping units without high frictional drag between the upper impellers and their respective diffusers.

Another object of the present invention is the provision of a submersible pump, of the type described, which pump includes a device to compensate for dimensional tolerances in the impeller and diffusers.

Yet another object of the present invention is the provision of a submersible pump, of the type described, which pump is formed from two or more pumping modules each having a limited number of pumping units.

Still a further object of the present invention is the provision of a submersible pump, of the type described, which pump is adapted to have its pumping capacity changed by including a standard cover and an additional pumping module having a limited number of pumping units.

The invention may take physical form in certain parts and arrangements of parts, the preferred embodiment of which will be described in detail in this specification and illustrated in the accompanying drawings which are a part hereof and wherein:

FIGURE 1 is a cross-sectional, partially cut away, side elevational view illustrating the preferred embodiment of the present invention;

FIGURE 2 is a side elevational view illustrating a pumping module assembled in accordance with the present invention;

FIGURE 3 is a partially cross-sectioned side elevational view illustrating a standard pump cover or casing constructed in accordance with the present invention;

FIGURE 4 is a partial exploded view illustrating the preferred embodiment of the present invention; and,

FIGURES 5–8 are partial, cross-sectional, side elevational views illustrating progressively the assembly of the preferred embodiment of the present invention.

Referring now to the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only and not for the purpose of limiting same, FIGURE 1 shows a submersible pump A including an inlet housing **10** with a fluid opening **12** and an upper mounting edge **10***a*; an outlet housing **14** with a valved fluid opening **16**; and, a driving motor or means **20** having a drive shaft **22** for rotating the various pumping members and an upper mounting sleeve **24** with an axially facing mounting edge **24***a*. The inlet housing **10** and outlet housing **14** are mounted together by two or more serially connected, pump covers or casings **30** which are substantially identical and are shown in FIGURE 3. Each cover **30** has an upper threaded portion **32** and a lower threaded portion **34**. Although only two covers **30** are shown, it will be hereinafter appreciated that more covers can be included to increase the axial length and the pumping capacity of submersible pump A. The lower cover **30** is threadably connected onto inlet housing **10** and the upper cover **30** is threadably connected onto the outlet housing **14** so that these covers define an inner pumping cavity which receives a plurality of serially arranged pumping modules B, C. Two pumping modules are sufficient to illustrate the present invention; however, it is appreciated that more modules can be used in a maner to be hereinafter described in detail to produce a higher capacity pump.

The upper pumping module C is illustrated separately in FIGURE 2. This module is illustrated with fifteen lineally positioned pumping units **40**. Fifteen pumping units are shown because it has been found that this number of units produces a one horsepower pumping capacity for the submersible pump. If desired, a lesser number of pumping units could be included within the module to produce a module less than one horsepower pumping capacity. Also, in some instances, slightly more than fifteen units can be used. All such variations in the number of pumping units in the module C are within the contemplation of the present invention and may be used without departing from the intended scope of the present invention.

As explained above, the module C and also the module B, includes a plurality of individual, or separate, pumping units **40**. In accordance with the illustrated embodiment of the present invention, each pumping unit includes a diffuser or first pumping member **42** having an inner pumping chamber **44**, a cover or manifold **46**, an upper mounting rib **48** and a lower mounting recess **49** and an impeller or second pumping member **50** with a mounting hub **52** adapted to be drivingly received by the shaft **22** of the lower module B or a shaft **60** of the upper module C. Referring more particularly to the drive shaft **60**, which drivingly engages the hubs **52** in the pumping units **40** of module C, the drive shaft **60** is journaled in an upper bearing **62** and receives a clamping sleeve **64** which is tightened down upon the hub of the upper impeller **50** by a plurality of nuts **66** to clamp the impellers in module C onto the shaft **60**.

Many details of the pump have been eliminated for the purposes of simplicity; however, it is appreciated that the pump includes a plurality of lineally stacked pumping units **40**, each including a rotatable member, impeller **50**, and a stationary member, diffuser **42**, which forms a

pumping chamber 44 in which the impeller is rotated. As indicated by the arrows in FIGURE 1, liquid enters the pump through opening 12 and progresses axially into the lowermost impeller 50 which is rotated within a chamber 44. The walls of chamber 44 are appropriately contoured in a manner not shown in detail, to direct the liquid upwardly into the inlet of the next higher impeller 50. This pumping procedure continues with the liquid going from one pumping unit 40 to the next higher pumping unit until the liquid reaches valved opening 16 through which it is forced to an appropriate pump output.

The axial spacing of the diffusers 42 along the shafts 22 and 60, is determined by the interaction of the mounting rim 48 and the mounting recesses 49 of adjacent diffusers; therefore, the upper diffusers are positioned within the covers 30 in accordance with the axial dimensions of the lower diffusers. The same is true of the impellers 50. The axial position of the impellers, with respect to shafts 22, 60, is determined by the axial dimensions of hubs 52 and the position of the uppermost impellers is controlled by the axial dimensions of the lower impellers.

It is seen in FIGURE 1 that each impeller 50 is freely movable in an axial direction with respect to the diffusers so that no axially facing surfaces are in rubbing contact. This reduces the friction against which motor 20 must rotate; however, it also allows the upper impellers to come in contact with the surfaces of chamber 44. If this happens, then the impellers will rub or scrape on the diffusers and the frictional forces will be increased. In some instances the friction is prohibitively increased or there is a complete interference of parts so that the parts cannot rotate freely. In the past, increased pumping capacity of a pump, such as submersible pump A was accomplished by including more pumping units 40. As more units were assembled onto the drive shaft 22, the tolerance allowed on the axial dimensions of the diffusers and impellers would often cause a complete mislocation of the upper impellers with respect to the upper diffusers. The present invention is directed toward an inexpensive and effective solution of this problem.

In accordance with the present invention, the capacity of the pump A is not increased by simply including more pumping units 40 on shaft 22. In accordance with the present invention, a device D, see FIGURE 4, is positioned between module B and module C. This device functions to compensate for any dimensional variation between the impeller 50 and diffuser 42 at the upper end of module B. After this dimensional compensation of device D, the impellers and diffusers of the upper module C start at the optimum axial position and any error in the dimensions of these members in the upper module C only affects the diffusers and impellers in that particular module. If a higher pumping capacity is desired, another pumping module C is positioned over the illustrated module C; and a similar device D is positioned between these two modules to compensate for any variation in the position of the impeller and diffuser at the upper position of the lowermost module C. It is apreciated that a number of modules C can be positioned between the housings 10 and 14 to substantially increase the pumping capacity of pump A without causing dimensional difficulties caused by the dimensional tolerances in the pumping units 40.

Although the dimensional error compensating device D could take a variety of structural embodiments, in accordance with the present invention, the device D includes an outer cylindrical ring or first element 70 having an upper mounting edge 70*a* and a lower mounting edge 70*b*, a hub 72 connected onto the ring 70 by circumferentially spaced, radially extending webs 74, a bearing sleeve 76, an outer threaded portion 78 adapted to receive the threaded portions 32, 34 of covers 30, and mounting recesses 79 dimensioned in accordance with the recesses 49 of diffusers 42 so that the ring 70 can fit over the upper portion of diffuser 42 in a manner shown in FIGURE 1. Axially slidable and journaled within the bearing sleeve 76 is an adjustable sleeve or second element 80 having an inner threaded bore and an upper mounting edge 80*a* and extending between the upper impeller of module B and the lower impeller of module C. A bearing washer 82 is adapted to be positioned on hub 52 of the uppermost impeller 50 in module B, as shown in FIGURE 1. Between this washer and the adjustable sleeve 80 there is positioned a biasing means, taking the form of a coil spring 84. Sleeve 80 has internal threads to coact with the threads on shaft 22 and form a means for adjusting the relative axial location of the first element 70 and the second element or sleeve 80.

Referring now to FIGURE 5, the uppermost portion of module B is illustrated in detail. The lines 48*a* illustrate the position of the lower edge of the next higher diffuser which is to be positioned over mounting rim 48. The position of line 48*a* on each diffuser is determined by the depth of recess 49 in the bottom of the diffusers. Since the bottom of the next higher diffuser should be exactly in line with the bottom of the next higher impeller to properly align the impeller in the diffuser, the distance *x*, as shown in FIGURE 5, represents the dimensional stacking error caused by stacking the various impellers, one on top of the other, and stacking the various diffusers, one on top of the other. If the capacity of pump A were increased by increasing the number of pumping units 40, this error *x* would be increased at the uppermost pumping unit so that the impeller 50 of such a pumping unit would rub the manifold 46 or the lower surface of the pumping chamber 44. The error *x* is representative in nature and it is to be appreciated that this error could be an impeller hub 52 higher than line 48*a*, as shown in FIGURE 5, or a hub 52 lower than the line 48*a*. Irrespective of the deviation between the upper surface of the uppermost impeller in module B and line 48*a* of the uppermost diffuser, the device D will compensate for this variation in a manner to be hereinafter described in detail.

FIGURE 6 illustrates the initial step in assembling the device D onto the upper end of module B. The threaded portion 78 of ring 70 is screwed into threaded portion 32 of cover 30 until the recess 79 abuts rim 48 of the upper diffuser 42. A slight amount of torque on the ring 40 will secure all of the diffusers within the cover 30. The upper mounting edge 70*a* of ring 70 is located in accordance with the position of line 48*a* of the upper diffuser. Thereafter, the washer 82 is positioned around shaft 22 and on the upper surface of hub 52 and coil spring 84 is dropped over the shaft 22. Adjustable sleeve 80, which is slidably and rotatably journaled within bearing sleeve 76, is then screwed onto the upper threaded portion of shaft 22. Sleeve 80 is threaded downwardly until the upper mounting edge 80*a* is aligned with edge 70*a* of ring 70. In other words, the edges 70*a*, 80*a* form what could be termed an upper aligned surface for device D. To determine the alignment of edges 70*a*, 80*a*, a straight edge E is positioned over the two edges until both edges are in contact with the lower surface of the straight edge.

Referring now to FIGURE 7, after the sleeve 80 is axially positioned on drive shaft 22, the drive shaft 60 of module C is threaded into the sleeve 80 until it abuts the upper end of shaft 22. By exerting sufficient torque on shaft 60, a rigid connection between shaft 60 and shaft 22 is accomplished within the sleeve 80. Thereafter, the sleeve 80 is axially fixed and forms a bearing with sleeve 76 to radially position the drive shaft between the upper and lower modules. In other words, the device D not only compensates for dimensional errors between the impeller 50 and diffuser 42 of the module B, but also, forms an intermediate bearing between the lower module B and the upper module C. In FIGURE 7, it is noted that the upper mounting edges 70*a*, 80*a* remain in axial alignment with respect to each other.

Referring now to FIGURE 8, the upper cover 30 is threaded onto threaded portion 78 of ring 70. Torque is

exerted on the upper cover to lock this upper cover with the lower cover **30** which is also threadably mounted on the ring **70**. After the upper cover is positioned on the device D, the pumping units **40** forming the upper module C are positioned over the drive shaft **60** with the lower surface of the lowermost diffuser **42** in module C resting on mounting edge **70***a* and the lower surface of the lowermost impeller hub **52** in module C resting upon the mounting edge **80***a* of sleeve **80**. In this manner, the diffuser and impeller of the lowermost pumping unit **40** of module C are axially positioned irrespective of the error *x* in the uppermost pumping unit **40** of module B.

A device similar to device D will be positioned at the upper part of module C if a further module C is to be positioned thereon. This could be continued until the desired pumping capacity of the pump A is obtained. It is appreciated that the shaft **60** may be modified at the upper portion so that the upper and lower ends of this shaft are identical, without departing from the intended spirit and scope of the invention. If these shafts are identical, having the form of the lower end of shaft **60** as shown, it is not necessary to determine which direction the shaft should be mounted within the module C. Also it is within the contemplation of the present invention to mount the shaft **60** with the module C so that the shaft and pumping units **40** can be taken as a unit and added to the pump A to increase the pump capacity. The standard cover or casing **30** as shown in FIGURE 3, is used with the module C to increase the pumping capacity. By using a standard cover, only one size cover is required for a small capacity pump or a larger capacity pump. The only difference being that the larger capacity pump will have more serially arranged covers forming the outer casing of the pump.

The present invention has been described in connection with one structural embodiment; however, various structural changes may be made in this embodiment without departing from the intended spirit and scope of the present invention as defined in the appended claims.

Having thus described my invention, I claim:

1. In a submersible pump having at least first and second axially spaced pumping modules, each of said modules comprising a number of lineally stacked pumping units with each unit having a first pumping member with a pumping chamber and a second pumping member within said pumping chamber and axially movable with respect to said first member, said second pumping members being rotatable in said chambers without contact with said first members each module having an initial and final pumping unit at opposite ends thereof, means for causing relative rotational movement between said members to cause a pumping action with the output of one pumping unit communicated with the input of the next higher pumping unit, the axial length of said first pumping members in each module being determined by the summation of the axial thickness of the first members in that module and the axial length of said second pumping members in each module being determined by the summation of the axial thickness of the second members in that module, a tolerance error at one end of said first module, said error being the difference between the axial lengths of said first and second members in that module and being exhibited by a deviation in the relative locations of said first and second members in the final pumping unit of said first module, the improvement comprising: an error compensating device between the first and second members of said final pumping unit of said first module and the first and second pumping members in the initial pumping unit of said second module, said device comprising a first element extending between said first members, a second element extending between said second members and means for adjusting the relative axial location of said first and second elements so that the first and second members of the initial pumping unit of said second module are symmetrically located irrespective of said tolerance error of the first and second members of said final unit of said first module.

2. The improvement as defined in claim **1** wherein said first element abuts said first members of said final pumping unit of said first module and said initial pumping unit of said second module and fixes the axial spacing of these first members, said second element abuts said second member of said initial pumping unit of said second module, and said adjusting means includes a drive shaft extending from said first module and means for adjustably locating said second element on said drive shaft so that the first and second members of said initial pumping unit are symmetrically positioned in an axial direction.

3. The improvement as defined in claim **2** wherein said second element is threadably secured onto said shaft for adjustment thereon.

4. The improvement as defined in claim **2** wherein there is included a spring surrounding said drive shaft and extending between said second element and the second member of the final pumping unit of said first module.

5. The improvement as defined in claim **1** wherein said first and second elements are concentric sleeves, said first element including an inner concentric bearing, and said second element being journaled in said bearing for rotation with respect to said first element.

6. The improvement as defined in claim **1** wherein each module includes an outer cover with a threaded portion at each end thereof, said first element being a sleeve having an outer threaded surface matching the threaded portions of said covers of each module whereby said covers of said modules can be threadably joined by said first element extending between said covers.

7. The improvement as defined in claim **1** wherein said first element is a sleeve having an inner bearing, said second element is a sleeve reciprocally mounted in said bearing, said first and second modules each having a drive shaft with a threaded end portion, said second element having a threaded inner bore for receiving said threaded portions, and said adjusting means including the threaded inner bore of said second members and said threaded portions of said drive shafts.

8. The improvement as defined in claim **1** wherein said modules include 15 or less pumping units.

9. A submersible pump including at least first and second pumping modules, each of said modules comprising a number of lineally stacked pumping units with each unit having a first pumping member with a pumping chamber and a second pumping member within said pumping chamber and axially movable with respect to said first member, said second pumping members being rotatable in said chambers without contact with said first members each module having an initial and final pumping unit at opposite ends thereof, means for causing relative rotational movement between said members to cause a pumping action with the output of one pumping unit communicated with the input of the next higher pumping unit, and a device between said first and second modules to compensate for error in the axial location of said first member with respect to said second member in the final pumping unit of said first module so that said error is not transmitted to said second module, said device comprising a cylindrical body portion resting on the first member of said final pumping unit in said first module, and an upper aligned surface for supporting both said first and second members of said initial pumping unit of said second module.

10. A submersible pump as defined in claim **9** wherein said first members are stationary and said second members are rotated in unison, and said upper aligned surface is formed from the end of said body portion opposite said final pumping unit and the end of a sleeve within said body portion and concentric therewith.

11. A submersible pump as defined in claim **10** wherein there is included a biasing spring between said sleeve and said second member in the final pumping unit of said first module.

12. A submersible pump as defined in claim **10** including a means for axially adjusting said sleeve with respect to said body portion to assure alignment of said ends.

13. A submersible pump as defined in claim **8** wherein said modules includes 15 or less pumping units.

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