

April 19, 1955

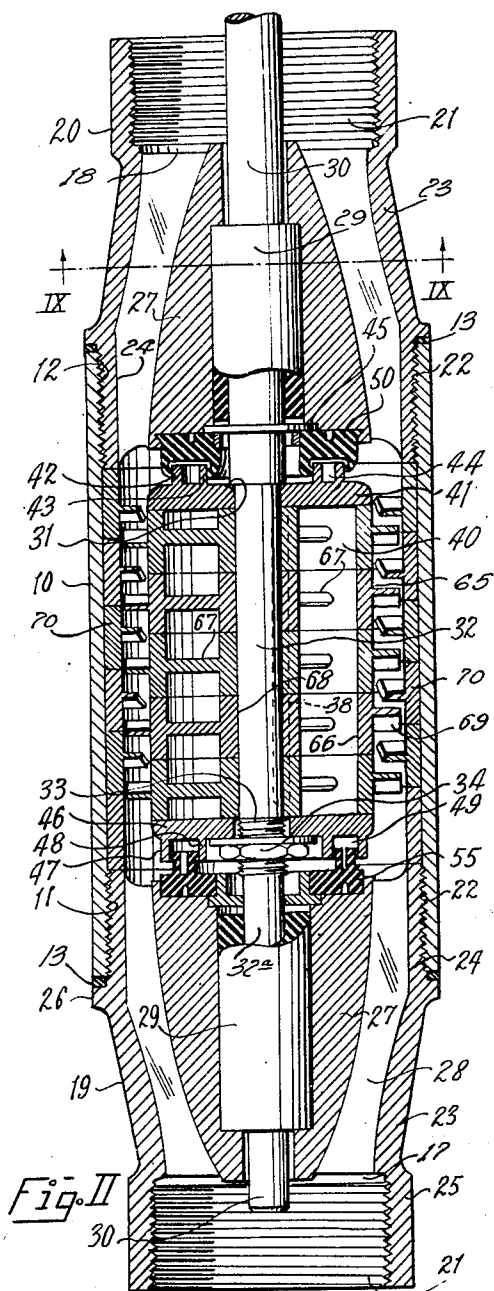
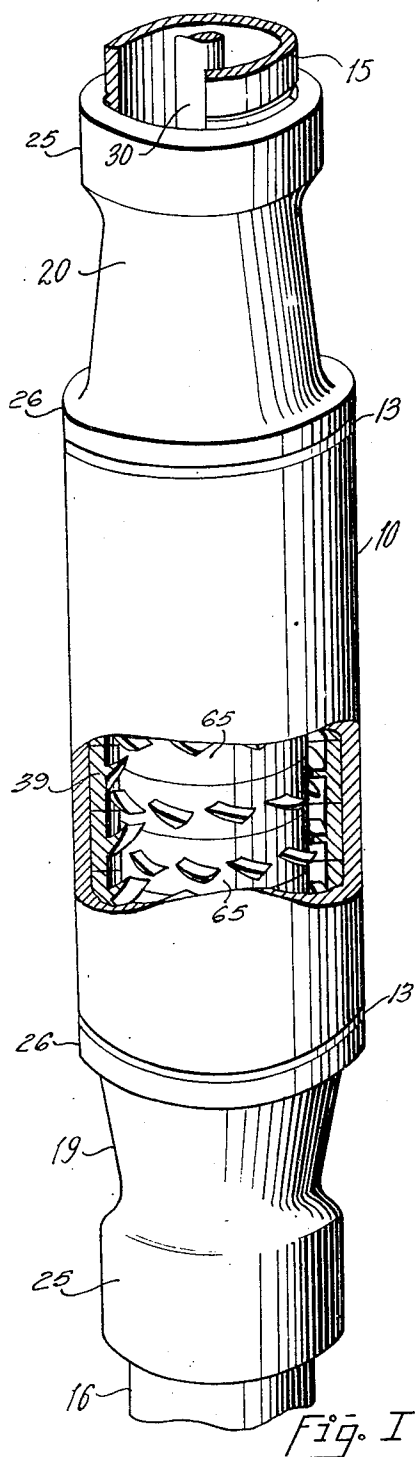
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2,706,451

AXIAL FLOW PUMP

Filed Oct. 20, 1948

8 Sheets-Sheet 1



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AXIAL FLOW PUMP

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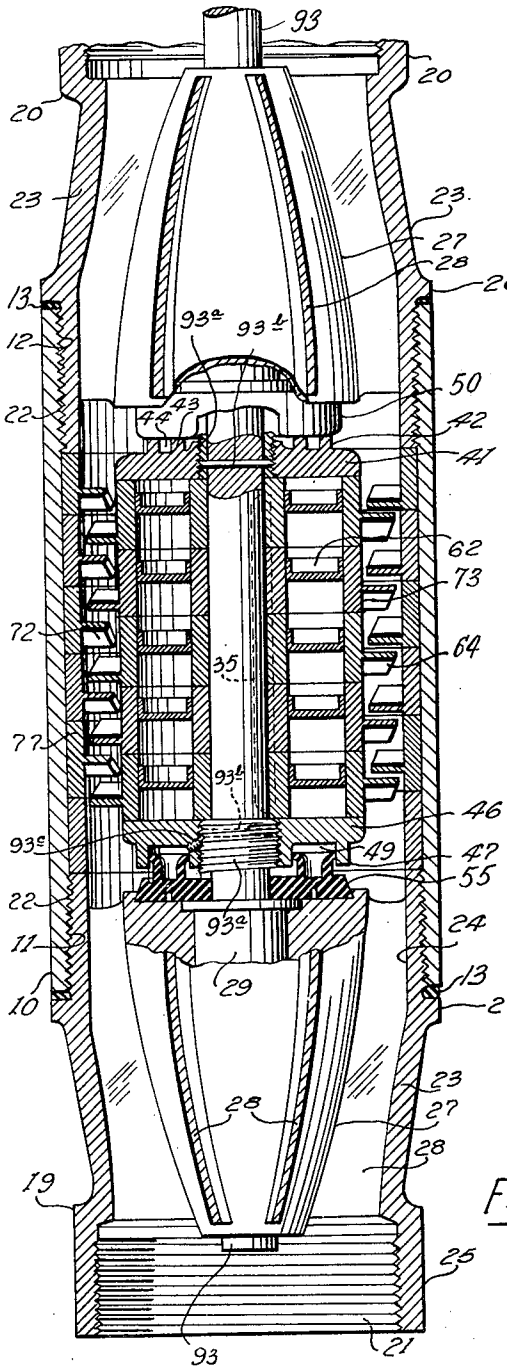


Fig. III

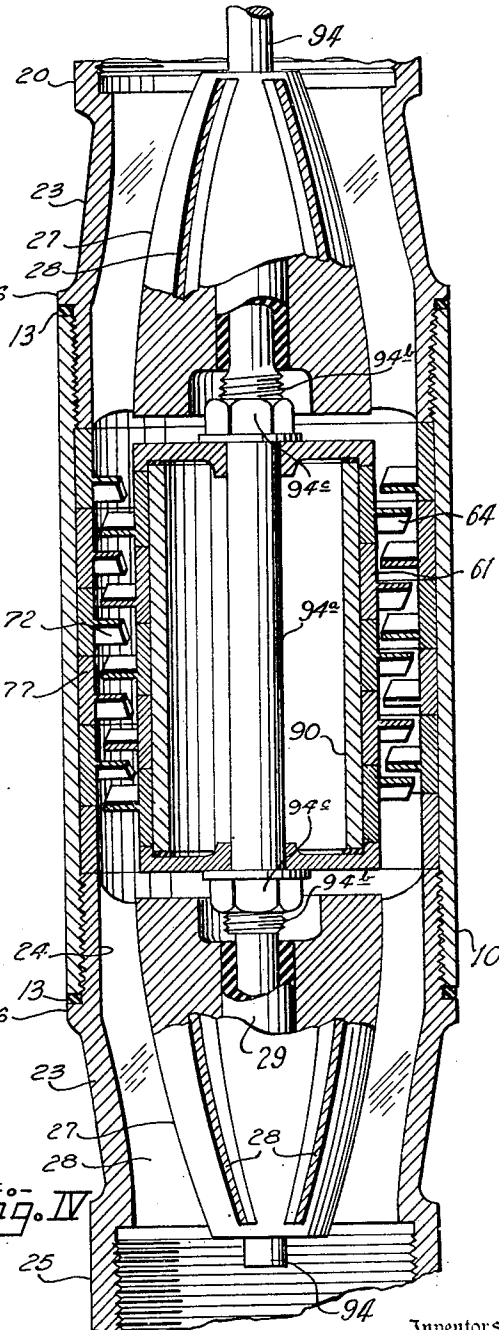


Fig. IV

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AXIAL FLOW PUMP

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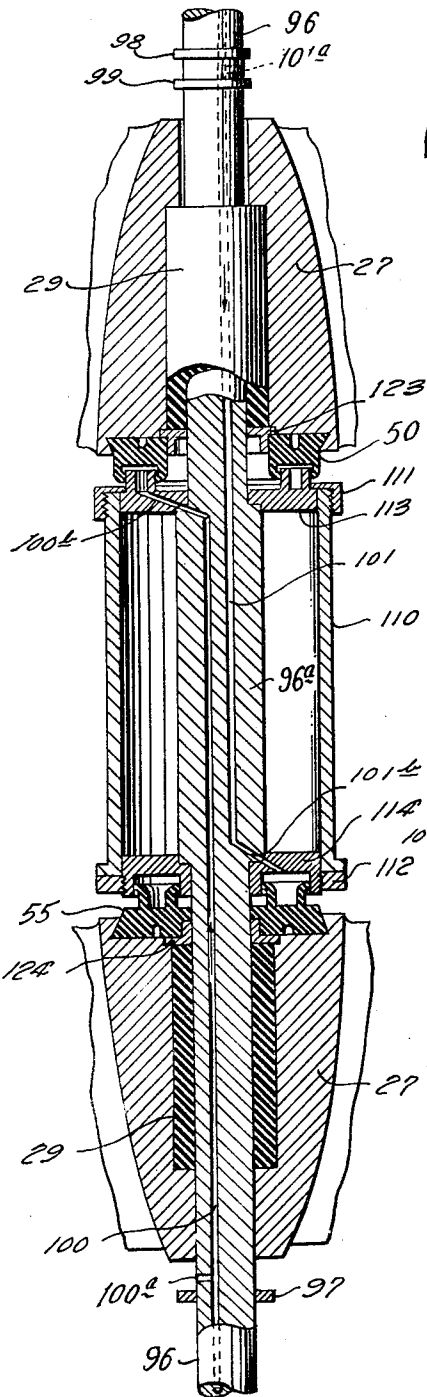


Fig. V

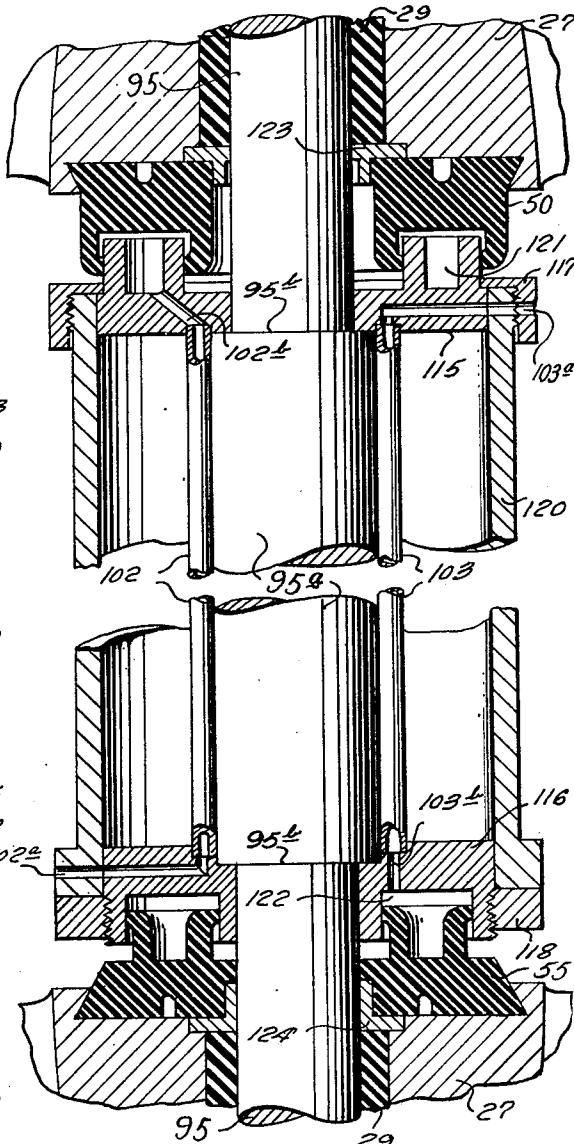


Fig. VI

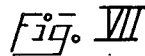
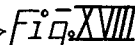
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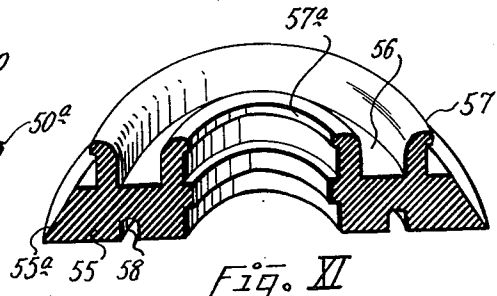
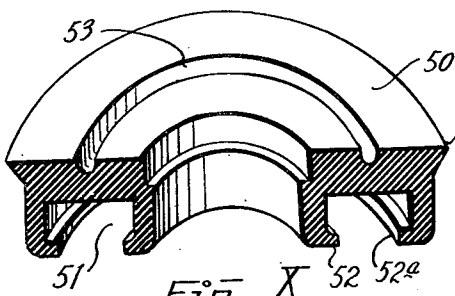
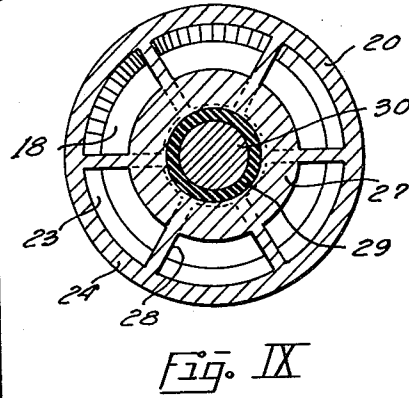
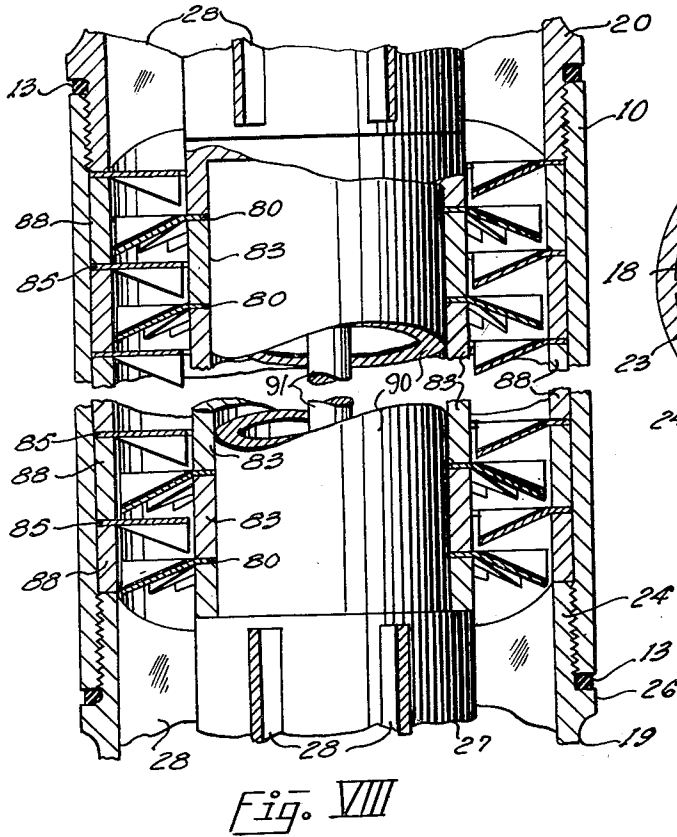
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8 Sheets-Sheet 5



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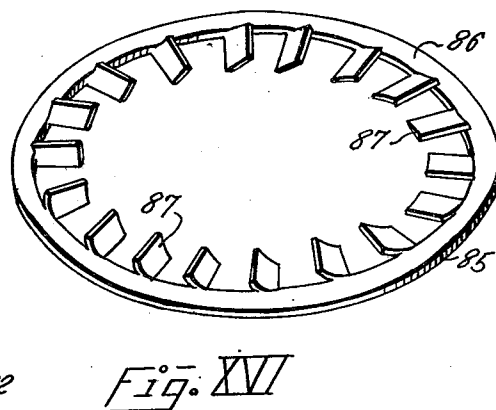
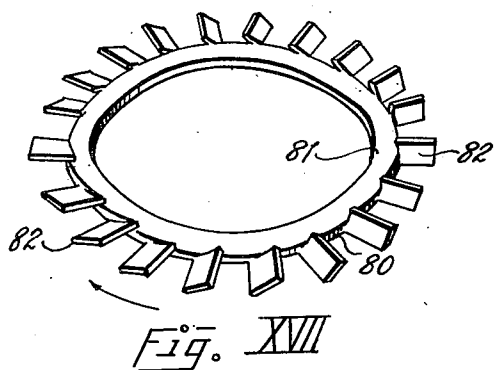
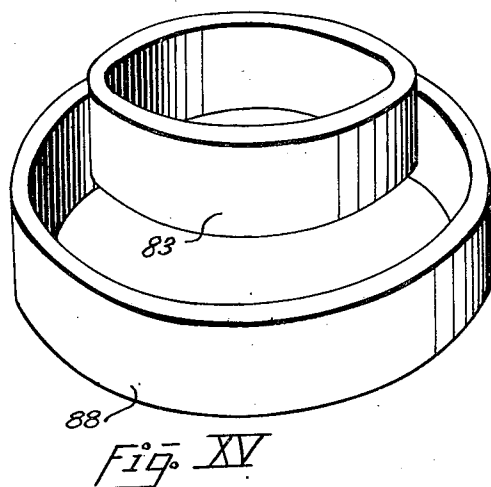
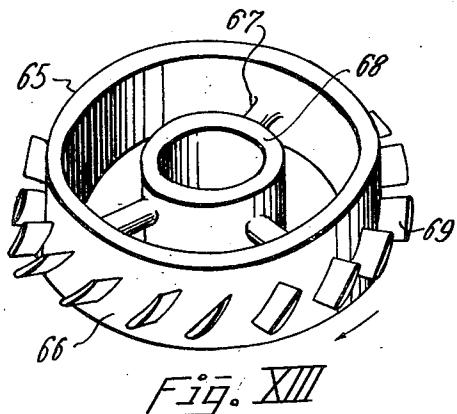
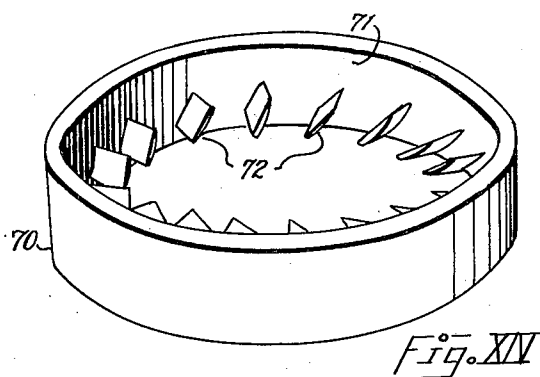
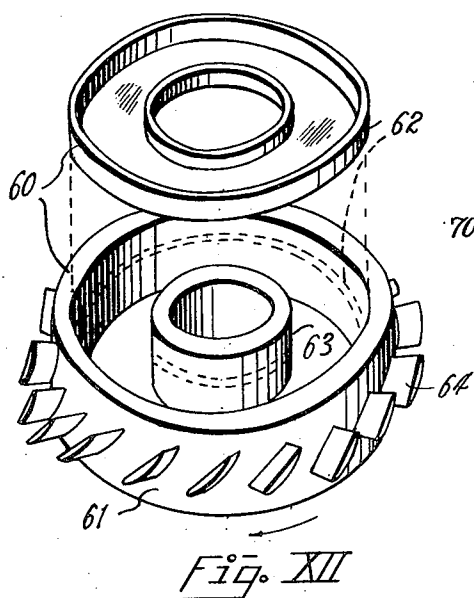
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Filed Oct. 20, 1948

8 Sheets-Sheet 6



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AXIAL FLOW PUMP

Filed Oct. 20, 1948

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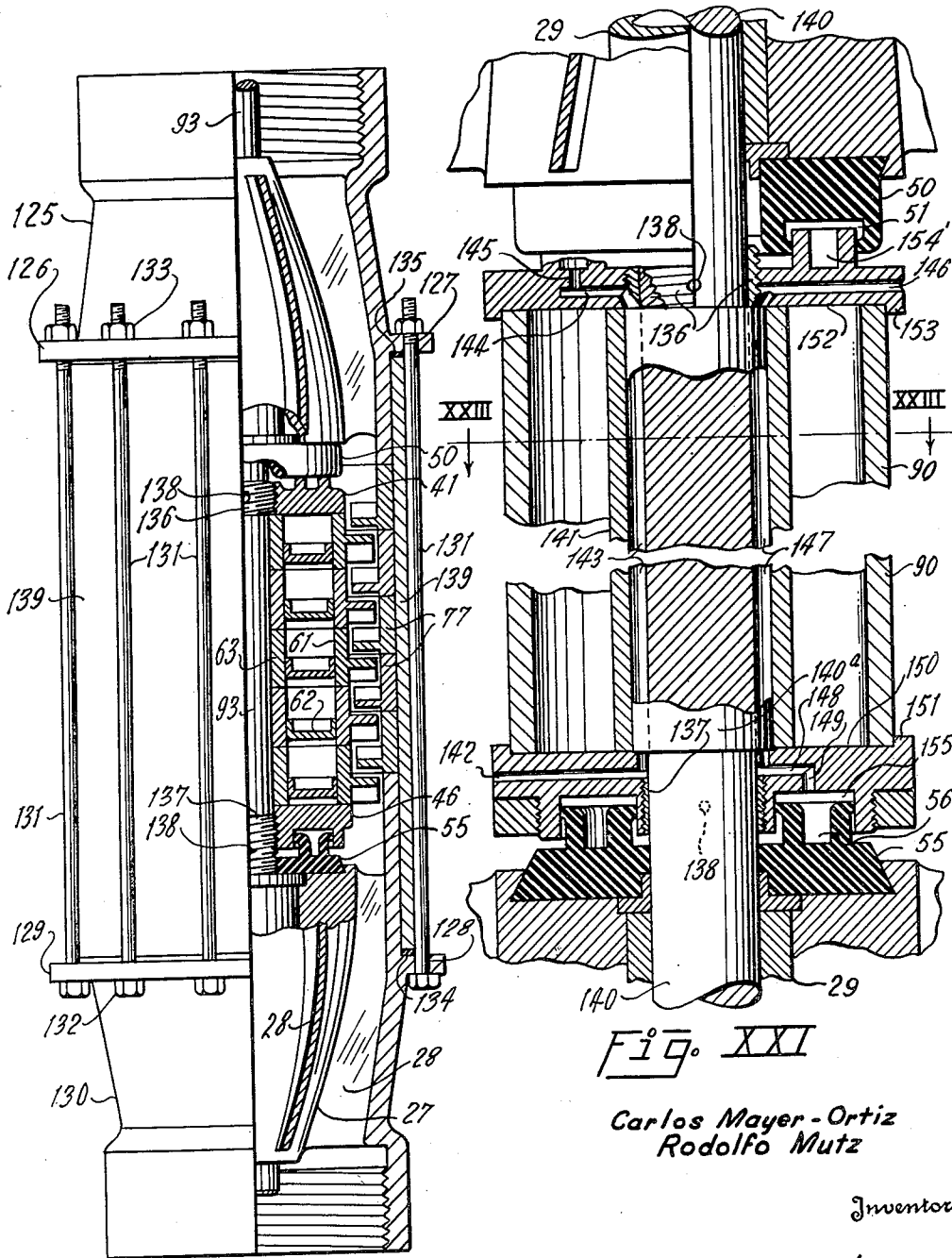


Fig. XXI

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Fig. XX

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AXIAL FLOW PUMP

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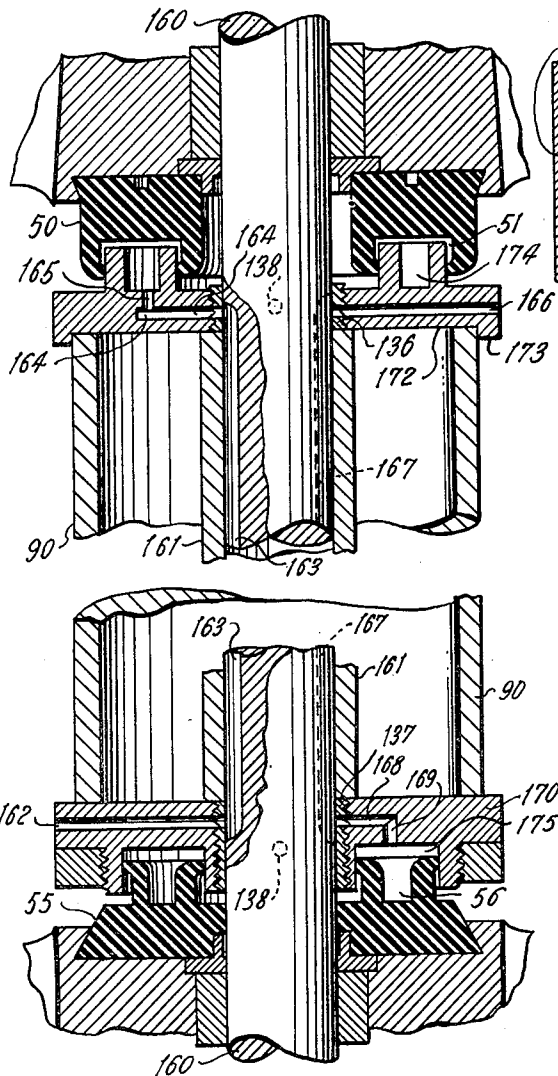


Fig. XXII

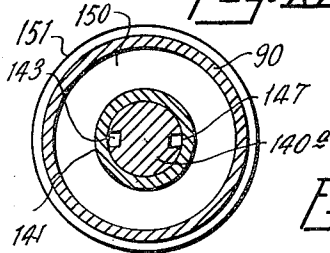


Fig. XXIII

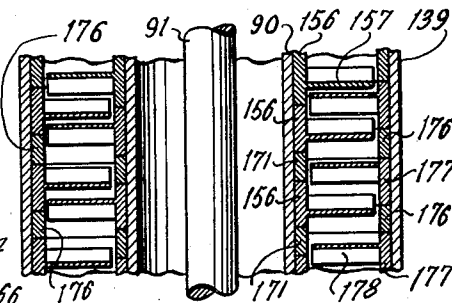


Fig. XXIV

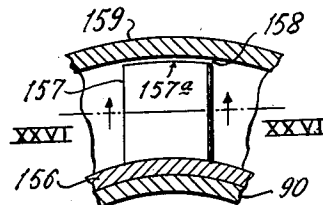


Fig. XXV



Fig. XXVI

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2,706,451

AXIAL FLOW PUMP

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Mexico City, Mexico

Application October 20, 1948, Serial No. 55,512

3 Claims. (Cl. 103—93)

This invention has to do with an axial flow pump provided with both fixed impellers and rotating impellers, and in which both types of impellers increase axial thrust. We present a deep well pump in which a rotating impeller so coacts with a fixed impeller that both operate within an annular space having almost as great a diameter as the tubular casing enclosing it; and in which the stream of moving fluid is subjected to the very minimum of frictional resistance while passing through the pump, there being no abrupt changes or turns in the intake or in the discharge or within the pump itself.

In the annular flow space of our pump the impeller blades operate at their maximum efficiency, such space being located within a relatively narrow band arranged just within the outer periphery of the pump casing.

In our pump multiple stages of great efficiency and increased pumping capacity may be added simply by using a longer and quite straight cylindrical casing, and placing therein a greater number of standard pumping stages, each such stage being comprised of a single rotating impeller unit and its related and coacting fixed impeller unit.

Our pump is one in which each stage has been reduced to minimum height, so that more stages may be placed within a casing of any given overall length than may be used in any other pump. Our pump appears to be the first axial flow pump in which impeller blades may be made of thin sheet material, allowing a construction of extreme lightness and compactness, cheapness and simplicity.

We here present a very cheap method and arrangement for making and maintaining axial thrust bearings. We cause the rotating impeller assembly to actually float or ride upon a stream or annular body of liquid. Our liquid-borne thrust bearings are practically indestructible, the parts thereof which are in relative rotative motion being practically free of actual frictional contact; and the extreme minimum areas thereof which are in actual physical contact support no thrust load whatsoever, they being merely employed to seal off the ring of water or other liquid on which the rotor assembly rides.

A matter of prime importance is that the bearing structure just indicated (which may well be regarded as an axial thrust compensator), can operate without the introduction of liquid therein. When it operates, it becomes a novel thrust bearing not heretofore known, carrying the force of the axial thrust, and protecting the pump parts from damage.

Among the specific objects of our invention may be found the following:

The provision of a multiple-stage pump in which there is a maximum number of stages within a minimum axial length, and in which the flow of fluid is in the direction of the axis of the impellers and without substantial departure from a straight course, thus minimizing resistance and friction and the distance required to be travelled by the fluid.

The provision of an axial-flow pump having a straight walled cylindrical casing carrying therein a centrally disposed drum of a diameter not less than one-half that of the casing, and carrying rotating impeller blades which operate in the annular space between drum and casing, such space also being afforded for the operation of fixed impeller blades carried on the inner wall of the casing, one series of which alternates with one series of the rotating blades.

The provision of a pump in which there are arranged, in

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succession, multiple pumping stages, each stage including a rotative impeller and a fixed impeller, the relation and inclination of the blades of each of which is such as to cause fluid to be alternately moved from one type of impeller to another, so as to be forced to ascend the pump.

The provision of a multiple stage pump, so arranged and constructed as to be of extreme minimum height per stage, as compared to the diameter of the pump, and provided with only a pair of shaft bearings, one above and one below the entire assembly of multiple stages.

The provision of a pump in which there is a guiding effect in its suction end and also in its discharge end, between which there is an axial flow of fluid about a shaft having one bearing on each end thereof, and such flow of fluid being limited to a peripheral annular space having a width not exceeding one-fourth the diameter of the pump casing.

The provision of a pump having therein a centrally disposed and rotatable impeller body, the total cubic annular space lying between said body and the casing of the pump, in which space move impeller blades carried by said body, and in which space are located impeller blades carried by said casing.

A peripheral-flow pump, provided with an elongated and rotatable impeller drum arranged about the axis of the drive shaft and disposed centrally of an elongated cylindrical casing, so as to provide a peripheral flow space between drum and casing.

Impeller blades carried by a rotatable pump drum and extending into an annular space thereabout, and impeller blades carried by a pump casing and extending into such space; an axial thrust bearing arranged above the drum and another below the drum, each such thrust bearing being provided with an annular channel, one such channel having a conduit opened to fluid in the suction end of the pump, and the other such channel having a conduit opened to fluid in the discharge end of the pump.

A pump casing provided on its inner face with relatively short and fixed impeller blades, which cooperatively react to complement impeller blades carried on a rotatable drum disposed centrally of such casing and rotated by a drive shaft passing through the drum, both the fixed and the rotatable impeller blades being formed from sheets of suitable material so as to provide each with a circular band continuing around and connecting such blades; and such bands having distention stubs arranged between them.

The drawings

In the drawings, preferred forms of construction have been indicated. However, it is to be understood that these are merely indicative of suitable mechanisms which may employ our pumping methods, and that modifications may be made in the structures disclosed in the drawings without in any way departing from the spirit or objects of the invention.

Fig. I shows a perspective view of a typical pump with part of the casing cut away to reveal both fixed and rotating impellers.

Fig. II is a sectionalized elevational view of a typical pump, in which the moving impeller blades are made integral with the rings carrying them; and in which a series of impeller units are made up to form an impeller drum.

Fig. III is a sectionalized elevation of a pump in which the rotor units are each made up of a hub, disc and ring, disposed about the central drive shaft and keyed thereto, and assembled to form an impeller drum.

Fig. IV shows a sectionalized elevational view of a pump assembly provided with a drive shaft having an enlarged mid-section with threads thereon to receive nuts, one above and one below the rotor; and the rotor is here made up about a separate drum.

Fig. V is a sectionalized elevation of a rotating impeller drum, fixed to the drive shaft, together with immediately related mechanism, including means for adjusting and compensating axial thrust in the pump, such means employing conduits extending through the drive shaft and delivering fluid to liquid bearing channels in upper and lower rotor races.

Fig. VI is a sectionalized elevational view of a drum type rotor, employing axial thrust compensating means,

which include fluid conduits arranged outside of the drive shaft and within the drum.

Fig. VII shows a sectionalized elevational view of a pump employing a further modification of means for adjusting axial thrust, such means including pipes arranged outside of the pump casing.

Fig. VIII is a sectionalized elevation of part of a modified pump in the region lying between the upper and lower cones, disclosing both fixed and rotating impeller blades pressed or formed from sheets of material, then placed and held in laminated positions between spacing stubs.

Fig. IX is a cross-section taken along line IX—IX of the discharge cone in Fig. II.

Fig. X is a sectionalized perspective view of an upper rotor race which may be employed to form part of an axial thrust compensator bearing.

Fig. XI is a sectionalized perspective view of a lower rotor race which may be employed to form part of an axial thrust compensator bearing.

Fig. XII is an exploded perspective view of a typical rotating impeller unit having blades attached to the outer face of the ring and being provided with an inside hub, and the hub and the ring being united by means of a disc extending therebetween.

Fig. XIII is a form of rotating impeller unit made up of hub, spokes and ring, the latter carrying the blades on its outer face.

Fig. XIV is a perspective view of a typical fixed impeller segment, including an outer ring with blades attached to the inner face thereof.

Fig. XV shows a pair of spacing stubs, being the outer and inner stub, used, respectively, in spacing the outer band shown in Fig. XVI and the inner band shown in Fig. XVII.

Fig. XVI is the blade-carrying flat outer band of a modified fixed impeller, pressed or formed from suitable material.

Fig. XVII is the blade-carrying, flat inner band of a modified rotating impeller, pressed or formed from suitable material.

Fig. XVIII shows an exploded perspective view of the flat band form of fixed and a rotating impeller units arranged above the top of a suction cone.

Fig. XIX is a partially cut away perspective view of an impeller unit provided with a centrifugal anti-abrasive belt.

Fig. XX is a partially sectionalized elevation of a special form of heavy duty pump having a flanged and bolted casing.

Fig. XXI is a sectionalized elevation of the rotating impeller drum of a pump provided with modified form of shaft and conduit construction employed in axial thrust equalizer.

Fig. XXII is a sectionalized elevation of the rotor drum section of a pump provided with a further modification of the axial thrust equalizer system.

Fig. XXIII is a plan view taken along the line XXIII—XXIII of Fig. XXI.

Fig. XXIV is a sectionalized view taken through part of the rotor section of a pump provided with two pairs of stretch rings.

Fig. XXV is a plan view of a typical fitted impeller blade provided with a curved end to follow the contour of the housing.

Fig. XXVI is a section taken along the line XXVI—XXVI of Fig. XXV, showing the impeller blade to be of uniform thickness throughout.

Construction and operation

The various parts of this invention, as exemplified in the drawings, have been given numeral indications, and where the parts are alike the numerals are alike.

We provide an elongated cylindrical outer casing for the pump, and such casing is indicated by the numeral 10. In its preferred form this casing is a straight-walled steel tube, or tube of other suitable material. It may be made with exactness to any desired diameter and length. However, we find advantage in using a sleeve or casing 10 of relatively narrow diameter and relatively long length. Such will better fit within the small casings of numerous wells where large pumps may not be introduced.

Low cost in the production and manufacture of our pump is made more certain by the extreme flexibility

of pump capacities, as the needs of the job or work to be done may require. Such capacity can be increased or decreased by lengthening or shortening the sleeve or casing 10, to include more or less pumping units.

The ends of casing 10 should be provided with some form of connections, so they may be attached to the suction and discharge members of the pump. One such form is in the female threads 11 arranged on the lower end of casing 10, and the female threads 12 on the upper end of such casing.

Suction cone assembly 19 is provided for attachment to the lower end of casing 10; and discharge cone assembly 20 is provided for attachment to the upper end of such casing.

Cones 19 and 20 are preferably identical structures, and should be made interchangeable. A preferred form would be somewhat conical in shape, having one end slightly larger than the other. The intake end of the suction cone is smaller than the other end of such cone; and the outlet end of the discharge cone is smaller than the other end of that cone. Where the members 19 and 20 are made somewhat conical, then the inclined walls 23 are constructed to provide funnel-like enclosures to these cones. However, it must be understood that it is not at all necessary that the intake and discharge member of this pump be made conical in shape or appearance.

As shown in several of the views, male threads 22 are provided on the larger ends of the cones 19 and 20; and such threads are made complementary to those female threads 11 and 12, provided on opposite ends of the casing 10.

Gasket 13 may be provided between the ends of casing 10 and the shoulders 26 on the side walls of the cones. Thus when the entire housing of the pump is properly made up, so that the suction and discharge cones are affixed to the casing, then the gasket will prevent leaks from the housing.

The discharge pipe from cone 20 is indicated as at 15; and the suction pipe to supply cone 19 is shown as at 16. Female threads 21 may be arranged within the open ends of cones 19 and 20 to receive the threaded suction and discharge pipes 15 and 16. A suction passage 17 is provided in cone 19; and a discharge passage 18 is provided in cone 20.

For the purpose of affording a cylindrical wall for threading or connecting it is well to have straight side walls 24 provided on the cones; and it is well to so construct these end members that the interior faces of their side walls provide a bore equal to the maximum diameter of the passage through the pump. Of course, it is not necessary to have straight side walls on the cones.

Cone collars 25 are provided with walls of extra thickness so that pipe tongs, pipe wrenches or other tools, may be safely used in making up the threads between the pump and the pipes to which it is attached. The collars 25 may be made with flat side walls to provide a square shape, a hexagonal shape or any other flat walled shape, as desired.

The cone shoulders 26 will provide some protection to the open threads on the cones before they are made up into the pump or casing; and such shoulders provide an excellent lodgment for gasket 13.

We provide a cone heart 27, which is preferably made of solid material. The cone heart widens the conical flow of the incoming fluid, and it narrows the conical flow of the outgoing fluid. That is, the cone heart distributes the fluid which comes into the pump from the suction end, and delivers it beyond the cone and into the body of the pump to form an annular peripheral ring of fluid or wall of liquid, ascending the pump. The upper cone, with its elongated or parabolic heart therein, will act to peripherally collect the column of fluid discharged annularly along the outer wall of the pump and to assemble it into a column of fluid of only slightly smaller diameter than the casing of the pump, and then deliver it through the discharge end of the pump to a conducting pipe.

To hold the cone heart 27 within the walls of the cones there should be provided a plural number of ribs 28. These ribs, or webs, are preferably made integrally with the walls of the cone and also with the heart of the cone, so as to keep them properly spaced apart, and provide the suction and discharge passages 17 and 18, as required, these passages being defined by the outer walls

of the heart 27 and the inner walls of the cones themselves. The webs are primarily spacing members.

One important function of the cone heart is to provide a housing and sustaining member for the shaft bearings 29, it being desired that the interior space of the cone heart be employed as convenient mounting for such bearings, so as not to unduly lengthen the pump. Such construction also protects such bearings, through which the drive shaft rotates.

The drive shaft may take any one of several forms, as clearly set out in several different views in the drawings. One form of drive shaft is that shown as at 30, which includes the parts having the numbers 31 to 35.

On shaft 30 the shoulder 31 may be provided to afford a lodging place for the upper drum plate 41. The reduced section 32 of the drive shaft 30 may be so arranged as to provide the smaller diameter necessary to afford the shoulder 31; and a further reduced section 32a of this shaft may be arranged to allow for the making of the threads 33, which are external threads arranged to receive the locking nut 34. This locking nut is constructed with internal threads to cooperate with the threads 33, so as to allow the lower drum plate 46 to be drawn up tightly into place to hold together the members which make up the rotating drum assembly 40, which drum carries on its outer walls the moving impeller blades.

A keyway 35 should be arranged longitudinally of the shaft 30, to cooperate with the key 38, all of which is arranged to prevent relative rotative motion between the shaft 30 and the drum 40 carried by it.

Obviously, any shaft, whether like the shaft 30 or of any other design, may be provided with a suitable keyway, or with other appropriate means to secure thereto the rotating drum arranged thereabout, or any other assembled structure which carries the rotating impeller blades. Any such structure together with such blades may be collectively referred to as the rotor.

Coacting with the impeller blades which rotate with the drive shaft, there is arranged an assembly of fixed impeller blades, such assembly being shown as at 39; and it may be made up as a single continuous casting, or it may be otherwise integrated, as by spot welding together segments carrying the fixed impeller blades. Such a fixed impeller assembly is but one form of construction, and is to be distinguished from other forms hereinafter indicated, such as that disclosed in the drawings as at 70. In the latter form of construction the fixed impeller blade assembly is made up of a plurality of separate units, which may be easily added to as desired, when lengthening the pump to increase its capacity. Likewise, such fixed units may be withdrawn as desired, to make a shorter pump or one of less capacity. Any such assembly of fixed impeller blades may be called the stator.

The moving impeller assembly, or rotor, may also take several forms. One suitable form is shown as at 40, presenting a hollow drum, surrounding a solid shaft, of which the drive shaft 30 is typical. In this form the drum 40 is made up of a series of members which may be known as rotor units 65. Each such unit is comprised of a rotor ring 66, spokes 67, a hub 68 and impeller blades 69. A series of such rotor units may be set up, one upon the other, to form the hollow drum assembly 40, such as is shown in Fig. VII.

A circular top plate, such as that shown at 41, may be arranged on any drive shaft or impeller drum. See that shown in Fig. VII. Such plate may be provided with an outer circular rail 42. There is also provided a companion and inner circular rail 43, on the plate 41. This rail is disposed in spaced relation within the outer rail 42, so as to allow the formation therebetween of the annular space 44. This space is designed to receive a liquid which may operate as an anti-friction bearing, when cooperation between the channel 44 and the tunnel 51 is arranged in the upper bearing race. However, even when no liquid is carried within such space the function of a bearing is still carried out in the relation between the top plate, with its rails 42 and 43, and the upper rotor race 50, with its tunnel 51.

An annular washer 45 should be arranged between the upper rotor race 50 and the heart 27 of the discharge cone 20. Such washer will fix the lower limits of the shaft bearing 29 and the upper limits of the rotor race 50.

A circular bottom plate 46 is arranged to close and complete the hollow drum, such as drum 40; and on such bottom plate there should be arranged the outer circular rail 47 and its companion inner circular rail 48, providing therebetween the annular liquid-bearing channel 49, so as to cooperate with lower rotor race 55 and afford a confining housing for a liquid, itself to constitute a bearing, as will hereinafter be more fully explained in detail.

The upper rotor thrust bearing race 50 may be provided with an outwardly disposed flared part 50a, the better to anchor the race within the heart 27.

The tunnel 51, in the member 50, is arranged between the inner and the outer walls of the race; and the inner wall is provided with an inwardly turned lip 52, while the outer wall is provided with an inwardly turned lip 52a. These lips are made to provide sealing and engaging means between the race 50 and the walls of the annular liquid-bearing channel 44 on the upper rotor plate 41.

It may be well to provide accommodation groove 53 on the top face of the race 50. This groove is an annular recess which ordinarily has no connection with the tunnel 51. There is an exception, however, and that is when the modified form of upper rotor race 36 is provided, the modification being effected by the addition of hole 54 to an ordinary race 50. Such holes are not provided and such modified race 36 is not used unless there is required to be made a conduit connection with the groove 53, to implement the construction of the liquid thrust bearing equalizer when it is so arranged that part of the conduit passes through the heart of the cone.

The lower rotor thrust bearing race is shown as at 55, in its usual or standard form. It may be provided with an outwardly flared lip 55a, the better to anchor the rotor race within the heart 27. Tunnel 56 is arranged within race 55, and the walls of such tunnel should have outwardly turned lip 57 and inwardly turned lip 57a, and an annular bottom groove 58 in the lower face of the race 55. As in the upper race, the lower race is ordinarily made with no connection between the groove and the tunnel. However, in the modified form of axial thrust bearing compensator shown in Fig. VII, we have provided the modified rotor race 37, the modification being simply the addition of hole 59, as a means of communicating between tunnel and groove, in the usual and standard race 55.

A single rotor unit, in typical form, is shown as at 60, wherein such impelling unit is of the design known as the "hub and disc" type. The several members of this unit 60 are clearly shown in the drawings in Fig. XII; and they include the parts numbered 61 to 64, 61 being the rotor ring, 62 the rotor disc, 63 the rotor hub, and 64 indicating the rotor blades.

The rings 61 may be provided with blades made integrally therewith; or blades may be separately fashioned and attached thereto, as with spot welding. The hub 63 is but a simple ring designed to fit closely around the drive shaft; and the disc 62 should have an upturned edge at its outer side arranged to fit tightly within the ring 61, and it should have an upturned edge on its inner side to fit tightly against the hub 63. Where it is not desired that this assembly be pressed in place and held together by friction, then any slight deformation may be made between the assembled members otherwise held by friction.

A completed impeller drum may be made up by setting a number of units 60 on top of one another, until the required number of units has been reached and a drum of the required length has been made and provided with the required number of blades.

Many modifications may be made of impeller drums; and the possible designs are numerous, as will be evident from the disclosures in Figs. XIII, XIV, XV, XVI, XVII and XVIII, the last being particularly important as a departure from the form first mentioned herein, as it is considered the quickest, cheapest, simplest and lightest weight of all rotor assemblies.

A modified form of rotor unit is shown as at 65, it being known as the "hub and spoke" type. See Fig. XIII for an example of its use. A single rotor unit 65 is made up of the parts numbered 66 to 69, in which the rotor ring is 66, on the outer face of which are carried the rotor blades 69. These blades may be added

to, attached in some manner, or made integral with this ring 66. The hub 68 is provided to fit snugly around the drive shaft of the pump; and a plurality of spokes, such as shown as at 67, connect the hub with the ring. The typical impeller units 60 and 65 may be machined, or cast, or assembled by welding or made by any combination of these arts.

However, a vastly cheaper, equally effective, and much lighter weight, moving impeller unit, of thinner section, may be stamped out of metal or other suitable sheet material, to produce the modification shown in Figs. XVII and XVIII as unit 80. A companion stamped out stator impeller unit is shown as at 85 in Figs. XVI and XVIII, it being stamped out of a relative thin sheet of suitable material.

A typical stator unit 70, representing one single unit of fixed impeller blades, is shown in Fig. XIV; and it is designed to operate with and coact against the standard rotating impeller blades carried by rotor units 60 or 65. Stator or fixed impeller unit 70 is composed of parts 71 and 72, the former being the tire and the latter being the blades which are carried on the inner wall of the tire. The blades 72 may be affixed to the tire 71 by being cast integrally therewith, or they may be attached by welding or otherwise.

While the standard impeller unit, typical of which are the unit 60 and 65, show that the blades on their outer walls are arranged near the middle portion of the wall, vertically considered, it is to be understood that such blades may be attached at the upper edge or the lower edge, or as desired. A modified form of rotor unit 73 shows such a change. It will be found disclosed in Fig. III. In this modification the impeller blades, such as blades 64, may be carried at or near the top or the bottom of the rotor ring, such as the ring 61. This modification may be used in the hub and disc type of impeller or in the hub and spoke type, equally as well.

Rotor units may be employed without hub and spokes and without hub and disc. See Fig. IV. A series of rotor units may be mounted outside of and encasing a special straight side walled drum, as the drum 90, and held firmly to it.

In any type of pump, old or new, materials, thrown outwardly by the centrifugal force of a whirling rotor unit, will cut away the encasing side wall of the pump housing and do other damage. It is possible to obviate such damage in our pump by the addition of a modifying belt 75, which is optional. It is an anti-abrasive belt. It prevents attrition arising by reason of the cutting and scoring action of foreign materials carried by fluid flowing through the pump. It eliminates damage to the pump housing from such source. Such wear (unless prevented) eventually greatly reduces the efficiency of any pump, by making the clearance or spacing beyond the ends of impeller blades greater than that spacing which would be most efficient.

An example of this attrition-preventing belt is shown in Fig. XIX, which discloses, by way of illustration, the belt attached to the outer ends of blades 69 of a typical rotor unit 65, such as that shown in Fig. XIII. Belt 75 may be as easily and as effectively attached to rotor unit 60, shown in Fig. XII. Belt 75 may as well be attached to rotor unit 80, shown in Fig. XVIII. Any suitable form of attachment may be employed.

Many modifications may be effected in the stator unit, or fixed impeller unit. Some changes are shown in Figs. III, IV and XIV.

A most valuable design, constituting a complete impeller unit, or rotor unit 80, is of very simple and inexpensive construction. Such unit 80 is made up of the parts numbered 81 and 82, wherein 81 is the flat inner band of the unit, and 82 are the impeller blades carried by the band.

Sheet metal, alloyed or not, resistant to many destructive agencies, such as acids, strong alkalis, and other deteriorating chemicals, may be used as the flat material out of which the special light blade units 80 and 85 are made. Plastic, of suitable physical properties, may be employed for the making of such units. When pressed out of a single sheet, the members 80 and 85 are integral in all of their parts. Any such member may be pressure cast or die cast, if desired. Also, any simple flat band may have blades attached thereto by welding or riveting or by other means.

When rotating impeller unit 80 is used opposite fixed impeller unit 85, a spacing stub is used with each such unit. A typical stub 83 is employed as an inside spacer stub, one of which is placed immediately below, and another of which is placed immediately above the flat band 81, so as to suitably space impeller units 80 from one another, and leave room for blades 87 of stator unit 85 therebetween. The exploded view in Fig. XVIII shows an assemblage of this type.

Outer spacer stub 88 is employed for spacing and holding units 85. One such stub is placed immediately above and one immediately below the flat band 86, of the modified form of stator impeller unit 85, carrying the blades 87. Such spacing allows room for the operation of revolving blades 82, carried by rotor unit 80.

A revolving hollow drum, such as the member 90, may be arranged around any drive shaft, or it may have a solid shaft fixed to the center of each end plate of the drum, without passing therethrough. Such a drum is firmly attached to whatever form of drive shaft is used with it; and it may be arranged to support and carry any form of impeller blade unit disclosed in this specification, or any modification thereof. Suitable forms of enlarged hollow shafts or drums carrying rotor impeller blades are disclosed in Figs. IV, V, VI, VIII, XXI, and XXII.

It must be borne in mind that all of the rotor drums disclosed have purposely been made to occupy the non-efficient zone of the pump, which is the region immediately surrounding the central drive shaft. It is the slow speed or "dragging" region of the pump; and it is not employed in our pump for the transmission of fluid. On the other hand, it is filled with the drum, whether the drum be a single tube or cylinder or laminated or otherwise built up of a series of impeller units, placed one upon the other. Such space-occupying drum so carries the impeller blades thereabout as to extend them into, and only into, the exceedingly effective annular region lying between the drum and the inner wall of the pump housing; and in operating only in this efficiency band our pump is unusually effective.

From the foregoing it will be seen that we have provided an axial flow pump, having substantially the appearance of an extended cylinder, with a centrally disposed drive shaft arranged therein, and that an enlarged and centrally located elongated hub or impeller drum is attached to the shaft and arranged to carry moving impeller blades on its outer wall, so carrying such rotating impeller blades as to extend them into a region which we call the efficiency band, lying between the drum and the inner wall of the pump casing, wherein, and reacting with each moving impeller unit, there is a fixed impeller blade-carrying unit arranged inwardly of the pump housing or casing; and it is desired that it be well understood that both units are true impellers.

Our invention causes the moving water or other liquid or fluid to ascend the pump in an axial stream, travelling in a most direct manner and with the least possible deflection laterally. It may be said that the liquid practically walks up a ladder. It is thrown from the moving impeller blade to the fixed impeller blade nearest its path; and from the fixed impeller blade the liquid is then thrown upon the next moving impeller blade travelling immediately above it; and the fluid is so thrown back and forth, all the while rapidly ascending the pump stairway or ladder. When liquid enters this pump, it travels upwardly; when it is discharged from this pump, it is still travelling upwardly; and all the while that liquid is travelling through this pump it is travelling upwardly without being at any time unduly deflected outwardly, or allowed to flow in great curves, or put through abruptly changed channels, or caused to substantially or suddenly alter its course. This is not true of the usual centrifugal pump or of the usual turbine pump.

Because our impeller blades are relatively short, and because they are very narrow (as compared to conventional pumps) we have been enabled to put a relatively large number of blades on each moving impeller unit and on each stationary impeller unit. Such design and construction has worked to reduce the vertical space or height occupied by each complementary pair of impeller units to a very minimum. Because a combination of one moving impeller unit and one fixed impeller unit makes up a pumping stage, then it will be seen that, by reason of the very fact that each of these units is extremely thin, a pumping stage is unusually thin, occupying little vertical

rise in the pump. Further, this construction has made possible the incorporation into a pump of this character of an unusually large number of stages within any given height of pump.

Because our drum construction (whether the drum be a cylindrical unit by itself, encased by the moving impeller units, or whether it be made up of banded moving impeller units themselves) is very rigid, and because of the considerable diameter of our drum, requiring the moving impeller blades therebeyond to be very short and stubby, it will be seen at once that the axial thrust of the many pumping stages carried in the single pump is not and cannot be or become excessive or multiplied by leverage so as to exert the usual stress or deflecting action on the drive shaft, such as is found in the usual old style pump having long impeller blades.

Because our pump is exceedingly short, considering the great and multiplied number of stages that may be incorporated therein, we have found it not only possible but highly satisfactory and very desirable to have only two bearings on the central drive shaft. One is situated immediately above the rotating impeller drum and the other is situated immediately below it. This does away with the expensive and extravagantly wasteful old method of having drive shaft bearings located in between the various stages of the pump.

Because we have arranged an axial thrust bearing race 50 above the rotating impeller drum and a companion bearing race 55 below the drum, we have been enabled to provide vertical latitude for the impeller drum, accommodating increased loads and stretch in the drive shaft itself. Either race may be made of suitable plastic, properly conditioned rubber or of graphite or other appropriate materials.

In Fig. II we have shown an upper bearing race 50 together with lower bearing race 55, each made of suitable plastic composition.

When properly constructed and assembled, each race is spaced apart from the face of the drum disc with which it is associated. This will allow for up and down movement of the drum and of the rotating blades it carries, when load is increased and decreased thereon. It is recommended that the lower plate of the drum be made of suitable material and well finished to provide a bearing surface cooperating with race 55. These two members should be made of dissimilar materials, thus reducing friction and wear.

Certain light duty pumps, not having too great a load to carry, can be constructed without the use of the special rotor races 50 and 55. Such simplified construction is disclosed in Fig. IV, wherein a suitable rotor or whirling drum is arranged around a shaft and kept at a certain predetermined place thereon by the use of lock nuts. In this design there is considerable space left between the end plates of the rotor drum and the cone hearts adjacent thereto. This will allow some considerable stretch in the shaft, without allowing the plates to touch the hearts, and without allowing the moving impeller blades to touch the fixed impeller blades. This is a much cheapened and simplified construction; and it is not recommended for heavy duty pumps.

Where the axial thrust is considerable, where the pump capacity is relatively great, where there is considerable load carried by the pump, and where there is expected to be substantial stretch in the drive shaft, then we very strongly recommend the use of our axial thrust compensator, which is in effect a liquid bearing, responsive in magnitude and pressure to the increase or decrease of pressure in the discharge end of the pump. Such improvement represents a great advance in the pump art.

One form of axial thrust inhibitor or compensator is found in Fig. VII. Such form of compensator is here exhibited for the primary reason that it may be attached to and made a part of one of our pumps previously made without such compensator. This is done by drilling a hole through the heart of the lower cone and attaching pipes therefrom to form a conduit leading up to and receiving liquid from the discharge end of the pump. When this is done, the hole 59 is provided through the lower bearing race 37. With no more addition than this one conduit to flood the annular bearing space 49 with high pressure fluid and lift the rotating drum on a race of such fluid, the ordinary pump of our type can be converted into one carrying the axial thrust compensator. The upper bearing race 36 (modified with its hole 54) may be

provided with a conduit leading therefrom to the low pressure area surrounding the suction cone in the base of the pump.

Compensating conduits may be arranged through the drive shaft, as disclosed in Fig. V, to supply the axial thrust bearings with liquid. A less expensive form of construction is shown in Fig. VI, where small tubes are simply placed against the outside of the central drive shaft and within the confines and protection of a rotating drum, to pick up high pressure fluid from the top of the pump and deliver it within the closed space 122 of the lower bearing race 55. A companion conduit may be arranged to allow communication between the space 121 in the upper bearing race 50 and the low pressure area in the suction end of the pump. Such construction will be discussed in detail further on in this specification. However, attention is called to further modifications of axial thrust compensating conduits, which are very inexpensively made. These are exemplified in the Figs. XXI and XXII.

In order to make clear suitable mechanical arrangements and appropriate parts of our pump so constructed as to accommodate variations in the location and use of ducts, channels and conduits for the operation of axial thrust compensators, we have delineated a number of varieties of central drive shafts, inasmuch as such conductors are more conveniently, appropriately and satisfactorily carried by or associated with the drive shaft. There are various ways of attaching the rotor unit to the central drive shaft; and we have caused variations in forms of attachment to be shown. These modified shafts will be here discussed in some detail.

A modified form of solid shaft is shown as at 91, and it may be made straight throughout and unthreaded. An appropriate hollow impeller drum is provided or rotor units may be made up in drum-fashion, by placing individual units on top of one another; and any such rotor unit is fastened to the drive shaft by any appropriate means, such as pins, cap screws, set screws, keys and keyways. Such rotor units (or any other) may be held to shaft 91 (or other shaft), by having a top and a bottom confining plate fastened to the shaft. Such attachment will prevent the rotation of the drum, relative to the shaft itself. Illustrations of the use of shaft 91 may be found in Figs. VIII and XXIV.

Drive shaft 92 (being another form of shaft) may be provided with a shoulder 92a, to cooperate with the upper plate 41 of the rotor, and a collar 92b, which may be pinned to the shaft with pin 92c, and arranged to cooperate with the lower plate 46 of the rotor, so as to firmly fasten the rotor to the solid shaft at the proper place. See Fig. VII.

A further suitably made shaft is shown as at 93 (Fig. III) wherein there are no shoulders. A shaft of this character should be perfectly smooth and straight from end to end, without being threaded. It should be provided with suitable exteriorly threaded bushings, as at 93a, attached by welding, brazing or by set screws or pins, such as at 93b. The bushing may be pressure-mounted, or sweated on. Such a bushing may be heated and placed on the shaft at the proper place and allowed to cool. The shaft may be frozen, to further reduce its size, and allow the hot bushing to be fitted onto it.

One such exteriorly threaded bushing should be mounted on the upper part of the shaft, and another on the lower part of the shaft, so as to receive suitable confining plate members 41 and 46, having threaded holes through their centers, so that they may be screwed up on the bushing threads. A suitable pin 93c may then be placed to hold the plates securely to the bushing and prevent their turning thereon.

A different form of central drive shaft is shown as at 94 (Fig. IV) in which the section thereof in the immediate proximity of the rotor assembly, and passing there-through, is enlarged, as at 94a. This will facilitate the making of threads 94b at the upper and lower ends of such section; and such last named threads will receive locknuts 94c, for holding the rotor assembly tightly in place, such assembly being positioned between a pair of such nuts.

Further and different shaft construction is shown as at 95 (Fig. VI), wherein a shaft has an enlarged mid-section 95a, provided at the upper and lower ends thereof with shoulders 95b. On these shoulders may be mounted and carried the upper and lower plates 115 and 116, to

hold in proper place the rotor units carrying impeller blades.

A central drive shaft provided with conduits there-through for the operation of axial thrust compensators is shown as at 96 (Fig. V). It has a midsection 96a enlarged to provide shoulders. It is rifle-drilled to provide conduits 100 and 101. To make the construction less expensive, it is recommended that the shaft be drilled to its very ends; and thereafter these ends should be plugged. (Plugging is not shown in the drawings.)

Below the suction cone heart there should be made a cross drilling to provide the entrance 100a, leading into the conduit 100; and just below this entrance there should be arranged the diffuser ring 97. This ring will help to keep trash and foreign material from entering the conduit.

Likewise, a pair of upper diffuser rings 98 and 99, should be arranged about the drive shaft 96 above the heart of the discharge cone, so that one will be on each side of the entrance 101a to conduit 101. This arrangement will minimize the amount of foreign material which can enter these conduits. Such material, usually being heavier than the liquid pumped, is thrown outwardly when the liquid carrying it strikes these spinning diffusers.

Transverse conduit leg 100b leads from the bottom part of the annular liquid bearing channel 44, to communicate with the low pressure or suction side of the pump, through conduit 100 and entrance 100a. Such construction will allow the tunnel 51, of the upper rotor race 50, to carry fluid or liquid of the character being pumped. This will lubricate the rotor race, and allow the bearing walls 42 and 43 to rotate in a bath of liquid, confined in an area below the upper rotor race 50. See the arrangement made in the region immediately above plate 113, in Fig. V.

It is to be carried in mind that conduit 100 is a low pressure conduit. In the interest of economy, it may be desired to dispense with this conduit and its related legs. Then, to do so will not work impairment in the function or operation of the pump. The bearing walls 42 and 43, which are carried on the upper face of confining plate 113, in themselves form a very satisfactory bearing surface, especially in view of the fact that they rotate within a confining channel or tunnel 51, arranged within the rotor race 50. This race is made of graphite, smoothly polished metal or plastic material suitable for a bearing surface. Even though the space between the bearing walls and the underside of the rotor race, just described, may not be filled with liquid, nevertheless long life and satisfactory service can be had from a bearing of this character. This, of course, is largely due to the fact that practically all of the weight of fluid and axial thrust incident to the operation of this pump is carried on the lower rotor race 55, where it is very much desired that we provide a bearing surface of liquid, whenever this be possible. Through our construction it is not only possible but easily done and highly advantageous.

Again referring to the construction shown in Fig. V, but illustrating the principle employed throughout in constructing and operating our special axial thrust compensator, attention is called to the highly important conduit 101, which is a high pressure conduit, receiving fluid under the discharge pressure of the pump. Entry 101a allows high pressure fluid, such as water being pumped, to be forced into the conduit 101, and downwardly there-through, and transversely across the lateral conduit 101b, and into the annular space provided between the bearing walls on the underside of the lower confining plate 114 of the rotating impeller drum 110. Tunnel 56 in lower rotor race 55 receives this liquid; and the pressure thereof tends to spread apart the lips 57 and 57a on the upper edges of the tunnel walls. These lips then are pressed closely against the side faces of the bearing walls carried on the underside of rotor plate 114. The result of this construction is to constantly provide and carry within the annular space defined by these bearing members a rope of liquid, a band of water or oil, or of whatever fluid is being pumped.

Therefore, we have provided a constantly renewable and indestructible stream of liquid on which our rotor drum floats. As axial thrust and pressure increases, the band of liquid on which the rotor drum rotates expands and lifts up the drum itself. The greater the tendency for the drum to sag because of heavier load carried by it, the higher rises the liquid in the liquid bearing space below the base of the drum. This is truly an axial thrust

compensator or inhibitor; and it is of utmost importance. We recommend its use in every pump of our design where there is any considerable load to be carried. And when only one axial thrust compensator is to be used, it should be so constructed as to operate beneath the rotor drum and lift it up, by being put in the bottom part of the pump (receiving water from the discharge end of the pump).

The liquid bearing thus formed exerts a greater pressure of liquid to cushion the rotor races as the head of the liquid lifted by the pump increases. The whirling rotor is practically floating at all times that it is moving fluid. The anomalous situation is achieved in our pump wherein there is less wear and friction in a pump carrying a heavy load than in a pump not lifting any fluid at all.

The construction disclosed in Fig. V is only one form of arrangement of conduits and axial thrust compensating devices. However, the compensating conduits are not required to pass through the solid shaft. Other arrangements may be made.

For instance, modified conduit 102 may be constructed of a tube which will pass outside of and parallel to the axis of the solid drive shaft 95. See Fig. VI. Conduit 102 will be contained within the hollow impeller drum 120, which will carry the impeller blades, arranged thereabout. Conduit 102 is a low pressure conduit connected to the upper rotor race. It will function in the same manner that the conduit 100, previously described in detail, will function. To complete the construction of conduit 102, there is provided entrance channel 102a at the lower end of primary conduit 102, and transverse conduit 102b at the upper end of such primary conduit.

The more important and high pressure conduit 103 may likewise be made of a simple tube arranged outside of the central solid drive shaft and within the rotor drum. It should be constructed to communicate with an entry section 103a, which will take up liquid from the high pressure or discharge end of the pump and supply it to the conduit 103. Discharge section 103b will deliver liquid under pressure into the lower rotor race, to form a liquid bearing therein. All this operates in the manner heretofore detailed in discussions centering around high pressure conduit 101.

The protected conduits, employed in the provision and operation of liquid bearings supporting the rotor drum, as shown in Figs. V and VI, are very much protected, and therefore have a longer life than those conduits arranged externally of the pump casing itself, such as disclosed in Fig. VII. The external low pressure conduit 104, shown in this last named figure, could be easily broken off, and so could the external high pressure conduit 105. Exposed conduits may well be employed on pumps which are themselves well protected, and do not have to be moved often, if at all. It is recommended that conduits be well protected, whenever possible, by being placed within the housing of the pump, and preferably they should be placed within the rotor drum, though not necessarily within the central drive shaft itself.

The drum member 110, shown in Fig. V, may be adjusted and kept in place by the use of the internally threaded cap ring 111 which holds together the upper plate or disc 113 and the upper end of the cylinder 110, appropriate threads being provided on the wall of the latter.

Likewise, a lower cap ring 112, internally threaded, will hold together the lower plate or disc 114, below the lower part of cylinder 110, which may be provided with a suitable flange, instead of a thread.

Upper plate 113, closing drum 110 at the top, may be so constructed as to rest upon a shoulder provided by the enlarged section 96a of the modified shaft 96. Likewise, lower plate 114, of somewhat similar construction, may be arranged below a shoulder on the shaft, so as to cooperate with the outer wall of drum 110 at its lower end, and to afford bearing walls or rails therebelow spaced apart to provide the annular liquid space wherein liquid under pressure forms the high pressure axial thrust bearing heretofore described in detail. Such construction is disclosed in Fig. V.

In Fig. VI is shown a device of somewhat parallel construction, changed to accommodate a different arrangement of conduits for making liquid bearings. In this figure upper plate 115 closes drum 120. Such plate falls against shoulder 95b of the shaft 95; and it is drilled to

provide transverse conduit 103a to connect with vertical high pressure conduit 103.

Lower plate 116 is provided with a transverse channel 102a therethrough to communicate with the vertically disposed low pressure conduit 102. This lower plate is held tightly against lower shoulder 95b of shaft 95. Cap ring 117 holds upper plate and drum together; and cap ring 118 holds the lower plate and the drum together.

The annular liquid bearing channel 121, in top plate 115 is filled with liquid under low pressure. The annular liquid bearing channel 122, in lower plate 116, is constantly supplied with high pressure liquid, coming through conduit 103 from the high pressure or discharge end of the pump. Annular washer 123 is placed between the upper rotor race and the cone heart; and annular washer 124 is placed between the lower rotor race and its adjacent cone heart.

On specially heavy duty jobs it is proper to provide a heavy duty pump with a protected and extra strong casing and housing. Fig. XX discloses one such form of heavy duty pump, in which the modified discharge cone 125 is provided with a strong external flange 126 thereabout. The heavy duty suction cone 130 is provided with external flange 129, through which flange a series of holes 128 are arranged. In alignment with such holes there is provided a series of companion holes 127 in the flange 126. A series of threaded rods 131 extend between these flanges. Such rods are in effect long bolts; and they pass through the holes 127 and 128, the heads 132 resting on one flange and the nuts 133 making up on the other flange, to securely fasten, hold together and further protect the heavy duty pump housing, composed of suction cone 130, discharge cone 125 and side wall casing 139.

A compressible leak-proof gasket 134 is arranged about the face of flange 129 to receive the lower end of casing wall 139; and a like gasket 135 is arranged between the upper end of such wall and the lower face of flange 126, so that when the bolts 131 are made up, the pump housing is rendered leak-proof.

In the heavy duty pump shown in Fig. XX, we may use an externally threaded bushing 136 arranged about the shaft 93 and pinned thereto with pin 138. A like bushing 137 is arranged on the lower end of the shaft and fastened with a like pin.

However, in order to provide a heavy duty pump of great carrying capacity, in which threads alone are not depended on to suspend or carry the rotating drum, a modified structure is employed, such as that shown in Figure XXI, wherein special shoulders result from providing an enlarged midsection 140a of the central drive shaft 140.

Enlarged midsection 140a is made just long enough to accommodate the rotor drum 90 between the flanged upper plate 152 and the flanged lower plate 150. The confining flange on the upper plate is shown as at 153, and the confining flange on the lower plate is shown as at 151.

However, the enlarged midsection 140a of the central drive shaft has another and quite important function, beside furnishing shoulders for carrying and securing the impeller drum. Along the entire length of this enlarged midsection, there is milled out, or otherwise cut out or formed, a pair of channels. One of these channels is the high pressure, vertically disposed channel 147, into which upper cross channel 146 leads, and from which lower cross channel 148 and vertical connecting channel 149 conduct high pressure liquid into annular space 155 arranged between the concentric rings on the lower face of plate 150 to form a liquid bearing. The other channel, also cut out as one would cut a keyway, or otherwise suitably fashioned, is that shown as at 143. It is the low pressure channel. It communicates with transverse conduit 144 and vertical conduit 145 in the upper plate 152. It also communicates with transverse channel 142 in the lower plate 150.

The conduit construction indicated immediately above is one quickly, cheaply and easily made. Because they are made in the manner indicated, both the channels 143 and 147 may be very easily cleaned out when the pump is disassembled or taken apart for inspection or repairs.

The channels are enclosed and finished by fitting confining tube 141 tightly around the midsection 140a of the central drive shaft. It covers this entire midsection and completes inexpensive conduits.

Conduits 143 and 147 could both be cut as grooves within the inner face of a tube 141 having side walls of

sufficient thickness, if desired (instead of being cut on the outer face of the shaft).

Whenever desired, thin compressible gasket rings may be placed at both ends of the tube 141 and at both ends of the drum 90, so that when the plates confining both of these members are drawn up tight, then these two concentric cylinders will be leak-proof.

With the construction indicated, it will be seen that the space 154, below the upper bearing race 50, communicates with the low pressure or suction end of the pump; and the high pressure liquid bearing space 155, in the lower part of the pump, above race 55, communicates with the discharge or high pressure end of the pump.

A pump which is not required to do extra heavy duty may nevertheless incorporate some of the features of the heavy duty pump shown in Figures XX and XXI. Such modified construction is shown in Fig. XXII, where a drive shaft 160 has been made without shoulders, perfectly straight and without threads. However, there may be made therein a keyway 163 and a keyway 167, each of which will be converted into conduits simply by enclosing and encasing the section of the shaft provided with such grooves with a tight-fitting tubular casing 161.

An alternate form of construction would allow inexpensive conduits to be made by grooving the inner wall of tube 161, without cutting any grooves in the shaft. In this form the shaft need not be weakened at all. The grooved tube 161 would simply be fitted around a shaft having smooth walls.

The lower pressure end of the pump communicates with groove 163 through passage 162 in lower plate 170. At the upper end of conduit 163 will be found the passages 164 and 165 leading into the open area 174 beneath the upper rotor race bearing 50, such area then merging with the open area 51 in such race.

The high pressure inlet transverse channel 166 will conduct fluid through the upper plate 172 and into the descending conduit 167, to be discharged through auxiliary conductors 168 and 169 and into the spaces 175 and 56 arranged below the lower plate 170 and above the lower rotor race 55, so that again we may provide a liquid bearing which also acts as an axial thrust compensator.

The upper plate 172 may be provided with a downwardly disposed flange 173 so as to hold a drum cylinder 90 in line; and the complete rotor assembly will be affixed to the drive shaft in any suitable manner.

Impeller blades, both rotating and stationary, may be made in various designs and shapes. The may be flat; they may be curved; and they may be built to carry out the air-foil designs of various forms of airplane propellers. Working conditions, the load to be carried, required cubic delivery in a given time, the nature of the fluid to be pumped, together with other factors, including speed, have a great deal to do with determining the proper contour, shape and design of impeller blades.

All impeller blades have to be pitched; and the angle of pitch is varied to meet the requirements of various physical conditions under which the pump is required to operate, including the factors indicated immediately above.

Impeller blades having efficient air-foil contours are indicated in Figs. XII, XIII and XIV, and again in Fig. XXVI. Impeller blades may be flat, and set to the right pitch, including those which are pressed out of sheet material, such as shown in Figs. VIII, XVII and XVIII. Curved blades may be used, including the form appearing in Fig. XIX.

We find in whatever blade design is used to fashion the impellers, both moving and fixed, that efficiency is heightened by providing the blade with a uniform cross-sectional area throughout its length, which length should always be relatively short; and the width should always be relatively narrow. Such provisions are fundamental in our blade designs.

In Figs. XXIV, XXV and XXVI we show forms of impeller blades exemplifying the principles of uniform cross sectional area, shortness and relative narrowness. In these views we make clear that the blades are mounted and necessarily move only with the high efficiency area wherein pumping is carried on throughout all of our pumps, in accordance with the principles of the efficiency area or band discussed in some detail herein elsewhere.

In the three figures last herein referred to, a moving impeller blade unit is shown as at 156, including the blade 157, which is provided with a rounded end 157a, conforming to the arc of the housing 159 (which housing may be a composite of circular members 176 and 177) so as to leave between such housing and the ends of the blades only the very narrow arcuate space 158.

Blade 157 may be made of the design shown in Fig. XXVI, or it may be made much thinner, or it may be made more curved, as the working conditions require. However, it is to be observed that such blade is indicated as having a uniform cross-sectional area throughout its entire length. Such arrangement and construction, as is shown in the figures presenting blade 157, results in the rapid flow of fluid with the practical elimination of all eddying and with a minimum of turbulence; and the operation is marked by unusual freedom from drag and by a lack of vacuum tendencies in the rear of the moving blades. Such factors give rise to a very smooth flow and to very efficient pumping performance.

The companion stationary impeller blade 178, arranged to operate opposite moving impeller blade 157, should be made in the same manner, and of the same design, except that the free end of the stationary impeller blade would have a concave shape, the better to conform to the cylindrical wall presented immediately therebeyond by the ring member 156, being the outer wall of the whirling impeller drum. In other words, the fixed blade has a concave end, while the moving blade has a convex end. It is highly desirable that the clearance beyond the ends of these blades be quite limited, and continuously maintained as a very narrow and limited space.

The non-moving impeller blade 178 may be carried by the fixed ring 177; and such ring may make up the outer wall of the efficiency pumping band. The smaller ring 156, rotating with impeller drum 90 (or some other) carries the moving impeller blades 157; and such rings may make up the inner wall of the special efficiency band or annular space through which our pumping is most effectively carried on.

However, both the ring members 156 and 177 may need to have auxiliary rings to extend the walls of this efficiency pumping area, especially where the pump is a very long one, or the head is great or the axial thrust is unusual.

Under such conditions of great load the central drive shaft may be stretched beyond the normal space allowed for clearance between moving and non-moving impeller blades, in the pumping area discussed. This situation is adjusted, and the need for greater stretching room is accommodated by the introduction in both the outer wall and inner wall of the efficiency band space of suitable stretch rings. The innermost or smaller stretch rings is shown as at 171; and its companion stretch ring, being the larger and outermost, is shown as at 176. Where only two companion stretch rings are used, then both of such rings are necessarily of the same height; and they both perform the same function. Of course, stretch rings can be extremely short, or they may be made of greater height, as the needs for space dictate.

We claim:

1. In an axial flow pump, an elongated cylindrical casing; an elongated drum of constant external diameter occupying at least three fourths of the internal diameter of the casing, arranged therein and in uniform spaced relation thereto; a drive shaft maintaining said drum rotatably on an axis common to that of the casing, a drive shaft bearing arranged about such shaft externally of each end of such drum; the spaced relation between casing and drum being such as to provide therebetween a pumping zone through which fluid may be impelled; impeller blades of uniform inclination attached to the outer face of the drum and arranged to extend into said zone; impeller blades of uniform inclination fixed on the inner face of said casing and arranged to extend into said zone, and the angle of inclination thereof being opposite to that of the first mentioned blades, so as to deflect upwardly the movement of fluid occasioned by the blades attached to the drum whenever there is relative rotative motion effected between the drum and the casing; a conical intake conduit and a conical discharge conduit, each such conduit so surrounding said drive shaft as to allow axial flow thereabout; and a liquid filled thrust

bearing arranged at each end of the drum between the adjacent shaft bearing and the drum end.

2. In an axial flow pump, a hollow cylindrical drum, a vertically disposed casing arranged in spaced relation therearound, the cylinder and the casing having a common vertical axis; a plurality of rings of blades extending outwardly from the drum and said rings being vertically arranged in equally spaced relation and the blades of each such ring being horizontally arranged in equally spaced relation; a plurality of rings of blades extending inwardly from the casing and said rings being vertically arranged in equally spaced relation and the blades of each such ring being horizontally arranged in equally spaced relation; each ring of blades carried by the drum being arranged to alternately overlap an adjacent ring of blades carried by the casing with equal vertical clearance between overlapped and overlapping blades; all drum carried blades being inclined at the same angle, and all casing carried blades being oppositely inclined as to direction but at the same angle; a vertical drive shaft carrying said drum and arranged centrally thereof; a bearing arranged at each end of said shaft; and a spider arranged within each end of the casing and attached thereto, each spider carrying one of the said shaft bearings; and a liquid filled thrust bearing arranged between each end of the drum and the spider adjacent thereto.

3. In an adjustable capacity multi-stage axial flow pump, a rotor drum assembly, comprising: a plurality of circular rotor spacing stubs; a plurality of rotor rings having angularly disposed blades radiating therefrom; the stubs being so arranged between the rings as to provide predetermined spacing between such rings; the drum being capable of elongation by the addition of stub and ring elements as desired; the stubs and the body of the rings having substantially equal external diameters; and a circular cap closing each end of the drum so formed; a drive shaft passing through such closed drum axially thereof; securing means associated with the shaft whereby the drum may be compressively held together; fastening means securing the drum to the shaft as a unit rotatable therewith; a shaft bearing arranged externally of each drum cap; a bearing cone having its base adjacent each such cap and carrying one such shaft bearing; liquid thrust bearing means arranged between each cap and its adjacent bearing cone; a stator assembly, comprising: a plurality of circular stator spacing stubs; a plurality of stator rings having angularly disposed blades extending inwardly thereof, the stator blades having a pitch opposed to the pitch of the rotor blades, whereby liquid thrown from the rotor blades will ascend the face of the stator blades; the stator stubs being so arranged between the stator rings as to provide predetermined spacing between such rings; the blades of each stator ring being arranged to extend inwardly of the space between the blades of each pair of spaced rotor rings; a straight walled cylindrical pump housing of sufficient length to encase the stator assembly; a conical intake conduit removably attached at one end of said housing; a conical discharge conduit removably attached at the other end of said housing; and both such conduits having securing means associated therewith whereby said stator assembly is compressively held together as a unit between the opposed ends of such conduits and in fixed relation with such housing.

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