

March 27, 1962

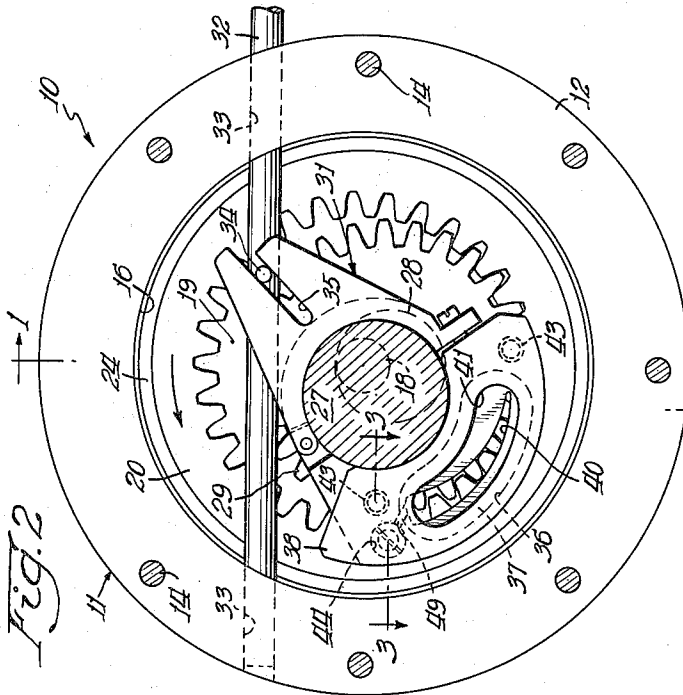
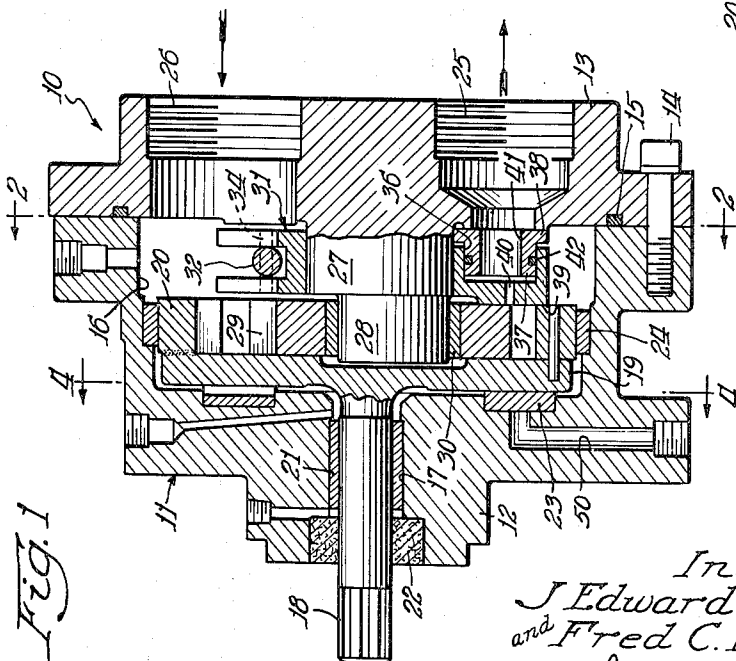
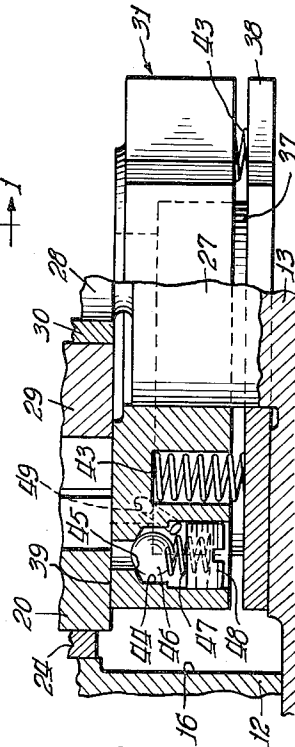
J E. C. ANDERSON ETAL

3,026,809

INTERNAL-EXTERNAL GEAR PUMP

Filed April 6, 1956

7 Sheets-Sheet 1



Inventors:
J Edward C. Anderson
and Fred C. Haberland
Joseph R. Dwyer
Att'y.

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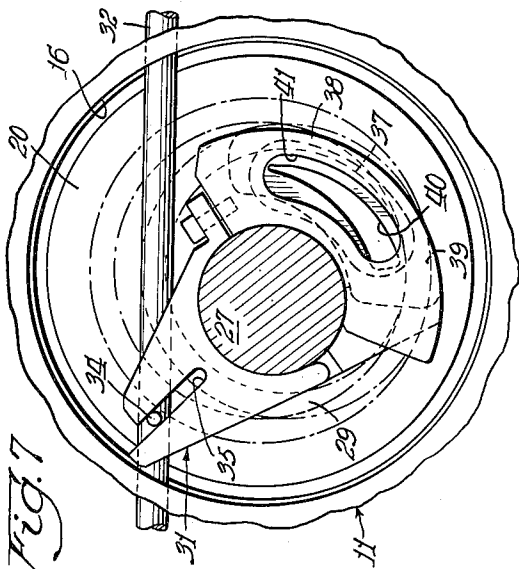
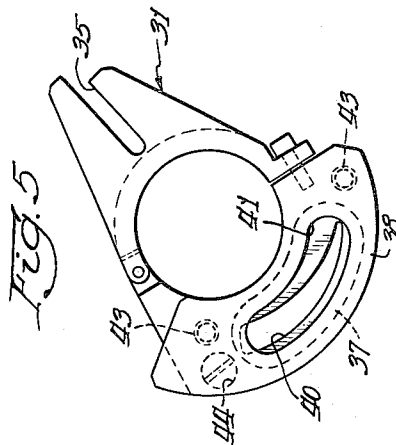
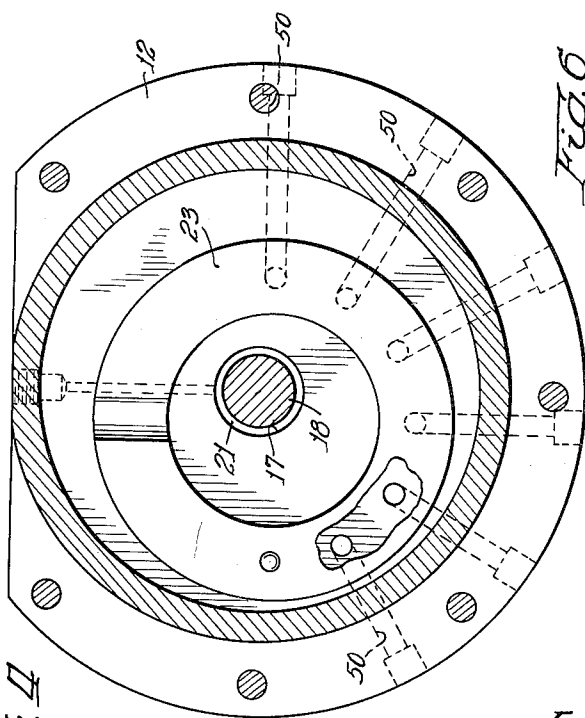
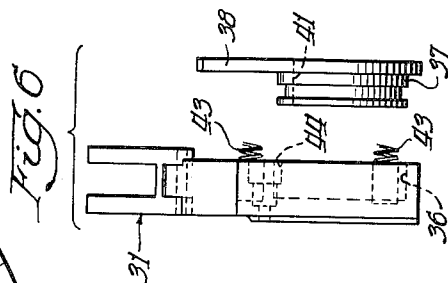
J. E. C. ANDERSON ETAL

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Inventors:
J. Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Dwyer

March 27, 1962

J E. C. ANDERSON ETAL

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INTERNAL-EXTERNAL GEAR PUMP

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Fig. 10

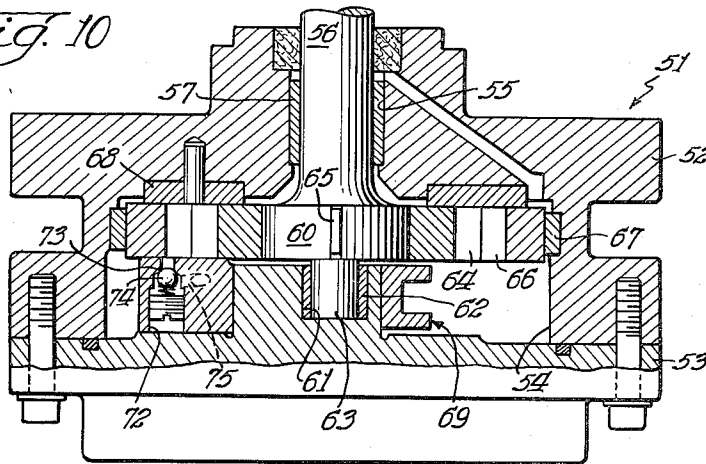


Fig. 8

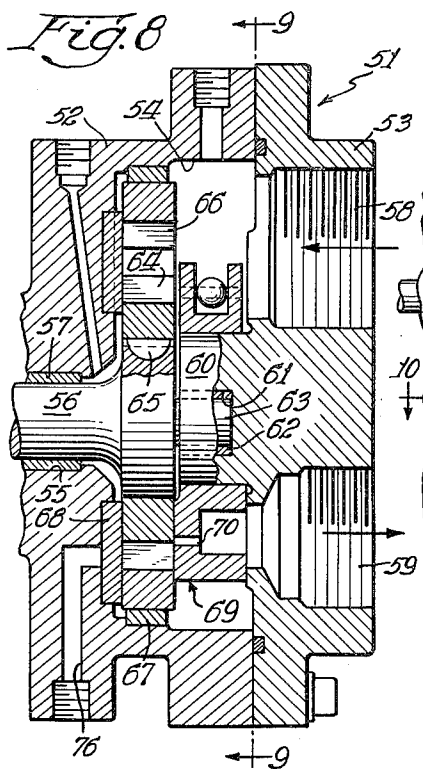
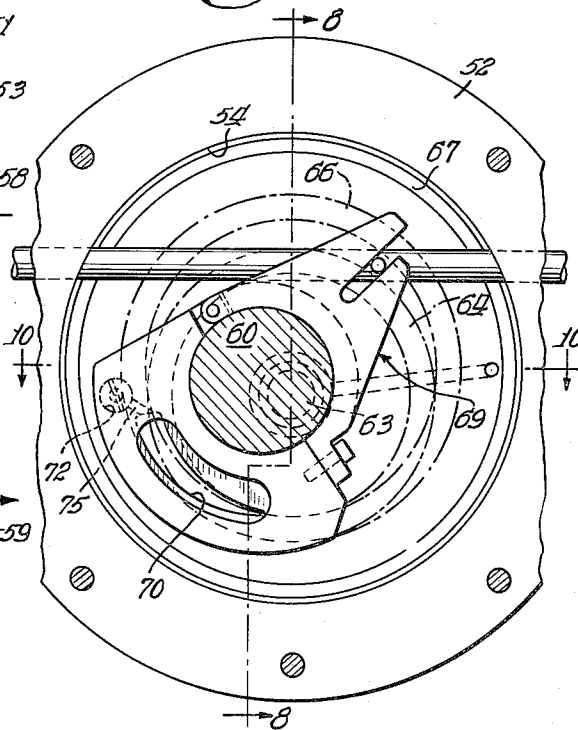


Fig. 9



Inventors:
J Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Swyer
Att.

March 27, 1962

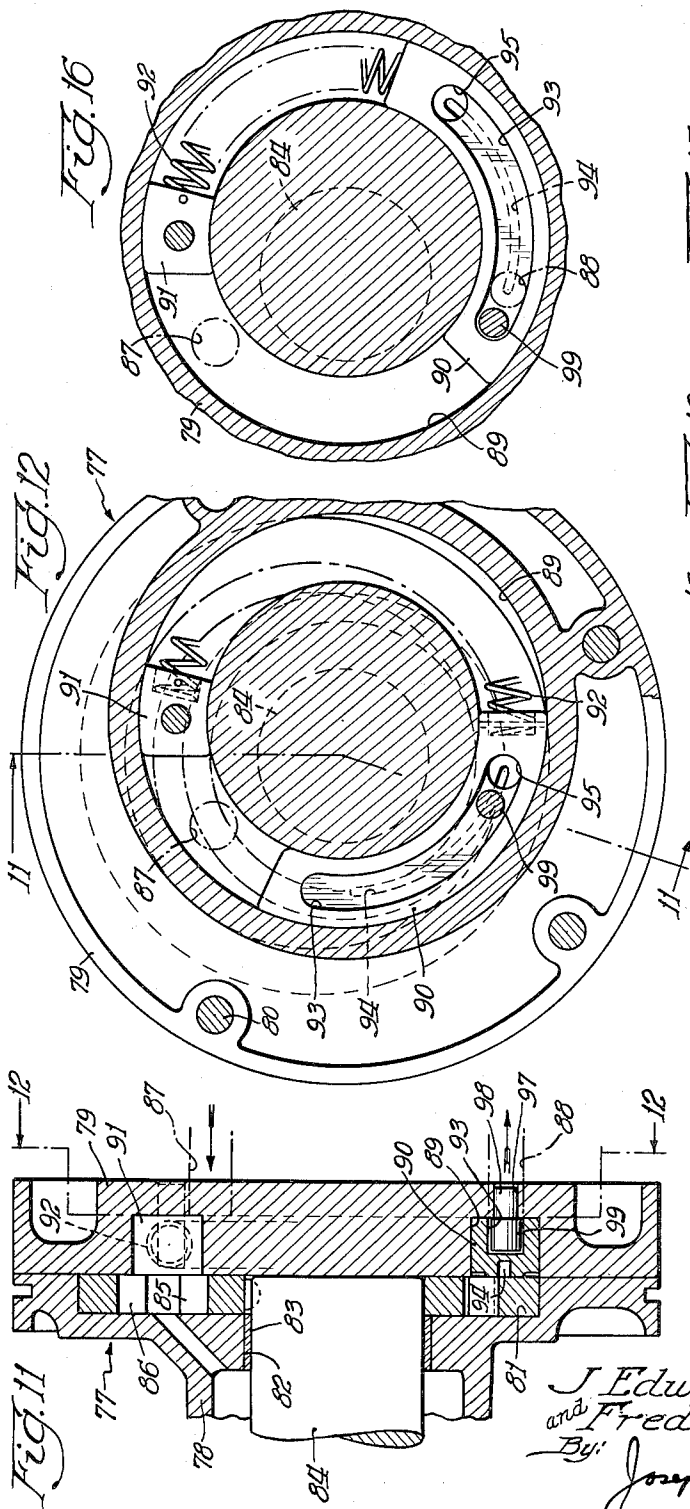
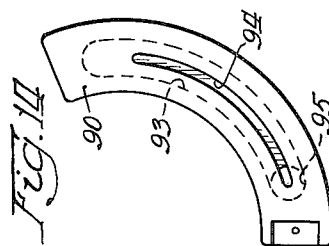
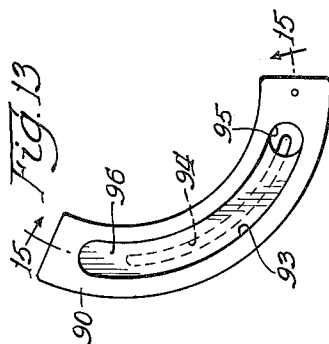
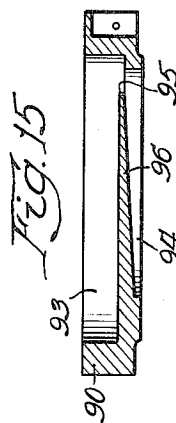
J E. C. ANDERSON ETAL

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7 Sheets-Sheet 4



Inventors:
J Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Dwyer
Att'y.

March 27, 1962

J E. C. ANDERSON ETAL

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INTERNAL-EXTERNAL GEAR PUMP

Filed April 6, 1956

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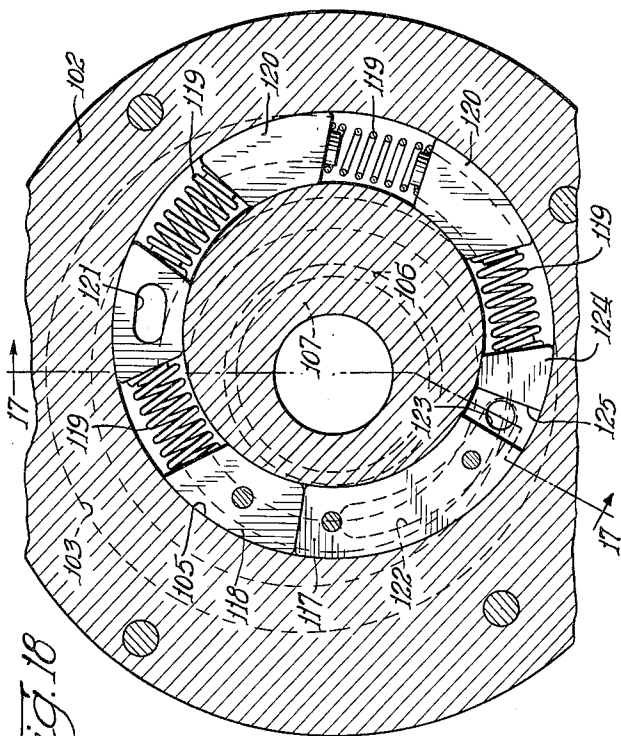


Fig. 18

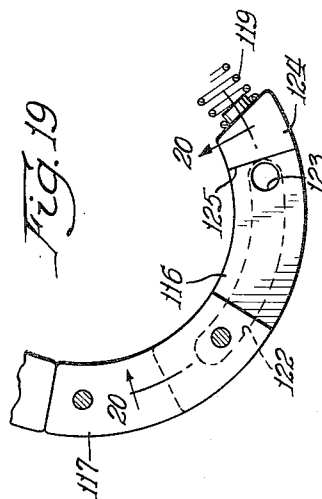


Fig. 19

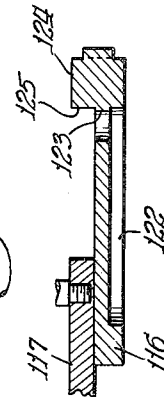


Fig. 20

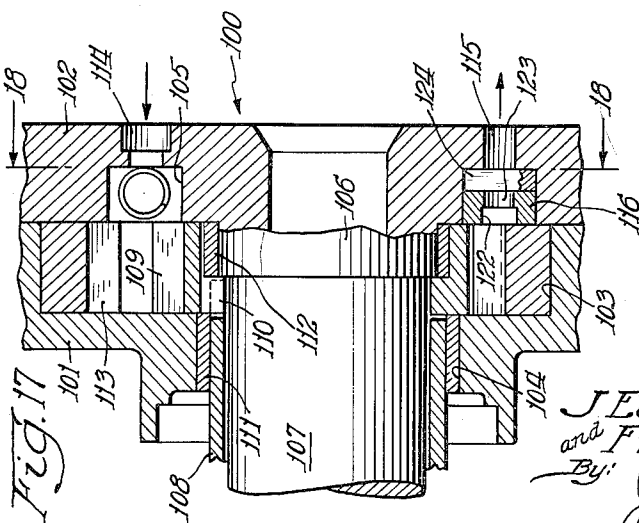


Fig. 17

Inventors:
J. Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Burge

March 27, 1962

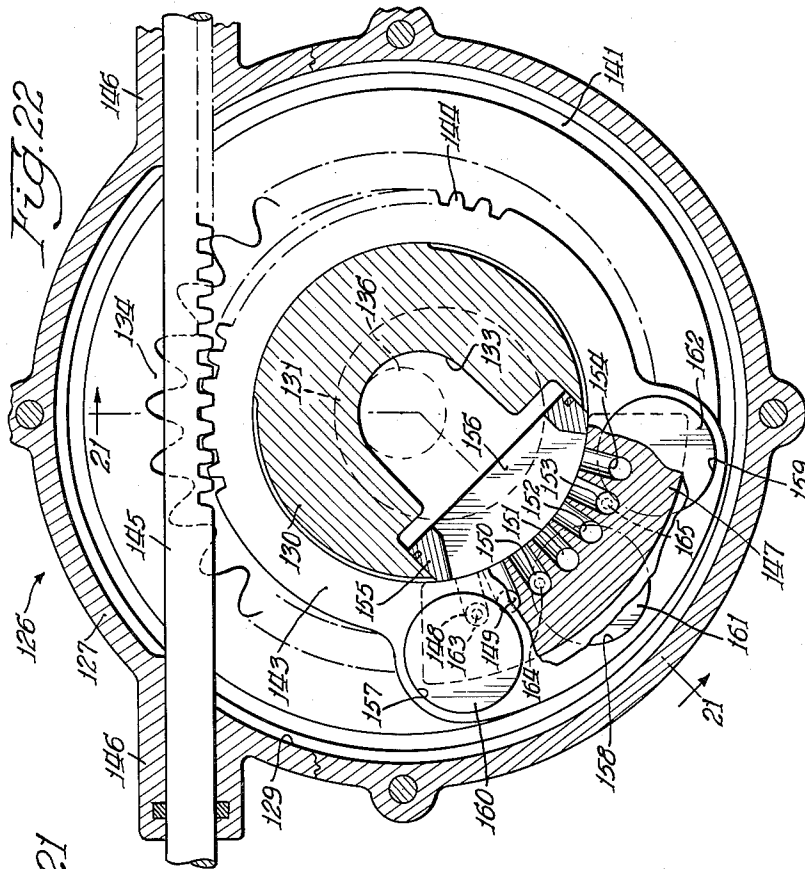
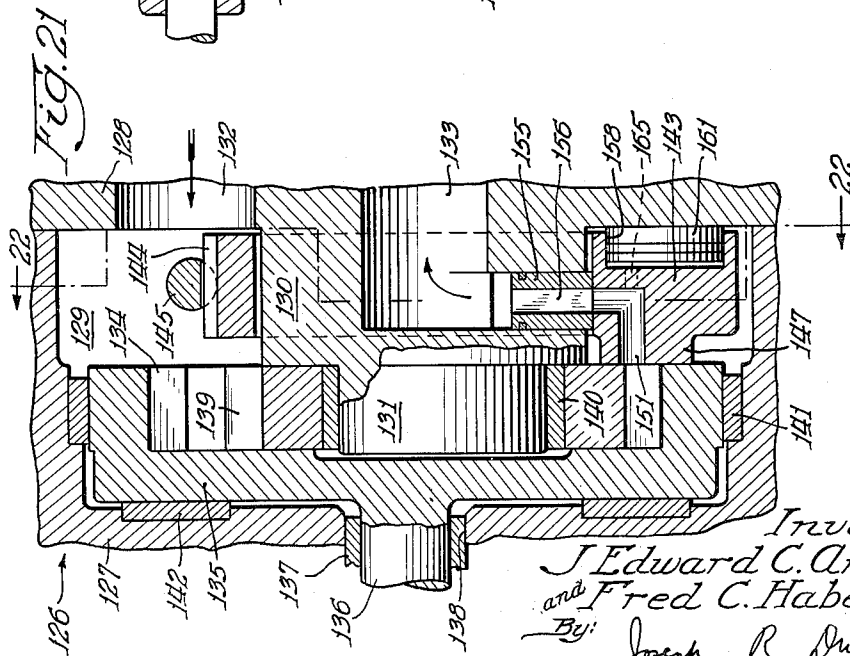
J E. C. ANDERSON ETAL

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7 Sheets-Sheet 6



Inventors:
J Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Dwyer Att'y.

March 27, 1962

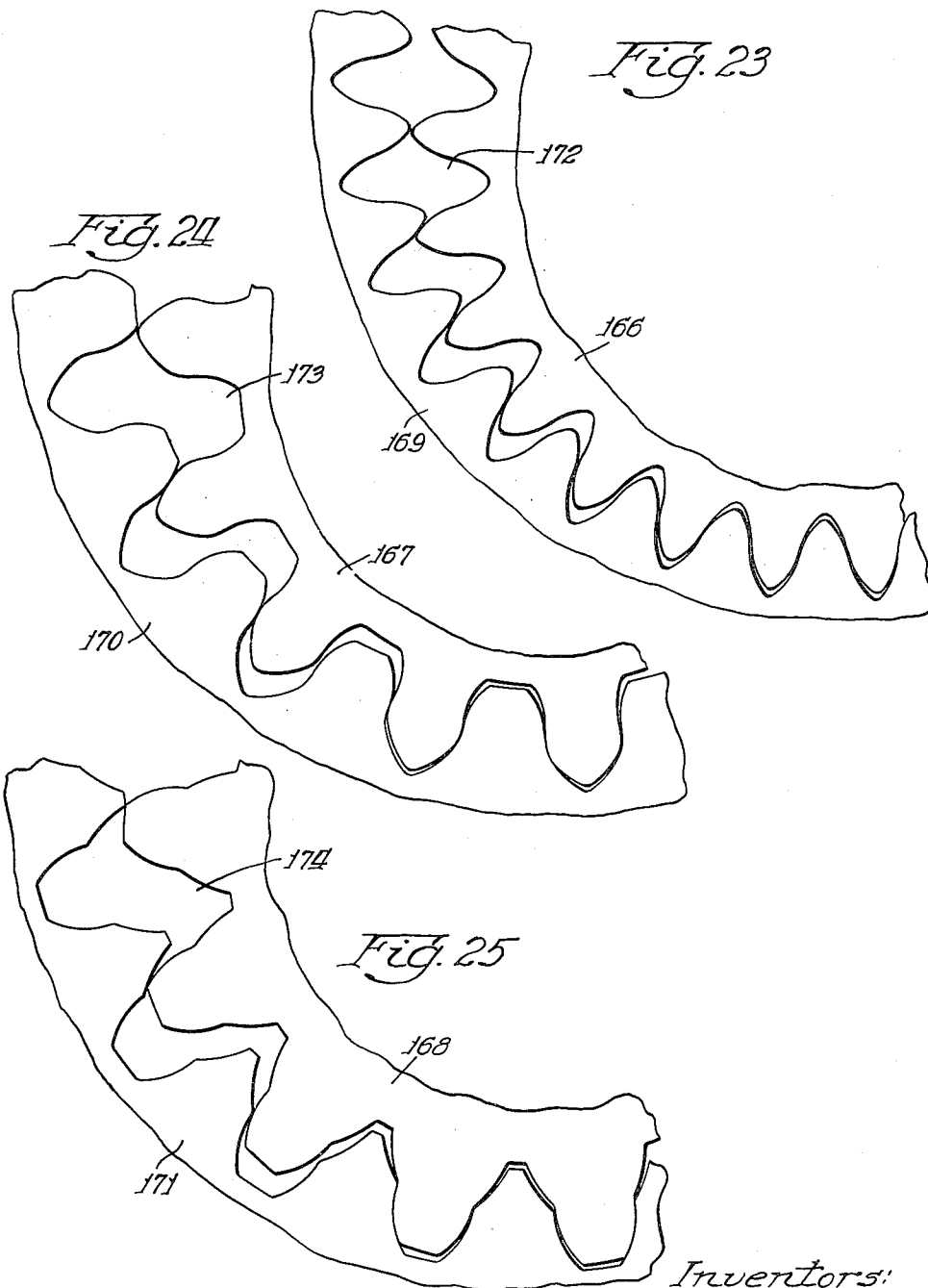
J E. C. ANDERSON ETAL

3,026,809

INTERNAL-EXTERNAL GEAR PUMP

Filed April 6, 1956

7 Sheets-Sheet 7



Inventors:
J Edward C. Anderson
and Fred C. Haberland
By: Joseph R. Hagen atty

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3,026,809

INTERNAL-EXTERNAL GEAR PUMP

J Edward C. Anderson and Fred C. Haberland, Cleveland, Ohio, assignors to Borg-Warner Corporation, Chicago, Ill., a corporation of Illinois

Filed Apr. 6, 1956, Ser. No. 576,568

15 Claims. (Cl. 103—120)

This application relates to fluid pumps, metering devices, and motors, and more particularly to a fluid pump or a fluid operated motor including intermeshing internal-external gears, the internal gear being smaller than the external gear and being mounted eccentrically thereto.

In the usual internal-external gear pump, the output of the pump remains substantially constant for a particular input and for a particular rotational speed imparted to the gears. Because of this, pumps of this type are precluded from use in certain applications, as when it is desired to vary the displacement of the pump over a wide range without varying the input flow or the rotational speed of the gears, or when it is desired to provide a constant pressure output regardless of the rotational speed of the gears and the particular input pressure, or when it is desired to provide a pump having a constant output flow regardless of the input flow thereto and the speed of rotation of the gears. By this invention we successfully overcome the drawbacks of the prior art pumps by providing means disposed between the intermeshing gears adjacent their full meshing position and the outlet or discharge port of the pump, which means is movable between various positions to provide a variance in the output of the pump; the term output being used in a broad sense, including pressure or flow. More particularly, the intermeshing gears provide isolated pockets or chambers therebetween which diminish in volume toward the full meshing position of the gears and the means above referred to is so constructed and arranged to be movable or slidable between various positions so as to vary the degree of communication between the pockets or chambers and the outlet or discharge port of the pump. The movement of the means referred to may be manual or under the control of a device, such as a servo, or may be responsive to pressure or flow, depending on the particular construction of the pump, and upon the use to which the pump is to be put.

In the case of a fluid operated motor, the above referred to discharge port becomes a high pressure port for the flow of fluid to the intermeshing gears to cause rotation of the gears, and by providing a movable or slidable member between the high pressure port and the intermeshing gears, it is possible to feed the input fluid selectively to the pockets, so as to allow different expansion characteristics of the fluid as the gear teeth move from their full meshing position and thereby provide selectively different power output characteristics from the motor.

The device may be employed as a metering device by selectively choosing the number of fluid pockets in communication with a discharge port, so as to control the amount of fluid discharged into a system from a zero value to a maximum value.

Therefore, the principal object of this invention is to provide an improved geared apparatus for operation by or on fluid.

A still further object of this invention is to provide a selectively variable fluid metering device.

Another object of this invention is to provide an internal-external gear pump having means to vary the output therefrom, whether the output is measured by pressure or flow.

A still further object of this invention is to provide a gear pump having means to selectively and infinitely vary

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the displacement of the pump for any given rotational speed and input flow.

Another object of this invention is to provide a geared fluid pump having output responsive means associated therewith to provide a constant output pressure for all speeds of rotation of the gears and for any input pressure thereto.

A still further object of this invention is to provide a fluid pump having output responsive means associated therewith for providing a constant flow of fluid from the discharge for any speed of rotation and input flow of fluid thereto.

A still further object of this invention is to provide a fluid motor in which the power output may be selectively and infinitely varied for any fluid input thereto.

It is also contemplated to construct the pumps with fixed clearance bushing means or pressure loaded bushing means and, also, to differentially pressure load the bushing means. Therefore, a still further object of this invention is to provide improved pumps of the type described with fixed or pressure loaded bushing means.

These and other objects of the invention will become apparent from the following description when taken with the accompanying drawings in which:

FIGURE 1 is a partial sectional view of the first embodiment of the apparatus of this invention taken on line 1—1 of FIGURE 2;

FIGURE 2 is a view of the first embodiment of this invention taken on line 2—2 of FIGURE 1 and illustrating the output varying means in its full output position;

FIGURE 3 is a partial sectional view with parts broken away taken on line 3—3 of FIGURE 2;

FIGURE 4 is a view taken on line 4—4 of FIGURE 1;

FIGURE 5 is a plan view of the means to vary the output of the apparatus shown in FIGURE 1;

FIGURE 6 is an exploded side view of the means shown in FIGURE 5;

FIGURE 7 is a partial sectional view similar to FIGURE 2 and showing the means of FIGURE 5 in its zero output position;

FIGURE 8 is a partial sectional view of a second embodiment of this invention taken on line 8—8 of FIGURE 9;

FIGURE 9 is a partial view of the second embodiment taken on line 9—9 of FIGURE 8;

FIGURE 10 is a partial sectional view of the second embodiment similar to FIGURE 8 but taken on line 10—10 of FIGURE 9;

FIGURE 11 is a partial sectional view of a third embodiment of this invention which provides constant flow characteristics, taken on line 11—11 of FIGURE 12;

FIGURE 12 is a partial sectional view taken on line 12—12 of FIGURE 11 and showing the slidable means in one position;

FIGURE 13 is a front plan view of the slidable means of FIGURE 12;

FIGURE 14 is a rear plan view of the slidable means shown in FIGURE 13;

FIGURE 15 is a sectional view of the slidable means taken on line 15—15 of FIGURE 13;

FIGURE 16 is a partial sectional view, similar to FIGURE 12, showing the slidable means in a different position;

FIGURE 17 is a partial sectional view of a fourth embodiment of this invention, which provides constant pressure characteristics, taken on line 17—17 of FIGURE 18;

FIGURE 18 is a partial sectional view taken on line 18—18 of FIGURE 17 and showing the slidable means in one position;

FIGURE 19 is a partial view showing the slidable means in plan;

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FIGURE 20 is a sectional view of the slidable means taken on line 20--20 of FIGURE 19;

FIGURE 21 is a partial sectional view of a fifth embodiment of this invention;

FIGURE 22 is a view taken on line 22--22 of FIGURE 21;

FIGURE 23 is a plan view with parts broken away illustrating one embodiment of the gear contours and showing the gear teeth approaching full meshing position;

FIGURE 24 is a view similar to FIGURE 21 and illustrating a different embodiment of the gear contours; and

FIGURE 25 is a view similar to FIGURE 23 and illustrating a third embodiment of the gear contours.

Detailed Description

Reference is now directed to FIGURES 1 to 7 illustrating the first embodiment of the invention and wherein there is illustrated a pump 10 comprising a substantially circular housing assembly generally indicated at 11, having a first housing part 12 and a second housing part 13 suitably connected by means, such as bolts 14. Means, such as an O-ring seal 15 is disposed between the housing parts to render the housing assembly fluid tight. The housing part 12 is provided with a substantially cylindrical cavity 16, and with a communicating bore 17 to receive a splined shaft 18 adapted to be driven by a suitable drive mechanism (not shown) and constituting the drive for the pump. The cavity 16, when the parts 12 and 13 are assembled constitutes the pumping chamber for the pump 10. The shaft 18 is integrally formed with an annular flange portion 19 received in the chamber 16 and to which an internal or ring gear 20, constituting the driving gear, is attached, either by welding or other suitable means. Suitable bearing means 21 are received in the bore 17 surrounding the shaft 18, and a packing member 22 is received in the housing part 12 surrounding the shaft 18 to prevent the egress of any fluid therefrom, or the in-flow of air thereto. A circular bearing member 23 is received in the housing part 12 for contact with the annular flange portion 19, and a suitable ring bearing 24 is received in the housing part 12 for contact with the internal gear member 20.

The housing part 13 is provided with a high pressure port 25 and a low pressure port 26, and is provided with extending stud portions 27 and 28, as illustrated. When the apparatus functions as a pump, fluid from a source (not shown) is supplied to the port 26 and fluid is discharged from the port 25. When the apparatus functions as a motor, fluid is supplied to the port 25 and is discharged from the port 26. The stud portions 27 and 28 are eccentric with regard to each other and also eccentric with regard to the shaft 18, the bore 17 and the cavity 16. An external gear or pinion 29 is rotatably received on the stud portion 28 and meshes with the gear 20, as illustrated, and a suitable ring bearing 30 is provided between the stud portion 28 and the gear 29.

A sliding block member, generally indicated at 31, is rotatably disposed around the stud portion 27 and is adapted to be rotated therearound by means, such as a rod 32 slidably disposed within bores 33, 33 formed in the housing portion 12. The rod member 32 is provided with an extending pin 34, which is received in an elongated slot 35 in the block member 31, so that upon movement of the rod member 32 to the right or left, the pin 34 will ride in the slot 35 and rotate the block member 31 around the stud portion 27 between the limits shown in FIGURES 2 and 7, which represent respectively, full and zero displacement positions. The rod member 32 may be moved by hand or by means of suitable mechanism, such as a servo (not shown).

The block member 31 is positioned between the gears, adjacent their meshing positions, and the port 25 and is provided with an elongated cavity 36 to receive a complementary-shaped extending portion 37 of a plate member 38 having sliding contact with the housing part 13. The block member 31 is also provided with an outwardly

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extending bearing surface 39 for sliding contact with the intermeshing gears 20 and 29 and a semi-crescent shape opening 40 between the bearing surface 39 and the cavity 36. The plate member 38 and the extension 37 thereof are provided with an elongated opening 41 to provide communication between the opening 40 and the port 25. A suitable O-ring seal 42 is provided between the cavity 36 and the portion 37 of the member 38, and, also, coil springs 43 are provided between the block member 31 and the plate member 38 to maintain an initial seal between the gears and the surface 39 and the housing member 13 and the plate member 38.

The block member 31 is also provided with a check valve, comprising a bore 44 having a diameter which decreases in steps from a surface removed from the gears to the sealing surface 39, so as to provide a seat 45 upon which a ball 46 is adapted to be retained by means of a spring 47. The spring 47 is positioned and retained in the bore 44 by means of a screw-threaded closure member 48. A passage 49 connects the bore 44 and the opening 40 adjacent the shorter one of its three sides, as illustrated.

The housing portion 12 is provided with a plurality of bores 50 spaced around a portion of its periphery (see FIGURE 4), which bores communicate with the rear of the bearing ring 23.

Attention is now directed to FIGURES 8, 9 and 10 of the drawings which illustrate the second embodiment of this invention. This embodiment differs from the embodiment shown in FIGURES 1 to 7 in the manner of imparting rotation to the gears, the first embodiment being a ring or internal gear driven one, while the instant embodiment is an external gear or pinion driven one, and in the construction slidable block means to vary the output of the pump or motor.

With reference to FIGURE 8, there is shown a housing assembly generally indicated at 51 comprising a first portion 52 and second portion 53. The first portion 52 is provided with a substantially cylindrical cavity 54 which forms the pumping cavity when the member 53 is assembled with the member 52, and the parts 52 and 53 are assembled in the same manner as the parts 12 and 13 of the first embodiment. The housing part 52 is also provided with a bore 55 through which a drive shaft 56 extends and a bearing ring 57 is received within the bore 55 and around the shaft 56. The housing member 53 is provided with a low pressure port 58 and a high pressure port 59, and with an extending stud portion 60 eccentric with regard to the bore 55 and the cavity 54. The stud portion 60 is provided with a cavity 61 having a bearing ring 62 disposed therein and in which an extension portion 63 of the shaft 56 is piloted. An external gear or pinion 64 constitutes the driving gear and is keyed, as at 65, to the shaft 56 and meshes with an internal or ring gear 66 disposed in the cavity 54. A suitable bearing ring 67 is disposed in the cavity 54 surrounding the gear 66 and a bearing ring 68 is also disposed within the housing portion 52 for contact with the sides of the gears 64 and 66.

A sliding block member 69 is rotatably disposed on the stud portion 60 between the gears 64 and 66 adjacent their intermeshing portions and a wall of the housing portion 53 adjacent the port 59 and is provided with a semi-crescent shaped opening 70 and a communicating elongated opening 70 for providing communication between the output sector of the intermeshing gears and the port 59. This sliding block arrangement is adapted for movement in the same manner and by the same means as the block 31 of the first embodiment of the invention; however, it is a one-piece member and thereby differs slightly in construction from the block member 31 of the first embodiment.

The block member 69 is provided with a check valve comprising a bore 72 of decreasing diameters from the port side to the gear side of the block member, and forms

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a seat 73 for a spring pressed ball 74. A passage 75 communicates the bore 72 and the shortest of the three sides of the opening 70.

A series of passages 76 are provided around a portion of the periphery of the housing portion 52 and communicate to the rear of the bearing ring 68.

Reference is now made to FIGURES 11 to 16 inclusive illustrating the third embodiment of the invention which provides a pump having constant output flow characteristics. In this embodiment of the invention the external gear or pinion is driven and a different sliding block arrangement is provided for maintaining the constant flow characteristics regardless of the rotational speed of the gears and the input flow to the pump; the block being responsive to the output flow of the pump.

Attention is directed to FIGURE 11 showing a housing generally indicated at 77 comprising a first portion 78 and a second portion 79 joined by any suitable means such as bolts 80. The housing portion 78 is provided with a substantially cylindrical cavity 81 and a communicating bore 82, the latter being eccentric to the cavity 81 and receiving a bearing 83 and shaft 84. An external gear or pinion 85 constituting the driving gear is splined or keyed to the shaft 84 and meshes through a portion of its periphery with an internal or ring gear 86 disposed in the cavity 81. The housing portion 79 is provided with an input port or inlet 87 and a discharge port or outlet 88, and also, an annular cavity 89 disposed eccentrically to the cavity 81 and the shaft 84, as illustrated.

An arcuate block member 90 (see FIGURES 12 to 16) is received for sliding movement in the cavity 89, and a fixed block member 91 is also received in the cavity 89. A coiled compression spring 92 is disposed within the cavity 89 and is fixed at its opposite ends to the block members 90 and 91. The block member 90 is provided with an arcuate, elongated cavity 93 and a smaller, arcuate, elongated cavity 94, the cavities communicating with one another by means of an opening 95 and being separated from one another throughout the remainder of their lengths by means of a tapered wall 96, as illustrated in FIGURE 16. As may be seen, the cavities 93 and 94 and the opening 95 theretbetween provide communication between the gears adjacent their positions of intermeshing and the outlet 88, the block 90 being slidable to vary the degree of the aforementioned communication.

The housing portion 79 is provided with a bore 97 extending from its outer wall to the cavity 89, as illustrated, and the bore receives a stepped dowel member 98 having its enlarged portion 99 disposed within the cavity 89. The enlarged dowel portion 99 is slidable within the cavity 93 of the block member 90, the diameter of the enlarged portion 99 being slightly smaller than the width of the cavity 93, so that the enlarged dowel portion 99 will be slightly spaced from the side walls of the cavity 93.

Attention is now directed to FIGURES 17 to 20 illustrating a fourth embodiment of this invention and constituting a pump to provide a constant pressure output; the means providing the constant pressure output being pressure responsive. There is illustrated a housing assembly 100 comprising a first portion 101 and second portion 102 joined by suitable means, as in the same manner as the housing parts of the first embodiment. The first housing portion 101 is provided with a substantially cylindrical pumping cavity 103 and an eccentrically disposed communicating bore 104, and the second portion 102 is provided with an annular cavity 105, eccentric to the cavity 103 and the bore 104, as illustrated, and extending stud portions 106 and 107 concentric to the bore 104. A hollow drive shaft 108 is disposed within the bore 104 and has an external gear 109, constituting the driving gear, keyed thereto, as at 110. Suitable bearing rings 111 and 112 are disposed within the bore 104 surrounding the shaft 108 and around the stud portion 106 within the gear 109, respectively. An internal or ring

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gear 113 meshing with the external gear 109 over a portion of its toothed area is received in the cavity 103.

The housing portion 102 is provided with an inlet port 114 and a discharge port or outlet 115 which communicate with the cavities 105 and 103. An arcuate block member 116 (see FIGURES 18 to 20) is received for sliding movement in the cavity 105, and a pair of fixed block members 117 and 118 are also received in the cavity 105. The members 117 and 118 could be combined into one element, if desired. Coiled compression springs 119 and a plurality of support blocks 120 are disposed between the blocks 116 and 118 and within the cavity 105. One of the blocks is provided with an opening 121 to communicate the inlet port 114 and the pump cavity 103, as illustrated. The block member 116 is positioned for sliding movement between the gears and the block member 117 and is provided with an elongated arcuate cavity 122 disposed adjacent the meshing position of the gears, a passage 123 and an upstanding enlarged portion 124 having a height substantially equal to the depth of the cavity 105, so as to provide a surface 125 for a purpose to be described. The passage 123 provides communication between the cavity 122 and ultimately the discharge port 115.

Attention is now directed to FIGURES 21 and 22 wherein there is illustrated a fifth embodiment of my invention incorporating a modified form of sliding block arrangement and having provisions for a stepped pressure loading of the block. The pump comprises a housing, generally indicated at 126, which includes a body member 127 and a cover member 128, the members being secured in assembled relationship by means such as bolts. The body member 127 is provided with a cylindrical cavity 129 which forms the pumping chamber for the pump, and the cover member 128 is provided with inwardly extending stud portions 130 and 131, concentric to one another but eccentric with regard to the cavity 129. The cover member 128 is also provided with an inlet passage 132 and an angularly arranged outlet passage 133, the latter being formed in the stud portion 130, as illustrated.

A pair of pumping gears are disposed within the pumping chamber 129 and comprise a ring or internal gear 134, forming the driving gear of the pump, welded or otherwise attached to a cylindrical flanged member 135 of a shaft 136 suitably journaled, as at 137, in an opening 138 formed in the body member 127. An external gear or pinion 139 is disposed around suitable bearing means 140 on the stud portion 131 of the cover member 128. The gear 139, as may be seen by an inspection of the drawings, is eccentric with regard to the gear 134, and meshes therewith over a portion of its periphery. The body member 127 is provided with suitable bearing means 141 and 142 for engagement with the ring gear 134 and the flanged member 135, respectively.

To provide for varying the displacement of the pump, there is provided a sliding or rotatable block member 143 disposed around the stud portion 130. For adjustment of the position of the sliding block member 143, a portion of its periphery is provided with teeth, as at 144, for cooperation with a toothed rack member 145, slidably journaled within a pair of bosses 146 extending from the body member 127. By moving the rack to the right or to the left, the position of the block member 143 may be varied between its full displacement position, as illustrated in FIGURE 22, and its zero displacement position, which would be the case when the block member 143 is rotated counter-clockwise for about 90°. A suitable servo mechanism (not shown) may be provided for moving the rack 145 and thereby changing the displacement of the pump, when necessary or desirable.

As may be clearly seen in FIGURE 21, the sliding block 143 is provided with an inwardly extending portion 147 engaging the gear teeth adjacent their intermesh-

ing position and is provided with a plurality of angularly arranged openings 148, 149, 150, 151, 152, 153 and 154 (see FIGURE 22) which are adapted to communicate with the fluid pockets formed between the teeth of the intermeshing gears 134 and 139. These openings allow a flow of fluid under pressure to the outlet 133 of the pump. An elongated member 155 having an elongated fan-shaped opening 156 is disposed within a portion of the outlet 133, so as to cooperate with the passages 148 to 154 for the flow of fluid therethrough.

The sliding block member 143 is provided with a plurality, for example three, cavities 157, 158 and 159, and piston members 160, 161 and 162, respectively, are disposed therein. The piston members 160, 161 and 162 are adapted to form a pumping seal with the inner surface of the cover member 128 and are pressure loaded by means of passages 163, 164 and 165, which communicate with the passages 148, 150, 153, respectively, formed in the sliding block member 143. Since the pressure in each of the passages 148, 150 and 153 is different, the pressure increasing as the gears 134 and 139 approach their full meshing position, there is thus provided a stepped pressure loading of the block member 143, to prevent the flow of fluid across the gear teeth and across the inner face of the cover member adjacent the full meshing position of the gears.

As in the previous embodiments, and in all high pressure pumps, suitable O-ring sealing means are provided where necessary.

Attention is now directed to FIGURES 23, 24 and 25 illustrating various gear contours for use in the embodiments of this invention previously described. There is shown meshing portions external gears or pinions 166, 167 and 168 and internal or ring gears 169, 170 and 171, respectively, which form isolated pockets or chambers, indicated at 172, 173 and 174, respectively, which decrease in as the respective pair of gears approach their full meshing positions and which pockets are isolated from one another to perform their fluid pressure functions. In each of the three embodiments of the gear illustrated in FIGURES 23, 24 and 25, the contour of the gear teeth are so constructed that the pinion teeth do not "foul" with the internal gear teeth.

In each of the gear contour embodiments, it will be seen that the gear teeth begin to mesh with a tooth on the external gear or pinion contacting a tooth on the internal or ring gear, thus trapping fluid within a pocket formed with the next preceding gear teeth, and as the teeth gears rotate toward their full meshing positions, the external gear tooth will ride on the surface of the internal gear tooth, decreasing the volume of the pocket, but maintaining the pocket isolated from the preceding pocket or the succeeding pocket. This riding action of one tooth on another is smooth with no fouling therebetween.

With regard to the tooth form illustrated in FIGURE 23, it is possible to develop a similar tooth form by a mathematical approach. The basic premise for such a tooth form is that the contact points of the teeth in the "pumping" sector is half-way between the points formed by the intersection of the contacting tooth center lines and their respective pitch circles. The contact point is at the midway point of a line connecting the intersection of the ring gear pitch circle and tooth center line with the intersection of the pinion gear pitch circle and tooth center line when the gears are meshed and the tooth center lines are of contacting teeth. The following formulae represent one side of the addendum contour of the respective teeth; the other side of the tooth addendum is obtained by reversing the sign for the Y values. The dedendum portions of the teeth are generated from the addendum portions, so that no contact between addendum and dedendum portion of the teeth is possible.

The formulae developed from this premise are: Ring gear tooth contour where the X axis is each tooth center

line, the origin is the center of the gear, the Y axis is at right angles to the X axis and in the same plane.

$$X = \frac{1}{2} \left[R + (R - P) \cos \left(\theta + \frac{90}{T} \right) + P \cos \left(\frac{R - P}{P} \theta - \frac{R + P}{P} \frac{90}{T} \right) \right]$$

$$Y = \frac{1}{2} \left[P \sin \left(\frac{R - P}{P} \theta - \frac{R + P}{P} \frac{90}{T} \right) - (R - P) \sin \left(\theta + \frac{90}{T} \right) \right]$$

Pinion gear tooth contour; where the X axis is each tooth centerline, the origin is the center of the gear, the Y axis is at right angles to the X axis and in the same plane.

$$X = \frac{1}{2} \left[P - (R - P) \cos \left(\phi - \frac{90}{S} \right) + R \cos \left(\frac{R + P}{R} \frac{90}{S} - \frac{R - P}{R} \phi \right) \right]$$

$$Y = \frac{1}{2} \left[(R - P) \sin \left(\phi - \frac{90}{S} \right) + R \sin \left(\frac{R + P}{R} \frac{90}{S} - \frac{R - P}{R} \phi \right) \right]$$

In the above formulae:

R = pitch radius of the ring gear

P = pitch radius of the pinion gear

T = number of teeth in ring gear

S = number of teeth in pinion gear

θ = angle through which ring gear is rotated

ϕ = corresponding rotation angle of pinion gear

also:

$$\theta = \frac{R}{P} \phi \text{ and } T = \frac{R}{P} S$$

$\left(\theta + \frac{90}{T} \right)$ = angular location of ring gear tooth centerline

and:

$\left(\phi - \frac{90}{S} \right)$ = corresponding angular location of pinion tooth centerline when the tooth contours are in contact. Angles are in degrees and are measured from the centers of the respective gears.

The path of action for the above teeth is the curve containing the points represented by:

$$X = \frac{1}{2} \left[R \cos \left(\theta + \frac{90}{T} \right) + P \cos \left(\phi - \frac{90}{S} \right) + (R - P) \right]$$

$$Y = \frac{1}{2} \left[R \sin \left(\theta + \frac{90}{T} \right) + P \sin \left(\phi - \frac{90}{S} \right) \right]$$

where the X axis is the common centerline of the two gears, the origin is the center of the ring gear, angles

$$\theta \text{ and } \frac{90}{T}$$

in degrees are from the X axis at the origin, angles

$$\phi \text{ and } \frac{90}{S}$$

in degrees are measured from the X axis about the center of the pinion which is at the point $X = (R - P)$, $Y = 0$. Maximum values for the angles θ and ϕ are determined from the tooth contour formulae by setting $Y = 0$ and solving for θ or ϕ .

For a gear tooth contour substantially as illustrated in FIGURE 23, T minus S is greater than 1 and less than 8.

Detailed Operation

In the first embodiment illustrated in FIGURES 1 to 8, the internal gear 20 is driven and meshes with the external gear or pinion 29, thereby imparting rotation to the latter. The gears mesh over a portion of their toothed areas, and form pockets (see FIGURES 24, 25 and 26) which diminish as the gears approach their full meshing position. When employed as a pump, fluid from a source is fed to the inlet port 26, flows within the cavity 16 and becomes trapped in the aforementioned pockets or chambers between the gear teeth, so that the fluid trapped in the pockets is subjected to increasing pressures.

Without the sliding block assembly, it will be readily understood that for any given inlet flow and speed of rotation of the gears, the output flow of the pump will be substantially constant. However, the sliding block assembly 31 allows the output flow to be selectively varied, this being so because the semi-crescent shaped opening 40 communicates all, a portion of, or none of the pockets between the intermeshing gears with the discharge port 25. As before stated, the block 31 is illustrated in a full displacement position on FIGURE 2 and a zero displacement position in FIGURE 7, and is movable between these positions by means of the rod 32. Because of the eccentric mounting of the block 31, as the block is moved toward its zero displacement position from its full or part displacement position, the opening 40 will be partially blocked by the adjacent side surface or face of the external gear or pinion 29; the remainder of the opening being in communication with some of the pockets between the gears adjacent their full meshing position. Therefore, by such movement of the block member 31, the displacement of the pump may be varied from zero to full displacement, depending on the requirements of use.

The block member 31, in addition to its function of varying the displacement of the pump, constitutes bushing means for the gears, and to prevent the by-passing of fluid across the side faces of the gears adjacent their meshing position means are provided for applying forces to the bushing means to urge the bushing means toward the gears and toward the interior of the housing, so as to provide the necessary seals with the gears and the housing, such bushing means being pressure loaded by means of discharge pressure from the pump. As may be seen from the drawings, and especially FIGURES 1 and 3, the extension 37 of the plate member 38 is spaced from the bottom of the cavity 36 in the block member 31, thereby forming a pressure motive chamber therebetween. Fluid pressure from the gear pockets when flowing to discharge through the openings 40 and 41, acts within the pressure motive chamber and applies a force to the block member 31 on the bottom of the cavity 36 to urge the block member toward the gears, so as to maintain a proper fluid seal between the side faces of the gears and the surface 39, and also applies a force to the extension portion 37 to urge the plate member 38 toward the adjacent inside wall of the housing, so as to maintain a proper fluid seal between the plate member 38 and the adjacent inner surface of the housing part 13. The coil springs 43 provide initial seals when the pump is started, and the O-ring seal 42 prevents the escape of fluid between the cavity 36 and the exterior of the extension portion 37 which would reduce the loading force.

The check valve housed within the block member 31 is provided to initially relieve fluid pressure in a gear pocket as it approaches the shortest of the three sides of the semi-crescent shaped opening 40, the fluid moving the ball 46 off its seat 45 and allowing the fluid to pass through the cavity 44, through the passage 49 and into the opening 40 and thereby to discharge. This check valve is necessary to reduce the erosive effects on the

short side of the opening 40 due to the high pressure fluid trapped in the gear pocket rushing to a zone of lower pressure, and avoids the destruction of the block member 31 within a short period of use.

The passages 50 are employed, as illustrated, to allow a flow of leakage fluid around the bearing ring 23 to a source of fluid supply. However, the bearing ring 23 also constitutes bushing means and may be pressure loaded around a portion of its periphery by merely connecting the passages 50 to a source of high pressure fluid, such as the discharge port 25. It is also contemplated that this pressure loading may be accomplished differently, by constructing the ring bearing 23 in a plurality of segments and applying a different fluid pressure through the passages 50 to each of the segments.

With regard to the pressure loading, it will be apparent that this is accomplished only adjacent the high pressure portion of the gears, it not being necessary adjacent the low pressure position.

The embodiment, just described, may be provided with an external gear or pinion drive and/or, may be constructed with a block of the same construction as illustrated in the second embodiment (FIGURES 8 to 10) which is not adapted to be pressure loaded providing fixed clearance bushing means and which will be later described.

When the first embodiment of this invention is operated as a fluid motor, high pressure fluid is fed to the port 25 and exhausted from the port 26, and drives the gears in the opposite direction when employed as a pump. The fluid input may be varied by moving the block member 31 to thereby vary the motor output over a wide range.

The second embodiment of the invention as illustrated in FIGURES 8, 9 and 10 differs from the above described first embodiment in the manner of driving the gears and in the sliding block construction.

When operated as a pump, fluid from a source is fed to the port 58 and is discharged from the port 59. The external gear or pinion 64 constitutes the driving gear and the sliding block 69 is constructed without means to pressure load its bushing portions, so that in effect, a fixed bushing pump results. However, the operation of the block member in being moved from its full displacement position (see FIGURE 9) to its zero displacement position (not illustrated, but corresponding to FIGURE 7) is the same as in the above described first embodiment. The check valve comprising the spring pressed ball 74 on the seat 73 and the passage 75 operates in the same manner and performs the same function as the check valve in the first embodiment, and also, the passages 76 are for the purpose of exhausting fluid which may leak past the bearing ring 68.

It is to be understood that an external gear or pinion driven pump may be provided with pressure loaded bushing means in the same manner as described with reference to the first embodiment of this invention.

Further, when the structure of the second embodiment is operated as a fluid motor, high pressure fluid is fed to the port 59 and exhausted from the port 58, and the structure will operate in the same manner as described with reference to the first embodiment, with the gears being driven in the opposite direction from that when the structure is operated as a pump.

From the foregoing description, it may be readily seen that the structure may be constructed with either a ring or internal gear drive; however, with a ring or internal gear drive a larger number of pockets are provided which results in a larger displacement pump and a higher output motor, than with a pinion drive device with a corresponding input.

The third embodiment of the invention illustrated in FIGURES 11 to 16 comprises a pump especially adaptable for use in automotive hydraulic systems wherein a constant flow of fluid is required. The shaft 84 consti-

tutes either a drive shaft or a crankshaft of an automobile and therefore will rotate at various speeds, resulting in the driving of the external gear or pinion 85 at various speeds.

Fluid is fed to the pump from a source through the port 87 and discharged from the port 88. Fluid trapped in the pockets formed between the gear teeth as they approach their full meshing position flows into the cavity 94 in the block member 90, through the opening 95, into the cavity 93 and to the port 88. Fluid in the cavity 93 will flow around the dowel portion 99, so as to provide an orifice effect, resulting in a pressure drop between the opposite ends of the cavity 93. The pressure of the fluid on the end of the cavity 93 adjacent the opening 95 will have the greatest value and will result on a force on the block member 90 tending to move the block member against an opposite force due to the coil spring 92. When the force on the end of the cavity becomes sufficient to overbalance the force of the spring 92, the block 90 will be moved and such movement will result in the communication of a fewer number of pockets between the gear teeth and the cavity 94, i.e., the block 90 moves to a lower displacement position with regard to the gears. Variations in the speed of the driving means are reflected in variations in pressure in the chamber 93, so that the block member 90 will oscillate between its full displacement position shown in FIGURE 12 and its zero displacement position shown in FIGURE 16 and maintain a substantially constant flow from the discharge port 88.

This pump could if desired, be constructed with an internal or ring gear drive, by merely connecting the shaft 84 to the ring gear 86 instead of its connection with the pinion or external gear, as illustrated.

The fourth embodiment of the invention, illustrated FIGURES 17 to 20 comprises a pump especially adapted for use in connection with automotive hydraulic systems which require a constant pressure supply of fluid regardless of the speed of the shaft 108 forming the drive for the external gear or pinion 109, which shaft may be the drive or countershaft of the automobile.

Fluid from a source is fed to the pump through the port 114 and discharged to a hydraulic system (not shown) through the port 115, the fluid flowing from the pockets formed by the intermeshing gears into the cavity 122 in the block member 116, through the opening 123 and to the port 115. With increases in speed of the shaft 108, there will be a tendency to increase the pressure of the fluid discharged; however, the fluid provides a force acting on the surface 125 tending to move the block member 111 against the force of the springs 119, and when the latter force is overbalanced, the block member 116 will move to a lower displacement position. Therefore the pressure of the fluid discharged will be lowered and equal to the spring load. So, with frequent changes in the speed of the shaft 108, the block member 116 will oscillate between its full displacement position shown in FIGURE 18 and its zero displacement position shown in FIGURE 19, resulting in the obtaining of a substantially constant pressure of the fluid output from the pump.

As in the previous embodiments, it will be understood that in the instant embodiment, a ring or internal gear drive may be provided in lieu of the external gear or pinion drive illustrated.

The fifth embodiment of the invention, as is illustrated in FIGURES 21 and 22 operates in substantially the same manner as the first embodiment of this invention in that fluid is fed into the inlet and discharged under pressure from the outlet. As may be readily understood, various pressures of fluid are fed to the cavities containing the piston members for pressure loading the pump, this being true because of the particular gear tooth pocket in communication therewith at a particular time. This stepped pressure loading provision prevents

the binding of the gears with the block member adjacent the lower pressure gear pockets and increases as the pressure in the pockets increases, the latter being necessary to prevent the flow of fluid across the gears and inner surface of the cover member as previously described, since wear and friction reflected in pump operation will be compensated for. Since the operation is essentially the same, further description is considered repetitious and unnecessary.

Therefore, from the foregoing, it is seen that by providing a sliding block arrangement, as described, it is possible to vary the output of a pump or fluid motor, regardless of variable in the operation thereof. The device is simple, yet effective to adapt internal-external gear pumps or motors to a wide variety of uses.

While we have described our invention in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not by way of limitation and the scope of our invention is defined solely by the appended claims which should be construed as broadly as the prior art will permit.

We claim:

1. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising an internal or ring gear and an external gear or pinion for pumping fluid from said inlet through said chamber and out said outlet, said gear means being eccentric to one another and having teeth which mesh and provide a plurality of fluid pockets therebetween of various diminishing sizes whereby fluid in said pumping chamber is trapped in said pockets and subjected to increasing pressure, said teeth having contours maintaining continuous contacts between said pockets while performing said fluid pressure function, and a member disposed within said pumping chamber between said gear means and said outlet and having passage defining means therein for communicating said pockets and said outlet, said member being eccentrically disposed with regard to said gear means and being mounted for movement between a position wherein said passage defining means provides communication between a plurality of said pockets and said outlet and a position wherein said passage defining means is blocked by one of said gear means so that no communication is provided between said pockets and said outlet, said member thereby varying the degree of communication between said pockets and said outlet by being moved to various intermediate positions between the two said positions.

2. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising a ring gear and a pinion for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas and meshing over a portion of said areas to provide a plurality of fluid pockets therebetween of various diminishing sizes, and movable means disposed within said chamber between said gear means and said outlet and eccentric with respect to said gear means provided with a semi-crescent shaped opening therein for movement between various positions wherein fluid in said pockets is discharged through said opening to said outlet or blocked by said movable means, said movable means thereby varying the degree of communication between said pockets and said outlet by being moved to its various positions.

3. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising an internal or ring gear and an external gear or pinion for pumping fluid from said inlet through said chamber and out said outlet, said gear means being eccentric to one another

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and having teeth which mesh and provide a plurality of fluid pockets therebetween of various diminishing sizes whereby fluid in said pumping chamber is trapped in said pockets and subjected to increasing pressures, said teeth having contours maintaining continuous contacts between said pockets while performing said fluid pressure function, a member disposed within said pumping chamber between said gear means and said outlet and having passage defining means therein for communicating said pockets and said outlet, said member being eccentrically disposed with regard to said gear means and being mounted for movement between a position wherein said passage defining means provides communication between a plurality of said pockets and said outlet and a position wherein said passage defining means is blocked by one of said gear means so that no communication is provided between said pockets and said outlet, said member comprising a first portion in engagement with the adjacent sides of said gear means and a second portion in engagement with the adjacent side wall of said chamber and defining a pressure motive chamber therebetween, said member varying the degree of communication between said pockets and said outlet by being moved to various intermediate positions between the two said positions, and means to communicate fluid pressure to said pressure motive chamber to thereby pressure load said portions and prevent the flow of fluid across said gear means and said chamber wall adjacent said member.

4. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising a ring gear and a pinion for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas and meshing over a portion of said areas to provide a plurality of fluid pockets therebetween of various diminishing sizes, movable means disposed within said chamber between said gear means and said outlet provided with a three-sided opening therein for movement between various positions so that fluid in said pockets is discharged through said opening to said outlet or blocked by said movable means, said movable means thereby varying the degree of communication between said pockets and said outlet by being moved to its various positions, said opening having one of its sides of smaller dimension than its other two sides and defining an edge which is subjected to a high fluid pressure as a fluid pocket is placed in communication with said opening, and a relief valve in said means to allow a reduction of said high fluid pressure from said last-named pocket to prevent the erosion of said edge.

5. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid receiving pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising an arcuate-shaped member movable within means defining a recess in said housing eccentric to the axis of said gear means and having passage defining means therein for communicating said pockets and said outlet, said pressure responsive means being movable between a first position wherein said passage defining means is in communication with a plurality of said pockets and a second position wherein said passage defining means is partially blocked by the sides of said gear means.

6. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means re-

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ceived in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid receiving pockets of varying diminishing sizes so as to perform fluid pressure functions, pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising an arcuate-shaped member movable within means defining a recess in said housing eccentric to the axes of said gear means and having passage defining means therein for communicating said pockets and said outlet, said pressure responsive means being movable between a first position wherein said passage defining means is in communication with a plurality of said pockets and a second position wherein said passage defining means is partially blocked by the sides of said gear means, and a spring disposed within said means defining a recess and opposing movement of said pressure responsive means, said spring allowing movement of said pressure responsive means when overbalanced by fluid pressure.

7. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising a ring gear and a pinion for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas and meshing over a portion of said areas to provide a plurality of fluid pockets therebetween of various diminishing sizes, movable means disposed in said chamber provided with a three-sided opening therein for movement between various positions so that fluid in said pockets is discharged through said opening to said outlet or blocked by said movable means, said movable means thereby varying the degree of communication between said pockets and said outlet by being moved to its various positions, said opening having one of its sides of smaller dimension than its other two sides and defining an edge which is subjected to a high fluid pressure as a fluid pocket is placed in communication with said opening, means defining a pair of communicating passages in said output varying means, one of which also communicates with a fluid pocket in advance of said opening and the other of which also communicates with said opening adjacent said edge, and a relief valve disposed within one of said last-named means to allow a reduction of said high fluid pressure from said last-named pocket to prevent the erosion of said edge.

8. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising a member having a pair of recesses therein and means defining an opening providing communication between said recesses, one of said recesses being in communication with said pockets when said member is in a first position and out of communication therewith when said member is in a second position, said member being movable between said first and second positions to vary the degree of communication with said pockets, said movement of said member being in response to a pressure drop between the ends of said second one of said recesses so that a constant flow output is provided.

9. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received

in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising a member having a pair of recesses therein and means defining an opening providing communication between said recesses, one of said recesses being in communication with said pockets when said member is in a first position and out of communication therewith when said member is in a second position, said member being movable between said first and second positions to vary the degree of communication with said pockets, a dowel member fixed in said housing and having a portion disposed within a second one of said recesses, said portion being of a smaller dimension than the width of said second recess so as to provide an orifice effect, said movement of said member being in response to a pressure drop across said dowel portion and between the ends of said second one of said recesses to thereby provide a constant flow output from said pump.

10. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising a member having a pair of recesses therein and means defining an opening providing communication between said recesses, one of said recesses being in communication with said pockets when said member is in a first position and out of communication therewith when said member is in a second position, said member being movable between said first and second positions to vary the degree of communication with said pockets, a dowel member fixed in said housing and having a portion disposed within a second one of said recesses, said portion being of a smaller dimension than the width of said second recess so as to provide an orifice effect, said movement of said pressure responsive means being in response to a pressure drop across said dowel portion and between the ends of said second one of said recesses to thereby provide a constant flow output from said pump, and spring means resisting movement of said member and allowing movement thereof when overbalanced by fluid pressure.

11. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising a member having a recess and a communicating opening and means defining an upstanding surface, said recess being in communication with said pockets when said member is in a first position and out of communication when said member is in a second position and movable between said positions to vary the degree of communication with said pockets, said movement being in response to fluid pressure acting on said upstanding surface so that a constant pressure output will be provided.

12. In a fluid pump, the combination of a housing, a

pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber for pumping fluid from said inlet through said chamber and out said outlet, said gear means having toothed areas which mesh over a portion thereof to provide a plurality of fluid pockets of varying diminishing sizes so as to perform fluid pressure functions, and pressure responsive means disposed between said gear means and said outlet to provide a varying degree of communication between said pockets and said outlet, said pressure responsive means comprising a member having a recess and a communicating opening and means defining an upstanding surface, said recess being in communication with said pockets when said member is in a first position and out of communication when said member is in a second position and movable between said positions to vary the degree of communication with said pockets, said movement being in response to fluid pressure acting on said upstanding surface so that a constant pressure output will be provided, and spring means resisting movement of said member and allowing movement thereof when overbalanced by fluid pressure active on said surface.

13. In a fluid pumping apparatus, the combination of a housing, an inlet leading to and an outlet leading from said housing, intermeshing gear means disposed in said housing for pumping fluid from said inlet through said housing and out said outlet, said gear means having teeth providing a plurality of fluid pockets therebetween of various diminishing sizes wherein fluid trapped in said pockets is subjected to increasing pressures, said teeth having contours maintaining continuous contact between said pockets while performing said fluid pressure functions, and a block member disposed within said housing between said gear means adjacent said pockets and said outlet and having a plurality of passage defining means therein each of which communicates with a fluid pocket when said block member is in one position and some of which are out of communication with said fluid pockets when said block member is in a different position, said block member being movable to vary the communication between said pockets and said outlet.

14. In a fluid pumping apparatus, the combination of a housing, an inlet leading to and an outlet leading from said housing, intermeshing gear means disposed within said housing for pumping fluid from said inlet through said housing and out said outlet, said gear means having teeth providing a plurality of fluid pockets therebetween of various diminishing sizes wherein fluid trapped in said pockets is subjected to increasing pressures, said teeth having contours maintaining continuous contact between said pockets while performing said fluid pressure functions, a block member disposed within said housing adjacent said gear means, and a valve member disposed between said block member and said outlet, said block member having a plurality of passage defining means therein each of which communicates with a fluid pocket when said block member is in one position and some of which are out of communication with said fluid pocket when said block member is in a different position, said block being movable to vary the communication between said pockets and said outlets, said valve member having an elongated opening therein, and said passage defining means being substantially L shaped in section and communicating with said elongated opening.

15. In a fluid pump, the combination of a housing, a pumping chamber in said housing, an inlet leading to and an outlet leading from said chamber, gear means received in said chamber and comprising an internal gear and an external gear for pumping fluid from said inlet through said chamber and out said outlet, said gear means being eccentric to one another and having teeth which mesh and provide a plurality of fluid pockets therebetween of various diminishing sizes whereby fluid in said pumping chamber is trapped in said pockets and subjected to increase pressures, said teeth having contours maintaining

continuous contact between said pockets while performing said fluid pressure function, a member disposed within said pumping chamber between said gear means and said outlet and having passage defining means therein for communicating said pockets and said outlet, said member being eccentrically disposed with regard to said gear means and being mounted for movement between a position wherein said passage defining means provides communication between a plurality of said pockets and said outlet and a position wherein said passage defining means is blocked by one of said gear means so that no communication is provided between said pockets and said outlet, said member including a plurality of fluid receiving chambers, piston means received in said fluid receiving chambers and means communicating spaced ones of said passage defining means with said fluid receiving chambers to communicate fluid pressure to said pressure receiving chambers to thereby differentially pressure load said pistons and prevent the flow of fluid across said gear means and said chamber wall adjacent said member, said member varying the degree of communication between said pockets and said outlet by being moved to various intermediate positions between the two said positions.

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