Sept. 20, 1960 J. WORDSWORTH 2,953,367

HYDRAULIC PISTON AND CYLINDER APPARATUS

Filed April 17, 1959 8 Sheets-Sheet 1

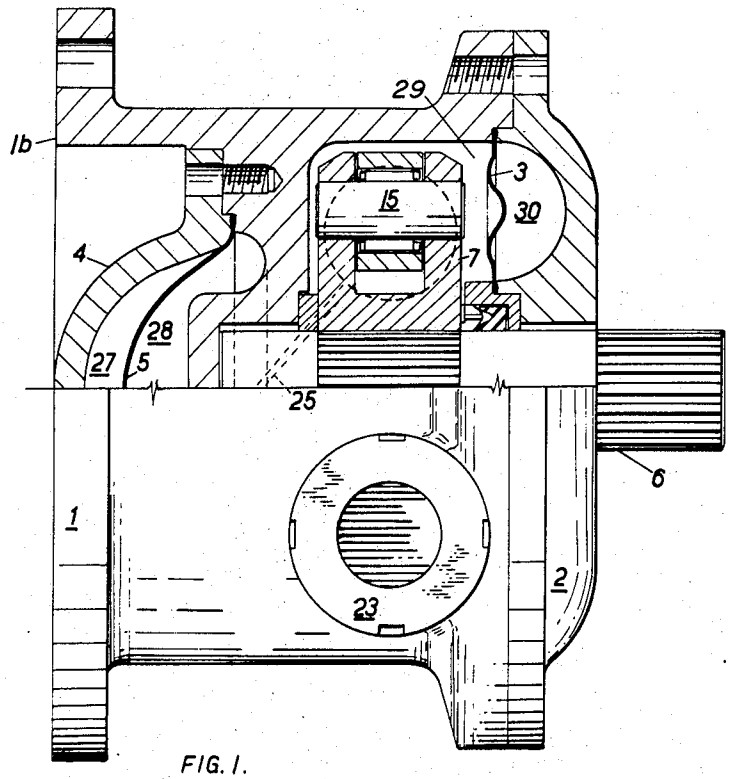

FIG. 1.

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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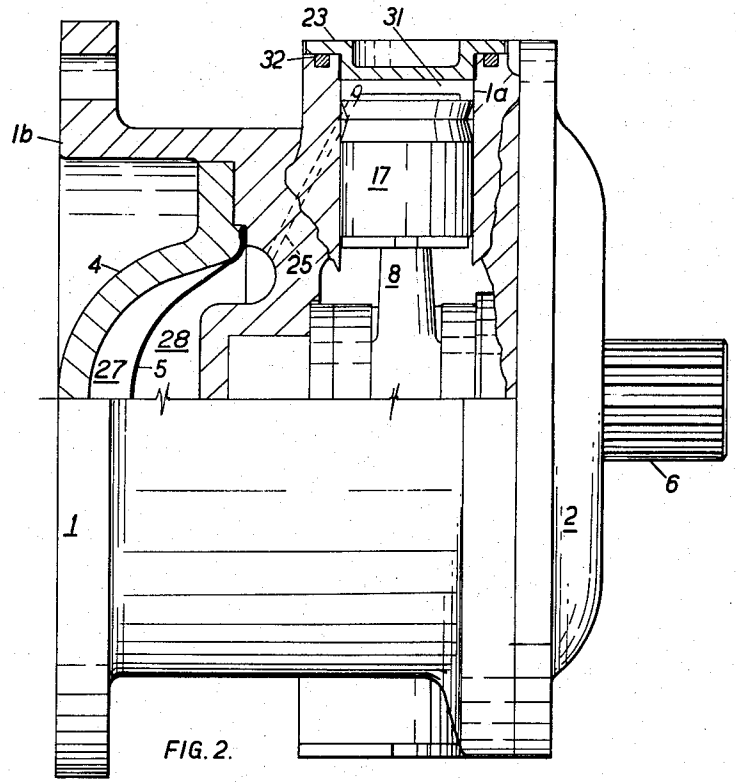

FIG. 2.

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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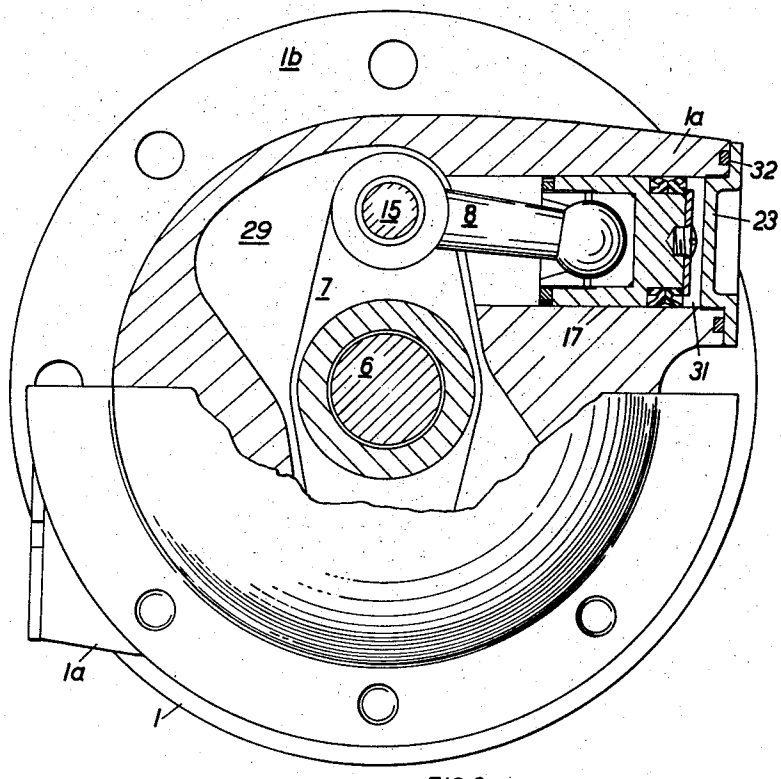

FIG.3.

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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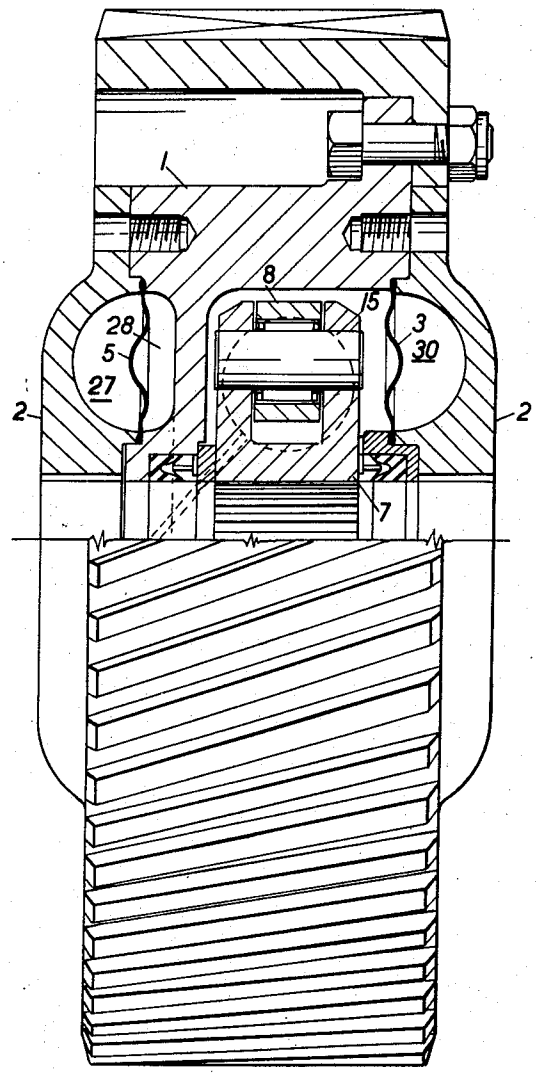

FIG. 4.

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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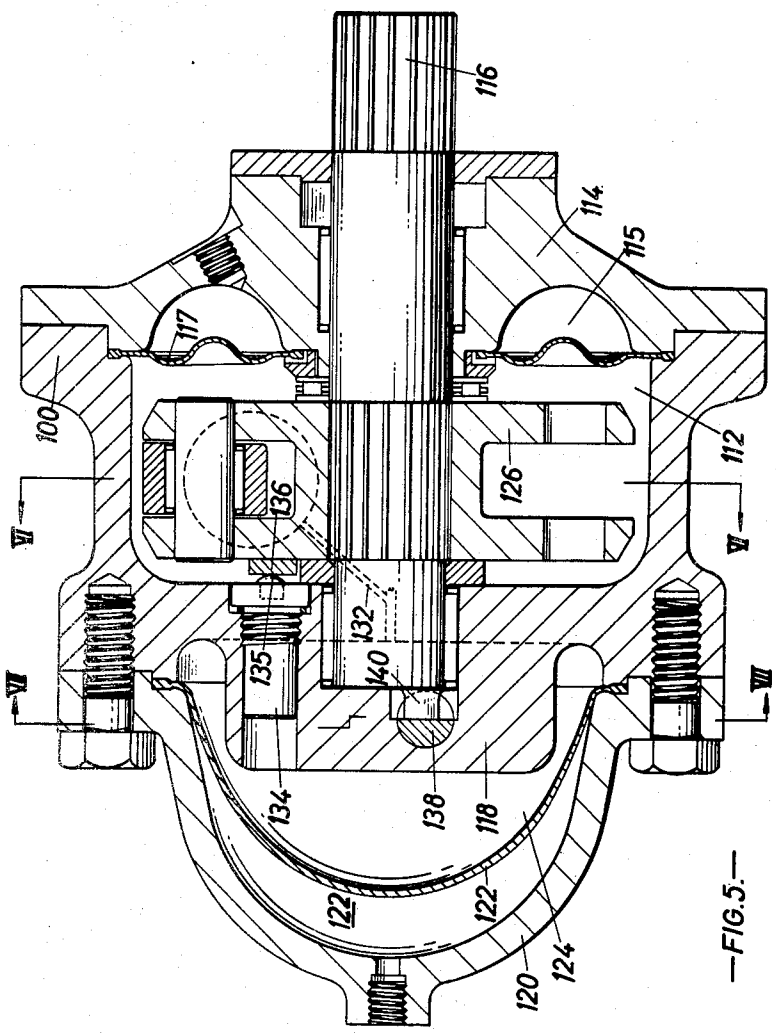

—FIG.5.—

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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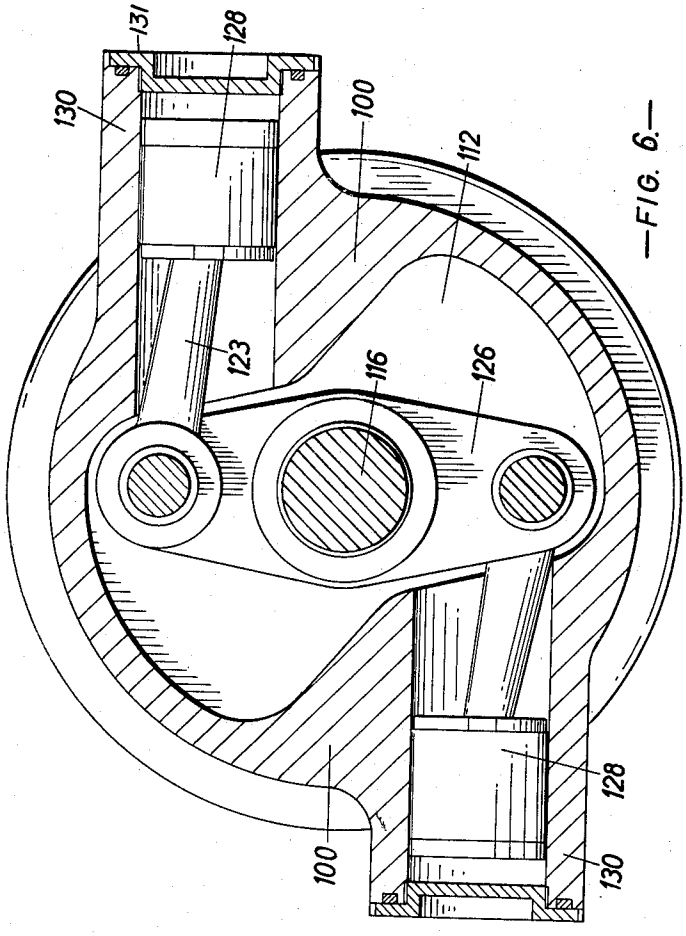

—FIG. 6.—

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HYDRAULIC PISTON AND CYLINDER APPARATUS

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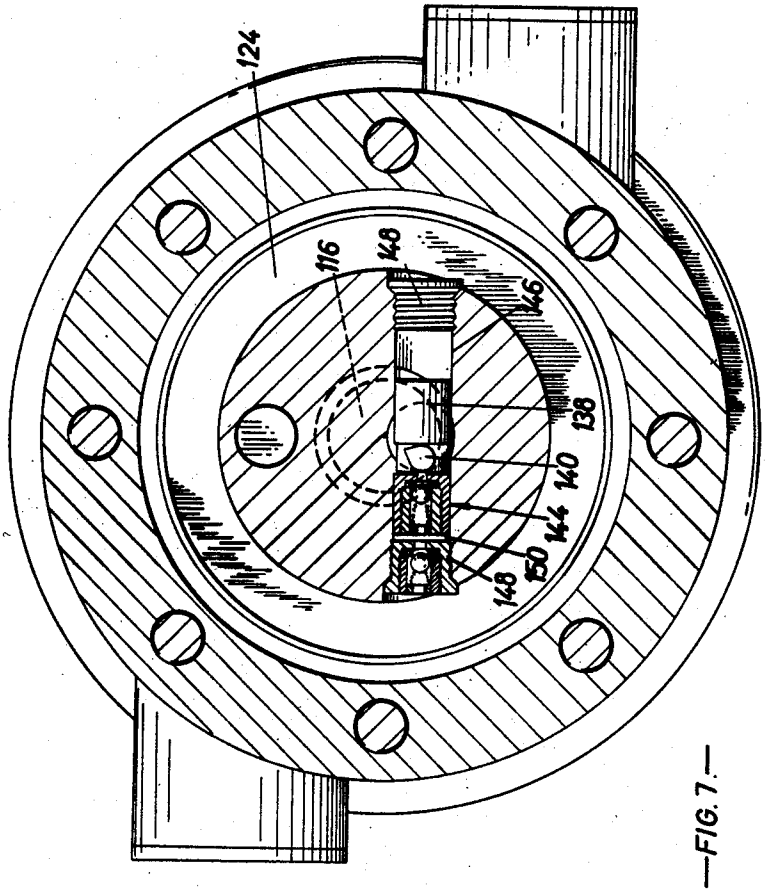

—FIG. 7.—

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HYDRAULIC PISTON AND CYLINDER APPARATUS

Filed April 17, 1959 8 Sheets-Sheet 8

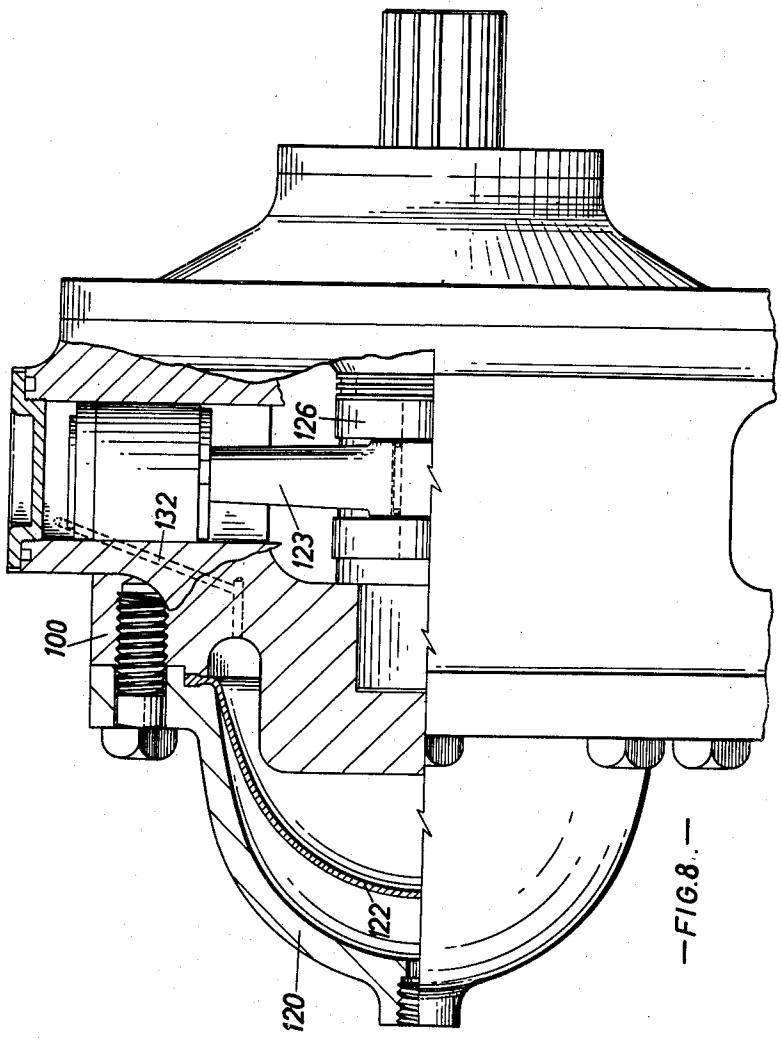

FIG.8.

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Patented Sept. 20, 1960

2,953,367

HYDRAULIC PISTON AND CYLINDER APPARATUS

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Filed Apr. 17, 1959, Ser. No. 807,092

Claims priority, application Great Britain Apr. 18, 1958

14 Claims. (Cl. 267—15)

This invention concerns hydraulic piston and cylinder apparatus for use in power transmission and load-bearing systems.

In its broadest aspect, the present invention accordingly provides a power transmission and load-bearing device wherein a confined volume of hydraulic medium serving as a power- or load-transmitting connection between the piston and cylinder means of said device, and a pneumatic spring is provided to balance the force applied to said hydraulic medium, characterized by a plurality of hydraulic cylinders provided in a body member and arranged symmetrically about a semi-rotary spindle journalled in said body member, a piston in each cylinder, the space in each cylinder in front of the piston therein communicating with said hydraulic chamber, and means connecting said spindle with said pistons in such a manner as to cause equal loads to be transmitted between each piston and said spindle.

Conveniently, the device may comprise an at least partly hollow body, the hollow interior of which is adapted to be at least partly filled with a hydraulic medium, a semi-rotary spindle journalled in said body and extending within said hollow interior, a plurality of hydraulic cylinders opening from said hollow interior and located symmetrically about said spindle, a piston within each cylinder, means closing the end of each cylinder remote from said hollow interior and defining with the adjacent end of the piston in said cylinder, a hydraulic chamber adapted to be filled with hydraulic medium, means connecting said spindle with each piston for displacing said piston within its cylinder responsive to turning movements of said spindle, an elastic diaphragm secured to said body and defining therewith a second hydraulic chamber adapted to contain hydraulic medium, said second chamber being arranged symmetrically relative to and communicating with each of said first-mentioned hydraulic chambers, and means secured to said body and enclosing said elastic diaphragm to define with said diaphragm a pneumatic chamber adapted to be filled with a compressed pneumatic medium and thereby to constitute a pneumatic spring acting to balance the load exerted on the hydraulic medium in said hydraulic chambers.

Each piston may conveniently have a connecting rod extending out of its cylinder towards the semi-rotary spindle, and said spindle may carry a crank having a plurality of identical crank arms, one for each connecting rod, arranged symmetrically therearound, each said connecting rod being pivotally connected to its associated crank arm.

It is of advantage, in some circumstances, to incorporate a hydraulic medium flow restricting means in the communication between each cylinder and the hydraulic chamber bounded by the elastic diaphragm, in order to provide a shock absorbing or vibration damping action to the movements of said pistons.

Preferably the device proposed by the invention is provided with a second elastic diaphragm bounding one

side of the hollow interior of said body and in turn enclosed by means which define with said second elastic diaphragm a second pneumatic chamber which, when filled with a pneumatic medium under pressure, acts to cushion outward movement or retraction of the pistons in their cylinders.

Thus, by adapting the semi-rotary spindle for connection to the driving member of a power transmission system, and by adapting the body of the device for connection to the driven member of such a system, the device may be employed as a flexible coupling between the driving and driven members of the transmission system. Moreover, by providing only a restricted communication between the first and second hydraulic chambers, the device may act as a torsional vibration damper in a power transmission system.

Again, by making the body of generally circular form and providing the external cylindrical circumference thereof with gear teeth, the device may be employed as a resilient gear adapted for incorporation in a gear transmission between driving and driven gears thereof in order to provide a resilient connection between said driving and driven gears.

A particularly important application of the device proposed by the invention is in the field of vehicle suspension units of the hydro-pneumatic type, in connection with which it will be appreciated that the invention represents a particular form of that type of hydropneumatic suspension unit wherein the load exerted on a confined volume of hydraulic medium is cushioned by a pneumatic suspension spring. In this particular application of the invention, it is merely necessary to secure the body of the unit to the sprung mass of a vehicle and the semi-rotary spindle to the unsprung mass thereof, or vice versa, in order to provide a combined hydraulic shock-absorber and pneumatic suspension spring between the said masses. Preferably, however, when used as a suspension unit, the present invention incorporates means such as a hydraulic pump operable responsive to vehicle riding movements to continually supply a hydraulic medium from a reservoir thereof, which may conveniently be the hollow interior of the unit body, to the space in each cylinder in front of its piston, thereby constantly urging said pistons to retract in their cylinders, and a relief valve adapted to open when the pistons have attained desired mean positions in their cylinders, so as to exhaust excess hydraulic medium from said cylinders and said second hydraulic chamber back into said reservoir. In this way a desired relative attitude may be maintained between a vehicle frame and wheel, irrespective of the load carried by the vehicle.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is an elevation, partly in diametrical section, of a flexible coupling embodying the invention;

Fig. 2 is an elevation, partly in diametrical section, of the flexible coupling shown in Fig. 1, the section being rotated through 90° relative to Fig. 1;

Fig. 3 is a transverse vertical section of the flexible coupling;

Fig. 4 is an elevation, partly in longitudinal section, of a resilient gear embodying the invention;

Fig. 5 is a central vertical section through a hydro-pneumatic suspension unit constructed according to the invention;

Fig. 6 is a section taken on the line VI—VI of Fig. 5;

Fig. 7 is a section taken on the line VII—VII of Fig. 5; and

Fig. 8 is a plan view, partly in section, of the suspension unit.

Referring firstly to Figs. 1 to 3 of the drawings, the

flexible coupling shown therein includes a generally cylindrical body 1 which has journalled therein a spindle 6 whereon is keyed a crank 7 extending symmetrically on either side of the spindle 6 and capable of undergoing angular displacement, or rocking, within the hollow interior of the body 1 when the spindle 6 is angularly displaced relative to said body. Within the body 1 are provided two cylinders 1*a*, arranged symmetrically on either side of the spindle 6, and each cylinder 1*a* slidably receives a piston 17 which is connected to the crank 7 by means of a connecting rod 8 and connecting pin 15, whereby the pistons are displaced in their respective cylinders responsive to turning movements of the spindle 6.

The free outer end of each cylinder 1*a* is closed by means of a sealing plate 23 and an O-ring 32, and a hydraulic chamber 31 is thereby defined between each sealing plate 23 and the adjacent end of the piston 17. At its end remote from that at which the spindle 6 is introduced, the body 1 is closed by means of an end cap 4, and the end cap 4 serves also to secure to the body 1 an elastic diaphragm 5 between which and the body 1 is defined a hydraulic chamber 28 adapted to be filled with a hydraulic medium. A second chamber 27 adapted to be filled with a pneumatic medium under pressure is defined between the elastic diaphragm 5 and the end cap 4, and the hydraulic chamber 28 communicates with each of the hydraulic chambers 31 by means of a duct 25 formed in the body 1. The hollow interior of the body 1 itself constitutes yet another hydraulic chamber which, at the end of the body where the spindle 6 enters the same, is closed by an end cap 2 serving to secure a second elastic diaphragm 3 to the body 1, and the end cap 2 is formed adjacent its periphery with an annular depression such as to define with the elastic diaphragm 3, a second chamber 30 adapted to be filled with a pneumatic medium under pressure.

In the operation of the flexible coupling described with reference to Figs. 1 to 3, and when employed, for example, in a power transmission system, the spindle 6 may constitute the driving member or may be secured to a driving member, whilst the body 1 is provided with an annular flange 1*b* by which it may be connected to a driven member. If the outwardly projecting portion of the spindle 6 is so connected to the driving member that clockwise movement of the driving member imparts a clockwise rotation to the spindle 6, then this rotation is applied by crank 7 and connecting rod 8 to cause an inward motion of each piston 17 in its cylinder and towards the adjacent sealing plate 23. Hydraulic medium present in the chamber 31 between each piston and its adjacent sealing plate 23 is thus forced through the co-operating duct 25 and into the hydraulic chamber 28. The entry of fresh hydraulic medium into the chamber 28 will thus deform the diaphragm 5 to compress the pneumatic medium in the chamber 27, whereby said compressed pneumatic medium acts as a pneumatic spring to balance the load exerted by the pistons on the hydraulic medium and to co-operate with said hydraulic medium in transmitting the drive applied to the spindle to the body 1. Conversely, anticlockwise movement of the driving member will impart an anticlockwise rotation to the driving spindle 6 with consequent outward or retracting motion of the pistons 17 away from their sealing plates 23. In this case, hydraulic medium within the hollow interior 29 of the body 1 is displaced to deform the flexible diaphragm 3, thereby compressing the pneumatic medium contained within the chamber 30 and causing the pneumatic medium in said chamber to act also as a pneumatic spring.

It will be appreciated that the device is reversible, in that the spindle 6 may be connected to the driven element and the flange 1*b* may be connected to the driving element; and that the ducts 25 may be dimensioned to restrict the flow of hydraulic medium between chambers 31 and the chamber 28 in order to provide a shock-absorbing or vibration damping action, the device thereby being enabled to act as a torsional vibration damper.

The resilient gear shown in Fig. 4 is of similar construction to the flexible coupling shown in Figs. 1 to 3, except that the elastic diaphragm 5 is here made of identical form to the elastic diaphragm 3, both diaphragms being secured to the body 1 by means of identical end caps 2 in such a manner that the device is generally symmetrical on either side of a transverse bisecting plane as well as on either side of a longitudinal bisecting plane.

In the construction of Fig. 4, the external circumference of the body 1 is formed with gear teeth 35, and hence the device may be included, for example, in a gear transmission to provide a resilient connection between cooperating driving and driven gears of said transmission.

Figs. 5 to 8 of the drawings show a vehicle hydropneumatic suspension unit which has a body 100 wherein is journalled one end of a spindle 116, the body 100 being closed by an end cap 114 wherein is provided a bearing for the opposite end region of the spindle 116. The extreme end of the spindle 116 will be seen to project somewhat from the body 100 and is adapted for connection in any suitable manner to an appropriate part of a vehicle, e.g. the wheel mounting, in order that the vehicle riding movements may be transmitted thereto.

The side of the body 100 opposite the cap 114 is closed by a domed end cap or cupola 120 which also serves to retain in position a flexible diaphragm 122 defining with said domed end cap a pneumatic pressure chamber 121 which is filled with a compressed gaseous medium constituting a first pneumatic suspension spring. The end cap 114 is formed with an annular chamber 115 having one face bounded by an annular flexible diaphragm 117, and the chamber 115 is also filled with a compressed gaseous medium constituting a second pneumatic suspension spring for rebound purposes.

Within the interior of the body 100 is formed a chamber 112 which acts as a hydraulic reservoir and accordingly is completely filled with hydraulic medium, and within the chamber 112 the spindle carries a symmetrical crank 126, to the ends of the arms of which are pivotally secured connecting rods 123 each adapted to displace a piston 128 in a cylinder 130, the two cylinders 130 being oppositely directed and arranged symmetrically with respect to the spindle 116. Each cylinder 130, in front of its piston 128 is closed by means of a sealing plate 131, and communicates by way of a duct 132 formed in the body 110, with a confined space 124 defined between the flexible diaphragm 122 in the body 110, and the ducts 132 may be so dimensioned as to constitute fluid flow restrictors providing for a shock absorbing action as the pistons 128, during bump strokes, displace hydraulic medium from their cylinders into the confined space 124. Thus, the suspension unit described provides for a symmetrical and balanced arrangement of shock absorbing pistons and cylinder and eliminates any radial thrust reaction on the spindle 116.

As more particularly shown in Fig. 7 the suspension unit also includes a double acting hydraulic pump having a plunger 138 which is relieved at its central region so as to receive a spigot 140 arranged eccentrically on the inner end of the spindle 116 and extending axially thereof. On each side of this central relieved portion the plunger 138 is provided with a recuperation valve generally designated 144, and said plunger is received in a bore 146 formed in the body 100, each end of said bore being closed by a non-return valve 148.

Between each recuperation valve and the adjacent non-return valve there is thus defined a chamber 150, and the operation of the pump is such that as one half of the plunger 138 executes a delivery stroke on rotational movement of the spindle 116, the other half of the plunger carries out an induction stroke whereby hydraulic

medium is drawn from the reservoir **112**, through the recuperation valve **144** and into the chamber **150**, whence it is discharged through the non-return valve **148** on a subsequent delivery stroke of the plunger in the appropriate direction. From the valve **148** the hydraulic medium passes directly into the confined space **124**, and as the amount of hydraulic medium in the space **124** increases, it passes through the two ducts **132** into the cylinders **130** to set up retraction of the pistons therein.

This retraction continues until the pistons assume a desired position within their cylinders, as determined by the angular position of a cam **136** carried by the crank plate **126** and arranged to act on a valve operating member **135** of a relief valve **134**. Opening of the relief valve **134** then allows excess hydraulic medium to exhaust from the confined space **124** through a groove (not shown) in the operating member **135** directly back into the hydraulic reservoir **112**. In this way, by continual pumping of hydraulic medium into the confined space **124**, allied to continually recurring, intermittent opening of the relief valve **134**, the pistons **128** are retained in a desired mean position within their cylinders **130**, irrespective of the load carried by the vehicle.

I claim:

1. As a new article of manufacture, the combination comprising an at least partly hollow, generally cylindrical body, the hollow interior of said body being adapted to be at least partly filled with a hydraulic medium, a spindle journalled within and rockable relative to said body, said spindle extending within said hollow interior, a plurality of identical chordally directed hydraulic cylinders opening from said hollow interior and located at equiangularly separated positions about said spindle in spaced radial relation thereto, a piston within each cylinder, means connecting the spindle with each piston for displacing said pistons all in the same sense their respective cylinders responsive to turning movement of said spindle relative to said body, an elastic diaphragm secured to one end face of said body and defining therewith an hydraulic chamber adapted to be filled with hydraulic medium, passage means placing said hydraulic chamber in communication with the end of each hydraulic cylinder remote from said hollow interior, and means secured to said end face and enclosing said elastic diaphragm to define with said diaphragm, a pneumatic chamber adapted to be filled with a pneumatic medium under pressure and thereby to constitute a pneumatic spring for balancing displacements of hydraulic medium resulting from said piston displacements.

2. A hydraulic piston and cylinder power- or load-transmitting device comprising an at least partly hollow, generally cylindrical body, the hollow interior of which is adapted to be at least partly filled with a hydraulic medium, a spindle journalled within and rockable relative to said body, said spindle extending within said hollow interior, a plurality of identical, chordally directed hydraulic cylinders each communicating at one of their ends with said hollow interior, said cylinders being located at equiangularly spaced positions about said spindle in spaced relation thereto, a piston within each cylinder, means closing the end of each cylinder remote from said hollow interior and defining with the adjacent end of the piston in said cylinder, a first hydraulic chamber adapted to be filled with hydraulic medium, means connecting the spindle with each piston for displacing said pistons all in the same sense within their respective cylinders responsive to turning movements of said spindle relative to said body when power or load is applied to said spindle, an elastic diaphragm secured to an end face of said body and defining therewith a second hydraulic chamber adapted to contain hydraulic medium, said second chamber being arranged symmetrically relative to and communicating with each of said first-mentioned hydraulic chambers, and means secured to said end face and enclosing said elastic diaphragm to define with said diaphragm, a pneumatic chamber adapted to be filled with a compressed pneumatic medium and thereby to constitute a pneumatic spring acting to balance the load transmitted by the pistons from the spindle to the hydraulic medium in said hydraulic chambers.

3. A device as set forth in claim 2, wherein the means connecting the spindle to said pistons comprise a crank mounted on said spindle, a plurality of identical, radially directed arms on said crank and arranged at equiangularly spaced intervals therearound, there being one crank arm for each piston, and a plurality of connecting rods each pivotally connected at one end to one of the pistons and at the other end to one of said crank arms.

4. A device as set forth in claim 2, wherein the communication between each of said first hydraulic chambers and said second hydraulic chamber comprises a hydraulic medium flow restricting means.

5. A device as set forth in claim 2, further comprising a second elastic diaphragm secured to said body member to enclose one side of said hollow interior, and means in turn enclosing said second diaphragm to define therewith, a second pneumatic chamber adapted to be filled with a pneumatic medium under pressure and thereby to constitute a pneumatic spring for cushioning movement of hydraulic medium into and out of said hollow interior responsive to piston displacements within said cylinders.

6. A flexible coupling comprising an at least partly hollow, generally cylindrical body member, the hollow interior of said body member being adapted to be at least partly filled with a hydraulic medium, a spindle journalled within and rockable relative to said body member and extending within the hollow interior thereof, said spindle and body member constituting power input and output means for said flexible coupling, a pair of identical hydraulic cylinders each communicating at one of their ends with said hollow interior, said cylinders having their axes directed along parallel chords of said body member lying on opposite sides of and equally spaced from the axis of said body member, a piston slidably arranged in each cylinder, means connecting said pistons with said spindle for displacement of said pistons both in the same sense in their respective cylinders responsive to turning movements of said spindle relative to said body member, an end cap secured to said body member, and an elastic diaphragm secured to said body member between said body member and said end cap, said elastic diaphragm defining with said body member, a hydraulic chamber adapted to be filled with hydraulic medium and communicating with the other ends of said cylinders, and said end cap defining with said elastic diaphragm, a pneumatic chamber adapted to be filled with a pneumatic medium under pressure to thereby constitute a pneumatic spring for cushioning movements of hydraulic medium into and out of said hydraulic chamber resulting from said piston displacements.

7. A flexible coupling as set forth in claim 6, further comprising a second end cap secured to the body member at a position thereon spaced from said first end cap, and a second elastic diaphragm secured to said body member between said body member and said second end cap, said second elastic diaphragm being arranged to close one side of said hollow interior and to define with said second end cap, a second pneumatic chamber adapted to be filled with a pneumatic medium under pressure and thereby to constitute a pneumatic spring for cushioning movement of hydraulic medium into and out of said hollow interior responsive to said piston displacements.

8. A flexible coupling as set forth in claim 6, wherein the communication between the hydraulic chamber and said hydraulic cylinders constitutes a hydraulic medium flow restricting means.

9. A resilient power transmission gear comprising an at least partly hollow, generally cylindrical body member, the hollow interior of said body member being

adapted to be filled with a hydraulic medium, a plurality of gear teeth formed around the external cylindrical surface of said body member, a pair of hydraulic cylinders each communicating at one of their ends with said hollow interior, said cylinders having their axes directed along parallel chords of said body member lying on opposite sides of and equally spaced from the axis of said body member, a piston slidably arranged in each cylinder, means including a crank pivotally supported in said body member for effecting displacement of said pistons both in the same sense in their respective cylinders responsive to turning movements of said crank relative to said body member, said body member and said crank constituting power input and output means for said gear a first end cap secured to said body member, an elastic diaphragm secured to said body member between said body member and said end cap, said elastic diaphragm defining with said body member a hydraulic chamber adapted to be filled with hydraulic medium, and said end cap defining with said elastic diaphragm, a pneumatic chamber adapted to be filled with a pneumatic medium under pressure to thereby constitute a pneumatic spring, passage means in said body member and placing said hydraulic chamber in communication with the other ends of said cylinders, a second elastic diaphragm bounding one side of said hollow interior, and a second end cap enclosing said second diaphragm and securing the same to said body member, said second end cap and diaphragm defining therebetween, a second pneumatic chamber adapted to be filled with a pneumatic medium under pressure to constitute a second pneumatic spring, said pneumatic springs acting to cushion movement of hydraulic medium into and out of said hollow interior and said hydraulic chamber during said piston displacements.

10. A vehicle hydro-pneumatic suspension unit comprising an at least partly hollow, generally cylindrical body member, the hollow interior of said body member being adapted to be at least partly filled with a hydraulic medium, a semi-rotary spindle adapted for the application of vehicle riding movements thereto, said spindle being journalled within said body member and extending within the hollow interior thereof, a plurality of identical, chordally directed hydraulic cylinders provided in said body member and arranged at equiangularly separated positions around said spindle, said cylinders each communicating at one of its ends with said hollow interior, a piston in each cylinder, means connecting said pistons with said spindle for displacement of said pistons all in the same sense within their respective cylinders responsive to turning movements of said spindle relative to said body member, an elastic diaphragm secured to said body member to enclose therewith, a hydraulic chamber adapted to be filled with a hydraulic medium, said body member being formed with a restricted communication between said hydraulic chamber and the other end of each of said cylinders, and means secured to said body member and enclosing said elastic diaphragm to define therewith, a pneumatic chamber adapted to be filled with a pneumatic medium under pressure to thereby constitute a pneumatic suspension spring.

11. A hydro-pneumatic suspension unit as set forth in claim 10, further comprising a hydraulic pump mounted in said body member between said hollow interior and said hydraulic chamber, means operatively connecting said spindle with said pump for operation of said pump responsive to spindle turning movements to thereby continually supply hydraulic medium from said hollow interior to said hydraulic chamber and continually urge said pistons to retract in their cylinders, a relief valve mounted in said body member between said hydraulic chamber and said hollow interior, and means operatively connecting said spindle with said relief valve to open said relief valve and exhaust hydraulic medium from said chamber to said hollow interior when said pistons attain desired mean positions in said cylinders.

12. A vehicle hydro-pneumatic suspension unit comprising an at least partly hollow, generally cylindrical body member, the hollow interior of said body member being adapted to be filled with a hydraulic medium, a semi-rotary spindle journalled in said body member and extending within the hollow interior thereof, said spindle being adapted for the application of vehicle riding movements thereto, a pair of identical hydraulic cylinders having their axes directed along parallel chords of said body member lying on opposite sides of and equally spaced from said spindle, a piston in each cylinder, a crank on said spindle and extending radially and symmetrically on either side thereof, a piston connecting rod connecting each said piston to said crank for displacement of said pistons both in the same sense in their respective cylinders responsive to turning movements of said spindle relative to said body member, an elastic diaphragm secured to said body member to enclose therewith, a hydraulic chamber adapted to be filled with a hydraulic medium, each cylinder communicating at one of its ends with said hydraulic chamber and at the other of its ends with said hollow interior, means secured to said body member and enclosing said elastic diaphragm to define a pneumatic chamber adapted to be filled with a pneumatic medium under pressure and thereby constitute a pneumatic suspension spring, a hydraulic pump mounted in said body member between said hollow interior and said hydraulic chamber, means operatively connecting said pump with said spindle for operation of said pump responsive to turning movements of said spindle, said pump thereby being caused to continually pump hydraulic medium from said hollow interior to said hydraulic chamber for effecting retraction of said pistons within said cylinders, a relief valve mounted between said hydraulic chamber and said hollow interior, means operatively connecting said relief valve with said crank and adapted to open said relief valve when said spindle and crank are caused by said piston retraction to assume a predetermined angular position relative to said body member to thereby exhaust hydraulic medium from said chamber to said hollow interior, a second elastic diaphragm secured to said body member and bounding one side of said hollow interior, and means secured to said body member and enclosing said second diaphragm to define therewith, a second pneumatic chamber adapted to be filled with a pneumatic medium under pressure to thereby constitute a pneumatic spring, said pneumatic springs acting to cushion movement of hydraulic medium into and out of said hollow interior and said hydraulic chamber responsive to said piston displacements.

13. A hydro-pneumatic suspension unit as set forth in claim 12, wherein said spindle terminates at its inner end adjacent said hydraulic chamber, and has a spigot projecting from said end and arranged eccentrically thereon, said body member being bored transversely to and adjacent said spindle end, and wherein said hydraulic pump comprises a plunger received in said transverse bore, said plunger being formed with a central recessed portion communicating directly with said hollow interior and with an axial bore communicating with said recessed portion, a pair of inlet valves arranged in said axial bore one on either side of said recessed portion, and a pair of outlet valves arranged one at each end region of said axial bore, said spigot engaging in said plunger recessed portion to effect reciprocation of said plunger responsive to turning movements of said spindle.

14. A hydro-pneumatic suspension unit as set forth in claim 12, further comprising a plunger operating member in said relief valve and adapted to open said valve on depression of said plunger operating member, and

a cam carried by said crank, said plunger operating member extending towards and bearing against said cam, and said cam being arranged to depress said plunger when said spindle and crank attain said predetermined angular position.

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