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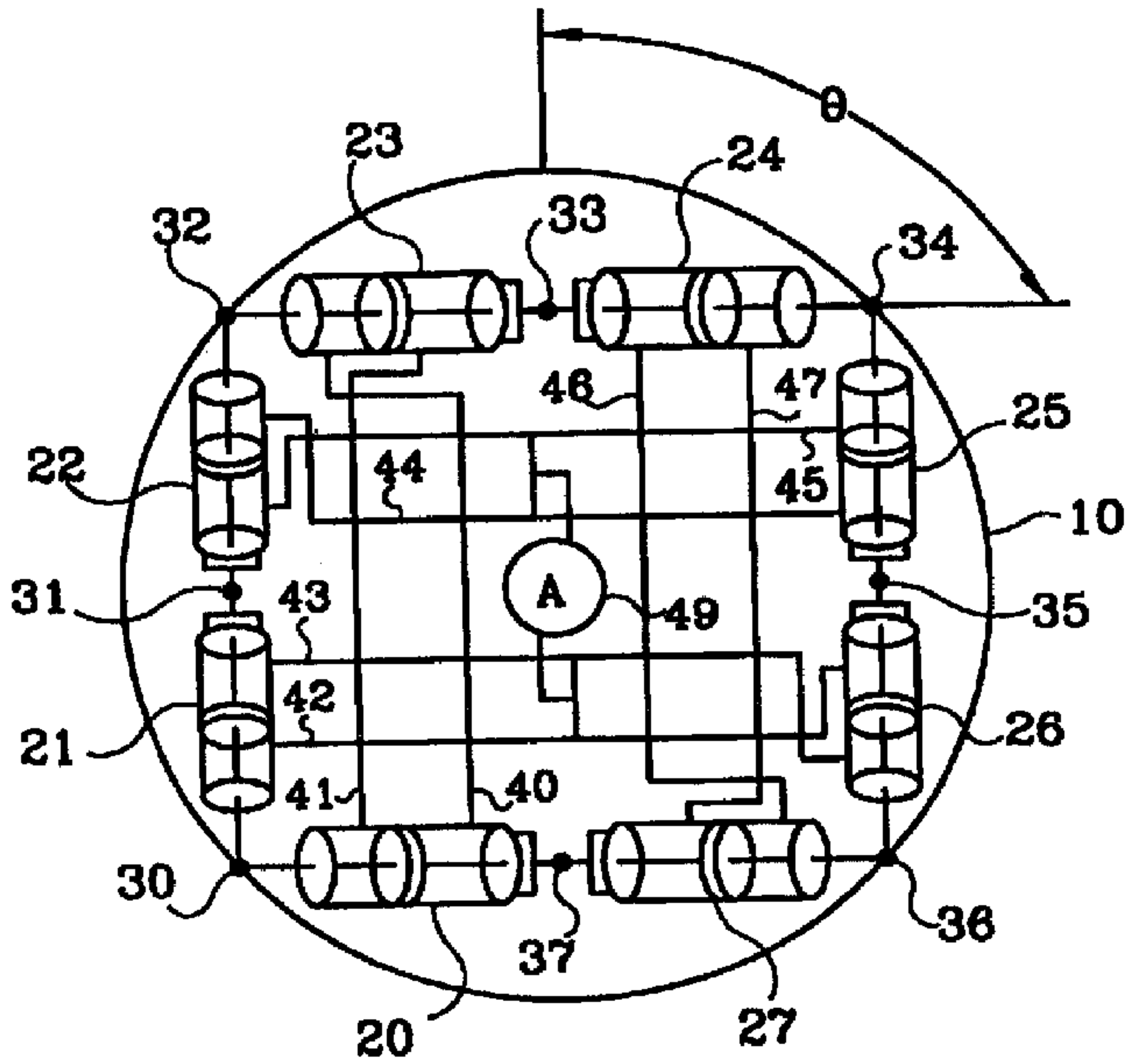
(54) **DISPOSITIF SERVANT A ISOLER UNE CHARGE**
(54) **LOAD ISOLATOR APPARATUS**



(57) Structure amortissante conçue pour être utilisée entre deux éléments (10, 12) afin d'absorber les modifications de mouvement et incorporant une pluralité d'amortisseurs (20-27) reliés entre les deux éléments selon une forme géométrique fermée et mettant en application des accouplements croisés entre les amortisseurs (20-27) situés des côtés opposés de la forme géométrique, de sorte que le mouvement de translation entre les deux éléments (10, 12) est moins raide que le mouvement de rotation entre lesdits deux éléments.

(57) A damping mounting structure for use between two members (10, 12) for isolating motion changes which incorporated a plurality of dampers (20-27) connected between the two members in a closed geometric shape and which uses cross connections between the dampers (20-27) located on opposite sides of the geometric shape so that translation motion between the two members (10, 12) is less stiff than rotational motion between the two members.

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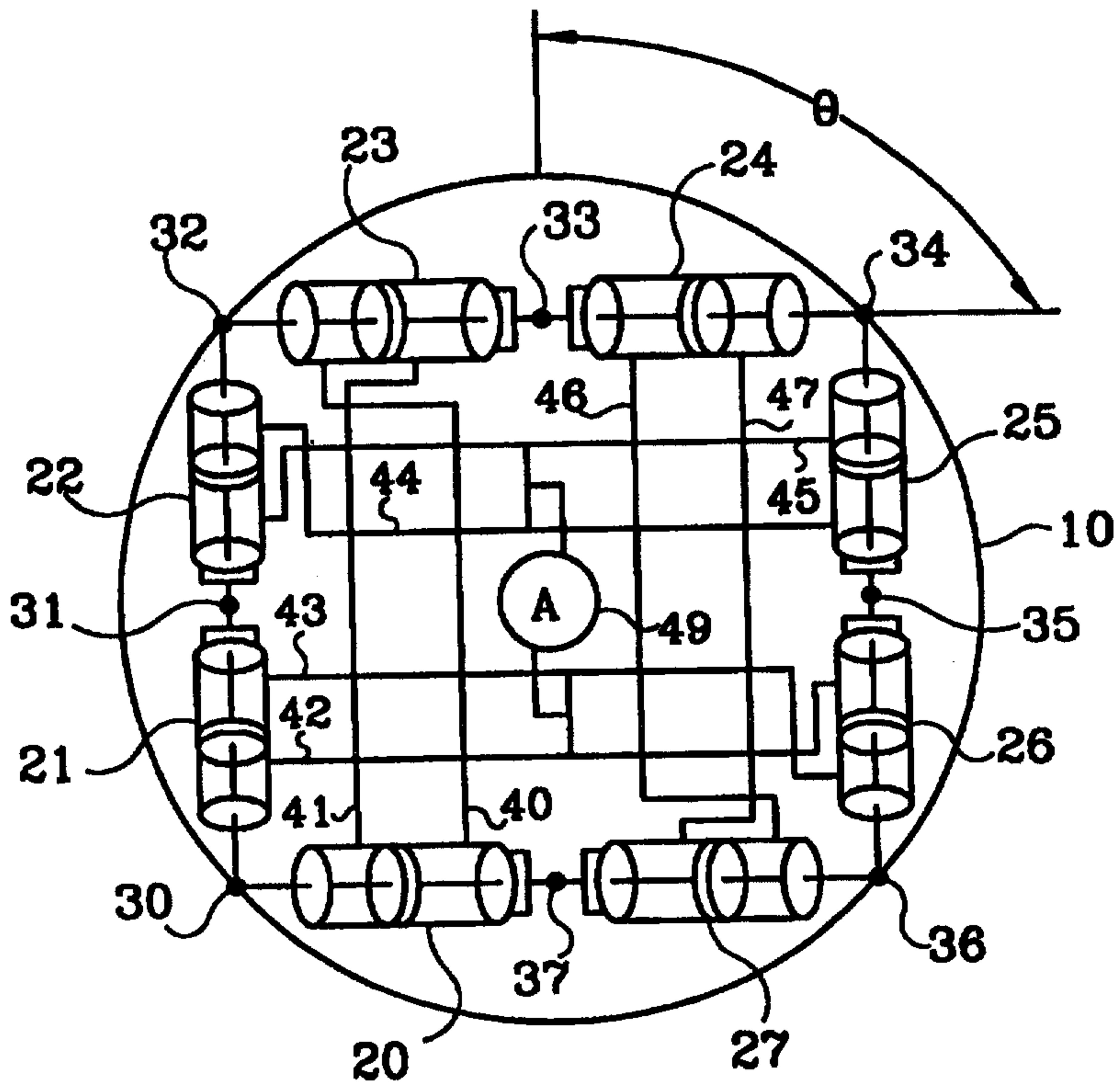
(54) Title: LOAD ISOLATOR APPARATUS

(57) Abstract

A damping mounting structure for use between two members (10, 12) for isolating motion changes which incorporated a plurality of dampers (20-27) connected between the two members in a closed geometric shape and which uses cross connections between the dampers (20-27) located on opposite sides of the geometric shape so that translation motion between the two members (10, 12) is less stiff than rotational motion between the two members.



LOAD ISOLATOR APPARATUS

BACKGROUND OF INVENTION

1. Field of the Invention

The present invention relates to apparatus operable to isolate a load from the base device to which it is attached and more particularly to utilize a novel suspension and damping concept to provide vibration isolation between the load and the base in translational degrees-of-freedom while increasing the stiffness for rotational degrees-of-freedom.

2. Description of the Prior Art

Although load vibration isolation has application in various fields including automotive, machinery and the like, the present invention is described in the environment of launch vibration isolation of a payload or satellite, mounted on a launch vehicle. Isolation is achieved by placing elastic members between the launch vehicle and the payload and then placing damping members across the elastic members to provide damping. In such applications, it is difficult to support the payload at the center-of-gravity allowing translational motion to be cross-coupled into rotational motion causing the payload to sway. This rotation is undesired since, for payloads such as inertial measurement units (IMU's) their alignment must be maintained with respect to the vehicle, and, for satellites, the sway uses up the available "rattle space" between the satellite and the inside of the aerodynamic faring. Accordingly, it is advantageous to stiffen the rotational degrees-or-freedom while softening the translational degrees of freedom.

In the prior art, the payload has been supported by independent spring/damper units, typically mounted at various angles to provide the proper stiffness in each degree-of-freedom. In such a configuration, each spring/damper unit operates independent of the others. Other approaches have been to distribute the stiffness and damping around the base of the payload. The rotational stiffness of these isolation systems are limited by the center-of-gravity offset of the payload and the diameter across the base (mounting circle) and, while changing the angles of the spring/damper units allows some freedom in selecting the proper stiffness, the results are limited.

A German patent DE 44 06 650 AL shows a pneumatic spring system using different sizes pressure chambers with unthrottled cross connections therebetween.

A French patent 2,434,739 shows a railway car support using pistons to divide a cylindar into two chambers and conduits connecting two of these in a crosswise manner

A French patent 2,276,623 shows a plurality of cross connected hydraulic chamber spaces around the peripheries of body to be supported and suitable for use supporting a payload of a missile.

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BRIEF DESCRIPTION OF THE INVENTION

The present invention overcomes the limitations of the prior art by cross-coupling opposite damping elements, rather than having them operate independently, to provide a soft damped suspension in transition and a stiff damped suspension in rotation. The invention may also use an accumulator connected to the system to provide volumetric compensation for fluid expansion over temperature variations and to pressurize the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a spring/damper device known in the prior art;

Figures 2a and 2b show a top view and side view of the spring/dampers (without the springs) in an isolation section between a vehicle and a payload of the present invention; and,

Figure 3 shows the cross coupling arrangement of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a spring/damper device 1 presently available in the prior art. Spring damper 1 has a spring 2 wound around a viscous damper 3 having a housing 4. Spring 2 provides static stiffness and damper 3 provides a damping force which is generated by a fluid in chambers 5 and 6 in housing 4 flowing either around a piston 7 separating chambers 5 and 6 or through a restrictive passage 7a in piston 7. Piston 7 has a piston rod 8 extending upwardly through a seal in the top of chamber 6 and downwardly through a seal in the bottom of chamber 5. Rotational pivots 9 are connected to the piston rod 8 and to the lower part of housing 4 to allow small rotations when spring/damper 1 is connected between a payload and a launch vehicle as will be better seen in connection with Figures 2a and 2b.

Figures 2a and 2b show how an arrangement of spring/dampers can be configured to support and isolate a load 10 from a launch vehicle 12. It is seen that eight spring/dampers shown by reference numerals 20 - 27 are configured in a rectangular arrangement in a vibration isolation section 29 between the load 10 and the vehicle 12. Each spring/damper is divided into first and second chambers by a piston as was the case in Figure 1. The springs, such as spring 2 in Figure 1, have not been shown in Figures 2a and 2b to avoid unnecessary complexity. It takes a minimum of six spring/dampers to fully constrain the system in all degrees of freedom but eight spring dampers have been shown in Figures 2a and 2b as a convenient number for the preferred embodiment. It will be understood that a number smaller or larger than eight spring/dampers may be used and configurations other than rectangular may be employed.

It is seen in Figures 2a and 2b that dampers 20 and 21 are connected together at a common point 30 to the load 10, dampers 21 and 22 are connected at a common point 31 to the vehicle 12, dampers 22 and 23 are connected at a common point 32 to the load 10, dampers 23 and 24 are connected at a common point 33 to the vehicle 12, dampers 24 and 25 are connected at a common point 34 to the load 10, dampers 25 and 26 are connected at a common point 35 to the vehicle 12, dampers 26 and 27 are connected at a common point 36 to the load 10 and dampers 27 and 20 are connected at a common point 37 to the vehicle 12.

While I have shown the piston of each damper connected to piston of the adjacent dampers, these connections can be independent and connected to the load 10 and the vehicle 12 at individual points. Each spring/damper is at an angle α between the vehicle 12 and the load 10 as seen from the side in Figure 2b and at an angle θ between the vehicle 12 and the load 10 as seen from the top in Figure 2a. By adjusting angles α and θ, the ratio of the various stiffnesses and damping in the rotational and translational axes may be adjusted. Unfortunately, the stiffness and damping about the rotational axes can only be controlled very slightly by changing the damper angles and while the rotational stiffness and damping can be better adjusted by spacing the dampers apart in larger and smaller mounting circles, this changes the space requirements of the system.

In the present invention, cross coupling conduits 40 - 47 are supplied to allow fluid flow between oppositely placed damper chambers and an accumulator 49 is connected to each cross coupled conduit by connections which may be better seen in Figure 3.

In Figure 3, two of the oppositely located dampers 21 and 26 are shown as an example, it being understood that each of the dampers and its oppositely placed counterpart in Figures 2a and 2b are similarly interconnected. In Figure 3, damper 21 is shown having a first or upper chamber 50 and a second or lower chamber 52 within a housing 53, filled with an incompressible fluid and separated by a piston 54. No restricted passage through or around piston 54 is needed since fluid flow between chambers 50 and 52 is provided by cross conduits 42 and 43. A first piston rod 56 extends upwardly from piston 54 to the exterior of damper 21 where it will be connected to load 10 at point 30 (not shown in Figure 2) by a pivot 57 similar to the pivot 9 of Figure 1. A second piston rod 58 extends downwardly from piston 54 to the exterior of damper 21 where it will not connect to anything. The purpose of piston rod 58 is to provide an area on the lower surface of piston 54 which has the same area exposed to the fluid in the first and second chambers 50 and 52. This allows piston 54 to displace equal volumes (although of opposite signs) of the incompressible fluid in both chambers 50 and 52 when piston rod 56 is moved in or out of damper 21.

The housing 53 of damper 21 is shown connected by a "U" shaped structure 59 extending downwardly for connection to vehicle 12 at point 31 (not shown in Figure 2) by another pivot 57 similar to the pivot 9 of Figure 1.

Hermetic seals are shown using an upper or first bellows 60 and a lower or second bellows 62 on either end of damper 21 to provide a motion transmitting fluid seal for chambers 50 and 52. A conduit 64 joins the interiors of bellows 60 and 62 respectively and is selected to be relatively non-restrictive to fluid flow. It is understood that various other sealing techniques can be used including sliding non-hermetic seals without effecting the operation of the present invention. A spring 66 which may be mounted as shown in Figure 1, is shown mounted in Figure 3 in a parallel load path with damper 21 to provide static stiffness. The spring arrangement can also be co-axial or distributed as in a flexible structure without effecting the operation of the present invention.

Damper 26 is arranged the same as damper 21 having a first or upper chamber 70 and a second or lower chamber 72 within a housing 73 separated by a piston 74. Again, no restricted passage through or around piston 74 is needed since fluid flow between chambers 70 and 72 is provided by cross conduits 42 and 43.. A first piston rod 76 attached to piston 74 extends upwardly to the exterior of damper 26 where it will be connected to load 10 at point 36 (not shown in Figure 3) through a pivot 77 similar to piston 9 of Figure 1. A second piston rod 78 extends downwardly from piston 74 to the exterior of damper 26 where it will not connect to anything for the same reasons explained for damper 21. The housing of damper 26 is shown connected by a "U" shaped structure extending downwardly for connection to vehicle 12 at point 35 (not shown in Figure 3) through another pivot 77 similar to pivot 9 of Figure 1. Hermetic seals are shown using an upper or first bellows 80 and a lower or second bellows 82 to provide a motion transmitting fluid seal for chambers 70 and 72. A conduit 84 connects the interiors of bellows 80 and 82 to permit fluid flow therebetween. A spring 86, which may mounted like spring 2 in Figure 1, is shown in Figure 3 mounted in a parallel load path with damper 26 to provide stiffness. Damper 26 operates the same as damper 21.

The fluid conduit 42 is shown in Figure 3 connected between the first chamber 50 of damper 21 and the second chamber 72 of damper 26. Similarly, the conduit 43 is shown connected between the second chamber 52 of damper 21 and the first chamber 70 of damper 26. A more restrictive conduit 90 is connected between conduits 42 and 43 and is connected to the accumulator 49 by a conduit 92. Accumulator 49 is shown having a housing 94 and a piston 96 positioned by a spring 98 to provide a pressurized chamber 100 within the housing 94 which operates to pressurize the system. Each of the oppositely positioned pairs of dampers in Figure 1 is connected in the same fashion. It should also be understood that while I have shown a single accumulator 49 in Figure 1 connected to all of the conduits 40 - 47, a plurality of accumulators could be used each connected to different pairs of conduits. After all connections are made, the system is evacuated and is filled with the incompressible fluid.

It is seen that translational motion of load 10 with respect to vehicle 12 causes the two dampers 21 and 26 of Figure 3 to see the same direction and magnitude of motion. If, for example, payload 10 moves upward with respect to vehicle 12 then piston rods 56 and 76 of Figure 3, move upward as do pistons 54 and 74 forcing the incompressible fluid out of chambers 50 and 70 through conduits 42 and 43, and into chambers 72 and 52 respectively. The area of pistons 54 and 74, the viscosity of the fluid and the length and diameters of lines 42 and 43 can be selected to provide the proper damping of this motion. No significant amount of fluid flows between conduits 42 and 43 through conduit 90 since the pressure is essentially equal across it.

The same action, above described, occurs with each of the oppositely disposed dampers in the arrangement of Figures 2a and 2b so that with translational motions , the cross coupling arrangements of conduits 40 - 47 provide the desired damping for the payload 10.

On the other hand, rotational motion of the payload 10 with respect to vehicle 12 causes the dampers 21 and 25 to see motion in opposite direction which may or may not be of equal magnitude depending on the angles of the damper and where the center of rotation of the payload 10 is located. If, for example, payload 10 is rotated clockwise in Figure 2b around a line perpendicular to the plane of the Figure and passing through point 37, this motion causes point 30 to rise and point 36 to lower relative to the vehicle 12. Responding to this, damper 21 would see piston rod 56 and piston 50 try to rise while damper 26 would see piston rod 76 and piston 74 try to lower. However, since chambers 50 and 72 are connected by line 42 and filled with incompressible fluid, the motion is resisted by the fluid pressure in chamber 50 and 72. This increases the rotational stiffness over that of a conventional system since this rotation is resisted by both the springs and the hydraulics. This also causes a pressure difference between conduit 42 and conduit 43 forcing fluid through the highly restrictive conduit 90. The length and diameter of conduit 90 is selected to provide the proper damping for this rotation motion.

The same action, above described, occurs with each of the oppositely disposed dampers in the arrangement of Figures 2a and 2b so that with rotational motions the cross coupling arrangements of conduits 40 - 47 provide the desired damping for the payload 10.

In the event of a temperature variation which causes a change in volume of the fluid in the system, the chamber 100 in the accumulator 49 will expand or contract, as necessary, against the force of spring 98 to permit a flow of fluid between chamber 94 and the conduits 42 and 43 through conduit 92. Temperature variations are usually quite slow in nature so the necessary flow through the restrictive conduits 90 and 92 can be accomplished.

It is thus seen that the damping system shown herein, can be made soft and damped for translation motions, better isolating the payload from the vehicle vibrations while dynamically stiffening and damping the rotational motions to reduce the sway or rocking of the payload and reduce the rattle space required between the payload and the aerodynamic faring or to isolate a payload, such as an IMU, while retaining it's angular alignment.

Many variations and alterations will occur to those having skill in the art, as for example, while I have shown piston type dampers, bellows or other type dampers may also be employed and while I have shown eight dampers in a rectangular configuration, other numbers of dampers and different configurations may be employed. The springs can be discrete devices aligned co-linear with the dampers, or they may be located separately, or they can be a single distributed spring such as a compliant structure. Also, the mounting need not necessarily be at the bottom of the load and may be placed elsewhere, for example at the center of gravity. Accordingly, I do not wish to be limited to the specific structures used to describe the preferred embodiments of the invention.

CLAIMS

1. In a suspension and damping system for use in mounting a first device (10) to a second device (12), which includes spring means (66, 86) connecting the first and second devices to provide stiffness, a first fluid chamber (50) having a first end (top of 54) connected to the first device and a second fluid chamber (62) having a first end (59) connected to the second device, first means (54) connecting the first and second chambers so that an increase in volume of the first chamber is accompanied by a decrease in volume of the second chamber, a third fluid chamber (70) having a first end (end of 74) connected to the first device, a fourth fluid chamber (72) having a first end (79) connected to the second device and second means (74) connecting the third and fourth chambers so that an increase in volume of the third chamber is accompanied by a decrease in volume of the fourth chamber, the improvement comprising:

a first fluid passage (42) connecting the first and fourth chambers and a second fluid passage (43) connecting the second and third chambers, the first and second fluid passages constructed to provide a predetermined restriction to fluid flow to cause a desired damping for translational motions and so that translational motions between the first and second devices is less stiff than rotational motions between the first and second devices.

2. Apparatus according to claim 1 wherein the predetermined restriction is produced by properly selecting the length and diameter of the first and second fluid passages.

3. Apparatus according to claim 1 further including a reservoir (49) having a fluid connection (92) to the first and second fluid passages to supply pressured fluid to the first, second, third and fourth chambers and to receive excess fluid due to temperature increases, the fluid connection having greater restriction to fluid flow than the restriction produced by the first and second fluid passages so as to cause a desired damping for rotational motions.

4. Apparatus according to claim 3 wherein greater restriction is produced by properly selecting the length and diameter of the fluid connection.

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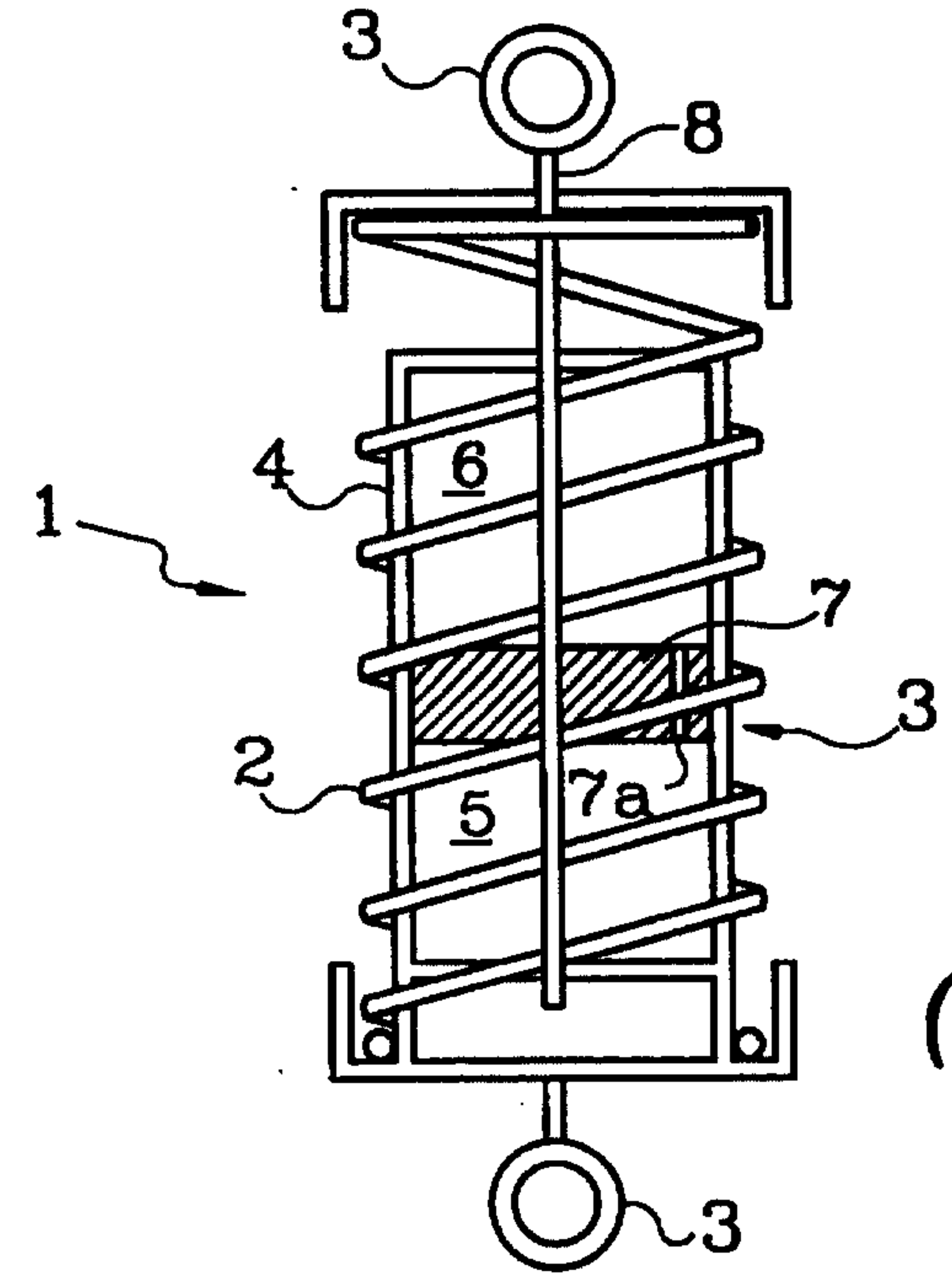

Fig. 1
(PRIOR ART)

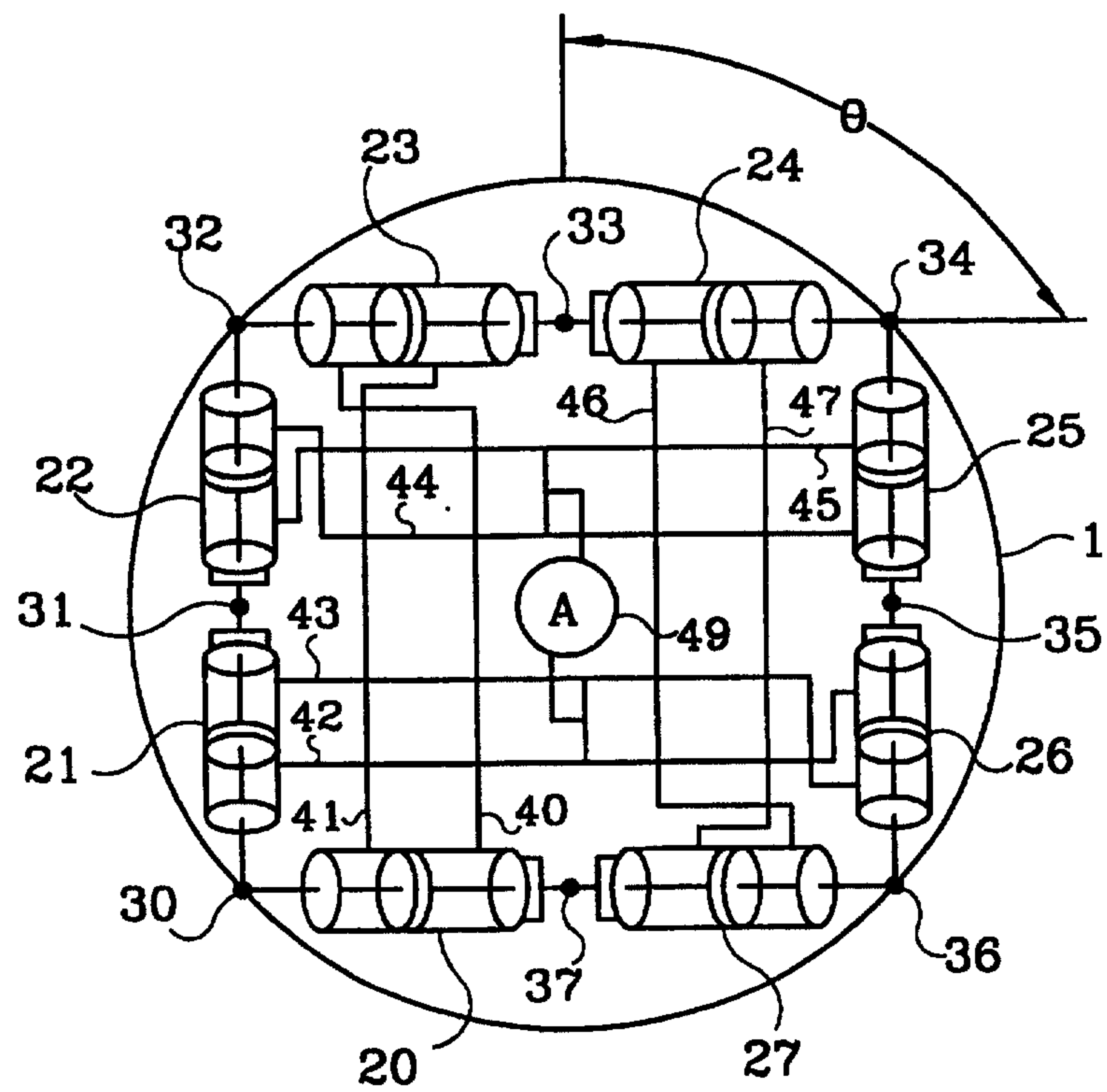

Fig. 2a

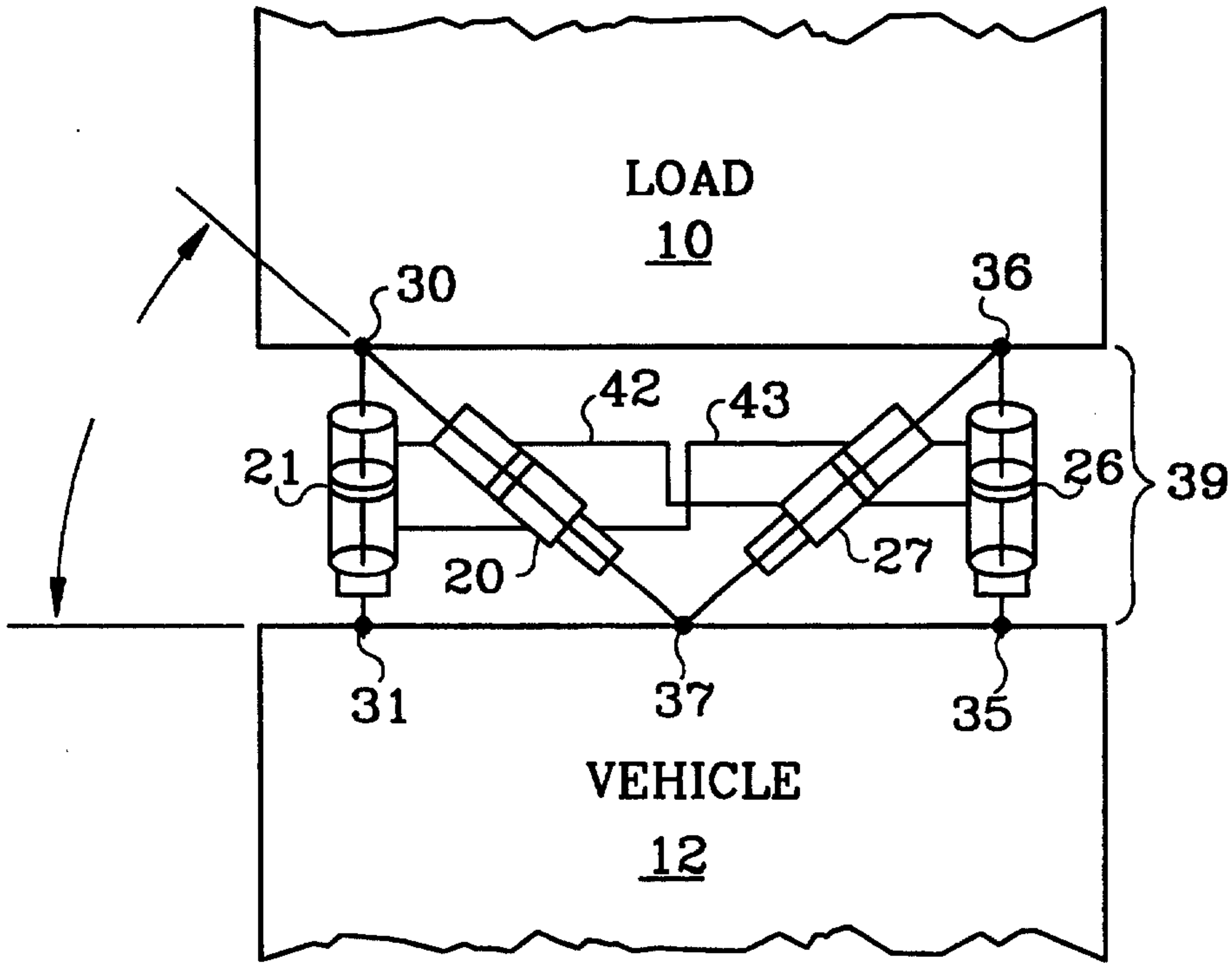
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Fig. 2b

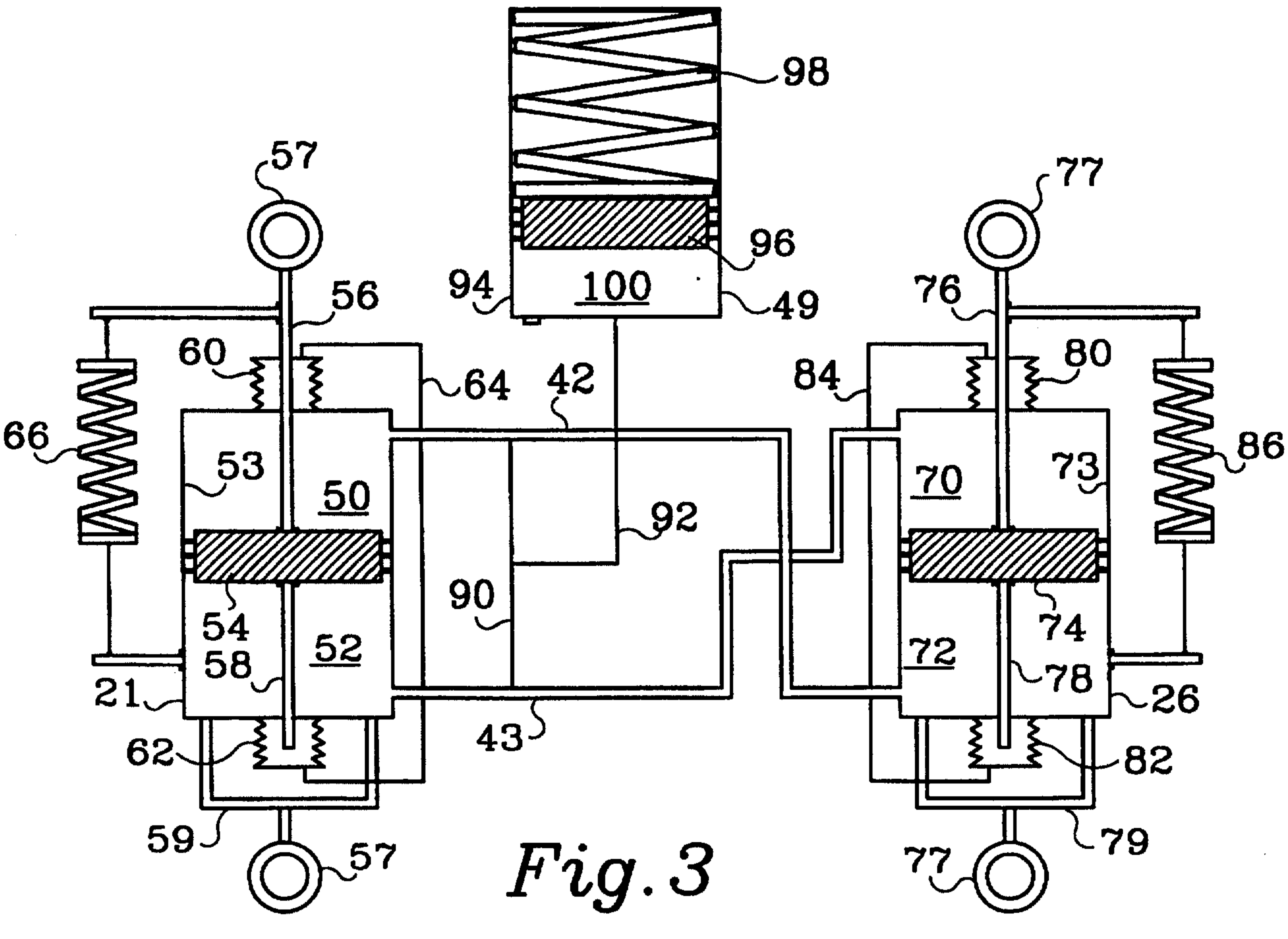
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Fig. 3