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B7D
G1G
Selected US specifications from IPC sub-classes B60G
F16F

(54) Suspension systems

(57) In a suspension system, a fluid pressure spring comprises a hollow body supported on a pair of end members (16,17) movable towards and away from one another in an axial direction of the spring, and apparatus (31) is provided on one end member (16) to measure the axial spacing of the end members by emitting ultrasonic pulses in the axial direction, e.g. to be reflected from the other end member (17), so as to enable the transit time of the pulses along the body to be measured and thus to provide a measure of the length of the body between the end members at any given time. Preferably a transmitter/receiver is located on one end member (16) and a reflector (44) on the other end member (17), and a fixed reflector (43) is provided for comparison. A control unit responsive to the pulse transit time is operatively connected to a control valve for the fluid pressure within the spring.

Fig. 1.

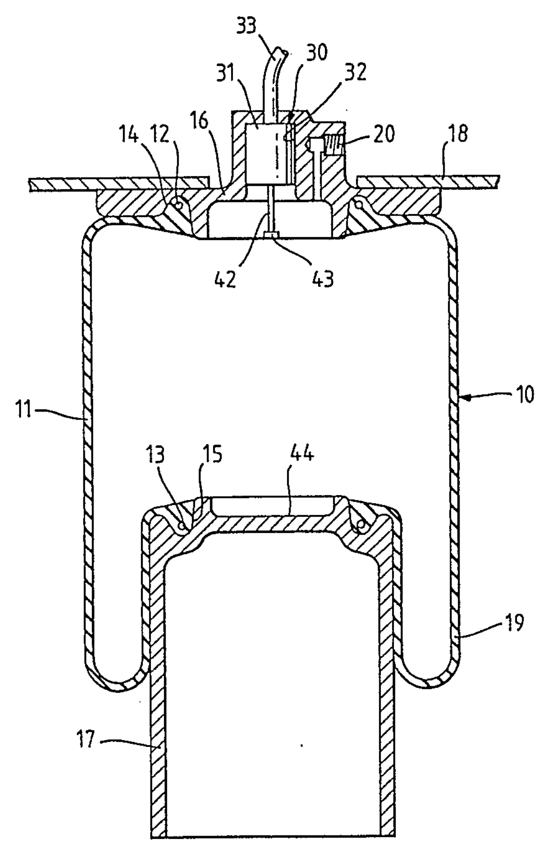

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Fig. 1.

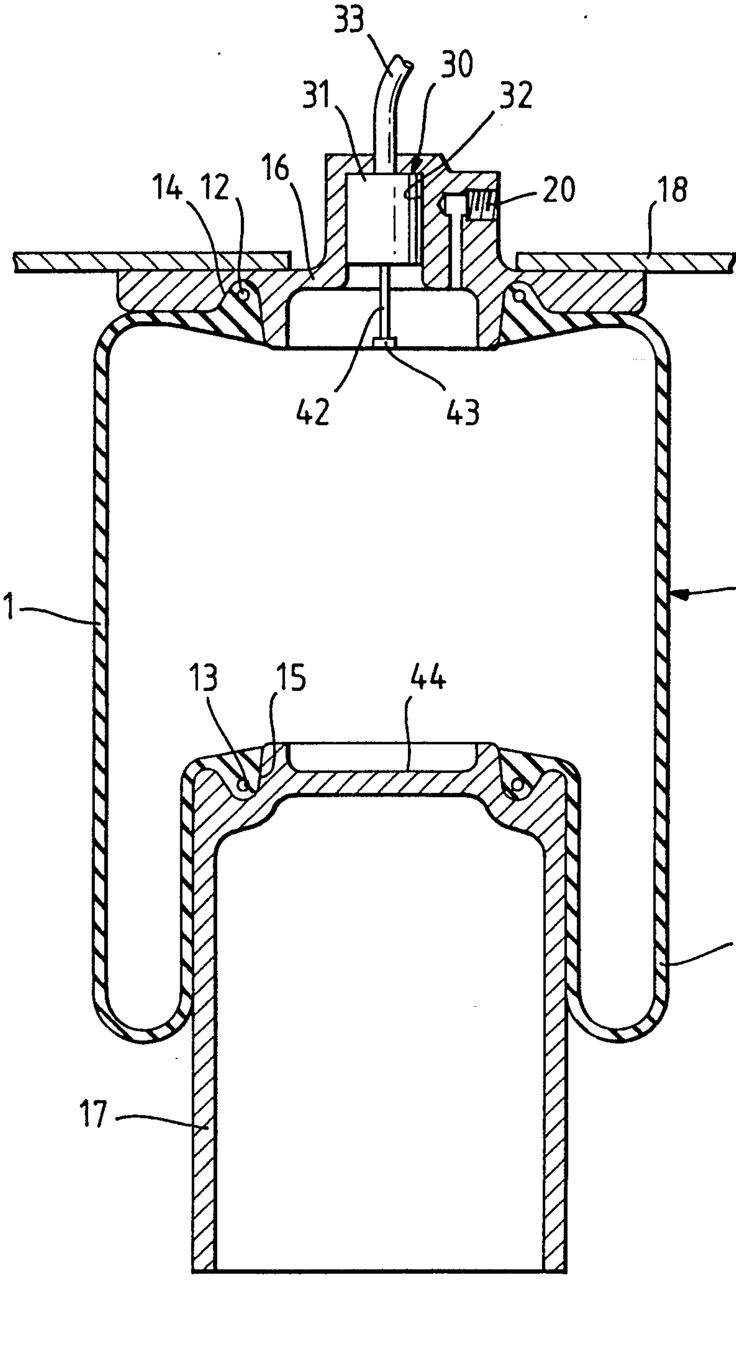


Fig. 2.

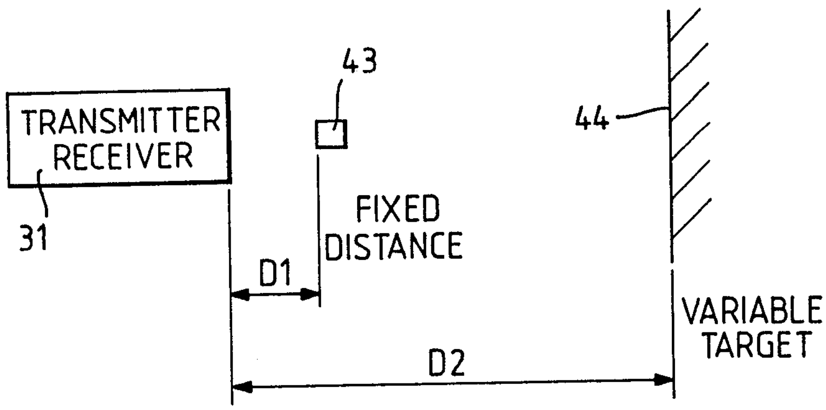
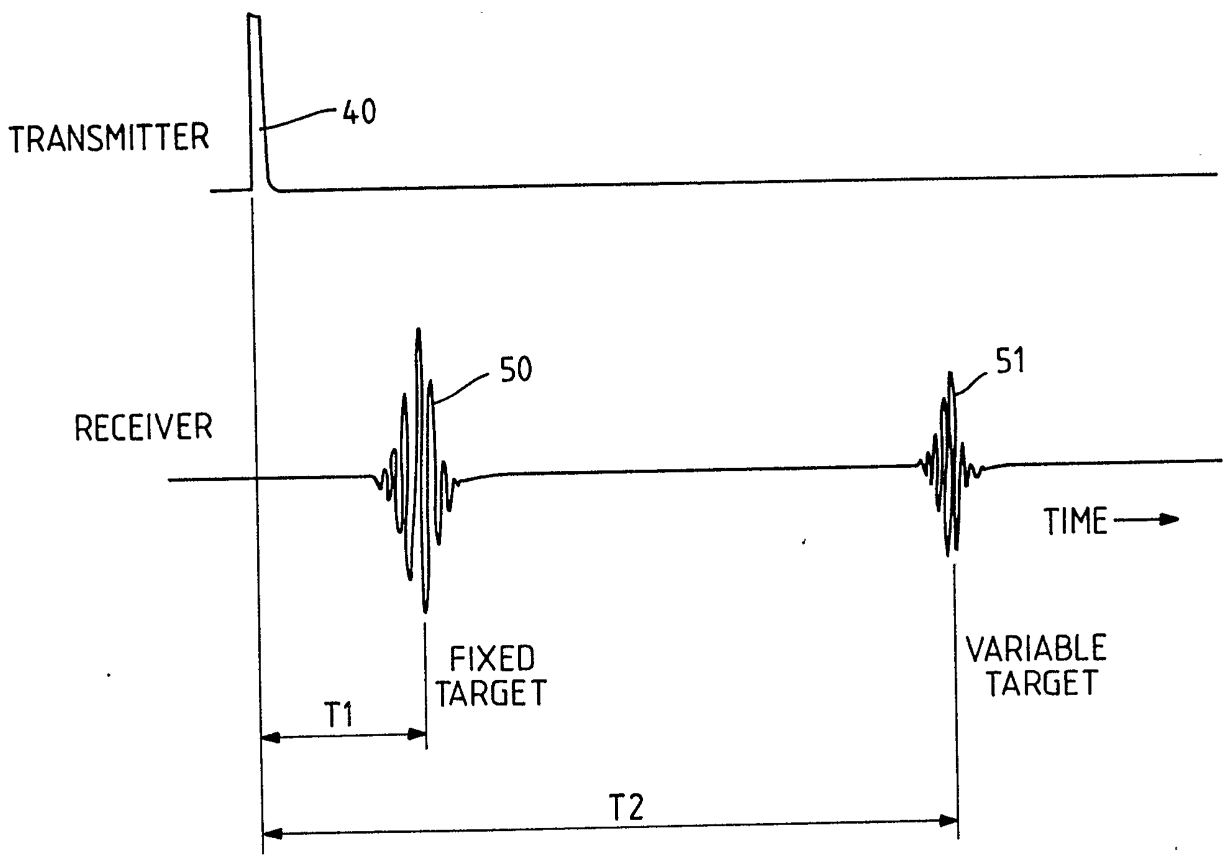

TRANSMITTER
RECEIVER
31
43
44
FIXED
DISTANCE
D1
VARIABLE
TARGET
D2

Fig. 3.


TRANSMITTER
40
RECEIVER
50
51
TIME
FIXED
TARGET
VARIABLE
TARGET
T1
T2

SPECIFICATION

Suspension systems

This invention relates to suspension systems, and particularly to suspension systems for vehicles, of the kind in which a fluid-pressure spring is mounted between sprung and unsprung parts of the vehicle and is arranged to be connected to a source of fluid pressure via a valve mechanism which enables fluid to be supplied to, or released from a spring in order to adjust the height of the sprung part above the unsprung part.

The valve employed for the above purpose is commonly referred to as a "levelling valve", and, conventionally, may be operated by a mechanical actuating arm responsive to relative movement between the sprung and unsprung parts. Such systems have the disadvantage that the valve and its operating mechanism are exposed to the hostile environment under the vehicle and are subjected to the effects of mud, water, and corrosive substances, (e.g. road salt), thrown up by the wheels. Further, the mechanisms of a valve of this kind need to be relatively complex in order to prevent unnecessary operation of the levelling system in short-duration relative movements of the sprung and unsprung parts.

The invention has the object of providing actuation means for a levelling valve which is shielded from the hostile working environment, and which is capable of providing a more sophisticated control of the fluid pressure spring than current actuation mechanisms.

According to the invention, a suspension system comprises a fluid pressure spring in the form of a hollow flexible body having a pair of relatively movable end members, movable towards and away from one another in an axial direction of the spring, and apparatus located within the hollow flexible body responsive to changes in the axial spacing of the end members, said apparatus comprising a pulse-emitting device mounted on one end member and arranged to emit trains of pulses in the axial direction of the body and a receiver device arranged to receive said pulses after the pulses have passed at least once axially along the body, and a control unit comprising means responsive to the pulse transit time and being arranged to be operatively connected to a control valve for the fluid pressure within the spring.

The apparatus may comprise a pulse-emitting device mounted on one end member and a receiver device on the other end member, but in a preferred arrangement the two devices are both mounted on one end member and a reflector for the pulses is mounted on the other end member so as to reflect said pulses to the receiver. In a further preferred arrangement, a fixed reflector is secured to the end member carrying the pulse-emitting device, the fixed reflector being spaced at a fixed distance within the hollow flexible body from the pulse-emitting device to provide a reference pulse transit time.

The pulses employed are preferably ultrasonic pulses.

One embodiment of the invention will now be described with reference to the accompanying drawings, in which :-

Figure 1 is a diagrammatic axial cross-section through a pneumatic spring;

Figure 2 is a diagram showing the spatial relationship of elements of a height-sensing apparatus contained within the spring shown in Figure 1, and

Figure 3 is a graph showing the time relationship of pulses reflected from a fixed target and a movable target within the spring.

The pneumatic spring 10 shown in Figure 1 comprises a conventional rolling-lube cord-reinforced rubber air bellows 11 which includes inextensible wire-reinforced beads 12 and 13 suitably clamped against seatings 14 and 15 on a base plate 16 and a piston 17 respectively. The base plate 16 is secured to a vehicle chassis member 18 and the piston 17 is secured to an axle of the vehicle (not shown). The rolling lobe 19 of the bellows 11 permits vertical (axial) displacement of the piston 17 relative to the base plate 16, upward movement of the piston towards the base plate 16 being resisted by pneumatic pressure within the spring supplied through an air connection 20 which in service is connected to a conventional pressure source on the vehicle via a control unit (not shown). The control unit comprises an electrically actuated pneumatic valve which can be actuated to supply air pressure to the interior of the bellows, thus tending to raise the base plate and chassis relative to the axle, or to exhaust air pressure from the bellows so as to lower the chassis relative to the axle. Such systems for vehicle "ride height" adjustment are well known : the present invention resides in the provision, within the bellows 11, of height-sensing apparatus 30.

The height-sensing apparatus 30 comprises an ultrasonic pulse piezo-electric transmitter-receiver 31 of conventional form which is located in a cylindrical recess 32 of the base plate 16 and connected to a source of electrical power and the associated control unit through a multi-core cable 33. The apparatus 30 is sealed into the recess 32 by conventional means (not shown) to retain the pneumatic pressure in the bellows. The transmitter-receiver 31 is electrically actuated to produce a train of ultrasonic pulses 40 (Figure 3) which pass axially downwardly through the bellows.

A rigid stem 42 secured to the apparatus 39 carries a fixed reflector in the form of a target 43 (such as a flat metal disc secured to the stem 42) which is capable of reflecting ultrasonic pulses back to the transmitter-receiver. A movable reflector or target 44 is provided by a flat surface on the end of the piston 17 which is also capable of reflecting ultrasonic pulses back to the transmitter-receiver.

In operation, the control unit needs to be supplied with information as to the height at which the vehicle chassis is held, by the pneumatic pressure in the spring 10, above the axle. Short-term fluctuations in this height will of course occur as the vehicle travels over uneven ground, and long-term variations will occur when the amount of the load carried by the vehicle is changed.

The apparatus 30 is arranged to provide signals to the associated control unit, spaced in time, corresponding to the emission of an ultrasonic pulse 40 and the subsequent arrival at the receiver of a pulse 50 reflected from the target 44 which is movable with vertical movement of the piston 17. As shown in Figure 3 the returning pulses 50 and 51 are received at the transmitter-receiver 31 at times T1 seconds and T2 seconds respectively after the initial emission of a pulse 40.

As shown in Figure 2, the fixed-distance target 43 is positioned at a distance D1 from the transmitter-receiver and the movable target 44 at a distance D2 from the transmitter-receiver.

The distance D2 is easily calculated from the equation

$$D2 = D1 \times \frac{T2}{T1}$$

assuming that the velocities of the pulses 50 and 51 are the same – which is of course the case. It will be noted that the actual velocity of the pulses does not enter into the equation : the use of the pulse 50 from the fixed target provides a reference pulse transit time, allowing the effects of pulse velocity changes (which may occur as a result of air pressure, temperature, and humidity within the bellows) to be eliminated.

In the control unit, which is a solid-state electrical circuit of conventional type, pulse timing circuits are provided to enable T1 and T2 to be compared and thus provide, either in digital or analogue form, a signal which is a measure of D2. By use of a suitable integrating circuit the control unit can be made to ignore short-term fluctuations in D2 and to respond only to long-term variations in ride height which are caused by changes in vehicle loading. The control unit is arranged via its electrically operated pneumatic valve to supply air pressure to, or release air pressure from, the spring 10 so as to maintain the ride height of the vehicle constant under changing vehicle conditions. The system can also be arranged to enable any desired height (within a suitable range) to be selected by the vehicle driver.

A major advantage of the ride height control system described above is that by the novel step of incorporating a pulse-emitting device to constitute height sensing apparatus within the hollow body of the spring the device is protected against accidental damage or the effects of mud, water, and corrosive agents encountered in normal usage on a vehicle. The system described, involving the use of a fixed target to provide a reference pulse transit time, has the major advantage of eliminating the errors which could otherwise arise in an ultrasonic pulse system due to the effects of temperature, humidity etc.

CLAIMS

1. A suspension system comprising a fluid pressure spring in the form of a hollow flexible body having a pair of relatively movable end members, movable towards and away from one another in an axial direction of the spring, and apparatus located within the hollow flexible body responsive to changes in the axial spacing of the end members, said apparatus comprising a pulse-emitting device mounted on one end member and arranged to emit a train of pulses in the axial direction of the body and a receiver device arranged to receive said pulses after the pulses have passed at least once axially along the body, and a control unit comprising means responsive to the pulse transit time and being arranged to be operatively connected to a control valve for the fluid pressure within the spring.
2. A suspension system according to Claim 1 wherein the pulse-emitting device and the receiver device are both mounted on one end member and a reflector for the pulses is arranged on the other end member so as to reflect said pulses to the receiver.
3. A suspension system according to Claim 2 wherein a fixed reflector is secured to the end member carrying the pulse-emitting device, the fixed reflector being spaced at a fixed distance within the hollow flexible body from the pulse-emitting device to enable a reference pulse transit time to be determined.
4. A suspension system according to Claim 3 wherein the fixed reflector is carried on a stem extending axially within the hollow flexible body from the end member carrying the pulse-emitting device.
5. A suspension system according to any of Claims 1 to 4 wherein the pulse-emitting device emits ultrasonic pulses.
6. A suspension system according to any of the preceding claims wherein the hollow flexible body is a pneumatic spring.
7. A suspension system according to any of the preceding claims wherein the control unit is arranged to maintain an associated vehicle at a constant ride height.

8. A suspension system constructed and arranged substantially as described and illustrated in the accompanying drawings.
9. A vehicle comprising a suspension system as claimed in any of the preceding claims.

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