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(54) **Vehicle suspension unit with end-of-stroke damping**

(57) A vehicle ride strut includes a piston 143, which reciprocates in a cylinder 20 to divide the cylinder into two compartments 146, 148, flow of liquid between compartments on a contraction stroke in the operating range being less restricted than flow on an extension stroke in the operating range, which is in turn less restricted than flow on extreme extension. The piston is formed with passages 160 provided with check valves 158 and also with constricted passages 174. A valve member 180, formed with narrow passages 194 leading to an annular groove 196 adjacent the piston 143, engages the piston 143 upon extreme strut extension to greatly diminish flow of liquid through the piston 143.

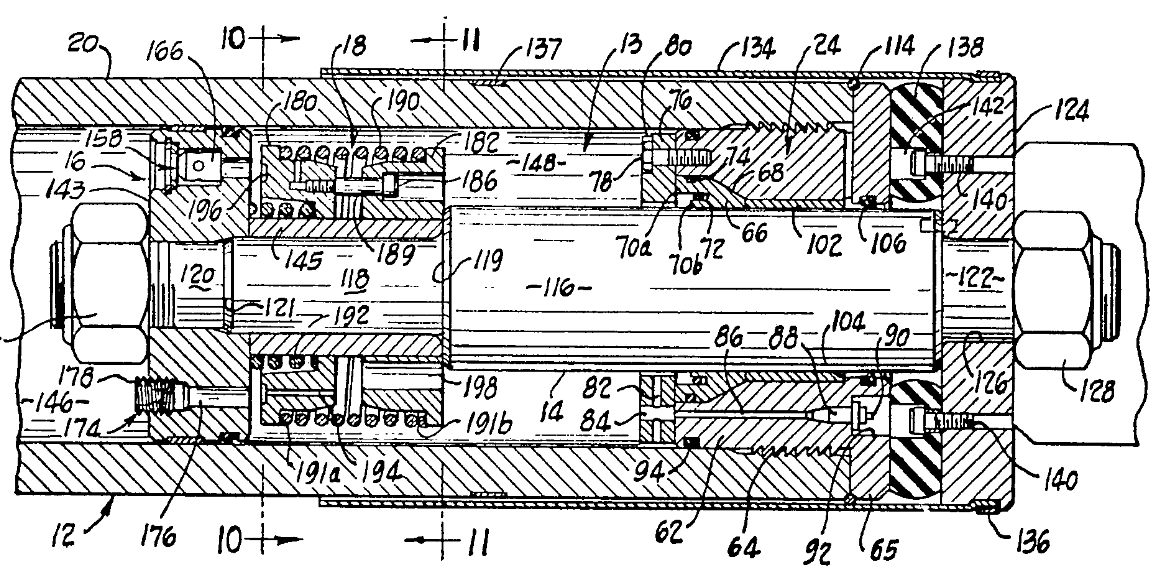

Fig. 8

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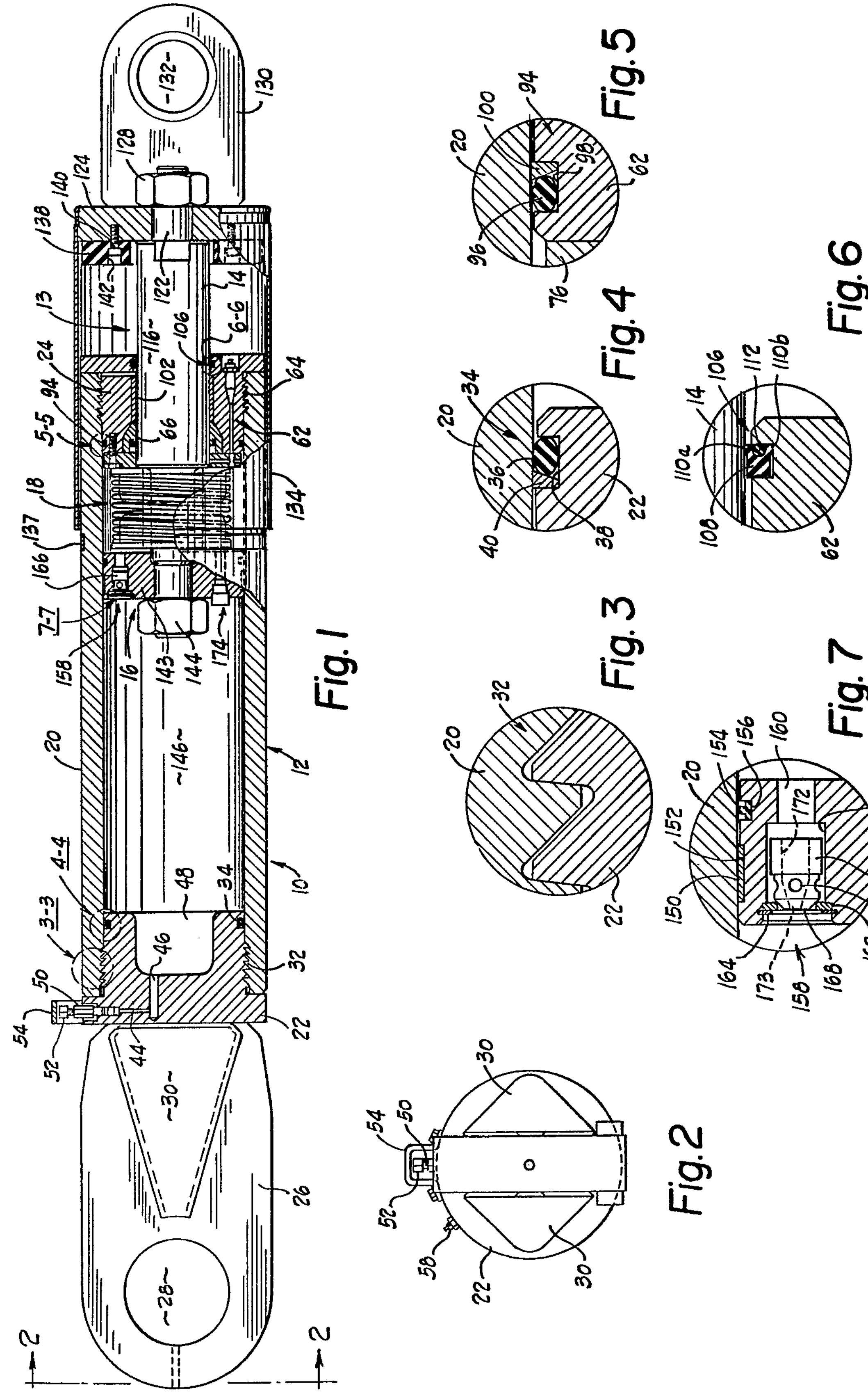

Fig.1 Fig.2 Fig.3 Fig.4 Fig.5 Fig.6 Fig.7

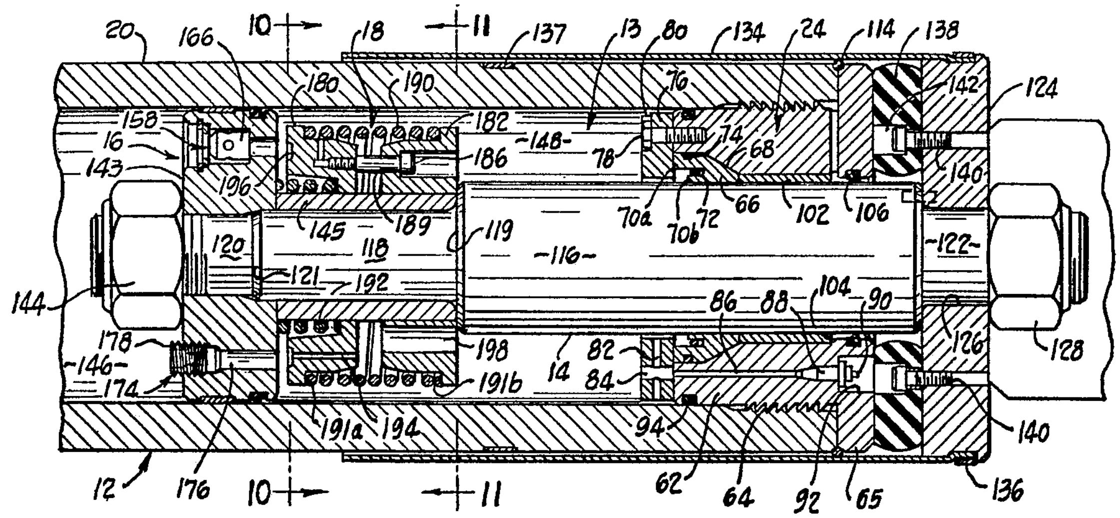

Fig. 8

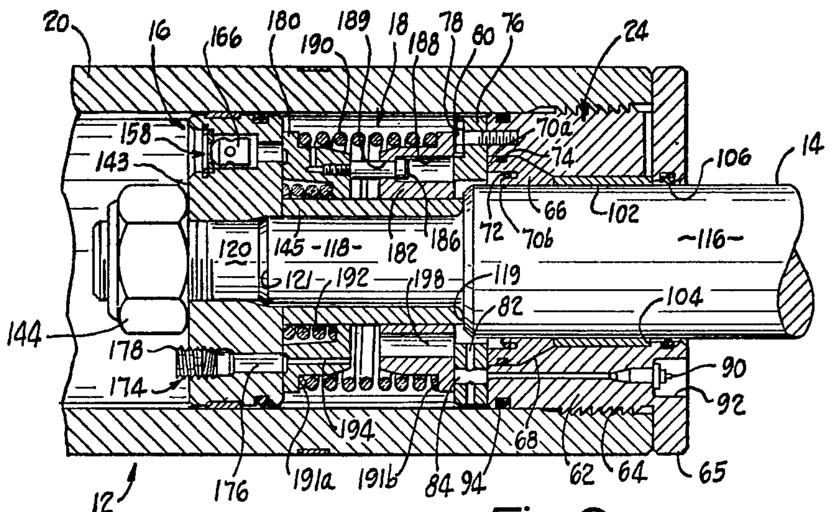

Fig. 9

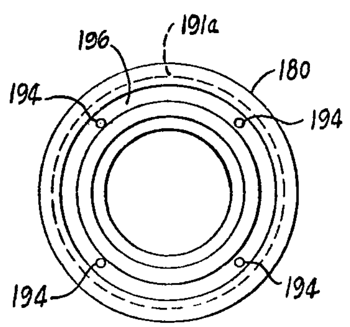

Fig. 10

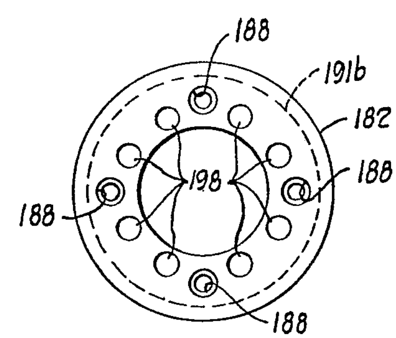

Fig. 11

SPECIFICATION

Vehicle ride strut

This invention relates generally to off-highway load haul vehicles and more particularly to ride struts used on such vehicles.

Load hauling off-highway vehicles are used in such applications as highway construction and mining. For many years these vehicles were constructed without any spring suspension of any kind except for the limited amount of springing provided by the vehicle tyres. These unsprung vehicles were operated at relatively slow speeds of the order of ten miles per hour and at those speeds both the operators and the vehicles were able to tolerate the punishment inflicted by the rigid suspensions.

Modern off-highway haulers are no longer operated at such low speeds. In mining operations, for example, these off-highway vehicles are operated along haul roads at speeds of the order of forty miles per hour. Carrying capacities, like speeds of operation, have also greatly increased and payloads may be of the order of two hundred tons or more. With such speeds and payloads, sprung suspensions have become a necessity because fatigue of both operator and vehicle would be prohibitive without them.

The first sprung suspensions were rather similar in principle to those used in normal highway vehicles. For example, vehicles were constructed with coil spring suspensions and shock absorbers to damp the spring action.

In recent times, ride struts have been developed which are intended to perform both suspension and shock absorbing functions. These struts have used various types of internally contained springs including rubber, metal and liquids.

While many different ride struts have both been proposed and developed, none has been fully satisfactory because the punishment inflicted in off-highway load hauling causes excessive failures. Failures are inordinately expensive because (a) struts are expensive, (b) the lost vehicle's production is extremely expensive, and (c) repairs on load haul vehicles are often difficult, especially when the breakdowns occur at remote locations where weather conditions may be severe.

So-called "liquids spring" ride struts, that is to say in which the spring effect is provided by compressible liquid, have been known for some applications for many years but they have exhibited shortcomings in off-highway load haul applications. With these struts, the compressible liquid, such as a liquid silicone, provides spring suspension. A typical strut has a cylinder that defines a liquid-containing chamber enclosing a ported piston connected to a piston rod extending from one end of the cylinder. The weight of the vehicle pushes the piston rod into the cylinder to compress the liquid and effect a springing action. The ported piston functions to damp that action and thus functions as a shock absorber.

One major advantage of a liquid strut is that, so long as the strut itself does not fail, the liquid spring has effectively an endless life, since additional liquid can be supplied to replenish lost liquid. So long as there is a proper quantity of the correct liquid the appropriate spring capacity is maintained, and, as contrasted with metal and rubber springs, spring fatigue is eliminated as a factor in suspension life.

Another advantage of liquid struts is that with an appropriately ported piston to permit controlled liquid flow from one side of the piston to the other, the liquid ride strut functions both as a spring suspension and a shock absorber to damp spring action.

While liquid struts have these and other advantages, previous struts have also has shortcomings, one of which has been their inability to properly withstand the forces imposed under so-called "rebound" conditions. A rebound condition occurs when a vehicle bounces and leaves the ground or when a wheel drops into a hole or the like so that the strut becomes extended and is in tension supporting the weight of a wheel and axle assembly rather than being compressed to support the vehicle above its wheel and axle.

Attempts have been made to solve the rebound problem in ride struts, but none has been fully satisfactory. For example, attempts have been made to use rubber discs as a rebound cushion but they tend to degrade at an excessive rate when exposed to liquid spring materials such as liquid silicones.

Other attempts at rebound control have not provided both (a) a high damping rate desired for rebound conditions which will function to inhibit and substantially to prevent damage to the strut or other vehicle components; and (b) ample flow rates through a ported piston to permit the desired rate of piston movement when the strut is operating to function as a vehicle support.

According to the present invention a vehicle ride strut comprises a housing defining a cylinder divided into two compartments by a piston which is mounted in the cylinder for sliding movement over an operating range and a rebound range and is connected to a piston rod extending through an opening at the end of the housing, the construction being such as to establish a fluid flow path between the compartments and including a valving arrangement establishing (i) a first flow condition through the flow path when the piston rod and housing move relatively in a compressive direction in the operating range; (ii) a second more restrictive flow condition when the piston rod and housing move relatively in an extending direction in the operating range; and (iii) a third and still more restrictive flow condition when the piston rod and housing move relatively in an extending direction and the structures are in the rebound range. When the compartments of the cylinder are filled with a compressible liquid superior rebound characteristics are obtained owing to the provision of a high rebound damping rate.

The valving arrangement preferably includes piston passages to permit fluid flow through the piston upon relative movement of the piston and housing. The valving arrangement preferably also includes a valve member carried by the piston rod and engageable with one face of the piston upon the attainment of a predetermined piston rod extension, the valve member being formed with openings to permit some liquid flow through the valve member, and hence the piston, under all circumstances. The valve member thus reduces the liquid flow from one of the two compartments to the other through at least one of the piston passages as the piston is displaced to the predetermined extension.

As a result of its construction a ride strut in accordance with the invention has a high liquid flow rate through the piston upon compression, and intermediate liquid flow rate through the piston upon extension through a normal operating range and a very low flow rate during rebound extension.

The foregoing features provide a ride strut of extreme strength and simplicity and one which can be tailored quite accurately to diverse, demanding conditions.

An example of a liquid ride strut in accordance with the invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 is a side view partly in section;

Figure 2 is an end view of the strut as seen from the plane indicated by the line 2–2 of Fig. 1;

Figure 3 is an enlarged sectional view of area 3–3 of Fig. 1, showing in more detail a thread construction;

Figures 4, 5 and 6 are enlarged views of areas 4–4, 5–5 and 6–6, respectively of Fig. 1 showing seal and wiper constructions in more detail;

Figure 7 is an enlarged view of area 7–7 of Fig. 1, showing a piston check valve and passage;

Figure 8 is an enlarged view, partly in section, showing the relationship of ride strut components under full compression;

Figure 9 is a view similar to Fig. 8, showing the ride strut components in a rebound range of strut extension; and

Figures 10 and 11 are views as seen from the planes indicated by the lines 10–10 and 11–11 respectively, of Fig. 8 each showing an end view of valve components.

The ride strut assembly 10 shown in Fig. 1 comprises several sub-assemblies, including a body 12, a rod assembly 13 including a piston rod 14, a piston 16 and a valve section 18. The ride strut is for use in large off-highway haul vehicles in which loads of up to two hundred tons or more are carried.

As an example, a ride strut for use on a one hundred and seventy ton capacity vehicle will, in the extended position, have a overall length of approximately 82 inches, a piston diameter of about 8 inches, and a piston rod diameter of about 4.25 inches. The ride strut will have a stroke (or compression excursion) from the vehicle rest position of the order of 4.50 inches, and a rebound extension (or expansion excursion) from the vehicle rest position of the order of 1.50 inches.

The body 12 is filled with compressible silicone liquid which provides the spring action. An acceptable liquid is silicone liquid with compressibility ranging from 0.36 per cent to 500 psi to 11.60 per cent at 30,000 psi. Approximately 4.4 gallons of liquid are required for a ride strut of the dimensions given.

The body is a tubular housing including an elongate cylinder 20 which is closed at its lower end (the left hand end as seen in Fig. 1) by an end cap 22. An annular gland element 24 is screwed into the upper end of the cylinder 20 in a sliding, sealing relationship with the piston rod 14 to close the upper end of the cylinder. A rod eye 26 extends outwardly of the end cap and has an opening 28 for attachment to a vehicle axle. Reinforcing members 30 are on either side of the rod eye 26. The end cap, rod eye and reinforcing members are secured permanently to each other by welds.

The end cap is secured within the cylinder 20 by buttress threads 32, illustrated in detail in Fig. 3. Buttress threads have been chosen because they are adapted well for taking heavy loads in one direction, as will occur in the present case due to the internal body pressure tending to force the end cap from the end of the cylinder.

A seal 32 is interposed between the end cap and the cylinder to prevent liquid from leaking from the housing. Referring to Fig. 4, the seal 34 comprises a O-ring 36 disposed within a circumferential groove 38 formed in the end cap. A chamfered ring 40 also is disposed in the groove 38 to compress the O-ring and to be compressed itself against the inner surface of the cylinder 20.

Shock-absorbing liquid is charged into the ride strut (and bled from the ride strut if need be) through the end cap. A first passage 44, Fig. 1, extends radially inwardly from an exposed portion of the end cap towards the centre of the end cap. The passage 44 communicates with a second, longitudinally extending passage 46 which, in turn, communicates with a recessed portion 48 formed in the inner end of the end cap. Referring especially to Fig. 2, a charge valve 50 having a closure cap 52 is fitted into the exposed end of the first passage 44. The charge valve and closure cap are protected by a U-shaped bracket 54 which is secured to the end cap by a bolt 56. When the bolt and U-shaped bracket have been removed, access may be had to the closure cap 52 and thence to the charge valve 50.

A separate air bleed valve 58 is provided for the end cap, Fig. 2. The bleed valve is displaced angularly from the charge valve 50 and communicates with the interior of the body via passages (not shown) similar to the first and second passages 44, 46. When liquid is charged into the body, internal pressure eventually increases to the point where the ride strut becomes extended. This is the way vehicle ride height and internal ride strut pre-load are controlled. Similarly, if ride height and pre-load are too great, liquid can be bled from the body through the charge valve.

Referring to Figs. 1, 8 and 9, the gland element 24 includes an inwardly extending collar 62 secured within the cylinder by buttress threads 64. The buttress threads 64 are identical to the buttress threads 32 illustrated in Fig. 3. The gland element also has an end flange portion 65 which over-lies and engages the end of the cylinder 20. The gland element functions to provide a leak-free closure with, and aligment of, the piston rod 14. A rod seal 66 having a bore of approximately the same diamerter as the piston rod is carried by the collar 62. Reforming to Figs. 8 and 9, the rod seal 66 has (a) a frusto-conical portion 68 which mates with a complementary portion of the collar 62 and (b) a pair of spaced lips 70*a*, 70*b* which face axially toward the lower end of the ride strut. The rod seal 66 is formed of polytetrafluoroethylene (TEFLON, Registered trade mark) because of the anti-friction and sealing characteristics of this material.

An O-ring 72 is positioned between lips 70*a*, 70*b* to maintain appropriate radial spacing between them. Another O-ring 74 surrounds the outer lip 70*a* and engages the inner surface of the collar 62.

An annular retainer and rebound stop 76 is secured to the inner end of the collar 62 by bolts 78 (only one of which is shown). The retainer 76 engages the outer lip 70*a* of the seal 66 to retain the seal in place. The bolts 78 are fitted into counter-sunk portions 80 of the retainer. The inner diameter of the retainer is larger than the outer diameter of the piston rod so that liquid may flow between them.

The retainer includes a radially extending passageway 82 which inter-sects an axially extending passageway 84. An axial passageway 86 extends through the collar 62 and is aligned with the axially extending passageway 84. A bleed valve 88 having a plug 90 is fitted into the passageway 86. By this construction, air may be bled from the strut when liquid is charged into it during assembly. The bleed valve and plug are fitted within a counter-sink 92 formed in the collar 62 so that the bleed valve and plug will not be damaged upon full strut compression.

An outer seal 94 is provided for the collar 62 to minimise or prevent liquid from leaking to the buttress threads 64. Referring to Fig. 5, the seal 94 comprises an O-ring 96 disposed within a circumferential groove 98 formed in the collar. A chamfered ring 100 also is disposed in the groove 98 to compress the O-ring outwardly and to be compressed itself against the inner surface of the cylinder 20.

A split ring guide 102 is disposed between the collar 62 and the piston rod 14, (Figs. 1, 8 and 9). The guide 102 engages the upper end of the rod seal 66. The guide 102 is held stationary by engagement with a shoulder 104 of the gland 24 best seen in Fig. 9.

In order to exclude dirt or other contaminants from the guide 102 and the rod seal 66, a dirt wiper 106 is provided for the interface between the flange 104 and the piston rod 14. Referring to Fig. 6, the wiper 106 comprises an annular ring 108 having axially facing lips 110*a*, 110*b*. An O-ring 112 is fitted between the lips 110*a*, 110*b* to expand the lips and thus effect a sealing function.

The piston rod 14 comprises an elongate, cylindrical section 116 from which cylindrical sections 118, 120 of progressively decreasing diameter project. The sections 118, 120 are connected by a bevelled surface 121 while the sections 116, 118 are connected by a radially disposed shoulder and bevel 119. The valve section 18 is carried by the intermediate-sized cylindrical section 118 and the piston is carried jointly by the section 118 and the smallest section 120.

As is best seen in Fig. 8, threaded cylindrical section 122 projects from the other end of the rod. A disc 124 having an opening 126 is secured to the piston rod by a nut 128 screwed on to the end of the section 122. A two-part rod eye 130 (only one leg of which is shown in Fig. 1) extends outwardly of the disc and includes an opening 132 for attachment to the vehicle frame. The disc and rod eye are secured permanently to each other by welds.

In order to shield the piston rod from dirt or other contaminants, a cylindrical rubber shroud or boot 134 is secured to the perimeter of the disc. The boot is concentric with the outer surface of the cylinder 20 and surrounds a dust seal O-ring 114. The shroud overlaps the body 20 a convient distance to make the entrance of dirt difficult. The boot is deformed into a perimetral groove in the disc 124 and secured there by a circumferential clamp 136.

In order to determine whether the amount of liquid in the ride strut is correct, a band 137 is secured about the circumference of the cylinder 20. The axial location of the band 137 is chosen so that when the proper amount of the liquid is in the strut when the vehicle is empty, the bottom edge of the boot will overlap the band. The band preferably comprises tape of a colour contrasting with that of the cylinder and the boot, so that the position of the boot with respect to the band may be determined readily.

A resilient pad 138 is secured to the inner face of the disc 124 to cushion any impact with the end of the collar 62 upon maximum strut compression. The pad is secured to the disc by bolts 140 which are fitted into counter-sunk portions 142 of the pad. Clearance is provided between the inner diameter of the pad and the cylindrical section 116; clearance is also provided between the outer diameter of the pad and the boot 134. These clearances, along with the counter-sunk portions 142, permit the pad to flex upon compression to minimise the chance of damage to any of the components.

The piston sub-assembly is an annular sub-assembly carried near the inner end of the piston rod. The sub-assembly includes a piston 143 having a through bore contoured to co-act with the surfaces of the projecting cylindrical sections 118, 120 and to be spaced from the bevelled connection 121 between them. A nut 144 is screwed to the end of the protecting portion 120. The piston is torqued securely onto the end of the piston rod and against a spacing sleeve 145 around the section 118 and abutting the shoulder 119 so that relative motion between the piston and rod is prevented, (Figs. 8 and 9).

The piston sub-assembly performs two main functions: (a) it maintains the concentric relationship of the cylinder and piston rod; and (b) during rapid piston excursions, the piston acts as a dashpot. To achieve these goals, the piston sub-assembly engages the inner surface of the cylinder 20 in a sliding, sealing relationship so that the body chamber is divided into first and second compartments of sections 146, 148 (Fig. 8). It is apparent that their volumes will change relatively as the piston sub-assembly is moved up and down within the cylinder, althouth the first section 146 is always larger than the second section 148. The relationship between volumes does not vary linearly because the piston rod occupies an increasingly greater portion of the second section upon piston rod compression. Thus the total volume of the chamber decreases as the piston rod enters the body and the liquid is compressed.

The piston 143 includes openings so that liquid can be passed from one section to another upon displacement of the piston. In order to achieve the desired flow rate upon compression and expansion in the normal operating range of the piston, it has been found that a combination of orifices and check valves is effective.

The seal and check valve construction is shown in detail in Fig. 7. A split bearing ring 150 is disposed within a circumferential groove 152 in the outer periphery of the piston. Sealing action is also obtained by a piston seal ring 154 disposed within a circumferential groove 156 formed in the periphery of the piston. Taken together, the bearing ring and the seal ring act to establish an effective sliding, sealing relationship with the inner surface of the cylinder 20.

Two check valves spaced diametrically from each other are provided. Only one of these valves is shown at 158 in each of Figs. 1, 8 and 9 because the cross-section of the piston is taken in two planes to show both a valved passage and a constricted passage 174. Referring to Fig. 7, the check valve 158 controls fluid flow through a passage 160 extending completely through the piston and including a counter-bore 161. An annular valve seat 162 is held in place at the lower end of the counter-bore by a snap ring 164. A valve body 166 is disposed in the counter-bore 161 for limited axial movement. The valve body 166 includes a tapered end 168 which selectively engages the seat to provide a substantially liquid-tight seal. The valve body also includes a number of radially extending passages 170 in communication with a longitudinally extending valve body bore 172. The bore 172 communicates with a reduced diameter, axially disposed constricting bore 173.

Upon compression of the ride strut, the piston will be advanced to the left in Fig. 1, and the valve body 166 will be forced to the right by the action of impinging liquid to the position shown in Fig. 8. The tapered end of the valve body thus will be unseated and liquid will flow both through the passages 170 and through the constricting bore 173 into the valve body bore 172. Upon extension of the ride strut, the piston will be advanced to the right in Fig. 1, and impinging liquid will drive the tapered end of the valve body against its seat so that liquid can flow through the check valve only through the constriction bore 173 and not through the passages 170.

Two-way flow of liquid through the piston is also provided by the two constricted passages spaced diametrically from each other, only one of which is shown at 174 because they are identical. In the drawings, the illustrated constricted passage 174 is shown as if it were displaced 180° relative to the valved passage 160, for purposes of illustration, rather than its actual 90° relationship. The constricted passage is formed by an opening 176 extending completely through the piston into which a constricting orifice body 178 is screwed (Figs. 8 and 9). By selection of orifice bodies and check valve bodies having openings of appropriate sizes, the damping characteristics of the ride strut can be established quite accurately. The orifice bodies and check valve bodies are relatively inexpensive but provide precise flow control so that one the desired sizes have been empirically selected ride struts having consistent damping characteristics can be manufactured rapidly and with favourable tooling expense.

The valve section has spaced, annular valve and co-acting spools or members 180, 182 adapted for limited axial sliding movement on the spacer sleeve 145 under the influence of a spring bias. The valve and co-acting members are held together by shoulder bolts 186, the heads of which are normally positioned in counter-bores 188 formed in the co-acting member 182 while the shanks of the bolts are slidable in connecting bores 189. A helical spring 190 is disposed between flanged portions 191*a*, 191*b* of the valve and co-acting members to bias them apart to the extent permitted by the bolts 186.

A smaller diameter helical spring 192 is disposed between the piston 16 and the valve member 180. The smaller spring 192 acts on the valve member 182 to bias the valve section to the right as shown in Fig. 8. This spring action maintains the co-acting member in engagement with the shoulder 119 and the valve section spaced from the piston passages except during rebound conditions.

Referring to Figs. 10 and 11, the valve and co-acting members 180, 182 include various openings for permitting the passage of liquid. The valve member 180 includes four openings 194 extending completely through it. An annulus 196 is formed in that face of the valve member 180 facing the piston 143 and connecting the openings 194 so that when the valve member is pressed against the piston, liquid still can flow through the valve and the piston, but at a greatly reduced rate due to the constricting effect of the openings 194. The rebound flow path is through the openings 194, the annulus 196, and the valve member and constriction passages 172, 174 in the piston assembly 16.

The co-acting member 182 includes a number of openings 198 extending completely through the valve spool. The openings 198 permit the effective and complete air bleeding when strut is initially charged with liquid.

The relationship of the ride strut components under an unloaded vehicle condition is not shown in the drawings. Fig. 1 shows the relationship of the parts removed from the vehicle when sufficient liquid has been charged into the body 12. In an empty vehicle the piston rod and piston sub-assemblies 13, 16 will shift to the left, as viewed in Fig. 1, relative to the cylinder sub-assembly 12, until the bottom of the boot 134 overlaps the band 137. Under these conditions the valve section 18 is spaced from both the piston and the retainer and rebound stop 76 as shown in Fig. 8 which shows the full compression position of the strut. Thus in the normal operating range of movement the valve section has no influence on liquid flow.

When the ride strut is under load the strut components will be moved towards the position shown in Fig. 8. Because of the impinging liquid encountered during the compression excursion, each valve body 166 has been driven away from its seat so that liquid has flowed through the piston at its maximum rate in flowing from the lower chamber section to the upper. In the Fig. 8 condition the collar 62 including its flange 65 has impacted the resilient pad 138 so that energy from the force applied to the ride strut is being absorbed by the pad.

When the piston and rod sub-assemblies rise from the position of Fig. 8 (i.e. move to the right), each valve body 166 seats against its valve seat 162 to restrict flow. This flow restriction provides a shock absorbing effect damping the spring action of the compressible liquid. This condition continues during strut extension until the vehicle empty position of the strut is obtained.

As the strut is unloaded in an extreme rebound condition the co-acting member 182 engages the annular retainer and rebound stop 76, Fig. 9. As slight further extension continues the relatively light smaller spring 192 is compressed until the valve member 180 contacts the piston as shown in Fig. 9. Positioning the valve member against the piston greatly increases the damping characteristics of the ride strut. Liquid flow through the piston is reduced drastically because all of the openings in the piston are covered by the valve member. Except for the small valve spool openings 194 communicating with the valve member passages 172 and the constricted orifices 174 via the annulus 196, liquid flow from the upper chamber section to the lower is no longer possible.

Under normal circumstances, the ride strut will be operated between the positions shown in Figs. 8 and 9. Because the springs 190, 192 and the pad 138 are not compressed under these circumstances, the compressibility characteristics of the liquid and the dashpot characteristics of the piston will define the damping capabilities of the strut.

CLAIMS

1. A vehicle ride strut comprising a housing defining a cylinder divided into two compartments by a piston which is mounted in the cylinder for sliding movement over an operating range and a rebound range and is connected to a piston rod extending through an opening at the end of the housing. The construction being such as to establish a fluid flow path between the compartments and including a valving arrangement establishing

(i) a first flow condition through the flow path when the piston rod and housing move relatively in a compressive direction in the operating range;
(ii) a second more restrictive flow condition when the piston rod and housing move relatively in an extending direction in the operating range; and
(iii) a third and still more restrictive flow condition when the piston rod and housing move relatively in an extending direction and the structures are in the rebound range.

2. A ride strut according to claim 1 wherein the valving arrangement includes piston passages to permit fluid flow through the piston upon relative movement of the piston and housing.

3. A ride strut according to claim 2 wherein the valving arrangement includes a valve member carried by the piston rod and engageable with one face of the piston upon the attainment of a predetermined piston rod extension, the valve member being formed with openings to permit some liquid flow through the valve member, and hence the piston under all circumstances.

4. A ride strut according to claim 2 wherein the valving arrangement includes a valve member for reducing the liquid flow from one of the two compartments to the other through at least one of the piston passages as the piston is displaced to a predetermined position relative to the housing.

5. A ride strut according to claim 3 or claim 4 wherein the valving arrangement includes a bias for urging the valve member away from engagement with the piston until the predetermined position is reached.

6. A ride strut according to claim 5 wherein the bias comprises a compression spring between the piston and the valve member, and the said predetermined position is defined by an obstruction engageable by the valve member.

7. A ride strut according to claim 6 wherein the valve member includes a pair of valve spools displaceable along the longitudinal axis of the piston rod and biased apart by a spring between them, The compression spring being located between the piston and one of the valve spools and being compressed when the other valve spool engages the obstruction.

8. A ride strut according to claim 7, in which the spring between the valve spools is stronger than the compression spring so as to be compressed only when the valve spool closer to the piston engages the piston.

9. A ride strut according to claim 7 or claim 8 and including a stop limiting relative movement of the valve spools away from one another under the action of the spring between them.

10. A ride strut according to any one of claims 2 to 9 wherein at least one of the piston passages permits a two-way flow of liquid through the piston, and at least one of the other piston passages has a check valve to permit relatively unobstructed liquid flow from one compartment to the other for relative movement of the piston rod and housing in the compressive direction and relatively more restricted flow for relative movement in the opposite direction.

11. A ride strut according to any one of the claims 3 to 10 wherein the valve member engages the piston and completely over-lies the ends of the piston passages when the piston reaches the predetermined position, and the valve member itself includes at least one passage in communication with the piston passages.

12. A ride strut according to any one of the preceding claims in which the compartments of the cylinder are filled with a compressible liquid.

13. A vehicle ride strut substantially as described and as illustrated with reference to the accompanying drawings.

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