648045

Section 29 (1)
Regulation 3.1 (2)

AUSTRALIA

Patents Act 1990

NOTICE OF ENTITLEMENT

We, TOWERHILL HOLDINGS PTY LIMITED, of Fern Road, Eagle Bay, Cape Naturaliste, Dunsborough, WESTERN AUSTRALIA, 6281, AUSTRALIA, being the applicant in respect of Application No. 65015/90 state the following:-

The Person nominated for the grant of the patent has entitlement from the actual inventor by assignment.

The person nominated for the grant of the patent is the applicant of the application listed.

The basic application listed on the request form is the first application made in a Convention country in respect of the invention.

By our Patent Attorneys,
WATERMARK PATENT & TRADEMARK ATTORNEYS

Tom A. Barnes
Registered Patent Attorney

2 February 1994

(54) Title
INTERCONNECTED FLUID SUSPENSION FOR VEHICLES

International Patent Classification(s)
(51)[5] B60G 021/067 B60G 021/073

(21) Application No. : 65015/90 (22) Application Date : 02.10.90

(87) PCT Publication Number : WO91/04877

(30) Priority Data

(31) Number	(32) Date	(33) Country
PJ6652	29.09.89	AU AUSTRALIA
PJ7661	01.12.89	AU AUSTRALIA
PJ9313	26.03.90	AU AUSTRALIA
PJ9428	03.04.90	AU AUSTRALIA

(43) Publication Date : 28.04.91

(44) Publication Date of Accepted Application : 14.04.94

(71) Applicant(s)
TOWERHILL HOLDINGS PTY. LTD.

(72) Inventor(s)
CHRISTOPHER BRIAN HEYRING

(74) Attorney or Agent
WATERMARK PATENT & TRADEMARK ATTORNEYS , Locked Bag 5, HAWTHORN VIC 3122

(56) Prior Art Documents
GB 1488254
GB 1076556
FR 1273466

(57) Claim

1. A vehicle having a load support body,

a pair of front ground engaging wheels and a pair of rear ground engaging wheels connected to the body to support same and each being displaceable relative to the body in a generally vertical direction,

means interconnected between each wheel and the body including first and second fluid filled chambers that varies in volume in response to vertical movement between the respective wheel and the body,

respective first fluid communicating means connecting said first chamber of the front and rear wheels on the same side of the vehicle to provide respective individual fluid circuit between interconnected chambers,

respective second fluid communicating means connecting the second chambers of the front wheels and of the rear wheels respectively to provide respective individual fluid circuits between interconnected chambers,

whereby in use the fluid pressure in the two chambers of any individual fluid circuit is substantially the same thereby inducing all wheels to maintain tractive ground engagement,

.../2

at least said two second fluid communicating means each including respective main pressure accumulator means,

and control means operable in response to a selected vehicle operating condition to vary the rate of flow of fluid to the respective main pressure accumulator means of at least the second fluid communicating means,

said control means including a valve operable in response to the pressure differential between the two second fluid communication means, said valve being arranged to reduce the rate of flow of fluid to the main pressure accumulator of one second fluid communicating means in response to the pressure in that one second fluid communicating means being greater than the pressure in the other second communicating means by a predetermined amount.

OPI DATE 28/04/91 APPLN. ID 65015 / 90
PCT AOJP DATE 13/06/91 PCT NUMBER PCT/AU90/00474

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B60G 21/067, 21/073

A1

(11) International Publication Number: WO 91/04877

(43) International Publication Date: 18 April 1991 (18.04.91)

(21) International Application Number: PCT/AU90/00474

(22) International Filing Date: 2 October 1990 (02.10.90)

(30) Priority data:

PJ 6652	29 September 1989 (29.09.89)	AU
PJ 7661	1 December 1989 (01.12.89)	AU
PJ 9313	26 March 1990 (26.03.90)	AU
PJ 9428	3 April 1990 (03.04.90)	AU

(81) Designated States: AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), SU, US.

Published
With international search report.

SECTION 113 (71) DIRECTION SEE FOLIO 4

NAME DIRECTED Towerhill Holdings Pty Ltd.
Lot 38, Fern Road, Eagle Bay, Dunsborough. W.A.

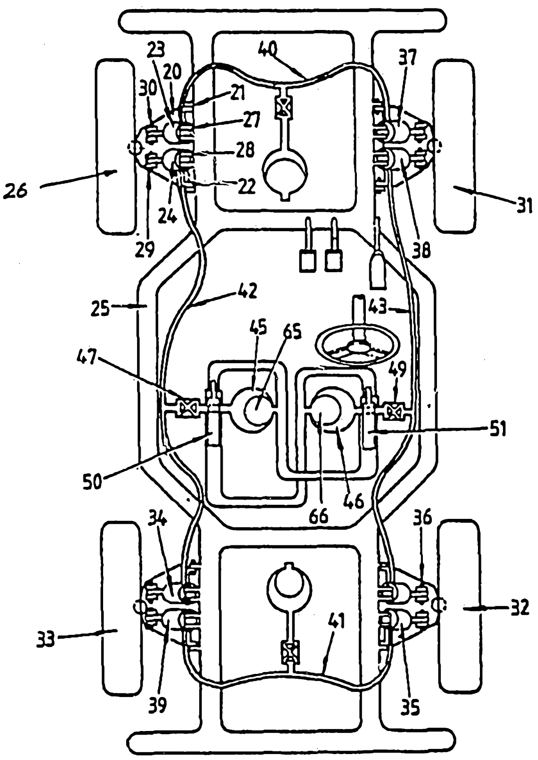
AUSTRALIAN PATENT OFFICE SEC. 113

648045

(54) Title: INTERCONNECTED FLUID SUSPENSION FOR VEHICLES

(57) Abstract

A vehicle having a body (25) supported respective pairs of front and rear wheels (30, 31, 32, 33), two piston and cylinder units (23-24, 35-36, 37-38, 34-39) being associated with each wheel and connected between the wheel (30) and body (25) so the piston moves in the cylinders in response to relative movement between the wheel and the body. An individual fluid circuit (40, 41, 42, 43) connecting one piston and cylinder unit (23) of each wheel (30) to a corresponding unit (34) longitudinally spaced therefrom on the same side of the vehicle, and the other piston and cylinder unit (24) of each wheel to a corresponding unit (35) on the transversely opposite side of the vehicle. This arrangement results in the fluid pressure in any two piston and cylinder units interconnected by an individual fluid circuit being equal, and relative movement between any one wheel and the vehicle body induces an opposite relative movement between the vehicle body an the wheel in fluid circuit therewith to maintain tractive ground engagement of all wheels.



* See back of page

INTERCONNECTED FLUID SUSPENSION FOR VEHICLES

This invention relates to a suspension system for a vehicle, and is specifically related to controlling the movement of the wheels relative to the vehicle body when traversing uneven surfaces and turning at speed.

In known suspension systems resilient means such as springs or torsion bars are provided to perform a multiplicity of functions ranging from the absorption of impact loading (as from hitting bumps at speed) to the provision of flexible support to enable all the wheels to maintain contact with uneven terrain. Additionally applied loads such as cargo deflects traditional suspensions to induce wheel travel in a similar manner to dynamic or contour loadings.

Traditional resiliently sprung suspensions are based on each wheel assembly being provided with an individual resilient component which mechanically supports the respective "corners" of the vehicle. The resilient components are rapidly progressive and normal vehicle weight is only distributed to each wheel when all the wheels collectively describe a flat plane surface. When a wheel of a vehicle passes over (or is parked on) a bump, this wheel carries more vehiclular weight than it normally carries on flat ground. Meanwhile the other wheels are correspondingly relieved of some of that weight.

These rapidly progressive resiliently sprung suspension systems work satisfactorily only within a very narrow spectrum of dynamic, static and applied loading situations, and any type of overloading or even underloading of a vehicle normally adversely affects its abilities to maintain traction, average ground clearance, and quality of ride. Moreover the scope of demands upon known resilient suspension systems leads to self conflicting performance characteristics as there is no inherent ability in the system to detect and react differently to diverse situations, which cause resonant rebounding, requiring excessive damping with shock absorbers limiting free movement of unsprung weight.

Recently resilient spring suspension systems have begun to incorporate variable damping and spring rates in an attempt to redress some of the shortcomings. Some other more advanced suspension systems (active and semi-active suspensions) incorporate a number of electronic sensors and accelerometers which monitor information such as vertical wheel travel and body roll, as well as speed, steering and breaking commands. This and other data is processed by a computer which instructs hydraulic actuators to override the normal function of resilient springs in order to interpret, compensate and adjust the suspensions performance to suit speed, terrain and other factors in order to maintain a level ride and even distribution of weight onto the wheels. These suspension systems therefore need an external intelligent back-up system and the actuators require a substantial input of external energy drawn from the vehicle engine.

A range of active and semi-active suspensions for vehicles have been proposed recently including systems operating on the basis of compression and/or displacement of fluids and a limited number of versions of these forms of suspension are already incorporated in production vehicles. However, the systems currently in use employing a liquid and/or gaseous medium usually incorporate a pump to maintain the liquid or gas at the required pressure and distribution, and sophisticated control mechanisms to regulate the operation of the suspension system in accordance with sensed road and/or vehicle operating conditions. These known systems incorporating pumps and electronic control systems, are comparatively expensive to construct and maintain and require energy input, and therfore have limited acceptability in the vehicle industry.

It is therefore the object of the present invention to provide a suspension system which has the advantages of the liquid and/or gas systems, but is considerably simpler in construction and operates more effectively.

With this object in view, there is provided by the present invention a ~~vehicle having a load support body,~~

a vehicle having a load support body,

a pair of front ground engaging wheels and a pair of rear ground engaging wheels connected to the body to support same and each being displaceable relative to the body in a generally vertical direction,

means interconnected between each wheel and the body including first and second fluid filled chambers that varies in volume in response to vertical movement between the respective wheel and the body,

respective first fluid communicating means connecting said first chamber of the front and rear wheels on the same side of the vehicle to provide respective individual fluid circuit between interconnected chambers,

respective second fluid communicating means connecting the second chambers of the front wheels and of the rear wheels respectively to provide respective individual fluid circuits between interconnected chambers,

whereby in use the fluid pressure in the two chambers of any individual fluid circuit is substantially the same thereby inducing all wheels to maintain tractive ground engagement,

at least said two second fluid communicating means each including respective main pressure accumulator means,

and control means operable in response to a selected vehicle operating condition to vary the rate of flow of fluid to the respective main pressure accumulator means of at least the second fluid communicating means,

said control means including a valve operable in response to the pressure differential between the two second fluid communication means, said valve being arranged to reduce the rate of flow of fluid to the main pressure accumulator of one second fluid communicating means in response to the pressure in that one second fluid communicating means being greater than the pressure in the other second communicating means by a predetermined amount.

Also, it is convenient to provide means to selectively vary the rate or terminate fluid flow through one or more of the fluid circuits between the chambers in one or both directions.

The vehicle suspension above described differs greatly from all the known systems in that the wheel travel is not dependent upon progressive resilient suspension mechanisms which require variable reactions to the many ever changing conditions experienced by the vehicle.

In the present proposal all wheels can freely follow even extremely uneven terrain without changing the normal weight distribution onto all wheels, while also maintaining a substantially average vehicle body height and inclination, and without limiting the extent of wheel travel movements. Furthermore there is an unprecedented working interrelationship between wheels which are directly interconnected to each other by the individual fluid circuits and collectively related to the vehicle body so that resilient spring suspension means are only normally used to absorb and dampen dynamic shock, and do not inhibit the translation of wheel travel motions induced by uneven roads or terrain.

A vehicle supported on wheels in the above described manner allows free vertical travel of the individual wheels with respect to the vehicle body or chassis without having to first overcome the resistance of the conventional springing mechanisms normally incorporated between the wheels and the vehicle body. Thus, there is provided a vehicle in which the wheels are individually unrestrained and free to move to follow the undulations of the surface being travelled without continually changing the vehicle weight distribution between the individual wheels. This reduction or elimination of changes in weight distribution significantly improves the traction of the wheels to the surface being traversed and the handling characteristics of the vehicle.

Furthermore, in known suspension systems the springs or like resilient displaceable mechanisms used are intended to both absorb dynamic forces as well as permit non-dynamic wheel travel. However, in the vehicle suspension now proposed, the resilient displaceable mechanisms may be optionally ommitted or temporarily deactivated whilst still allowing unrestricted wheel travel in a generally vertically direction, and maintaining constant contact between the wheels and the ground, even when travelling rough terrain.

The invention will be more readily understood from the following description of one practical arrangement of one practical arrangement of the vehicle as illustrated in the accompanying drawings.

In the drawings,

Figure 1 is a diagrammatic layout of a vehicle suspension;

Figure 2 is a schematic plan view of a vehicle incorporating the suspension system;

Figure 3 is a schematic sectional view of suspension means and control unit used in the suspension system;

Figure 4 is a diagrammatic layout similar to Figure 1 of a modification to the suspension system.

Figure 5 is a sectional view of the one construction of accumulator as used with double acting piston/cyliner units as referred to in relation to Figure 1.

Figure 1 shows in a diagrammatic form the basic layout of a vehicle wheel which operates a suspension system in accordance with the present invention. In this drawing the body or chassis of the vehicle is shown diagrammatically at 50 as a rectangular component, however, it is to be understood that the the body or chassis can take a wide variety of forms and shapes depending on the particular construction and purpose of the vehicle. The body 50 is supported by four wheels comprising two front steerable wheels 51 and 52 and two rear non-steerable wheels 53 and 54. It is to be understood that the vehicle may also have all four wheels either steerable or non-steerable, or the front wheels may be fixed and the rear wheels steerable, depending upon the particular requirements of any vehicle. Four double acting hydraulic cylinders or rams of basically conventional construction are provided identified as 61, 62, 63 and 64. Each cylinder is pivotally connected to a respective wheel at one end and to the body 50 at the other end so that it may pivot relative to the wheel and body about respective parallel axes extending generally in the longitudinal direction of the vehicle body. It is to be understood that additional components will be provided to connect the respective wheels to the vehicle body which will pivot relative to the wheel and body about axes parallel to the pivot axes of the cylinders, however, such additional members have been omitted from the drawing for the sake of clarity.

Each of the double acting cylinders 61, 62, 63 and 64 are of conventional construction having an outer housing with a cylindrical bore therein and a piston mounted in the bore with a piston rod coupled to the piston and extending through one end of the cylinder. A suitable seal is provided between the piston rod and the end of the cylinder through which it projects so that there is provided on each side of the piston a fluid tight chamber with the volume of each chamber varying in response to movement of the piston in the cylinder. For the sake of convenience the chamber at the piston rod end of the cylinder shall be identified as chamber A and that at the opposite end of the cylinder, that is, above the piston, will be identified as chamber B. Thus in respect of cylinder 61, the piston rod end chamber shall hereinafter be referred to as chamber 61A and the chamber above the piston will be referred to as chamber 61B. The corresponding chambers in the other cylinders 62, 63 and 64 will be similarly identified.

The chambers 61B and 63B are interconnected by a fluid line 70 and the chambers 62B and 64B are interconnected by a fluid line 71. Similarly chamber 61A is connected to chamber 62A by the fluid line 73 and chamber 63A and 64A are connected by line 74.

It is therefore seen that the respective chambers A of each wheel is in direct fluid communication with its corresponding chamber A associated with the wheel on the transversely opposite side of the vehicle, and the respective chambers B of each wheel is in direct communication with the corresponding chamber B of the wheel at the opposite longitudinal end and on the same side of the vehicle. It will also be noted that the chambers at the piston rod end of the cylinders are connected to the corresponding cylinder at the other wheel and the chamber above the piston is connected to the corresponding chamber on the other wheel. Thus it will be appreciated that any variation in the capacity of chamber A and B of the double acting cylinder associated with one wheel will displace corresponding quantities of fluid from one double acting cylinder to the other two double acting cylinders connected thereto by the fluid lines.

It will be understood that although the layout in Figure 1 employs a single double acting cylinder connected between each wheel and the vehicle chassis 50, the same operational result could be achieved by providing two single acting cylinders connecting each wheel to the vehicle chassis, with the transverse fluid lines 73 and 74 connecting one cylinder of each wheel to the corresponding cylinder on the transversely opposite wheel and the longitudinal fluid lines 70 and 71 connecting the other cylinder from each wheel to the corresponding cylinder of the longitudinally spaced wheel on the same side of the vehicle.

With the cylinders arranged between the wheels and the vehicle chassis and interconnected as above described by fluid lines, a vehicle suspension system is created whereby relative movement in a vertical direction between any one wheel and the chassis 50 will result in a corresponding opposite movement between the transversely opposite wheel and the vehicle nd between the movement of the wheel longitudinally spa ed wheel and the vehicle on the same side of the vehicle. Expressed another way, if one vertical movement between a wheel and the vehicle chassis in one direction, results in a similar vertical movement between the diagonally opposite wheel and the chassis while the other two wheels will move in the opposite direction by a corresponding amount.

The result of this configuration of movements is that the vehicle chassis 50 will remain substantially level although its average height with respect to a selected ground datum may vary while all wheels remain in ground contact. It is also most important to note that in view of the interconnection by the respective hydraulic lines of the four cylinders 61, 62, 63 and 64, the pressures in the interconnected chamber of the four double acting cylinders will be substantially the same. Thus the weight transferred from the chassis through the cylinders to each of the wheels will be substantially the same, whereby all of the wheels will remain in effective tractive engagement with the surface upon which the vehicle is supported or moving over.

Each of the fluid lines 70, 71, 73 and 74 are in communication with respective hydraulic accumulators 75, 76, 77 and 100, and 78 and 101 with a control or damping valve 80, 81, 82 and 108, and 83 and 109, interposed between the respective fluid line and accumulators. Each accumulator is divided in the known manner into two chambers by a movable internal wall. For convenience the chambers are designated C and D in each accumulator, compartment C being in communication with the respective fluid line and compartment D containing a compressed gas. The hydraulic accumulators 75, 76, 77 and 78 as illustrated are the common flexible diaphragm type, however, accumulators of other constructions may be used, including piston type, and accumulators using springs or other resilient mechanisms as a substitute for the compressed gas compartment. The accumulators 100 and 101 are of a specific construction that will be described in detail hereinafter.

When the valves 80, 81, 82, 83, 108 and 109 are open, the accumulators perform the primary function of providing a degree of resilience in the suspension systems as during upward movement of any one wheel part of the displaced fluid in the associated cylinder can enter or leave the chamber C of the accumulator thus changing the amount of fluid transferred to the interconnected cylinder and also compressing the gas in the chamber D, thereby increasing the pressure of the fluid in the fluid line interconnecting the two cylinders and hence also increasing the pressure in the respective cylinder. When the vehicle is travelling in a generally straight line on an even surface, each of the control valves will normally be in an open position so as to provide a high level of resilience in the suspension system to thereby accommodate minor irregularities that may be encountered in the road surface with minimum vehicle body movement.

It will be noted that in the arrangement shown in Figure 1, the fluid lnes 73 and 74 will normally be subjected to a velow or sub-atmospheric pressure or suction when the vehicle is stationary or being supported normally on its wheels. It is therefore preferable to include specially constructed accumulators to operate with sub-atmospheric pressure in the lines, and which provide progressive resilience to increasing sub-atmospheric pressures. Accumulators 200 and 201 included in fluid lines 73 and 74 respectively are of this construction. These accumulators may be of any known construction and one preferred construction is shown in Figure 5.

Referring now to Figure 5, the accumulator comprises a rigid housing 210 with a cylindrical bore 111 and a dividing wall 212. The piston rod 207 extends through the wall 212 in sealed sliding relation and rigidly interconnects the pistons 202 and 203 each in sealed sliding engagement with the bore 211. The pistons form with dividing wall 212, the chamber 215 which is vented to atmospheric by passage 213, and the chamber 206 which is charged with a gas under pressure. The charging port 214 is provided for connecting to a suitable gas recharging facility.

The piston 202 forms with the housing 210 the chamber 204 which in use is in communication with one of the fluid lines 73 or 74 via the control valve 208 or 209 as previously referred to.

In operation when the control valve is open and the sub-stmospheric pressure increases in the fluid line connected to the accumulator the piston 202 is drawn downwardly in the chamber 204 as viewed in Figure 5. This causes the piston 203 to also move downwardly in the chamber 206 thereby compressing further the gas in chamber 206, until a balance is achieved between chambers 204 and 206, thus providing resilience to the suspension system.

Under dynamic loading situations or when the wheels may be temporarily relieved of the vehicle weight the accumulators 77 and 78 provide the resilience to downward motions of the wheels relative to the body or chassis 50. The progressive shut-off valves 82 and 83, therefore, are normally open when the lines 73 and 74 are positively pressurised and closed when the lines are subject to sub-atmospheric pressures or in suction, while the shut-off valves 208 and 209 are normally open as the associated lines are usually at sub-atmospheric pressure in most operating conditions.

In many circumstances accumulators 77 and 78 along with their valves 82 and 83 may be totally omitted, as when known rubber stops are incorporated in the wheel assemblies to prevent them bottoming out. It should be understood that although the drawings show the transverse lines 73 and 84 as being associated with the accumulators of the construction shown in Figure 5 and the chambers "A" of the piston/cylinders units, the lines between chamber "A" may equally well be located longitudinally of the vehicle between cylinders 61, 63, and 62, 64 respectively while the lines between chambers B may be located transversely between chambers of cylinders 61, 62, 63 and 64.

In the case of this latter arrangement the accumulators 100 and 101 would be in communication with longitudinal lines 70 and 71 and will in this configuration provide roll control of the vehicle instead of pitch control and reislience as shown in Figure 1 as well as assisting wtih maintaining vehicle height above ground.

When the vehicle is turning, particularly at speed when significant centrifugal forces are generated, the accumulator connected to the fluid line between the front and rear wheels on the outer side of the turning circle is preferably isolated by closing the control valve associated therewith, whilst the accumulator on the opposite side of the vehicle and at the front and rear remain connected to the respective fluid lines. Thus as shown in Figure 1 when the vehicle is turning to the left, the valve 81 would be closed to isolate the accumulator 76 from the fluid line 71 and the remaining valves 80, 82 and 83 remain open.

Under braking conditions, when there is a high dynamic load placed on the front wheels, the valve 108, as seen in Figure 1, would be closed to isolate the fluid line 73 from the accumulator 100, thus preventing dipping of the front of the vehicle. Similarly under acceleration when a dynamic load is placed on the rear wheels, the valve 109 would be closed to prevent dipping of the rear of the vehicle. Closing of any such valve does not restrict normal articulation movement.

Suitable sensors can be provided on the vehicle to detect turning, braking and acceleration, and the signals from these sensors are processed through an ECU (electronic control unit) which controls the operation of the valves 80, 81, 82 and 108, and 83 and 109. These valves can be solenoid operated, preferably of a construction that permit the valves to be opened to varying degrees to regulate the rate of flow of fluid into and out of the accumulators. Thus the solenoid valves may in addition to being opened and closed, may be set at any intermediate position to control the rate of flow of fluid into and out of the accumulators thus functioning as a variable damper.

It is to be understood that multiple accumulators may be provided in communication with each of the fluid lines 70, 71, 73 and 74 with the respective accumulators on any one fluid line having an independent solenoid valve controlling the communication between the accumulator and the fluid line. Further, where more than one accumulator is provided in each fluid line, the nominal pressure rating of each accumulator may be different such that when the vehicle is operating under light loads a lower pressure accumulator is used than when it is operating under high loads.

Also when cornering, such as to the left in Figure 4, the low pressure accumulator on the outer side of the vehicle (fluid line 71 in Figure 1) is isolated and the high pressure accumulator on the inner side (fluid line 70 in Figure 1) is isolated to minimise outward roll of the vehicle.

Figure 2 of the drawings illustrates an alternative form of the suspension system to that shown diagrammatically in Figure 1. In Figure 2, the vehicle chassis is shown in a more realistic form but is still to be considered as fundamentally diagrammatic. In this drawing, each of the wheels, such as the wheel 26, are connected to the chassis by a wishbone type arm 20 which is pivotally connected to the chassis 25 by respective co-axial pivot connections 21 and 22. Further, the single double acting cylinders or rams, as described with respect to Figure 1, connected between the vehicle chassis and the respective wheels, have each been replaced by two single acting cylinders 23 and 24, each pivotally connected to the chassis 25 at 27 and 28 and to the arm 20 at 29 and 30. The pivot connections at the respective ends of the cylinders 23 and 24 are aligned in the generally longitudinal direction of the chassis 25 whereby as the wheel 30 and the arm 20 carrying the wheel pivots relative to the chassis 25, each of the cylinders 23 and 24 expand or retract.

The above description with respect to the mounting of the wheel 26 and the interacting pair of cylinders 23 and 24 also applies to the connection of each of the other three wheels 31, 32 and 33 of the vehicle, however, for the sake of clarity individual reference numerals for the corresponding components are not shown for each wheel mounting although the respective cylinders on each wheel have been individually identified.

The cylinders 23 and 37 interacting respectively with the front wheels 26 and 31 of the vehicle are interconnected by the fluid line 40 whilst the cylinders 30 and 35 associated with rear wheels 32 and 33 are interconnected by the fluid line 41. Similarly the cylinders 24 and 34 associated with the front and rear wheels 26 and 33 respectively, are interconnected by the fluid line 42, whilst the front and rear wheels 31 and 32 on the opposite side of the vehicle are interconnected by the fluid line 43. Thus the operation of the respective pairs of single acting cylinders associated with each wheel produce the identical effect in relation to the relative movement between the respective wheels of the vehicle and the vehicle chassis as has previously been described with respect to Figure 1 wherein a single double acting cylinder is provided between each wheel and the vehicle chassis.

The front and rear fluid lines 40 and 41 are in communication with respective accumulators via individual damping valves as has previously been described with respect to Figure 1, however, the accumulators 45 and 46, connected respectively to the fluid lines 42 and 43, as shown in Figure 2 are provided with automatic damping or control valves 50 and 51 in addition to damper valves 47 and 48 which functionally correspond to damper valves 80 and 81 in Figure 1.

The automatic damper valves 50 and 51 are of identical construction and each comprises a shuttle 52 as shown in more detail in Figure 3 axially slidable in a housing 54. The shuttle is of a stepped piston form having a small end 55 and a large end 56 with a transverse passage 57 through the large end 56. The housing 54 also has a transverse passage 58 which in use communicates with the accumulator 45 on one side and the damping valve 47 on the other side. When the passages 57 and 58 in the shuttle and housing respectively are in alignment, there is free passage for fluid to pass between the damping valve 47 and the accumulator 45 whilst axial displacement of the shuttle 52 in the housing 54 in a downward direction as seen in Figure 3 will progressively restrict the flow passage between the damping valve 47 and the accumulator 45.

The shuttle 52 and housing 54 are provided with respective shoulders 60 and 61 arranged so that when the shoulde 0 of the shuttle engages the shoulder 61 of the housing, the transverse passage 57 in the shuttle will be in direct alignment with the transverse passage 58 of the housing so as to not restrict the flow through the passage 58. However, as the shuttle 52 is displaced from that position, the transverse passage 58 in the housing 54 will be progressively reduced in the cross-sectional area thereby restricting the fluid flow to and from the accumulator 45.

As can be seen in Figure 2 and 3, the small end 55 of the shuttle 52 is subjected to the pressure in the compressible chamber 65 of the accumulator 45 and the large end 56 of the shuttle 52 is subjected to the pressure in the compressible chamber 66 of the accumulator 46. Thus, when the pressures in the chambers 65 and 66 are equal, the shuttle 52 will be moved upwardly as seen in Figure 2 so that the shoulders 60 and 61 will abut and therefore the shuttle would offer no restriction of the the flow between the damper valve 47 and the accumulator 45. However, when the pressure difference between the chambers 65 and 66 is such that the force applied to the small end 55 of the shuttle 52 is greater than the force applied to the large end 56 of the shuttle 52, then the shuttle will commence to move downwardly as seen in Figure 2, thereby introducing a restriction to the flow of fluid into or out of the accumulator 45.

Under normal operating conditions when the pressure differential between the accumulators 45 and 46 as a result of normal irregularities in the surface being traversed will not be sufficient to cause the shuttle 53 to be displaced and thus it will not generate a restriction to the flow of fluid to or from the accumulator. However, under more severe conditions, such as when the vehicle is turning and there is a substantial centrifugal force component applied to the vehicle wheels on the outer side of the turn, a sufficient pressure difference will be developed between the accumulators 45 and 46 to close the passage 58 in the housing of the automatic damper valve on the outside of the vehicle whilst that on the inside of the vehicle will remain open. A spring, such as indicated at 63 in Figure 3 may be provided so as to achieve a progressive movement of the shuttle as the pressure differential increases thereby obtaining a progressive opening and closing of the passage 58.

Figure 4 is a diagrammatic layout similar to that shown in Figure 1 and like components in Figure 4 have been given the same reference numerals as in Figure 1. In the construction shown in Figure 4 there are two accumulators provided in each of the fluid lines 70, 71, 73 and 74 identified as 90, 91, 94, 95, 92, 93, 96 and 97 respectively. With the respective accumulators in each line having different nominal pressures. That is in respect of line 70 the accumulator 91 has a higher pressure in the gas cavity 98 than in the gas cavity 99 in the accumulator 90. Each of the accumulators is provided with a respective control valve numbered 100 to 107 which are solenoid or otherwise operated so that either one or both of the accumulators associate with each line may be in active communication with that fluid line. Thus by way of example, as the accumulator 90 has a lower nominal operating pressure than accumulator 91, then when the vehicle is operating in conditions requiring heavier springing the accumulator 91 would be in communication with the fluid line 70 and the accumulator 90 isolated from the fluid line 70. Under light springing requirement both accumulators may be in communication with the fluid line as accumulator 91 having the high operating pressure will not function. The respective accumulators in each of the other fluid lines would be similarly operated.

There is also provided in the configuration shown in Figure 4 a shut-off valve in each of the fluid lines, these shut off valves being designated by the reference numerals 110 to 113, respectively. When the shut-off valves are closed, it will be appreciated that there will be no transfer of fluid or pressure from the cylinder associated with one wheel to the cylinder of the wheel transversely and longitudinally spaced therefrom. However, there will still be a degree of springing available through the respective accumulators where at least one accumulator will be in communication with each end of each cylinder.

The advantage of providing the shut-off valves is that under high speed conditions when the vehicle is cornering it is desirable to limit the amount of movement between the front wheels and the chassis and to a lesser extent between the rear wheels and the chassis.

Thus, when the vehicle is turning to the left as shown in Figure 4, shut-off valves 110 and 111 will be closed, thus resisting the downward movement of the chassis relative to the wheel 52 arising from the centrifugal forces developed during cornering. Also it would be preferable for the low pressure accumulators 95 on the outer side of the vehicle, to be isolated from the fluid line 71, thus also restricting the movement of the body relative to the rear wheel 54 on the outer side of the vehicle. Under most severe cornering conditions at very high speed, it would be preferable to also close shut-off valve 112 and isolate the accumulator 96 from the fluid line 74.

It will be appreciated that with the provision of the shut-off valves as above discussed, and also valves between the respective accumulators and fluid lines, a high degree of control and variation in the performance of the suspension system can be achieved particularly where the respective accumulators coupled to each fluid line have different load ratings, and those accumulators can be selectively coupled or de-coupled from the fluid line. Further, the control valves may be of a variable nature to provide variable degree of damping between the respective accumulators and the fluid lines.

Where the suspension system includes a range of controls to vary the performance characteristics of the suspension as referred to above and elsewhere in this specification, it is convenient to provide an electronic control unit (ECU) and a plurality of sensors to provide input to the ECU which in turn will control the operation of the various valves, accumulators and dampers in the system to adjust the suspension system to meet different vehicle operating conditions. In particular, as referred to elsewhere in this specification, the characteristics of the suspension system can be varied in response to acceleration, braking and turning of the vehicle, and appropriate sensors for detecting such operational conditions of the vehicle are known and used in other suspension systems. Accordingly, details of such sensors and the interaction thereof with ECUs shall not be described in further detail herein.

It is also to be understood that fixed or variable restrictors may be provided in the fluid lines to control the rate of fluid movement through the lines between respective interconnected cylinders. A fixed restriction may be achieved by variation in the bore of the fluid line at one or more locations along its length. Also if the fluid used in the system was an electro rheological fluid, then an appropriate magnetic field generating device could be located on or in the fluid lines so that the rate of fluid flow through those lines could be controlled by varying the strength of the magnetic field.

In reference to Figures 2 and 3, the automatic damping valves 50 and 51 are interconnected with the fluid lines running longitudinally of the vehicle and intercommunicating the cylinders of the front and rear axles. However, it is to be understood that the same automatic damping system can be incorporated between the frnot and rear transverse fluid lines such as fluid lines 40 and 41 in Figure 2 so as to operate in a like manner as described with respect to automatic dampers 50 and 51. Also, in the one suspension system, such automatic dampers may be provided both between the longitudinal fluid lines and the transverse fluid lines.

It is also envisaged that a pump may be provided which may be selectively operated to transfer fluid from one side fluid line to the other, or alternatively from the front to the rear fluid lines and vice versa. Preferably a single pump may be used with a suitable switchable porting arrangement to connect the appropriate fluid lines to the pump. By transferring fluid between the front and rear fluid lines, there is provided a control over the pitch trim of the vehicle whilst transferring fluid between the respective side fluid lines adjust the roll of the vehicle.

Also, the pump can be arranged so that it can be coupled to a fluid reservoir so that more or less fluid may be provided in the fluid lines thereby raising or lowering the nominal height of the vehicle body. It is, however, to be understood that the provision of a pump to carry out the above operations is not essential to the operation of the suspension system, but merely provides additional capabilities of the system which may be used in connection with specific operating conditions of the vehicle.

Although the invention has been described herein with reference to a two-axle vehicle, it will be readily appreciated that it may be applied to a vehicle having multiple axles such as commonly referred to as tandem axle assemblies. In a vehicle having a tandem wheel assembly each wheel of the assembly is provided with two cylinders or a single double acting cylinder as previously described with reference to Figures 1 or 2. One cylinder of each assembly is connected to a common fluid line extending longitudinally of the vehicle, one on each side of the vehicle. The other cylinder of each wheel is connected by an independent fluid line to the corresponding cylinder on the transversely opposite wheel.

Also it is to be understood that although not shown in the drawings a conventional resilient suspension element can be provided, such as a spring or torsion bar, connected between each wheel and the chassis. Where such a resilient suspension element is used it is preferably designed to support only the static weight of the suspended portion of the vehicle or a major portion thereof, the dynamic loading being accommodated by the fluid suspension hereinbefore described. Further it is to be understood that although the suspension system has been herein described with reference to an hydraulic fluid being used in the cylinders and fluid lines, the system is equally operable with air or other gas as a substitute for the hydraulic fluid.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A vehicle having a load support body,

a pair of front ground engaging wheels and a pair of rear ground engaging wheels connected to the body to support same and each being displaceable relative to the body in a generally vertical direction,

means interconnected between each wheel and the body including first and second fluid filled chambers that varies in volume in response to vertical movement between the respective wheel and the body,

respective first fluid communicating means connecting said first chamber of the front and rear wheels on the same side of the vehicle to provide respective individual fluid circuit between interconnected chambers,

respective second fluid communicating means connecting the second chambers of the front wheels and of the rear wheels respectively to provide respective individual fluid circuits between interconnected chambers,

whereby in use the fluid pressure in the two chambers of any individual fluid circuit is substantially the same thereby inducing all wheels to maintain tractive ground engagement,

at least said two second fluid communicating means each including respective main pressure accumulator means,

and control means operable in response to a selected vehicle operating condition to vary the rate of flow of fluid to the respective main pressure accumulator means of at least the second fluid communicating means,

said control means including a valve operable in response to the pressure differential between the two second fluid communication means, said valve being arranged to reduce the rate of flow of fluid to the main pressure accumulator of one second fluid communicating means in response to the pressure in that one second fluid communicating means being greater than the pressure in the other second communicating means by a predetermined amount.

2. A vehicle as claimed in claim 1 wherein the control means operable to vary the flow rate to the main pressure accumulator means included in said two second fluid communicating means are operable to selectively prevent flow of fluid to any one of the main pressure accumulator means.

3. A vehicle as claimed in claim 2, wherein said control means is operable in response to braking of the vehicle to prevent flow of fluid to the main pressure accumulator means communicated with the second fluid communicating means interconnecting the second chambers of the front wheels of the vehicle.

4. A vehicle as claimed in claim 2 wherein said control means is operable in response to acceleration of the vehicle to prevent flow of fluid to the main pressure accumulator means communicated with the second fluid communicating means interconnecting the second chambers of the rear wheels of the vehicle.

5. A vehicle as claimed in any one of claims 1 to 4 wherein said second fluid communicating means each include a further pressure accumulator means.

6. A vehicle as claimed in claim 5, wherein said further pressure accumulator means are operable at different pressure than that of the main pressure accumulator means of the second fluid communicating means.

7. A vehicle as claimed in claim 5 or 6, wherein further control means are provided operable in response to a selected vehicle operating condition to vary the rate of flow of fluid to the respective further pressure accumulator means of at least the second fluid communicating means.

8. A vehicle as claimed in any one of claims 1 to 7, wherein said two first fluid communicating means also each include a respective main pressure accumulator means.

9. A vehicle as claimed in claim 8 wherein the control means are operable to also selectively prevent flow of fluid to any of the main pressure accumulator means included in said first fluid communicating means.

10. A vehicle as claimed in claim 8 or 9, wherein said control means is operable in response to turning of the vehicle to prevent flow of fluid to the main pressure accumulator means communicating with the first fluid communicating means connecting the first chambers of the front and rear wheels on the outer side of the vehicle with respect to the direction of turning.

11. A vehicle as claimed in claim 8 or 9, wherein at least said first fluid communicating means each include respective further pressure accumulator means.

12. A vehicle as claimed in claim 11, wherein said further pressure accumulator means are operable at different pressures than that the main pressure accumulator means of the first fluid communicating means.

13. A vehicle as claimed in claim 11 or 12, wherein further control means are provided operable in response to a selected vehicle operating condition to vary the rate of flow of fluid to the respective further pressure accumulator means of at least the first fluid communicating means.

14. A vehicle as claimed in any one of the preceding claims including damping means operably interposed between each main pressure accumulator means and the remainder of the fluid communicating means to vary the rate of flow to that main pressure accumulator means.

15. A vehicle as claimed in any one of claims 5 to 13, including damping means operably interposed between each further pressure accumulator means and the remainder of the fluid communicating means to vary the rate of flow to that further pressure accumulator means.

 0095/1.5

16. A vehicle as claimed in any one of the preceding claims wherein at least one fluid circuit includes means operable to selectively control the rate of flow of fluid between the chambers in that fluid circuit.

~~17. A vehicle as claimed in any one of the preceding wherein the control means includes a valve operable in response to the pressure differential between the two second fluid communication means, said valve being arranged to reduce the rate of flow of fluid to the main pressure accumulator of one second fluid communicating means in response to the pressure in that one second fluid communicating means being greater than the pressure in the other second communicating means by a predetermined amount.~~

17 ~~18~~. A vehicle as claimed in claim ~~17~~ 1, wherein said valve is arranged to terminate the flow of fluid to main pressure accumulator of said one fluid communicating means when the pressure in said one fluid communicating means is greater than the other by a predetermined maximum amount.

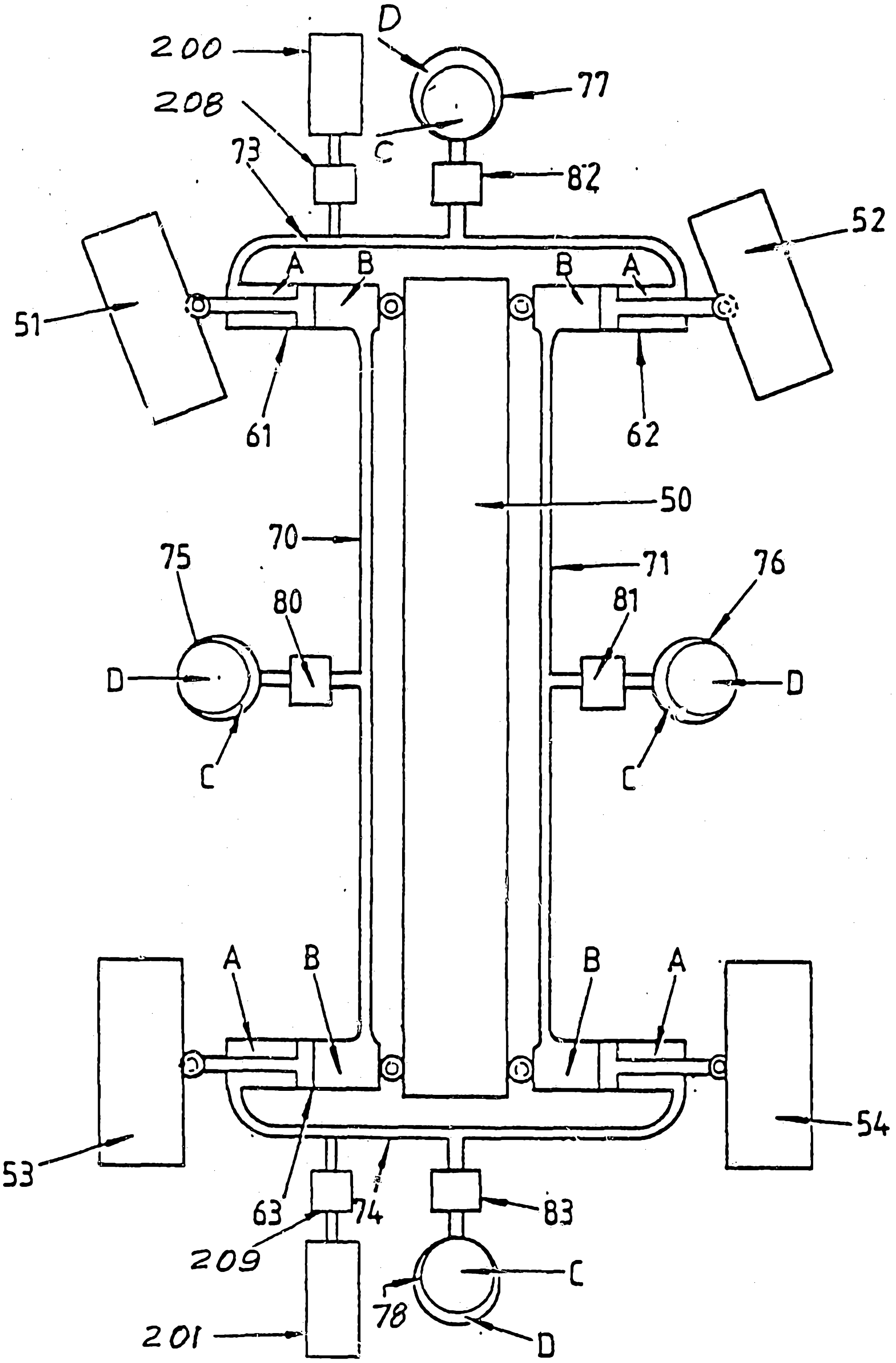
18 ~~19~~. A vehicle as claimed in any one of claims 9 to 13, ~~17~~ or ~~18~~ 17, wherein the control means include valve means operable in response to the pressure differential between the two first fluid communication means, said valve means being arranged to reduce the rate of flow of fluid to the main pressure accumulator means of one first fluid communicating means in response to the pressure in that one first fluid communicating means being greater than the pressure in the other first communicating means by a predetermined amount.

19 ~~20~~. A vehicle as claimed in claim ~~19~~ 18, wherein said valve means is arranged to terminate the flow of fluid to the main pressure accumulator means of said one first fluid communicating means when the pressure in said one first fluid communicating means is greater than that of the other, by a predetermined maximum amount.

65015/90

1/5

Fig 1.



65015/90

2/5

Fig 2.

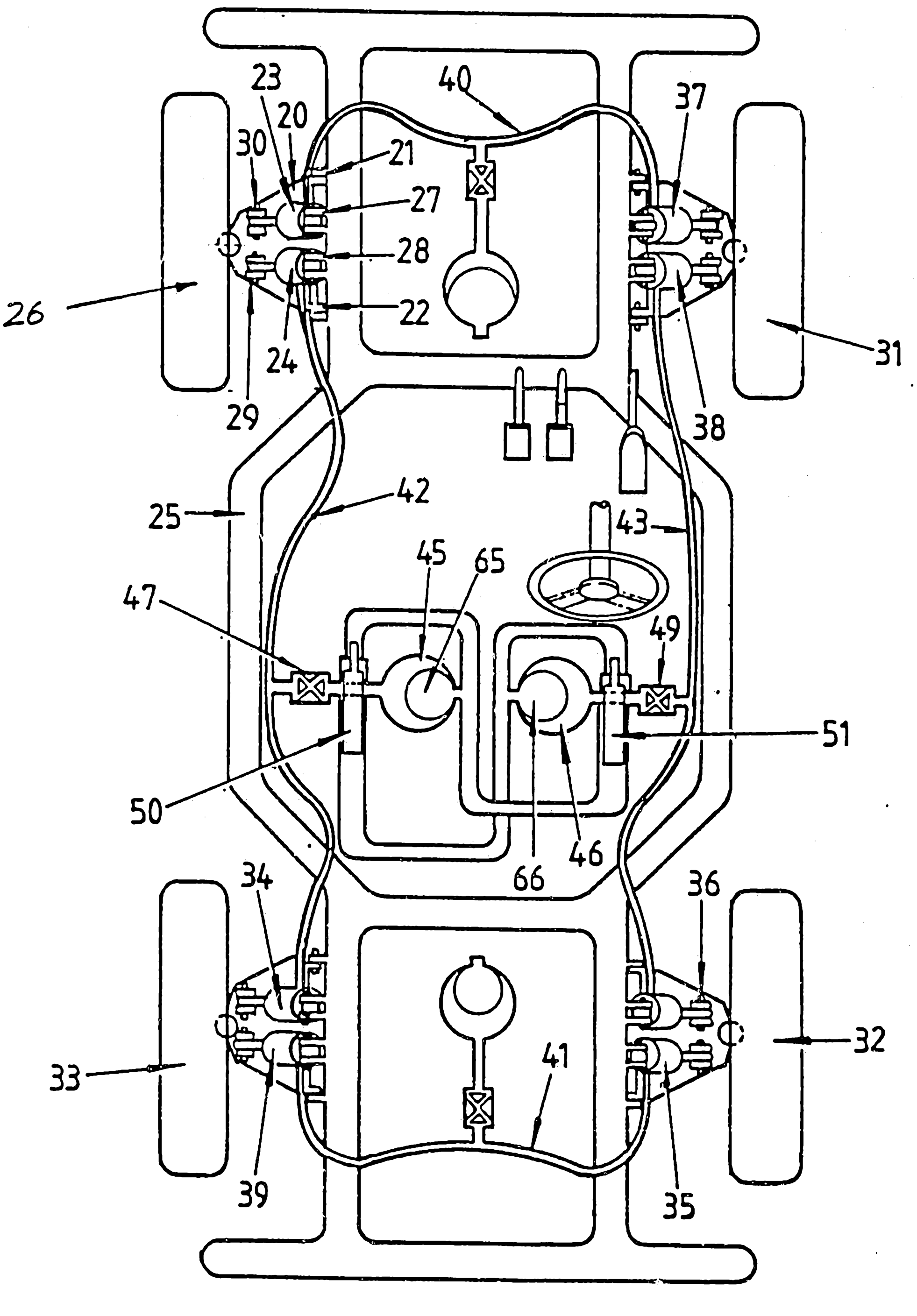
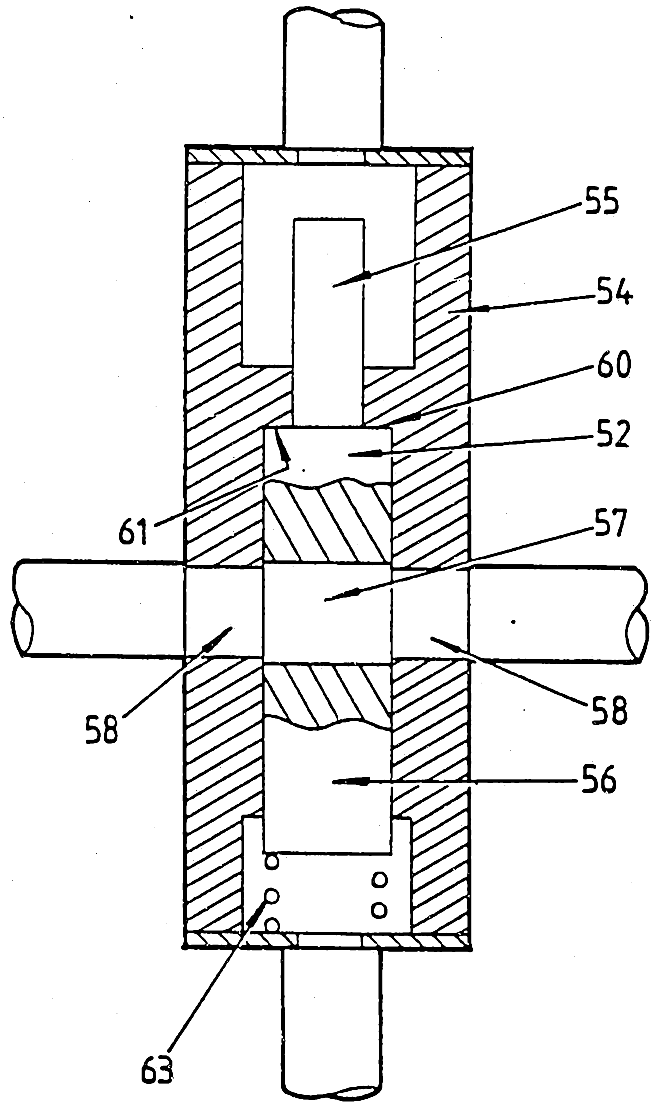


Fig 3.



65015/90

4/5

Fig 4.

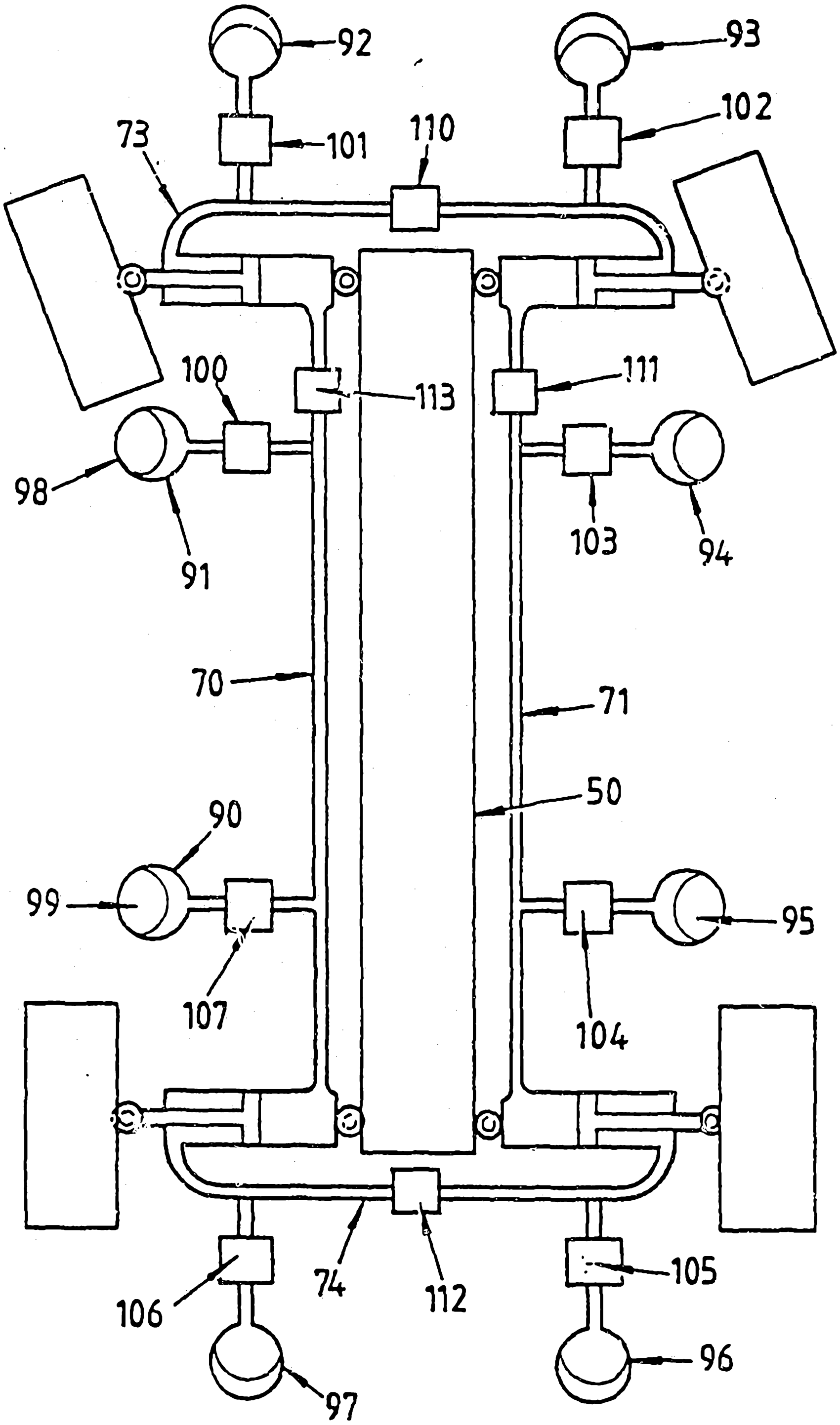
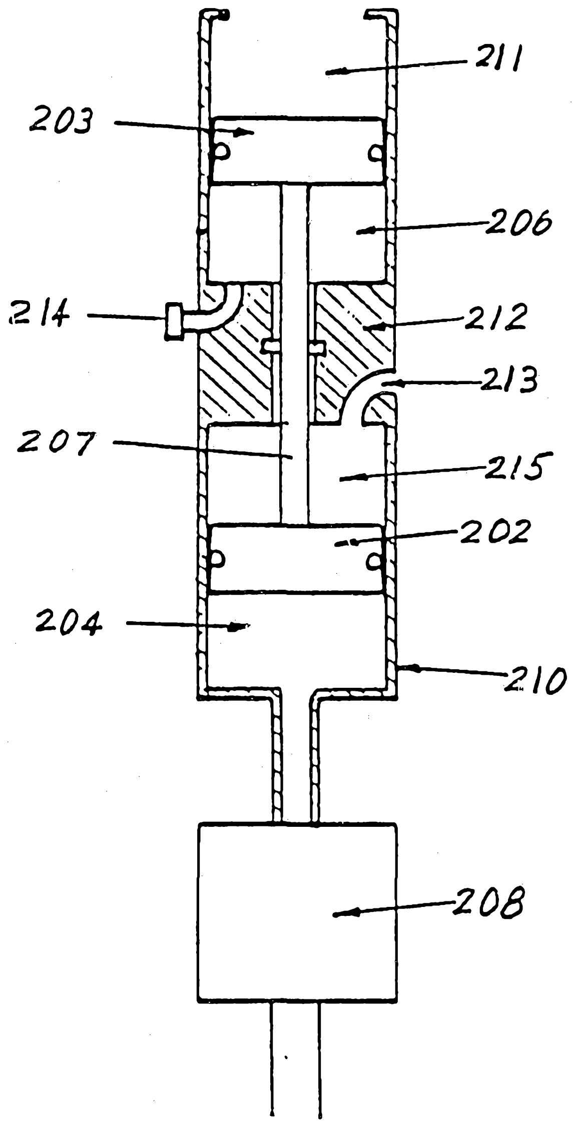


Fig 5.



INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00474

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{5} B60G 21/067, 21/073

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	B60G 21/067, 21/073

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	FR,A, 1273466 (LANTELME) 4 September 1961 (04.09.61) See page 1 column 1 lines 12-42	(1-6,8,10-15)
X	US,A, 2988372 (HIGGINBOTHAM) 13 June 1961 (13.06.61) See column 1 line 51 to column 2 line 17	(1,10,15)
X,Y	GB,A, 1086556 (MASCHINENFABRIK AUGBURG-NURNBERG AKTIENGESELLSCHAFT) 11 October 1967 (11.10.67) See page 2 lines 59-130, Figs 1 and 2	(1,8,9,1 ,15)
Y	GB,A, 1488254 (AUTOMOTIVE PRODUCTS LIMITED) 12 October 1977 (12.10.77) See page 2 lines 70-97	(2-7,11-14)
A	EP,A, 0201425 (AUTOMOBILES PEUGEOT) 17 December 1986 (17.12.86)	
	(continued)	

* Special categories of cited documents: 10

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
5 December 1990 (05.12.90)	10 December 1990
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	P.J. WHITE

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	GB,A, 363811 (ADAMSON) 31 December 1931 (31.12.31)	
A	DE,A, 1129846 (VOLKSWAGENWERK AKTIENGESELLSCHAFT) 17 May 1962 (17.05.62)	

V. [ ] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 1

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.[ ] Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2.[ ] Claim numbers , because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.[ ] Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [ ] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 2

This International Searching Authority found multiple inventions in this international application as follows:

1.[ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.[ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.[ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

[ ] The additional search fees were accompanied by applicant's protest.

[ ] No protest accompanied the payment of additional search fees.