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(54) **METHOD OF CONTROLLING A PNEUMATIC SUSPENSION OF A BOGIE OF A RAIL VEHICLE, AND BOGIE PROVIDED WITH A PNEUMATIC SUSPENSION**

VERFAHREN ZUR STEUERUNG DER DRUCKLUFTAUFHÄNGUNG EINES BOGIES EINER SCHIENENFAHRZEUGS SOWIE MIT EINER DRUCKLUFTAUFHÄNGUNG AUSGERÜSTETER BOGIE

PROCÉDÉ DE COMMANDE D'UNE SUSPENSION PNEUMATIQUE D'UN BOGIE D'UN VÉHICULE FERROVIAIRE, ET BOGIE COMPORTANT UNE SUSPENSION PNEUMATIQUE

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## Description

### TECHNICAL FIELD OF THE INVENTION

**[0001]** The invention relates to a bogie for a rail vehicle, provided with a frame and a pneumatic suspension comprising at least a secondary suspension stage, and to a method of controlling such a pneumatic suspension. As is well-known in the art, the secondary suspension of a bogie is the suspension stage for supporting a superstructure of the rail vehicle, e.g. a car or coach body, on the frame of the bogie. This secondary suspension may or may not be complemented by a primary suspension stage between the wheels and frame of the bogie.

### BACKGROUND ART

**[0002]** Pneumatic secondary suspension arrangements for controlling the tilt of the coach body are well known in the art. They usually involve at least two levelling valves located on each side of the bogie frame for controlling the left and right air springs of the secondary suspension. In order to better control the positioning of the coach body on the front and rear bogies, four-point secondary suspensions have been proposed, in which each of the four air springs supporting the car body on front and rear bogie frames is individually controlled. As a variant, three-point suspensions are also known in the art, as disclosed e.g. in US 3 738 680 A.

**[0003]** The arrangement disclosed in US 4 693 185 A provides a control system for a vehicle secondary suspension system consisting of four fluid springs, which support the car body from two longitudinally-spaced trucks. Typically such a vehicle is a rail car employing air springs. The two air springs on each truck are disposed on opposite sides of the longitudinal centreline of the vehicle, corresponding to its direction of travel. Three of the springs are provided with levelling valves, which keep them at a constant height. A measuring device, either mechanical or electrical, measures the difference in internal spring pressure in the two springs on one truck that both have levelling valves; it also measures the difference in internal spring pressures in the two springs on the other truck and then adjusts the pressure in the spring without a levelling valve until the pressure difference is the same as for the two springs on the other truck. The arrangement avoids the establishment of unequal pressures diagonally of the vehicle that normally result from height adjustment errors in the levelling valve links and can seriously affect wheel loading and control of braking. However, the system does not provide a joint control of the height of the car body and of other components of the suspension of the vehicle, e.g. the primary suspension for controlling the movement of the frame of the truck or bogie with respect to the wheels, or lateral springs or actuators for controlling the lateral motion of the car body with respect to the bogie.

**[0004]** Prior art document DE 30 48 516 A1 (corresponding to the preambles of product claim 1 and method claim 17) discloses a bogie provided with a multi-stage pneumatic suspension comprising secondary suspension air springs as well as a primary suspension stage including a set of combined rubber springs and air springs. The chambers of the primary suspension air springs and secondary suspension air springs are all connected with one another. The rubber springs are chosen so as to support the weight of the frame of the bogie. Thanks to this arrangement, the height of the frame of the bogie does not substantially change with the load, if the effective area of the primary suspension air springs is equal or close to the effective area of the secondary suspension air springs. However, the height will not remain constant if the effective areas of the primary and secondary suspension stages differ substantially. Moreover, the response of the suspension to loads unequally distributed on each side of the bogie is not well controlled.

### SUMMARY OF THE INVENTION

**[0005]** The foregoing shortcomings of the prior art are addressed by the present invention. According to the invention as defined in claim 1, there is provided a bogie for a rail vehicle, comprising

- a frame,
- a set of wheels,
- a pneumatic suspension comprising:
  - a secondary suspension for vertically supporting a superstructure of the rail vehicle on the frame, the secondary suspension comprising at least one left secondary air spring and one right secondary air spring respectively located on a left and a right side of a median longitudinal vertical plane of the bogie,
  - levelling valve means independently connecting each of the left and right secondary air springs to a pressure source or to the atmosphere based on at least one height signal representative of a distance between a car

body of the rail vehicle and one of the bogie frame and the set of wheels,

- additional pneumatic means for controlling relative motion between the frame and at least one of the superstructure and of the set of wheels,

- control valve means for connecting the additional pneumatic means to a pressure source or to the atmosphere based on one or more pressure signals derived from the pressures of the left and/or right secondary air springs.

**[0006]** Thanks to the control valve means, the additional pneumatic means can easily be controlled. Unlike the prior art, this control is based on a pressure information from the secondary suspension, which creates a control link between the secondary suspension and the additional pneumatic means, which can be used in order to fully compensate suspension deflection under load (i.e. the deflection of both the primary and secondary suspension) and/or to compensate roll motion or create an inclination control.

**[0007]** The levelling valve means may include a left levelling valve for connecting the left secondary air spring to the pressure source or to the atmosphere and a right levelling valve for connecting the right secondary air spring to the pressure source or to the atmosphere. Preferably, the levelling valve means comprise sensor means for sensing a left distance and a right distance between the vehicle superstructure and one of the bogie frame and the set of wheels, respectively on the left and right sides of the median longitudinal plane. Any type of transducer can be used to measure the varying distance between the car body and the frame (or the car body and the axle boxes or wheels) e.g. mechanical transducers such as levers and telescopic transducers or optical sensors.

**[0008]** The pressure signals for controlling the additional pneumatic means preferably include the pressures of the left and right secondary air springs. However, in certain circumstances, the pressure difference between the left and right secondary springs or the average of the pressures of the left and right secondary springs can be sufficient.

**[0009]** Preferably, the control valve means are such as to vent or isolate the additional pneumatic means if a predetermined condition is met, e.g. if the pressure of the left or right secondary springs is below a predetermined threshold or if the average of the pressures of the left and right secondary springs is below a predetermined threshold. This is used in particular to avoid undesired application of the additional pneumatic means when the secondary suspension is under a tare pressure of the vehicle, e.g. during initial inflation of the pneumatic system.

**[0010]** According to a preferred embodiment, the additional pneumatic means include one or more first air chambers and one or more second air chambers, which are preferably variable volume chambers. Hence, the application of pressure to the additional pneumatic means may result in an increase of stiffness of the additional pneumatic means and/or the production of mechanical work (i.e. the product of the displacement of a wall or piston of the variable volume chamber by the force applied).

**[0011]** One option to implement the invention is to provide means for controlling the air chambers based on a signal, preferably a pneumatic signal, which itself is a function of the pressure difference between the first and secondary air springs. In one embodiment, the first and second air chambers are part of a double acting cylinder.

**[0012]** As a preferred alternative, however, each of the two air chambers is controlled with the pressure of a respective one of the two secondary air springs only. According to a preferred embodiment, the pressure of the one or more first air chambers is a function F1 of the pressure of the left secondary air spring and is independent from the pressure of the right secondary air spring, the pressure of the one or more second air chambers is a function F2 of the pressure of the right secondary air spring and is independent from the pressure of the left secondary air spring, wherein F1=F2. Preferably, the function F=F1=F2 is a positive increasing function (increasing meaning that it increases strictly or remains constant). Preferably, no action is taken if the pressure $P_S$ of the secondary air spring and is below a predetermined tare pressure $P_T$. Hence, the function F is such that

$$F(P_S) = 0 \text{ if } P_S \leq P_T$$

where $P_S$ the pressure of a secondary air spring and $P_T$ is a tare pressure. The function F is preferably linear above the tare pressure, such that

$$F(P_S) = K \cdot (P_S - P_T) \text{ if } P_S > P_T$$

where K is a positive constant.

**[0013]** The control valve means may include a first valve for feeding air to the one or more first air chambers and a second valve for feeding air to the one or more second air chamber, wherein the first valve is controlled by the pressure

of the left secondary air spring and the second valve is controlled by the pressure of the right secondary air spring.

**[0014]** According to one embodiment, the control valve means are such that the difference of pressure between the one or more first air chambers and the one or more second air chambers is a function of a difference of pressure between the first secondary air spring and the second secondary air spring.

**[0015]** According to a preferred embodiment, the additional pneumatic means include left and right primary air springs located on the left and right sides of the median longitudinal vertical plane, respectively, for vertically supporting the frame on the set of wheels. The control valve means are preferably such as to increase and/or decrease the pressure of the left and right primary air springs to the effect that the overall resulting force applied by the left and right primary air springs on the frame is larger than or equal to the overall resulting force applied by the left and right secondary air springs to the frame, respectively. In this instance, the one or more first air chambers are part of the left primary air springs and the one or more second air chambers are part of the right primary air springs.

**[0016]** Alternatively or additionally, the additional pneumatic means may include means for controlling the lateral displacement of the frame relative to the superstructure perpendicular to the median longitudinal vertical plane of the frame. In this variant the means for feeding air to the additional pneumatic means are preferably such that the frame is deflected laterally towards the one of the left and right secondary air springs which encounters the lower pressure.

**[0017]** According to a further aspect not belonging to the invention, there is provided a pneumatic circuit for a pneumatic suspension of a rail vehicle, comprising

- left and right secondary branches provided with left and right secondary air springs respectively,
- levelling valve means for independently connecting each of the left and right secondary branches to a pressure source or to the atmosphere,
- additional pneumatic actuator means including at least a first and a second additional variable volume chambers,
- control valve means for feeding air to and releasing air from the first and second additional volume chambers as a function of the pressure in the left and right secondary branches, respectively.

**[0018]** In a preferred embodiment, the first and second primary air springs are mounted in parallel with first and second primary rubber springs.

**[0019]** Alternatively or additionally, the additional pneumatic means may include means for controlling the lateral displacement of the frame relative to the superstructure perpendicular to the median longitudinal vertical plane of the frame. The means for feeding air to the additional pneumatic means may be used to feed air to the additional pneumatic means such that the frame is deflected laterally towards the one of the first and second secondary air springs that encounters the greater pressure.

**[0020]** According to another aspect of the invention as defined in claim 17, there is provided a method of controlling a pneumatic suspension of a bogie of a rail vehicle, the bogie being provided with a frame and a set of wheels, the pneumatic suspension comprising at least a secondary suspension for vertically supporting a superstructure of the rail vehicle on the frame and additional pneumatic means for controlling relative motion between the frame and at least one of the superstructure and of the set of wheels, the secondary suspension comprising at least a first secondary air spring located on a first side of a median longitudinal vertical plane of the frame and a second secondary air spring located on a second side of the median longitudinal vertical plane of the frame, the additional pneumatic means including at least a first air chamber and a second air chamber, wherein the method comprises feeding air to the additional pneumatic means such that the difference of pressure between the first air chamber and the second air chamber is a function of a difference of pressure between the first secondary air spring and the second secondary air spring.

**[0021]** Where the additional pneumatic means include a primary suspension for vertically supporting the frame on the set of wheels as disclosed above, the method may include feeding air to the first primary air spring and/or to the second primary air spring such that the difference of pressure between the first primary air spring and the second primary air spring is a positive increasing function, e.g. a linear function, of a difference of pressure between the first secondary air spring and the second secondary air spring.

**[0022]** Where the additional pneumatic means include means for controlling the lateral displacement of the frame relative to the superstructure perpendicular to the median longitudinal vertical plane of the frame, the method may include feeding air to the additional pneumatic means such that the frame is deflected laterally towards the one of the first and second secondary air springs which encounters the greater pressure.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0023]** Other advantages and features of the invention will become more clearly apparent from the following description

of specific embodiments of the invention given as non-restrictive examples only and represented in the accompanying drawings in which:

- Figure 1 is a plan view of a bogie provided with a multi-stage pneumatic suspension according to one embodiment of the invention;
- Figure 2 is an enlarged vertical sectional view of a primary stage of the suspension taken on line A-A of figure 1;
- Figure 3 is an enlarged vertical sectional view of a secondary stage of the suspension taken on line C-C of figure 1;
- Figure 4 is a diagrammatic view of a pneumatic circuit of the multi-stage pneumatic suspension of figure 1;
- Figure 5A and 5B depict two alternative embodiment of a control valve for the pneumatic circuit of Figure 4;
- Figure 6 is a plan view of a bogie provided with a multi-stage pneumatic suspension according to another embodiment of the invention;
- Figure 7 is an enlarged vertical sectional view of a king pin of the suspension of figure 6;
- Figure 8 is a diagrammatic view of a pneumatic circuit of the multi-stage pneumatic suspension of figure 6.

## DETAILED DESCRIPTION OF VARIOUS EMBODIMENTS

**[0024]** Referring to figures 1 to 3, a bogie 10 of a rail vehicle includes two wheelsets, each composed of a wheel axle received in two axle boxes 12L, 12R and provided with wheels at each end. Each of the four axle boxes 12L, 12R, one of which (12L) is illustrated in figure 2, supports one branch 14 of a H-shaped frame 16 via a primary suspension air spring 18L, 18R. Each end of the transverse beam 20 of the bogie frame 16 receives a secondary suspension element comprising at least one air spring 22L, 22R, which supports a corresponding end of a bolster 24 provided with a king pin or centre bearing 26 for supporting the car body of the rail vehicle. The structure of the bogie assembly and in particular of the primary and secondary suspension is symmetrical with respect to a longitudinal central plane P of the bogie (and of the rail vehicle 100).

**[0025]** As shown in Figure 2, each combined air and rubber spring 18L, 18R of the primary suspension (hereinbelow also referred to as air spring) includes a lower cup 28 attached to the axle box 12, an upper central tapered pin 30 attached to the bogie frame 16 and a multilayer tapered rubber and metal spring 38 attached at one end to the central pin 30 and at the other end to the lower cup 28. A closed air chamber 34L, 34R is defined by the pin 30, rubber spring 38 and lower cup 28. This primary suspension variable volume air chamber 34L, 34R is connected to a pneumatic circuit 36 as will be described below in order to feed the air chamber 34 with air under pressure.

**[0026]** As illustrated in Figure 3, each air spring 22L, 22R of the secondary suspension 22 comprises an inflatable air bag 40 defining a closed variable volume air chamber 42 with an upper cup 44 attached to the bolster 24 and a lower cup 46, which is linked to bogie frame 14 via a coil spring 48 and guided in translation with respect to the bogie frame 14.

**[0027]** In Figure 4, the pneumatic circuit 36 for controlling the secondary suspension of the two bogies 10 supporting the car body 100 of a rail coach is illustrated. The circuit 36 includes four identical sub-circuits, namely a left and a right sub-circuit 52L, 52R for each of the two bogies 10, fed by a common pressure source 53.

**[0028]** It will be understood that the other left and right sub-circuits 52L, 52R are identical. Hence, in the figures, the components which will be described with a suffix "L" below have counterparts with the suffix "R" on the right side of the bogie. The sub-circuit 52L includes a primary branch 54L and a secondary branch 56L. The primary branch connects the air chambers 34L of the four primary air springs 18L in parallel and is provided with a control valve to connect the air chambers 34L to the pressure source 53. Air pressure is applied to the deformable chamber 42L of the air spring 22L of the secondary suspension via the secondary branch 56L of the circuit, which may comprise an additional non-deformable chamber or reservoir 59L in series with the deformable chamber 42L, in order to increase the overall volume of air and decrease the corresponding pneumatic stiffness of the secondary air spring 22L. A levelling valve 60L is added to the secondary branch 56L of the circuit to control the pressure of the secondary branch 56L and secondary air spring 22L as a function of the height of the coach body with respect to the bogie frame. Each levelling valve 60L is operated by a lever attached to one end of a link, whose other end is fixed to the car body. Any vertical movement between the car body and the bogie is detected by the lever 61L, which adjusts the levelling valve accordingly.

**[0029]** A differential valve 62L may be added between the secondary branch 56L of the left and right sub-circuits 52L of each bogie, such that the difference of pressure between the left and right secondary suspension elements remains within a predefined range.

**[0030]** One embodiment of the control valve 58L used to control the pressure of the primary suspension air springs 18L, 18R in each branch is illustrated in Figure 5A. The control valve 58L is shown in its intermediate position, in which the port leading to the primary branch 54L and to the chambers 34L of the primary air springs 18L is isolated. The position of the control valve 58L is controlled by an actuator 66, which moves according to the pressure differential between the primary and secondary air springs. More specifically, the pressure of the primary suspension chambers 34L and of the primary branch 54L is fed to one chamber 68B of a differential cylinder 68 of the actuator 66, while the other chamber 66A of the differential cylinder 68 is connected to the chamber 42L of the secondary suspension air spring 22L. Preferably, a differential valve 70 is connected between the secondary branch 56L and the chamber 68B, such that the control valve 58L remains in the intermediate position as long as the pressure of the secondary air spring 22L as not reached a pressure threshold. This pressure threshold is predetermined e.g. as a tare pressure $P_T$ of the vehicle.

**[0031]** During initial inflation of the pneumatic system, the levelling valve 60L remains open so that air from the pressure source 53 is fed through the levelling valve 60L to the secondary air spring 22L until the deformable chamber 42L has raised the car body to its target position. At the beginning of this initial phase, the pressure in the secondary branch 56L of the circuit remains below the tare pressure and the primary branch 54L of the circuit remains isolated. At some stage during the raising phase, however, before the target position has been reached, the pressure in the secondary branch of the circuit reaches the tare pressure and pushes the piston rod 72 of the actuator 66 of the control valve 58L towards the right in Figure 5A. As a result, the pressure source 53 is connected to the primary branch 54L of the pneumatic circuit to inflate the primary air springs chambers 34L, until the increased primary air spring pressure moves the actuator 66 back to the neutral position to isolate the primary air springs 18L. When the car body has reached its target position, the levelling valve 60L isolates the secondary branch of the circuit. The same raising phase occurs simultaneously in the four sub-circuits 52L, 52R, each controlled by one of the levelling valves 60L, 60R.

**[0032]** After the initial inflation phase, the pressure and stiffness of the primary suspension is controlled as follows. Starting from a neutral position of the control valve 58L, 58R, if the load is increased on the left side of the bogie, e.g. in a curve, the pressure of the secondary suspension air spring 22L on that side of the bogie will increase proportionally. If this increase exceeds the threshold defined by the differential valve 70, the increased pressure is directed to the actuator 66 and pushes the piston rod 72 of the actuator towards the right in Figure 5A, such that the pressure source 53 becomes connected to the primary air springs 18L on the same side of the bogie to increase the pressure said primary air springs, until the increased primary air spring pressure moves the actuator 66 back to the neutral position to isolate the primary air springs 18L. If, on the other hand, the pressure of the secondary air spring 22L decreases, the actuator 66 is moved towards the left and air from the primary branch 54L is released to the atmosphere until the pressure of the primary air springs 18L reaches a lower value, which enables the actuator to return to the neutral position.

**[0033]** Hence, the control valves 58L, 58R selectively increase the pressure of the primary air springs 18L, 18R on the side of the bogie 10 which experiences an increased secondary air spring pressure. This increase of the primary air spring pressure results in an increased stiffness of the primary air springs and a lifting of the corresponding side of the bogie frame with respect to the wheels.

**[0034]** As an indirect result of the control of the primary suspension, the difference of pressure between the left and right air springs of the primary suspension is a function of the difference of pressure between the left and right air springs of the secondary suspension.

**[0035]** As an alternative to the pneumatically controlled control valve of Figure 5A, an electro-pneumatic control valve can be used, as shown in Figure 5B. The person skilled in the art will also see that the somewhat complex three-position control valves of Figures 5A and 5B can be replaced with a set of two two-position control valves.

**[0036]** In the embodiment of Figures 1 to 5A, the pressure of the left and right pneumatic suspension elements is used to selectively control the left and right elements of the primary suspension. By analogy, other components of the suspension can be controlled using as input the pressure of the left and right part of the secondary suspension.

**[0037]** Figures 6 to 8 depict an example of a pneumatic circuit for controlling the lateral displacement of the coach body with respect to the bogie as a function of the pressures of the left and right elements of the secondary suspension. Identical reference numbers will be used to identify identical components of the first and second embodiments.

**[0038]** Remarkably, the king pin 126 of the bogie is allowed to move laterally with respect to the frame and its position is constrained and controlled by two lateral pneumatic actuators 118L, 118R, each very similar to the air and rubber springs 18L, 18R of the primary suspension of the first embodiment and each provided with a chamber 134L, 134R. The two pneumatic actuators 118L, 118R constitute lateral abutments for the king pin 126.

**[0039]** As illustrated in figure 8, each of the pneumatic actuators 118L, 118R is part of an additional branch 154L, 154R of the pneumatic circuit and connected to a control valve 58L, 58L in a manner similar to the primary suspension springs 18L, 18R of the first embodiment. Accordingly, each of the two lateral pneumatic actuators is individually controlled by the pressure in the corresponding secondary branch 56L, 56R of circuit on the same side of the bogie, such that an increase of the pressure of the secondary air springs 22L, 22R on one side of the bogie will result in an increased pressure of the lateral pneumatic actuator 118L, 118R on the same side. Accordingly, the lateral actuator will apply an increased force to the king pin towards the opposite side of the bogie and its stiffness will increase.

**[0040]** The invention is not limited to the embodiments described hereinbefore.

**[0041]** According to a non-illustrated variant, the secondary suspension of the bogie can be provided with a lateral double acting cylinder, pivotally attached at one end to the bogie frame and at the other end to the bolster of the bogie. One of the chambers of double acting cylinder is connected to the right secondary air spring while the other chamber of the double acting cylinder is connected to the left secondary air spring. The connections are such that the piston of the double acting cylinder will move to push the frame of the bogie in the lateral direction of the secondary air spring with the lowest pressure.

**[0042]** Several components can be simultaneously controlled with the pressure on the left and right side of the secondary suspension, e.g. primary suspension elements and lateral actuators.

**[0043]** While the preferred embodiment includes two wheelsets, the invention is also applicable to a bogie provided with a set of four individual wheels, each supported from one of four journal boxes. According to still another variant, the bogie may include only one wheelset, composed of an axle with a bearing and wheels at each end.

**[0044]** While the bogie of the preferred embodiment is provided with a bolster, a similar control of the primary suspension elements based on the pressure applied to each side of secondary suspension can be advantageous for a bolsterless bogie.

## Claims

**1.** A bogie (10) for a rail vehicle, comprising

- a frame (16),
- a set of wheels,
- a pneumatic suspension comprising:

  - a secondary suspension for vertically supporting a superstructure of the rail vehicle on the frame, the secondary suspension comprising at least one left secondary air spring (22L) and one right secondary air spring (22R) respectively located on a left and a right side of a median longitudinal vertical plane of the bogie,
  - levelling valve means (60L, 60R) connecting each of the left and right secondary air springs (22L, 22R) to a pressure source (53) or to the atmosphere,
  - additional pneumatic means (18L, 18R; 118L, 118R) for controlling relative motion between the frame and at least one of the superstructure and of the set of wheels,

**characterised in that**:

- the levelling valve means (60L, 60R) independently connect each of the left and right secondary air springs (22L, 22R) to the pressure source (53) or to the atmosphere based on at least one height signal representative of a distance between a car body of the rail vehicle and one of the bogie frame and the set of wheels,
- the pneumatic suspension further comprises control valve means (58L, 58R) for connecting the additional pneumatic means selectively to a pressure source or to the atmosphere based on one or more pressure signals derived from the pressures of the left and/or right secondary air springs (22L, 22R).

**2.** The bogie of claim 1, wherein the levelling valve means (60L, 60R) include a left levelling valve (60L) for connecting the left secondary air spring to the pressure source or to the atmosphere and a right levelling valve (60R) for connecting the right secondary air spring to the pressure source or to the atmosphere.

**3.** The bogie of claim 1 or claim 2, wherein the levelling valve means (60L, 60R) comprise sensor means for sensing a left distance and a right distance between the vehicle superstructure (100) and one of the bogie frame (16) and the set of wheels, respectively on the left and right sides of the median longitudinal plane (P).

**4.** The bogie of any one of the preceding claims, wherein the one or more pressure signals are selected from a group consisting of:

- the pressures of the left and right secondary air springs (22L, 22R),
- the pressure difference between the left and right secondary air springs (22L, 22R),
- the average of the pressures of the left and right secondary air springs (22L, 22R).

**5.** The bogie of any one of the preceding claim, wherein the control valve means (58L, 58R) are such as to vent or

isolate the additional pneumatic means (18, 118) if a predetermined condition is met, said predetermined condition being selected from a group consisting of:

- the pressure of the left or right secondary air springs (22L, 22R) is below a predetermined threshold;
- the average of the pressures of the left and right secondary air springs (22L, 22R) is below a predetermined threshold.

**6.** The bogie of any one of claims 1 to 5, wherein the additional pneumatic means (18L, 18R; 118L, 118R) include one or more first air chambers (34L, 134L) and one or more second air chambers (34R, 134R).

**7.** The bogie of claim 6, wherein the first and second air chambers are variable volume chambers.

**8.** The bogie of claim 6 or claim 7, wherein the control valve means (58L, 58R) are such that the pressure of the one or more first air chambers (34L, 134L) is a function F1 of the pressure of the left secondary air spring (18L) and is independent from the pressure of the right secondary air spring (18R), the pressure of the one or more second air chambers (34R, 134R) is a function F2 of the pressure of the right secondary air spring (18R) and is independent from the pressure of the left secondary air spring (18L), wherein F1 =F2.

**9.** The bogie of claim 8, wherein the function F=F1=F2 is a positive increasing function.

**10.** The bogie of claim 9, wherein the function F is such that

$$F(P_S)=0 \text{ if } P_S \leq P_T$$

where $P_S$ the pressure of a secondary air spring and $P_T$ is a tare pressure.

**11.** The bogie of claim 10, wherein the function F is such that

$$F(P_S)=K\cdot(P_S-P_T) \text{ if } P_S > P_T$$

where K is a positive constant.

**12.** The bogie of any one of claims 6 to 11, wherein the control valve means include a first valve (58L) for feeding air to the one or more first air chambers and a second valve (58R) for feeding air to the one or more second air chamber, wherein the first valve is controlled by the pressure of the left secondary air spring and the second valve is controlled by the pressure of the right secondary air spring.

**13.** The bogie any one of the preceding claims, wherein the additional pneumatic means include left and right primary air springs (18L, 18R) located on the left and right sides of the median longitudinal vertical plane, respectively, for vertically supporting the frame on the set of wheels.

**14.** The bogie of claim 13, wherein the control valve means are such as to increase and/or decrease the pressure of the left and right primary air springs to the effect that the overall resulting force applied by the left and right primary air springs on the frame is larger than or equal to the overall resulting force applied by the left and right secondary air springs to the frame, respectively.

**15.** The bogie of any one of the preceding claims, wherein the additional pneumatic means include means (118) for controlling the lateral displacement of the frame relative to the superstructure perpendicular to the median longitudinal vertical plane of the frame.

**16.** The bogie of the preceding claim, wherein the means for feeding air to the additional pneumatic means are such that the frame is deflected laterally towards the one of the left and right secondary air springs which encounters the lower pressure.

**17.** A method of controlling a pneumatic suspension of a bogie (10) of a rail vehicle, the bogie (10) being provided with

a frame (16) and a set of wheels, the pneumatic suspension comprising at least a secondary suspension for vertically supporting a superstructure (100) of the rail vehicle on the frame (10) and additional pneumatic means (18L, 18R, 118L, 118R) for controlling relative motion between the frame (16) and at least one of the superstructure (100) and of the set of wheels, the secondary suspension comprising at least a first secondary air spring (22L, 22R) located on a first side of a median longitudinal vertical plane (P) of the frame (16) and a second secondary air spring (22R, 22L) located on a second side of the median longitudinal vertical plane (P) of the frame (16), the additional pneumatic means including at least a first air chamber (34L, 134L, 34R, 134R) attached to the frame on the first side of a median longitudinal vertical plane (P) of the frame and a second air chamber (34R, 134R, 34L, 134L) attached to the frame on the second side of the median longitudinal vertical plane (P) of the frame, wherein the method comprises feeding air to and releasing air from the additional pneumatic means **characterised in that** said feeding is carried out as a function of at least one or more pressure signals derived from the pressures of the first and/or second secondary air springs (22L, 22R).

**18.** The method of claim 17 comprising:

- measuring a pressure difference between the first and second secondary air springs (22L, 22R) over time and
- feeding air to the additional pneumatic means based at least on the measured pressure difference over time.

**19.** The method of claim 17, comprising feeding air to the first air chamber (34L, 134L, 34R, 134R) as a function of the pressure of one of the first and second secondary air springs (22L, 22R) and feeding air to the second air chamber (34R, 134R, 34L, 134L) as a function of the pressure of the other one of the first and second secondary air springs (22L, 22R).

**20.** The method of any one of claims 17 to 19, wherein the additional pneumatic means include a primary suspension for vertically supporting the frame (16) on the set of wheels, the first air chamber (34L, 134L, 34R, 134R) being a first primary air spring located on the first side of a median longitudinal vertical plane (P) of the frame and the second air chamber (34R, 134R, 34L, 134L) being a second primary air spring located on the second side of the median longitudinal vertical plane (P) of the frame, wherein the method comprises feeding air to the first primary air spring (34L, 134L, 34R, 134R) and/or to the second primary air spring (34R, 134R, 34L, 134L) such that the difference of pressure between the first primary air spring and the second primary air spring is a positive increasing function of a difference of pressure between the first secondary air spring (22L, 22R) and the second secondary air spring (22L, 22R).

**21.** The method of the preceding claim wherein the positive increasing function is a linear function.

**22.** The method of any one of claims 17 to 21, wherein the additional pneumatic means (18L, 18R, 118L, 118R) include means (118L, 118R) for controlling the lateral displacement of the frame relative to the superstructure perpendicular to the median longitudinal vertical plane (P) of the frame, the method comprising feeding air to the additional pneumatic means such that the frame is deflected laterally towards the one of the first and second secondary air springs (22L, 22R) which encounters the greater pressure.

**Patentansprüche**

**1.** Drehgestell (10) für ein Schienenfahrzeug, umfassend

- einen Rahmen (16),
- einen Radsatz,
- eine pneumatische Aufhängung, umfassend:

  - eine sekundäre Aufhängung, um vertikal einen Oberbau eines Schienenfahrzeugs auf dem Rahmen zu stützen, wobei die sekundäre Aufhängung wenigstens eine linke sekundäre Luftfeder (22L) und eine rechte sekundäre Luftfeder (22R) umfasst, die jeweils auf einer linken und einer rechten Seite einer medianen, vertikalen Längsebene des Drehgestells angeordnet ist,
  - Höhenverstellungsventilmittel (60L, 60R), die jeweils die linken und rechten sekundären Luftfedern (22L, 22R) an eine Druckquelle (53) oder an die Atmosphäre anschließen,
  - zusätzliche pneumatische Mittel (18L, 18R; 118L, 118R) zur Steuerung der relativen Bewegung zwischen dem Rahmen und wenigstens eines des Oberbaus und des Radsatzes,

**dadurch gekennzeichnet, dass**:

- die genannten Höhenverstellungsventilmittel (60L, 60R), unabhängig voneinander jede der linken und rechten sekundären Luftfedern (22L, 22R) an eine Druckquelle (53) oder an die Atmosphäre basierend auf wenigstens einem Höhensignal anschließen, das eine Entfernung zwischen einem Wagenkörper des Schienenfahrzeugs und einem Drehgestellrahmen und dem Radsatz repräsentiert,
- die pneumatische Aufhängung weiterhin Steuerventilmittel (58L, 58R) umfasst zum Anschließen der zusätzlichen pneumatischen Mittel selektiv an eine Druckquelle oder an die Atmosphäre, basierend auf einem oder mehreren Drucksignalen, die von den Drücken der linken und / oder rechten sekundären Luftfedern (22L, 22R) abgeleitet sind.

**2.** Drehgestell gemäß Anspruch 1, wobei Höhenverstellungsventilmittel (60L, 60R) ein linkes Luftfederventil (60L) zum Anschließen der linken sekundären Luftfeder an die Druckquelle oder an die Atmosphäre und ein rechtes Luftfederventil (60R) zum Anschließen der rechten sekundären Luftfeder an die Druckquelle oder an die Atmosphäre einschließen.

**3.** Drehgestell gemäß Anspruch 1 oder Anspruch 2, wobei die Höhenverstellungsventilmittel (60L, 60R) Sensormittel zum Erfassen einer linken Entfernung und einer rechten Entfernung zwischen der Fahrzeug-Oberstruktur (100) und einem der Drehgestellrahmen (16) und dem Radsatz jeweils auf der linken und der rechten Seite der medianen Längsebene (P) umfassen.

**4.** Drehgestell gemäß irgendeinem der voranstehenden Ansprüche, wobei das oder die Drucksignal(e) ausgewählt ist / sind aus der Gruppe, bestehend aus:

- den Drücken der linken und rechten sekundären Luftfedern (22L, 22R),
- der Druckdifferenz zwischen den linken und rechten sekundären Luftfedern (22L, 22R),
- dem Durchschnitt der Drücke der linken und rechten sekundären Luftfedern (22L, 22R).

**5.** Drehgestell gemäß irgendeinem der voranstehenden Ansprüche, wobei die Steuerventilmittel (58L, 58R) derart sind, dass die zusätzlichen pneumatischen Mittel (18, 118) belüftet oder isoliert sind, wenn eine vorbestimmte Bedingung erfüllt ist, wobei die genannte vorbestimmte Bedingung ausgewählt ist aus der Gruppe, bestehend aus:

- der Druck der linken oder rechten sekundären Luftfedern (22L, 22R) liegt unter einem vorbestimmten Schwellenwert;
- der Durchschnitt der Drücke der linken und rechten sekundären Luftfedern (22L, 22R) liegt unter einem vorbestimmten Schwellenwert.

**6.** Drehgestell gemäß irgendeinem der Ansprüche 1 bis 5, wobei die zusätzlichen pneumatischen Mittel (18L, 18R; 118L, 118R) eine oder mehrere erste Luftkammern (34L, 134L) und eine oder mehrere zweite Luftkammern (34R, 134R) einschließen.

**7.** Drehgestell gemäß Anspruch 6, wobei die ersten und zweiten Luftkammern Kammern mit variablem Volumen sind.

**8.** Drehgestell gemäß Anspruch 6 oder Anspruch 7, wobei die Steuerventilmittel (58L, 58R) derart sind, dass der Druck der einen oder mehreren ersten Luftkammern (34L, 134L) eine Funktion F1 des Drucks der linken sekundären Luftfeder (18L) ist und unabhängig von dem Druck der rechten sekundären Luftfeder (18R) ist, der Druck der einen oder mehreren sekundären Luftkammern (34R, 134R) eine Funktion F2 des Drucks der rechten sekundären Luftfeder (18R) ist und von dem Druck der linken sekundären Luftfeder (18L) unabhängig ist, wobei F1 = F2.

**9.** Drehgestell gemäß Anspruch 8, wobei die Funktion F = F1 = F2 eine positive ansteigende Funktion ist.

**10.** Drehgestell gemäß Anspruch 9, wobei die Funktion F derart ist, dass

$$F(P_s) = 0, \text{ wenn } P_s \leq P_t$$

wobei $P_s$ der Druck einer zweiten Luftfeder ist und $P_t$ ein Tara-Druck ist.

**11.** Drehgestell gemäß Anspruch 10, wobei die Funktion F derart ist, dass

$$F(P_s) = K \cdot (P_s - P_t), \text{ wenn } P_s > P_t$$

wobei K eine positive Konstante ist.

**12.** Drehgestell gemäß irgendeinem der Ansprüche 6 bis 11, wobei die Steuerventilmittel ein erstes Ventil (58L) zum Einspeisen von Luft in die erste (n) Luftkammer (n) und ein zweites Ventil (58R) zum Einspeisen von Luft in die zweite(n) Kammer(n) einschließt, wobei das erste Ventil durch den Druck der linken sekundären Luftfeder gesteuert ist und das zweite Ventil durch den Druck der rechten sekundären Luftfeder gesteuert ist.

**13.** Drehgestell gemäß irgendeinem der voranstehenden Ansprüche, wobei die zusätzlichen pneumatischen Mittel linke und rechte primäre Luftfedern (18L, 18R) einschließen, die jeweils auf den linken und rechten Seiten der medianen, vertikalen Längsebenen angeordnet sind, um vertikal den Rahmen auf dem Radsatz zu stützen.

**14.** Drehgestell gemäß Anspruch 13, wobei die Steuerventilmittel derart sind, dass der Druck der linken und rechten primären Luftfedern mit der Wirkung erhöht und / oder gesenkt wird, dass die gesamte resultierende Kraft, die von der linken und rechten primären Luftfedern auf dem Rahmen angewendet sind, größer ist als die oder gleich der gesamte(n) resultierende(n) Kraft, die jeweils von den linken und rechten sekundären Luftfedern auf den Rahmen angewendet sind.

**15.** Drehgestell gemäß irgendeinem der voranstehenden Ansprüche, wobei die zusätzlichen pneumatischen Mittel Mittel (118) für die Steuerung der lateralen Verschiebung des Rahmens relativ zum Oberbau lotrecht zu der medianen, vertikalen Längsebene des Rahmens einschließen.

**16.** Drehgestell gemäß irgendeinem der voranstehenden Ansprüche, wobei die Mittel zum Einspeisen von Luft in die zusätzlichen pneumatischen Mittel derart sind, dass der Rahmen lateral zu der einen der linken und rechten sekundären Luftfedern abgelenkt ist, die auf den unteren Druck stößt.

**17.** Verfahren zur Steuerung einer pneumatischen Aufhängung eines Drehgestells (10) eines Schienenfahrzeugs, wobei das Drehgestell (10) mit einem Rahmen (16) und einem Radsatz bereitgestellt ist, wobei die pneumatische Aufhängung wenigstens eine sekundäre Aufhängung umfasst, um vertikal einen Oberbau (100) des Schienenfahrzeugs auf dem Rahmen (10) und zusätzliche pneumatische Mittel (18L, 18R, 118L, 118R) zu stützen, um die relative Bewegung zwischen dem Rahmen (16) und wenigstens einem des Oberbaus (100) und des Radsatzes zu steuern, wobei die sekundäre Aufhängung wenigstens eine erste sekundäre Luftfeder (22L, 22R) umfasst, die auf einer ersten Seite einer medianen, vertikalen Längsebene (P) des Rahmens (16) angeordnet ist, und eine zweite sekundäre Luftfeder (22R, 22L), die an einer zweiten Seite der medianen, vertikalen Längsebene (P) des Rahmens (16) angeordnet ist, wobei die zusätzlichen pneumatischen Mittel wenigstens eine erste Luftkammer (34L, 134L, 34R, 134R) einschließen, die an dem Rahmen auf der ersten Seite einer medianen, vertikalen Längsebene (P) des Rahmens befestigt ist, und eine zweite Luftkammer (34R, 134R, 34L, 134L), die an dem Rahmen auf der zweiten Seite der medianen, vertikalen Längsebene (P) des Rahmens befestigt ist, wobei das Verfahren das Einspeisen von Luft in die und Freisetzen von Luft aus den zusätzliche(n) pneumatische(n) Mitteln (18L, 18R; 118L, 118R) umfasst, **dadurch gekennzeichnet, dass** das Verfahren das genannte Einspeisen als eine Funktion von wenigstens einem oder mehreren Drucksignalen umfasst, die von den Drücken der ersten und / oder zweiten sekundären Luftfedern (22L, 22R) abgeleitet sind.

**18.** Verfahren gemäß Anspruch 17, umfassend:

- Messen einer Druckdifferenz zwischen den ersten und zweiten sekundären Luftfedern (22L, 22R) im Zeitverlauf und
- Einspeisen von Luft in die zusätzlichen pneumatischen Mittel basierend auf wenigstens der im Zeitverlauf gemessenen Druckdifferenz.

**19.** Verfahren gemäß Anspruch 17, umfassend das Einspeisen von Luft in die erste Luftkammer (34L, 134L, 34R, 134R) als eine Funktion des Drucks einer der ersten und zweiten sekundären Luftfedern (22L, 22R) und Einspeisen von Luft in die zweite Luftkammer (34R, 134R, 34L, 134L) als eine Funktion des Drucks der anderen der ersten und

zweiten sekundären Luftfedern (22L, 22R).

**20.** Verfahren gemäß irgendeinem der Ansprüche 17 bis 19, wobei die zusätzlichen pneumatischen Mittel eine primäre Aufhängung einschließen, um den Rahmen (16) auf dem Radsatz vertikal zu stützen, wobei die erste Luftkammer (34L, 134L, 34R, 134R) eine erste primäre Luftfeder ist, die auf der ersten Seite einer medianen, vertikalen Längsebene (P) des Rahmens angeordnet ist und die zweite Luftkammer (34R, 134R, 34L, 134L) eine zweite primäre Luftfeder ist, die an der zweiten Seite der medianen, vertikalen Längsebene (P) des Rahmens angeordnet ist, wobei das Verfahren das Einspeisen von Luft in die erste primäre Luftfeder (34L, 134L, 34R, 134R) und / oder die zweite primäre Luftfeder (34R, 134R, 34L, 134L) derart umfasst, dass die Druckdifferenz zwischen der ersten primären Luftfeder und der zweiten primären Luftfeder eine positive ansteigende Funktion einer Druckdifferenz zwischen der ersten sekundären Luftfeder (22L, 22R) und der zweiten sekundären Luftfeder (22L, 22R) ist.

**21.** Verfahren gemäß dem voranstehenden Anspruch, wobei die positive ansteigende Funktion eine lineare Funktion ist.

**22.** Verfahren gemäß irgendeinem der Ansprüche 17 bis 21, wobei die zusätzlichen pneumatischen Mittel (18L, 18R, 118L, 118R) Mittel (118L, 118R) zur Steuerung der lateralen Verschiebung des Rahmens relativ zum zum Oberbau lotrecht zur medianen, vertikalen Längsebene (P) des Rahmens einschließen, wobei das Verfahren das Einspeisen von Luft in die zusätzlichen pneumatischen Mittel derart umfasst, dass der Rahmen lateral zu der einen der ersten und zweiten sekundären Luftfedern (22L, 22R) abgeleitet ist, die auf den größeren Druck stößt.

**Revendications**

**1.** Bogie (10) pour un véhicule ferroviaire comprenant :

- un châssis (16),
- un ensemble de roues,
- une suspension pneumatique comprenant :

  . une suspension secondaire pour supporter verticalement une superstructure du véhicule ferroviaire sur le châssis, la suspension secondaire comprenant au moins un ressort à air secondaire gauche (22L) et un ressort à air secondaire droit (22R) disposés respectivement sur un côté gauche et un côté droit d'un plan vertical longitudinal médian du bogie,
  - des moyens de vannes de nivellement (60L, 60R) reliant chacun des ressorts à air secondaires gauche et droit (22L, 22R) à une source de pression (53) ou à l'atmosphère,
  - des moyens pneumatiques additionnels (18L, 18R ; 118L, 118R), pour contrôler le mouvement relatif entre le châssis et au moins l'un parmi la superstructure et l'ensemble de roues,

**caractérisé en ce que** :

- les moyens de vannes de nivellement (60L, 60R) relient indépendamment chacun des ressorts à air secondaires gauche et droit (22L, 22R) à la source de pression (53) ou à l'atmosphère en fonction d'au moins un signal de hauteur représentatif d'une distance entre une caisse de voiture du véhicule ferroviaire et l'un parmi le châssis de bogie et l'ensemble de roues,
- la suspension pneumatique comprend en outre des vannes de commande (58L, 58R) pour relier les moyens pneumatiques additionnels de manière sélective à une source de pression ou à l'atmosphère en fonction d'un signal ou de plusieurs signaux de pression dérivé(s) des pressions des ressorts à air secondaires gauche et/ou droit (22L, 22R).

**2.** Bogie selon la revendication 1, dans lequel les moyens de vannes de nivellement (60L, 60R) incluent une vanne de nivellement gauche (60L) pour relier le ressort à air secondaire gauche à la source de pression ou à l'atmosphère et une vanne de nivellement droite (60R) pour relier le ressort à air secondaire droit à la source de pression ou à l'atmosphère.

**3.** Bogie selon la revendication 1 ou la revendication 2, dans lequel les moyens de vannes de nivellement (60L, 60R) comprennent des moyens formant capteurs pour détecter une distance gauche et une distance droite entre la superstructure de véhicule (100) et l'un parmi le châssis de bogie (16) et l'ensemble de roues, respectivement du côté gauche et du côté droit du plan longitudinal médian (P).

4. Bogie selon l'une quelconque des revendications précédentes, dans lequel le signal ou les signaux de pression est/sont sélectionné(s) dans le groupe consistant en :

- la pression des ressorts à air secondaires gauche et droit (22L, 22R),
- la différence de pression entre les ressorts à air secondaires gauche et droit (22L, 22R),
- la moyenne des pressions des ressorts à air secondaires gauche et droit (22L, 22R).

5. Bogie selon l'une quelconque des revendications précédentes, dans lequel les vannes de commande (58L, 58R) sont conçues pour mettre à l'air libre ou pour isoler les moyens pneumatiques additionnels (18, 118) si une condition prédéterminée est satisfaite, ladite condition prédéterminée étant sélectionnée dans un groupe consistant en :

- la pression des ressorts à air secondaires gauche ou droit (22L, 22R) est inférieure à un seuil prédéterminé ;
- la moyenne des pressions des ressorts à air secondaires gauche et droit (22L, 22R) est inférieure à un seuil prédéterminé.

6. Bogie selon l'une quelconque des revendications 1 à 5, dans lequel les moyens pneumatiques additionnels (18L, 18R ; 118L, 118R) comprennent une ou plusieurs première (s) chambres (s) à air (34L, 134L) et une ou plusieurs seconde(s) chambre(s) d'air (34R, 134R).

7. Bogie selon la revendication 6, dans lequel les premières et secondes chambres d'air sont des chambres à volume variable.

8. Bogie selon la revendication 6 ou la revendication 7, dans lequel les vannes de commande (58L, 58R) sont telles que la pression de la ou des première(s) chambre(s) à air (34L, 134L) est une fonction F1 de la pression du ressort à air secondaire gauche (18L) et est indépendante de la pression du ressort à air secondaire droit (18R), la pression de la ou des seconde(s) chambre(s) à air (34R, 134R) est une fonction F2 de la pression du ressort à air secondaire droit (18R) et est indépendante de la pression du ressort à air secondaire gauche (18L), dans lequel F1 = F2.

9. Bogie selon la revendication 8, dans lequel la fonction F = F1 = F2 est une fonction croissante positive.

10. Bogie selon la revendication 9, dans lequel la fonction F est telle que

$$F(Ps) = 0, \text{ si } Ps \leq Pt$$

où $P_s$ est la pression d'un ressort à air secondaire et $P_l$ est une pression de tare.

11. Bogie selon la revendication 10, dans lequel la fonction F est telle que

$$F(Ps) = K \cdot (Ps - Pt), \text{ si } Ps > Pt$$

où K est une constante positive.

12. Bogie selon l'une quelconque des revendications 6 à 11, dans lequel les vannes de commande incluent une première vanne (58L) d'alimentation en air de la ou des première (s) chambre(s) à air et une seconde vanne (58R) d'alimentation en air de la ou des seconde(s) chambre (s) d'air, dans lequel la première vanne est commandée par la pression du ressort à air secondaire gauche et la seconde vanne est commandée par la pression du ressort à air secondaire droit.

13. Bogie selon l'une quelconque des revendications précédentes, dans lequel les moyens pneumatiques additionnels incluent des ressorts à air primaires gauche et droit (18L, 18R) disposés sur les côtés gauche et droit du plan vertical longitudinal médian, respectivement, pour supporter verticalement le châssis sur l'ensemble de roues.

14. Bogie selon la revendication 13, dans lequel les vannes de commande sont propres à augmenter et/ou réduire la pression des ressorts à air primaires gauche et droit de manière telle que la force résultante globale appliquée par les ressorts à air primaires gauche et droit sur le châssis est supérieure ou égale à la force résultante globale

appliquées par les ressorts à air secondaires gauche et droit sur le châssis, respectivement.

**15.** Bogie selon l'une quelconque des revendications précédentes, dans lequel les moyens pneumatiques additionnels incluent des moyens (118) pour commander le déplacement latéral du châssis par rapport à la superstructure perpendiculairement au plan vertical longitudinal médian du châssis.

**16.** Bogie selon la revendication précédente, dans lequel les moyens d'alimentation en air des moyens pneumatiques additionnels sont tels que le châssis fléchit latéralement vers celui des ressorts à air secondaires gauche et droit qui rencontre la pression la moins élevée.

**17.** Procédé de commande d'une suspension pneumatique d'un bogie (10) d'un véhicule ferroviaire, le bogie (10) étant équipé d'un châssis (16) et d'un ensemble de roues, la suspension pneumatique comprenant au moins une suspension secondaire pour supporter verticalement une superstructure (100) du véhicule ferroviaire sur le châssis (10) et des moyens pneumatiques additionnels (18L, 18R ; 118L, 118R) pour commander le mouvement relatif entre le châssis (16) et au moins l'un parmi la superstructure (100) et l'ensemble de roues, la suspension secondaire comprenant au moins un premier ressort à air secondaire (22L, 22R) disposé sur un premier côté d'un plan vertical longitudinal médian (P) du châssis (16) et un second ressort à air secondaire (22R, 22L) disposé sur un second côté du plan vertical longitudinal médian (P) du châssis (16), les moyens pneumatiques additionnels incluant au moins une première chambre à air (34L, 134L, 34R, 134R) fixée sur le châssis sur le premier côté d'un plan vertical longitudinal médian (P) du châssis et une seconde chambre à air (34R, 134R, 34L, 134L) fixé sur le châssis sur le second côté du plan vertical longitudinal médian (P) du châssis, le procédé comprenant l'alimentation en air et l'évacuation d'air des moyens pneumatiques additionnels (18L, 18R ; 118L, 118R), **caractérisé en ce que** ladite alimentation en air est effectuée en fonction d'au moins un signal ou plusieurs signaux dérivé(s) des pressions des premier et/ou second ressorts à air secondaires (22L, 22R).

**18.** Procédé selon la revendication 17, comprenant :

- la mesure d'une différence de pression entre les premier et second ressorts à air secondaires (22L, 22R) au fil du temps et
- l'alimentation en air des moyens pneumatiques additionnels en fonction d'au moins la différence de pression mesurée au fil du temps.

**19.** Procédé selon la revendication 17, comprenant l'alimentation en air de la première chambre à air (34L, 134L, 34R, 134R) en fonction de la pression de l'un des premier et second ressorts à air secondaires (22L, 22R) et l'alimentation en air de la seconde chambre à air (34R, 134R, 34L, 134L) en fonction de la pression de l'autre des premier et second ressorts à air secondaires (22L, 22R).

**20.** Procédé selon l'une quelconque des revendications 17 to 19, dans lequel les moyens pneumatiques additionnels incluent une suspension primaire pour supporter verticalement le châssis (16) sur l'ensemble de roues, la première chambre à air (34L, 134L, 34R, 134R) étant un premier ressort à air primaire disposé sur le premier côté d'un plan vertical longitudinal médian (P) du châssis et la seconde chambre à air (34R, 134R, 34L, 134L) étant un second ressort à air primaire disposé sur le second côté du plan vertical longitudinal médian (P) du châssis, dans lequel le procédé comprend l'alimentation en air du premier ressort à air primaire (34L, 134L, 34R, 134R) et/ou du second ressort à air primaire (34R, 134R, 34L, 134L) de telle manière que la différence de pression entre le premier ressort à air primaire et le second ressort à air primaire est une fonction croissante positive d'une différence de pression entre le premier ressort à air secondaire (22L, 22R) et le second ressort à air secondaire (22L, 22R).

**21.** Procédé selon la revendication précédente, dans lequel la fonction croissante positive est une fonction linéaire.

**22.** Procédé selon l'une quelconque des revendications 17 à 21, dans lequel les moyens pneumatiques additionnels (18L, 18R, 118L, 118R) incluent des moyens (118L, 118R) permettant de commander le déplacement latéral du châssis par rapport à la superstructure perpendiculairement au plan vertical longitudinal médian (P) du châssis, le procédé comprenant l'alimentation en air des moyens pneumatiques additionnels de telle manière que le châssis fléchit latéralement en direction de celui des premier et second ressorts à air secondaires (22L, 22R) qui rencontre la pression la plus élevée.

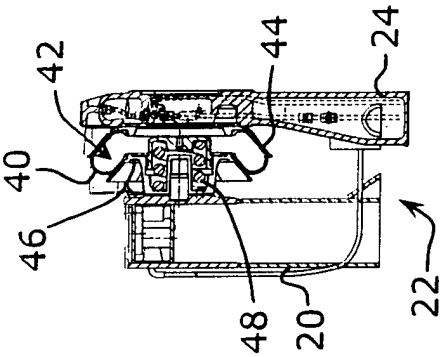



Fig. 3

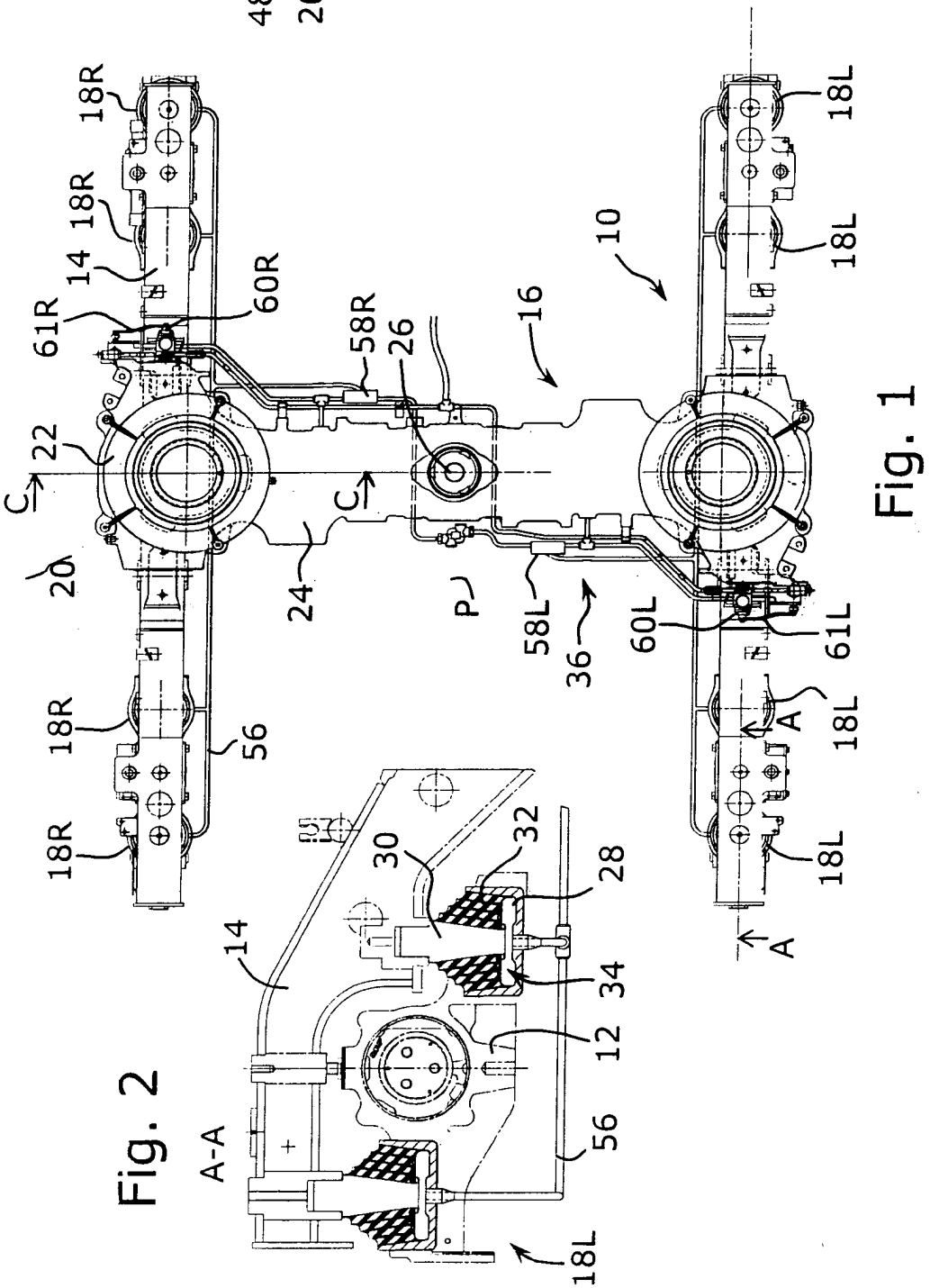



Fig. 2

Fig. 1

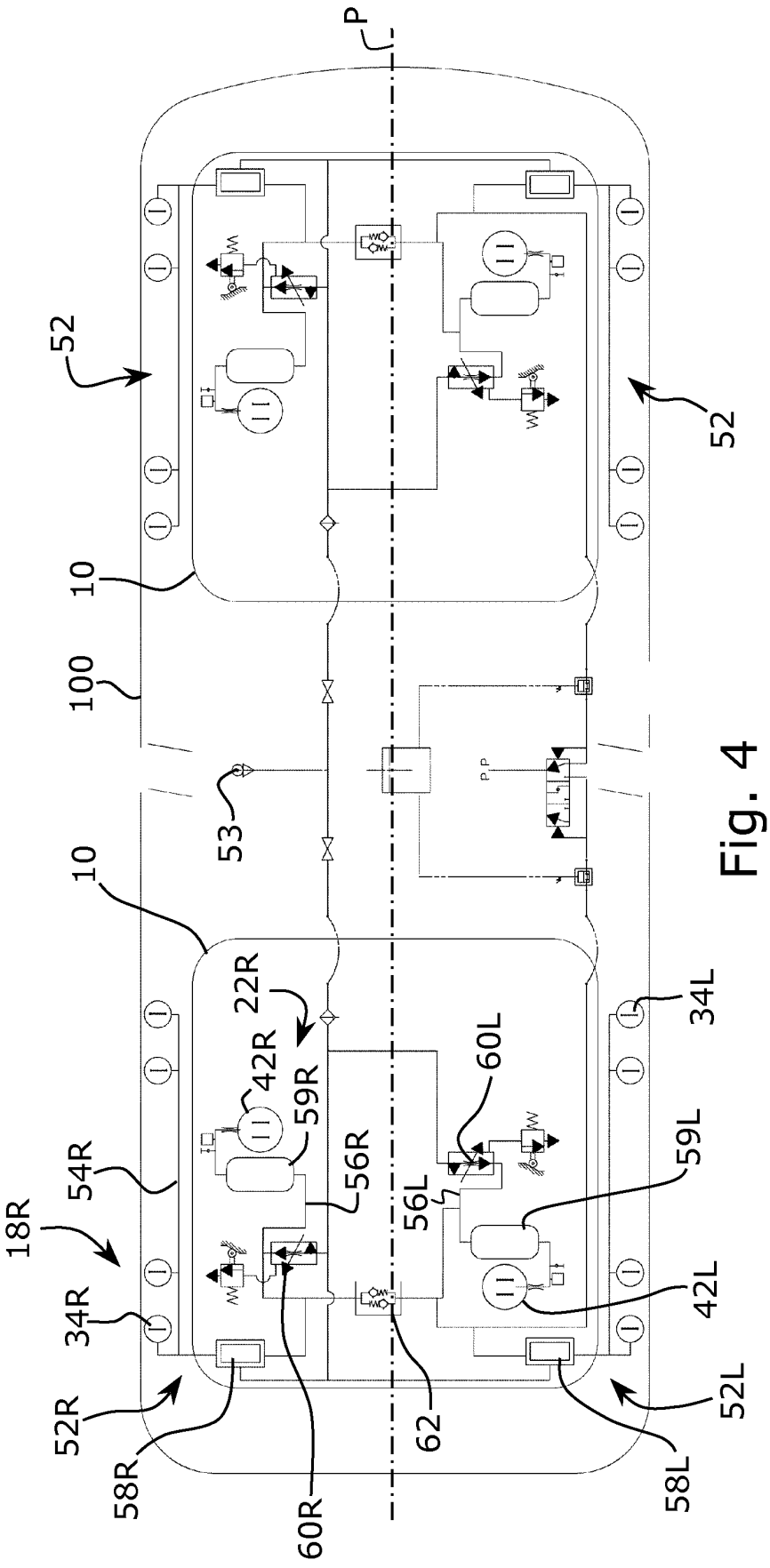

P
52
52
10
100
53
10
22R
42R
59R
56R
54R
18R
34R
52R
58R
60R
62
56L
60L
59L
42L
34L
52L
58L
P P

Fig. 4

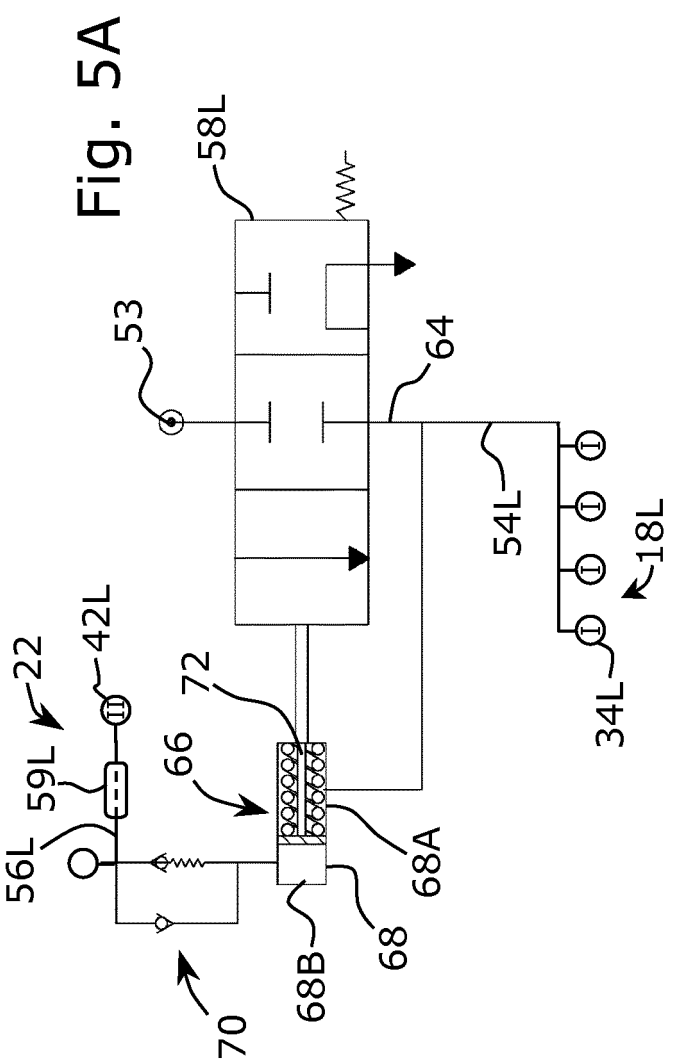



Fig. 5A

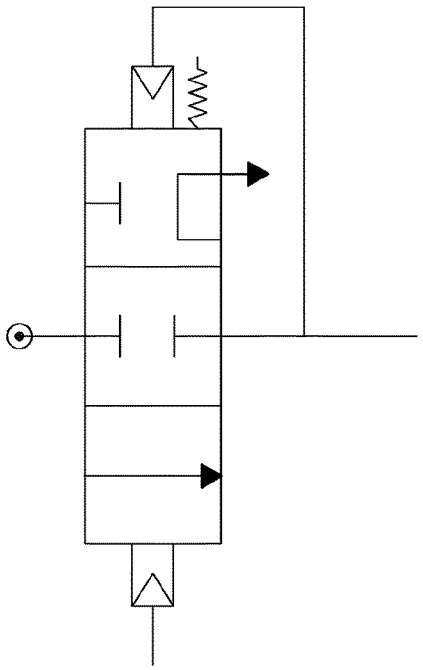


Fig. 5B

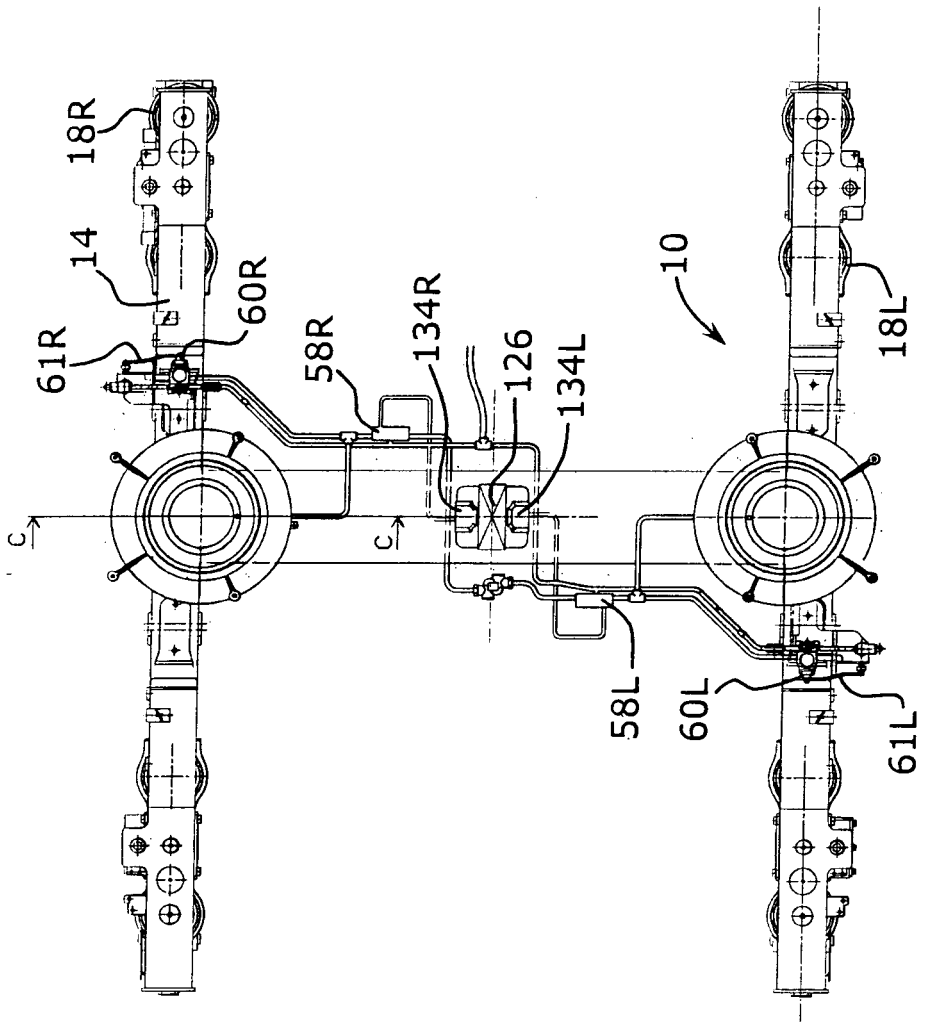

18R
14
60R
61R
58R
134R
126
134L
10
18L
C
C
58L
60L
61L

Fig. 6

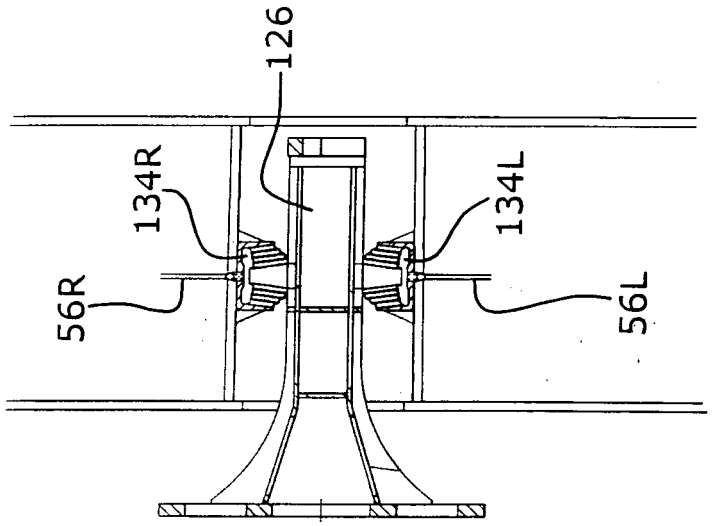

126
134R
134L
56R
56L

Fig. 7

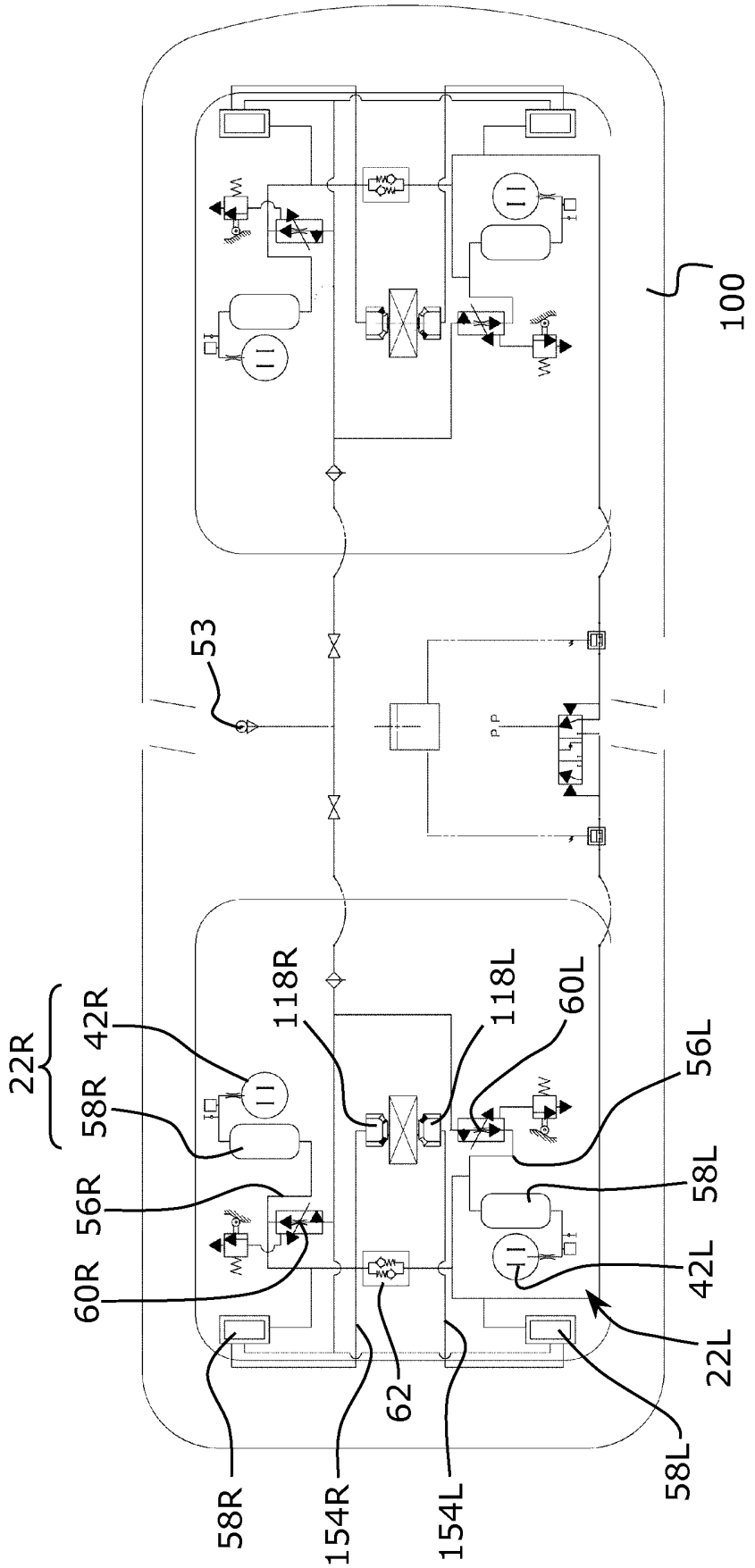

100
53
22R
42R
58R
56R
60R
118R
118L
60L
56L
58L
42L
22L
58L
58R
154R
62
154L

Fig. 8

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- US 3738680 A **[0002]**
- US 4693185 A **[0003]**
- DE 3048516 A1 **[0004]**