



(22) Date de dépôt/Filing Date: 2015/01/15

(41) Mise à la disp. pub./Open to Public Insp.: 2015/07/21

(30) Priorité/Priority: 2014/01/21 (EP14151987.6)

(51) Cl.Int./Int.Cl. *B60G 5/047* (2006.01),
B60G 13/08 (2006.01), *B60G 17/00* (2006.01),
B60G 17/017 (2006.01), *B60G 3/28* (2006.01),
B64C 25/58 (2006.01), *F16F 9/54* (2006.01)

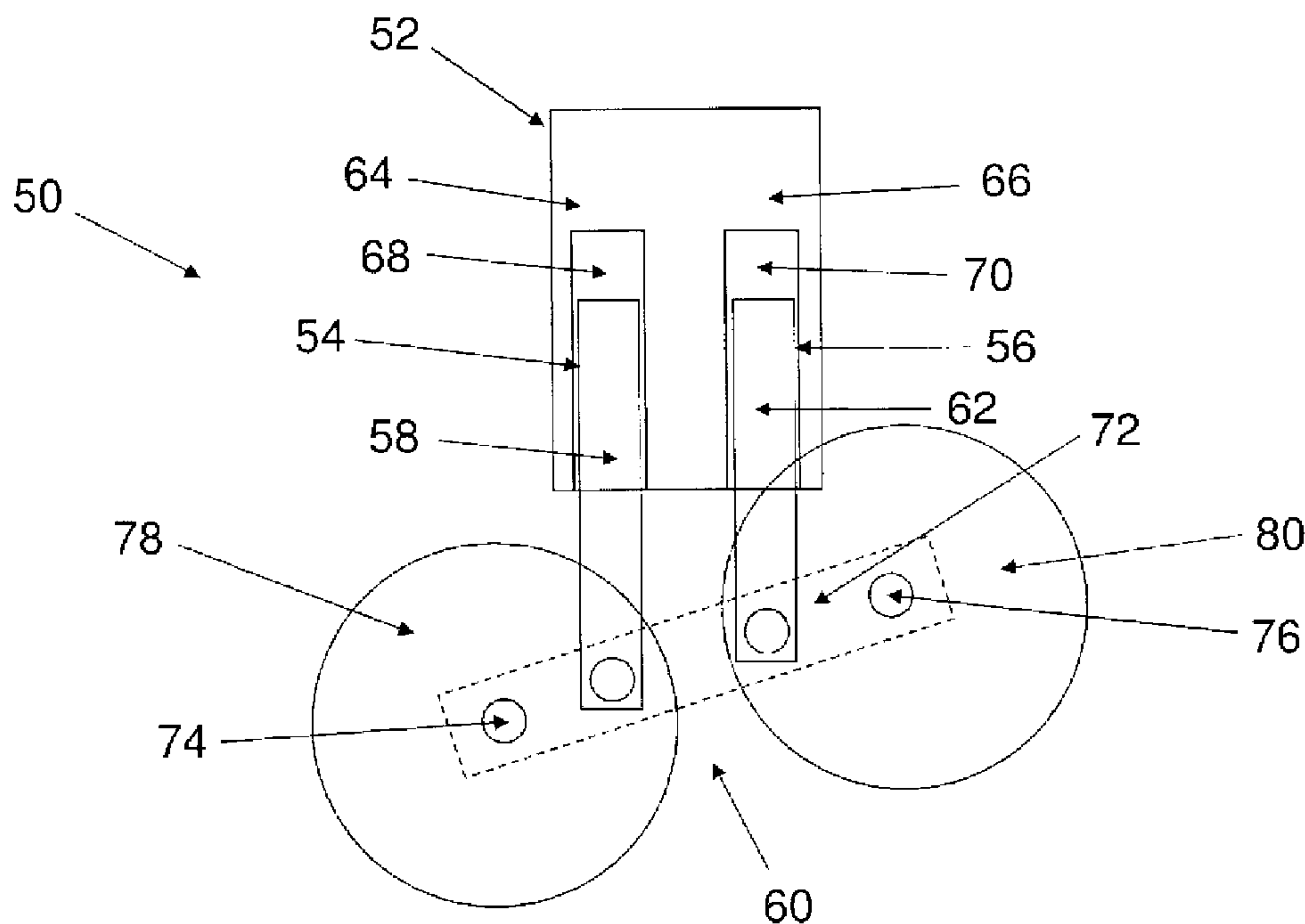
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(54) Titre : ENSEMBLE AMORTISSEUR

(54) Title: SHOCK ABSORBER ASSEMBLY



(57) Abrégé/Abstract:

A shock absorber assembly (50) arranged to be coupled to a vehicle, the shock absorber assembly (50) comprising: a wheel assembly (60) including a first coupling point and a second coupling point; a first shock absorber element, the first shock absorber element comprising: a first housing portion (64) defining a first bore (54); and a first rod (58), slidably coupled within the first bore (54) such that the first shock absorber element has a variable length, the first rod (58) being coupled to the first coupling point of the wheel assembly (60); and a second shock absorber element comprising: a second housing portion (66) defining a second bore (56); and a second rod (62), slidably coupled within the second bore (56) such that the second shock absorber element has a variable length, the second rod (62) being coupled to the second coupling point of the wheel assembly (60), wherein the shock absorber assembly (50) is arranged to maintain the relative positions of the first and second housing portions (64, 66) such that the longitudinal axis of the first bore (54) has a generally fixed relationship with respect to the longitudinal axis of the second bore (56).

ABSTRACT

5 A shock absorber assembly (50) arranged to be coupled to a vehicle, the shock
absorber assembly (50) comprising: a wheel assembly (60) including a first coupling
point and a second coupling point; a first shock absorber element, the first shock
absorber element comprising: a first housing portion (64) defining a first bore (54);
and a first rod (58), slidably coupled within the first bore (54) such that the first shock
10 absorber element has a variable length, the first rod (58) being coupled to the first
coupling point of the wheel assembly (60); and a second shock absorber element
comprising: a second housing portion (66) defining a second bore (56); and a second
rod (62), slidably coupled within the second bore (56) such that the second shock
absorber element has a variable length, the second rod (62) being coupled to the
15 second coupling point of the wheel assembly (60), wherein the shock absorber
assembly (50) is arranged to maintain the relative positions of the first and second
housing portions (64, 66) such that the longitudinal axis of the first bore (54) has a
generally fixed relationship with respect to the longitudinal axis of the second bore
(56).

SHOCK ABSORBER ASSEMBLY

Technical Field

The present invention relates to a shock absorber assembly arranged to be coupled to
5 a vehicle.

Background to the Invention

Current shock absorber assemblies generally comprise a cylinder and a sliding rod in
a telescopic configuration. Additional external elements are provided to mechanically
10 connect the cylinder to the sliding rod in order to inhibit rotation of the rod relative to
the cylinder; for example, in the context of aircraft landing gear, a torque link.

The present inventors have realised that known shock absorber assemblies can be
improved in terms of one or more of: simplicity; weight; strength/robustness;
15 aerodynamic performance and aeroacoustic performance.

Summary of Invention

According to a first aspect of the present invention there is provided a shock absorber
assembly arranged to be coupled to a vehicle, the shock absorber assembly
20 comprising:

- a wheel assembly including a first coupling point and a second coupling
point;
- a first shock absorber element, the first shock absorber element comprising:
 - a first housing portion defining a first bore; and
 - 25 - a first rod, slidably coupled within the first bore such that the length
of the first shock absorber element can be varied, the first rod being coupled to the
first coupling point of the wheel assembly; and
- a second shock absorber element comprising:
 - a second housing portion defining a second bore; and
 - 30 - a second rod, slidably coupled within the second bore such that the
length of the second shock absorber element can be varied, the second rod being

coupled to the second coupling point of the wheel assembly, wherein the shock absorber assembly is arranged to maintain the position of the first housing portion relative to the position of the second housing portion such that the longitudinal axis of the first bore has a generally fixed relationship with respect to the longitudinal axis of the second bore.

Thus, the shock absorber assembly according to the first aspect is arranged to inhibit unwanted rotation of the wheel assembly; a torsion force acting on one of the shock absorber elements is reacted by the other shock absorber element.

10

According to a second aspect of the present invention there is provided a shock absorber assembly arranged to be coupled to a vehicle, the shock absorber assembly comprising:

a shock absorber element comprising:

15

a housing portion defining a linear bore having a non-circular cross section; and

an elongate rod slidably coupled within the bore to permit axial movement of the rod, the rod having a non-circular profile arranged to engage with the bore to inhibit rotation of the rod relative to the housing

20

Thus, the shock absorber assembly according to the second aspect is arranged to inhibit unwanted rotation of the wheel assembly; a torsion force acting on the rod is reacted by the non-circular side wall profile of the rod. The shock absorber assembly according to the second aspect therefore provides an alternative solution to the technical problem of inhibiting rotation of the rod in comparison to that of the first aspect.

The first and second rods are slidably coupled within the first and second bores so that the length of the shock absorber elements may be varied by varying the position of the rods along the longitudinal axes of the bores. The length of each of the first and second shock absorber elements may each be independently variable.

30

The shock absorber assembly may comprise three or more shock absorber elements, each shock absorber element having a respective housing portion and a rod coupled to a respective coupling point the wheel assembly.

- 5 A plurality of the shock absorber elements may have different shock absorbing properties resulting in, for example, different spring curves and/or levels of damping. This may be achieved by different shock absorber designs.

10 The first housing portion and the first rod may together define a first chamber for containing a first fluid.

The first fluid may comprise any fluid suitable for use in a shock absorber and may be liquid or gas or a combination thereof. For example, the first fluid may comprise oil or gas or a combination of the two.

15

In some embodiments the second housing portion and the second rod may together define a second chamber for containing a second fluid.

20 The second fluid may comprise any fluid suitable for use in a shock absorber and may be liquid or gas or a combination thereof; for example, the second fluid may be oil or gas or a combination of the two.

25 Thus, in some embodiments, the different shock absorbing properties of the first and second shock absorber may be achieved by providing different amounts of fluid in the shock absorber. Additionally or alternatively, different types of shock absorbing fluid could be provided in the first and second chambers to cause the first and second shock absorber elements to have different shock absorbing properties.

30 An advantage of providing first and second shock absorber elements which have different shock absorbing properties from each other is that a two-stage shock absorption function may be achieved. If more than two shock absorber elements are used, a multi-stage or quasi continuously variable shock absorption function may be

achieved. Thus the overall shock absorbing properties of the shock absorber assembly may vary depending on the force applied to the shock absorber assembly.

Each of the first and second rods may be coupled to the wheel assembly via a lug or
5 other suitable coupling means.

The length of the first shock absorber element may be different from the length of the second shock absorber element when the shock absorber assembly is in a first condition.

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For example, the vehicle may be an aircraft and the first condition may be when the aircraft is in the air, with no ground loads acting on the shock absorber assembly. The first and second shock absorber elements may automatically assume different lengths when the aircraft is in the air. A second condition may be when the aircraft is on the
15 ground, in which case the ground loads acting on the shock absorber assembly may automatically cause the shock absorber elements to assume the same length. Thus, the wheel assembly may be caused to assume a first angular orientation relative to the first housing portion when the aircraft is in the air, and a different angular orientation with respect thereto when the aircraft is on the ground, without the need for additional
20 external elements such as a pitch trimmer.

The wheel assembly may include a bogie beam, pivotally coupled to the first and second rods.

25 The first and second housing portions may be defined by a unitary housing; for example, in some embodiments, the first and second bores may be defined by a single cylinder such as a main fitting of an aircraft landing gear. An advantage of defining the first and second housing portions by a unitary housing is that this may improve the aerodynamic and aeroacoustic properties of the shock absorber assembly over known
30 systems which include external torque links or the like.

One or more of the shock absorber elements may be in fluid communication with a reservoir containing the first and/or second fluid, the shock absorber assembly further

comprising a control system operable to control fluid transfer between the one or more shock absorber elements and the reservoir such that the length of the one or more shock absorber elements may be controlled by controlling the amount of fluid in the chambers thereof.

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Thus the length of at least one of the shock absorber elements may be actively controlled. This gives rise to an advantage that the orientation of the wheel assembly can be controlled and changed between two or more different orientations by changing the amount of fluid in one or more of the shock absorber elements.

10

In some embodiments, only the first shock absorber element may be connected to a reservoir. In this case, the length of the first shock absorber element can be controlled and the orientation of the wheel assembly may be controlled by controlling the length of the first shock absorber element to change the relative lengths of the first and second shock absorber elements.

15

Alternatively, both the first and second shock absorber elements may be connected to a reservoir, enabling the length of both of the shock absorber elements to be controlled by controlling the amount of fluid present in the chambers of the shock absorber elements at any given time. The first and second shock absorber elements may be in fluid communication with a single reservoir or the first and second shock absorber elements may each be in fluid communication with a separate reservoir. The lengths of the first and second shock absorber elements may be changed relative to each other, in order to change the orientation of the wheel assembly. Additionally or alternatively, the lengths of the first and second shock absorber elements may be increased or decreased together in order to alter the distance between the wheel assembly and the vehicle.

20

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Additionally or alternatively, the first and second shock absorber elements may be in fluid communication with each other and the shock absorber assembly may further comprise a control system operable to control fluid transfer between the shock absorber elements such that the relative lengths of the shock absorber elements may be controlled by controlling the amount of fluid exchanged between the chambers

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thereof. In some embodiments comprising more than two shock absorber elements, more than two of the shock absorber elements may be in fluid communication with each other.

- 5 An advantage associated with using the shock absorber elements to control the orientation of the wheel assembly is that an external element such as a pitch trimmer may not be required. Moreover, the shock absorber elements may be able to apply a greater force to the wheel assembly than alternative systems for controlling the orientation of a wheel assembly such as a pitch trimmer. Thus, the orientation of the
10 wheel assembly may be controlled even when the wheel assembly is experiencing large loads, such as from the weight of the vehicle, which is the context of aircraft may be in excess of 30 tonnes.

- An advantage associated with using the shock absorber elements to alter the distance
15 between the wheel assembly and the vehicle is that the ride height of the vehicle may be increased or decreased as required. For example, in some embodiments in which the vehicle is an aircraft, the ride height of the aircraft may be increased during landing or take-off when the tail of the aircraft is at risk of hitting the ground.

- 20 In some embodiments, the wheel assembly may include two or more wheels and the control system may be operable to lift at least one of the wheels off the ground when the vehicle is on the ground.

- In some embodiments, the wheel assembly may include two or more sets of wheels,
25 each set coupled to an axle, and the control system may be operable to lift at least one of the sets of wheels off the ground when the vehicle is on the ground.

- The control system being operable to lift at least one of the wheels or one set of wheels off the ground gives rise to increased manoeuvrability of the vehicle. For
30 example, manoeuvrability of a vehicle such as an aircraft may be increased by lifting an axle of the wheel assembly off the ground to enable the vehicle to make tighter turns. This is particularly advantageous when the wheel assembly does not have a

steering mechanism as in this case the forces exerted on the wheel assembly are reduced which may prevent twisting of the shock absorber assembly.

According to a third aspect of the invention, there is provided an aircraft landing gear
5 comprising a shock absorber assembly in accordance with the first or second aspects of the invention.

Brief Description of the Drawings

10 Embodiments of the invention will now be described, strictly by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation showing a side view of a known landing gear shock absorber assembly;

15

Figure 2 is a schematic representation showing a cross-sectional view through a housing of a known shock absorber assembly;

Figure 3 is a schematic representation showing a side view of a shock absorber
20 assembly according to an embodiment of the invention;

Figure 4 is a schematic representation showing a cross-sectional view through a housing of the shock absorber assembly of Figure 3;

25 Figure 5 is a schematic representation showing a side view of the shock absorber assembly of Figure 3 in a first condition;

Figure 6 is a schematic representation showing a side view of an actively controllable shock absorber assembly according to an embodiment of the invention; and

30

Figures 7a and 7b are a schematic representations each showing a cross-sectional view through a housing of a shock absorber assembly according to a further embodiment of the invention.

5 Description of the Embodiments

Referring first to Figure 1, a known aircraft landing gear shock absorber assembly, is shown generally at 10. The shock absorber assembly has a cylindrical housing 12, also referred to as a main fitting of the landing gear. A first end of a cylindrical rod 14 is slidably coupled within a bore, formed within the housing 12. A second end of the rod 14 which is disposed outside of the housing 12, is coupled to a wheel assembly 16.

The wheel assembly 16 comprises a bogie beam 18 and first and second axles 20, 22 coupled to the bogie beam 18, the first and second axles 20, 22 supporting first and second sets of wheels 24, 26. Each of the first and second sets of wheels 24, 26 may consist of a single wheel or a plurality of wheels.

The housing 12 and the first rod 14 together define a chamber for containing a fluid. The fluid may be liquid such as oil, or gas such as air or nitrogen. The chamber may include both gas and liquid, for example, a oleo-pneumatic shock absorption system may be used.

A torque link 30 couples the rod 14 to the housing 12 to inhibit relative rotation between the housing 12 and the rod 14.

The aircraft landing gear includes a pitch trimmer actuator 32. The pitch trimmer actuator 32 is connected at one end to the bogie beam 16 and at the other end to the rod 14 via a mechanical linkage in a triangular configuration. The pitch trimmer actuator 32 may be a hydraulic, pneumatic or electrical actuator.

Figure 2 shows a cross-sectional view through the housing 12 of the shock absorber assembly 10 of Figure 1. A single cylindrical bore 34 is formed within the housing 12.

The longitudinal axis of the bore is parallel to the longitudinal axis of the housing. A cylindrical rod 14 is slidably coupled within the bore 34.

- 5 When torsion loads are applied to the rod 14, such as the force indicated by arrow T, rotation of the rod can occur, which can lead to unwanted rotation of the wheel assembly 16. The torque link 30 inhibits rotation of the rod 14 relative to the housing 12.
- 10 In Figure 3 a shock absorber assembly according to an embodiment of the invention is shown generally at 50. The shock absorber assembly 50 comprises a cylindrical housing 52, which in some embodiments may be the main fitting of an aircraft landing gear. Within the housing there is a first bore 54, and a second bore 56. The first and second bores 54, 56 are cylindrical in shape. The longitudinal axis of the first bore 54
- 15 is generally parallel with respect to the longitudinal axis of the second bore 56. In the embodiment shown in Figure 3, the first and second bores have the same length and diameter. However in other embodiments the first and second bores 54, 56 may have different shapes, lengths and/or diameters.
- 20 The shock absorber assembly further comprises a first rod 58, which is cylindrical in shape, coupled within the first bore 54 at a first end. The cross-sectional dimensions of the first rod 58 and the first bore 54 are complementary such that the first rod 58 is free to slide within the first bore 54 along the longitudinal axis of the first bore 54. The travel of the first rod 58 is limited by conventional means such as a shoulder
- 25 portion or other type of end stop. A second end of the first rod 58 extends out of the first bore 54. The second end of the first rod 58 is coupled to a wheel assembly 60

The shock absorber assembly further comprises a second rod 62, which is cylindrical in shape, coupled within the second bore 56 at a first end. The cross-sectional

30 dimensions of the second rod 62 and the second bore 56 are complementary such that the second rod 62 is free to slide within the second bore 56 along the longitudinal axis of the second bore 56. The travel of the second rod 62 is limited by conventional means such as a shoulder portion or other type of end stop. A second end of the

second rod 62 extends out of the second bore 54. The second end of the second rod 62 is coupled to the wheel assembly 60.

The length of the first rod 58 is greater than the length of the second rod 62. However,
5 in other embodiments the length of the first rod 58 may be equal to or shorter than the length of the second rod 62.

The diameter of the first rod 58 is equal to the diameter of the second rod. However in
10 other embodiments the diameter of the first rod 58 may be different from the diameter of the second rod 62.

The housing 52 includes a first housing portion 64, within which the first bore 54 is disposed. The first portion of the housing 64, the first bore 54 and the first rod 58 collectively make up a first shock absorber element. The housing 52 also includes a
15 second housing portion 66, within which the second bore 56 is disposed. The second housing portion 66 of the housing 52, the second bore 56 and the second rod 62 collectively make up a second shock absorber element. The first and second shock absorber elements therefore define a parallel coupling between the aircraft, on the one hand, and the wheel assembly 60, on the other hand such that the longitudinal axis of
20 the first bore has a generally fixed relationship with respect to the longitudinal axis of the second bore.

The first housing portion 64 and the first rod 58 together define a first chamber 68 for containing a fluid. The fluid may be liquid such as oil, or gas such as air or nitrogen.
25 The chamber 68 may include both gas and liquid, for example, an oleo-pneumatic shock absorption system may be used.

The second housing portion 66 and the second rod 62 together define a second chamber 70 for containing a fluid. The fluid may be liquid such as oil or gas such as
30 air or nitrogen. The chamber 70 may include both gas and liquid, for example, a oleo-pneumatic shock absorption system may be used.

The wheel assembly 60 comprises a bogie beam 72 and the first and second rods 58, 62 are each pivotally coupled to the bogie beam 72 such that the first and second rods 58, 62 are aligned parallel to each other. The wheel assembly 60 further comprises first and second axles 74, 76, coupled to the bogie beam, the first and second axles 74, 76 supporting first and second sets of wheels 78, 80. Each of the first and second sets of wheels may consist of a single wheel or a plurality of wheels 78, 80.

The skilled person will appreciate that in embodiments of the invention, any suitable types of wheel assembly could be used. For example, in some embodiments, the wheel assembly may comprise a single wheel or a set of wheels, having an axle to which the first and second rods may be coupled.

Figure 4 shows a cross-sectional view through the housing 52 of Figure 3. It can be seen that a torsion force T acting on the first rod 58 is reacted by the second rod 62. Therefore, rotation of the wheel assembly 60 is inhibited, since the first and second rods 58, 62 are each coupled to the wheel assembly 60.

Figure 5 shows the shock absorber assembly 50 in a first condition. In the example shown here, the first condition corresponds to the shock absorber assembly 50 bearing no load from the vehicle. The length of the first shock absorber element is different from the length of the second shock absorber element when the shock absorber assembly is in a first condition. The length of a shock absorber element may be the axial length from the second end of the rod of the shock absorber element to the end of the housing arranged to be coupled to the vehicle. In the example shown in Figure 5, the length of the first rod 58 is greater than the length of the second rod 62. The first and second bores 54, 56 are of equal length and the first and second housing portions 64, 66 are also of equal length. Therefore the length of the first shock absorber element is greater than the length of the second shock absorber element when the shock absorber assembly is in a first condition. Thus, the bogie beam is held in a tilted orientation in which the second set of wheels 80 is closer to the housing than the first set of wheels 78.

However, in some embodiments, shock absorber elements of different lengths may be achieved by differences in other dimensions of the shock absorber such as the length of the bore, or by the first rod and the first bore having cross-sections of different diameters to the second rod and the second bore. Additionally or alternatively, the
5 shock absorber elements may be provided with different levels or different types of shock absorbing fluid within the first and second chambers 68, 70.

Figure 6 shows an embodiment in which the lengths of the shock absorber elements can be actively controlled in order to change the orientation of the bogie beam, thereby eliminating the need for a pitch trimmer. The shock absorber assembly 90 is
10 shown in a first condition in which the weight of the vehicle is off the shock absorber assembly 90. Features 92 to 120 of shock absorber 90 correspond to features 52 to 80 of the shock absorber 50 shown in Figure 5 and therefore will not be described in detail here.

15

Shock absorber 90 additionally includes a control unit 122 which controls a valve 124. The valve 124 is in fluid communication with each of the first and second chambers 108, 110 via a tube 126. Thus, fluid flow between the two chambers may be controlled by the control unit 122. In embodiments of the invention, the valve 124
20 may be a restrictor valve arranged to provide various levels of fluid restriction through the tube 126. Many suitable valve and control unit configurations will be apparent to the skilled person and as such, for brevity, these are not described in detail.

In the example shown in Figure 6, the total amount of fluid in the first and second
25 chambers 108, 110 remains constant and the control system controls the proportion of the total amount of fluid present in each of the chambers at any given time. However, it will be appreciated that in other embodiments, one or more reservoirs of fluid, in fluid communication with one or both of the chambers 108, 110 may be provided. In that case, fluid may flow to one or both of the first and second chambers 108, 110
30 from the reservoir(s) via one or more valves controlled by one or more control units. Any suitable control system may be provided for modifying the length of one or both shock absorber elements in order to change the orientation of the bogie beam 72. An

example of a control circuit for supplying fluid to a shock absorber is described in US6120009A with reference to Figure 3.

Although embodiments of the invention have been described as having a plurality of
5 shock absorber elements, in other embodiments of the invention the shock absorber
assembly 130, 140 may, as illustrated in Figures 7a and 7b, consist of a single rod
134, 144 and bore each having non-circular cross sections so as to inhibit rotation of
the rod within the housing 132, 142. For example, the bore and/or rod may have one
of the following profiles: elliptical, rectangular or a figure of eight. Thus, the
10 elongate rod 134, 144 may be slidably coupled within the bore to permit axial
movement and may have a non-circular profile arranged to engage with the bore to
inhibit rotation of the rod relative to the housing.

Although the invention has been described above with reference to one or more
15 preferred embodiments, it will be appreciated that various changes or modifications
may be made without departing from the scope of the invention as defined in the
appended claims. The word "comprising" can mean "including" or "consisting of" and
therefore does not exclude the presence of elements or steps other than those listed in
any claim or the specification as a whole. The mere fact that certain measures are
20 recited in mutually different dependent claims does not indicate that a combination of
these measures cannot be used to advantage.

CLAIMS

1. A shock absorber assembly arranged to be coupled to a vehicle, the shock absorber assembly comprising:
- 5 a wheel assembly including a first coupling point and a second coupling point;
a first shock absorber element, the first shock absorber element comprising:
a first housing portion defining a first bore; and
a first rod, slidably coupled within the first bore such that the length of
the first shock absorber element can be varied, the first rod being coupled to the first
10 coupling point of the wheel assembly; and
a second shock absorber element comprising:
a second housing portion defining a second bore; and
a second rod, slidably coupled within the second bore such that the
length of the second shock absorber element can be varied, the second rod being
15 coupled to the second coupling point of the wheel assembly,
wherein the shock absorber assembly is arranged to maintain the relative positions of
the first and second housing portions such that the longitudinal axis of the first bore
has a generally fixed spatial relationship with respect to the longitudinal axis of the
second bore.
- 20 2. The shock absorber assembly of claim 1 wherein the length of the first shock
absorber element is different from the length of the second shock absorber element
when the shock absorber assembly is in a first condition.
- 25 3. The shock absorber assembly of claim 1 or 2 wherein the wheel assembly
includes a bogie beam.
4. The shock absorber assembly of any preceding claim comprising a housing
defining the first and second housing portions.
- 30 5. The shock absorber assembly of any of claims 1 to 3, wherein the first housing
portion is rigidly coupled to the second housing portion by a mechanical coupling
element.

6. The shock absorber assembly of any preceding claim wherein the first housing portion and the first rod together define a first chamber for containing a first fluid.

5 7. The shock absorber assembly of claim 6 wherein the second housing portion and the second rod together define a second chamber for containing a second fluid.

8. The shock absorber assembly of claim 6 or 7 wherein one or more of the shock absorber elements are in fluid communication with a reservoir, the shock absorber
10 assembly further comprising a control system operable to control fluid transfer between the one or more shock absorber elements and the reservoir such that the length of the one or more shock absorber elements may be controlled by controlling the amount of fluid in the chambers thereof.

15 9. The shock absorber assembly of any preceding claim wherein the first and second shock absorber elements are in fluid communication with each other, the shock absorber assembly further comprising a control system operable to control fluid transfer between the shock absorber elements such that the length of the one or more shock absorber elements may be controlled by controlling the amount of fluid
20 exchanged between the chambers thereof.

10. The shock absorber assembly of claim 8 or 9, wherein the wheel assembly includes two or more wheels and wherein the control system is operable to lift at least one of the wheels off the ground when the vehicle is on the ground.

25

11. The shock absorber assembly of claim 10 wherein the wheel assembly includes two or more sets of wheels, each set coupled to an axle, and wherein the control system is operable to lift at least one of the sets of wheels off the ground when the vehicle is on the ground.

30

12. A shock absorber assembly arranged to be coupled to a vehicle, the shock absorber assembly comprising:

a shock absorber element comprising:

a housing portion defining a linear bore having a non-circular cross section; and

an elongate rod slidably coupled within the bore to permit axial movement of the rod, the rod having a non-circular profile arranged to engage with
5 the bore to inhibit rotation of the rod relative to the housing.

13. A shock absorber assembly according to claim 13, wherein the bore and/or rod have an elliptical or rectangular profile.

10 14. An aircraft landing gear comprising a shock absorber assembly in accordance with any preceding claim.

15. A shock absorber assembly or aircraft landing gear substantially as herein described with reference to figures 3 to 7.

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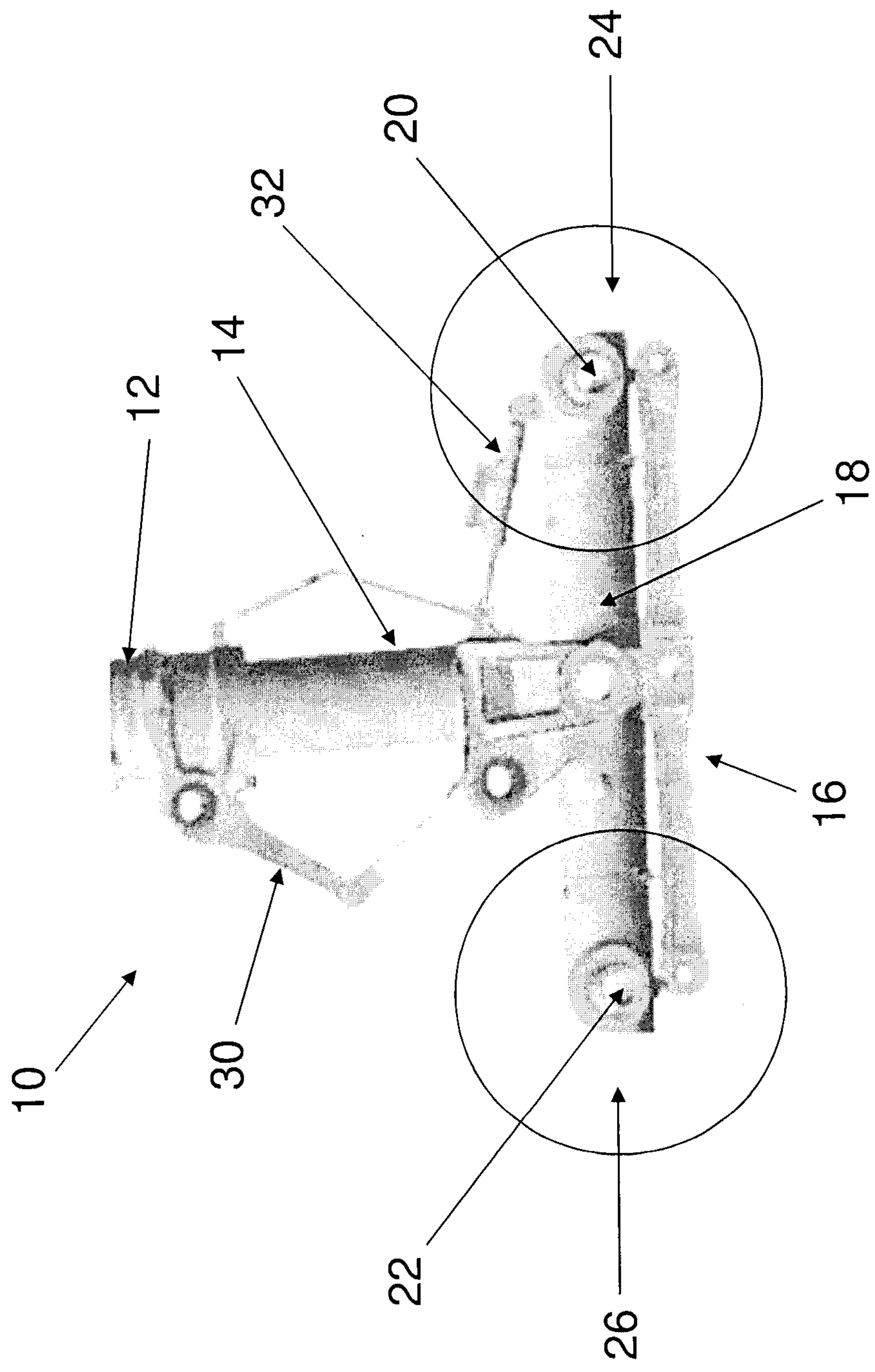


Figure 1

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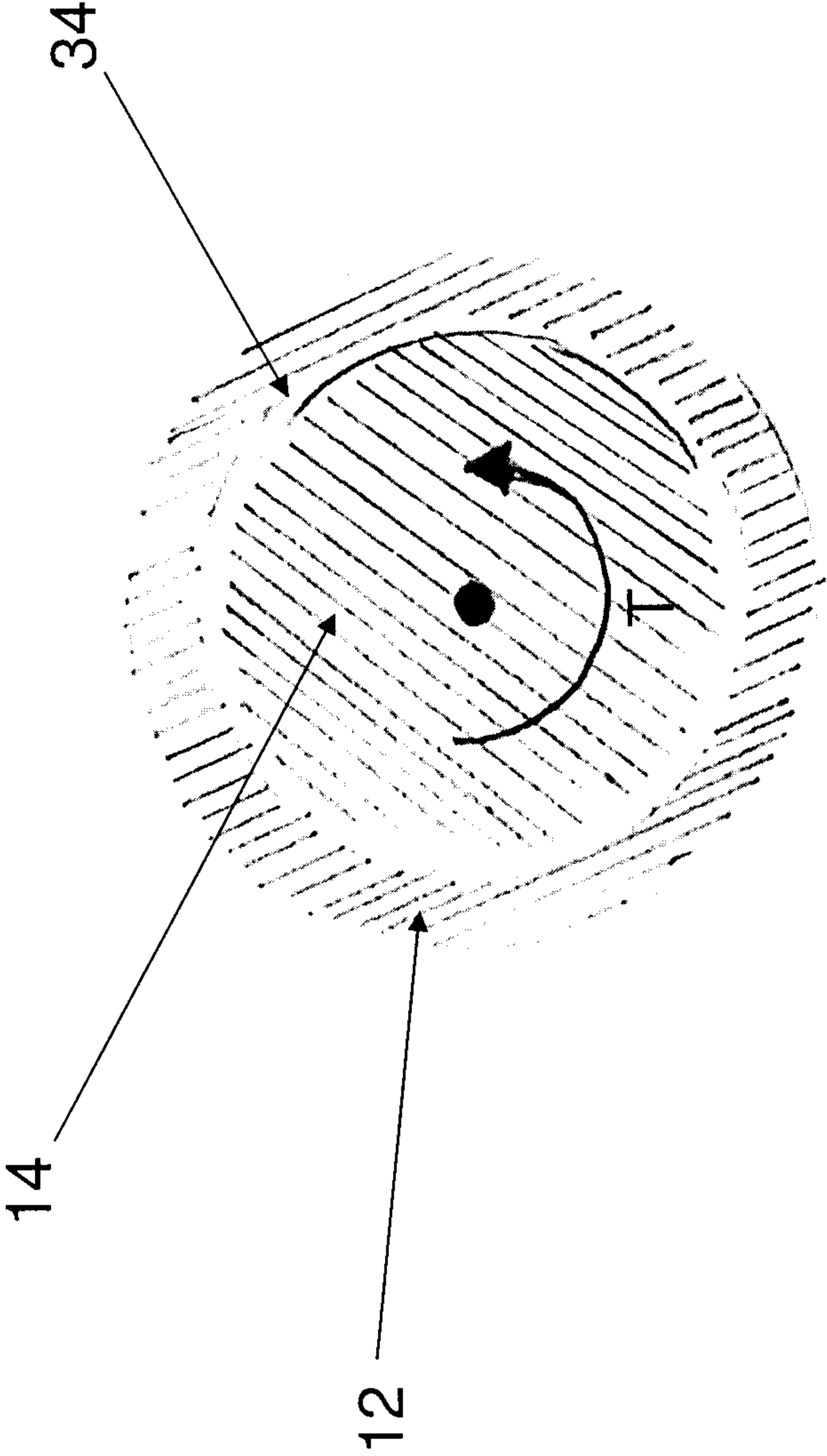


Figure 2

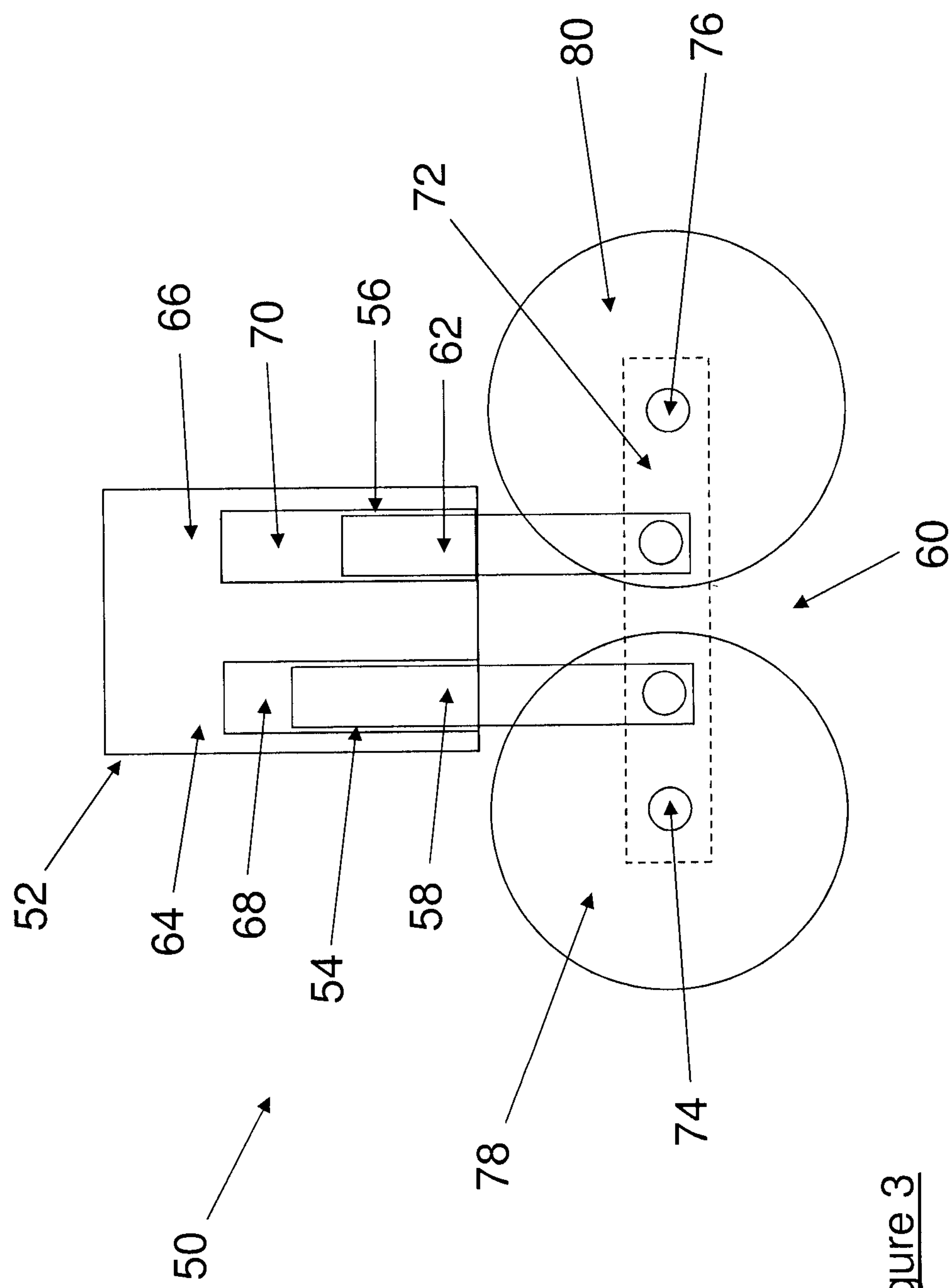


Figure 3

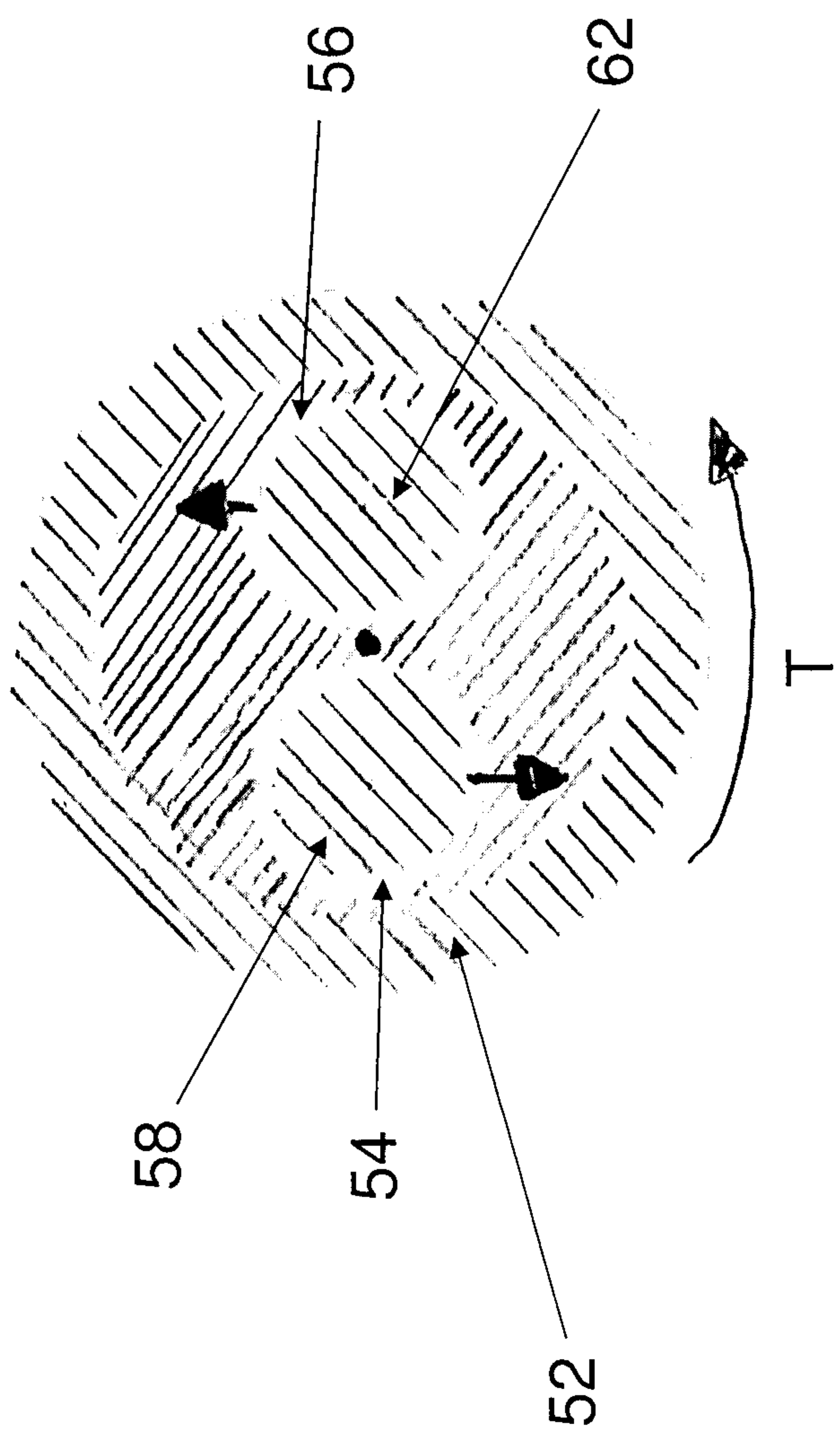


Figure 4

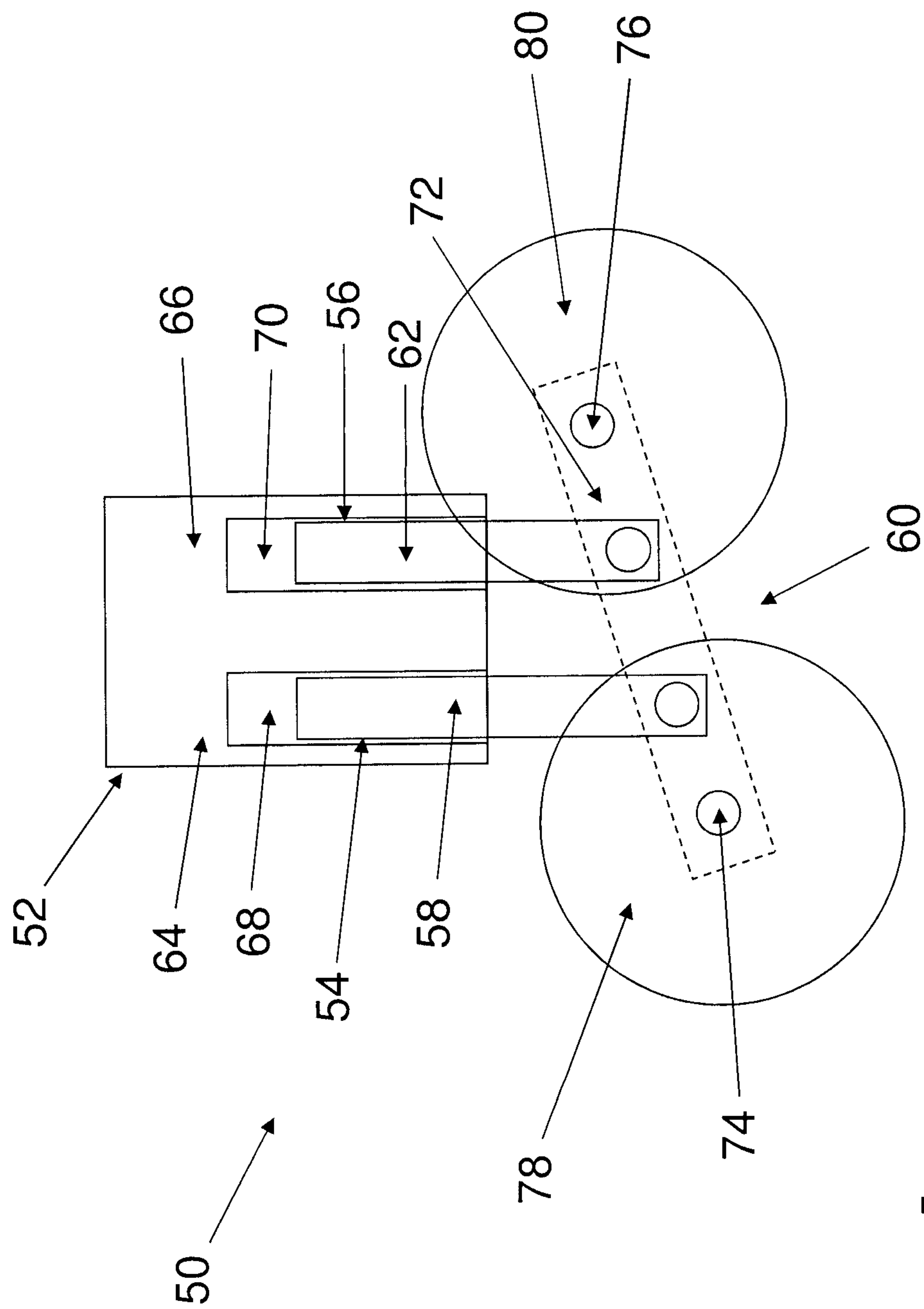


Figure 5

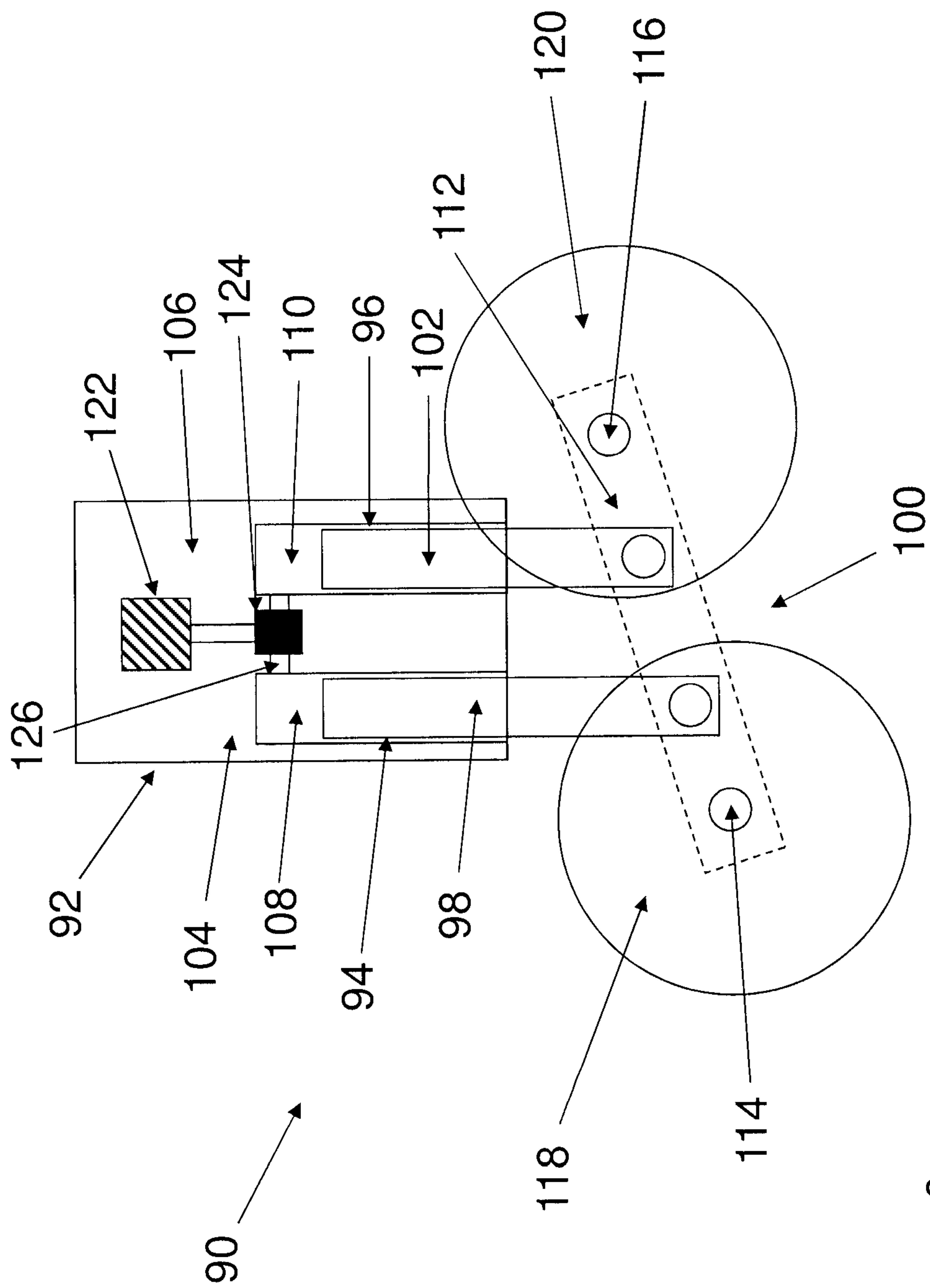


Figure 6

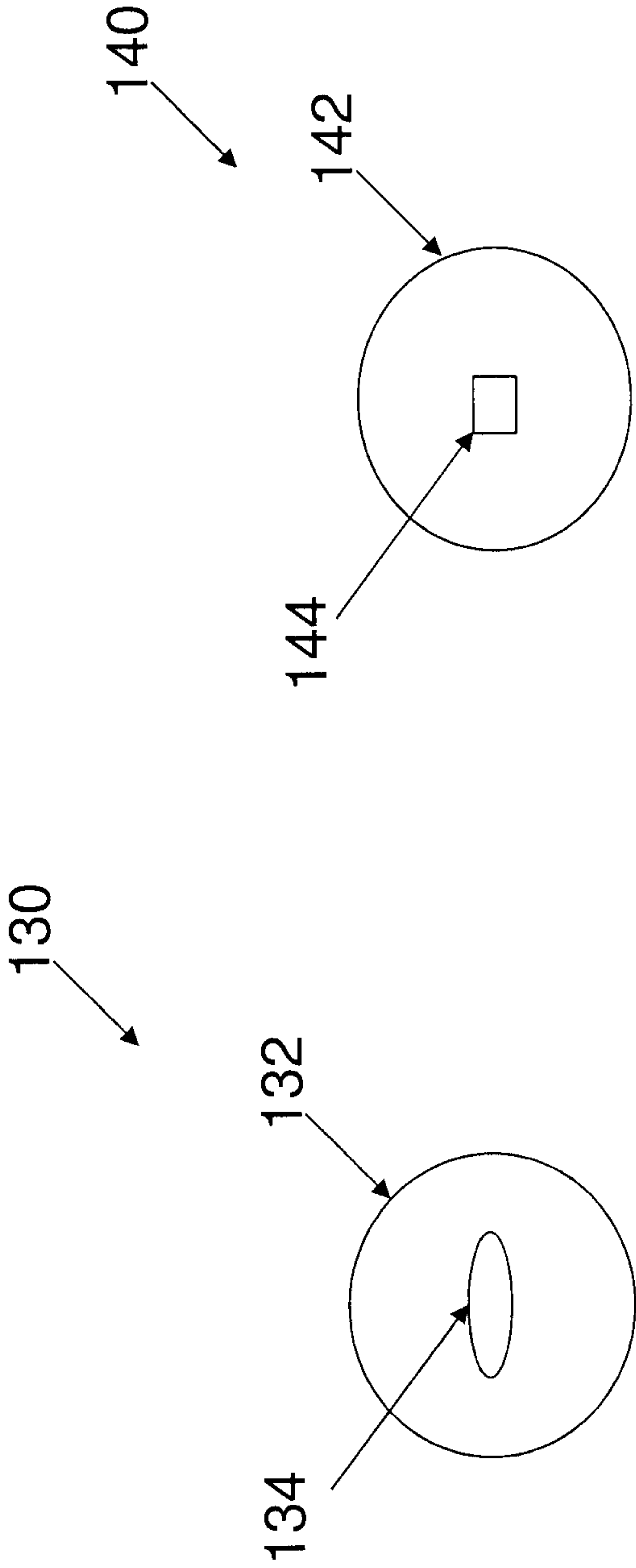


Figure 7a

Figure 7b

