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AGRICULTURAL IMPLEMENT WITH IMPROVED INCLINATION CONTROL

Description

The invention relates to an agricultural implement. Furthermore, the invention relates to a method for controlling and/or regulating an agricultural implement.

- 5 A wide variety of agricultural implements are known for spreading materials such as fertilizers, pesticides or seeds, for example field sprayers. In order to spread the material over a large area and efficiently on the field soil to be worked, the agricultural implement has a distributor boom with a plurality of dispensing elements, such as spray nozzles. The distributor linkage extends transversely to
- 10 the direction of travel and can have working widths of up to 40 m. During operation, the distance between the distributor boom and the ground should remain as constant as possible across the entire working width of the distributor boom. This means that the distributor boom is kept as parallel as possible to the ground to be worked, even if the ground to be worked is uneven.
- 15 It is problematic if the agricultural vehicle drives in ruts of varying depths in the ground, on one side in a furrow or on a slope in the field to be worked. Such uneven ground can cause the ends of the distributor boom to come into contact with the ground and/or plants and become damaged. In addition, the homogeneous distribution of the material to be applied is no longer possible due to
- 20 the inclined position of the distributor boom to the ground, and thus a larger or smaller distance between the ground and individual nozzles.

In order to compensate for this inclination and undesired movements about the longitudinal vehicle axis, devices are known which have a pendulum suspension and inclination sensors or distance sensors, and which attempt to establish a

25 constant distance from the ground via actuating devices.

The inclination adjustment of the arms of the distributor boom is often carried out by hydraulic cylinders and spring/damper systems that are connected to the corresponding arms. For example, reference is made to FR 2 795 913 A1, EP 1 167 095 A1 and EP 0 922 385 A1. The known control approaches use the

30 distance between the arm and the ground and/or the relative angle between the

arm and the tractor as measurement variables. The known control approaches have the disadvantage that they are inaccurate and do not allow real-time control.

Therefore, the field sprayer according to EP 1 444 894 A1 has a multi-link suspension in which both the signals from the distance measurement between
5 the arm and the ground and inclination signals which represent the relative inclination between the vehicle and the arm are included in the control. The arm is mounted on a height-adjustable lifting frame and can rotate about a rotation axis pointing in the direction of travel. A rotating intermediate frame is mounted coaxially with the arm on the lifting frame. The intermediate frame and the arm
10 are coupled together by two centering springs and a damper. A hydraulic cylinder is provided between the intermediate frame and the lifting frame.

To adjust the inclination, the hydraulic cylinder is extended or retracted and rotates the intermediate frame relative to the lifting frame. This lengthens one of the two centering springs and shortens the other. The spring force acting on the arm pulls
15 the arm according to the movement of the intermediate frame so that it is centered again in the inclined final position in relation to the intermediate frame. The centering springs also compensate for rapid relative movements between the vehicle and the arm, so that the arm remains stable in its position during operation.

The inclination control incorporates, on the one hand, the signals from the
20 ground clearance measurement between the arm and the ground and, on the other hand, an inclination signal which forms a measure of the spring force acting on the arm. This allows the hydraulic cylinder to be activated precisely. Oversteering of the arm is largely avoided.

However, this inclination control is slow. In addition, the structure with the
25 intermediate frame and the springs connected between the intermediate frame and the arm is complex.

DE 10 2017 104 814 A1 discloses an adjustment of the damping to reduce unwanted movements in or against the direction of travel.

The object of the present invention is therefore to provide an agricultural implement with improved inclination control. A further object of the invention is to provide a method for controlling an agricultural implement.

These objects are achieved by an agricultural implement according to claim 1 and a
5 method according to claim 11. Preferred embodiments are described in the dependent claims.

The agricultural implement can in particular be a field sprayer. The field sprayer can be self-propelled. It can also be a towed or carried sprayer. The hydraulic connecting line enables a direct coupling of the two hydraulic actuating elements. In other words,
10 a force applied to one of the two actuating elements can be transmitted to the other actuating element. The fact that each of the actuating devices and the connecting line is assigned a pressure control valve enables flexible inclination control of the distributor boom. Due to the corresponding activation of the pressure control and shut-off valves, the system allows both arms to be angled up and down together, one
15 arm to be angled up and down selectively, and the entire distributor boom to be tilted.

Here and in the following, the angling up and down of an arm is understood to mean a rotational movement of the arm about the given axis of rotation. In other words, angling up or down causes a change in the angle of the particular arm relative to the horizontal. When angled up, the corresponding arm moves away
20 from the ground and towards the central portion of the agricultural implement; and when angled down, it moves towards the ground. Tilting the distributor boom means angling up one arm while angling down the other arm accordingly.

In the agricultural implement according to the invention, changes in the inclination of the distributor boom can therefore be achieved, unlike in the known agricultural
25 implements described above, by directly controlling the arms. This means that an additional intermediate frame with a hydraulic cylinder is no longer necessary.

For example, a synchronous angling up or down of the two arms can be achieved as follows: the pressure control valves assigned to the corresponding actuating devices are activated in order to generate a pressure on the actuating
30 devices, which results in the arm being angled up or down. The movement of the actuating devices transmits a corresponding pressure to the fluid in the hydraulic

connecting line. Depending on the pressure change, fluid can flow out of the hydraulic connecting line or into the hydraulic connecting line.

Selective angling up or down of only one arm can be achieved in an analogous manner. In this case, the pressure control valve of the arm in question is activated to
5 supply the corresponding actuating device with a pressure that leads to the arm in question being angled up or down. The movement of the actuating device in turn transmits a corresponding pressure to the fluid in the hydraulic connecting line.

Depending on the pressure change, fluid can flow out of the hydraulic connecting line or into the hydraulic connecting line. The other actuating device, and thus the other
10 arm, is not affected, since any pressure transmission to the hydraulic connecting line is compensated for by the flow of fluid out of the connecting line. Furthermore, the pressure control valve of the other actuating device can be activated to maintain the applied pressure. This keeps the other arm in its current position.

On the other hand, the system also makes it possible to tilt the entire distributor
15 boom. For this purpose, the pressure control valve of one of the arms is activated in order to supply the corresponding actuating device with a pressure which leads to an angling up or down of this arm. Furthermore, the pressure control valve of the other arm is activated in order to supply the corresponding actuating device with a pressure which leads to an angling up or down of this arm. The
20 pressure control valve of the hydraulic connecting line can be activated to maintain the pressure there. Thus, the actuating devices communicate hydraulically, which leads to a uniform joint rotational movement of the two arms.

Furthermore, the first actuating device, the second actuating device and the connecting line can each be assigned a shut-off valve assigned to the
25 corresponding pressure control valve. Such a shut-off valve can be used in particular to prevent hydraulic fluid from flowing out of the corresponding actuating device or the connecting line. This allows each of the arms to be locked in a target position. This may be desirable, for example, in situations such as road transport or when extending and retracting the distributor boom, where the distributor boom
30 is to be rigidly connected to the agricultural implement via the actuating device.

The shut-off valves can also be used during the angling up or down and/or tilting processes described above.

This makes it possible, during a selective angling up or down, that for the other actuating device, the associated shut-off valve is closed as an alternative or in
5 addition to setting a pressure at the pressure control valve. This locks the corresponding arm and ensures that angling up or down one arm does not affect the other arm.

Similarly, for a tilting together, it is possible to close the shut-off valve assigned to the pressure control valve of the hydraulic connecting line. This prevents
10 hydraulic fluid from flowing out of the connecting line and ensures hydraulic communication between the actuating devices.

If shut-off valves are assigned to the pressure control valves, these shut-off valves can be closed after the angling up or down and/or tilting has ended in order to lock the actuating devices in a target actuating state.

15 The hydraulic devices can also be assigned one or more pressure sensors. The pressure sensors can be designed as pressure sensors for direct pressure measurement, in particular as pressure transducers. Such a design has the advantage that both relative pressure and absolute pressure can be determined. Furthermore, the pressure sensors can preferably be designed as differential
20 pressure transducers for determining a differential pressure or an occurring pressure difference. Advantageously, the pressure transducers can detect the pressure to be measured via a measuring membrane, which is mechanically deformed according to the corresponding pressure. This mechanical change can be measured electronically, output as an analog or digital output signal, and
25 transmitted, for example, to the control unit.

The arms can be designed in a plurality of parts. They can include hinged segments that can be moved about an axis perpendicular to the direction of travel. Each segment of the arms can furthermore be extended and retracted. They can also assume intermediate positions. This makes it possible to adjust the working width of
30 the agricultural implement by deploying a specific number of segments. In particular, this can be done for one arm independently of the other arm. Sensors, in particular

potentiometers, can be attached to the joints between the hinged segments to determine the extension states. These sensors can detect fully retracted/extended segments as well as intermediate positions of the joints between adjacent segments, and transmit the corresponding extension state to the control unit.

- 5 The hydraulic actuating devices and the hydraulic connecting line can be connected to a hydraulic circuit via the pressure control valves and the associated shut-off valves. The hydraulic circuit can be an open circuit, for example comprising a pump and a hydraulic tank.

- The control unit can be configured so that the pressure control valves are adjusted
- 10 to an associated start target pressure when the shut-off valves are opened. Such a start target pressure can, for example, be stored in a memory assigned to the control unit. In particular, it is possible to provide a plurality of start target pressure values, with a start target pressure value being assigned to each extension state of an arm. Since opening the shut-off valves can in principle lead to uncontrolled
 - 15 movements of the distributor boom, the control for the inclination setting when the shut-off valves are opened can be carried out as precisely as possible based on an assigned start target pressure value. This value is preferably set immediately before opening, and maintained during opening. In this way, uncontrolled movements of the distributor boom can be counteracted particularly quickly and efficiently.
 - 20 The pressure control valves can be designed to maintain a pressure at the load end dependent on an electrical control signal, in particular a control current.

- The pressure control valve is then, for example, a directly controlled and spring-loaded three-way valve, for example a slider. When there is no power or no control signal, the pressure at the load is relieved to the tank. When there is a
- 25 maximum control signal, the maximum possible pressure (either the pressure supply or the maximum value of the pressure control valve) is routed to the load.

- When a control signal is applied, the spring load in the valve is counteracted electromagnetically and the pressure on the load side is thus kept constant according to the control characteristic curve of the valve. For example, the set pressure is then
- 30 proportional to the control signal, which is in particular a control current. However, such a proportional control characteristic curve is not absolutely necessary and can

be replaced by a non-proportional actuation, for example for cost reasons. For this purpose, any control characteristic curves can be stored in the control unit in order to calculate and output control signals matching individual target pressure values.

The valves can in particular comprise a valve body with a control piston, a return
5 spring and a solenoid coil with a magnet armature for electrical actuation. When an electrical signal is applied via the control unit, the magnet armature can press on the control piston with a force corresponding to the signal. This allows oil to flow through the valve and pressure to be built up or released, which can activate the actuating device. This continues until the applied pressure corresponds to the
10 target pressure according to the electrical signal.

In general, the functionality of proportional pressure control valves is based on regulating an occurring pressure difference. If a preset pressure level is fallen below, the valve automatically supplies oil from the hydraulic reservoir until the target value is reached again. Otherwise, oil will be drained if the pressure level is
15 too high. The use of proportional pressure control valves offers efficient control and stability characteristics, as well as low hysteresis of the valves, which can occur due to friction and magnetization. Furthermore, proportional valves enable space-saving installation as well as easy assembly and replaceability.

The pressure control valves can be electronically controlled and adjusted to a
20 target value based on a known characteristic curve. The characteristic curves describe, for example, the relationship between an occurring pressure and the associated required electric current across a control coil of the valve. By way of example, a target value to be set for the pressure control valves can be determined via the pressure sensors described above, whereby a control current
25 to the valves is switched on using the characteristic curve in order to set the corresponding pressure. This has the advantage that the pressure on the distributor boom can be precisely adapted to a target value via the characteristic curve of the pressure control valves. Such a target value can also correspond to one of the start target pressure values mentioned above.

30 The agricultural implement may further comprise a sensor device assigned to a arm for detecting a vertical acceleration of the corresponding arm acting on the arm. Such

vertical acceleration can occur, for example, when the agricultural implement drives over an obstacle, such as uneven ground. The measurement of the vertical acceleration makes it possible to determine the forces acting on the arm due to such vertical acceleration. From these forces, conclusions can be drawn about the forces acting on a hydraulic actuating device assigned to the corresponding arm. This makes it possible to determine the pressure that should be set at the pressure control valve in response to these forces, in particular to compensate for these forces.

The sensor device can, for example, comprise an acceleration sensor for detecting vertical accelerations. It may also include a rotational rate sensor. The acceleration sensor and the rotational rate sensor can be separate sensors. Alternatively, it can be a combined rotational rate and acceleration sensor. The acceleration sensor can be mounted on the agricultural implement. Alternatively or additionally, a combined rotational rate and acceleration sensor can be located on each arm. In particular, the acceleration sensor can be attached close to the corresponding axis of rotation of the arm – “close” meaning that the distance of the sensor from the axis of rotation is less than 0.5 m, in particular less than 0.1 m. In such a configuration, the sensor detects almost no accelerations resulting from a rotational movement of the arm. These measured values can be used, as described above, to determine the pressure to be set at the pressure control valves to compensate for forces on the arms that occur, for example, when driving over an obstacle. Advantageously, so-called inertial measuring units (IMU) are used for this purpose. Such sensors are relatively inexpensive.

On the other hand, it may be advantageous to determine the actual acceleration acting on the arm. This is made up of the “external” vertical acceleration that acts on the device, for example when driving over an uneven surface, the acceleration that occurs due to vibrations of the arm, and the acceleration that results from the subsequent controlling. In this case, the acceleration sensor can be mounted on the arm at a fixed distance from the corresponding axis of rotation. The distance to the axis of rotation refers to the normal distance of the attachment point from the axis of rotation. In particular, the distance can be between 1 m and 3 m, in particular between 1 m and 2 m. Such an arrangement of the sensor makes it possible to determine both the vertical acceleration of the arm and, since the distance between the pivot point and the sensor is known, also the rotational acceleration of the arm. This is advantageous because it allows a closed control loop to be realized for the

acceleration acting on the arm. The target acceleration for such a control loop can be 0 m/s^2 or the acceleration due to gravity, i.e. 9.81 m/s^2 . IMUs can also be used here.

It is also possible to combine the arrangements just described, i.e., to provide a first acceleration sensor near the axis of rotation and to attach a second acceleration
5 sensor to the arm at a distance from the corresponding axis of rotation. This makes it possible to determine the pure rotational acceleration of the arm by processing the sensor values of both sensors. This can be done, for example, by calculating the difference between the sensor values. Such a combination makes it possible to precisely determine both forces that occur due to a vertical movement of the
10 agricultural implement and forces that occur due to a rotational movement of an arm. This also makes it possible to react to these forces, in particular by controlling the corresponding pressure control valves accordingly.

In addition to the sensors described, the sensor device may comprise one or more additional sensors. For example, the sensor device may comprise
15 additional sensors for measuring a distance of the arm from the ground. Such sensors can be designed, for example, as ultrasound distance sensors. Additionally or alternatively, the sensor device may include sensors for determining a rotation rate of the arm. Additionally or alternatively, the sensor device may comprise further sensors on the distributor boom configured to
20 determine a rotation about a hinge axis and/or a position of a boom portion and/or arm. These sensors can be designed, for example, as potentiometers. The potentiometer determines whether an individual boom portion or the entire arm is deflected from its target position and how its position or location changes.

The control unit may be configured to control the pressure control valves based on
25 values from the sensor device. This allows the position of the corresponding arm to be controlled based on the measured values. In particular, deviations from a target position of the arm can be corrected, in particular during the working procedure of the device.

In particular, the combination of different measured values in the data processing unit
30 enables very precise adjustment of the actuating devices or pressure control valves.

The control unit can further be configured to control the pressure control valves, in particular by means of a PID controller, such that a target value of the vertical acceleration acts on the corresponding arm. In particular, the control unit can control the pressure valves in such a way that the vertical acceleration acting on the corresponding arm is set to 0 m/s² or 9.81 m/s². This allows the transmission of force from the arm to the central portion of the device to be minimized.

The control unit can be configured to continuously collect and process the measurement data of the sensor device at regular intervals. The time intervals can be the same for all sensors of the sensor device. However, they can also be different for different sensors. The time intervals are preferably between 5 ms to 1 s, preferably between 5 ms to 100 ms. The control unit can be configured to filter the measurement data using a filter, for example a PT1 element. By choosing a suitable time constant, measurement noise can be suppressed, for example.

The first and the second actuating device can each be designed as a hydraulic cylinder, in particular as a double-acting hydraulic cylinder. Such cylinders provide a cost-effective and simple means of controlling the distributor boom. The double-acting hydraulic cylinders can, for example, each be designed with a piston which can be pressurized on both sides.

The connecting line can connect the piston chambers of the first and second actuating devices. In this case, the pressure control and shut-off valves of each of the first and second actuating devices are assigned to the corresponding rod chambers. This means that the pressure in the piston chambers can be adjusted jointly for the first and second actuating devices by means of the pressure in the connecting line.

The pressure control valves can be activated independently of each other. This means that the pressure control valves can each be controlled independently via an electronic signal from the control unit. Therefore, efficient control is possible for both symmetrical and asymmetrical extension states of the distributor boom. In asymmetrical extension states with an asymmetrical working width, different pressure conditions inevitably prevail at the two pressure control valves due to the different mass distribution. Due to their independent adjustability, even an

asymmetrical distributor boom can be reliably held in the target, particularly horizontal, position above the ground.

The actuating devices can each also be suitable for transferring the corresponding arm from a transport position to a working position and vice versa. Here, a
5 transport position is understood to be a position of the arm in which the arm is completely angled in towards the agricultural implement. By using the same actuating devices for inclination control and the transfer from the working and transport positions and vice versa, easy control of the distributor boom is possible.

The invention further provides a method according to claim 10 for controlling an
10 agricultural implement. The agricultural implement here can have one or more of the features described above. The method includes the following steps:

- Setting a first target pressure in the connecting line by means of the associated pressure control valve.
- Setting a second target pressure at the first actuating device by means of
15 the associated pressure control valve.
- Setting a third target pressure at the second actuating device by means of the associated pressure control valve.

This allows the distributor boom to be set to any extension state. For example, the corresponding target pressures can be determined by the control unit based on a
20 particular target extension state of the corresponding arm. After setting these target pressures, the arms are each transferred to the corresponding extension states.

Furthermore, in the method, a shut-off valve assigned to the connecting line is closed after first target pressure is set, setting the second target pressure can involve increasing the pressure at the first actuating device, and setting the third
25 target pressure can involve a corresponding reduction in the pressure at the second actuating device. In this way, it can be achieved that the entire distributor boom is tilted by a certain angle, as described above.

Alternatively, a shut-off valve assigned to the connecting line can remain open after the first target pressure has been set. In this way, as described above, the arms can be angled up or down simultaneously.

The method may further include the following steps:

- 5 • Detecting a vertical acceleration of an arm.
- Determining a force acting on each of the actuating devices as a result of the detected vertical acceleration.
- Determining adjusted pressure values for each of the actuating devices and/or the connecting line.
- 10 • Activating the control valves in order to set the specific adjusted pressure values.

In this way, the compensation for accelerations as described above and thus a stabilization of the corresponding arms can be achieved. In particular, the adjusted pressure value is determined in such a way that it compensates as
15 much as possible for the force acting on the actuating device.

The method may further comprise detecting a distance of the arm from the ground. This can be done, for example, using ultrasonic distance sensors. Additionally or alternatively, the method may include determining a rotation rate of the arm. Additionally or alternatively, the method may include detecting a
20 rotation about a hinge axis and/or a position of a boom portion and/or arm. This can be done, for example, using potentiometers. The method may further comprise activating the control valves based on the detection of one or more of the aforementioned measured values. In particular, the activation can be carried out using target values for one or more of the aforementioned measured values.
25 In other words, the method may include a regulation to these target values. Here, the adjusted pressure values can be determined, in particular by means of a PID circuit, such that a target value of the vertical acceleration acts on the arm.

Also disclosed is an agricultural implement for spreading material, such as fertilizer, crop protection agents, or seeds, comprising a distributor boom that can

hinge on both sides and has a central portion and two lateral arms connected to the central portion by joints, a first hydraulic actuating device for moving one of the arms about a first axis of rotation pointing in the direction of travel of the agricultural implement, a second hydraulic actuating device for moving the other
5 arm about a second axis of rotation pointing in the direction of travel of the agricultural implement, and a control unit, wherein two first pressure control valves are assigned to the first actuating device and two second pressure control valves are assigned to the second actuating device.

In this case, two first shut-off valves can be assigned to the two first pressure
10 control valves, and two second shut-off valves can be assigned to the second pressure control valves.

In particular, in this embodiment of the invention the pressure control valves are respectively assigned to a first side and a second side of the corresponding actuating device. In the case of double-acting hydraulic cylinders, one pressure
15 control valve is assigned to the piston chamber and one pressure control valve is assigned to the rod chamber of the corresponding cylinder.

Such an arrangement allows the two arms to be angled up or down completely separately. The above-mentioned advantages of the invention can also be achieved by corresponding activation of the individual pressure control valves by
20 the control unit. In particular, the control unit can activate the pressure control valves and shut-off valves in such a way that a joint tilting of the entire distributor boom, a joint angling up or down of the two arms, as well as an independent angling up or down of the corresponding arms is possible.

The pressure control valves can be designed as described above. The actuating
25 devices can be designed as described above. The arms can have the segmented shape described above.

Furthermore, an agricultural implement according to this embodiment can also comprise the sensors described above for detecting a vertical acceleration of each arm. Accordingly, with this embodiment it is also possible to carry out the
30 above-described correction of an occurring vertical acceleration or the regulating of the acceleration to a target value.

Furthermore, a method according to claim 16 for controlling an agricultural implement is disclosed. The agricultural implement here can have one or more of the features described above. The method includes the following steps:

- Setting a first target pressure at the first actuating device by means of one
5 of the first two pressure control valves.
- Setting a second target pressure at the first actuating device by means of the other of the two first pressure control valves.
- Setting a third target pressure at the second actuating device by means of one of the two second pressure control valves.
- 10 • Setting a fourth target pressure at the second actuating device by means of the other of the two second pressure control valves.

Further features and advantages of the invention are explained below with reference to the exemplary figures. wherein:

Figures 1a to 1c show schematically the rear view of an agricultural implement;

15 Figure 2 shows schematically a detailed section of an agricultural implement;

Figure 3 shows schematically a detailed section of an agricultural implement;

Figures 4a to 4c show schematic rear views of an agricultural implement;

Figures 5a to 5c show schematic rear views of an agricultural implement;

Figures 6a to 6c show schematically the rear view of an agricultural implement; and

20 Figure 7 shows a schematic of a control loop for controlling an agricultural implement.

Figures 1a to 1c show an agricultural implement 1, which is designed as a field sprayer, in rear view. It can be seen that the implement 1 comprises a distributor boom 10 with a central portion 11. Furthermore, the distributor boom 10 has two
25 arms 12 a, b, which are connected to the central portion 11 by joints. Each arm 12 a, b is assigned an actuating device 14 a, b. In the case shown, the actuating

devices 14 a, b are designed as double-acting hydraulic cylinders. The actuating devices 14 a, b can move the arms 12 a, b about their respective axes of rotation, wherein each axis of rotation is parallel to the direction of travel of the agricultural implement 1. In the case shown, the actuating devices 14 a, b are designed such that they can transfer the corresponding arm 12 a, b from a position completely angled in to the implement 1, which occurs for example during road transport of the implement 1, into a completely horizontal position, which occurs for example during field work, and vice versa.

It can also be seen that the arms 12 a, b each have a plurality of boom portions which are connected to each other via hinged joints. The individual boom portions can be articulated about a vertical axis so that the working width of the agricultural implement can be adjusted. The boom portions can be tilted independently for the corresponding arm 12 a, b. Fig. 1a shows a state in which the arms 12 a, b are completely extended. Figure 1b shows a state in which only the innermost boom portion of the arms 12 a, b is extended, while the remaining boom portions are retracted. Figure 1c shows a state in which all boom portions of the arm 12 b are extended, while only the innermost boom portion of the arm 12 a is extended.

The agricultural implement 1 further comprises at least one sensor device 20 a, b for each of the arms 12 a, b. The sensor device 20 a, b can comprise one or more sensors. In particular, the sensor device 20 a, b comprises sensors for measuring the vertical acceleration acting on the arm 12 a, b. Said sensor device may further comprise sensors for measuring a distance of the arm 12 a, b from the ground and/or sensors for determining an angular rotation rate of the arm 12 a, b and/or sensors for determining the extension state of the boom portions of the arm 12 a, b. Please note that the sensors do not all have to be installed in the same place. In Figure 1, a sensor 20 a, b is indicated, which is located approximately in the middle of the extended arm 12 a, b. This position is suitable, for example, to measure the actual vertical acceleration acting on the arm 12 a, b.

The actuating devices 14 a, b are connected by a hydraulic connecting line 15. It can be seen that the connecting line 15 in the embodiment shown connects the corresponding piston chambers of the hydraulic cylinders 14 a, b with each other.

Figure 2 shows a detailed section of the field sprayer shown in Figure 1. In addition, the hydraulic connections and switching elements are shown schematically. It can be seen that each of the actuating devices 14 a, b is connected to a pressure control valve 16 a, b. In the example shown, the pressure control valves 16 a, b are

5 connected to the rod chambers of the hydraulic cylinders 14 a, b. The connecting line 15 is also connected to a pressure control valve 16 c. The pressure control valves 16 a, b, c are connected to the hydraulic lines P and T of a hydraulic circuit. Here, T denotes the line to a hydraulic tank and P denotes the line to a hydraulic pump.

10 A shut-off valve 17 a, b, c is installed between the pressure control valves 16 a, b and the hydraulic cylinders 14 a, b and also the pressure control valve 16 c. The pressure control valves 16 a, b, c and the shut-off valves 17 a, b, c are controlled via the control unit 2 (not shown). Each of the valves can be controlled individually.

The locking of one of the shut-off valves 17 a, b, c means that no hydraulic fluid can flow from the direction of the hydraulic cylinders 14 a, b or the connecting
15 line 15 towards the tank. This means that the corresponding hydraulic cylinder 14 a, b cannot move in the corresponding direction. The corresponding arm 12 a, b is thus locked in this direction. If, for example, the shut-off valve 17 a is locked, the hydraulic cylinder 14 a cannot be extended.

It should be noted that when the inclination control is active, the shut-off valves
20 17 a, b, c are generally open based on measurement data from the sensor device 20 a, b in order to achieve the fastest possible control.

Figure 3 shows an alternative embodiment of an agricultural implement 1'. Like the embodiment described with reference to Figure 2, the embodiment shown here has two actuating devices 14 a, b, which are designed as double-acting hydraulic
25 cylinders. The rod chambers are in turn assigned pressure control valves 16 a, b and shut-off valves 17 a, b. Instead of a hydraulic connecting line, however, this embodiment has two additional pressure control valves 16 d, e and shut-off valves 17 d, e. Each of the valves can again be controlled individually via a control unit 2.

Figures 4a to 4c show the states of the arms 12 a, b of the distributor boom 10
30 with the associated actuation states of the pressure control valves 16 a, b, c and

shut-off valves 17 a, b, c in different phases of a hinging process – in this case, the joint angling up of the two arms 12 a, b.

In Figure 4a, the shut-off valves 17 a, b, c are locked. A pressure p_0 a, b prevails in the two rod chambers of the corresponding hydraulic cylinders 14 a, b. In the
 5 connecting line 15, and thus in the two piston chambers of the hydraulic cylinders 14 a, b, there is also a pressure p_1 . In the situation shown, the arms 12 a, b are extended symmetrically. Therefore, the pressures p_0 a, b in the rod chambers of the hydraulic cylinders 14 a, b are identical. In other words, the same pressure
 10 difference exists between the corresponding piston chamber and the corresponding rod chamber on both hydraulic cylinders 14 a, b. In the case of an asymmetrical angling up, or in the event that one of the arms 12 a, b is not fully extended, the mentioned pressure differences for the hydraulic cylinders 14 a, b may be different.

If one or more of the shut-off valves 17 a, b, c are opened, the control unit 2 controls the corresponding pressure control valve 16 a, b, c in such a way that a
 15 corresponding target pressure prevails in the corresponding cylinder chambers or the hydraulic connecting line. The target pressure in each case can, for example, be set by the control unit 2 based on preset pressure values for the current extension state. The pressure values can, for example, be stored in a memory of the control unit 2. However, they can also be determined based on sensor measurement data.

20 It should be noted that the annular and piston surfaces of the hydraulic cylinder can be taken into account when calculating a target pressure to be set. This is because the hydraulic cylinders 14 a, b have two differently sized effective areas on the two sides of the piston. The effective area of the hydraulic cylinder facing the piston rod is smaller than the effective area facing away from the piston rod.
 25 Accordingly, when the forces are in equilibrium, there is a different, in particular greater, pressure on the annular surface than on the piston surface.

Figure 4b shows the state during angling up. It can be seen that the shut-off valves 17 a, b, c are open. As described above, the control unit 2 has set a target pressure in each of the cylinder chambers when the shut-off valves are opened.
 30 Subsequently, the pressure in the rod chambers of the hydraulic cylinders 14 a, b is increased equally to the pressure p_2 by means of the pressure control valves

16 a, b. The pressure p_2 can in particular correspond to a target pressure for a desired extension state. By increasing the pressure in the rod chambers of the hydraulic cylinders 14 a, b, a force acts on each of the annular surfaces of the pistons of the hydraulic cylinders 14 a, b. Since the shut-off valve 17 c is open, hydraulic fluid can flow from the connecting line 15 towards the tank T, and the piston of the hydraulic cylinders 14 a, b moves towards the central portion 11. This results in a synchronous angling up of both arms 12 a, b.

Alternatively (not shown here), it is also possible to open only the shut-off valve 17c during the process just described, since the shut-off valves 17a, b prevent the hydraulic fluids from flowing out of the rod chambers of the hydraulic cylinders 14a, b. In the present case, the pressure p_2 set there is higher than the initial value p_0 a, b. The force acting on the pistons of the hydraulic cylinders 14 a, b will therefore always result in a displacement of the corresponding piston towards the central portion 11. Since the shut-off valve 17 c is open, hydraulic fluid can flow from the connecting line 15 towards the tank T and the corresponding piston can move accordingly, as described above.

Figure 4c shows the state after the angling up is completed. It can be seen that all shut-off valves 17 a, b, c are closed again. The pressure p_2 prevails in the rod chambers of the hydraulic cylinders 14 a, b. A pressure p_3 prevails in the connecting line 15 and thus in the piston chambers of the hydraulic cylinders 14 a, b. The pressure p_3 will generally be equal to the previous pressure p_1 . However, it can also be different. The two arms 12 a, b were angled up equally.

Figures 5a to 5c show the states of the arms 12 a, b of the distributor boom 10 with the associated actuation states of the pressure control valves 16 a, b, c and shut-off valves 17 a, b, c in different phases of a hinging process – in this case, the one-sided angling up of the arm 12 a.

In Figure 5a, the shut-off valves 17 a, b, c are locked. A pressure p_0 a, b prevails in the two rod chambers of the corresponding hydraulic cylinders 14 a, b. In the connecting line 15, and thus in the two piston chambers of the hydraulic cylinders 14 a, b, there is a pressure p_1 . In the situation shown, the arms 12 a, b are extended symmetrically. Therefore, the pressures p_0 a, b in the rod chambers of the hydraulic

cylinders 14 a, b are identical. In other words, the same pressure difference $p_0 - p_1$ prevails on both hydraulic cylinders 14 a, b between the corresponding piston chamber and the corresponding rod chamber. In the case of an asymmetrical angling up, or in the event that one of the arms 12 a, b is not fully extended, the
5 mentioned pressure differences for the hydraulic cylinders 14 a, b may be different.

If one or more of the shut-off valves 17 a, b, c are opened, the control unit 2 controls the corresponding pressure control valve 16 a, b, c in such a way that a corresponding target pressure prevails in the corresponding cylinder chambers or the hydraulic connecting line. The target pressure in each case can, for example, be
10 set by the control unit 2 based on preset pressure values for the current extension state. The pressure values can, for example, be stored in a memory of the control unit 2. However, they can also be determined based on sensor measurement data.

Figure 5b shows the state during the angling up of the arm 12a. It can be seen that the shut-off valves 17a and 17c have been opened, but the shut-off valve 17b is
15 still closed. As described above, the control unit 2 has set a target pressure in each of the cylinder chambers when the shut-off valves are opened.

Subsequently, the pressure in the rod chamber of the hydraulic cylinder 14 a is increased to the pressure p_2 by means of the pressure control valve 16 a. The pressure p_2 can, for example, correspond to a target extension state of the arm
20 12a. As a result, a force acts on the annular surface of the piston of the hydraulic cylinder 14 a. Since the shut-off valve 17 c is open, hydraulic fluid can flow out of the connecting line 15 in the direction of the tank T, and the piston of the hydraulic cylinder 14 a moves in the direction of the central portion 11. This results in an angling up of the arm 12 a. In contrast, the pressure in the rod chamber of the
25 hydraulic cylinder 14 b remains unchanged. Since the shut-off valve 17 b is closed and the shut-off valve 17 c is open, there is no movement of the piston of the hydraulic cylinder 14 b. The arm 12 b therefore remains in its position.

Figure 5c shows the state after the angling up of the arm 12a is completed. It can be seen that all shut-off valves 17 a, b, c are closed again. The set pressure p_2 prevails
30 in the rod chamber of the hydraulic cylinder 14 a, and the pressure p_0 prevails in the chamber of the hydraulic cylinder 14 b. A pressure p_3 prevails in the connecting line

15 and thus in the piston chambers of the hydraulic cylinders 14 a, b. The pressure p_3 will generally be equal to the previous pressure p_1 . However, it can also be different.

Figures 6a to 6c show the states of the arms 12 a, b of the distributor boom 10 with the associated actuation states of the pressure control valves 16 a, b, c and
5 shut-off valves 17 a, b, c in different phases of a hinging process, here the joint tilting of the arms 12 a, b.

In Figure 6a, the shut-off valves 17 a, b, c are locked. A pressure p_0 a, b prevails in the two rod chambers of the corresponding hydraulic cylinders 14 a, b. A preset pressure p_1 prevails in the connecting line 15, and thus in the two piston chambers of
10 the hydraulic cylinders 14 a, b. In the situation shown, the arms 12 a, b are extended symmetrically. Therefore, the pressures p_0 a, b in the rod chambers of the hydraulic cylinders 14 a, b are identical. In other words, the same pressure difference $p_0 - p_1$ prevails on both hydraulic cylinders 14 a, b between the corresponding piston
15 chamber and the corresponding rod chamber. In the case of an asymmetrical angling up, or in the event that one of the arms 12 a, b is not fully extended, the mentioned pressure differences for the hydraulic cylinders 14 a, b may be different.

If one or more of the shut-off valves 17 a, b, c are opened, the control unit 2 controls the corresponding pressure control valve 16 a, b, c in such a way that a
20 corresponding target pressure prevails in the corresponding cylinder chambers or the hydraulic connecting line. The target pressure in each case can, for example, be set by the control unit 2 based on preset pressure values for the current extension state. The pressure values can, for example, be stored in a memory of the control unit 2. However, they can also be determined based on sensor measurement data.

Figure 6b shows the state during tilting. It can be seen that the shut-off valve 17 c
25 assigned to the connecting line 15 remains locked, while the shut-off valve 17 a and the shut-off valve 17 b are open. As described above, the control unit 2 has set a target pressure in each of the cylinder chambers when the shut-off valves are opened. Subsequently, the pressure in the rod chamber of the hydraulic cylinder 14 a is increased to the pressure p_2 a by means of the pressure control
30 valve 16 a, while the pressure in the rod chamber of the hydraulic cylinder 14 b is reduced to the pressure p_2 b by means of the pressure control valve 16 b. The

pressure $p2a$ corresponds to a preset pressure for an extension state in which the arm 12 a is angled up by an angle α with respect to the initial position shown in Figure 6a. The pressure $p2b$ corresponds to a preset pressure for an extension state in which the arm 12 b is angled down by an angle α with respect to the initial position shown in Figure 6a. By increasing the pressure in the rod chamber of the hydraulic cylinder 14 a, a force acts on the annular surface of the piston of the hydraulic cylinder 14 a. This force is transmitted via the connecting line to the piston chamber of the hydraulic cylinder 14 b, since the shut-off valve 17 c is closed. Since the pressure in the rod chamber of the hydraulic cylinder 14 b is reduced at the same time, the two pistons of the hydraulic cylinders 14 a, b move in the same direction (to the left in the figure). This leads to an angling up of the arm 12 a and a simultaneous angling down of the arm 12 b.

Figure 6c shows the state after the tilting of the distributor boom is completed. It can be seen that all shut-off valves 17 a, b, c are closed again. The set pressure values $p2a$, $p2b$ prevail in the rod chambers of the hydraulic cylinders 14 a, b. A pressure $p3$ prevails in the connecting line 15 and thus in the piston chambers of the hydraulic cylinders 14 a, b. The pressure $p3$ will generally be equal to the previous pressure $p1$. However, it can also be different.

It is understood that a control of the arms 12 a, b as described with reference to Figures 4a-c, 5a-c and 6a-c is also possible with an agricultural implement as shown in Figure 3. In this case, instead of opening and locking the shut-off valve 17 c in the connecting line 15, the pressure control valves 16 d, e and shut-off valves 17 d, e are activated to control the pressure in the piston chambers of the hydraulic cylinders 14 a, b.

Thus, in a situation corresponding to Figure 4b, the shut-off valves 17 d, e would be opened. The adjustment of the pressure in the rod chambers of the hydraulic cylinders 14 a, b, however, would be done in the same way as described with reference to Figure 4b. Hydraulic fluid would then flow out of the rod chambers of the hydraulic cylinders 14 a, b in the direction of the tank T, and, as described above, a joint angling up of the arms 12 a, b would result. The same applies to the situations shown in Figures 5b and 6b.

Figure 7 shows schematically an example of a control loop with which the position of one of the arms 12 a, b can be controlled. It can be seen that various measurement data serve as input values for the control. The measurement data are captured, for example, by means of the sensor device 20 a, b.

- 5 In the case shown, the input values include the distance of the arm 12 a, b from the ground, the rotation rate of the arm 12 a, b, and the vertical acceleration of the arm 12 a, b. It should be understood that these examples are not an exclusive list. Furthermore, not all measured values shown have to be used as input values.

- 10 A joint control value is determined from the individual measured values using the corresponding control parameters k_1 , k_2 , k_3 . It should be noted that the values k_1 , k_2 , k_3 can be simple proportional factors. However, they can also take the form of a PID controller. For example, it is possible that the part of the circuit designated “ k_1 ” corresponds to a PID controller with the measured angular deviation as input value and a predetermined angular deviation as target value.
- 15 The same applies to the other input values shown. In particular, the part relating to the vertical acceleration can be a PID controller with the measured vertical acceleration as input value and either 0 m/s^2 or 9.81 m/s^2 as target value.

- In general, it can be said that the output values of the parts k_1 , k_2 , k_3 are each such that they transfer the arm 12 a, b from a measured actual value of the corresponding
- 20 measured value to a desired target value of the corresponding measured value.

- The initial values of the parts k_1 , k_2 , k_3 are then combined, for example additively. This is done in order to correctly record the total movement of the arm 12 a, b. For example, when driving over an uneven surface in the ground, branch k_1 and branch k_2 can emit opposite signals: the distance of the arm 12 a, b from
- 25 the ground is reduced by driving over it, so the corresponding branch k_1 will produce a control to raise the arm. At the same time, however, a positive vertical acceleration, i.e. one acting away from the ground, acts on the arm 12 a, b. The branch k_3 will control the lowering of the arm accordingly. By combining the output signals, both components can be taken into account and there is no
- 30 opposing control, as could occur with two independent control systems.

When the arm is in the target or rest position, the combined signal is equal to 0; i.e., no influence is exerted on the position of the arm 12 a, b.

The combined output signal is then combined with a pressure offset that exists in the rest position on both sides of the hydraulic cylinder 14 a, b. The pressure offset
5 takes into account both external forces acting on the arm 12 a, b in the target position and the different effective areas of the two piston sides. Such forces can occur, for example, if the rod is not extended completely symmetrically. They can also occur when driving on slopes or curves. The pressure offset can vary individually for the corresponding hydraulic cylinders 14 a, b. The pressure offset
10 should therefore take into account the forces actually acting on the distributor boom 10 during normal operation. Finally, a control signal is generated for the pressure control valves 16 a, b, c in order to generate pressure values for the chambers of the actuating device 14 a, b. It is possible, as indicated in the figure, that the control signal is limited to a maximum value. This makes it possible, for
15 example, to limit the forces acting on the distributor boom 10 during the controlling.

In summary, the control loop shown ensures that the arm 12 a, b is held in a target position or is deflected as little as possible from the target position.

The described control system can, for example, be implemented in the control unit 2. It should be noted that, in general, when the described control system is in
20 operation, the shut-off valves 17 a, b, c are open in order to achieve rapid pressure control in the chambers of the hydraulic cylinders 14 a, b and the connecting line 15. The same applies to the embodiment of the implement 1' described with reference to the drawing. The shut-off valves 17 a, b, c generally serve to fix the positions of the pistons of the hydraulic cylinders 14 a, b, and
25 thus the position of the arm, when the control is switched off.

It goes without saying that geometries shown in the drawings are only examples and are also possible in any other configurations.

PATENTKRAV

1. Landbrugsmaskine (1) til udspredning af materiale såsom gødningsmiddel, plantebeskyttelsesmiddel eller såsæd, **kendetegnet ved**

en fordelerbom (10), der kan sammenklappes på begge sider og har en
5 midterdel (11) og to sidearme (12 a,b), der med led er forbundet med midterdelen (11);

en første hydraulisk aktiveringsindretning (14 a) til bevægelse af én af armene (12 a) omkring en første rotationsakse, der peger i landbrugsmaskinens (1) køreretning;

10 en anden hydraulisk aktiveringsindretning (14 b) til bevægelse af den anden arm (12 b) omkring en anden rotationsakse, der peger i landbrugsmaskinens (1) køreretning;

en hydraulisk forbindelsesledning (15), der hydraulisk forbinder den første aktiveringsindretning (14 a) og den anden aktiveringsindretning (14 b); og

15 en styreenhed (2);

hvor en trykstyreventil (16 a,b,c) i hvert enkelt tilfælde er tilknyttet den første aktiveringsindretning (14 a), den anden aktiveringsindretning (14 b) og forbindelsesledningen (15); og

hvor trykstyreventilerne (16 a,b,c) kan styres med styreenheden (2).

20 2. Landbrugsmaskine ifølge krav 1, hvor den første aktiveringsindretning (14 a), den anden aktiveringsindretning (14 b) og forbindelsesledningen (15) hver især er tilknyttet en spærreventil (17 a,b,c), der er tilknyttet den relevante trykstyreventil (16 a,b,c).

3. Landbrugsmaskine ifølge krav 1 eller 2, der endvidere omfatter en
25 sensorindretning (20 a,b), som er tilknyttet en arm (12 a,b), til detektering af en vertikal acceleration af den relevante arm (12 a,b), og som indvirker på den relevante arm (12 a,b).

4. Landbrugsmaskine ifølge krav 3, hvor sensorindretningen (20 a,b) er fastgjort med en forudbestemt afstand, især med en afstand på mellem 1 m og 3 m, i forhold til den relevante rotationsakse.

5. Landbrugsmaskine ifølge et hvilket som helst af kravene 3 eller 4, hvor styreenheden (2) er konfigureret til at styre trykstyreventilerne (16 a,b,c) på basis af værdier fra sensorindretningen (20 a,b).

6. Landbrugsmaskine ifølge et hvilket som helst af kravene 3 til 5, hvor styreenheden (2) er konfigureret til at styre trykstyreventilerne (16 a,b,c), især ved hjælp af en PID-styreenhed, således at en målværdi for den vertikale acceleration indvirker på den relevante arm (12 a,b).

7. Landbrugsmaskine ifølge et hvilket som helst af de foregående krav, hvor den første og den anden aktiveringsindretning (14 a,b) er udformet som dobbeltvirkende hydrauliske cylindre.

8. Landbrugsmaskine ifølge krav 7, hvor forbindelsesledningen (15) forbinder de stempelvendte kamre i den første og den anden aktiveringsindretning (14 a,b).

9. Landbrugsmaskine ifølge et hvilket som helst af de foregående krav, hvor trykstyreventilerne (16 a,b,c) kan styres uafhængigt af hinanden.

10. Landbrugsmaskine ifølge et hvilket som helst af de foregående krav, hvor de respektive aktiveringsindretninger (14 a,b) er egnet til at overføre den relevante arm (12 a,b) fra en transportposition til en arbejdsposition og vice versa.

11. Fremgangsmåde til styring af en landbrugsmaskine ifølge et hvilket som helst af de foregående krav, hvilken fremgangsmåde omfatter følgende trin:

indstilling af et første måltryk i en forbindelsesledning (15), der hydraulisk forbinder en første aktiveringsindretning (14 a) og en anden aktiveringsindretning (14 b), ved hjælp af den tilknyttede trykstyreventil (16 c);

indstilling af et andet måltryk ved den første aktiveringsindretning (14 a) ved hjælp af den tilknyttede trykstyreventil (16 a); og

indstilling af et tredje måltryk ved den anden aktiveringsindretning (14 b) ved hjælp af den tilknyttede trykstyreventil (16 b).

12. Fremgangsmåde ifølge krav 11, hvor spærreventilen (17 c), der er tilknyttet forbindelsesledningen (15), lukkes efter indstilling af det første måltryk, og
- 5 hvor indstilling af det andet måltryk omfatter forøgelse af trykket ved den første aktiveringsindretning (14 a), og indstilling af det tredje måltryk omfatter en tilsvarende reduktion i trykket ved den anden aktiveringsindretning (14 b).

13. Fremgangsmåde ifølge krav 12, hvor spærreventilen (17 c), der er tilknyttet forbindelsesledningen (15), forbliver åben efter indstilling af det første
- 10 måltryk.

14. Fremgangsmåde ifølge et hvilket som helst af kravene 11 til 13, der endvidere omfatter følgende trin:

detektering af en vertikal acceleration af en arm (12 a,b);

- bestemmelse af en kraft, der indvirker på den relevante
- 15 aktiveringsindretning (14 a,b) på basis af den detekterede vertikale acceleration;

bestemmelse af justerede trykværdier for den relevante aktiveringsindretning (14 a,b) og/eller forbindelsesledningen (15);

styring af styreventilerne (16 a,b,c) med henblik på at indstille de specifikke justerede trykværdier.

- 20 15. Fremgangsmåde ifølge krav 14, hvor de justerede trykværdier bestemmes, især ved hjælp af et PID-kredsløb, således at en målværdi for den vertikale acceleration indvirker på armen (12 a,b).

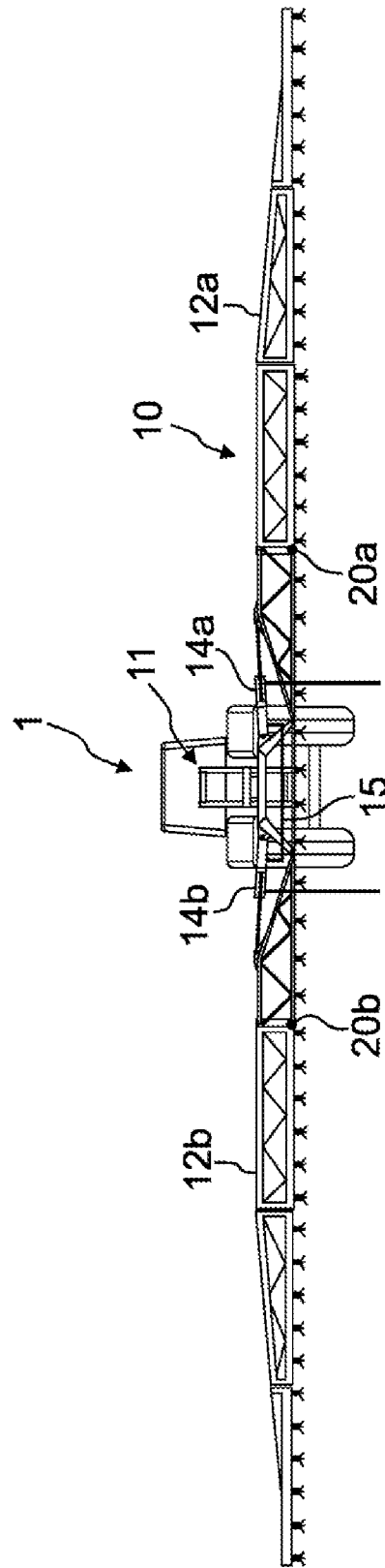


Fig.1a

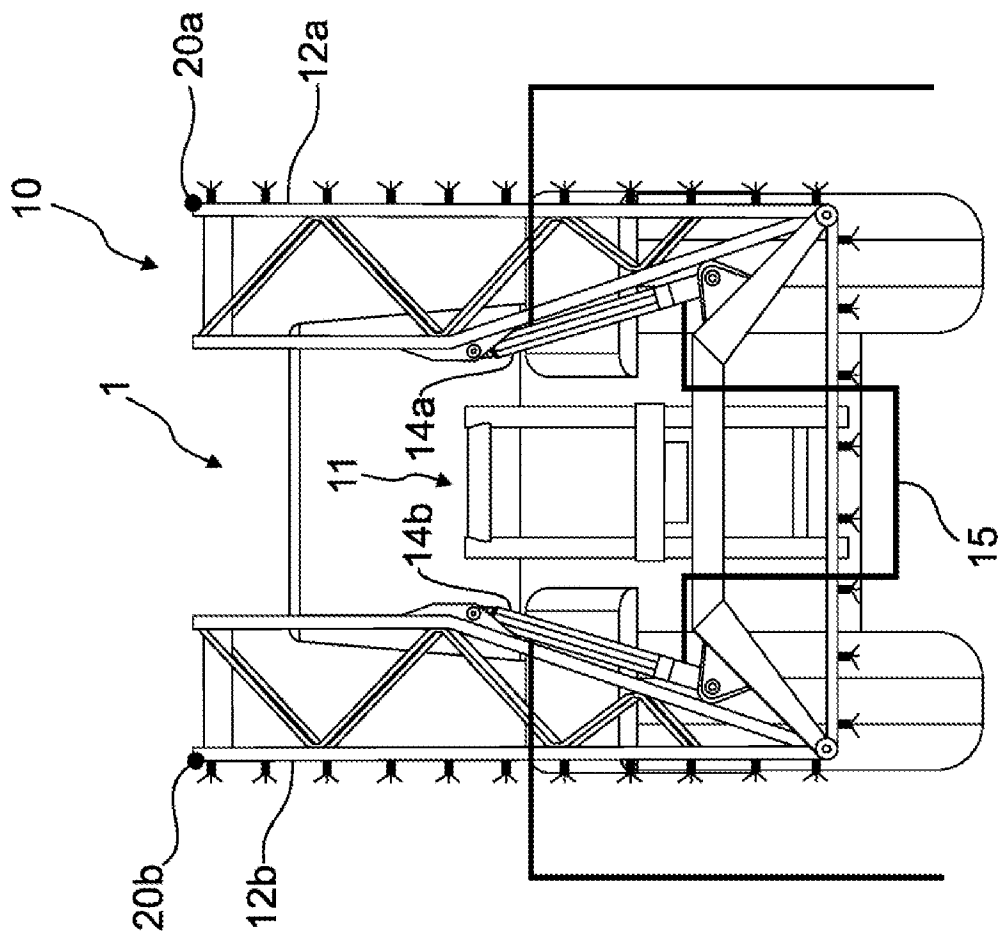


Fig.1b

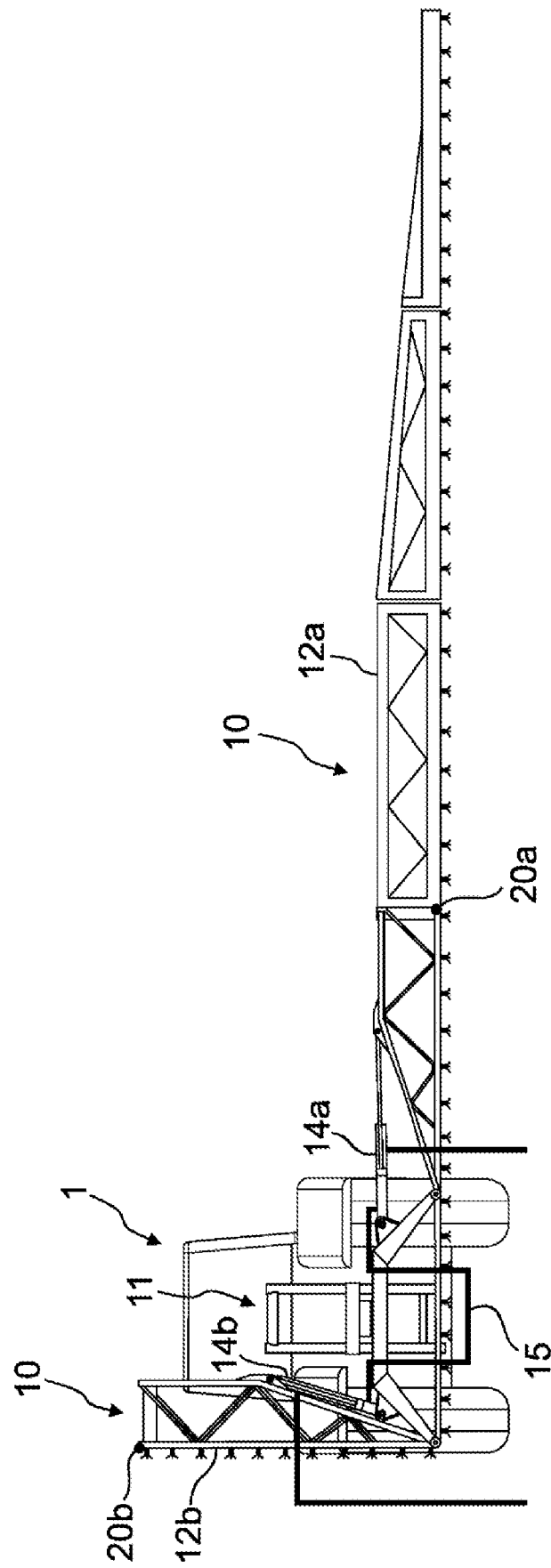


Fig.1c

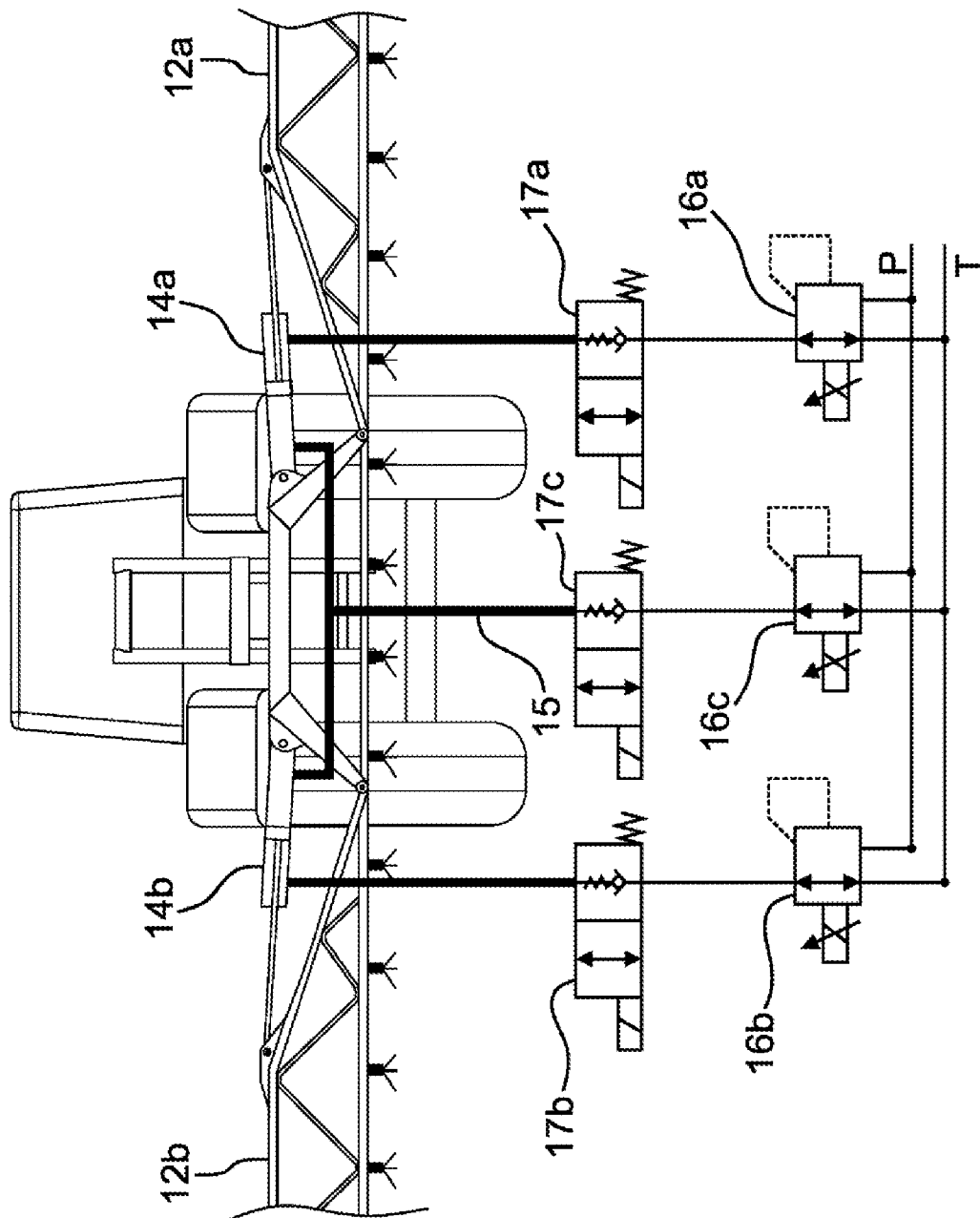


Fig.2

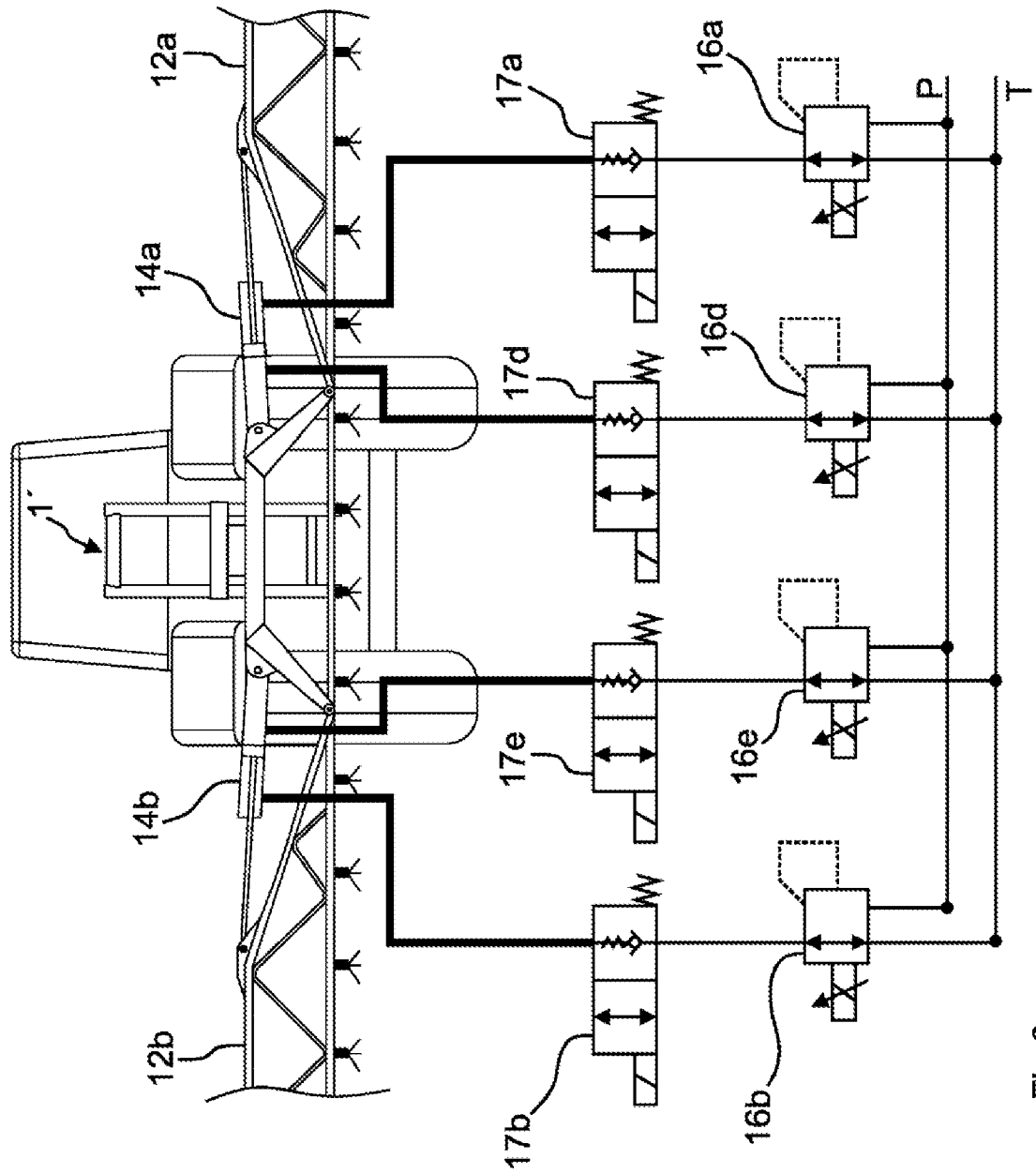


Fig.3

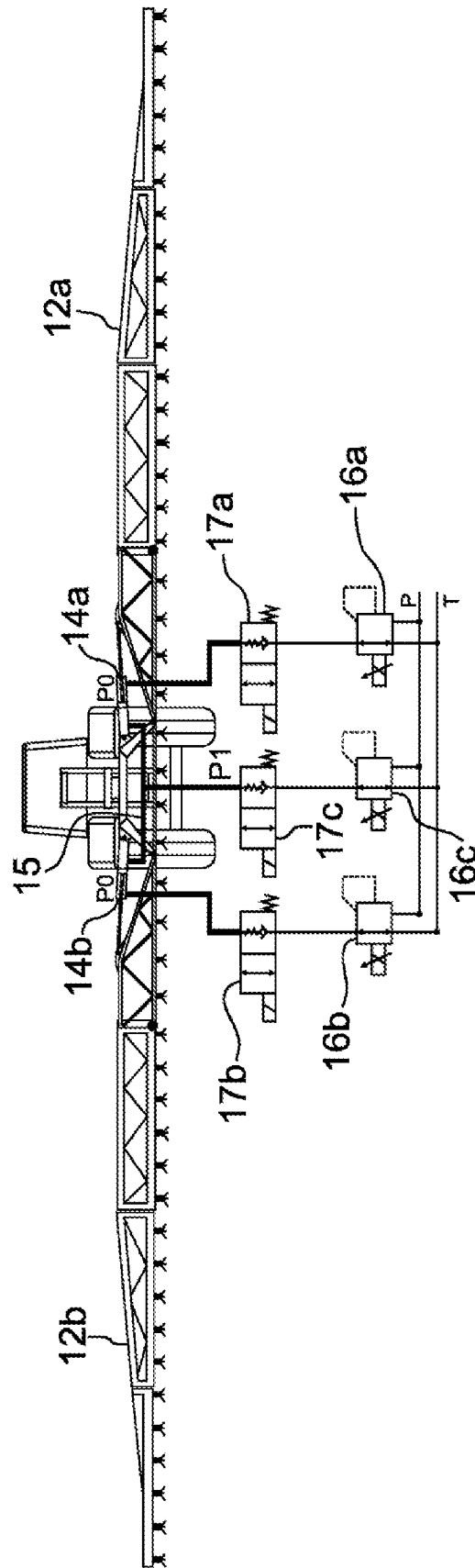


Fig. 4a

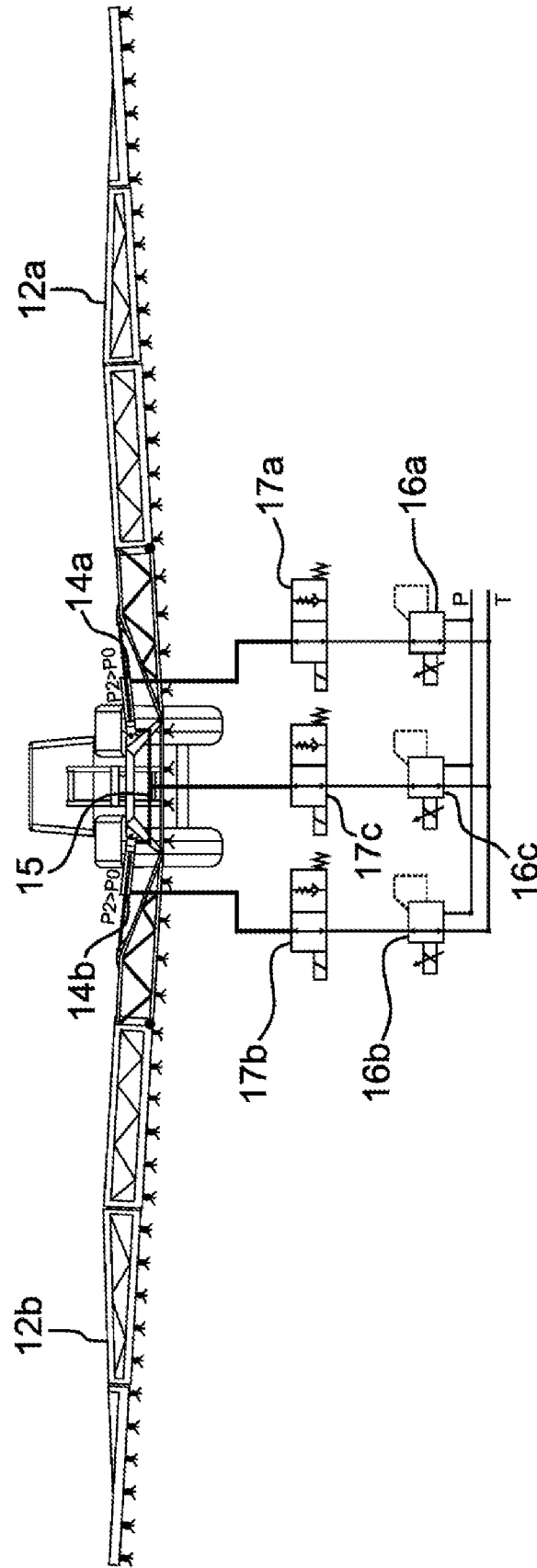


Fig.4b

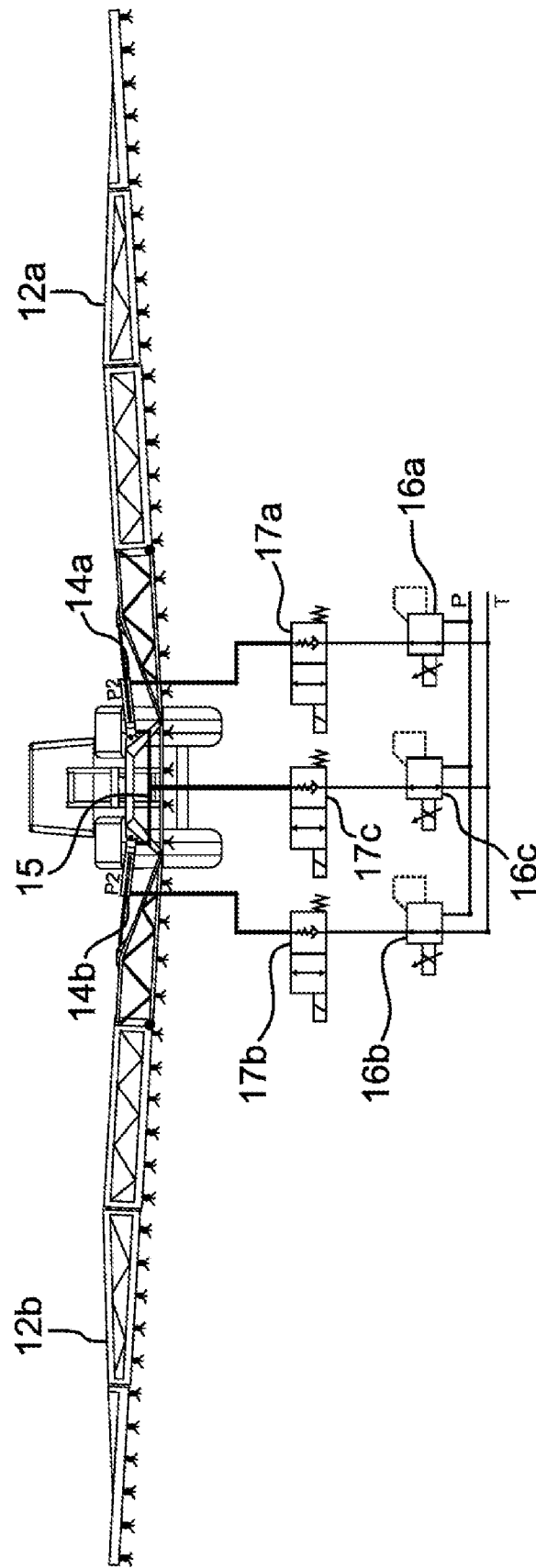


Fig.4c

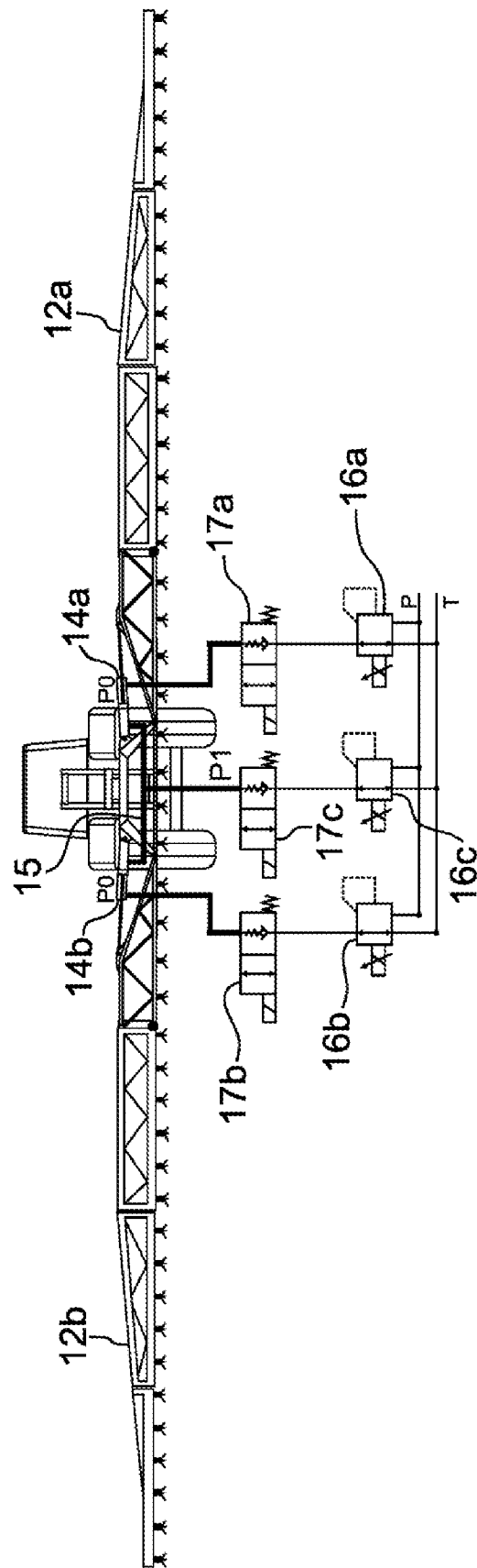


Fig.5a

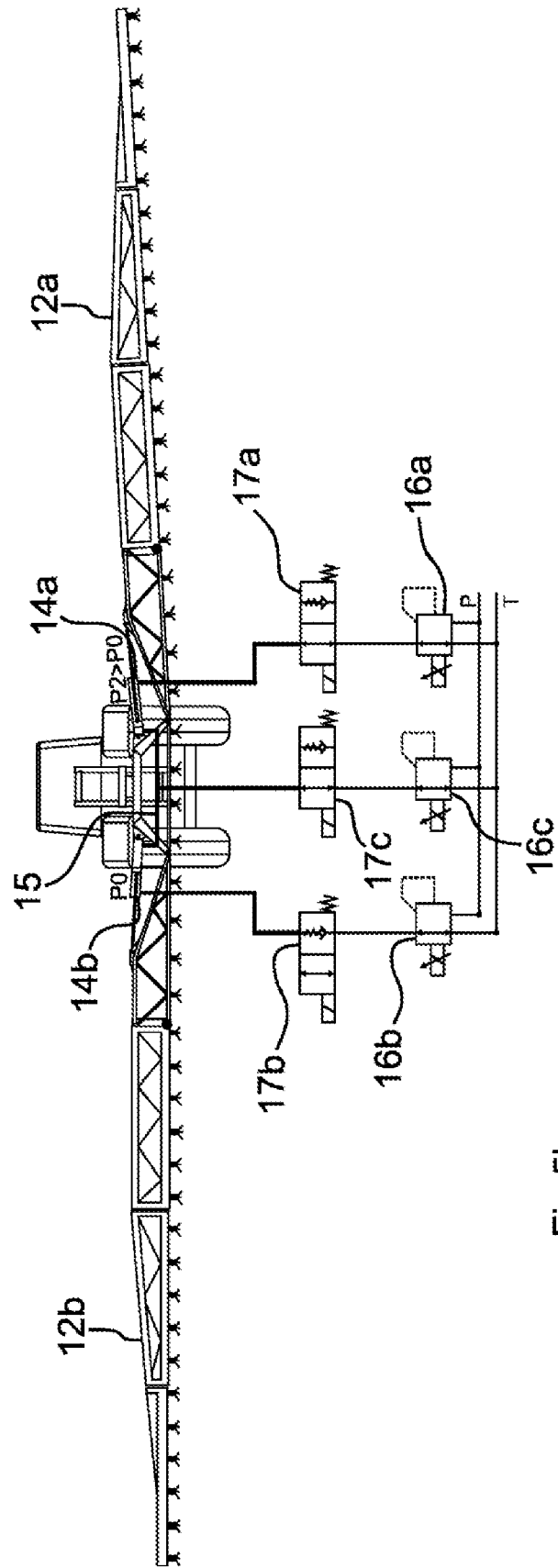


Fig. 5b

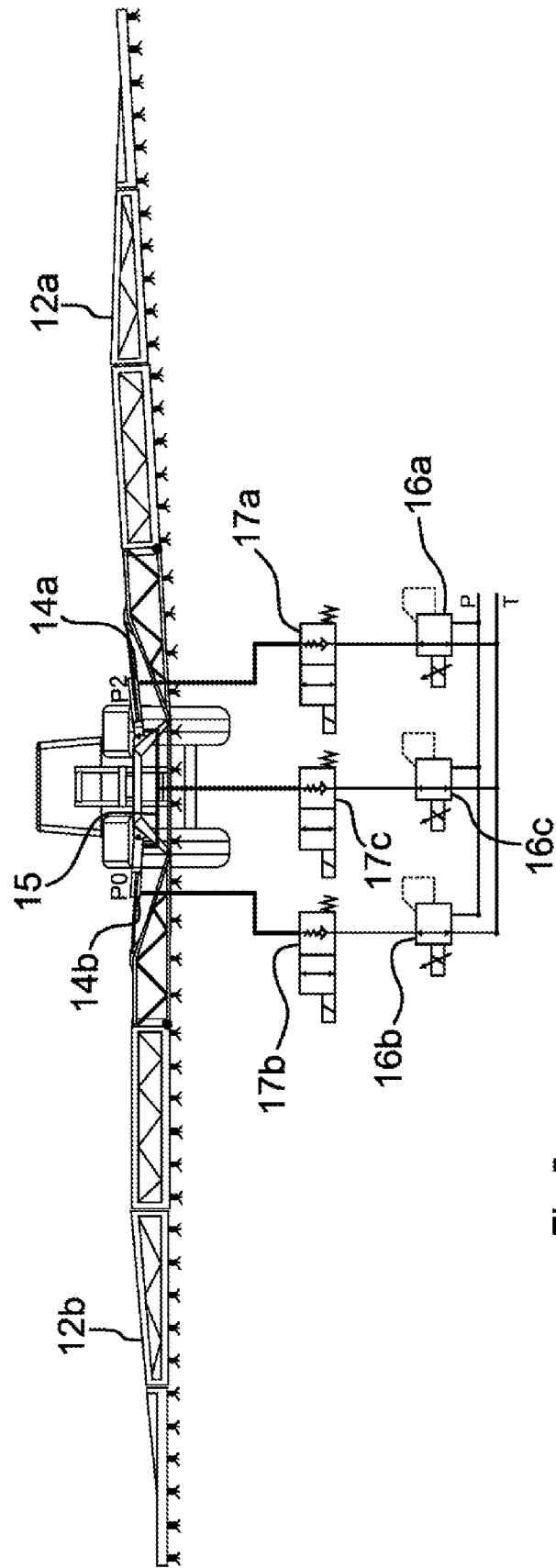


Fig. 5c

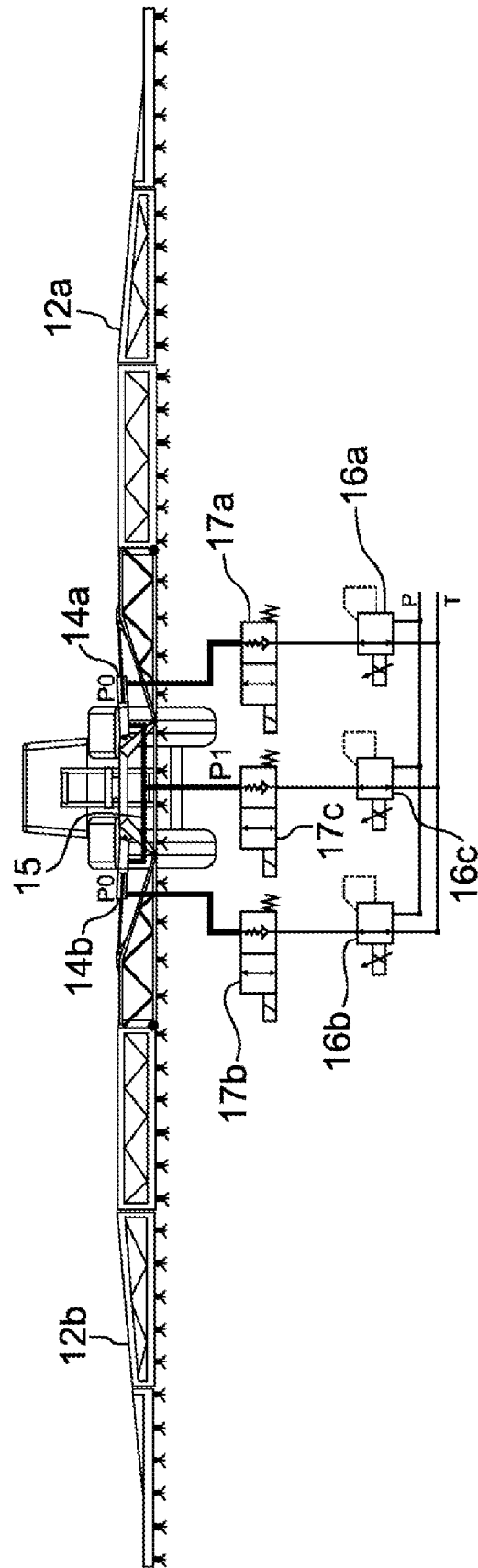


Fig.6a

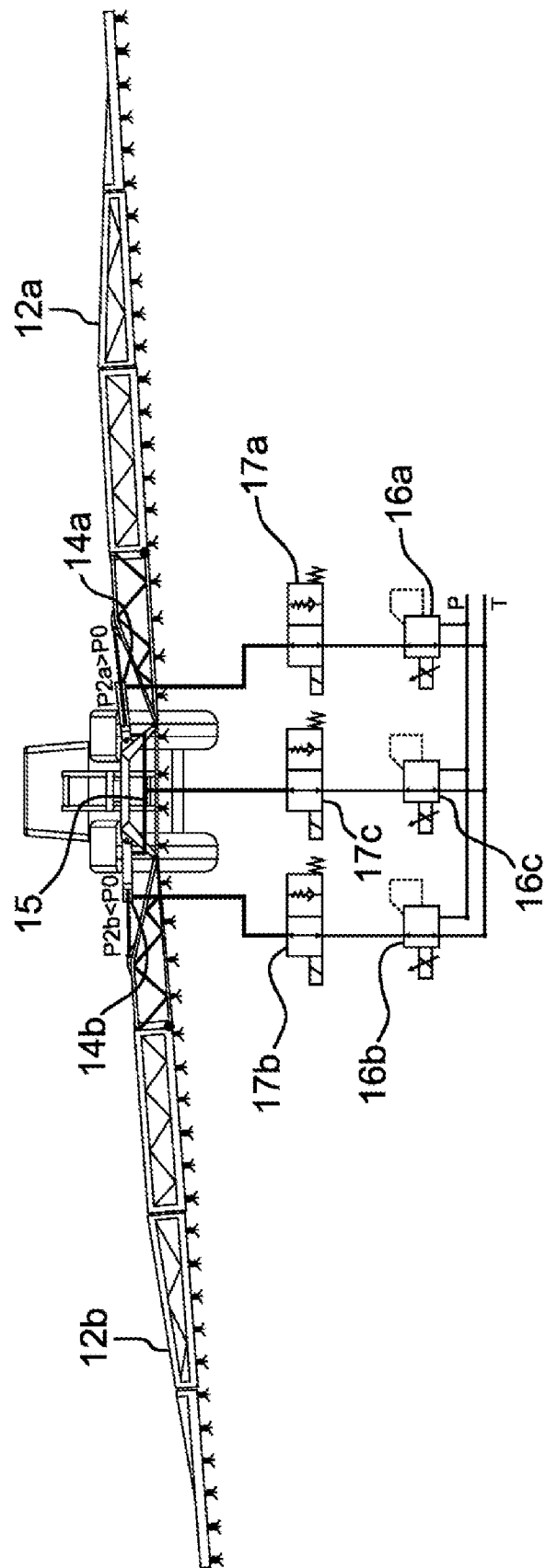


Fig. 6b

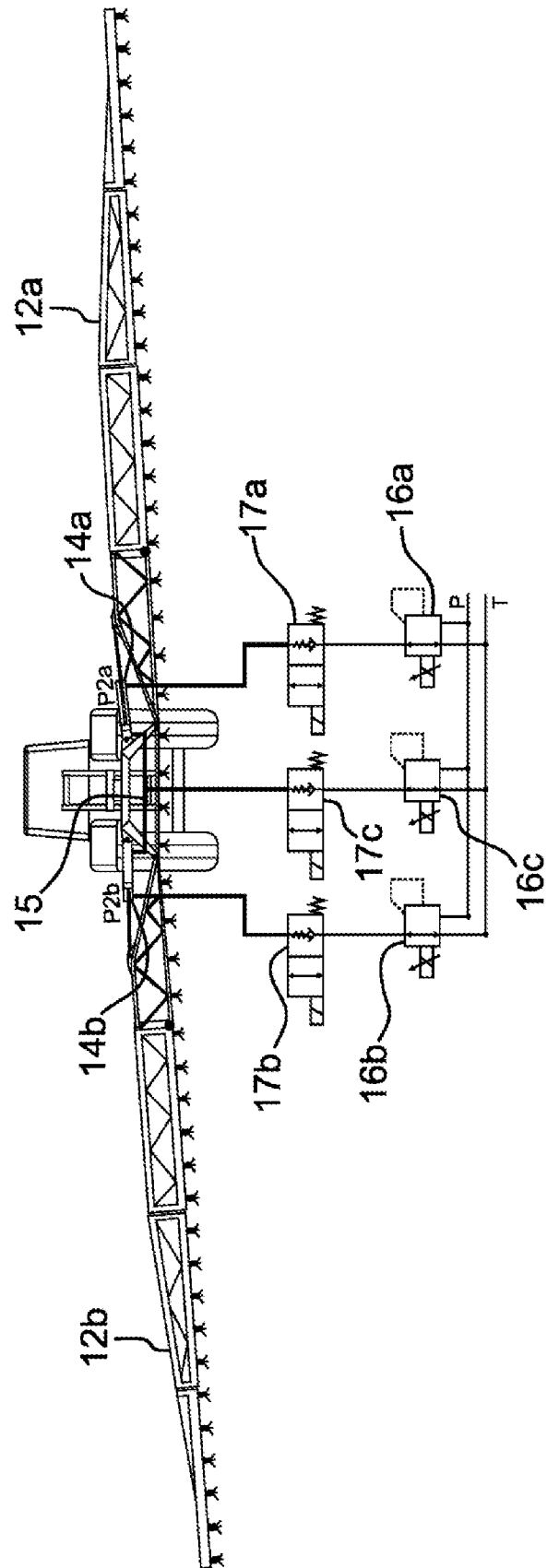


Fig.6c

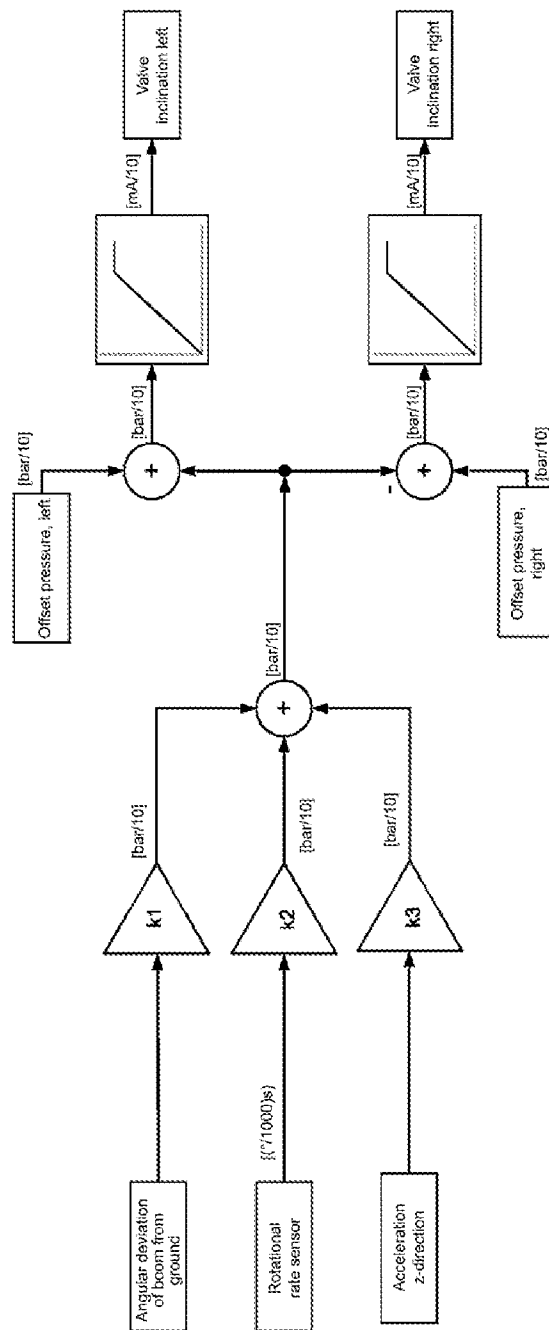


Fig.7