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# (54) Implement damping and control systems

(57) A damping system for an implement support system in which a bucket 10 is mounted on a pair of support arms (12) which are pivoted relative to a tractor by a pair of hydraulic lift cylinders (15) controlled by electrically actuated hydraulic valve means (16) in response to commands (22) from a vehicle operator and/or an electrical control unit (21). The damper system includes a pressure level control loop having a pressure sensing means (15a) for sensing the pressure in the lift cylinders (15) due to a load currently carried in the bucket (10), storing means (21) for storing this sensed lift cylinder pressure as a reference value, the pressure sensing means also monitoring the lift cylinder pressure as the load is transported, and control means (21) for actively adjusting the pressure in the lift cylinders using the electrically actuated hydraulic valve means (16) if said pressure varies outside a predetermined deadband (r,s) either side of the reference value (P) in order to return the lift cylinder pressure to within said deadband and to maintain the support arm carrying position (Q). There is also disclosed a particularly useful joystick (22) control arrangement and a visual display (32) of current bucket orientation etc.

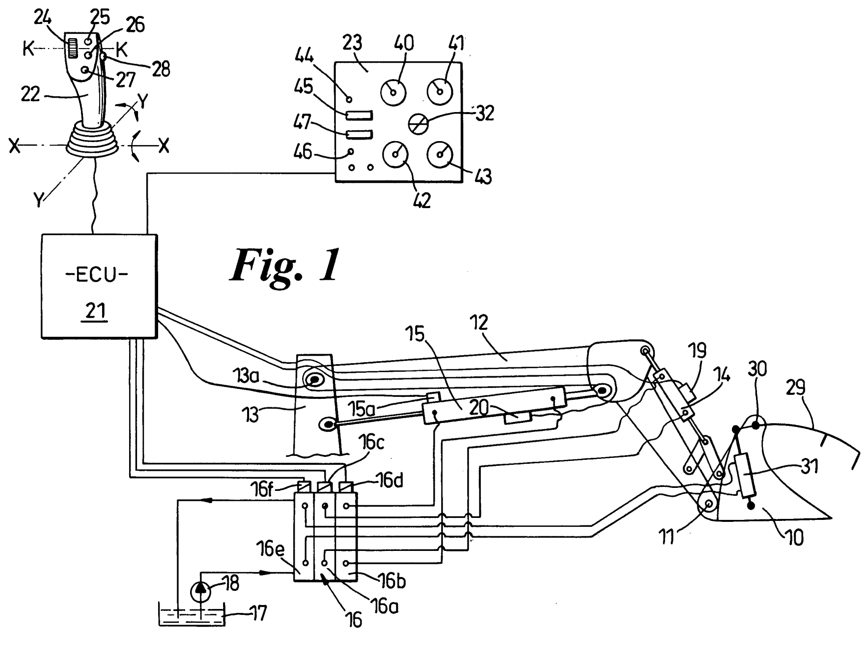


Fig. 1

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## Description

**[0001]** This invention relates to implements support systems (hereinafter referred to as being of the kind described) which comprise:-

- a pair of implement support arms pivotally mounted on a vehicle (such as a tractor),
- hydraulic lift cylinders for pivoting the support arms relative to the vehicle, and
- electrically actuated hydraulic valve means for controlling the flow of pressurised fluid to and from the cylinders in response to commands from a vehicle operator and/or an electrical control unit.

**[0002]** Examples of implement support systems of the kind described are:-

- front loader systems where the pair of support arms carry an implement in the form of a bucket, or
- front mounting implement support linkages in which the pair of support arms carry an implement such as a seed drill or plough on the front of the vehicle.

**[0003]** Problems can occur when such implement support systems are driven over uneven ground whilst carrying a load. This can lead to excessive fluctuations in the pressure in the hydraulic cylinders which support the support arms due to the oscillation of the load. Attempts have been made to damp such pressure fluctuations using accumulators or damping orifices in the hydraulic system which supplies fluid to the lift cylinders but these attempts, whilst reasonably successful from a practical standpoint, are relatively costly to implement.

**[0004]** When such implement support systems are used as part of a front loader further hydraulic cylinders controlled by further hydraulic valves are provided for pivoting the bucket relative to the arms. These arm and bucket control valves are typically controlled by the loader operator via a joystick and such a loader control system may also include a control module which can include automatic routines for controlling a variety of parameters such as bucket angle and maximum bucket height.

**[0005]** It is an object of the present invention to provide an improved form of dampening system for an implement support system of the kind described which does not use an accumulator or damping orifice to control the pressure fluctuations in the system fluid.

**[0006]** It is a further object of the present invention to provide an improved form of joystick for the control of a loader and an improved loader control system with improved operability.

**[0007]** Thus according to a first aspect of the present invention there is provided a damping system for an implement support system of the kind described carrying a given load in a given support arm position, the damping system including a pressure level control loop having a pressure sensing means for sensing the pressure in the lift cylinders due to the load currently carried by the support arms, storing means for storing this sensed lift cylinder pressure as a reference value, the pressure sensing means also monitoring the lift cylinder pressure as the load is transported, and control means for actively adjusting the pressure in the lift cylinders using the electrically actuated hydraulic valves if said pressure varies outside a predetermined deadband either side of the reference value in order to return the lift cylinder pressure to within said deadband and to maintain the support arm carrying position.

**[0008]** Such an arrangement provides all the necessary control of the lift cylinders pressure fluctuations without the need to employ relatively costly accumulators etc. Further in the case of a front loader, sensors for the cylinder pressure are likely to be already incorporated into the loader control system for other uses such as weighing the load in the loader bucket. Thus the only additional cost to implement the damping function is a software/hardware cost associated with the enhancement of the electrical control unit.

**[0009]** In a preferred arrangement the damping system also includes a position control loop having its own predetermined deadband on either side of an initial support arm position determined at the outset of the operation of the damping control.

**[0010]** Normally the pressure control loop is dominant as long as the support arm position is within the position deadband. However, for safety reasons, if the position control loop detects that the current support arm position is outside the position deadband the control of the system switches to the position control loop which acts to move the support arms back to within the position deadband.

**[0011]** One embodiment of the present invention will now be described by way of example only with reference to the accompanying drawings in which:-

Figure 1 shows a system diagram of a loader control system which includes a damping system in accordance with the present invention;

Figure 2 shows on a time basis the operation of the pressure and position control loops of a damping system in accordance with the present invention;

Figure 3 shows the layout of a display screen which forms part of the loader control system, and

Figure 4 shows diagrammatically a bucket position indicator which forms part of the display screen of Figure 3.

**[0012]** Referring to the drawings, a tractor loader comprises a bucket 10 pivotally mounted at 11 on a pair of loader arms 12 which are themselves pivotally mounted at 13a on a pair of posts 13 which are mounted on the associated tractor. The loader is provided with a control system which includes a pair of first cylinders 14 which pivot the bucket relative to the arms 12 and a pair of second cylinders 15 which pivot the arms relative to the posts 13. A block of valves 16 is provided for controlling the flow of fluids to and from the first and second pairs of cylinders. Valve 16a controls the flow of fluid to and from cylinders 14 and valve 16b the flow of fluid to and from cylinders 15. The valves receives their fluid flow from a reservoir 17 where a pump 18.

**[0013]** A first sensor 19 is provided for measuring the angular position of the bucket 10 relative to the arms 12. A second sensor 20 measures the angular position of the arms 12 relative to the posts 13. These sensors may operate on a linear principle or may be rotary units associated with the pivot 11 of the bucket on the arms 12 or the pivot 13a of the arms on the posts 13.

**[0014]** An electronic control unit 21 is provided which receives the signals from sensors 19 and 20 and the inputs from a driver operated command means in the form of a joystick 22.

**[0015]** The electronic control unit 21 issues control signals to solenoids 16c and 16d of control valves 16a and 16b respectively so that the associated cylinders 14 and 15 are moved to position the bucket 10 and arms 12 in the position selected by the operators manipulation of the joystick 22.

**[0016]** The control unit 21 is also connected with a display means 23, which in the example disclosed is in the form of a LCD screen. This display screen (shown in more detail on Figure 3) displays a wide variety of operating parameters of the loader.

**[0017]** The control unit 21 also includes a number of automatic operating routines which may be initiated by the loader operator.

**[0018]** In the centre of the display is provided a bucket position indicator 32 which is also shown diagrammatically in Figure 4. The indicator includes a fixed graticule 33 which indicates a horizontal position of the rim of the bucket, a moveable graticule 34 which indicates a predetermined stored position of the bucket rim to which the operator requires the bucket to return during manual operation and/or during automatic routines, and a further graticule 35 which moves as the bucket rim moves to indicate the actual current position of the bucket rim. Conveniently, the stored position graticule 34 may be highlighted by red arrow heads 36 and actual position graticule may be highlighted by yellow arrow heads 37. As will be appreciated, this bucket position indicator provides a convenient method of communicating to the operator the actual current position of the bucket rim using graticule 35 when the bucket is being controlled directly by the operator's manipulation of the joystick thus enabling the operator to see at all times what movements he needs to make to move the bucket (whose current position is indicated by graticule 35) towards the bucket rim position which the operator requires. This is particularly convenient since the bucket may not be easily visible at all times to the operator.

**[0019]** Additionally the display unit 23 includes a simulated pointer dial 40 whose pointer 40a indicates the fluid flow rate available to power the cylinders 14 and 15, for example litres per minute. A further simulated dial 41 with moveable pointer 41a indicates the pressure in the hydraulic system to power the cylinder 15. Simulated dials 42 and 43 with their associated pointers 42a and 43a indicated the actual orientation of loader arms 12 and bucket 10 respectively.

**[0020]** The control system includes a further weighing function which is invoked by pressing button 51 at the left side of screen 23. A light 44 is illuminated on the display screen when the weighing routine is activated. After pressing button 51 a maximum height position button 25 on joystick 22 is also pressed and the automatic weighing routine automatically moves the bucket arms and bucket to predetermined weighing positions in which the pressure in the cylinders 15 is sensed to determine the weight of material currently in the bucket 10. This pressure is measured by pressure sensors 15a fitted to cylinders 15 and connected with control unit 21. After this pressure is sensed the arms continue their movement to the maximum height position. This measured weight is displayed on screen line display 45. Each time the weighing routine is invoked the weight currently in the bucket is added to the weights which have been lifted by the bucket since the weighing system was last reset by pressing reset button 52 which illuminates a light 46. This accumulative weight is shown on screen line display 47. Thus line display 45 displays the current weight being lifted whilst line display 47 indicates the accumulative weight lifted which can be useful when loading a vehicle to prevent total overload of the vehicle or when measuring out, for example, feed rations for animals.

**[0021]** The display screen includes addition buttons 53 and 54 along its left side. Button 53 is an "set up" button used during a "dealer only" menu-driven calibration of the system during which the various dials and movement indicators/sensors are calibrated by the dealer to the particular loader and tractor. Button 54 is a "Help" button which when pressed informs the system operator how to use the system and the function of the various buttons etc.

**[0022]** Additional buttons 55 to 59 are provided along the button edge of screen 23. Button 55 and 56 are spare buttons with no predetermined assigned function. Buttons 57 and 58 are respectively used to decrease and increase the time to open the grapple fork 29. Button 59 is used to validate a new system parameter when this is changed during part of a "set up" routine and buttons 57 and 58 can also be used to step between menu instructions during "set up".

**[0023]** As will be appreciated some or all of buttons 51 to 59 could be incorporated into screen 23 as touch sensitive areas on the screen.

**[0024]** The joystick is pivotable in a fore and aft sense about an axis X-X which is generally transverse relative to the tractor in order to raise and lower the lift arms 12. A knurled wheel 24 is partially recessed into the top of the joystick, this wheel is rotatable by the operator's thumb about a general transverse axis K-K to roll back and tip the bucket 10 relative to the arms 12. Thus fore and aft movement of the joystick about and axis X-X raises and lowers the lift arms 12 and the movement of the knurled wheel 24 moves the bucket relative to the arms to give simple and complete control of the loader to the operator.

**[0025]** The joystick includes push button 25 previously referred to above and additional push button 26. These buttons when pressed by the operator invoke automatic routines which drive the loader arms to a preset maximum height position when button 25 is operated and a preset minimum height position when button 26 is operated. A further button 27 is provided for driving the bucket to a memorised position (e.g. the horizontal bucket position or some other predetermined bucket position set by the operator).

**[0026]** To set, for example, the maximum height position of the loader arms the loader arms are driven to the required maximum height position by manipulation of the joystick 22 whereupon the maximum height position button 25 and a "save" button 28 position on the side of the joystick is pressed simultaneously to memorise this maximum height position. Each subsequent depression of the button 25 will drive the arms to this save maximum height position. Similarly the preset positions associated buttons 26 and 27 are stored with the aid of the "save" button 28 when the buttons 26 and 27 are pressed simultaneously with button 28.

**[0027]** If desired pivoting of the joystick 22 side to side about the fore and aft axis Y-Y can be arranged to operate a further function of the loader. For example, a grapple fork 29 pivoted on the bucket at 30 can be moved relative to the bucket by actuation of cylinder 31 under the control of additional valve 16e whose solenoid 16f operated by the control unit 21 in response to pivoting of joystick 22 about axis Y-Y. Movement of the joystick to the right can, for example , open the grapple fork whilst movement to the left can close the fork. The joystick can be set up to invoke an automatic grapple fork full opening routine if the joystick is held in the maximum right pivoting for say 1.5 seconds of if the joystick is moved to the maximum right position and the button 28 is pressed.

**[0028]** In accordance with the main aspect of the present invention, a damping system for the front loader is provided which includes a pressure control loop in which the pressure in lift cylinders 15 (measured by sensors 15a) is fed as a control signal into control unit 21 and which also includes a position control loop in which the position of lift arms 12 (measured by sensors 20) is also fed as a further control signal into control unit 21.

**[0029]** The control unit 21 includes a damping control algorithm which determines how the pressure and position control loops interact. This interaction will now be described with reference to Figure 2 which shows in its upper half the operation of its pressure control loop and in the lower half the operation of its position control loop.

**[0030]** To activate the damping system the vehicle operator moves the joystick to position the support arms 12 in the desired carrying position and then releases the joystick to allow it to return to neutral. He then presses the button 51 which also illuminates light 44 and begins operation of the system.

**[0031]** Initially the system measures the pressure in lift cylinders 15 using sensors 15a by sampling the pressure say 6 times in a given sampling time of say 3 seconds to establish the mean pressure present in the lift cylinders due to the weight supported by the support arms. This sampling procedure is variable depending on the particular loader. This mean pressure is recorded in the control unit 21 and used as the reference pressure for the operation of the damping system. This pressure is shown as 'P' in Figure 2. The time period during which this reference pressure is established is shown as 't' in Figure 2.

**[0032]** At the time when this reference pressure P is recorded in the control unit the actual position of the support arms (measured by sensors 20) is also recorded in the control unit 21 and is used as the reference position signal for the operation of the damping system. This position is shown as 'Q' in Figure 2.

**[0033]** If the loader with its bucket load is now, for example, driven over rough ground the pressure in the support cylinders 15 varies as shown by the curve p in the upper half of Figure 2. Similarly the position of the loader arms will vary due to the change in cylinder pressure as shown by the curve 'q' in the lower half of Figure 2.

**[0034]** On establishment of the mean position P a deadband is set up on either side of this reference pressure as indicated by the dotted lines r and s in the upper part of Figure 2. Similarly a deadband is established either side of the reference position Q which is shown by dotted lines u and v in the lower half of Figure 2. These deadbands are adjustable depending on the operating parameters of the particular loader.

**[0035]** As the loader moves over the uneven ground and the pressure varies according to curve p no corrective action is taken until this pressure moves outside the deadband established by limits 'r' and 's'.

**[0036]** Referring to the upper half of Figure 2, at point p1 the pressure in the support cylinders has risen to the upper deadband limit of r and corrective action begins to be required. After a short reaction period of say 2 milliseconds (shown in Figure 2 as time period 'c') the system reacts to the fact that the support cylinder pressure has risen to the upper limit 'r' and the control valve 16b is opened to begin the reduction in the support cylinder pressure as indicated by the portion p2 of curve 'p'. This corrective action continues until the pressure has fallen to point p3 when the upper deadband pressure limit 'r' is reached. After a further reaction period 'c' further reduction of the pressure in support cylinders 15 to control the damping is terminated at point p4.

**[0037]** The effect of this reduction in the pressure in support cylinder 15 is to cause the position of the lift arms 12 to fall as indicated by the portion q2 of curve 'q'. This falling of the arms continues until point q4.

**[0038]** Since the cylinder pressure p4 is still within the deadband, the position control loop takes over and increase the cylinder pressure to move the position of the lift arms back towards the initial stored position Q as indicated by the portion q5 of the position curve. This results in the pressure increasing in the support cylinders indicated by portion p5 of the pressure curve. If this pressure increase remains inside the upper limits 'r' of the pressure control loop the position of the support arms will be restored to the initial reference position Q as indicated by portion q6 of the curve.

**[0039]** Thus, as long as the current position signal is within the deadband, once the pressure signal has been reduced to within the deadband the position control loop takes over to try to restore the initial support arm position.

**[0040]** The control algorithm includes the safety feature that, should the current support arm position stray outside the position deadband, the position control loop takes over to immediately adjust the support cylinder pressure to bring the support arms back within the deadband before any support cylinder pressure adjustment is made to provide damping. This safety feature is necessary in order to avoid dangerous movements of the support arms in an attempt to damp large surges in support cylinder pressure.

**[0041]** This feature of the system is shown diagrammatically in Figure 2 which shows a second large surge in support cylinder pressure at portion p6 of the curve with a subsequent reduction in support cylinder pressure after reaction time 'c' along portion p7 of the curve back to point p8 and the point p9 due to the reaction delay 'c'. Again during this damping pressure reduction the position of the lift arms moves along the portion q7 of the position curve to corresponding points q8 and q9 and at point q9 is still within the position control loop deadband. Thus the position control loop increases the cylinder pressure (potion p10 of the curve) to move the position of the support arm back towards the initial position Q (portion q10 of the curve.

**[0042]** If a further extreme increase in support cylinder pressure then occurs as shown in portion p11 of the curve to a pressure p12 this will result in further displacement of the lift arms along the portion q11 of the curve to a position q12 corresponding to the pressure level p12. Normally the system would operate to reduce the cylinder pressure from p12 along curve p13 to effect damping. However, since the current position of the lift arms at q12 is now outside the deadband lower limit 'v', the position control loop takes over and the support cylinder pressure is increased to drive the current position of the lift arms back to the lower deadband limit as indicated by the portion q13 to the position q14 of the curve. This will result in a temporary further increase of the pressure in the lift arms to the position p14 and to an overshoot to pressure to p15 and position q15 due to the system reaction time 'c'.

**[0043]** Once the current support arm position is within the position deadband the pressure control loop again becomes dominant and reduces the cylinder pressure back towards the mean pressure P to effect damping of the pressure variations in the cylinders 15 (see curve portions p16 and q 16 respectively).

**[0044]** Such an arrangement provides all the necessary control of the lift cylinders pressure fluctuations without the need to employ relatively costly accumulators etc. and uses sensors for lift cylinder pressure which are already incorporate into the loader control system for weighing the load in the loader bucket.

**[0045]** Thus the only additional cost to implement the damping function is a software/hardware cost associated with the implementation of the damping algorithm control unit 21.

**[0046]** Although described above in relation to a specific joystick arrangement using a knurled wheel 24 to control the loader bucket, the damping system is applicable to a wide range of loader control systems, for example, where the loader arms and bucket are controlled by the more conventional pivoting of the joystick about the X-X and Y-Y axis respectively.

## Claims

1. A damping system for an implement support system of the kind described carrying a given bucket load in a given support arm position, the damper system being **characterised by** including a pressure level control loop having a pressure sensing means (15a) for sensing the pressure in the lift cylinders (15) due to the load currently carried on the support arms (12), storing means (21) for storing this sensed lift cylinder pressure as a reference value, the pressure sensing means also monitoring the lift cylinder pressure as the load is transported, and control means (21) for actively adjusting the pressure in the lift cylinders using the electrically actuated hydraulic valve (16b) if said pressure varies outside a predetermined deadband (r,s) either side of the reference value (P) in order to return the lift cylinder pressure to within said deadband and to maintain the support arm carrying position (Q).

2. A system according to Claim 1 which also includes a position control loop having its own predetermined deadband (u,v) on either side of an initial support arm position (Q) determined at the outset of the operation of the damping control.

3. A system according to Claim 1 or 2 in which normally the pressure level control loop is dominant as long as the support arm position (Q) is within the position deadband (u,v), the control system (21) switching to the position control loop if the current support arm position (2) moves outside the position deadband.

**4.** A system according to any one of claims 1 to 3 in which a loader bucket (10) is pivotally mounted on the arms (12) and further hydraulic cylinders (14) are provided for pivoting the bucket relative to the arms, the lift cylinders (15) and bucket cylinders (14) being operator controlled lever control means (22).

**5.** A system according to claim 4 in which the control lever means comprises a joystick (22) whose pivotal movements about a first axis (X-X) control the hydraulic valve (16b) to raise/lower the arms (12), the joystick carrying a knurled wheel (24) partially recessed into the joystick, rotation of the wheel controlling the bucket (10) relative to the arms (12).

**6.** A system according to claim 5 in which the joystick (22) carries one or more additional control means (25-28) for activating control routines such as driving the arms (12) to a predetermined height position.

**7.** A system according to claim 6 in which the joystick (22) has a first button (25) which if pressed generates a signal to drive the arms (12) to a preset maximum height position, a second button (26) which if pressed generates a signal to drive the arms (12) to a preset minimum height position, and a third button (27) which if pressed generates a signal to drive the bucket (10) to a predetermined bucket position.

**8.** A system according to any one of claims 5 to 7 in which pivoting of the joystick (22) about a second axis (Y-Y) inclined relatively to the first axis (X-X) generates a signal to operate the valve (16e) to control a further function (29) which can be pivoted relative to the bucket (10) by a further hydraulic cylinder (31).

**9.** A system according to claim 8 in which pivoting about the first and second axes (X-X,Y-Y) provides simultaneous and proportional control of two separate functions (12,29).

**10.** A system according to claim 4 having first sensor means (19) for measuring the pivot angle of the bucket (10) relative to the arms (12), second sensor means (20) for measuring the pivot angle of the arms (12) relative to the vehicle (13), operator controlled control lever means (22) for issuing commands as to the desired bucket and arm positions, and an electronic control means (21) which receives inputs from the control lever means (22) and the first and second sensor means (19,20) and controls the valves (16a, 16b) so that the cylinder means (14,15) are operated in order that the desired bucket and arm positions set on the control lever means are attained, and visual display means (23) connected with the electronic control means (21) on which the current angular position (35) of the bucket (10) is displayed to the operator.

**11.** A system according to claim 10 in which the electronic control means (21) includes a number of automatic control functions such as maintaining a chosen bucket orientation relative to the ground (e.g. bucket rim horizontal) as the arms (12) are raised and lowered and the display means (23,32) displays the current bucket orientation (35) relative to the chosen orientation (33) to assist the operator when the bucket is under the control of the operator.

**12.** A system according to claim 10 or 11 in which the visual display means (32) include an indication (33) of a horizontal bucket orientation, an indication (34) of the desired bucket orientation, and an indication of the current bucket orientation (35) which moves as the bucket (10) moves.

**13.** A system according to any one of claims 10 to 12 in which the visual display means (23) provides an indication of the one or more of the following further parameters:-

- Orientation (35) of lift arms (12);
- fluid flow available (40a) to power the cylinders (e.g. in lts/min);
- pressure (41a) in the hydraulic system which powers the cylinders;
- weight of substance currently being lifted in the bucket (45); and
- total weight of substance lifted in the bucket (47) since last reset.

**14.** A joystick control lever (22) for the control of a loader of the kind described in which pivoting movements of the joystick about a first axis (X-X) generates a signal which controls the hydraulic valve (16b) to raise/lower the arms (12), the joystick carrying a moveable control member (24) which when moved relative to the joystick generates a signal which controls the hydraulic valve (16a) to pivot the bucket (10) relative to the arms (12).

**15.** A loader control system for a bucket (10) pivoted on one end of a pair of lift arms (12) the other ends of which are pivoted on a support vehicle (13) with first cylinder means (14) for pivoting the bucket relative to the arms and second cylinder means (15) for pivoting the arms relative to the vehicle, the control system comprising valve means (16a,16b) for controlling the flow of fluid to and from the first and second cylinder means, first sensor means (19) for measuring the pivot angle of the bucket relative to the arms, second sensor means (20) for measuring the pivot angle of the arms relative to the vehicle, driver operated command means (22) for issuing commands as to the desired bucket and arm positions, electronic control means (21) which receives inputs from the command means (22) and the first and second sensor means (19,20) and controls the valve means (16a,16b) so that the first and second cylinder means (14,15) are operated in order that the desired bucket and arm positions set on the command means are attained, and visual display means (23) connected with the electronic control means (21) on which the current angular position (35) of the bucket (10) is displayed to the operator.

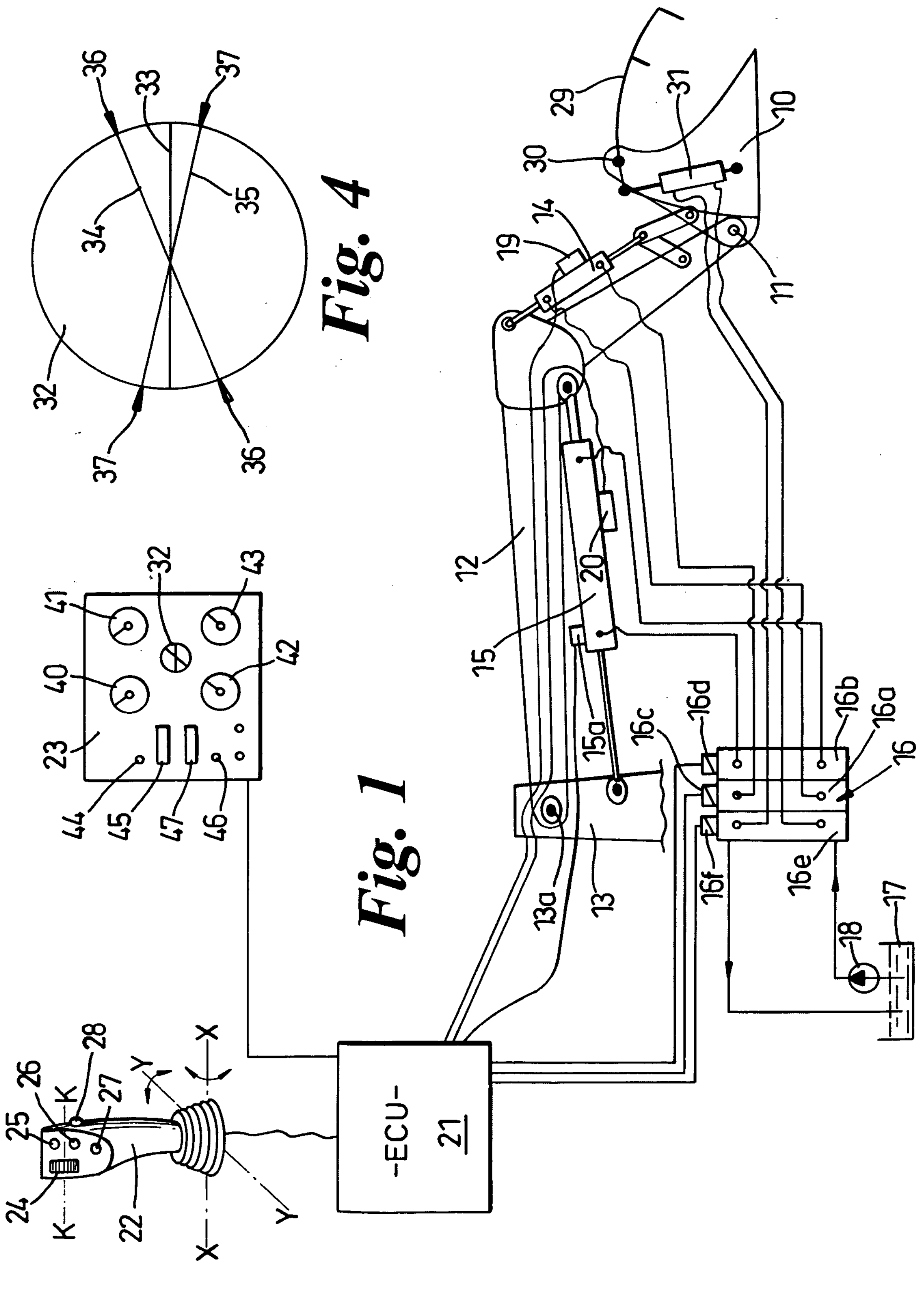


Fig. 4

Fig. 1

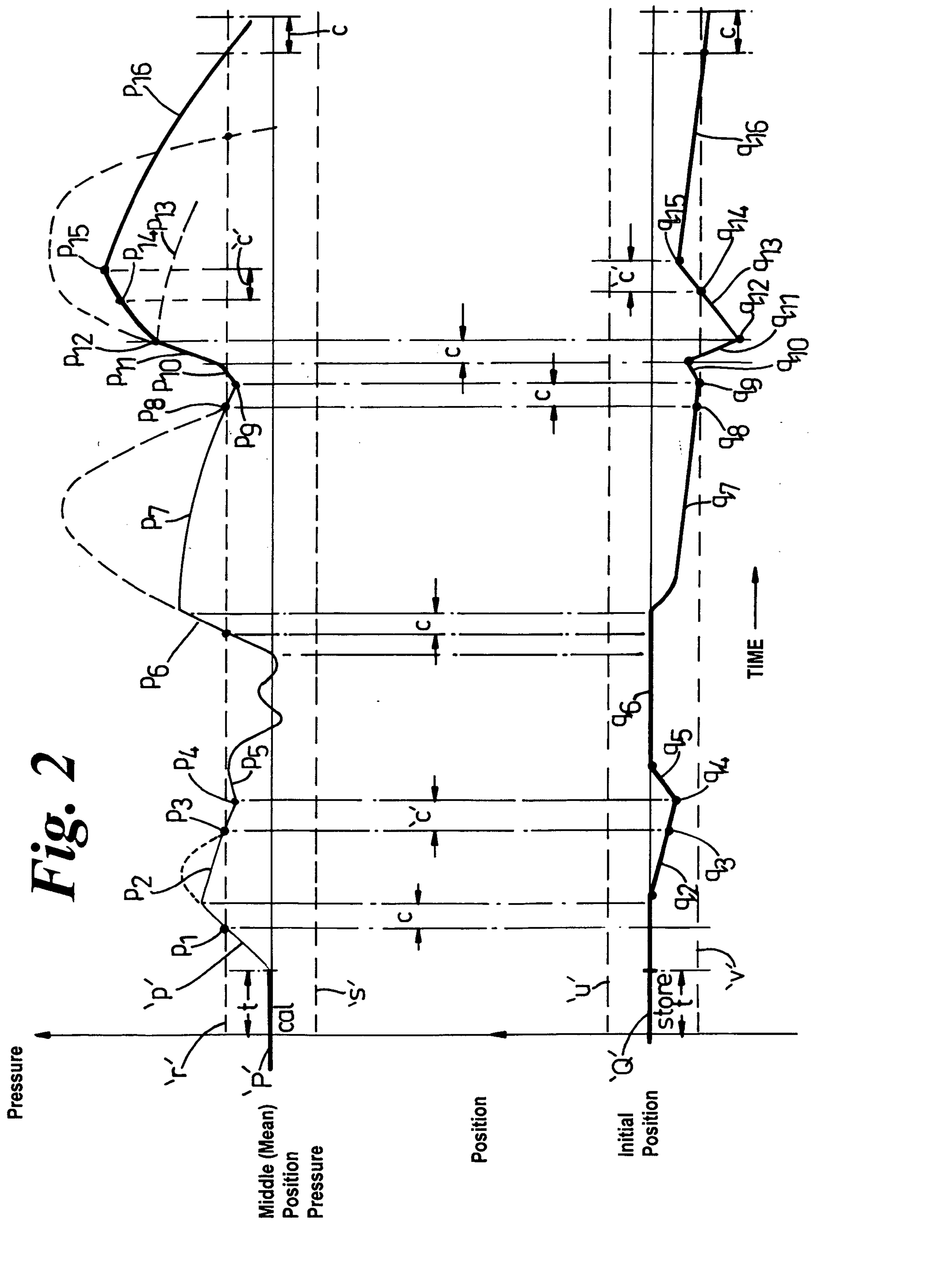
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*Fig. 2*

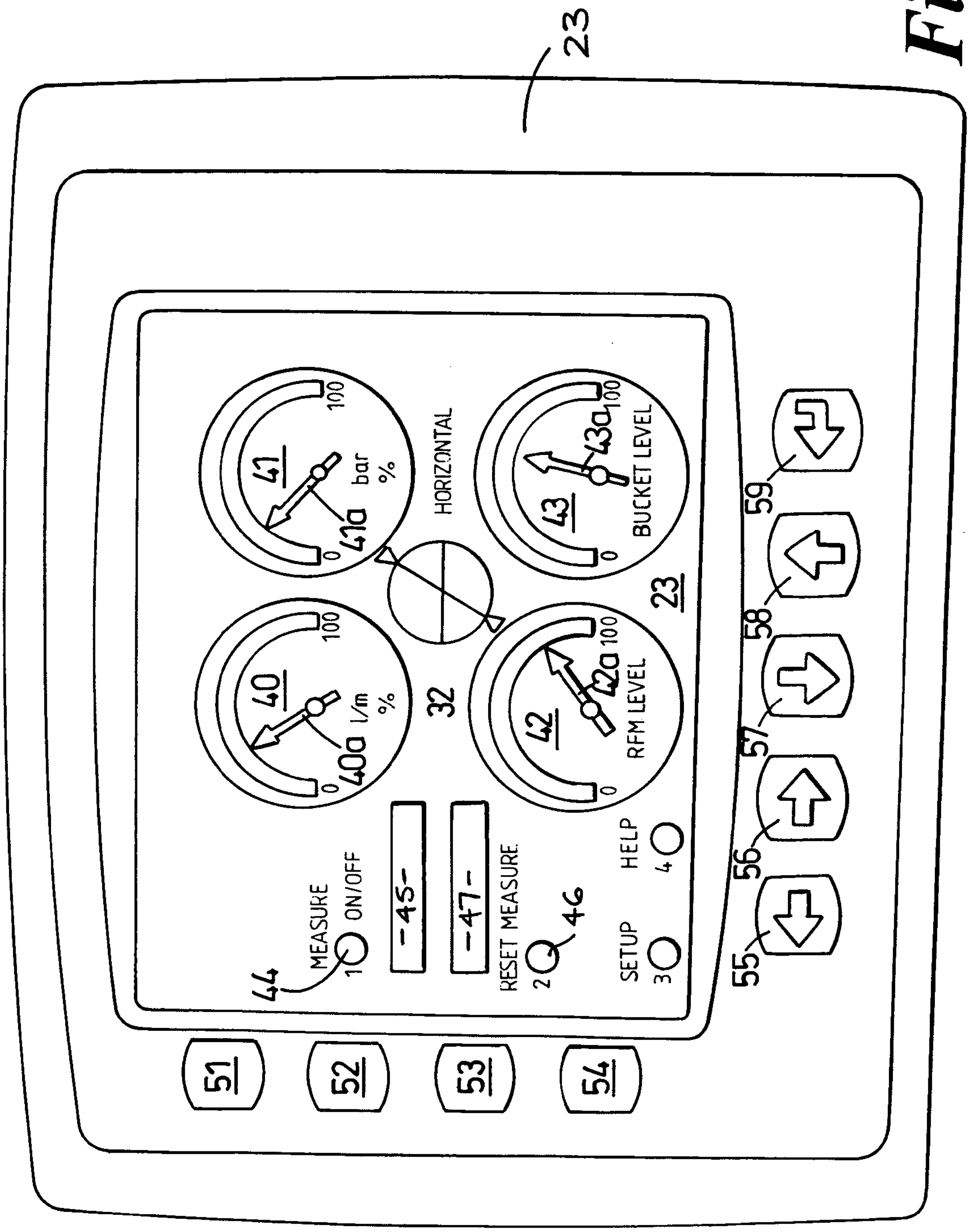
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Fig. 3