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Howells, Jr. et al.

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[45] **Oct. 8, 1974**

[54] **ELECTRO-HYDRAULIC CONTROL CIRCUIT FOR BACKHOE**

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[73] Assignee: **International Harvester Company**, Chicago, Ill.

[22] Filed: **Oct. 1, 1973**

[21] Appl. No.: **402,219**

Related U.S. Application Data

[60] Division of Ser. No. 266,883, June 28, 1972, abandoned, which is a continuation of Ser. No. 887,012, Dec. 22, 1969, abandoned.

[52] **U.S. Cl.** ..... **214/138 R**, 91/413, 91/459, 60/DIG. 2

[51] **Int. Cl.** **F02f 3/32**

[58] **Field of Search** ..... 214/138 R; 91/413, 459

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2,873,762	2/1959	Tennis	137/596.13
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Primary Examiner—Edgar W. Geoghegan

Attorney, Agent, or Firm—Ronald C. Kamp; Floyd B. Harman

[57] **ABSTRACT**

A control system for a hydraulic motor including a source of fluid power, a directional flow control valve interposed between the source of fluid power and the hydraulic motor, a bridge circuit including a source of electrical energy and having a first variable impedance branch varied by a command control lever and a second variable impedance branch associated with the flow control valve, comparator means connected to the output of the bridge circuit for detecting and amplifying an unbalance in the bridge circuit and means interconnected between the comparator and the directional flow control valve for controlling said valve in a manner corresponding to command movement of the variable impedance branch.

1 Claim, 10 Drawing Figures

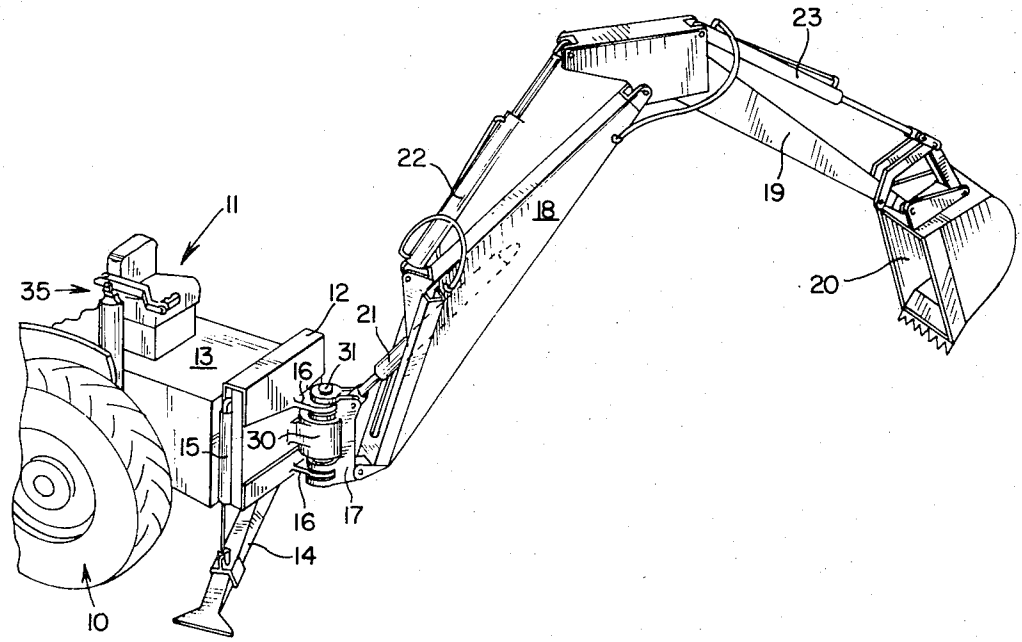
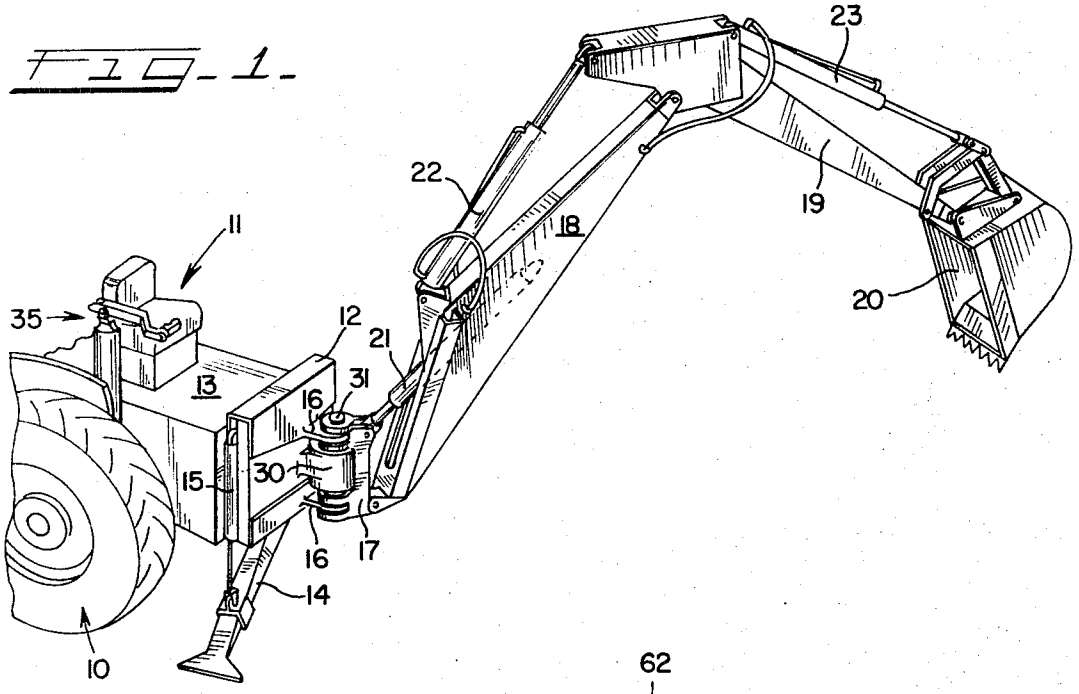


FIG. 1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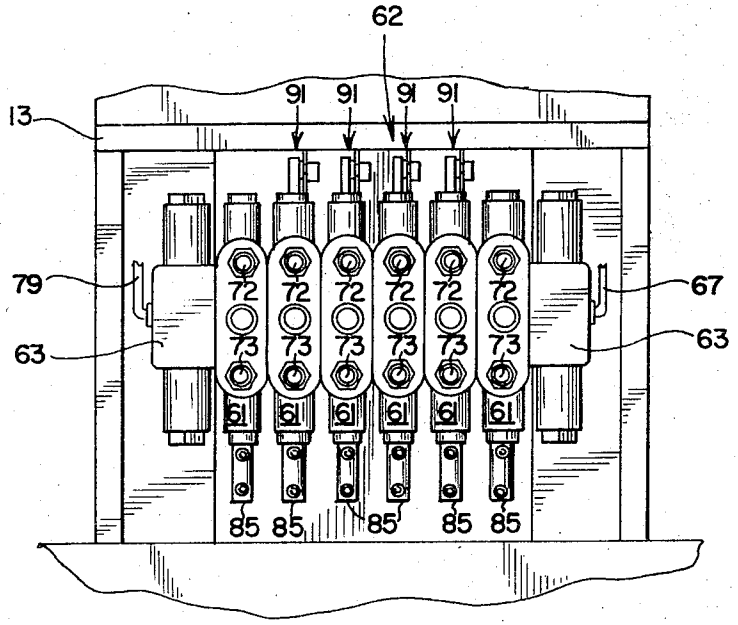
62
13
91
91
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91
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67
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63
72
73
61
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FIG. 2

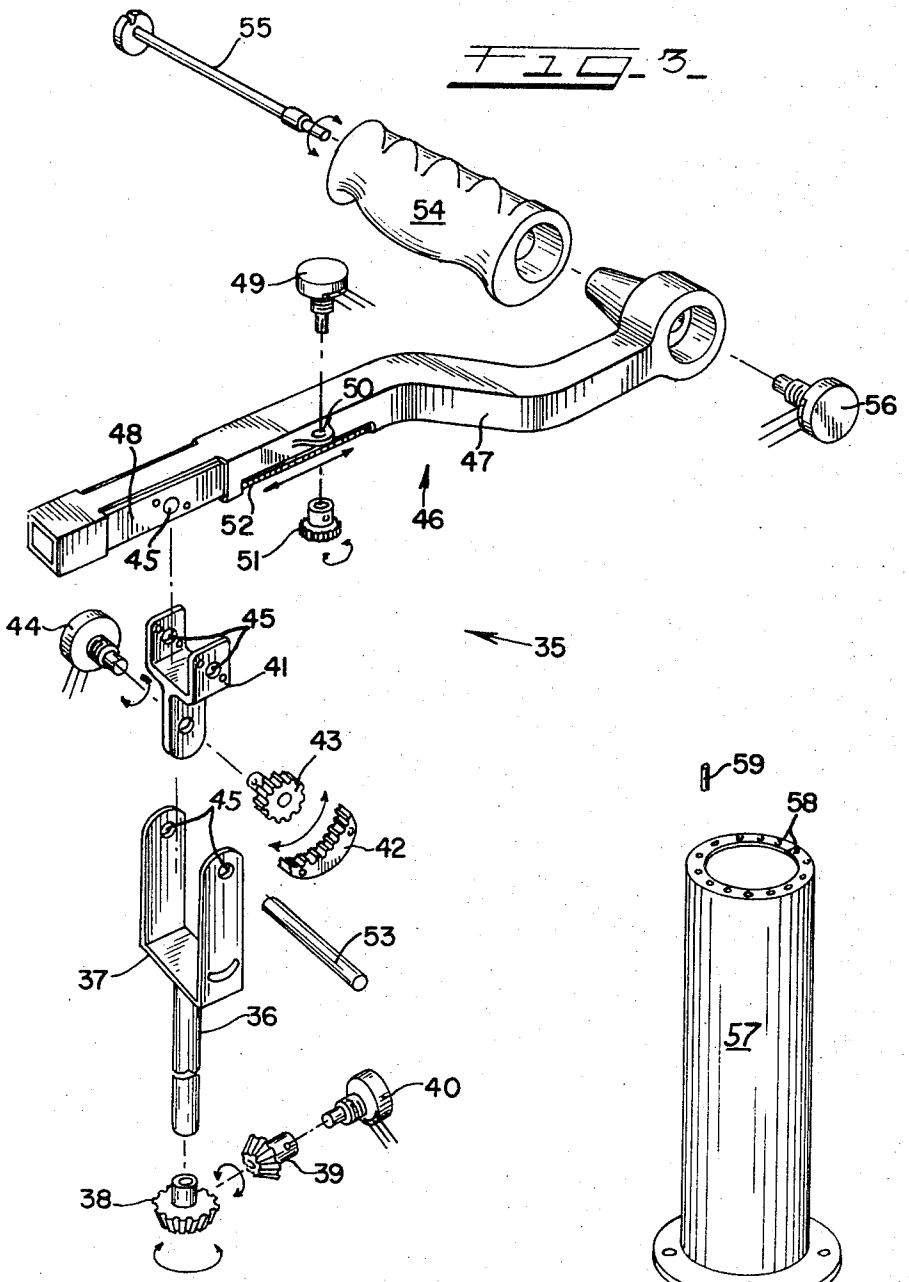
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FIG. 3

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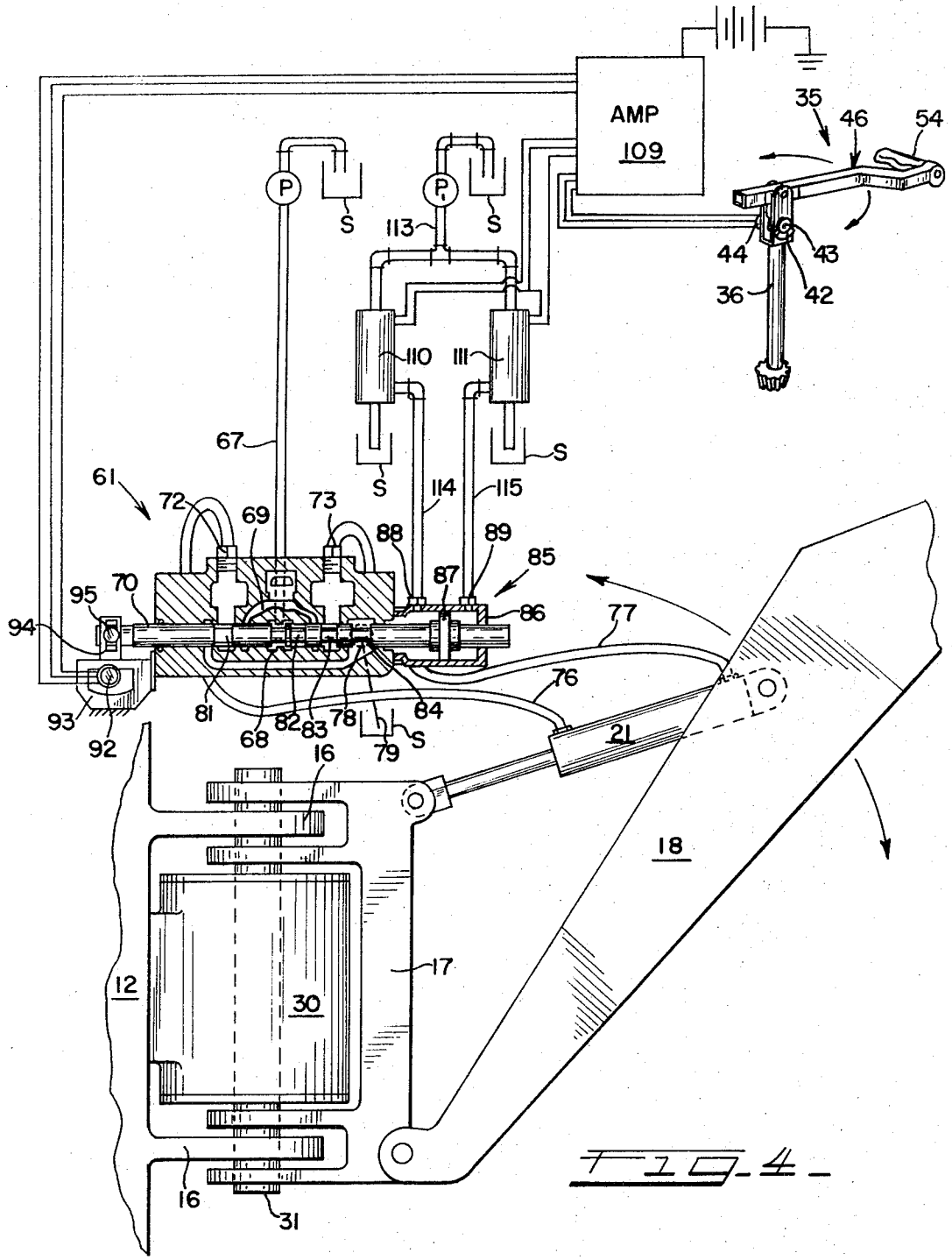
57

FIG. 9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73
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70
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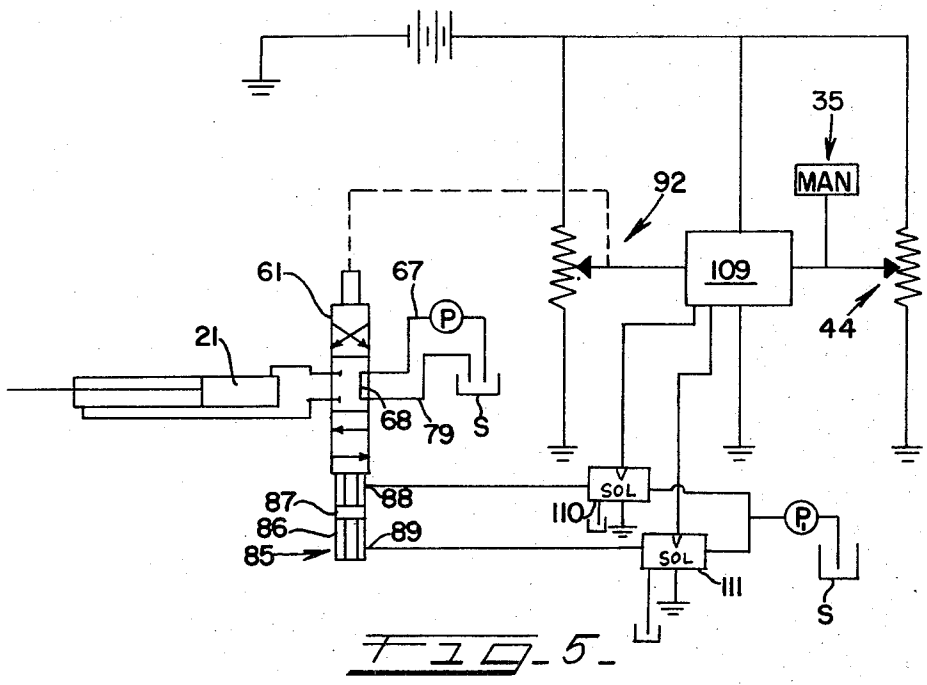
FIG. 4


35
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92
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61
67
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44
68
79
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87
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86
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SOL
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111
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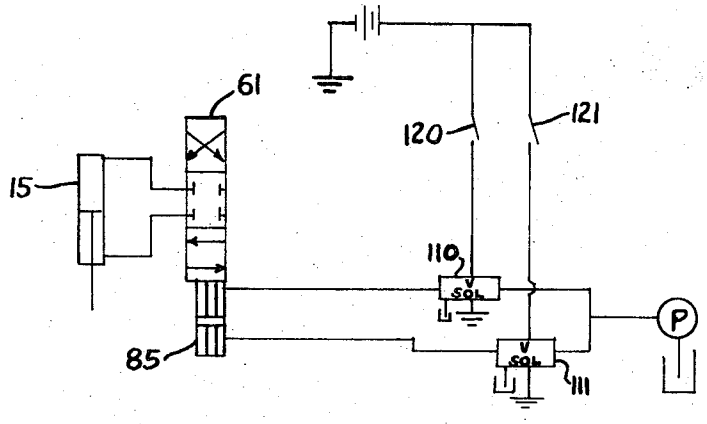
S

FIG. 5


61
120
121
15
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SOL
SOL
111
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85

FIG. 10

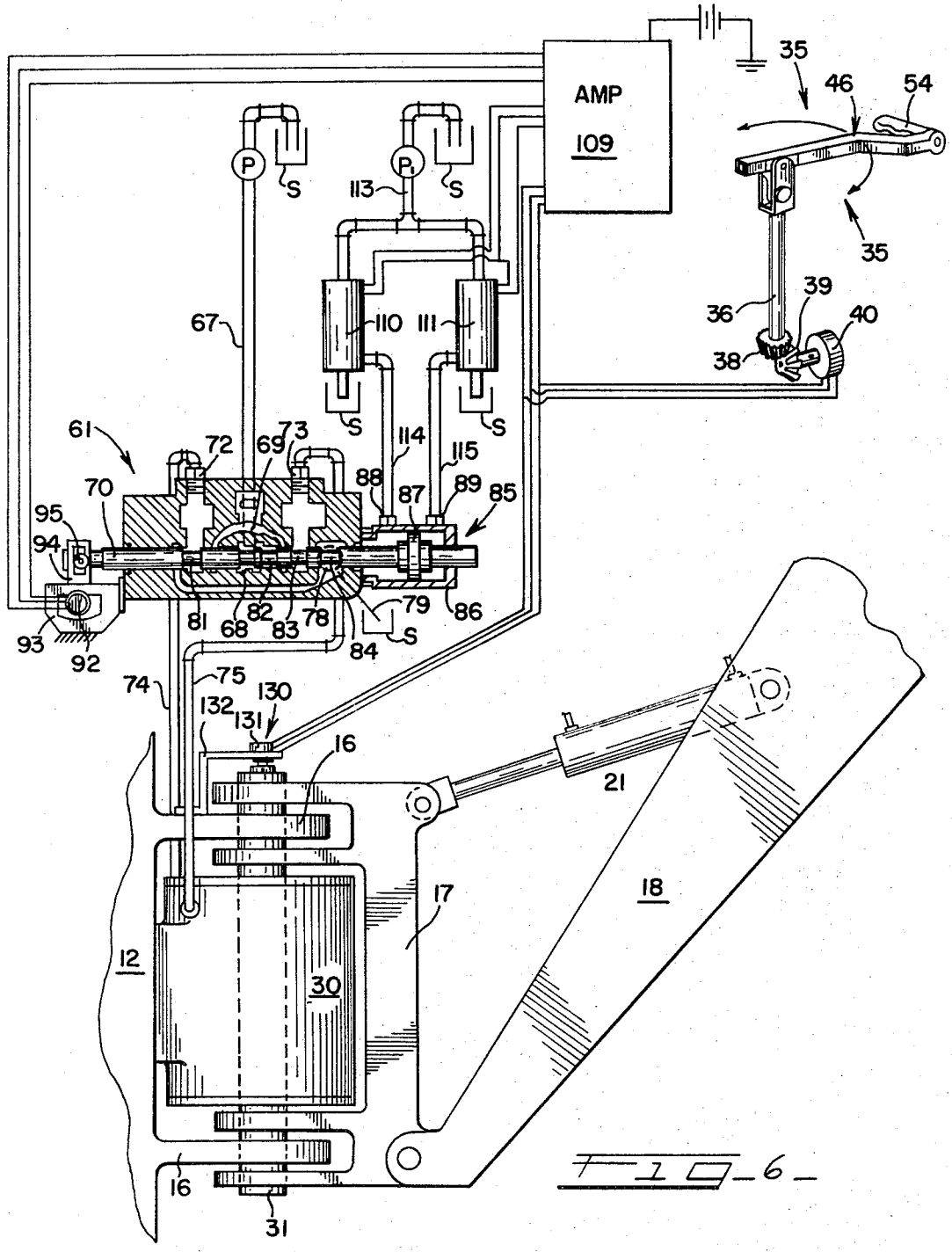
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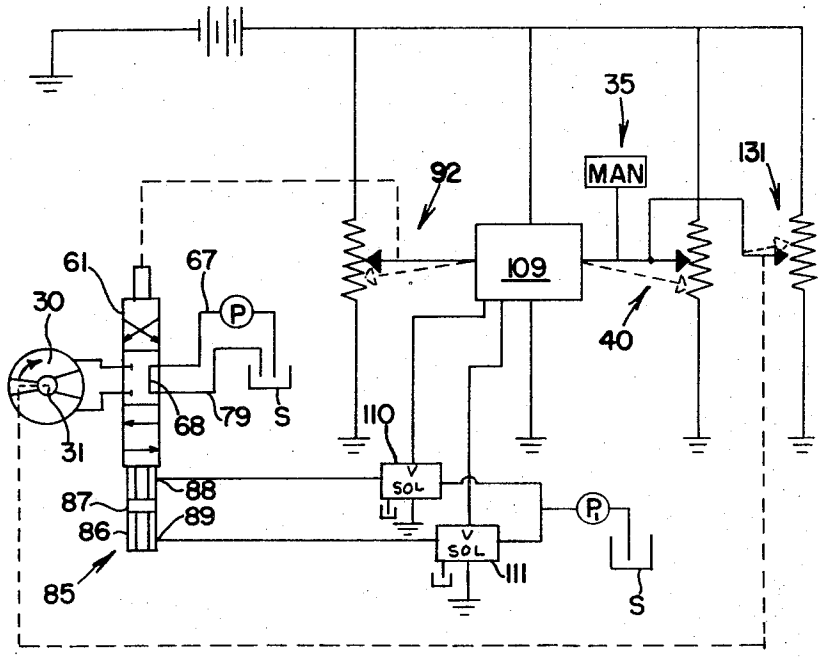
FIG_6_


35
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131
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109
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SOL
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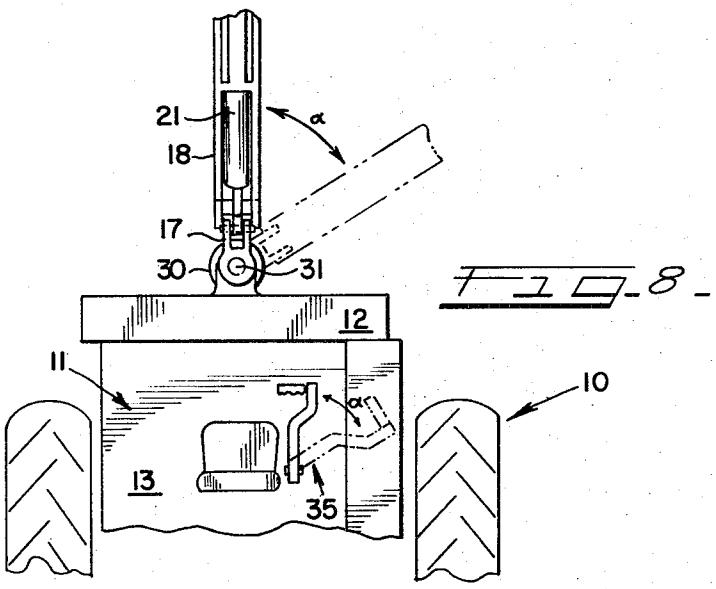
FIG. 7


21
α
18
17
30
31
12
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10
α
13
35

FIG. 8

ELECTRO-HYDRAULIC CONTROL CIRCUIT FOR BACKHOE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a division of application Ser. No. 266,883, filed June 28, 1972, abandoned, which application was a continuation of application Ser. No. 887,012, filed Dec. 22, 1969, abandoned.

BACKGROUND OF THE INVENTION

This invention relates to a unique electro-hydraulic or electrical control system for controlling one or more hydraulic motors. More specifically the invention concerns a control system for accurately controlling the direction and flow rate of fluid to a hydraulic motor.

Flow control systems of the prior art are illustrated by a directional flow control valve interconnected between a motor and a source and actuated by mechanical linkages. When utilized on vehicles to control material handling devices, the location of the valves as well as the number thereof often require complicated and numerous linkages to facilitate their operation from a convenient position. For example, backhoes in production today utilize a separate lever controlling each flow control valve which separately actuates the boom, rotary actuator, dipper stick and bucket.

Thus four separate levers are utilized to perform digging operations for the current backhoes, and convenient location as well as simplicity is required to economically utilize such devices. Similarly, the prior art utilizes purely mechanical linkages for controlling directional flow control valves which actuate the rotary actuator, boom, dipper stick and bucket.

SUMMARY OF THE INVENTION

Accordingly, the instant invention relates to a novel and unique electrical control circuit for controlling actuation of directional flow control valves. Preferred embodiments, hereinafter disclosed, incorporate a circuit between a command lever and the flow control valve in such a manner to easily control actuation of the flow control valve and is of such simple construction as to permit utilization of a single lever to operate several such valves. It is an object of the instant invention to provide a single lever control system for material handling mechanisms in which a plurality of directional flow control valves and hydraulic motors must be controlled. Similarly, it is an object of the instant invention to further correlate the direction of movement of the single control lever with directional movement of the structure to be controlled. Not only is such directional movement correlated to provide a follow-up system, but a unique and novel position control system is proffered herein. It is a further object of the instant invention to provide a relatively simple control system which eliminates the dexterious requirements of operators of material-handling equipment.

With respect to the control system per se, it is a general object to provide an economical and easily assembled electrical control circuit for any hydraulic motor which results in unique operating characteristics of precise and accurate control of a linkage or hydraulic motor as well as the ability to accurately meter fluid through a directional flow control valve. Such a control system may be easily adapted in fields unrelated to article handling and would include machine tools and other diverse areas. Finally, it is an object of the instant invention to provide an electrical control system for a hydraulic motor in which either a follow-up system or a position control system can be readily realized.

DESCRIPTION OF THE DRAWINGS

The manner in which the objects of the instant invention is attained will be made clear by consideration of the following specification and claims when taken in conjunction with the accompanying drawings in which:

FIG. **1** is a perspective view of the rear portion of a vehicle having mounted thereon a conventional backhoe;

FIG. **2** is a rear elevational view of the directional flow control valves which are utilized to direct flow to and from the hydraulic motors actuating the various linkages of the backhoe;

FIG. **3** is an exploded perspective view of the single handle control utilized to actuate the directional flow control valves which in turn direct fluid to and from the hydraulic motors;

FIG. **4** is a side elevational view of the rotary actuator of the backhoe having the boom attached thereto with a schematic disclosure of the electro-hydraulic control system utilized in controlling the boom of the backhoe;

FIG. **5** is a schematic view of an electro-hydraulic circuit for controlling the hydraulic motor which in turn operates the boom of the backhoe;

FIG. **6** is a side elevational view of the rotary actuator and the boom of the backhoe attached thereto with a schematic view of an electro-hydraulic control system which actuates the rotary actuator in turn controlling rotational movement of the backhoe boom;

FIG. **7** is a schematic view of the electro-hydraulic control system of FIG. **6**;

FIG. **8** is a top view disclosing rotary actuation of the backhoe unit and its correlated movement of the control handle;

FIG. **9** is a perspective view of a mounting element for the control lever of FIG. **3**; and

FIG. **10** is a schematic view of an additional control circuit.

DETAIL DESCRIPTION

As exemplified in the attached drawings, the preferred embodiments of our unique invention are incorporated into a tractor **10** to which a material-handling apparatus is attached. The tractor **10** is provided with an operator's station **13** having thereon a seat **11** adjacent to which is a single handle control lever **35** operative to control all of the movements of the associated material-handling apparatus. In the instant disclosure, this material-handling apparatus comprises a backhoe having a support stand **12** suitably attached to the tractor by conventional means and being further supported upon the ground surface by stabilizer arms **14** (only one of which is here shown), the stabilizer itself being controlled by hydraulic motor **15.** Appropriate brackets **16, 16** extending rearwardly from support stand **12** carry a rotary hydraulic motor **30** constrained from rotation by suitable means and having a shaft **31** extending therethrough for rotatably driving the swing mount **17** as fluid energy is directed to the actuator **30.** The swing mount **30** in turn rotatably mounts a boom **18,** dipper stick **19** and bucket **20,** these linkages and the

bucket being controlled in their movement by hydraulic rams **21, 22,** and **23** respectively.

Disposed underneath the operator's station **13** for conveniently controlling the movement of the rams **15,** the rotary actuator **30,** and the hydraulic rams **21, 22** and **23,** is a valve bank **62** comprising six directional flow control valves **61.** Upon one end of this valve bank is mounted a conventional end cap **63** to which is connected an intake conduit **67** for delivering fluid from a pump to the valves. Adjacent the opposite end of the valve bank **62** is another identical end cap **63** to which is connected a conduit **79** for returning hydraulic fluid to the reservoir. These valves **61** are substantially similar to that disclosed in U.S. Pat. No. 2,873,762 issued to F. H. Tennis and dated 17 Feb. 1959. Further reference may be had to a cross sectional view of these same valves in FIGS. **4** and **6** for a clearer understanding thereof.

ELECTRO-HYDRAULIC CONTROL CIRCUIT

Reference may now be had to FIGS. **4** and **5** in which one of the control valves **61** is integrated into the control circuit of the instant invention for the hydraulic motor **21** which effectuates movement of the boom **18** of the backhoe. (As later explained, such a circuit is associated with each element of the backhoe). A pump P delivers fluid from reservoir S to directional control valve **61** through a conduit **67.** As disclosed in FIG. **2** such fluid would normally be delivered to an end cap **63** of valve bank **62,** such being omitted from FIG. **4** for purposes of simplicity. This fluid is then directed into an open center passage **68** and normally flows directly out of this valve and into the opposite end cap and back to sump. As more fully disclosed in U.S. Pat. No. 2,873,762, a spool **70** is reciprocable within the valve **61** whereby the reduced diameters of said spool in conjunction with various lands and porting will control the direction of fluid flow to and from the hydraulic motor **21.** Briefly setting out such structural and functional characteristics of this well known valve, it will be observed that if spool **70** is shifted either to the right or to the left and fluid can no longer flow through the open or low pressure passage **68** since the normal diameter of the spool precludes such, and fluid is then directed into a high pressure passage **69** for delivery to the hydraulic motor **21** via one of the motor ports **72** or **73.** Thus, assuming the spool is shifted to the right, the low pressure, open center feature of the valve is closed by a normal diameter of the spool, and hydraulic fluid is then urged into the high pressure passage **69,** across the reduced diameter of the spool at **81** and out port **72** to contract the hydraulic ram **21.** Fluid is then returned from the opposite end of the ram **21** via conduit **77,** motor port **73,** across reduced diameter **83** of the spool and out of exhaust port **78** to the sump S through a conduit **79.** Reciprocation of the spool in the opposite direction merely reverses the direction of flow above explained. These passages and portings of the open center valve being quite conventional, no further explanation is deemed necessary other than reference to the above identified patent.

Movement of the spool **70** of the valve **61** is controlled by expansionable chamber device or servo motor **85** and includes a housing **86** connected to the valve **61** and having a piston element **87** attached to the spool **70** whereby any unbalance of fluid energy delivered through a port **88** or a port **89** is effective to cause reciprocation of the piston **87** and the spool **70** to control the direction of fluid flow to hydraulic motor **21.** Fluid is supplied to the servo motor **85** from a pump P1 delivering fluid through a conduit **113** to solenoid operated valves **110** and **111.** These solenoid valves may appropriately be a conventional "normally open" three-way valve in which the fluid is normally directed through the valve to the ports **88** and **89** of servo motor **85** but upon selective actuation they will dump both supply fluid and fluid on the appropriate side of piston **87** to sump S whereby the normal pressure on the opposing side of the piston will cause the spool to reciprocate. Another preferable solenoid valve would include the "four-way normally open — normally open solenoid valve, Type V955" made and sold by Skinner Precision Industries, Inc. of New Britain, Conn. This valve is basically a combination of two three-way valves disclosed above, but incorporated into one housing.

For controlling actuation of the solenoid valve **110** or **111** and consequent actuation of spool **70,** a bridge circuit is interposed between a control member or lever **35** and spool **70** of the control valve **61.** As more clearly depicted in FIG. **5,** a bridge circuit is established in which two potentiometers **44** and **92** are connected in parallel and a voltage impressed across them. The wiper of potentiometer **44** is rotatably attached to the control lever **35** as hereinafter explained, and the wiper of potentiometer **92** is rotatably attached by assembly **91** (see FIG. 2) to the spool **70** of control valve **61.**

The wiper leads are then connected to a null detector means or comparator means **109** which will detect any unbalance or voltage differential in the bridge circuit and amplify a signal created by said unbalance to actuate the appropriate solenoid valve **110** and **111.** Thus, upon varying the resistance in potentiometer **44,** the comparator means **109** will actuate solenoid valve **110** or **111** so as to dump fluid from the appropriate chamber on one side of piston **87** and normal pressure on the opposite side will effectuate reciprocation of spool **70,** the spool movement rotating the wiper of potentiometer **92** such that the bridge circuit will again be balanced. Thus, it should be appreciated that movement of a control lever **35** about a horizontal axis will produce a corresponding proportional movement of spool **70.** With reference to the components of the electro-hydraulic control system, it is to be noted that the null detector or comparator means **109** is a conventional item and readily obtainable in the market in various forms. An example of other forms of the electrical circuits which may provide excellent alternatives would include a series connection of two variable resistances in parallel with a series connection of two fixed resistances, the comparator **109** being interconnected between the resistances of each parallel branch. The pump delivering fluid to the solenoid valves is preferably a low volume and low pressure pump, but may be the same pump utilized to deliver fluid to the backhoe itself if acceptable flow rates are provided. The solenoid valves selected for the system should preferably have a small flow rate for the intended pump and pressure since more accurate movement of the spool **70** may be obtained. It should be appreciated that solenoid members acting directly upon the spool could be utilized as well as other systems including conventional electro-hydraulic servo valves should the potentiometer reading be taken from the valve in such a manner

as to be proportional to the flow rate through such valve.

Referring back to FIG. 4, the potentiometer 92 is attached to the spool 70 in a simple mechanical manner. For example, a bracket 93 is fixedly attached to the console 13 of the backhoe apparatus with the potentiometer secured therein and constrained against rotation. A link 94 is then constrained for rotation with the wiper of the potentiometer 92, reciprocation of the spool causing rotation of this link through a pivotal element 95 so as to vary the impedance of this branch of the bridge circuit.

Each of the directional flow control valves 61 associated with the rotary actuator, and the hydraulic motors 21, 22 and 23 may be conveniently provided with such an electrical control circuit.

SINGLE LEVER CONTROL

For manipulating the command potentiometer 44 as well as a command potentiometer for each control circuit associated with motors 30, 21, 22 and 23, applicants have provided a unique control means whereby movement of said control means produces a similar directional movement of an appropriate element of a material handling mechanism. As disclosed in FIG. 3 this control means 35 comprises a vertical support 36 which may be appropriately journalled in a housing 57 in a manner permitting rotational movement thereof. Attached to the lower end of this vertical support 36 is a gear 38 which upon rotation will drive a pinion 39 constrained for rotation with the stem of a potentiometer 40, the latter being fixedly supported in housing 57. Thus, as the lever 35 is rotated about a vertical axis, a varying resistance in a potentiometer 40 is incurred and since this variable command impedance forms one branch of a bridge circuit which is part of an electro-hydraulic circuit associated with a valve 61 controlling flow to actuator 30 and otherwise identical to that disclosed in FIGS. 4 and 5, the rotational movement of the lever 35 about a vertical axis will control rotational movement of the shaft 31 of rotary actuator 30.

In order to control command impedance 44 and boom 18 and motor 21, as previously explained in FIGS. 4 and 5, a yoke 37 is provided on the upper end of vertical support 36, and common apertures 45 connect same to another yoke member 41 as well as to an extensible arm 46, the latter connection being made rigid by pin connections extending the adjacent diagonal apertures (unnumbered). The yoke 41 then extends downwardly from the pivotal connection 53 with the extending arm carrying the potentiometer 44 constrained for movement therewith. The stem of the potentiometer 44 carries a pinion 43 which is driven by a rack 42 mounted on yoke 37, and thus as the extensible arm 46 is rotated about a horizontal axis passing through a pivotal connection 53, the stem of the potentiometer 44 is rotated so as to obtain a variable impedance or resistance. This potentiometer 44 appropriately controls movement of the boom 18 as previously discussed in relation to FIGS. 4 and 5 by connecting same with another bridge circuit element attached to the spool of the directional flow control valve 61 associated with hydraulic motor 21.

The extensible arm 46 may additionally consist of an outer extensible member 47 and an inner member 48 over which the outer member is telescoped. A potentiometer 49 is then fixed by a bracket 50 upon said outer member, and upon extension and retraction of outer member 47, a rack 52 and a gear 51 constrained for rotation with the stem of potentiometer 49 creates a variable impedance in said potentiometer. Appropriately, this potentiometer may be integrated in a bridge circuit with a potentiometer associated with the flow control valve 61 which is connected to hydraulic motor 22 effectuating movement of the dipper stick 19.

Finally a handle 54 is rotatably secured upon the end of extensible member 47, and a bolt member 55 constrained for rotation by any conventional means with handle 54 extends through the handle and is joined to the stem of potentiometer 56 secured to member 47. Again, rotation of the control handle 54 will vary the impedance of potentiometer 56, and if this potentiometer is integrated into the electro-hydraulic circuit of FIGS. 4 and 5 which is further associated with motor 23, rolling movement of control handle 54 will cause rolling of the bucket 20.

Thus it should be appreciated that, as constructed, the control means 35 permits motions analogous to that of the backhoe itself. For example if the operator desires to rotate the backhoe, he merely rotates control lever 35 about its vertical axis causing an unbalance in the bridge circuit of the associated potentiometers and fluid may be directed to the hydraulic actuator 30 to rotate the backhoe. Similarly rotational motion of the extensible arm 46 about a horizontal axis passing through the pivotal connection 53 causes actuation of the hydraulic valve controlling the boom and such movement is somewhat analogous to movement of the control means. Similarly extension and retraction of hydraulic ram of extensible member 47 will operate the directional flow control valve associated with hydraulic motor 22 to extend and retract the dipper stick 19 in an analogous fashion, and finally rotational movement of member 54 will cause similar rotational movement of bucket 20. This analogous and corresponding movement directional of the control member and the backhoe is a most significant advantage since such is effective to reduce cycle time of the handling operation as well as enabling an operator with little experience to rapidly master the techniques of such a machine. Thus it should be appreciated that by utilization of a control system as disclosed in FIGS. 4 and 5 with a single control lever 35 and applying same to each of the control valves 61 located within the valve bank 62, significant advantages may be obtained.

POSITION CONTROL SYSTEM

FIGS. 6 and 7 disclose an additional embodiment of the instant invention in which the directional control valve movement not only corresponds to movement of the control means 35, but the hydraulic motor and associated linkage itself will accurately correspond to movement of control means 35 whereby a position control system may be obtained. In this embodiment a bracket 132 is disposed upon flange 16 and extends above the rotational shaft 31 of rotary actuator 30, and has mounted thereon a potentiometer 131 whose stem is constrained for rotation with the shaft 31 of the motor 30. As schematically disclosed in FIG. 7, this potentiometer 131 is placed in parallel with the potentiometer 40 but stem rotation is such that a positive increasing voltage of potentiometer 40 will result in a decreasing voltage in potentiometer 131 upon rotation of actuator 30. Thus, the comparator 109 compares the

voltage difference between potentiometer **91** and potentiometers **40** and **130.** Accordingly, if the control lever **35** is rotated to the right, the wiper of potentiometer **40** will be moved downwardly as shown in FIG. **7,** and the comparator will detect an unbalance and actuate solenoid valve **111** to permit spool **70** to be moved downwardly. This downward movement will deflect the stem of potentiometer **91** as shown by dotted lines and simultaneously fluid will be directed to the rotary actuator so as to rotate same in a clockwise direction. This clockwise movement of the rotary actuator in turn controls the wiper potentiometer **130** to reduce its impedance as the actuator approaches the corresponding position of control lever **35.** Thus, the total resistance seen by the comparator on one side of the bridge circuit diminishes upon rotation of the actuator and the null detector will then gradually actuate solenoid valve **110** to return the spool to neutral such that potentiometer **91** is again in balance with potentiometers **40** and **130** in parallel. As disclosed in FIG. **8,** an annular movement alpha of control arm **35** will thus result in a corresponding annular movement alpha of the boom **18** and a position control system is effectuated.

As more fully pointed out in FIG. **9,** a tubular member **57** may be mounted upon the console **13** to rotatably support control lever **35,** apertures **58** being provided in the upper end surface of member **57.** Appropriately, dowel pins **59** may be inserted into these apertures to limit the rotational movement of control means **35** about a vertical axis. Consequently, if the position control system of FIGS. **6** and **7** is utilized to control swing movement of the backhoe, a position controlled system may additionally yield a return to dig system. For example, if dowel pins are placed in the end surface of tubular member **57** corresponding to a position of the proposed trench, and corresponding to a position for bucket dump, the outer limits of rotational movement of the backhoe will be fixed and by merely rotating the lever **35** between these limits, the rotary motor **30** will always return the boom to these limits. Under such circumstances the dowel pin may reflect a return to dig position and the operator need not concern himself with accurate positioning of the bucket in a trench.

Although not a part of the instant invention, FIG. **10** discloses a circuit for controlling hydraulic motors **15** which position the stabilizer arms **14,** and support the boom structure during the digging operation. Since continuous movement is not desired, the two end valves of bank **62** are not provided with potentiometers, and the solenoid valves are operated by on-off switches, **120** and **121.** As opposed to the bridge arrangement previously discussed the remainder of the system, e.g., valve **61,** solenoids, and chamber device **85** remain the same.

SUMMARY

In summary, applicants have disclosed a novel, unique, and most advantageous electrical hydraulic system for controlling movement of associated hydraulic motors by electrically controlling actuation of a flow control valve. A single lever capable of several distinct movements may effectively be designed so as to control several directional flow control valves and their associated hydraulic motors. Further, such movements may be correlated with the anticipated movement of the elements to be controlled and a follow-up system is effected in which a command signal is followed by a correlated movement of the associated motor controlled element. In addition to this follow-up system, provision has been made for an accurate position control. Finally, in addition to the aforesaid advantages and results, applicants, by incorporating into their system a solenoid actuated valve which is effective to control movement of the flow control valve, accurate metering of fluid through the flow control valve may be effected and infinite and incremental movements of the associated hydraulic motors and linkages may result therefrom. It should be readily appreciated that the system herein disclosed may be employed with numerous vehicles so as to control many material handling operations by a single lever. Even in the utilization of continuously rotating hydraulic motors, the herein disclosed control system may be effective to accurately control said motor so as to afford braking and incremental movement, such not being heretofore attainable. Naturally, various utilizations as well as variations of the system herein disclosed will find application in many fields.

We claim:

1. In a vehicle having a hydraulic fluid source and equipped with a backhoe having a swing mount, a swing motor operatively connected between the vehicle and the swing mount for pivoting said swing mount about an upright axis relative to the vehicle, a boom pivotal about a horizontal axis on the swing mount, a boom motor connected between the swing mount and the boom, a dipper stick pivotally carried on the free end of the boom, a dipper motor connected between the dipper stick and the boom, a bucket pivotally carried on the free end of the dipper stick, and a bucket motor operatively connected between the bucket and the dipper stick, the improvement comprising:

swing, boom, dipper and bucket valves for independently directing fluid pressure from said source to the associated one of said motors;

said swing valve and said bucket valve having a spool and a servo-motor for controlling the position of the spool within the associated valve;

solenoid-actuated valve means connected to each servo-motor for selectively directing fluid pressure from said source to each of said servo-motors;

a first potentiometer operatively connected to the spool of said swing valve and providing a resistance related to the displacement from neutral of the swing valve spool;

a manually operable swing control means including a second potentiometer for providing a resistance related to the position of the swing control means from a given position;

a third potentiometer operatively connected between the swing mount and the vehicle for providing a resistance related to the displacement from a given position of the swing mount relative to the vehicle;

a first bridge circuit including said first, second and third potentiometers with said first potentiometer being in one arm of the bridge circuit and second and third potentiometers being in another arm of the bridge circuit;

a first comparator in said first bridge circuit for detecting an imbalance between said one arm and said another arm and for energizing said solenoid valve means for said swing valve in response to a detected imbalance, whereby the swing mount will

be moved to a position corresponding to the position manually provided for the swing control means;

a fourth potentiometer operatively connected to the spool of said bucket valve and providing a resistance related to the displacement from neutral of the bucket valve spool;

a manually operable bucket control means including a fifth potentiometer for providing a resistance related to the position of the bucket control means from a neutral position;

a second bridge circuit including said fourth and fifth potentiometers located in different arms thereof;

a second comparator in said second circuit for detecting an imbalance between said different arms and for energizing said solenoid valve means for said bucket valve in response to a detected imbalance, whereby the bucket valve spool will be initially displaced from its neutral position an amount corresponding to the displacement of the bucket control means from its neutral position.

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