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[54] **BUCKET TILT CONTROL SYSTEM FOR LEVEL-CROWD TYPE LOADERS**
15 Claims, 5 Drawing Figs.

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[50] Field of Search 214/138, 137, 133, 132, 771, 773, 774, 775, 776; 37/103

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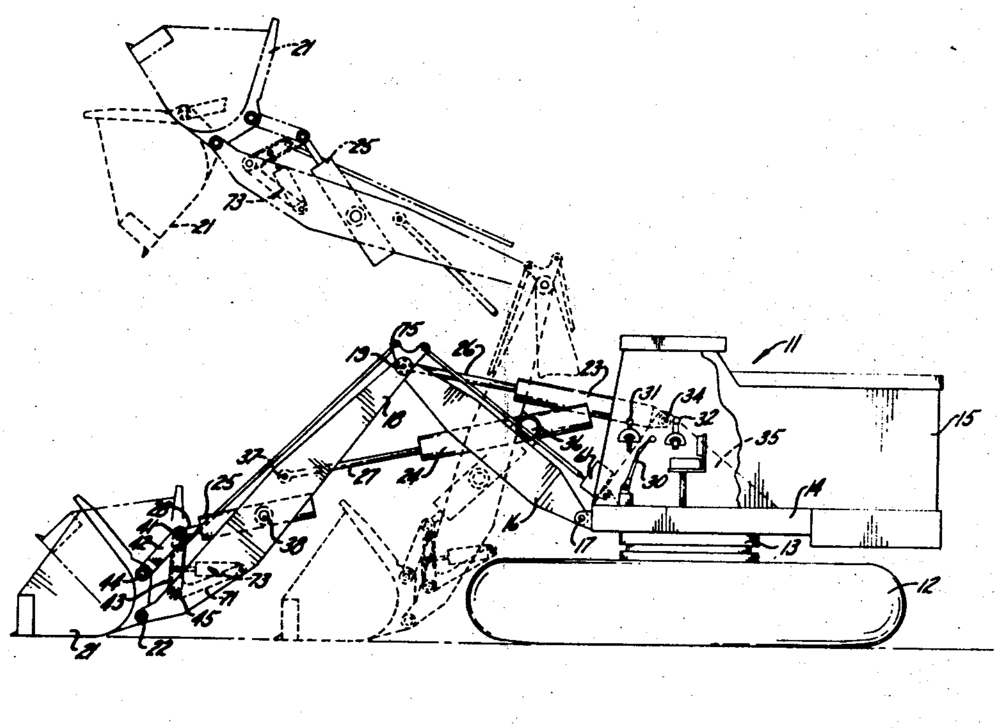
ABSTRACT: An automatic control system for a level-crowd-type loader to automatically and correctively adjust the angle of the loader bucket relative to the ground as the inner and outer booms of the loader are swung. A motion sensing linkage operates a servovalve in response to any undesired change in such angle, and the servovalve in turn actuates a hydraulic motor to correctively rotate the loader bucket. An independent control means is provided to operate the valve so that the operator may preselect the desired angular relationship to suit the particular loader operation to be performed.



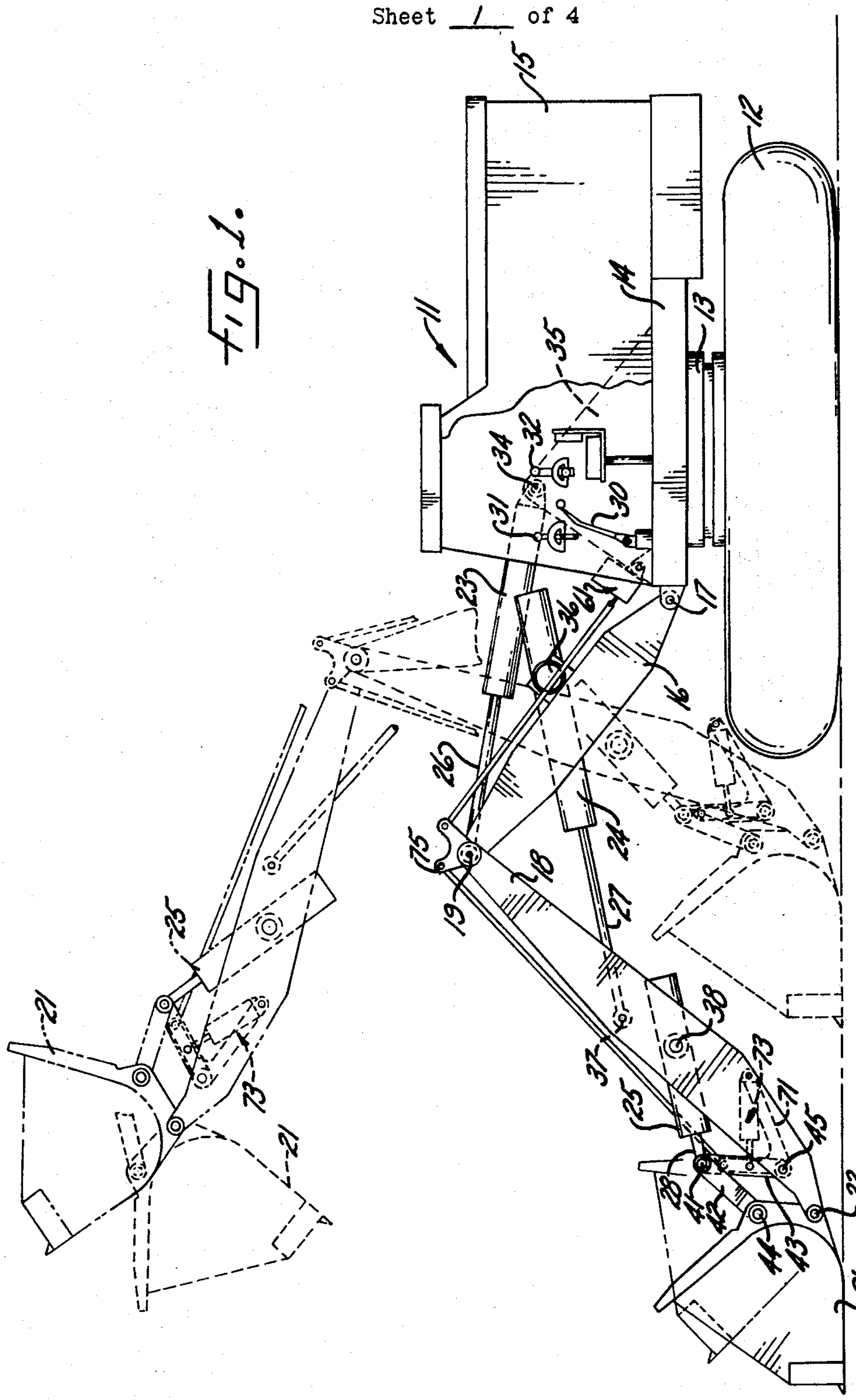


Fig. 1.

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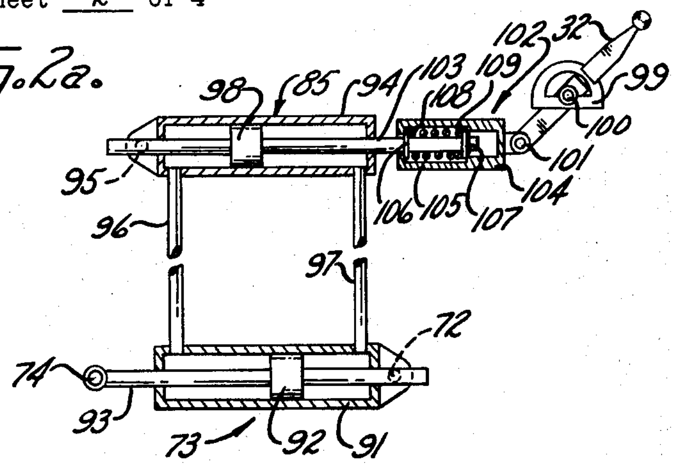
Fig. 2a.



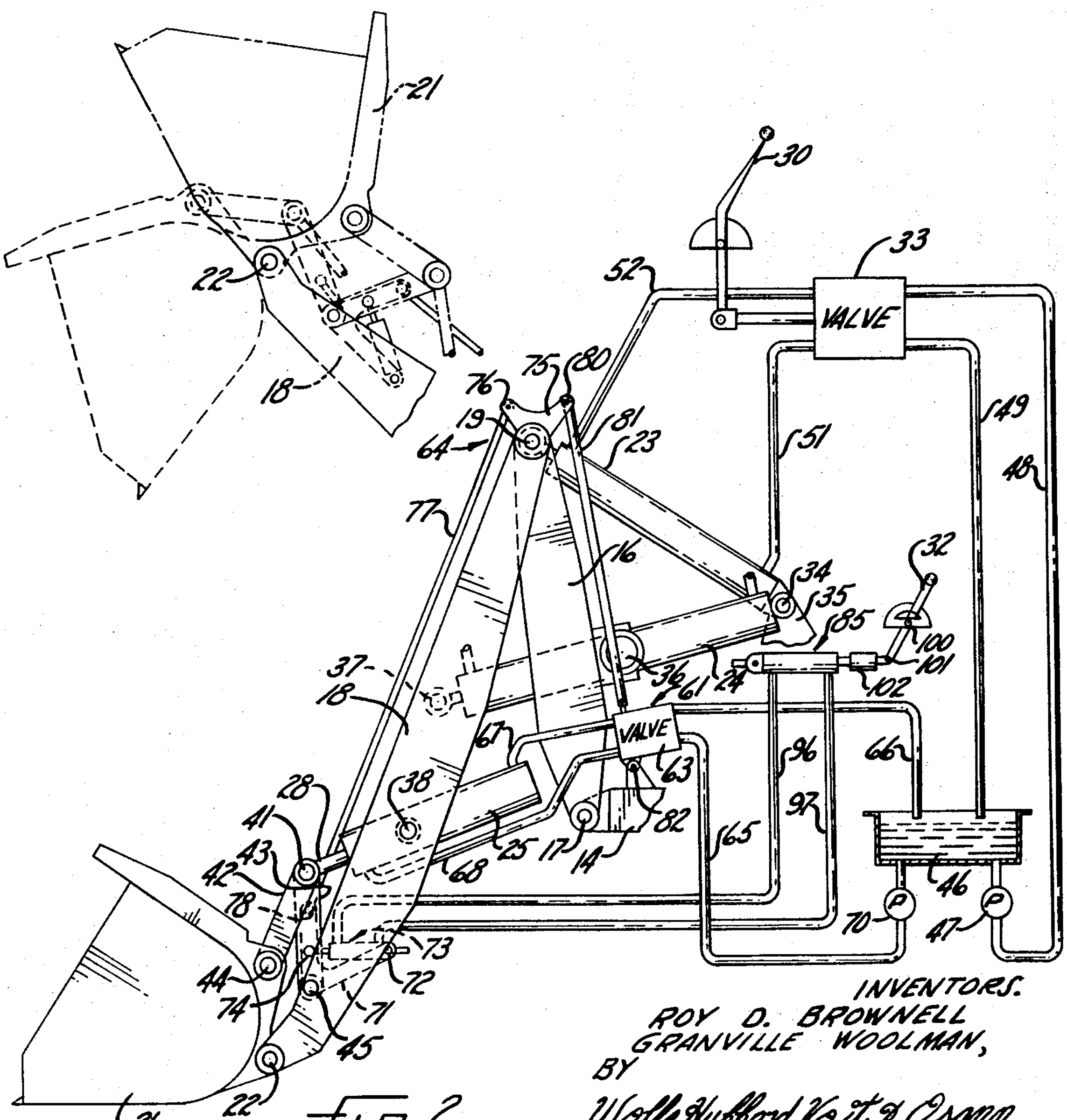


Fig. 2.

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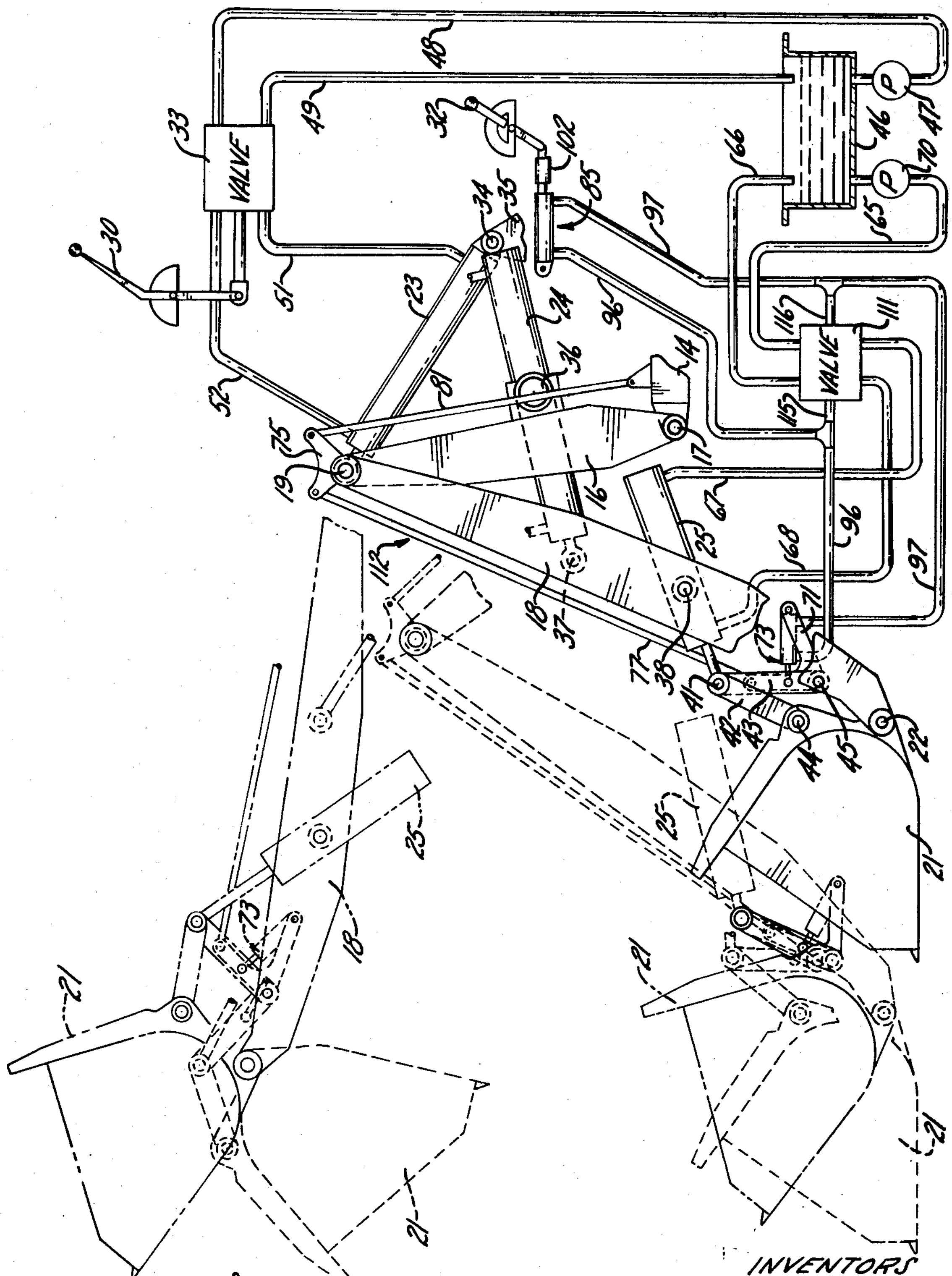

Fig. 3.

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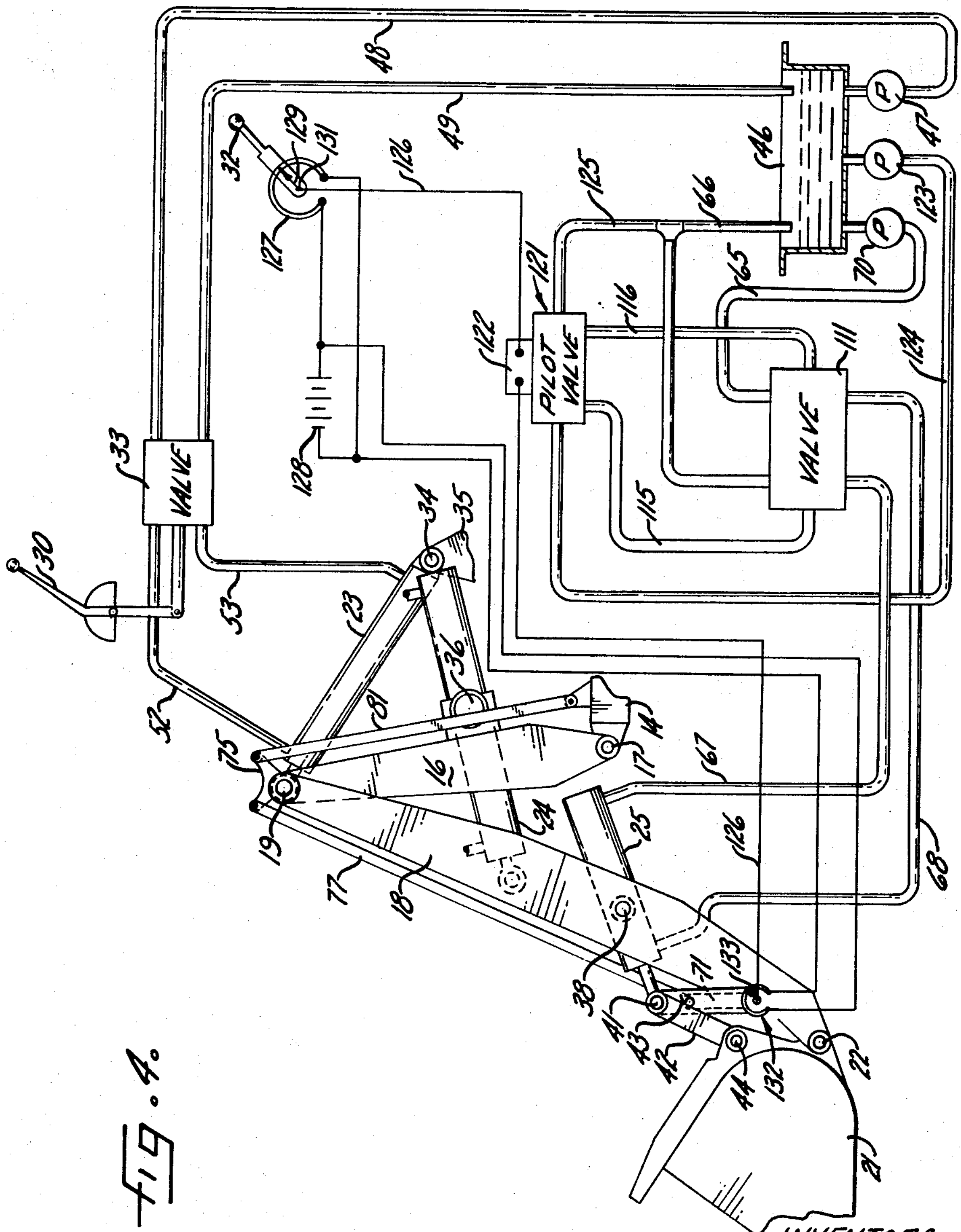

Fig. 4.

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BUCKET TILT CONTROL SYSTEM FOR LEVEL-CROWD TYPE LOADERS

BACKGROUND OF THE INVENTION

The present invention relates to level-crowd-type loaders, and more particularly to control systems for automatically correctively adjusting the tilt angle of the loader bucket of such loaders.

Typically, level-crowd-type loaders have an inner boom which is pivotally connected to the loader frame, an outer boom which is pivotally connected to the inner boom, and a loader bucket which is pivotally connected to the the outer boom. In general terms, loading is effectuated by simultaneously swinging the inner and outer booms to extend or "-crowd" the bucket substantially horizontally into the material to be loaded, an action commonly referred to as "level-crowding". Thereafter, the loaded bucket is tilted upright and the booms are swung to lift the bucket to a carry or lift position permitting transport of the loaded material to dump position. Finally, dumping is effectuated by tilting the bucket forwardly to discharge the load.

Of course, as the booms are swung, the angle of the bucket relative to the ground, the "bucket tilt angle", tends to follow the changes in the angle of the outer boom relative to the ground. This is, however, unacceptable since if the bucket tilt angle is permitted to follow such changes effective crowding and lifting are both hampered. Accordingly, conventional level-crowd-type loaders are typically provided with some means for correctively adjusting the bucket tilt angle. This corrective adjustment is known as "bucket leveling".

Heretofore, bucket leveling for level-crowd-type loaders has generally been provided by a parallelogram-type mechanical linkage which is connected between the bucket and the loader frame. With this arrangement, the bucket tilt angle is initially selected by adjusting the length of the linkage, and, thereafter, it is forcefully maintained by the linkage as the booms are swung. The distinct disadvantage of this arrangement is that the linkage is necessarily heavy to withstand the tremendous forces that are developed as the booms are swung and must be supported, for the most part, by the booms. As a result of this increased weight, the effective payload capacity of the loader is materially reduced.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of this invention to provide an automatic bucket-leveling control system for a level-crowd-type loader which does not materially reduce the payload capacity of the loader. A related object is the provision of a servo-type bucket-leveling control system. More particularly, it is an object to provide a control system of the foregoing type in which a motor is automatically actuated to correctively adjust the bucket tilt angle so that it substantially corresponds with an operator selected tilt angle regardless of the angle of the booms relative to one another and relative to the ground. Another object of the present invention is to provide a control system of the foregoing type where the operator may change the bucket tilt angle by simply moving a control lever to a position corresponding to a newly selected angle. A detailed related object is the provision of means enabling the operator to rapidly move the bucket tilt angle control lever to a position corresponding to a newly selected tilt angle and to be assured that the loader bucket will thereafter automatically rotate to such angle.

A further object of the present invention is to provide a servo-type bucket-leveling control system which automatically supplies a desired amount of increased rearward tilt to the loader bucket as it is raised to a lift position.

It is also an object of this invention to provide an automatic bucket-leveling control system that is simple and reliable and which may be readily installed on new or existing level-crowd-type loaders of a wide variety of types and sizes.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will be apparent upon reading the following detailed description with reference to the attached drawings, in which:

FIG. 1 is a side elevation of a level-crowd-type loader with the dotted lines showing the booms and loader bucket retracted from their extended solid line positions, and the dot–dash line showing the outer boom and loader bucket swung up from their retracted positions;

FIG. 2 is an enlarged fragmentary schematic of one embodiment of an automatic bucket-leveling control system for a loader such as shown in FIG. 1;

FIG. 2*a* is further enlarged view, partly in section, of a portion of the control system of FIG. 2, and illustrates an arrangement which permits the bucket tilt angle to be changed with a minimum of operator attention;

FIG. 3 is an enlarged fragmentary schematic of a hydraulic pilot-type embodiment of the present invention; and

FIG. 4 is an enlarged fragmentary schematic of an electrohydraulic pilot-type control system for automatic bucket leveling in a accordance with the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Turning now to the drawings, and particularly to FIG. 1, there is shown a level-crowd-type loader, indicated generally at 11. As illustrated here, the loader 11 is supported by ground-engaging tracks 12, and is provided with a turntable mechanism 13. The turntable mechanism carries the loader frame 14 and permits rotations of the frame in either direction about a vertical axis in the usual manner. Mounted on the frame 14 there is a cab 15 which encloses the drive motor (not shown) and in which the controls for operating the loader are located.

The loader 11 includes an inner boom 16 which is pivotally mounted at 17 on a forward portion of the frame 14, an outer boom 18 which is pivotally mounted at 19 adjacent the upper end of the inner boom 16, and a loader bucket 21 which is pivotally mounted at 22 adjacent the outer end of the outer boom 18. While the inner and outer booms 16, 18 are both described and illustrated herein the singular, it will be appreciated that the present invention may be practiced with loaders having inner and outer booms formed by respective pairs of laterally spaced boom members. Similarly, it will be appreciated that this invention is not limited to use with track-laying-type loaders.

For swinging the inner boom 16, the outer boom 18, and the loader bucket 21 about their respective horizontal pivots 17, 19 and 22, separate power units are provided. As illustrated, each of the power units is a reversible hydraulic motor and comprises a cylinder, 23—25, respectively, a piston (not shown) which is slidable within the cylinder, and a piston rod 26—28, respectively, which is fixed to the piston in the usual manner. Preferably the cylinders 23—25 are double-acting and are operated by control levers 30—32 located within the cab 15.

To drive the inner boom 16 about its pivot 17, the cylinder 23 is pivotally connected at 34 to an anchor plate 35 and has its piston rod 26 connected adjacent the upper end of the inner boom 16, in this instance to the inner and outer boom pivot 19. The anchor plate 35 is rigidly secured to the frame 14. Likewise, to drive the outer boom 18 about its pivot 19, the cylinder 24 is pivotally connected at 36 intermediate the ends of the inner boom 16 and has its piston rod 27 pivotally connected at 37 intermediate the ends of the outer boom 18. Finally, to drive the loader bucket 21 about its pivot 22, the cylinder 25 is pivotally connected at 38 intermediate the ends of the outer boom 18 and its piston rod 28 is connected to the pivotal connection 41 which joins one end of each of the bucket tilt arms 42 and 43. The other ends of the tilt arms 42 and 43 are pivotally connected at 44 and 45, respectively, to the loader bucket 21 and the lower end of the outer boom 18.

The pivot 44 is spaced from the bucket pivot 22 to establish a lever arm of sufficient length therebetween to permit the extension and retraction of the piston rod 28 to control the bucket tilt angle.

Referring now to FIG. 2, the inner boom 16 is swung about its pivot 17 as the operator moves the control lever 30 which is coupled to a four-way valve 33. Hydraulic fluid from a reservoir 46 is delivered to the valve 33 by a pump 47 through a supply line 48 and is returned from the valve to the reservoir through a return line 49. The valve 33 selectively supplies and drains hydraulic fluid to and from the head end and rod end of the inner boom cylinder 23 through lines 51 and 52, respectively. In a conventional level-crowd-type loader the outer boom 18 is also swung about its pivot 19 by operation of the control lever 31 shown in FIG. 1 which is coupled to a hydraulic circuit (not shown) similar to that employed for the inner boom cylinder.

To accomplish level-crowding, the bucket pivot 22 is maintained along a predetermined horizontal level as the bucket 21 is extended into the material being loaded. To this end, it is required that the inner and outer boom cylinders 23 and 24 be substantially simultaneously actuated and, while this can be done manually, provision is preferably made to accomplish this automatically in response to the operation of the control lever 30. Further, to permit the operator to select the elevation of the bucket pivot 22 for level-crowding and to enable the loader bucket 21 to be raised to a lift position, provision is desirably made for the operator to independently actuate the outer boom cylinder 24 through operation of the control lever 31. A preferred form of such a control system for operating the inner and outer boom motors in the foregoing manner is fully described in the copending U.S. Pat. application Ser. No. 663,815, entitled Level-crowd Control System for Material-Handling Loaders, and assigned to the instant assignee now U.S. Pat. No. 3,463,335.

While the most effective loader control is afforded when the control system of the present invention is used conjointly with a level-crowd control system capable of performing the various functions performed by the system described in the aforementioned application, it should be understood that the present invention is in no way limited to use with the particular level-crowd control system disclosed in such application. To the contrary, inasmuch as the functions that are automatically performed by the level-crowd control system of the copending application can be manually performed by a skillful operator, the control system of the present invention does not require or depend upon the existence of an automatic level-crowd control system of any description.

As will be appreciated, even with provision made to maintain the bucket pivot 22 along a horizontal level as the bucket is crowded into the material to be loaded, it is still necessary to in some way overcome the tendency of the bucket tilt angle to follow changes in the angle of the outer boom relative to the ground during both level-crowding and bucket-elevating operations. This is the primary reason that a bucket-leveling provision of some type is usually made in level-crowd-type loaders.

To supply automatic bucket leveling in accordance with the present invention, the bucket-leveling control provided includes a selector means for enabling the operator to preselect a desired bucket tilt angle, a motion-sensing means coupled between the loader bucket and a reference plane for detecting undesired changes in the bucket tilt angle, and a control means which is operated by the motion-sensing means to actuate the bucket tilt cylinder for correctively rotating the bucket back to the desired tilt angle. Necessarily, the reference plane selected must have a substantially fixed angular relationship relative to the ground and it is preferably an integral part of the loader. For these reasons, in carrying out the invention, the loader frame 14 is used as the reference plane, and the bucket tilt angle is controlled indirectly by controlling the angle of the loader bucket 21 relative to the frame. More specifically, the motion-sensing means provided compares changes in the angle of the outer boom 18 relative to the frame with changes in the angle of the loader bucket 21 relative to the outer boom, and operates the control means whenever a change in one of these angles is not accompanied by a substantially equal and opposite change in the other.

At this point it should be mentioned that the foregoing comparison could be precise to the extent permitted by the tolerances of the system, *i.e.*, the motion-sensing means could be designed to maintain a fixed bucket tilt angle regardless of the manner in which the booms are swung. However, in keeping with one of the more detailed features of the present invention, the motion-sensing means is preferably designed so that the rearward tilt of the bucket is progressively increased by a slight amount as the bucket is raised to a lift or carry position. This increased rearward tilt compensates for the forward momentum that is encountered as the bucket is raised and aids in preventing premature loss of part of the loaded material.

Referring now to FIG. 2 for a more detailed consideration of one embodiment of the present invention, it will be seen that as here illustrated the control means is a mechanically operated servovalve 61 which has a spool that is movable in a valve body 63 to selectively supply and drain pressure fluid to and from the opposite ends of the bucket tilt cylinders 25. Further, the motion-sensing means is a mechanical linkage 64 which extends from the loader bucket 21, over the inner–outer boom pivot 19, and to the loader frame 14. In this instance, where the servovalve 61 is a mechanically operated type, it may conveniently be included as a component of the motion-sensing linkage 64.

Considering the servovalve 61 first, its input ports are respectively connected to a supply line 65 and a return line 66, while its output ports are respectively connected to the head end and rod end of the cylinder 25 through hydraulic lines 67 and 68. Accordingly, if the spool of the valve 61 is shifted in a manner calling for increased rearward tilt of the loader bucket 21 (*i.e.*, clockwise rotation of the bucket relative to the outer boom 18), pressure is supplied, typically from the reservoir 46 by a pump 70 through the lines 65 and 68 to the rod end of the cylinder 25. At the same time, pressure fluid is drained from the head end of the cylinder 25 through the hydraulic lines 67 and 66 and back to the reservoir 46.

Turning now to the motion-sensing mechanical linkage 64, to detect changes in the angle of the loader bucket 21 relative to the outer boom 18 a lower bellcrank 71 is pivotally mounted at 45 near the outer end of the outer boom. As can be seen, the forward arm of the bellcrank 71 extends forwardly of the center line of the outer boom 18 (*i.e.*, the line joining the pivots 19 and 22) and the rearward arm thereof is pivotally connected at 72 to one end of a link 73. The outer end of the link 73 is, in turn, pivotally connected at 74 to the inner bucket tilt arm 43. In this embodiment, the length of the link 73, once set for a given bucket tilt angle as hereinafter discussed, remains constant. Consequently, the lower bellcrank 71 is rotated about its center pivot 45 through an angle proportional to any change in the angle of the loader bucket 21 relative to the outer boom 18.

To detect changes in the angle of the outer boom 18 relative to the frame 14, the motion-sensing linkage further includes an upper bellcrank 75 which is pivotally mounted adjacent the inner end of the outer boom 18, typically by the pivot 19. As will be appreciated, in a level-crowd-type loader, the angle of the outer boom relative to the frame depends on two variables; namely, (1) the angle of the outer boom relative to the inner boom and (2) the angle of the inner boom relative to the frame. Accordingly, to sense changes in the angle of the outer boom relative to the inner boom, one arm of the bellcrank 75 extends forwardly of the center line of the outer boom 18 and is pivotally connected at 76 to the inner end of an outer link 77. The outer end of the outer link is, in turn, pivotally connected at 78 to the forward arm of the lower bellcrank 71. On the other hand, to sense changes in the angle of the inner boom 16 relative to the frame 14, the other arm of the upper bellcrank 75 extends rearwardly of the center line of the outer boom 18 and is pivotally connected at 80 to the upper end of an inner link 81. In this embodiment, for convenient operation of the servovalve 61, the lower end of the inner link 81 is pinned to the spool of valve 61 and the valve body 63 is pivotally connected at 82 to the loader frame 14.

The effective lengths of the inner and outer links 81 and 77 (*i.e.*, the distances between the pivots 80 and 82 and the pivots 76 and 78, respectively) and the effective lengths of the arms of the upper bellcrank 75 (the respective spacings of the pivots 76 and 80 from the pivot 19) are selected so that the upper bellcrank compares changes in the angle of the outer boom 18 relative to the inner boom 16 with changes in the angle of the inner boom relative to the loader frame, and tends to be rotated about its center pivot 19 through an angle proportional to any net change in the angle of the outer boom 18 relative to the loader frame 14.

As the upper bellcrank begins to rotate, of course, the servovalve 61 is operated to actuate the bucket tilt cylinder 25 for compensating rotation of the loader bucket 21 relative to the outer boom 18. This, in turn, causes rotation of the lower bellcrank 71 thereby providing motion which is transmitted through the outer link 77 to the upper bellcrank 75 and which tends to restore the upper bellcrank to its original angular position. In other words, if the outer boom 18 is extended to increase its angle relative to the loader frame 14, the upper bellcrank 75 rotates clockwise thereby causing the valve spool to shift relative to the valve body 63 whereupon pressure fluid is supplied to the head end of the cylinder 28 and drained from the rod end thereof. Consequently, the piston rod 28 is extended to rotate the loader bucket 21 counterclockwise about its pivot 22 thereby increasing its angle relative to the outer boom and causing the lower bellcrank 71 to rotate counterclockwise about its pivot 45.

In keeping with the present invention, so that the bucket tilt cylinder 25 is automatically actuated to maintain a preselected bucket tilt angle, an effective comparison between changes in the angle of the outer boom 18 relative to the loader frame 14 and changes in the angle of the loader bucket relative to the outer boom is provided. To this end, the effective lengths of the arms of the lower bellcrank 71 (the respective spacings of the pivots 72 and 78 from the pivot 45) are selected so that the motion transmitted to the upper bellcrank 75 by the outer link 77 restores the upper bellcrank to its initial angular position when the bucket has been rotated in a manner to compensate for a given change in the angular relationship of the outer boom relative to the frame.

As a matter of definition, the "maintenance of a preselected bucket tilt" is intended to imply that undesired changes in the angle of the bucket relative to the ground are eliminated, but not to exclude whatever slight changes are desired to provide the aforementioned progressively increasing rearward tilt of the loader bucket as it is lifted to a carry position. Noteworthy in this connection is that to provide this progressively increasing rearward tilt of the loader bucket as the bucket is lifted to a carry position, all that is required is that the effective lengths of the various members of the linkage 64 be designed so that, for a given change in the angle of the outer boom relative to the frame, a slightly smaller change in the angle of the bucket relative to the outer boom is required to recenter the spool in the valve body 63.

To enable the operator to select and change the bucket tilt angle to be maintained by the action of the aforedescribed motor control means and motion-sensing means, the selector means 85 provided in the embodiment of FIG. 2 enables him to preset the length of the link 73. For this reason, as shown in FIGS. 2 and 2*a*, the link 73 may conveniently comprise a double acting slave cylinder 91 which is connected to the lower bellcrank 71 by the pivot 72, a piston 92 which is slidably housed within the cylinder 91, and a piston rod 93 which is fixed to the piston 92 and connected to the inner bucket tilt arm 43 by the pivot 74. This enables the length of the link 73 to be adjusted simply by selectively supplying and draining pressure fluid to and from the opposite ends of the cylinder 91. Accordingly, the selector means 85 comprises a double-acting master cylinder 94 which is pivotally connected at 95 typically to the loader frame and which has each of its opposite ends connected to a respective one of the opposite ends of the slave cylinder 91 by hydraulic lines 96 and 97. Slidably housed within the master cylinder 95 there is a piston 98 which is selectively positioned through the operation of the manually operable bucket tilt angle control lever 32. Preferably, the master and slave cylinders are both of the balanced displacement type.

The control lever 32 is the self-locking type that is releasable and movable upon application of a manual force on its upper end; but, a force applied to its lower end is resisted by the locking device (not shown) and is ineffective to move the lever 32. More particularly, as illustrated, the control lever 32 is pivotally connected intermediate its ends at 100 to a quadrant 99 secured to the loader frame 14. The lower end of the control lever is pivotally connected at 101 to a bias member 102 (hereinafter explained) which is carried by one end of a piston rod 103, and the piston rod 103 is, in turn, fixed to the piston 98 in the usual manner.

As an example of the operation of the selector means 85, movement of the control lever 32 to the right causes the piston 98 to shift to the left thereby creating a pressure differential between the lines 96 and 97. This pressure differential causes the piston 92 to shift to the right thereby retracting the piston rod 93 to decrease the length of the link 73. This results in counterclockwise rotation of the lower bellcrank 71 which, in turn, acts through the remainder of the linkage 64 to operate the servovalve 61 for supplying pressure fluid to the rod end of the bucket tilt cylinder 25 and draining pressure fluid from the head end thereof. As a result the piston rod 28 is retracted thereby rotating the bucket tilt arms 42 and 43 clockwise to tilt the bucket 21 rearwardly as from a crowding attitude to a lifting attitude. The clockwise rotation of the arms 43 is accompanied by clockwise rotation of the lower bellcrank 71 so that, when the loader bucket 21 reaches its newly selected angular relationship relative to the frame 14, the spool of the valve 61 is recentered to terminate actuation of the cylinder 25.

Preferably, means are provided to permit the operator to rapidly move the control lever 32 to a setting corresponding to a desired bucket tilt angle with assurance that the bucket 21 will assume such tilt angle without further attention. The bias member 102 is provided to store a biasing force corresponding to the movement of the control lever 32 and to apply this force to move the piston 98 within the master cylinder 92 to the position corresponding to the selected bucket tilt angle. As illustrated in FIG. 2*a*, the bias member 102 has a housing 104 to which the lower end of the control lever 32 is connected by the pivot 101. Within the housing there is a compression spring 105 which is held between a pair of locating washers or collars 106 and 107 which, in turn, abut respective annular shoulders 108 and 109 provided by the housing 104. Consequently, movement of the operating lever 32 in either direction compresses the spring 105 thereby storing a biasing force therein which is applied to the piston 98 and which is gradually released as the piston 98 moves to the position corresponding to the setting of the control lever 32.

Turning now to FIG. 3, there is illustrated a modified embodiment of the present invention comprising a hydraulic pilot control system interconnecting the bucket 21 and the control lever 32 with a pilot-type angle adjusting servovalve 111. It will be noted that the remainder of the control system is as previously described and has therefore been identified by similar reference numerals.

The motion-sensing linkage 112 of this embodiment is quite similar to that shown in FIG. 2 with the exception that it does not include the angle-adjusting servovalve. To the contrary, the servovalve 111 is provided with a pilot section to each side of which a respective one of a pair of pilot lines 115 and 116 is connected. These pilot lines are each hydraulically connected to a respective one of the hydraulic lines 96 and 97. Consequently, movement of the control lever 32 creates a pressure differential between the pilot lines 115 and 116 thereby operating the valve 111 to actuate the bucket tilt motor 25. Actuation of the bucket tilt cylinder 25 rotates the bucket tilt arms 42 and 43 which, in turn, rotate the bucket 21 to the newly selected bucket tilt angle. The rotation of the arm 43 shifts the piston 92 of the slave cylinder 91 so that, when the bucket 21 has assumed the newly selected tilt angle, the pressure differential between the pilot lines 115 and 116 is eliminated thereby terminating the actuation of the cylinder 25. Thereafter, departures of the bucket 21 from this selected tilt angle are detected by the linkage 112 and result in rotation of the bellcrank 71 in the same manner as previously discussed with reference to FIG. 2 and the operation of the linkage 64. This rotation of the bellcrank 71 shifts the piston 92 of the slave cylinder 91 thereby creating a pressure differential between the pilot lines 115 and 116, and this pressure differential causes actuation of the bucket tilt cylinder 25 to eliminate the departure. The restoration of the bucket 21 to the preselected bucket tilt angle is accompanied by a shifting of the piston 92 in the cylinder 91 to eliminate the pressure differential between the pilot lines 115 and 116 and, consequently, operation of the valve 111 terminates.

Again, to permit rapid movement of the bucket tilt angle control lever 32, a bias means, such as the bias means 102 described with reference to FIG. *2a*, is connected between the lower end of the control lever 32 and the piston rod 103 of the master cylinder 94.

Another pilot operated embodiment of the present invention is shown in FIG. 4 to include an electrohydraulic system interconnecting the loader bucket 21 and control lever 32 with the pilot operated servovalve 111. As illustrated, the electrohydraulic system includes an electrically operated pilot valve 121 which is operated by current flow through a control element 122, typically a coil, to provide a pressure differential between the pilot lines 115 and 116. Pressure fluid is supplied to the pilot valve 121 from the reservoir 46 by a small pump 123 which is connected in a supply line 124. In the absence of current flow through the control element 122, the pressure fluid is drained from the pilot valve 121 through a drain line 125 which is connected to return to the reservoir 46 through the return line 66.

In this embodiment, for establishing the bucket tilt angle to be maintained, the selector means includes means for applying a reference voltage between one end of the control element 122 and a common lead 126. For changing the bucket tilt angle, the selector means further includes means for changing this reference voltage. As shown, the means for applying the reference voltage may conveniently be a rotary potentiometer 127 which is connected across a voltage source, typically a battery 128, and which has a slider 129 electrically connected to one end of the control element 122. For changing this reference voltage, the bucket tilt angle control lever 32 has its lower end pivotally connected at 131 to a fixed point, such as a point on the frame 14, concentrically with the potentiometer 127, and the slider 129 is fixed to the control lever 32 for rotation about the pivot 131 as the control lever is moved.

The motion-sensing means includes means for applying a voltage between the other end of the control element 122 and the common lead 126. This voltage is varied as the bucket tilt angle is changed. Again, this may be conveniently accomplished through the use of a rotary potentiometer 132 which is connected across the battery 128 and which has a slider 133 electrically coupled to the other end of the control element 122. With this arrangement, for detecting changes in the angle of the loader bucket 21 relative to the outer boom 18, the potentiometer 132 is carried by the bucket tilt arm 43 concentrically with the pivot 45. For detecting changes in the angle of the outer boom 18 relative to the frame 14, the slider 133 is carried by the rockable link 71 for rotation about the pivot 45. In this instance, the rockable link 71 is preferably a simple lever arm. Accordingly, any change in the angle of the outer boom 18 relative to the frame 14 is compared with the accompanying change in the angle of the loader bucket 21 relative to the outer boom 18, and, if the bucket tilt angle changes, the voltage between the slider 133 and common lead 126 is changed.

In operation, as the operating lever 32 is moved to establish a new bucket tilt angle, the reference potential between the slider 129 and the common lead 126 is varied causing current to flow through the control element 122 thereby creating a pressure differential between the pilot lines 115 and 116. This pressure differential operates the valve 111 to actuate the bucket tilt cylinder 25 causing rotation of the bucket tilt arms 42 and 43 and resulting rotation of the bucket 21 to the newly selected tilt angle. The rotation of the arm 43 causes rotation of the potentiometer 132 thereby changing the potential between the slider 133 and the common line 126 so that this potential comes into balance with the reference potential when the bucket 21 has assumed the desired angular relationship. As a result, actuation of the cylinder 25 terminates. Thereafter, swinging of the inner or outer booms 16, 18 in such a manner as to cause the bucket 21 to depart from the selected tilt angle results in current flow through the control element 122 thereby causing actuation of the cylinder 25 to restore the bucket 21 to the selected tilt angle.

From the foregoing, it will be appreciated that, in each of the illustrated embodiments, selector means are provided to enable the operator to preselect the bucket tilt angle and that detector means are provided to detect any departure of the bucket 21 from this selected tilt angle. Furthermore it will be understood that, in each of the embodiments, angle-adjusting means which are responsive to the operation of both the selector means and the motion-sensing means are provided for actuating the bucket tilt cylinder 25 to establish and maintain the selected bucket tilt angle.

We claim:

1. An automatic bucket leveling control system for a material-handling loader having a frame, an inner boom pivotally mounted on the frame, an outer boom pivotally mounted on the inner boom, a bucket pivotally mounted on the outer boom and motive means operable to pivot said inner and outer booms to extend and retract said bucket horizontally for level-crowding and to lift said bucket for dumping, said control system comprising the combination of power means for tilting said bucket relative to said outer boom, manually operable selector means for actuating said power means to establish a selected bucket tilt angle relative to said frame, motion-sensing means coupled between said bucket and said frame for detecting departures of said bucket from said selected tilt angle as said inner and outer booms are moved about their pivots during level-crowding, lifting and lowering operations, and angle-adjusting means coupled to said motion-sensing means and to said power means and responsive to said departures detected by said sensing means for actuating said power means to restore said bucket to said selected tilt angle relative to said frame.

2. A control system as defined in claim 1 wherein said motion-sensing means includes a mechanical linkage interconnecting said bucket and said frame with an intermediate element thereof mounted for rotation about the same axis as said pivotal mounting of said outer boom on said inner boom.

3. A control system as defined in claim 2 wherein said power means includes a hydraulic motor, said angle-adjusting means includes a valve for controlling the supply and discharge of hydraulic fluid to and from said motor, and said mechanical linkage is operatively connected to actuate said valve.

4. A control system as defined in claim 3 wherein said valve includes a valve body and a valve spool shiftable within said valve body for controlling the supply and discharge of hydraulic fluid to and from said motor, and one of said valve body and valve spool being connected to said mechanical linkage and the other being connected to said frame whereby departures of said bucket from said selected tilt angle shift said valve spool in relation to said valve body to thereby actuate

said motor until said bucket is restored to said selected tilt angle.

5. A control system as defined in claim 3 wherein said motion-sensing means also includes a first piston and cylinder arrangement coupled to said mechanical linkage, said selector means includes a control lever connected to a second piston and cylinder arrangement and said first and second cylinders are hydraulically interconnected whereby movement of said control lever causes relative movement of both of said piston and cylinder arrangements and also said mechanical linkage for operating said valve.

6. A control system as defined in claim 5 wherein each of said piston and cylinder arrangements includes a double-acting balanced displacement-type cylinder having a piston slidable therein, and each of the balanced displacement-type cylinders has its respective ends hydraulically interconnected with the opposite end of the other cylinder whereby operation of the control lever causes the piston in its cylinder to shift to thereby cause the angle-adjusting means to actuate the power means for rotating the bucket until a condition of balance between said piston and cylinder arrangements is again obtained.

7. A control system as defined in claim 5 wherein the selector means further includes a lost motion connection between the control lever and the second piston and cylinder arrangement for permitting rapid selection of the angular relationship of the bucket relative to the frame, the lost motion connection including resilient means for storing a biasing force upon movement of the control lever to a selected position and means for applying the biasing force to move the second piston relative to its cylinder to a position corresponding to the selected position of the control lever.

8. A control system as defined in claim 3 wherein said valve is pilot operated and controls the supply and discharge of hydraulic fluid to and from the motor in response to a pressure differential between a pair of pilot lines, and wherein said motion-sensing means includes a double-acting cylinder having each of its ends hydraulically interconnected with a respective one of said pilot lines to thereby create a pressure differential between the pilot lines in response to departures of the bucket from the selected tilt angle.

9. The control system of claim 8 wherein the selector means includes a double-acting, balanced displacement-type cylinder having a piston slidable therein and a control lever manually operable to position the piston of the selector means cylinder and wherein the cylinder of the motion-sensing means is a balanced displacement type having each of its respective ends interconnected with the opposite end of the control means cylinder whereby operation of the control level shifts the piston of the selector means cylinder to create a pressure differential between the pilot lines thereby causing the valve to actuate the hydraulic motor to rotate the bucket to a position such that the pressure differential is eliminated thereby terminating actuation of the power means.

10. A control system as defined in claim 9 wherein the selector means further includes a lost motion connection between the control lever and the selector means cylinder thereby permitting rapid movement of the control lever to a position corresponding to a selected angular relationship of the bucket relative to the frame followed by automatic actuation of the power means until the bucket assumes that angular relationship, the lost motion connection including resilient means for storing a biasing force upon movement of the control lever, and means for applying the biasing force to move the piston of the selector means cylinder to the position corresponding to the selected angular relationship of the bucket.

11. A control system as defined in claim 3 wherein the valve is pilot operated and actuates the motor in response to a pressure differential between a pair of pilot lines, the angle-adjusting means further including an electrically operated valve having a pair of outputs each connected to a respective one of the pilot lines and an electrical input responsive to an input signal to create a pressure differential between the pilot lines, and wherein the motion-sensing means includes an electrical element connected to supply an input signal to the input of the electrically operated valve upon departures of the bucket from the selected tilt angle.

12. A control system as defined in claim 11 wherein the selector means includes an electrical element for establishing a reference potential corresponding to the selected tilt angle of the bucket, the motion-sensing means electrical element provides a potential corresponding to the actual tilt angle of the bucket and the electrical input of the electrically operated valve is connected between the respective electrical elements of the motion-sensing means and the selector means whereby a pressure differential is created in the pilot line thereby operating the pilot operated valve for actuating the motor when the potential provided by the electrical element of the motion-sensing means differs from the reference potential established by the electrical element of the selector means.

13. A control system as defined in claim 12 wherein the motion-sensing electrical element and the control means electrical element are respective potentiometers each connected across a potential source and each with a slider electrically interconnected with the slider of the other by the input of the electrically operated valve.

14. A control system as defined in claim 13 wherein the motion-sensing means potentiometer is secured to the bucket, the control means further includes an operating lever connected for manually moving the slider of the control means potentiometer to a position corresponding to the selected angular relationship of the bucket relative to the ground, and the motion-sensing means further includes a mechanical linkage connected for automatically moving the slider of the motion-sensing means potentiometer to a position corresponding to the actual angular relationship of the bucket relative to the ground.

15. A control system as defined in claim 14 wherein the mechanical linkage includes an outer link having an upper end and a lower end and extending generally parallel to the outer boom, an inner link having an upper end and a lower end and extending generally parallel to the inner boom, a slider-carrying arm pivotally connected to the lower end of the outer link, a motion-transmitting means pivotally connected to the upper ends of the inner and outer links at respective points spaced apart a fixed distance, and means pivotally connecting the lower end of the inner link to the frame.