Sept. 5, 1967 J. A. CAYWOOD ETAL 3,339,763

AUTOMATIC BACK HOE CONTROL SYSTEM

Original Filed Aug. 19, 1965 5 Sheets-Sheet 1

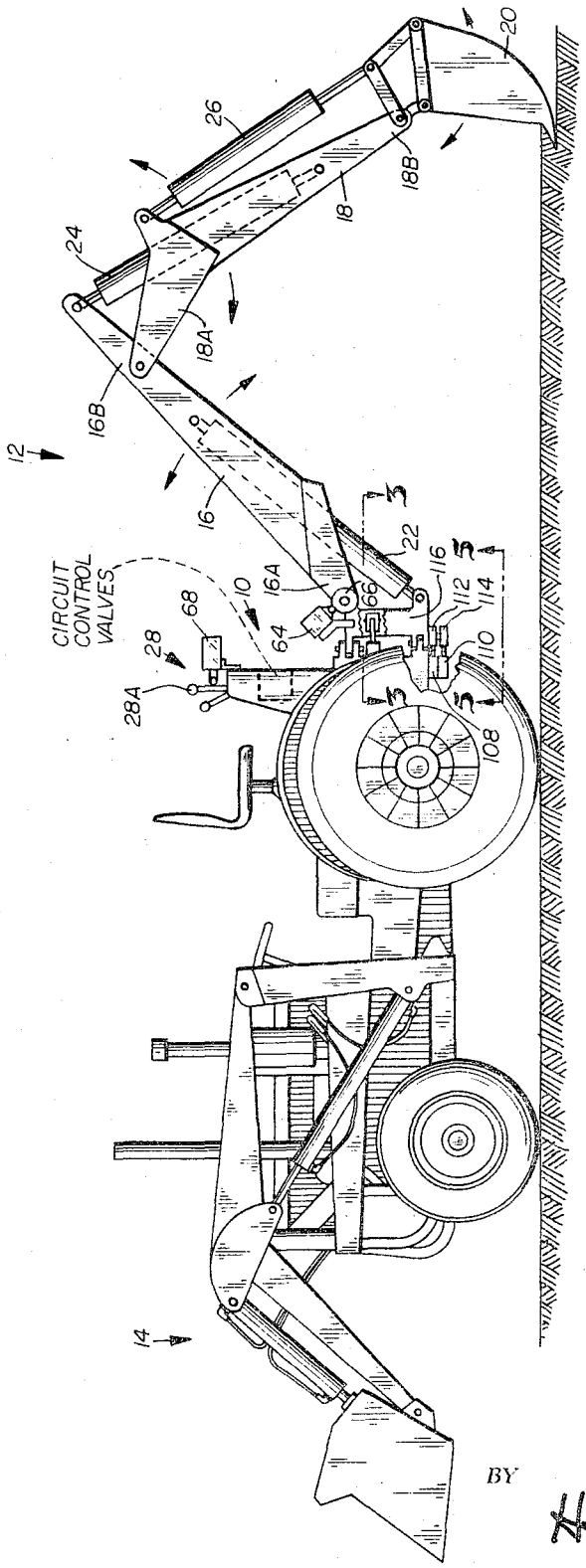

Fig. 1.

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Original Filed Aug. 19, 1965 5 Sheets-Sheet 2

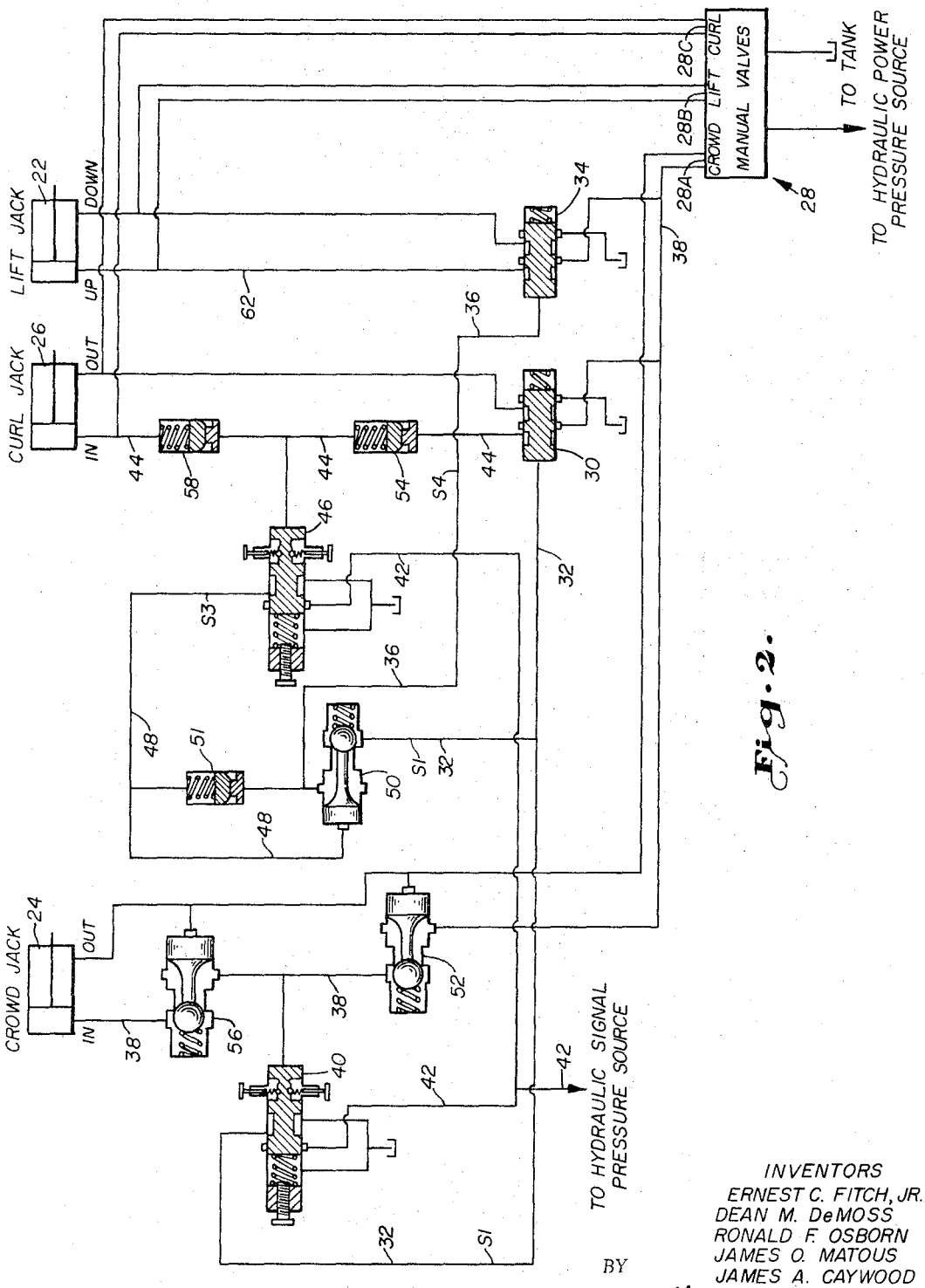

Fig. 2.

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AUTOMATIC BACK HOE CONTROL SYSTEM

Original Filed Aug. 19, 1965 5 Sheets-Sheet 3

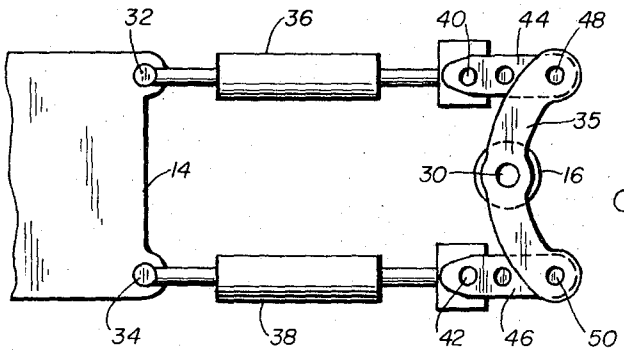

Fig. 3.

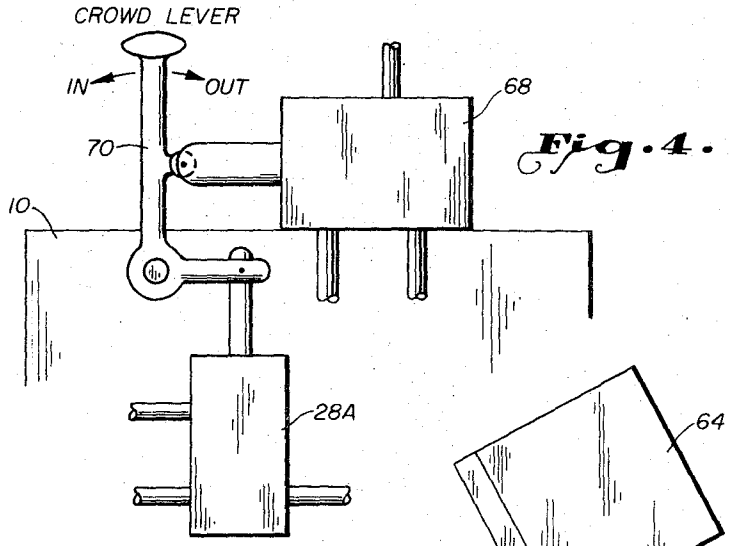

Fig. 4.

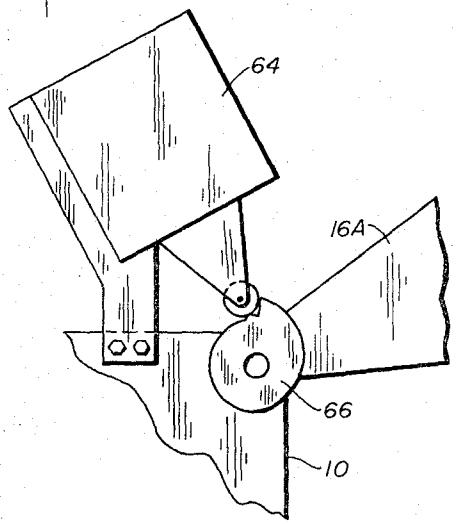

Fig. 6.

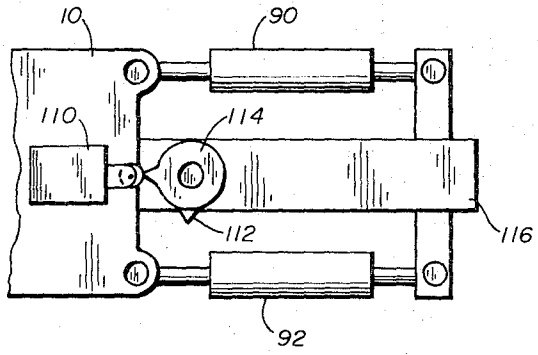

Fig. 5.

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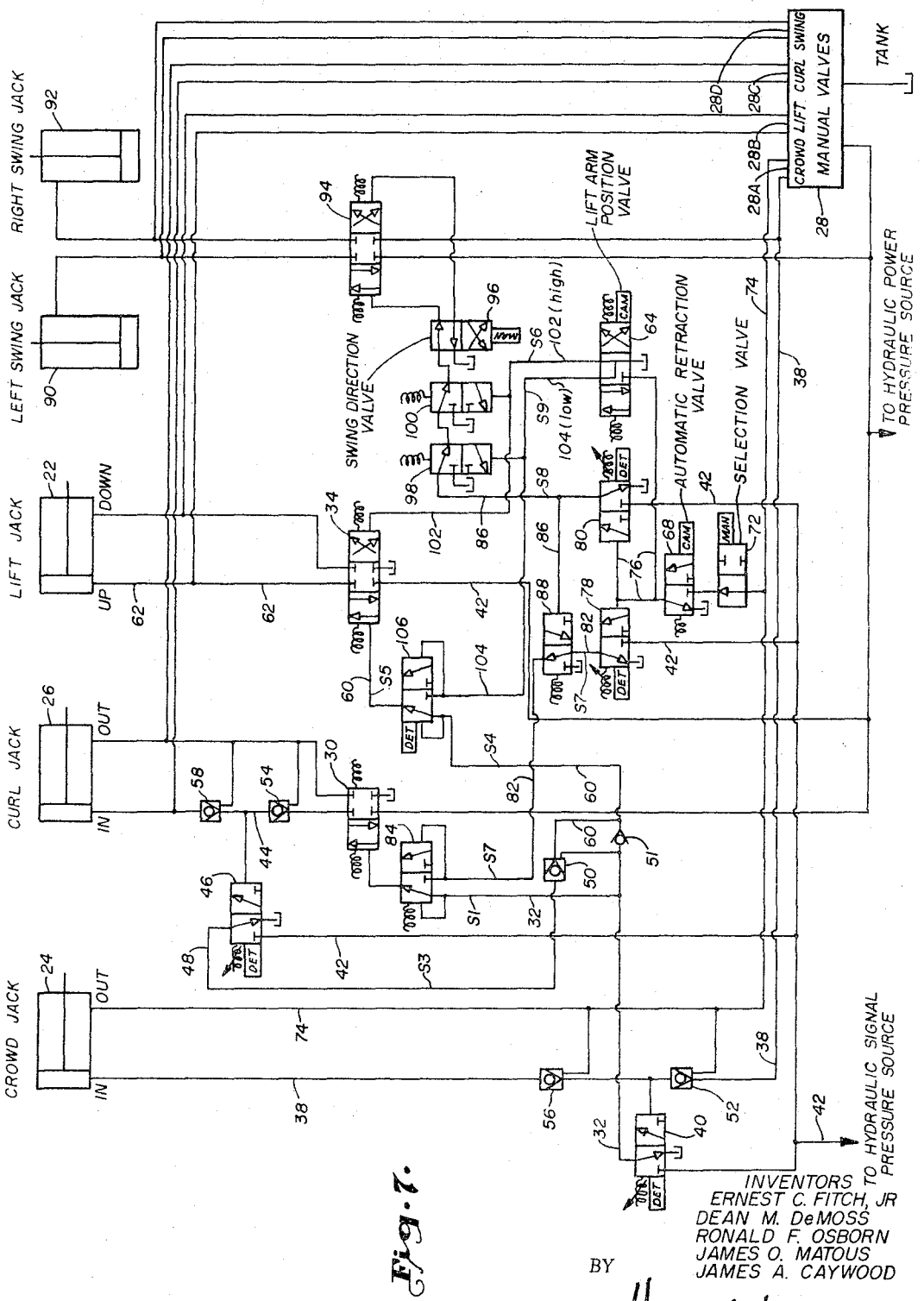
AUTOMATIC BACK HOE CONTROL SYSTEM

Original Filed Aug. 19, 1965 5 Sheets-Sheet 4



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AUTOMATIC BACK HOE CONTROL SYSTEM

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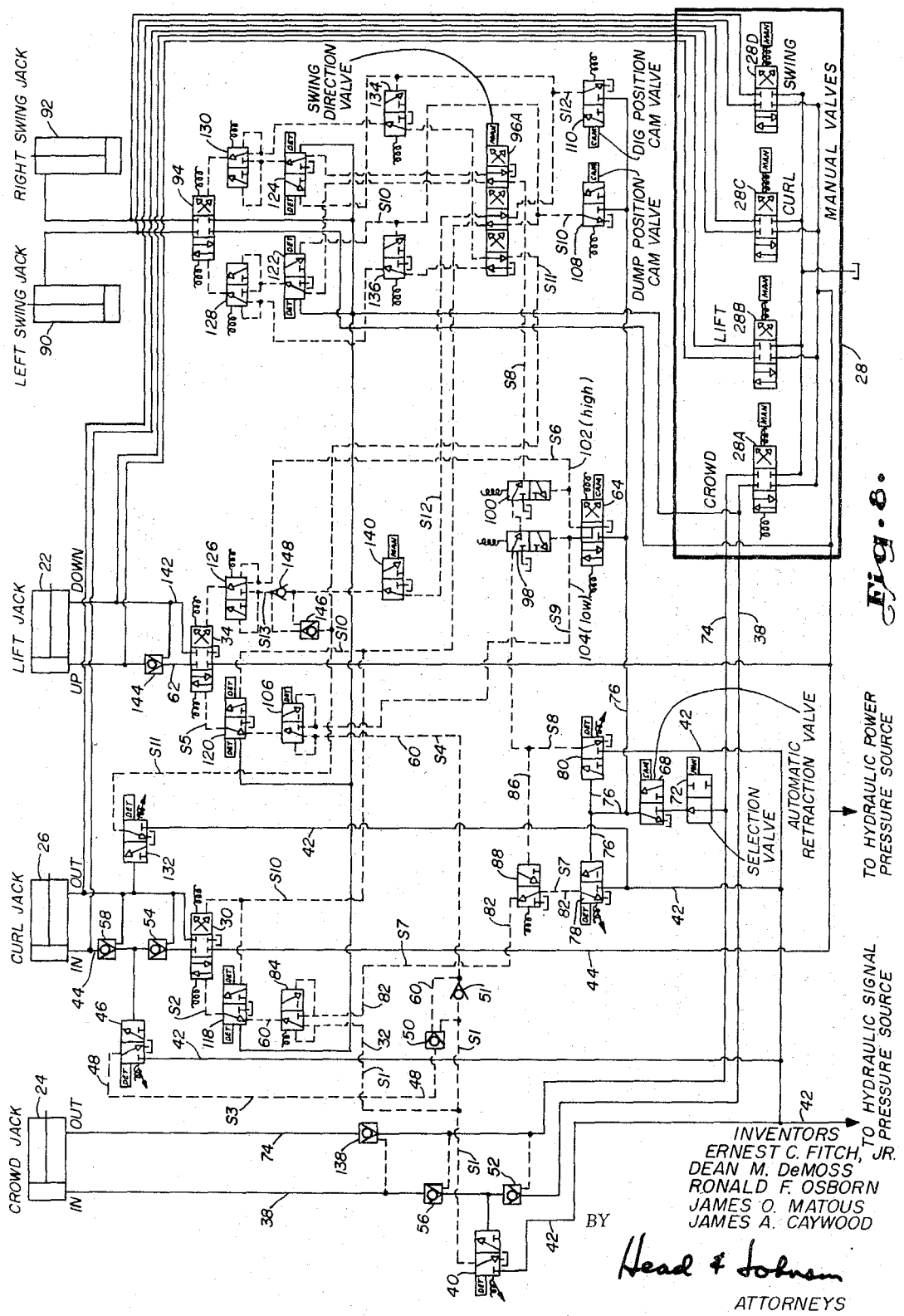

Fig. 8.

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AUTOMATIC BACK HOE CONTROL SYSTEM

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Continuation of application Ser. No. 480,860, Aug. 19, 1965. This application Oct. 14, 1966, Ser. No. 587,385
22 Claims. (Cl. 214—138)

This is a continuation of application Ser. No. 480,860 filed Aug. 19, 1965, now abandoned.

This invention relates to a backhoe, and more particularly to a hydraulically actuated backhoe. Still more particularly, this invention relates to an automatic hydraulic backhoe control system which may be placed in parallel arrangement with a manually operated control system.

Backhoe units generally consist of a series of sequentially longitudinally pivotally attached arms mounted on a tractor chassis at the extremity of which arms is located a bucket or digging attachment oriented to perform its digging operation by movement toward the tractor unit. The movement of the arms and bucket are generally hydraulically controlled. The name "backhoe" is given units mounted in this manner since they are normally mounted at the rear of the tractor unit and perform the digging or trenching operation toward the tractor, the direction in which the tractor is positioned to travel. By being positioned in this manner, the backhoe is capable of digging a narrow trench while the tractor itself proceeds ahead of the digging operation on solid ground. The backhoe units find their most valuable application in the digging of trenches for the laying of cables, pipelines, sewage lines, and so forth.

The description of this invention will be given by reference to a type of tractor mounted backhoe unit in common usage, however, it is understood that the invention relates to, and the word "backhoe" as used herein refers to, any type of digging machine utilizing a bucket on the end of a hydraulically actuated hinged boom.

The hydraulically operated backhoes in present use require the constant attention of the operator to the various functions. The operator must attentively operate numerous levers to carry out the necessary sequence of operations. Throughout each step of the digging process the operator must make continual decisions as to the necessary attitudes and movements of the components of the backhoe, and pull or push levers at the proper time to direct the digging cycles. For these reasons considerable time is required to train a skillful backhoe operator. Even after the skill is acquired, the work is demanding and tiring, requiring continuous mental and physical alertness to maintain maximum digging rates.

The primary object of this invention is to provide a hydraulic system which liberates the human operator from most of the intricate hand and finger manipulations presently required to operate a backhoe machine.

Another object of this invention is to provide an automatic hydraulically operated backhoe which can be operated with a minimum amount of attention of the operator.

Another object of this invention is to provide an automatic backhoe hydraulic circuit which may be placed in parallel arrangement with a conventional manually operated hydraulic backhoe system.

Another object of this invention is to provide an automatic backhoe hydraulic circuit in which the digging cycle functions and/or the retraction cycle functions can be initiated by the operation of a single lever.

Other objects and advantages as well as a full understanding of the invention will be had from the following description and claims, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a side elevational view of a tractor and backhoe machine to which the automatic hydraulic control system of this invention has been applied.

FIGURE 2 is a pictoral flow diagram of the basic digging cycle hydraulic control system of this invention.

FIGURE 3 is a sectional view through the line 3—3 of FIGURE 1 showing the cylinders controlling the lateral or horizontal swing of the backhoe boom.

FIGURE 4 is a partial enlarged side elevational view showing the manual crowd lever and related control valve.

FIGURE 5 is a partial cross-sectional view through the line 5—5 of FIGURE 1 showing the swing detection cams and swing detection valves.

FIGURE 6 is an enlarged elevated view of the lift attitude cam and valve.

FIGURE 7 is a composite schematic diagram of the automatic backhoe hydraulic circuit of this invention providing automatic digging and retraction cycles.

FIGURE 8 is a composite schematic diagram of the automatic backhoe hydraulic circuit of this invention providing a completely automatic full cycle.

The automatic hydraulic control system of this invention is adaptable to operate in parallel with a manually operated control system so that the operator of the backhoe may choose either manually or automatically to operate the machine and may switch from manual to automatic operation and vice versa at any stage of the operation. Manual operation of the backhoe unit requires the operator to dexteriously position the various components of the backhoe by manipulation of levers which operate valves to admit hydraulic fluid under pressure to jacks which control the movement of the machine components. This invention provides an automatic control system in which the elements of the backhoe machine are automatically actuated, relieving the operator of substantially all the effort and judgment normally required.

This invention may be described as an automatic hydraulic control system for a backhoe machine, or a backhoe machine including automatic hydraulic control systems. More particularly, but not by way of limitation, the invention may be described as a backhoe machine having a tractor, a boom consisting of a lift arm pivoted at one end to the tractor, a crowd arm pivoted at one to the other end of the lift arm, and a bucket pivoted to the other end of the crowd arm, a double acting hydraulic jack, termed a lift jack, pivotally affixed at one end to the tractor and at the other end to the lift arm whereby the lift arm is pivotally positioned relative to the tractor in a vertical plane, the lift arm being raised to a decreased digging attitude and lowered to an increased digging attitude, a hydraulic jack, termed a crowd jack, pivotally affixed at one end to the lift arm and at the other end to the crowd arm whereby the crowd arm is pivotally positioned in a vertical plane relative to the lift arm, the crowd arm being moved inwardly to increased digging attitude or outwardly to decreased digging attitude, a double acting hydraulic jack, termed a curl jack, pivotally affixed at one end to the crowd arm and at the other end to the bucket whereby the bucket is pivotally positioned in a vertical plane relative to the crowd arm, the bucket being pivoted inward to decreased digging attitude or outwardly to an increased digging attitude, a source of hydraulic fluid pressure carried by the tractor, a manual lift valve controlling fluid communication between the pressure source and the lift jack, a hydraulically operated valve, termed a lift valve, controlling fluid pressure to the lift jack to move the lift jack to increased or decreased digging attitude, a hydraulically operated curl valve controlling hydraulic fluid flow to the curl jack to pivot the bucket to increased or decreased digging attitude, an overload signal valve in

communication with and sensitive to the hydraulic pressure in the crowd jack and providing a signal output when the hydraulic pressure in the crowd jack moving the crowd arm to increased digging attitude exceeds a preselected level, and means responsive to the overload signal valve of actuating the curl power valve and thereby the curl jack to move the bucket to decreased digging attitude when overload condition is detected in the crowd jack. In further particular, the backhoe machine of this invention includes, in addition to the above described elements, an overload signal valve detecting pressure in the curl jack as the curl jack is moved to decreased digging attitude and including means responsive to overload detection by both the crowd overload signal valve and the curl overload signal valve of actuating the lift jack power valve to pivot the lift arm to decreased digging attitude so that, as the backhoe is operated and the crowd arm is moving inwardly towards the tractor in the digging operation, lift jack and curl jack are automatically controlled to accomplish the digging cycle. In a still further definition of this invention, in addition to the above described elements, the backhoe machine includes means responsive to the hydraulic pressure in the crowd jack as hydraulic pressure is applied to the jack to move the arm outward in the initial stages of the retraction cycle including means of actuating the curl jack power valve to pivot the bucket inwardly whereby the bucket is pivoted inwardly as the crowd is moved out to automatically maintain the bucket in substantially level position as the crowd arm is moved out during the boom retraction cycle. In still further particularity, the invention includes, in addition to the above described elements, means of automatically swinging the boom arm in a horizontal plane to one side, automatically dumping the bucket, and automatically returning the boom to the proper position for the initiation of a new digging cycle.

The expression "increased digging attitude" with reference to the lift arm, the crowd arm and the bucket means the change in attitude which would result in fully filling the bucket quickly under ideal conditions, and particularly means the lift arm is pivoted downwardly, the crowd arm is pivoted towards the tractor and the bucket pivoted outward. In like manner the expression "decreased digging attitude" means the lift arm is pivoted upwardly, the crowd arm is pivoted away from the tractor, and the bucket is pivoted inwardly. In other words, the expressions "increased digging attitude" and "decreased digging attitude" are used only to indicate direction of pivotation of the elements of the backhoe and are not synonymous with faster, slower, better or worse instantaneous digging effectiveness.

Referring now to the drawings and first to FIGURE 1, a backhoe machine is shown consisting of the basic components of a tractor **10** having mounted at the rear thereof a boom, indicated generally by the numeral **12**. Typically, a backhoe tractor **10** is provided with a front end loader, generally' indicated by the numeral **14**, which has no part in the invention.

The boom **12** consists of six basic components. These are:

A lift arm **16** having ends **16A** and **16B** pivoted at end **16A** to the tractor **10**;

A crowd arm **18** having ends **18A** and **18B** pivoted at end **18A** to end **16B** of the lift arm;

A bucket **20** pivoted to the end **18B** of the crowd arm **18**;

A double acting hydraulic jack **22** pivotally connected at one end to the tractor **10** and at the other end to the lift arm **16** whereby the lift arm **16** is pivoted in a vertical plane, this jack being referred to as the lift jack;

A double acting hydraulic jack **24** pivotally connected at one end to the lift arm **16** and at the other end to crowd arm **18** whereby the crowd arm **18** is pivoted in a vertical plane relative to the lift arm **16**, this jack being referred to as the crowd jack; and

A double acting hydraulic jack **26** pivotally connected at one end to the crowd arm **18** and at the other end to bucket **20** whereby the bucket is pivoted in a vertical plane relative to the crowd arm, this jack being referred to as the curl jack.

All of the components of the backhoe machine described to this point are more or less standard in the industry. The boom **12** is controlled by hydraulic fluid pressure directed into the jacks **22**, **24** and **26**, the fluid flow being normally directed by an operator manipulating manual valves, generally indicated by the numeral **28**. Typically, there are four levers operating the manual valve **28**, each of which basically consists of an open-center double position valve wherein the valve pushed outwardly conducts fluid to cause a jack to operate in one direction and when pulled inwardly conducts fluid flow to cause a jack to move in the opposite direction, with the center position being the off or no-flow position.

This invention consists essentially of applying to the typical hydraulically operated tractor backhoe unit described to this point a hydraulic control system whereby substantially all of the manual manipulation of the valves **28** is replaced by automatically controlled systems.

Referring now to FIGURE 2, a pictoral flow diagram is shown of the basic hydraulic circuit of the invention constituting the first phase of the invention, wherein the digging cycle of the backhoe boom is automatically controlled.

Positioned in parallel with the curl manual valve **28C** is a hydraulically operated four-way blocked center valve **30**, termed a curl power valve. This valve controls hydraulic fluid pressure to the curl jack **26** paralleling operation of the manual valve. The curl power valve is a three-position valve hydraulically controlled by fluid pressure in conduit **32**.

In like manner, a hydraulic operated four-way blocked center valve **34** parallels the lift manual valve **28B** and is controlled by hydraulic fluid through conduit **36**. This valve is termed the lift power valve **34**.

The operation of the hydraulic circuit of FIGURE 2 is initiated when the boom **12** (see FIGURE 1) is positioned in an extended attitude with the lift arm **16** low, the crowd arm **18** extended outwardly substantially horizontally, and the bucket **20** extended outwardly in the maximum digging attitude. To initiate digging to fill the bucket **20**, the operator pulls the manual crowd valve **28A** towards him which causes hydraulic fluid pressure to flow into the crowd jack **24** through conduit **38**. This starts a retraction of the crowd arm **18** moving the bucket **20** into the earth. Normally the operator must make continuous manual adjustments as the crowd arm is moved in, raising and lowering the boom by hydraulically controlling the lift jack and correcting the attitude of bucket **20** so that the system will not be overloaded but at the same time maximum digging will be provided so that ideally at the end of the digging cycle, a full bucket of earth is obtained. In the automatic control system of FIGURE 2, these continuous manual adjustments are automatically achieved. An overload signal valve **40** is connected to conduit **38** and is sensitive to the hydraulic pressure in the crowd jack **24**. As hydraulic pressure in the crowd jack increases, the valve **40** is actuated providing a hydraulic crowd overload signal **S1** in conduit **32**. The overload signal valve **40** is supplied with a hydraulic signal pressure by conduit **42**. The source of hydraulic signal pressure may be provided, such as by means of a pressure reducing valve or the like (not shown), connected to the tractor hydraulic pressure system source. Usually the hydraulic signal pressure source is at a lower pressure than the main hydraulic pressure source of the machine and for successful operation of the automatic controlled backhoe machine of this invention, such hydraulic pressure signal source should be at a substantially constant level.

In communication with the conduit **44** by which hydraulic fluid is conducted to the "in" port of curl jack **26** is a second overload signal valve **46**, termed a curl overload signal valve. When overload is experienced in the conduit **44**, the curl overload signal valve **46** provides a hydraulic signal S3 at conduit **48**. A pilot operated check valve **50** is controlled by signal S3 in conduit **48** as previously indicated. A check valve **51** is provided between conduits **36** and **48** so that signal S4 is relieved when conduit **48** is tanked by overload signal valve **46**.

A pilot operated check valve **52** is interposed in conduit **38** so that the pressure which the crowd overload signal valve **40** receives from the crowd jack **24** is isolated from the rest of the system. In this way the pressure monitored by the crowd overload signal valve **40** is not affected by other devices in the system. In like manner, check valve **54** isolates the signal received by the curl overload signal valve **46**. Check valves **56** and **58** serve as low pass filters for the overload signal valves **40** and **46**.

Operation of automatic digging cycle control system

As previously indicated, FIGURE 2 illustrated the first basic portion of the automatic backhoe hydraulic system of this invention whereby automatic digging cycle control is obtained. To illustrate the operation of this circuit it will be assumed that the backhoe boom **12** (as shown in FIGURE 1) is positioned ready to begin the digging cycle with the lift arm **16** in relatively low position, the crowd arm **18** extended and the bucket **20** extending in the out or maximum digging position. To initiate the digging cycle, the operator pulls the lever of manual crowd valve **28A** towards him which causes hydraulic fluid to flow through conduit **38** to the hydraulic jack **24** moving the crowd arm inwardly towards the tractor. This causes the bucket **20** to dig into the earth and start the digging or filling of the bucket. The inward movement of the crowd arm will continue with the bucket in the maximum digging attitude until an overload condition is reached. This overload will cause pressure build-up in the crowd jack **24** and in conduit **38**. This pressure is monitored by crowd overload signal valve **40** causing the hydraulic signal S1 in conduit **32**. This hydraulic signal is applied to curl power valve **30** pivoting it to cause hydraulic fluid flow through conduit **44** to curl jack **26**. Actuation of curl jack **26** causes inward pivotation of the bucket **20** to a decreased digging attitude, that is, the bucket is not inclined to dig as deeply into the earth. At this point in the operation, two conditions may occur. The first is that such inward pivotation of the bucket **20** relieves the overload condition. If this occurs the hydraulic pressure in conduit **38** drops causing the closure of crowd overload signal valve **40**. The crowd jack continues to actuate the crowd arm inwardly. Relief of the crowd overload removes the overload signal S1 in conduit **32** causing the curl power valve **30** to move back to center position so that no further adjustment is made in the bucket attitude. The crowd jack will continue to actuate by fluid flow through conduit **38** until further action.

The second possible occurrence when overload condition is detected in crowd jack **24** and curl jack **26** is actuated by signal S1 is that the curl jack itself will become overloaded. This occurs as pressure build-up in conduit **44** increases. Such pressure build-up is detected by the curl overload signal valve **46** providing a curl overload hydraulic signal S3 in conduit **48**. When such overload signal is detected, the pilot operated check valve **50** is actuated providing an open path between conduit **32** and conduit **36** which connects with the lift power valve **34**. The pilot operated check valve **50** and check valve **51** functions as an "and" control circuit, that is, a hydraulic signal S4 is provided in conduit **36** only when both signals S1 and S3 are provided in conduits **32** and **48**. When a signal S4 is applied in conduit **36**, which occurs only when both the crowd and curl jacks **24** and **26** are overloaded, the lift power valve **34** is pivoted to cause hydraulic fluid flowing in conduit **62** actuating lift jack **22** to pivot the lift arm **16** in an upward or decreased digging attitude. As the lift arm **16** is pivoted upward, the bucket **20** is moved to decreased contact with the earth which will immediately result in either the crowd, the curl, or both the crowd and curl jack overload conditions being relieved. When this occurs the overload signal S4 in conduit **36** is removed terminating any further upward pivotation of lift arm **16**.

As the boom continues to move inwardly towards the tractor by the inward pivotation of crowd arm **18**, the hydraulic control system of this invention continually monitors the pressure condition and adjusts the attitude of the bucket and lift arm to relieve overload conditions. Such overload conditions are relieved rapidly insuring maximum digging efficiency. By the application of the automatic control system of FIGURE 2, the operator accomplishes a complete digging cycle by merely manually moving the crowd valve **28A** to initiate the inward pivotation of the crowd arm. The operator does not have to utilize the manual lift or curl valves **28B** and **28C** since all necessary adjustments in the curl and lift jacks are made by the control system of the invention.

Automatic digging and retraction control system

Referring to FIGURE 1, a lift position valve **64** is shown supported to the tractor and is controlled by a lift position cam **66**. This is best shown in the enlarged view of FIGURE 6. The cam **66** is affixed to the end **16A** of the lift arm **16**. The lift position valve **64** which is controlled by cam **66** is a cam operated four-way three positioned spring offset center bypass valve, the purpose and function of which will be described subsequently.

Referring again to FIGURE 1, an automatic retraction valve **68** is shown supported to the tractor and is actuated by the lever of manual crowd valve **28A**. This is best shown in the enlarged view of FIGURE 4. The automatic retraction valve **68** is supported to the tractor **10** in close relationship to a crowd lever **70**, the lever which operates the crowd valve **28A**. The automatic retraction valve **68** is a three-way two position spring biased cam actuated valve. The valve is shown in the spring position in FIGURE 7. When the crowd lever **70** (see FIGURE 4) is in either the neutral position or in the "crowd in" position the valve **68** is in the spring position shown and is in the cam position when the crowd lever **70** is in the "crowd out" position.

A manual-automatic selection valve **72** is provided whereby either manual or automatic retraction of the boom is selectable. In FIGURE 7 the valve is shown in the "automatic" position. Other than the lift arm position valve **64**, the automatic retraction valve **68**, the swing direction valve **96**, and the selection valve **72**, all of the other valves making up the automatic digging and retraction cycle system of this invention as shown in FIGURE 7 are hydraulically controlled.

All of the valves as previously described with reference to FIGURE 2 providing the automatic digging cycle are included in the automatic digging and retraction cycle system of FIGURE 7, however, the function of lift power valve **34** and check valves **54** and **58** are changed somewhat in type and function as indicated in FIGURE 7 and as will be subsequently described. In addition to the components of the automatic digging cycle system of FIGURE 2, the system of FIGURE 7 provides the necessary elements to achieve both automatic digging and retraction cycles of the boom. Upon completion of the digging cycle, the retraction cycle is initiated by the operator switching the manual crowd valve **28A** to the "crowd out" position which is done by merely pushing the crowd lever **70** outwardly. This provides hydraulic pressure in conduit **74** connecting to the crowd jack **24** causing the crowd arm to start moving outwardly. When the crowd lever **70** is moved to the out position, automatic retraction valve **68** is moved to the cam position so that hydraulic fluid pres-

sure in conduit **74** is communicated to conduit **76**. The hydraulic pressure in the crowd jack **24** is therefore reflected in the conduits **76** and is monitored by a low pressure overload signal valve **78** and a high pressure signal valve **80**. When overload pressure in the crowd jack out conduit **74** is detected by the low pressure overload signal valve **78**, a hydraulic signal S7 is imposed through conduit **82** to a curl signal shuttle valve **84**. This signal passes through valve **84** to curl power valve **30** actuating it and causing fluid flow to curl jack **26** resulting in inward pivotation of the bucket for purposes to be described subsequently. The curl signal shuttle valve **84** functions as an "or" valve, that is, it permits actuation of the curl power valve **30** by either signal S1 or signal S7.

As previously mentioned, the hydraulic pressure in crowd jack out conduit **74** and thereby in conduit **76** is also monitored by the high pressure overload signal valve **80**. This valve **80** is set so that only the pressure build up which is experienced when the crowd jack **24** reaches the outer limits of its travel will the valve be actuated. When it is actuated, a hydraulic signal S8 is provided in conduits **86**. The pressure signal S8 serves two functions, the first being to actuate a hydraulic curl signal block valve **88** which blocks signal S7 thereby blocking any further inward pivotation of the curl jack **26**. The second function of the hydraulic signal S8 in conduits **86** is to begin the initiation of the swing of the backhoe boom to the left or the right of the tractor so that dirt accumulation in the bucket during the digging cycle can be emptied.

The swinging of the boom to the left or right in a horizontal plane to afford dumping of earth removed by the backhoe is accomplished by a left hydraulic swinging jack **90** and a right hydraulic swinging jack **92**. These swinging jacks **90** and **92** are controlled by means of manual swing valve 28D. Typically such a valve is arranged so that the operator can by pushing a single valve lever away from him cause the boom to swing in one direction and by pulling it towards him cause the boom to swing in the opposite direction. In parallel with the manual swing valve **28D** is a hydraulically operated swing power valve **94**. This is a pilot operated four-way blocked center valve. A manually operated swing direction selection valve **96** directs the hydraulic operating signal into the swing power valve **94** so that the direction which the boom will swing is manually selectable. Interposed between the conduit **86** which carries hydraulic signal S8 are two swing blocking valves, a low lift arm blocking valve **98** and a high lift arm blocking valve **100**. Blocking valve **98** is controlled by signal S9 and blocking valve **100** by signal S6. If the lift arm **16** (FIGURES 1 and 6) is too high, the lift position valve **64** provides a hydraulic signal S6 in conduit **102** which actuates the high lift arm blocking valve **100**, thereby blocking signal S8. If the lift arm **16** is too low, the lift position valve **64** provides a hydraulic signal S9 in conduit **104** which actuates the low lift arm blocking valve **98** to block the signal S8. Conduit **102** which carries the high lift arm signal S6 from valve **64** also connects to the lift power valve **34** so that with signal S6 present valve **34** is actuated to lower the lift arm. When signal S9 is provided in conduit **104**, it is communicated through a lift signal shuttle valve **106** to conduit **60** and becomes signal S5 to actuate lift power valve **34** to cause hydraulic fluid to flow from conduit **42** to the lift jack **22** to raise the lift arm. Thus the lift signal shuttle valve **106** is in effect an "or" valve in that the lift power valve is actuated by either signal S4 or S9.

Automatic retraction cycle

Assuming the automatic backhoe machine of this invention has completed a digging cycle as previously described, all the operator has to do to cause the machine to automatically perform the retraction cycle is to move the crowd lever **70** (see FIGURE 4) to the crowd out position. This has two results. First, the manual crowd valve **28A** is moved to the out position so that hydraulic fluid pressure is supplied to conduit **74** which connects with the crowd jack **24** so that the crowd arm is pivoted outwardly. Second, the automatic retraction valve **68** is actuated. This provides hydraulic fluid in conduit **76**. The pressure in conduits **76** is the reflection of the pressure in the crowd jack **24** and is monitored by the low pressure overload signal valve **78** and the high pressure overload signal valve **80**. The purpose of the low pressure overload signal valve **78** is to maintain the bucket **20** (see FIGURE 1) in a substantially level position as the crowd arm is pivoted outwardly to prevent the dirt which has been forced into the bucket during the digging cycle from spilling out. As the crowd arm **18** pivots outwardly the hydraulic pressure required in the crowd jack **24** increases. This pressure increase is detected by the low pressure overload signal valve **78** which, when actuated, applies a hydraulic signal S7 by way of conduit **82** through the curl signal block valve **88** and the curl signal shuttle valve **84** to actuate the curl power valve **30**, causing the curl jack **26** to pivot the bucket **20** towards the inward position. As the arm **18** pivots further outwardly, the pressure in crowd jack **24** increases and by the continuous monitoring of the pressuring by the overload signal valve **78**, the curl jack **26** is actuated to continually pivot the bucket **20** inwardly maintaining it in a level position.

The second important function which must be automatically provided to achieve automatic retraction of the backhoe boom is to correct for the attitude of the boom when it has completed the digging cycle. The attitude of the boom is detected by the angle of pivotation in the vertical plane of the lift arm **16**. The arm **16** may be in one of three positions, that is, it may be too high, too low or at a correct position. If, at the completion of the digging cycle, the arm **16** is in a correct position for the retraction cycle, the lift arm position valve **64** remains in the center position as shown in FIGURE 7 and no further correction of the lift arm position is required. However, if the lift arm is too high, the lift arm position valve **64** is moved by cam **66** so that a hydraulic pressure signal S6 is applied to conduit **102**. The pressure signal S6 serves two functions. First, it moves the high lift arm blocking valve **100** to the blocking position so that as long as the lift arm is too high the swing power valve **94** cannot be actuated. At the same time signal S6 is applied to the lift power valve **34** to raise the lift arm. If the lift arm is too low at the initiation of the retraction cycle, signal S9 from lift arm position valve **64** is applied through lift shuttle valve **106** to produce signal S5 which in turn actuates the lift power valve **34** to pivot the lift arm upwardly. Signal S9 also actuates swing blocking valve **98** to prevent the boom from swinging until the low position of the lift arm is corrected.

If the lift arm position has been corrected by the time the crowd jack reaches the outer limit of its travel, signals S6 and S9 will not be present and valves **98** and **100** will be in the open position as shown. With these conditions when the crowd jack **24** reaches its outer limit the high crowd pressure actuates overload signal valve **80** applying signal S8 through the blocking valves **98** and **100** and the swing direction valve **96** to actuate the swing power valve **94** to in turn actuate either the left swing jack **90** or the right swing jack **92** depending upon the setting of the swing direction selection valve **96**. This initiates the swing of the boom. If the attitude of the lift arm has not been corrected when crowd jack **24** reaches its outer limit, that is, if the lift arm is still pivoted too high or too low for the proper swing and dumping of the bucket, the signal S6 or S9 will continue to be applied until the correct attitude of the lift arm is achieved before swing initiation will begin.

Thus, it can be seen that by the automatic digging cycle previously described and the automatic retraction cycle described with reference to the system arrangement of FIGURE 7, the operator can achieve automatic digging by merely pulling the crowd lever towards him and when the operator determines to terminate the digging cycle,

which usually is when the crowd arm has reached the maximum inward point or the bucket is filled, all the operator has to do to cause automatic retraction of the backhoe machine is to push the crowd lever forward to the crowd out position. The leveling of the bucket, correcting of the attitude of the lift arm and the automatic initiating of the swing are all automatically accomplished by the system of this invention. When the boom has swung to the required position for dumping, the operator stops the swing by moving the manual crowd valve **28A** back to the center position.

In the disclosed embodiment of the invention a novel system of automatically maintaining the bucket level during the retraction cycle is provided by means responsive to the crowd jack hydraulic pressure. Other methods of maintaining the bucket level during retraction include the use of a pendulum or a gyroscopically actuated valve as well as other similar and equivalent devices.

Complete automatic backhoe digging machine

To this point in the description the automatic operation of the digging cycle of the backhoe machine has been first described and then the automatic operation of a digging and retraction cycle system has been described. The third phase of the invention, which will now be described, includes a complete composite automatic backhoe machine.

As shown in FIGURE 1 and FIGURE 5, two cam operated valves, designated a dump position cam valve **108** and a dig position cam valve **110**, are mounted on the tractor **10** and are actuated by a dump position cam **112** and a dig position cam **114**. The cams **112** and **114** are tandem mounted and affixed to the boom support base **116** to which the lift arm **16** is attached so that the cams **112** and **114** move with and indicate the position in the horizontal plane of the boom **12** as it is moved by the swing cylinders **90** and **92**. The function of the dump position cam valve **108** and dig position cam valve **110** will be subsequently described.

In addition to the control valves which have been previously described with reference to the automatic digging system of this invention of FIGURE 7, the total automatic system of this invention of FIGURE 8 includes eleven additional hydraulically operated valves. The purpose and function of these will be described with reference to the operation of the composite circuit. These eleven additional hydraulically operated valves are as follows:

(1) a curl in locking valve **118** positioned between the curl signal shuttle valve **84** and the curl power valve **30**;

(2) a lift up detent locking valve **120** positioned between the lift signal shuttle valve **106** and the lift power valve **34**;

(3) a left swing detent dig cycle blocking valve **122** positioned between the swing direction valve **96A** and the swing power valve **94**;

(4) a right swing detent dig cycle blocking valve **124** positioned between the swing direction valve **96A** and the swing power valve **94**;

(5) a lift shuttle valve **126** directing the down hydraulic signal to the lift power valve **34**;

(6) a left swing shuttle valve **128** controlling signal input to the left swinging side of the swing power valve **94**;

(7) a right swing shuttle valve **130** controlling signal input into the right swing side of swing power valve **94**;

(8) a curl empty overload signal valve **132** which monitors the hydraulic pressure of the out conduit of curl jack **26**;

(9) a right swing blocking valve **134** positioned between the swing direction valve **96A** and the right of swing shuttle valve **130**;

(10) a left swing blocking valve **136** positioned between the swing direction valve **96A** and the left swing shuttle valve **128**; and

(11) a pilot operated crowd hold check valve **138** positioned in the out conduit **74** of the crowd jack **24**. In addition to these hydraulically controlled valves a manual digging attitude initiation selector valve **140** provides a means whereby the operator can select either one of two conditions. In the first position, when the valve is closed, the automatic cycle terminates when the back swing is completed with the boom extending over the ditch. In the second position, when the valve is open, the boom automatically lowers into the ditch in digging attitude at the end of the back swing.

In the complete automatic backhoe system of FIGURE 8, as compared with the automatic digging and retraction system of FIGURE 7, swing direction valve **96A** and curl power valve **30** are changed somewhat in type and function. A pilot check valve **146** and a check valve **148**, comprising an "and" circuit, are added which function to actuate lift down shuttle valve **126** upon the occurrence of signal **S11** and **S12**.

The operation of complete automatic backhoe system

The basic steps in the operation of the automatic backhoe as illustrated in the diagram of FIGURE 8 are as follows:

(1) The operator selects the direction he wishes the backhoe to swing to dump by moving the manual swing direction valve **96A**. In addition, the dump position cam **112** and dig position cam **114** (see FIGURES 1 and 5) are set to correspond with the selected swing direction. The operator then positions the backhoe boom in position to start the digging cycle.

(2) The operator pulls crowd lever **70** (see FIGURE 4) back to actuate manual valve **28A** to initiate the digging cycle.

(3) The backhoe automatically executes the digging cycle as previously described.

(4) The operator arbitrarily decides when the digging cycle is completed and pushes crowd lever **70** forward to initiate the retraction cycle.

(5) The backhoe automatically retracts from the hole, maintaining the bucket in approximately level attitude, and initiates the swing cycle as previously described.

(6) The backhoe automatically swings until it reaches the preselected dump position as established by the dump position cam **112**.

(7) The backhoe swing stops and the load carried by the bucket is automatically dumped.

(8) The dumping completed, the boom automatically swings back to the preselected dig position as established by dump position cam **112** (see FIGURES 1 and 5) and automatically lowers into the hole.

(9) The operator pulls the crowd lever **70** back to begin a new digging cycle.

Thus, all that is required of the operator is that he pull the crowd lever back to begin the digging cycle, push the crowd lever forward when the bucket is full to cause the boom to begin automatic retraction, swing, dump and reswing to digging position, and then pull the crowd lever back to begin a new cycle.

The function of the composite automatic control system of this invention will now be described. As previously mentioned, after positioning the boom of the backhoe in digging attitude, the operator actuates the manual control valve **28A** so as to cause hydraulic pressure in conduit **38**. At the same time conduit **74** is tanked. Pressure in conduit **38** passes through pilot check valves **52** and **56** to extend the crowd jack **24** forcing the crowd arm inwardly and into the ground. The same fluid pressure also resets the curl-in detent blocking valve **118**, lift-up detent blocking valve **120**, lift swing detent dig cycle blocking valve **122**, and right swing detent dig cycle blocking valve **124**. Overload signal valve **40** monitors the working pressure in the crowd line **38**. The overload signal valve **40**, as well as the other overload signal valves in this invention, are supplied from a hydraulic signal pressure force by conduit **42**.

When the working pressure in the crowd line **38** builds to a preselected level, the crowd overload signal valve

40 is actuated producing a hydraulic signal S1 which proceeds through the curl signal shuttle valve 84 and conduit 60 to the curl-in detent blocking valve 118 to produce signal S2 which pilots the curl power valve 30. The curl power valve 30 as previously described serves as a directional power valve for the curl jack 26. Hydraulic flow in line 44 through pilot check valves 54 and 58 extends the curl jack 26 to curl inward the backhoe bucket 20 (see FIGURE 1). When the signal S2 pilots curl power valve 30 the pressure in the backhoe system will reduce due to the lack of resistance encountered by the curl jack. Therefore, pilot check valve 52 in the crowd-in conduit 38 locks the high pressure which has activated the overload signal valve 40 in the crowd conduit. This means that the overload pressure condition on the crowd jack must be actually relieved in the jack and not by reduction in system pressure. Pilot check valve 56 serves as a low pass filter for the crowd overload signal valve 40. This prevents shock waves which might be generated in the crowd pack 24 from actuating the signal valve 40.

Curl overload signal valve 46 monitors working pressure in the curl jack 26 and produces a hydraulic signal S3 when the curl signal pressure reaches a preselected overload condition. Signal S3 is normally blocked by pilot operated check valve 50 except when this valve has been actuated by signal S1. Thus, the pilot check valve 50 functions, with check valve 51, as an "and" gate to generate a signal S4 when both signals S1 and S3 are present. Signal S4 in conduit 60 precedes through the lift signal shuttle valve 106 and the lift-up detent blocking valve 120 to produce signal S5 which pilots the lift power valve 34. As previously indicated, the lift power valve 34 serves as the directional power valve for the lift jack 22. When signal S5 is present, conduit 62 is pressurized causing the lift jack 22 to extend pivoting the lift arm upwardly.

When the lift jack 22 is being extended, pilot check valve 54 in the curl line 44 isolates the curl overload signal in the same manner as previously described with reference to valve 56. Pilot operated check valve 58 serves as a low pass filter for the curl overload signal valve 46.

If the overload condition on the curl jack 26 is relieved by the extension of lift jack 22, signal S3 in conduit 48 is lost and the lift power valve 34 is returned to the center position. The crowd and curl jacks 24 and 26 are still actuated and performing the digging action. If the overload condition on the crowd jack 24 or on both the crowd jack 24 and the curl jack 26 are relieved by the extension of the lift jack 22, both the lift and curl power valves 34 and 30 are returned to block center position leaving only the crowd jack 24 actuated and attempting to dig. The backhoe performs the digging cycle by continuously repeated action of the events just described.

When the operator decides that the digging cycle is completed, he reverses the crowd lever 70 (see FIGURE 4) which reverses the manual crowd valve 28A. This action pressurizes conduits 74 and tanks conduit 38. If the operator desires automatic retraction, selection valve 72 is positioned in the open position as shown in FIGURE 8. Automatic retraction valve 68 is operated when the crowd lever 70 is pushed forward (see FIGURE 4). Physical action of the automatic retraction-swing circuit which results from reversal of the crowd lever is the next step in any complete automatic operation of the backhoe of this invention.

Upon initiation of the retraction cycle, the lift arm 16 of the boom can be in one of three positions. These positions are (1) the left arm 16 (see FIGURE 1) is too high for swinging at the end of the digging cycle; (2) the left arm 16 is too low for swinging at the end of the digging cycle; and (3) the lift arm 16 is in correct position for swinging at the end of the digging cycle. The correct position for swinging is preselected by positioning the left position cam 66 (see FIGURE 6) which operates the lift position detection valve 64.

When the position of the lift arm 16 is too high, lift position valve 64 gives a signal S6 in conduit 102 which signal passes through the lift down shuttle valve 126 to actuate the lift power valve 34, providing fluid pressure in conduit 142. This tends to drive the lift arm 16 and thereby the boom down until signal S6 from the lift position valve 64 is eliminated. While the boom is moving downward, the crowd jack 24 is being actuated, thus raising the crowd arm 18 (see FIGURE 1) from the hole. Overload signal valves 78 and 80 monitor the pressure existing in the crowd-out line conduit 74 and in conduit 76. The pressure overload signal valve 78 is set at a relatively low threshold pressure to provide bucket leveling action as the backhoe boom is being withdrawn from the hole. The action of this valve, which has been previously described, provides signal S7 which passes through the curl signal block valve 88, by way of conduit 82, through the curl signal shuttle valve 84 and the curl-in detent blocking valve 118 to actuate curl power valve 30. As the crowd arm moves outward, the pressure in the crowd jack out conduit 74 increases which increased pressure continues to actuate the curl power valve 30 extending the curl jack 26 so that the leveling action is continuously repeated in a stepwise manner as the crowd arm proceeds outwardly maintaining the bucket in substantially level position. The crowd arm 18 continues out until it reaches the limit of travel which produces a high pressure rise in crowd out conduit 74, thereby in conduit 76, which actuates the high pressure overload signal valve 80 producing signal S8. The threshold setting of the high pressure signal valve 80 is substantially greater than that of the overload signal valve 78 to insure that valve 80 will not actuate until the crowd arm reaches its limit of travel. Signal S8 actuates the curl signal block valve 88 which tanks signal S7 and allows curl power valve 30 to return to blocked neutral position. Signal S8 also passes through low lift arm blocking valve 98, high lift arm blocking valve 100, swing direction valve 96A and initiates the automatic swing cycle. If the boom is too high or too low when the crowd jack reaches its outer limit, the signal S8 will be blocked by either blocking valve 98 or 100 so that the signal S8 cannot pass through to initiate the swinging cycle. When the boom is in the correct position for swinging, as will be indicated by the center position of the lift position valve 64, there will be no signal to actuate the blocking valves 98 and 100 to prevent the signal S8 from passing through.

If the boom lift arm 16 happens to be in the correct swing position at the end of the digging cycle, the circuit action is the same as previously described with the exception that the lift arm remains stationary while the crowd arm 18 raises to swing position. When the crowd arm is in position, signal S8 is produced and passes through the blocking valves 98 and 100 to initiate the swinging cycle.

In the case where the lift arm 16 is too low at the end of the digging cycle, the sequence of action is as follows: (1) The operator as previously described pushes the crowd valve 28A to initiate retraction, and pressure is thereby direction applied to the crowd jack 24 through conduit 74 tending to force the crowd arm 18 out. (2) Signal valves 78 and 80 monitor the pressure in the crowd out line. (3) The lift position cam valve 64 is in position providing signal S9 in conduit 104. Signal S9 passes through the lift signal shuttle valve 106 and the lift-up detent blocking valve 120 to pilot the lift power valve 34 to cause the boom to raise and to swing into position. However, the pressure required to raise the lift arm is much greater than the pressure required to drive the crowd out, therefore, the lift arm 16 will not raise until the crowd arm 18 has reached the limit of travel. Pilot check valve 144 in con-

duit 62 retains the lift arm in position until the crowd arm 18 has reached the outward extremity of its travel. (4) As crowd arm 18 proceeds outward, signal valve 78 monitors the crowd pressure in order to level the bucket as previously described. (5) When the crowd jack 24 reaches its limit of travel, signal valve 80 is actuated. At this time pressure build up in the system will become sufficient to raise the lift arm 16 into swing position, allowing signal S8 to pass valves 98 and 100 to initiate the automatic swing cycle.

As previously mentioned, the operator has the option of making the backhoe boom swing to the left or right by positioning the swing direction valve 96A. The dump position cam valve 108 and the dig position cam valve 110 are swing position detection valves and are adjusted according to the direction the operator desires to swing. When the swing direction selection valve 96A is positioned as shown in FIGURE 8, the backhoe boom will swing to the left with the dump position cam valve 108 detecting the position at which to dump the load and the dig position cam valve 110 detecting the position selected to lower the backhoe boom into the hole for another digging pass. If the swing direction valve 96A is shifted to its other position, the backhoe boom will swing right with the valve 110 serving to detect the dump position and the valve 108 serving to detect the dig location. Thus, it can be seen that the cam valves 108 and 110 must be physically adjusted to correspond with the shifting of the swing direction valve 96A.

With the swing direction valve 96A positioned as shown in FIGURE 8, signal S8 can pass through valves 96A, left swing dig cycle blocking valve 122, the left swing shuttle valve 128 to pilot the swing power valve 94. This causes fluid pressure to flow into the left swing jack 90, causing the backhoe boom to begin its swing cycle.

The dump position cam valve 108 actuates when the backhoe boom has reached the desired dump position. Actuation of the dump position cam valve 108 produces a signal S10 which passes through the swing direction valve 96A and sets the curl in detent blocking valve 118 and the lift up detent blocking valve 120, and pilots the curl power valve 30 to cause the bucket 20 (see FIGURE 1) to be pivoted out or open to dump the load. At the same time the signal S10 sets the left swing detent dig cycle blocking valve 122 which causes the pilot signal to the swing power valve 94 to be tanked, returning the valve 94 to the center position stopping the boom from further swinging. Pilot operated crowd hold check valve 138 prevents the crowd arm from falling when the load is being dumped. This is necessary because of the low pressure existing in the hydraulic system during load dumping.

Curl empty overload signal valve 132 produces a signal S11 when the curl jack 26 reaches the end of its downward travel. This signifies that the dumping action is completed and the backhoe is ready to swing back into digging location. Signal S11 passes through the swing direction valve 96A, the right swing blocking valve 134, the right swing shuttle 130, to pilot the swing power valve 94 so as to make the backhoe boom swing back to digging location. Dig position cam valve 110 actuates when the backhoe boom has swung to the digging position. The actuation of the dig position cam valve 110 produces a signal S12 which actuates the right swing blocking valve 134 stopping further swinging action of the boom. Signal S12 also passes through the swing direction valve 96A, the manual digging attitude initiation selector valve 140 and pilot valve 146 to pass signal S11 to produce signal S13. Signal S13 passes through the lift down shuttle valve 126 to pilot the lift jack power valve 34. This action causes the lift jack 22 to be actuated so as to cause the backhoe boom to lower into the hole for another operation cycle. When the operator observes that the boom is lowered far enough into the hole, he reverses the crowd lever 70 (see FIGURE 4) and a new digging cycle begins.

A manual dig attitude initiation selector valve 140 lets the operator determine if he wants the backhoe boom to automatically lower into the hole when it returns from the dumping cycle or if he wants the boom to automatically stop and be manually located into digging position.

The pilot operated check valve 146 in conjunction with a check valve 148 forms an "and" circuit so that signal S11 and signal S12 produce signal S13 which passes through the lift down shuttle valve 126 to pilot the lift power valve 34 to lower the boom into position. If valve 140 is closed, signal S12 and thereby signal S13 is blocked so the lift jack 22 will have to be actuated manually to lower the boom.

By switching the swing direction valve 96A and repositioning the dump position cam 112 and the dig position cam 114 so as to exchange the functional rolls of valves 108 and 110, the backhoe boom is caused to swing to the right and the circuit action duplicates that described for the left swing action.

In FIGURE 8 the dotted line represents conduits which carry signals. The solid line represents conduits which carry hydraulic fluid pressure used in the actuation of the jacks which control the components of the backhoe boom.

A type of valve which is specifically adaptable to function as overload signal valves 40, 46, 80, 82, and 132 in the system of this invention is described in our copending patent application Ser. No. 482,829 entitled "Hydraulic Signal Valve."

In the working embodiment of the systems of this invention, it is desirable that flow control valves be utilized in certain instances to slow the action of the jacks. In addition, devices to cushion the stopping of the swing cylinders are desired. Since such devices are not basic to the systems of this invention, they have not been shown.

While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this disclosure.

What is claimed:

1. A back hoe machine comprising:
   (a) a tractor;
   (b) a boom consisting of
      (1) a lift arm pivoted at one end to said tractor,
      (2) a crowd arm pivoted at one end to the other end of said lift arm, and
      (3) a bucket pivoted to the other end of said crowd arm;
   (c) a double acting hydraulic lift jack pivotally affixed at one end to said tractor and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude;
   (d) a double acting hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude;
   (e) a double acting hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm to increased or decreased digging attitude;
   (f) a source of hydraulic pressure carried by said tractor;
   (g) a hydraulically operated lift power valve controlling hydraulic fluid flow to said lift jack;
   (h) a hydraulically operated curl power valve controlling hydraulic fluid flow to said curl jack;
   (i) a crowd overload signal valve in communication with and sensitive to the hydraulic pressure in said crowd jack and providing hydraulic signal when the pressure in said crowd jack exceeds a preselected level as said crowd jack moves said crowd arm to increased digging attitude, said hydraulic signal coupled to said curl power valve whereby overload in

said crowd overload signal valve actuates said curl power valve to control said curl jack to decrease the digging attitude of said bucket;

(j) a curl overload signal valve in communication with and responsive to the hydraulic pressure in said curl jack and actuating to provide a hydraulic signal when the pressure in said curl jack exceeds a preselected level as said curl jack pivots said bucket to increased digging attitude; and

(k) a pilot operated valve actuated by hydraulic signal from said crowd overload signal valve and said curl overload signal valve providing a hydraulic lift control signal upon occurrence of said two signals, such lift control signal actuating said lift power valve to control said lift jack to decrease the digging attitude of said lift arm.

2. A back hoe machine according to claim 1 including means of tanking said lift control hydraulic signal when said curl overload signal valve is unactuated.

3. With a back hoe machine including

a tractor,

a boom consisting of

a lift arm pivoted at one end to said tractor,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a hydraulic lift jack pivotally affixed at one end to said tractor and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude,

a hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude,

a double acting hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm to increased or decreased digging attitude, and

a source of hydraulic pressure carried by said tractor, and means of directing hydraulic pressure to said crowd jack, the improvement providing means of automatically controlling the pivotation of said lift arm, crowd arm and bucket to achieve automatic digging, the improvement comprising:

a hydraulically operated lift power valve controlling hydraulic fluid flow to said lift jack;

a hydraulically operated curl power valve controlling hydraulic fluid flow to said curl jack;

a crowd overload signal valve in communication with and responsive to the hydraulic pressure in said crowd jack and providing a hydraulic signal when the pressure in said crowd jack exceeds a preselected level as said crowd jack moves said crowd arm to increased digging attitude, said hydraulic signal coupled to said curl power valve whereby overload in said crowd overload signal valve actuates said curl power valve to control said curl jack to decrease the digging attitude of said bucket;

a curl overload signal valve in communication with and responsive to the hydraulic pressure in said curl jack and actuating to a hydraulic signal when the pressure in said curl jack exceeds a preselected level as said curl jack pivots said bucket to decreased digging attitude; and

a pilot operated valve actuated by hydraulic signal from said crowd overload signal valve and said curl overload signal valve providing a hydraulic lift control signal upon occurrence of said two signals, such lift control signal actuating said lift power valve to control said lift jack to decrease the digging attitude of said lift arm.

4. The improvement of claim 3 including means of tanking said lift control hydraulic signal when said curl overload signal valve is unactuated.

5. With a back hoe machine including

a tractor,

a boom consisting of

a lift arm pivoted at one end to said tractor,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a double acting hydraulic lift jack having an up port and a down port, the jack pivotally affixed at one end to said tractor and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude,

a double acting hydraulic crowd jack having an in and an out port, the jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude,

a double acting hydraulic curl jack having an in and an out port, the jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm to increased or decreased digging attitude,

a source of hydraulic pressure carried by said tractor,

a manual lift valve controlling fluid communication between said pressure source and said lift jack,

a manual crowd valve controlling fluid communication between said pressure source and said crowd jack, and

a manual curl valve controlling fluid communication between said pressure source and said curl jack, the improvement providing means of automatically controlling the pivotation of said lift arm, crowd arm and bucket to achieve automatic digging, the improvement comprising:

a pilot operated hydraulic lift power valve paralleling said manual lift valve;

a pilot operated hydraulic curl power valve paralleling said manual curl valve;

a crowd overload signal valve in communication with and responsive to the hydraulic pressure in said jack and providing a hydraulic crowd overload signal when the pressure in said crowd jack exceeds a preselected level;

means communicating said crowd overload signal to pilot said curl power valve to actuate said curl jack to decrease the digging attitude of said bucket;

a curl overload signal valve in communication with and responsive to the pressure in said curl jack and providing a hydraulic curl overload signal when the pressure in said curl jack exceeds a preselected level;

a pilot operated check valve having an inlet, an outlet and a control port;

means communicating said crowd overload signal with one of the said inlet and control ports of said pilot operated check valve;

means communicating the other of said inlet and control ports of said curl overload signal with pilot operated check valves whereby a hydraulic lift control signal is provided at said outlet port upon the simultaneous occurrence of said crowd and curl overload signals; and

means communicating said lift control signal to said lift power valve pilot port to actuate said lift jack to pivot said lift arm towards decreased digging attitude when said crowd jack and said curl jack are overloaded,

6. The improvement of claim 5 including means of dumping said lift control signal when said curl overload signal valve is unactuated.

7. The improvement of claim 5 including a first and second pilot operated check valve in series with said crowd jack in port, each check valve piloted by hydraulic pressure in said crowd jack out port, said crowd overload signal valve communicating with said crowd jack intermediate said check valves whereby overload hydraulic pressure in said crowd jack applied to said crowd overload signal valve is isolated from reductions in pressure in said source of hydraulic pressure.

8. The improvement of claim 5 including a first and second seriesed check valve between said curl jack in port and said curl power valve, said curl overload signal valve communicating with the pressure in said crowd jack intermediate said seriesed check valve whereby the pressure actuating said curl overload signal valve is isolated from reductions in pressure in said source of hydraulic pressure.

9. With a back hoe machine including

a tractor,

a boom consisting of

a lift arm pivoted at one end to said tractor,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a hydraulic lift jack pivotally affixed at one end to said tractor and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude,

a hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude,

a hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm increased or decreased digging attitude,

a source of hydraulic pressure carried by said tractor,

a manual lift valve controlling fluid communication between said pressure source and said lift jack,

a manual crowd valve controlling fluid communication between said pressure source and said crowd jack, and

a manual curl valve controlling fluid communication between said pressure source and said curl jack, the improvement comprising:

a hydraulically operated lift power valve paralleling said manual lift valve;

a hydraulically operated curl power valve paralleling said manual curl valve;

means responsive to overload pressure in said crowd jack of actuating said curl power valve to cause pivotation of said bucket to decreased digging attitude; and

means responsive to the simultaneous overload pressure in said crowd jack and said curl jack to cause pivotation of said lift arm to decreased digging attitude.

10. A back hoe machine comprising:

a tractor,

a boom consisting of

a lift arm pivoted at one end to said tractor,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a double acting hydraulic lift jack pivotally affixed at one end to said tractor and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude,

a double acting hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally postioned relative to said lift arm to increased or decreased digging attitude,

a double acting hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm increased or decreased digging attitude,

a source of hydraulic pressure carried by said tractor,

a manual lift valve controlling fluid communication between said pressure source and said lift jack,

a manual crowd valve controlling fluid communication between said pressure source and said crowd jack,

a manual curl valve controlling fluid communication between said pressure source and said curl jack,

a hydraulically operated four way blocked center curl power valve paralleling said manual curl valve, and

means responsive to overload pressure in said crowd jack of actuating said curl power valve to cause inward pivotation of said bucket as said crowd arm is pivoted outwardly whereby said bucket is automatically maintained substantially level as said crowd arm is extended outwardly.

11. With a back hoe machine including

a tractor,

a boom consisting of

a lift arm affixed at one end to said tractor, said lift arm affixed to pivot in both the horizontal and vertical plane relative to said tractor,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a double acting hydraulic crowd jack having an in and an out port, this jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned in the vertical relative to said lift arm,

a hydraulic left swing jack having one end pivotally affixed to said tractor and the other end to said boom whereby said boom is pivotally positioned in the horizontal plane in the direction left relative to said tractor,

a hydraulic right swing jack having one end pivotally affixed to said tractor and the other end to said boom whereby said boom is pivotally positioned in the horizontal plane in the direction right relative to said tractor, and

a source of hydraulic pressure carried by said tractor, the improvement comprising:

a hydraulically operated swing power valve controlling fluid communication between said pressure source and said left and right swing jacks, said swing power valve having a right swing pilot port and a left swing pilot port;

a manually operated swing direction valve selectably providing fluid communication between said swing power valve and one or the other of said left and right swing jacks;

means responsive to overload pressure in said out port of said crowd jack of providing a hydraulic signal when said crowd jack reaches its outer limit of travel; and

a manually positioned swing direction valve selectably providing communication between said crowd overload pressure responsive means and one or the other of said left and right swing ports of said swing power valve whereby said boom automatically swings when said crowd jack reaches its outer limit of travel.

12. With a back hoe machine including

a tractor,

a boom consisting of

a lift arm affixed at one end to said tractor, said

lift arm affixed to pivot in the vertical plane relative to said tractor,
a crowd arm pivoted at one end to the other end of said lift arm, and
a bucket pivoted to the other end of said crowd arm,
a double acting hydraulic crowd jack having an in and an out port, this jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned in the vertical relative to said lift arm, and
a source of hydraulic pressure carried by said tractor, the improvement comprising:
a hydraulically operated lift power valve controlling fluid communication between said pressure source and said crowd jack;
a lift position detector valve affixed to said tractor and actuated by said lift arm providing a first hydraulic signal when said lift arm is pivoted in the vertical plane above a selected angle relative to said tractor and a second hydraulic signal when said lift arm is pivoted in the veritcal plane below the selected angle relative to said tractor, and no signal when the said lift arm is pivoted in the selected angle; and
means connecting said lift position detector valve to said lift power valve whereby said first hydraulic signal of said lift position detector valve actuates said lift power valve to lower said lift arm and said second hydraulic signal of said lift position detector valve actuates said lift power valve to raise said lift arm.

13. A back hoe machine according to claim **12** wherein said lift position detector valve communicates with said crowd jack out port whereby said first and second hydraulic signals are provided only when hydraulic pressure is applied to said crowd jack out port.

14. With a back hoe machine including
a tractor,
a boom consisting of
a lift arm affixed at one end to said tractor, said lift arm affixed to pivot in both the horizontal and vertical plane relative to said tractor,
a crowd arm pivoted at one end to the other end of said lift arm, and
a bucket pivoted to the other end of said crowd arm,
a double acting hydraulic crowd jack having an in and an out port, this jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned in the vertical relative to said lift arm,
a hydraulic left swing jack having one end pivotally affixed to said tractor and the other end to said boom whereby said boom is pivotally positioned in the horizontal plane in the direction left relative to said tractor,
a hydraulic right swing jack having one end pivotally affixed to said tractor and the other end to said boom whereby said boom is pivotally positioned in the horizontal plane in the direction right relative to said tractor, and
a source of hydraulic pressure carried by said tractor, the improvement comprising:
a hydraulically operated swing power valve controlling fluid communication between said pressure source and said left and right swing jacks, said swing power valve having a right swing pilot port and a left swing pilot port;
a manually operated swing direction valve selectably providing fluid communication between said swing power valve and one or the other of said left and right swing jacks;
means responsive to overload pressure in said out port of said crowd jack of providing a hydraulic signal when said crowd jack reaches its outer limit of travel;
a manually positioned swing direction valve selectably providing communication between said crowd overload pressure responsive means and one or the other of said left and right swing ports of said swing power valve whereby said boom automatically swings when said crowd jack reaches its outer limit of travel;
a lift position detector valve affixed to said tractor and actuated by said lift arm providing a first hydraulic signal when said lift arm is pivoted in the vertical plane above a selected angle relative to said tractor and a second hydraulic signal when said lift arm is pivoted in the vertical plane below the selected angle relative to said tractor, and no signal when the said lift arm is pivoted in the selected angle;
means connecting said lift position detector valve to said lift power valve whereby said first hydraulic signal of said lift position detector valve actuates said lift power valve to lower said lift arm and said second hydraulic signal of said lift position detector valve actuates said lift power valve to raise said lift arm; and
a first and a second pilot operated normally open swing blocking valve, each of said valves having a pilot port, said valves in series connection between said swing power valve and said means responsive to pressure in said out port of said crowd jack, said pilot port of one of said valves connected to receive the first signal of said lift position detector valve, said pilot port of the other of said valves connected to receive the second signal of said lift position detector valve, whereby either signal from said lift position detector valve blocks one of said swing blocking valves.

15. With a back hoe machine including a tractor, a boom consisting of a lift arm pivoted at one end to said tractor, a crowd arm pivoted at one end to the other end of said lift arm and a bucket pivoted to the other end of said crowd arm, a hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm, for pivotation of said crowd arm, a hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket, for pivotation of said bucket, a source of hydraulic pressure and means of selectably directing hydraulic pressure to said crowd jack and said curl jack, the improvement providing means of automatically maintaining said bucket level as said crowd arm is pivoted outwardly, the improvement comprising:
a hydraulically actuated curl power valve controllably directing pressure from said hydraulic source to said curl jack;
an overload signal valve in communication with and responsive to hydraulic pressure in said crowd jack and providing a hydraulic signal responsive to the pressure increases as said crowd jack pivots said crowd arm outwardly; and
means coupling said hydraulic signal from said overload signal valve to said curl power valve whereby said curl power valve is actuated to actuate said curl jack to pivot said bucket inwardly in response to increased pressure in said crowd jack as said crowd arm is pivoted outwardly.

16. A back hoe machine for mounting on a tractor, including:
a boom support base adapted to be mounted for horizontal swinging movement on the tractor;
a boom consisting of a lift arm pivoted at one end to the boom support base;
a crowd arm pivoted at one end to the other end of said lift arm; and
a bucket pivoted to the other end of said crowd arm;
a hydraulic lift jack pivotally affixed at one end to said boom support base and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude;

a hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude;

a hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm increased or decreased digging attitude;

a source of hydraulic pressure carried by said tractor;

a manual lift valve controlling fluid communication between said pressure source and said lift jack;

a manual crowd valve controlling fluid communication between said pressure source and said crowd jack; and

a manual curl valve controlling fluid communication between said pressure source and said curl jack, the improvement comprising:

means responsive to overload pressure in said crowd jack for directing fluid under pressure to said curl jack to cause pivoting of said bucket to decreased digging attitude, and

means responsive to simultaneous overload pressure in said crowd jack and said curl jack for directing fluid under pressure to said lift jack to cause pivoting of said lift arm to decreased digging attitude.

17. A back hoe machine for mounting on a tractor, including:

a boom support base adapted to be mounted for horizontal swinging movement on the tractor;

a boom consisting of

a lift arm pivoted at one end to the boom support base,

a crowd arm pivoted at one end to the other end of said lift arm, and

a bucket pivoted to the other end of said crowd arm,

a hydraulic lift jack pivotally affixed at one end to said boom support base and at the other end to said lift arm whereby said lift arm is pivotally positioned relative to said tractor to increased or decreased digging attitude;

a hydraulic crowd jack pivotally affixed at one end to said lift arm and at the other end to said crowd arm whereby said crowd arm is pivotally positioned relative to said lift arm to increased or decreased digging attitude;

a hydraulic curl jack pivotally affixed at one end to said crowd arm and at the other end to said bucket whereby said bucket is pivotally positioned relative to said crowd arm increased or decreased digging attitude;

a source of hydraulic pressure carried by said tractor;

a lift valve controlling fluid communication between said pressure source and said lift jack;

a crowd valve controlling fluid communication between said pressure source and said crowd jack; and

a curl valve controlling fluid communication between said pressure source and said curl jack, the improvement comprising:

means responsive to overload pressure in said crowd jack for actuating said crowd valve to direct fluid under pressure to said curl jack to cause pivoting of said bucket to decreased digging attitude; and

means responsive to simultaneous overload pressure in said crowd jack and said curl jack for activating said lift valve to direct fluid under pressure to said lift jack to cause pivoting of said lift arm to decreased digging attitude.

18. A back hoe machine as claimed in claim **17**, having means for directing fluid under pressure to said crowd jack to cause outward pivoting of said crowd arm and means responsive to said pivoting movement of the crowd arm to direct fluid under pressure to said curl jack to cause pivoting of the bucket to maintain it in substantially level position.

19. A back hoe machine as claimed in claim **18** having means for sensing height of the lift arm and directing fluid under pressure to the lift cylinder if required to raise the lift arm to retract the bucket from the excavation.

20. In a back hoe for mounting on a tractor, said back hoe comprising:

a boom support base mounted for horizontal swinging movement on an end of the tractor;

a boom consisting of:

a lift arm having an end pivotally mounted for vertical swinging movement on the boom support base;

a crowd arm having an end pivotally mounted for vertical swinging movement on the other end of the lift arm; and

a bucket pivotally mounted for vertical swinging movement on the other end of the crowd arm;

a hydraulic lift jack extending between the lift arm and boom support base for raising and lowering the lift arm to decreased and increased digging attitudes, respectively,

a hydraulic crowd jack extending between the lift arm and crowd arm for pivotally positioning the crowd arm to increased and decreased digging attitude;

a hydraulic swing cylinder connected between the tractor and the boom support base for pivotally positioning said boom support base;

a hydraulic curl jack connected between the crowd arm and the bucket for pivotally positioning the bucket to increased and decreased digging attitude;

a source of hydraulic fluid under pressure associated with the back hoe;

a lift valve controlling flow of fluid under pressure to said lift jack;

a crowd valve controlling flow of fluid under pressure to said crowd jack; and

a curl valve controlling flow of fluid under pressure to said curl jack, the improvement comprising:

means for directing fluid under pressure to said crowd jack to cause outward pivoting of said crowd arm towards decreased digging attitude; and

means responsive to said pivoting movement of the crowd arm to direct fluid under pressure to said curl jack to cause pivoting of the bucket to maintain it in substantially level position.

21. In a back hoe as claimed in claim **20**, means for sensing height of the lift arm and directing fluid under pressure to the lift cylinder if required to raise the lift arm to retract the bucket from the excavation.

22. In a back hoe as claimed in claim **21**, means responsive to positioning of the lift arm and crowd arm so as to retract the bucket from the excavation for directing fluid under pressure to the swing cylinder to institute swing of the back hoe from above the excavation.

No references cited.

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