May 16, 1967 J. C. CHRISTENSON 3,319,816

TILT AND HOIST CONTROL MECHANISM FOR A LIFT TRUCK

Filed March 15, 1965 4 Sheets-Sheet 1

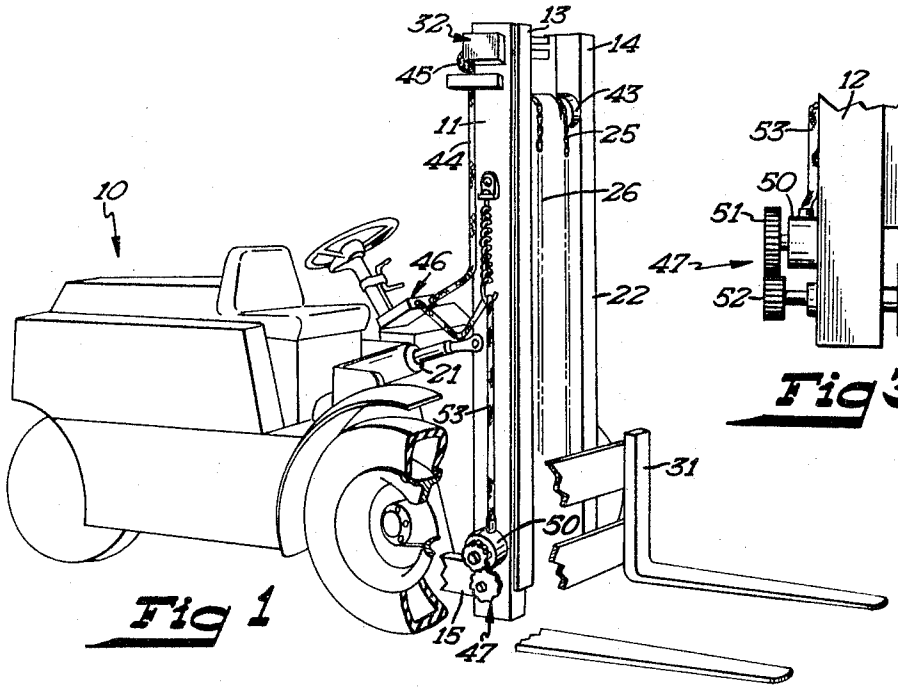


Fig 1

Fig 3

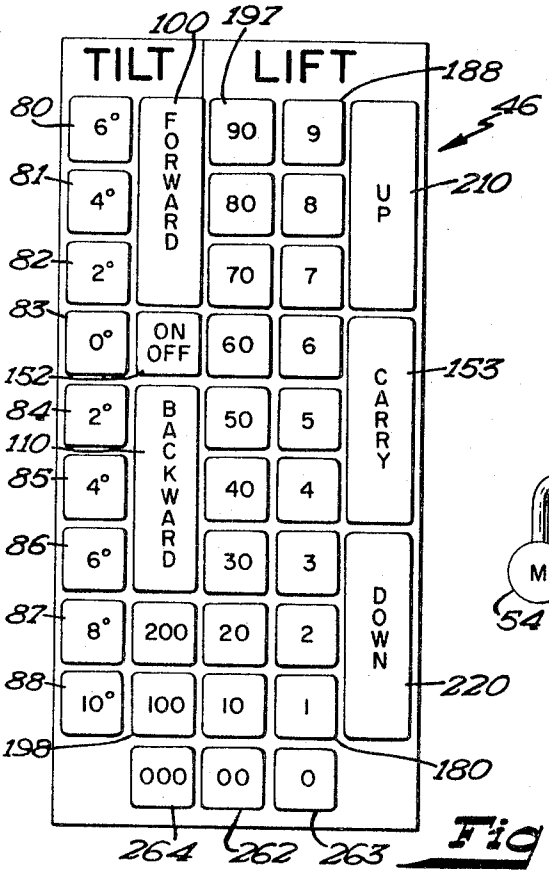


Fig 4

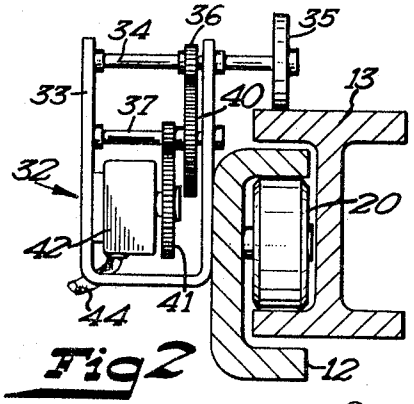


Fig 2

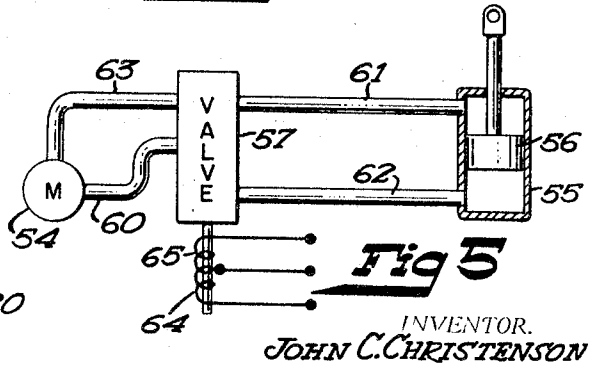


Fig 5

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TILT AND HOIST CONTROL MECHANISM FOR A LIFT TRUCK

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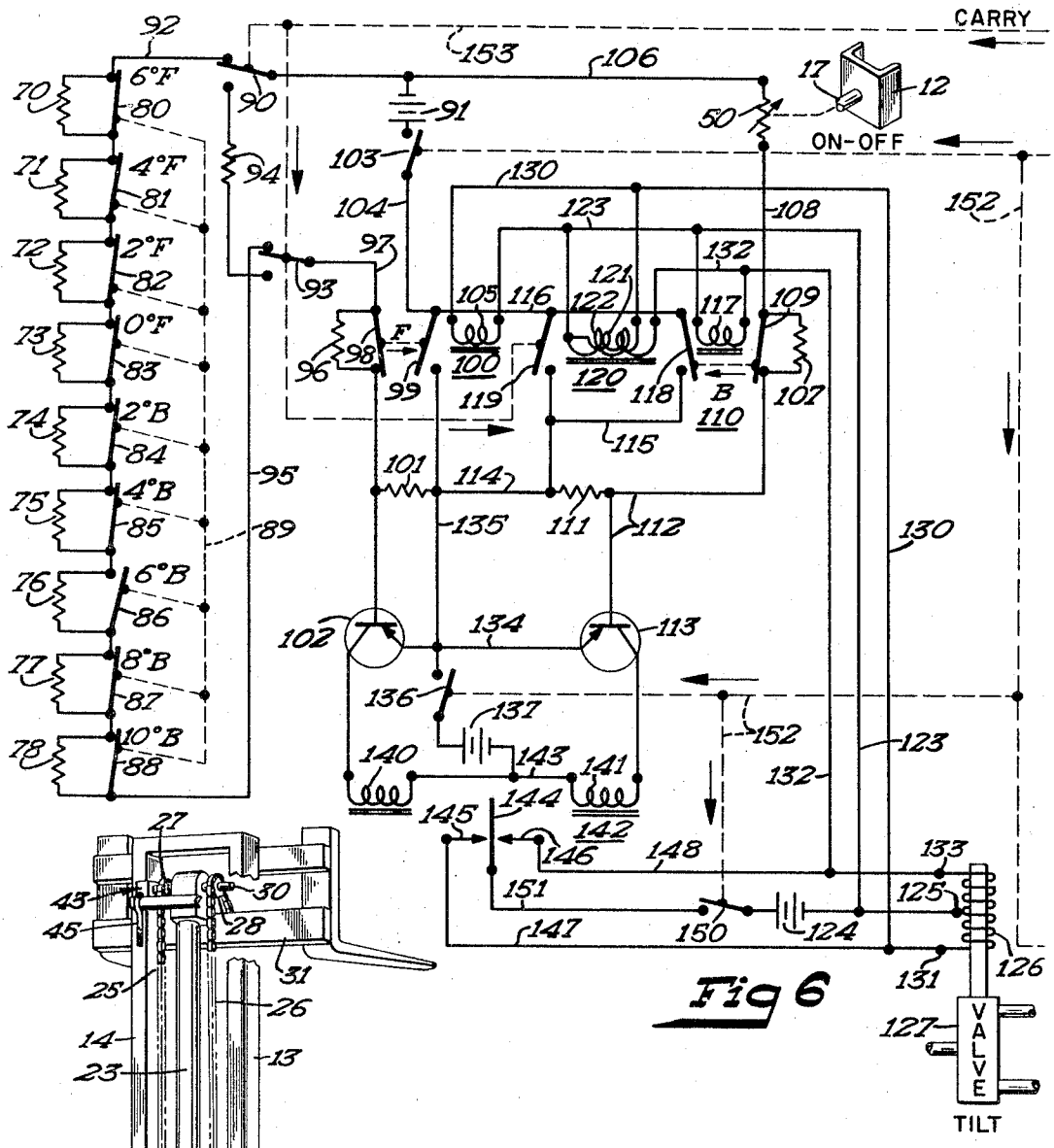


Fig 6

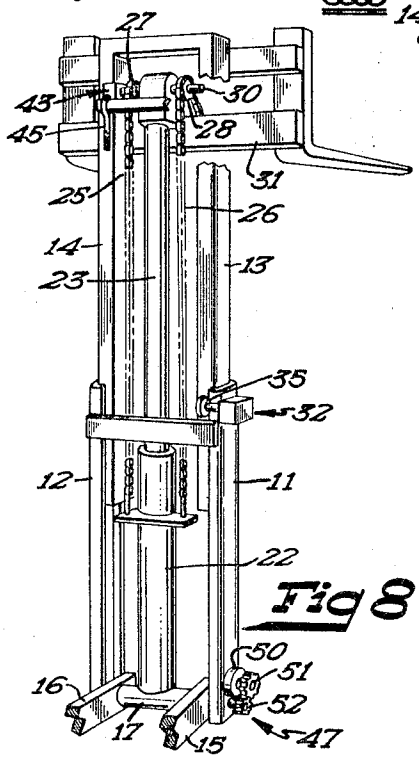


Fig 8

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TILT AND HOIST CONTROL MECHANISM FOR A LIFT TRUCK

Filed March 15, 1965 4 Sheets-Sheet 3

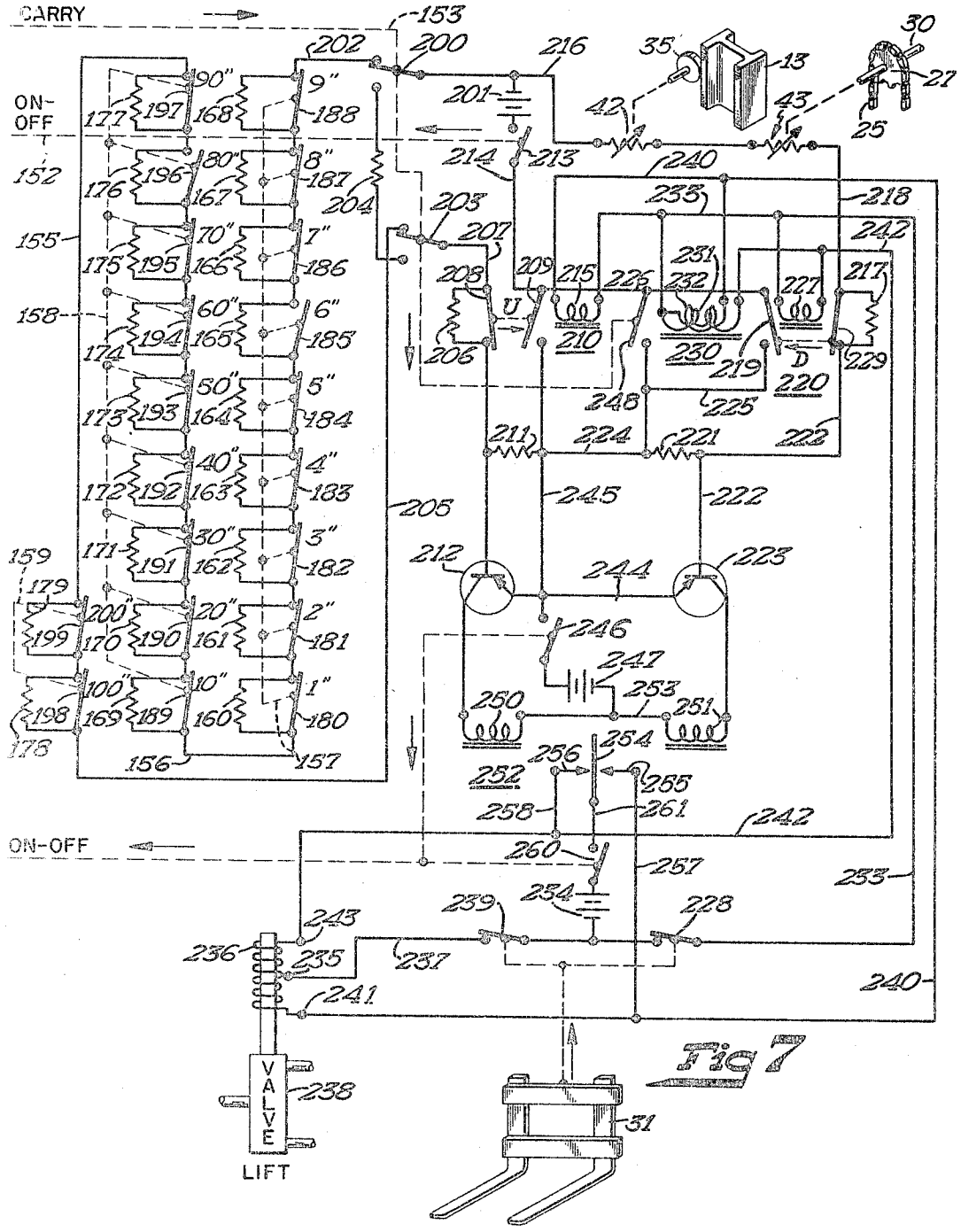


Fig 7

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TILT AND HOIST CONTROL MECHANISM FOR A LIFT TRUCK

Filed March 15, 1965 4 Sheets-Sheet 4

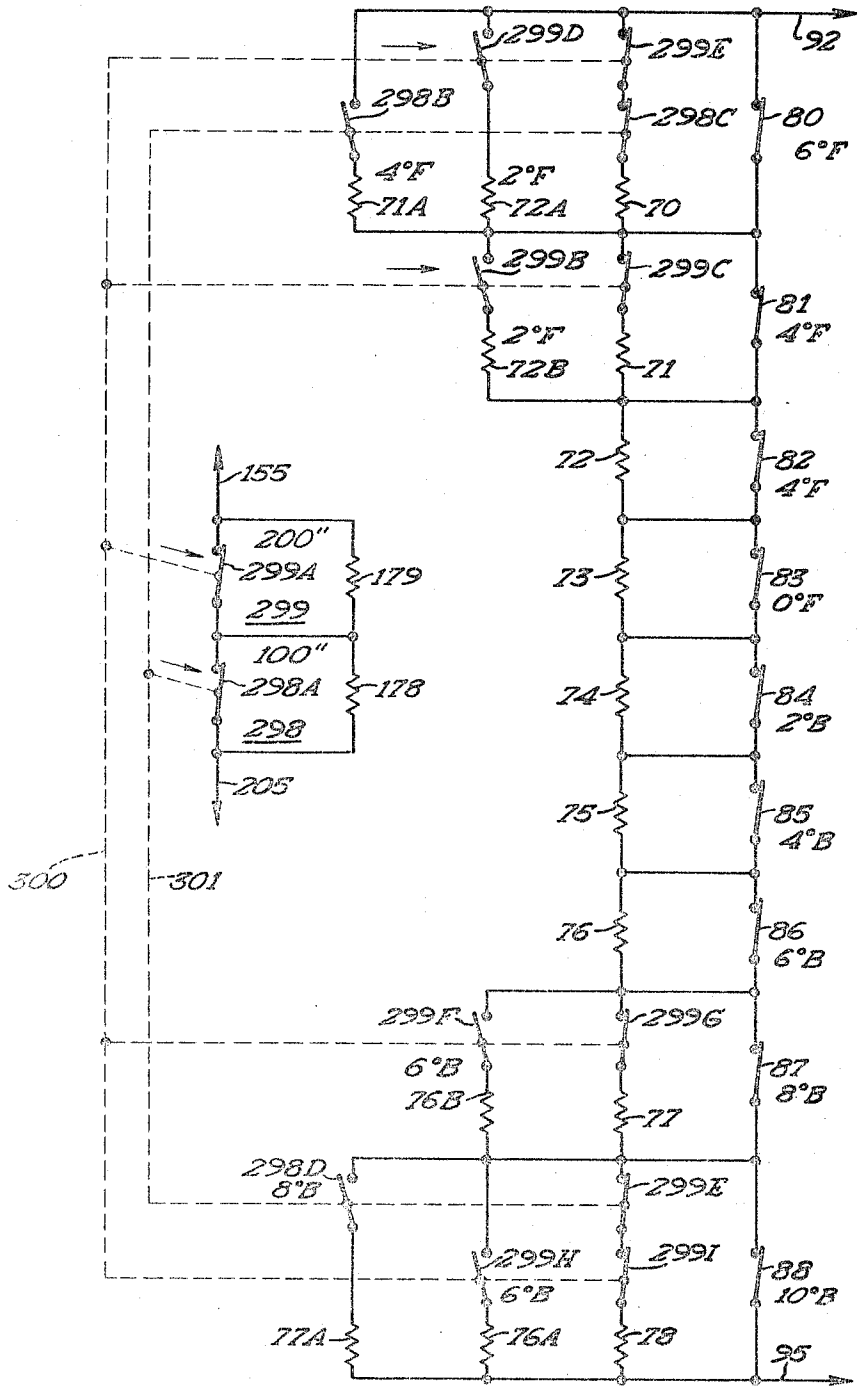


Fig 9

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United States Patent Office 3,319,816
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3,319,816

TILT AND HOIST CONTROL MECHANISM FOR A LIFT TRUCK

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Filed Mar. 15, 1965, Ser. No. 439,885
12 Claims. (Cl. 214—673)

This invention relates to the field of material handling equipment and more particularly to the field of automatic controls for controlling the upright members and fork assembly of a mobile fork lift.

It is common practice in the materials handling field to use mobile fork lifts for moving material units from one place to another by placing them upon a pallet and moving the pallet from one location to another. Moving the pallet from one location to another is generally accomplished by the use of a fork lift wherein the fork arms pass under the pallet, usually by driving the fork lift up to the pallet with the fork at its lowermost position, and then lifting the pallet for transfer to another location. While the pallet is being moved by the fork lift, the operator must then determine at what angle of tilt the upright members and fork assembly should assume as well as the height the fork assembly should be set for so that the pallet may be moved into and deposited in a bin or upon a stack. Thus, the operator must be performing several operations simultaneously in attempting to have the fork assembly and the pallet with its load thereon, positioned so as not to fall from the fork assembly and yet not waste additional time upon reaching a stack area or deposit area. All of these operations must take place while the operator is driving the fork lift from one location to another. Because the driver is generally concerned with controlling the fork lift into the stack by inching and steering, he cannot devote his full attention to the other requirements for movement of the fork assembly and thus must concentrate, generally, upon either the steering or the movement of the fork assembly with its pallet and load.

The present invention is directed to a means for providing automatic control of the upright structures or members both in elevation and tilt as well as control of the fork assembly handling the pallet. The invention makes use of the fact that an impedance bridge may be unbalanced and by using resistors to rebalance the bridge upon relative movement of the upright members and fork assembly, a predetermined height and tilt may be imparted to the fork assembly at the same time the driver is moving the pallet and its material units from one location to another. The signal provided from the bridge circuit is used to control and modulate the lift and tilt valves of the hydraulic circuit used in driving the tilt and lift hydraulic cylinders so that high speeds may be used with a high degree of safety in elevating and tilting the fork assembly with a pallet and its load thereon. The close observation of the handling of the pallet by the fork lift is obviated by the invention and the driver may concentrate upon the task of moving the fork lift from one location to another.

In operating the fork lift, the operator has to be conscious of the tilt angle applied to the upright members when the fork assembly and its load are at a certain elevation or higher. If the operator is not cautious about controlling the tilt at certain elevations, the fork lift may become unstable or unbalanced and thus the load could be dropped, causing harm not only to the operator but to the fork lift equipment and the surrounding area. Therefore, it is also desirable to regulate or limit the angle of tilt as a function of the elevation of the fork assembly and thus overcome the instability or unbalance

problem when stacking and retrieving material at, or above certain heights.

It is therefore a general object of the present invention to provide an improvement in means for controlling the operation of the fork assembly of a mobile fork lift.

It is another object of this invention to provide a means of driving a fork assembly to a predetermined elevational and tilt position.

A still further object of the present invention is to provide means for measuring the substantially vertical and rotational movement of the fork assembly.

It is yet another object of this invention to provide a means of controlling the position of the fork assembly during a critical period of stacking.

It is a further object of this invention to provide means to control the lift and tilt hydraulic valves to modulate the flow of hydraulic fluid to the lift and tilt cylinders of the fork lift.

It is yet another object of this invnetion to provide means to control the tilt mechanism as a function of the vertical position of the fork assembly and thus provide greater stability to the fork lift when the fork carriage is above a predetermined height.

It is still a further object of this invention to provide console control means for the operator of a fork lift to increase the safety of its operation.

These and other objects and advantages of my invention will more fully appear from the following description, made in connection with the accompanying drawings, wherein like reference characters refer to the same or similar parts throughout the several views, and in which:

FIG. 1 is a perspective view of a fork lift with a section broken away to show relative placement of the transducer thereon;

FIG. 2 is a plan view of the right hand upright members and transducer showing the means for measuring the relative movement between the upright members;

FIG. 3 is an illustrative diagram of the right hand upright member with a transducer affixed thereto for determining the tilt of the upright member with respect to the fork lift;

FIG. 4 is a plan view of the control panel or console;

FIG. 5 is a diagram of the hydraulic system for control of a lift or tilt cylinder;

FIG. 6 is a schematic diagram of the tilt control;

FIG. 7 is a schematic diagram of the lift control;

FIG. 8 is a diagrammatic representation of the upright members and fork assembly showing the relative placements of the transducers and their driving mechanisms; and

FIG. 9 is a schematic diagram of a modification of the tilt and lift circuits to provide greater stability to the fork lift when the fork carriage is above a predetermined height.

A mobile fork lift **10** is shown by way of illustration (FIG. 1) having a pair of upright channel members **11** and **12** which cooperate with a pair of I beams **13** and **14**, respectively. Upright channels **11** and **12** are rotatably secured to a pair of forwardly extending arms **15** and **16** by a shaft **17**. Upright members **12** and **13** are cooperatively guided by a number of rollers, such as roller **20** found in FIG. 2. The upright members are caused to tilt by a pair of hydraulic cylinders such as cylinder **21** which is located at the front of the fork lift **10** and is rotatably connected to member **11** in normal manner at a location sufficiently far enough above shaft **17** to provide a proper tilting motion to the upright members.

A lift cylinder **22** has an extendible piston **23** which is attached at its upper end to suitable mechanisms such as a bar **24** to cause a vertical movement of I beams **13** and **14** as it is extended.

To provide a compound lifting action, a pair of chains **25** and **26** are anchored to cylinder **22** and are passed over a pair of sprockets **27** and **28** which are rotatably supported by a shaft **30** at the uppermost end of piston **23**. The fork assembly **31** is connected to the other end of chains **25** and **26** to provide the uplifting action.

To measure the relative direction and distance of movement of upright members **13** and **14** with respect to members **11** and **12** respectively, a transducer **32** is secured to the upright member **12** by suitable means such as welding or by machine screws. Transducer **32** is shown using a U-shaped channel member **33** which has a shaft **34** journalled near its open end to provide rotation thereof. Situated on the end of shaft **34** is a friction wheel **35** which engages the rearward side of I beam **13**. In other words, wheel **35** is rotated by the movement of I beam **13** with respect to upright channel member **12**. A gear **36** is secured to shaft **34** to impart a rotational movement to another shaft **37** which is also journalled in U-shaped member **33** parallel to shaft **34** and has a compound gear **40** secured thereto which includes a gear wheel for engaging gear **36** and a pinion gear for engaging a gear **41**. Gear **41** is secured to the shaft of a variable resistor **42**. Thus as I beam **13** moves with respect to upright channel member **12**, the resistance of variable resistor **42** is changed.

A transducer **43**, similar to the transducer **32**, is secured to I beam **14**, and is rotatably connected to shaft **30** so that the relative movement of the fork assembly **31** with respect to I beams **13** and **14** may be detected and measured. The electrical connections to transducers **32** and **43** are made through a pair of cables **44** and **45** respectively where they are connected to a control console **46** that is located on the fork lift at a position easily accessible to the fork lift operator.

Another transducer **47** is formed from a variable resistance **50** which is secured to upright channel member **12**. The shaft of variable resistor **50** is secured to a gear **51** which engages a gear **52** that is secured to the shaft **15** by suitable means such as a machine screw or is secured to a reduced portion of shaft **17**. As upright member **12** is rotated about shaft **17** by the tilt cylinders, gear **51** is rotated with respect to **52** and thus the resistance of the variable resistor **50** is changed in accordance with such movement. An electrical cable **53** is used to connect the variable resistor **50** of transducer **47** to control console **46**.

The hydraulic control system is essentially the same for the lift portion of the fork assembly as that for controlling the tilt of the fork assembly. The hydraulic motor **54** (FIG. 5) supplies hydraulic fluid to a cylinder **55** having a piston **56** therein through a solenoid operated control valve **57**. A hydraulic line **60** from motor **54** is connected to solenoid control valve **57** at its central delivery point and a pair of hydraulic lines **61** and **62** connect control valve **57** to cylinder **55**. A return line **63** connects control valve **57** to motor **54**. Valve **57** is a conventional hydraulic control valve employing a solenoid operator **64** which will be more fully explained later. Of course the control valve **57** directs the hydraulic fluid either above or below piston **56** in proportion to the magnitude of the current flowing through a coil **65** of the solenoid operator **64** and in the proper direction depending upon the position of the double ended spool contained within the valve body controlled by the coil. It will also be recognized that the lift cylinder may use a single ended spool if desired. Valve **57** may use the "center off" spring driving arrangement so that when there is no current in the solenoid operator, valve **57** remains at a neutral point and the hydraulic fluid from motor **54** is merely circulated through valve **57** and back to pump **54** without any movement imparted to piston **56**. Diagrammatically cylinder **55** is used to represent the tilt cylinder **21** or a pair of cylinders if required and cylinder **22** for creating the lift to the fork assembly.

The control circuit for producing the cooperative tilting and elevating or lifting action is shown in FIGS. 6 and 7 where FIG. 6 is directed to the tilt portion of the control circuit and FIG. 7 is directed to the lift portion. Beginning with FIG. 6, there will be found nine fixed resistances, **70** through **78**, all of which are connected in series with each other. Connected in parallel with each resistance **70** through **78** are nine switches, **80** through **88** respectively. The normal position of the switch arms of switches **80** through **88** is such that the resistances **70** through **78** respectively are shorted out of the electrical circuit so that the electrical circuit would have a theoretical value of zero resistance. When the resistances **70** through **78** are added to a bridge circuit yet to be described, they will produce tilt of the fork asasembly in two-degree increments from 6° forward to 10° backward respectively. In other words, when switch **80** is open, resistance **70** produces 6° of forward tilt and in like manner when switch **88** is open, resistance **78** produces 10° of backward tilt. In some cases the value of the resistances **70** through **78** may be chosen to produce a tilt of more or less than the 2° set forth. Switches **80** through **88** are mechanically linked together by an arm **89** so that only one switch may be open at any time and depressing another switch button automatically closes the one which is open.

A single pole double throw switch **90** has its common terminal connected to the negative terminal of a battery **91**. Of course battery **91** may be any source of unidirectional voltage. Switch **90** has its normally closed terminal connected to the unconnected end of resistor **70** through a conductor **92** and the normally open terminal of switch **90** is connected to a normally open terminal of a single pole double throw switch **93** through a resistor **94**. Resistor **94** is pre-selected to produce 4° of backward tilt to the upright members of the fork lift and further explanation of the purpose of this resistor will be described later. The normally closed terminal of switch **93** is connected to the unconnected end of resistor **78** through a conductor **95**. The common terminal of switch **93** is connected to a resistor **96** through a conductor **97**. Resistor **96** serves a particular purpose in the circuit by in effect creating a slight unbalanced condition to insure that the bridge is completely balanced at the time the output signal is of zero voltage. This will also be further described later.

A latching switch **100** has an armature **98** connected to one end of a resistor **96** and a normally closed terminal connected to one end of a resistor **101** and to the base element of a transistor **102**. The other end of resistor **101** is connected to a normally open terminal of latching switch **100** and a second armature **99** which is ganged to armature **98** and is connected to a single pole single throw switch **103** through a conductor **104**. The other terminal of switch **103** is connected to the positive terminal of battery **91**. As thus far described, resistor **101** appears in one leg of the tilt control bridge and resistors **70** through **78** may be applied in another leg of the bridge where resistor **94** may be substituted for resistors **70** through **78** and resistor **96** may be added in series with either of the legs just described using resistors **70** through **78** or **94** depending upon the position of switches **90** and **93**. The voltage across the two legs of course is applied by battery **91** when the appropriate switches are closed.

Latching switch **100** is designated the FORWARD switch or control button and when it is desirable to create a forward tilt, latching switch **100** is depressed (armatures **98** and **99** move in the direction of the arrow marked F) and will remain latched until the current flowing through a coil **105** thereof reaches a zero value at which time the contacts will return to their normal position as shown in FIG. 6. In other words, the latching switch remains engaged as long as current flows through coil **105** to keep it "pulled in" and upon losing the current, the armatures of the latching switch snap back to the position shown

(which may be by way of a spring or other suitable means, not shown).

Variable resistor 50 has one terminal connected to the negative terminal of battery 91 through a conductor 106 and has its other terminal connected to one terminal of a resistor 107 through a conductor 108. Resistor 107 serves the same purpose as resistor 96 when a backward tilt is desired for the carriage assembly and this is produced by actuating a latching switch 110 like latching switch 100 which is designated BACKWARD. Latching switch 110 has an armature 109 connected to conductor 108 and a normally closed terminal connected to the other end of resistor 107 and to one end of another resistor 111 through a conductor 112. Conductor 112 also connects the normally closed terminal of latching switch 110 to the base element of a transistor 113. The other end of resistor 111 is connected to the normally open terminal of latching switch 100 through a conductor 114 and is also connected to a normally open terminal of latching switch 110 through a conductor 115. An armature 118 of latching switch 110 which engages the normally open contact, is electrically connected to armature 99 of latching switch 100 through a conductor 116 which is also connected to conductor 104. A coil 117 of latching switch 110 keeps armatures 109 and 118 (which are ganged together) of BACKWARD switch 110 in the position other than that shown in FIG. 6 (armatures 109 and 118 move in the direction of the arrow marked B) while current is flowing therethrough and upon current ceasing to flow in coil 117 the armatures are allowed to "drop out."

Another latching switch 120 has a pair of coils 121 and 122 with one terminal of each connected together which in turn is connected to one terminal of coil 105 and one terminal of coil 117 through a common conductor 123. The other end of conductor 123 is connected to a negative terminal of a battery 124 and to a common or center terminal 125 of a solenoid coil 126, which with its plunger forms a solenoid relay to control a hydraulic valve 127 used to control the tilt action of the upright members and fork assembly. An armature 119 of latching switch 120 is connected to conductor 116 and the normally open terminal is connected to conductors 115 and 114. The other terminal of coil 121 is connected to the other terminal of coil 105 through a conductor 130 which is in turn connected to a terminal 131 of solenoid coil 126. The other end of coil 122 is connected to the other end of coil 117 through a conductor 132 which in turn is connected to a terminal 133 of solenoid coil 126.

The emitters of transistors 102 and 113 are connected to each other by a common conductor 134 and are further connected to conductor 114 through a conductor 135. The emitters, through conductor 134 are connected to a terminal of a single pole single throw switch 136 and the other switch terminal is connected to the positive terminal of a battery 137. The collector elements of transistors 102 and 113 are each connected to one end of a pair of coils 140 and 141 respectively of a relay 142. The other ends of coils 140 and 141 are connected to each other by a common conductor 143 which is also connected to the negative terminal of battery 137. An armature 144 of relay 142 is actuated by the energization of either coils 140 or 141 and thus makes contact with one of a pair of contacts 145 and 146. Contact 145 is connected to terminal 131 of coil 126 through a conductor 147 and contact 146 is connected to terminal 133 of coil 126 through a conductor 148. The positive terminal of battery 124 is connected to a single pole single throw switch 150 and has its other terminal connected to armature 144 of relay 142 through a conductor 151.

Switches 103, 136, and 150 are all connected together by suitable mechanical linkages and are of the type that upon pressing an ON-OFF switch button 152, the switches just mentioned are all either opened or closed.

In addition thereto, switches 90, 93, and latching switch 120 are mechanically linked to each other so that they are all in their normally opened or closed positions at the same time. These switches are actuated into their latched position by a control button 153 designated CARRY.

Referring now to FIG. 7, the lift portion of the control will be found where twenty fixed resistances, 160 through 179 are connected in series with each other. Connected in parallel with each resistance 160 through 179 are twenty switches, 180 through 199 respectively. The switches are arranged in three columns, with switches 180 through 188 being in the "units" column, switches 189 through 197 being in the "tens" column and switches 198 and 199 being in the "hundreds" column. Switch 180 is electrically connected in series with switch 160 by a conductor 156 and the opposite end of the series circuit is completed by connecting switch 197 to 199 through a conductor 155. The normal position of the switch arms of switches 180 through 199 is such that the resistances 160 through 179, respectively, are shorted out of the electrical circuit so that the electrical circuit would have a theoretical value of zero resistance. When the resistances 160 through 179 are added to the bridge circuit yet to be described, they will produce vertical movement or lift of the fork assembly in one inch increments from one inch to 299 inches above the level of the fork lift position on the ground or floor. In other words, when switch 185 is open, resistance 165 produces six inches of vertical lift above the floor and in like manner when switch 196 is open, resistance 176 produces an additional 80 inches of lift to provide a total lift of 86 inches. Furthermore, switches 180 through 188 are mechanically linked by an arm 157 in the same manner as switches 80 through 88 described previously, switches 189 through 197 are mechanically linked by an arm 158 in like manner as are switches 198 and 199 which are mechanically linked by an arm 159.

A single pole double throw switch 200 has its common terminal connected to the negative terminal of a battery 201. Battery 201 may be any source of unidirectional voltage or direct current. Switch 200 has its normally closed terminal connected to the unconnected end of resistor 168 through a conductor 202 and the normally open terminal of switch 200 is connected to a normally open terminal of a single pole double throw switch 203 through a resistor 204. Resistor 204 is preselected to produce 12 inches of upward lift to the upright members of the fork lift and further explanation of this resistor and its purpose will be made later. The normally closed terminal of switch 203 is connected to the unconnected end of resistor 178 through a conductor 205. The common terminal of switch 203 is connected to resistor 206 through a conductor 207. Resistor 206 serves a particular purpose in the circuit by in effect creating a slight unbalanced condition to insure that the bridge is completely balanced at the time the output signal is of zero voltage. This will also be explained in greater detail later.

A latching switch 210 has an armature 208 connected to one end of resistor 206 and a normally closed terminal connected to one end of a resistor 211 and to the base element of a transistor 212. The other end of resistor 211 is connected to a normally open terminal of latching switch 210 and a second armature 209 which is ganged to armature 208 and is connected to a single pole single throw switch 213 through a conductor 214. The other terminal of switch 213 is connected to the positive terminal of battery 201. As thus far described, resistor 211 appears in one leg of the lift control bridge and resistors 160 through 179 may be applied to another leg of the bridge where resistor 204 may be substituted for resistors 160 through 179 and resistor 206 may be added in series with either of the legs just described using resistors 160 through 179 or 204 depending upon the position of switches 200 and 203. Thus the resistances with their accompanying switches in both bridge circuits form controllable impedances when used in the bridge circuits. The voltage across the two legs of the lift

bridge is applied by battery **201** when the appropriate switches are closed.

Latching switch **210** is designated the UP switch or control button and when it is desirable to create an upward lifting motion, latching switch **210** is depressed (armatures **208** and **209** move in the direction of the arrow marked U) and will remain latched until the current flowing through a coil **215** thereof reaches the zero value at which time the contacts will return to their normal position as shown in FIG. 7. In other words, the latching switch remains engaged as long as current flows through coil **215** to keep it "pulled in" and upon losing the current, the armatures of the latching switch snap back to the position shown (which may be by way of a spring or other suitable means, not shown).

Variable resistor **42** has one terminal connected to the negative terminal of battery **201** through a conductor **216** and has its other terminal connected to one terminal of variable resistor **43**. The other terminal of variable resistor **43** is connected to one terminal of a resistor **217** through a conductor **118**. Resistor **217** serves the same purpose as resistor **206** when a downward lifting motion is desired for the carriage assembly and this is produced by actuating a latching switch **220** like latching switch **210** which is designated DOWN. Latching switch **220** has an armature **229** connected to conductor **218** and a normally closed terminal connected to the other end of resistor **217** and to one end of another resistor **221** through a conductor **222**. Conductor **222** also connects the normally closed terminal of latching switch **220** to the base element of a transistor **223**. The other end of resistor **221** is connected to the normally open terminal of latching switch **210** through a conductor **224** and is also connected to the normally open terminal of latching switch **220** through a conductor **225**. An armature **219** of latching switch **220** which engages the normally open contact, is connected electrically to armature **209** of latching switch **210** through a conductor **226** which is also connected to conductor **214**. A coil **227** of latching switch **220** keeps armatures **219** and **229** (which are ganged together) of DOWN switch **220** in the position other than that shown in FIG. 7 (armatures **219** and **229** move in the direction of the arrow marked D) while current is flowing therethrough and upon current ceasing to flow in coil **227**, the armatures are allowed to "drop out."

Another latching switch **230** has a pair of coils **231** and **232** with one terminal of each connected together which in turn is connected to one terminal of coil **215** and one terminal of coil **227** through a common conductor **233**. The other end of conductor **233** is connected to one terminal of a single pole single throw switch **228**. The other terminal of switch **228** is connected to a negative terminal of a battery **234** and to one terminal of a single pole single throw switch **239**. The other terminal of switch **239** is connected to a common or central terminal **235** of a solenoid coil **236** by a conductor **237**. Solenoid coil **236** and its plunger forms a solenoid relay to control a hydraulic valve **238** which is used to control the lifting action of the fork assembly. An armature **248** of latching switch **230** is connected to conductor **226** and the normally open terminal is connected to conductors **225** and **224**. The other terminal of coil **231** is connected to the other terminal of coil **215** through a conductor **240** which is also connected to a terminal **241** of solenoid coil **236**. The other end of coil **232** is connected to the other end of coil **227** through a conductor **242** which is further connected to a terminal **243** of solenoid coil **236**.

The emitters of transistors **212** and **223** are connected to each other by a common conductor **244** and are further connected to conductor **224** through a conductor **245**. The emitters, through conductor **244** are connected to a terminal of a single pole single throw switch **246** and the other switch terminal is connected to the positive terminal of a battery **247**. The collector elements of transistor **212** and **223** are each connected to one end of a pair of coils **250** and **251**, respectively, of a relay **252**. The other ends of coils **250** and **251** are connected to each other by a common conductor **53** which is also connected to the negative terminal of battery **247**. An armature **254** of relay **252** is actuated by the energization of either coils **250** or **251** and thus makes contact with one of a pair of contacts **255** and **256**. Contact **255** is connected to terminal **241** of coil **236** through a conductor **257** and contact **256** is connected to terminal **243** of coil **236** through a conductor **258**. The positive terminal of battery **234** is connected to a single pole single throw switch **260** and has its other terminal connected to armature **254** of relay **252** through a conductor **261**.

Switches **228** and **239** have their switch arms connected or ganged together through a suitable mechanical linkage or are constructed and arranged in such a manner to be actuated simultaneously by the movement of fork assembly **31** when the fork assembly moves to the top of I beams **13** and **14** thus acting as limit switches. As will be described later, in certain instances, should the particular control be used with a fork lift which does not have the particular extension necessary to provide the height required by the unbalance of the bridge circuit, the limit switches **228** and **239** will prevent any damage to the fork assembly **31**.

Switches **213**, **246**, and **260** are all connected together by suitable mechanical linkages and are of the type that upon pressing of ON-OFF switch button **152**, the switches just mentioned are either opened or closed in the same manner as switches **103**, **136**, and **150** of the tilt control circuit.

In addition thereto, switches **200**, **203**, and latching switch **230** are mechanically linked to each other so that they are all in their normally opened or closed positions at the same time and they are actuated into their latched positions by the CARRY control button **153** as are switches **90**, **93** and latching switch **120** of the tilt control circuit, and if desired, switches **200**, **203**, **230**, **90**, **93** and **120** may be a six-pole, double throw switch.

FIG. 9 shows an improvement to control the stability of the fork assembly when the fork assembly is to be raised over 100 inches from the floor. This is accomplished by limiting the amount of unbalance attainable in the tilt bridge circuit and thus limit the angle of tilt. A switch **298** is substituted for switch **198**, which may be a five pole single throw switch and is shown using five switches **298A**, **298B**, **298C**, **298D**, and **298E**. Resistor **178** is the same resistor **178** found in the circuit shown in FIG. 7.

A switch **299** is substituted for switch **199** and may be a nine pole single throw switch. Switch **299** is shown using nine switches **299A**, **299B**, **299C**, **299D**, **299E**, **299F**, **299G**, **299H** and **299I**. Resistor **179** is the same resistor **179** found in the circuit in FIG. 7.

The object of using switch **298** is to control the amount of tilt between vertical lift positions of 100 inches and 199 inches and switch **299** is used to control the amount of tilt available while the fork assembly is at an elevation between 200 inches and 299 inches above the floor. As shown, all of the switch arms of switch **299** are connected by a common linkage **300** and switch **298** has all of its switch contacts connected together by a linkage **301**, so that all of the contacts of each switch are opened or closed simultaneously. Resistances **72** through **76** are retained in their same operative manner and values as are switches **82** through **86** to provide 2° forward tilt through 6° backward tilt respectively.

Resistor **71** is connected in series with switch **299C**, the combination being in parallel with switch **81** and in like manner, a resistor **72B** is connected in series with switch **299B**, the combination also being in parallel with switch **81**. Switch **299C** is normally closed and switch **299B** is normally open. Resistance **72B** is of the same value as

resistance 72, in other words when switched into the bridge circuit, resistance 72B will produce 2° of forward tilt when resistance 71 is electrically disconnected from the circuit by switch 299C.

In like manner, resistance 70 is connected in series with switch 298C and switch 299E, the combination being connected in parallel with switch 80. Switches 299E and 298C are normally closed. Another resistance 72A is connected in series with switch 299D, the combination being connected in parallel with switch 80. Resistance 72A is of the same value as resistor 72, thus providing 2° of forward tilt when that is the only resistance connected into the bridge circuit. A resistor 71A is connected in series with switch 298B and the combination is also connected in parallel with switch 80. Switches 298B and 299D are normally open and resistance 71A is of the same value as resistance 71, thus producing 4° of forward tilt when that is the only resistance applied to the bridge circuit.

In similar manner, resistance 77 is connected in series with switch 299G, the combination being in parallel with switch 87. Resistor 77 is of the same value as resistor 77 found in FIG. 6 and switch 299G is normally closed. Another resistor 76B is connected in series with switch 299F which is normally open, the combination being connected in parallel with switch 87. Resistance 76*b* is of the same value as resistor 76 thus producing 6° backward tilt when only that resistor is in the bridge circuit.

In similar manner, resistance 78 is connected in series with switch 299I and 298E both of which are normally closed, the combination being connected in parallel with switch 88. Resistor 78 is of the same value as resistor 78 in FIG. 6. Another resistor 76A is connected in series with switch 299H, the combination also being connected in parallel with switch 88. Resistor 76A is of the same value as resistor 76 thus producing 6° of backward tilt when only that resistance is added to the bridge circuit. Another resistor 77A is connected in series with switch 298D, the combination also being connected in parallel with switch 88. Resistor 77A is of the same value as resistor 77 thus producing 8° of backward tilt when only that resistance is added in the bridge circuit. Switches 298D and 299H are normally open.

Thus it will be seen that whenever switch 298 is actuated, resistance 178 is added to the lift bridge circuit to produce 100 inches of lift and upon so doing, it will be seen that if the tilt has been set for 10° of backward tilt, in other words, with switch 88 open, resistor 78 cannot be added to the bridge circuit because switch 298E would open the circuit, switch 299H remains open, and switch 298D upon closing, would thus add resistor 77A to the circuit, producing 8° of backward tilt rather than the usual 10° of backward tilt.

Should switch 80 have been opened, normally producing 6° of forward tilt, it will be seen that switch 298C will be opened thus removing resistor 70 from the circuit and because switch 299D is also open, resistor 72A has no effect on the circuit but resistor 71A is added in parallel with switch 80 because switch 298B completes the circuit thus providing 4° of forward tilt rather than the usual 6°.

In a similar manner, when switches 299 and 81 are actuated to place resistor 179 in the bridge circuit and thus provide at least 200 inches of vertical lift and normally produce 4° of forward tilt, switch 299B will be closed and switch 299C will be opened, providing 2° forward tilt in place of the 4° forward tilt provided when switch 81 is depressed. In the event the 6° forward tilt switch 80 is opened, switch 299D will be closed, switch 298B remains open, and switch 299E will be opened, thus adding resistor 72A to the bridge circuit and producing 2° of forward tilt rather than the usual 6°. In a similar manner, if the 8° backward tilt switch 87 is actuated, switch 299F will be closed and switch 299G will be opened, thus adding resistor 76B to the bridge circuit and providing 6° of backward tilt. In the event switch 88 is opened to provide 10° of backward tilt, it will be seen that switch 299H will be closed, switch 298D remains open, and switch 299I will be opened thus again adding resistor 76A to the bridge circuit and providing only 6° of backward tilt instead of the normal 10°. In other words, for operations requiring over 100 inches of vertical height, tilt of only 4° forward and 8° backward can be obtained and where the vertical lift of the fork assembly is at least 200 inches or higher, there can be no greater tilt than 2° forward and 6° backward.

Operation

To set the control system in operation, the driver depresses the ON-OFF switch which operates or closes switches 103, 213, 136, 150, 246 and 260. Upon the closing of these switches, power is made available to both the tilt and lift control bridge circuits. However, because switch arms 99 and 209 as well as the switch arm for latching switch 120 and 230 remain open, no current flows in the bridge and therefore, relays 142 and 252 remain unenergized and solenoid coils 126 and 236 are unenergized and thus valves 127 and 238 are uneffected.

The operator next depresses the CARRY switch button 153 and upon so doing, switches 90, 93, 200, 203, 120 and 230 are temporarily actuated into engagement with the contacts other than those shown being engaged in FIGS. 6 and 7. Switches 90 and 93 place resistor 94 in one leg of the bridge circuit. Resistor 94 produces unbalance in the tilt bridge circuit equal to 4° of backward tilt. Because variable resistor 50 would generally be at a position representative of 0° tilt because of the first action taken in driving the forks under the pallet, the resistance in the leg of the bridge circuit containing variable resistor 50 will be higher than that containing resistor 94 and because resistors 101 and 111 are of equal value, current will flow in the bridge circuit causing transistor 113 to conduct current and act as an amplifier. Upon current flowing through transistor 113, current passes through coil 141 of relay 142 thus attracting armature 144 to engage contact 146 and complete the circuit through terminals 133 and 125 of solenoid coil 126 to operate the solenoid tilt control valve 127 causing the oil from the hydraulic pump 54 to engage the piston in cylinder 21 (or an additional cylinder if required) and produce the rearward tilting action. Because relay armature 144 was energized into engagement with contact 146, power is also applied to holding coil 122 through conductors 123 and 132 thus keeping switches 90, 93 and the armature of latching switch 120 in engagement. While coil 117 also has current applied thereto, as long as backward switch 110 is not depressed by the operator, armatures 109 and 118 remain uneffected. As the upright members and the fork assembly 31 move towards the rearward tilt position of 4°, variable resistor 50 changes its resistance until the resistance of variable resistor 50 equals that of resistor 94 at which time there is no current flow through the bridge and consequently no current flows through transistor 113. Since there is no current flow through transistor 113, the magnetic field in coil 141 collapses and allows armature 144 to disengage contact 146 thereby breaking the circuit to coil 126 causing the solenoid tilt valve 127 to return to its neutral position and thus keep the fork assembly 31 and the upright members at a 4° backward tilt position. The field in the holding coil 122 of latching switch 120 also collapses and thus releases switches 90 and 93 along with the armature of latching switch 120, allowing them to return to the position shown in FIG. 6.

Coincidentally with the operation of the tilt bridge control circuit, switches 200 and 203 of the lift bridge control circuit, switch resistor 204 into the bridge control circuit. Resistor 204 was picked to produce 12 inches of vertical lift unbalance in the bridge circuit when variable resistors 42 and 43 sense that the position of the fork assembly 31 is at ground level since resistors 211

and 221 are of equal value. It should be remembered that variable resistors 42 and 43 sense the position of the I beam members 13 and 14 with respect to upright members 11 and 12 and the position of the fork assembly 31 to I beam members 13 and 14 respectively. As the forks start at the floor level to pick up the pallet load, there is more resistance in resistor 204 than in the other leg of the bridge containing variable resistors 42 and 43 and therefore current flows to the base of transistor 212 and causes current to flow through coil 250 of relay 252. Upon coil 250 being energized, armature 254 engages contact 256 thus applying power to coil 236 of the solenoid control valve 238 to initiate a lifting action. Because coil 232 of latching switch 230 is also energized by means of conductors 233 and 242, latching switch 230 and switches 200 and 203 remain in the latched position. As the fork assembly rises, the combined resistance of variable resistors 42 and 43 increases until their resistance equals the resistance of fixed resistor 204 at which time current ceases to flow to transistor 212 thus causing a collapse of the magnetic field in coil 250 and allowing armature 254 to disengage contact 256 and thus de-energize coil 236. The solenoid valve 238 thus returns to its neutral position and the fork assembly 31 remains stopped at a position 12 inches above the floor. Because the current ceases to flow in coil 232, the latching function ceases and switches 200 and 203 as well as the armature of latching switch 230 return to their normal position as shown in FIG. 7. It will be observed that at this point, the load on the fork assembly is supported on the forks approximately 12 inches above the ground and at about a 4° backward tilt of the upright members.

The driver or operator at this point proceeds to transport the load to the stacking location and determines the desired lift and tilt positions of the fork assembly for depositing the load in a stack. As an example, assume the load is to be placed on a rack 86 inches above the floor. The operator then selects the 0° button 83 on the tilt panel 46 and depresses switch 196 representing 80 inches of lift and instead of depressing switch button 185 representing 6 inches of lift, the operator would most likely select a height several inches higher such as switch 188 representing 9 inches of lift. The additional height is required to insure that the pellets clear the stack while being driven into the bin. Depressing switch buttons 83, 196, and 188, place their respective resistances 73, 176, and 168 in the bridge circuits to produce an unbalance representative of the heights and tilt desired.

As the operator approaches the stacks, he depresses the latching switch 100 marked FORWARD and in so doing, armature 98 disengages the normally closed terminal and places resistor 96 in the circuit with resistor 73 and because there is a bridge unbalance such as that described previously, transistor 102 is caused to conduct and energize coil 140 causing armature 144 to engage contact 145, and thus cause the tilt control valve 127 to move the upright members and fork assembly back towards the 0° tilt position at which time current passing through coil 105 goes to a 0° value because the bridge becomes balanced and current stops flowing in coil 140 thus allowing armatures 99 and 98 to assume their normal position as shown in FIG. 6. Resistor 96 is picked to produce an unbalance in the bridge circuit and cause current flow therein equal to the "drop out" current of relay 142.

The operator now operates switch 210 by depressing the UP button and upon doing so, armature 208 disengages its normally closed contact and places resistor 206 in the bridge leg in series with resistors 168 and 176. At the same time, armature 209 engages the normally open terminal and applies voltage to the bridge circuit. The unbalance of the bridge circuit causes transistor 212 to again be actuated and work in the manner described just previously while causing the fork assembly to rise 12 inches above the floor for the CARRY operation. While the fork assembly is raising, the driver may then steer the truck into the stack and needs no control over the upright but may concentrate on inching and steering the fork lift.

Once the fork assembly is inside the bin, the driver or operator pushes the 6-inch button or the 7- or 8-inch button, depending upon the size of the material forming the pallet and makes the deposit in the stack. The operator then backs the fork lift away from the stack. It will of course be understood that operation of the BACKWARD button 110 and DOWN button 220 produces a similar operation in the bridge circuit.

The operator then pushes the CARRY button 153 which again returns the fork assembly to the 12 inch height and 4° of backward tilt while the fork lift is returning to pick up another load. As the operator approaches the load, he depresses the 0° tilt button, the FORWARD button, and a pair of switch buttons 262 designated "00" and 263 designated "0," respectively. Should the fork assembly 31 have been at a location above 100 inches, another push button 264 designated "000" would also be actuated. In so doing, switches 262, 263, and 264 are mechanically linked to the other switches in each column as found on control panel 46 so that they mechanically disengage the other switches and short out all of the resistors associated with the switches in the bridge circuit legs. The operator then presses the DOWN button which places the fork assembly at the ground level for entry under the next pallet. To shut the entire system off, the driver engages the ON-OFF button again which mechanically re-releases switches 103, 213, 136, 150, 246 and 260 thus removing all power from the control system.

Switches 239 and 228 serve to limit the vertical travel of the fork assembly 31 as explained previously should the operator attempt to cause the fork assembly 31 to be raised above physical limits of the upright members. If desirable, limit switches may be employed in the tilt circuit to limit the angle through which the vertical upright members are moved.

During the operation of moving the fork assembly upwardly when the circuit is used to limit the angle of tilt, any time switch 298 or 299 is depressed indicating that the fork assembly and its load will be raised at least 100 inches or 200 inches, the angle of tilt would be restricted automatically. Thus the operator does not have to be concerned with raising the load to a height which will cause instability due to the position of tilt of the fork assembly. Since the critical angle of tilt will most likely vary for different fork lifts, the angles described herein are only illustrative and may be varied to suit the needs of the individual fork lift.

From the foregoing description it will be seen that I have provided a control system for automatically controlling the position of a fork lift fork assembly both in elevation and tilt. The control device may be used upon any fork lift to control the movement of the fork assembly independent of the steering operation by the driver and thus the driver or operator is free to devote his time to properly drive the fork lift.

It will, of course, be understood that various changes may be made in the form, details, arrangement and proportions of the parts without departing from the scope of my invention which consists of the matter shown and described herein and set forth in the appended claims.

I claim:

1. Apparatus for use with a mobile fork lift having upright members guiding a fork assembly in substantially vertical and rotational movement, the rotational movement being about an axis transverse to the upright members and to the direction of movement of the fork lift, the axis being adjacent the lowermost portion of the upright members, said apparatus comprising:

(a) first transducer means connected to the upright members and the fork lift for sensing rotational

movement therebetween and producing an output impedance change representative of the rotation sensed;

(b) second transducer means connected to the fork assembly and the fork lift for sensing substantially vertical movement therebetween and producing an output impedance change representative of the movement sensed;

(c) first bridge circuit means having a plurality of controllable impedances and said first transducer means connected therein, said transducer means impedance varying between balancing and unbalancing said first bridge circuit means to produce output signals representative of the unbalance of said first bridge circuit means;

(d) second bridge circuit means having a plurality of controllable impedances and said second transducer means connected therein, said transducer means impedance varying between balancing and unbalancing said second bridge circuit means to produce output signals representative of the unbalance of said second bridge circuit means;

(e) power means for driving the fork lift upright members and fork assembly in substantially vertical and rotational movement;

(f) first control means connected to said first bridge circuit means and said power means, said power means being controlled by said first bridge circuit means output signals to provide a rotational movement of the fork assembly as long as said first transducer means causes said first bridge circuit means to be unbalanced;

(g) and second control means connected to said second bridge circuit means and said power means, said power means being controlled by said second bridge circuit means output signals to produce a substantially vertical movement of the fork assembly as long as said second transducer means causes said second bridge circuit means to be unbalanced.

2. The invention as set forth in claim 1 wherein:

(h) said first control means includes latching switch means connected to said power means and to one of said plurality of controllable impedances of said first bridge circuit means for maintaining an electrical connection while energized, said one controllable impedance having a predetermined value to produce a predetermined angle of tilt of the fork assembly causing said first transducer means to be driven until said first circuit bridge means is balanced and de-energizes said latching switch means.

3. The invention as set forth in claim 1 wherein:

(i) said second control means includes latching switch means connected to said power means and to one of said plurality of controllable impedances of said second bridge circuit means for maintaining an electrical connection while energized, said one controllable impedance having a predetermined value to produce a predetermined amount of lift of the fork assembly causing said second transducer means to be driven until said second bridge circuit means is balanced and de-energizes said latching switch means.

4. The invention as set forth in claim 1 wherein:

(j) said first control means includes relay means having a predetermined drop-out current and second latching switch means connected to said power means and to another of said plurality of controlling impedances of said first bridge circuit means for maintaining an electrical connection while energized, said other controllable impedance having a predetermined value to produce to a predetermined current in said first bridge circuit means equal to the drop out current of said relay means causing said first transducer means to be driven until said first circuit bridge means is balanced and de-energizes said latching switch means.

5. The invention as set forth in claim 1 wherein:

(k) said second control means includes relay means having a predetermined drop out current and second latching switch means connected to said power means and to another of said plurality of controllable impedances of said second bridge circuit means for maintaining an electrical connection while energized, said other controllable impedance having a predetermined value to produce a predetermined current in said second bridge circuit means equal to the drop out current of said relay means causing said second transducer means to be driven until said second bridge circuit means is balanced and de-energizes said latching switch means.

6. The invention as set forth in claim 1 including:

(l) a first plurality of switch means connected in series, each of which is connected in parallel with one of said plurality of controllable impedances of said first bridge circuit means to increase or decrease the impedance of the leg in which said impedances are connected, each of said controllable impedances producing an unbalance in said bridge circuit means equal to a predetermined angle of tilt of the fork assembly;

(m) and a second plurality of switch means connected in series, each of which is connected in parallel with one of said plurality of controllable impedances of said second bridge circuit means to increase or decrease the impedance of the leg in which said impedances are connected, each of said controllable impedances producing an unbalance in said bridge circuit means equal to a predetermined increment of elevation of the fork assembly.

7. Apparatus on a mobile fork lift for imparting tilt and elevation control to the fork assembly, comprising:

(a) a first impedance bridge having a first unidirectional voltage source connected thereto and having a plurality of controllable impedances electrically connected therein, said bridge producing output signals representative of the unbalance of said first bridge;

(b) a second impedance bridge having a second unidirectional voltage source connected thereto and having a plurality of controllable impedances connected therein, said bridge producing outut signals representative of the unbalance of said second bridge;

(c) first and second upright structures, the first of which is rotatably secured to the front of the fork lift at a lowermost position for producing a forward and backward tilting motion and the second of which slidably cooperates with said first structure and is constructed and arranged to extend upwardly thereabove;

(d) first power means attached to the mobile fork lift and to said second upright structure and the fork assembly to produce movement of the fork assembly along said first and second upright structure, one of said plurality of controllable impedances of said first bridge connected to said first and second upright structures for measuring relative movement therebetween, and another of said plurality of controllable impedances of said first bridge connected between said second upright structure and the fork assembly for measuring relative movement therebetween, both of said controllable impedances producing unbalance in said first bridge representative of the direction and distance of the movement measured;

(e) first hydraulic control means electrically connected to said first impedance bridge and to said first power means for controlling said first power means in accordance with the magnitude and polarity of the unbalance of said first bridge;

(f) second power means attached to the mobile fork lift and to said first upright structure for imparting a forward and backward tilting motion to said first and second upright structures and the fork assembly moved therealong, one of said plurality of controllable impedances of said second bridge connected to said first upright structure and the fork lift for measuring relative rotational movement therebetween and producing an unbalance in said second bridge representaive of the direction and angle of the rotational movement measured;

(g) and second hydraulic control means electrically connected to said second impedance bridge and to said second power means for controlling said second power means in accordance with the magnitude and polarity of the unbalance of said second bridge.

8. Apparatus for use with a mobile fork lift having a hydraulic motor and at least two hydraulic cylinders connected to a pair of upright members guiding a fork assembly in substantially vertical and rotational movement, the rotational movement occurring about an axis transverse to the upright members and to the direction of movement of the fork lift, the axis being adjacent the lowermost portion of the the upright members, said apparatus comprising:

(a) first transducer means connected to the upright members and the fork lift for sensing rotational movement therebetween and producing an output impedance change representative of the rotation sensed;

(b) second transducer means connected to the fork assembly and the fork lift for sensing substantially vertical movement therebetween and producing an output impedance change representative of the movement sensed;

(c) first bridge circuit means having a plurality of controllable impedances and said first transducer means connected therein, the impedance of said transducer means varying between a balanced and unbalanced condition of said first bridge circuit means to produce output signals representative thereof;

(d) second bridge circuit means having a plurality of controllable impedances and said second transducer means connected therein, the impedance of said transducer means varying between a balanced and unbalanced condition of said second bridge circuit means to produce output signals representative thereof;

(e) first amplifying means connected to said first bridge circuit means to respond to said output signals therefrom, said first amplifying means having parallel output stages, only one of which at any one time provides signals in accordance with the polarity of said output signals received from said first bridge circuit means;

(f) first solenoid control valve means connected to said first amplifying means for energization and to the hydraulic motor and at least one of the hydraulic cylinders to control the flow of hydraulic fluid and cause a tilting movement of the pair of upright members and fork assembly, thereby driving said first transducer means in a direction to produce a balanced condition in said first bridge circuit means and de-energize said first solenoid control valve means to stop the tilting movement;

(g) second amplifying means connected to said second bridge circuit means to respond to said output signals therefrom, said second amplifying means having parallel output stages, only one of which at any one time provides signals in accordance with the polarity of said output signals received from said second bridge circuit means;

(h) and second solenoid control valve means connected to said second amplifying means for energization and to the hydraulic motor and at least one of the hydraulic cylinders to control the flow of hydraulic fluids and cause a substantially vertical movement of the fork assembly, thereby driving said second transducer means in a direction to produce a balanced condition in said second bridge circuit means and de-energize said second solenoid control valve means to stop the substantially vertical movement.

9. The invention as set forth in claim 8 including:

(i) limit switch means constructed and arranged to be actuated when the fork assembly is raised to its highest position and connected electrically between said parallel output stages of said second amplifying means and said second solenoid control valve means to de-energize said second solenoid control valve means and stop the substantially vertical movement of the fork assembly.

10. Apparatus for use with a mobile fork lift having a hydraulic motor and at least two hydraulic cylinders connected to a pair of upright members guiding a fork assembly in substantially vertical and rotational movement, the rotational movement occurring about an axis transverse to the upright members and to the direction of movement of the fork lift, the axis being adjacent the lowermost portion of the upright members, said apparatus comprising:

(a) first transducer means connected to the upright members and the fork lift for sensing rotational movement therebetween and producing an output impedance change representative of the rotation sensed;

(b) second transducer means connected to the fork assembly and the fork lift for sensing substantially vertical movement therebetween and producing an output impedance change representative of the movement sensed;

(c) first bridge circuit means having a plurality of controllable impedances and said first transducer means connected therein, the impedance of said transducer means varying between a balanced and unbalanced condition of said first bridge circuit means to produce output signals representative thereof;

(d) second bridge circuit means having a plurality of controllable impedances and said second transducer means connected therein, the impedance of said transducer means varying between a balanced and unbalanced condition of said second bridge circuit means to produce output signals representative thereof;

(e) first electrical connecting means;

(f) first solenoid control valve means connected to said first bridge circuit means by said first electrical connecting means for energization and connected to the hydraulic motor and at least one of the hydraulic cylinders to control the flow of hydraulic fluid and cause a tilting movement of the pair of upright members and fork assembly, thereby driving said first transducer means in a direction to produce a balanced condition in said first bridge circuit means and de-energize said first solenoid control valve means to stop the tilting movement;

(g) second electrical connecting means;

(h) and second solenoid control valve means connected to said second bridge circuit means by said second electrical connecting means for energization and connected to the hydraulic motor and at least one of the hydraulic cylinders to control the flow of hydraulic fluids and cause a substantially vertical movement of the fork assembly, thereby driving said second transducer means in a direction to produce a balanced condition in said second bridge circuit means and de-energize said second solenoid control valve means to stop the substantially vertical movement.

11. Apparatus for use with a mobile fork lift having upright members guiding a fork assembly in substantially vertical and rotational movement, the rotational movement being about an axis transverse to the upright members and to the direction of movement of the fork lift, the axis being adjacent the lowermost portion of the upright members, said apparatus comprising:

(a) first transducer means connected to the upright members and the fork lift for sensing rotational movement therebetween and producing an output impedance change representative of the rotation sensed;

(b) second transducer means connected to the fork assembly and the fork lift for sensing substantially vertical movement therebetween and producing an output impedance change representative of the movement sensed;

(c) first bridge circuit means having a plurality of controllable impedances and said first transducer means connected therein, said transducer means impedance varying between balancing and unbalancing said first first bridge circuit means to produce output signals representative of the unbalance of said first bridge circuit means;

(d) second bridge circuit means having a plurality of controllable impedances and said second transducer means connected therein, said transducer means impedance varying between balancing and unbalancing said second bridge circuit means to produce output signals representative of the unbalance of said second bridge circuit means;

(e) bridge unbalance limiting means connected between said first and second bridge circuit means for controlling said first bridge circuit unbalance as a function of a predetermined unbalance in said second bridge circuit;

(f) power means for driving the fork lift upright members and fork assembly in substantially vertical and rotational movement;

(g) first control means connected to said first bridge circuit means and said power means, said power means being controlled by said first bridge circuit means output signals to provide a rotational movement of the fork assembly as long as said first transducer means causes said first bridge circuit means to be unbalanced;

(h) and second control means connected to said second bridge circuit means and said power means, said power means being controlled by said second bridge circuit means output signals to produce a substantially vertical movement of the fork assembly as long as said second transducer means causes said second bridge circuit means to be unbalanced.

12. Apparatus on a mobile fork lift for imparting tilt and elevation control to the fork assembly, comprising:

(a) a first impedance bridge having a first unidirectional voltage source connected thereto and having a plurality of first controllable impedances electrically connected therein, said bridge producing output signals representative of the unbalance of said first bridge;

(b) a second impedance bridge having a second unidirectional voltage source connected thereto and having a plurality of second controllable impedances connected therein, said bridge producing output signals representative of the unbalance of said second bridge;

(c) control means interconnected between a predetermined number of said plurality of first and second controllable impedances of said first and second impedance bridges for controllably connecting said first and second controllable impedances into said first and second impedance bridges, certain of said second controllable impedances being limited in value upon certain of said first controllable impedances being connected in said first impedance bridge;

(d) first and second upright structures, the first of which is rotatably secured to the front of the fork lift at a lowermost position for producing a forward and backward tilting motion and the second of which slidably cooperates with said first structure and is constructed and arranged to extend upwardly thereabove;

(e) first power means attached to the mobile fork lift and to said second upright structure and the fork assembly to produce movement of the fork assembly along said first and second upright structure, one of said plurality of controllable impedances of said first bridge connected to said first and second upright structures for measuring relative movement therebetween, and another of said plurality of controllable impedances of said first bridge connected between said second upright structure and the fork assembly for measuring relative movement therebetween, both of said controllable impedances producing unbalance in said first bridge representative of the direction and distance of the movement measured;

(f) first hydraulic control means electrically connected to said first impedance bridge and to said first power means for controlling said first power means in accordance with the magnitude and polarity of the unbalance of said first bridge;

(g) second power means attached to the mobile fork lift and to said first upright structure for imparting a forward and backward tilting motion to said first and second upright structures and the fork assembly moved therealong, one of said plurality of controllable impedance of said second bridge connected to said first upright structure and the fork lift for measuring relative rotational movement therebetween and producing an unbalance in said second bridge representative of the direction and angle of the rotational movement measured;

(h) and second hydraulic control means electrically connected to said second impedance bridge and to said second power means for controlling said second power means in accordance with the magnitude and polarity of the unbalance of said second bridge.

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