United States Patent

Sterner et al.

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[54] SAFE LOAD CONTROL SYSTEM FOR TELESCOPIC CRANE BOOMS

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[52] **U.S. Cl.** **340/267**, 212/39

[51] **Int. Cl.** **G08b 21/00**

[58] **Field of Search** ....212/39; 340/267 C

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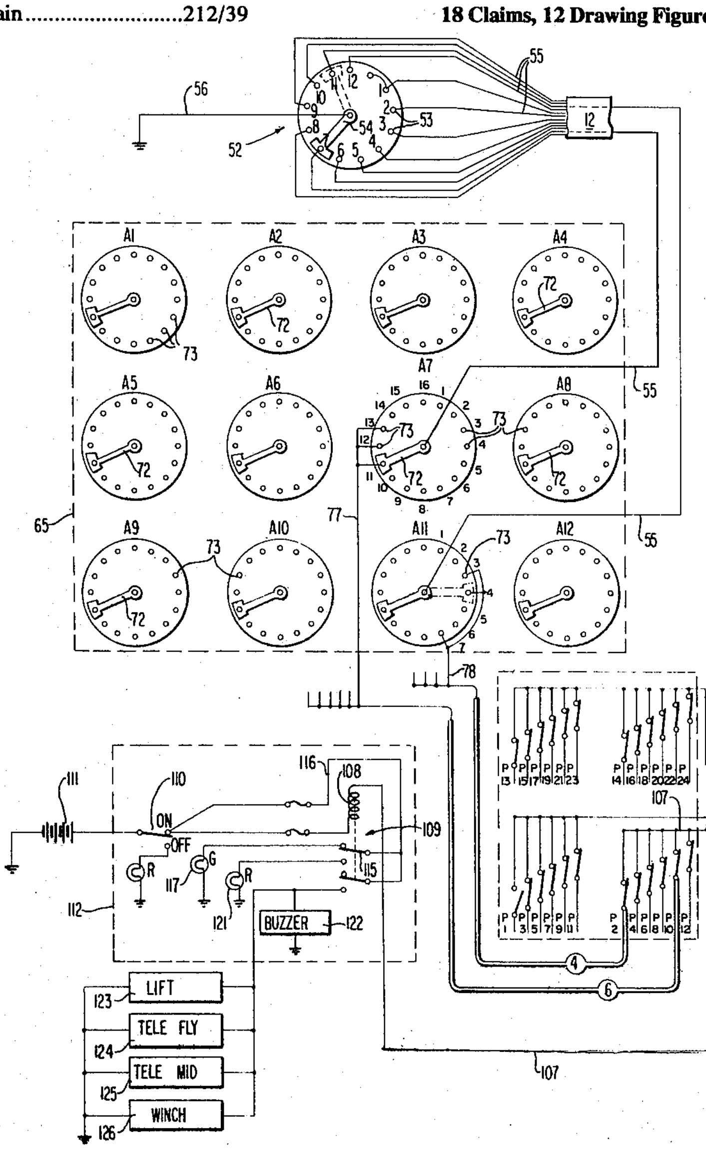
[57] **ABSTRACT**

An overload prevention and indicator system for telescopic boom cranes of the stationary and/or mobile types in which the boom is pivotally raised and lowered in vertical planes by hydraulic lift motor means, the system including first electrical circuit means responsive to complete a selected on of a plurality of circuits corresponding to the length of the boom, the plurality of circuits being respectively connected in series to a corresponding plurality of second electrical circuit means, each representative of a predetermined increment of boom length, responsive to angular position of the telescopic boom in the vertical plane. The plurality of angular position outputs of each second electrical circuit means are connected according to predetermined crane overload information to a plurality of third circuit means representative of pressure range increments, and a pressure switch responsive to fluid pressure in the lift motor means, which is indicative of boom load, is connected to successively operate said third circuit means as the fluid pressure in said lift motor means increases and actuate an indicator and render inoperative selected operations of the crane when the crane approaches an overload or tipping condition at the particular length, angle and load condition at which it is operating at any instant.

18 Claims, 12 Drawing Figures



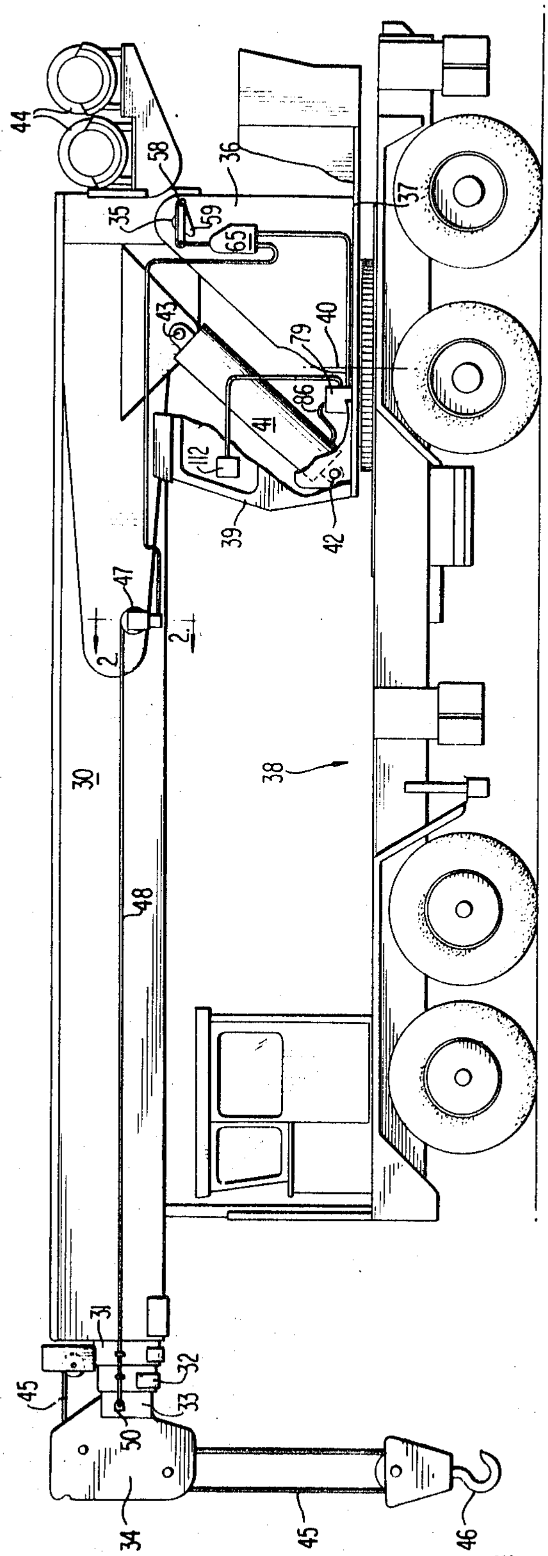


FIG 1

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FIG.2

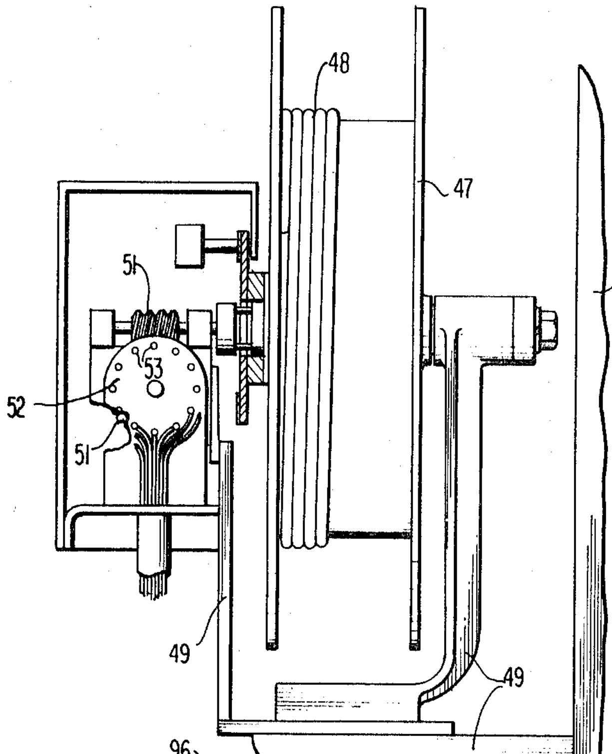
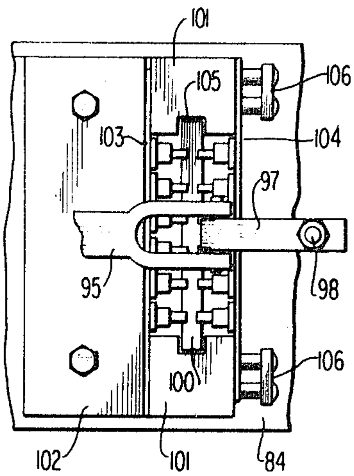


FIG.7



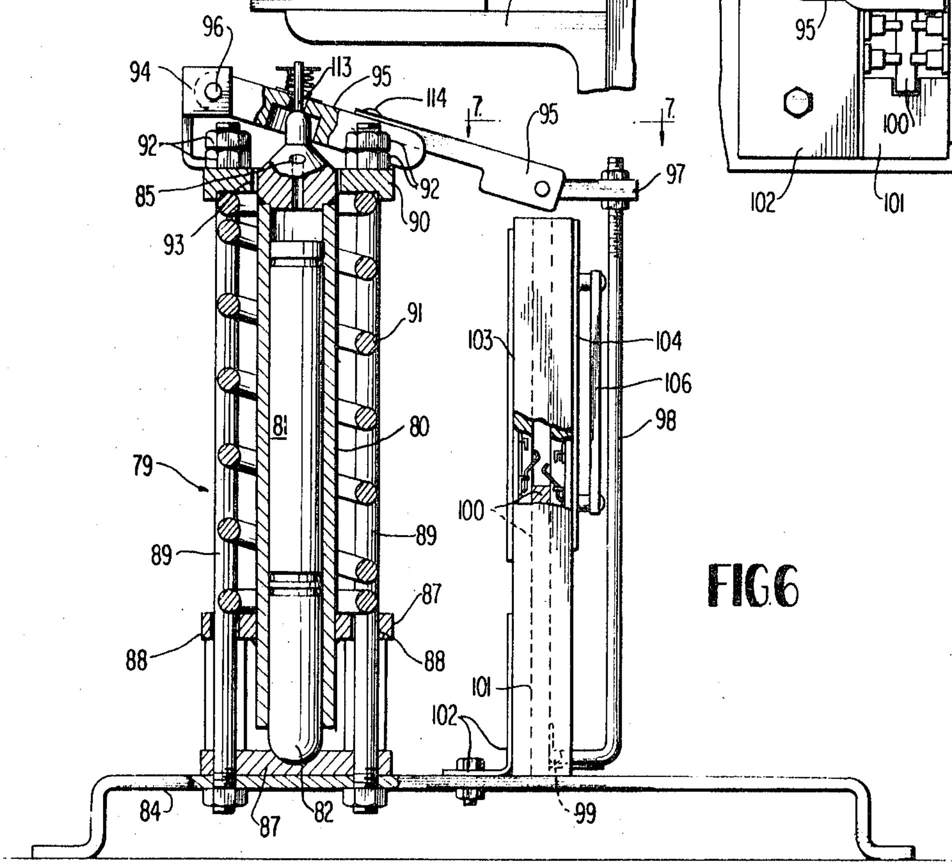


FIG.6

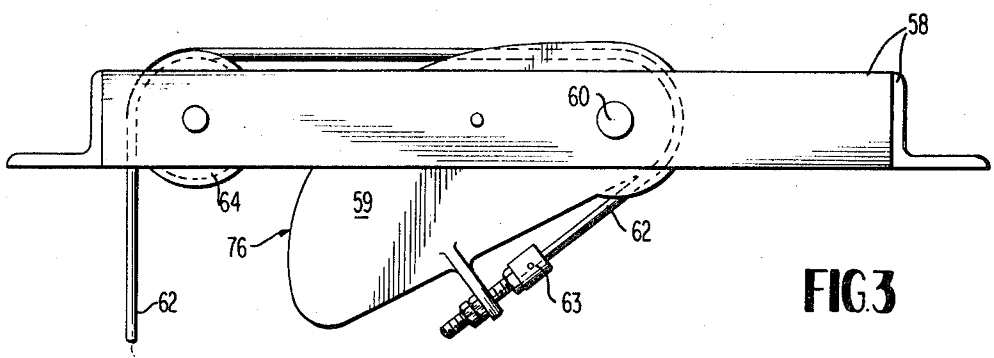


FIG.3

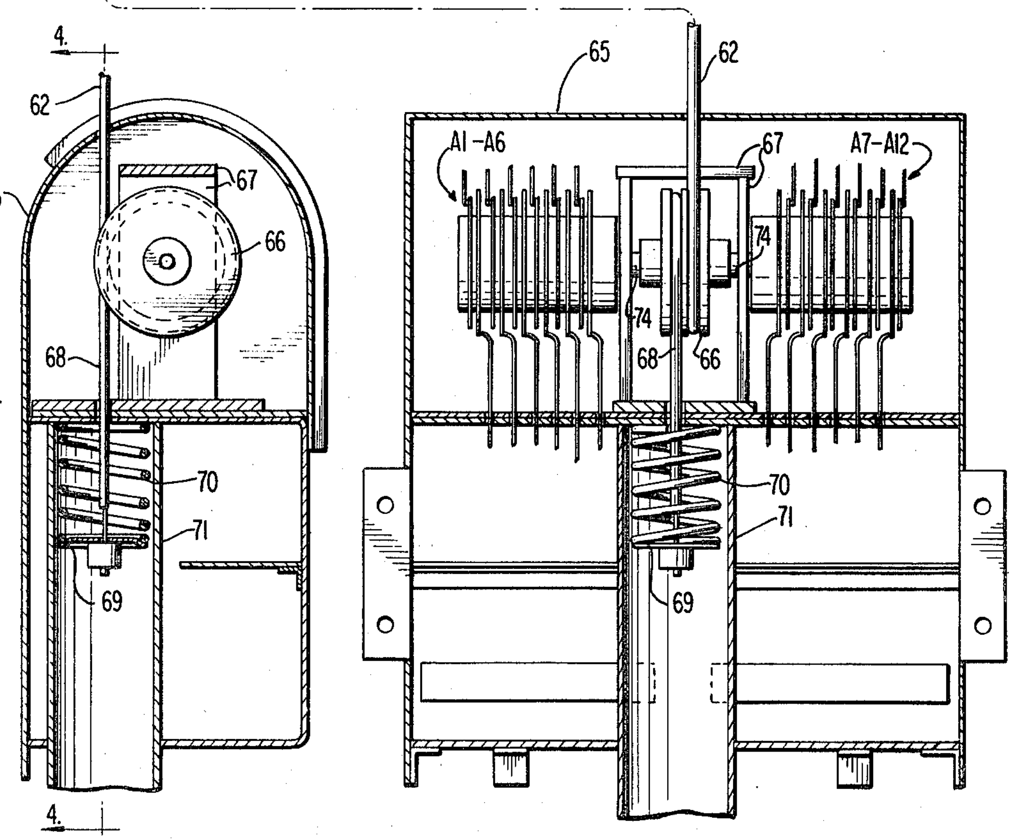


FIG.4

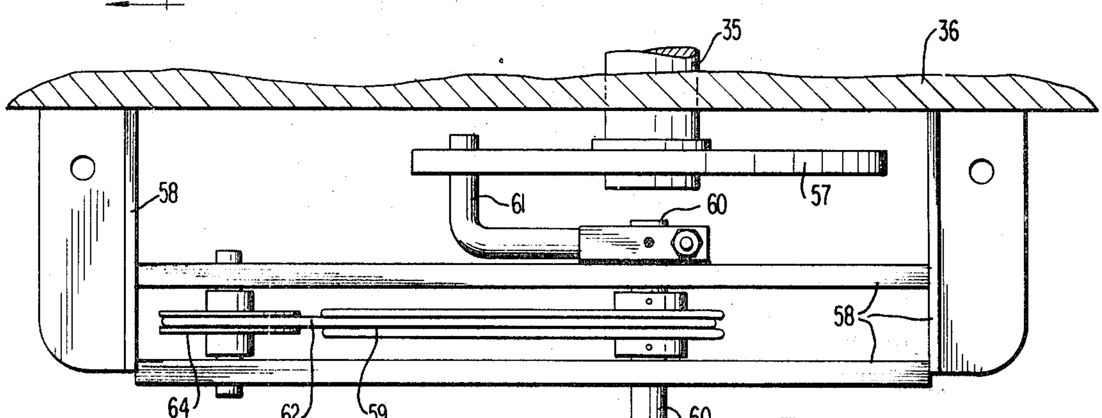


FIG.5

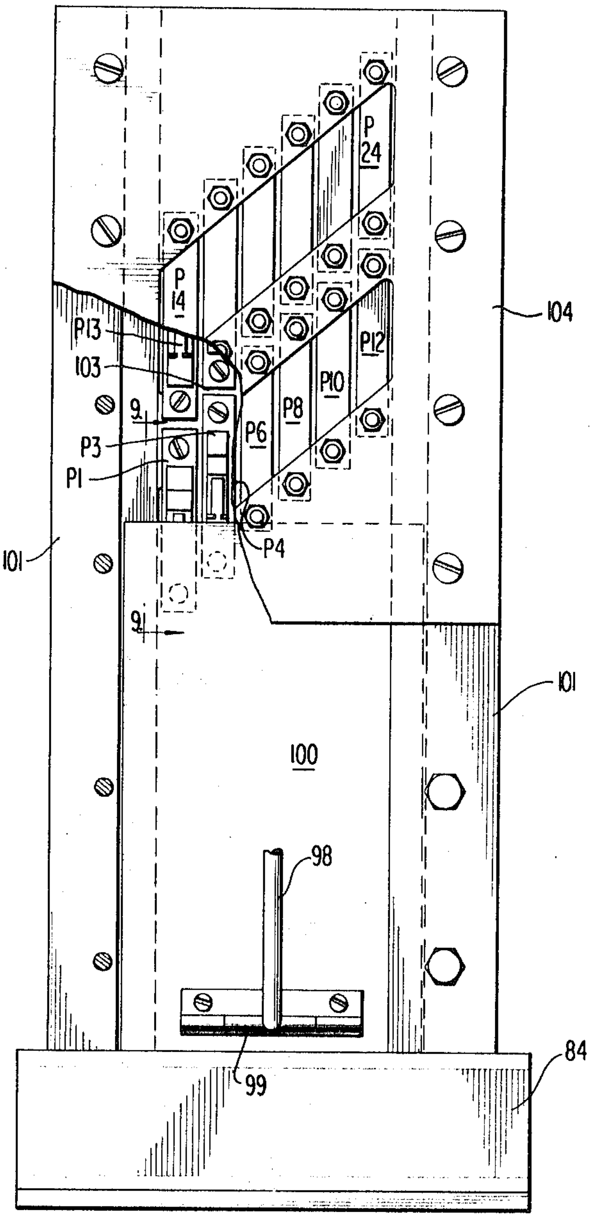


FIG.8

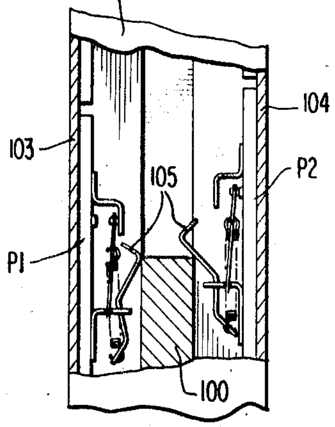


FIG.9

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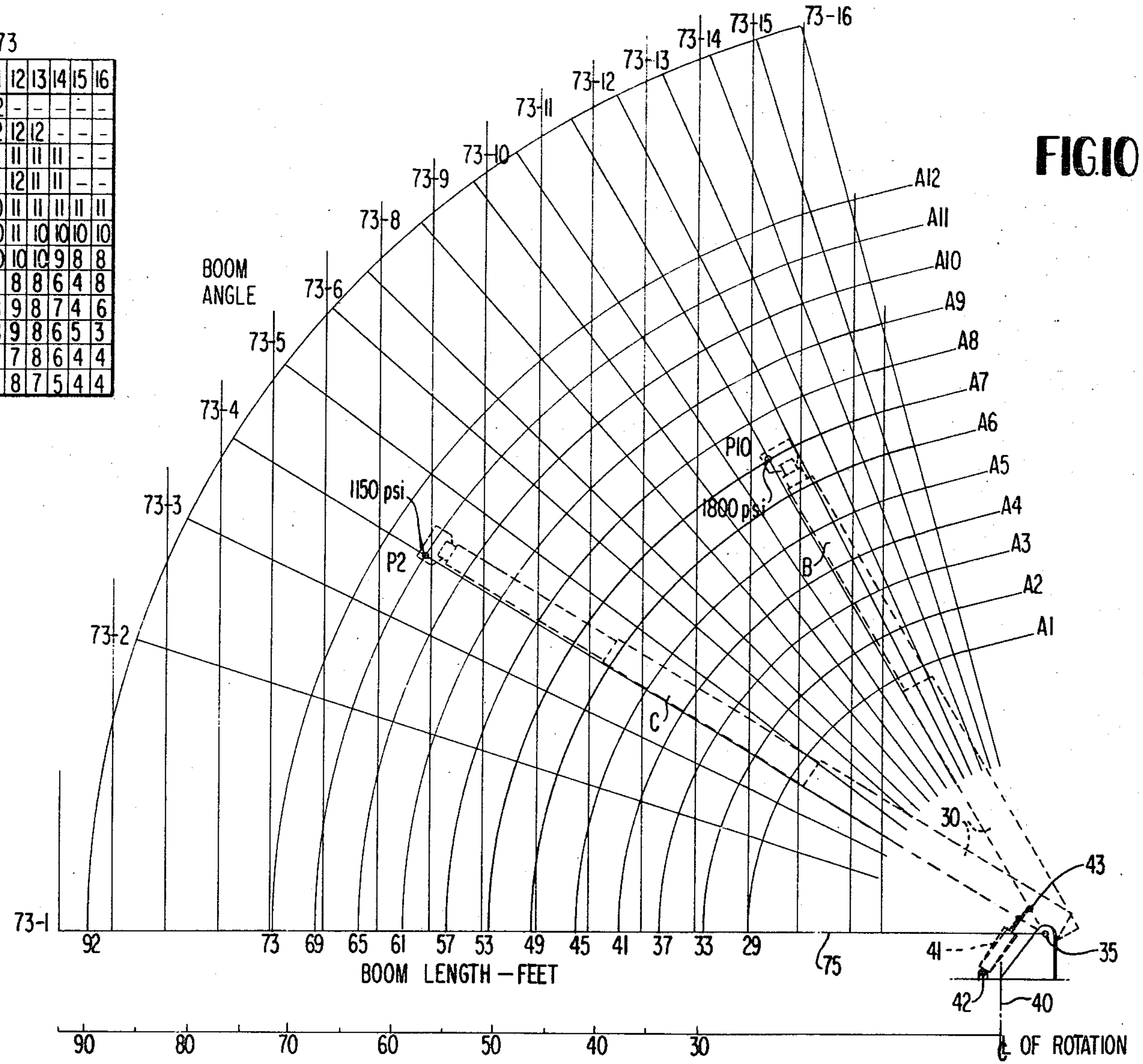


FIG.10

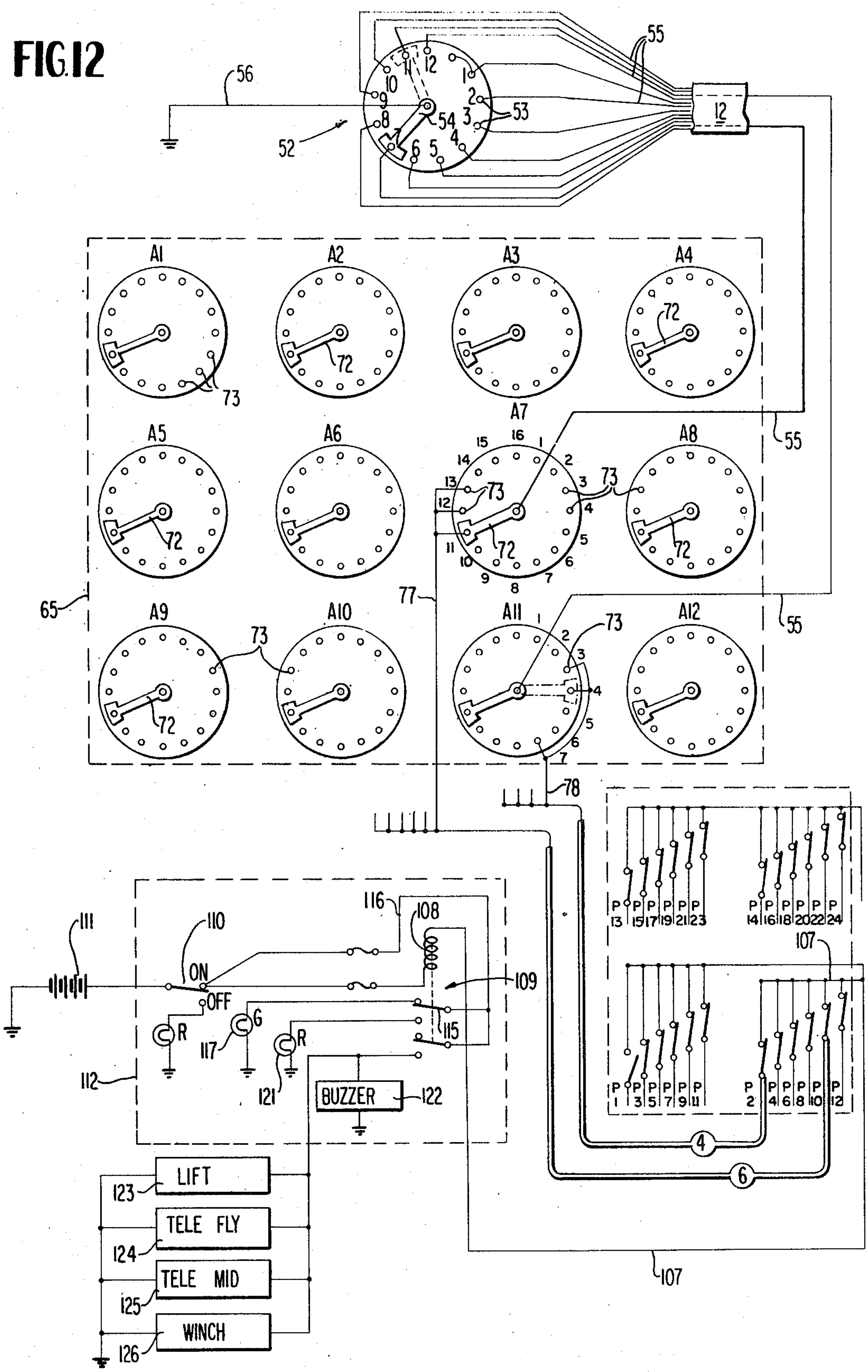
ANGLE CONTACT 73

EXTENSION SWITCH A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		9	9	10	11	11	11	11	11	11	12	-	-	-	-	-
2		9	8	9	10	10	11	11	12	12	12	12	12	-	-	-
3		9	5	6	7	9	9	12	12	12	11	11	11	11	-	-
4	11	8	6	6	6	7	8	9	10	10	11	12	11	11	-	-
5	10	6	6	6	6	7	7	9	9	9	10	11	11	11	11	11
6	10	6	4	5	6	6	6	7	8	10	10	11	10	10	10	10
7	9	6	3	3	5	5	7	7	8	11	10	10	10	9	8	8
8	9	4	3	3	3	5	6	7	7	7	8	8	8	6	4	8
9	8	4	3	3	3	4	6	6	7	7	8	9	8	7	4	6
10	7	3	2	2	3	3	4	6	7	8	8	9	8	6	5	3
11	7	3	2	2	3	3	2	4	6	8	8	7	8	6	4	4
12	5	2	2	2	2	2	4	3	2	7	8	8	7	5	4	4

FIG.11

FIG.12



56
52
54
53
55
12
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A12
72
73
65
77
78
111
110
ON
OFF
R
G
R
117
121
116
108
109
115
112
BUZZER
122
107
LIFT
123
TELE FLY
124
TELE MID
125
WINCH
126

SAFE LOAD CONTROL SYSTEM FOR TELESCOPIC CRANE BOOMS

BACKGROUND OF THE INVENTION

In telescopic boom cranes of either the stationary or mobile types which are adapted to lift a load by means of a cable depending from the outer extremity of the boom which is controlled by a winch, and wherein the booms are rotatable in azimuth and can also be pivotally angularly raised and lowered in the vertical plane at any given azimuth, when the moment of force exerted by the boom and the load being lifted by the boom approaches a value greater than the moment of resistance exerted by the structure supporting the telescopic boom, the boom and the supporting structure is subject to pitching about the tilt axis of the supporting structure, which may be either a stationary structure or a mobile support frame, which would cause damage to the crane and injury to the operator. If the boom-supporting structure is a stationary platform which is not susceptible to pitching then the boom is susceptible to bending when the moment of force exerted by the load approaches or exceeds the bending strength of the boom.

In order to prevent such damage and possible injury to the crane operator, overload indicator and safe load control systems have been proposed, one of such systems being shown in U.S. Pat. No. 3,371,800 issued to John L. Grove on Mar. 5, 1968 and owned by the assignee of the present application. The system shown in the mentioned patent is one of the few safe load control systems for use on telescopic crane booms as opposed to fixed length booms. The problem of determining pitching moments is more difficult for telescopic boom structures and of devising a safe load control system for such structures because for any given vertical angular position of the boom there are a plurality of boom lengths and thus a plurality of different pitching moments which must be taken into account in devising an automatic safe load system. The system shown in U.S. Pat. No. 3,371,800 is sufficiently accurate and reliable for shorter length and lower lifting capacity telescopic booms but this system is not sufficiently accurate for use on the much larger telescopic boom cranes now being produced in the industry which for instance have telescoping ranges from 27 to 92 feet and from 33 to 105 feet with respective higher lifting capacities in the range of 25 to 55 tons.

With the shorter length telescopic booms it was found that the center of gravity of the entire boom structure, at any given elevation angle of the boom, whether extended or retracted, varied over a relatively short predetermined range so that the problems involved in devising a safe load control system were relatively uncomplicated. However, with the present telescopic boom construction, having much greater extended lengths than heretofore known in the art, it has been found that the center of gravity of the boom for the various extended lengths and elevation angles varies over a much greater and a more complex range which greatly complicates the problem of devising an efficient safe load control circuit to warn the operator when the boom is moving toward an area of unsafe operating conditions. The complex shifting of the center of gravity as outlined, thus making it more difficult to determine the tipping moments and safe operating limit of the crane, is partly attributable to the positioning of the boom lift cylinders and the positioning of the point of connection of the cylinders of the boom relative to the boom pivot point, as in the higher capacity and higher strength telescopic booms it has been found necessary to change the angular attitude of the lift cylinders relative to the boom from the attitudes they assumed in the prior art lower capacity boom. The safe load control system for these larger capacity cranes, with a much greater operating radius and thus with a much greater range of operating radii, must, therefore, be able to supervise the machine stability and capacity limitations over a much greater range than can be attained with known prior art systems.

SUMMARY OF THE INVENTION

The deficiencies of the prior art systems are overcome by the present invention by providing a safe load control system in which more safe operating range limitations for more operating points in the operating range of the telescopic boom are programmed into the system than have heretofore been possible in prior art systems. The system of the present invention can be constructed to contain programmed data of safe operating limitations for as many individual boom operating points at individual boom lengths and angles, as desired, in the entire operating range of the boom.

A cable connected to the end of the boom on one end and at the other end to a rotary drum on the boom base section moves the wiper contact of an electrical switch over successive fixed contacts for each extension of the boom by a predetermined distance. The movable contact thus selects a circuit connected to a fixed contact which is representative of a boom length corresponding to the actual instantaneous operating length of the boom, and thus completes a segment of the safe load control circuit. The circuits from the fixed contacts of the boom length switch are correspondingly connected to the movable contacts of a plurality of boom angle switches wherein each switch corresponds to a predetermined length as represented by one of the fixed contacts on the boom length switch. The boom angle switches each have a plurality of fixed contacts successively representative of predetermined increasing boom elevation angles. A cam mechanism connected to the boom pivot point, to translate the boom angle into a corresponding linear horizontal component of the angle, is connected to simultaneously move the movable contacts of the plurality of boom angle switches successively into connection with the fixed contacts as the boom elevation angle increases. Thus for a particular boom elevation angle the circuit completed by the boom length switch is thus completed through the movable contactor of the boom angle switch to the fixed contact thereof representative of the operating angle of the boom.

A pressure gage having a movable piston therein is connected in communication with the fluid pressure in the bottom of the boom lift cylinders, with the movable piston of the gage connected through a linkage arm to successively open a plurality of normally closed switches, each representative of a predetermined pressure range as the pressure in the bottom of the boom lift cylinders increases. The pressure in the bottom of the lift cylinders varies according to the boom load. For each operating attitude of the boom, that is, for each operating point having an individual elevation angle and boom length, there is a safe operation limitation beyond which the entire crane may tip or the boom may bend. The safe operation limitation for any individual working attitude of the boom can be determined by the pressure in the bottom of the lift cylinder. When this pressure is determined for a given boom attitude, that is angle and length, any increase in the lift cylinder pressure beyond that point would move the crane into an unsafe area of operation. Therefore, the pressure switches are connected to render an indication when the boom moves toward an area of unsafe operation, and at the same time the circuitry disables or automatically locks out those portions of the boom hydraulic control system which could be used to manipulate the boom into the overload condition, and maintains those portions of the hydraulic control system in engagement by which the boom may be manipulated away from the unsafe or overload condition.

The fixed contacts of the plurality of boom angle switches are thus connected to the normally closed pressure switches where the circuit for any particular fixed angle switch contact is connected to the pressure switch representative of lift cylinder pressure beyond which the boom cannot be safely operated at that particular boom attitude. The circuit previously described is thus completed through the normally closed pressure switch at the particular operating angle and the outputs of all the normally closed pressure switches are connected together to one end of a normally energized relay. When the boom moves beyond the safe operating limitation for the particular attitude of the crane at any instant, the pressure gage linkage arm opens the normally closed pressure switch which normally completes the circuit for the particular boom attitude that keeps the relay energized causing the relay to deenergize, sound an alarm, and, as previously indicated, lock out those portions of the hydraulically controlled system which could be used to manipulate the boom further into the unsafe operating range.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of a mobile telescopic boom crane, with parts broken away, showing the general arrangement of the components of the system of the invention on the crane;

FIG. 2 is a fragmentary cross-sectional view, of the boom length switch assembly, on an enlarged scale, with parts broken away, taken substantially on line 2—2 of FIG. 1;

FIG. 3 is an enlarged foreshortened side elevational view of the boom angle cam and switch assembly shown in FIG. 1;

FIG. 4 is a cross-sectional view taken substantially along line 4—4 of FIG. 3;

FIG. 5 is a top plan view of the boom angle cam assembly of FIG. 3;

FIG. 6 is a side elevational view, partly in section, of the pressure gage and switch assembly;

FIG. 7 is a fragmentary top plan view thereof taken substantially on line 7—7 of FIG. 6;

FIG. 8 is an enlarged elevational view of the right-hand end thereof as seen in FIG. 6, with parts broken away to shown the arrangement of switch contactors on opposite sides of the switch assembly;

FIG. 9 is an enlarged fragmentary cross-sectional view taken substantially on line 9—9 of FIG. 8 and particularly showing the offset positioning of oppositely disposed switches;

FIG. 10 is a moment arm diagram for a telescopic boom on which are plotted boom angle, hook distance from the boom pivot point and hook distance from the center line of boom relation in feet;

FIG. 11 is a circuit connection chart programming the connection of the boom angle switches to the pressure switches; and

FIG. 12 is a simplified electrical schematic diagram, with only exemplary circuits completed, of the safe load control circuit of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings in greater detail, and particularly to FIGS. 1 and 2, the system of the invention is shown on a mobile hydraulic crane having a telescopic boom with a base section 30 connected to telescopically receive therein an inner midsection 31 into which is telescoped an outer midsection 32 which telescopically receives a fly section 33 having a boom nose assembly 34 connected to the outer end thereof. The fly section and the two midsections are connected to be respectively extendible and retractable by means of double-acting hydraulic rams or the like, not shown, as disclosed in U.S. Pat. No. 3,371,800. The boom base section 30 is provided with a pivot 35 by which the boom is pivotally connected to a pair of spaced upstanding supports 36 on turntable 37 which is rotatably connected to the base structure 38, which is disclosed by way of example as comprising a mobile vehicle chassis, but which may also comprise a stationary structure. The turntable carrying operator's cab 39 is connected to the base structure for 360° continuous rotation about the turntable rotation axis 40. A pair of double-acting elevation or lift fluid motors, such as hydraulic rams 41, are pivotally connected at 42 and 43 between the turntable 37 and the boom base section 30 respectively, for raising and lowering the boom to selected elevation angles in the vertical plane about pivot 35. The hydraulic lift cylinders 41 are controlled for example by a control system as outlined in the previously mentioned patent.

Hydraulic winches 44 are supported on the end of the boom base section for controlling hoist cable 45 extending along the top of the boom and over sheaves in nose assembly 34 to thus control hook assembly 46 adapted to lift a load. In FIG. 1 the boom sections are shown in the fully retracted, stored position, and when the boom is fully elevated in this position, it can be appreciated that the moment arm of the boom is the smallest at such an attitude and the moment of force exerted by a particular load connected to cable 45 is a minimum. As the boom is extended by selectively extending the telescoped sections, the moment arm successively increases and also successively increases as the boom is lowered so that the moment arm of the boom is the longest and the moment of force exerted by the particular load on the lift cable is a maximum when the boom sections are fully extended when the boom is in its lowermost or horizontal position. Thus elevating the boom and/or retracting the telescopic boom sections decreases the moment of force exerted by a load, while extending the boom sections and/or lowering the boom increases the moment of force exerted by the load. The moment of force exerted by a load can also be relieved by lowering the load on the lift cable by means of the winch to thus unload the boom.

A spring-loaded cable reel 47, having a cable 48 or the like wound thereon, is rotatively connected to the side of boom base section 30 by means of a mounting bracket 49. The outer end of cable 48 is connected at 50 to the outer end of fly section 33. Cable reel 47 is connected through worm gearing 51 or the like to drive the movable contactor of boom length switch 52 supported by bracket 49 and also shown schematically in FIG. 12. This switch, as well as the other switches in the safe load control switch circuitry of the invention, are shown and described as rotary switches, but it is to be understood that they may also comprise any of the well-known-type slide switches including linear-type slide switches. One type of rotary switch which may be used for all of the rotary switches in the circuit of the invention, for example, is a switch designated as Model 20M-1201S, manufactured by J-B-T Instruments, Inc., New Haven, Conn.

As the telescopic boom sections 31, 32 and/or 33 are selectively extended and retracted relative to the boom base section, cable 48 is respectively pulled off of and reeled up on spring-loaded cable reel 47. As the reel rotates on its journals, as the boom is extended, movable connector 54 of boom length switch 52 is rotated in a clockwise direction (FIG. 12) by worm gearing 51 to successively move over and make electrical contact with the plurality of fixed contacts 53. The contacts of this rotatable switch are of the overlapping type so that as the removable contact 54 moves from one fixed contact 53 to another, the circuit is never broken. Each fixed contact 53 represents a predetermined length of the telescopic boom and preferably the plurality of fixed contacts represent equal increments of boom length, such as, for example, successive fixed contacts represent successive 4-foot extension increments of the boom with contact 53–1 representing the fully contacted length of the boom such as 29 feet, contact 53–2 representing the boom extended to a 33-foot length, etc., and contact 53–12 representing the boom extended to a length of 73 feet, which, for instance, could be the full extended length of the boom. It is to be understood that switch 52 may have as many fixed contacts 53 as desired to accommodate the full length of the boom in any desired number of length increments, and has been illustrated in FIG. 12 as having only twelve fixed contacts by way of example. As the telescopic boom is retracted, movable contactor 54 is rotated counterclockwise as cable 48 is reeled in by spring loaded reel 47. Switch 52, by means of cable 48, thus continuously provides the safe load control circuit with boom length information corresponding to the length of the boom at all instances during operation of the boom. Switch 52 provides a plurality of output circuits 55 individually connected to corresponding fixed contacts 53 with the number of output circuits corresponding to the number of fixed contacts such that the output circuits 55 are representative of different boom lengths. A circuit 56 connected to a common source of potential, such as ground, is connected to movable contact 54 which in turn is connected to one of the output circuits 55 through the corresponding fixed contact 53, depending upon the operating length of the boom.

The boom length switch output circuits 55 each terminates in an individual second circuit means comprised of one of the boom angle switches A1–A12. The boom angle switches comprise part of the boom angle cam and switch assembly shown in greater detail in FIGS. 3–5.

The end of boom pivot 35 that extends through support 36 (FIG. 5) is provided with a body portion 57 connected thereto for movement with the pivot 35. A bracket assembly 58 is connected to the side of the corresponding boom support 36 and a boom angle cam 59 through arm 60 is rotatively journaled on bracket 58 such that the axis of arm 60 is axially disposed in alignment with boom pivot 35. Arm 60 is connected by linkage 61 to body portion 57, such that when the telescopic boom is pivoted in the vertical plane about pivot point 35, the boom is pivoted in the vertical plane about pivot point 35, the boom angle cam 59 is also correspondingly pivoted in the vertical plane, since the two members share a common pivot axis. The perimeter edge of cam 59 is grooved to retain a cable 62 having one end connected to the lower edge of the cam through cable tightener 63. The cable passing off of the cam is threaded over pulley 64 which is journaled on bracket assembly 58 and is disposed in substantially the same horizontal plane as the cam. From pulley 64 cable 62 extends downwardly into boom angle switch assembly housing 65 wherein the opposite end of the cable is connected to pulley 66 journaled to support member 67 within the housing. Pulley 66 is spring loaded by any appropriate means, such as by another cable 68 having one end connected to rotate pulley 66 in the opposite direction from cable 62, and the opposite end terminating in a plate 69 biased by means of a compression spring 70 within tubular housing 71 which tends to pull cable 68 off of the pulley and thus rotate it in the opposite direction from cable 62. This arrangement enables pulley 66 to automatically retract cable 62 as the vertical angle of the boom is decreased and cam 59 (FIG. 5) is rotated counterclockwise.

The previously mentioned plurality of boom angle switches A1–A12, which are disclosed, by way of example only, as comprised of individual rotary switches, each having a movable or rotatable contactor 72 and a plurality of fixed contacts 73, are connected in stacked groups such as A1–A6 and A7–A12 to opposite sides of support member 67 with the trunnions 74 of pulley 66 connected to simultaneously rotate the movable contactors 72 of all of the boom angle switches in unison as the telescopic boom is raised and lowered in the vertical plane. Each of the boom angle switches A1–A12 has been shown as having 16 fixed contacts 73–1 to 73–16 wherein successive fixed contacts represent predetermined increasing boom angles in the vertical plane, as indicated by the radial lines, in the diagram of FIG. 10, bearing the corresponding reference numerals of the fixed contacts of boom angle switches A1–A12. The fixed contacts 73–1 to 73–16 represent equal increments along the abscissa 75 of the moment arm diagram of FIG. 10, and this is accomplished by boom angle cam 59, the peripheral edge 76 of which, which controls cable 62 and the movement of the rotatable contactors 72, is profiled to translate the angular attitude of the telescopic boom in the vertical plane at any given instance into the linear horizontal component of the angle, that is, the component of the angle that lies along the abscissa 75. As previously indicated the distance between successive fixed contacts 73–1 to 73–16 represent equal horizontal footage increments along abscissa 75, such as 4 or 5 feet, and it will be noted that when the boom is moved from the horizontal position designated by abscissa 75 and fixed contact 73–1 to the maximum elevated position, designated by fixed contact 73–16, and the similarly designated radial line in FIG. 10, at lower boom angles it may take approximately 18° of angular elevation of the boom, for instance, from the horizontal position, to move movable contactor 72 from fixed contact 73–1 to contact 73–2, whereas at higher boom angles it may take only approximately 3° of angular elevational movement of the boom to move the movable contactor 72, for instance, from fixed contact 73–11 to fixed contact 73–12, although the horizontal footage movements for the switch contacts to thus calculate the moment arm of the boom for any particular elevational attitude thereof.

Two illustrative examples of connections of portions of the safe load control circuit of the invention are illustrated in FIGS. 10 and 12 for the operating boom shown at B and C in the moment arm diagram of FIG. 10. The positions of the movable contactors 54 and 72, shown in full lines in FIG. 12, are representative of the boom attitude indicated at B, in FIG. 10, whereas the dotted line positions of the movable contactors indicated in switches 52 and All are representative of the boom attitude illustrated at C in FIG. 10. In FIG. 10 it will be noted that the arcs designated A1–A12 are representative of successive 4 foot incremental increases in boom length and correspond to the boom lengths represented by the correspondingly labeled boom angle switches A1–A12 in FIG. 12. The telescopic boom, as illustrated at B, is operating at an extended length in which the hook distance from the boom pivot 35 is 53 feet. Cable 48 thus positions movable contactor 54 of boom length switch 52 on fixed contact 53–7 which chooses the circuit 55 that is connected to the movable contactor 72 of boom angle switch A7 which is representative of the 53 foot operating length of the boom. Boom length switch 52 thus chooses a particular boom angle switch, in this case A7, which is representative of the instantaneous operating length of the boom. Boom angle cam 59 through cable 62 and pulley 66 positions movable contactor 72 on fixed contact 73–11 of the angle switch, which is representative of the approximate 63° angle at which the boom is operating and the cam edge 76, as previously explained, automatically converts the angular attitude of the boom to the horizontal component of the angle so that the output circuit 77 from fixed contact 73–11 of switch A7 represents the length of the moment arm for the extended length and angular attitude of the boom in the position indicated at B. From the abscissa 75 it will be observed that the moment arm is approximately 27 feet.

In a similar manner, the boom indicated at C is shown operating at a length of 69 feet and at an angle of approximately 31 ½° from the horizontal. For this operating length the cable 48 of length switch 52 positions movable contactor 54 thereof on fixed contact 53–11 which completes the circuit to the movable contactor 72, dotted line showing, of boom angle switch All which is the wafer switch that is representative of the 69 foot operating range of the boom. Movable contactor 72 is positioned by cam 59, etc., in contact with fixed contact 73–4 of angle switch All, thus completing the circuit to output circuit 78 connected thereto which is representative of the boom moment arm of approximately 59 feet, that is, the horizontal component of the operating attitude of the boom at the moment it is operating in the position shown at C. The safe load control circuit of the invention has thus, by a first circuit means 52, chosen a particular second circuit means All that is representative of the instantaneous operating length of the boom, and the second circuit means is correlated with the instantaneous operating elevation angle of the boom to compute the instantaneous moment arm of the boom. In a similar manner, the remaining contacts in the group 53–1 to 53–12 are respectively connected by output circuits 55 to the movable contactors 72 of the switches A1 to A12, although these connections are not shown.

A multiplicity of boom operating points in the boom operating range are connected into the safe load control circuit of the invention in a comparable way, but for sake of clarity the circuit connections have been shown in FIG. 12 for only the two positions of boom operation illustrated in FIG. 10. The circuit shown is arranged to determine the moment arms for 12 different operating lengths of the telescopic boom at 16 different elevational angles, for a total of 192 operating points in the boom operating range. It can be appreciated that any number of operating points can be connected into the system merely by increasing the number of switch circuits or the usable number of fixed contacts in the various switches, so that the system is applicable to telescopic booms of any length.

Referring to FIGS. 1, 6–9 and 12 a pressure gage and switch assembly, indicated generally at 79, is mounted on turntable 37 and is arranged to sense the pressure of the hydraulic fluid in the bottom of lift cylinders 41, as this pressure is indicative of the moment of force exerted by the telescopic boom and the load carried hereby on the base structure 38. The pressure gage comprises a cylinder 80 having a piston 81 disposed therein for axial movement and having a rod end portion 82 extending from the cylinder and frictionally seated in plate 83 carried by bracket 84 which mounts the pressure gage at an appropriate place adjacent the lift cylinders. The opposite end of cylinder 80 is closed and is provided with an input port 85 connected in fluid communication with the hydraulic fluid in the bottom of lift cylinders 41 by means of hydraulic line 86 (FIG. 1). Cylinder 80 is provided with a head member 87 connected thereto adjacent the rod end of the cylinder which is provided with through-holes 88 at the four corners thereof in sliding contact with bolts 89 connected between bracket 84 and top plate 90. A relatively heavy spring 91 is disposed about cylinder 80 between the cylinder and bolts 89, and is confined in a state of initial compression between head member 87 and top plate 90. The initial compression, for example, equivalent to approximately 1,000 p.s.i. is imparted to spring 91 by tightening nut members 92 on the ends of bolts 89. Top plate 90 is provided with a central aperture 93 larger than the diameter of cylinder 80 to allow the cylinder to move freely therethrough.

An upstanding bracket 94 is connected to top plate 90 and a lever arm 95 is pivotally connected at 96 to bracket 94 with the opposite bifurcated end thereof pivotally connected to arm 97 rigidly connected to one end of vertically disposed drag linkage 98. The opposite end of the drag linkage is connected through a horizontal hinged pivot 99 to a slide member 100 connected for vertical sliding movement in vertically disposed U-shaped guides 101 which engage oppositely longitudinal edges of the slide member and which are connected to bracket 84 through the adjustable mount 102. Slide member 100 and guides 101 are preferably constructed of electrical insulation material.

Guides 101 and slide member 100 form the pressure switch assembly which also includes switch mounting cards 103 and 104 connected to opposite side vertical surfaces of the guides 101. The switch mounting cards are preferably constructed of insulation material and a plurality of normally closed electrical switch members P1, P3, P5, P7, P9, P11, P13, P15, P17, P19, P21 and P23 are connected to card 103 in two rows, one above the other, with the adjacent switches in each row being successively staggered upwardly in the vertical plane. Normally closed electrical switch members P2, P4, P6, P8, P10, P12, P14, P16, P18, P20, P22, and P24 are connected to card 104 in two rows, one above the other, with the adjacent switches in each row being successively staggered upwardly in the vertical plane, as best shown in FIG. 8, with the switches on card 104 being vertically offset between the switches on card 103. Each of these normally closed electrical switches may comprise, for example, a Cherry Switch No. S25–00T, wherein each switch is provided with an actuator 105 which protrudes into the path of movement and is adapted to be contacted by the upper edge of slide member 100. When the actuator 105, as shown in FIG. 9, is contacted by the leading edge of slide 100, it is moved inwardly causing the switch to move from its normally closed position, as indicated by the position of switch P2, in FIG. 9, to the open position, as shown by the position of switch P1, in the same figure. The electrical connections to the various switches are made through the terminal strips 106, FIGS. 6 and 7, with the normally closed terminals of all of the switches on both cards commonly connected to conductor 107 (FIG. 12), the opposite end of which is connected through coil 108 of normally energized relay 109 on control panel 112 in the crane operator's cab 39, and ON-OFF switch 110 to the positive terminal of battery 111 which, for instance, may be a 12-volt battery, the opposite terminal of which represents the common source of potential to which circuit 56 of the boom length switch 52 is connected.

As the pressure in the bottom of lift cylinders 41 increases which, for a predetermined load on the boom, is caused by an increase in the moment of force exerted by the boom on the supporting structure which is caused by increasing the length of the boom or decreasing the operating angle of the boom in the vertical plane, or a combination of both, cylinder 80 moves upwardly on the restrained piston 81 and the top portion 113 of the cylinder pivots lever arm 95 about connection 96 and moves the opposite end thereof upwardly in an arc which in turn moves drag linkage 98 upwardly to move the top edge of slide member 101 successively into contact with the actuators of switch members P1, P2, P3, P4, etc., to actuate the switches from the normally closed position in which the electrical circuit is completed to the open position in which the electrical circuit is broken. Lever arm 95 is adjustable in length at 114 to allow for an adjustment for inaccuracies in spring rates between different springs 91.

The pressure gage and switch assembly 79 is calibrated so that the leading edge of slide member 100 moves upwardly and progressively opens one of the successive normally closed switches for each predetermined equal incremental increase in fluid pressure in the bottom of the lift cylinders 41. For instance, the electrical switches P1–P11 on card 103 may be arranged to progressively open on each increase of 50 or 100 p.s.i. pressure in the lift cylinders, and the switches P2–P12 on card 104 may be similarly arranged, but since the switches are offset relative to each other in the vertical plane, as shown in FIG. 9, a switch will be opened on each increase in pressure of 25 or 50 p.s.i. The circuit of FIG. 12 utilizes only pressure switches P1–P12 but it is to be understood that as many pressure switches as desired can be used in the circuit to give a more refined operation of the system, and any desired incremental pressure range may be assigned to the switches. By calculations the maximum safe moment of force, which may be safely exerted by the boom on the supporting structure without exceeding the boom strength and which will not cause the supporting structure to pitch or tip for any operating length and attitude of the boom, can be calculated and in this manner the hydraulic pressure in the bottom of the lift cylinders 41 corresponding to the maximum safe moment of force can be calculated, or this pressure can be determined by actual tests. In this manner, a maximum pressure that can be tolerated in the bottom of the lift cylinders can be determined for every point on the moment arm diagram of FIG. 10 where the radial lines 73–1 to 73–16 cross the arcuate lines A1–A12, since these intersections represent the points in the boom operating range that are programmed into the safe load circuit. A separate such chart must be made up for each particular model of extensible boom crane since each model has individual loading characteristics. With such a pressure chart a circuit connection chart, such as shown in FIG. 11, can be made up for each model crane which is utilized for programming the circuit connections, such as circuits 77 and 78, from the fixed contacts 73–1 to 73–16 of each of the boom angle switches A1–A12 to the pressure switches P1–P12.

As previously indicated, preselected pressure values are assigned to the switches P1–P12, such as, for example, switch P2 being assigned pressure 1,150 p.s.i. and switch P10 the pressure 1,800 p.s.i. This means that whenever the pressure in the bottom of the lift cylinders exceeds the respective pressures, the respective switches move from the normally closed position to the open position to open the safe load circuit.

In the chart of FIG. 11, the boom angle switchs A1–A12 representing boom extension length appear in the vertical column plotted against the fixed contacts 73–1 to 73–16 in the horizontal column which are representative of boom angle. The numbers filling in the the chart represent the pressure switches P1–P12 to which the fixed contacts 73–1 to73–16 of the various angle switches A1–A12 are connected. By way of example, referring to FIG. 10, the maximum pressure that can be tolerated in the bottom of lift cylinders 41 at the boom attitude shown at B, for a particular boom, was determined as being 1,800 p.s.i. This is the pressure limitation assigned to switch P10. This boom operating position is represented in the circuit by fixed contact 73–11 of angle switch A7. Therefore, in the chart of FIG. 11, where the columns from switch A7 and contacts 73–11 intersect the number 10 representative of switch P10 appears in FIG. 12. Output circuit 77 is thus connected to switch P10 as indicated, and all of the other angle switch contacts in the chart of FIG. 11 having a similar designation are connected to switch P10. In the present example it will be seen that contacts 73–11 to 73–13 of switch A7 are all connected to switch P10. From the chart it will also be noted that contacts in angle switches A1, A2, A4, A5, and A6 are also connected to switch P10 so output circuits from six different angle switches, including circuit 77, are connected to switch P10.

The attitude of the boom illustrated at C, in FIG. 10, is represented in the safe load circuit by fixed contact 73–4 of boom angle switch All. The maximum pressure in the bottom of the lift cylinders which provides safe operation at this boom position was determined to be 1,150 p.s.i. which pressure is represented by pressure switch P2. From the coordinates in the chart of FIG. 11, it will be noted that the number 12 is entered as representing the pressure switch connection for this point. The chart also shows that test data indicated that fixed contacts 73–3 and 73–7 of this same switch are also connected to pressure switch P2 and such circuit connection is shown by output conductor 78 in FIG. 12. The chart also indicates that fixed contacts in boom angle switches A9, A10, and A12 are also connected to pressure switch P2 and thus output circuits from four different angle switches, including output circuit 78, are connected to switch P2 as indicated in FIG. 12. The remaining fixed contacts of the angle switches in FIG. 12 connected to the other pressure switches in like manner according to the connection chart of FIG. 11. Pressure switches P1–P12 represent successively higher pressures.

As previously indicated, the output circuits, such as 77 and 78, represent the moment arm of the boom at the different operating positions and when wired to the pressure switches the completed circuit represents maximum moment of force that can be tolerated from the boom for the particular position without exceeding safe operating conditions. For instance, the boom operating at position C with a certain load may be producing a pressure in the bottom of the lift cylinders of approximately 1,145 p.s.i. In this position, the pressure of switch P1 is exceeded and pressure gage 79 moves slide member 100 upwardly, such that switch P1 is opened as shown in FIG. 12. The safe load control circuit however is completed by the circuit including the elements 56, 54, 53–11, 55, All–72, 73–4, 78, P2, 107, 108, 110 and 111. If the boom is extended, for example, another 3 feet, the boom is moved toward a condition of unsafe operation as it approaches a tipping condition, and the pressure in the boom of the lift cylinders exceeds the 1,150 p.s.i. limitation of switch P2 and slide member 100 is moved upwardly by pressure gage 79 against the actuator 105 causing switch P2 to move from the normally closed position to the normally open position, thus opening the safe load control circuit and deenergizing coil 108 of normally energized relay 109.

In the normally energized position of relay 109 movable contactor 115, connected to battery 111 by circuit 116 energizes green light 117 which indicates that the system is operating and the crane is operating in a safe condition. When relay 109 is deenergized on the opening of the pressure switch, such as P2, which completes the circuit for the particular boom operating attitude, relay contactors 115 and 118 drop out and through circuit 116 supply power from battery 111 to relay contacts 119 and 120, respectively, extinguishing green light 117, illuminating warning light 121, energizing an audible alarm 122, if desired, and energizing hydraulic solenoid valves 123, 124, 125 and 126. Light 121 and/or alarm 122 warn the operator that the overload condition has been approached for the particular operating attitude of the boom. The hydraulic solenoid valves comprise hydraulic valves connected into the hydraulic fluid control system of the crane which are electrically controlled by solenoids. Valve 123 is the lift solenoid valve disposed in the hydraulic control circuit of the hydraulic lift cylinders 41. Valve 124 is disposed in the hydraulic control circuit of the hydraulic ram that extends and retracts the boom fly section 33 and reference numeral 125 represents two solenoid valves connected in the control circuit of the hydraulic rams which extend and retract the boom inner midsection 31 and outer midsection 32. The winch solenoid valve 126 is connected in the hydraulic control circuit of the hydraulic winches 44 which controls the raising and lowering of hoist cable 45. The hydraulic control circuit may be substantially the same as that shown and described in U.S. Pat. No. 3,371,800.

On operation of the safe load control circuit the solenoid valves 123–126 are energized, thus locking out the boom operations of lifting with the winch 44, extending the boom sections 31, 32, 33, and lowering the boom by means of lift cylinders 41, since these operations would move the boom further into the area of unsafe operation as they would increase the moment of force exerted by the boom on the supporting structure. However, as in the previously mentioned patent, the operations of raising the boom with the lift cylinders, retracting any or all of the boom sections and lowering the load with the hydraulic winch, are maintained in operating condition, as these operations manipulate the boom away from or out of the unsafe operating condition as they decrease the boom moment arm or unload the boom, thus decreasing the hydraulic pressure in the bottom of the lift cylinders 41. When the boom is manipulated back into an attitude of safe operation for the particular load on the boom the pressure in the bottom of the cylinders no longer exceeds the pressure programmed into the system for the instantaneous boom attitude and the pressure switch assembly 79 lowers slide member 100 to the point where the pressure switch in the group P1–P12 representing the instantaneous boom attitude is released to again close the safe load control circuit and putting it back in operating condition by energizing relay 109.

It is to be understood that the system of the invention can be used merely as an overload indicator system, using the warning light 121 and/or the audible alarm 122 without automatically controlling operation of the hydraulic solenoid valves in the hydraulic control system.

The terms and expressions which have been employed herein are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

We claim:

1. A safe load control system for preventing the overloading and/or tipping of material-handling apparatus of the type comprising an extensible boom 30–33 pivotally connected 35 on a supporting structure 36, and extensible fluid motor means 41 connected between the boom and supporting structure for angularly moving the boom in the vertical plane; said control system comprising first circuit means 52, 54, 56 connected 47–51 with said boom and responsive to the variable extensible length of the boom; a plurality of second circuit means A1–A12 respectively corresponding to predetermined boom lengths from the retracted to the fully extended positions, and each having an input 72 and output means 73; said first circuit means 52 connected 55 to the inputs 72 of said plurality of second circuit means A1–A12 and operative to select and connect in circuit therewith the second circuit means A1–A12 corresponding to the instantaneous length of said boom 30–33; said output means 73 corresponding to predetermined boom elevation angles; control means 59, 62, 66 connecting said inputs 72 to said boom 30–33 for response to the varying

elevation angles of the boom and operative to connect the inputs 72 in circuit with the output means 73 corresponding to the instantaneous elevation angle of the boom; signal circuit means 112; a plurality of switch circuit means P1–P24 connecting said output means 73 to said signal circuit means 112; pressure-responsive means 79 connected to normally progressively operate said plurality of switch circuit means P1–P24 in response to the pressure of the fluid in the fluid motor means 41 corresponding to the loading of said boom; whereby the switch circuit means P1–P24 is only operated to operate the signal circuit means 112 when the moment of force at a particular boom length and angle exceeds the safe moment of force for that boom attitude.

2. A safe load control system as set forth in claim 1 in which said first circuit means comprises a switch means having a movable contractor and a plurality of output contacts corresponding to said predetermined boom lengths of said second circuit means.

3. A safe load system as set forth in claim 2 including boom length responsive means connected on said boom and responsive to extension and retraction of the boom, and said boom length responsive means connected to adjust the position of said movable contactor relative to said plurality of fixed contacts.

4. A safe load system as set forth in claim 1 in which said plurality of second circuit means each comprises a second switch means having a plurality of output contacts and a movable input contactor progressively connectable therewith as the boom elevation angle increases.

5. A safe load system as set forth in claim 4 in which said control means includes a cam connected for movement with the boom in the vertical plane, linkage means connected between said cam and said movable contactors of said second switch means for movement by said cam to move said movable contactors in response to varying boom elevation angles.

6. A safe load system as set forth in claim 5 in which said linkage means is a flexible element, said cam including a surface profiled to translate boom elevation angles into the horizontal components of the angles, and disposed to control said flexible elements.

7. A safe load control system for preventing the overloading and/or tipping of material-handling apparatus of the type comprising an extensible boom 30–33 pivotally connected 35 on a supporting structure 36, and vertically swingable to different elevation angles by extensible lift fluid motor means 41 connected between the boom and supporting structure, said control system comprising first electrical circuit means 52 responsive to variations in the length of the boom, second electrical circuit means A1–A12 responsive to the elevation of the boom in the vertical plane, said first and second electrical circuit means connected in series and having a plurality of output circuits 73, said first 52 and second A1–A12 electrical circuit means operative to complete a circuit to one of said output circuits 73 corresponding to the moment arm for the instantaneous operating attitude of the boom, signal circuit means 112, a plurality of third circuit means P1–P24 corresponding to predetermined maximum pressure ranges for predetermined moment arms of the boom connecting said plurality of output circuits 73 to said signal circuit means 112, pressure-responsive means 79, a body portion connected for movement by said pressure-responsive means normally progressively operate said plurality of third circuit means P1–P24 in response to the fluid pressure in the lift fluid motor means 41 corresponding to the loading of said boom 30–33, and said plurality of third circuit means P1–P24 connected to operate the signal circuit means 112 only when the moment of force at the particular boom operating attitude exceeds the predetermined corresponding safe moment force.

8. A safe load control system as set forth in claim 1, in which said signal circuit means includes a source of power and a relay connected in circuit with said plurality of third circuit means, said relay having contacts, and signal means connected for operation by said contacts when said relay is operated by said third circuit means.

9. A safe load control system as set forth in claim 8, including additional means connected for operation by said contacts to render at least said extensible fluid motor means inoperative to lower said boom.

10. A safe load control system as set forth in claim 2, in which said switch means is a first rotary switch, said plurality of second circuit means each comprising a second rotary switch having a plurality of output contacts and a movable input contactor rotatable into progressive contact with the output contacts thereof as the boom elevation angle increases, said plurality of output contacts of said first rotary switch respectively connected to the movable input contactors of said plurality of second rotary switches, and the plurality of output contacts of said second rotary switches connected according to predetermined maximum moment of force information to said plurality of third circuit means.

11. A safe load control system for preventing the overloading and/or tipping of material-handling apparatus of the type comprising an extensible boom pivotally connected on a supporting structure, and extensible fluid motor means connected between the boom and supporting structure for angularly moving the boom in the vertical plane; said control system comprising first circuit means connected with said boom and responsive to the variable extensible length of the boom; a plurality of second circuit means respectively corresponding to predetermined boom lengths from the retracted to the fully extended positions, and each having an input and output means; and first circuit means connected to the inputs of said plurality of second circuit means and operative to select and connect in circuit therewith the second circuit means corresponding to the instantaneous length of said boom; said output means corresponding to predetermined boom elevation angles; control means connecting said inputs to said boom for response to the varying elevation angles of the boom and operative to connect the inputs in circuit with the output means corresponding to the instantaneous elevation angle of the boom; signal circuit means; a plurality of third circuit means connecting said output means to said signal circuit means; a fluid piston-cylinder assembly; a fluid connection between said piston-cylinder assembly and the fluid in the bottom portion of said extensible fluid motor means, a member guided for sliding movement; a lever arm linkage connected to said guided member and engaged for movement by said piston-cylinder assembly, said plurality of third circuit means connected in the path of movement of said guided member for progressive operation thereby upon increase of fluid pressure in said piston-cylinder assembly in response to the pressure of the fluid in the fluid motor means corresponding to the loading of said boom to correspondingly move said guided member, whereby the third circuit means is operated to operate the signal circuit means when the moment of force at a particular boom length and angle exceeds the safe moment of force for that boom attitude.

12. A safe load control system as set forth in claim 11 in which said plurality of third circuit means comprise a plurality of individually operable switch elements having actuator means protruding into the path of movement of said guided member whereby said switch elements are operated upon contact of the corresponding actuator by said guided member.

13. A safe load control system as set forth in claim 11 in which said third circuit means comprise a plurality of normally closed switch elements each having an input terminal and an output terminal, the output terminals of all said switch elements commonly connected to said signal circuit means, the input terminals of said switch elements connected according to predetermined maximum moment of force information to said output means of said plurality of second circuit means, and said plurality of switch elements protruding into the path of movement of said guided member to be moved to an open circuit position when contacted thereby.

14. A safe load control system as set forth in claim 12 in which said plurality of switch elements are effectively staggered in a plane substantially parallel with said guided member, and an edge portion on said guided member movable

into contact with said plurality of actuators, whereby said plurality of switch elements are progressively operated by said edge portion as the moment of force of the extensible boom increases.

15. A safe load control system for preventing the overloading and/or tipping of material-handling apparatus of the type comprising an extensible boom pivotally connected on a supporting structure, and extensible fluid motor means connected between the boom and supporting structure for angularly moving the boom in the vertical plane; said control system comprising first circuit means connected with said boom and responsive to the variable extensible length of the boom; a plurality of second circuit means respectively corresponding to predetermined boom lengths from the retracted to the fully extended positions, and each having an input and output means; said first circuit means connected to the inputs of said plurality of second circuit means and operative to select and connect in circuit therewith the second circuit means corresponding to the instantaneous length of said boom; said output means corresponding to predetermined boom elevation angles; control means connecting said inputs to said boom for response to the varying elevation angles of the boom and operative to connect the inputs in circuit with the output means corresponding to the instantaneous elevation angle of the boom; signal circuit means; a plurality of third circuit means connecting said output means to said signal circuit means; a fluid piston-cylinder assembly; a fluid connection between said piston-cylinder assembly and the fluid in the bottom portion of said extensible fluid motor means, a member connected for movement by said piston-cylinder assembly, said plurality of third circuit means connected in the path of movement of said member for progressive operation thereby upon increase of fluid pressure in said piston-cylinder assembly in response to the pressure of the fluid in the fluid motor means corresponding to the loading of said boom to correspondingly move said member, whereby the third circuit means is operated to operate the signal circuit means when the moment of force at a particular boom length and angle exceeds the safe moment of force for that boom attitude.

16. A safe load control system as set forth in claim 15 in which said plurality of third circuit means comprise a plurality of individually operable switch elements having actuator means protruding into the path of movement of said member whereby said switch elements are operated upon contact of the corresponding actuator by said member.

17. A safe load control system as set forth in claim 15 in which said third circuit means comprise a plurality of normally closed switch elements each having an input terminal and an output terminal, the output terminals of all said switch elements commonly connected to said signal circuit means, the input terminals of said switch elements connected according to predetermined maximum moment of force information to said output means of said plurality of second circuit means, and said plurality of switch elements protruding into the path of movement of said member to be moved to an open circuit position when contacted thereby.

18. A safe load control system as set forth in claim 15 in which said plurality of switch elements are effectively staggered in a plane substantially parallel with said member, and an edge portion on said member movable into contact with said plurality of actuators, whereby said plurality of switch elements are progressively operated by said edge portion as the moment of force of the extensible boom increases.

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