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Kezer et al.

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[45] **June 19, 1973**

[54] **WARNING SYSTEM FOR LOAD HANDLING EQUIPMENT**

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[21] Appl. No.: **146,682**

[52] **U.S. Cl.** ..... **235/151.3,** 212/39 A, 235/151.33, 340/267 C

[51] **Int. Cl.** **G06g 7/22,** G08b 21/00

[58] **Field of Search** ..... 235/151, 151.3, 151.33, 235/184, 189; 340/267 C, 272, 282; 73/100; 212/39 A

[56] **References Cited**

UNITED STATES PATENTS

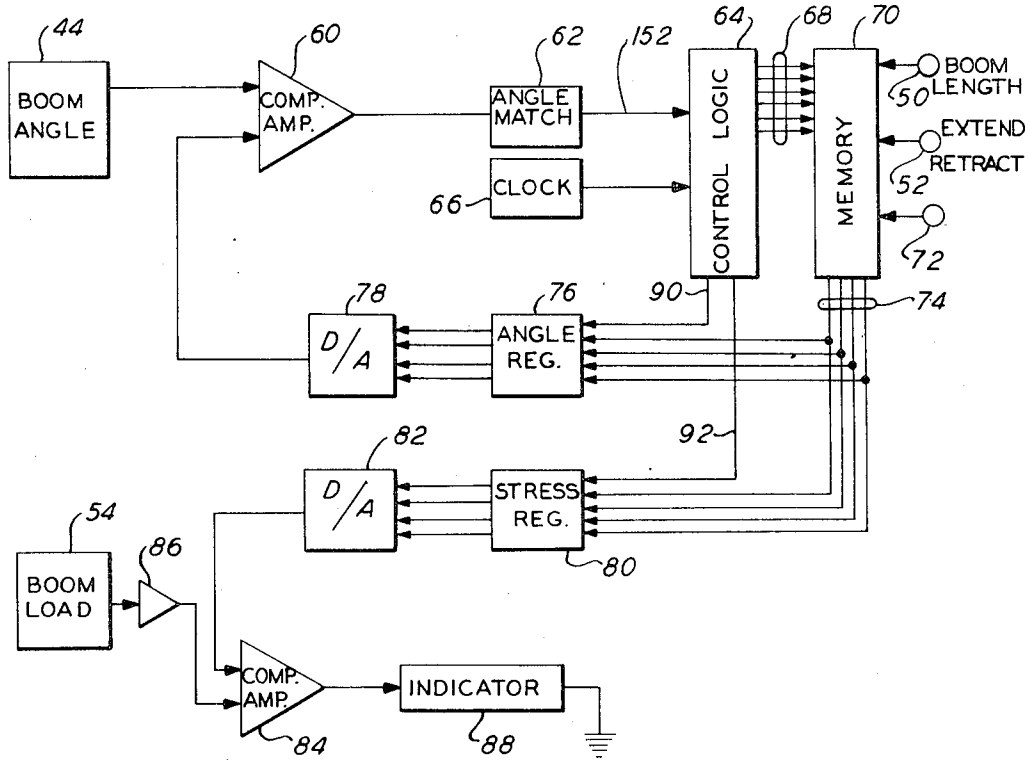
3,638,211	1/1972	Sanchez	235/151.33 X
3,534,355	10/1970	Fathauer	340/267 C
3,641,551	2/1972	Sterner et al.	340/267 C
3,505,514	4/1970	Fathauer	235/151.33 X
3,549,876	12/1970	Hamilton	340/267 C X
3,618,064	11/1971	Hamilton	235/151.33 X
3,631,537	12/1971	Zibolski et al.	340/267 C

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[57] **ABSTRACT**

A warning system for load handling equipment is shown capable of warning an operator of the load handling equipment, such as a crane hoist, that his lifted load is about to cause a failure due to the crushing of the boom or tipping of the crane. A memory stores information peculiar to the crane hoist, while control logic selects data corresponding to a set of boom angles and applies the data to a differential amplifier. The amplifier compares the selected angles against the actual boom angle and applies an indicating signal to the control logic as the selected angle matches the boom angle. The control logic then selects the stored maximum stress for the matched angle and applies this stress through a digital to analog converter to a second differential amplifier where a comparison is made with a stress generated by the lifted load. As the load approaches its maximum, an alarm circuit provides a warning to the equipment operator.

12 Claims, 9 Drawing Figures



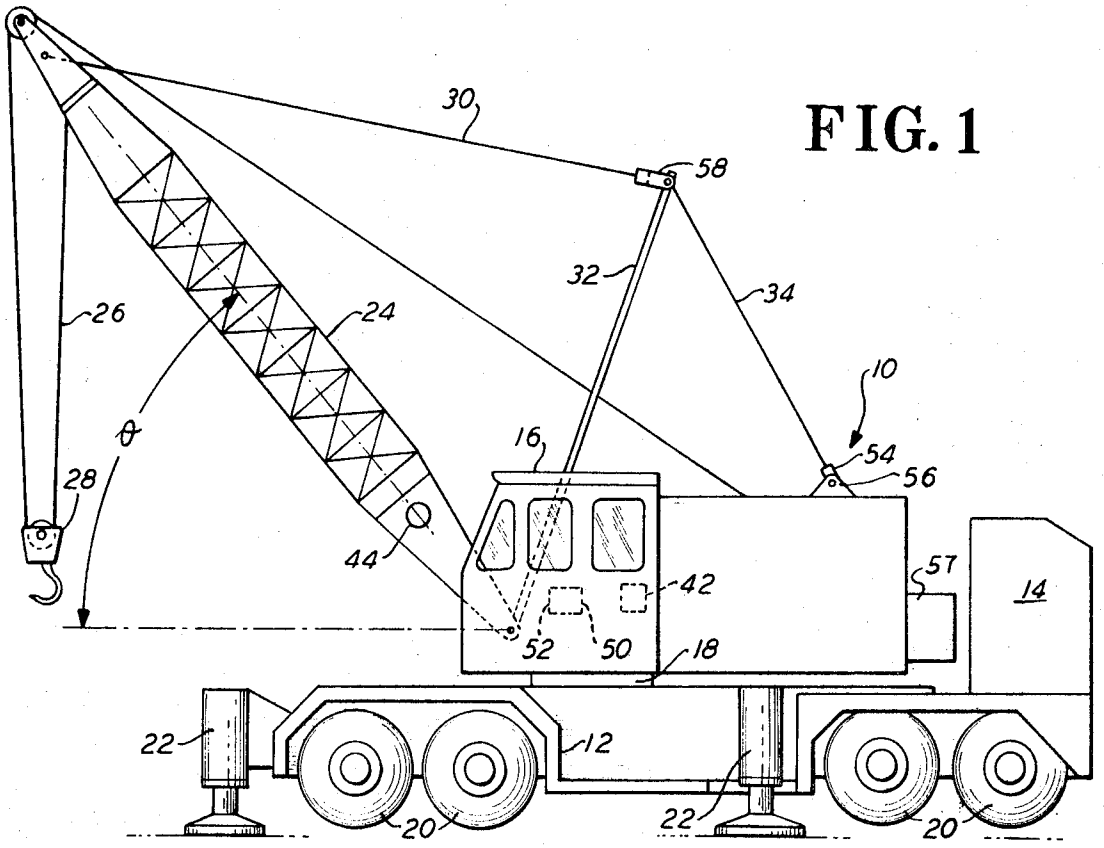


FIG. 1

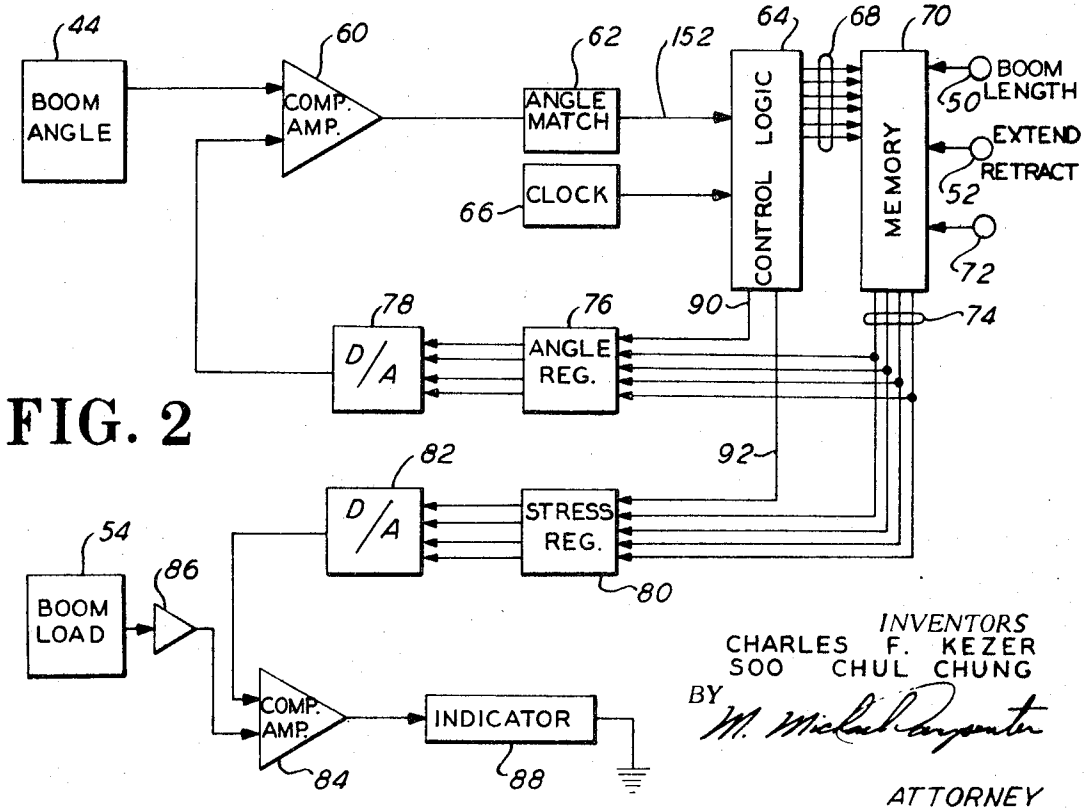


FIG. 2

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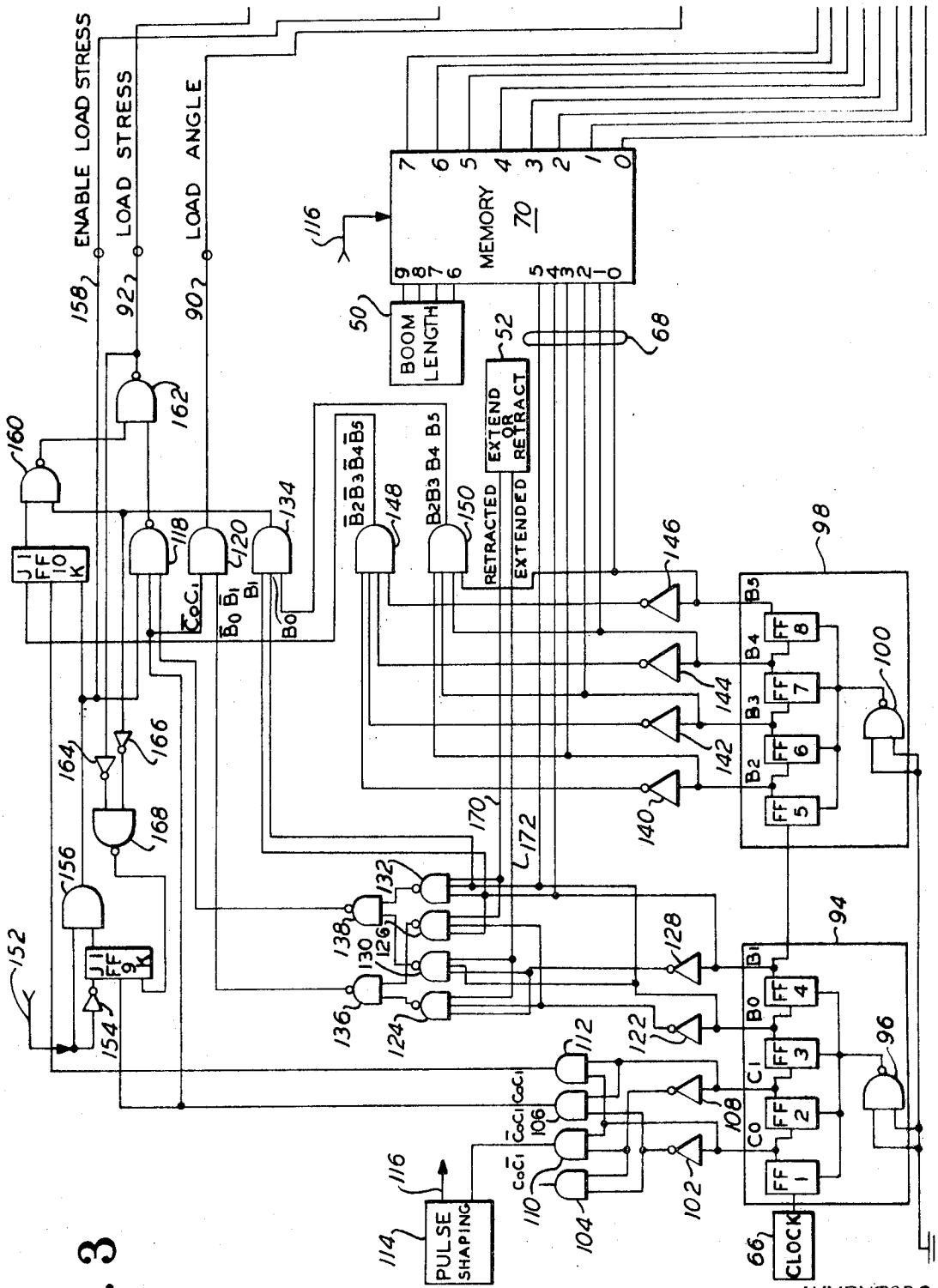


FIG. 3

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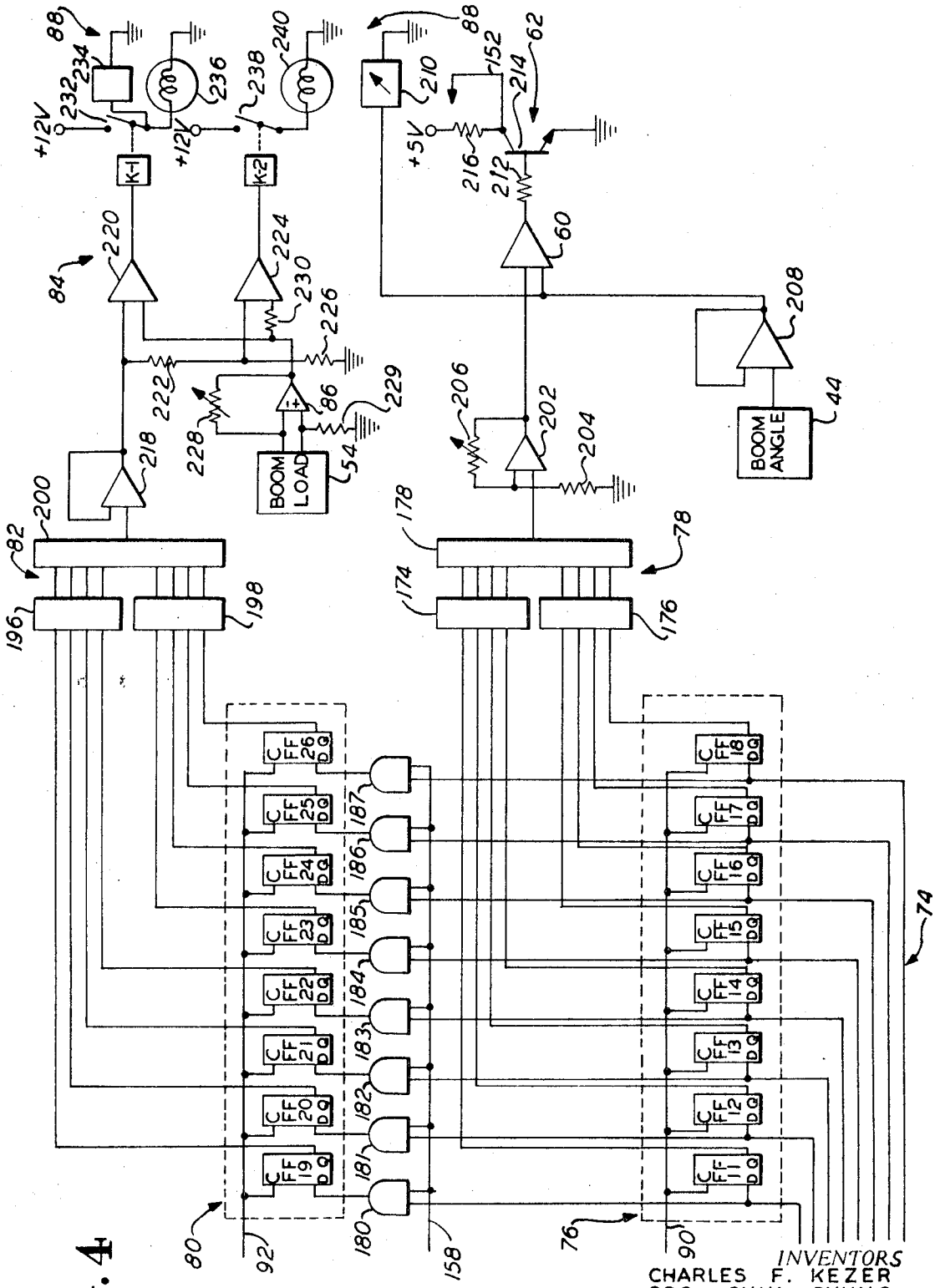


FIG. 4

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FIG. 5

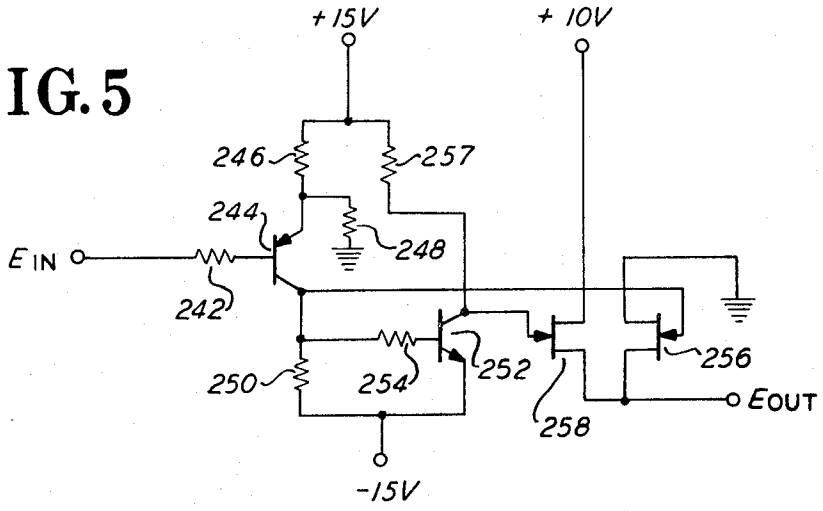
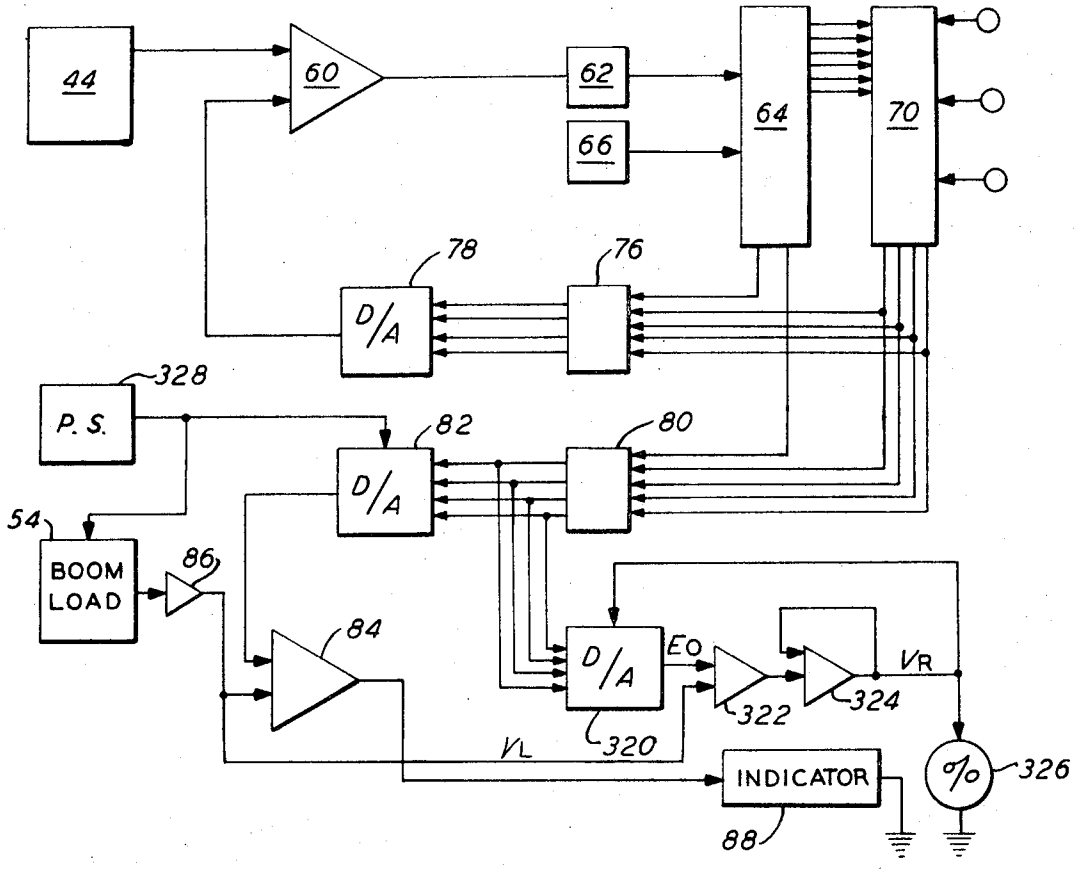


FIG. 8



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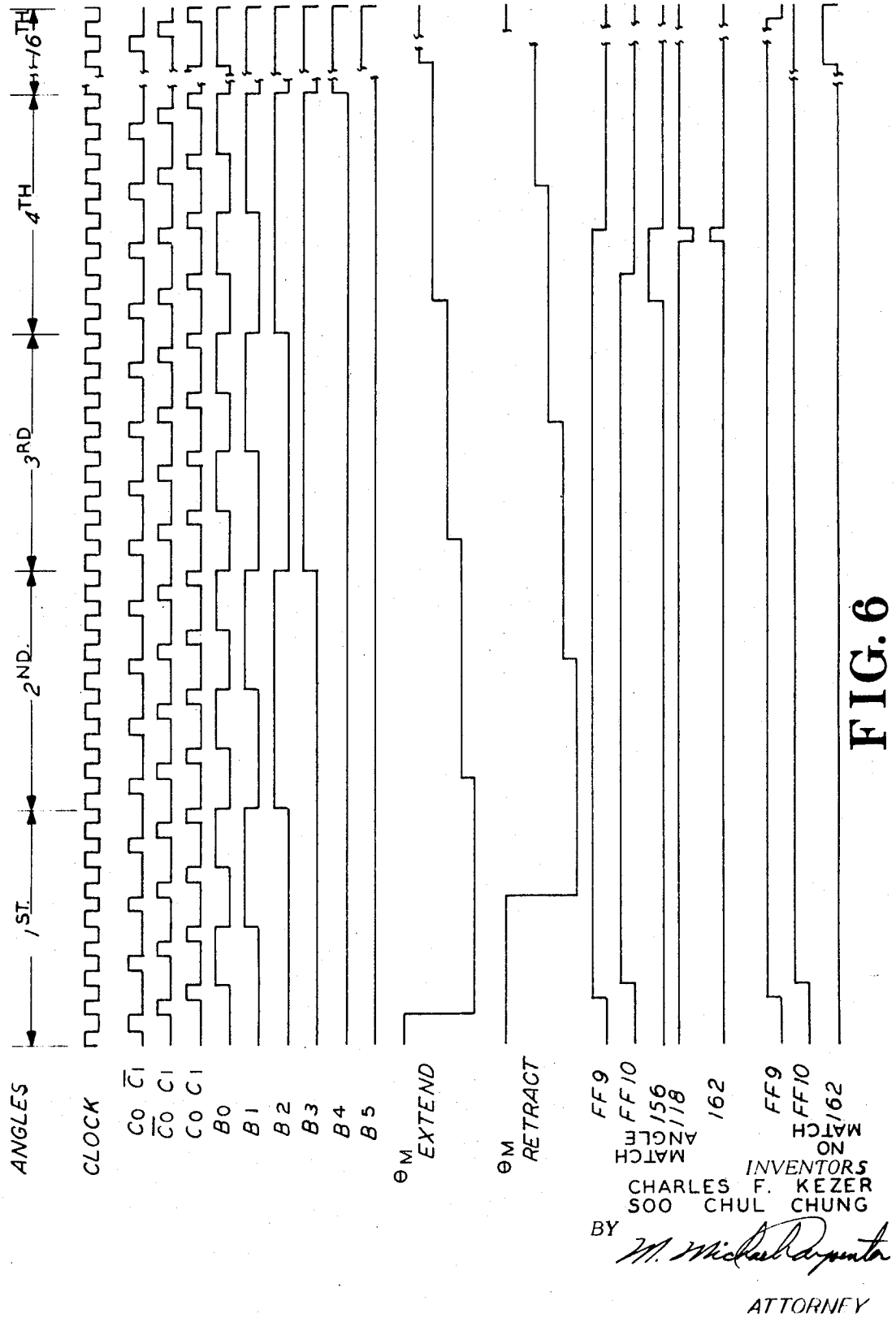
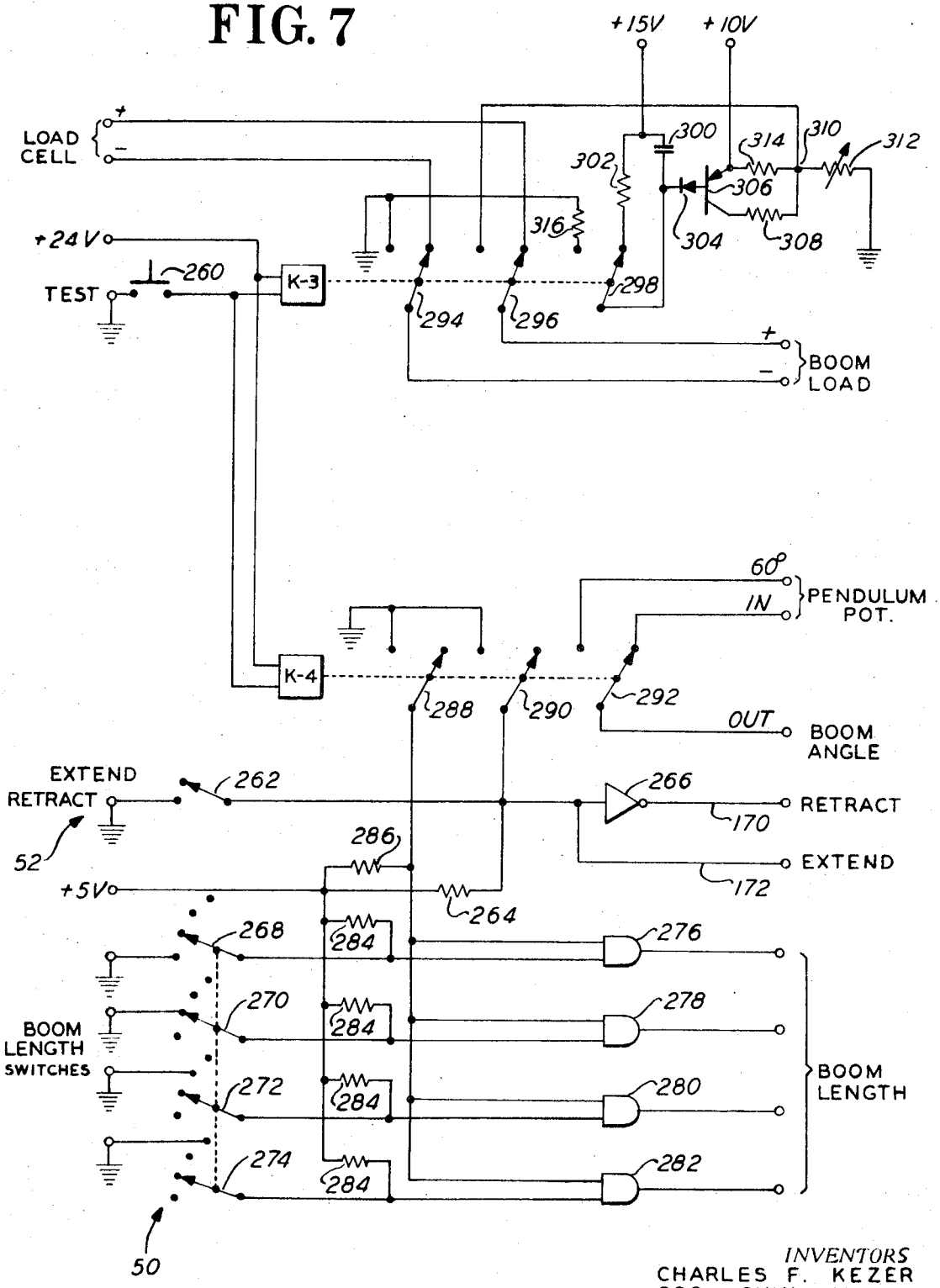

ANGLES
1ST.
2ND.
3RD.
4TH
11/6TH
CLOCK
Co C̄1
C̄o C1
Co C1
Bo
B1
B2
B3
B4
B5
θM EXTEND
θM RETRACT
FF9
FF10
MATCH ANGLE 156/118
162
FF9
FF10
MATCH ON 162
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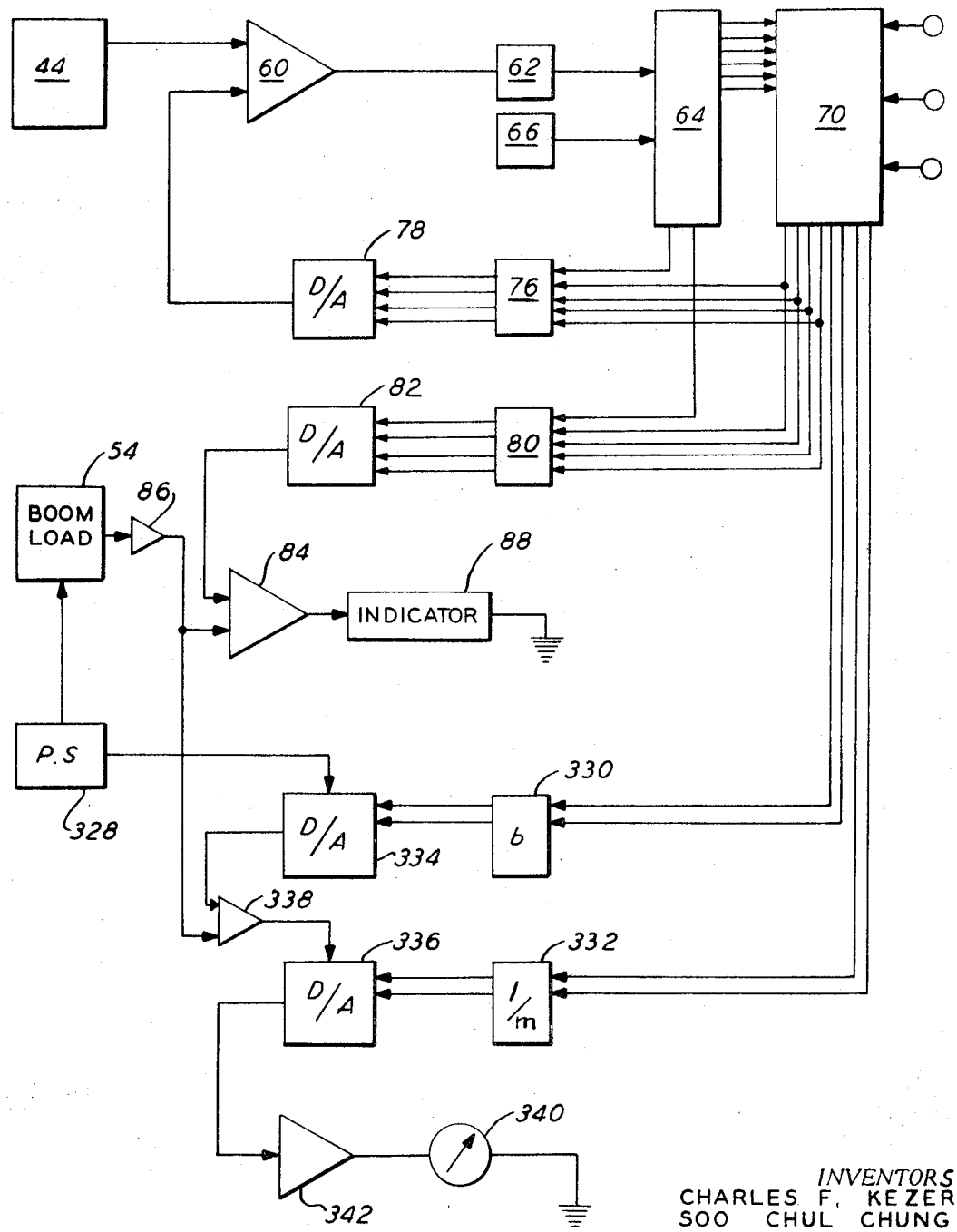
FIG. 6

FIG. 7



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FIG. 9



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WARNING SYSTEM FOR LOAD HANDLING EQUIPMENT

BACKGROUND OF THE INVENTION

The present invention relates to a warning system for load handling equipment and, more particularly, to a warning system for load handling equipment such as a crane warning system for use within a crane hoist that senses various crane parameters during the lifting of a load for providing a warning signal to the operator of the crane as the crane approaches a dangerous condition.

It is well known in the prior art to provide load handling equipment including cranes with safety or warning systems in various forms. For example, one crane safety device, shown in U.S. Pat. 2,858,070, by Schaff, provides a crane with load and angle measuring sensors which are used to compute the moment of the crane and generate a warning signal when the crane is in danger of overturning. The Schaff device utilizes analog signals to provide a computation of the lifting moment. This device has several limitations; for example, the moment generated by the load is a function of the variable length of the crane boom and is not accounted for within the analog system measuring only load and boom angle. Secondly, when the boom is in a near vertical position, the maximum lifting ability of a crane may be limited by the strength of the boom itself. In this near vertical position, the boom is in danger of crushing under the stress of a lifted load. Further, the crane is in danger of tipping backwards, a circumstance which has cost more than one life of a crane operator. Warning the operator of a possible tipping condition in the forward condition alone, therefore, will not provide the operator with suitable information necessary for his safety, the safety of those working around him, or the safety of his equipment. Finally, the conditions which cause the boom of a crane to tip or crush do not follow straight line functions and do not readily lend themselves to computations by typical analog devices of the prior art.

Some of these problems were presented along with a solution in a pending patent application, Ser. No. 864,728, filed Oct. 8, 1969, by Albert A. Sanchez, entitled Crane Safety System, now U.S. Pat. No. 3,638,211. This crane safety system uses a memory which stores stress and angle information peculiar to the crane in which it is being utilized. The boom angle is converted from an analog signal to a digital signal and applied to control and process units where it is matched against a stored angle. Once the measured boom angle has been matched as closely as possible to the stored boom angle, the maximum stresses for the stored boom angles on the high and low side of the measured angle are presented to the process unit by the control unit which interpolates these values and provides a digital output representing the maximum interpolated stress for the measured boom angle. This digital information is then converted to an analog signal where it is compared against an analog input signal representing the boom load. An alarm is actuated as the signal representing the boom load approaches the signal representing the maximum stress. This arrangement, while functioning adequately, requires a control and process unit capable of conducting the needed interpolation. It is also necessary to convert the boom angle from an analog to a digital signal for use during interpolation. The requirements for conversion and interpolation complicate the logic required within the control and process units of the system and add to the construction cost of the crane warning system.

SUMMARY OF THE INVENTION

The present invention eliminates these disadvantages by providing a simplified arrangement utilizing a read only memory which requires no data manipulation or interpolation. The crane warning system of the present invention eliminates the need for analog to digital converters, reduces the number of control components required, simplifies the control logic, and simplifies the memory required. Further, the simplified warning system is more easily adaptable to modification and variations. For example, th present system is provided with a test circuit which automatically tests the operability of the system by the simple push of a buttom.

Accordingly, it is an object of the present invention to provide an improved crane warning system that is capable of warning a crane operator of an impending failure.

Another object of the invention presented herein is to provide a crane warning system which utilizes fewer components than prior warning systems, which requires a simplified memory and logic arrangement wherein the stored data is not converted or otherwise manipulated, and which eliminates the necessity for conversion of the input data.

A further object of the invention presented herein is to provide a crane warning system with simplified self testing circuitry, with an indicating means for indicating the percent of safe load being lifted, and with means indicating the weight of the lifted load.

In accomplishing these and other objects, there has been provided a read only memory which is addressed by control logic for selecting and reading out a series of stored angles. Each stored angle is compared with the measured boom anlge until a matched angle is found. The control logic then selects and reads out the maximum stress for the matched boom angle which is compared with the measured boom load. If the measured boom load is within a predetermined range of the stored maximum stress, an indicating signal is applied to the control panel of the crane warning system for warning the operator.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present invention and of the objects and appendant advantages thereof will be obtained by reference to the following description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a side elevational view, showing a crae hoist in which the crane warning system of the present invention may be utilized;

FIG. 2 is a schematic block diagram, showing the circuitry of the crane warning system;

FIG. 3 and 4 are schematic diagrams, showing the circuitry of the present invention in greater detail;

FIG. 5 is a schematic diagram, showing the switching circuitry of FIGS. 3 and 4 in more detail;

FIG. 6 is a timing diagram, illustrating the switching sequences of the control logic;

FIG. 7 is a schematic diagram, illustrating the test circuitry of the present invention; and

FIG. 8 and 9 are schematic block diagrams, similar to FIG. 2, incorporating circuitry for indicating the load as a percentage of maximum safe load and for measuring and indicating the load in pounds.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIG. 1 shows a crane 10 having a crane transportation system including, in this illustration, a truck frame 12 and truck cab 14. A crane cab 16 which houses the operator and his controls is rotatably mounted upon the truck frame 12 by means of a turn table bearing plate 18. The truck frame 12 is normally transported upon crawler treads or drivable tires 20. If the crane 10 is mounted on drivable tires, it may be operated either on the tires 20 or on outriggers 22 which, when extended, increase the lifting capacity thereof. If the crane 10 is mounted upon crawler treads, the treads may be extended to increase the lifting capacity in a manner similar to the extension of the outriggers 22. A boom structure 24 is hinged at the base of the crane cab 16 from which a weight hoist cable 26 may be rigged. The end of the hoist cable 26 may be equipped with a suitable hook block, sling, clamsheel, dragline, or magnet shown at 28 as a hook block driven from a cable drum, not shown, to provide lifting capacity.

The boom structure 24 is lifted by a gantry hard line 30 attached to a gantry strut 32 that, in turn, is connected to the crane cab 16 by a gantry hoist cable 34. The angle between the center line of the boom structure 24 and the horizontal plane is referred to herein as the vertical boom angle θ.

The vertical boom angle θ is measured by a boom angle sensor 44 including a pendulum potentiometer mounted within a housing on the boom structure 24. The pendulum potentiometer consists of a weighted wiper arm mounted within an oil filled housing for contacting a slide wire mounted therein. The oil provides motion damping as the weighted wiper arm moves to orient itself in a downward pointing direction. The wiper arm thus generates an analog signal which represents the boom angle θ. A boom length sensor 50 consisting of a multiposition switch adjusted by the operator to correspondence to the length of the boom 24 is mounted within the crane cab 16 to provide a digital input to a memory within the crane warning system circuitry. An extended or retracted sensor 52 may be also located within the crane cab 16 in the form of a two position switch. In the alternative, this switch could be located in the area of the outriggers 22 and arrange to function automatically depending upon the extended or retracted position thereof. A boom load sensor 54 including a load cell constructed from a plurality of strain gages arranged in a wheatstone bridge circuit may be mounted within the back hitch pin 56 which connects the gantry hoist cable 34 to a counter weight 57 mounted on the cab 16. The boom load sensor 54 could alternatively be located within the clevis 58 which connects the gantry hard line 30 to the gantry strut 32.

The circuitry that forms the crane warning system is shown generally in FIG. 2 wherein the boom angel sensor 44 is connected to the input stage of a comparator amplifier 60 whose output stage is connected through an angle matching circuit 62 to a control logic circuit 64. The control logic circuit 64 is synchronized by clock pulses generated by a clock 66 connected thereto. The output of the control logic circuit 64 includes a plurality of memory address lines 68 over which digital bit information is addressed to a read only memory 70. The read only memory 70 stores angle and stress information relating to various crane operating conditions. The boom length sensor 50 and the extended or retracted sensor 52 apply digital information to the read only memory 70 for limiting the selection of the boom angle and stress information stored therein to the conditions applied thereto. Other crane condition sensors 72 may also be utilized to limit the selection of information from the read only memory 70, such as a sensor for sensing the quadrant in which the boom 24 is operating or a sensor for sensing the type of counterweight that is being used. The output of the memory 70 is applied by digital output lines 74 to a first shift register 76 for storing angle information whose output, in turn, is applied through a first digital to analog converter 78 to the input stage of the comparator amplifier 60.

The digital output lines 74 are also connected to a second shift register 80 from which signals representing the maximum stress are applied to a second digital to analog converter 82. The analog output of a digital to analog converter 82 is applied to the input stage of a comparator amplifier or differential amplifier 84. The boom load sensor 54 applies an analog signal generated by the load cell therein via a load cell amplifier 86 to the second input terminal in the input stage of the differential amplifier 84. The output stage of the differential amplifier 84 connects to an indicator or control panel 88 and then to ground. The indicator 88 provides an indication to the operator of the crane when the load sensed by the boom load sensor 54 approaches the maximum load stored within the memory 70.

In operation, the boom length sensor 50 and the extended or retracted sensor 52 select the appropriate portion of the read only memory 70 which is to be sequentially applied to the shfit registers 76 and 80. The control logic 64 sequentially applies a series of stored, increasing angles to the angle register 76 under the control of signals generated over a load angle line 90 connected to the angle shift register 76. The angles sequentially stored within the register 76 are applied by the digital to analog converter 78 to the input stage of the comparator amplifier 60. When the stored angle becomes greater than the boom angle, the output of the comparator amplifier 60 applies a signal to the angle matching circuit 62. This signal initiates a laod stress signal within the control logic 64 via a laod stress line 92 to the stress shift register 80. The digital signals loaded within the register 80 are then converted by converter 82 to analog signals and compared by the differential amplifier 84 with the measured load from the boom sensor 54. As the measured load from boom sensor 54 becomes substantially equal to the load represented by the stress stored within the memory 70, the differential amplifier 84 applies a signal to the indicator 88 which, in turn, warns the operator of the dangerous condition.

The details of the circuitry shown generally in FIG. 2 are shown more completely in FIGS. 3 and 4. In FIG. 3, clock 66 is connected to the clock terminal of a first JK flip-flop FF1 whose 1 output terminal connects to the clock terminal of a second JK flip-flop FF2 in turn connected to flip-flops FF3 and FF4. These flip-flops

are mounted within a first counter 94 and are mutually connected to ground by a NAND gate 96. The 1 output terminal of flip-flop FF4 is connected to the clock input terminal of flip-flop FF5 arranged within a second counter circuit 98 including flip-flops FF5-FF8 connected internally in an identical manner to the first counter 94 and to ground via a NAND gate 100. Through this counter arrangement, the circuit logic is driven by clock pulses which are generated by the first two flip-flops FF1 and FF2 including C_0 from the 1 output of FF1 and C_1 from the 1 output of FF2. The remaining six flip-flops FF3-FF8 generate command pulses over the memory address lines 68 to address the memory 70 wherein the various angles stored therein are sequentially selected and read therefrom. In the preferred embodiment, the angles include 16 angles which are sequentially read from the memory 70.

The 1 output terminal of FF1 is connected through an inverter 102 to the input terminals of AND gates 104 and 106, while the 1 output terminal of FF2 is connected through an inverter 108 to the second input terminal of the AND gate 104 and first input terminal of AND gate 110. The noninverted signal C_0 from flip-flop FF1 is connected to the second input terminal of AND gate 110 and the first input terminal of an AND gate 112. Similarily, output C_1 of flip-flop FF2 is connected directly to the second output terminals of AND gate 106 and AND gate 112.

The output of AND gate 110, $C_0 \overline{C}_1$, is applied to the input terminal of a pulse shaping circuit 114 which consists of a one shot multivibrator for shortening the pulse applied thereto and applies the pulse from the output terminal thereof via a conductor 116 to the input terminal of the read only memory 70. This signal is utilized to initiate the sequential cycling of the memory. The output of the AND gate 106 conducts the signals $\overline{C}_0 C_1$ to the clock terminal of a JK flip-flop FF9, to the first input terminal of a NAND gate 118, and to the first input terminal of an AND gate 120. The output of AND gate 112, $C_0 C_1$, is applied to the clock terminal of a JK flip-flop FF10.

The 1 output terminal of flip-flop FF3 connects the signal B_0 through an inverter 122 to the input terminal of a NAND gate 124 and a NAND gate 126, while the output of flip-flop FF4 connects the signal B_1 through an inverter 128 to the input terminal of the NAND gate 124 and a third NAND gate 130. The noninverted output of flip-flop FF3 is connected to a second input terminal of NAND gate 130, a first input terminal of a NAND gate 132, the first input terminal of an AND gate 134, and an input terminal 5 of the read only memory 70. Similarily, the noninverted output signal of flip-flop FF4 connects to the input terminals of NAND gates 126 and 132, to the second input terminal of AND gate 134, and to the input terminal 4 of read only memory 70. The outputs of NAND gates 124 and 126 are connected to the first and second input terminals of a NAND gate 136 whose output signal controls the load angle timing and connects to the second input terminal of AND gate 120. In the same manner, the outputs of NAND gates 130 and 132 connect to the input terminals of a NAND gate 138 whose output signal controls the load stress timing and connects to the second input terminal of a NAND gate 118.

The outputs of flip-flops FF5-FF8; B_2,B_3, B_4, B_5, are connected through inverters 140, 142, 144 and 146, respectively, to the four input terminals of an AND gate 148. Similarily, the noninverted outputs of these flip-flops are connected directly to the four input terminals of a second AND gate 150. Through these connections, the AND gate 148 provides a timing signal which is high or positive only during the first of the 16 sequential angles; while the AND gate 150 provides a timing signal which is high only during the last or 16th angle of the sequential set of angles. The output of AND gate 148 connects to the J input terminal of the flip-flop FF10 while the output of AND gate 150 connects to the third input terminal of AND gate 134.

The J input terminal of flip-flop FF9 receives a feedback signal from the angle matching circuitry 62 over matched angle line 152 through an inveer 154. inverter 1 output terminal of the flip-flop FF9 is connected to the input terminal of an AND gate 156 whose second input terminal connects to the matched angle line 152. The output of AND gate 156 connects to the K input terminal of flip-flop FF10, the third input terminal of AND gate 118, and over an enable load signal line 158 to the input stage of the stress register 80. The 1 output terminal of flip-flop FF10 connects to the first input of an NAND gate 160 whose second input is connected to the output of AND gate 134. The output of NAND gate 160 connects to the input of a NAND gate 162 whose second input terminal is connected to the output of the NAND gate 118. The output of the NAND gate 162 connects to the load stress line 92 which also connects to the stress register 80. The signal from NAND gate 160 is utilized to reset the flip-flop FF9 through NAND gate 162 having the output thereof connected to the input terminal of an inverter 164. A second inverter 166 receives the timing signal from the AND gate 134 and applies this inverted signal to the input terminal of an NAND gate 168 whose second input terminal is connected to the inverter 164. The output of NAND gate 168 is connected to the K input terminal of flip-flop FF9. The signal applied over this circuit is utilized to reset the flip-flop FF9 after the boom angle has matched the stored memory angle or, if there is no match, during the 16 th angle.

The extended or retracted sensor 52 will be described in greater detail hereinbelow with regard to FIG. 7. However, it should be noted here that the extended or retracted sensor 52 includes a retracted signal line and an extended signal line, 170 and 172 respectively. The retracted signal line 170 connects to the third input terminals of NAND gates 126 and 132, while the extended signal line 172 connects to the third input terminals of NAND gates 124 and 130. The signals over the extended or retracted lines, 170 and 172, are utilized to enable NAND gates 124, 130 or 126, 132 depending on whether the crane is being operated with its tires or crawler treads extended or retracted. It will be seen that the signals B_0 and B_1 from flip-flops FF3 and FF4, respectively, are used to establish the timing utilized to address the extended or retracted condition to the memory which, in the preferred embodiment, includes stored angle and stress information for each extended or retracted condition. The noninverted signals B_2, B_3, B_4 and B_5 are connected over lines 68 to the input terminals 3, 2, 1 and 0, respectively, of the read only memory 70. These signals are utilized to select the proper angle during the sequential selection of the angle and stress information from the memory.

As mentioned hereinabove, the read only memory 70 receives a memory initiate signal over the conductor

116. The selection of the total information stored within the memory is limited by the digital input received from the boom length sensor 54 which is connected to the input terminals 6–9 thereof. This digital information disables a large portion of the memory and enables only that portion thereof relating to the length of the boom being immediately utilized by the crane. In the preferred embodiment, the angle and or stress information is stored within the memory for both extended or retracted conditions and one condition or the other is selected from the memory under the control of the extended or retracted sensor 52. As each angle is selected from the memoroy under control of the digital input received at input terminals 0–5, the information representing that angle is read out from output terminals 0–7 over digital output lines 74 to the input terminals of the first shift register 76 utilizing FF11–FF18 for storage. The shift register 76 is ideally suited for use as a digital storage of binary information between the read only memory 70 and the digital to analog converter 78. Information presented at each data input D of the register 76 is transferred to the Q outputs when the clock, applied over line 90, is high. The Q outputs will follow the data inputs D as long as the clock remains high. When the clock goes low, the information present at the data inputs D at the time the transfer occured, is retained at the Q outputs until the clock is permitted to go high. In the arrangement shown here, the data terminals D are connected to the output terminals of a memory unit 70 while the Q terminals are connected to the input terminals of FET switching circuits 174 and 176. The internal circuitry of the FET switching circuits is shown in greater detail in FIG. 5. The output from these FET switching circuits 174 and 176 is applied to the input of a resistive ladder network 178.

The digital output lines 74 from the read only memory 70 are also connected directly to the input terminals of AND gates 180–187. The second input terminal of each of the AND gates 180–187 is connected to the enable load signal line 158, wherein information stored within the read only memory 70 is passed through the AND gates 180–187 when a positive signal is applied over the enable load signal line 158. The output of each of these AND gates 180–187 is applied to the data input terminals D of the second shift register 80 which is comprised of flip-flops FF19–26. The clock terminal of each of the flip-flops FF19–26 is connected to the load stress line 92. A positive signal over this line transfers the data received from the AND gates 180–187 to the digital to analog converter 82 which consists of third and fourth FET switching circuits 196 and 198 connected to the input of a ladder resistive network 200.

The output of the first ladder resistive network 178 is connected to the first input terminal of an amplifier 202 whose second input terminal is connected by a resistor 294 to ground. The output terminal of the amplifier 202 connects through a variable feedback resistor 206 to the second input terminal thereof. This amplifier functions as a booster amplifier to increase the voltage and current outputs of the resistance ladder network 200 and completes the circuit of the first digital to analog converter 78. The output of amplifier 202 connects to the inverting input terminal of the comparator amplifier 60. The boom angle sensor 44 is connected to the input terminal of a current amplifier 208 whose output terminal connects in feedback relationship to the second input terminal thereof. The output terminal of the current amplifier 208 is further connected to the noninverting input terminal of the comparator amplifier 60 and to the input terminal of a current meter 210. The current meter 210 mounts on the indicator panel 88 and is provided with a scale for indicating the boom angle θ of the boom structure 24. Comparator amplifier 60 connects via resistor 212 to the base of an NPN transistor 214. The collector of transistor 214 is connected to a +5 volt power source via a resistor 216 while the emitter thereof is connected to ground. The matched angle line 152 is connected to the junction between the collector of transistor 214 and the resistor 216 for providing a signal to the input of flip-flop FF9 and AND gate 156. Thus, it will be seen that the angle matching circuit 62 includes the transistor 214 and resistors 212 and 216.

The output of the resistive ladder network 200 is connected to the input terminal of a unity gain amplifier 218 having the output thereof connected to a second input terminal in a feedback arrangement. The output terminal of the amplifier 218 also connects to the inverting input terminal of a comparator amplifier 220 and through a resistor 222 to the inverting input terminal of a second comparator amplifier 224. The inverting terminal of amplifier 224 is connected to ground through a resistor 226. The output from the boom load sensor 54 includes a positive and negative terminal connected to the positive and negative input terminals of the load amplifier 86 having an output terminal connected through a variable resistor 228 to the negative input terminal thereof and the positive terminal connected to ground through resistor 229 for providing a high gain amplifier. The output terminal of the load amplifier 86 is also connected directly to the second noninverting input terminal of the comparator amplifier 220 and through a resistor 230 to the second noninverting input terminal of the second comparator amplifier 224. The output of the first comparator amplifier 220 connects to a relay K-1 which, when actuated, closes a single-pole, single-throw switch 232 for applying a positive voltage to a warning buzzer 234 and an overload lamp 236. Similarily, the output of the second comparator amplifier 224 connects to a relay K-2 which closes a second single-pole, single-throw switch 238 for applying a positive voltage to a caution lamp 240. In the preferred embodiment, the combination of resistors 222, 226 and 230 provides a resistive network wherein the relay K-2 is energized when the actual load reaches 85 percent of the stress signal stored within the read only memory 70. Relay K-1 is energized when these signals are equal.

The FET switching circuits 174, 176, 196 and 198 include four individual FET swtiching circuits, shown more clearly in FIG. 5. An input signal E_{IN} is received through a resistor 242 at the base of a PNP transistor 244. The emitter of transistor 244 is connected to a positive potential through a resistor 246 and to ground through a second resistor 248. The collector of the transistor 244 connects to a negative potential through a resistor 250 and to the base of an NPN transistor 252 through a resistor 254. The collector of transistor 244 connects to the gate of a field effect transistor 256 having its drain terminal connected to ground and the source terminal connected to an output terminal E_{OUT}. The collector of the NPN transistor 252 is connected to the positive potential via resistor 257 and to the gate

of a second field effect transistor 258 whose source connects to a positive voltage supply and whose drain connects to the output terminal E_{OUT}. In operation, an increasing input signal at E_{IN} turns off the transistor 244 and applies a decreasing potential to the gate of the FET 256 for removing the output terminal E_{OUT} from its connection to ground therethrough. As the potential decreases at the base of transistor 252, it is turned off for increasing the potential to the gate of the FET 258 for connecting the output terminal E_{OUT} to the positive potential. Through this arrangement, digital outputs from the shift registers 76 and 80 are converted to precise voltage levels for application to the resistance ladder networks 178 and 200.

The operation of the crane warning system illustrated in FIGS. 3 and 4 will be understood more easily by reference to the timing digram of FIG. 6. As mentioned, the clock signal is reduced to signals $C_0 \overline{C}_1$, $\overline{C}_0 C_1$, and $C_0 C_1$ by the counter 94 and AND gates 106, 110 and 112. The signals B_0, B_1, B_2, B_3, B_4 and B_5 which control the angle addressed from the memory are generated by the second portion of the counter 94 and the second counter 98. Each of the 16 sequential angles are read out of the read only memory 70 to the angle register 76 under the control of the signals from the counters 94 and 98. Assuming the crane crawler treads or outriggers are extended, NAND gates 124 and 130 are enabled while NAND gates 126 and 132 are disabled. Thus, the $\overline{B}_0 \overline{B}_1$ signal is applied to the AND gate 120 through NAND gate 136; while the $\overline{C}_0 C_1$ timing signal is also applied thereto. It will be seen that this causes the angle from the memory Θ_M to be read therefrom during the first portion of each of the sequential angles. This signal is applied through the first register 76 to the digital to analog converter 78 under the control of a singnal is also the AND gate 120 applied over the load angle line 90. The digital signal is converted to an analog signal by the resistive ladder network 178 as indicated by the signal Θ_M extend, shown in FIG. 6. It will be remembered that the angle signal applied to the comparator amplifier 60 will be either Θ_M extend or retract depending on the position of the extended or retracted sensor 52 which enables or disables the gates 124, 126, 130 and 132.

As the memory angle is sequentially read from the read only memory 70, the analog output signal applied from the amplifier 202 to the comparator amplifier 60 increases to represent increasing stored boom angles θ_M. When the stored boom angle becomes equal to or greater than the actual boom angle, the output signal of th amplifier 60 will decrease to a zero level thereby turning off the transistor 214 and applying a high potential over the matched angle line 152 to the inverter 154 and AND gate 156. In the example illustrated in FIG. 6, this occurs during the fourth sequential angle.

During the initiation of each cycle of 16 sequential angles, the first angle read into the shift register 76 normally produces a low output from the angle matching circuit 62 which is applied over line 152 to the AND gate 156 and inverted by the inverter 154 to be applied as a high signal to the J input terminal flip-flop FF9. As the clock signal $\overline{C}_0 C_1$ is applied to the clock terminal of flip-flop FF9, the output at the 1 terminal thereof goes high on the trailing edge of the timing signal, see FIG. 6. This high in combination with the low from line 152 causes the output of the AND gate 156 to remain low. When the angles are matched, the low signal on line 152 goes high for applying a second high to the input of AND gate 156 and causing the output thereof to go high, as shown in the fourth angle of FIG. 6.

During the first angle of the 16 angle sequence, flip-flop FF10 receives at the J input terminal a positive signal from the AND gate 148. Thus, the 1 output terminal goes high when the trailing edge of the timing signal $C_0 C_1$ is applied from the AND gate 112 to the clock terminal of flip-flop FF10, as shown in FIG. 6. As the angles are matched, the resulting positive signal applied to the K input terminal of flip-flop FF10 causes that flip-flop to toggle on the negative going edge of the timing signal $C_0 C_1$ for producing a zero output at the 1 terminal. The low applied to the input of the NAND gate 160 combines with the low applied to the other input terminal from the NAND gate 134. As the gate 160 is a NAND gate, it will be seen that the change from high to low at the 1 output terminal of flip-flop FF10 causes no change in the output of the NAND gate 160, due to the continuous presence of a low on the second input terminal thereof. The low on the second input terminal of the NAND gate 160 is generated from the AND gate 134, and it will be seen that the AND gate 134 goes high only during the last quarter of the sixteenth angle when the signal $B_0 B_1 B_2 B_3 B_4 B_5$ is applied to the input terminal of the NAND gate 160. This signal is utilized for the prupose of resetting the flip-flop FF9 and alarming should there be no match between the stored angles and the anles within the memory 70. When a matched angle is present, flip-flop FF10 prevents the signal from AND gate 134 from affecting the NAND gate 162 during the 16 th angle.

As the boom angle is matched with the memory angle, the positive output of the AND gate 156 is applied to the input terminal of the NAND gate 118 along with the timing signals $\overline{C}_0 C_1$ and the signals $B_0 \overline{B}_1$. The $B_0 \overline{B}_1$ signal is applied through the NAND gate 130 which is enabled by the high signal applied over the extended signal line 172, as hereinabove described. Thus, the output of the NAND gate 118, which is normally high, goes low as the timing signals $\overline{C}_0 C_1$, $B_0 \overline{B}_1$ and the high from the AND gate 156 are applied thereto. As shown in FIG. 6, the output of the NAND gate 162 goes high as the input from the NAND gate 118 goes low. It will be recalled that the input from NAND gate 160 remains high.

The output from the AND gate 156 is also applied as a positive signal over the enabled load stress line 158 to the AND gate 180–187. It will be seen that the AND gates 180–187 are thereby enabled depending upon the digital stress information applied thereto from the memory 70. When the load stress signal, as shown on line 162 FIG. 6, is applied over the load stress line 92 to the clock terminals of flip-flops FF19–FF26 within the stress register 80, the stress information then applied to the data terminal D of these flip-flops is read into the FET switching circuits 196 and 198 within the second digital to analog converter 82. The signal is then applied through the resistive ladder network 200 to the unity gain amplifier 218 and the comparator amplifiers 220 and 224. If the analog signal applied thereto is equal to or less than the analog signal applied from the boom load sensor 54, the output of the comparator amplifier 220 will energize the relay K-1 for closing the switch 232 and energizing the buzzer 234 and light 236 in the indicator panel 88. If the stress signal from the converter 82 is within a fixed proportion of the stress

signal applied by the boom load sensor 54, the output of the amplifier 224 will energize relay K-2 for closing the switch 238 and energizing the caution light 240. The ratio between the boom load at which the caution light 240 is energized and that required to energize light 236 is determined by the resistance network established by resistors 222, 226 and 230. It will be seen that the meter 210 within the indicator panel 88 provides a visual indication of the boom angle to the operator of the crane via the connection to the output of amplifier 208.

A crane operator while manipulating a load can place the crane boom at an angle so low that the crane can not safely lift any load or at an angle so high as to create a backward tipping condition. The present invention provides an alarm for either of these conditions by alarming when the boom angle is either less than the lowest stored memory angles, i.e., boom too low, or greater than all stored memory angles, i.e., boom too high.

Should the boom angle be greater than any of the stored memory angles, it will be seen that the signal applied over the matched angle line 152 never goes high. Thus, the output of an AND gate 156 remains low with the result that the output of NAND gate 118 always remains high. Under these circumstances the output of the NAND gate 162 remains high until a timing signal from gate 134 applies a high to the NAND gate 160. As discussed hereinabove, the output of the flip-flop FF10 is high. Thus, the ouput of gate 160 goes low causing the output of gate 162 to go high during the last portion of the sixteenth angle, as shown in FIG. 6. As the ouput of gate 162 goes high, a load stress signal is applied over the line 92 to the stress shift register 80. However, as no enable load stress signal has been applied to the gates 180–187 over the line 158, the signal loaded into the register 80 is an all zero signal and the output applied to the comparator amplifiers 220 and 224 is therefore an analog signal representing a zero load. Obviously, this zero load is less than the boom load for causing an alarm condition which is immediately sensed by the devices within the indicator panel 88. As the output of the AND gate 156 never went high, there was never a high signal applied to the K input terminal of flip-flop FF10 and the output thereof remains high through the next cycle. However, the high from the NAND gate 162 is also applied to the inverter 164 and the NAND gate 168 which receives an input from the AND gate 134 via inverter 166. The normal output of the NAND gate 168 is low and changes to high with either the last portion of the 16 th angle or the high output from NAND gate 162. When this occurs, the high input to the K input terminal of the flip-flop FF9 causes the 1 output terminal to go low as the clock signal C_0 C_1 goes low. It will be seen that the flip-flop FF9 is reset at the very last portion of the 16 th angle in the event that the boom angle and stored angle are never match. When there is a match as described above, the flip-flop FF9 is reset on the negative going edge of the timing pulse C_0 C_1 during the presence of the positive output from the NAND gate 162.

Conversely, if the boom angle is less than the first memory angle applied to the comparator amplifier 60, the output over the angle matching line 152 would be high. This would apply a low to the J input terminal of flip-flop FF9 causing the output at the 1 output terminal thereof to remain low. The high applied to the AND gate 156 directly from the line 152 causes that gate output to remain low throughout the 16 th sequential angles. Under this circumstance, an alarm condition would occur at the end of the 16 th angle in the same way that an alarm is generated when the boom angle is too large.

The preferred embodiment of the present invention includes a push-to-test button 260, shown in FIG. 7, which is located on the indicator 88. In FIG. 7, the push-to-test circuitry is illustrated along with other details of the crane warning system. For example, the extended or retracted sensor 52 includes a single-pole, single-throw switch 262 whose contact arm is connected to a positive potential through a resistor 264. In the extend position, a positive potential is applied to the extended signal line 172; while an negative signal is applied through an inverter 266 to the retracted signal line 170. When the switch 262 is closed, the normally closed terminal is connected to ground for removing the positive potential from the line 172 and thereby placing a positive or high signal on the retracted line 170.

The boom length sensor 50 is illustrated as a plurality of single-pole, multithrow switches 268, 270, 272 and 274 ganged together such that one pole of each switch is connected to ground for each of the four illustrated switch positions. The wiper arms of switches 268, 270, 272 and 274 are each connected to an input terminal of NAND gates 276, 278, 280 and 282 is connected to a positive potential through a single resistor 286 and to the wiper arm of a switch 288 within a first relay K-4. The normally opened terminal of the switch 288 is connected to ground. When the push-to-test switch 260 is depressed for energizing the relay K-4, the switch 288 connects the input of each of the AND gates 276, 278, 280 and 282 to ground for disabling the boom length sensor 54. This same relay includes a second switch 290 which connects the extended or retracted sensor 52 to ground for ensuring that the output on the extended line 172 is low while the output on the retracted line 170 is high.

The boom angle sensor 44 is connected into the circuit shown in FIG. 7 at the terminals labeled pendulum pot. These terminals include two inputs labeled IN and 60° and an output labeled OUT. In the normal operating condition, the relay K-4 provides a path through which the signal from the boom angle sensor 44, in the form of a signal from a pendulum potentiometer, is applied from the IN terminal, through the switch 292, to the OUT terminal. When the relay K-4 is energized by pushing the push-to-test button, the boom angle OUT terminal is connected to the fixed potential applied at the 60° terminal. Thus, the relay K-4 disables the boom length sensor, places the extended or retracted sensor in the known condition, and places a known condition at the output of the boom angle sensor 44.

The load cell within the boom load sensor 54 is connected to the normally closed terminals of switches 294 and 296 which make up the first and second switches of a relay K-3. The wiper arms of switches 294 and 296 are connected directly to the output terminals of the boom load sensor 54. Thus, under normal operating conditions, the load cell signal passes directly through the push-to-test circuit. Once the push-to-test switch 260 has been energized, the relay K-3 closes switches 294 and 296 for connecting the negative terminal of the boom load sensor to ground through the normally

opened terminal of the switch 294 and connecting the positive terminal of the boom load sensor to a test circuit through the normally opened terminal of the switch 296. This test circuit includes a third switch 298 within the relay K-3. The wiper arm of the switch 298 is connected to one electrode of the capacitor 300 having a second electrode connected to a source of positive potential. The second electrode and positive potential are connected through a resistor 302 to the normally closed terminal of the switch 298. Thus, it will be seen that the capacitor 300 is charged to a fixed potential across the electrodes thereof during the normal operation of the crane. The first electrode of capacitor 300 is also connected to the cathode of a diode 304 whose anode connects to the base of a PNP transistor 306. The emitter of the transistor 306 connects to a source of positive potential while the cathode thereof connects through a resistor 308 to a junction 310 which, in turn, connects to ground through a variable resistor 312. The emitter of transistor 306 is also connected to the junction 310 through a resistor 314. The junction 310 is then connected to the normally opened terminal of the switch 296 to complete the test circuit.

When the push-to-test switch 260 is depressed, the negative terminal of the boom load sensor output is connected to ground and the positive terminal thereof is connected to the junction 310. At the same time, the output of the test circuit is connected to ground through the normally opened terminal of the switch 298 and a resistor 316. The positive potential applied to the emitter of transistor 306 from capacitor 300 causes a first level of potential to be applied to the normally opened contact of the switch 296 over the positive line of the boom sensor to the amplifier 86. As the capacitor 300 discharges through the resistor 316, the transistor 306 is turned off for increasing the potential at the junction 310 and increasing the signal applied over the positive terminal of the boom load sensor. Thus, the push-to-test button establishes a first lower level signal which energizes the caution lamp 240 and provides a second larger output signal which energizes the buzzer 234 and the caution lamp 236. Through this arrangement, an operator may depress the switch 260 and establish that his warning devices within the indicator panel 88 of the crane warning system are properly functioning.

The indicators illustrated in FIG. 2 and FIGS. 3–4 are capable of providing a warning as the lifted load approaches and becomes greater than the maximum load stored within the read only memory 70. FIG. 8 illustrates a circuit which may be embodied within the present invention for providing a percent of safe load indicator. That is, a crane operator can often be assisted by a continuous indication of the remaining lift capacity of his crane. This infomation is helpful, for example, as an operator lowers or raises his boom while manipulating or reaching with a load. Under these dynamic conditions, an arbitrary warning that the crane is approaching a dangerous condition may occur too late for the operator to take corrective action. The presentation of the percentage of safe load information is accomplished in the present invention by unique circuitry which allows for relatively simple manipulation of the existing crane warning system. For example, the output of the stress register 80 in FIG. 8 is applied to a third digital to analog converter 320 and also to the second digital to analog converter 82. This information is converted and applied through a comparator amplifier 322 and a voltage follower amplifier 324 to the input terminal of a percent of safe load indicating meter 326. The signal from the amplifier 324 is also feedback to the digital to analog converter 320 wherein it is used as the reference voltage. A power supply 328 is utilized to provide a fixed voltage reference to the boom load sensor 54 and to the second digital to analog converter 82 each of which are connected to the comparator amplifier 84. The output V_L of the load cell amplifier 86 is applied to the indicator panel 88, as described hereinabove, and is also applied to the second input terminal of the comparator amplifier 322.

In operation both digital to analog converters 82 and 320 take their inputs from the digital values of the maximum safe load stored in the stress register 80. Digital to analog converter 82 operates from the fixed voltage from the power supply 328. The digital to analog converter 320, however, uses as its reference voltage the output voltage V_R of the differential amplifier 322. The amplifier 324 is a unity gain voltage follower amplifier, while differential 322 is a high gain amplifier having a gain of u. The output of the differential amplifier 322 is thus proportioned to the difference between the input voltage V_L from the load cell amplifier 86 and the input voltage E_0 is proportional to the load value L_M contained in the stress register 80 and the reference voltage V_R fedback from the amplifier 324. The reference voltage may be expressed as follows:

$$V_R = (V_L - E_0)\, u$$

V_L is defined as aL where a is the scaling factor and L is the load, and E_0 is defined as bL_M V_R where b is a scaling factor and L_M the maximum stored load for a given crane condition. Thus, substituting these values in the equation above for V_L and E_0 V_R may be expressed as follows:

$$V_R = (aL - BL_M V_R)\, u$$

$$V_R\,(1 + ubL_M) = aLu$$

As the quantity ubL_M is much larger than 1 the equation can be approximated as follows:

$$V_R\, ubL_M = aLu$$

$$V_R = (a/b)\,(L/L_M)$$

a and b can be choosen to make $V_R = 10 \cdot (L/L_M)$ thus the 10 volt full scale meter 326 will read full scale when $L = L_M$ and with the scale marked 0 to 100 percent it will indicate percent of load with respect to the maximum safe load value stored in the memory 70.

A final embodiment of the present invention is shown in FIG. 9 wherein the crane warning system is used to provide a load weight indication. In this arrangement the equation for the back hitch tension is expressed in terms of:

$$BHT = mL + b$$

Where L = load, m = slope and b = back hitch tension at zero load. The quantities m and b are constant for each combination of boom length and boom angle. Therefore, by solving the above equation, it is possible to express the load L in terms of:

$$L=(BHT-b)/m$$

The quantities b and $1/m$ can be stored in an expanded read only memory 70 of the crane warning system along with the values of boom angle and maximum stress.

FIG. 9 illustrates how the load equation can be solved. Two additional registers 330 and 332 are provided for receiving the back hitch tension at zero load b and the inverted slope value $1/m$, respectively. The registers 330 and 332 each connect to a digital to analog converter 334 and 336. The power supply 328 which supplies power to the boom load sensor 54 also provides the fixed reference voltage to the digital to analog converter 334. The output of the digital to analog converter 334 is applied to a comparator amplifier 338 which also receives the amplified input from the boom sensor 54. The output of the comparator amplifier 338 is the quantity BHT—b, i.e., the back hitch tension at zero load subtracted from the actual back hitch tension. This output voltage signal is used as a reference voltage for the digital to analog converter 336 which receives its input from the register 332. The output of the digital to analog converter 336 drives a meter 340 through an amplifier 342. As the output of the digital to analog converter 336 is proportional to both the digital input $1/m$ and the reference voltage from the amplifier 338, its output is proportional to load. The scale on the meter 340 is therefore chosen to allow a 10 volt input to indicate full scale or 100 percent of the rated load of the crane. Thus, it will be seen, that the scale will be adjusted for each condition of the crane and will reflect the load sensed by the boom load sensor 54 in terms of pounds.

A crane warning system has been described herein which is capable of storing a large amount of tabulated information peculiar to the particular crane within which the system is used. This information is then selected from storage by narrowing the portion of the memory in which the information is stored that may be utilized during any given set of crane operating conditions. By storing all the necessary information and selecting only that portion necessary for a given crane condition, the crane warning system of the present invention is capable of instantaneously sensing all conditions of pending crane failure. The memory arrangement of the present invention provides a crane warning system that alarms as the load lifted by the crane exceeds a maximum predetermined value including loads which create a potential tipping of the crane or a potential crushing of the boom. An alarm is further provided if the operator of the crane places the boom in a position too low or too high for the crane he is operating. Further, the crane operator is provided with a crane warning system that warns of pending crane failure through the utilization of circuitry which is capable of alarming before a maximum load is reached, circuitry which indicates a percent of safe load remaining, or circuitry which indicates the load in pound. These circuits are all easily incorporated into the main circuitry of the present invention. There has also been described a simple push-to-test circuit which allows the crane operator to quickly establish that his warning devices are functioning properly.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A warning system for producing a warning signal indicating a condition of failure or approach to failure of load handling equipment, comprising:
- memory means for storing digital data pertaining to discrete operating parameters of said load handling equipment;
- selection means for selecting portions of the stored digital data from within said memory means in dependence upon at least one operating condition of said equipment;
- digital to analog conversion means for converting said selected digital data from within said memory means into analog signals;
- means for generating analog signals representing at least two further operating conditions of said load handling equipment;
- at least two comparator means for receiving and comparing said analog signals converted from selected digital data from said memory means with said generated analog signals representing at least two further operating conditions and producing, without interpolation between discrete values of said stored digital data, a warning signal when the compared signals reach a predetermined relation.

2. A warning system for load handling equipment as claimed in claim 1, additionally comprising:
- said load handling equipment including a crane having a cab mounted boom lifted by cables;
- said means for generating analog signals including load cell means for measuring the load to be lifted by the boom, one of said further operating conditions thus including said load;
- a back hitch pin assembly connecting said crane cable to said crane cab; and
- a pin within said back hitch pin assembly housing said load cell, whereby said warning system may be installed within said crane by changing pins within said back hitch pin assembly and connecting said warning system thereto without connecting externally from said cab.

3. A warning system for load handling equipment as claimed in claim 1, additionally comprising:
- means for generating fixed signals for said analog signals representing said at least one operating condition and for said analog signals representing said at least two further operating conditions of said load handling equipment; and
- switching means for connecting said fixed signals to said warning system including said memory means for establishing a predetermined test sequence to test said warning system including said memory means thereof.

4. A warning system for load handling equipment, comprising:
- memory means for storing data peculiar to said equipment;
- selection means for selecting portions of the stored data from within said memory means and presenting said stored data as sequential sets of output data;
- first holding and converting means for receiving one set of sequentially presented output data;
- first sensing means for sensing one equipment parameter;
- comparing means to which said first holding and converting means and said first sensing means are connected being connected to said selection means for

presenting an output signal thereto when said one set of sequentially presented output data reaches a predetermined proportion of said one equipment parameter;

second holding and converting means for receiving a second set of sequentially presented output data from said memory means after said output signal is presented to said selection means;

second sensing means for sensing a second equipment parameter;

compraing means to which said second holding and converting means and said second sensing means are connected for generating an output warning signal when said second set of sequentially presented output data reaches a predetermined proportion of said second equipment parameter.

5. A warning system for load handling equipment such as a crane, comprising:

memory means for storing data peculiar to said crane including stored data for first and second crane parameters;

sensing means for selecting portions of the stored data within said memory means to reflect present operating conditions of said crane;

logic means for selecting the remaining portions of the stored data within said memory means to selectively provide said data as output data;

first converting means connected to said logic and memory means for converting said output data into a signal representing possible values of said first crane parameter;

first parameter measuring means for generating a first parameter signal;

comparing means connected to said logic means for comparing the signals from said first converting means and said first parameter measuring means and for applying an output signal to said logic means as said compared signals approach each other;

second converting means connected to said logic and memory means for converting said output data into a signal representing maximum values of said second crane parameter as said output signal from said last mentioned comparing means is received by said logic means;

second parameter measuring means for generating a signal representing said second crane parameter; and

comparing and warning means for comparing said signal representing maximum values of said second crane parameter with said signal representing said second crane parameter and for generating a warning as said second crane parameter signal approaches said maximum value of said second crane parameter signal.

6. A warning system for load handling equipment as claimed in claim **5**, wherein:

said sensing means includes a first sensor having switching means for providing logic signals to said logic means for enabling portions thereof and disabling other portions thereof and thereby controlling the selection of said stored data from within said memory means; and

said sensing means further includes a second sensor having switching means for providing logic signals directly to said memory means for controlling the selection of said stored data from within said memory means.

7. A warning system for load handling equipment as claimed in claim **6**, wherein:

said stored data for said first crane parameter is boom angle data;

said stored data for said second crand paprameter is maximum boom load data;

said first sensor is an extended, retracted sensor for generating a digital signal; and

said second sensor is a boom length sensor for generating a plurality of digital signals.

8. A warning system for load handling equipment as claimed in claim **5**, wherein:

said memory means includes a read only digital memory;

said stored data for first and second crane parameters includes stored digital boom angle data and digital maximum load data;

said first crane parameter measuring means includes boom angle measuring means and said second crane parameter measuring means includes load measuring means;

said sensing means include means for disabling portions of said read only digital memory depending upon the sensed crane conditions;

said first and second converting means connected to said logic and memory means include registers for receiving said stored digital data, and digital to analog converters for generating and applying analog signals to said comparing means and said comparing and warning means; and

said comparing means and said comparing and warning means include comparator amplifiers connected for comparing said analog signals and for generating said output signal as the compared analog signals reach a predetermined proportion.

9. A warning system for load handling equipment as claimed in claim **8**, additionally comprising:

said comparing and warning means including two comparator amplifiers;

a resistive network connecting said two comparator amplifiers to said second converting means and said load measuring means;

said warning means further including first and second switching means connected to receive said output signals from said two comparator amplifiers, and first and second indicating means connected to said first and second switching means for providing a first and then a second warning signal as said crane approaches and then reaches a dangerous operating condition.

10. A warning system for load handling equipment as claimed in claim **9**, additionally comprising:

a test circuit including a reference potential, resistive network and delay switching means for generating a first reference signal and a delayed second reference signal; and

switch means for disconnecting said load measuring means from said two comparator amplifiers and instead connecting said test circuit thereto for providing said first reference signal and said delayed second reference signal to said two comparator amplifiers, whereby said first and second indicating means are respectively energized.

11. A warning system for load handling equipment as claimed in claim **8** for further indicating the percentage

of safe load being handled by said crane, additionally comprising:

third converting means including a digital to analog converter connected to receive said signal representing maximum load from said register within said second converting means;

a comparator amplifier connected to receive signals from said third converting means and said load measuring means for comparing said signals;

an indicating device connected to receive the output signal from said last mentioned comparator amplifier; and

said output from said last mentioned comparator amplifier connected to said third converting means for providing a reference voltage thereto, whereby said indicating device indicates percentage of safe load being handled.

12. A warning system for load handling equipment as claimed in claim **8** for further indicating the weight of the load being handled by said crane, additionally comprising:

said memory means for storing digital data peculiar to said crane further including stored slope data and crane cable tension at zero load data;

third and fourth converting means connected to said memory means including registers for repsectively receiving said slope data and said crane cable tension at zero load data and digital to analog converters for generating analog signals representing said slope data and crane cable tension at zero load data;

a comparator amplifier connected to receive said crane cable tension at zero load signal from said third digital to analog converter and connected to receive said signal representing the crane load from said load measuring means, the output of said comparator amplifier thereby equalling the difference between said measured crane load and said zero load;

said fourth digital to analog converter connected to receive said slope data and connected to receive said output from said last mentioned comparator amplifier as a reference potential, the output signal therefrom thereby represents a value proportional to the load being handled; and

indicating means connected to receive said last mentioned output signal for indicating the weight of the load being handled.

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