United States Patent

Sanchez

[15] **3,638,211**

[45] **Jan. 25, 1972**

[54] CRANE SAFETY SYSTEM

[72] Inventor: **Albert A. Sanchez,** Wilmington, Mass.

[73] Assignee: **Litton Systems, Inc.,** Beverly Hills, Calif.

[22] Filed: **Oct. 8, 1969**

[21] Appl. No.: **864,728**

[52] **U.S. Cl.** **340/267,** 212/39, 235/151.33, 235/189, 340/272, 340/282

[51] **Int. Cl.** **B66c 15/00**

[58] **Field of Search** ....340/267 C, 282; 235/189, 151.33, 235/39 MS; 212/39 I

[56] **References Cited**

UNITED STATES PATENTS

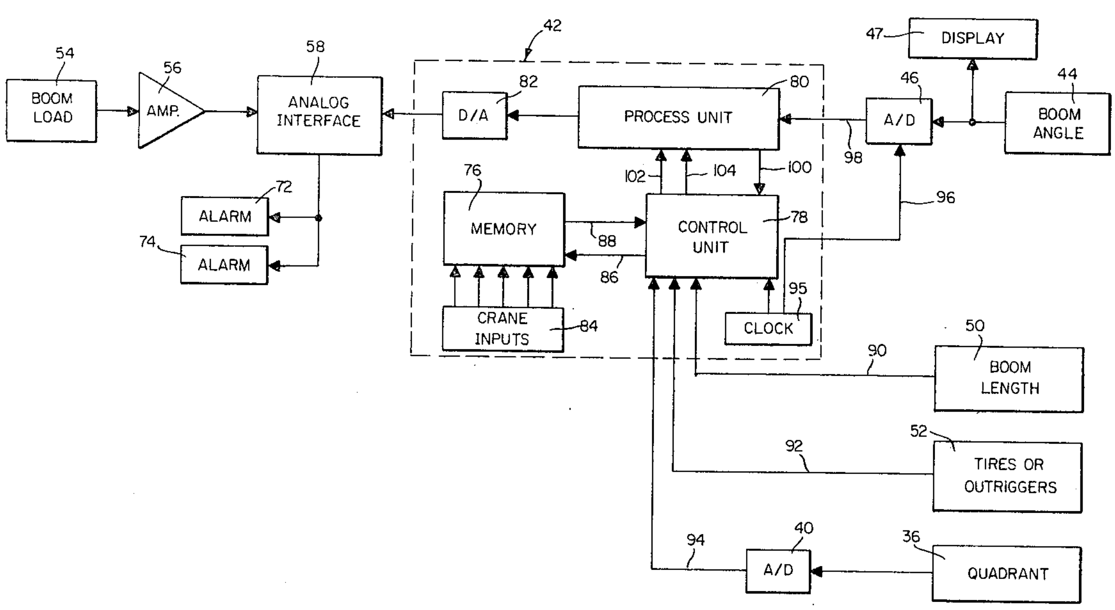
3,505,514	4/1970	Fathauer	340/267 C
3,489,294	1/1970	Greb et al.	212/39

Primary Examiner—John W. Caldwell
Assistant Examiner—J. Michael Bobbitt
Attorney—M. Michael Carpenter, Alan C. Rose and Alfred B. Levine

[57] **ABSTRACT**

A system is shown for warning the operator of a crane when the crane is about to overturn due to the moment of a heavy load or when the weight of that load could cause structural failure of the crane. Sensors for measuring the boom length, boom angle, condition of the crane support, and the quadrant in which the crane is operating are connected to the crane and apply signals to a computer which selects previously stored information from a memory unit depending on the signals received. This stored information is applied to a comparator which compares the stored signal against a measured load signal and provides a warning alarm to the crane operator when the two signals approach each other.

12 Claims, 4 Drawing Figures



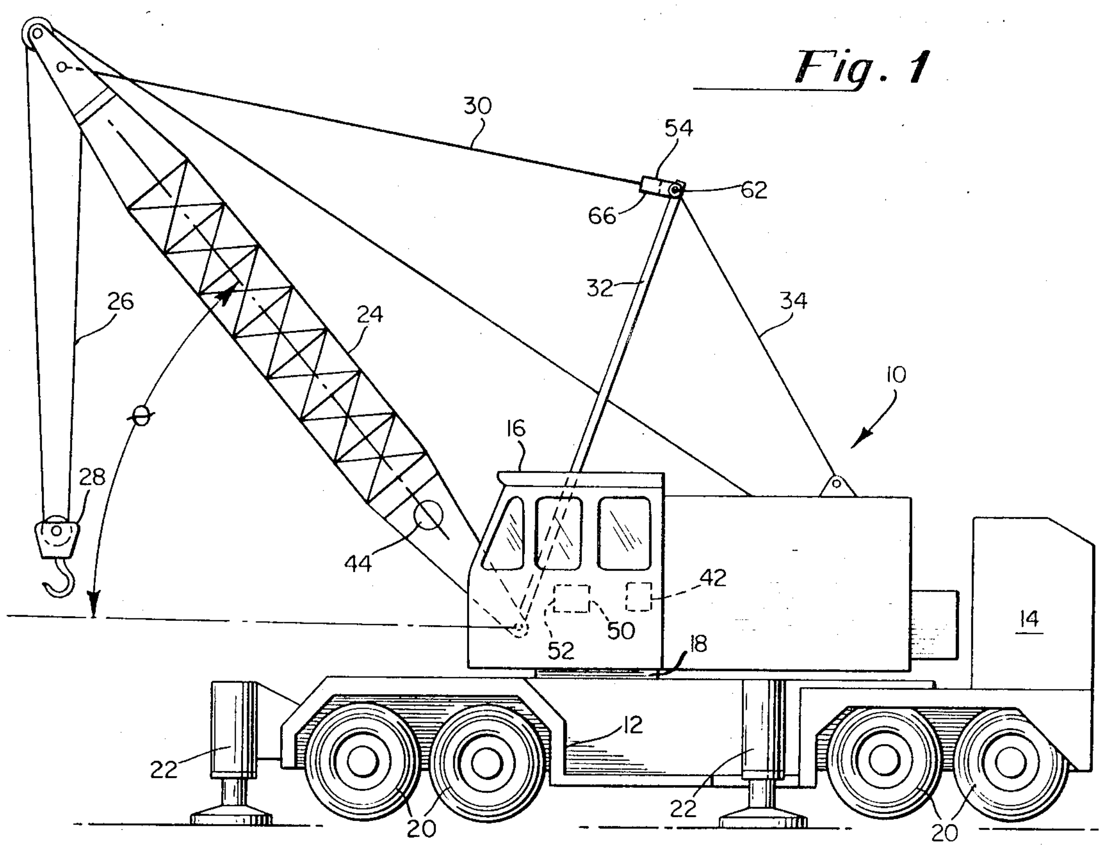


Fig. 1

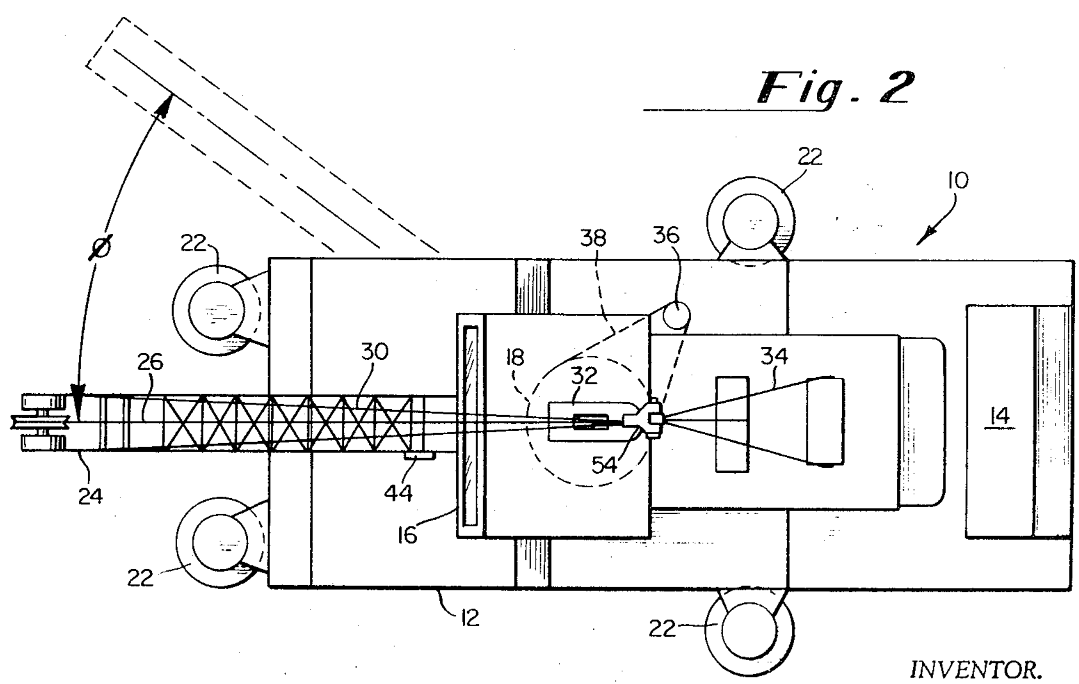


Fig. 2

INVENTOR.
Albert A. Sanchez
BY
M. Michael Carpenter
ATTORNEY.

PATENTED JAN 25 1972

3,638,211

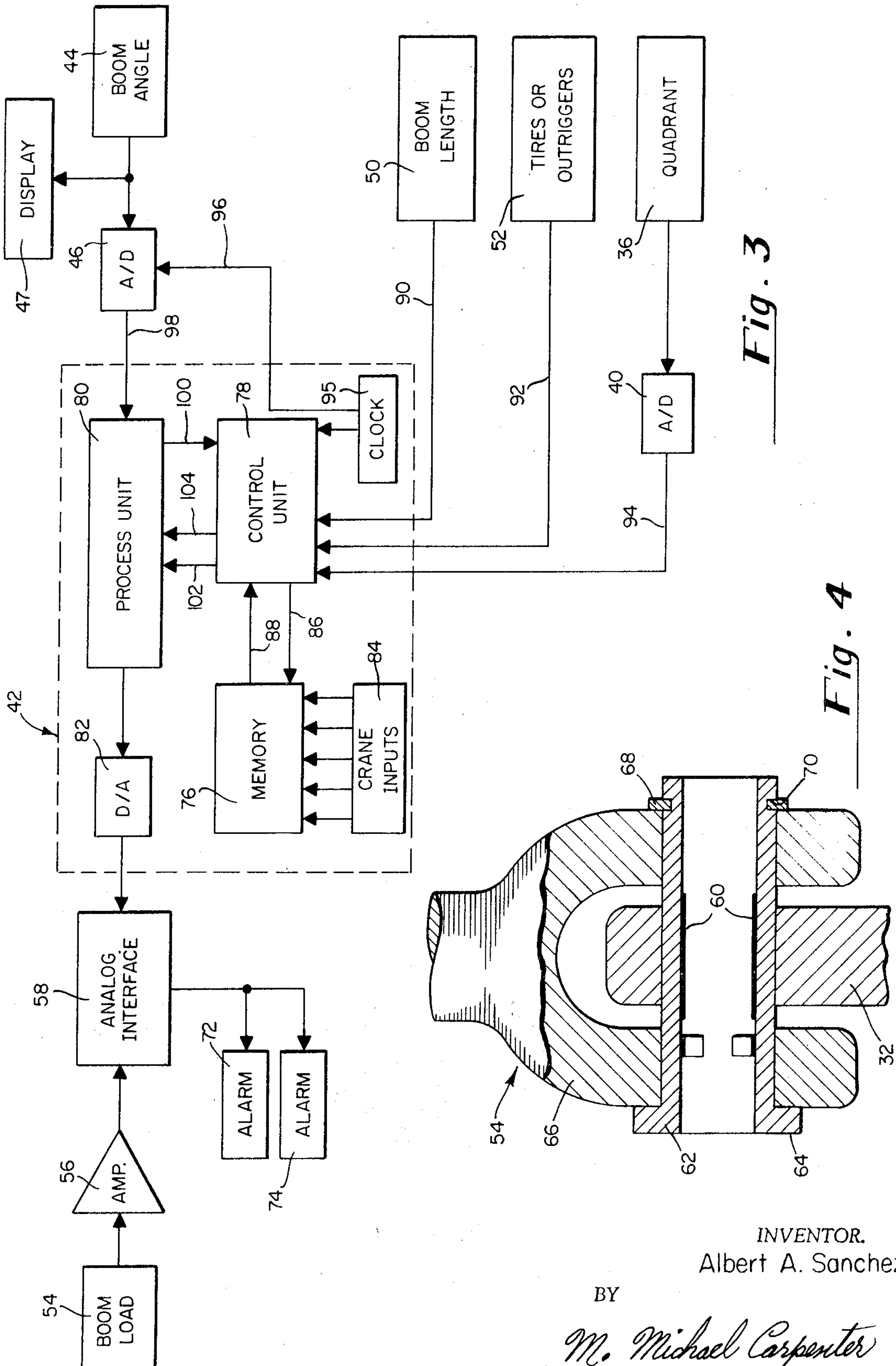


Fig. 3

Fig. 4

INVENTOR.
Albert A. Sanchez

BY

M. Michael Carpenter
ATTORNEY.

CRANE SAFETY SYSTEM

The present invention relates to a crane safety system; and, more particularly, to a crane safety system capable of sensing various crane parameters and providing a warning to an operator thereof should that operator place the crane in a dangerous condition.

It is well known in the prior art to provide material handling equipment including cranes with a safety or a warning system in one form or another. For example, one crane safety device provides a crane with load and angle measuring sensors which are used to compute the moment of the crane and generate a warning when that crane is in danger of overturning. A second crane safety device simply weighs the load as it is lifted by the crane operator and relies on his expertise to know when the load is too heavy or about to overturn. The second device is obviously inadequate, while the first has several serious limitations. The first device measures angle and load to compute moment. However, the overturning of a crane is only one area of failure. The lifted load may be made so heavy that the crane boom crushes under stress and simply warning the operator of a possible tipping condition will not warn him of the possible crushing condition. Further, the conditions which cause the boom to tip or crush do not generate a simple straight line function which can be solved and indicated by an analog device of the prior art. That is, a crane will tip or crush at various loads depending on the boom length and angle of the boom to the plane of the earth. This relationship between load, boom angle, and boom length generates a nonlinear function which varies from crane to crane.

Accordingly, it is an object of the present invention to provide an improved crane safety system capable of warning when the crane is about to fail due to an impending tipping condition or due to an excess load that would cause the crane boom to crush.

Another object of the invention herein presented is to provide a crane safety system which may be adjusted to warn of an unsafe condition peculiar to the crane in which the safety system is utilized.

Still another object of this invention is to provide a crane safety system which is rugged, reliable, insensitive to heat and humidity, and relatively inexpensive to produce.

A further object of the invention presented here is to provide a crane safety system which may be programmed to store information relating to the crane in which it is installed and which thereby provides a more accurate warning of when that crane is about to enter a fail condition. Still a further object of the invention as presented is to provide a crane safety device which warns of an approaching unsafe condition before warning of the unsafe condition.

In accomplishing these and other objects, there has been provided a computer having a memory unit which stores information relating to the lifting capacity of the crane. Crane condition sensors provide information to a control unit within the computer which selectively applies a portion of the stored information within the memory unit to a data processing unit, also in the computer. The data processing unit selects the maximum stress which the crane can lift under the sensed conditions and supplies this data to a comparator where the load, in the form of a generated stress signal, is compared thereto. As the two signals approach each other, an alarm signal is applied to an alarm device for warning the crane operator of a pending unsafe condition.

Other objects and many of the attendant advantages of the present invention will become apparent to those skilled in the art as a better understanding thereof is 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 crane in which the present invention may be utilized;

FIG. 2 is a plan view, showing the crane;

FIG. 3 is a schematic block diagram showing the present invention; and

FIG. 4 is a side elevational view, partially in cross section showing the load sensor of the present invention.

Referring now to the drawings, FIG. 1 shows a crane **10** having a carrier including a truck frame **12** and truck cab **14** with an operator cab **16** rotatably mounted upon the truck frame **12** by means of a turntable bearing plate **18**. The truck frame **12** is normally transported upon driveable tires **20** and operated upon these tires **20** or upon outriggers **22**. A boom structure **24** is hinged at the base of the operator cab **16** from which a suitable weight hoist cable **26** may be rigged. The end of the hoist cable **26** may be equipped with a hook block, hook, sling, or grapple, shown at **28**, and driven from a cable drum, not shown, for providing a load lifting capacity. The boom structure itself is lifted via a gantry hard line **30** which is attached to a gantry strut **32** connected to the operator cab **16** by a gantry hoist cable **34**. The angle between the center line of the boom structure **24** and the horizontal plane of the crane is referred to herein as the vertical boom angle θ.

The crane **10** may be operated either on its tires **20** or upon the outriggers **22**. When operated upon the tire, the boom structure **24** may be rotatably turned through a horizontal slewing angle ϕ FIG. 2, of 360° and is capable of lifting a load at any horizontal slewing angle ϕ through this turn. The standards established for a crane lifting upon tires dictate that a rear lifting position is defined as ϕ equal to ±1.5° from the longitudinal axis of the crane, while a side lifting position is defined as the remainder of the 360+ turn. The crane may lift a larger weight from the rear than from the side. On outriggers, the rear is defined as ϕ equal to ±45° while the side is limited between the rear, as defined, and ±90°. That is, the crane can not life over the front of the truck cap **14** when operated on outriggers **22**. Thus it will be seen that the rotational movement of the boom **24** may be divided into quadrants which vary depending on the method used to support the truck frame **12**. The quadrants are established by an output signal generated from a quadrant sensor in the form of a linear potentiometer **36** driven by the turning motion of the turntable bearing plate **18** attached thereto by a suitable driving chain **38**. The linear signal is applied to the input stage of six differential amplifiers shown as an analog to digital converter **40**, FIG. 3, which are provided with a reference voltage that represents one of the slew angles ϕ. When the signal from the potentiometer **36** equals or exceeds the reference voltage applied to one of the amplifiers, that amplifier applies a signal through suitable gates to a control unit within a digital computer circuit **42**, as will be hereinafter discussed.

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 which also contains a slide wire. 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 ϕ. This analog signal is converted by a second analog to digital converter **46**, connected to the boom angle sensor **44**, and applied to a process unit within the computer circuit **42**, as will be described hereinbelow. The analog signal from the boom angle sensor **44** is also applied to display **47** mounted within the operator cab **16**.

A boom length sensor **50** consists of a multiposition switch which is adjusted by the operator to the length of the boom being used. The boom length sensor is generally located within the operator cab **16** and provides various voltage levels to the control unit within the computer **42**. Also adjusted by the operator is a tires or outrigger sensor **52** which may be a two position operator adjusted switch or a switch automatically adjusted by extending the outriggers **22**. The signal generated by the tires or outrigger sensor **52** is also a voltage level applied to the control unit in the computer **42**. The tires or outrigger sensor **52** is generally located in the operator cab **16**.

The last crane safety sensor is a boom load sensor **54**. This sensor is constructed from a plurality of strain gages arranged within a wheatstone bridge circuit and connected through an amplifier **56** to a comparator in the form of an analog interface circuit 58. As shown in FIG. 4, strain gages 60 within the wheatstone bridge circuit are bonded against the inner surface of a tubular pin member 62 constructed from stainless steel. The pin member 62 is provided with an outwardly extending collar 64 and passes through an aperture within one leg of a clevis 66 for engaging the collar 64 against the outer surface of that leg. The pin 62 is secured within the clevis by a C-shaped ring 68 which fits into a groove 70 therein and engages the opposite leg of the clevis 66. The clevis 66 is located at the point where the gantry hard line 30 is attached to the gantry strut 32. In this manner, the load is not actually weighed; but the strain generated by the load in the gantry hard line 30 is sensed and applied as a stress representing a weight transfer function to the analog interface circuit 58.

The analog interface circuit 58 includes a differential amplified connected to receive the actual boom load in the form of an amplified stress signal from the boom sensor 54 connected thereto. The analog interface circuit is also connected to receive the maximum boom load in the form of a stress signal from the memory of the computer 42. The output of the differential amplified within the analog interface circuit 58 connects to a pair of first and second alarm devices 72 and 74. These alarm devices are connected through a voltage dividing network wherein the first alarm 72 will be energized when the actual load stress equals 85 percent of the stores stress, and the second alarm 74 is energized when the actual load stress equals the stored stress.

The digital computer circuit 42 includes a memory unit 76, a control unit 78, a process unit 80, and a digital to analog converter 82. The memory unit 76 may be provided with an information input circuit 84. The purpose of this circuit is to permanently store information within the memory unit 76 that is peculiar to the crane in which the crane safety system of the present invention is being used. Each crane is provided with a specification giving the maximum safe weight which that crane can lift under varying conditions, such as boom length, boom angle, the quadrant the boom is located in, and the mounting condition of the crane. This information may be placed within the memory through the use of devices such as digital potentiometers. In the preferred embodiment however the memory unit 76 is a read only memory wherein a plurality of wires pass through the ferrite cores comprising the memory. The route of each wire represents one word of stores information and is passed through only those cores that define the word to be stored. Thus, the read only memory unit 76 is connected by two sets of interconnections 86 and 88 to the control unit 78. Connections 86 carry addressing signals that initiate control read signals which are returned over connections 88 to the control unit 78 as the stored information including stress and boom angle. While read only memories are well known, a more complete description of one which is commercially available may be found in an article by Marino, John J. and Sirota, Jonathan J., "Wearing a Braided Memory That's Fast and Inexpensive," Electronics (Sept. 18, 1967) pp. 121–126. Circuits showing suitable connections 86 are more completely illustrated on page 123, while connections 88 are shown on page 124.

The control unit is connected to receive the digital input information from the boom length sensor 50, the tires or outrigger sensor 52, and the quadrant sensor 36 over lines 90, 92, and 94, respectively. The control unit 78 includes a clock circuit 95 driven in the standard manner by an oscillator which provides the timing pulses for operating the switching circuitry therein. This clocking signal is also applied over line 96 to the analog to digital converter 46 which applies the digital value of the actual boom angle θ to the precess unit 80 over line 98 under the timing control of the clock pulses.

The control unit 18 is connected to the process unit 80 by a line 100 over which digital signals representing the relation between the actual boom angle and the stored boom angle are transmitted, as will be described below. The control unit 78 has two further connections to the process unit, 102 and 104, which respectively carry the digital values of the stores stress and stored boom angle information within the memory 76 and the digital control signals for solving an arithmetic function within the process unit.

The control unit 78 is addressed from the boom length sensor 50, the tires or outrigger sensor 52, and the quadrant sensor 36. This digital information is switched by the control unit 78 to the memory unit 76 over connections 86 and used to select only that portion or block of the permanently stored information therein applicable to the sensed conditions. A block of data is considered to be a group of eight maximum stress vs. boom angle values arranged in the memory 80 from the lowest permissible boom angle to the highest permissible boom angle. Under control of the block 95, the analog to digital converter 46 sequences the digital value of the actual boom angle θ into the process unit 80 over line 98 where is compared with the lowest of the eight selected stored digital boom angle values sequentially applied to the process unit 80 from the memory unit 76 over connections 88 and line 102 under the control of the clock 95. The process unit 80 compares the lowest stored digital boom angle against the actual digital boom angle from the boom angle sensor 44 with a digital comparator. If the actual digital boom angle θ is less than the lowest stored digital boom angle, the operator has placed his boom at a point too low for the conditions of his crane i.e., boom length, quadrant, etc., and the digital comparator within the process unit 80 provides an immediate (less than) 000 alarm signal through the analog interface 58 to the alarms 72, 74. Digital comparators capable of generating three independent outputs signals of greater than, equal to, and less than for two digital input values are well known. One such device suitable for use within the process unit 80 may be purchased from the Digital Equipment Corporation, as No. K–174. See the *Digital Logic Handbook*, by Digital Equipment Corp. (March 1969) pp. 148–149. If the actual digital boom angle θ is equal to the lowers stores digital boom angle, the digital comparator within process unit 80 passes this equal-to signal information to the control unit 78 over line 100 and the control unit 78 passes the signal on to address the stored digital stress information for that angle from the memory unit 76 over lines 88 and 102 to the process unit 80. The process unit 80 then passes the stored digital stress information to the digital to analog converter 82 where it is converted to an analog stress signal and applied to the analog interface circuit 58. If the analog stored stress signal is greater than the stress signal representing the load, the alarm remains quiescent. If the analog stored stress is within 85 percent of the load stress, the warning alarm 72 is energized. If the stored stress is equal to or less than the load stress, the alarm 74 is energized.

When the actual digital boom angle θ is greater than the lowest stored digital boom angle addressed over lines 88 and 102, a greater-than signal is passed to the control unit 78 which sequences the next stored digital boom angle to the digital comparator in the process unit 80. If this stored digital angle is equal to the actual digital angle, the control unit and process unit repeat the procedure outlined above. If the actual boom angle remains greater than the next stored boom angle, the next largest stored digital boom angles is sequenced to the process unit 80 by the control unit 78 until the actual boom angle becomes less than the stored boom angle. At this point, the digital comparator within the process unit 80 generates a less-than signal which follows a previous greater-than signal. The control unit 78 then sequences signals from the memory 76 which control the arithmetic phase of the process unit 80 to conduct a simple linear interpolation which solves the equations as follows:

$$\theta_1<\theta<\theta_2$$
$$S_1<S<S_2$$

where θ is the actual digital boom angle, θ_1 is the stored digital boom angle less than θ and θ_2 is the stored digital boom angle greater than θ. Thus, S_1 is the maximum digital stress value for θ_1; while S_2 is the maximum digital stress value for θ_2. S is the digital stress value to be determined by interpolation. A proportioned equation is set up as follows:

$$\frac{\theta_2-\theta_1}{S_2-S_1}=\frac{\theta-\theta_1}{S-S_1}$$

$$S-S_1=\frac{\theta-\theta_1}{\theta_2-\theta_1}(S_2-S_1)$$

$$S=S_1+\frac{\theta-\theta_1}{\theta_2-\theta_1}(S_2-S_1)$$

These equations interpolate between the two known values (S_1 and S_2) and the second set of known values (θ_1, θ and θ_2) to solve for S. When the value of the stored stress has been interpolated by the process unit **80** for the actual boom angle θ, the interpolated value of stores stress S is applied to the analog interfacer circuit **58** through the digital to analog converter **82**. The idea of using a digital memory to store several values of a function from which the desired value may be determined by interpolation is known, see, Ledley, F. Robert, *Digital Computer and Control Engineering*, McGraw-Hill, Inc., 1960, pp. 186–190. Further, the interpolation described above is accomplished by subtracting, dividing, multiplying and adding. Addition of two numbers is performed by a binary adder, while subtraction is performed by the same adder circuit on two's complement binary numbers. Multiplication is accomplished by successively adding one number to itself as many times as is required by the second number. While division is accomplished by cumulatively subtracting the divisor from the dividend and counting the number of times a positive result occurs. This count becomes the quotient. Devices capable of performing these digital processes are well known and the hardware for performing each process may be purchased from several sources, for example, see the *Digital Logic Handbook* referred to hereinabove.

It becomes apparent that the control unit **78** is a simple switching interface between the clock **95**, process unit **80**, and the memory **76**. The interface may be accomplished through the combination of suitable gates which are addressed by the clock pulses from clock **95**, by the input signals of the digital sensors, and by signals from the digital comparator within the process unit **80**. A suitable arrangement for receiving these address bits is shown in the Marino and Sirote article referred to above.

The arrangement herein described is capable of storing a large amount of tabulated information which relates to a particular crane. This information is then selected by narrowing that portion of the stored information to a few important features, i.e., boom angle and maximum stress at that boom angle. By storing all the necessary information and selecting only that portion necessary for a given condition, the control and process unit circuitry has been greatly simplified. The present invention allows the stored stress to be selected from a large set of values by focusing upon a selected portion of the stored information and then applies this information quickly to the alarm device. Further, the stored information may be adjusted within each crane safety system to fit the peculiar features of the crane involved. Finally, the memory and storage of stress information provides a crane safety system which will alarm when the stress exceeds a fixed limit regardless of whether or not the crane is about to overturn. This provides the operator with a crane safety system which warns him of pending structural failures and potential tipping conditions within the same device.

While the alarm has been described as activating when the operator places the boom structure **24** too low, it should be understood that the operator may also place the boom structure too high and cause a backward tipping condition. When this occurs, the actual boom angle never becomes less than the stored boom angle sequences to the process unit **80**. Upon sensing this condition, an immediate alarm signal is provided through the analog interface circuit **58** to the alarms **72, 74**.

Obviously, many modifications within the circuitry described hereinabove will come readily to the minds of those skilled in the art; and it is to be understood that the present invention is intended to be limited only by the appendant claims.

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

1. A crane safety system for use within a crane having a load-lifting boom structure, comprising:
   - boom length sensor means for sensing the length of the boom structure;
   - boom angle sensor means for sensing the vertical angular relation of the axis of said boom structure to a horizontal plane;
   - digital memory means for storing information peculiar to said crane;
   - means connecting said boom angle sensor means and said boom length sensor means to said digital memory means for addressing signals thereto;
   - said digital memory means receiving said addressed signals from said sensor means and selecting a portion of said stored information determined by said addressed signals as a selected output signal;
   - boom load-sensing means for generating a measured load signal;
   - comparator means connected to said boom load-sensing means and said digital memory means for comparing said measured load signal and said selected portion of said stored information output signal; and
   - alarm means connected to said comparator means for producing an alarm when said load signal approaches said stored information output signal.

2. A crane safety system as claimed in claim **1**, wherein, said stored information includes maximum safe load in the form of digital stress information, and said measured load signal is generated by a strain-sensitive device in the form of stress signals.

3. A crane safety system as claimed in claim **2** wherein said crane includes a gantry hard line connecting said boom structure to a gantry strut and wherein said strain-sensitive device for generating said measured load stress signal, comprises, circuit means including a plurality of strain gages, connecting means for connecting said gantry hard line to said gantry strut, and said circuit means including a plurality of strain gages mounted upon said connecting means for sensing the strain therein and for generating said measured load stress signals.

4. A crane safety system as claimed in claim **3** wherein said connecting means includes a pin and clevis, said pin is formed from a tubular member, and said plurality of strain gages are mounted upon the inner surface of said tubular member.

5. A crane safety system as claimed in claim **1**, wherein said digital memory means additionally comprises:
   - stored information within said digital memory means including digital values of various boom angles and digital values of maximum load in the form of stress at each of said various boom angles;
   - control means including clock means connecting said boom length sensor means to said memory means for sequentially addressing said memory means and receiving said selected portions of said stored information including said digital values of various boom angles;
   - process means including said clock means connecting said boom angle sensor means to said memory means for matching said sensed boom angle with the stored digital value of various boom angles and selecting a stored information signal representing said digital values of maximum load at said sensed boom angle; wherein said stored digital value of maximum load is compared with said measured load signal.

6. A crane safety system as claimed in claim **1**, additionally comprising, further sensor means for sensing the support condition of said crane connected to said digital memory means for selecting said stored information therefrom.

7. A crane safety system as claimed in claim **1**, wherein, said alarm means connected to said comparator means includes a first alarm which alarms as said measured load signal approaches said stored information and a second alarm which alarm as said measured load signal equals said stored information.

8. A crane safety system for warning the operator of a pending crane failure, comprising:

sensor means for sensing a plurality of crane conditions and generating information signals in response thereto;

memory means for storing information peculiar to said crane;

selection means for selecting portions of said stored information from said memory means in response to said generated information signals received from said sensor means and for presenting said portions of said stored information as a stored information signal representing a particular crane function;

further sensing means for actually measuring said particular crane function and generating an actual information signal; and

means for comparing said actual information signal against said stored information signal and generating a warning signal as said actual and stored information signals approach each other.

9. A crane safety system as claimed in claim 8, wherein, a said particular crane function presented by said selection means and sensed by said further sensing means is the crane load.

10. A crane safety system as claimed in claim 9, wherein said memory means stores the maximum crane load in the form of stress which said crane will support under said plurality of crane conditions for warning the operator thereof when the crane may fail due to a structure limitation or due to pending overturning of the crane.

11. A crane safety system as claimed in claim 8, wherein, said memory means additionally comprise a digital read only memory.

12. A crane safety system for warning an operator of a pending crane failure while manipulating a load, comprising:

memory means for storing information peculiar to a plurality of crane-operating conditions including the maximum load under each of said operating conditions;

means for sending said plurality of crane-operating conditions and selecting the stored value of maximum load for the particular crane-operating condition sensed; and

means for comparing said selected stored value of maximum load against said manipulated load and for producing a warning as said manipulated load approaches said stored value of maximum load.

* * * * *