73-151

SEARCH ROOM

June 14, 1966 K. DOIG ETAL 3,255,627

DRILL PIPE STRESS INDICATOR

Filed April 16, 1963 3 Sheets-Sheet 1

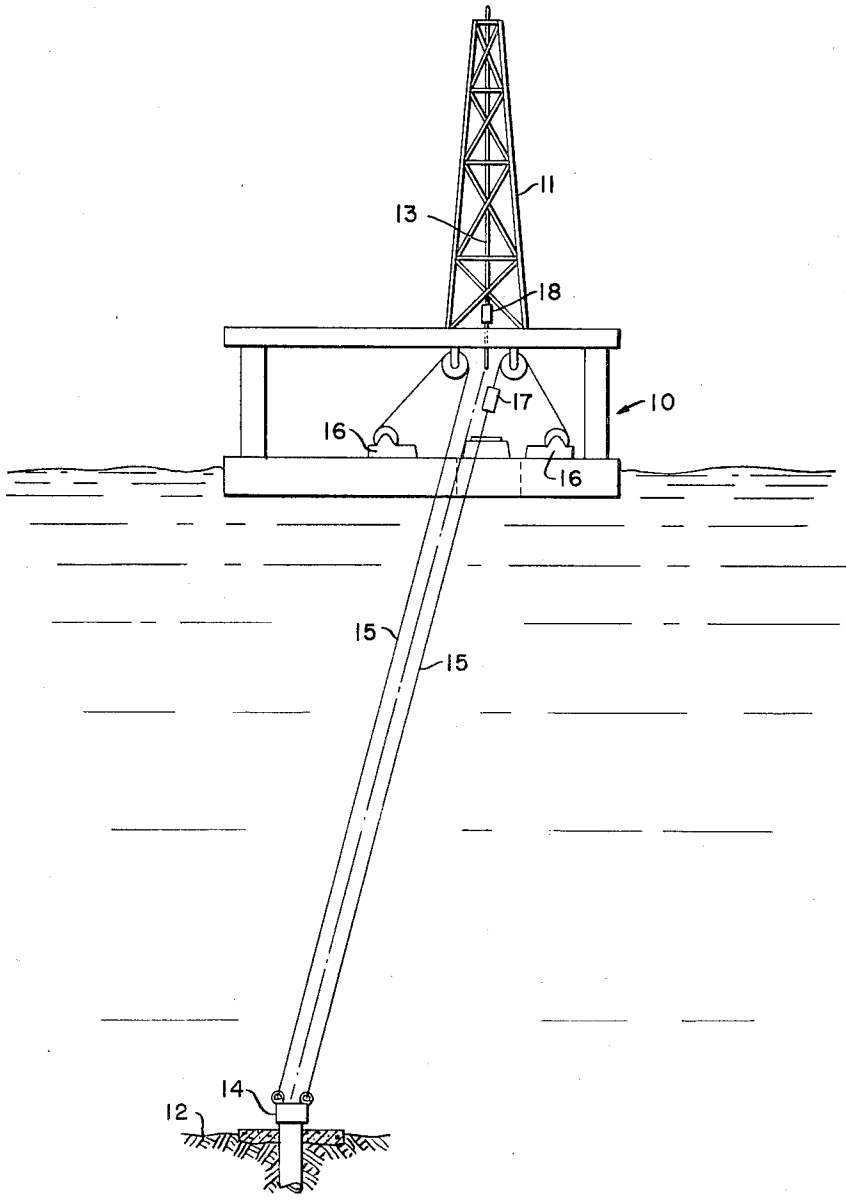


FIG. 1

INVENTORS:
K. DOIG
K. W. FOSTER
BY: Theodore E. Bieber
THEIR ATTORNEY

June 14, 1966 K. DOIG ETAL 3,255,627

DRILL PIPE STRESS INDICATOR

Filed April 16, 1963 3 Sheets-Sheet 2

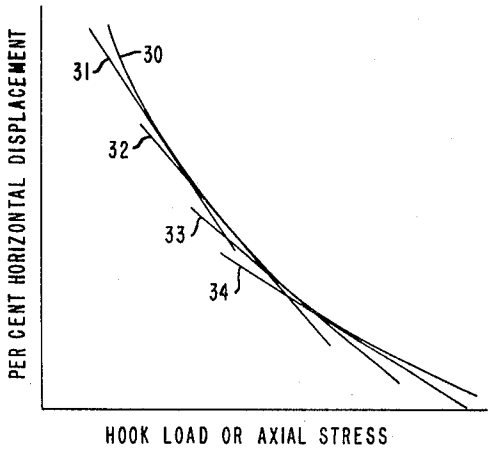


FIG. 2

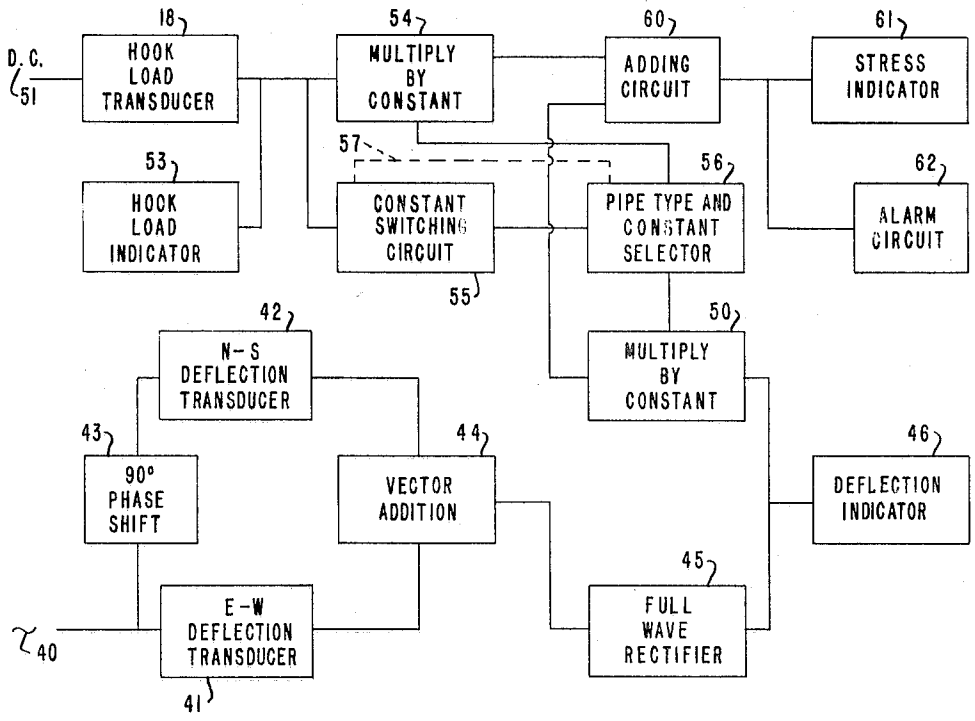


FIG. 3

INVENTORS:
K. DOIG
K. W. FOSTER
BY: [signature]
THEIR ATTORNEY

June 14, 1966 K. DOIG ETAL 3,255,627

DRILL PIPE STRESS INDICATOR

Filed April 16, 1963 3 Sheets-Sheet 3

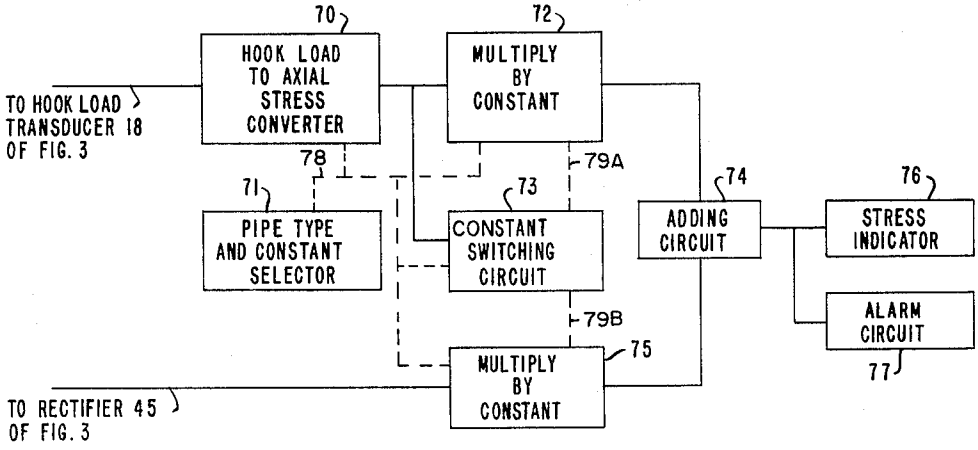


FIG. 4

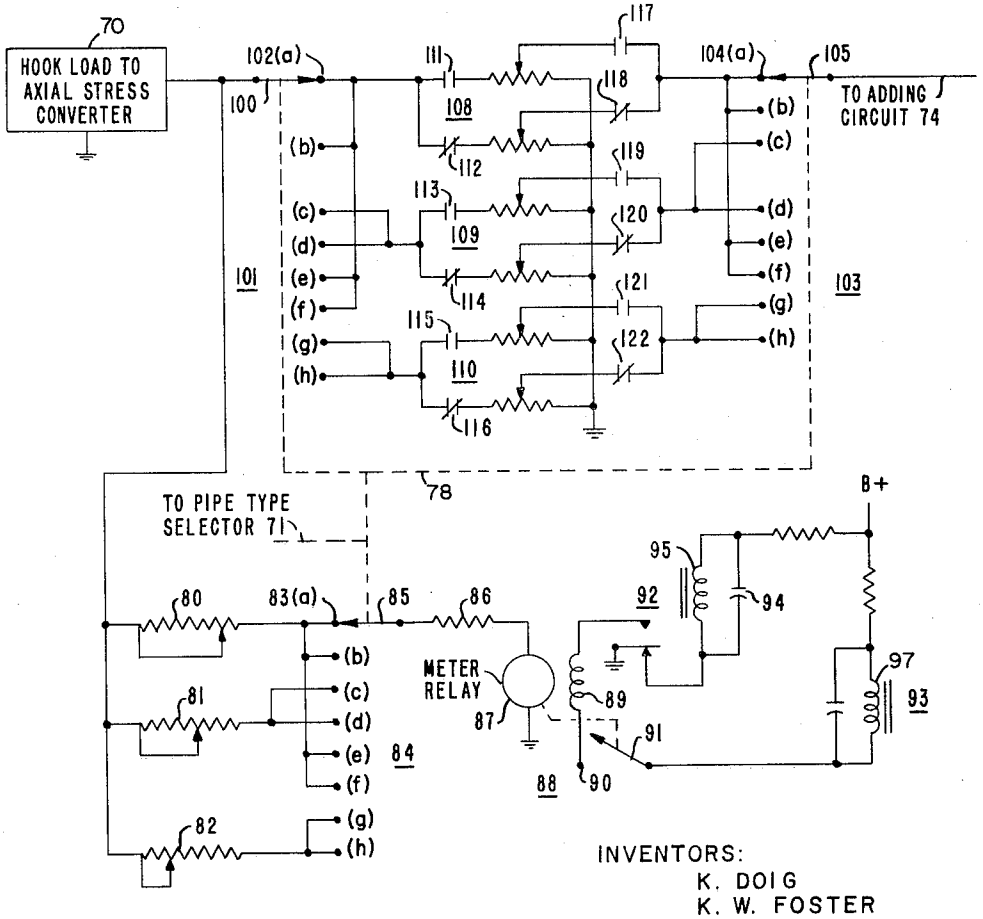


FIG. 5

INVENTORS:
K. DOIG
K. W. FOSTER

BY: N N Kunitz
THEIR ATTORNEY

United States Patent Office 3,255,627 Patented June 14, 1966

3,255,627

DRILL PIPE STRESS INDICATOR

Keith Doig, Westport, Conn., and Kenneth W. Foster, Houston, Tex., assignors to Shell Oil Company, New York, N.Y., a corporation of Delaware

Filed Apr. 16, 1963, Ser. No. 275,180
12 Claims. (Cl. 73—151)

This application is a continuation-in-part of United States patent application Serial No. 24,478, filed April 25, 1960, now abandoned.

This invention pertains to oil well equipment and more particularly to a means for determining the total stress on the drill pipe used in the drilling of oil wells.

In the drilling of oil wells by means of rotary drilling rigs, the drill pipe is subject to an axial stress commonly referred to as the hook load and a bending stress due to deflection of the drill pipe from the vertical. In most wells drilled on land the stress due to the deflection of the drill pipe can be negleted. When drilling offshore or underwater wells however, the stress due to deflection cannot be neglected since it contributes greatly to the total stress in the drill pipe. The stress due to deflection is especially important in wells which are drilled from floating platforms where the platform may move a considerable distance from the wellhead located on the floor of the body of water.

In the past, the stress on the drill pipe has been determined by noting the hook load and then determining the deflection of the drilling platform from the axis of the well. While this method may be used, it involves considerable effort on the part of the operating personnel, and the results are not readily obtainable. Also, in the past, charts have been prepared to show the safe operating condition of the drill pipe as related to a particular hook load and deflection. In an offshore drilling operation from a floating platform, the position of the drilling platform relative to the well, and thus the deflection of the drill pipe, is apt to change from moment to moment. In an operation involving such changes the previously employed procedures for determining stresses by applying the deflection and hook load in determinations involving calculations or charts, has numerous disadvantages. It requires the continuous attention of one of the operating personnel to keep current with the changes. The determinations of the stresses would tend to lag behind the applications of the stresses and fail as a warning of the approach of dangerous conditions. It would be difficult to answer questions such as whether in a given emergency situation a materially increased hook load could be quickly applied, for example, to release or prevent the pipe sticking without breaking the drill pipe.

Accordingly, it is the principal object of this invention to provide an automatic means for determining the stress on a drill pipe subject to both a hook load or axial stress and a stress due to the deflection of the drill pipe from a vertical condition.

A further object of this invention is to provide an automatic means for determining if one can safely change the drilling conditions without exceeding the allowable stress on the drill pipe.

A still further object of this invention is to provide a computer which will solve the equation $AX+BY=C$ in which X represents a value proportional to the hook load on the drill pipe, Y equals the stress due to the deflection of the drill pipe from the vertical, A and B are constants, and C is the computed variable.

The above objects and advantages of this invention are achieved by providing a means which determines the deflection of the drill pipe from the vertical and supplies an electrical signal which is related to this deflection. A

similar electrical signal is provided for the hook load or axial stress and both signals are multiplied by suitable constants. The products of the multiplication are then used to provide an output signal which is related to the total stress in the drill pipe. This output signal can then be used to determine whether this total stress is within the safe working limits of the drill pipe. A unique feature of the invention is the means used for determining the deflection of the drill pipe. This means consists of two tiltmeters or a single tiltmeter having two axes of freedom similar to those disclosed in the copending application of Kenneth W. Foster, Serial No. 830,604, filed July 30, 1959, entitled "Position Locating Device," now Patent No. 3,121,954, issued February 25, 1964. The two tiltmeters or the axes of the single tiltmeter are disposed at right angles to each other and supplied with separate alternating currents which are displaced 90 electrical degrees apart. By vectorially combining the two signals from the tiltmeters, one will obtain a single signal whose amplitude is related to the deflection of the drill pipe.

The above objects and advantages of this invention will be more easily understood from the following detailed description of the preferred embodiment when taken in conjunction with the attached drawing in which:

FIGURE 1 is a schematic drawing of a floating platform showing the axis of the drill pipe and guide lines used for lowering material from the platform to the wellhead;

FIGURE 2 shows a representative curve of the stress in the drill pipe with relation to the horizontal deflection and either the hook load or the axial stress;

FIGURE 3 is a block diagram of one form of apparatus suitable for carrying out this invention;

FIGURE 4 is a block diagram of a second form of the apparatus for carrying out this invention; and,

FIGURE 5 is a schematical diagram of the contents of one of the multipliers and of the constant switching circuit of the block diagram of FIGURE 4.

Referring now to FIGURE 1, there is shown a floating platform **10** which is anchored over the location of the well by any desired means, not shown. Mounted on the platform is a drilling derrick **11** having a drill pipe **13** extending therethrough. The wellhead **14** for the well is secured to the floor **12** of the body of water by any desired means. Secured to the wellhead **14** are a plurality of guide lines **15** which pass upwardly to the platform and are secured to tensioning devices **16**. These tensioning devices may be winches which are constantly driven through suitable slip arrangements in order to maintain a predetermined tension on each guide line at all times. Secured to one of the guide lines is a tiltmeter **17** having means for determining the deflection of the guide line in two directions which are at substantially right angles to each other. The above structure is more fully described and shown in the copending application referred to above and thus a further explanation will not be included in this application.

It is sufficient for this invention that the tiltmeter **17** will supply electrical signals indicating the deflection of one of the guide lines **15** in two separate directions which are substantially at right angles to each other. Since the guide lines **15** are parallel with the axis of the drill pipe between the floor of the derrick **11** and the wellhead **14**, the signal will also be related to the deflection of the drill pipe. Thus, two signals are obtained which indicate the deflection of the drill pipe in two directions at 90° to each other. From these signals one can determine the instantaneous maximum deflection of the drill string and its direction.

Secured to the traveling hook on the derrick **11** is a transducer means **18** which provides an electrical signal related to the longitudinal stress or hook load on the drill pipe. While no particular form of transducer is shown or described, many commercial types are known in the oil fields and they are readily available.

Referring now to FIGURE 2, there is shown a curve **30** which represents the maximum safe working stress in a representative drill pipe with relation to both the horizontal deflection and the hook load of the drill pipe. Also shown is a series of straight lines **31–34** which when taken together closely approximate the shape of the curve **30**. It is well known that the curve for a straight line, such as any one of the lines **31–34**, has the form $AX+BY=C$, in which X represents the hook load and Y the deflection. Accordingly, if one changes the constants A and B as the variable X increases, a series of straight lines **31–34** will be obtained closely approximating the curve **30**. Of course, various types of drill pipe will have different curves but they will all have the same general shape of the curve **30**. It is to be noted, however, that since the stress due to the hook load is a function of both the type of material used in the drill pipe and the thickness of the wall of the drill pipe, that a different curve results for each type of drill pipe and thickness used.

Referring now to FIGURE 3, there is shown an apparatus which will solve the above equation and provide an answer either in terms of actual stress on the drill pipe or an indication that the stress is within the safe working stress of the drill pipe. A source of alternating current **40** is coupled to a transducer **41** which is indicated as being an east-west deflection transducer. The source is also coupled to a second transducer **42** through a 90 electrical degree phase shifting network **43**. The two transducers **41** and **42** are part of the tiltmeter **17** shown in FIGURE 1. Of course, if one desired, these transducers could be provided in the form of single axis tiltmeters attached to two guide lines and disposed at substantially right angles to each other. Preferably though the two transducers are part of a single tiltmeter having two degrees of motion such as those shown in the above-referenced application. The signals from the two transducers **41** and **42** are coupled to a circuit **44** which is capable of vectorially adding the signals. Since the power supply to the two transducers is displaced 90 electrical degrees, the signals from the transducers will likewise be displaced 90 electrical degrees and will represent the displacement of the drill string in two planes at right angles to each other. Accordingly, if the two signals are vectorially added, it will result in a single signal whose amplitude is related to the deflection of the drill pipe.

The signal from the circuit **44** is passed through a full wave rectifying circuit **45** and then to a multiplying circuit **50** where it may be multiplied by a suitable constant. The signal from the full wave rectifying circuit is also displayed on a suitable indicator **46** in order that one may ascertain the deflection of the drill pipe.

A source of direct current power **51** is coupled to the hook load transducer **18** which in turn supplies an output signal related to the axial load on the drill pipe. The output signal from the hook load transducer may be displayed directly on an indicator **53** to provide an indication of the hook load on the drill pipe. The signal from the transducer **18** is also coupled to a multiplying circuit **54** and a switching circuit **55**. The switching circuit **55**, which may consist of any standard voltage magnitude responsive switching network, is designed to control a manually preset selecting circuit **56** to provide the proper constants A and B to the multiplying circuits **50** and **54** to insure that the curved relationship between hook load and deflection for the drill pipe being used is maintained. The selecting circuit **56** may, for example, consist of a plurality of voltage sources, the particular output signals of which correspond to the particular constants to be inserted into the multipliers **50** and **54**. The outputs of the voltage sources are connected to the multipliers **50** and **54** through a rotary switch having one position for each particular type of drill pipe to be used. A plurality of the voltage sources, one for each of the straight lines **31–34** used in the approximation of the stress curve for the particular drill pipe being used, are connected through individual pairs of relay contacts to each position of the rotary switch. The selecting circuit **56** is preset manually for the particular drill pipe being used and is then controlled by the switching circuit **55** which will open or close the proper relay contact whenever the magnitude of the signal from the hook load transducer **18** is greater than or less than a value corresponding to the intersection of two of the straight line approximations of the curves shown in FIGURE 2. As explained above with reference to FIGURE 2, the curved relationship between the hook load and deflection can be closely approximated by a series of straight lines. By utilizing the hook load signal, the switching circuit **55** can determine which straight line is applicable and control the selecting circuit **56** to supply the proper constants to the multiplying circuits **50** and **54**. Since however, the hook load on a drill pipe is merely a measure of the longitudinal force on the derrick hook, the signal produced by the hook load transducer **18** can vary over a very large range of values depending on the parameters of the particular drill pipe being used. Furthermore, since each different type of drill pipe will result in a separate maximum safe working stress curve, the points at which the switching circuit **55** must switch from one set of constants to the next for each type of pipe will occur at different values of the hook load. A connection **57** is therefore provided between the constant selector **56** and the switching circuit **55** whose function it is to insure that the switching circuit **55** always receives a hook load signal within a single range of values. This function may be provided, e.g., by placing a voltage divider across the input terminals of the switching circuit **55** whose center tap is positioned by means of the mechanical connection **57** depending on the particular position of constant selector **56**.

The two signals from the multiplying circuits **50** and **54** are added in a circuit **60** and displayed on an indicator **61**. The indicator **61** should be calibrated so as to indicate whether the total stress on the drill pipe is within or exceeds the safe working stress for the drill pipe being used. The signal from the adding circuit **60** is also used to trigger an alarm circuit **62** to warn the operating personnel when the stress on the drill pipe exceeds a pre-set safe working limit.

From the above description it is easily appreciated that the transducers **41** and **42** plus the circuits **44** and **45** will supply a direct current signal which is related to the magnitude of the deflection of the drill pipe. This signal, of course, corresponds to Y in the equation for the straight lines of FIGURE 2. The signal from the transducer **18** in addition to being related to hook load is used to switch constants connected in the selecting circuit **56** in order that the signals representing X and Y will be multiplied by the proper constant for the straight line corresponding to a particular portion of the curve shown in FIGURE 2. From an inspection of this curve it can be seen that the constants A and B are related to the total hook load and thus the signal which represents the hook load may be used to switch constants in the selecting circuit. The selecting circuit also, of course, is provided with a means so that the proper constants A and B are selected for various types and sizes of pipes.

Although the stress indicator just described will function properly, the number of separate constant generating sources necessary makes the equipment rather large and complex. For example, with a stress displacement indicator which can be used with twenty different types of

drilling pipe and assuming even a two line approximation of each of the stress curves, eighty different constants, forty for each multiplier, would be required.

The embodiment shown in FIGURE 4, through proper proportioning of the hook load signal, will effectively reduce the number of constants necessary by reducing the number of equations to be solved by the computer. This is brought about by converting the hook load signal to a signal proportional to the axial stress for the particular drill pipe being used and then solving for the relationship between the axial stress and the stress caused by the horizontal displacement. By converting the hook load to axial stress, all the various sizes and grades of drill pipe having the same maximum design stress will fall along the same curve of horizontal displacement versus axial stress which will take the same form as the curves shown in FIGURE 2. This has the effect of requiring the computer to solve only a single equation for each value of drill pipe design stress rather than a separate equation for each type of drill pipe.

Referring now to FIGURE 4, there is shown a block diagram of the stress indicator just described. The signal from the hook load transducer **18** (FIGURE 3) is applied to a hook load to axial stress converter **70** wherein the hook load signal is multiplied by a factor inversely proportional to the area of the particular pipe being used. In its simplest form the hook load to stress converter may consist of nothing more than a plurality of voltage dividers, one for each value of pipe area, which are selectively connected across the output terminals of the hook load transducer **18** by the constant selector **71** which in the preferred embodiment is a manually operated multiposition rotary switch having one position for each type of drill pipe whose stress is to be analyzed. Since the selector **71** is in effect only a multiposition switch which, as in the previously described embodiment, controls the selection of the constants in a plurality of locations in the system, for simplicity of illustration the output thereof may be considered to be a single mechanical movement, i.e., the rotation of a shaft, and the contacts on the switch to be portions of the individual circuits which are controlled. Accordingly, the connection between the selector **70** and the various circuits controlled thereby is indicated by a broken line **78** representing a mechanical connection.

The output signal from the hook load converter **70** is then fed to a multiplier **72** wherein the axial stress signal is multiplied by a suitable constant (B) corresponding to the design stress curve for the particular drill pipe being used. The particular multiplying factor introduced by the multiplier **72** is controlled both by the constant selector **71** via connection **78** and by a constant switching circuit **73** which is responsive to the magnitude of the axial stress signal and whose operation will be more fully explained below with respect to FIGURE 5. The connection between the circuit **73** and the multiplier **72** in order to control the multiplying factor selected in the multiplier **72** is indicated by the broken line **79A**. The output of the multiplying circuit **72** is coupled to one of the input terminals of an adding circuit **74**.

The horizontal displacement signal after being rectified by rectifier **45** (FIGURE 3) is applied to the respective input terminals of constant switching circuit **73** and a multiplier **75** where it is multiplied by a suitable constant (A) corresponding to the design stress of the particular drill pipe being used. The particular constant introduced being again controlled by both the pipe type selector **71** (connection **78**) and the constant switching circuit **73** as indicated by broken line connection **79B**. The output of the multiplier **75** is coupled to the second input of adding circuit **74**, the output of which is coupled to an indicator **76** and an alarm circuit **77** in the same manner as described with relation to FIGURE 3.

Referring now to FIGURE 5, there is shown a schematical diagram of the multiplier **72** and the constant switching circuit **73** for a computer capable of solving three different horizontal stress versus axial stress curves using a two line approximation of each of the aforementioned curves.

The output signal from the hook load to axial stress converter **70** is applied to the input of the switching circuit **73** which consists of a plurality of preset variable resistances **80–82** (one for each stress curve) whose function it is to proportion the axial stress signal so that the magnitude of the axial stress signal at which the intersection of the two straight lines used in the approximation of the stress curves occurs at the same value regardless of which curve is being solved at the particular moment. Each of these resistances **80–82** has one of its ends connected to the output of the hook load converter **71** and its other end connected to one or more contacts **83**(a)–**83**(h) of a switch **84** having a moving contact **85**, the position of which is controlled by the pipe type selector **71**. Each of contacts **83** of the switch **84** corresponds to a position of the pipe type selector **71** and therefore to a particular type of drill pipe. Once the signal has been properly proportioned or scaled by the resistances **80–82**, it is applied through a resistor **86** to the meter movement **87** of a meter relay **88** having a locking coil **89** and a pair of normally open contacts **90, 91**. The locking coil **89** and contacts **90, 91** are connected through a periodic interrupting circuit, comprising an interrupting relay **92**, to the relay coil **97** of a control relay **93** which controls the constants switched into the multipliers **72** and **75**. The interrupting relay **92** is continually being switched from an energized to an unenergized condition due to the charging and discharging of the capacitor **94** connected across the relay coil **95** of relay **92**. This has the effect of continuously sampling the signal applied to the meter relay **88** and also of permitting the contacts **90, 91** to open when the signal applied to the meter relay is below the value necessary to initially energize the relay **88**. The particular meter relay switching circuit including the interrupting circuit is old and well known in the art and per se forms no part of applicants' invention. The particular circuit shown, as well as other examples of meter relay control circuits which may be used, can be found in Bulletin 104A, April 1957 of Assembly Products, Inc. Whenever the axial stress signal applied to the switching circuit **73** exceeds the value corresponding to the intersection of the two lines used to approximate the stress curve for the particular pipe being used, the meter relay movement **87** will close the contacts **90, 91**; thus applying power to the control relay **93**, which will change the constants in the multipliers **72** and **75**.

The axial stress signal from the hook load converter **70** is also applied to the multiplier **72** via the moving contact **100** of a multicontact switch **101** having a plurality of stationary contacts **102**(a)–**102**(h), each of which again corresponds to a particular position of the pipe type selector **71**. The output of the multiplier **72** is a second multicontact switch **103** having a like plurality of stationary contacts **104**(a)–**104**(h) and a moving contact **105** which is connected in tandem with moving contact **100** and controlled by the pipe type selector **71**. To each of the stationary contacts **102**(a)–**102**(h) is connected one end of one of a plurality of pairs of parallelly connected voltage dividers **108–110**. Each of the voltage dividers is connected to its respective contact **102**(a)–**102**(h) through a pair of relay contacts **111–116** which form a portion of the relay **93** of the switching circuit **73** and are controlled by the relay coil **97**. The relay contacts **111, 113** and **115** are normally open while the relay contacts **112, 114, 116** are normally closed. The other end of each of the voltage dividers is connected to ground. The preset center taps of each of the respective pairs of voltage dividers **108–110** are connected in parallel to the corresponding contact **104**(a)–**104**(h). Each of the center taps is also connected in series with a pair of relay contacts **117–122** which likewise are a part of relay **93** and are controlled

by relay coil **97**. The contacts **117–122** are either normally open or normally closed in accordance with a like condition of the relay contacts of the respective voltage divider of which they are a part. Each of the pairs of voltage dividers corresponds to the contact which must be supplied to the multiplier **72** for each stress curve, with the individual voltage dividers corresponding to the contacts for each of the lines used to approximate the curves. Although not shown it is understood that the multiplier **75** is similar in structure to multiplier **72** and is controlled in like manner by the switching circuit **73**. It is also understood that although the multiplier **72** and switching circuit **73** have been described for a two line approximation of the stress curves, that the circuits may be modified to accommodate any number of straight line approximations simply by adding additional voltage dividers to each group of voltage dividers in the multipliers and making the switching circuit **73** responsive to more than one voltage level.

Briefly then the operation of the stress computer of FIGURE 4 is as follows: The operator after determining the particular type of drill pipe that is to be used will manually position the pipe type selector **71** to the proper position. Proper positioning of the pipe type selector **71** will in turn simultaneously insert the proper multiplying constant into the hook load to axial stress converter **70**, the proper scaling resistor **80–82** into the switching circuit **73** and the proper group of constants **108–110** into the multipliers **72** and **75**; the particular constant used in each of the multipliers **72** and **75** at any instant being controlled by the condition of the constant switching circuit **73**. The horizontal deflection signal is applied directly to multiplier **75** where it is multiplied by the proper constant and then applied to the adding circuit **74** the output of which controls the indicator **76** and alarm circuit **77**. The hook load signal is applied to the hook load converter **70** where it is multiplied by a proper constant to convert the hook load signal to a signal proportional to the axial stress in the drill pipe. The resulting axial stress signal is then applied to multiplier **72** where it is multiplied by the proper constant and then applied to the adding circuit **74**. The axial stress signal is also applied to the constant switching circuit **73**. Should the axial stress signal exceed a preset value, the switching circuit **73** will be energized thereby simultaneously changing the multiplying constants in the multipliers **72** and **75**. In the particular example shown in FIGURE 5 for the multiplier **72**, this would result in the opening of relay contacts **112** and **118** and the closing of relay contacts **111** and **117**. It should be noted that when the switching circuit **73** is energized, all of the contacts **111–122** will change their condition but since the moving contacts **100** and **105** are connected to contacts **102**(*a*) and **104**(*a*) respectively, only the relay contacts **111, 112, 117** and **118** which control the voltage divider pair **108** will effect the output of multiplier **72**.

Although the stress indicator systems have been described using direct current signals, it is understood that a system using alternating signals will operate just as well. In the latter case, however, the alternating signals should be converted to direct current signals before they are applied to the adding circuit since, if the two alternating signals are out of phase an erroneous indication of the total stress will appear. It is further understood that although the system has been described for measuring the stress in a drillpipe, it is not limited to this particular use but may also be used to measure the stress in any type of pipe, e.g. well casing, which is being run into the well from the drilling platform.

Obviously, various modifications of the present invention are possible in view of the above teachings. For example, a single deflection transducer could be used giving a direct current signal proportional to the deflection of the drill pipe. Of course, a means would be required for positioning the single transducer at the point of maximum deflection. On the other hand it is equally well understood that signals from additional transducers which, for example, measure the deflection of the drill pipe due to pitch and roll of the floating drilling platform could be added to the horizontal deflection signal without departing from the spirit of the invention.

We claim as our invention:

1. A system for determining the stress on a drill pipe comprising: a first transducer means disposed to determine the deflection of the drill pipe from the vertical and supply an output signal proportional thereto; means, including a second transducer means, for determining the axial load on said drill pipe and supplying a signal related thereto; a first circuit means coupled to said first transducer means for multiplying the deflection signal by a constant related to the type of material used in the drill pipe; a second circuit means coupled to the output of said means for determining the axial load on said drill string for multiplying the signal related to the axial load by a constant related to the type of material used in the drill pipe; an adding circuit coupled to said first and second circuit means for combining the output signals of the first and second circuit means to provide a signal related to the actual stress on the drill pipe.

2. The apparatus of claim **1** wherein said second multiplying circuit is directly coupled to the output of said second transducer means.

3. The apparatus of claim **1** wherein said means for determining said axial load includes means coupled to the output of said second transducer means for converting the axial load signal from said second transducer to an axial stress signal, said second multiplying circuit being coupled to the output of said last mentioned means.

4. A system for determining the stress on a drill pipe comprising: a first deflection transducer for supplying a first alternating signal related to the deflection of the drill pipe in one direction; a second deflection transducer for supplying a second alternating signal related to the deflection of the drill pipe in a second direction at right angles to said one direction, said second alternating signal being 90 electrical degrees out of phase with said first alternating current signal; circuit means coupled to said first and second transducer means for vectorially combining said first and second alternating signals to obtain a deflection signal related to the deflection of the drill pipe from the vertical; rectifying means coupled to said circuit means for converting the deflection signal to a unidirectional signal; a load transducer for determining the axial load on the drill pipe and supplying a unidirectional signal related to the axial load; a first multiplying circuit for multiplying the deflection signal by a first constant coupled to the output of said rectifying means; a second multiplying circuit for multiplying the load signal by a second constant; a selecting circuit coupled to said load transducer and responsive to the load signal for selecting said first and second constants depending on the material and physical characteristics of the drill pipe, said selecting circuit being coupled to said first and second multiplying means for respectively introducing said selected first and second constants thereto; and an adding circuit coupled to said first and second multiplying circuits for combining the output signals of the first and second multiplying circuits to obtain a single signal representing the stress in the drill pipe.

5. A system for determining the stress on a drill pipe comprising: first and second transducer means disposed to determine the deflection of the drill pipe in two planes at right angles to each other, said first and second transducers being energized by separate alternating current sources, one of said separate sources being displaced 90 electrical degrees with respect to the other source; first circuit means coupled to said first and second transducer means for vectorially combining the signals from the first and second transducers to obtain a single signal representing the deflection of the drill pipe; a third transducer

means disposed to determine the axial load on said drill pipe and supplying a signal related thereto; second circuit means coupled to said first circuit means for multiplying the deflection signal by a constant related to the type of material used in the drill pipe; third circuit means coupled to said third transducer for multiplying the axial load signal by a second constant related to the type of material used in the drill pipe; and, an adding circuit coupled to said second and third circuit means for combining the output signals of said second and third circuit means to provide a signal related to the actual stress on the drill pipe.

6. A system for determining the stress on a drill pipe comprising: first and second transducer means disposed to determine the deflection of the drill pipe in two planes at right angles to each other, said first and second transducers being energized by separate alternating current sources, one of said separate sources being displaced 90 electrical degrees with respect to the other source; first circuit means coupled to said first and second transducer means for vectorially combining the signals from the first and second transducers to obtain a single signal representing the deflection of the drill pipe; a third transducer means disposed to determine the axial load on said drill pipe and supplying a signal related thereto; a switching circuit coupled to said third transducer means; a constant selecting circuit coupled to said switching circuit, said switching circuit controlling said constant selecting circuit to supply first and second constants related to the material used in the drill pipe and the magnitude of the axial load; second circuit means coupled to said first circuit means and to said constant selecting means for multiplying the deflection signal by said first constant; third circuit means coupled to said third transducer and to said constant selecting means for multiplying the axial load signal by said second constant; and an adding circuit coupled to said second and third circuit means for combining the output signals of the second and third circuit means to provide a signal related to the actual stress of the drill pipe.

7. The apparatus of claim **6** wherein said selecting circuit may be selectively positioned for various types of drill pipe and wherein said switching circuit is energized by an axial load signal of a preset magnitude; and means included in said switching circuit and controlled by said selecting circuit for proportioning said axial load signal so that the axial load signal applied to said switching circuit always falls within a common range of values.

8. A system for determining the stress on a drill pipe comprising: a first transducer means disposed to determine the deflection of the drill pipe from vertical and supply an electrical signal related thereto; a second transducer means disposed to determine the axial load on the drill pipe and supply an electrical signal related thereto; a selecting circuit coupled to said second transducer and responsive to said axial load signal for supplying first and second constants related to the material used in the drill pipe; a first circuit means coupled to said first transducer for multiplying said deflection signal by said first constant; a second circuit means coupled to said second transducer for multiplying said axial load signal by said second constant; and an adding circuit coupled to said first and second circuits for combining the output signals of the first and second circuit means to provide a signal related to the actual stress in the drill pipe.

9. A system for determining the stress on a drill pipe comprising: a first deflection transducer for supplying a first alternating signal related to the deflection of the drill pipe in one direction; a second deflection transducer for supplying a second alternating signal related to the deflection of the drill pipe in a second direction at right angles to said one direction, said second alternating signal being 90 electrical degrees out of phase with said first alternating current signal; circuit means coupled to said first and second transducer means for vectorially combining said first and second alternating signals to obtain a deflection signal related to the deflection of the drill pipe from the vertical, rectifying means coupled to said circuit means for converting the deflection signal to a unidirectional signal; a load transducer for determining the axial load on the drill pipe and supplying a unidirectional signal related to the axial load; axial load converter means coupled to the output of said load transducer for converting said axial load signal to a signal proportional to the axial stress in the drill pipe; a first multiplying circuit for multiplying the deflection signal by a first constant coupled to the output of said rectifying means; a second multiplying circuit for multiplying the axial stress signal by a second constant; circuit means coupled to said first and second multiplying means and responsive to the axial stress signal for selecting said first and second constants depending on the material and physical characteristics of the drill pipe, said selecting circuit being coupled to said first and second multiplying means for respectively introducing said selected first and second constants thereto; and an adding circuit coupled to said first and second multiplying circuit for combining the output signals of the first and second multiplying circuits to obtain a single signal representing the stress in the drill pipe.

10. A system for determining the stress on a drill pipe comprising: first and second transducer means disposed to determine the deflection of the drill pipe in two planes at right angles to each other, said first and second transducers being energized by separate alternating current sources, one of said separate sources being displaced 90 electrical degrees with respect to the other source; first circuit means coupled to said first and second transducer means for vectorially combining the signals from the first and second transducers to obtain a single signal representing the deflection of the drill pipe; a third transducer means disposed to determine the axial load on said drill pipe and supplying a signal related thereto; means for converting said axial load signal to an axial stress signal coupled to the output of said third transducer means; second circuit means coupled to said first circuit means for multiplying the deflection signal by a constant related to the type of material used in the drill pipe; third circuit means coupled to the output of said means for converting said axial load signal to an axial stress signal for multiplying the axial stress signal by a second constant related to the type of material used in the drill pipe; and, an adding circuit coupled to said second and third circuit means for combining the output signals of said second and third circuit means to provide a signal related to the actual stress on the drill pipe.

11. A system for determining the stress on a drill pipe comprising: first and second transducer means disposed to determine the deflection of the drill pipe in two planes at right angles to each other, said first and second transducers being energized by separate alternating current sources, one of said separate sources being displaced 90 electrical degrees with respect to the other source; first circuit means coupled to said first and second transducer means for vectorially combining the signals from the first and second transducers to obtain a single signal representing the deflection of the drill pipe; a third transducer means disposed to determine the axial load on said drill pipe and supplying a signal related thereto; axial load converter means coupled to the output of said third transducer for converting said signal related to the axial load to a signal proportional to the axial stress in the drill pipe selecting means; a constant selecting means for supplying respective pairs of first and second constants related to the material used in the drill pipe; second circuit means coupled to said first circuit means and to said constant selecting means for multiplying the deflection signal by one of said first constants; third circuit means coupled to said axial stress converter and to said constant selecting means for multiplying the axial stress signal by one of said second constants; switching circuit means coupled to the output of said axial stress converter for connecting one of

said first and one of said second constants to said second and said third circuit means respectively depending on the magnitude of said axial stress signal; and an adding circircuit coupled to said second and third circuit means for combining the output signals of the second and third circuit means to provide a signal related to the actual stress on the drill pipe.

12. A system for determining the stress on a drill pipe comprising: a first transducer means disposed to determine the deflection of the drill pipe from vertical and supply an electrical signal related thereto; a second transducer means disposed to determine the axial load on the drill pipe and supply an electrical signal related thereto; axial load converter means coupled to the output of said second transducer for converting said signal related to the axial load on the drill pipe to a signal proportional to the axial stress on the drill pipe; means coupled to said axial load converter means and responsive to said axial stress signal for supplying first and second constants related to the material used in the drill pipe; a first circuit means

coupled to said first transducer for multiplying said deflection signal by said first constant; a second circuit means coupled to said axial load converter means for multiplying said axial stress signal by said second constant; and an adding circuit coupled to said first and second circuits for combining the output signals of the first and second circuit means to provide a signal related to the actual stress in the drill pipe.

References Cited by the Examiner

UNITED STATES PATENTS

2,022,844	12/1935	Christian	212—2
2,030,529	2/1936	Nash	116—124
2,478,720	8/1949	Sourwine et al.	73—88.5
2,930,137	3/1960	Arps	73—151 X
2,966,221	12/1960	Kinney	175—5

RICHARD C. QUEISSER, *Primary Examiner.*

J. P. BEAUCHAMP, *Assistant Examiner.*