BORE HOLE TOOL ORIENTING APPARATUS AND SYSTEMS

Original Filed March 15, 1963 2 Sheets-Sheet 1

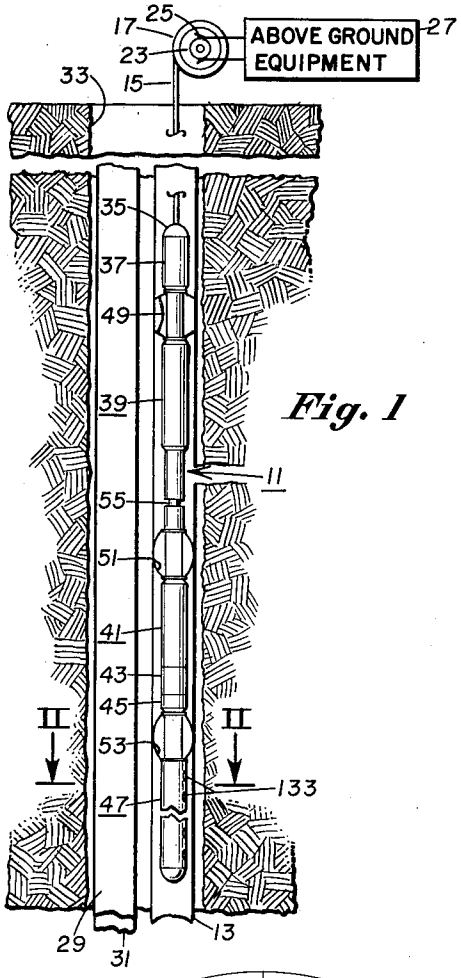


Fig. 1

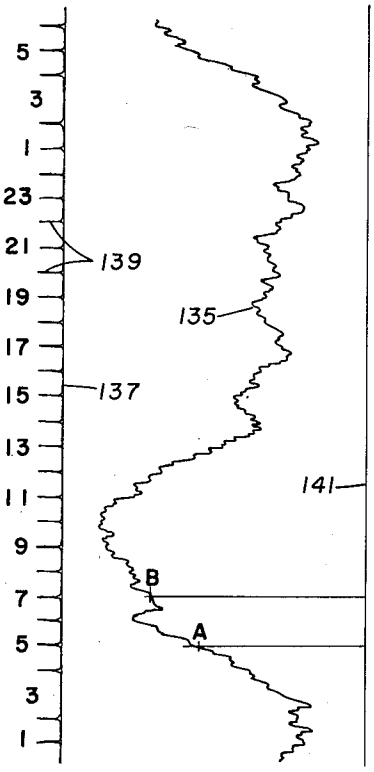


Fig. 5

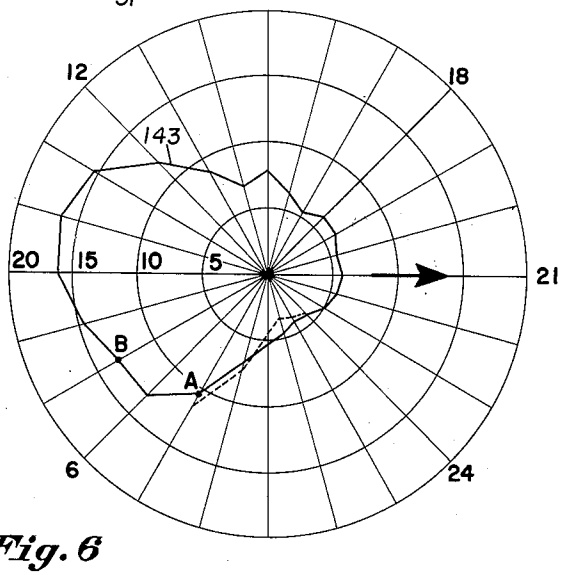


Fig. 6

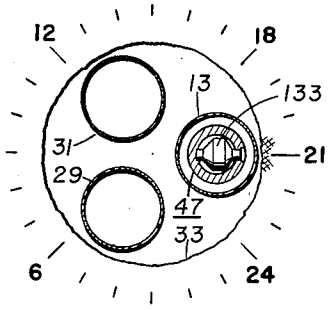


Fig. 2

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BORE HOLE TOOL ORIENTING APPARATUS AND SYSTEMS

Original Filed March 15, 1963 2 Sheets-Sheet 2

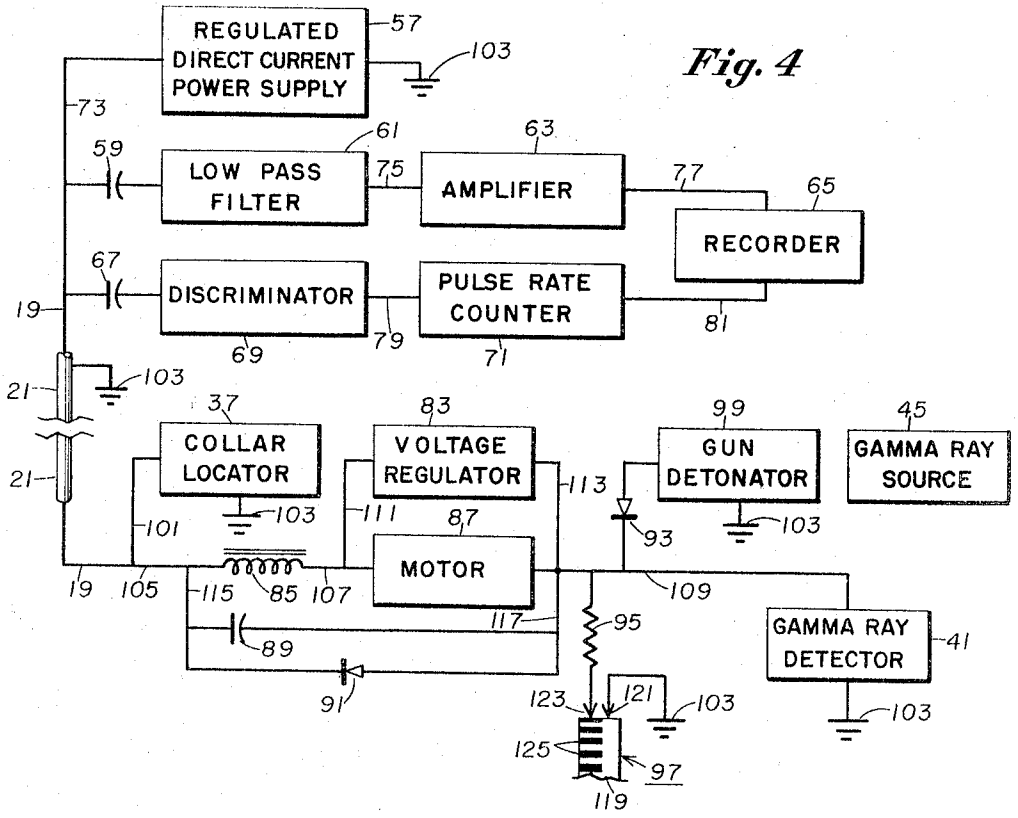


Fig. 4

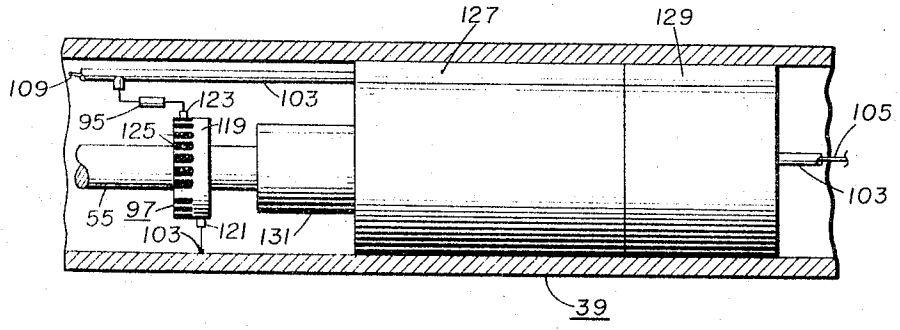


Fig. 3

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United States Patent Office 3,307,642 Patented Mar. 7, 1967

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BORE HOLE TOOL ORIENTING APPARATUS AND SYSTEMS

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Continuation of application Ser. No. 265,469, Mar. 15, 1963. This application June 1, 1965, Ser. No. 466,498
3 Claims. (Cl. 175—4.51)

This application is a continuation of my copending application, Serial No. 265,469 filed March 15, 1963, now abandoned.

The present invention relates to apparatus for orienting tools in bore holes, and more particularly to apparatus and systems wherein a tool is orientable relative to phenomena indicative of an azimuthal pattern.

The invention is especially applicable to apparatus and systems wherein a perforator device is orientable relative to plural tubing strings in certain types of so-called multiple completion wells. The term "multiple completion well" as used herein is specifically restricted to embrace only those types of multiple completion wells wherein a plurality of tubing strings are cemented in a bore hole at a perforating location.

In earth formations traversed by a bore hole and wherein there are a plurality of petroleum bearing strata at different bore hole depths, it is now common practice to insert a plurality of tubing strings into the uncased bore hole and then, by cementing the bore hole, to isolate the strata outside the tubing strings from each other so that there may be provided a plurality of petroleum production zones. Multiple completion wells may in some cases involve many producing zones; with two to four producing zones being quite common. Tubing strings are usually run so that within a given production zone there may be a plurality of tubing strings. Now, after the tubing strings are installed and cemented, it is necessary to perforate the tubing string that is to carry the output of a particular production zone. This perforating is accomplished by lowering a perforating device (usually a shaped charge gun) within the tubing string to be perforated, then, orienting the device so that only the desired tubing string will be perforated, and then actuating the perforating device. It is essential in every case that the perforator device shall be fired so as to avoid perforation of any other tubing string. It is therefore quite apparent that apparatus and systems for accomplishing orientation of the perforator device should be dependably accurate and effective. Unfortunately, the apparatus and systems for accomplishing this orientation in the prior art of which I am aware, leave much to be desired.

It is accordingly a general object of this invention to provide improved perforator orienting apparatus and systems.

Another object of this invention is to provide perforator orienting apparatus and arrangements which shall be dependably and effectively accurate.

Another object of this invention is to provide perforator orienting apparatus and arrangements wherein the probability of producing and acting upon false orientation information is minimal.

Another object of this invention is to provide perforator orienting apparatus and arrangements wherein reliable orientation information is derived.

These and other objects are effected by this invention, as will be apparent from the following description taken in accordance with the accompanying drawings, forming a part of this application, in which:

FIG. 1 is a diagrammatic showing of the general layout of a perforating orienting apparatus and system utilizing the present invention, with the down-hole portion of the apparatus disposed inside a tubing string in a typical multiple completion well;

FIG. 2 is a schematic sectional view taken at line II—II of FIG. 1;

FIG. 3 is an enlarged fragmentary longitudinal section view showing in schematic form certain details of the drive section of the down-hole assembly of FIG. 1;

FIG. 4 is a schematic electric circuit diagram of the perforator orienting apparatus and system in accordance with a preferred embodiment of the present invention;

FIG. 5 is a graph showing in schematic form a typical strip chart produced by the apparatus of FIGS. 1 and 4; and,

FIG. 6 is a polar plot or orientation chart made up from information taken from the strip chart of FIG. 5.

Referring now to the drawings, in FIG. 1 there is shown a typical down-hole assembly **11** suspended within a tubing string **13** by means of a cable **15** which is reeled off a conventional cable drum **17** which is powered and controlled by conventional means (not shown). The cable **15**, in addition to supporting the down-hole assembly **11**, has an inner-conductor **19** which is insulated from the outer sheath **21** which acts as a common conductor. The cable drum shaft is provided with slip rings **23**, with associated brushes **25**, through which electrical signals are transmitted to and from the cable conductors to the down-hole assembly **11** and to components of the above-ground equipment, indicated generally by the block **27**. The first tubing string **13** is disposed together with second and third tubing strings **29**, **31** within a typical uncased earth bore hole **33**. The tubing strings are assumed to be cemented in the bore hole, but for clarity, the cement is not indicated in FIGS. 1 and 2 of the drawings.

The sections of the down-hole assembly **11** as shown by FIG. 1 may include, by way of illustration, reading from top to bottom, a cable head **35**, a collar locator section **37**, a motor drive section **39**, a radioactivity detector section **41**, a spacer section **43**, a radioactivity source section **45**, and a perforator device section **47**. Secured on the down-hole assembly **11** in a conventional manner between the collar locator section **37** and the motor drive section **39** are a set of conventional drag springs **49**. Also secured on the down-hole assembly **11** in a conventional manner immediately above the radioactivity detector section **41** and immediately above the perforator device **47** are respective sets of conventional centralizing springs **51**, **53**.

The various sections of the down-hole assembly **11** are coupled together and appropriately sealed against entry of well fluids, all in accordance with conventional down-hole tool practices. The upper sections of the down-hole assembly, namely the collar locator section **37** and the motor drive section **39** are of course movable up or down in the tubing string **13**, but they are prevented by the drag springs **49** from having any rotational movement in the tubing **13**. The lower sections of the down-hole assembly **11**, namely all sections below the motor drive section **39**, are fixed to an output shaft **55** of the motor drive section **39**. The centralizer springs **51**, **53** act to maintain the lower section centered within the tubing **13**, but they do permit the lower sections **41**, **43**, **45**, **47** to rotate within the tubing **13**.

As shown in FIG. 4, the above-ground equipment (included within the block **27** of FIG. 1) includes a regulated direct current power supply **57**, a first coupling capacitor **59**, a low pass filter **61**, an amplifier **63**, a recorder **65**, a second coupling capacitor **67**, a discriminator **69**, and a pulse rate counter **71**. The regulated direct current power supply **57** may be of a conventional type capable of supplying about two hundred fifty volts at its output. The power supply output is connected via lead **73** to the center conductor **19** of the cable **15**. The above-

ground equipment provides a first channel, which may be termed the radioactivity signal channel, and a second channel, which may be termed the perforator position indicator channel. The recorder **65** is of the two pen strip chart type, and also has two channels, one for each pen. In the perforator position indicator channel, the first coupling capacitor **59** is connected to the cable center conductor **19**, and in series with the input of the low pass filter **61**, the output of which is connected via lead **75** to the input of the amplifier **63**, the output of which is connected via lead **77** to the input of one channel of the recorder **65**. In the radioactivity signal channel, the second coupling capacitor **67** is connected to the cable center conductor **19** and in series with the input of the discriminator **69**, the output of which is connected via lead **79** to the input of the pulse rate counter **71**, the output of which is connected via lead **81** to the input of the other channel of the recorder **65**.

As shown in FIG. 4, the down-hole assembly **11** includes the collar locator **37**, a voltage regulator **83**, a choke **85**, a drive motor **87**, a by-pass capacitor **89**, a first diode **91**, a second diode **93**, a current limiting resistor **95**, a perforator position signal generator **97**, a gun detonator **99**, gamma ray detector **41**, and gamma ray source **45**. The collar locator **37** is connected via lead **101** to the cable center conductor **19**, and to common or ground at **103**. A series circuit may be traced from the cable center conductor **19** via lead **105** through the choke **85** and via lead **107** through the motor **87** and via lead **109** through the gamma ray detector **41** and to common or ground at **103**. The voltage regulator **83** is connected via leads **111, 113** in parallel with the drive motor **87**. The by-pass capacitor **89** and the first diode **91** are connected in parallel and via lead **115** to lead **105**, and via lead **117** to lead **109**. The second diode **93** is connected to lead **109** and in series with the gun detonator **99** to ground at **103**. The first and second diodes **91, 93** are poled to conduct in the direction away from common or ground **103**. The perforator position signal generator **97** includes a ring **119** which is fixed to the motor drive output shaft **55** and rotates therewith. A first contact **121** rides on a portion of the ring **119** which is continuously conductive around the ring peripheral surface. The first contact **121** is connected to ground or common at **103**. A second contact **123** rides on a portion of the ring **119** wherein the conductive portion is interrupted by a plurality of insulating segments **125** for a purpose to be hereinafter explained. The second contact **123** is connected in series with the current limiting resistor **95** to the lead **109**. The gamma ray source **45** has no electrical connection, but is shown as a block in FIG. 4 for the sake of completeness.

Referring now to FIG. 3, the motor drive section **39** may include a first inner housing **127** containing the drive motor **87** and suitably supporting same within the drive section outer housing, and a second inner housing **129**. Suitably mounted within the second inner housing are the choke **85**, the voltage regulator **83**, the by-pass capacitor **89**, and the first diode **91**. The motor drives a gear reduction **131** which in turn drives the motor section output shaft **55**. Also, the perforator position signal generator **97** is disposed on the output shaft **55** and within the motor drive section **39**.

The operation of the perforator orienting apparatus and system of the invention may now be considered. The regulated direct current power supply **57** supplies about 250 volts at its output terminals. Of this voltage, some is dropped in the power cable **15**, and some across the choke **85**, leaving about 107 volts for the motor **87** and about 120 volts for the gamma ray detector **41**. The motor **87** is of permanent magnet direct current type arranged to operate at a speed that will cause the output shaft **55** to rotate at an appropriate speed, for example, about 1° per second. The choke **85** may have a value of about 2 henries, and serves to filter out motor brush noise and thus prevents its transmission up-hole. The voltage regulator **83** may be a type OB2 gas regulator tube, which serves not only to maintain a constant voltage across the motor **87** and thus keep the motor speed constant, but also to conveniently by-pass direct current power to the gamma ray detector section. The collar locator **37** may be a conventional magnetic type the output signals of which are indicated by above-ground equipment not shown. The radioactive source may be of any suitable conventional type, with a corresponding conventional detector section. In the embodiment shown, the radiation source is simply a pellet of radioactive material which produces gamma radiation, and the detector is of a conventional type which produces output pulse signals at a rate which is proportional to the quantity of gamma radiation present at the detector input. It will of course be recognized that the gamma ray source **45** as well as the detector **41** must have azimuthal directional properties. This is conventionally and conveniently accomplished by shielding both the source and the detector with suitable high density materials, so that each has only a window or unshielded portion located in the same vertical plane. One satisfactory arrangement for this purpose is shown and described by M. P. Lebourg and W. T. Bell: "Perforating of Multiple Tubingless Completions," in Journal of Petroleum Technology, May 1960, vol. 219, pp. 88–93. The perforator device **47** may be of any appropriate conventional type, but in the embodiment shown is a shaped charge gun of the non-expendable type wherein a plurality of shaped charges **133** are mounted in a carrier and are all oriented to fire in the same direction. Included within the gun carrier is the conventional gun detonator device and arrangement **99**, including the second diode **93**.

To perform a perforating operation, the down-hole assembly **11** is lowered inside the tubing string **13** to be perforated and into the bore hole **33** to the desired depth within the chosen production zone. The depth positioning is done in a conventional manner utilizing the collar locator **37** along with bore hole log information that was previously obtained. After the down-hole assembly **11** has been positioned at the desired depth the orienting apparatus is energized so that orientation recording operations may begin. The motor **87** then starts running, so that the gamma ray detector **41** rotates, with the window (not shown) at its output scanning the bore hole **33** in the radial directions from the detector rotational axis. In about six minutes, the detector will scan one full revolution, or 360° (assuming that the output shaft **55** is driven at about 1° per second).

The recording operation is arbitrarily started from whatever azimuthal position the detector **41** happens to be in when the apparatus is energized. As hereinbefore mentioned, the recorder has two pens, the first of which makes a first trace on the strip chart in accordance with the output of the radioactivity signal channel and the second of which makes a second trace in accordance with the output of the perforator position indicator channel. A typical strip chart that has been produced in accordance with the present invention is shown schematically in FIG. 5, wherein the right hand or first trace **135** was produced by the first recorder pen and the left hand or second trace **137** was produced by the second recorder pen. The numbers at the left of the chart correspond to 24 equal intervals in a single scanning revolution, and are thus each 15 scanning degrees apart.

The radiation which the detector **41** sees as it scans is converted to pulses by the detector section, which pulses are transmitted via lead **109**, by-pass capacitor **89**, leads **105**, to cable **15** and thence up-hole and via coupling capacitor **67** to the discriminator **69**. The discriminator **69** acts to separate the radioactivity signal pulses from the other signals present on the cable **15**, and then passes the separated pulses to the pulse rate counter **71**. The pulse rate counter integrates the pulses and delivers to

the recorder **65** a signal which varies in magnitude proportional to the pulse rate, which in turn is a function of the radiation present at the input of the detector **41**. The recorder **65** then produces the chart first trace **135** as the scanning operation proceeds.

As the detector **41** performs its scanning operation the ring **119** of the perforator position signal generator is also rotating at the same rate of about 1° per second, or about one revolution per six minutes. The ring **119** is continuously connected to common or ground **103** by means of the first contact **121** which continuously rides on the conductive portion of the ring. The second contact **123** rides the conductive portion of the ring **119** during spaced intervals within each scanning revolution, and during these conductive intervals the current limiting resistor is connected via the contacts **123**, **121** to common or ground. These conductive intervals are however interrupted by the presence of the insulating segments **125**. There are 23 insulating segments **125** disposed with their outer surfaces on the cylindrical peripheral surface of the ring **119** such that there is a junction between a trailing edge of an insulating segment and the leading edge of a ring conductive portion at each 15° interval of the ring surface except at one place, where the interval is 30° for a purpose to be hereinafter explained. These junctions are represented on the chart of FIG. 5 by the numbers **1** through **24** (with only odd numbers being shown and with a gap indicating no junction at position **3**).

Each time the second contact **123** arrives at a junction, the regulated direct current power supply **57** is shunted via current limiting resistor **95** to ground **103**. This shunting action produces a slight but abrupt change in direct current load current resulting in the production of a transient signal which is immediately sensed aboveground by the perforator position indicator channel. The transient signal is transmitted from the cable **15** via coupling capacitor **59** and low pass filter **61** to the input of the amplifier **63**. The low pass filter **61** acts of course to exclude signals other than the desired transient. The amplifier **63** is assumed to include suitable conventional means for shaping the transient signals to the sharp marker or position indicator pulses **139** that appear on the recorder second trace **137**. The amplifier **63** is also assumed to include suitable conventional means to exclude the unwanted or extraneous transient signal that is produced when the second contact **123** arrives at junction at the conductive portion trailing edges and the insulating segment leading edges.

When the recordng operation has proceeded for a sufficient time to produce postion marker pulses **139** for at least one complete revolution of the detector **41** and including at least two gaps in the position marker pulse train, the apparatus may be de-energized. It being known that the position marker gaps always occur at position **3**, these gap positions may be numbered **3** on the chart and then the rest of the position numbers may be properly applied to the chart. The chart positions are now definitely correlated with the aforementioned junction positions on the ring **119**, and therefore also with the corresponding detector positions. Thus, at the instant the contact **123** arrived at a given junction, as represented by a position marker pulse on the chart, the first trace recorder pen was indicating at the same chart position the radiation magnitude seen by the detector at the same instant. It is thus apparent that the recorder second trace **137** provides position indicator markers **139** which positively correspond to the orientation of the detector **41** and are positively correlatve with the recorder first trace **135**.

It is known that when the radioactivity source is incorporated in the down-hole assembly within the tubing to be perforated, which is the case thus far herein descrbed, the radiation at the detector input is minimum when the detector is seeing an obstruction. Thus it may be observed in FIG. 5 that the first recorder trace **135** is at a minimum in the region where it most nearly approaches the second trace **137**, or roughly between positions **6** and **12**. It can be seen from FIG. 2, wherein markers are numbered **1** through **24** and and are oriented correlative to those bearing like numbers in FIG. 5, that the obstruction in the form of the second and third tubing strings **29**, **31** do in fact occur in the region between numbers **6** and **12**. It is also apparent that a safe direction to fire the perforator gun **47** would be in the direction opposite or 180° away from the central portion of the obstruction region. This desired firing direction is then clearly at about position **21**. It is noted that the gun **47** in FIGS. 1 and 5 has been oriented so as to fire at position **21**, as is evidenced by the orientation of the shaped charges **133**. It will be obvious to those skilled in the art that the perforator gun **47** has been initially oriented in a known manner relative to the detector **41**. While no particular specific orientation relation is essential, the most convenient is to have the gun pointed 180° away from the detector.

In order to actually fire the gun it is only necessary to momentarily reverse the polarity of the direct current power supply (by conventional means not shown) so that current may pass from ground **103** through the gun detonator **99**, diodes **93**, **91** and lead **105** to the cable center conductor **19** and thence up-hole to the power supply **57** and again to ground **103**.

In practice it is convenient and helpful to translate the information produced on the recorder strip chart (FIG. 5) to a polar plot or chart as shown in FIG. 6. To accomplish this, the radial lines of the polar chart paper are marked with position numbers **1** through **24** correlative to the same numbers on the strip chart. In addition, an arbitrary zero line **141** disposed parallel to the direction of strip chart movement is established on the strip chart as indicated in FIG. 5. The zero line **141** is not to be confused with the recorder zero output signal trace, which would be to the left of trace **137** in FIG. 5. Then the points on the recorder first trace **135** corresponding to each position marker (for example, points A and B corresponding respectively to position markers **5** and **7**) are determined. Then the corresponding points are determined on the polar chart (FIG. 6) by measuring the distance between the zero line **141** and the determined point on the recorder first trace **135** and then laying off such distance (or a proportional distance) on the proper radial of the polar chart. In this manner, the curve or trace **143** of the polar chart is plotted. It is noted that the solid line portion of the trace **143** may be considered to begin at position **5** (point A) and proceed counterclockwise around the plot to close at position **5**. However, there is a dotted line porton of trace **143** that extends between position **5** and position **24**. This dotted line merely indicates that the first recorder trace **135** covers a complete revolution of the detector **41** plus a portion of a second revolution.

It is easy to see from the trace **143** of the polar plot that the obstructions (tubing strings **29**, **31**) are in the region between radials or positions **6** and **12**, and that the gun **47** can be safely fired toward position **21** as indicated by the arrow.

From the foregoing it will be apparent that a first important concept of the present invention is to generate at the down-hole assembly orienation signals which are positively related to discrete azimuthal positions of the detector and the perforator device, and to present and record such orientation signals at the above-ground equipment in positive time correlation with the presentation and recording of corresponding detector output signals. A second important concept of the present invention is to interpose in a sequential train of the orientation signals above-mentioned a periodically recurring identifiable anomaly.

Application of the first concept above-mentioned provides the equipment operator with positive indicatons of the azimuthal movement of the detector, such indications being positively correlated with the detector output sig-

nals. Thus, the likelihood of acting upon false orientation information is substantially reduced. Application of the second concept above-mentioned together with the first, provides the equipment operator a way to check the veracity of the orientation signals and thus ensures that the orientation information acted upon is unmistakably accurate and dependable. Also, application of said second concept obviates the necessity of establishing a predetermined initial orientation of the tool.

The preferred embodiment of the present invention as shown and described herein demonstrates one way in which the important concepts above-mentioned may be applied in practice to achieve the desired results. It is realized, of course, that the actual physical configuration of the apparatus used to apply said concepts may certainly be varied in a number of ways that will be apparent to those skilled in the art. For example, there are certainly various ways in which the orienting signals could be initiated in the down-hole assembly, and there are various ways in which they could be presented to the above-ground equipment. Also, the anomaly above-mentioned could take various forms and could be produced by various means. Further, the radiation source (in cases where radioactivity signals are employed) need not necessarily be carried by the down-hole assembly); it may, if desired, be suspended in another tubing string.

The foregoing disclosure and the showings made in the drawings are merely illustrative of the principles of this invention and are not to be interpreted in a limiting sense.

I claim:

1. Apparatus for perforating in a bore hole having a plurality of tubing strings disposed therein in side by side relation comprising:

(a) a down-hole assembly including a first section and second section;

(b) above-ground equipment;

(c) means for disposing said down-hole assembly within a first one of said tubing strings which is to be perforated at the desired perforation depth;

(d) means included in said first section of said down-hole assembly for preventing rotation of said first section relative to said first tubing string;

(e) means included in said first section of said down-hole assembly for rotating said second section relative ot said first section;

(f) a perforating tool, a radioactive source, and a radioactivity detector included in said second section;

(g) means included in said down-hole assembly for generating orientation signals which are positively related to azimuthal positions of said detector;

(h) said orientation signal generating means including means to interpose in a sequential train of said orientation signals a periodically recurring identifiable anomaly;

(i) means for transmitting signals derived from said detector, and said orientation signals to said above-ground equipment;

(j) and means included in said above-ground equipment for recording said signals.

2. Apparatus for perforating in a bore hole having a plurality of tubing strings disposed therein in side by side relation comprising:

(a) a down-hole assembly including a first section and a second section;

(b) above-ground equipment, and a down-hole signal source;

(c) means for disposing said down-hole assembly within a first of said tubing strings which is to be perforated at the desired perforation depth;

(d) means included in said down-hole assembly for preventing rotation of said first section relative to said first tubing string and for rotating said second section relative to said first section;

(e) detector means included in said second section and responsive to said down-hole signal source, for generating signals indicative of the azimuthal location of other said tubing strings relative to said first tubing string;

(f) a perforating tool included in said second section;

(g) means included in said down-hole assembly for generating orientation signals which are positively related to azimuthal positions of said detector;

(h) said orientation signal generating means including means to interpose in a sequential train of said orientation signals a periodically recurring identifiable anomaly;

(i) means for transmitting signals derived from said detector, and said orientation signals to said above-ground equipment;

(j) and means included in said above-ground equipment for recording said signals.

3. Apparatus for orienting a tool in a bore hole comprising:

(a) a down-hole assembly including a first section and a second section;

(b) above-ground equipment, and a down-hole signal source;

(c) means for disposing said down-hole assembly within the bore hole at a desired depth;

(d) means included in said down-hole assembly for preventing rotation of said first section relative to the bore hole and for rotating said second section relative to said first section;

(e) detector means included in said second section and responsive to said down-hole signal source, for generating signals indicative of an azimuthal pattern;

(f) a tool to be oriented included in said second section;

(g) means included in said down-hole assembly for generating orientation signals which are positively related to azimuthal positions of said detector;

(h) said orientation signal generating means including means to interpose in a sequential train of said orientation signals a periodically recurring identifiable anomaly;

(i) means for transmitting signals derived from said detector, and said orientation signals to said above-ground equipment;

(j) and means included in said above-ground equipment for recording said signals.

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