

**Aug. 13, 1968**

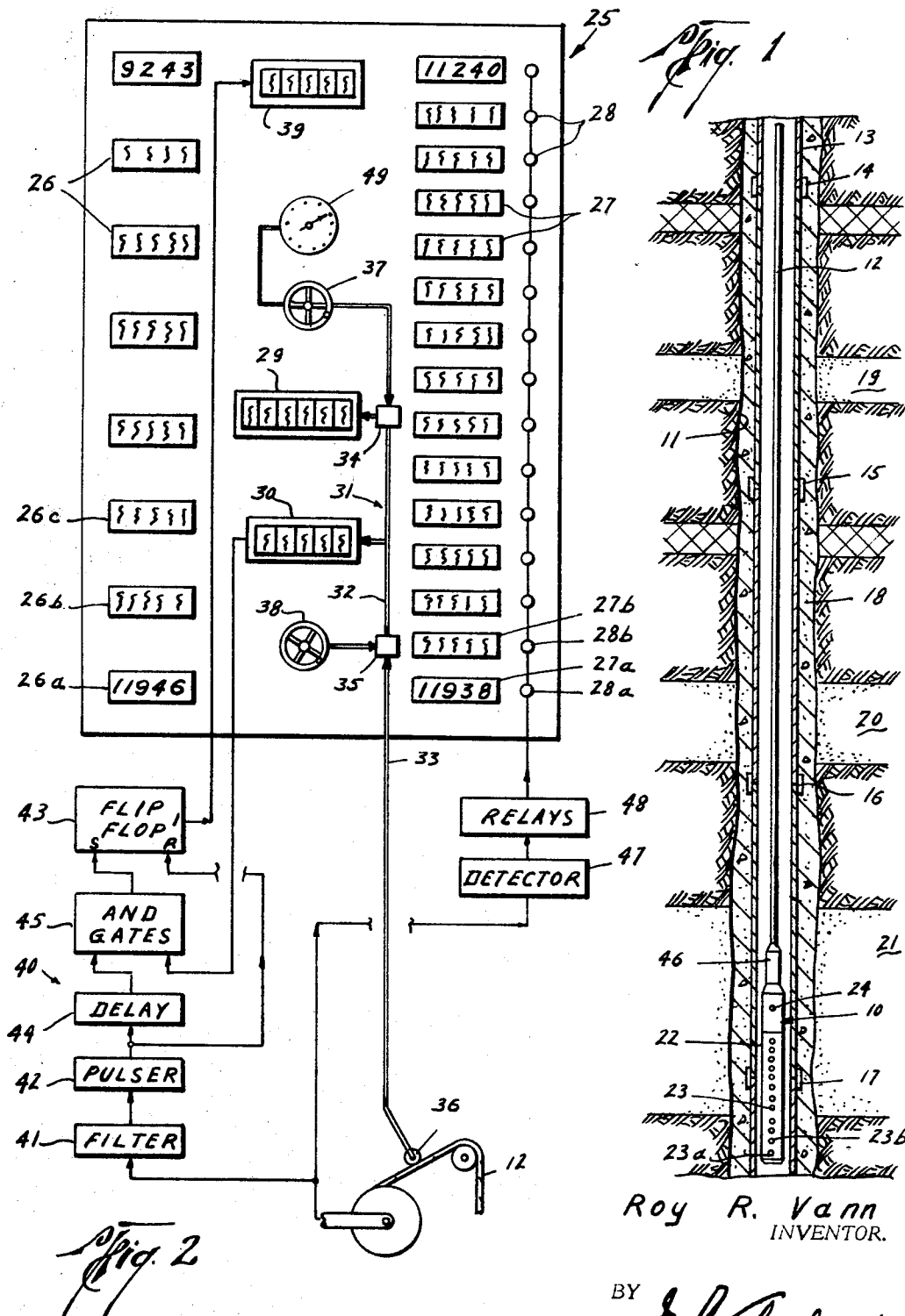
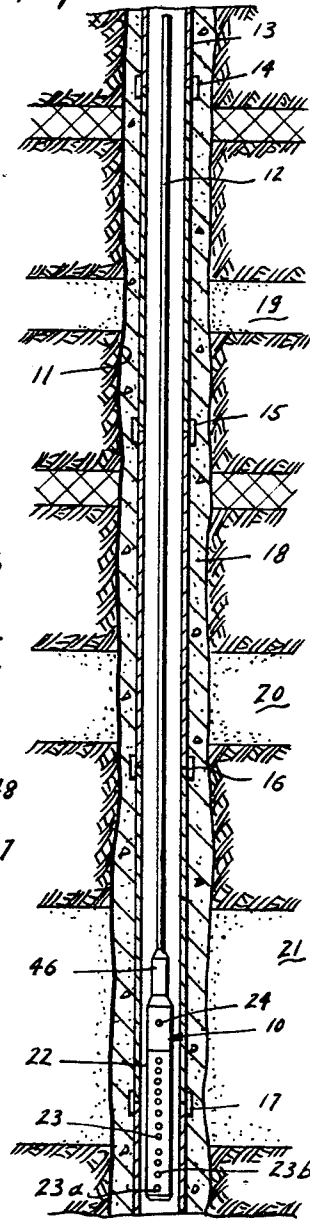
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**3,396,787**

## DEPTH CONTROL METHODS AND APPARATUS

Filed Aug. 31, 1966

4 Sheets-Sheet 1



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**Aug. 13, 1968**

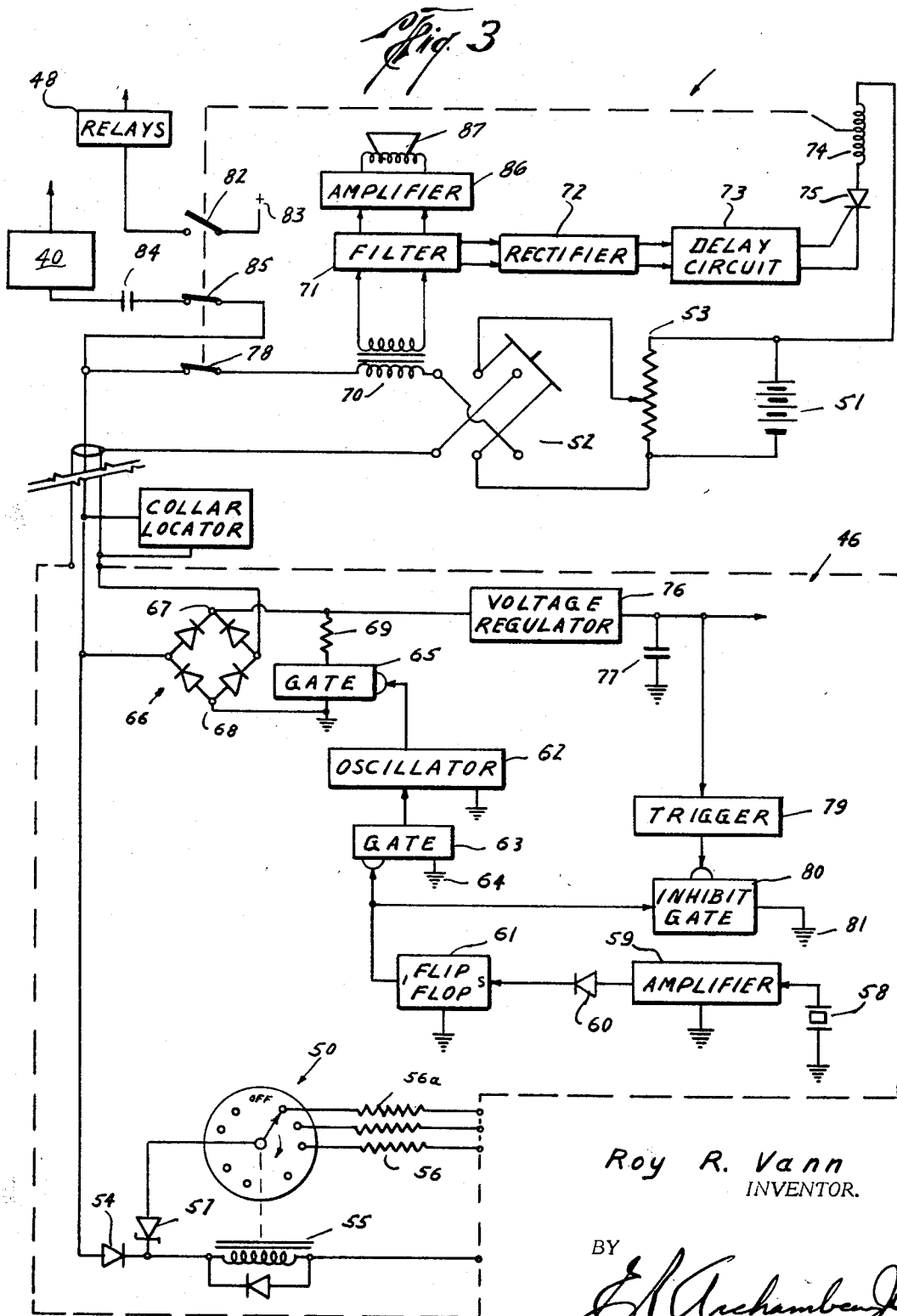
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## DEPTH CONTROL METHODS AND APPARATUS

Filed Aug. 31, 1966

4 Sheets-Sheet 2



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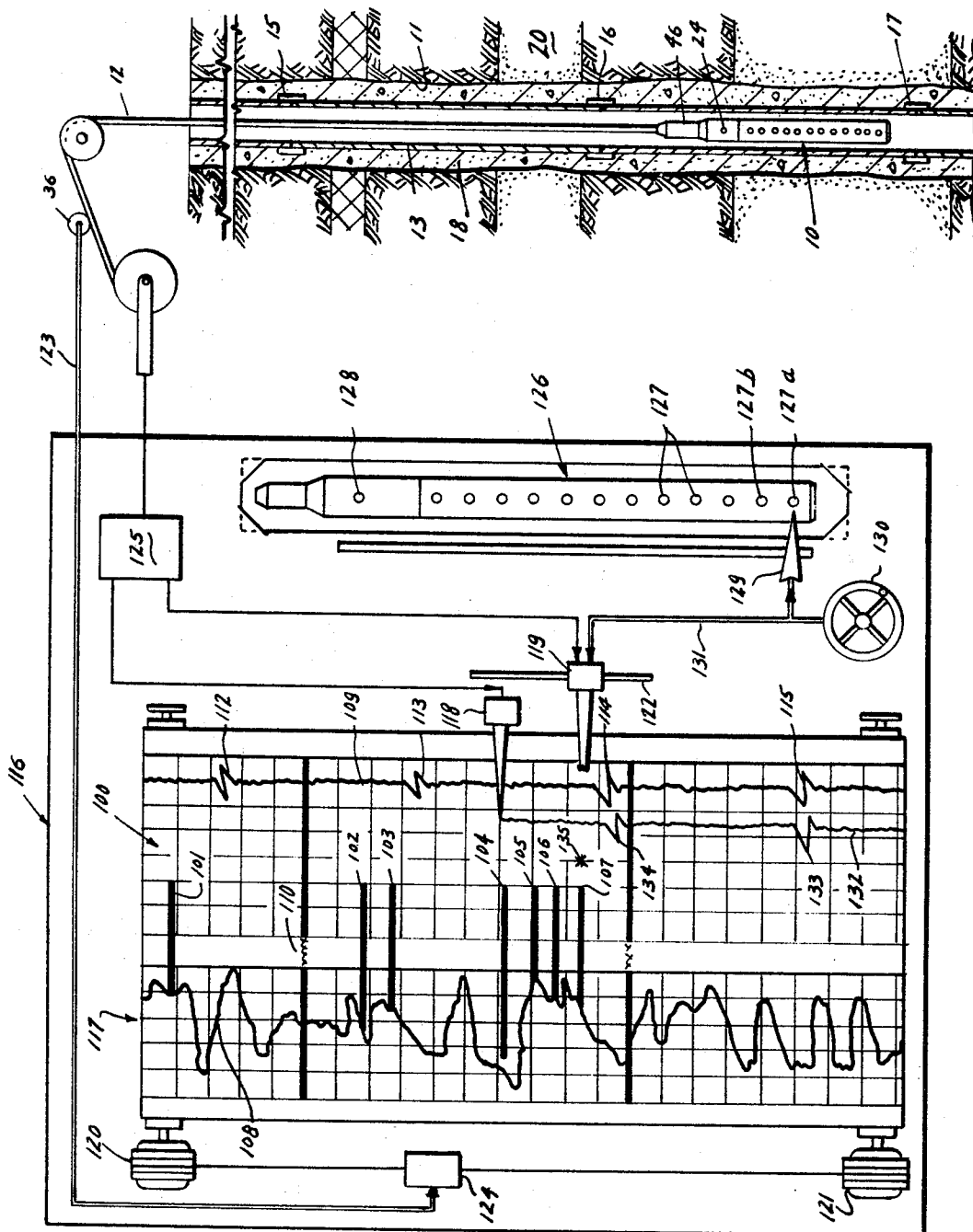
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DEPTH CONTROL METHODS AND APPARATUS

Filed Aug. 31. 1966

4 Sheets-Sheet 3



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*Fig. 4*

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DEPTH CONTROL METHODS AND APPARATUS

Filed Aug. 31, 1966

4 Sheets-Sheet 4

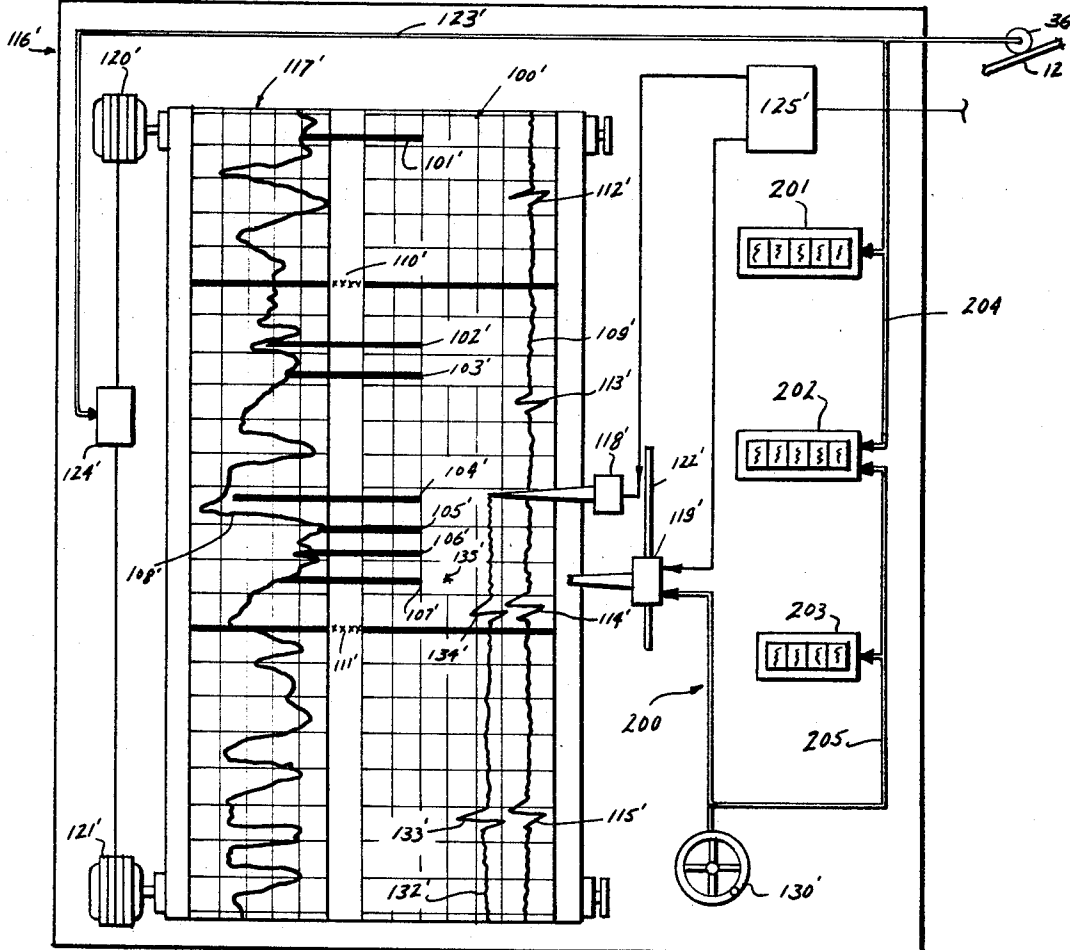
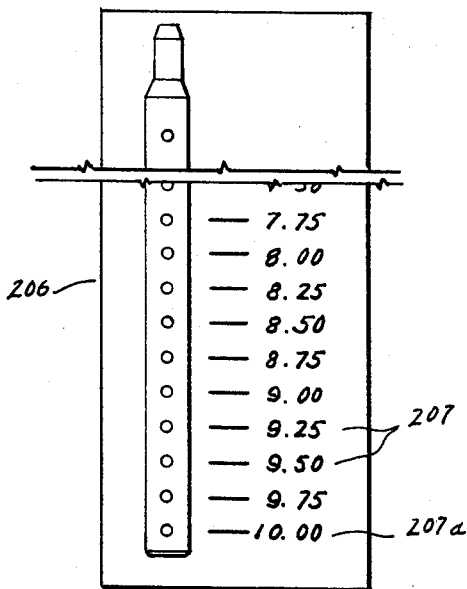


Fig. 5

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3,396,787

**DEPTH CONTROL METHODS AND APPARATUS**  
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Filed Aug. 31, 1966, Ser. No. 576,389  
15 Claims. (Cl. 166-4)

This invention relates to methods and apparatus for positioning well tools in a well bore; and, more particularly, to new and improved methods and apparatus for accurately positioning selectively operable well completion devices at predetermined depths in a well bore and displaying at the surface indications of the location of these devices in the well bore.

Once the casing has been set in a well bore, the usual practice is to obtain a log that will in some manner identify at least certain formations and determine their depth. In one manner of doing this, a logging tool is passed through the well bore to simultaneously obtain a log of the natural or induced formation radioactivity as well as some detectable indicia of the positions of the casing collars as a function of well depth. In this manner, the depths of particular formations in relation to certain ones of the collars can be established. Subsequently, by using these logs and, for example, employing a casing collar locator with a completion tool, the completion tool can be located fairly accurately at any particular depth in the well bore. To accomplish this, the position of the completion tool is ascertained by visually comparing the original collar log with the collar log being obtained as the completion tool is being positioned. Then, by using this comparative data, the cable is payed out or reeled in as required to bring the completion tool to the particular depth desired.

One of the most frequent uses for such a depth-correlating procedure is to position a perforator in a well bore. To perforate a well at several depths, a perforator having a number of selectively operable perforating devices thereon is dependently coupled from a casing collar locator and lowered into the well bore. It will be realized, of course, that although the collar locator is a known distance above each of the perforating devices, these different spacings must be taken into consideration to locate each device. For example, assuming that the first device to be actuated is at the lower end of the tool, a particular correction must be made to compensate for the spacing of the collar locator from that device. Then, as further perforating devices are successively actuated, this spacing will decrease as the devices are fired, with a different spacing correction being required to accurately locate each device.

Accordingly, where a number of completion operations are to be carried out at different depths in a well bore, it is essential to know at all times not only the spacing between the collar locator and the device next to be actuated but also the actual depth of that device as well. Although the above-mentioned procedure itself is basically accurate, where a number of operations are to be made in a well bore at several depths, it is not at all too uncommon to make some error that causes the well to be completed incorrectly. For example, in addition to making such simple errors as subtracting rather than adding the spacing to the depth indicated by the collar log, it is not at all too uncommon to sometimes even overlook the successive changes in spacing as the various devices are actuated. Thus, where a larger number of completion devices are to be actuated at various depths in a well bore, one or more such human errors can result in the well being incorrectly completed.

Consequently, it is an object of the present invention

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to provide new and improved methods and apparatus for accurately positioning well tools having a plurality of selectively operable devices in a well bore and providing visual indications at the surface of the position of each of the selectively operable devices as it is being operated.

This and other objects of the present invention are accomplished by displaying visual representations of the known depths of one or more detectable distinctive depth-reference means in a well bore as well as the depths at which a well tool is to be positioned. Then, as this tool is being positioned in the well bore, detecting means associated therewith will detect these detectable depth-reference means and display indications of their depth. By correlating these visual representations with the displayed depth indications, appropriate corrections can be made to these indications. In addition to these displayed depth indications, similar presentations are made of the apparent depth of the well tool. These second indications are corrected simultaneously with the first as required. Upon reaching the proximity of where the well tool is to be first positioned, the tool is located by correlating the second indications with the representation of the first depth at which the tool is to be positioned. When the two displays coincide, the well tool is halted and operated as desired. To correctly reposition the well tool, the displayed indication of the depth of the well tool is corrected as necessary to show any change in relative positions on the tool, and the tool is repositioned by correlating the indicated depth of the tool with the representation of the second depth at which the tool is to be positioned.

The novel features of the present invention are set forth with particularity in the appended claims. The operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows a typical perforator in a well bore to be perforated at a number of depths;

FIG. 2 depicts one embodiment of apparatus employing the principles of the present invention and that may be used in its practice;

FIG. 3 depicts a circuit diagram of apparatus that may be used in the practice of the present invention;

FIG. 4 is a typical log of the portion of the well bore illustrated in FIG. 1; and

FIG. 5 schematically illustrates a different arrangement of apparatus and certain successive steps taken in the practice of another and improved embodiment of the present invention.

Turning now to FIG. 1, a typical well tool 10 is shown suspended in a well bore 11 from a cable 12. As is customary, the well bore 11 is completed by a string of casing joints 13 connected to one another by couplings or collars, as at 14-17, and secured in place in the well bore by cement 18.

It will be understood, of course, that the present invention is applicable to any operation involving the positioning of one or more devices in a well. Moreover, it is to be realized that any one or more means can be used to determine the relation of particular earth formations to each other as well as to some identifiable point in the well bore.

As one example of the present invention, however, it is assumed that the well tool 10 is to be used to make a selected number of perforations (not shown) in several producible earth formations 19-21. To accomplish this, the well tool 10 is appropriately arranged to include a perforator 22 having thereon a number of perforating devices as, for example, a plurality of shaped charges 23 that may be selectively detonated as required. Inasmuch

as the particular arrangement of the perforator 22 plays no part in the present invention, it is necessary only to understand that the perforator is suitably arranged so a predetermined number of one or more of its shaped charges 23 can be detonated upon command from the surface. To assist in positioning the perforator 22 at the correct depth, depth-correlating means, such as a casing anomaly or collar locator 24 which, for example, may be one of those shown in Patent No. 3,144,876 to Nick A. Schuster are mounted on the upper end of the well tool 10. Such locators, as at 24, can also detect previously located magnetic anomalies as, for example, a short "pup" joint or other device in the string 13. It should also be understood that any detecting means that can detect an identifiable formation characteristic such as, for example, the natural or induced radioactivity of earth formations can also be used in the place of or in conjunction with the locator 24.

Turning now to FIG. 2, a control panel 25 arranged in accordance with the present invention is shown. On the left of the panel 25, a series of display means 26 are provided to designate the depth at which certain pre-placed detectable depth-reference points are known to be in the well bore 11. On the right of the panel, a similarly arranged group of display means 27 are provided to designate the depths at which certain well operations are scheduled to be conducted. If desired, indicator lights 28 can also be provided adjacent to each of these last-mentioned display means 27.

These display means 26 and 27 may take any convenient form to provide a suitable indication that is translatable into a depth reading. Although it will be recognized that more sophisticated alpha-numerical electronic or electro-mechanical display devices of various forms are available, for purposes of simplifying the explanation of the present invention, it will be assumed that these means 26 and 27 are merely prepared tags or labels on which the particular depths are written.

Similarly, the detectable depth-reference points may take various form such as, for example, pre-placed detectable markers or bullets (such as those described in Patent No. 2,228,623) or even outstanding measurements of certain parameters of each formation characteristics such as measurements of either natural or induced radioactivity in the formations. However, to facilitate the explanation of the present invention, it will be assumed that the depth-reference points employed are detectable magnetic anomalies such as provided by the collars, as at 14-17, in the casing string 13 and that a typical collar locator 24 is employed to detect them.

At the bottom of the panel 25, a pair of numerical depth-indicating means 29 and 30 are mounted and synchronously connected to actuating means, as at 31, to simultaneously display continuously changing depth indications in response to travel of the tool 10. Although the depth-indicating means 29 and 30 and the travel-responsive actuating means 31 may be any suitable arrangement of electronic means, electro-mechanical devices, or the like, it is preferred, however, to employ a conventional remote-readout counter or totalizer for one of the depth-indicators 30 and a simple totalizer for the other indicator 29. With these indicators 29 and 30, the actuating means may take the form of a convenient arrangement of mechanical drives, as at 32 and 33, and gear and/or clutch devices, as at 34 and 35, to synchronously drive the indicators in response to movement of a wheel 36 frictionally engaged with the cable 12. Reset controls 37 and 38 are respectively connected to the indicators 29 and 30 so that adjustment of the control 38 will change both indicators simultaneously and adjustment of the other control 37 will change only the indicator 29. For reasons to be explained subsequently, the indicator 29 is preferably arranged to display a depth reading in tenths of a foot.

It will be appreciated, therefore, that the indicators 29

and 30 will be driven by the various drives 31-36 in response to travel of the tool 10 in the well bore 11. Thus, by setting the indicators 29 and 30 while the tool 10 is at the surface, as the cable 12 is unreeled, each of the indicators will display a continuously increasing depth measurement. By setting the indicator 30 to display the depth of the collar locator 24 and the other indicator 29 to display the depth of a selected one of the shaped charges 23 in the perforator 22, the indicators will provide a continuous display of the depth of these two means as the tool 10 is positioned in the well bore 11. The difference between the readings of the two indicators 29 and 30 will, of course, remain the same since it represents the actual distance between the collar locator 24 and that particular completion device 23. This differential can, however, be varied or reset by adjustment of the reset control 37 as will be subsequently explained.

It will be realized, of course, that slight errors will occur as the cable 12 is being unreeled so that by the time the tool 10 is at a substantial depth, the indicators 29 and 30 may no longer be displaying accurate depths. Accordingly, the present invention includes additional depth-indicating means 39 at the top of the panel 25 that are arranged to display depth indications by which the indicators 29 and 30 can be corrected.

To accomplish this, the depth indicator 39 may be a remote-readout device that may be either a servo or an electrical alpha-numerical display unit that is connected by suitable circuitry 40 to the electrical output of the indicator 30. Although other arrangements may be employed, the circuitry 40 is arranged so that each time the collar locator 24 passes a collar, as at 14-17, whatever depth measurement is displayed at that moment on the indicator 30 will be reproduced on the remote indicator 39 and remain there until the next collar is passed. To accomplish this, the output of the collar locator 24 is connected through a low-pass filter 41 to a monostable multivibrator or pulser 42. In this manner, only the relatively low frequency signals from the collar locator 24 will be capable of causing the reproduction of the display on the indicator 30 on the indicator 39. The output of the pulser 42 is divided, with one portion of the signal being bypassed to the "reset" inputs of a plurality of flip-flops 43 and the other portion of the signal being connected through a delay circuit 44 to one of the inputs of each of a plurality of AND gates 45. The outputs of the indicator 30 are each separately connected to the other input of one of each of the AND gates 45. The outputs of the AND gates 45 are each individually connected to the "set" inputs of the flip-flops 43 and the "1" outputs of these flip-flops are individually connected to the appropriate digit display means in the remote indicator 39.

It will be realized, of course, that for each digit that is to be reproduced from the indicator 30 to the indicator 39, ten individual and separate circuits must be provided. Thus, if five digits are to be displayed on the indicators 30 and 39, fifty AND gates 45 and fifty flip-flops 43 will be required. Of these, only five of each of the flip-flops 43 and AND gates 45 will be in use at any given moment.

Thus, each time a collar locator signal is received, it will pass through the filter 41 to start the multivibrator 42. The multivibrator 42 is appropriately arranged to provide a single pulse of sufficient duration to ensure reliable operation of the AND gates 45 and to permit the collar locator 24 to pass a single casing collar at the usual speed that the tool 10 is moved in the well bore 11. The output pulse of the multivibrator 42 will simultaneously reset each of the flip-flops 43 before that pulse can travel through the delay circuit 44 to the AND gates 45. It will be appreciated, of course, that only those of the AND gates 45 that have a signal at their input from one of the digits on the indicator 30 will function. The other AND gates 45 will remain "off." Thus, those flip-flops 43 that are connected to the AND gates 45 that are turned-on will

develop a signal that is received by the appropriate signal-responsive means of the remote display indicator 39.

Accordingly, each time the collar locator 24 passes a collar, it will actuate the appropriate ones of the AND gates 45 and flip-flops 43 and momentarily couple the indicator 30 to the indicator 39. By momentarily connecting the indicators, whatever depth is being displayed at that moment on the indicator 30 will be redisplayed on the other indicator 39. As the tool 10 moves further, the AND gates 45 and flip-flops 43 will be turned off and the displayed depth on the "slave" indicator 39 will remain although the reading on the "master" indicator 30 continues to move.

As the tool 10 is lowered into the well bore 11, the "master" indicator 30 will, therefore, successively change to provide a continuous display of the assumed depth of the collar locator 24. Each time that the collar locator 24 passes a collar in the casing string 13, the circuitry 40 will respond to transfer the reading on the indicator 30 at that moment to the "slave" indicator 39. This latter reading will remain on the "slave" indicator 39 until the collar locator 24 passes another collar.

Accordingly, by previously designating the known true depths of certain selected ones of the collars in the casing string 13 on the display means 26, when the collar locator 24 reaches one of these selected collars the reading on the "slave" indicator 39 should correspond to the depth displayed on that label. If the two readings correspond, the "master" indicator 30 (as well as the indicator 29) will, of course, be displaying an accurate depth measurement.

On the other hand, if the reading on the "slave" indicator 39 does not correspond with that on the appropriate display means 26, it will be readily apparent that the indicators 29 and 30 must be corrected. This correction can be easily made by the reset control 38 whether the tool 10 is halted or moving. Thus, once the difference between the reading on the "slave" indicator 39 and the appropriate one of the display means 26 is corrected on the "master" indicator 30, both the "master" indicator and the indicator 29 will again be displaying accurate readings. By selecting several collars at spaced intervals in the casing string 13, the indicators 29 and 30 can be adjusted as required during the descent of the tool 10. In this manner, by the time the tool 10 reaches the vicinity of its first completion operation the indicators 29 and 30 will be known to be displaying substantially accurate readings. This accuracy can of course be verified by selecting as a depth-reference point still another collar, as at 16, just above the first depth that the tool 10 is to be positioned and displaying it as at 26a.

Accordingly, as the tool 10 nears the depth at which it is to be operated, the indicator 30 will be displaying the true depth of the collar locator 24 and the indicator 29 will be displaying the true depth of a predetermined one of the completion devices 23. Assuming that this first completion device is the lowermost shaped charge 23a in the perforator, the tool 10 is halted when the reading on the indicator 29 corresponds with the depth displayed on, for example, the lowermost marker 27a. This correlation will verify that the tool 10 is in fact at the correct depth for the first completion operation to be conducted.

The perforator 22 is then actuated to detonate the first shaped charge 23a. As will subsequently be explained, concussion-responsive means 46 (FIG. 1) on the tool 10 actuate a detector 47 which, in turn, actuate means, such as a group of stepping relays 48, to turn on the first indicator light 28a. This assures the observer that the first completion operation has been conducted; that this operation was at the depth shown on the indicator 29; and that the depth shown on the indicator corresponded with that displayed at 27a.

The reset control 37 is then operated to change the reading on the indicator 29 to designate the true depth of the next completion device on the tool as, for example, the shaped charge 23b. Adjustment of the control 37

changes only the indicator 29 to a new reading differing from that on the indicator 30 by a differential equal to the actual spacing between the collar locator 24 and the shaped charge 23b. If desired, a dial indicator 49 arranged to make, for example, one revolution per foot of travel can be employed to indicate when the reset control 37 had been correctly changed.

Once the indicator 29 is reset, the tool 10 is then repositioned to bring the reading on the indicator 29 to the depth displayed on the next marker, as at 27b. Then, when the tool 10 is correctly repositioned, the perforator 22 is again actuated to detonate the shaped charge 23b at that depth. Here again, the correlation of the indicator 29 and marker 27b as well as lighting of the pilot light 28b will provide indications of the accuracy of the operation.

These steps are repeated until all operations are completed. Should these operations be at various depths, as for example, in the formations 19 and 20, the accuracy of the reading on the indicators 29 and 30 will be verified each time the collar locator 24 passes a collar, as at 15 and 16, which has its depth displayed on the markers 26b and 26c. These corrections are made as previously described.

Turning now to FIG. 3, a schematic representation is shown of a suitable firing circuit for selectively detonating the shaped charges 23 and the means 46 and 47 for detecting their detonation. Inasmuch as the firing circuit and detecting means 46 and means 47 are respectively arranged in accordance with commonly owned earlier-filed applications Serial No. 420,345, now Patent No. 3,327,791 filed December 22, 1964, by John W. Harrigan, Jr., and Serial No. 569,316, filed August 1, 1966, by George W. Brock, only a brief explanation of the principles of each of these inventions and their relation to one another to the present invention is believed to be sufficient.

Briefly stated, the firing circuit is comprised of a solenoid-actuated selector switch 50 that is selectively operated by a DC power source 51 at the earth's surface and connected across the monocable 12. To regulate the output of the power source 51, a conventional polarity-reversing switch 52 and potentiometer 53 are appropriately arranged. A diode 54 connected to the solenoid 55 of the selector switch 50 ensures that it will be actuated only when a voltage of the correct polarity is applied thereto.

The selector switch 50 is selectively connected in turn to one side of each of the typical detonators 56 (schematically represented as resistors in FIG. 3), with the other sides of these detonators being returned electrically through the body of the perforator 22. In this preferred arrangement, the selector switch 50 is arranged to be indexed only one position at a time and remain at that position until de-energized. Thus, only by successively energizing and de-energizing the solenoid 55 can the switch 50 be advanced.

To control the detonation of the shaped charges 23, a Zener diode 57 is connected between the diode 54 and the switch 50. By selecting the Zener diode 57 to have a Zener level somewhat in excess of the voltage required to actuate the solenoid 55, the selector switch 50 will connect the next detonator 56 into the firing circuit without immediately detonating it. Thus, it is not until after the solenoid 55 has moved the switch 50 to its next position that the voltage across the monocable 12 will reach the Zener level so as to cause the Zener diode 57 to conduct and apply voltage to the detonator 56 in the circuit at that time. Then, by continuing to advance the potentiometer 53, the voltage will reach a magnitude sufficient to detonate the desired detonator 56. It will be recalled, of course, that once the selector switch 50 has been advanced, it can not advance further until the voltage is first removed and then re-applied to the solenoid 55. This will assure that voltage is at least applied in turn to each of the detonators 56 and minimize the risk of unintentionally skipping of a shaped charge 23.

Turning now to the shot-detecting means 47 and concussion-responsive means 46 depicted in FIG. 3. Briefly, the concussion-responsive means 46 includes signal-generating means, such as a transducer or piezoelectric crystal 58, that upon being subjected to a physical shock or the like to the well completion tool 10 will cause a detectable signal to be sent to the earth's surface through the cable 12. Once this signal has reached the surface, the shot-detecting means 47 are employed first to ascertain with reasonably certainty that the signal is not spurious and then secondly to actuate the relays 48 and indicator lights 28.

To accomplish this, the output of the crystal 58 is amplified by an amplifier 59 and connected by a diode 60 to the "set" input of a flip-flop circuit 61 that controls an oscillator 62 which will generate a repetitive output signal such as, for example, a sine wave or a square wave. One of the outputs of the flip-flop 61 is connected to the control terminal of a gate 63 that is in turn connected to the "initiate" input of the oscillator as seen in FIG. 3. This gate 63 is of the so-called "enable" type wherein application of a signal to its control terminal will cause a very low impedance to be across it. Thus, by connecting the gate 63 between an appropriate connection on the oscillator 62 and a ground, as at 64, initiation of the gate 63 by the flip-flop 61 will connect the oscillator to ground and start the oscillator. For reasons to be explained shortly, the output of the oscillator 62 is connected to the control terminal of another so-called "enable" type gate 65. Connected across the monocable 12 is a bridge circuit 66 which maintains the polarity of its output terminal 67 positive and that of the other output terminal 68 negative in either position of the polarity-reversing switch 52 to maintain a positive voltage on the various components in the downhole circuitry.

One end of a low-resistance resistor 69 is connected between the positive terminal 67 of the bridge circuit 66 and the "enable" type gate 65 which is in turn connected to ground and the negative terminal 68 of the bridge circuit. It will be appreciated, of course, that when the gate 65 is not operating, the other end of the resistor 69 is not connected to ground and is merely "floating." When the "enable" type gate 65 is operated, however, it will connect the "floating" end of the resistor 69 to ground so that the resistor is then across the output terminals 67 and 68 of the bridge circuit 66. By using a low value of resistance for the resistor 69, each time it is connected across the bridge circuit 66 by operation of the gate 65, the impedance across the monocable 12 will be decreased. Accordingly, since the gate 65 will be repetitively enabled and disabled by the oscillator 62, the impedance across the monocable 12 will be changing at the same rate to develop cyclic current changes therein at the same frequency as the oscillator.

To detect these cyclic changes in the current flowing through the monocable 12, the shot-detecting means 47 includes a transformer 70 that has its primary in series with the monocable 12 and its secondary connected to a bandpass filter network 71 designed to pass only the frequency of the cyclic changes. Thus, the cyclic changes in the current flowing through the monocable 12 will induce a corresponding signal in the secondary of the transformer 70. The signal passing through the filter 71 is rectified by a rectifier 72 and directed through a delay circuit 73 to a relay solenoid 74 controlled by a silicon-controlled rectifier 75 for actuating the relays 48 and indicator lights 28 as well as opening normally-closed relay switch means 76 in series with the monocable 12. This delay circuit 73 is of the well-known type wherein a voltage must be present on the input for a given period of time before a signal is generated. The silicon-controlled rectifier 75 inherently functions to continue conducting once it is initiated so long as power is not removed.

Thus, so long as no signal has been sent through the delay circuit 73, the rectifier 75 will not conduct and

the solenoid 74 will remain de-energized. Once it is initiated, the silicon-controlled rectifier 75 will continue conducting to energize the relay solenoid 74 so long as power is applied. When the power is interrupted, however, the silicon-controlled rectifier 75 will discontinue its operation until a second signal is applied through the time-delay circuit 73.

It should be noted in passing that the downhole portion of the circuitry 46 also includes a suitable voltage regulator 76 connected to the positive terminal 67 of the bridge circuit 66. A large capacitor 77 is also connected across the output of the voltage regulator 76 to prevent transients from affecting the B+ voltage to the balance of the circuits.

It will be noted that the time-delay circuit 73 and flip-flop 61 will prevent the presence of transients on the monocable 12 from initiating the shot-detecting means 46. Since transients are typically of a short interval, a sufficient delay interval in the delay circuit 73 will prevent a transient from energizing the relay solenoid 74. The flip-flop 61, will, of course, maintain the oscillator 62 operating so long as power is applied thereto. Thus, the oscillator 62 will continue operating until the relay solenoid 74 is energized. Opening of the relay contacts 78 will remove power from the downhole circuitry.

Because of the inherent nature of flip-flops, however, it is possible that the flip-flop 61 can be "set" in the wrong state so that it would immediately start the oscillator 62 when sufficient voltage is first applied across the monocable 12 as the solenoid 55 is being energized. This would, of course, cause the oscillator 62 to operate prematurely without energization of the crystal 58. Accordingly, to ensure that the flip-flop 61 is properly set so as not to initiate the oscillator 62 until a concussion energizes the crystal 58, a reset circuit comprised of a voltage-sensitive control 79 (such as a Schmitt trigger or the like) connected from the output of the voltage regulator 76 to the control input of a so-called "inhibit" gate 80 is provided. The inhibit gate 80 is in turn connected between the output of the flip-flop 61 and ground.

Thus, until the gate 80 is energized by the trigger 79, the previously mentioned output of the flip-flop 61 is grounded, as at 81, to prevent it from prematurely initiating the oscillator 62. When the output voltage of the voltage regulator 76 reaches a first predetermined value, however, as the potentiometer 53 is being advanced, the connection of this flip-flop output to ground through the gate 80 will ensure that the flip-flop 61 is set in the correct reset state. Then, at some higher second voltage, the voltage-sensitive trigger 79 will supply an output signal to the inhibit gate 80 to disconnect the grounded connection 81 from the output of the flip-flop 61. Once its output is ungrounded, of course, the flip-flop 61 will function as soon as the crystal 58 is energized. It will be understood, of course, that these first and second voltages are well below the voltage required to operate either the solenoid 55 or the Zener level of the Zener diode 57.

In operation, therefore, the perforating apparatus 10 is positioned as already described with reference to FIGS. 1 and 2. When the coincidence of the reading on the indicator 29 with one of the markers, such as 27a for example, indicates that the first shaped charge 23a is at the correct depth, the perforating apparatus 10 is halted. Then, the potentiometer 53 is slowly advanced. As the voltage across the monocable 12 is first increased, the output voltage of the voltage regulator 76 will initially be below the threshold level of the trigger 79 hereby ensuring that the flip-flop 61 will be placed into the reset state. When the flip-flop 61 is in this reset state the inhibit gate 80 holds the "1" output of the flip-flop at ground potential so that the oscillator 62 can not be initiated. As some higher voltage output of the voltage regulator 76, the voltage-sensitive trigger 79 will energize the inhibit gate 80 and remove the "1" output of the flip-flop 61 from ground potential so that whenever the

crystal 58 is energized by a concussion shock, the set input of the flip-flop will be energized to start the oscillator 62. It will be recalled, of course, that the threshold level of the trigger 79 is well below the voltage necessary to energize the selector switch 50.

The voltage across the monocable 12 will subsequently reach a level whereby the solenoid 55 will index the selector switch 50 to connect the detonator 56a for the first shaped charge 23a into the firing circuit 49. Then, once the voltage across the monocable 12 has reached the Zener level of the Zener diode 57, voltage will be applied to the detonator 56a. Once the potentiometer 53 has been advanced still further, the detonator 56a will be actuated and the shaped charge 23a detonated if all is functioning properly. If no detonation occurs, failure of the shot-detection circuit 47 to function will immediately give notice to the operator who will then take whatever remedial action is desired.

Assuming, however, that the shaped charge 23a does detonate, the resultant shock to the perforating apparatus 10 will momentarily impulse the crystal 58. This will then energize the flip-flop 61 and start the oscillator 62 which will then cause the resistor 69 to be repetitively connected and disconnected across the monocable 12. As previously explained, this cycle change of impedance across the monocable 12 will induce a corresponding cyclic signal in the transformer 70. Since the frequency of the signal is in the bandpass range of the filter 71, it will be rectified by the rectifier 72 and applied to the input of the time-delay circuit 73. Once the rectifier signal is applied to the input of the delay circuit 73 for a sufficient time, the silicon-controlled rectifier 75 will be enabled which in turn energizes the relay solenoid 74.

Once the relay solenoid 74 is energized, the normally-closed relay contacts 78 will open and normally-open relay contacts 82 will be closed. These contacts 82 connect a DC source 83 to the relays 48 which in turn control the indicator lights 28. Opening of the switch contacts 78 will, of course, break the circuit between the monocable 12 and DC power source 51. Once the circuit is broken, no further power can be applied down the monocable 12 since the relay solenoid 74 will continue to draw current through the silicon-controlled rectifier until power to the rectifier 75 is interrupted. Thus, it is necessary for the operator to return the potentiometer 53 to its "zero" position to discontinue the conduction of the rectifier 75 and reclose the normally-closed relay contacts 78 and re-open the normally-open contacts 82.

The collar locator 24 is connected across the monocable 12 in the usual manner. To prevent DC from reaching the circuitry 40, a blocking capacitor 84 is connected between the circuitry and the monocable 12. As a further safety measure, normally-closed relay contacts 85 can be provided so as to momentarily interrupt the circuit whenever the solenoid 74 is energized. If desired, an amplifier 86 and speaker 87 can be used to provide an audible signal of the detonation of the shaped charges 23.

Turning now to FIG. 4, an improved embodiment is shown of apparatus also employing the principles of the present invention. This embodiment is also described in a co-pending application Serial No. 576,340 filed concurrently herewith by Nick A. Schuster and William T. Bell and directed to that improvement. In general, this embodiment differs from the one already described in that a previously recorded log, as at 100, (e.g., a so-called "collar log" or the like) is employed as a display of the known depths at which certain detectable depth-reference points are located. By rerunning this log 100, it can be compared with the newly obtained depth measurements to establish the depth at which the tool 10 is positioned. Furthermore, a record is made on this log of the position of the tool 10 at any time as well as of the depths at which the various completion operations are performed. In addition, by placing marks, such as at

101-107, on the log 100 to identify which depths the various operations are to be conducted, these identifying marks can be used to designate that each completion device is correctly positioned before it is actuated.

The typical log 100 is on paper, film, or the like, and shows a log of that portion of the well bore 11 illustrated in FIG. 1 such as would customarily be obtained after the casing 13 has been set to provide an accurate indication of the depth of the collars 14-17 and, in one manner or another, their spatial relation to the productive earth formations 19-21. To obtain this log 100, a well tool (not shown) including detecting means of some nature for identifying particular earth formations as well as determining depth is passed through the cased well bore 11. In one manner of accomplishing this, the detecting means could include radioactivity-measuring means that can either detect previously placed radioactive markers for depth-reference points in the formations and/or on the collars or also measure only the natural or induced radioactivity of the formations. Irrespective of how a given characteristic of the formations is detected, where the collars, as at 14-17, are used as depth-reference points, another means for determining depth could also be a typical casing collar locator.

Accordingly, although other means of presenting such information can be used, the log 100 will be assumed to include some indicia of some characteristic of at least the formations of interest as, for example, a continuous trace 108 on the left of the log indicating natural or induced radioactivity. For purposes of depth correlation, the relative positions of the collars in the casing string 13 may be assumed as being represented as either a series of separate indicia marks or a continuous trace, as at 109, that is recorded as a function of depth, as at 110 and 111, and having irregularities, as at 112-115, respectively representative of the casing collars in the string 13 along that interval.

Accordingly, as known by those skilled in the art, once this log 100 has been obtained, the trace 108 can be compared with one or more other logs (not shown) made previously to determine which of the formations are most likely capable of being produced. By comparing previously obtained logs of the same or different nature with the trace 108, the various formations can be identified and their relative locations determined with respect to one another as well as to the casing collars 14-17.

As seen in FIG. 4, the log 100 is first marked in some suitable manner, as by the lines at 101-107, to designate the depth at which each perforation is desired. Then, the prepared log 100 is arranged on means, such as a control panel 116. The control panel 116 is comprised of recording means, such as a chart recorder 117 or the like, arranged to accept the log 100 and including selectively responsive marking means, such as a pair of conventional recorder pens 118 and 119, and driving means, such as Selsyn motors 120 and 121, that are suitably arranged to drive the log 100 in either direction. The recorder pen 119 is movably mounted on and arranged for movement along a support 122 parallel to the longitudinal axis of the log 100. Although the recorder pens 118 and 119 can be as normally provided on conventional chart recorders, either one or both of them may be so-called solenoid-actuated "event markers" that produce a suitable indication upon receiving a signal of a particular nature. Control means 123 and 124 (similar to 31 in FIG. 2) connected to the wheel 36 are provided to synchronously advance or reverse the log 100 in unison with the unreeling or reeling in of the cable 12.

To actuate the recorder pens 118 and 119, means, as at 125, are provided to respond to a first signal indicative of the depth of the well tool 10 as well as to respond to a signal indicating that the well tool has been actuated. In one manner of accomplishing this, the recorder pen 118 is coupled to the collar locator 24 to provide a record each time a collar in the casing string 13 is passed by the collar locator. The other recorder pen 119 is cou-

pled through the responsive means 125 to means, as at 46, on the well tool 10 for detecting the detonation of each of the shaped charges 23 and providing a signal in response thereto for actuating the recorder pen 119. This control means 125 can be generally as shown in FIG. 3 but with the recorder pen 119 connected in the same manner as the relays 48. The circuitry 40 in FIG. 3 would be replaced with an amplifier (not shown) for the collar locator 24 and connected to the recorder pen 118.

On the right of the control panel 116 and parallel to the longitudinal axis of the log 100, scaled facsimiles of the perforator 22 and collar locator 24 are provided which are preferably comprised of a replaceable template 126 or the like that may be mounted thereon in some suitable manner. This template 126 is accurately scaled to represent not only the relative positions 127 and spacing of each of the shaped charges 23 on the perforator 22 but also to show the relative position 128 of the casing collar locator 24. A movable pointer 129 is provided on the control panel 116 adjacent to the template 126 and arranged to be moved parallel to the longitudinal axis of the template by a control knob 130 which, by means of a pulley arrangement, gear train, pantograph or other suitable mechanism 131, will also simultaneously position the shot-indicator recording pen 119. By suitably arranging the mechanism 131, movement of the control knob 130 will shift the pointer 129 a scaled distance along the template 126 that is directly proportional both to the scaled distance that the recorder pen 119 is being simultaneously shifted longitudinally in relation to the scale of the log 100 as well as to the actual distance along the perforator 22 corresponding to the positions 127 being indicated by the pointer. Thus, the actual distance between the collar locator 24 and a given shaped charge 23 will be simultaneously presented by the scaled spacing or chart divisions on the log 100 between the pens 118 and 119 and the visual portrayal on the template 126 of the spacing between the pointer 129 and the position 128.

After the log 100 has been marked to provide the indications 101-107 representative of the depths at which each of the perforations are to be made, the marked-up log is then mounted on the control panel 116. A suitable template 126 is prepared and mounted on the panel 116 and the well completion apparatus 10 is then lowered into the well bore 11. The pointer 129 will be aligned with the position 127a.

During the descent of the perforating apparatus 10 into the well bore 11, the log 100 and the usual depth-measuring totalizers or registers and the like (not shown) as typically used are "tied-in" to the collars in the casing string. Although this can be done in several manners, by observing the correspondence of the newly-obtained collar log with an older collar log the operator can keep track of just where the apparatus 10 is in the well. Then, since the depth of each collar is known from the older collar log, the operator can adjust the depth-measuring registers as the apparatus 10 is being lowered to keep them in the proper relation to the known depths of the collars. It is, of course, not necessary to actually record a new collar log as the tool 10 is being lowered since visual observation of the measurements being obtained on the measuring instrument typically used will indicate how closely the old collar log is being followed. Thus, in one manner or another, by merely keeping the depth-measuring registers or "odometer"-like totalizers in step with the old collar log as the apparatus 10 is being lowered, the log 100 will still be unmarked.

The well completion apparatus 10 is preferably lowered below the first depth at which a perforation is to be made. Then, as the well tool 10 is moved upwardly in the well bore 11, the collar locator 24 will detect each of the casing collars as the tool is raised thereby. The control means 123 and 124 and motors 120 and 121 are simultaneously driving the log 100 at a speed directly proportional to the

rate of ascent of the perforating apparatus 10. As the log 100 is moved, the collar-locator recorder pen 118 will make a trace 132 having successive irregular marks, such as at 133 and 134, indicative of the casing collars that the well completion apparatus 10 has just passed.

Accordingly, by observing the correspondence (or lack of correspondence) of the marks (as at 133) on the newly obtained trace 132, final adjustments may be made on the recorder 117 so as to bring the irregularities 115 and 133 on the two traces 109 and 132 respectively, into register with one another. Once this has been accomplished, it will be appreciated, of course, that the collar-locator recorder pen 118 will indicate and record on the log 100 the precise depth at which the collar locator 24 is at that point. Similarly, the shot-indicator recorder pen 119 will be pointed on the log 100 to the depth at which the particular shaped charge 23 next to be fired is then actually positioned. The shot-indicator pen 119 may or may not be providing a continuous trace as desired. Similarly, it is, of course, not necessary to continuously record a trace, as at 132, on the log 100 so long as a record of some nature, as at 133 or 134, is provided of the collars passed.

By keeping the newly recorded collar log trace 132 synchronized with the original collar log trace 109, whenever the well apparatus 10 has reached the depth at which the first perforation is to be made, the shot-indicator recorder pen 119 will provide a visual indication which, when it is brought into register or alignment with the first mark 107 on the log 100, will indicate that the first shaped charge 23a is precisely located at that depth. It is, of course, apparent that with this displayed presentation, no calculation need be made to know positively that the well completion apparatus 10 is correctly positioned at the correct depth in the well bore 11. The correspondence of the collar log marks 115 and 133 will assure the observer that the tool 10 is at the correct depth. Moreover, once the shot-indicator pen 119 is aligned with the mark 107 previously drawn on the log 100 to designate the precise depth at which the first perforation is to be made, there is no reason to become confused about the precise location of the shaped charge 23a.

Accordingly, once the perforator 22 has been actuated and the concussion-responsive means 46 initiated, the electrical means 125 will actuate the shot-indicator recorder pen 119 to print a mark, as at 135, on the log 100 immediately opposite the mark 107. This will provide a positive permanent indication on the log 100 that this perforation was made at the correct depth.

Once this first perforation has been made, the control knob 130 is then adjusted to shift the pointer 129 upwardly to the next position 127b on the template 126 and, at the same time, also move the shot-indicator recorder pen 119 upwardly on its support 122. This simultaneously shifts the shot-indicator recorder pen 119 relative to the collar-locator recorder pen 118 so as to space the two pens apart a distance which can be scaled on the vertical scale of the log 100 and will also be directly proportional to the actual spacing between the casing collar locator 24 and the shaped charge 23b next to be fired. Once this is done, the cable 12 will be reeled-in to raise the tool 10 in the well bore 11 (and move the log 100) until the mark 106 on the log is brought into alignment with the stationary shot-indicator pen 119.

Once the shot-indicator pen 119 and mark 106 are aligned, the observer will be assured that the perforator 22 is correctly positioned in the well bore 11 and is in fact in position to safely make the next perforation. When the perforator 22 is actuated, the shaped charge 23b will produce a perforation (not shown) and the resultant shock on the electrical means 46 will again actuate the electrical means 125 to cause the shot-indicator pen 119 to make a confirming mark (not shown) adjacent to the previously drawn mark 106 on the log 100. Here again, this second confirming mark will provide a positive and permanent record that a perforation was made while the

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second shaped charge 23b on the perforator 22 was at that depth. Moreover, the correspondence, as at 114 and 134 of the collar log 109 and 132 will verify that the perforating apparatus 10 was at the correct depth at that time and provide a record thereof.

Turning now to FIG. 5, still another embodiment of the present invention is shown. This embodiment is described in a co-pending application filed concurrently herewith by William T. Bell and directed to that improvement. It will be appreciated that FIG. 5 shows that many of the same features already described with reference to FIG. 4 are included in this second embodiment and so, where applicable, the same reference numerals but with prime marks added have been employed. It will be understood, therefore, that these common means are basically the same as those already described.

In general, the control panel 116' is similar to the panel 116, with the chart recorder 117' being arranged to accept the log 100' with its previously designated locating marks as at 101'-107'. Indicating means, such as the event markers or recorder pens 118' and 119' are provided to indicate respectively the depths at which the collar locator 24 and a selected one of the shaped charges 23 are with respect to the log 100'. The recorder pen 119' is slidably mounted on the support 122' and arranged for movement thereon by a suitable mechanism 200 controlled by the control knob 130'.

Three display means, such as for example, "odometer"-type totalizing registers 201-203 are mounted on the panel 116' with the totalizers 201 and 202 being arranged to respond to travel of the tool 10 by means, as at 204, of suitable electronic means, electro-mechanical devices, or typical arrangements of gears, pulleys, clutches and the like, as also shown in FIG. 2. The totalizer 203 is arranged to display only a fixed differential between the totalizers 201 and 202 and is adjusted by means, as at 205, controlled by the knob 130'. This adjusting means 205 is also connected to the totalizer 202 to adjust the reading displayed there in accordance with the differential being displayed on the totalizer 203.

The totalizer 201 is arranged to continuously display the true depth at which the collar locator 24 is at any given time. It will be recognized, of course, that the depth displayed at any given time on the totalizer 201 will be the same depth indicated by the recorder pen 118' on the log 100' once the log is "tied-in." The totalizer 202 is arranged to keep pace with the totalizer 201 as it changes; however, this totalizer 202 will instead be displaying a depth that is greater than that displayed on the totalizer 201 by whatever differential is displayed on the totalizer 203. Thus, by interconnecting the totalizers 202 and 203 through the mechanism 205, each time the control knob 130' is changed to reset the differential on the totalizer 203, the totalizer 202 will be simultaneously adjusted by the same amount so that at any given moment the difference between the readings displayed on the totalizers 201 and 202 will be displayed on the totalizer 203. Inasmuch as it is usually necessary to know this differential in increments of less than a foot, the totalizer 203 is arranged to display the differential in at least tenths of a foot. It will be noted also that the totalizer 202 will display the depth at which the recorder pen 119' is indicating on the log 100'. Moreover, the differential displayed on the totalizer 203 will be equal to the spacing between the pens 118' and 119' as scaled on the log 100'.

Accordingly, once the prepared log 100' is "tied-in," both the totalizer 201 and the recorder pen 118' will visually display the depth at which the collar locator 24 is at any given time. Similarly, the totalizer 202 and recorder pen 119' will each be providing an indication of some depth greater than that of the collar locator 24 which difference is indicated on the totalizer 203. It will be recalled that this differential is established by adjusting the knob 130' to set both the recorder pen 119' and the totalizer 203. This adjustment will also appropriately re-

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set the totalizer 202 to display a depth differing from that shown on the totalizer 201 by this difference.

By previously preparing a tabulation, drawing or even a facsimile, as at 206, of the well tool 10 being used, an indication is provided of the spacing between the collar locator 24 and each of the shaped charges 23. In this manner, the spacing between the collar locator 24 and each shaped charge 23 can be compared with the differential reading displayed on the totalizer 203. By knowing (as shown on the drawing 206) the distance below the collar locator that a particular shaped charge 23 is located, the control knob 130' can be used to position the recorder pen 119' as desired as well as adjust the readings on the totalizers 202 and 203.

Accordingly, to employ the control panel 116' for accurately placing the shaped charges 23, the control knob 130 is adjusted to successively bring the reading on the totalizer 203 to each of the measured dimensions, as at 207, in turn that a selected one of the shaped charges is below the collar locator 24. Once the totalizer 203 is displaying this differential, as at 207a, the recorder pen 119' will have been moved along the support 122' to the same scaled spacing according to the chart divisions on the log 100'. The readings on the totalizer 202 will be greater than those on the totalizer 201 by this differential. Accordingly, as the well tool 10 is maneuvered in the well bore 11, the totalizer 201 will indicate the depth of the collar locator 24 and the totalizer 202 will indicate the depth of the selected shape charge 23a. The totalizer 203 will show a figure equal to the differential between these depths and and therefore (by reference to the drawing 206) serves as an indirect reminder as to which of the shaped charges 23 is next to be detonated.

When the well tool 10 has reached the depth at which the first shaped charge 23a is to be detonated, the tool will be halted when the pen 119 is aligned with the prepared mark 107'. The shaped charge 23a may then be detonated and a perforation (not shown) will be produced at the correct depth. As previously described, the recorder pen 119' will produce an identification mark 135' to provide a verification record of the depth perforated.

The knob 130' is then readjusted to reset the differential reading on the totalizer 203 to that indicated on the drawing 206 to be the spacing for the next shaped charge. This adjustment also brings the recorder pen 119' proportionately closer to the pen 118'. Then, the well tool 10 is again raised in the well bore 11 until the recorder pen 119' is aligned with the next prepared mark 106'. The procedure is again repeated to detonate the remaining shaped charges 23.

It will be appreciated that although these last two procedures have been described as using the collar log trace 109 (or 109') for depth correlation, the formation log at 108 (or 108') could be used just as well. This would not change the operation and the pen 118 (or 118') would instead be appropriately arranged to provide a verifying identification such as a continuous trace similar to that at 109 (or 109') (but reproducing the log trace 108 (108') of course). In this event, it would not even be necessary to include a collar locator 24 on the apparatus 10.

As an alternate, the log 100 (or 100') could be obtained at the beginning of the last two above-described operations. If this were done, the well tool 10 would include the appropriate logging device either along or in conjunction with the collar locator 24. The tool 10 so equipped would be first used to produce the log 100 (or 100'). Then, after the designations, as at 101-107 (or 101'-107'), are placed, the operations would be conducted as described.

It will also be recognized that so long as the log 100 (or 100') is in position on the recorder 116 (or 116'), it will be readily determinable that the tool 10 is correctly positioned. Once the log 100 (or 100') is removed, however, there is nothing by which it can be determined whether the tool 10 was at the correct depth when the

shaped charges 23 were detonated. Accordingly, to provide such a record, the event marker or pen 118 (or 118') could be arranged to also make a characteristic mark (not shown) each time that the event marker or pen 119 (or 119') makes a mark as at 135 (or 135'). In one manner of accomplishing this, a second marker could be aligned horizontally (as seen in the figures) with the pen 118 (or 118') and connected to make a mark as in the margin of the log 100 (or 100') each time the pen 119 (or 119') is actuated.

It will be appreciated, therefore, that the present invention has provided new and improved methods and apparatus for accurately positioning a well tool in a well and providing visual indications of the depth of the tool each time it is actuated. In practicing the present invention, it is necessary only to establish that the well tool is "tied-in" with the known depths of the distinctive markers. Then, by comparing the various displayed depth indications, the position of the tool can be verified. Each time the tool is actuated, an indication is also made of the actuation to designate the depth of the tool at that time.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method for positioning a well tool in a well bore having distinctive depth-reference means therein at a known depth, comprising: displaying at the earth's surface first and second designations respectively of the known depth of the distinctive depth-reference means and of a desired depth at which a well tool is to be positioned; placing into the well bore, means for detecting the distinctive depth-reference means and a well tool spaced a known distance therefrom; moving said detecting means and said well tool into the vicinity of the distinctive depth-reference means for obtaining with first depth-indicating means a first indication of the apparent depth of said detecting means and for obtaining with second depth-indicating means, a second indication of the apparent depth of said well tool; correlating said first indication with said first designation to verify the accuracy of said first indication and adjusting at least said second depth-indicating means accordingly to obtain a corrected indication of the true present depth of said well tool; and, thereafter, moving said well tool to bring said second depth-indicating means into correspondence with said second designation.

2. The method of claim 1 further including the step of: operating said well tool whenever said second depth-indicating means correspond with said second designation.

3. The method of claim 1 further including the steps of: displaying a third designation of another desired depth at which said well tool is to be positioned; and, after adjusting said second depth-indicating means, moving said well tool to bring said second depth-indicating means into correspondence with said third designation.

4. The method of claim 3 further including the step of: operating said well tool whenever said second depth-indicating means correspond with at least one of said second and third designations.

5. A method for positioning a well tool in a well bore having distinctive depth-reference means therein at a known depth, comprising: displaying first and second designations respectively of the known depth of the distinctive depth-reference means and of a plurality of desired depths at which a well tool is to be positioned; placing into the well bore, means for detecting the distinctive depth-reference means and a well tool having a plurality of well-completion means thereon each spaced a known distance from said detecting means; moving said detecting means and said well tool into the vicinity of the distinctive depth-

reference means for obtaining with first depth-indicating means a first indication of the apparent depth of said detecting means and for obtaining with second depth-indicating means a second indication of the apparent depth of one of said well-completion means; correlating said first indication with said first designation to verify the accuracy of said first indication and adjusting at least said second depth-indicating means accordingly to obtain a corrected indication of the true present depth of said one well-completion means; moving said well tool to bring said second depth-indicating means into correspondence with one of said second designations; operating said one well-completion means while said second depth-indicating means correspond with said one second designation; adjusting said second depth-indicating means until the difference between said adjusted second depth-indicating means and said first depth-indicating means now equals the known spacing between said detecting means and another of said well-completion means; moving said well tool to bring said second depth-indicating means into correspondence with another of said second designations; and operating said other well-completion means while said second depth-indicating means correspond with said other second designation.

6. A method for perforating a well bore having distinctive depth-reference means therein at a known depth, comprising: displaying at the earth's surface first and second designations respectively of the known depth of the distinctive depth-reference means and of a depth at which the well bore is to be perforated; placing into the well bore a well tool including means for detecting the distinctive depth-reference means and perforating means mounted at a known spacing from said detecting means; moving said well tool into the vicinity of the distinctive depth-reference means for obtaining with first depth-indicating means a first indication of the apparent depth of said detecting means and for obtaining with second depth-indicating means a second indication of the apparent depth of said perforating means; correlating said first indication with said first designation to verify the accuracy of said first indication and adjusting at least said second depth-indicating means accordingly to obtain a correlated indication of the true present depth of said perforating means; moving said well tool to bring said second depth-indicating means into correspondence with said second designation; and, thereafter, actuating said perforating means while said second depth-indicating means correspond with said second designation.

7. The method of claim 6 wherein the well bore is cased and the distinctive depth-reference means includes an anomaly in the casing string; and wherein said detecting means includes means for detecting such an anomaly.

8. A method for perforating a well bore at a plurality of different depths and which has distinctive depth-reference means therein at a known depth, comprising: displaying at the earth's surface a first designation of the known depth of the distinctive depth-reference means and a plurality of second designations each showing a depth at which the well bore is to be perforated; placing into the well bore a well tool including means for detecting the distinctive depth-reference means and a plurality of perforating means each mounted at a known spacing from said detecting means; moving said well tool into the vicinity of the distinctive depth-reference means for obtaining with first depth-indicating means a first indication of the apparent depth of said detecting means and for obtaining with second depth-indicating means a second indication of the apparent depth of one of said perforating means; correlating said first indication with said first designation to verify the accuracy of said first indication and adjusting said first and second depth-indicating means accordingly to obtain corrected indications of the true present depths respectively of said detecting means and of said one perforating means; moving said well tool

to bring said second depth-indicating means into correspondence with one of said second designations; actuating said one perforating means while said second depth-indicating means correspond with said one second designation; adjusting said second depth-indicating means so that the difference between said adjusted second depth-indicating means and said first depth-indicating means now equals the known spacing between said detecting means and another of said perforating means; moving said well tool to bring said second depth-indicating means into correspondence with another of said second designations; and operating said other perforating means while said second depth-indicating means correspond with said other second designation.

9. Apparatus for completing a well bore at a desired depth and in which distinctive depth-reference means are located at a known depth, comprising: a well tool adapted for movement in the well bore and including detecting means for providing a characteristic signal upon detection of the depth-reference means and well-completion means spaced a known distance from said detecting means; first and second means responsive to movement of said well tool in the well bore for respectively indicating in unison the apparent depths of said detecting means and of said well-completion means; and means for verifying the accuracy of said first and second indicating means including first means displaying the true depth of said depth-reference means, means responsive to said signal for obtaining a comparison between said first indicating means and said first display means from which a correction can be derived, second means displaying said desired depth, and means for adjusting said second indicating means in accordance with such a correction to indicate the true depth of said completion means for correlation with said second display means.

10. The apparatus of claim 9 wherein the distinctive depth-reference means is an anomaly in the casing in the well bore and said detecting means is a casing-anomaly detector.

11. The apparatus of claim 9 further including means responsive to operation of said completion means for indicating operation of said completion means.

12. The apparatus of claim 11 wherein said completion means includes perforating means.

13. Apparatus for completing a well bore at a plurality of desired depths and in which distinctive depth-reference means are located at a known depth, comprising: a well tool adapted for movement in the well bore and including detecting means for providing a characteristic signal upon detection of the depth-reference means and a plurality of well-completion means each spaced a known distance from said detecting means and from one another; first and second means responsive to movement of said well tool in the well bore for respectively indicating in unison the apparent depths of said detecting means and of one of said well-completion means; and means for verifying the accuracy of said first and second indicating means including first means displaying the true depth of said depth-reference means, means responsive to said signal for obtaining a comparison between said first indicating means and said first display means from which a correction can be derived, second means displaying each of said desired depths, first means for adjusting said first and second indicating means in accordance with such a correction to respectively indicate the true depths of said depth-reference means and of said one completion means for correlation with a respective one of said second display means, and second means for adjusting only said second indicating means in accordance with the known spacing between said one completion means and another completion means to indicate the true depth of said other completion means for correlation with another of said display means.

14. The apparatus of claim 13 wherein said well completion means are each perforating means.

15. The apparatus of claim 14 further including means responsive to operation of each of said perforating means for indicating their operation.

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**UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION**

Patent No. 3,396,787

August 13, 1968

Roy R. Vann

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 22, "depth" should read -- depths --; line 40, "form" should read -- forms --; line 43, "each" should read -- earth --. Column 4, line 37, "montostable" should read -- monostable --. Column 7, line 9, "reasonably" should read -- reasonable --. Column 9, line 25, "cycle" should read -- cyclic --. Column 10, line 35, "and", first occurrence, should read -- or --. Column 14, line 18, "as", second occurrence, should read -- at --; line 30, cancel "and". Column 16, line 42, "correlated" should read -- corrected --.

Signed and sealed this 10th day of March 1970.

(SEAL)

Attest:

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Attesting Officer

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Commissioner of Patents