This invention relates to apparatus for attaining the precise control of a remotely disposed stepping switch in a well bore apparatus with a minimum number of connecting conductors between the remote stepping switch to be controlled and a surface located control station. In particular, this invention is related to apparatus for obtaining a precise control of a stepping switch in a gun disposed in a well bore from a surface located control panel.

Selective operation of a gun in a well bore is often desirable, and for certain types of guns it is a necessity. Since the electrical cable coupled to a gun in a well bore has a limited number of electrical conductors, it will be appreciated that some sort of electrical distribution system in the gun is necessary if a large number of gun igniter conductors to the explosives in the gun to a single electrical conductor of the cable which, in turn, serves as the carrier or electrical path for the firing current. However, in this system there is no way to determine if the switch malfunctions, for example, by a contact connection of the switch being skipped. Hence, once the gun is in the well bore, there is no way of determining if the stepping switch is functioning properly.

Accordingly, it is an object of this invention to provide new and improved apparatus for the precise control of a remotely disposed stepping switch with a minimum number of connecting conductors between the remote stepping switch to be controlled and a control station.

It is a further object of this invention to provide new and improved apparatus for indicating a selective operation of a stepping switch circuit in a remote location while using only a minimum of electrical connections between a control station and the remote location.

Still another object of this invention is to provide new and improved apparatus for indicating selective operation of a stepping switch circuit in a gun for use in well bores.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by reference to the accompanying drawings in which:

FIG. 1 illustrates a typical core taking gun for which the invention is particularly suitable;

FIG. 2 schematically illustrates a typical stepping switch which is precisely controllable from a remote station by means of the present invention; and

FIG. 3 is an electrical schematic arrangement illustrating the present invention in connection with a core taking gun.

Referring now to FIG. 1, the numeral 10 designates a typical core taking apparatus with which the present invention may be integrated. The apparatus 10 may, for example, be comprised of an upper gun block 11 and lower gun block 12 each containing a plurality of core taking bullets 13. Each bullet 13 in a gun block is received by a transverse bore and held by or associated with the bottom or rear of each bullet is an explosive load 14. An explosive load 14 when detonated serves to propel a bullet 13 from the gun block into adjacent earth formations. While not shown, each explosive load 14 is adapted to be detonated by an individual igniter and each core bullet 13 is connected to the gun block by a retrieving cable arrangement. The gun blocks 11 and 12 may be suspended in a well bore by means of a multiconductor electrical cable coupled at the surface of the earth to a winch (not shown).

In a typical core sampling operation, the apparatus 10 would be lowered to the lowest depth in a well bore at which a core sample of earth formations is desired. The precise depth at which a core is taken is determined by the length of cable between a datum point relative to the earth surface and the apparatus 10 and also the length or distance from the cable connection 18 at the top of apparatus 10 to the particular bullet 13 selected for firing. The lowest core bullet 13 in the apparatus is generally fired first.

After firing the first bullet to obtain the first formation sample at a given depth in the well, the apparatus 10 is raised and the retrieving cable between the bullet in the formation and gun block pulls or dislodges the core bullet 13 from the earth formations so that this particular bullet (which contains the core sample) falls to the side of the apparatus. The apparatus 10 is then raised to the next level or depth of interest and the next core bullet to be fired (the second lowest core bullet in the apparatus) is correlated to the depth by a consideration of the cable length from the datum point and the distance from the cable connection 18 to the core bullet to be fired. The above operation is repeated for obtaining as many core samples with other core bullets as desired or provided for in the gun.

It will be appreciated from the foregoing described operation that it is extremely important to fire only the selected bullet since inadvertent firing of a bullet other than a desired one will provide a core which is not correlated with a depth value and might also cause the loss of previously taken core bullets.

Before describing how the invention is coordinated with a core taking gun as mentioned above, reference will be made to FIG. 2 to briefly and generally describe the mechanical structure of a stepping switch. It will, of course, be appreciated that a stepping switch serves the purpose of indexing sequentially at least two electrical contacts in a predetermined manner relative to one
another. In a common application, a single electrical contact arm is constructed and arranged to move relative to a bank of stationary electrical contacts to provide a plurality of different contact connections, and more than one bank can be selectively provided simultaneously by the use of a common shaft coupling to the indexing or actuating means of a switch.

As schematically illustrated in the drawings, an exemplary stepping switch 21 includes an indexing motor part 23, an indexing coupling 24 and a common shaft 25 which can be manually coupled simultaneously to electrical contact banks 26, 27 and which is rotatable relative to an electrical contact bank 28. The banks 26–28 include non-conductive discs upon which are respectively disposed sets of stationary electrical contacts 26a–28a. Preferably, each bank has twelve such electrical contacts which are arranged annularly about the disc and are equidistantly spaced from one another thereby providing a relative angular spacing of 30° between adjacent electrical contacts. Bank 26 has associated therewith, a pair of spring-loaded electrical contact arms 29, 30 respectively arranged to be in contact with an individual electrical contact 26a. Bank 27 also has associated therewith, a pair of spring-loaded contact arms 31, 32 which respectively are arranged to be in contact with an individual contact 27a. The spacing arrangement between the contact arms 31, 32 is such that the stationary contacts 27a are angularly disposed to opposite sides of an intermediate contact 27a are electrically coupled to the respective arms 31, 32. Bank 23 has associated therewith a movable, spring-loaded, electrical arm contact 34 arranged to successively contact with the stationary contacts 28a of bank 28. Contact 34 is carried by a radial extension 33 of shaft 25 so as to rotate with the shaft 25 relative to contacts 28a.

The indexing motor part 23 may, for example, be a "LEDEX" rotary solenoid assembly (manufactured by G. H. Leland, Inc., Dayton 2, Ohio) which, when energized, produces both longitudinal and rotational motion of an output shaft 31 about an axis, the arrangement being such that when the motor 23 is de-energized, the output shaft 31 returns to its initial condition. The indexing coupling 24 may, for example, be a conventional ratchet mechanism. The motor 23 and coupling 24 are each arranged to rotate the shaft 25 of the common coupling through say, an angle of 30°. Hence, one complete rotation of the shaft 25 of the common coupling will occur after twelve distinct indexing movements. Thus, the relative movement permits the contact arms and each of the contact banks on the remote apparatus to move into close contact once during one revolution of shaft 25. A conventional ball snap lock 35 can be provided to releasably retain the shaft 25 in a given indexed position.

Referring now to FIG. 3, the elements depicted above the dashed line 20 in the drawings are disposed at a control location at the earth's surface while the elements depicted below the line 20 are disposed at a remote station, for example, in a borehole apparatus 10, as previously described. The elements in the borehole apparatus 10 are coupled electrically to the elements at the control station by means of conductors 17a–17c of a multiconductor armored cable 17 in a well known manner. The armor of the cable serves as an electrical ground and return electrical path and is designated as 17f.

In FIG. 3, a stepping switch 21 in the surface-located control panel 10 and a stepping switch 42 in the remote apparatus are simultaneously operated by means of a source of power, for example, a battery 46 provided in the control panel. Also in the control panel are indicator means 44 to ascertain the operative position of the control panel stepping switch 21 and a separate indicator means 45 to ascertain the operative position of the stepping switch 42 in the remote apparatus. In the case of a well gun, a source of firing current, for example, a battery 46 is coupled via a firing selector circuit 47 to one of two cable conductors 17c, 17d to the stepping switch 42 in the gun, and via the stepping switch 42 to one of a plurality of explosive means 65.

In accordance with the present invention, at the surface-located control panel, the indicator means 44 for the stepping switch 21 provides an indication of the operating position of the stepping switch 21 while the indicator means 45 provides a separate indication of the operating position of the stepping switch 42 at the remote location. In the event that the operating positions of the stepping switches 21 and 42 are misaligned, reset means are provided in the respective switches to return the switches to pre-set known positions.

To actuate the stepping switches 21 and 42, a single pole switch 50 is provided to selectively couple the battery 43 to the energizing coil 51 of switch 21 via a conductor 52 and also, to couple the battery 43 to the energizing coil 54 of switch 42 via a cable conductor 17a. The energizing coils 51, 54 when supplied with power, actuate the coupling mechanisms 24, 24a and index the shafts 25, 28a of the respective switches from one position to another position.

In the control panel, the stepping switch 21 includes electrical banks 26, 27, 28 where banks 26 and 27 are part of the reset circuit for the switch and bank 28 is a part of the indicator means 44 to provide an indication of the operational position of the switch.

With respect to bank 28, the rotary electrical contact arm 34 is connected to a battery 48 and is arranged to selectively make an electrical connection with one of the twelve stationary contacts 28a for each indexed position of the switch. The contacts 28a are respectively connected to indicator lamps L–1–L–12. It will immediately be appreciated that illumination of a particular lamp will indicate the connection of the contact arm 34 with a particular one of the contacts 28a. Thus, for an exemplary operation of switch 21, when the selector switch 50 couples the battery 43 to the coils 51 and 54, the contact 34 of bank 28 moves from the illustrated position to its next position to sequentially disconnect lamp L–1 from the power source 48 and connect the next lamp L–2 to the power source. The selective successive illumination of lamps L–1 to L–12 thereby provides an indication of the position of the contact arm 34 relative to a contact 28a of bank 28 in the panel stepping switch 21.

In the remote stepping switch 42, there are illustrated five banks 52–56 of which banks 52, 53 are concerned with resetting of the switch; banks 54, 55 are concerned with the distribution of non-conductive discs to close contact once during one revolution of shaft 25. A conventional ball snap lock 55 can be provided to releasably retain the shaft 25 in a given indexed position.

Battery 46 is coupled via a firing selector circuit 47 to one of two cable conductors 17c, 17d to the stepping switch 42 in the gun, and via the stepping switch 42 to one of a plurality of explosive means 65.

For example, considering a stationary contact 56a (identified as A) as the contact selected to indicate an initial position of the contact arm 57 of switch 42, this contact A is connected via an electrical return path having a resistance R to the electrical ground of the battery 60. The electrical resistance R in the return path has a given value adequate to develop a given indication by the indicating means 61 at the earth's surface. A stationary contact 56a...
(identified as B) which is adjacent to the stationary contact A (as well as every alternate contact thereafter) is coupled via an electrical return path such as a conductor 64 to electrical ground of the battery 60. Hence, when the contact arm 57 is connected to such a stationary contact B, the indicating means 61 will provide a given indication of the coupling of the contact arm to the stationary contact B which is, of course, in a known sequential position relative to the initial position contact A. Thus, if contact A is selected, the closing of contact 5 which is adjacent to the stationary contact B will represent the 2, 4, 6, etc., or even positions of the stationary contacts relative to the original contact. The remaining alternate contacts (other than the contact A) identified as C are coupled via an electrical return path having a resistance R to the electrical ground of battery 60. The resistance R is significantly different in value from resistance R such that when the contact arm 57 is connected to a stationary contact C, the indicating means 61 will indicate such a connection. Hence, the contacts C would represent the 3, 5, 7, etc., or odd numbered stationary contacts C other than the initial position contact A.

Hence, in switch 42, the movement of contact arm 57 from one position to another, disconnects the contact arm 57 from a return path with a given impedance and thereafter connects the arm with an adjacent return path having a different characteristic impedance. The different impedances develop different indications of the operation and particular connections. It will therefore be appreciated that when switches 42 and 21 operate simultaneously, the indications from indicating means 44 and 45 can be correlated to determine if each switch operated correctly. Hence, should a malfunction of one of the relays occur wherein a succeeding contact position is skipped, the disagreement will become readily apparent.

In the event that the stepping switches 21 and 42 get out of step or misaligned, the reset means provided in each switch can be actuated to return the switches to an initial starting or given position where they automatically are re-aligned. Since the reset means in each switch may be similarly arranged, a description of one will suffice for the other.

In switch 21, the twelve contacts 26a of the bank 26 are electrically connected to one another and hence for each given indexed position of the bank 26 relative to contact arms 29, 30, the two contact arms 29, 30 have electrical continuity. However, when the bank 26 is rotated, the continuity between contact arms 29, 30 is momentarily broken. Bank 26 and arms 29, 30 therefore serve as a discontinuity or interrupter switch.

In bank 27 of switch 21 eleven contiguously arranged contacts 27a are electrically connected to one another with the remaining 12th contact electrically open. The arrangement of stationary arms 31, 32 relative to contacts 27a is such that there is electrical continuity between contacts 31, 32 in all of the rotative positions of the bank 27, except for the position shown.

To achieve resetting of the switch to an initial position, the banks 26, 27 are electrically connected as follows: arm contact 29 of bank 26 is coupled to pole 67 of selector switch 50; arm contacts 30, 31 are connected to another; and arm contact 32 is connected to energizing coil 51. Thus, when battery power is applied to the pole 67 of selector switch 50 and the banks 26, 27 are in the initial shown position, the circuit is broken by a discontinuity in bank 27. For whatever rotative position of the banks 26, 27 there will be electrical continuity to actuate the energizing coil 51. The coil 51, when energized, will rotate the banks 26, 27 through their operative angle and bank 26 serves to momentarily disconnect the continuity of the energizing circuit to permit the solenoid 51 to de-energize. Thereafter bank 26 once again connects the coil 51 to the battery and the coil is re-energized. This action will continue as long as the battery 43 is coupled to the banks 26, 27 by selector switch 50 or until the bank 27 reaches the illustrated position which automatically breaks the continuity of the reset circuit. It will therefore be apparent that the reset means allows the switch 21 to be returned to its initial starting position.

Switch 42 is operated in a similar manner by means of selector switch 50 so that if the switches 21 and 42 are misaligned the closing of the selector switch 50 with pole 67 will automatically reset each of the switches 21, 42 to its initial, known starting position.

From the foregoing description it will be appreciated that the position of the switch 42 can be precisely controlled from a remote location. In a core-taker gun, the contacts 54a, 55a of banks 54 and 55 can respectively and individually be coupled to igniters 65 associated with the explosive means 14 in the gun. The selector circuit 47 at the surface can include a switch 66 to couple one of the banks 54 or 55 to the source 46 of firing current and an ammeter 68 in the circuit provides an indication of the detonation of the explosive 14.

It should be appreciated from the foregoing that the gun is positioned at its selected location and the indicating means 44, 45 are checked to determine the position of the switches 21 and 42. The switches 21 and 42 are then simultaneously operated, if necessary by means of selector switch 50 to connect the movable contact with the desired stationary contact on either banks 54 and 55. Following this, switch 42 is operated so that the firing current is relayed to the selected igniter 65. However, should indicating means 44, 45 disclose a misalignment of switches 21 and 42, selector switch 50 is then coupled to switch pole 67 and the reset means in each of the switches 21 and 42 will return the respective switches to their initial positions.

It should further be appreciated that only three different impedances, i.e., R, r, and conductor 64 are disclosed since this is adequate to distinguish the various stepped positions of the switch 42 with a minimum of complexity and maximum of resolution for the indicating means 61.

However, further refinements to include more than three characteristic different impedances for the stationary contacts of bank 56 can readily be appreciated. Likewise, reset means for the stepping switches may assume other forms, i.e., bank 26 and contacts 29, 30 could be replaced by a cam operated switch.

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 aims 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. Apparatus including: a support adapted for passage through a well bored in the position at various levels in a well bored by means of an electrical cable having cable conductors; a plurality of individual explosive means disposed in said support, and electrical firing means for each said explosive means so that such explosive means may be individually detonated at various levels in a well bore; an electrical distribution circuit in said support including first stepping switch means providing sequential electrical connection of a first cable conductor to each of said electrical firing means, and means for selectively supplying firing current via the first cable conductor to said first stepping switch; means synchronized to the movement of said first stepping switch for providing an electrical indication signal of the particular electrical connection of said first stepping switch, said signal indication means including two different characteristic different impedance means for alternately providing only two indication signals, surface located, first indicating means coupled via a secondary conductor in the electrical cable to said signal indication means for indicating the particular electrical connection of said first stepping switch; surface located means including a second stepping switch means providing...
ing sequential electrical connections identical to said sequential connections of said first stepping switch and including means for providing an electrical indication signal of the particular electrical connection of said second stepping switch, and second indicating means coupled to said second stepping switch for indicating the particular electrical connection of said second stepping switch; surface located means coupled to said first and second switches for stepping said switches simultaneously.

2. Apparatus including: a support adapted for passage through a well bore for positioning at various levels in a well bore by means of an electrical cable having cable conductors; a plurality of individual explosive means disposed in said support, and electrical firing means for each said explosive means so that such explosive means may be individually detonated at various levels in a well bore; an electrical distribution circuit in said support including first stepping switch means providing sequential electrical connection of a first cable conductor to each of said electrical firing means, and means for selectively supplying firing current via the first cable conductor to said first stepping switch means synchronized to the movement of said first stepping switch for providing an electrical indication signal of the particular electrical connection of said first stepping switch; surface located, first indicating means coupled via a second conductor in the electrical cable to said signal indication means for indicating the particular electrical connection of said first stepping switch; surface located means including a second stepping switch means providing sequential electrical connections identical to said sequential connections of said first stepping switch and including means for providing an electrical indication signal of the particular electrical connection of said second stepping switch, and second indicating means coupled to said second stepping switch for indicating the particular electrical connection of said second stepping switch; surface located means coupled to said first and second switches for stepping said switches simultaneously; and surface located, selectively operable reset means coupled to said switches for simultaneously resetting the electrical connection of one switch relative to the electrical connection of the other switch so that said switches get out of step.

3. Apparatus including: a support adapted for passage through a well bore by means of an electrical cable having cable conductors; a plurality of individual explosive means disposed in said support, and electrical firing means for each said explosive means; an electrical distribution circuit in said support including first stepping switch means providing sequential electrical connection of a first cable conductor to each of said electrical firing means, and means for selectively supplying firing current via the first cable conductor to said first stepping switch; means synchronized to the movement of said first stepping switch for providing an electrical indication signal of the particular electrical connection of said first stepping switch, said signal indication means including two characteristically different impedance means for alternately providing only two indication signals, surface located, first indicating means coupled via a second conductor in the electrical cable to said signal indication means for indicating the particular electrical connection of said first stepping switch; surface located means including a second stepping switch providing sequential electrical connections identical to said sequential connections of said first stepping switch and including means for providing an electrical indication signal of the particular electrical connection of said second stepping switch, and second indicating means coupled to said second stepping switch for indicating the particular electrical connection of said second stepping switch; surface located means coupled to said first and second switches for stepping said switches simultaneously; and surface located, selectively operable reset means coupled to said switches for simultaneously resetting the electrical connection of one switch relative to the electrical connection of the other switch so that said switches get out of step.

4. An electrical indicating circuit for use with a well tool comprising: a well bore apparatus having a first stepping switch including at least one set of stationary electrical contacts and at least one arm contact, said one set of stationary electrical contacts and said one arm contact being relatively movable to establish sequential electrical coupling connection between said one arm contact and individual stationary contacts of said one set; an indicating arrangement for ascertaining an electrical coupling connection between said one contact arm and an individual contact including a source of electrical potential coupled to said one contact arm, characteristically distinct impedance means respectively coupled to each of said stationary contacts in a sequential arrangement to provide characteristic distinct impedance means for successive electrical coupling connections, and surface located, first indicating means coupled to said one contact arm and responsive to said impedance means to provide an indication of the electrical coupling connection of said stepping switch; a surface located, second stepping switch including a set of stationary contacts and an arm contact, said set of stationary contacts and said arm contact of said second stepping switch being relatively movable to establish a sequential electrical coupling connection between said one arm contact and individual stationary contacts of said set; second indicating means coupled to said surface located, second switch for ascertaining an electrical coupling connection between said one arm contact and an individual stationary contact; said first and second switches having predetermined like sequences of electrical coupling connections, means coupled to said first and second switches for simultaneously stepping said switches; and selectively operable reset means coupled to said first and second switches to simultaneously reset said switches to said predetermined sequences of electrical coupling connections should one of said switches be out of step.

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