Aug. 24, 1965 M. EZRAN 3,202,227

SWITCH CONTROL SYSTEMS

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Fig. 2

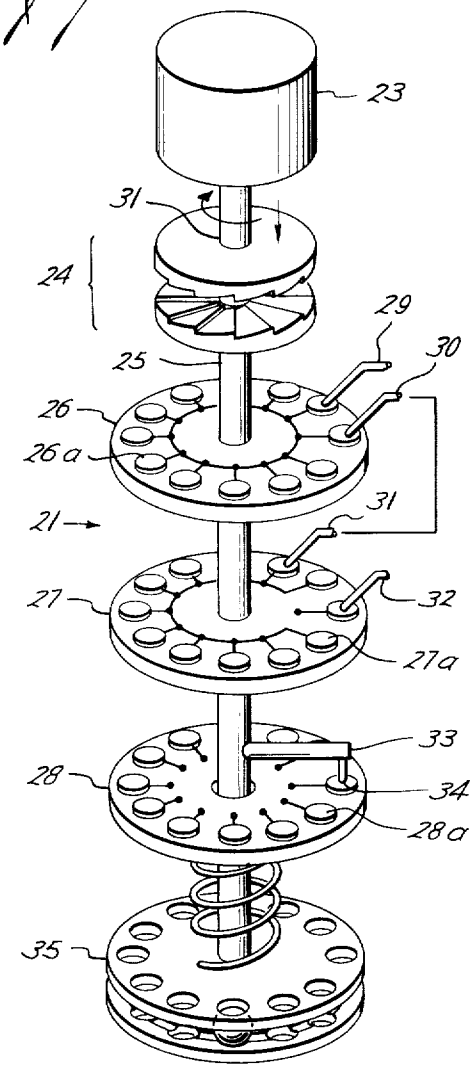
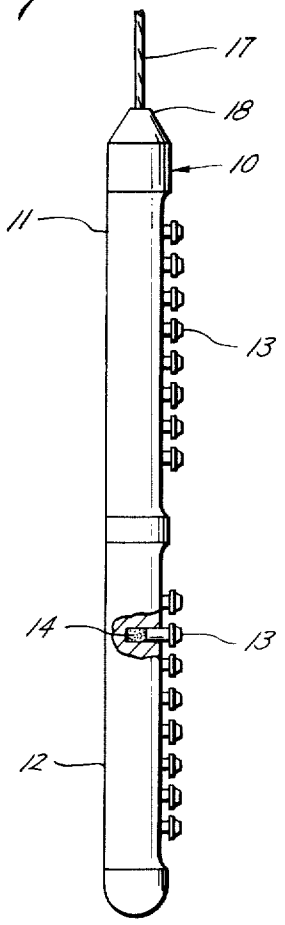


Fig. 1

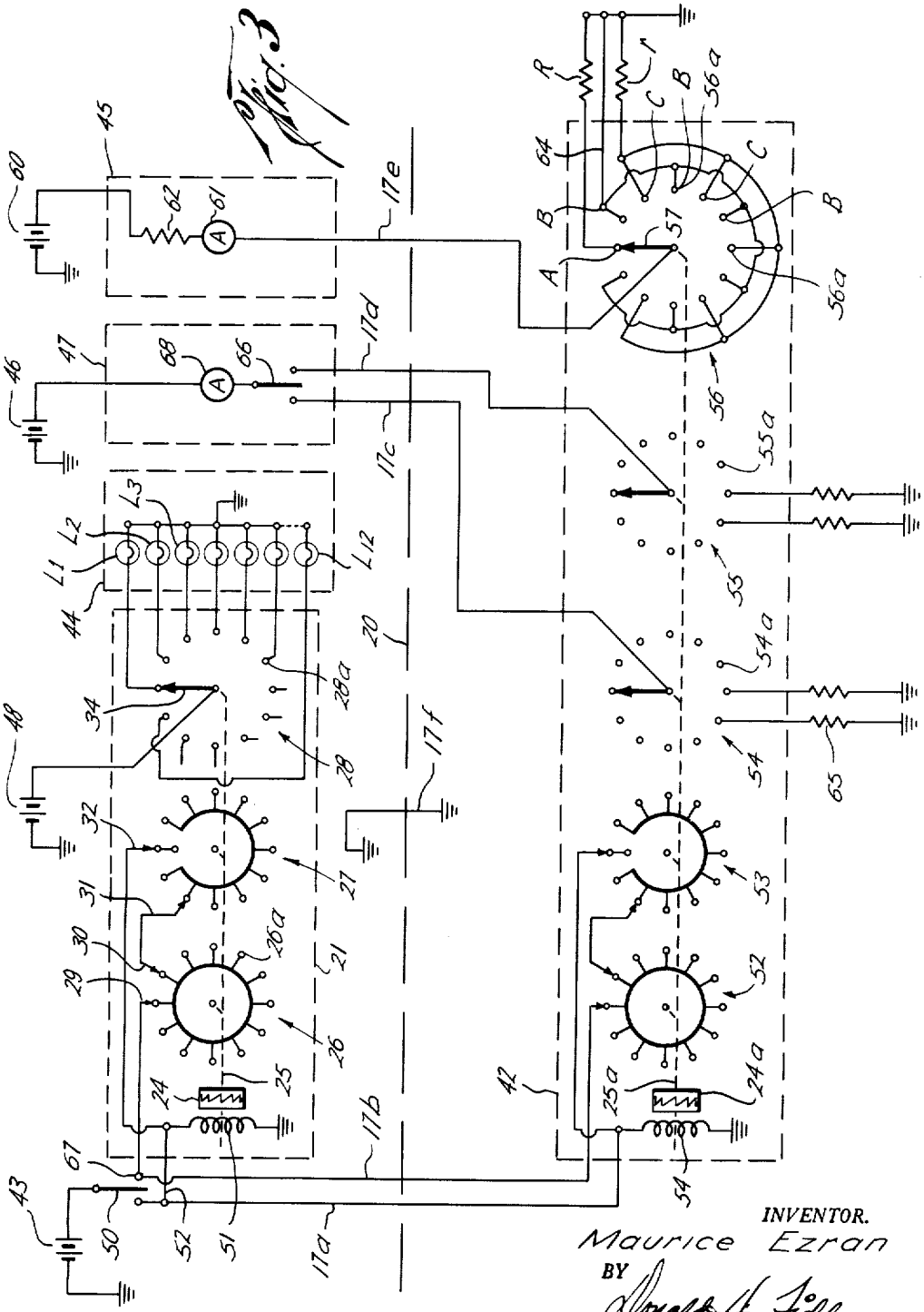


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SWITCH CONTROL SYSTEMS

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4 Claims. (Cl. 175—4)

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 condrctors 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 bullets are to be selectively fired. Selective operation of a gun, of course, refers to the selection and firing of a given one of a plurality of explosive means in a gun disposed in a well bore by operation of a control circuit at the earth's surface. The firing of an explosive means is accomplished by conveying a firing current from a control panel circuit to the selected explosive means via the armored electrical cable and an electrical distribution system in the gun.

A typical gun which is selectively operated is a core taker or core sampling gun. In this type of gun, core taker bullets are fired into earth formations to obtain solid cores or core samples of earth formations. Individually selected core taker bullets are respectively fired at various depths to obtain samples of the earth formations at various selected depths along a well bore. The cores or samples of earth formations thus obtained may be analyzed to provide valuable information relative to the formations at the depths that the respective cores were taken.

In one type of gun which is selectively operable, an electrical distribution system in the gun includes a stepping switch which serves to connect the various electrical 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 way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a typical core taker 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 taker 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 behind 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 ignitor 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). None of the foregoing elements are illustrated to any detailed extent since they are conventional in the art.

In a typical core sampling operation, the apparatus **10** would be lowered to the lowermost 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's 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 lowermost core bullet 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 lowermost bullet in the apparatu) 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 taker 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 manipulated simultaneously by 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 is mechanically coupled or fixed relative 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 **26***a*–**28***a*. 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 **26***a*. 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 **27***a*. The spacing arrangement between the contact arms **31**, **32** is such that the stationary contacts **27***a* angularly disposed to opposite sides of an intermediate contact **27***a* are electrically coupled to the respective arms **31**, **32**. Bank **28** has associated therewith a movable, spring-loaded, electrical arm contact **34** arranged to successively contact with the stationary contacts **28***a* 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 **28***a*.

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 easily 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 stationary contacts on the respective non-conductive discs to 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 **17***a*–**17***e* 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 **17***f*.

In FIG. 3, a stepping switch **21** in the surface-located control panel and a stepping switch **42** in the remote apparatus are simultaneously operated by means of a source of power, for example, a battery **43** 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 **17***c*, **17***d* 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 **17***a*. The energizing coils **51**, **54** when supplied with power, actuate the coupling mechanisms **24**, **24***a* and index the shafts **25**, **25***a* 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 rotatable 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 **28***a* for each indexed position of the switch. The contacts **28***a* 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 **28***a*. 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 **28***a* 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 distribution of the firing current from the surface battery **46**; and bank **56** is concerned with obtaining an indication of the relative position of the shaft **25***a* of the remote stepping switch **42**.

With respect to bank **56**, a movable contact arm **57** successively and sequentially is coupled with different electrical contacts **56***a* for each successive operative position of the stepping switch **42**. The movable arm contact **57** is coupled via a cable conductor **17***e* to a source of power such as a battery **60**. An indicating means such as an ammeter **61** together with a resistance **62** are also connected to the movable arm contact **57**. The various stationary contacts **56***a* of the bank **56** are connected via electrical return paths to the battery **60** wherein adjacent or successively arranged return paths have different impedances to provide a characteristic identification of the connection between the movable contact **57** and a particular stationary contact **56***a*.

For example, considering a stationary contact **56***a* (identified as A) as the contact selected to indicate an initial position of the contact arm **57** of switch **42**, this contact A is coupled via an electrical return path having a resistance R to 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 **56***a*

(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 the initial position #1, the alternate contacts B would 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 thereby develop distinct characteristic 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 **26***a* 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 **27***a* are electrically connected to one another with the remaining 12th contact electrically open. The arrangement of stationary arms **31**, **32** relative to contacts **27***a* 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 a pole **67** of selector switch **50**; arm contacts **30**, **31** are connected to one 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 position shown, the circuit is broken by a discontinuity in bank **27**. However, for any other 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 **54***a*, **55***a* 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 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 **66** can be 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 position.

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 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. 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, 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 means provid-

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 should 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 should said switches get out of step.

4. An electrical indicating circuit for use with a well tool comprising: 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 connections 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, characteristicly 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 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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