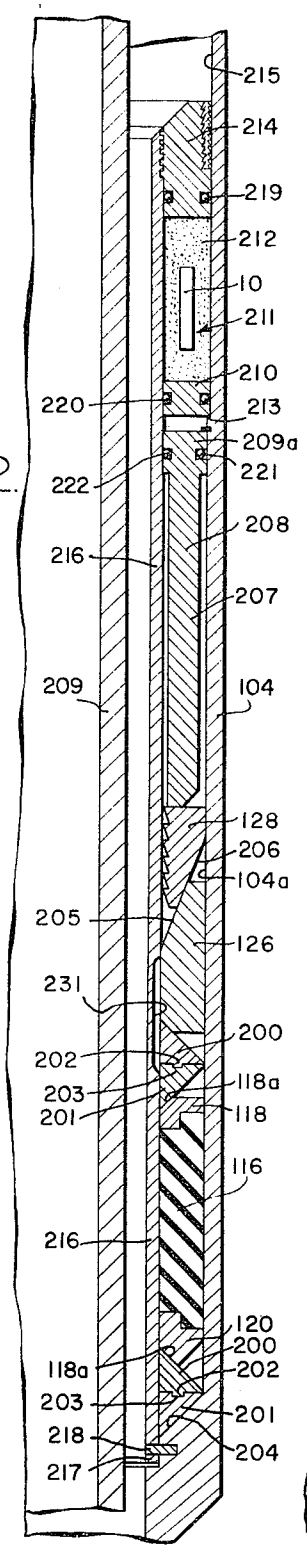
Aug. 9, 1966 K. LEUTWYLER 3,264,994

SUBSURFACE WELL APPARATUS

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Fig. 2.



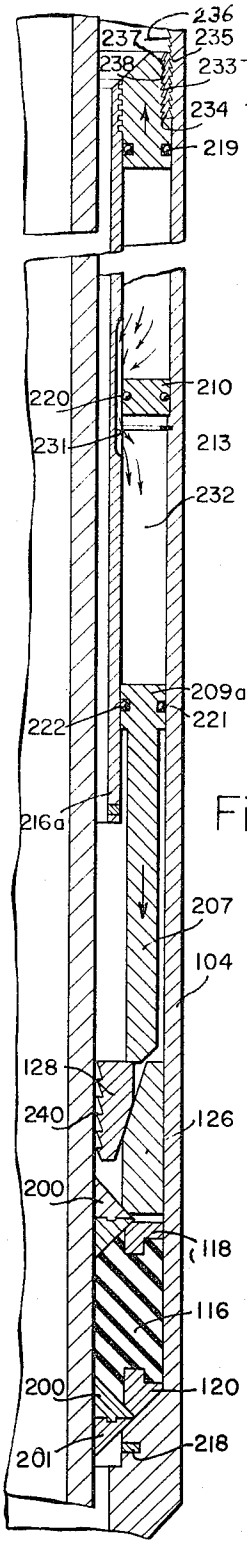


Fig. 3.

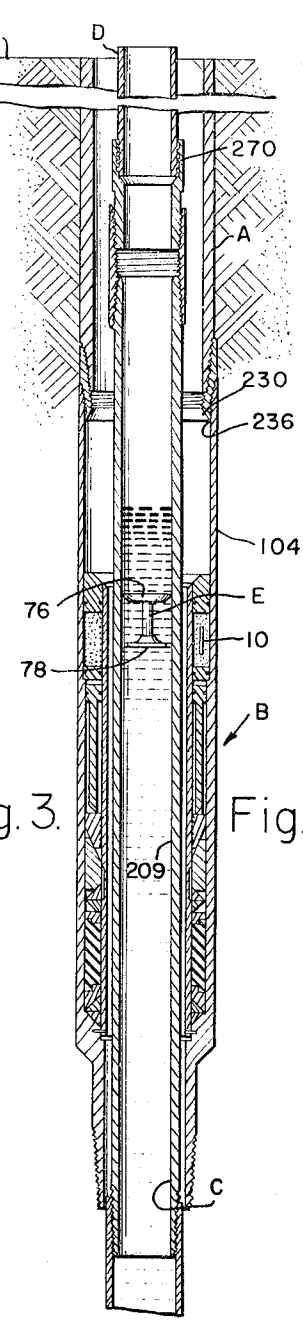


Fig. 1.

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SUBSURFACE WELL APPARATUS

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Fig. 4

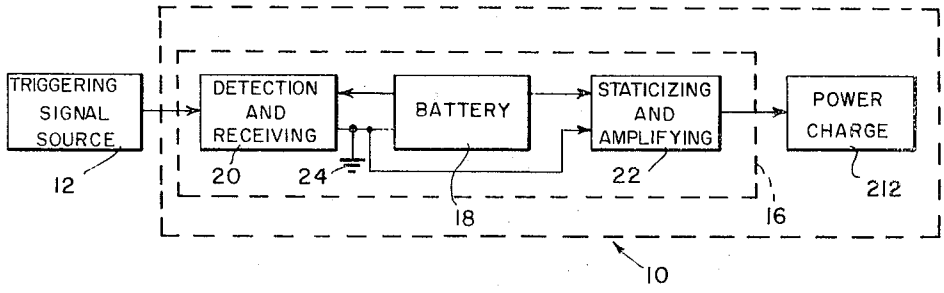
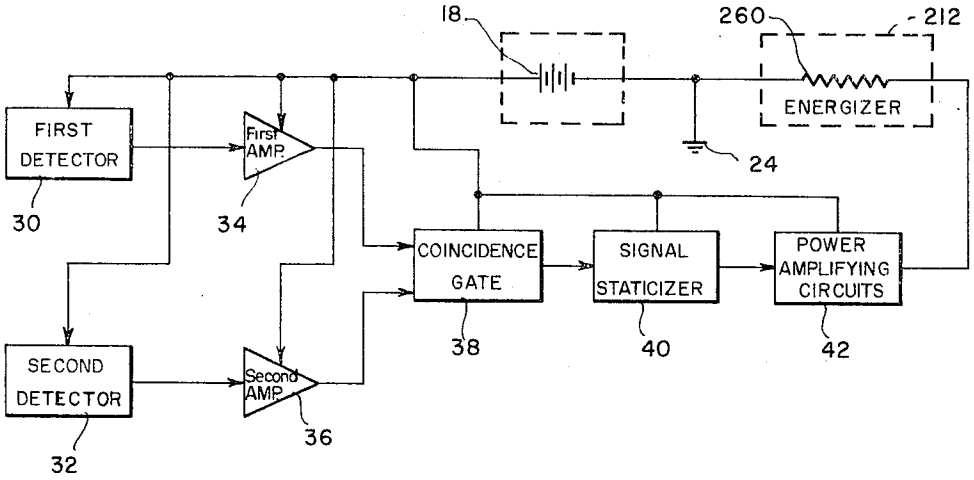


Fig. 5



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SUBSURFACE WELL APPARATUS

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Fig. 7

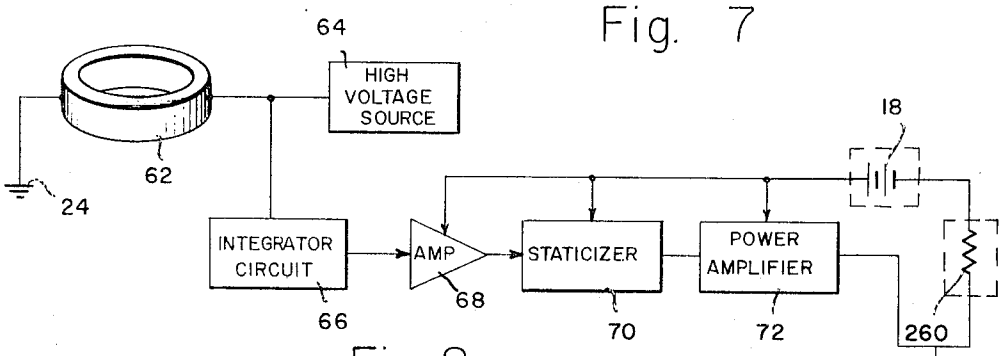
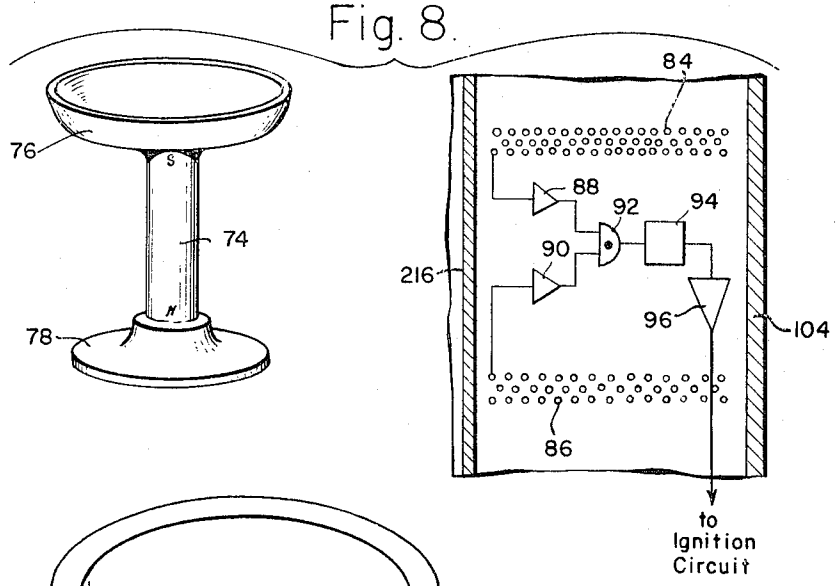


Fig. 8



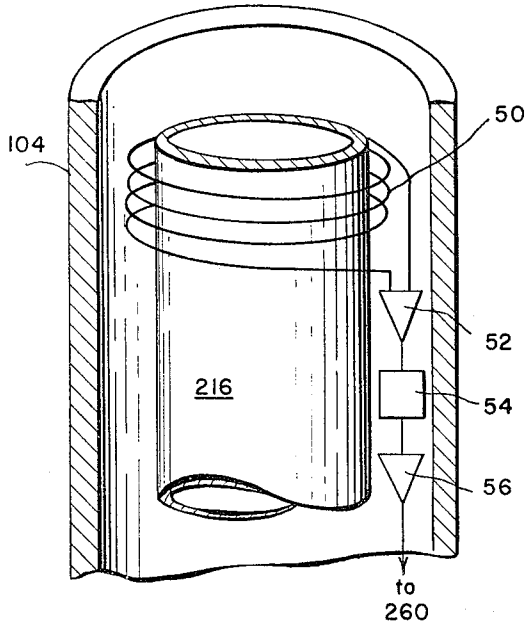


Fig. 6

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United States Patent Office 3,264,994 Patented August 9, 1966

3,264,994

SUBSURFACE WELL APPARATUS

Kurt Leutwyler, Whittier, Calif., assignor to Baker Oil Tools, Inc., Los Angeles, Calif., a corporation of California

Filed July 22, 1963, Ser. No. 296,815
21 Claims. (Cl. 102—70.2)

The present invention relates to subsurface well appatus, and more particularly to an apparatus for the remote operation of oil well tools.

The basic concept of the invention is to provide an oil well tool with a self-contained powering source of potential energy which can be transformed into kinetic energy by the provision of a triggering signal or combination of signals at an extremely low level of energy. That is, a predetermined combination of physical phenomena, such as a supersonic signal or signals, a magnetic field, or a radioactive element will provide energy sufficient to actuate a stored power source adequate to do the physical work involved in operating the particular tool. Through the use of modern, computer-type electronic circuitry, it is possible to transform such a low level impinging signal into an electrical signal of sufficient magnitude and duration to operate electrical igniting or electro-mechanical releasing circuits. The working power system can be the energy stored in a compressed spring compresesd gas, hydrostatic pressure, or a gas generator such as a pyrotechnic type mechanical compound which rapidly generates gas. The actual tool operation may be accomplished by the release of the compressed spring, or a hydraulic or pneumatic actuating system built into the tools and which is operated by expanding gas or other fluid under pressure.

According to the present invention, an integral, annular power charge or propellant, preferably a chemical energy source, as well as means for igniting the stored power charge, are incorporated in the body of a down-hole tool, and also electrical circuitry, responsive to a low power, externally supplied triggering signal. Upon receipt of the proper triggering signal or signal combination, the normally quiescent electrical circuits are activated to provide an ignition current to the power charge, operating the down-hole tool.

The present invention, therefore, contemplates the incorporation of an electronic ignition package adjacent to the stored power charge, all in the down-hole device. The ignition package includes a detector-transducer which, in response to a signal, generates a low level electrical impulse. The term "signal" herein is intended to include all of the various forms of energy that can be transmitted and detected, including the electrical, magnetic, sonic and radiant forms thereof. A "signal" source, such as a permanent magnet, can induce an electrical signal in a suitable inductive transducer. By providing a pair of transducers, properly spaced, a travelling magnet can induce a pair of signals separated in time, which can be recognized by coincidence circuits.

Through the use of electronic computer-type circuits, the recognized signals can be amplified and staticized to the magnitude and duration necessary to provide electrical energy sufficient to ignite the stored power charge. Typically, an electrical ignition device, such as a resistance wire or a blasting cap, is employed to ignite the charge.

Conventional electronic computer-type circuits, such as "and," "or" gates, one-shot multivibrators, or other bi-level static storage devices, are easily combined to perform the decoding and triggering tasks. Proximity detectors, such as inductive or capacitive pick-offs, or radiant energy detectors, which convert impinging energy

into an electrical signal, permit a choice of many alternative systems according to the present invention.

In an embodiment of the invention, a down-hole tool has an annular cavity in which is placed a power charge or propellant ignitable by a bridge wire. An electronic system, including detection and ignition circuits and an electrical power supply, is also placed in the cavity adjacent to the stored power charge. Two inductive coils concentric with the annular cavity are axially spaced to provide separate electrical responses to the passage of a permanent magnet, which is adapted to either be lowered gravitationally, or pumped, down the well.

By proper spacing and winding of the coils, the magnet generates a signal in the first and then the second coil. The coincidence of a pulse in the first coil with a pulse of similar polarity in the second coil generates a signal which, when applied to staticizing and amplifying circuits, activates the ignition system to fire the power charge.

In another embodiment, the detector portion of the electronic system is a radiation-sensitive device, such as an ionization chamber, which is responsive to the emanations of a radioactive nuclear source which is transported through the well. When the source is in close proximity with the detector, the increasing of ionizing radiation over the background radiation is sufficient to activate the ignition system.

In a copending application of the present inventor, filed concurrently herewith, Serial No. 296,618, filed July 23, 1963, for "Subsurface Well Apparatus," there is described and claimed a similar system in which appropriate sonic triggering signals are encoded and transmitted to corresponding decoding receivers in the down-hole tool. Upon recognition of the proper code combination, an electrical signal is generated, which is staticized and amplified to operate the ignition system.

Accordingly, it is an object of the present invention to provide a remotely actuated stored power charge which is incorporated in an oil well tool.

Another object of the present invention is to provide improved oil well apparatus with integral power charges and ignition circuits.

It is a further object of invention to provide an oil well tool with an integral power charge, electrical power supply, and normally quiescent electronic circuitry adapted to respond to a received triggering signal.

It is yet another object of invention to provide a down-hole oil well tool which is energized by the reception of a determined signal combination.

It is still another object of the invention to provide a downhole oil well tool that can be operated by the passage of a passive triggering assembly.

A further object of invention is to provide a down-hole oil well tool containing an integral power charge, internal electronic circuitry, and necessary electrical power supply operable in response to the receipt of predetermined, low energy triggering signals.

Still a further object of invention is to provide in a down-hole oil well tool an integral powering package responsive to externally supplied low power signals for actuating the tool.

It is yet another object of invention to provide in a down-hole oil well tool an integral power charge, a normally quiescent electronic circuit for firing said power charge, and receiving circuits response to low level magnetic signals for operating the tool.

It is still another object of the present invention to provide in a down-hole oil well tool an integral power charge and ignition package, including normally quiescent electronic circuitry, adapted to be activated upon receipt of a predetermined combination of low level magnetic signals.

A further object of the invention is to provide in a down-hole oil well tool an integral power package, including a power charge, electronic circuitry having a first, normally quiescent state, and a second active state and detecting apparatus reponsive to applied radiant energy for triggering the electronic circuits into the second state for operating said tool.

It is yet a further object of invention to provide in a down-hole oil well tool an integral power package, including a stored power charge, an electrical power supply, normally quiescent electronic circuitry having a second, active state for firing said power charge, and detection circuitry responsive to the passage of a permanent magnet to trigger said quiescent circuitry into said second state for operating the oil well tool.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a longitudinal section of an apparatus embodying the invention disposed in a well bore;

FIG. 2 is an enlarged longitudinal section of a portion of a subsurface oil well device forming part of the apparatus disclosed in FIG. 1, prior to its actuation;

FIG. 3 is a view similar to FIG. 2 after actuation of the oil well device;

FIG. 4 is a block diagram of the elements of the tool operating system according to the present invention;

FIG. 5 is a block diagram in somewhat greater detail of the electronic ignition package according to the present invention;

FIG. 6 is a partially block, partially schematic representation of an electronic triggering package operable in response to an applied magnetic field;

FIG. 7 is a block diagram of an alternative electronic triggering package adapted to be energized by a radioactive source;

FIG. 8 is a block diagram of an alternative electronic triggering package adapted to be energized by a moving permanent magnet.

As disclosed in FIG. 1, a string of oil well casing A is disposed in a well bore and has a liner hanging apparatus B formed in its lower portion, which is adapted to support a liner C which can be lowered down through the well casing into a well bore below the casing by means of a suitable tubular string D extending to the top S of the well bore. The liner hanging apparatus B embodies its own source of energy for effecting its setting against the liner, initiation of the actuating mechanism being triggered from a suitable source, as for example, by lowering or pumping a suitable device E down through the tubular string from the top of the well bore.

As disclosed most clearly in FIGS. 2 and 3, the liner hanger apparatus is of the general type disclosed in the application of Hiram H. Fisher, Jr., and William D. Myers, for "Liner Hanging Apparatus," Serial No. 281,409, filed May 20, 1963. It includes a cylinder or housing **104** forming the lower portion of the casing string A extending to the top of the well bore and is capable of supporting the liner C therewithin that extends into the well bore below the hanger.

The hanger apparatus further includes an elastic packing sleeve **116**, made of rubber or rubber-like material, positioned between a pair of thrust rings **118, 120**. The thrust rings have tapered outer surfaces **118***a* engaging sets of split upper and lower extrusion preventing rings **200, 201** that are interconnected for joint lateral movement by providing a circular key **202** on one ring fitting

within a companion circular groove **203** in the adjacent ring. The splits of each pair of rings are out of phase to avoid a straight-through longitudinal passage through them.

The bottom ring **201** of the lower pair engages a downwardly tapering surface **204** of the housing or casing collar member **104**; whereas, the upper ring **200** of the upper pair engages an expander **126** slidable along the wall **104***a* of the housing or cylinder. The expander has an inner tapered surface **205** engageable with an external companion tapered surface **206** of a split slip sleeve or ring **128** adapted to move downwardly along the expander and inwardly into engagement with the periphery of a liner hanging member **209**. A depending skirt portion **207** of a piston **208** engages the upper end of the split slip ring **128**, this piston having an upper piston head **209***a* slidable along the inner wall **104***a* of the cylinder **104** and located below the lower head **210** of a chamber **211** adapted to contain a power charge or propellant **212**. The head **210** bears against an upwardly facing shoulder **213** of the housing to prevent its downward movement, the upper end of the chamber being defined by an annular piston **214** slidable along the inner wall **215** of the cylinder **104** and secured to a protector sleeve **216** extending along the lower head **210** and the piston **208**, and disposed initially across the entire liner hanging apparatus B to protect the same. The lower end of the sleeve **216** is located within a lower recess **217** in the housing, the sleeve being held in its initial position, covering the liner hanging members, by one or more shear screws or pins **218** securing it to the housing **104**.

The annular piston head **214** carries a suitable side seal ring **219** adapted to slidably seal against the cylinder wall **215**, leakage of fluid between the protective sleeve **216** and the lower chamber head **210** being prevented by an inner seal ring **220** on the head slidably sealing against the periphery of the sleeve. Leakage of fluid between the piston head **209***a* and the cylinder wall **104***a* is prevented by a piston ring **221** slidably sealing against the latter; whereas, leakage of fluid between the protective sleeve **216** and piston head is prevented by an inner seal ring **222** on the latter slidably sealing against the periphery of the sleeve.

When the power charge or propellant **212** is ignited, as described hereinbelow, gas under an increasing pressure is generated in the annular chamber **211**, acting upwardly on the annular piston **214**. When the force on the piston **214** is sufficient to overcome the shear strength of the lower screws **218**, the latter are disrupted and the piston and its protector sleeve **216** moved upwardly in the housing or cylinder **104** to the extent limited by engagement of the piston with a stop member **230** at the upper end of the cylinder or housing **104**. At this time, a by-pass groove or grooves **231** in the periphery of the sleeve **216** are disposed across the lower chamber head **210** (FIG. 3), allowing the gases to pass from the chamber **211** through the by-pass groove **231** into the annular cylinder space **232** formed between the protective sleeve **216** and the cylinder wall **104***a*, to exert a downward force on the piston **208**.

When the protector sleeve piston **214** engages the stop member **230**, the lower end **216***a* of the protector sleeve is disposed above the slip device **128**, thereby removing the protector sleeve from its covering position relative to the inwardly movable elements of the liner hanger B. Return or downward movement of the protector sleeve **216** within the housing **104** is prevented by a suitable one-way ratchet or latch device mounted on the piston and engagaing the enclosing housing. As shown, a split sleeve **233** is mounted in a recess **234** in the piston **214** and has external teeth **235** thereon facing in a downward direction and adapted to engage companion internal ratchet teeth **236** in the housing **104** adjacent to and immediately below its stop member **230**, such teeth facing in an up-

ward direction. The ratchet sleeve **233** has cam teeth **237** adapted to coact with companion cam teeth **238** in the piston **214**, so that any tendency for the piston to move downwardly will cause the downwardly tapering and coacting cam teeth **237**, **238** to urge the sleeve **233** laterally outwardly to main its ratchet teeth **235** fully meshed with the housing ratchet teeth **236**.

As the propellant or power charge **212** burns away, so as to generate the gaseous fluid at an increasing pressure, the piston **208** shifts downwardly in the annular cylinder space **232**, forcing the slip sleeve **128** and expander **126** downwardly to shift the upper extrusion preventing members **200**, **201** and the upper thrust ring **118** toward the lower thrust ring **120** and lower extrusion preventing members **200**, **201**, shortening the length of the packing sleeve **116** and contracting it laterally inwardly into engagement with the liner hanging member **209**. Continued downward movement of the piston **208** shifts the slip sleeve **128** downwardly along the expander **126** and contracts it radially inwardly into anchoring engagement with the periphery of the liner hanging member **209**, the slip sleeve having internal upwardly facing wickers or teeth **240** adapted to anchor themselves in the periphery of the liner hanging member. As the gas pressure increases, the packing sleeve **116** is shortened to a greater extent and is forced more firmly into engagement with the periphery of the liner hanging member. The development of sufficient force will also shift the upper and lower sets of extrusion preventing rings **200**, **201** into engagement with the liner hanging member **209**, bridging the annular spaces between the upper expander **126** and liner hanging member, and between the lower portion **204** of the housing and liner hanging member, to preclude flow of the pliant, elastic packing material through such spaces. The exertion of an increasing downward force on the piston **208** by the gaseous fluid will wedge the slip sleeve **128** more firmly into engagement with the liner hanging member, insuring that the weight of the liner C will thereafter maintain the slip sleeve embedded in the hanging member, the downward force being transmitted through the expander **126**, upper extrusion preventing rings **200**, **201**, and thrust ring **118** to the packing member **116**, to maintain the latter effectively sealed against the periphery of the liner member **209**.

The propellant or power charge **212** embodied in the annular chamber **211** between the protective sleeve **216** and the outer housing or cylinder **104** contains its own source of oxygen, and will gradually burn away to generate the required gaseous fluid under pressure for operating the apparatus B. Preferably, maximum pressure will be generated during a substantial period, which, for example, may be from about one-half second, after ignition of the propellant **212**, to about ten to thirty seconds after ignition. Such relatively slow burning of the propellant is preferred, since its explosion, accompanied by its sudden release of energy, might damage the parts of the apparatus.

Ignition of the propellant occurs as a result of heating a suitable ignition wire **260** (FIG. 5) embedded in the propellant, or within a readily ignitable match compound surrounding the ignition resistance wire and disposed in the propellant. Such ignition wire forms part of an electronic package **10** mounted within the chamber **211** itself. An appropriate circuit is disposed in the chamber **211**, which is responsive to a triggering signal for effecting completion of the circuit through the resistance igniter or bridge wire **260**.

With reference now to FIG. 4, the tool operating power charge **212** and electronic ignition package **10** is represented as a single block, which is incorporated in the annular recess **21** of the down-hole, subsurface well tool B. A triggering signal source **12**, adapted to energize the circuit of the package **10** is represented by a separate block. It will be understood that the particular type of signalling device selected is determined by the choice of signal detection apparatus employed for incorporation in the subsurface well apparatus.

Assuming that the signal source **12** provides some unique and recognizable phenomenon to which the down-hole tool B can respond, the integral power charge **212** and ignition package **10** can be roughly divided into two element, a first, power charge element **212** and a second, electrical element **16**. The power charge element **212** is preferably a gas generator, such as a propellant, railway flare, or other combustible chemical composition combined with an oxidizer, that is substantially self-contained and complete. Such a power charge can be energized by electrical igniting means, such as a resistance bridge wire **260**, or a cartridge adapted to be fired by the provision of an electrical current.

A storage battery **18** provides the electrical current necessary to ignite or fire the stored power charge element **212**. The storage battery **18** also powers the electrical circuits, providing the necessary stand-by electrical energy to maintain the electronic circuits in a quiescent state, as well as the energy to operate them in response to a received energizing signal. The electrical element **16**, in addition to the battery **18**, includes a detection and receiving circuit **20** and staticizing and amplifying ignition circuits **22**.

In operation, the predetermined signal combination is detected at the detecting and receiving circuit **20** which, in response thereto, generates an electrical signal impulse at a low power level which is then applied to the staticizing and amplifying circuits **22**. These circuits hold and amplify the signal impulse and, through suitable circuitry, provide electrical current of electrical energy sufficient to ignite the power charge element **212**, which then generates the requisite mechanical energy for actuating the down-hole subsurface well too. A common reference potential source, represented by the conventional ground symbol **24** has also been shown.

Turning next to FIG. 5, there is shown a generalized block diagram of an electrical system corresponding to the electrical element **16** of FIG. 4, applicable to the present invention. It is understood, however, that detailed circuit diagrams are unnecessary and that those skilled in the art will be familiar with the specific manner of interconnecting these circuits.

A first detector **30** and a second detector **32**, both powered by the battery **18**, are provided to detect and decode the impinging signal. The first detector **30** responds to a first stimulus and the second detector **32** responds to a second stimulus, both of which must be present before the down-hole apparatus is actuated. The output of the first detector **30** is applied to a first amplifier **34** and similarly, the output of the second detector **32** is applied to a second amplifier **36**. If the signal stimuli are sufficiently great, the detectors generate signals which do not need amplification, and, in such an event, the amplifiers **34** and **36** may be omitted.

The outputs of the amplifiers **34**, **36** are applied to a coincidence gate **38**, which may be any of the well known electronic circuits adapted to provide an output signal on the occurrence of signals at all of the input terminals. In the present example, two inputs are provided and an output signal is generated in response to the coincidence of input signals. The output of the coincidence or "and" gate **38** is applied to a signal staticizer **40**, which may be a conventional "one-shot" or monostable multi-vibrator circuit, or a "flip-flop" or bistable multi-vibrator circuit, both well known in the fields of electronic computer circuits. Other bi-level, or two state, memory type elements may be used to staticize the transient output of the detectors.

A one-shot is a device which operates in a first, stable mode to produce a first, low-level signal, but which, on the application of a suitable triggering signal, switches to a second, unstable mode of operation to produce a second, high level signal for an adjustable limited period of

time, after which it returns to the first, stable mode. In the second mode of operation, the high level signal output is sustained to be of greater duration and magnitude than the output of the detector circuits. This operating signal output of the signal staticizer **40** is applied to power amplifying circuits **42**, which, through the use of suitable power amplifiers, provide electrical power to activate the stored power charge energizing device.

In operation, therefore, a triggering signal at an extremely low energy level can, through the use of intermediate electronic detecting, staticizing and amplifying circuits, energize the stored power charge **212** adequate to operate the subsurface well tool B, which may be rugged and complex.

In the embodiment illustrated in FIG. 6, a signal detector, which may be located in the chamber **211**, is adapted to respond to the presence of a moving magnetic field. An induction coil **50**, made up of several turns of wire, is wound into a helical solenoid and located in the annular space **211** coaxial of the tool B. As is well known, a permanent magnet moving through a helix induces an electric current in the coil, which is connected to an amplifier circuit **52**. The output of the amplifier circuit **52** is applied to a staticizer **54**, the output of which is applied to a second, power amplifier **56**. The power amplifier **56** may be only a power transistor, the base of which is connected to the output of the staticizer **54**, and the emitter and collector of which serially connect an igniting device, such as the bridge wire **260**, to the source of electrical energy. The circuitry just described is all located in the space **211**, which also contains the propellant **212**.

It will, of course, be recognized that to be operable in the down-hole environment, the tool parts **216**, **104** defining the annular space will be made of non-magnetic material. This is to enable the induction coil **50** to detect the change in the magnetic field induced by the passage of a permanent magnet.

In operation, the velocity of the magnet will determine the amplitude of the induced electrical signal in the induction coil **50**. The signal is amplified to trigger the staticizer **54** to provide a relatively high level signal for a fixed time interval. The staticized output signal is adequate to "turn on" the power transistor in the power amplifier **56**, which conducts current sufficient to energize the bridge wire **260** and ignite the power charge **212**.

In FIG. 7, there is shown an alternative electronic package adapted to be responsive to the presence of a radioactive source and which is located in the space **211**. In this embodiment, the down-hole tool may assume any shape and need not be a hollow cylinder concentric with the well casing. However, assuming the same tool as shown in FIG. 6, an annular ionization chamber **62** is disposed in the space **211** and is connected to a source of relatively high voltage **64**. The ionization chamber **62** may be a gas-filled hollow ring with an internal grid electrode that is maintained at the relatively high electrical potential.

As ionizing radiation passes through the chamber, an electrical discharge takes place between the grid and the surrounding walls which are maintained at the common or ground potential. An integrator circuit **66** is connected to the chamber **62** and is adjusted so that its leakage rate approximately equals the charging rate resulting from background radiation. The output of the integrator circuit **60** is applied to an amplifier **68**, the output of which is applied to a signal staticizer **70**, which, as above, may be a one-shot. The triggering threshold of the one-shot is adjusted so that the amplified output of the integrator circuit is normally below the threshold in the environment of background radiation alone. The output of the staticizer **70** is applied to a power amplifying stage **72**, which, in turn, is connected to the power charge igniting circuits, including the igniter **260**. As in the prior forms of the invention, all portions of the radiation detector circuitry are located in the chamber **211**.

A radioactive source brought into proximity with the ionization chamber **62** discharges with a greater frequency, causing the output of the integrator circuit **66** to rise in magnitude until the triggering threshold of the staticizer **70** is exceeded. The output of the staticizer **70** is then amplified to provide an electrical signal of sufficient magnitude and duration to fire the power charge **212**, thereby effecting setting of the tool B against the device **209**. If the configuration of the down-hole tool does not provide a hollow cylinder or cavity **211**, then the ionization chamber may be a conventional Geiger-Mueller tube or similar radiation detector.

In the form of device shown in FIG. 8, there is shown an embodiment that is triggered by a permanent magnet lowered into or pumped down the well. A permanent magnet **74** may be provided with upper and lower packing elements **76**, **78** so that it can be pumped through the well or the tubing string D.

The tool itself is modified to permit the magnet to affect the inductive coil, best accomplished by the provision of aluminum, austenitic steel, or other non-magnetic metallic inserts in the tool, which define the boundaries of the annular space **211**. Thus, the parts **216**, **104**, and also the liner member **209**, are made of non-magnetic metal.

A receiver-detector circuit, suitable for activation by the moving permanent magnet **76**, which is not subject to false triggering by the presence of stray magnetic fields, is illustrated here. Referring to FIG. 8, there is shown here a pair of induction coils, each of which may be identical to the helical induction coil **50** of FIG. 6. A first helix **84** and a second helix **86** are oppositely wound and disposed concentrically in the space **211**, being spaced apart axially by a distance equal to the effective separation of the poles of the permanent magnet **74**, which is used as a triggering signal source. Each helix **84**, **86** is connected to a separate amplifier circuit **88**, **90**, the outputs of which are connected to a coincidence circuit **92**.

The output of the coincidence circuit **92** is applied to a staticizer **94**, the output of which is applied to a power amplifier stage **96**. It will be noted that once the triggering signal is received and amplified, substantially all of the above-described embodiments utilize a similar combination of coincidence circuits feeding a signal staticizer, which in turn, drives the firing circuits through a power amplifier stage. It will be understood that all components of the electronic ignition package shown in FIG. 8 are housed in the chamber **211** of the tool B.

In operation, the circuits are normally quiescent until the permanent magnet **74**, with a fairly strong magnetic field associated therewith, is caused to move through the well tubing D at a fairly rapid rate of speed and through the non-magnetic liner member **209**. The magnet **74** travels in the axial direction with respect to the two helices **84**, **86**. When either of the magnetic poles passes through the first helix **84**, an electrical pulse is induced therein, which, for example, may be assumed to be initially positive and then negative. As this first pole approaches the second helix **86**, the opposite pole approaches the first helix **84**, and, because the helices are oppositely wound, the signals induced in each of the helices simultaneously undergo the same voltage excursions.

Stray magnetic fields, on the other hand, simultaneously induce only oppositely directed electrical signals through both helices. Therefore, the passage of magnet **74** results in a substantially identical voltage excursion in both helices **84**, **86**, no matter which magnetic pole precedes. The induced voltages, amplified in the respective amplifier circuits **88**, **90**, are applied to the coincidence circuit **92**, which responds to the simultaneous occurrence of signals of identical polarity at its inputs. The

coincidence circuit **92** then provides a signal to the staticizer **94**, the output of which, as described above, is sufficient to drive the power amplifier **96** into saturation, igniting the power charge **212**.

In the operation of the apparatus illustrated in FIGS. 1 and 8, the liner hanger B, with its movable elements protected by the sleeve **216**, has been disposed in the well bore as a result of lowering the casing A therewithin, which is usually cemented in place. The liner hanger apparatus B contains the package, disclosed in FIG. 8, in its cavity **211**. The hole below the casing is then drilled and the liner C lowered in the well bore on the tubular string D, until the liner is in its appropriate location with its upper hanging member **209** overlapping the casing and disposed within the apparatus B. The magnet device E is then pumped down through the tubing string D and into the hanging member **209**, energizing the coils **84** and **86** and triggering the resistance wire **206** to effect ignition of the power charge **212**.

Upon its ignition, the power charge burns away, generating gas under an increasing pressure, which will elevate and remove the protector sleeve **216** and shift the slip sleeve **128** and packing structure **116, 200, 201** inwardly into firm engagement with the periphery of the liner hanging member **209**. Following full setting of the liner hanger against the member **209**, the tubing string can be rotated, as to the right, to effect its disconnection from the liner hanging member **209**. Such disconnection is facilitated by providing a left-hand threaded connection **270** between the lower end of the tubular string and the member **209**, in a known manner.

I claim:

1. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means operable in response to an applied energy signal for providing an output signal; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal of duration and magnitude greater than that of said output signal; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby an applied energy signal triggers the apparatus into operation; wherein said detecting means include signal amplifying means connected between said detecting means and said staticizing means; said staticizing means include a monostable multi-vibrator circuit and further include signal amplifying means connected between said staticizing means and said powering means; and wherein said powering means include gas generating means and means responsive to said operating signals for energizing said gas generating means.

2. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including an inductive coil operable in response to an applied magnetic field signal for providing an output signal; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal having a magnitude and duration greater than that of said output signal; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signals for applying work energy to the apparatus, whereby an applied magnetic field signal triggers the apparatus into operation.

3. Apparatus of claim **2**; wherein said detecting means include signal amplifying means connected between said detecting means and said staticizing means; said staticizing means include a monostable multi-vibrator circuit and further include signal amplifying means connected between said staticizing means and said powering means; and wherein said powering means include gas generating means and means responsive to said operating signals for initiating operation of said gas generating means.

4. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including an inductive coil operable in response to an applied magnetic field signal for providing an output signal; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal having a magnitude and duration greater than that of said output signal; and powering means connected to said staticizing means, including gas generating means for operating the apparatus, and means operable in response to said operating signal for initiating operation of said gas generating means to apply work energy to the apparatus, whereby an applied magnetic field signal triggers the apparatus into operation.

5. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including an inductive coil concentric with the well bore and operable in response to an applied magnetic field signal for providing an output signal; means for applying a magnetic field to said detecting means including a permanent magnet adapted to be transported through the well bore for inducing an electrical signal in said inductive coil; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal having a magnitude and duration greater than that of said output signal; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signals for applying work energy to the apparatus, whereby a magnetic field signal applied by the moving magnet triggers the apparatus into operation.

6. Apparatus of claim **5**; wherein said staticizing means include a monostable multi-vibrator circuit and further include signal amplifying means connected between said staticizing means and said powering means; and wherein said powering means include gas generating means and means responsive to said operating signal for initiating operation of said gas generating means.

7. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of radiation detecting means operable in response to an applied radioactive energy signal for providing an output signal; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal of duration and magnitude greater than that of said output signal; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby an applied radioactive energy signal triggers the apparatus into operation.

8. The apparatus of claim **7**; wherein said radiation detecting means include an ionization chamber operable in response to impinging radioactivity for conducting an electrical current, and further including integrating circuit means connected to said ionization chamber and operable to provide an output signal in response to more than a predetermined electrical current in a unit time interval.

9. The apparatus of claim **7**; wherein said radiation detecting means include an ionization chamber operable in response to impinging radioactivity for conducting an electrical current, and further including integrating circuit means connected to said ionization chamber and operable to provide an output signal in response to more than a predetermined electrical current in a unit time

interval, and amplifying means connected between said integrating circuit means and said staticizing means.

10. Apparatus of claim 7; wherein said staticizing means include a monostable multi-vibrator circuit and further include signal amplifying means connected between said staticizing means and said powering means, and wherein said powering means include gas generating means and means responsive to said operating signal for initiating operation of said gas generating means.

11. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of radiation detecting means operable in response to an applied radioactive energy signal for providing an output signal; staticizing means connected to said detecting means including a monostable multi-vibrator circuit operable in response to said output signal to provide an operating signal of duration and magnitude greater than that of said output signal; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby an applied radioactive energy signal triggers the apparatus into operation.

12. In subsurface well apparatus adapted to be lowered in a well bore, means for operating the apparatus comprising the combination of radiation detecting means operable in response to an applied radioactive energy signal for providing an output signal; staticizing means connected to said detecting means and operable in response to said output signal to provide an operating signal of duration and magnitude greater than that of said output signal; and powering means connected to said staticizing means, including gas generating means adapted to provide work energy for operating the apparatus, and means operable in response to said operating signal for initiating operation of said gas generating means to apply work energy to the apparatus, whereby an applied radioactive energy signal triggers the apparatus into operation.

13. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic field signal for providing first and second output signals respectively; staticizing means connected to said detecting means and operable in response to the coincident occurrence of said first and second output signals to provide an operating signal of duration and magnitude greater than that of either of said output signals; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby a magnetic field signal applied simultaneously to said first and second coils triggers the apparatus into operation.

14. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic field signal for providing first and second output signals respectively; staticizing means connected to said detecting means including a monostable multi-vibrator circuit operable in response to the coincident occurrence of said first and second output signals to provide an operating signal of duration and magnitude greater than that of either of said output signals; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby a magnetic field signal applied simultaneously to said first and second coils triggers the apparatus into operation.

15. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic field signal for providing first and second output signals, and means for amplifying said first and second output signals; coincidence gate means connected to said detecting means and operable in response to the simultaneous provision of amplified first and second output signals to provide a third output signal; staticizing means connected to said coincidence gate means including a monostable multi-vibrator circuit operable in response to said third output signal to provide an operating signal of duration and magnitude greater than that of said third output signal; and powering means including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby a magnetic energy signal applied to both coils triggers the apparatus into operation.

16. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic field signal for providing first and second output signals; coincidence gate means connected to said first and second coils and operable in response to the simultaneous provision of said first and second output signals to provide a third output signal; staticizing means connected to said coincidence gate means and operable in response to said third output signal to provide an operating signal of duration and magnitude greater than that of said third output signal; and powering means including a source of work energy for operating the apparatus connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby a magnetic field signal applied simultaneously to said first and second coils triggers the apparatus into operation.

17. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic energy signal for providing first and second output signals; staticizing means connected to said detecting means and operable in response to the coincident occurrence of said first and second output signals to provide an operating signal of duration and magnitude greater than that of said output signals; and powering means connected to said staticizing means, including gas generating means adapted to provide a source of work energy for operating the apparatus, and means operable in response to said operating signal for initiating operation of said gas generating means to apply work energy to the apparatus, whereby an applied magnetic field signal triggers the apparatus into operation.

18. In a subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils independently operable in response to an applied magnetic field signal for providing first and second output signals respectively; means for applying a magnetic field signal, including a permanent magnet, adapted to be transported through the well bore for inducing an electrical signal in said inductive coils; staticizing means connected to said detecting means and operable in response to the coincident occurrence of said first and second output signals to provide an operating signal of duration and magnitude greater than that of either of said output signals; and powering means including a source of work energy for operating the apparatus connected to said staticizing means and oper-

able in response to said operating signal for applying work energy to the apparatus, whereby the permanent magnet transported through the well bore triggers the apparatus into operation.

19. Apparatus of claim **18**; wherein said first and second inductive coils are respectively counterwound to provide opposite polarity signals in response to a moving first magnetic pole; said coils being axially spaced by a distance equal to the effective spacing of the magnetic poles of said permanent magnet; said staticizing means include coincidence gate means connected to said first and second inductive coils for producing a third output signal on the simultaneous occurrence of first and second output signals of similar polarity; said staticizing means further include a monostable multi-vibrator circuit and signal amplifying means connected between said staticizing means and said powering means; and wherein said powering means include a gas generating means and means responsive to said operating signal for initiating operation of said gas generating means.

20. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second inductive coils concentric with the well bore and independently operable in response to an applied magnetic field signal for providing first and second output signals respectively; staticizing means connected to said detecting means, including a monostable multi-vibrator circuit, operable in response to the coincident occurrence of said first and second output signals of similar polarity to provide an operating signal of duration and magnitude greater than that of either of said output signals; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby magnetic field signals of opposite polarity applied simultaneously to said first and second coils triggers the apparatus into operation.

21. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for operating the apparatus comprising the combination of detecting means including first and second oppositely wound inductive coils independently operable in response to an applied first polarity magnetic field signal for providing first and second output signals, respectively, and operable in response to an applied second polarity magnetic field signal for providing second and first output signals, respectively; staticizing means connected to said detecting means and operable in response to the coincident occurrence of one of said first and second output signals in both coils to provide an operating signal of duration and magnitude greater than that of either of said output signals; and powering means, including a source of work energy for operating the apparatus, connected to said staticizing means and operable in response to said operating signal for applying work energy to the apparatus, whereby magnetic field signals of opposite polarity, respectively, applied simultaneously to said first and second coils trigger the apparatus into operation.

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