Feb. 8, 1966 K. LEUTWYLER 3,233,674

SUBSURFACE WELL APPARATUS

Filed July 22, 1963 3 Sheets-Sheet 1

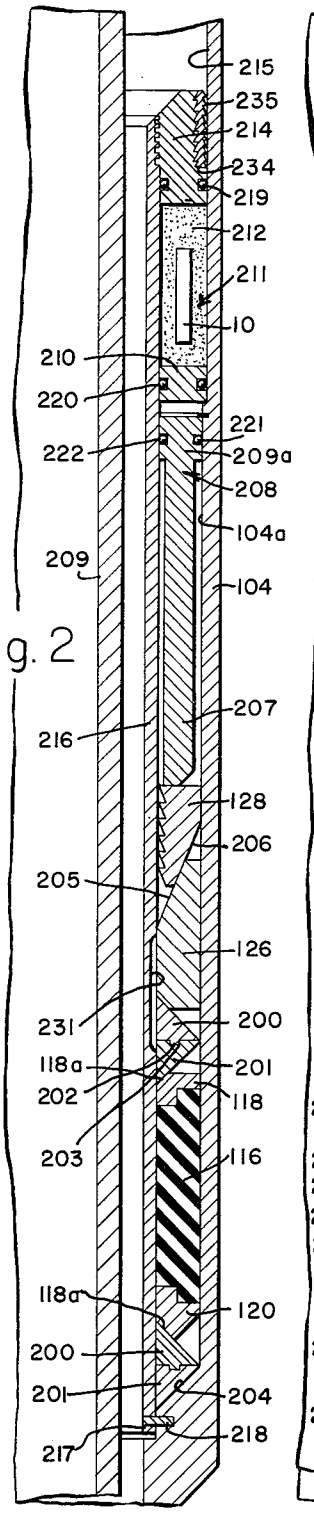

Fig. 2

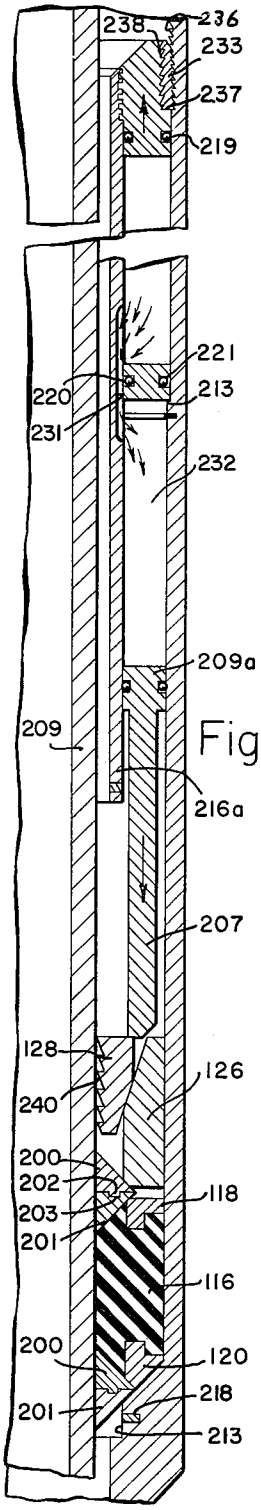

Fig. 3.

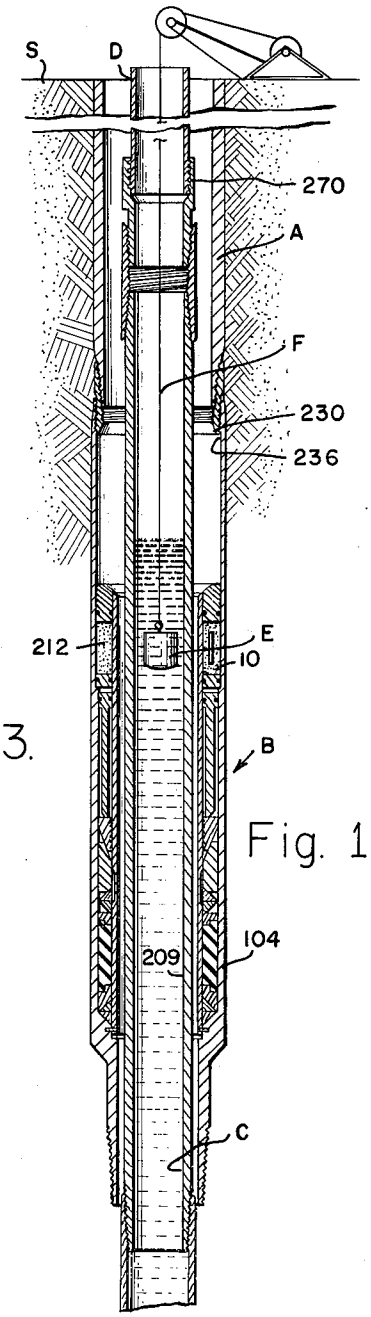

Fig. 1.

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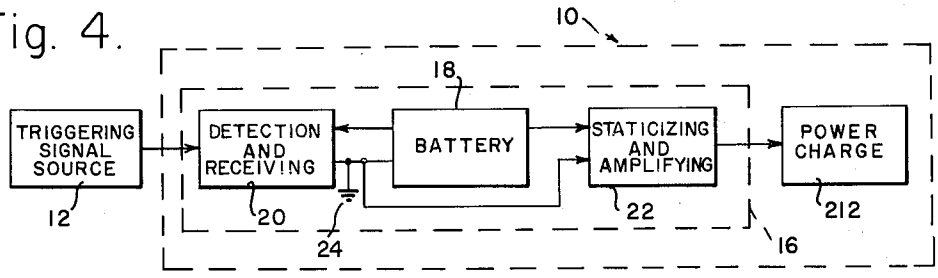
Fig. 4.



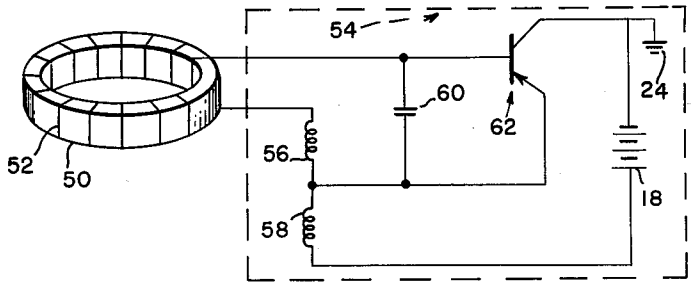


Fig. 6.

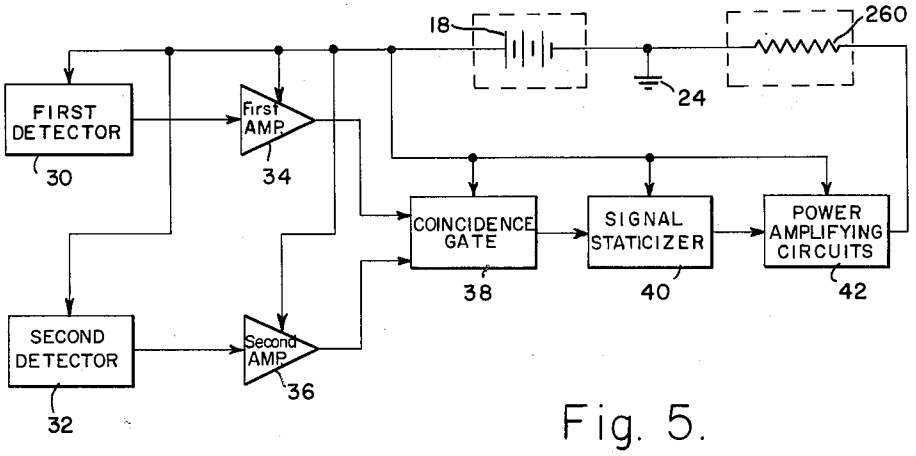


Fig. 5.

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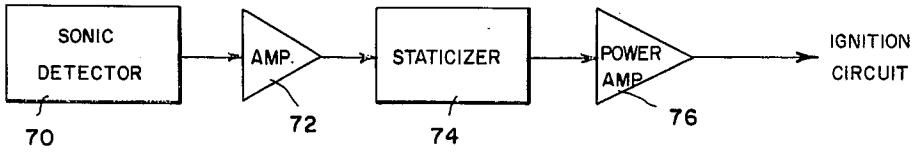
Fig. 7.



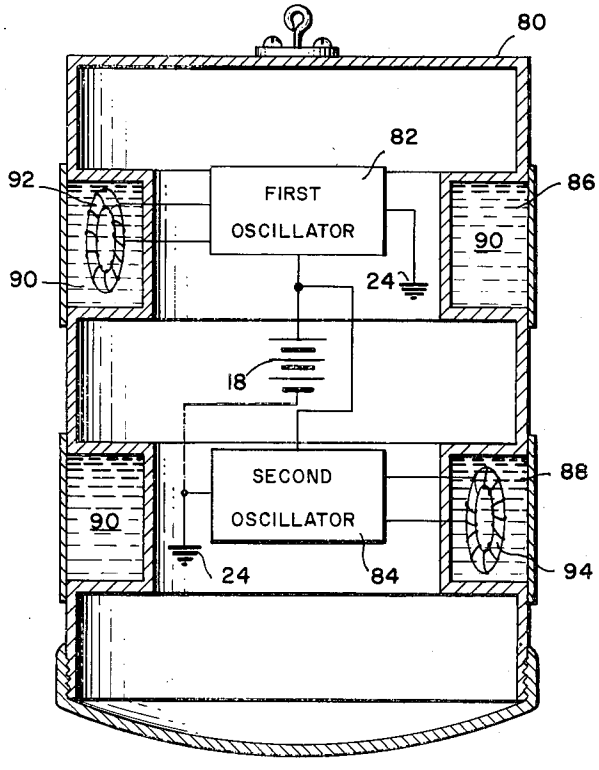


Fig. 8.

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United States Patent Office

3,233,674

Patented Feb. 8, 1966

3,233,674

SUBSURFACE WELL APPARATUS

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Filed July 22, 1963, Ser. No. 296,618
32 Claims. (Cl. 166—63)

The present invention relates to subsurface well apparatus, and more particularly to 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 an acoustical 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 of electro-mechanical releasing circuits. The working power system can be the energy stored in a compressed spring, compressed gas, hydrostatic pressure, or a chemical gas generator such as a pyrotechnic type chemical 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 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, as well as electrical circuits and an electrical power supply. Upon receipt of the proper triggering signal or signal combination, the normally quiescent electrical circuits are energized to provide an ignition current to the power charge, operating the down-hole tool.

The complete electronic ignition system is packaged adjacent to or within the stored power charge, all in the down-hole device. The ignition system includes a detector-transducer which, in response to an externally provided signal, generates a relatively low level electrical impulse. The term "signal" is intended to include all of the various forms of energy that can be transmitted and detected, including the electromagnetic and sonic forms thereof. Since the electronic ignition circuits can be sensitive to an extremely weak signal, suitable signals, properly encoded, can originate from the surface and travel through well fluid or the well casing to the decoder-transducer. Alternatively, the signal source and encoder can be incorporated in a package which can be sent into physical proximity with the tool and power charge.

Through the use of electronic computer-type circuits, the received signal can be transformed into an electrical impulse which then can be staticized and amplified to the duration and magnitude 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, memory circuits including various bi-level elements, such as one-shot multivibrators, and the like, are combined to perform the decoding and triggering tasks. Electronic signalling techniques, such as pulse communication or frequency mixing, can be used

in the transmission of the coded signals. Proximity detectors, such as inductive or capacitive pick-offs, and piezoelectric, magnetostrictive, or other transducers 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 hollow, cylindrical, down-hole tool, such as a liner hanger, is provided with an annular cavity in which is placed an integral package including a stored power charge, an electronic system with detection and ignition circuits and an electrical power supply, such as a battery. Two acoustical signal detectors, each tuned to a different, predetermined sonic frequency, are adapted to decode applied sonic signals and, on the coincidental occurrence of triggering signals at the two predetermined frequencies, an electrical impulse is generated which is applied to a pulse-stretcher of the one-shot multivibrator type. Where necessary, preamplification and post amplification stages assure that receipt of signals at the proper triggering frequencies will reliably energize the bridge wire and ignite the stored power charge.

The triggering signals, for energizing the down-hole circuitry, are produced by a pair of sonic frequency generators which are located either at the surface or, alternatively, can be packaged with suitable power supply in a container that is adapted to be either pumped down the well or lowered on a wire line or cable. Since acoustical waves can be propagated through fluid and through the casing wall itself, both methods are practical.

By selecting signalling frequencies which are not normally present in the well or other adjacent equipment, each of a plurality of different tools could be tuned to a different frequency combination. A tool could then be selectively energized by the provision of triggering signals of the proper frequencies. However, substantially the same power charge and associated electronic system can be used in each of the tools.

In a copending application of the same inventor, Serial No. 296,815, filed July 22, 1963, for "Subsurface Well Apparatus," detecting circuits responding to magnetic radiation and radioactive emanation are disclosed and claimed.

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.

It is another object of the invention to provide an oil well tool containing an integral power amplifying system capable of operating the tool upon receipt of a low energy activating signal.

It is yet another object of the present invention to provide oil well tools with integral power charges and ignition circuits therefor.

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 transmitted trigger signal.

It is a still further object of invention to provide a down-hole well tool which can be remotely energized from the surface.

It is yet another object of invention to provide a down-hole oil well tool which is energized by the transmission of coded triggering signals.

It is another object of invention to provide a down-hole oil well tool that is adapted to operate in response to a coded triggering signal from an active triggering device.

It is a still further object of invention 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.

It is yet a further object of invention 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 charge, and receiving circuits responsive to a low level sonic signal, 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 combination of low level, sonic signals.

It is still another object of the present invention to provide, in a down-hole oil well tool, an integral powering package including a stored power charge, normally quiescent electronic circuitry, a stored electrical power source, and receiving equipment responsive to a predetermined combination of coded signals from a remote transmitter for energizing the electrical circuitry and actuating the tool.

It is a still further object of invention to provide apparatus for generating and transmitting a coded combination of signals for energizing normally quiescent circuits stored in a down-hole oil well tool for igniting a stored power charge to operate the tool.

It is an additional object to provide an improved liner hanger apparatus having an integral energy source or power charge and ignition package.

It is yet another object to provide an improved liner hanger apparatus adapted to surround and to be engaged with a liner.

It is still an additional object to provide an improved liner hanger apparatus that has a self-energizing feature.

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 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 device;

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

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

FIG. 6 is an idealized schematic drawing of a sonic signal generator adapted for use in the present invention;

FIG. 7 is a block diagram of a sonic signal detector circuit adapted for use in the present invention;

FIG. 8 is an idealized diagram, partly in section, of an alternative sonic generator adapted for movement down through the well bore.

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 embodies its own source of energy for effecting its setting against the liner, initiation of the actuating mechanism being effected by transmitting a suitable signal to a portion of the liner hanging apparatus B, either from the top of the well bore, or by lowering a suitable signal generating device E down through the tubular string from the top of the well bore on a suitable wire line F, or other running-in string.

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. 276,434, filed April 29, 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 carcular 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 a pair of rings.

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** adapated 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 betwen 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 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 dis-

posed across the lower chamber head **210** (FIG. 3), allowing the gases to pass from the chamber **211** through the by-pass groove **213** 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 engaging 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 upward 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 maintain 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 ten to thirty seconds after ignition. Such relatively slow burning of the propellent 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**.

As shown in FIG. 4, the tool operating power charge **212** and electronic ignition package mounted in the chamber is represented as a single block **10**. A transmitting triggering signal source **12** adapted to energize the circiut of the ignition package is represented by a separate block. It will be understood that the signalling device is selected for cooperation with the signal detection apparatus chosen for incorporation in the subsurface well apparatus B.

Assuming that the triggering signal source **12** provides a unique and recognizable physical phenomenon to which the downhole liner hanger or other tool can respond, the integral power charge and electronic ignition package **10** can be roughly divided into two elements; a first, power charge element **212** and a second, electrical element **16**. The power charge element **212** may be the gas generating propellant or fuse previously referred to, 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 detonating means, such as the resistance bridge wire **260** embedded in the previously referred to match compound, or in an exploding cartridge, adapted to be fired upon attachment to an electric current through the wire.

A storage battery **18** provides the electrical energy necessary to ignite or fire the stored power charge or propellant **212**. The storage battery also powers the electric 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 energy signal.

The electrical element **16**, in addition to the battery **18**, includes a detection and receiving circuit **20** and staticizing and amplifying ignition circuit **22**. For completeness, a source of common reference potential is indicated by the conventional ground symbol **24**.

In operation, the predetermined signal combination is detected at the detector and receiver circuit **20**, which includes an energy transducer that generates an electrical signal impulse at a low power level, which is then applied to the staticizing and amplifying circuit **22**. These circuits hold and amplify the signal impulse and, through suitable circuitry, provide an electrical current of electrical energy sufficient to detonate and ignite the power charge **212**, which then generates the requisite power for actuating the subsurface well tool.

In FIG. 5, a generalized block diagram of an electrical system **10** is illustrated, corresponding to the electrical element **16** of FIG. 4. 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 the circuits. A first detector **30** and a second detector **32**, both powered by the battery **18**, are provided to detect and decode the impinging signals. 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 contemporaneously before the down-hole apparatus is actuated. The output of the first detector **30** is applied to a first amplifier **34**. 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 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 form of memory circuit, such as a conventional "one-shot" or monostable multi-vibrator circuit, a "flip-flop" or bistable multivibrator circuit, or any of several other two-level devices, all well known in electronic computer technology.

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 in which it remains for an adjustable limited period of time, producing a second high level signal, 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, provides electrical power to actually 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, which is adequate to operate a subsurface well tool, such as the liner hanger B described hereinabove.

As disclosed in FIG. 6, a sonic signal generator exemplifies a typical signal generating device suitable for use in the present invention. As illustrated, a toroidal core 50 of magnetostrictive material is wound with a plurality of turns of relatively fine wire 52, the ends of which are connected to an oscillator circuit 54 which includes inductive elements 56, 58, a capacitor 60, an active electronic element illustrated herein as a transistor 62, and a source of electrical power 18.

The values of the inductive and capacitative elements 56, 58, 60 are chosen so that when the source of electrical power is connected, the circuit oscillates at a frequency in the sonic range, approximately 10 kc./s. The magnetostrictive core 50 then vibrates at that frequency, due to the expansion and contraction of the core under the influence of an alternating magnetic field induced in the core.

A sonic frequency is chosen which does not normally occur in the equipment generally found in the vicinity of the apparatus, such as the liner hanger B, to be operated remotely. Moreover, the signal generator can be located at the top S of the well bore with a transmitting transducer such as the magnetostrictive core 50 acoustically coupled to either the well casing A or the fluid disposed in the well bore. The sonic energy is then transmitted from the surface to the detecting circuits which are integral with the remotely located tool, such as being disposed in the chamber 211 containing the power charge 212.

In a preferred embodiment, a pair of signal generators, each tuned to a different frequency, is employed together as an actuating signalling device. It is then necessary to recognize the coincidental occurrence of both frequencies before the tool is actuated. As is readily understood, a second circuit, substantially identical to that shown in FIG. 6, could generate the second sonic frequency with different values ascribed to the inductive and capacitative components of the circuits.

In another form disclosed in FIG. 7, there is shown a block diagram of a typical arrangement for detecting the acoustical energy triggering signal produced by the signal generator of FIG. 6 and which is adapted to be disposed in the chamber 211. Although the various elements are shown in blocks, the mechanizations are well known in the electronic arts and therefore will not be described in terms of particular circuit elements. A sonic detector 70, which may be a piezoelectric transducer typically found in sonic detection and ranging systems (sonar), can be used to transform the impinging sonic energy into an electrical output signal. Depending upon the signal strength of the applied sonic signal, an amplifier stage 72 may be employed to increase the amplitude of the electrical signal generated upon receipt of the sonic signal.

The output of the detector 70 and amplifier 72 is applied to a memory circuit or signal staticizer 74, the output signal of which is applied to a power amplifying circuit 76, which may be a power transistor that is serially connected to the source of potential through the ignition circuit, in this case the resistance wire 260 to be energized for the purpose of igniting the power charge or propellant 212.

In operation, the received sonic energy is transformed into electrical energy by the piezoelectric transducer in the sonic detector 70, and this electrical signal is amplified by the amplifier 72. The amplified output signal is sufficient to trigger the staticizer 74 into its high level state and the operating signal output is applied to the power amplifier 76. The power transistor of the power amplifier 76 is "turned on" into full conduction and draws a substantial current through the ignition circuit. The bridge wire 260 of the ignition circuit responds to the passage of a predetermined current to be heated and ignite the power charge or propellant 212 which is the source of operating power for the down-hole tool B, as described hereinabove.

The triggering signal described above can be transmitted from the top of the well bore downwardly to the sonic detector 70 forming part of the apparatus disposed in the well casing, or other down-hole tool. As illustrated in FIG. 8, an alternative sonic signal generator E is packaged in a container 80 adapted to be lowered into the well bore itself. In deep wells, it may be desirable to place the signal generator immediately adjacent to the detectors in a down-hole apparatus. The protective container 80 can be lowered on the cable F through the tubular string D, and protects the circuits housed therein.

As shown in FIG. 8, an electrical power source, indicated by the battery symbol 18, provides electrical energy to the signal generating circuits. A first tunable oscillator 82 and a second tunable oscillator 84 are connected to the electrical power source 18, and to complete the circuitry, are also connected to the source of common reference potential, represented by the ground symbol 24. A pair of resonating cavities 86, 88 filled with fluid 90 are provided to transmit the acoustical energy to the fluid normally present in the well.

A pair of sonic transducers 92, 94, each of which converts electrical energy into acoustical energy, such as those shown in FIG. 6, comprises a magnetostrictive core with appropriate turns of wire, the ends of which are respectively connected to the oscillator circuits 82, 84. It will be understood that the two sonic transducers 92, 94 are substantially identical and each generates a frequency determined by the frequency of the oscillator by which it is driven.

In operation, all necessary electrical connections are completed and the oscillators 82, 84 tuned to the desired driving frequencies. The triggering apparatus (FIG. 5) disposed in the power charge chamber 211 has previously been tuned to correspond to the combination of both these desired frequencies. Each sonic transducer 92, 94 then generates a signal at the frequency of the oscillator driving it within the resonating cavities 86, 88.

As the container **80** is lowered into the well bore, the acoustical waves generated therein are propagated through the well fluid.

When the triggering signal received by the detectors in the down-hole tool achieves a preset threshold, the circuits in the down-hole tool will respond and the tool operated by completing the circuit through the igniter **260**. If the triggering signals being generated by the sonic transducers are at an extremely low energy level, the tool will not operate until the container **80** is immediately adjacent to the down-hole tool signal detecting circuits in the chamber **211**. On the other hand, a sufficiently powerful sonic generator can activate the down-hole tool from the surface S of the well bore.

In the operation of the apparatus illustrated in the drawings, the liner hanger apparatus 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 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 portion or hanging member **216** overlapping the casing and disposed within the liner hanging apparatus B. A triggering signal can then be transmitted from the top S of the well bore down to the detecting device **10** embodied in the power charge chamber **211** to complete the circuit to the ignition resistance **260** and effect actuation of the apparatus B, or the triggering sonic signal generator E can be lowered through the tubing D on the wire line F, or the like, until it is sufficiently close to the tuned detectors in the liner handing apparatus as to trigger the latter and effect ignition of the power charge or propellant **212**.

With such ignition, the gas under pressure is generated for the purpose of elevating and removing the protector sleeve **216** and shifting the slip sleeve **128** and packing structure **116**, **200**, **201** inwardly into firm engagement with the periphery of the liner hanging member **209**. When the signal generator E has been lowered down through the tubular string for triggering the apparatus, it can be elevated and removed from the tubing D through the medium of the wire line F. The tubing string D can then be rotated, as to the right, to effect its disconnection from the liner hanging member **209**. Such disconnection is facilitated by providing a lefthand threaded connection **270** between the lower end of the tubular string and the member **209**, in a known manner.

I claim:

1. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate energizing signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied energizing signals for generating 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 energizing signal produced by said transmitting means remotely triggers the apparatus into operation.

2. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the appartus comprising transmitting means adapted to generate energizing signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied energizing signals for generating an output signal; staticizing means connected to said detecting means, including amplifying means and 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 enrgy to the apparatus, whereby an energizing signal produced by said transmitting means remotely triggers the apparatus into operation.

3. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate energizing signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied energizing signals for generating 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 for operating the apparatus, and means operable in response to said operating signal for activating said gas generating means to apply work energy to the apparatus, whereby an energizing signal produced by said transmitting means remotely triggers the apparatus into operation.

4. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate acoustical signals in the sonic range capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied acoustical signals for generating 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 acoustical signal generated by said transmitting means triggers the apparatus into operation.

5. The combination with subsurface well apparatus adapted to be lowered into a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate acoustical signals in the sonic range capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied sonic range acoustical signals for generating 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 sonic acoustical signal generated by said transmitting means triggers the apparatus into operation.

6. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to be lowered in a well bore for generating acoustical signals in the sonic range capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied sonic range acoustical signals for generating an output signal;

staticizing means connected to said detecting means and operable in response to said output signals 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 for operating the apparatus, and means responsive to said operating signal for activating said gas generating means to apply work energy to the apparatus, whereby an applied sonic range acoustical signal triggers the apparatus into operation.

7. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to be lowered in a well bore for generating acoustical signals in the sonic range capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, adapted to receive and be responsive to applied sonic range acoustical signals for generating an output signal; signal amplifying means connected to said detecting means for amplifying said output signal; staticizing means connected to said signal amplifying means and including a monostable multi-vibrator circuit operable in response to said amplified output signal to provide an operating signal of duration and magnitude greater than that of said amplified output signal; and powering means connected to said staticizing means, including gas generating means for applying work energy to the apparatus and means responsive to said operating signal for igniting said gas generating means, whereby a sonic range acoustical signal generated by said transmitting means triggers the apparatus into operation.

8. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate first and second acoustical signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, including first and second sonic transducing means, adapted to be responsive to applied first and second acoustical signals, respectively, for generating 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 the concurrent application of first and second acoustical signals triggers the apparatus into operation.

9. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate first and second acoustical signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, including first and second sonic transducing means, adapted to be responsive to applied first and second acoustical signals, respectively, for generating first and second output signals, respectively, and coincidence gate means responsive to concurrent first and second output signals to produce a third output signal; staticizing means connected to said detecting means and operable in response to said third 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 the concurrent application of both first and second acoustical signals triggers the apparatus into operation.

10. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate first and second acoustical signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, including first and second sonic transducing means, adapted to be responsive to applied first and second acoustical signals, respectively, for generating 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 the concurrent application of first and second acoustical signals by said transmitting means triggers the apparatus into operation.

11. The combination with subsurface well apparatus adapted to be lowered in a well bore of means for remotely operating the apparatus comprising transmitting means adapted to generate first and second acoustical signals capable of being propagated through a well structure; detecting means, incorporated in the structure of the apparatus, including first and second sonic transducing means, adapted to be responsive to applied first and second acoustical signals, respectively, for generating first and second output signals, and further including coincidence gate means connected to said first and second sonic transducing means for producing a third output signal on the simultaneous occurrence of said first and second output signals; staticizing means including a monostable multi-vibrator circuit connected to said detecting 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 connected to said staticizing means and including gas generating means for operating the apparatus and means responsive to said operating signal for igniting said gas generating means to apply work energy to the apparatus, whereby the concurrent application of first and second acoustical signals by said transmitting means triggers the apparatus into operation.

12. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for remotely operating the apparatus comprising sonic signal detecting means, incorporated in the structure of the apparatus, adapted to be responsive to an applied acoustical signal of predetermined frequency for generating 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 acoustical signal of predetermined frequency triggers the apparatus into operation.

13. Apparatus of claim 12; 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 igniting said gas generating means.

14. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for remotely operating the apparatus comprising sonic signal detecting means, incorporated in the structure of the apparatus, adapted to be responsive to an applied acoustical signal of predetermined frequency for generating 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 acoustical energy signal of predetermined frequency triggers the apparatus into operation.

15. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for remotely operating the apparatus comprising sonic signal detecting means, incorporated in the structure of the apparatus, adapted to be responsive to applied first and second acoustical signals of predetermined frequencies for generating 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 acoustical signal combination of first and second predetermined frequencies triggers the apparatus into operation.

16. Apparatus of claim 12; wherein said detecting means include coincidence means connected to said first and second sonic transducing means for producing said output signal on the simultaneous occurrence of both first and second acoustical signals, and signal amplifying means connected between said first and second sonic transducing means and said coincidence gate means; said staticizing means 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 gas generating means and means responsive to said operating signals for igniting said gas generating means.

17. In subsurface well apparatus adapted to be lowered in a well bore, means incorporated in the apparatus for remotely operating the apparatus comprising sonic signal detecting means, incorporated in the structure of the apparatus, adapted to be responsive to applied acoustical signals for generating first and second output signals, in response to applied signals of first and second predetermined frequencies, respectively; staticizing means connected to said detecting means, including a monostable multi-vibrator circuit, operable in response to the simultaneous provision of said first and second output signals to produce an operating signal of duration and magnitude greater than that 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 applied acoustical energy signals of first and second predetermined frequencies trigger the apparatus into operation.

18. In remotely operable apparatus for operatively associating a liner with a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; laterally movable means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to applied energizing signals for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, said powering means further including means for shifting said laterally movable means into operative engagement with the liner member when the liner member is disposed in the casing string.

19. In remotely operable apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; laterally movable gripping means in said tubular member; movable protective means disposed across said gripping means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to applied energizing signals for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, said powering means further including means for shifting said protective means to expose said gripping means, and means for shifting said gripping means into operative engagement with a liner member to be hung therefrom.

20. In apparatus for sealing against a liner located in a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; packing means in said tubular member; movable protective means disposed across said packing means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to applied energizing signals for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, said powering means further including means for shifting said protective means to expose said packing means, and means for shifting said packing means into sealing engagement with a liner member to be located in the casing string.

21. In apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; packing means in said tubular member; laterally movable gripping means in said tubular member; movable protective means disposed across said packing means and said gripping means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to applied energizing signals for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, said powering means further including means for shifting said protective means to expose said gripping means, and means for shifting said packing means and said gripping means into operative engagement with a liner member to be hung therefrom.

22. In apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string and further adapted to receive a liner member to be hung; packing means in said tubular member; laterally movable gripping means in said tubular member; movable protective means disposed across said packing means and said gripping means in said tubular member; detecting means incorporated in said tubular member

adapted to be responsive to applied energizing signals for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, said powering means further including means for shifting said protective means to expose said gripping means, and means for shifting said gripping means laterally inwardly into operative engagement with the liner member to be hung therefrom.

23. In apparatus for hanging a liner member from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string, a pliant, elastic packing element in said tubular member; an expander in said tubular member above said packing element; slip means in said tubular member above and engaging said expander; setting means in said tubular member above and cooperating with said slip means to move said slip means downwardly along said expander and said expander downwardly along said tubular member to shift said slip means and packing element inwardly into engagement with the liner member; said setting means including piston means, powering means for applying fluid pressure to said piston means for moving said piston means, and signal responsive energizing means adapted to activate said powering means in response to an applied triggering signal.

24. In apparatus for sealing against a liner located in a casing string disposed in a well bore; a tubular member adapted to be disposed in the well bore to constitute part of the casing string; packing means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to an applied triggering signal of predetermined frequency for generating an output signal; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to operating signals for energizing said powering means, and means for shifting said packing means into sealing engagement with the liner.

25. In apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; packing means in said tubular member; laterally movable gripping means in said tubular member; detecting means incorporated in said tubular member adapted to be responsive to applied energizing signals of first and second predetermined frequencies for generating an output signal on the simultaneous occurrence of said first and second frequency signals; staticizing means incorporated in said tubular member and 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 incorporated in said tubular member including means connected to said staticizing means and responsive to said operating signal for energizing said powering means, and means for shifting said packing means and said gripping means into operative engagement with a liner member to be hung therefrom.

26. In apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner hanging member adapted to be lowered in the casing string to a position within said tubular member; slip means in said tubular member; an expander removable in said tubular member and engaging said slip means; packing means in said tubular member engaging said expander; piston means in and carried by said tubular member operable in response to applied fluid pressure for moving said slip means downwardly of said expander and said expander downwardly against said packing means to shift said slip means and packing means inwardly into engagement with said liner hanging member; sonic signal detecting means in said tubular member adapted to be responsive to an applied acoustical signal of predetermined frequency for generating 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 for operating said piston means connected to said staticizing means and operable in response to said operating signal for applying fluid pressure to said piston means.

27. In apparatus for hanging a liner from a casing string disposed in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner hanging member adapted to be lowered in the casing string to a position within said tubular member; slip means in said tubular member; an expander movable in said tubular member and engaging said slip means; packing means in said tubular member engaging said expander; and cylinder and piston means in and carried by said tubular member and operable in response to applied fluid pressure for moving said slip means downwardly of said expander and said expander downwardly against said packing means to shift said slip means and packing means inwardly into engagement with said liner hanging member.

28. In apparatus for cooperation with a liner adapted to be disposed within a casing string located in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner member adapted to be lowered in the casing string to a position within said tubular member; laterally movable means in said tubular member; cylinder and piston means in and carried by said tubular member operable in response to applied fluid pressure for moving said laterally movable means inwardly against said liner member; and means in said tubular member providing a source of fluid pressure differential for application to said piston means.

29. In apparatus for cooperating with a liner adapted to be disposed within a casing string located in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner member adapted to be lowered in the casing string to a position within said tubular member; laterally movable means in said tubular member; cylinder means in and carried by said tubular member; piston means in said cylinder means and operatively connected to said laterally movable means; a source of energy in said tubular member; and means for releasing said energy source for action on said piston means to move said piston means in said cylinder means and shift said laterally movable means inwardly into engagement with said liner member.

30. In apparatus for cooperation with a liner adapted to be disposed within a casing string located in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner member adapted to be lowered in the casing string to a position within said tubular member; laterally movable means in said tubular member; cylinder means in and carried by said tubular member; piston means in said cylinder means and operatively connected to said laterally movable means; means providing a source of gas under pressure in said tubular member; and means for initiating generation of said gas and for conducting said gas to said cylinder means for operation on said piston means, whereby said piston means shifts said laterally movable means inwardly into engagement with said liner member.

31. In apparatus for cooperation with a liner adapted to be disposed within a casing string located in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner member adapted to be lowered in the casing string to a position within said tubular member; laterally movable means in said tubular member; cylinder means in and carried by said tubular member; piston means in said cylinder means and operatively connected to said laterally movable means; a power charge in said tubular member; means for igniting said power charge to effect generation of a gas under pressure; and means for conducting said gas under pressure to said cylinder means for action upon said piston means to shift said laterally movable means inwardly into engagement with said liner member.

32. In apparatus for cooperation with a liner adapted to be disposed within a casing string located in a well bore: a tubular member adapted to be disposed in the well bore to constitute part of the casing string; a liner member adapted to be lowered in the casing string to a position within said tubular member; laterally movable means in said tubular member; cylinder means in and carried by said tubular member; piston means in said

cylinder means operatively associated with said laterally movable means; a power charge in said cylinder means; and means for initiating combustion of said power charge to generate gas under pressure for action on said piston means to cause said piston means to shift said laterally movable means inwardly into engagement with said liner member.

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