April 30, 1957 N. A. MacLEOD 2,790,388

MEANS AND METHOD FOR STIMULATING THE FLOW OF WELL FLUIDS AND FOR DECLOGGING WELL BORE WALLS AND WELL CASING PERFORATIONS

Filed April 21, 1949 2 Sheets-Sheet 1

FIG. 1.

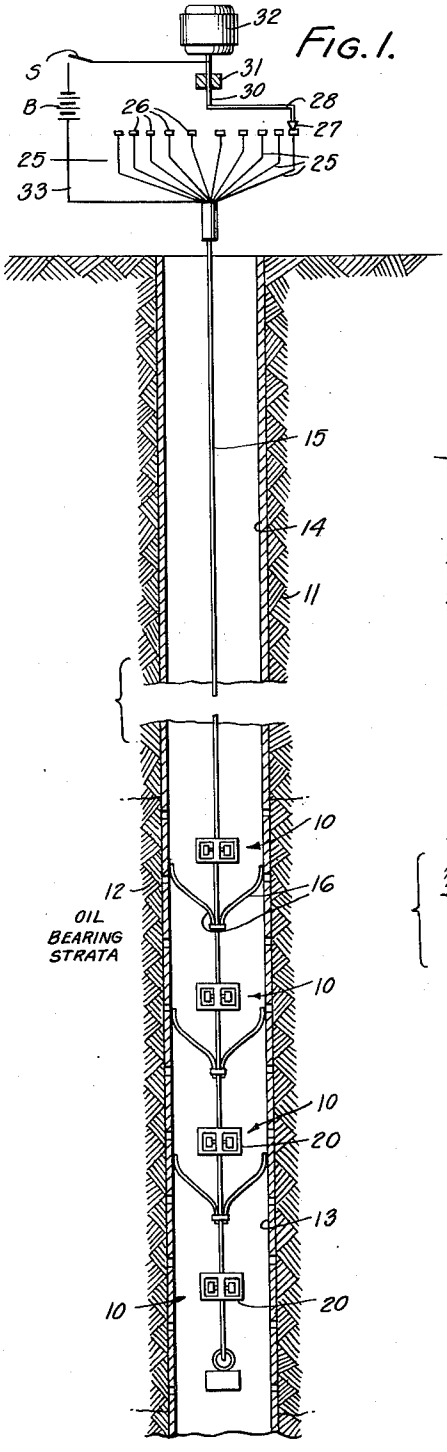


FIG. 2.

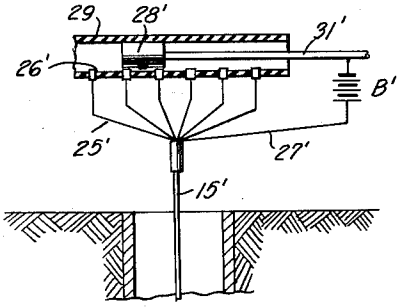


FIG. 3.

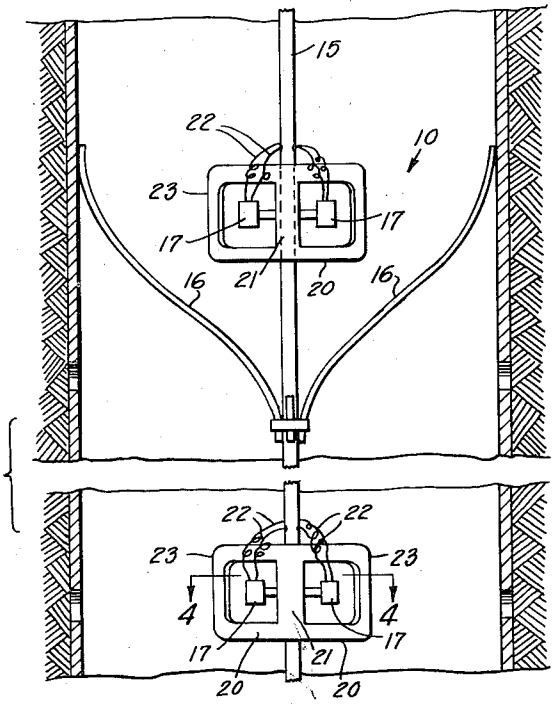
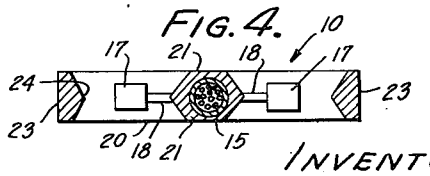


FIG. 4.



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FIG. 5.

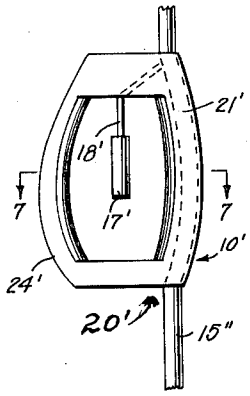


FIG. 6.

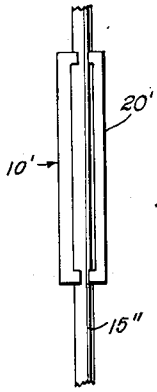
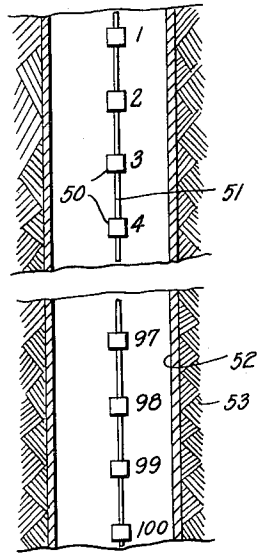


FIG. 11.



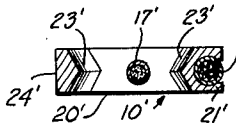


FIG. 7.

FIG. 8.

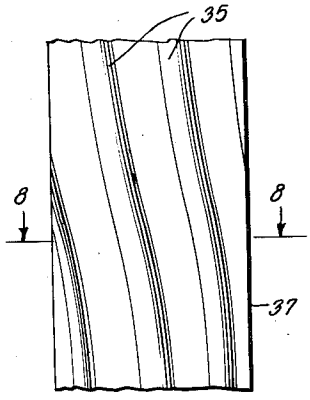


FIG. 9.

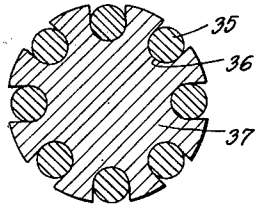
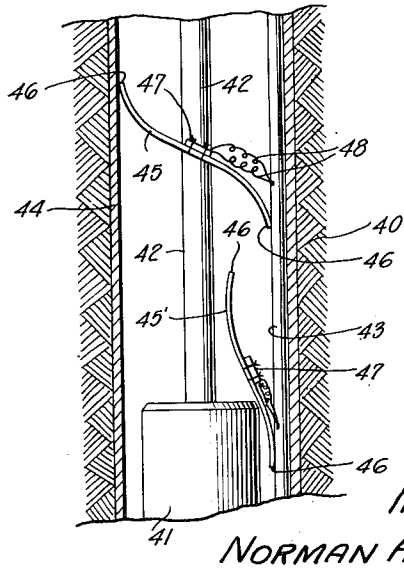


FIG. 10.



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MEANS AND METHOD FOR STIMULATING THE FLOW OF WELL FLUIDS AND FOR DECLOGGING WELL BORE WALLS AND WELL CASING PERFORATIONS

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Application April 21, 1949, Serial No. 88,818

7 Claims. (Cl. 102—21.6)

This invention relates to a means and method for stimulating the flow of well fluids and for declogging well bore walls and well casing perforations, and involves mainly the production of a series of vibrations or pulsations in or about the well or well strata, the periodicity of the pulsations being controllable both as to quality and quantity over any desired period of time, great or small, ranging from microseconds or milliseconds to seconds, minutes, or more, and the totality of the pulsations being as great as desired.

This invention involves the production of a series of shock waves to thereby produce regular or irregular and continuous vibrations in the desired location, such vibrations to be produced by a series of explosions or by other suitable means for producing periodic vibrations.

It is well known that the casing perforations commonly used throughout the bearing strata in oil, gas, and other wells, tend to become clogged with clay, sand, shale, paraffin, cement, corrosive incrustations, and the like, greatly reducing and sometimes entirely shutting off production from the well. Paraffin or asphaltum often accumulates inside and outside the casing, as well as in the perforations, all tending to stop the inflow of well fluid. And as time goes on, the productive formation immediately outside the perforated casing accumulates paraffin, asphaltum and the like, becomes tightly packed, hard, and of little or no porosity, thus forming an impermeable barrier about the casing. In fields in which the productive formation is not of a crumbling nature, the well hole is often uncased in the productive strata. While in such wells there are no casing perforations to become clogged, the walls of the hole accumulate paraffin, asphaltum, and the like, which fill and choke the pores of the formation, and greatly reduce production.

When production from the well decreased materially due to such conditions, washing and cleaning operations must be undertaken. However, known methods for washing and cleaning the perforations by outward flow of fluid are not always fully effective, and even though they may sometimes succeed in breaking the clogged casing perforations, they are not always effective to open or clean the tightly packed or clogged surrounding formation. Moreover, the perforated section of the casing may be from a hundred feet to fifteen hundred or more feet in length, and the job of washing and cleaning by the conventional methods in common use at the present time is a heavy and time consuming operation.

According to one common present practice of perforation cleaning, successive zones of the perforated section of the casing are packed off, and water is forced out through the perforations between the packers, the full length of the perforated section of the casing being cleaned a relatively few feet at a time. This practice has several serious disadvantages and shortcomings, some of which may be enumerated; first, numerous successive operations are required to cover the length of the perforated casing; second, the wash water tends to escape

through perforations that are already open, and often does not "break" tightly clogged perforations; third, the wash water does not open up the clogged formation outside the casing; and fourth, the wash water is incapable of removing any substantial proportion of the accumulated paraffin or asphaltum, which is insoluble in the wash water. Hot water or steam, hot oil, and sometimes acids, are used in an effort to dissolve and carry off the paraffin and asphaltum deposits in both cased and uncased wells, but usually with little or incomplete success.

In the past explosives have been used for the same general purposes, but whether there are a number of individually spaced explosive charges, as in Patent No. 2,362,829, or an explosive cord extending throughout the desired location, as in Patent 2,414,349; there is a substantially simultaneous single explosion produced, with but a single compressive wave followed by a single rarefication wave. This though, is like one, attempting to clean a small clogged tube, would hit it with a single blow of a hammer. With this invention, a series of explosions are caused, micro- or milli-seconds apart, as desired, causing a series of alternate compression and rarefication waves or pulsations. This is like using a pneumatic hammer to clean the small clogged tube, wherein the periodicity of the hammer is controllable, as desired, thus setting up a series of vibrations and causing a thorough shaking or jigging effect, and providing a complete declogging action.

A further object of this invention is to cause periodic or intermittent explosions to produce a series of shock waves and thereby provide continuous vibrations over a period in the ground or in any structure.

A further object of this invention is to provide the use of controlled explosions at different controllable time intervals to produce pulsations, such control involving the spacing of the explosions; the amount of explosive at each spaced location; the type of explosives; and the timing of the explosions to thereby produce any desired quality and quantity of shock wave series over any desired period of time.

A further object of this invention is to provide a controllable series of shocks to produce jarring effects on materials other than earth structures, such as for instance, in loosening a drilling tool which is jammed in the well hole, or in freeing a well casing which is "frozen" in the bore when the casing is being salvaged.

A further object of this invention is to use a controllably timed series of explosions in the well or on the ground adjacent to a well or wells to stimulate the flow in one well, or in the one well and in adjacent wells.

A further object of this invention is to provide a means and method of setting a controllably timed series of explosions in a well, wherein each individual explosive charge, or group of explosive charges, may be set off individually without simultaneous setting off of the other explosive charges already present in the well, and without disrupting the control means to such other explosive charges.

A further object of this invention is to provide a method and means of centralizing the explosive charges with the well and of spacing and centralizing such charges below a pump or other obstruction already deep within the well without the expense or necessity of first removing the pump or obstruction from the well.

Further, this invention is concerned particularly with methods of and means for stimulating flow of liquids from wells producing water, brine, oil, or sulphur (by the Frasch process), but generally the invention can be used in any application where a series of high energy pressure pulses can be usefully applied to produce vibration, or to cause a series of pressure waves and a series of interactions from these pressure waves to affect the

character of the medium in and through which they may be traveling.

In the particular case of oil wells, pores of the strata not only adjacent to but also for a considerable radius around the perforated well casing become clogged due to the flow of liquid carrying small solid particles. After initial flow, therefore, a tendency to lower delivery rate occurs due to this effect of interstices in the strata being clogged by such solids. In particular in heavy oil wells, due to high viscosities of the fluids, a considerable movement of fine solid particles may occur in the direction of low and settle in the interstices of grains and even against and in the well casing.

The effecting of diminishing flow in use is also produced by clogging of the perforations by solid accretions at the perforation by physical and chemical action.

In the methods cited in Patents 2,414,349 and 2,362,829, it is indicated that substantial simultaneity of effect is produced. In Patent 2,414,349, effectually one pulse of pressure is produced, the front of which bears a slight angle to the axis of the casing in which the primacord is contained, which is inclined upward or downward from the axis accordingly, as the primacord is detonated from the bottom or top of the length used. In the method disclosed in Patent 2,362,829, the simultaneous detonation of multiple charges causes severe local pressure build-up by a Dautrische effect when two shock waves from adjacent charges in the liquid collide. In both Patents 2,414,349 and 2,362,829—the substantial simultaneity of detonation of the explosive used does two adverse things: (*a*) The total explosive energy is delivered to the pipe in a very short time, hence there is a limit in the amount of explosive which can be used in such a pipe if the pipe is not to be ruptured or severely damaged. Even with primacord containing only 30 grains P. E. T. N. per foot, the explosive is set off at the rate of almost 90 lbs. per second, which can be, in the case of some casings in water wells, too high an energy delivery rate. (*b*) A substantially single pressure pulse is transmitted through the adjoining strata or rock formation.

The use of a single pressure pulse is not so effective as a multiple effect in which succeeding pressure waves travel through previously disturbed material which may not have come to rest, thereby causing a jigging action to greatly increase the de-clogging and flow-stimulating effect.

Other additional objects will more fully appear from the following description, and that the invention may be more fully understood, reference is had to the accompanying drawings forming a part of the present description and illustrating preferred embodiments of the invention, in which:

Fig. 1 is a schematic view of one form of the invention in position in an oil well;

Fig. 2 is a sectional view showing a different form of contact control;

Fig. 3 is an enlarged detail of the explosive supports, and cable protectors;

Fig. 4 is a section on line 4—4 of Fig. 3;

Fig. 5 is a modified form of explosive support and cable protector;

Fig. 6 is a side view of Fig. 5;

Fig. 7 is a sectional view on line 7—7 of Fig. 5;

Fig. 8 is a sectional view on line 8—8 of Fig. 9;

Fig. 9 is a fragmentary elevational view of another form of explosive support;

Fig. 10 is a schematic view of another form of explosive support; and

Fig. 11 is a schematic view of an arrangement of the explosives.

This invention involves the detonation of a multiplicity of explosive charges **10** distributed along the well **11** within the oil bearing strata **12** wherein is located the strainer portion **13** of the well casing **14**. The charges **10** are suspended in the well **11** by means of multiple conductor cable **15** having a plurality of spacing spring fingers **16**, at least two or more, interposed between each of the charges **10** to space the cable, and thus the charges, from the sides of the well and retain it along the axis of the well.

As shown in Figs. 3 and 4, the explosive charge **10** includes a pair of explosive elements **17**, each supported on an arm **18** extending from the middle arm **21** of a steel guard **20**. This middle arm **21** is hollow, the cable **15** extending therethrough and thus supporting it, and is hexagonal in cross-section, and of greater thickness than that of the explosive element **17**, so that when one of the explosive elements **17** is detonated by the electric charge from the leads **22** extending from cable **15**, the explosive force is directed away from the cable **15**, as well as the other explosive elements **17** within the other side of the same steel guard **20**. This steel guard **20**, it will be noted, is shaped like a figure **8** lying on its side, and the outer arms **23** thereof likewise have an angular face **24** on the side toward the explosive element **17** to help divert the explosive force therefrom. While the leads **22** are diagrammatically shown as extending directly from the cable **15**, it is obvious that such leads can extend through the supporting arms **18**, so long as they are properly armored to prevent the shock wave from the explosion from disrupting the cable **15** within the guard arm **21**.

This invention also involves means for detonating the explosive elements **17** at definite time intervals and patterns of events, as, for instance, successively within the elements along the well axis, alternately, every third detonator, or any combination and permutation of a large number so possible. Both elements **17** of the same charge **10** might be detonated simultaneously, or one element **17** might be part of one group, and the other part of another or alternate group. The various patterns are made possible by the provision of the multicable **15**, each sub-cable therein having a lead **25** going to an individual contact **26** which cooperates with switch arm contact **27** on an arm **28** rotatable by a motor shaft **30** in a bearing **31** on a motor **32**, which is controllably operated at a desired speed from any suitable source of power. The contacts **26** are arranged in an arc of a circle; suitably spaced from each other and with relation to the speed of rotation of the arm contact **27** over the individual contacts **26** so that the circuits will be completed to the individual contacts **26** at the desired number of milliseconds. Then, when the switch S is operated to complete the circuit from the battery B through the return wire **33**, a spark is created between the ends of the leads **22** in each of the various individual explosives **17** to detonate them in the desired pattern and the desired sequence, to thus set off a series of explosions properly timed from each other to provide a desired sequence of shock waves causing a pulsation of compression and rarefication waves throughout the desired areas of the well and of the surrounding strata, thus simulating the effect of a pneumatic hammer, rather than as in the prior art, that of a single blow of a hammer. The pulsation thus set up will have the effect of flushing the liquid normally present in a well back and forth through the strainer perforation and through the interstices of the strata thereabout, thus effectively cleaning such interstices and stimulating the flow of the well fluid therethrough. Such pulsation will have the effect of providing a continuous shaking or jiggling of the well and the strata, rather than merely a single blow. Further, inasmuch as a continuous shaking is far more effective than a single blow, the individual blows may be much gentler than is necessary in the case of a single blow, and the individual explosive elements may be much smaller in quantity and explosive force than when only a single blow is provided, hence the individual blow or force of the individual charge may be kept well within the safety limit, thus avoiding any

danger of collapsing either the well or of the well casing.

In Fig. 2, there is shown an alternate means of completing the circuits to the multicable at the desired timing. In this form, the contacts **26'** are arranged in an insulation cylinder **29** and connect the leads **25'** from the multicable **15'** through the piston contact **28'** and shaft **31'** to battery B' and returns wire **27'**.

In Figs. 5, 6 and 7, there is shown another form of explosive charge **10'**. In this form, the steel guard **20'** is substantially D-shaped and its arms **21'** and **24'** are each provided with angle faces **23'**, between which is supported the individual explosive element **17'** depending from an arm **18'** through which the leads extend from the multicable supporting conductor **15''**.

In Figs. 8 and 9, there is shown another type of explosive support. In this form, a series of explosive cords **35** countersunk in spiral grooves **36** in a rod **37** of a length suitable to the depth of the area to be stimulated. If the depth of the area is too great for a single rod **37**, suitably joined rods, one suspended on another by a suitable flexible joint, provide flexibility as the rod is run in the well. The cords **35** may be detonated by an arrangement like that already described to provide a series of explosions, eight with the rod as illustrated.

When it is desired to provide a series of pulsations in a well **40** having a pump **41** operated by a sucker rod **42** or otherwise, which it is not desired to remove because of the expense and time of so removing and replacing it, then a form may be used as shown in Fig. 10, this form also being useable in any type of well. In this form, the multicable **43** is lowered along one side of the well casing **44**, being pressed thereagainst by the somewhat S-shaped leaf springs **45** secured at one of their ends **46** to the multicable **43**, while their free ends **46** press against the opposite inner side of the casing **44**. At their mid points, each spring finger **45** carries an individual explosive element **47** connected by leads **48** to the multicable **43**. When the cable **43** is lowered, its end will pass through the circular or new-moon-shaped space about the pump, and the spring finger **45** will flex, as at **45'**, to bypass the pump, the explosive element being in the form of a flat disc thin enough to bypass the pump. When the pump **41** is bypassed, the fingers spring back to their original shape, holding the explosive elements **47** as substantially axially of the well casing **44** as is permitted by the pump suspending sucker rod **42**. Due to the number of individual charges that may be used, each individual explosive element is so comparatively small that no damage will result to the pump or its operating mechanism, yet with the multiplicity of pulsations set up, a thorough cleaning is easily provided, both of the well strainer perforations and of the surrounding strata to thus greatly stimulate the flow of the well fluids.

Fig. 11 shows diagrammatically how a substantially indefinite number of charges **50** may be provided on a cable **51** in a well casing **52** within a well stratum **53**. As shown, a hundred or more individual charges **50** may be provided. Using the ten contact cable of Fig. 1, the numerous charges could be set off in any desired ten groupings, such as 1, 11, 21, etc.; 2, 12, 22, etc. Also, the groupings may be of different sizes, if desired, thus one grouping being five in number, then ten in number, then five in number, etc., all made up and varied according to the particular conditions of the well.

As a result, it can readily be seen that as far as functioning of combinations only the number of explosive charges and number of leads limit the variations of firing sequences and arrangements. In all cases the time interval between successive firing of single explosive charges or groups of charges can be varied at will, allowing great flexibility of operation so that pulsing can occur at millisecond, hundredth second or any other interval.

The advantages of the invention are:

(1) That by detonating a series of explosive charges at different times, the rate of total explosive energy delivery can be kept below the failure point of the tube.

(2) That the total quantity of energy delivered to the well can be ten to a hundred or more times greater than that which is possible to deliver by substantially simultaneous detonation.

(3) That the vibratory action set up by a multiplicity of detonations variously spaced in the casing and in a time period produces an extremely effective clearing action and is well known and practiced in ordinary life, when, for instance, a multiplicity of impacts to free a clogged instrument is often better than a single blow.

(4) That the interaction of pressure waves arriving from different loci in a casing at any other point in the casing or adjoining strata produces a modified Dautrische effect which greatly enforces the pressure at that point. Such enforcement of pressure travels outward with the interacting pressure waves and produces zone in the strata in which an augmented effect is produced.

(5) If succeeding pressure waves are produced in symmetrical sequence from regularly spaced charges, the zones of high pressure described in (4) are traversed by succeeding interaction points and so may produce flow lines and even structural breaks in the strata at these zones.

(6) The energy delivery rate of any series of explosive charges arranged on a cable by a standard production method can be changed at the point of application as desired to adjust to the effect desired and to the strength of the casing.

(7) In every well containing casing of different strengths, it is possible to use different energy delivery rate to different lengths of well casing.

(8) The use of a relatively large amount of explosive and the enhanced effect of a persistent series of pressure pulses through a stratum, can so break down clogging conditions in the stratum, that the flow of liquid in adjacent wells will be improved.

In the same manner that the cable **43** with its spring finger **45** and explosives **47** may pass the pump **41**, it may likewise pass along a drilling tool jammed in the well bore and be operated to jar the tool loose. Likewise, any other structure, whether in a well or otherwise, may be vibrated and loosened by the means and method of this invention.

Obviously, the length of duration of the continuous pulsations may be varied as desired, by merely using an appropriate number of explosive charges on the string. If desired, additional explosive charges can be fed to the operation area continuously at a desired rate consistent with the desired periodicity of the pulsations.

While the invention has been described with reference to certain specific illustrative means for carrying it into effect, it will be understood, however, that various changes in design, structure and arrangement may be made, without departing from the spirit and scope of the invention, or of the appended claims.

What is claimed is:

1. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, a plurality of flexible supporting arms, each of said arms having its central portion connected to a separate one of said explosive charges and being secured at one end to said supporting cable to normally extend somewhat radially therefrom so that the cable will be held eccentrically of the axis of the well and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position.

2. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, each explosive charge including a leaf

spring of greater length than the diameter of the deep well, said leaf spring being secured at one end to said supporting cable to normally extend somewhat radially therefrom and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position, and an explosive element secured midway of each leaf spring to be held substantially axially of the well when in detonating position.

3. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, each explosive charge including a leaf spring of greater length than the diameter of the deep well, said leaf spring being secured at one end to said supporting cable to normally extend somewhat radially therefrom and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position, an explosive element secured midway of each leaf spring to be held substantially axially of the well when in detonating position, and detonating leads connecting said explosive element to said detonating cable.

4. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, each explosive charge including a leaf spring of greater length than the diameter of the deep well, said leaf spring being secured at one end to said supporting cable to normally extend somewhat radially therefrom and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position, an explosive element secured midway of each leaf spring to be held substantially axially of the well when in detonating position, and detonating leads connecting said explosive element to said detonating cable, said detonating cable including a plurality of individual conductors, the explosive charges being arranged in a plurality of groupings of one or more.

5. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, each explosive charge including a leaf spring of greater length than the diameter of the deep well, said leaf spring being secured at one end to said supporting cable to normally extend somewhat radially therefrom and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position, an explosive element secured midway of each leaf spring to be held substantially axially of the well when in detonating position, and detonating leads connecting said explosive element to said detonating cable, said detonating cable including a plurality of individual conductors, the explosive charges being arranged in a plurality of groupings of one or more, each individual cable conductor being connected to a particular grouping only.

6. A string of explosive charges arranged to be run into a deep well and to bypass a partial obstruction present therein, said string comprising a supporting and detonating cable, each explosive charge including a leaf spring of greater length than the diameter of the deep well, said leaf spring being secured at one end to said supporting cable to normally extend somewhat radially therefrom and arranged to temporarily yield toward the cable axis as the obstruction is being bypassed and then return toward normal position, an explosive element secured midway of each leaf spring to be held substantially axially of the well when in detonating position, and detonating leads connecting said explosive element to said detonating cable, said detonating cable including a plurality of individual conductors, the explosive charges being arranged in a plurality of groupings of one or more, each individual cable conductor being connected to a particular grouping only, and means for successively completing a detonating circuit through each individual cable conductor in a predetermined periodicity.

7. A string of explosive charges arranged to be run into a deep well and means arranged to detonate each explosive charge in a predetermined sequence so that the explosion of said charges will produce a series of shock waves time spaced so as to set up a well fluid stimulating pulsation in the well, said string including a detonating and supporting cable, a plurality of individual explosive charges spaced along said cable, each charge including an explosive element and means for supporting said explosive element axially of the well, said explosive element supporting means including a spring leaf secured at one end to said supporting cable and between its ends to one of said explosive charges.

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