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METHOD OF AND MEANS FOR WASHING AND CLEANING WELL CASING PERFORATIONS AND WELL HOLES BY EXPLOSIVES

Filed Aug. 25, 1941

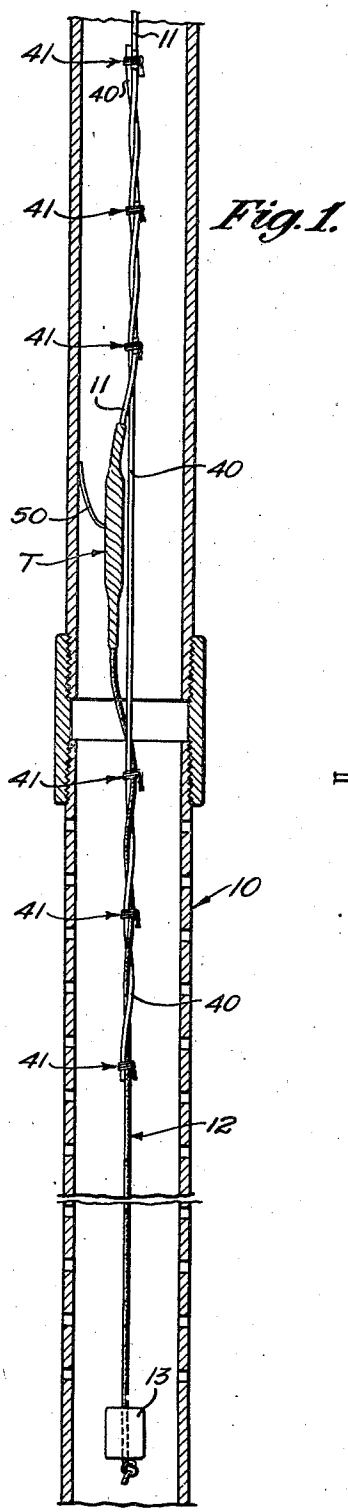


Fig. 1.

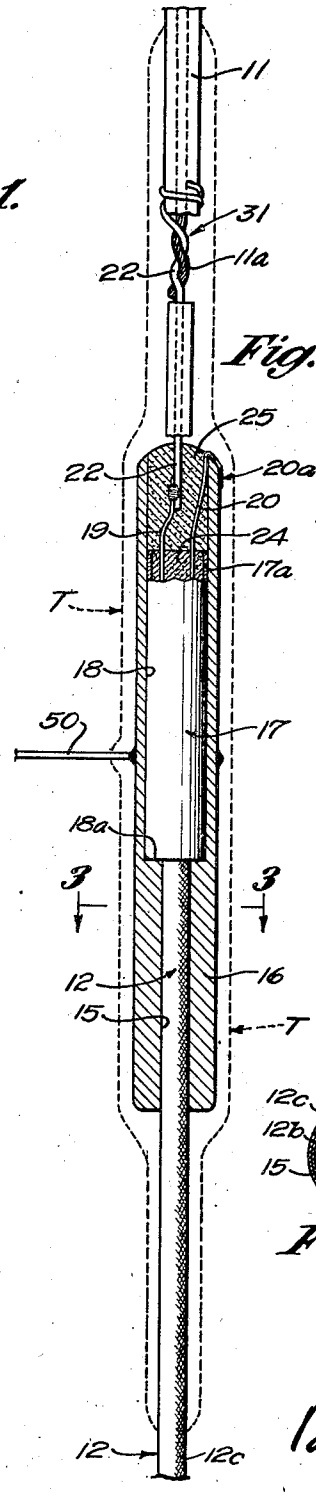


Fig. 2.

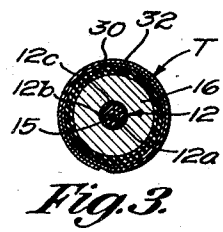


Fig. 3.

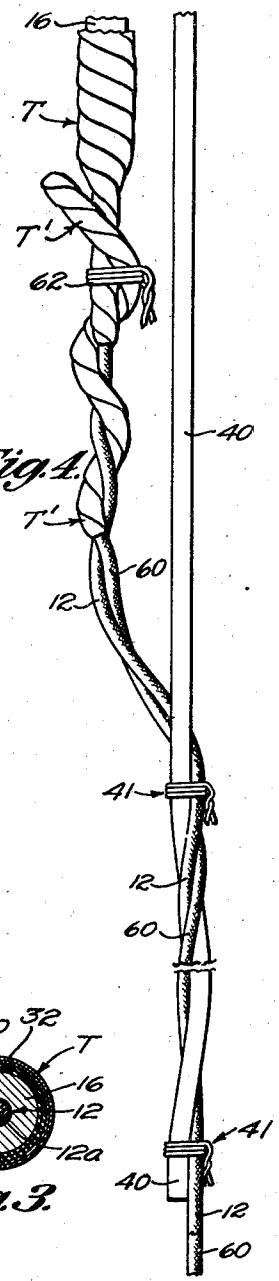


Fig. 4.

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METHOD OF AND MEANS FOR WASHING AND CLEANING WELL CASING PERFORATIONS AND WELL HOLES BY EXPLOSIVES

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5 Claims. (Cl. 166—20)

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This invention relates generally to methods of and means for washing and/or cleaning well casing perforations and well holes by explosive discharge.

It is well known that the casing perforations commonly used throughout the bearing strata in oil and gas 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 decreases 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.

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Another procedure attempted in the past is to simultaneously set off a number of explosive charges which are lumped at vertically spaced points within the casing. With this process, however, the operator was faced with the almost impossible task of striking a suitable compromise between the use of charges light enough to avoid rupturing the casing, and charges heavy enough to assure actually cleaning the casing at all points between charges. And a highly objectionable but inevitable consequence of the use of such lumped charges is the development of relatively intensive pressure waves travelling longitudinally of the casing. Such longitudinally travelling pressure waves build up cumulative peak pressures at localized points between charges which may become high enough to rupture the casing, even though the casing may not be ruptured at the locations of the charges.

The present invention also has application to the cleaning of newly drilled wells. As is well known, the drilling fluid used in rotary drilling consists of finely divided mud, containing various mineral substances to add weight and viscosity. Under the high pressure conditions existing in the drill hole during drilling, this mud fluid is often forced out into the pervious formation to a considerable distance, and becomes entrapped in the cells of the surrounding formation, so that when the drilling fluid is subsequently removed from the drill hole, substantial quantities of mud remain within the formation, as well as in a sheet on the sides of the drill hole. Under the usually prevailing conditions of high pressure and high temperature, this mud hardens, clogging the cells of the formation, and forming an impervious sheet on the sides of the hole. Acids are often introduced into the drill hole to liquefy the hardened mud and open the formation, but with variable and uncertain success, owing often to the fact that the operator may not know the precise nature of the condition with which he is contending. Moreover, formation "acidifying" is expensive, is dangerous to apply, is destructive of the casing and the acid used

must be neutralized before the well can subsequently be put on production.

The general object of the present invention is to provide a simple and improved method of and means for effectively washing and cleaning the full length of the perforated section of a well casing at once, without endangering the casing, and for effectively cleaning and opening the walls of the drill hole in the formation, whether or not the hole is cased, by the use of explosives.

Assuming first a perforation cleaning job, the method of the present invention contemplates the creation within the perforated section of the casing of a sharp, instantly relieved explosive concussion that originates substantially simultaneously from all points of a line extending throughout the length of the section to be cleaned. For this purpose I employ an extremely high-velocity explosive charge in the form of a long, relatively thin thread of explosive substance, which is suspended within the casing and extends the full length of the perforated section. For example, a small lead or copper tubing filled with liquid nitroglycerin or trinitrotoluene (TNT) might be employed, though it would probably in most cases be rather difficult to handle. Preferably I employ simply a suitable length of commercially available detonating cord, such as Cordeau, or Primacord. Primacord, manufactured by the Ensign-Bickford Company, is eminently suited to the requirements of the invention. This product consists of a core of pentaerythritetetranitrate (PETN), which has a detonating velocity of 20,350 feet per second, within a coal tar sheath which is in turn encased by a water-proofed textile covering. The core is approximately $\frac{3}{32}$'' in diameter. Cordeau, which has a core of TNT, is usually made up with a metal sheath, and for this reason is heavier, less flexible, and hence somewhat more difficult to handle. Moreover, the detonating velocity of PETN is almost 20% higher than that of TNT. I therefore prefer to use Primacord, though any other suitable detonating cord, or equivalent, of sufficiently high detonating velocity, may be utilized. This thread or core of high velocity explosive material is detonated at one end and the wave of detonation travels the length of the cord almost instantaneously, the explosive concussion being generated substantially simultaneously from end to end of the perforated section of the casing. For example, assuming a typical length of 200 feet of Primacord, the time of travel of the detonating wave from one end of the cord to the other is about one-hundredth of a second.

With the entire length of the cord thus detonated substantially simultaneously, longitudinal components of explosive pressure in the casing are largely equalized, and longitudinally travelling waves therefore reduced to negligible intensity. In general, this result follows from the use of an explosive having a velocity of detonation that is substantially higher than the velocity of travel of pressure waves in the well fluid, which is around 5,000 ft. per second. The explosive effect is accordingly directed substantially exclusively in a lateral or outward direction. Substantially the full explosive force generated is thus transmitted laterally to the walls of the casing, forcibly ejecting the fluid in the casing through the perforations and washing and cleaning them of clay, sand, paraffin, plugs of cement, or other debris, and is exerted through the perforations against the outside formation, opening it for free flow of well fluid, and dissolving or breaking up paraffin or asphaltum deposits. The following suction due to contraction of the explosive gases then draws the fluid back inside the casing, so that the fluid is forced twice through the perforations, from end to end of the perforated section. The effect produced by detonation of such an explosive element as described is in the nature of a sharp, substantially instantaneous "puff" throughout the full length of perforated section, followed instantly by a sharp suction, there being no substantial "follow-through" such as might permit cumulative build up of the explosive pressure to dangerous values. The concussion so generated is effective to perform the various washing and cleaning operations desired, without in any way endangering the casing.

There has been some use in the past of a method of casing installation involving running the casing in with its perforations temporarily plugged, the plugs being subsequently removed by any previously known procedure. It will be evident that the present invention is also applicable to the opening of such temporarily plugged perforations in newly installed casing, it making no difference in this aspect whether the perforations have become plugged through gradual accumulation of debris, or have been run in initially with temporary plugs in place in the perforations.

Assuming a well hole that is uncased in the bearing formation, the procedure may be as before, and the result is to break up and dissolve paraffin, asphaltum, or other accumulations or deposits, and to open the walls for free flow of well fluid. And in the instance of a newly drilled well, the described explosive discharge is effective to violently stir the set or hardened drilling mud adhering to the sides of the hole, and which may also have penetrated the formation to a substantial depth, and thus to break up such mud and dissolve it in the well fluid, so that it may be readily removed.

For most jobs of perforation cleaning I find it sufficient to use a single cord of Primacord, whose core of explosive substance is about $\frac{3}{32}$'' in diameter. In the event that the casing should be of large diameter, sturdy, and in good condition, it may in some instances become desirable to increase the explosive force employed. This is most conveniently done, in accordance with the invention, by using two or more parallel detonating cords. It is a further purpose of the invention to provide a method of splicing additional cords to the first cord, to which the blasting cap is connected, in such a way that detonation of the additional cords will be assured. It is understood by those skilled in the art that propagation of a wave of detonation from one cord to another requires special arrangements and methods of connection. And it has heretofore been believed that any cord spliced to another must be arranged at right angles to that other in order to assure that the wave of detonation will continue along both cords, and the detonation of one of the cords will not cut off the other. The present invention provides a novel and effective means for splicing additional cords to the first which enables the additional cords to be arranged parallel with the first, and still assures detonation of all the cords.

It is well known that great care must be taken in applying the cap to the cord to assure detonation of Primacord or Cordeau even under the best of conditions, and when the operations are carried on under water or well fluid, under high external pressure conditions, the difficulty is

multiplied many times, since the slightest moisture at the juncture will prevent detonation.

It is accordingly a further purpose of the invention to provide a novel and effective water and pressure proof juncture between the blasting cap and cord, such as will assure detonation of the cord even under the high external fluid pressures prevailing in deep wells.

The invention in all of its aspects, including various features, accomplishments and advantages not specifically enumerated above, will appear and be described in the course of the following detailed description of present illustrative means for carrying the invention into practical effect, reference for this purpose being had to the accompanying drawing, in which:

Fig. 1 is a view showing my complete device in place in the perforated section of a well casing;

Fig. 2 is a longitudinal section of the connection means between cap and detonating cord, showing also the connection between the lowering cable and a conductor that leads to the cap;

Fig. 3 is a section taken on line 3—3 of Fig. 2; and

Fig. 4 is a detail showing an additional detonating cord spliced to the detonating cord to which the cap is applied.

In the drawing numeral 10 designates generally the perforated section of a well casing, numeral 11 designates a lowering line, which may typically comprise a conventional insulation-covered stranded steel cable 11*a* (Fig. 2), and numeral 12 designates generally the elongated explosive member, preferably a suitable length of detonating cord, such as Primacord, or Cordeau. A weight 13 on the lower end of cord 12 facilitates lowering and keeps the cord straight.

The detonating cord has a core 12*a* of the explosive substance. The core of explosive material is encased in a suitable waterproof and pressure-proof sheath, which may comprise one or more layers. In the case of Primacord, the explosive is contained within a coal tar sheath 12*b* which is in turn encased by a waterproofed textile covering 12*c* (Fig. 3).

Referring now particularly to Fig. 2, the upper end of detonating cord 12 is inserted within the bore 15 of a connector sleeve 16, preferably formed of an electrically conductive metal such as brass. The end of the cord abuts the lower or butt end of an electric blasting cap 17, of any suitable type, the latter being received within an enlarged bore 18 in sleeve 16, and seating on an annular upwardly facing shoulder 18*a* formed at the juncture of bores 15 and 16. Cap 17 has the usual firing leads 19 and 20 extending from its upper end. Lead 19 is soldered to an insulated conductor 22. The shell 17*a* of the cap is tightly closed at the top by a plug 24 of litharge and cement, which seals around leads 19 and 20. Conductor 22 and lead 20 extend out through the upper end of sleeve 16, which is tightly closed in a water and pressure tight manner by a plug 25 of litharge and cement, sealing around conductor 22 and lead 20. Lead 20 is here shown as soldered to sleeve 16, as at 20*a*, and conductor 22 is spliced to the steel cable 11*a*, as indicated at 31.

In assembling the cap 17 and cord 12 within sleeve 16, the plugged cap is first inserted, the cement plug 25 then placed, and the lead 20 soldered to the sleeve. A small quantity of the explosive is then preferably introduced to the sleeve 16 through its bore 15. In the case of Primacord, the explosive is a finely divided white

powder; a little of this may be obtained from the cut end of a scrap piece of the cord, poured in the end of sleeve 16, and shaken down against the butt end of the cap. A freshly and cleanly cut end of the detonating cord is then inserted within the sleeve, care being taken that powder from the end of the cord is not lost, and the cord is then fastened to the sleeve with the end of the cord in tight abutment with the end of the blasting cap. The small quantity of introduced powder bridges any small space that might be left between the powder core of the cord and the end of the cap. The fastening of the cord to sleeve 16 is accomplished by wrapping of tape T (indicated in dotted lines in Fig. 2) which also serves the essential function of waterproofing. This tape is wrapped on the cord and sleeve and extends downwardly on the cord for a distance of several inches. The tape may also be extended upwardly on the conductor 23 to cover and waterproof the splice 31, so that the whole assembly is waterproofed from a point above splice 31 to a point below the lower end of sleeve 16. The tape wrapping T preferably consists of an inside waterproofing wrapping of rubber tape 30, and an outside protective wrapping of friction tape 32 (Fig. 3). Such a wrapping is water-tight, even under the high hydrostatic pressures encountered in deep wells. The fact that moisture at the juncture of cap and detonating cord prevents detonation of the cord has been mentioned above; the described juncture is water and pressure tight, and positively assures detonation.

It will be understood that the insulated steel cable 11*a* serves as a conductor to carry electrical current from one terminal of a source at the ground surface to conductor 22 and the lead 19 of blasting cap 17. The other lead 20 of the cap has been described as connected to sleeve 16, which is electrically grounded by means of a conductor 50 soldered to it midway of its length and extended out through the waterproof wrapping into the fluid in the well. It will be understood that the other terminal of the current source is grounded.

The weight of the detonating cord plus its lowering weight 13 is usually too great to be securely supported by the described connection between the cord 12 and the sleeve 16. Accordingly, to relieve the connection of weight I provide a by-passing tension line 40 which is connected to lowering line 11 above the sleeve, and to detonating cord 12 below the sleeve. The line 40 is conveniently given several turns around line 11 and around cord 12, as illustrated in Fig. 1. Preferably, and as here shown, the connection of line 40 with line 11 and cord 12 is made by binding tightly at several spaced points with several turns of wire, in the manner clearly indicated at 41 (Figs. 1 and 4). This by-passing line 40 serves the further purpose of providing a means for recovering the cord in the event the cap detonation should fail to detonate the upper end of the cord, though it might break the physical connection of the cord to the line 11.

The assembly as described is run in the well casing, which will usually contain well fluid or water to a height above the perforations. This water or well fluid desirably serves as tamping, as well as to aid in washing the perforations when the explosion occurs, though the presence of water or well fluid is not always essential. However, as stated, water or well fluid will usually be present or maintained in the casing to a level above the perforations, and will be assumed in

the following description. The length of the cord 12 is made commensurate with the length of perforated casing to be cleaned. This length may range between a hundred and fifteen hundred or more feet. The cord being lowered to a position opposite the perforated section of the casing, or to a position extending the length of the productive strata in the instance of an uncased hole, blasting cap 17 is fired to detonate cord 12.

The wave of detonation travels the length of the cord at the rate of propagation characteristic of the explosive employed; in the case of Primacord, the velocity is 20,350 feet per second, as stated before. The time of travel of the explosive wave from the upper to the lower end of the cord is so negligibly short for the lengths of cord used in the typical situation that the explosion may be said to occur substantially simultaneously at all points along the cord. The explosive force is accordingly effective laterally rather than longitudinally through the fluid in the casing, any substantial tendency for the initiation of pressure waves travelling longitudinally in the casing from any one given point of explosive discharge to another being counteracted by the substantially simultaneous generation of equal pressures at the two points. Substantially the total explosive force developed from each elemental segment of the cord is therefore exerted laterally outwardly against and through the perforations of the immediately surrounding elemental segment of the casing. Cumulative pressures owing to longitudinal waves, such as may endanger the casing, are thus kept down to negligible proportions, and substantially the full explosive force of each elemental length of the cord is directly effective to clean the portion of the casing (or of the well hole) laterally opposite it.

The explosive pressure generated by the relatively small diameter thread or core of high velocity explosive substance is almost instantly relieved, rather than sustained for any sensible time interval. No opportunity is therefore afforded for cumulative build up of explosive pressures to levels endangering the casing.

Contraction of explosive gases instantly following the explosive draws the ejected fluid forcibly back into the casing, so that the perforations are broken and washed by fluid forced twice through them. The concussion and surging of well fluid through the perforations not only breaks the perforations open and cleans them of sand, clay, cement, and the like, but dissolves or breaks loose the paraffin and asphaltum deposits inside and outside the casing, and opens and cleans the surrounding formation.

In the instance of an uncased hole, the explosion of the light thread of high velocity explosive substance is effective to break up and dissolve the accumulations and deposits of asphaltum, paraffin, mud, and the like, reaching into and cleaning out the pores of the surrounding formation, and opening them for free flow of well fluid, all without the generation of sufficient explosive force to endanger the walls of the well hole.

With a newly drilled well, the method may be employed to break up and dissolve the hardened drilling mud which has penetrated the formation during the drilling operation, and which has adhered to and formed an impermeable sheet on the walls of the drill hole.

The entire operation is simply performed, requires no substantial amount of time, is relatively

inexpensive, and leaves the well not only flowing freely, but entirely undamaged.

It is of course theoretically possible to regulate the strength of the charge for a given well condition by choosing detonating cord of different core sizes, or different explosive powers. However, at the present time manufacturing difficulties bar manufacture in sizes exceeding that of Primacord as now made, and I find it sufficient to use two or more cords in parallel when the casing is of such size or condition as requires or will withstand some increase in explosive power. Fig. 4 shows how an additional cord 60 may be hitched to the first cord 12, so as to be detonated by the cord 12.

It is well understood by those skilled in the art of explosives that detonating cord, such as Primacord, is rather difficult to detonate merely by tying it to the primary cord that is detonated by the cap. Furthermore, insofar as I am aware, it has heretofore been considered impossible to detonate a second cord hitched to a first unless the second be arranged at right angles to the first. With the second cord arranged parallel to the first, or at any angle much less than a right angle, the detonation wave along the first cord tends to travel ahead of the detonation wave along the second, and the explosive discharge from the first cord simply cuts off the second cord within an inch or so from the juncture. The present invention provides a novel form of hitch, shown in Fig. 4, which assures detonation of the second cord from the first, and assures that neither cord will cut off the other. As there illustrated, the cut upper end of the added cord 60 is first waterproofed by wrapping with tape T'. This wrapping may consist of an inner layer of rubber tape, and an outer protective layer of friction tape. The taped upper end of the cord 60 is then wrapped several times around the cord 12, and then bound tightly thereto by a wrapping of several turns of heavy wire 62. In Fig. 4, the cord 60 is wrapped on cord 12 over its tape wrapping T, and the wire 62 then applied around the wrappings T and T'. The tape wrappings thus serve as a protection against cutting of the cords by the wire. Below the wrapping 62, the two cords are bound tightly together by the vertically spaced wire wrappings 41, of which there may preferably be several, and below the lowermost wrapping 41 the two cords hang straight down, side by side, it being understood that each cord will be individually weighted at its lower end.

When the cord 12 is detonated, the wave of detonation travelling down it is transmitted to the cord 60, detonating the latter at the points where it is bound to the cord 12 by the wire wrapping 62 and the wire wrappings 41. The wire wrappings are of course burst by the explosion, but support the cord 60 in intimate contact with the cord 12 for a sufficient time interval for the cord 60 to be detonated. Without the wire wrappings, or equivalent, the cord 60 is blown loose from the cord 12, but not detonated. But with a strong and tight structural tie between the two cords, detonation of the second cord may be accomplished. The wire wrappings 41 and 62 are in effect tight fitting sleeves, of sufficient structural strength to resist bursting until the second cord is detonated from the first. Any other suitable equivalent form of tie or sleeve might of course be substituted, though that illustrated is preferred because of its simplicity.

Because of the wrapping of the second cord 60 several times about the first cord 12, the lengths

of the two cords may not be precisely equal between the upper wire wrapping 62 and the lower wire wrapping 41. This will permit the wave of detonation in one cord to get ahead of the wave of detonation in the other, and so cut off the latter. But below the lowermost wrapping 41, the two cords hang perfectly straight, side by side, so that the waves of detonation initiated at the lower wrapping 41 travel precisely together down the two cords all the way to their lower ends.

It will of course be understood that in extreme cases a third or even a fourth or fifth cord might be hitched on and detonated in similar manner.

The use of multiple cords also permits the explosive force to be made different in different zones where the conditions to be cleaned are variable. For instance, assuming that a heavier effect should be desired for an upper section of the perforated casing or hole than for a lower, a second cord may be hitched to the first near the top of the latter, and may be terminated at the lower limit of the section in which the heavier explosive effect is desired. Or, if the heavier effect should be desired in a lower section, the second cord may be hitched to the first at the upper limit of that lower section, so that there will then be one cord in the upper section and two in the lower.

The present invention has now been described with reference to certain specific illustrative means for carrying it into effect. It will be understood, however, that this is for illustrative purposes only, and 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.

I claim:

1. Means for clearing obstructions from openings in a vertically elongated section of a well-defining wall, said means consisting of a relatively thin and uniform thread of high velocity explosive having a length substantially equal to the vertical length of the section to be cleared, said explosive having a detonative velocity of substantially as much as fifteen thousand feet per second, means for suspending the explosive thread vertically in the well with its length substantially co-extensive with the vertical length of the section to be cleared, and means for detonating the thread.

2. The method of clearing obstructions from openings in a vertically elongated section of a well-defining wall, that comprises creating within the well a high velocity explosive lateral expansion which originates substantially simultaneously and uniformly at all points on a line extending throughout the vertical length of said section, whereby a uniform outward fluid movement against the obstructions and through the openings takes place substantially simultaneously and uniformly throughout the vertical length of said section.

3. The method of clearing obstructions from openings in a vertically elongated section of a well-defining wall, that comprises uniformly distributing a high velocity explosive in a substantially uniform and relatively thin body extending continuously vertically throughout said well section and substantially unconfined laterally, the explosive having a detonation velocity which is substantially greater than pressure wave velocity in the fluid present in the well, and detonating the distributed explosive, whereby an explosive lateral expansion takes place in the body of fluid in the well substantially simultaneously and uniformly throughout the length of said section and the fluid moves outwardly against said obstructions and uniformly through the openings.

4. The method of clearing and washing obstructions from openings in a vertically elongated section of a well defining wall, that consists in maintaining a body of liquid in the well throughout the vertical section to be cleared and washed, creating within said liquid body a sharp and substantially instantly relieved explosive lateral gaseous expansion which originates substantially simultaneously and uniformly at all points on a line extending throughout the vertical length of said section, whereby a uniform outward movement of the liquid against the obstructions and through the openings first takes place, followed immediately by inward movement of the liquid uniformly through the openings upon relief of the explosive expansion and contraction of the expanded gases.

5. The method of clearing and washing obstructions from openings in a vertically elongated section of a well-defining wall that consists in maintaining a body of liquid in the well throughout the vertical section to be cleared and washed, uniformly distributing a high velocity explosive in a substantially uniform and relatively thin body extending continuously vertically in the liquid body throughout said well section and substantially unconfined laterally, the explosive having a detonation velocity of substantially as much as fifteen thousand feet per second, and detonating the distributed explosive, whereby an explosive lateral gaseous expansion takes place within the body of liquid substantially simultaneously and uniformly throughout the length of said section, and whereby the liquid body is thrust laterally outwardly, simultaneously and uniformly at all points in the vertical length of said section to move outwardly against said obstructions and uniformly through said openings.

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