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United States Patent [19]

Brandon

[11] **3,923,099**

[45] **Dec. 2, 1975**

[54] **METHODS OF WELL COMPLETION OR WORKOVER OF FLUID CONTAINING SUBSURFACE FORMATIONS**

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[73] Assignee: **Orpha B. Brandon,** Nashville, Tenn. ; a part interest

[22] Filed: **Mar. 27, 1975**

[21] Appl. No.: **562,995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 355,239, April 30, 1973, abandoned, which is a continuation of Ser. No. 557,273, June 13, 1966, abandoned, which is a continuation-in-part of Ser. Nos. 853,405, Nov. 16, 1959, Pat. No. 3,255,820, and Ser. No. 665,995, June 17, 1957, Pat. No. 3,302,720, which is a continuation-in-part of Ser. No. 296,038, June 27, 1952, Pat. No. 2,866,509, and Ser. No. 241,647, Aug. 31, 1951, Pat. No. 2,796,129.

[52] **U.S. Cl.** **166/249;** 166/250; 166/286; 166/307; 166/308; 166/281

[51] **Int. Cl.**[2] **E21B 33/13;** E21B 43/26; E21B 43/27

[58] **Field of Search** 166/249, 250, 307, 308, 166/285, 286, 281, 299, 177, 256, 268

[56] **References Cited**

UNITED STATES PATENTS

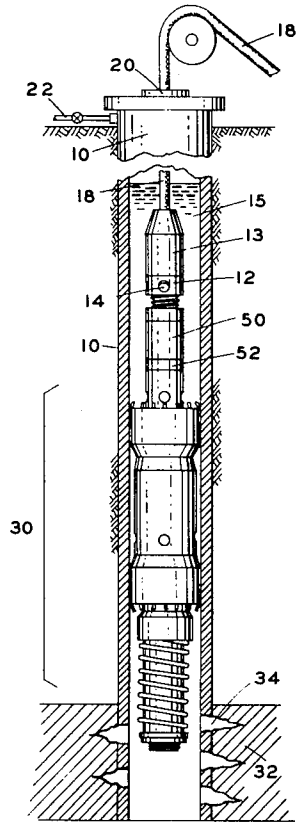
2,361,558	10/1944	Mason	166/299
2,915,122	12/1959	Hulse	166/249
3,189,092	6/1965	Bodine	166/249
3,240,273	3/1966	Solari et al.	166/299

Primary Examiner—Stephen J. Novosad

[57] **ABSTRACT**

The invention relates to well completion or workover of fluid containing subsurface formations by packing off that portion of the well bore adjacent the fluid containing formation from the well bore above this formation and thereafter creating a low pressure void in the packed off portion so as to cause a surge of fluid from the formation into the created low pressure void. This low pressure void impressed upon the fluid containing subsurface formation may be utilized as a source of seismic energy for delineating the type of fluid or formation existing in the subsurface formations adjacent to or surrounding the well bore.

39 Claims, 15 Drawing Figures



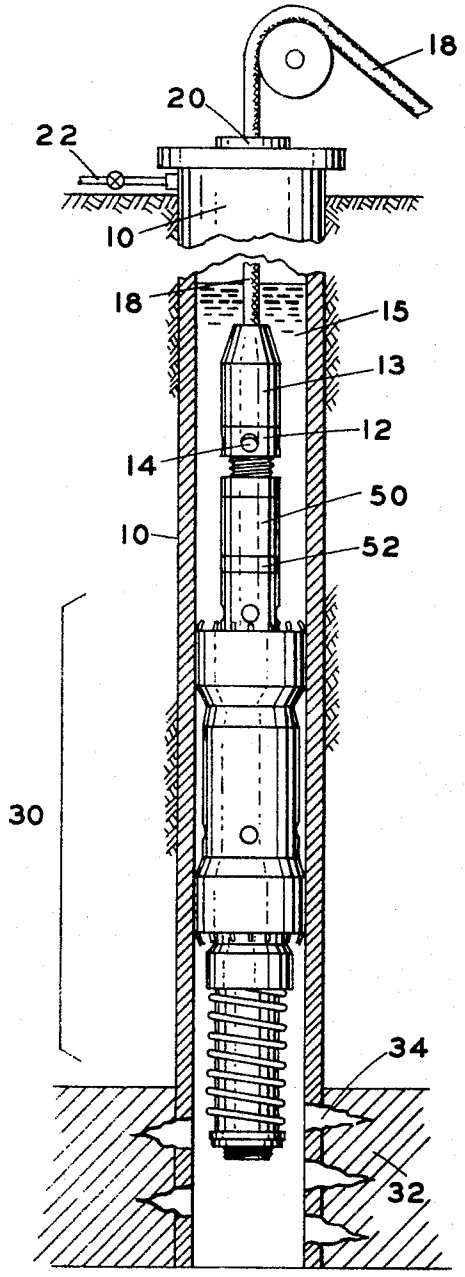

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FIG. 1

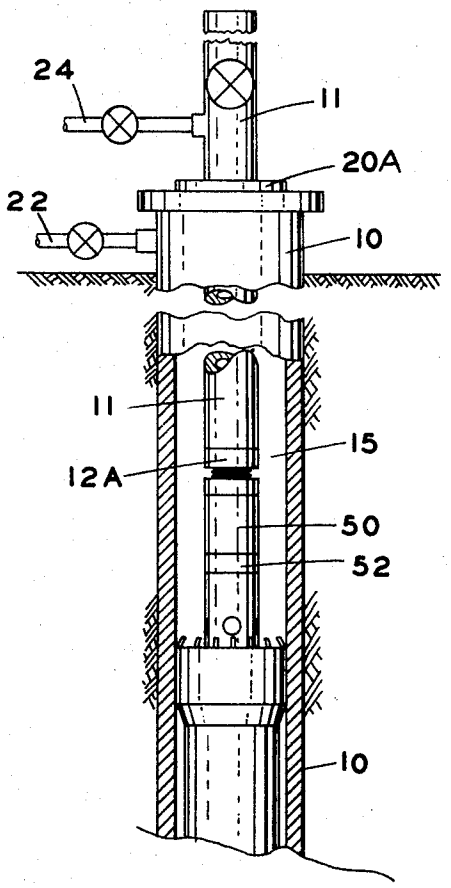

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20A
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12A
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FIG. 2

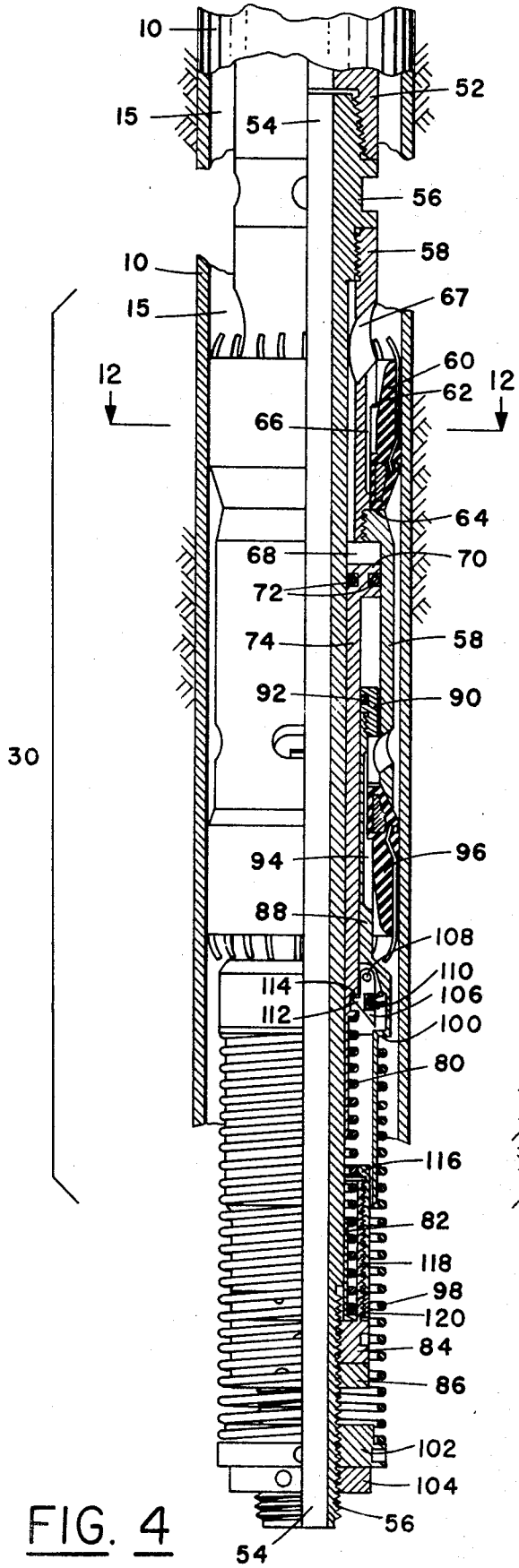

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FIG. 4

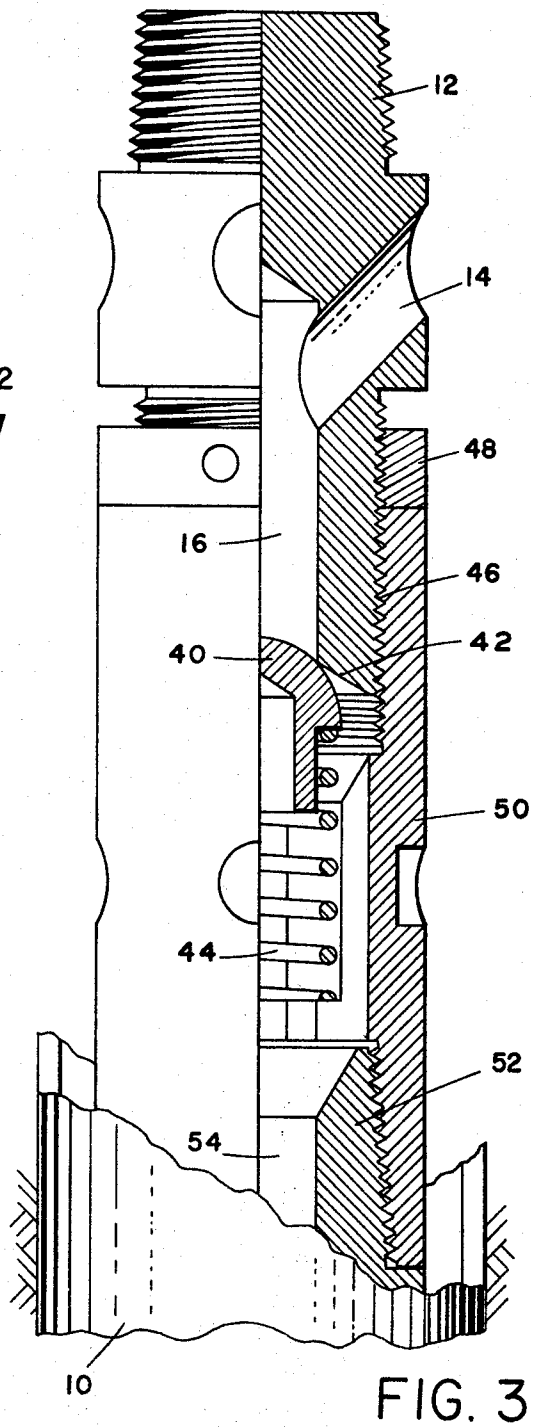

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FIG. 3

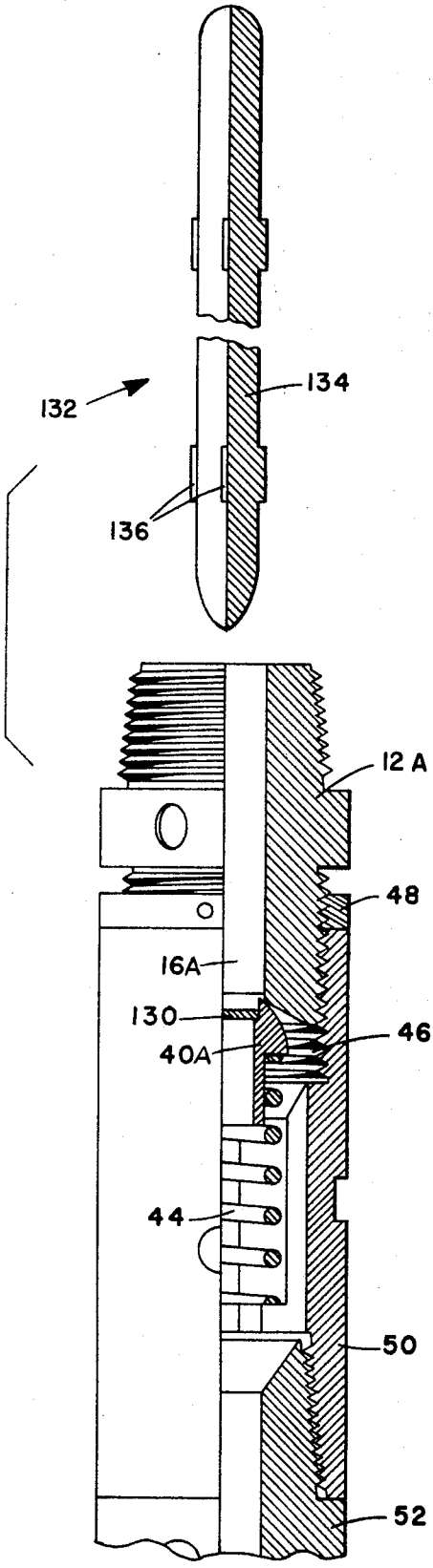

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12 A
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16A
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40A
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FIG. 5

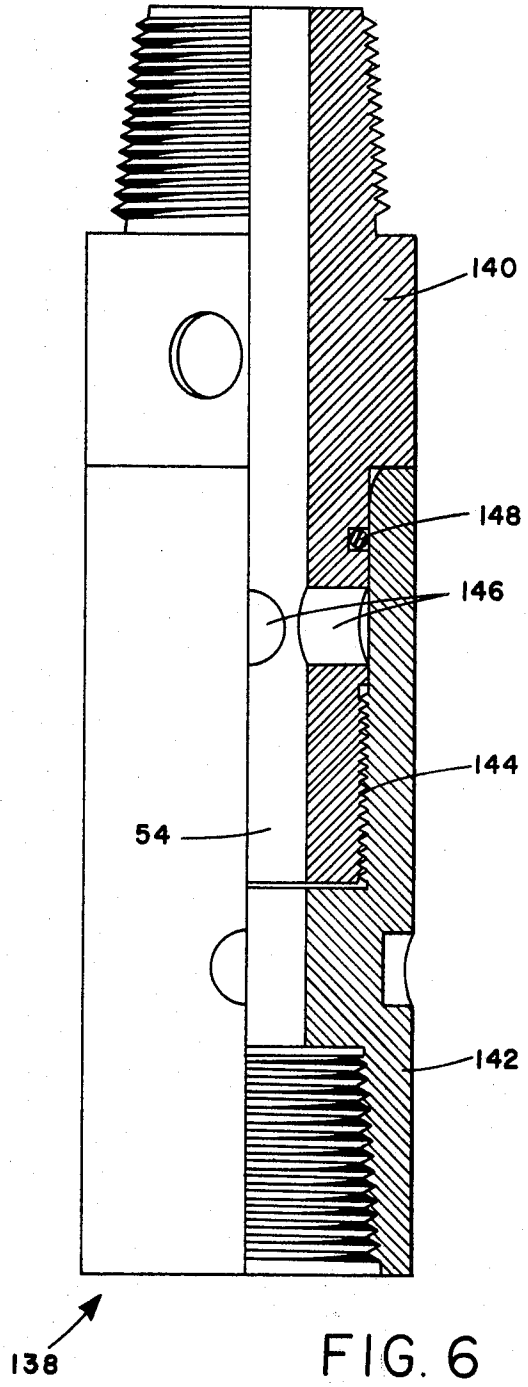

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FIG. 6

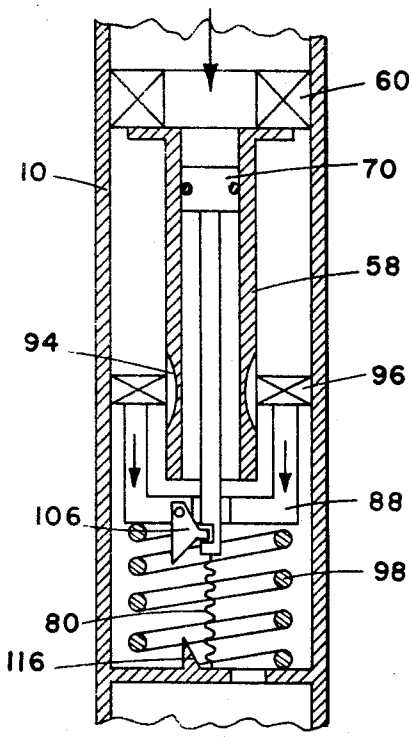


FIG. 7

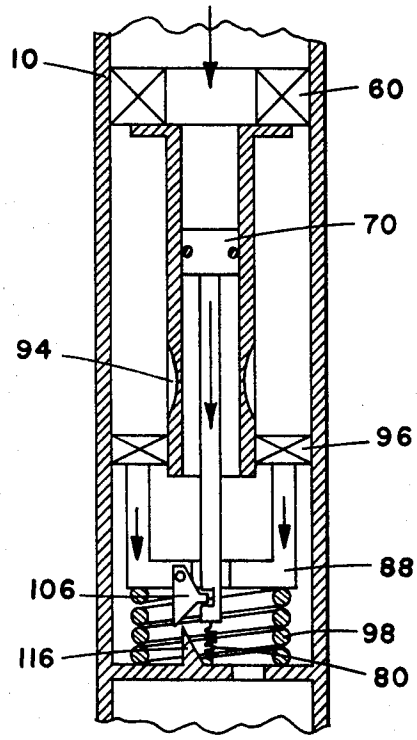


FIG. 8

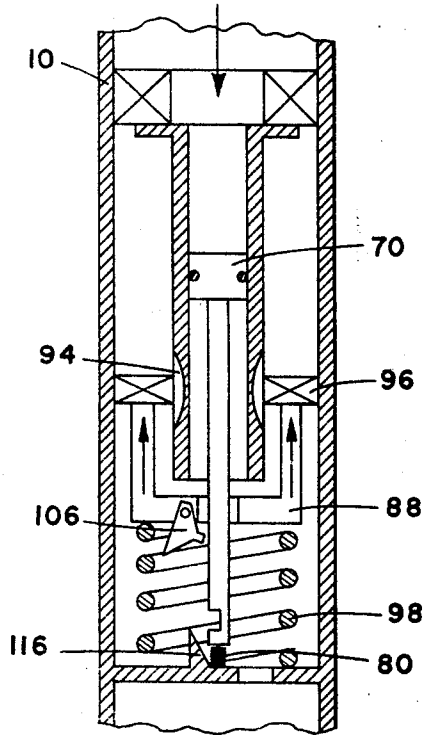
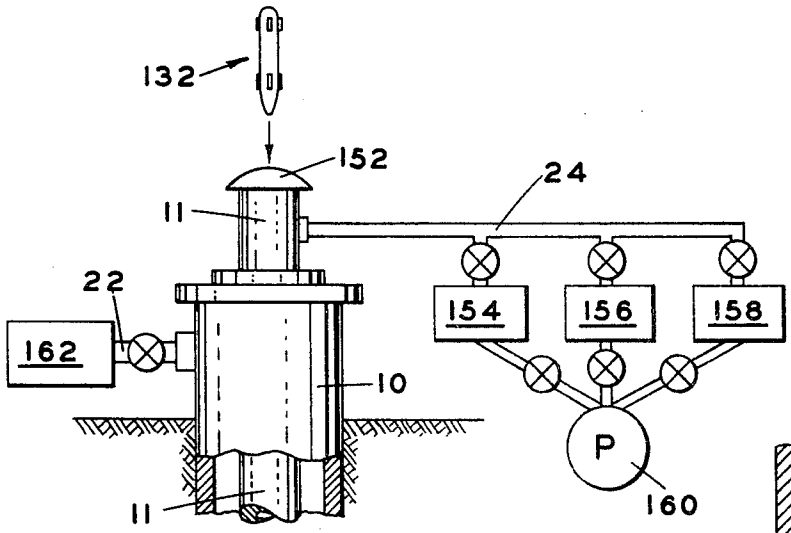


FIG. 9



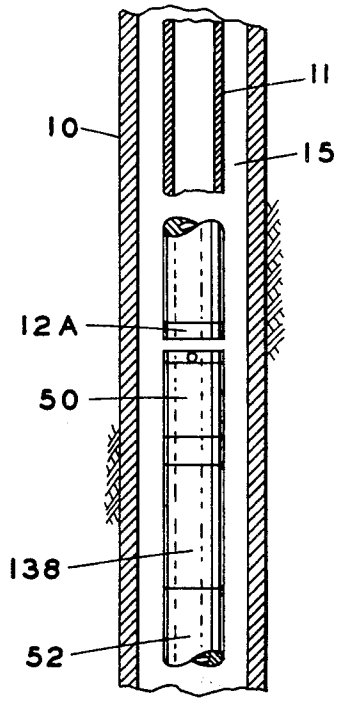


FIG. 11

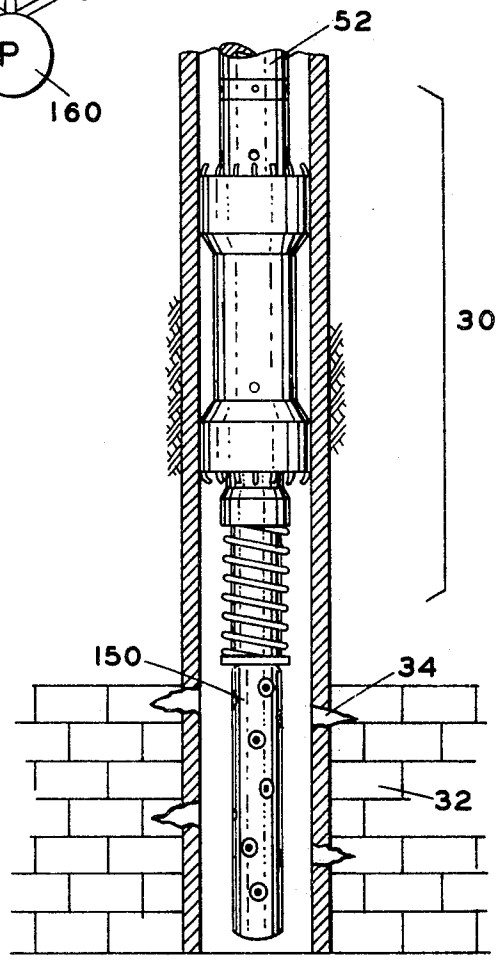


FIG. 10

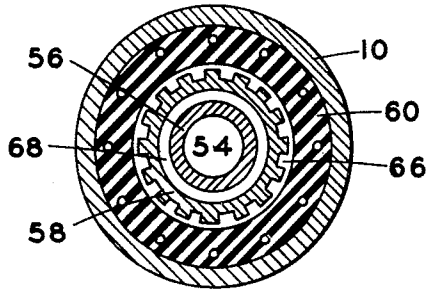


FIG. 12

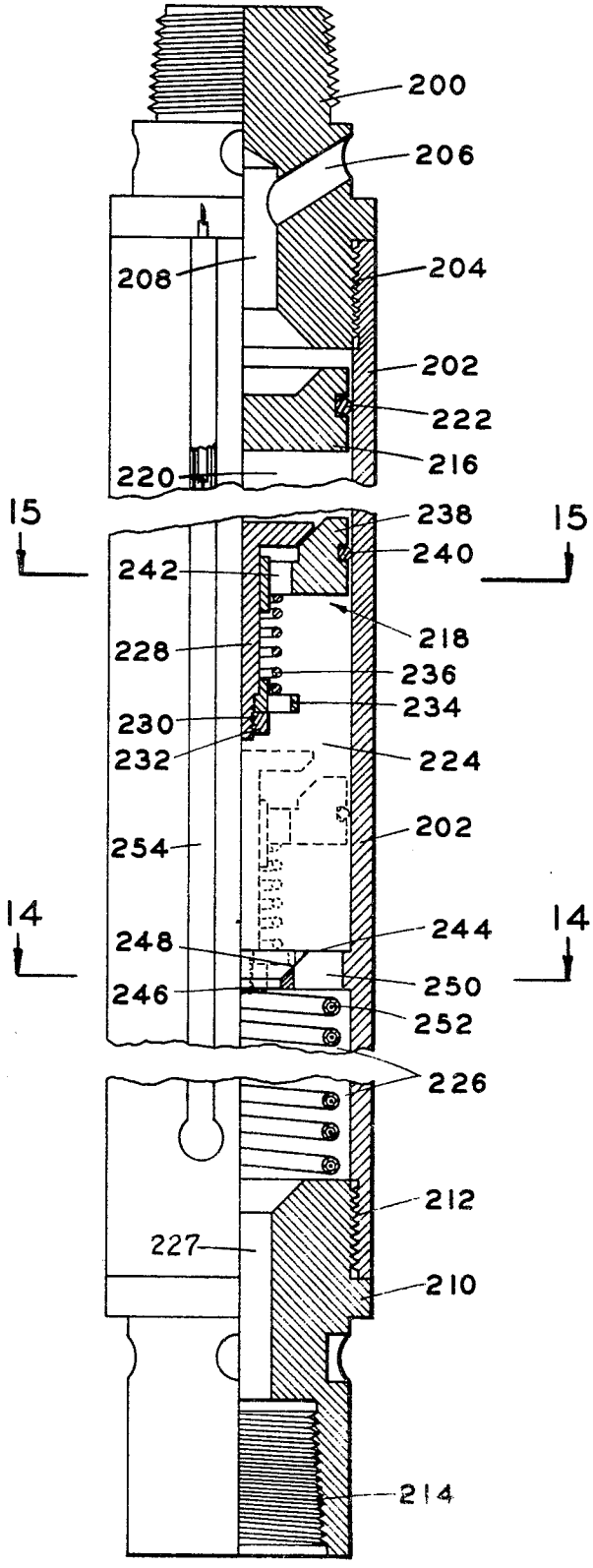


FIG. 13

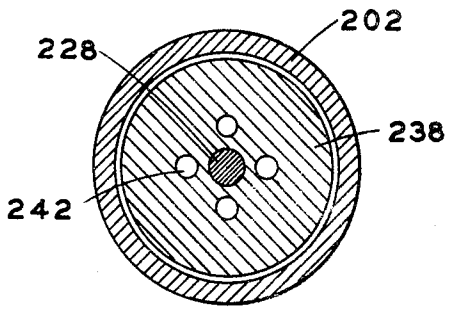


FIG. 15

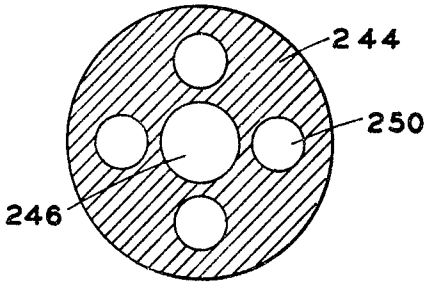


FIG. 14

METHODS OF WELL COMPLETION OR WORKOVER OF FLUID CONTAINING SUBSURFACE FORMATIONS

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a continuation-in-part of application Ser. No. 355,239 filed Apr. 30, 1973, now abandoned, which is a continuation of Ser. No. 557,273 filed June 13, 1966, now abandoned, which is a continuation-in-part of application Ser. No. 853,405 filed Nov. 16, 1959, now U.S. Pat. No. 3,255,820, and application Ser. No. 665,995 filed June 17, 1957, now U.S. Pat. No. 3,302,720, which in turn is a continuation-in-part of application Ser. No. 296,038 filed June 27, 1952, now U.S. Pat. No. 2,866,509, and application Ser. No. 241,647 filed Aug. 13, 1951, now U.S. Pat. No. 2,796,129.

BACKGROUND OF THE INVENTION

Broadly this invention discloses methods of use of created low pressure voids or zones of rarefaction within well bores at locations adjacent to fluid containing subsurface formations and wherein these created voids within the well bores causes a rarefied surge of fluids and other matter from the subsurface formations into the created voids within the well bores.

These low pressure voids impressed upon the fluids of the subsurface formations, which may be oil, gas, water or other types or mixtures of fluids, may become sources of seismic energy for delineation of various types of subsurface fluids or formation structures existing adjacent to or in the area surrounding the well bores in which the voids are created.

For the sake of clarification of the hereinafter disclosures relating to this invention, the creation of the low pressure voids or the zones of rarefaction and the substantially instantaneous primary negative pulse or surge of fluid thereinto is termed an implosion and the positive pulse or reactive surge of fluid outward therefrom is termed an implosive reaction.

An implosive effect, as distinguished from an explosive effect, is generally created by the primary immediate inrush of a high pressure fluid into a created zone of low pressure.

This invention relates to methods and apparatus for creating implosions and implosive reactions. More particularly, this invention relates to apparatus for creating implosions and implosive reactions within a relatively confined space having fluids under pressure. Still more particularly, this invention relates to apparatus and methods useful in treating subsurface formations.

This invention also relates to the use of implosions and implosive reactions as an augmenting or modulating method and means for sonic waves which are from a source either in the form of single pulses in any timed or irregular fashion or with periodic pulses being created or maintained in fluids.

This invention also is inclusive of method and means of transference of sonic or energy carrying waves across boundaries of various pressures and types of fluids within confined areas of fluids and particularly so in the treatment of subsurface formations. The problem of creating an implosive reaction resides first is establishing a zone or space of low pressure within the confines of a high pressure fluid. In some instances the high pressure is caused by hydrostatic pressures or in other

instances by mechanically created pressure such as with pumps, compressors, etc. Secondly, the problem is one of establishing instantaneous communication or collapse between the low pressure space and high pressure fluids. The enormity of the implosive reaction and its resultant pulses will vary according to the differential pressure established between the low and high pressure spaces, the volume of the low pressure space, and upon the instantaneous communication between the two spaces.

Typically, the implosive reaction caused by the instantaneous communication of high pressure and low pressure zones creates an initial negative or rarefaction wave impulse instead of a positive pulse as is created from an explosive reaction. Immediately following the rarefaction wave pulse is the opposite reactive, compression or positive high pressure pulse. In some instances this latter pulse energy is greater than the former. As used and defined herein the term implosive or implosion reaction pulses is defined to include both the initial rarefaction pulse and positive or compression pulse and those pulses resulting thereafter.

The above information relative to implosions and implosive reactions was substantiated by instrumentation and results by the use of the apparatus shown in detail in my earlier filed applications parent hereto, wherein the so-called cavitation valve, detailed in originally filed FIGURES therein herebefore is controllably operated as to timed periods of operation in the creating of and/or modulating of sonic waves. It was found that a substantially instantaneous collapse of high pressured fluid into a created low pressure zone within the confines of the high pressured fluid could be achieved by proper operating control of this so-called cavitation valve, and that the substantially instantaneous collapse of the high pressure into the void caused an implosive effect that was followed thereafter with a very severe impactual shock wave or an implosive reaction pulse. It was the results of these findings and the knowledge that this cavitation or implosive wave generator could be placed down within the well bore, next to the productive formation if desired, that resulted in the filing of my parental application Ser. No. 853,405 on Nov. 16, 1959, now U.S. Pat. No. 3,255,820.

In the art of drilling and producing subsurface formations containing typically oil, gas or water, or combinations of these, it becomes necessary from time to time to workover and/or completely clean out the well formation to more efficient production therefrom. Well known completion techniques such as hydraulic fracturing, acidizing and perforating have heretofore been taught and used by others. However, these completion and workover methods and apparatus typically involve the use of what might be broadly termed an explosive or positive pressure characteristic for their usefulness. In some instances it has been found that this prevents the immediate removal of debris, mud-cake, sand and the like from the plugged pores of the subsurface formation and usually tends to wedge them deeper into the formation.

In the normal production or swabbing of fluids from subsurface formations by the continuous withdrawal of a packer it appears that the low pressure area produced below the pump or swab brings debris, sand or cement materials into narrowed portions of the well causing plugged or decreased fluid permeability.

In some instances where a swab operation has been used alone in wells increased production has occurred

by the mixing of higher molecular weight hydrocarbons into the lighter produced crude aiding flow through previously blocked channels or pores. In other instances, however, the swabbing disturbs these heavier ends without solvent or blending action with the lighter ends, forcing them to the well and decreasing permeability.

In many wells the gas produced around the subsurface formation will come out of solution with the oil causing a reduction in temperature of the produced fluids which in turn causes the heavy end hydrocarbons of the produced fluids to deposit or settle out within the immediate area of the formation causing plugging and reduced permeability.

Accordingly, it becomes an important feature of this invention to provide methods and apparatus for use of implosive reactions which overcome the objections to methods and apparatus heretofore taught and used.

In the methods and apparatus disclosed in my parental application Ser. No. 665,995, filed June 17, 1957, now U.S. Pat. No. 3,302,720, it was found that this heretofore noted cavitation or implosion valve worked very satisfactorily at the surface in its initiating of cavitational or implosive reactions and in its augmentation or modulation of other sonic or energy carrying waves. Especially was this so where the subsurface formations had sufficient reservoir pressure or where the permeability was of small enough value so that the well bore could be pressured up with but small fluid loss into the interstices of the formation.

However, it was found that many productive formations would not sustain a column of pressured fluid without pumping in great amounts of unwanted fluids which will contaminate and lower the productive capacity of the formation or which will require a good deal of time for the fluids to be displaced from the interstices of the formation. Therefore, where it became desirable to controllably select the intensity or energy of pressure wave output from implosive reactions and/or modulated sonic waves, as by increasing the pressure of the fluid in which the pressure waves are being created, this method and means was provided whereby limited amounts of fluids are allowed to go into the formation whereby the well bore at the surface could be controllably pressured, yet permitting sonic or energy carrying waves created at the surface to have their energy content transferred into and out of the formation with substantially no loss except that which is helpful in increasing production from the formation. Such a method and means is provided as an object of this invention wherein apparatus as described is placed at selected locations in well bores, preferably adjacent a productive formation, and by controllable back pressure (and/or variance of exposed areas) between that of a high pressure hydrostatic column of fluid in the well bore and a lower pressure of fluid existing in the productive formation, a limited amount of fluid is shoved or injected back into the formation.

Besides the advantages of the method and means of this invention described above, when used in conjunction with the method and apparatus detailed and taught in my parental applications Ser. No. 241,647 filed Aug. 13, 1951, now U.S. Pat. No. 2,796,129, Ser. No. 296,038 filed June 27, 1952, now U.S. Pat. No. 2,866,509, and Ser. No. 665,995 filed June 17, 1957, now U.S. Pat. No. 3,302,720, there are other advantages and objects such as provision for method and means to introduce gases, preferably liquefied, into productive formations without interference to the transfer of sonic or pressure wave energy in the well bore by the gas becoming vaporized, as during rarefactions of the sonic waves or of the inplosions.

OBJECTS OF THE INVENTION

One object of this invention is to provide methods and apparatus for general industrial or well use of an implosive action or reaction by the collapse of high pressure fluids under pressure into a zone or space of low pressure and further to provide means for regulating said action or reaction by variations in volume between the two zones (i.e. vary either the high or low pressure volume), the resulting differential pressure and the speed of communication between the two zones.

Another important feature and object of this invention is to provide methods and apparatus for creating implosive reactions and to provide means for utilizing the resultant energy from such reactions.

Another object of this invention is to provide a method and apparatus for treating subsurface formations and fluids for increased production therefrom by the creation of an implosive reaction within the producing formations in situ, or within the well adjacent the formation.

A further object of this invention is to provide methods and apparatus for increasing production of fluids from subsurface formations and maintain solid material in suspension during swabbing or creation of a zone of low pressure below an upward moving piston device by simultaneously creating one or periodic implosive reaction pulses of predetermined amplitude and phase relationship, the motivating force for such reactions caused by the upward pull of said piston or swab.

Another object inclusive of the above object is to provide methods and apparatus for causing intense single or periodic pressure peaks following, equal to or greater than the pressure change of each negative implosive reaction pulse.

Another object of this invention is to provide implosive wave pulse forms having predetermined and controllable characteristics for application to subsurface formations.

Another object of this invention is to provide methods and apparatus for producing and lifting fluids from subsurface formations to the surface by implosive reaction pulses created within the well, said pulses continuing upward for maximum lift and/or radiated downward in a short periodic manner.

Another object of this invention is to provide apparatus for creating implosive and resultant impulses which is removably anchored in a well adjacent a subsurface formation, said impulses created by pressure fluid movement through the apparatus.

A further object of this invention is to provide methods and apparatus which is releasable under extensive hydrostatic fluid pressure within a well and further provide apparatus which is operable only under predetermined hydrostatic pressure loads to create implosive reactions.

A still further object of this invention is to provide method and apparatus for creating and utilizing implosive reactions and resultant pulses to rupture and fracture subsurface formations. An additional object of this invention is to provide methods and apparatus in accordance with the above which simultaneously maintains emulsification of fracturing liquids and/or suspension

of bridging and propping agents such as sand, etc., by the implosive reaction pulse or pulses.

A still further object of this invention is to provide methods and apparatus for creating implosive reaction impulses in combination with a reciprocating "cable tool" drilling rig which causes said impulses to not only assist said drilling but also lift fluids from the well.

A still further object of this invention is to provide apparatus adaptable to reciprocating type pumping equipment used in producing wells whereby implosive reaction pulses are created in combination with said reciprocation.

An additional object in accordance therewith is to provide a unitary pumping structure for wells which eliminates standing valves at the lower end of the production tubing and for creating kinetic energy from an implosive reaction to assist in pumping fluids from the formation. Additional methods and apparatus include selective and continuous fracturing of the subsurface producing formation by the combined pump and implosive reaction generator. A further object includes means for preselecting the intensity of the resultant implosive reaction prior to insertion within a well which is based on predetermined hydrostatic or mechanical pressure.

A yet further object of this invention is to provide apparatus which may be readily inserted and withdrawn from a well with appropriate bypass, safety and release mechanisms to prevent sticking and overloading by fluid columns in the well.

A still further object of this invention is to provide apparatus and method for creating implosive and resultant reactions of a desired pulse form and to further provide means for changing said pulse form as to intensity and frequency readily and simply by an operator at the surface such as by placement of the apparatus at preselected distances from the formation or device treated.

An even further object of this invention is to provide apparatus and method of creating implosive and resultant reaction pulses useful in secondary and tertiary recovery of oil from subsurface formations.

Still another object of this invention is to provide method and apparatus for treatment of subsurface formations with implosive and its resultant reaction pulses while simultaneously or in combination with well known well workover and completion techniques such as hydraulic fracturing, acidizing, perforating, and cementing, etc.

A further object in accordance therewith is to provide methods and apparatus for injection of treating fluids such as fracturing fluids, solvents, acids, etc., simultaneous with the aforesaid implosive reaction pulse or timed for introduction at predetermined phase angle of the initial pulse or resultant pulses.

Another object of this invention is to provide methods and apparatus for creating implosive reactions wherein the causative force for actuation of said apparatus occurs by fluid velocity or quantity of flow or pressure or by separate and distinct sonic wave generators.

Yet another very important object is to provide method and apparatus whereby sonic wave generators at the surface may have their sonic wave output, whether in the form of single pulses in any timed or irregular fashion or in the form of periodic sonic pulses capable of creating and maintaining sonic standing waves in the well bore and/or into the formation, augmented or modulated adjacent the formation for controllable effects upon, into and through productive formations.

Another important object in connection with the last above object is to use the means adjacent the formation as a controllable method and apparatus for allowing but limited entry of pressured fluid that is in the well bore into the formation while allowing transfer of sonic wave energy from the surface down the well bore and into and out of the formation.

A further object is to provide method and means whereby liquefiable gas may be introduced into and taken from productive formations without interference to sonic wave energy being transported in well bores.

Another very important object is to provide method and apparatus whereby sonic and energy carrying waves may be transformed and transferred across various pressure boundaries with substantially no attentuation of wave energy.

A further object is to provide methods and apparatus for producing implosive reactions simultaneously or in various phase relationships in two or more wells connecting with the same subsurface formation during swabbing, producing, treating or secondary recovery of the fluids from said well or wells.

A still further object of this invention is to provide methods and apparatus for creating implosive reactions in combination with subsurface reservoir testing means, said combination being of unitized construction to include other well known subsurface formation treating processes, solutions, and apparatus controlled at the surface in a step by step operation or in automatic timed sequence. In accordance therewith, it is an even further object of this invention to provide a unitized apparatus for perforating a formation or casing, fracturing said formation with an implosive pulse, treating the formation with treating fluids, testing the amount of formation reservoir energy and sequentially plugging same permanently or temporarily, if necessary.

An even further object of this invention is to provide apparatus useful particularly in wells for creating heat energy by producing an implosive reaction in or adjacent the well and by the means of the implosive reaction to transfer sensible heat from the well to a distance in the formation.

A still further object is to provide apparatus for creating implosive reaction pulse or pulses capable of operation in wells from a wire line, tubing, sucker rods, drill pipe and the like.

Another important object is to permit the use of treating fluids in a producing formation by the use of the implosive reaction wherein the means of causing the reaction and the treating fluids are isolated from fluids of the well bore and are lowered into place in the well bore on a wire line or pump rods. Yet another object in conjunction with the last above object is to use the pressure of the fluids within the well bore as an assisting means in causing the treating fluids to go into the producing formation. A further object in conjunction with the last two objects is to provide means so that fluids from the well bore may follow the treating fluids into the producing formation.

These and other objects will become more apparent upon further reading of the description, operation and claims of this invention when taken in conjunction with the following drawings of which:

FIG. 1 is an elevational view partly in section of apparatus constructed in accordance with this invention as suspended in operational position within a well on a wire line cable.

FIG. 2 is an additional diagrammatic illustration of the apparatus of FIG. 1 suspended within the well on a tubular attachment conduit.

FIG. 3 is a top continuation of the apparatus according to FIG. 4 and represents an enlarged elevational view partially in cross-section of apparatus for attachment to surface operational wireline, sucker rods, tubing or other apparatus, not shown.

FIG. 4 is a detailed front elevational view, partially in cross-section, of an implosive pulse generating apparatus useful in wells according to this invention.

FIG. 5 is a partial cross-sectional view of additional attachment apparatus for the apparatus of FIG. 4 useful according to another embodiment of this invention.

FIG. 6 represents a back-off or safety attachment device to the apparatus of FIG. 4 which is useful in a further embodiment according to this invention.

FIGS. 7, 8 and 9 are views of an implosive reaction method and apparatus constructed according to an embodiment of this invention.

FIG. 10 is an elevational view, partly in section, of the apparatus of this invention in combination with well completion or workover tools in accordance with an additional embodiment and method of this invention.

FIG. 11 is an upper continuation of the apparatus and methods described in FIG. 10.

FIG. 12 is a sectional view taken along the line 12—12 of FIG. 4.

FIG. 13 is a front elevational view partially in cross-section of a wireline operated embodiment for use in various well treating procedures using the implosive pulse generator according to this invention.

FIGS. 14 and 15 are cross-sectional views taken along the lines 14—14 and 15—15, respectively, of FIG. 13.

DESCRIPTION

Referring now to FIGS. 1 and 2, the apparatus of this invention is described in relation to use within a relatively smooth bore well casing 10. In the view of FIG. 1 connector 12 is for attachment to well known and used wirelines socket tools 13 or sucker rods (not shown) for movement, placement and operation of the apparatus of this invention in casing 10. The attachment 12 is more clearly illustrated in FIG. 3. For attachment to tubing 11, or hollow sucker rods, connector 12A is used. This is likewise described in FIG. 5 in greater detail. Numeral 14 (see FIG. 1) designates one or more passageways extending from the fluid filled annulus space 15 into tubular passageway 16, shown more clearly in FIG. 3. Wireline 18 extends from socket 13 to a winch or pulling apparatus at the surface, not shown. Stuffing boxes 20 and 20A are adapted to seal the annular space 16 between wireline 18 and casing 10. Valved connection 22 permits fluid control within space 15. Valved connection 24 (see FIG. 2) permits fluid control to tubing 11. The implosive reaction pulse generator is generally indicated by bracket 30 and extends within the well casing 10 to predetermined positions with respect to a subsurface formation 32 having perforations 34 providing communication with the well.

Referring now to the combined views of FIGS. 3 and 4, implosive reaction pulse generator 30 is described in relation to its use and placement within a well using a wireline or sucker rod, not shown.

A check valve 40 and seat 42 are adapted to regulate fluid flow through passageways 14 and 16. Resilient spring means 44 is adapted to maintain valve 40 in a normal closed position against seat 42 and further regulates the pressure at which valve 40 will be forced open or away from seat 42. Rotation of threads 46, part of attachment or connection 12 and valve seat 42 regulates the tension of spring 44 for control of the operating or opening pressure necessary to force valve 40 away from seat 42, the full operation and function of which will be hereinafter described.

Threaded lock nut 48 retains the spring tension position by movement about threads 46 into engagement with valve housing member 50. Valve 40 is retained in a non-opening position by threaded movement of adapter 12 to a lowermost position. In one embodiment valve 40 is forced in sealing abutment with a portion of the valve housing 50 therebelow by movement of adapter 12. Valve housing 50 threadably interconnects between adapter 12 and the implosive reaction generator 30 with one or more tubular subs 52 for attaining a desired length. The sub includes central bore 54 common throughout the length of the apparatus 30 from valve 40 into communication with the fluid in the lower portion of the well.

An inner mandrel 56 is threadably coupled to tubular sub 52 or in some instances directly to valve housing 50 and extends for the length of implosive pulse generator 30. An outer mandrel 58 is threadably connected to inner mandrel 56 at its upper end. The outer mandrel is adapted to receive unidirectional packing 60 such as the well known "cup type" packers as used in well servicing techniques and completions. The packer is adapted in one embodiment to be slidably received about mandrel 58 between an upper stop 62 and a lower stop 64. In the lower position shown, the packer is sealed to prevent fluid movement in the annular space 15 from above to below. The bottom portion of the packer, under fluid pressure above, tends to seal against stop 64. A splined or beveled portion 66 is provided adjacent packer 60 as shown such that when the packer is moved upward relative to mandrel 58, as occurs during lowering within the well, fluids will bypass from below to above. In the event an overloaded condition occurs during upward movement of the apparatus, or it becomes undesirable to swab the fluids above packer 60, a shear release mechanism can be incorporated between the packer and mandrel 58 to permit bypass of fluids. Bypass can likewise occur by opening of valve 40 permitting fluid flow across generator 30.

Passageway 67 extends from above bypass splines portion 66 and packer 60 providing communication from the annulus space 15 into main cylinder space 68 formed between outer mandrel 58 and inner tubular mandrel 56. A cylindrical piston 70 is sealed between the inner and outer mandrels using O-ring type seals 72. The piston includes a connected sleeve portion 74 adapted for reciprocation therewith. Movement of the piston and sleeve is regulated as desired by spring 80 which normally tends to force sleeve 74 and piston 70 upward. A retaining sleeve 82 about mandrel 56 is engaged with retaining nut 84 threaded along the inner mandrel at the lower end to adjust tension of spring 80. Threaded lock nut 86 is provided for maintaining such a setting..

Slidably received about piston sleeve **74** between it and the outer mandrel portion **58** is assembly sleeve **88** which, as seen in cross-section, comprises an upper sleeve portion **90** sealed with respect to the sleeve **74** by O-ring packing means **92.** A splined or slotted portion **94** exists longitudinally of assembly **88** to permit bypass of fluids in the annular space across unidirectional packer **96.** Packer **96** extends in an operational direction opposite that of upper packer **60.** This packer is in all respects similar to the packer **60** in its unidirectional operation and design, i.e., allows movement of fluids in one direction and prevents flow in the other direction when so positioned during operation. The cylindrical assembly **88** is normally in the position as shown permitting bypass of fluids within the annulus space across packer **96** through slots **94** by the tension of resilient spring means **98** acting between lower sleeve **100** and retaining nut **102** which is threaded about inner mandrel **56** and held by lock nut **104.** One or more spring loaded latching devices **106,** one of which is shown in cross-section, is provided about the periphery of assembly **88** to cause engagement with sleeve **74.** Latch **106** is movable about a shaft **108** maintained by spring means **110** abutting against cylindrical assembly **88,** in engagement through a lip **112** into a recessed portion **114** of piston sleeve **74,** the operational movement of which will be hereinafter described.

Latch member **106** is adapted, upon rotation about shaft **108** against the tension spring **110,** to be disengaged from recess **114** by striking release cylinder **116** which is threadably adjusted to a sleeve **118** formed as a part of nut **84.** A lock nut **120** prevents movement of the cylinder **116.** The lower outside threaded portion of the inner mandrel **56** is adaptable to be attached with other well servicing and drilling equipment, such as perforators, well pumps, etc.

Referring now to the embodiments described in FIG. **5,** the apparatus is similar to that described in FIG. **3** in that it describes a top continuation attachment for the implosive reaction pulse generator mechanism **30.**

The device has primary utility for attachment to tubing, drill pipe, hollow sucker rods and the like using adapter **12A** forming passageway **16A.** The passageway terminates with a rupture seal disc **130** formed as a part of valve **40A.** The "go-devil" device **132** illustrated is designed for operation with the device of FIG. **5** to rupture disc **130** and includes a body portion **134** and guide vanes **136.**

Referring now to the safety back-off device **138** of FIG. **6,** the apparatus is typically installed between implosive pulse generator **30** and the upper attachment valve housing **50.** However, in some instances it is attached above valve housing **50** to adapter **12A.** The device includes upper and lower cylindrical members **140** and **142** attached to each other by left-handed threads **144.** Bypass openings **146** are sealed from the annulus space by O-ring seal **148.** In the instance a release of pressure from space **54** becomes necessary, as for example when removal of generator **30** is desired without swabbing the well and/or creating implosive pulses, right-handed rotation of cylinder **140** with respect to fixed cylinder **142** releases the seal **148** and permits fluid communication from annulus **15** to interior space **54** through openings **146.**

Cylinder **140** of the safety back-off device **138,** in one embodiment, is rotated sufficiently to allow ports **146** to be opened without being physically parted. This is dependent upon the length of the threads **144** with respect to ports **146.** In those instances where the generator and/or parts connected thereto are stuck within the well, member **140** may be physically separated to permit appropriate fishing tools to connect with member **142** and remove the stuck apparatus from the well. The relative rotation in either of the above instances occurs by reason of the anchored generator which is held by pressure or stuck within the well.

FIGS. **7, 8** and **9** are views of an implosive reaction method and apparatus constructed according to an embodiment of this invention. The arrows are indicative of the motion of parts and pressure fluids.

FIGS. **10** and **11** show an assembly of an alternate embodiment using a bullet or shaped charge perforating device **150** attached at the lower end of implosive pulse generator **30.** Tubing **11** connects with tubing **52** above generator **30** through connector **12A,** valve housing **50** and safety back-off **138,** as described in FIGS. **5** and **6.** Tubing **11** terminates at the surface with cap **152.** Conduit **24** interconnects tubing **11** with various well treating materials schematically shown in containers **154** and **156** and **158,** such as acids, fracturing fluids, solvents, plugging materials such as cement, etc., which are appropriately connected with a pump means **160.** Block diagram **162** represents an energy source such as a pump, compressor, or sonic wave generator such as tose disclosed in my parental application Ser. No. 665,995 filed June 17, 1957, now U.S. Pat. No. 3,302,720, which connect with annulus space **15** to provide energy as may be desired to actuate implosive pulse generator **30,** as hereinafter described.

Referring now to FIGS. **13, 14** and **15,** apparatus is illustrated for operation in connection with the implosive reaction generator **30** when supported within a well on a wireline or pump rods and when it is desired to treat a subsurface formation with increment injection of fluids such as acids, fracturing fluids, solvents, emulsions, sealing or cementing agents, etc. Connector or adapter **200,** similar to adapter **12** (in FIGS. **1** and **3**) represents the top of the apparatus for attachment to a wireline socket or pump rod coupling, not shown. The adapter is threadably attached to barrel **202** at threads **204.** Passageway **206** provides communication between annulus space **15** and space **208.** Barrel **202** terminates at lengths up to several hundred feet or more for deep well use to a lower connector **210** at threads **212.** Lower threads **214** are usually attached to coupling **12A** and valve housing **50** of the device shown in FIG. **5,** safety sub **138** and thence generator **30,** respectively, somewhat similar to the view of FIG. **1.**

Barrel **202** is divided into a multiplicity of separate chambers using one or more piston devices such as **216** and **218.** Free piston **216** provides a solid seal separating chamber **208** and chamber **220** using an O-ring seal **222.** Free piston device **218** comprises a type of check valve permitting bypass of fluids within chamber **220** to lower chamber **224,** optional heating chamber **226** and thence space **227** above valve housing **50.** The valved piston **218** includes a solid valve seat **228** threaded at the lower end **230** for sleeve **232** which holds perforated retaining ring **234** and spring **236** acting against piston **238** sealed against valve seat **228** and against barrel **202** with O-ring seal **240.** One or more ports **242** are located about the interior of piston **238,** the functional use of which will be hereinafter described.

Chamber **224** terminates with a control orifice **244** which is seen in the cross-section of FIG. **14.** The ori-

fice includes a central opening **246** terminating the beveled stop surface **248.** At least one opening **250,** preferably more, are spaced about the outer portion of orifice **244** and are of such diameter that they intersect with the beveled surface **248.** Orifice **246** and openings **250** provide communication with optional heating chamber **226** from chamber **224.**

Heating chamber **226** includes a resistor type heating coil **252** such as sold under the trademark "CALROD" which is connected to insulated electrical connection **254** adaptable for connection and operation with conductor cable **18,** not shown in this view. The electrical connector **254** is attached or clamped to barrel **202** is a manner well known to those skilled in the art.

OPERATION OF IMPLOSIVE PULSE GENERATOR AND/OR SONIC WAVE MODULATOR

Although there are numerous methods and processes adaptable to this invention, broadly speaking, such as in industrial usage, the purpose of the apparatus described heretofore is the creation and usage of an implosive pulse and resultant pulses within high pressure fluids which is specifically adaptable to all phases of oil well seismic exploration, drilling, completion, workover and production or as an augmenting or modulating means to sonic or energy carrying waves used in various methods or processes thereto.

The implosive operation comprises two or more fundamental steps: (1) the creation of at least two separate fluid volumes having differential pressure therebetween, and (2) the instantaneous collapse or communication between such volumes and a resultant following high pressure pulse, and (3) if actuated by sonic or energy carrying pulse or waves steps (1) and (2) become a modulating means and method for the particular phase angle to which they are applied to the sonic pulse or waves and/or an intensifier of said sonic pulse or waves.

Referring specifically now to the apparatus illustrated in FIGS. **1, 3** and **4** and FIGS. **7, 8** and **9** which are a preferred mode of carrying out the invention, the numerals used in FIGS. **7, 8** and **9** refer to like numerals in the specific apparatus of FIGS. **3** and **4.** Packer **60** is described, however, as a fixed packer for the purpose of simplification. Preferably the apparatus **30** is used in conjunction with a confined bore such as a cased well **10** filled with a fluid supplied through conduit **22** or filled with produced fluid from formation **32.**

However, the use of apparatus **30,** or other means that will perform like methods of operation, is not confined to use in well bores but may be used generally in industrial methods and processes as well as those uses later described in this application wherein the following detailed description and mode of operation is applicable and wherein casing **10** may be any confining medium or means wherein the methods and processes herein may be performed.

Using connections **12** and **13,** valve housing **50** and tubular subs **52,** implosive pulse generator **30** is lowered on wireline **18** to a desired position within the well with respect to formation **32.** Well fluids are permitted to bypass packers **60** and **96** through splined areas **66** and **94** respectively during the lowering operation. The initial starting position will depend to a great extent upon the treatment desired. For example, it has been found that by locating lower packer **96** at distances from formation 32 equal to multiples of one-quarter of the wave length as predetermined or desired from generator **30** this causes reinforcement of reflected pulses from formation **32** when repetitive or periodic pulses are generated. Reinforcement of the compressive wave pulse following the rarefied implosion reaction pulse occurs through proper placement of valve **40** with respect to the end of mandrel **54** permitting fluid injection during the compression part of the pulse or wave. Even further reinforced energy of the compression wave occurs by injecting heated fluids, such as gases, solvents, light crudes or driving fluids such as water and liquefied petroleum gases. This added energy upon attenuation will drop the energy into reconversion of heat within the formation.

Under certain conditions such as when desired to prevent contamination of well fluids existing above generator **30,** valve **40** in housing **50** is adjusted to an inoperative position by movement of connector **12** heretofore described. Using proper length of subs **52** the distance valve **40** extending from the lower end of generator **30** becomes of critical importance in certain operations as hereinafter described.

In the initial starting procedure the pressure across packers **60** and **96** is in equilibrium. Upon the reversal of movement of wire line **18,** e.g., upward, bypass slots **66** are closed as packer **60** seals along mandrel **58** and shoulder **64.** Accordingly, fluid within the well space **15** is prevented from passing from above to below the packer **60,** by fluid pressure expanding same into sealing engagement with tubular casing **10.** Further upward movement of mandrels **56** and **58** force pressure fluid such as hydrostatic pressure fluid into bypass **67** and cylinder space **68,** forcing piston means **70** and its attached sleeve **74** downward. The amount of pressure necessary to force movement of piston **70** under the action of high pressure fluids is largely determined by the size, type and predetermined tension setting of spring members **80** and **98.** Due to interlocking engagement of latch **106** by lip **112** in recessed portion **114,** the cylindrical assembly **88** is likewise caused to move downward with the sleeve and piston. Spring **110** associated with latch **106** and assembly **88** maintains this interlocked relationship. Further movement of piston **70** and assembly **88** under the pressure existing in cylinder **68** forces the upper portion **90** of assembly **88** into sealing engagement with the lower packing means **96** thereby shutting off packer bypass channel **94.** Further movement thereof causes increased pressure to occur on the lower side of packing element **96** forcing it into sealing engagement with casing **10** similar to that described with packing element **60.** Continued movement and withdrawal of mandrels **56** and **58** upward begins the creation of a low pressure space between the two packing members **60** and **96** by the relative movement of the mandrel members and packer **60** upward with respect to downward movement of packer **96** in an opposite direction. This zone of low pressure is sealed from the fluids within the casing. It appears that the resultant force of the implosion is largely a function of the differential pressure across packer **96** and the volume of space between packers **60** and **96.** Accordingly, it is possible to arrive at a predetermined intensity of implosive effect by control of operational movement between the packers **60** and **96** and control of the amount of pressure existing about the low pressure zone created. Assembly **88** continues movement downward until latch means **106** strikes release or tripping member **116,** providing an instantaneous movement under the action of spring **98** against lower sleeve **100**

of assembly **88.** Since release member **116** is threadably adjusted upon retaining sleeve **118** the distance and length of movement and hence resultant implosive effect may be readily adjusted or pre-set. The total movement of packers **60** and **96** relative to each other depends upon many characteristics and conditions in addition to the type of workover or completion techniques required. This relative movement may be a matter of a fraction of an inch up to several inches or more.

Although there is some discrepancy as to actually where the implosive reaction pulse is created, it appears that upon the substantially instantaneous release of assembly **88** packer **96** likewise moves into abutment with mandrel **58.** This instantaneous packer movement away from the pressure fluid below creates a low pressure void into which the high pressure fluids below instantly communicate to cause the initial rarefaction wave pulse. In other instances, due to changes in spring tension and inertia between assembly **88** and packer **96,** there is instantaneous communication in space **94** between the low pressure space between the packers and the relatively high pressure fluid space outside. It is known that an "in-rush" of fluids establishes the implosive reaction.

Repeated or periodic implosive pulses occur by lowering generator **30** permitting spring tension **80** to return sleeve **74** and piston **70** into engagement with latch **106.** Another method consists of alternately releasing the pressure within cylinder **68.** A yet further method is the use of a sonic pulse or periodic sonic wave being caused in the fluid within space **15** of casing **10,** as for example using the various methods and apparatus referred to in parental application Ser. No. 665,995, filed June 17, 1957, now U.S. Pat. No. 3,302,720, which is a continuation-in-part of prior applications Ser. No. 241,647, filed Aug. 13, 1951, now U.S. Pat. No. 2,796,129, and Ser. No. 296,038, filed June 27, 1952, now U.S. Pat. No. 2,866,509. As taught therein these sonic pulses are either single pulses in any timed or irregular fashion or periodic pulses capable of creating and maintaining in the fluid above the implosive pulse generator **30** a sonic standing wave of multiples of a quarter wavelength of the fundamental frequency or one of its various harmonics. In many instances the created implosive and associated pulses release the pressure sufficiently to cause re-engagement with assembly **88.**

The generator unit **30** may be activated by periodic upward movement and return of the unit to the original position or by allowing the generator unit **30** to remain in a fixed position from the formation and the bottom of the well in combination with the activation means described in the previous paragraph, that is, by a sonic pulse or by momentarily increasing the pressure of the fluid above the generator **30** or by pressure fluid flowing past and through the unit **30.**

In operating the generator unit **30,** typically the operator selects the placement at a distance of a quarter wave length that was less than the quarter of a wave length of the fundamental frequency of a sonic wave in the medium being used and hence causes the generator unit to operate at one of the many quarter waves of the harmonics of the fundamental frequency and thus maintain a standing wave condition of sonic waves below unit **30.** If the unit is pulled upward continuously, as in a swabbing operation, then the reflected standing wave from the generator unit would be of an increase in wave length going through the various harmonics of the fundamental frequency of wave length in the particular fluid contained in the well. Accordingly, valve **40** would open due to the rarefaction portion of the pulse. The length of the tubing upward actually regulates in time the arrival of the fluid and its joining the fluid below the valve at a phase angle with the pulses from generator unit **30** and the particular quarter wave length of harmonics selected and the resultant position of unit **30** from the bottom of the well. This regulates the distance valve **40** will be above generator unit **30** in order to have the fluid combine with the standing wave impulses at the desired phase angle portion of the standing waves.

Operation in accordance with this invention using tubular apparatus of FIGS. **2, 5** and **6** is substantially the same as using the wireline apparatus described above, i.e., the implosive generator **30** operates in the same manner. The tubular apparatus has particular utility when it is desired to continuously add treating fluids or materials to the subsurface formation below the generator **30** independent of annulus fluids, as more particularly described heretofore and generally under the subheading WELL COMPLETION hereafter.

The implosive reaction occurring from the communication of high and low pressure zones in the fluid about packing members **60** and **96** causes a negative or rarefaction pressure pulse. This pulse is impressed upon the pores of the producing formation through the coupled fluid existing within the well and formation. The fluid exists within the well as produced fluids or is pumped into the well prior to inserting of generator **30.** Accordingly the coupling fluid used is an important phase of this invention in well completion and workover. If the apparatus is used primarily as a swabbing tool, the formation fluids will form the coupling medium whereas in other instances oil well acids, solvents, fracturing fluids and drilling fluids are also capable of use with the invention. Following the negative pulse there will be a positive pressure pulse of up to several thousand atmospheres per square inch or higher. Likewise, the high pressure pulse immediately following the rarefaction pulse enters the producing formation with increased beneficial effect for increasing production of fluids therefrom but unlike the rarefied pulse is also propagated upward within the well.

SWABBING WELLS

The apparatus is readily adaptable for use as a type of wire line swab for cleaning oil well formations as illustrated in FIG. **1.** By a continuous withdrawal of the device up the well an alternating implosive reaction occurs during such travel until the hydrostatic fluid pressure in space **15** is incapable of further movement of piston **70** within the generator.

Where the device is continuously withdrawn up the well valve **40** must be set in an operating condition whereby the upward pull of the device is not sufficient to cause opening of the valve. The valve is caused to be opened, however, when the rarefied wave pulse travels upward in tube space **54** and reaches the underside of valve **40.** The differential pressure across valve **40** causes the valve to open, allowing fluid thereabove to be induced down tube **54.** This same induction of fluid at valve **40** also causes piston **70** and member **74** to move upwardly by the action of spring **80** relatching into assembly **88** which carries lower packing member **96.** In this manner fluid above generator **30** is caused to go into the fluid existing below during the compressive

or high pressure pulse that follows the rarefied pulse due to the implosive reaction.

As the generator is pulled along the well the implosive reaction pulse begins to vary in frequency, such frequency and energy being sufficient in many instances to fracture the subsurface formation.

In some instances sufficient pressure is established in the fluid above the apparatus from auxiliary sources through conduit **22** to actuate the apparatus where hydrostatic pressure is not available or is insufficient. A unidirectional (check type) valve can be located within outlet conduit **22** operable under predetermined pressure conditions in order to maintain sufficient back pressure within well space **15** and cylinder **68** of generator **30** for operation. The implosive rarefaction pulse effect caused by the apparatus according to this invention places a momentary pressure differential between the well fluids and the fluids in the formation with the formation fluids tending to move towards the well. Thereafter, the rarefaction pulse effect is reversed by a high pressure impulse into the widened area of the formation near the well.

In another embodiment instead of a continuous lift swab an oscillating motion is transferred to wire line **18** from, for example, a cable tool drilling rig.

It can thus be seen that during what would be a normal swabbing of a well an implosive reaction occurs by proper setting of device **30** to the amount desired to formation **32.**

PUMPING WELLS

The apparatus of this invention has further utility when used in conjunction with a reciprocating type oil well pump. The implosive rarefaction pulse creates a momentary suction effect on the formation fluids bringing them into the pump proper for lifting to the surface. In addition, the high pressure positive pulse following causes debris, normally plugging the formation pores, to be forcefully radiated outward. The reciprocating movement of pump rods provides the necessary force to actuate generator **30** and to create the low pressure space with respect to the surrounding high pressure zones with further communication between them resulting in the implosive effect. This continued effect not only prevents clogging of the formation pores and fractures but is also sequence timed to assist fluid movement to the well surface. In one embodiment the implosive reaction pulse occurs during the upward pump stroke, however, this is not to be held limiting as the pulse can be initiated in the down stroke or on both strokes.

In reservoirs having substantial interstitial fluid pressures, the apparatus shown in FIGS. **3** and **4** may have its position inverted and be placed at a selected position in the well bore adjacent the productive formation. When used in this manner, implosion wave generator 30 may be caused to operate in a periodic manner from the sustained pressure of the reservoir fluids. Regulation of the pumping of this formation pressure induced implosive reaction operated pumping means may be controlled at the surface as desired by the amount of fluid allowed to escape from the well head.

By proper location of this formation pressure operated implosive reaction pump from the bottom of the well bore as compared to the casing or tubing to the well head at the surface so that even multiples of a quarter of a wave length or one of its harmonics may be allowed between wave generator **30** and the bottom of the well bore and to the top of the well bore, then standing wave conditions may be set up in the well bore that will assist the pressure energy of the formation in pumping fluids therefrom, as well as in assisting in the continuing operation of device **30.**

It is also possible to operate device **30** in the upright manner shown in FIGS. **3** and **4** as a pump actuated by sonic pulses or waves of any of the various types disclosed in my parental application Ser. No. 655,995, filed June 17, 1957, now U.S. Pat. No. 3,302,720, by placing apparatus **30** at a desired location in the well bore adjacent the productive formation wherein device **30** would be an assist in maintaining sonic wave energy in the well bore for pumping fluids from the formation.

WELL COMPLETION

A typical completion or workover of subsurface formations using the implosive pulse generator of this invention is illustrated in FIGS. **10** and **11.** Bullet or jet perforator **150** is fired from the surface or by timed sequence apparatus to provide openings **34** through casing **10** into formation **32.** Communication exists thereafter, for example, from the formation to central bore **54** of mandrel **56** through the perforator **150.**

Fracturing of the formation, if necessary or possible, occurs in many ways. For example, valve **40A** is placed in an inoperative position by placing sufficient tesion on spring **44,** shown in FIGS. **3** and **5,** so that the valve will not open at low fluid pressures above this valve **40A.** Generator **30** is actuated by pressure pulses in annulus fluid **15** from source **162** or which may be hydrostatic pressure. The implosive pulse plus the high pressure positive pulse reaches proportions sufficient to cause breakdown or rupture of the formation. In some instances incidental fracturing of the formation from the well bore occurs by the implosion effect. However, it is preferred to establish pressures in the space below generator **30** up to or near the formation breakdown pressure prior to initiating the implosive reaction pulse. Pressures sufficiently greater than the formation breakdown pressure are created to overcome the overburden pressure which is generally estimated as approximately equal in p.s.i. to the depth of the formation in feet.

As a further example of a fracturing procedure, valve **40A** in housing **50** is adapted to open at a predetermined pressure. The setting of that pressure occurs through adjustment of coupling **12A** being rotated with respect to threads **46** as described in FIGS. **3** and **5.** In the preferred embodiment the valve is regulated and pre-set to open when the implosive rarefaction pulse is initiated in the coupling or fracturing fluid existing below packer **96** and in tubular bore **54.** As the rarefaction pulse passes the lowermost portion of the mandrel an induced rarefaction wave is caused upward through the central bore creating a pressure differential across valve member **40A,** opening same and inducing a pulse of pressure fracturing liquid from storage **154.** The injection of such fluid in one embodiment is timed with the wave pulse directed toward the formation being treated to perform cancellation, reinforcement or augmentation of the induced wave pulses. The additional fluid or treating liquid in the wave pulse becomes useful as a makeup for fluids forced into the pores or fractures of the formation.

An even further procedure for rupturing or fracturing subsurface formations using apparatus of this invention includes use of rupture seal **130** and valve **40A** as illustrated in FIG. **5.** When it is desired to use large

quantities of fracturing fluid after initiation of the fracture using implosive pulse generator **30,** seal disc **130** is ruptured by pressure or go-devil **132.** Pump or pumps **160** thereafter force additional fracturing fluid from storage **154** into the well to expand the fracture with or without simultaneous implosive pulses.

Although fracturing fluids have been particularly described above, this is not limiting as other well treating fluids such as acids, solvents, etc., stored in container **156** may also be used in the completion or workover of wells in conjunction with the implosive pulse generator **30.**

As a further example of use of the apparatus particularly described in FIGS. **10** and **11,** after perforating and fracturing, a drill stem test of reservoir **32** can occur by rupture of seal disc **130** of valve **40A** permitting fluids to enter tubing **11** for measurement. In the event productivity is insufficient for producing the formation, or water encountered, a still further embodiment includes pumping or squeezing of sealing materials such as cement into the formation using a pump **160** and sealing materials from storage, e.g., **158,** in a manner well known to those skilled in the art. In some uses no more pressure is necessary than the hydrostatic head of cement within tubing **11** to effect operation.

Accordingly, it can be appreciated that this invention concerns apparatus which is capable of a multiplicity of separate well treating or completing operations assisted by implosive reaction pulses and the resultant energy therefrom. Typically, operation of generator **30** requires a separate power source **162** connected to the annular space and cylinder space **63.** As heretofore explained, this may be a sonic generator, pump or compressor. In that instance where generator **162** is a sonic generator and is adapted to maintain a sonic standing wave to cause actuation of implosive pulse generator **30,** it would be preferable to place the implosive pulse generator at a predetermined distance from the formation to be treated so that the distance therebetween can be acoustically coupled to a multiple of a quarter wave length of the sonic standing wave being created and/or maintained in the fluid above the implosive pulse generator **30** thereby causing reinforcement and augmentation of the implosion and their resultant reaction within the formation or at the face thereof by reflection.

The sonic generator **162** may impose on the produced sonic standing wave various modulations whereby the characteristics of the sonic standing wave actuating the implosive generator **30** may be extremely variable as to individual waves out of several composing the sonic standing waves. These periodic sonic waves actuating the implosive pulse generator **30** may be extremely variable as to individual waves in that they may have either variations of time and extent of the rarefaction or low pressure portion, or abruptness and shortness of time interval wherein vast pressure peaks may be imposed on the pressure portion, or at various phase angles of individual waves composing the periodic actuating sonic wave. Accordingly, implosive pulse generator **30** may have a predetermined setting given to its tripping means or member **116** in order that groups of the sonic waves from generator **162** that are substantially uniform or sinusoidal portion as to its rarefaction and compression portions thereof will cause the implosion device to be ineffective in operation and thus to serve merely as a transferring or transducing means for imposing sonic standing waves into the face of and within the interstices of the formation. When the modulations are imposed by the sonic generator **162** upon the periodic sonic standing wave actuating the implosive pulse generator **30,** so that waves of large magnitude of non-uniformity or non-symmetry of rarefaction and compression portions occur as previously taught, then the implosive pulse generator will actuate to produce periodic implosion reactions on the sonic standing wave resonating at the face of and within the formation. Accordingly, the modulations produced by sonic generator **162** will be greatly enhanced, augmented, and amplified in being transferred through the implosive pulse generator **30.** It is understood that the use of periodic sonic waves to actuate and enhance implosive pulse reactions as taught herein and in the above application and patents is applicable to the various methods taught in this application for uses of implosions including formation fracturing, fluid injection and producing methods as well as providing the pumping means for reservoir fluids of low vapor pressure with the lifting force being the type of modulations used on the pressure fluids maintained between the implosive pulse generator **30** and sonic generator **162.**

When the various methods and means of my prior parental application Ser. No. 665,995 filed June 17, 1957, now U.S. Pat. No. 3,302,720, are used as the sonic generator **162** to operate bottom hole device **30,** among several advantages as to the many uses listed in this application as to the combined use are the following:

It has been found during many years of use of various sonic wave methods and processes of treating subsurface formations that many productive formations have not sufficient interstitial fluid pressure and/or tightness of low enough permeability of the formation to sustain enough fluid pressure back onto a sonic wave generator operating at the surface so that enough intensity of sonic wave may be generated, unless relatively great amounts of fluids must be introduced through the sonic wave generator and into the well bore so that a highly pressured acoustic coupling may be maintained between the sonic wave generator and the formation.

Various pumping means have been attempted to be used in conjunction with the sonic wave generators in order to sustain high pressures upon the well heads, but it has been found that where the fluids were introduced apart from the sonic wave generator, the sonic waves had disruptive effects upon the pumping means and the pumping means often interfered with the desired output of the type of sonic wave from the sonic wave generator to the formation. In order to correct this, the fluids were introduced into the sonic wave at its point of generation in the sonic wave generator. Although this was extremely successful in operation in many formation treating methods and processes, the many variabilities of formations, even those in the same field or formation, varied the amount of fluid that was required to be pumped into the well bore in order to maintain a pressured fluid upon the sonic generator for it to generate the desired sonic wave intensity. This varying of the amount of fluid being introduced into the sonic wave at its moment of generation caused, where a piston type oscillator was the sonic wave generating means, an effective increase of lengthening of the stroke of the oscillator with an increase of input of fluid into the generated sonic wave. In order to be able to treat the extreme variability of formations found from well to well and from field to field, it was necessary to

have the sonic wave generator variably controllable as to its length of stroke, the accelerations available during said stroke, the control of amounts and pressures of inputing fluids into and through the sonic wave oscillator, and means to balance out the vibrations and pressures imposed upon the system by the sonic wave oscillators, among other things.

By use of device **30** in conjunction with my above described sonic wave generators, the control of the amounts of fluids desired to be introduced into a productive reservoir or formation can be selectively set prior to its introduction into a well bore by the adjustment of the compression of spring member **44** against valve means **40** or **40A** as shown in FIGS. **3** and **5.** By this means, device **30** may be moved from well to well in a particular field and a formation of substantially the same depth may be treated with about the same volume of fluid being introduced into each of the wells during a treatment of the same time period by a presetting of the opening pressure of valve means **40** or **40A.** Thus, considerable of the variability of controls required in the operation of sonic wave generator **162** may be eliminated and device **30** may be a transference as well as a modulating and intensifying means for the various forms of sonic or energy carrying wave or waves from sonic wave generator **162.**

In various treating and secondary recovery methods and processes wherein fluids in liquid form are imposed upon the deeper formations through well bores which often may be several miles in depth there is relatively enormous potential energy in the well bore adjacent the productive formation that may be effectively utilized by the combined use of the device **30** of this application and the methods and processes of my parental application Ser. No. 665,995 filed June 17, 1957, now U.S. Pat. No. 3,302,720.

This potential energy may be utilized by alternately applying or transforming its pressure force into an alternate implosive rarefaction and resultant reactive pressure shock wave which may be, if desired, combined with various forms of sonic pulses or periodic waves by varying as desired the effective area of piston means **70** relative to that of the effective area of piston means or member **96,** and the proper compression settings of spring compression means **80** and **98** as of FIG. **4** and applying to device **30** the controlling sonic pulse or waves from sonic generator **162** at the surface or well head. By proper matching of areas of piston means **70** and **96** relatively low pressures of formation fluids may be matched to high bottom hole pressures through device **30** and an acoustic coupling maintained therethrough so that a relatively high pressured small area of intense sonic wave may be transferred and transformed across into an effective larger area of sonic wave or waves that will be capable of allowing the gases contained in the fluids of the formation to come into and out of solution with the liquids so that effective treating of formations or driving of desired recoverable fluids from formations may be accomplished by being able to localize the sonic energy at the area upon which it is desired to be effectively used.

In regard to the last above, wherein it has been learned by considerable field experience that to effectively treat or drive fluids from formations that it is necessary to have a change of medium at the face of or in the formation at the areas in which the sonic wave energy is desired to be utilized. Where liquid is the acoustic coupling means between the sonic wave generating means and the formation, it has been found best to use some form of gas as a receiving or localizing station or means. However, where the gas is liquefiable or is miscible or absorbable with the liquids of the formation at the pressures imposed thereon by treating or drive fluids, then in order to localize or cause reception of the sonic wave energy at the area desired it is necessary that the sonic wave energy have rarefactions of sufficient extent as by implosions or rarefied portions of the wave or waves, so that the gas may come out of solution and effectively release its work effect whether as in fracturing of formations or in pulling oil from interstices of formations. To exceed those pressures wherein gas may remain liquefied or always in solution allows sonic wave energy to travel past areas upon which it is desired to localize its energy and continues out into the formation until the sonic wave energy is attenuated at various receiving boundaries.

In undersaturated oil and gas containing formations wherein it is desired to utilize sonic wave energy in the various methods and processes taught in this application, it has been found that gas, preferably in a liquefied form, must be introduced to the area whereupon sonic wave energy is to be utilized. When this has been done by surface sonic wave generators as depicted by **162** of FIG. **11** of this application or of any of the sonic wave generators of my prior parental application Ser. No. 665,995, filed June 17, 1957, now U.S. Pat. No. 3,302,720, it has been found that gas being released from the formation comes back up the well bore, particularly so during treating operations such as fracturing, so that it collects at the well head and, unless it is continuously bled off, enough gas may accumulate so that interference with sonic wave transmission to the formation from sonic wave generator may result.

Also attempting to introduce gas in its liquefiable form or as a miscible or absorbable agent in the treating of drive fluids at the surface along with the generation of sonic wave energy causes considerable problems such as the proper pressures to hold on the well head relative to the adjusted formation pressure surrounding the well bore at the bottom of the bore. By the proper use of bottom hole device **30** along with surface sonic wave generators **162,** gas may be introduced either intermittently or continuously as desired or dictated by formation conditions and the control of the amounts of gas and type thereof may be varied at will without interference with sonic wave transmission and control from the surface sonic wave generator **162.** In such use of device **30** it would be preferable to replace upper swab cup **60** with a fixed packer to retain gas therebelow. By referring to FIG. **11** it may be seen that heat may also be introduced at or adjacent the formation, either in the form of heated vapors or liquids of various types and these introduced into the sonic waves during the rarefactions of the implosions or even of sonic waves transferred and transformed across device **30** and thus be compressed into the implosive reaction or the compression portions of the sonic waves going into the formation.

As a further embodiment of this invention wire line apparatus constructed according to that illustrated in FIGS. **13** and **14** is of particular utility in completing wells where smaller quantities of treating fluids such as acids, emulsions and corrosion inhibitors, etc., are adequate.

In operation, the treating fluids are placed in chamber **220** above valved piston **238.** This is ordinarily

done at the surface with threaded member **200** and free piston **216** removed from the barrel **202.** Barrel **202** is of sufficient length to provide the required volume of space **220** for treatment of the well; lengths up to several hundred feet or more for deep wells are taught.

In some instances valve piston **218** is removed, filling barrel **202** including chambers **220** and **226** with treating fluids above valve **40** in housing **50,** which ordinarily attaches at lower threads **214.** Usually the back-off safety joint **138** and implosive pulse generator **30** are below housing **50.** Valved piston **218** or free piston **216** is placed on top of the treating fluid for isolation between batches of other treating fluids or well fluids acting through passage **206** and chamber **208** under hydrostatic pressure head. This latter pressure assists the entrance of treating fluid at predetermined phases of implosive reaction, usually the compression pulse through valve **40** into the producing formation.

If solid free piston **216** is used atop the treating fluids within chambers **220** and **226,** treating fluid entry ceases when the piston strikes stop orifice **244.** In many treating operations, however, it is necessary to follow one batch of treating fluid with a follower fluid. In that event valved piston **218** is placed atop the initial treating fluid with the follower treating fluid thereabove. In some instances one or more follower fluids are to be injected into the formation and this would necessitate additional valved piston members **218.** Atop the last of these treating fluids solid free piston member **216** is used for isolation from the annular fluids. In operation with valve piston device **218,** movement of the treating fluid into the formation occurs until piston **218** strikes stop orifice **244** as shown in the dotted line. Further pressure in the follower treating solution above forces the piston portion **238** from its seat **228** permitting fluid entry through orifices **242, 250** and/or **246** of the stop orifice. The follower treating fluid batches continue their injection until solid piston device **216** strikes valved piston **218.** In some instances it is desirable to follow the treating fluids with fluid from well space **15.** This is accomplished by utilizing valved piston device **218** as the top piston member.

In some well treating operations heating of the treatment fluids prior to their entrance to the formation is desired. Accordingly, a heating chamber **226** may be provided as shown attached to the lower portion of barrel **202.** Electrical conduit **254** supplies electricity to a resistance type heating coil or coils **252** such as that sold under the trademark CALROD which has an erosive and corrosion protected and insulated cover. Although it has been found that the implosive pulse generator **30** in itself creates heat energy which is capable of being utilized in the formation, the heating chamber **226** adds additional heat energy into a desired phase angle portion of the compressive pulse resulting from the implosive reaction. This heating chamber **226** and coils **252** as described above may also be used above valve **40A** where attachment means **12A** of FIG. **5** is used for connecting apparatus **30** to the surface in order to introduce therein fluids for treating formation **32.** In this manner heated fluids are directly introduced into the compression or high pressure pulse that follows the rarefied pulse of the implosive reaction into the formation and upon attenuation of the pulses out of the formation this heat will be deposited therein for beneficial effects.

In addition to use as a wireline treating fluid injection chamber, the apparatus described in FIGS. **13** and **14** is also capable of use with the implosive pulse generator **30** of this invention in combination with cement squeezing or plugging operations to seal off production of undesired fluids, patching leaks in casing, etc., at a minimum of trouble and expense.

SECONDARY RECOVERY

It has been found that in many secondary recovery projects, e.g., water drive from an injection well to a producing well implosive reaction pulses can assist removal of oil trapped in minute pore spaces. Accordingly, the apparatus taught according to this invention has further application by placement within an injection well or alternately in both injection well and producing wells. In the latter instance, it is highly possible to cause cyclic pulsation through the formation by proper timing of the implosive pulse generators. For such use the producing well apparatus would provide means for lifting the fluids from the well to the surface.

It is entirely within the purview of this invention that in gas drive or underground combustion recovery techniques that implosive reaction pulses generated in accordance with this invention be utilized to assist gas flow or maintain combustion within the formation respectively.

Although I have described the apparatus of this invention as a removable type apparatus, i.e., using tubing or wireline, the apparatus is also capable of being permanently anchored or formed as a part of a permanent well completion apparatus capable of being placed into use at the demand of the operator. Accordingly, anchor slips may be formed as a part of the apparatus, as is well known to those skilled in the art. In that event the upper packing member **60** is usually retained in a permanently sealed position. As heretofore described, a separate source of high pressure fluid is introduced into the generator **30** to cause operation.

In still another embodiment wherein valve **40** is allowed to operate, the device **30** may be anchored at a particular location and fluids pumped through the device and thus cause an alternating series of the implosive reactions, this being similar to the occurrence when device **30** is pulled upward against fluid in a well, as in swabbing. That is, actuating fluids are pumped downward through annulus space **15** and thence through passageway **67** into cylinder space **68** against the top of sleeve or piston **74.** This will cause an implosive reaction as previously described which in turn permits periodic release of the pressure fluid existing above valve **40.** The periodic release of pressure fluid through valve **40** coincides with the frequency of the standing wave of the particular harmonic of the fundamental wave frequency in the fluid used below the generator unit **30.** Additionally, the particular harmonic is created in accordance with the length of the unit **30** from the bottom of the well and the reflected quarter of a wave therefrom.

SEISMIC EXPLORATION

In seismic exploration and prospecting, a great many methods have been devised for furnishing the vibrational signal for reflection or refraction from or through geological formations deep within the earth in order to determine the depth and the degree and direction of slope of subsurface strata.

Among these methods the use of explosives has been the most popular. However, in the use of explosives for providing the energy for seismic profile signaling, there

has been considerable disadvantages in their use particularly as to marine seismic prospecting wherein destruction has been caused to marine life.

Many other methods have been devised to eliminate the use of explosives in marine seismic profiling, among them being the use of electrical sparks, gas exploders, etc., but the use of some of these methods does not provide enough vibrational energy to where the deeper subsurface strata is delineated or profiled as to its depths and contour.

By the proper use of implosions and the reactive implosive pulses seismic vibrational signals may be produced that will approach in strength those produced by explosives and these deeper strata may be profiled with less expense and destruction to the surroundings in which the seismic signaling is done as compared to the use of explosives.

In the use of implosion wave generator **30** of FIG. **4**, outer casing **10** may be towed behind a ship at a preselected depth in water and with device **30** anchored at a fixed position in the casing, the pressure of the water upon device **30** producing implosions and resultant implosive reactions whose sonic or vibrational energy would penetrate the earth to which the sea water was acoustically coupled and the seismic signals reflected from or refracted through the various subsurface strata could be detected and recorded by geophones towed behind the boat at various locations, as in conventional marine seismic profiling.

If it was desired to provide a continuous implosive wave marine seismic profiler that could utilize certain proportions of the implosive pulses for assisting in creating other implosions, then device **30** could be located at a proper location within casing **10**, which could be the center, and at certain towing speeds reflective pulses of a multiple of a quarter of a wave length or one of its harmonics of the two lengths of the pipe on either side of device **30** would set up standing wave conditions that would assist in continuing the implosive pulses within close tolerances as to periodic frequencies.

As an operating means, if desired, the forward end of casing **10** could be closed and have attached thereto liquid and sonic wave supplying means **162** and the actuation of the implosions could be sonic waves of any desired type and the implosions could be a modulating and intensifying means to the actuating sonic waves.

In location with enough water depth, casing **10** with device **30** therein could be vertically suspended from the ship or other buoyant member and actuation of the implosive reaction generator **30** could be by repeated lift ups and drops of the device within casing **10**, or the operation could be by connection to sonic generator **162** as described above in relation to towing the casing and its device in a substantially horizontal plane.

The above described use of implosions in marine seismic profiling is not meant to limit the use of implosions to marine use, for implosions could be used for onshore use by various means, such as enclosing the bottom of casing **10** with a heavy plate which would acoustically couple to the earth and thus send vibrational energy waves into the earth for use in seismic profiling.

Such a use of acoustically coupling a heavy casing member **10** to the earth and sending seismic signals into the earth as of many of the various types of sonic or energy carrying waves that may be produced from the sonic wave generators as are disclosed in my parental application Ser. No. 665,995, filed June 17, 1957 now U.S. Pat. No. 3,302,720, of which this application has a continuation-in-part effect, was tested in the use of a small pilot model of the apparatus as shown in parent application Ser. No. 296,038 filed June 27, 1952, now U.S. Pat. No. 2,866,509 before several individuals, among them being petroleum and reservoir engineers, wherein it was seen that with the casing member **10** being located some 60 feet away from the sonic wave generating apparatus means, vibrational signals could be detected coming from the heavy casing member **10** for a considerable distance.

Further, it was found where sonic standing wave conditions of its fundamental wave length or one of its harmonics was imposed on the system and then a controlled modulation of one resonating sonic wave out of a great many resonating waves was caused to be intermittently applied to the system by the sonic wave generating apparatus, the resultant intense vibrational shock wave which could be clearly detected from the other sonic waves resonating through the earth could be received at a much further distance than could the main body of the sonic waves resonating through the earth. It was also determined that the greater seismic signaling effect was obtained where sonic wave energy was allowed to build up and accumulate in the system for a controlled period of time and then one wave had sonic wave energy and fluid withdrawn in a cavitational or implosive effect during the rarefaction portion of only the one wave cycle and the more substantially instantaneous and the greater the amount of cavitational or implosive effect the greater and more far reaching the resultant reactive shock wave vibrational seismic signaling.

Several months of experimentation was conducted with electronic timing instrumentation with the use of the above various types of modulated sonic and vibrational waves as to their velocity or time travel through various fluids wherein a particular recognizable type of modulated wave was timed at its creation moment in the sonic wave generating apparatus, timed as to its reflection time interval from the end of the casing **10** approximately 60 feet away through various types of fluids such as water, crude oil, various amounts of gases that were miscible or absorbable in the water or the oil, which gases could be caused to come in and out of the liquids during rarefactions of the resonating sonic waves and/or during rarefactions or cavitations of the one sonic wave being modulated out of the many sonic waves resonating in the system.

Also tested, as above, was the time interval between the moment of creation of a particular type of modulated sonic or vibrational wave, as was recognizable by the phase angle at which it being modulated on the one sonic wave out of the many sonic waves whose energy was being accumulated in the system, and its reflection back through external lines containing various fluids including liquefiable gases of equal lengths with that which connected casing **10** with the sonic wave generating means **162**.

Some of the findings of the considerable experimentation was that a certain type or form of intense modulated sonic or vibrational wave could be easily recognized from the other sonic or vibrational waves and timed as to amount of length that the modulated wave traveled through a particular type of fluid. It was found that water appeared to allow the greatest velocity of wave travel in the liquids tested and the slower velocity of wave travel through crude oil could be timed in its relationship to sonic wave travel through water. It was

also found that where gases were introduced into the liquids, as by use of carbon dioxide with water or mixtures of methane and propane with crude oil, that proportionately as the increase of gas introduced in proportion to the amount of liquid used in the fluid system up to the saturation point of the gas into the liquid at the pressure maintained on the system above atmospheric pressure, then proportionately as to the velocity of sonic wave travel through the particular gas used and the amount of its relationship to the amount of the liquid used the velocity of sonic waves would be slowed down in its time travel by that proprotionate amount. Thus it was found that where a particular liquid was the acoustic coupling means from a sonic generating means **162** to the end of a casing or member **10** and a peculiar or particular type of sonic or vibrational wave is created by modulating one wave from built up or accumulating sonic standing wave energy of a great many waves, then this one wave may be recorded at its moment of creation, go through the many wave lengths of the prime fundamental or one of its harmonics that is resonating under standing wave conditions between sonic wave generator **162** and the bottom end of casing **10,** be reflected back through and on the standing waves to its source at **162** and be timed as to its travel from creation to reflection point and return.

Thus, by the above, as is well known, where the depth of the well bore of casing **10** is unknown it may be readily ascertained, where the velocity of sound in the particular liquid being used is known, by the recorded elapsed time between the time of creation of the modulated wave and its return.

When the large field model sonic wave generating apparatus as depicted in my co-pending application Ser. No. 406,045 filed Oct. 12, 1973 which is a continuing development of the small apparatus discussed as to its use in 1952, was placed into use in 1956 on waterflood injection wells and for fracture treating of productive formations considerable of the findings of experimentations of 1952 were substantiated in the field, as follows:

When the sonic generating apparatus **162** as of Ser. No. 406,045 filed Oct. 12, 1973 was placed upon an injection well and operated several hours with the use of sonic waves resonating in the well bore under standing wave conditions with the controllable modulation of one wave out of many sonic waves that were adding energy to the system, reflections of the modulated wave could be detected coming back onto sonic wave generator **162.** With the continued use of sonic wave generator **162** with the modulation of the sonic wave being of a type created by heavy cavitational or implosive effects which by proper control were able to gather up by-passed by the waterflood oil and gas in the formation, then there would gradually begin a heavier reflection of the modulated wave from the formation until a level of detectable reflected wave energy would be obtained which would continue until shut down of the wave generator **162.** It could be noted and detected that there were two reflections coming back to the well head, one a substantially uniform one that began after starting use of the modulated sonic waves in the well bore and another a later arriving in time reflected wave that increased to a heavy beat as the reflecting wall of gas and oil in the formation was built up. Thus recording means could not only record the distance to the bottom of the well bore but it could also delineate and give the underground distance to the progressing oil and gas front upon which the waterflood was pushing.

It was also found that the modulating sonic wave beats could be detected at some of the production wells, particularly those where water had broken through. Where a production well was gasing heavily the modulated sonic wave beat would be totally undetectable, showing that the gas in the interstices of the formation was reflecting or attenuating the sonic or vibrational wave energy. Those wells producing oil with very little free gas allowed a faintly detectable beat at the well head from the modulated sonic wave in the drive water to be recognized as coming through the banked up oil and gas front in the formation.

Later, in early 1957, when an oil producing well was being fractured and treated by the modulated sonic waves of the apparatus **162** as of Ser. No. 406,045 filed Oct. 12, 1973, and oil was used as the treating fluid, it was noticed that stronger beats were discernable and detectable at the well heads of offset oil producing wells then had been the case where the apparatus **162** was used on a water injection well and the change of sonic wave transmitting medium, as at the banked up oil and gas front, was between the well inputting the sonic waves and a well receiving seismic signals.

It could be seen from the above discussed results and observations that by acoustically coupling a sonic wave generator to a fluid containing formation, preferably liquid, that a change of medium or type of fluid could cause a change of signal strength in the different types of fluid mediums, or at a discontinuance thereof, so that geophones or like sensitive instruments for detecting and recording seismic signals could be used in contact with the earth at varying locations surrounding the well into which the sonic waves were being input and delineation or profiling of boundaries of fluids or fluid containing formations could be recorded and outlined as to their extent.

It was also obvious that the above methods and processes of outlining and profiling of various bodies or formations containing fluids as to the types or extent of the fluids as known by the seismic signal strength received and velocity or time travel between the recognizable seismic vibrational beats in different areas of the earth above the formation and/or between varying locations on the earth and the time at which the seismic signal was sent from the seismic signal source, all of which signals could be recorded on graphs for use as desired, could also be used to profile the subsurface contours of the fluid containing formations or surrounding formations or strata, by the seismic signals and/or the reflections or refractions therefrom received at varying locations on the earth or water above, as for instance by measurement of the distance between beats of the seismic signals received from a like seismic vibrational wave transmitting medium.

Thus it is possible to profile, delineate and outline substantially the extent of fluid containing reservoirs, the approximate boundaries of various types or mixtures of fluids contained in the reservoirs, as well as the subsurface contours of the fluid containing formations or the strata surrounding said fluid containing formations, with access being given to a fluid containing subsurface formation, preferably liquid, to which a seismic signaling means or apparatus may be acoustically coupled.

When the seismic vibrational wave signaling device is set at the surface as of **162** of FIG. **11,** it may be any type or of sonic wave generator as described in detail in my co-pending application Ser. No. 406,045 filed Oct.

12, 1973, that produce a pulse, periodic wave or modulated sonic wave and, if desired, device **30** of this application may be located adjacent the fluid containing formation and used in conjunction with apparatus **162** whereby any of the types of sonic waves from **162** may be the actuating means for operation of device **30** which may be a transforming, transferring, intensifying or modulating means for the sonic waves from generator **162.**

On the other hand, if desired, or if it be dictated by conditions, device **30** may be the sole source of seismic vibrational signaling and be actuated by any of the other means disclosed in this application.

Thus it may be seen that extremely vital and valuable information may be obtained by use of the various seismic signaling, profiling and recording methods and processes disclosed in this application and, if desired, this seismic delineating and profiling information may be secured, recorded and retained during sonic wave secondary recovery or formation treating operations with no necessity of halting or delaying these operations to obtain the desired seismic outlining or profiling data as the seismic vibrational signals used to obtain the data would be side effects or sonic wave vibrational energy being attenuated during the sonic wave fluid recovery or formation treating methods or processes.

It may also be discerned that among the various methods and processes described hereinbefore of the use of implosions or substantially instantaneously produced rarefactions in that portion of the well bore packed off from the rest of the bore, but in communication with the fluid containing subsurface formation, as a source of energy for seismic signaling, may be those field tested methods hereinabove described wherein a substantially instantaneous rarefaction or cavitation is imposed on a sonic wave and in so being utilized will form a modulated rarefaction or implosion of variable characteristics by varying the phase angle of use of the rarefaction impulse in its relationship to the rarefaction portion of the sonic wave as disclosed and described in considerable detail in my co-pending application Ser. No. 406,045 filed Oct. 12, 1973 with established continuity being maintained therein from my original parent application Ser. No. 241,647 filed Aug. 13, 1951 now U.S. Pat. No. 2,796,129.

There are considerable advantages and improvement in the last above cited methods and processes of the use of rarefaction impulses or implosions for seismic signaling, besides the already enumerated one as to the ability to be able to produce sources of seismic energy of variable characteristics so that the recorded seismic signals at adjacent well bores, at the surface surrounding the well bore or back upon the well bore from which the seismic energy originates within the packed off section of the well bore may have recognizable recordings so that the arrival times of the recorded signals may be concisely known and the location or presence is shown of various types of fluids or formations in the area surrounding the well bore in which the rarefactions or implosions are produced.

In the use of these advances found to be of proven worth in considerable field testing of the use of surging from fluids of subsurface formations into created rarefactions within packed off portions of subsurface well bores as a source of seismic energy, it has been found that the energy from these created implosions or rarefractions decreases outward from the well bore, so that where fluids or formations are at large subsurface distances from the rarefaction source of these seismic signals in the fluids within the lower packed off portion of the well bores they often will not record as proficiently as would be desired at the receiving station or stations.

It has been found in numerous instances of use that where a sonic wave or one of its harmonics was allowed to assume a standing wave or resonant condition within the fluid in the packed off portion of the well bore and in the fluid containing formation in communication therewith, that the variably phased cavitations or rarefactions impressed as a modulation thereon would travel to great distances within certain types of fluids in the fluid containing subsurface formation and become a source of seismic energy which could be utilized and recorded as seismic signals to delineate the extent, location or presence of various types of subsurface fluids or strata. Any desired use of one or more of these implosions or rarefactions and any desired intervals of timing of the phase angle impressing of one or more of these modulations upon the transporting sonic wave into the fluids within the lower packed off portion of the well bore allows corresponding recognizable characteristics of recorded seismic signal at the receiving station or stations.

What I claim is:

1. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation while providing controllable communication through tubing between said fluid containing formation and a wellhead at the surface of said well bore,

thereafter creating substantially instantaneously at least once a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation but beneath said controlled communication in said tubing, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation.

2. The method of claim **1** wherein said well bore has a casing or liner which is cemented through said fluid containing subsurface formation, comprising the additional step of packing off said cemented casing or liner above said fluid containing formation,

providing communication between said lower packed off portion of said well bore and said fluid containing formation by perforating through said casing or liner.

3. The method of claim **2** including testing the production of fluid from said subsurface formation through said tubing having controlled communication with said wellhead at the top of said well bore.

4. The method of claim **3** inlcuding testing the production of fluid from said subsurface formation, and

cementing or plugging through said tubing from said wellhead perforations producing undesired fluids.

5. The method of claim **1** including following said negative pulse or surge of fluid from said subsurface formation into said packed off portion of said well bore by an injection of fluid into said fluid containing formation through said tubing having controlled communica-

tion with said wellhead at the top of said well bore.

6. The method of claim 5 wherein said injected fluid is inclusive of gases, solvents or emulsions.

7. The method of claim 5 wherein said injected fluid is a gas or solvent.

8. The method of claim 5 including thereafter testing production of fluid from said subsurface formation through said tubing having controlled communication with said wellhead at the top of said well bore.

9. The method of claim 1 wherein said fluid containing formation is fractured by establishing formation fluid pressures up to or near the formation breakdown pressure in said packed off lower portion of said well bore which is in communication with said fluid containing formation prior to said creating of said negative pulse or low pressure void by the injecting of fluids at said wellhead through said tubing having controlled communication with said fluid containing formation.

10. The method of claim 9 wherein said established formation fluid pressures have included therein gases.

11. The method of claim 9 wherein said formation fluid pressures are created by pressurized gases, solvents or emulsions.

12. The method of claim 9 including the further step of injecting additional fracturing fluids into said formation following said negative pulse or surge of fluid from said subsurface formation into said lower packed off portion of said well bore through said tubing from said wellhead.

13. The method of claim 12 wherein said additionally injected fluid is inclusive of gases, solvents or emulsions.

14. The method of claim 12 wherein said additionally injected fluid is a gas or solvent.

15. The method of claim 12 including thereafter testing production of fluid from said subsurface formation through said tubing having said controlled communication with said wellhead at the top of said well bore.

16. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said substrate formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

including following said negative pulse or surge of fluid from said subsurface formation into said packed off portion of said well bore by an injection of fluid into said fluid containing subsurface formation,

wherein said injected fluid is inclusive of an acidizing agent or corrosion inhibitor.

17. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said substrate formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

including following said negative pulse or surge of fluid from said subsurface formation into said packed off portion of said well bore by an injection of fluid into said fluid containing subsurface formation,

wherein said injected fluid is heated prior to its injection.

18. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

including following said negative pulse or surge of fluid from said subsurface formation into said packed off portion of said well bore by an injection of fluid into said fluid containing subsurface formation,

wherein said injected fluid is a formation cementing or plugging agent.

19. A method of well completion or workover of oil, gas or other fluid containing subsurface formation into which is well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

wherein said fluid containing formation is fractured by establishing formation fluid pressure up to or near the formation breakdown pressure in said packed off lower portion of said well bore which is in communication with said fluid containing formation prior to said creating of said negative pulse or low pressure void,

including the further step of injecting additional fracturing fluids into said formation following said negative pulse or surge of fluid from said subsurface formation into said lower packed off portion of said well bore,

wherein said additional fracturing fluids are inclusive of an acidizing agent.

20. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

wherein said fluid containing formation is fractured by establishing formation fluid pressure up to or near the formation breakdown pressure in said packed off lower portion of said well bore which is in communication with said fluid containing formation prior to said creating of said negative pulse or low pressure void,

including the further step of injecting additional fracturing fluids into said formation following said negative pulse or surge of fluid from said subsurface formation into said lower packed off portion of said well bore, and

thereafter testing production of fluid from said subsurface formation, and

following said testing by cementing or plugging off undesired fluid production from said fluid containing formation.

21. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

including following said negative pulse or surge of fluid from said subsurface formation into said packed off portion of said well bore by an injection of fluid into said fluid containing subsurface formation,

thereafter testing production of fluid from said subsurface formation, and

following said testing by cementing or plugging off undesired fluid production from said fluid containing formation.

22. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

wherein said low pressure void or zone of rarefaction is occasioned by a sonic wave generator, pump or compressor operated by a separate power source which imposes sonic waves or an increase of fluid pressure upon fluid contained in said well bore above said packed off lower portion of said well bore which is in communication with said fluid containing formation.

23. The method of claim **22** wherein fluid contained in said well bore above said packed off portion thereof includes an acidizing agent and said operation by said separate power source allows the injection of said agent into said fluid containing formation following said creating of said negative pulse or surge of fluid from said subsurface formation.

24. The method of claim **22** wherein fluid contained in said well bore above said packed off portion thereof includes or consists of gases or solvents and said operation by said separate power source allows the injection of said fluid into said fluid containing formation following said creation of said negative pulse or surge of fluid from said subsurface formation.

25. The method of claim **22** wherein fluid contained in said well bore above said packed off portion thereof is a formation pressuring fluid and said operation by said separate power source allows the injection of said formation pressuring fluid into said subsurface formation following said creation of said negative pulse or surge of fluid from said formation.

26. The method of claim **22** including thereafter testing production of fluid from said subsurface formation.

27. The method of claim **22** including thereafter testing production of fluid from said subsurface formation, and following said testing by cementing or plugging off undesired fluid production from said fluid containing formation.

28. The method of claim **22** wherein said fluid containing formation is fractured by establishing formation fluid pressures up to or near the formation breakdown pressure in said packed off lower portion of said well bore which is in communication with said fluid containing formation prior to said creating of said negative pulse or low pressure void.

29. The method of claim **28** including the further step of injecting additional fracturing fluids into said formation following said negative pulse or surge of fluid from said subsurface formation into said lower packed off portion of said well bore.

30. The method of claim **29** including thereafter testing production of fluid from said subsurface formation.

31. The method of claim 29 including thereafter testing production of fluid from said subsurface formation, and

following said testing by cementing or plugging off undesired fluid production from said fluid containing formation.

32. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

wherein said creation of said low pressure void or zone of rarefaction becomes a source of seismic energy within said subsurface formation, and

wherein said source of seismic energy following its creation is recorded at adjacent well bores to indicate the type of fluid or formation existing between said source of seismic energy and said adjacent well bores.

33. The method of claim 32 wherein said low pressure void or zone of rarefaction is occasioned by a sonic wave generator, pump or compressor operated by a separate power source which imposes sonic waves or an increase of fluid pressure upon fluid contained in said well bore above said packed off lower portion of said well bore which is in communication with said fluid containing formation.

34. The method of claim 32 wherein said low pressure void or zone of rarefaction comprises a substantially instantaneous rarefaction or cavitational modulation imposed on a sonic wave in said fluid in said lower packed off portion of said well bore which is in communication with said fluid containing formation.

35. The method of claim 34 including varying the phase angle of said rarefaction or cavitational modulation in relation to said sonic wave, producing recognizable variations in said seismic energy recorded at said adjacent well bores.

36. A method of well completion or workover of oil, gas or other fluid containing subsurface formations into which a well bore has been drilled, which comprises the step of

packing off said fluid containing subsurface formation from said well bore which is above said subsurface formation,

thereafter creating substantially instantaneously a low pressure void or zone of rarefaction in that portion of the well bore which is in communication with said fluid containing subsurface formation, and

creating a negative fluid pulse or surge of fluid from said subsurface formation into said created low pressure void or zone of rarefaction in said packed off portion of said well bore that is in communication with said fluid containing formation,

wherein said creation of said low pressure void or zone of rarefaction becomes a source of seismic energy within said subsurface formation, and

wherein said source of seismic energy following its creation is recorded at the surface surrounding said well bore or at said well bore to indicate the type of fluid or formation existing in the subsurface formation.

37. The method of claim 36, wherein said low pressure void or zone of rarefaction is occasioned by a sonic wave generator, pump or compressor operated by a separate power source which imposes sonic waves or an increase of fluid pressure upon fluid contained in said well bore above said packed off lower portion of said well bore which is in communication with said fluid containing formation.

38. The method of claim 36 wherein said low pressure void or zone of rarefaction comprises a substantially instanaeous rarefraction or cavitational modulation imposed on a sonic wave in said fluid in said lower packed off portion of said well bore which is in communication with said fluid containing formation.

39. The method of claim 38 including varying the phase angle of said rarefaction or cavitational modulation in relation to said sonic wave, producing recognizable variations in said seismic energy recorded at said surface or at said well bore.

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