United States Patent

[11] 3,625,285

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[73] Assignee **Amoco Production Company Tulsa, Okla.**

[54] **STIMULATING WELLS WITH LIQUID EXPLOSIVES**

15 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **166/299,** 102/23
[51] **Int. Cl.** **E21b 43/26**
[50] **Field of Search** 166/299, 308, 63; 102/23, 22; 149/89

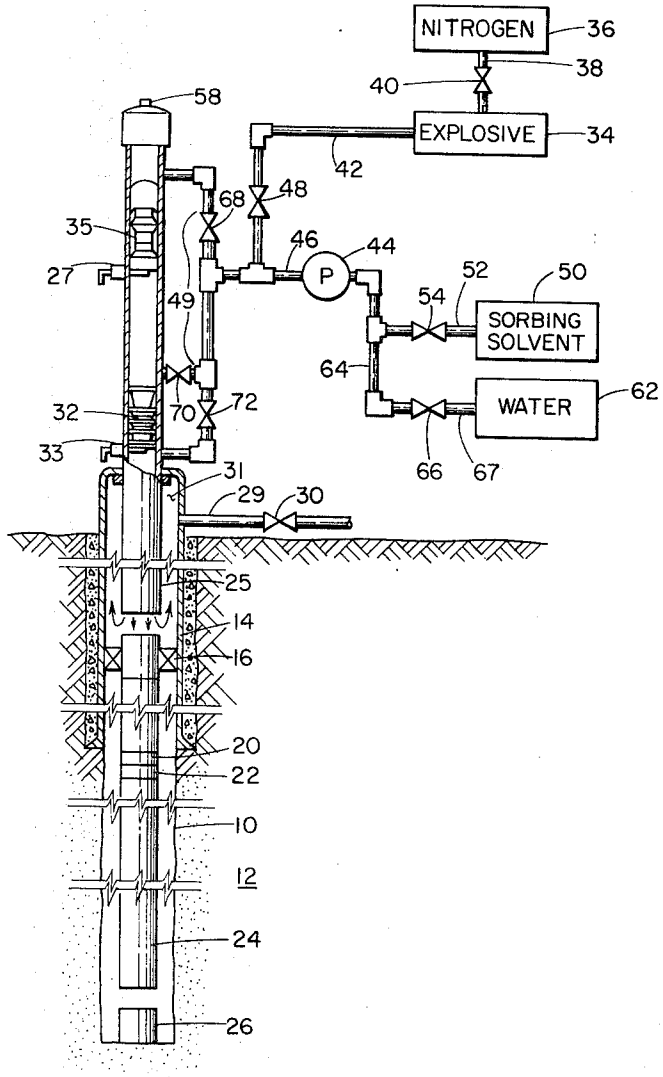
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ABSTRACT: This is a method for increasing the permeability of underground formations adjacent a well bore by explosive fracturing. This invention relates especially to a special method of placing the liquid explosive in the well. It includes setting a plugged packer in the well just above the formation to be stimulated. A tubing string is run in the well with the lower end just above the plugged packer. The selected amount of liquid explosive is then forced into the tubing string. After this, the tubing string is inserted in the packer and the plug of the packer is removed. The explosive is then forced downward into the well bore. The packer is replugged, tubing is removed and the well bore stemmed. The detonation is then effected.



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SHEET 1 OF 3

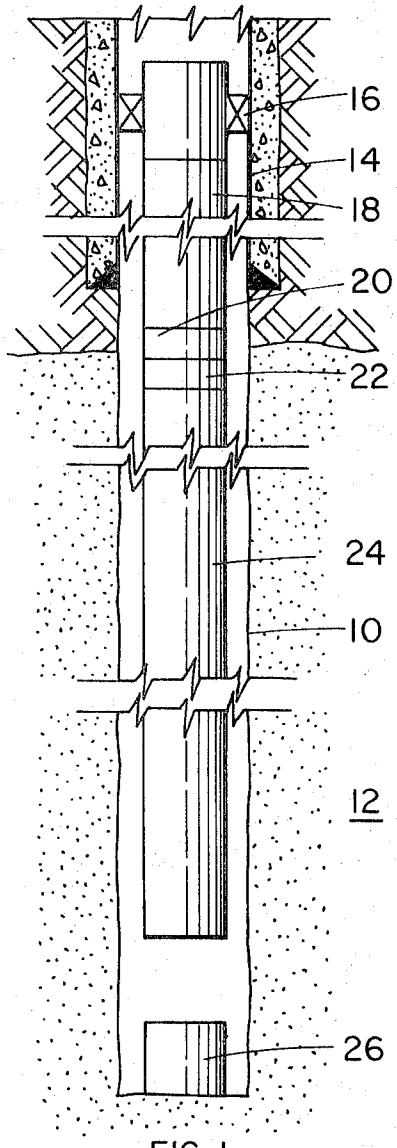


FIG. 1

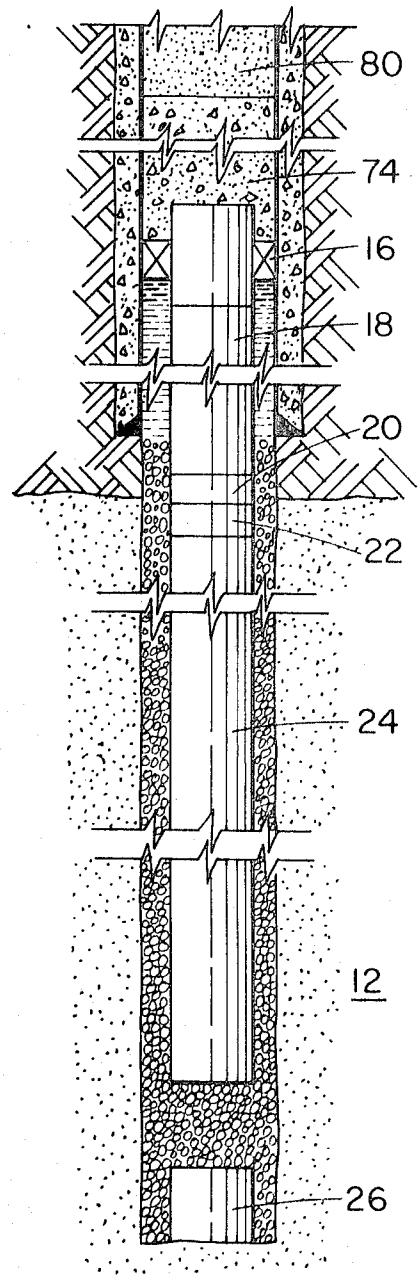


FIG. 3

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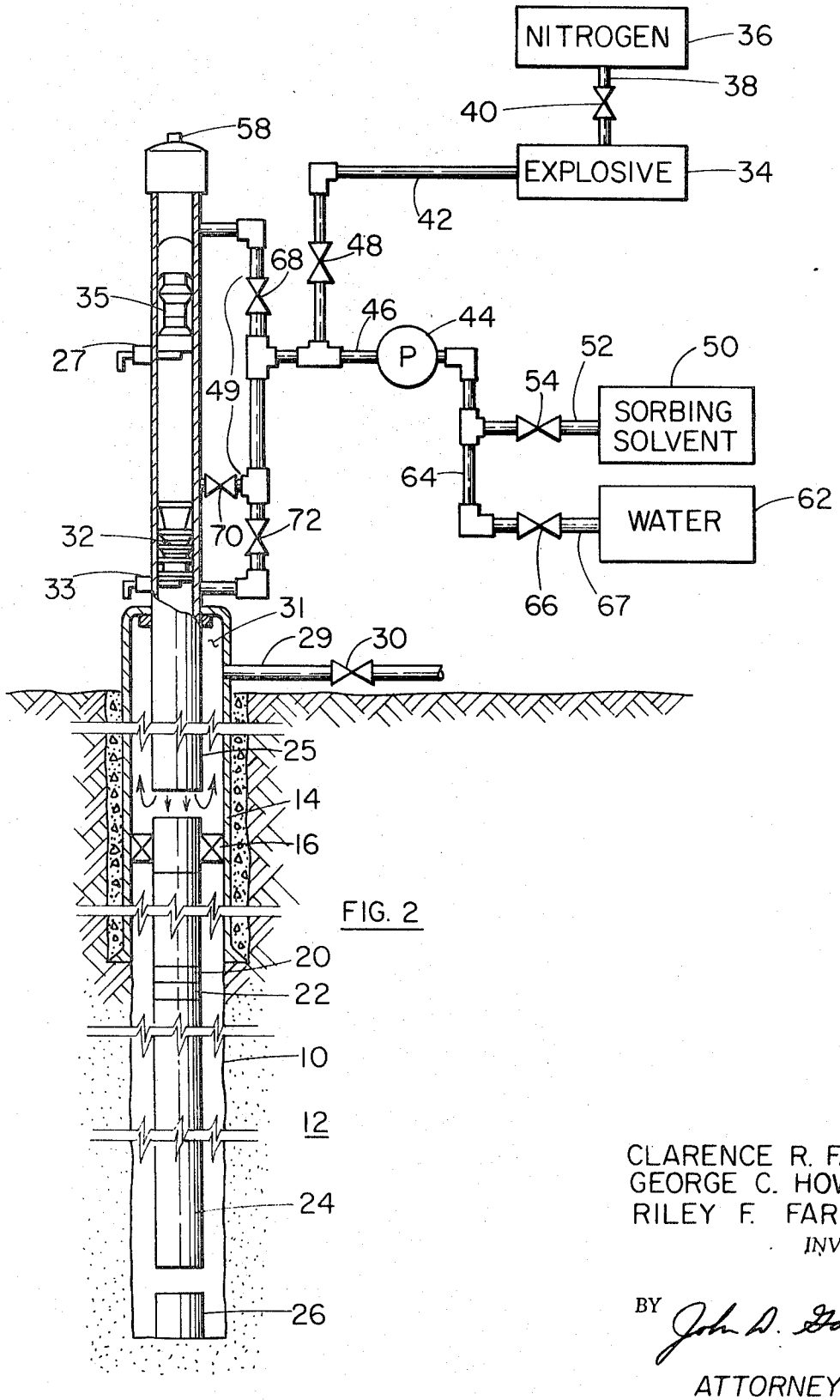


FIG. 2

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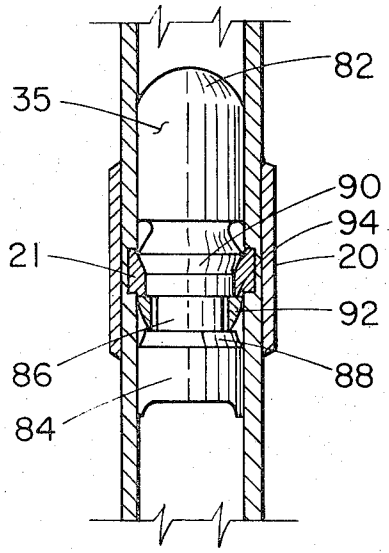


FIG. 4

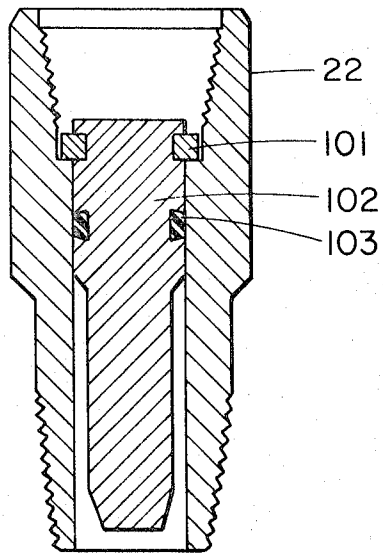


FIG. 5

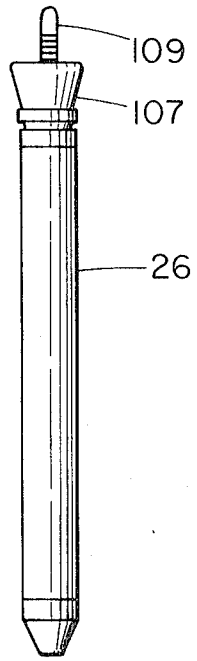


FIG. 6

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STIMULATING WELLS WITH LIQUID EXPLOSIVES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of increasing the permeability in a formation adjacent an oil and gas well which penetrates therethrough. It relates especially to a system of placing a liquid explosive in the well, subsequent detonation, and cleaning out operations to place the well on production.

2. Setting of the Invention

Many oil and gas wells are drilled into petroleum-bearing formations which have low permeability. That is, the formations are of a character that is difficult for the oil to be recovered; in other words, the formation is very reluctant to give up its petroleum. When such formation rocks are encountered, it becomes necessary to resort to one or more means to increase the permeability. One means which has been quite successful is the hydraulic fracturing technique. In this system a special hydraulic fracturing fluid is injected through the well bore adjacent to the formation. Fluid is continued to be pumped into the well bore so as to increase the pressure to the point where the formation is fractured. When this fracturing occurs there are usually propping agents left in the fractures so that the fractures will remain open, forming new paths for the oil to flow from the rock into the well bore. Frequently, this type stimulation does not result in desired production increases as it does not reach the unfractured matrix of the formation. Although hydraulic fracturing has permitted the production of billions of barrels of oil not heretofore recovered, there is still some room for improvement.

BRIEF DESCRIPTION OF THE INVENTION

A drillable packer is set in the well bore just above the formation to be fractured. The ordinary passage through the packer is plugged by a shear plug set in a shear plug sub beneath the packer. A string of tubing is run in the well with the lower end just above the packer. A liquid explosive is then forced into the tubing string until the desired amount is injected therein. At the same time liquid is removed from the annulus of the well. Next the tubing is connected into the packer and pressure applied to the liquid explosive to force the shear plug through the shear plug sub. The liquid explosive is then forced on downwardly into a well below the packer. The packer is replugged, the tubing removed and the well stemmed. After such stemming, the liquid explosive is detonated. The well is subsequently cleaned out and placed on production.

DESCRIPTION OF THE DRAWINGS

Various objectives and a better understanding of the invention can be had from the following description taken in conjunction with the drawings.

FIG. 1 is a vertical view partly in section and partly schematic of the lower part of a well penetrating an underground producing formation.

FIG. 2 is a vertical view partly in section and partly schematic of a well penetrating an underground producing formation and including means for injecting a liquid explosive in such well.

FIG. 3 is similar to FIG. 1 except it illustrates the well after liquid explosive has been placed therein.

FIG. 4 is a cross section showing details of a fill-up collar and a plug latched therein.

FIG. 5 is a cross section of a shear plug sub with a plug in place.

FIG. 6 shows a detonator with a specially modified housing.

DETAILED DESCRIPTION OF THE INVENTION

Attention is first directed to FIG. 1 which shows a well bore 10 which penetrates a producing formation 12. An upper part of the borehole 10 is cased with casing 14 cemented in place in a conventional manner. In this particular case, casing 14 does not extend through producing formation 12. FIG. 1 is merely the lower end of well 10 and illustrates the first equipment which is placed in the well bore in the carrying out of the process of this invention. A drillable packer 16 is set in the casing just above producing formation 12. Drillable packer 16 is of a character which has a vertical passage therethrough and which is adapted to receive a tubing with seal nipple so as to form a continuous conduit with a tubing string. Suspended beneath the drillable packer 16 is a first section 18 of a drillable tubing such as aluminum tubing and can be for example about 10 feet long. Connected to the lower end of tubing 18 is a fill-up collar with plug latch 20. Details of this are shown in the cross section view of FIG. 4. Immediately beneath the fill-up collar 20 is a shear plug sub 22. The details of this type sub are shown in FIG. 5. Immediately below shear plug 22 is a drillable tail tubing 24 which can for example be about 30 feet long.

A detonator 26 is shown in the bottom of the well 10 and was placed there with wire line prior to the setting of drillable packer 16 and its associated equipment. This bomb or detonator is a clocked detonator and is set to detonate at a time after the explosive and other operational steps have been taken, for example, it can be set to detonate in 48 hours.

Attention is next directed to FIG. 2 which illustrates a tubing 25 suspended in the well bore above packer 16. It also illustrates means for displacing the liquid explosive into the tubing.

A pipeline 29 having valve 30 therein connects the annulus 31 of the well bore with a pit or tank not shown. THis is used when displacing a fluid such as cement slurry into the casing 14 above packer 16.

Attention will now be directed briefly toward that part of the equipment located on the surface which is used for injecting the liquid explosive into the well bore. This includes a container or source 34 having an explosive slurry or liquid therein. A nitrogen source 36 is connected through line 38 having valve 40 to drive the liquid explosive from container 34. The outlet of container 34 is connected through line 42 to a well head manifold 49. Line 42 has a valve 48 adjacent container 34. The outlet of pump 44 is connected through line 46 to tubing string 25 through manifold 49. Pump 44 is high-pressure pump such as a triplex plunger positive displacement pump. A sorbing solvent source indicated as container 50 is provided. This has an outlet line 52 which connects into line 64 leading to pump 44. Line 52 has a valve 54 therein adjacent container 50. A water source 62 connects through conduit 67 having valve 66 to conduit 64. Conduit 64 is connected to pump 44. A packing gland 58 is in the upper end of tubing string 25 to be used in event it is desired to run a wire line into the well. A lower plug 32 and top plug 35 are held in position by suitable catches 33 and 27 respectively. Plug 32 will pass through fill-up collar 20. However, this fill-up collar will retain top plug 35. The operational reasons for this will become apparent.

OPERATION SYSTEM

In one embodiment of this operation, detonator 26 is first placed in the hole as shown in FIG. 1. Then the liquid explosive is injected. When we first inject the liquid explosive, tubing string 25 is suspended as shown in FIG. 2. That is, the lower end of tubing 25 is above packer 16. In this system the liquid explosive is injected down the tubing 25 and the well liquid is taken out through pipe 29 from the annulus. It was taught in copending application Ser. No. 875,843, filed Nov. 12, 1969, for Clarence R. Fast, George C. Howard and Morton A. Mallinger and assigned to a common assignee with this application, that it is sometimes desirable to use a sorbing solvent to prevent the formation of mixtures of air vapors, etc., adjacent the liquid explosive which when compressed gases, etc., can cause liquid explosive to ignite or detonate prematurely. As taught in that application a suitable sorbing solvent is one that desensitizes the explosives and, therefore, can be,

for example, dibutyl phthalate, toluene, benzene or the like for nitromethane base explosives.

Valves 72 and 54 are open (valves 68, 48 and 66 are closed) so that a sorbing solvent from container 50 can be pumped into the tubing 25 just below bottom plug 32. Then valve 72 is closed and valve 70 opened. Then the sorbing solvent is injected into the tubing extension through valve 70 on top of plug 32. Plug 32 fits rather closely in tubing 25 but can pass through fill-up collar 20. Valves 72 and 68 are closed. Valves 70, 48 and 40 are open and plug catch 33 released so that nitrogen may force explosive liquid through container 34, through line 42 into tubing 25 on top of plug 32 which will move down tubing string 25. Tubing 25 will ordinarily have sufficient capacity so that the desired quantity of explosive liquid can be displaced so that the top of the explosive is well below ground level. At this time valves 40, 48 and 70 are closed. The desired amount of liquid explosive will have been preselected and ordinarily may be typically in the range of 500 to 2,000 gallons. After the selected amount of explosive is injected into the tubing, valve 48 is closed and valve 54 is open so that a sorbing solvent can be placed next to the top of the liquid explosive. When the desired amount of sorbing solvent has been injected valves 54 and 70 are closed and valves 66 and 68 open. This is to permit the pumping of water on top of plug 35 so that the top plug and the explosive can be displaced further into the tubing. Catch 27 is then released. This displacement by water continues until the liquid explosive approaches the lower end of tubing 25. This can be determined by simple volumetric calculations. At this point tubing 25 is lowered into and fastened into packer 16. The only thing now which prevents a continuous conduit from being formed from the surface to well bore 10 opposite formation 12 is the plug in shear plug sub 22. This plug is axially removed simply by applying additional pressure to the liquid in tubing 25. This pressure is applied until shear pin 101 (shown in FIG. 5) is sheared. This permits plug 102 to be forced downwardly through tubing tail pipe 24. It will be noted that shear plug 102 has sealing means 103 so that while the plug is in place it forms a seal.

Now it is seen then there is a continuous conduit formed from the surface through tubing 25, packer 16 and tail pipe 24 with the well bore opposite formation 12. Water is continued to be pumped through the tubing forcing the liquid explosive on down into tail pipe 24. Lower plug 32 is a conventional cementing wiper plug with a soft outer elastomer body having a hard metal or plastic core. The plug is designed to wipe the pipe walls clean as it moves down the tubing. The dimensions of plug 32 are such that the plug will pass through fill-up collar 20, shear plug sub 22 and tail pipe 24.

Top plug 35, sub 20 and plug latching means 21 are shown in detail in FIG. 4. Latching means 21 is simply a reduced diameter ring that is fitted in the sub 20. Top plug 35 consists of elastomer wiper portions 82 and 84 connected by solid center portion 86. The dimension of center portion 86 are such that the bottom part 88 of the center portion 86 of plug 35 will pass through latching means 21. The top part 90 of center portion 86 of plug 35 is preferably a solid, essentially nondeformable ring which will not pass through latching means 21. The plug 35 also contains latching rings 92 which is a split ring that compresses on passing through latching means 21 and expands after passing through so that latching ring 92 bears against shoulder 94, thereby locking plug 35 in place so that it cannot move upward. Top part 90 of the plug prevents downward movement. Top plug 35 and catcher 21 are commercially available from Baker Oil Tools, Inc., Los Angeles, Cal., and are identified as Model C cementing plug and full flow fill-up collar. This particular commercially available equipment contains a steel top part 90 and steel latching means 21 and latching rings 92. These parts could also be made of plastic material.

Water is continued to be pumped until top plug 35 is securely latched into latch means 21. This is easily determined both by volumetric calculations and by the fact that when plug 35 is latched in place, the pump pressure on tubing 25 will show an abrupt increase. This lets us know that all the explosive is in the well bore or tail pipe 24 beneath packer 16. Tubing string 25 is then disconnected from packer 16 and is partially removed from the well bore or tract. Sufficient tubing is removed so that the lower end is sufficiently removed from the packer 16 so that when the explosive is detonated the tubing will not be damaged. Before the time for the detonation to occur, the well is stemmed. Above packer 16 is cement 74. It has been found that about 100 feet of cement would ordinarily be adequate. Above the cement, sand 80 has been placed and extends about 200 feet up into the casing. The remainder of the hole is filled with water to the surface. When the time set on the timed bomb 26 has elapsed, it ignites or detonates the explosive in the well bore causing shattering and fracturing of the rock immediately surrounding the well bore. After this has occurred the well bore is cleaned out using conventional equipment in a conventional manner. The well is then subsequently placed on production, also in a conventional manner.

While the above described operation is a preferred way of using our invention, it can be modified. For example if the particular liquid explosive used is not particularly heat sensitive, then it is not necessary to inject the sorbing solvent.

Other modifications include different ways of igniting the liquid explosive placed in the well bore below packer 16. In the system described above we place the time bomb or detonator 26 in the bottom of the well prior to the other operations. The above described system of placing the detonator in the well bore first has a possible disadvantage that the detonator is in the bottom of the well during the injection of the explosive. We can modify this procedure by the use of the detonator as shown in FIG. 6. In this modified procedure, detonator 26 is not placed in the well bore prior to injecting the liquid explosive. Rather, the liquid explosive is injected into tubing 25. Then, just before inserting top plug 35, the special detonator of FIG. 6 is inserted by a special lubricator. The special drop-type detonator shown in FIG. 6 is designed to fall slowly through the liquid explosive and the sub. This is accomplished by providing a rubber wiper plug 107 on top to cause the plug to move slowly through the liquid explosive. The top of the bomb also contains fishing neck 109 to facilitate the bomb removal from the tubing should this become necessary. The bomb is designed so that its casing can withstand the pressure required to inject the explosive. It is shown to have a rounded or cone-shaped nose and is preferably constructed of a drillable material which is partly cast iron or aluminum. The bomb inside this casing contains standard timing mechanisms with electric blasting caps and suitable detonators.

There are many suitable liquid explosives which can be used. One type liquid explosive is one in which nitromethane is the predominant composition and contains a thickening agent, sensitizer and other additives tailored to the bottom-hole temperatures, pressure and type formation. A suitable commercially available liquid explosive is TAL-1005 which is available from Talley Industries, Inc., Mesa, Arizona.

While the above embodiments of the invention have been described with considerable detail it is to be understood that various modifications of the device can be made without departing from the spirit or the scope of the invention.

We claim:

1. A method of stimulating a well by the use of a liquid explosive which comprises:

placing a timed detonator in the vicinity of the bottom of the well;

providing a drillable packer fitted with a plug catcher sub and a sub containing a pumpout blanking plug and setting said packer above the formation to be stimulated;

equipping a tubing string with a special locator tubing seal nipple near the bottom end;

running said tubing string in said well bore until said seal nipple is a few feet above the packer;

filling the well above the packer with a first liquid;

displacing the liquid explosive into the tubing while removing said first liquid from the well and the tubing until the desired amount of liquid explosive is injected into the tubing string;
thereafter connecting the tubing string to the packer;
then applying sufficient pressure to the tubing string to pump out the blanking plug;
then displacing the liquid explosive out of the tubing string into the well bore below the packer;
setting a plug in the plug-catcher sub;
stemming the well above the packer;
detonating the explosive;
after detonation of the explosive, cleaning out the well so that it may be placed on production.

2. A method as defined in claim 1 in which a rubber bottom plug is placed between said liquid and said liquid explosive.

3. A method as defined in claim 1 in which prior to said stemming, said tubing string is disconnected from said packer and withdrawn from the vicinity of said packer and in which said stemming includes placing said cement above the packer.

4. A method as defined in claim 1 including the step of attaching a drillable section of tubing below said packer with its lower end above the bottom of said well so that said liquid explosive can be displaced out the lower end of said drillable section of tubing.

5. A method of stimulating a well by the use of a liquid explosive which comprises:
setting a plug in said well above the formation to be stimulated;
running a tubing string with the lower end just above said plug;
forcing said liquid explosive into said tubing string until the desired amount is injected therein;
then forming a continuous conduit from the lower end of said tubing to below said plug;
forcing said liquid explosive from said tubing string through said continuous conduit to the well below said plug;
sealing said continuous conduit;
detonating said liquid explosive.

6. A method as defined in claim 5 including the step of removing said tubing string from the vicinity of said plug and stemming said well prior to said step of detonating said liquid explosive.

7. A method as defined in claim 6 in which the step of detonating said liquid explosive is accomplished by placing a timed detonator in the bottom of said well prior to the injection of said liquid explosive.

8. A method as defined in claim 6 in which the step of detonating said liquid is accomplished by dropping a detonator through said liquid explosive through said tubing string and said continuous conduit prior to the sealing of said continuous conduit.

9. A method as defined in claim 6 including the step of removing said tubing string from the vicinity of said plug, filling said well with liquid prior to said step of detonating said liquid explosive.

10. A method of stimulating a well by the use of a liquid explosive which comprises:
setting a packer in said well above the formation to be stimulated;
running a tubing string with the lower end just above said packer;
forcing said liquid explosive into said tubing string until the desired amount is injected therein;
connecting the lower end of said tubing string into said packer to form a continuous passage from said tubing to below said packer;
forcing said liquid explosive from said tubing string to the well below said packer;
sealing the passage through said packer so that the well bore below said packer is isolated from the well bore above; and
detonating said liquid explosive.

11. A method as defined in claim 10 including the steps of removing said tubing string from the vicinity of said packer and stemming said well prior to said step of detonating said liquid explosive.

12. A method of stimulating a well by the use of a liquid explosive which comprises:
providing a drillable packer fitted with a plug catcher sub and setting said packer above the formation to be stimulated;
equipping a tubing string with a special locator tubing seal nipple near the bottom and;
running said tubing string in said well bore until said seal nipple is a few feet above the packer;
filling the well above the packer with a first nonexplosive liquid;
forcing liquid explosive into the tubing until the desired amount of liquid explosive is injected into the tubing string;
thereafter connecting the tubing string to the packer;
retaining the liquid explosive in said tubing string until it is connected to the packer;
displacing the liquid explosive out of the tubing string into the well bore below the packer:
setting a plug in the plug catcher sub; and
detonating the explosive.

13. A method as defined in claim 12 including the steps of disconnecting the tubing string from the packer and removing it from the vicinity of the packer and stemming the well above the packer.

14. A method of stimulating a well by the use of a liquid explosive which comprises:
setting a packer in said well above the formation to be stimulated;
thereafter running a tubing string and latching same into the packer;
forming a continuous passage from said tubing to below said packer;
forcing said liquid explosive into said tubing string until the desired amount is injected therein;
forcing said liquid explosive from said tubing string to the well below said packer;
sealing the passage through said packer so that the well bore below said packer is isolated from the well bore above; and detonating said liquid explosive.

15. A method as defined in claim 14 including the steps of removing said tubing string from the vicinity of said packer and stemming said wall prior to said step of detonating said liquid explosive.

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