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[54] **METHOD AND APPARATUS FOR FRACTURING OIL AND GAS STRATA**

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[52] **U.S. Cl.** **166/299,** 166/63, 166/177, 166/308

[51] **Int. Cl.** **E21b 43/00,** E21b 43/26

[58] **Field of Search** 166/299, 308, 63, 177, 166/75

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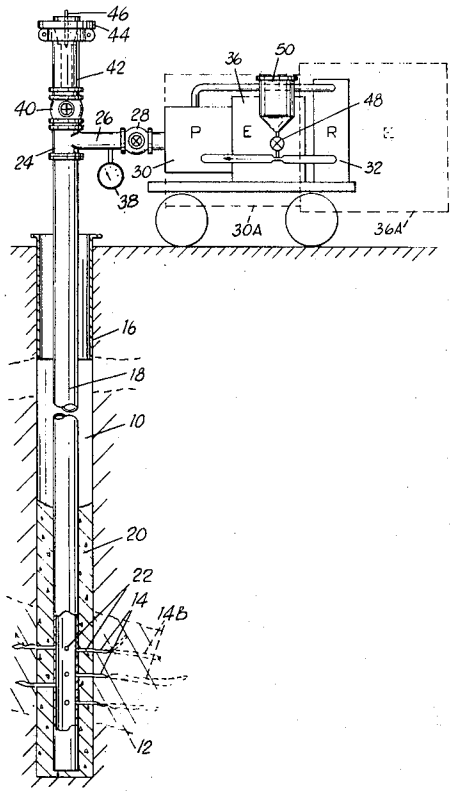
Primary Examiner—Stephen J. Novosad
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[57] **ABSTRACT**

A high pressure pipe has its lower end sealed in a well bore, and dispersed outlets are formed explosively through the pipe and seal at a fuel producing stratum of the well. A mechanically driven hydraulic pump connected to the top of the pipe fills the pipe and exposed surfaces of the stratum to be fractured with fracturing liquid at an intermediate pressure. A first valve in the pipe between the pump and the downwardly extending pipe is then closed. A second valve connecting the upper end of the pipe with an explosion chamber is closed while an explosive charge in the nature of a blank artillery shell is locked in the explosion chamber. The second valve is opened and the charge is exploded to create a very high over-pressure in the pipe. The over-pressure transmitted through the liquid creates multiple radiating fractures in the stratum. The valves are then reversed and the pump is again operated to force more fluid plus a quantity of a granular proppant such as fine sand into the newly created fractures.

The explosive step may be repeated with the same or progressively stronger explosive charges.

12 Claims, 3 Drawing Figures



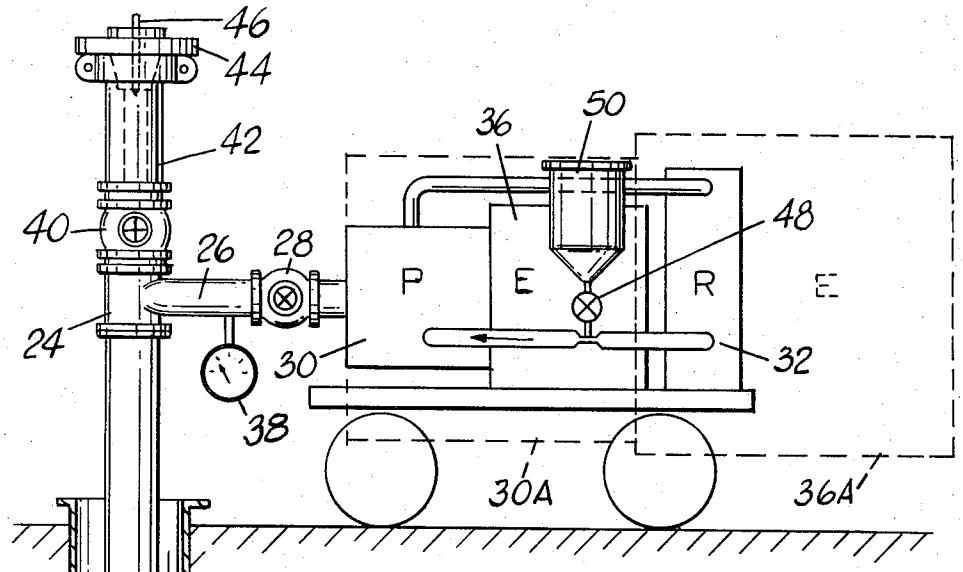
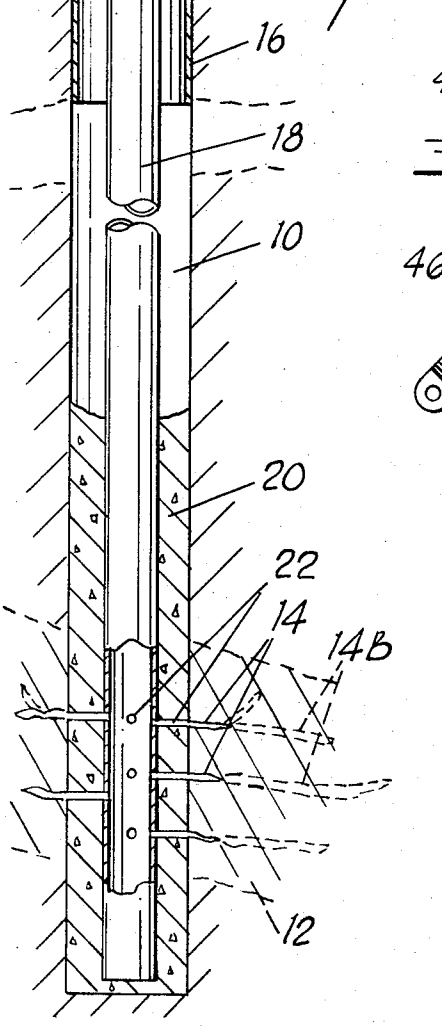


Fig. 1



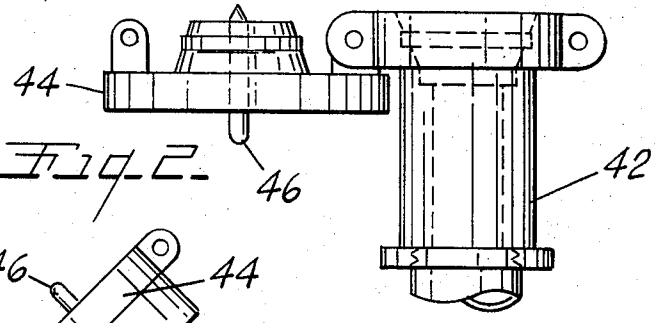


Fig. 2

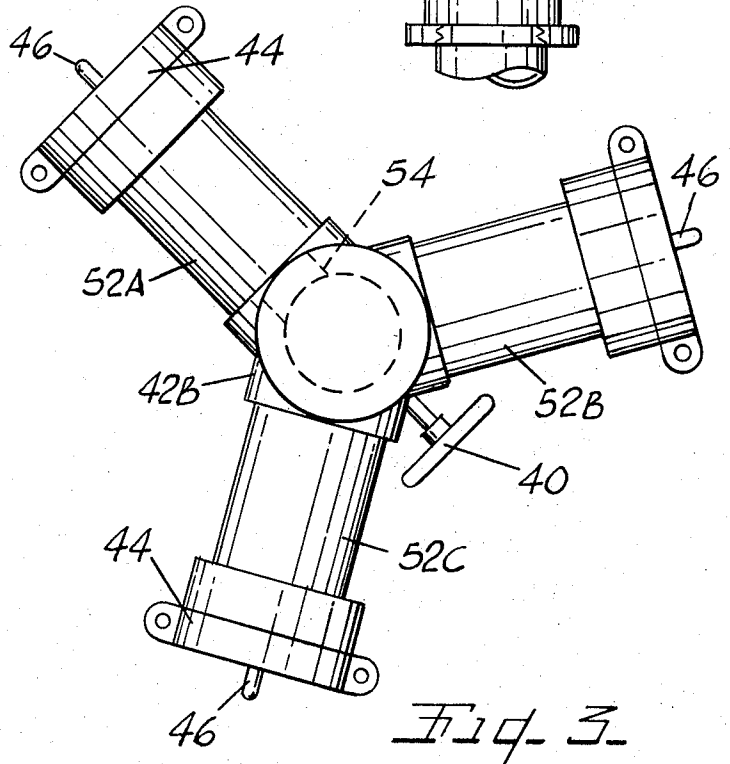


Fig. 3

METHOD AND APPARATUS FOR FRACTURING OIL AND GAS STRATA

DESCRIPTION

The drawings, of which there is one sheet, illustrate a preferred form of the apparatus and the method of performing the invention; together with a modified apparatus for successive pressure applications.

FIG. 1 conventionally illustrates an oil or gas well with the apparatus for performing the method of the invention connected thereto.

FIG. 2 is an elevational view of an explosive chamber connected to the pressure pipe.

FIG. 3 is a top plan view of three explosive pressure chambers connected to a pressure pipe for successive applications of high pressure explosions to the pipe.

FIELD OF INVENTION

Oil and gas wells often produce objectionably uneconomical amounts of oil or gas due to insufficient communication with pockets or pools of the oil or gas bearing stratum of the well. This may occur in newly drilled wells or in old wells that produce decreasing amounts of the oil or gas fluid over a period of time. It has been the practice to attempt to increase the flow of low production wells by a method known as "hydraulic fracturing." A special high pressure pipe is lowered into the well and the lower end of the pipe is sealed in the well through the producing stratum as by means of cementing a length of the pipe to the bore of the well. A plurality of holes are then formed through the pipe and the sealing cement to the wall of the bore by explosive devices lowered into the pipe. A mechanically driven pump located at the surface then pumps a fracturliquid, which may be ordinary water, into the pipe and the holes. The pump developes an intermediate pressure of an order of 1,000 to 1,500 p.s.i. in the pipe and the existing openings and fissures in the stratum. When this pressure is reached, as indicated by a gauge connected to the pipe, pumping is continued to increase the pressure to a fracturing pressure of the order of 3,000 to 4,000 p.s.i. When a sufficiently high pressure is reached, the fuel bearing stratum will break or fracture in multiple radiating fissures or cracks. The breaking or fracturing is recognized or noted above ground by a sharp reduction of the pressure in the pipe as the volume of the fracturing liquid is dispersed into the newly formed fissures and cracks. After fracturing of the stratum, a "proppant" material such as fine sand is introduced into the liquid delivered by the pump, and pumping is continued, at reduced pressure to fill the new fissures with the sand proppant. When pumping is stopped, gas and/or oil can flow through the newly opened fissures into the well. Hopefully increased production from newly tapped areas or pools in the stratum is experienced, and the high pressure fracturing equipment including the high pressure pipe can be removed from the well.

It is apparent that the mechanical pumps and driving engines for producing the high fracturing pressures must be extremely large, high powered, and expensive. It is the object of this invention to materially reduce the size and expense of the equipment necessary for performing the fracturing operation, and to reduce the time required to fracture the oil or gas bearing stratum.

As appears in FIG. 1, an oil well **10** extends from ground level down to a fuel bearing stratum **12** from which limited natural fissures shown in full lines at **14** radiate into the oil or gas bearing areas of the stratum. A casing **16** commonly projects part way into the upper end of the bore. In preparation for a flow increasing "hydraulic fracturing" operation, a high pressure pipe **18** of special pressure resistant properties is lowered into the flow producing lower level or area of the well. The lower end of the pipe is sealed to the wall of the bore, as by cement at **20** extending above and below the producing stratum and possibly through several strata. Ports or holes **22** are formed through the pipe and the layer of sealing cement by known explosive devices.

At the top of the well, the pressure pipe passes up from the top of the casing to a high pressure Tee **24.** A lateral branch **26** of the Tee connects through a valve **28** to a mechanical pump **30.** The pump **30** delivers fracturing liquid from a reservoir **32** and is driven by an engine **36** which is commonly an internal combustion engine. A pressure gauge **38** connected to the pipe indicates the pressure created in the pipe.

The pump and engine are conventionally illustrated and the dotted lines **30A** and **36A** indicate the relative sizes of these parts when used under the old conditions, as compared with the smaller full line parts required for the present invention.

Connected to the opposite end of the Tee **24** from the pressure pipe is a high pressure shut-off valve **40** which in turn connects to an explosive charge receiver and explosion chamber **42.** The top or outer end of the chamber has a breech or open end which is closed by a breech block or door **44.** The breech block carries a charge igniter in the form of a firing pin **46.** The details of construction of the charge receiver, breech block and igniter may vary widely, and are conventionally illustrated. It is contemplated that the receiver and breech portion of a 37 millimeter or 75 millimeter artillery piece could be fitted to the valve member **40.** Actuation of the igniter could be electrically or mechanically accomplished, as by striking the firing pin shown. The size of the explosive charge will vay according to the size and strength of the high pressure pipe **18.** The size and nature of the charge is selected to produce a momentary fracturing pressure on the column of liquid in the pressure pipe of the order of 2,000 to 5,000 p.s.i., or greater.

Operation

After sealing the high pressure pipe in the well and connecting the equipment as shown, valve **40** is closed and valve **28** is opened and the engine and pump **36–30** are operated to fill the lower portion of the well and the fissures **14** with fracturing liquid at an intermediate pressure of the order of 1,000 to 1,500 p.s.i. When this pressure is indicated on the gauge **38** and remains relatively steady indicating no further flow into the fissures **14,** valve **28** is closed to protect the pump. The charge receiving and explosion chamber is loaded, if it has not already been loaded, the breech door **44** is closed, and the charge is exploded. Depending on the size and burning rate of the explosive charge, this creates a practically instantaneous pressure surge or impact of the order of from 2,000 to 5,000 p.s.i. which is transmitted through the incompressible fracturing liquid into existing fissures and cracks. The peak pressure can

be observed on the gauge, and sensitive pressure recording instruments can of course be used in place of the crude gauge conventionally illustrated. A rather rapid reduction from the peak pressure indicates that the explosion of the charge has been successful, and that pressure has been dissipated in moving part of the fracturing liquid into newly formed fissures indicated by dotted lines at **14B**.

The high pressure impact process can be repeated by closing valve **40,** opening breech **44** and inserting a second (and possibly stronger) charge; if the strength of the pipe **18** and valves will withstand it.

After gauge **38** indicates a successful fracturing operation, valve **40** is closed and valve **28** is opened and the pump and engine are restarted; but at this time a valve **48** opening from a reservoir **50** is opened to introduce the fine granular proppant material from reservoir **50** to the liquid being pumped into the well. This mixture of liquid and proppant is forced at the intermediate pressure of the pump into the new fissures or cracks to hold them open. No attempt has been made to illustrate details of the mechanism for mixing the proppant with the liquid as such structure is well known.

FIG. **3** conventionally illustrates an impact pressure head for rapidly imparting successive shocks of the fracturing magnitude to the fuel bearing stratum. The head **42B** which fits rotatably around a pipe projecting from the valve **40** has three radially projecting charge receivers and explosion chambers **52** A, B and C. Rotation of the head brings the chambers successively into registry with a port **54** in the pipe and thence to valve **40.** Each chamber is provided with a breech block **44** and firing pin or igniter **46.** After the initial intermediate pressure has been built up in the well and the valves adjusted for high fracturing pressure, the three charges may be exploded successively by rotating the head. The several charges may be of the same or of increasing power to deliver widening or lengthening impacts to the new fissures **14B**.

The amount of fracturing liquid that can be forced into the enlarged fissures and fractures is obviously an unknown factor and depends on the nature of the stratum and the fracturing pressure. Thus, the extent or distance which the level of liquid will be lowered at the top of the pipe is variable. This creates a gaseous pocket or cushion of variable volume just below the explosion chambers, and this compressible cushion will absorb part of the energy of a second explosion if added liquid is not introduced after a first explosion. If multiple explosions are utilized to produce wider fracturing, it may be necessary to introduce additional liquid between explosions or to use successively stronger explosive charges.

What is claimed as new is:

1. Apparatus for developing sub-stratum fracturing pressure from an adjacent portion of a well bore having a high pressure pipe extending to the top of the bore and having its lower end sealed to the bore along said stratum with pressure openings in the pipe and the seal comprising,

means for introducing fracturing liquid into the top of said pipe,

a means defining charge receiving and explosion chamber adapted to be connected to the top of said pipe in pressure transmitting relation to the interior of the pipe,

and means for exploding an explosive charge in said chamber,

said pipe and said chamber being capable of withstanding pressures of at least 2,000 p.s.i.

2. Apparatus as defined in claim **1** in which said means for introducing the liquid is a pump connected to said pipe,

and a valve adapted to be closed between said pump and said chamber when a charge is exploded in the chamber.

3. Apparatus as defined in claim **2** which further includes:

means for selectively introducing a quantity of granular proppant material into the liquid delivered by said pump.

4. Apparatus as defined in claim **3** in which there is a second valve connected between said chamber and said pipe and adapted to be closed to isolate said chamber from said pump while said pump is operating.

5. Apparatus as defined in claim **4** in which said chamber has a breech closed opening at the rear and is permanently connected at its front end to said second valve.

6. Apparatus as defined in claim **3** in which there is a pressure gauge means connected to said pipe to indicate pressure therein.

7. Apparatus as defined in claim **1** in which there are plural explosion chambers associated with said pipe,

and means for successively bringing each chamber into communication with said pipe to the exclusion of the other chambers.

8. Apparatus as defined in claim **7** in which said means for bringing said chambers into communication with said pipe includes a body rotatable on said pipe and having said chambers mounted thereon and opening therethrough,

said port means in said pipe adapted to register with different chambers in different rotated positions of said body.

9. The method of stimulating the flow of fluid from wells by fracturing the fluid bearing stratum of the well which comprises the steps of:

lowering a high pressure pipe into said well and forming a seal between said pipe and said stratum,

forming flow openings through said pipe and said seal,

filling said pipe with a substantially imcompressible fracturing liquid,

connecting a charge receiving explosion chamber to the top of said pipe,

and exploding a charge of explosive in said chamber to produce a pressure in excess of 2,000 p.s.i. in said pipe and said liquid.

10. The method as defined in claim **9** which comprises the further step of:

introducing additional liquid with proppant granules therein into said stratum after said charge has been exploded.

11. The method as defined in claim **10** in which the step of introducing additional liquid is performed by a hydraulic pump.

12. The method as defined in claim **9** in which the step of filling said pipe is accomplished at an intermediate pressure not materially exceeding 1,200 p.s.i. but in excess of two atmospheres at the top of the pipe.

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