166-308

CROSS REFERENCE SEARCH ROOM

June 16, 1953 J. B. CLARK 2,642,142

# HYDRAULIC COMPLETION OF WELLS

Filed April 20, 1949

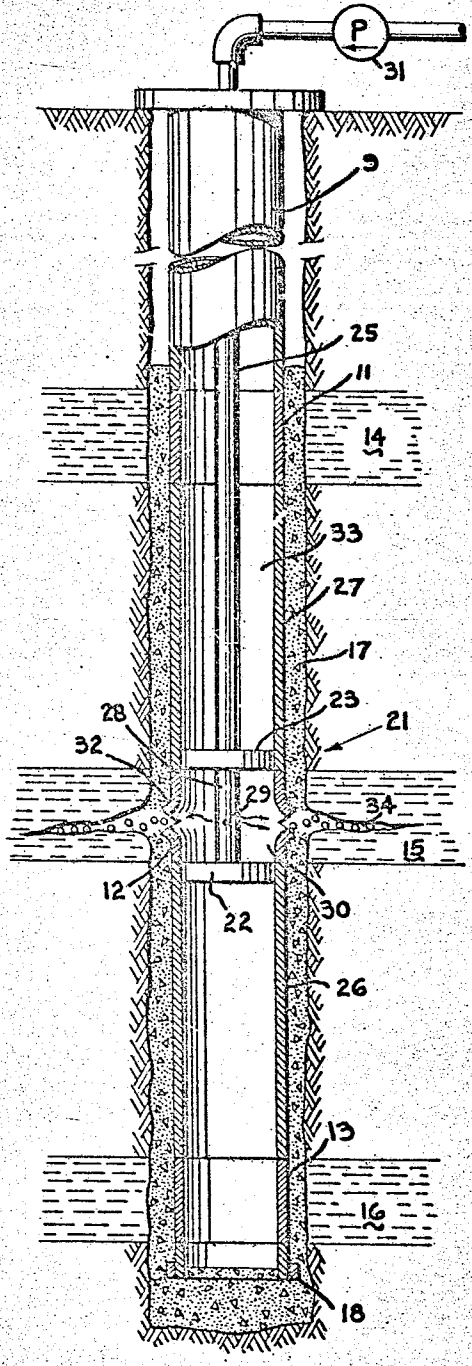


FIG. 2

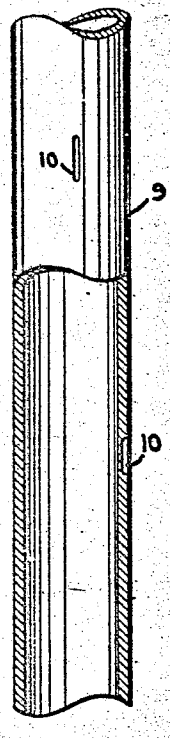


FIG. 1

*INVENTOR.*
JOSEPH B. CLARK
*BY*
L. Goodwin
ATTORNEY

Patented June 16, 1953 2,642,142

# UNITED STATES PATENT OFFICE

2,642,142

## HYDRAULIC COMPLETION OF WELLS

Joseph B. Clark, Tulsa, Okla., assignor to Stanolind Oil and Gas Company, Tulsa, Okla., a corporation of Delaware

Application April 20, 1949, Serial No. 88,616

9 Claims. (Cl. 166—22)

1

This invention pertains to the completion of wells. More particularly the invention is concerned with an improved method of perforating casing and with the simultaneous perforation of casing and fracturing of the strata behind the casing to increase the productivity of selected producing strata.

In the art of completing wells, various means have been proposed for setting casing in a well and then selectively perforating or otherwise opening up the casing to production in the various strata through which the casing has been set. Gun perforating is one example of this type of well completion. It has been found, however, that when a bullet is fired through a casing and into a producing strata, the walls of the bullet hole in the strata appear to be left in a glazed condition which substantially decreases the permeability and productivity of the perforation and thereby retards the flow of fluids into the well. It has also been proposed to place acid-soluble casing sections in the casing whereby the strata behind the acidizable section may be exposed to the well by contacting this section with a suitable acid. When such sections are exposed to acid, the acid also contacts the iron or steel casing and tubing, and is highly deleterious to them. Furthermore, sand formations, as is well known, are not reactive with the acid so the unspent acid left in the well after the soluble casing section is dissolved produces no beneficial effect. For these and other reasons, the acidizable section completion technique is seldom used. Various other processes and apparatus have been suggested for selectively exposing strata through which casing has been set in a well. In practically all cases, however, after the casing has been perforated or the formation otherwise exposed to the well, another service, such as hydraulic fracturing, is desirable to increase the permeability of the formation. Selective completion of a well is thus generally a long process and is very expensive.

It is therefore an object of this invention to provide an improved method of completing wells. Another object of this invention is to provide an improved method of perforating casing in a well. A further object of this invention is to provide a method of selectively completing wells by a process which can simultaneously perforate casing and increase the permeability of the strata exposed by such perforation. A more specific object of this invention is to provide an apparatus and method for completing wells in which the casing may be hydraulically ruptured at a selected elevation in the well and the strata thereby exposed to the well may be hydraulically fractured. A still more specific object of this invention is to provide an apparatus and method for completing wells in which a section of a cased well may be isolated, the casing may be hydraulically ruptured at a selected elevation, the strata thereby exposed to the well may be hydraulically fractured, the fractured strata may be tested; and, if necessary, cemented without removing the isolating means from the well. These and other objects of this invention will become more apparent as the description thereof proceeds. In this description reference will be made to the accompanying drawings in which:

2

Figure 1 is a cross-section of a casing showing a weakened section adapted to be hydraulically ruptured, and

Figure 2 is a diagrammatic representation—partially in cross-section—of an alternate means of producing a weakened casing section and a means for selectively perforating this weakened casing section and fracturing the adjacent strata.

This invention, in brief, may be described as an improved type of casing string which is adapted to be ruptured in a well at a selected depth and a method of completing wells including rupturing this casing by applying hydraulically a stress above the ultimate strength of the weakened section of the casing. The invention also contemplates the rupturing of a weakened casing section by use of a bodied fracturing fluid, the bodied fracturing fluid then being injected through the hydraulically perforated casing into the strata adjacent the perforation to fracture the formation and increase the permeability of the strata adjacent the casing perforation.

The well casing, which is preferably iron or steel, may be provided with weakened sections in a number of ways. In Figure 1, I have shown one way to produce a weakened section in an otherwise uniform casing string. In this embodiment the casing 9, which, as indicated, is preferably iron or steel, is provided with one or more grooves 10 milled in the outer surface. These grooves may, for example be cut with a ¼" end mill axially of the pipe. The depth and length may be varied as desired. I have found, for example, that such an axial groove 2" long in 3" pipe produces a bursting strength in air as indicated by the table.

*Table*

| Grade | Wall Thickness (Inches) | Wall Thickness in Groove (Inches) | Bursting Pressure in Air (p. s. i.) |
|---|---|---|---|
| Standard | .216 | .092 | 2,700 |
| Extra-heavy | .300 | .092 | 2,800 |
| Double-extra-heavy | .600 | .092 | 3,100 |

The grooves may obviously be milled radially to some advantage in some cases. For example, it is sometimes desirable to mill a groove around the periphery of the pipe near the lower end of the casing where the axial stress is not too

great to weaken a section which may later be ruptured by hydraulic pressure.

Numerous other methods for reducing the yield value of a casing string at a selected depth will be apparent. I have found it desirable in some cases to produce a weak section in a casing string by milling a hole or slot through the pipe completely and then filling this hole or slot with a weak material, for example, a plastic or a soft metal such as aluminum, brass, or the like, which may be sheared out of the hole or slot at a pressure substantially below the yield value of the casing at a strong section. The slotted section may be lined with a rupturable sleeve. Also, as indicated in Figure 2, the weak section may be produced by placing in the casing string 9 at selected intervals soft metal weak casing joints 11, 12, 13. For example, aluminum casing joints may be inserted at intervals in the casing, the aluminum joints having a calculated yield value in tension substantially below the yield value of the casing string in general.

The depth of the groove or the wall thickness as the bottom of the groove may readily be computed when the bursting pressure desired is decided upon. In determining the bursting pressure, the equipment available for producing the rupture and the modulus of rupture of the strata behind the weakened section must be considered. In this connection, I have found that in sandstones and limestones, from which most oil and gas is produced, the modulus of rupture is equal to about three times the ultimate strength of the sandstone or limestone in tension. In general, it appears that the modulus of rupture of the average sandstone and limestone is between about 500–2200 p. s. i. and is quite often about 2000 p. s. i. I have found empirically that the differential bursting pressure (internal pressure-external pressure) of the weakened casing section when added to the modulus of rupture of the strata behind the casing at the weakened section is a very close approximation to the rupture strength of the casing set in cement in the strata. In determining the depth of a groove therefore the surface pressure required to rupture the cemented casing must be less than the pressure capacity of the pump available for producing the rupture. Furthermore, it is generally desirable to reduce the yield value of the casing at the weak section to substantially less than, for example, to about ¼–½, to yield value of the casing at the strong sections so that when pressure is applied to rupture the weak section, the strong sections will not be damaged.

In completing wells in accordance with my preferred embodiment, the weakened sections of casing are placed in the casing string as the casing string is made up and lowered into the hole so that the weakened sections will, when the casing is landed and cemented, be spotted at the elevation of potentially productive strata. Weakened casing sections 11, 12, and 13 may thus be spotted at potentially productive strata 14, 15, and 16 respectively, as indicated in Figure 2. Abrading means, such as wall scratchers (not shown), may be attached to the casing, preferably throughout the producing horizons. In any case, it is highly desirable that the potentially productive strata be isolated behind the casing; a good cement job at the weakened casing sections in the potentially productive strata will generally not only be of assistance in producing a fracture in the strata, but will also isolate that fracture from other well production. Abrading means should, therefore, be placed especially on weakened sections of the casing to remove the mud sheath at these elevations and produce a strong bond between the well wall and the weakened casing.

After the casing is thus provided with weak sections at selected intervals and wall scratchers are provided at least at intervals along the outside of the casing, the casing is lowered into the well and landed with the weak sections in the potentially productive strata. The casing is then cemented in position by circulating a cement sheath 17 around the casing shoe 18. When wall scratchers are provided, the casing is moved during placement of this cement sheath to abrade the walls and produce a strong bond between the casing and the well walls, as indicated above. The cement sheath 17 preferably extends above the highest potentially productive strata 14. The cement sheath may be displaced from the casing into the annulus by following the cement with a non-penetrating liquid as hereinafter described. While Portland or other hydraulic cement may be used to produce the cement sheath 17, "cement sheath" as used herein refers to a sheath of any material such as plastics, sulphur, or the like used in setting casing.

After the cement sheath has been allowed to set for from 1 to 3 or more days, a straddle packer 21, adapted to be set in the casing, and consisting of a lower packer element 22 which prevents fluid flow downward in the casing, and an upper packer element 23 which prevents fluid flow upward, is lowered into the well on a tubing string 25. This straddle packer is then located in the casing at any weakened section 12 with the lower packer element 22 spotted in the strong section of the casing 26 below the weakened casing joint 12. The upper packer element 23 is spotted in the strong casing section 27 above the weakened casing joint 12. A spacer 28, between the upper and lower packer elements, is connected to and communicates with the tubing string 25. This spacer contains one or more perforations 29 through which fluid injected into the tubing by pump 31 may be discharged into the isolated section 30 between the packer elements 22 and 23.

After the upper and lower packer elements have been set in the strong sections of the casing, a fluid such as oil or water may be injected via the tubing into isolated section 30. Pressure will be built up in this isolated section by pump 31 until the bursting pressure of the weakened casing section is reached. When this pressure is reached, the weakened section of the casing, the surrounding cement sheath 17, and the potentially producing strata 15 adjacent the well fail in tension, producing a perforation 32, allowing the fluid to be injected into the strata and the pressure in the tubing to be reduced. The straddle packer may then, if desired, be moved to the elevation of one or more of the other potentially producing strata 14 or 16 penetrated by casing string 9 and the weakened casing sections opposite these strata may be selectively perforated. Alternatively the strata 15, exposed to the well by the perforation 32, may be tested while it is still isolated by the straddle packer 21 from the remainder of the well before the other weakened casing sections in the casing string are ruptured. To provide a representative test of the strata, the fluid is removed from the tubing by a circulation joint above straddle packer 21, by swabbing or the like, and

the productivity determined by flowing or pumping the well through tubing 25.

While it is desirable to isolate a weak casing section in order to rupture that casing section—particularly where there is more than one weak section in a casing string—I have found that these weak sections may be ruptured without being isolated. Under such circumstances the well is preferably cleaned out by displacing the mud in the casing string with a clean fluid such as oil or water. A high hydrostatic pressure is then applied to the entire casing string; and, since the weak sections have a substantially lower bursting pressure than the casing string in general, these weak sections will be ruptured in the same manner as if they had been isolated (as above described), and the strong sections of the casing string will not be damaged.

While my invention is adapted to exposing potentially productive strata behind the casing with a minimum of specialized apparatus and services, as above described, it is particularly adapted to the combined process of selectively perforating the casing at a weakened section and increasing the permeability of the potentially productive strata adjacent the perforations. In this regard, I have found that if the casing section is ruptured with a strong acid, acid may be injected into the strata through the perforation to increase the permeability of the strata adjacent the perforation. Furthermore, if the casing section is ruptured with a bodied or non-penetrating liquid, the bodied liquid will also extend a fracture in the strata at the level of the casing rupture a substantial distance back into the formation. In the preferred embodiment, therefore, I inject into the tubing 25 a viscous liquid, preferably, an oily liquid such as a higher alcohol, a crude oil, a refined oil such as gasoline, kerosene, naphtha, fuel oil, diesel oil, an animal oil such as lard oil or fish oil, a vegetable oil such as cottonseed oil, chlorinated hydrocarbons, or the like, containing a bodying agent, i. e., an agent which tends to thicken a liquid and thereby reduce substantially its filtrate rate. The bodying agent may comprise, for example, a high molecular weight linear molecule or polymer, such as salts of the fatty acids, rubber or the like, which are at least partially oil soluble. While the invention is not limited to oily liquids, liquids which are miscible with the interstitial crude oil in the formation to be fractured are preferred since liquids immiscible with the interstitial crude oil generally tends to reduce the permeability of the pores in the formation to oil. That is, aqueous liquids containing a bodying agent such as hydrated starch or water soluble soaps produce a fracture of the same type as the oily liquids; but, since the contamination of a formation having low permeability with water tends to decrease its permeability to oil, aqueous liquids are generally not used. Therefore, while aqueous liquids containing bodying agents are within the purview of this invention, I prefer an oily liquid containing a bodying agent. Soaps produced by or from ammonia or any metal of the alkali metal and alkaline earth metal groups or polyvalent metal groups such as, for example, magnesium, calcium, strontium, cadmium, mercury, lithium, cobalt, lead, nickel, or aluminum combined with a fatty acid produce suitable bodying agents for the lighter oily liquids. The fatty acid is preferably one of the aliphatic acids carrying at least one carboxyl group in aliphatic chain linkage, the aliphatic chain in either case having preferably at least 12 carbon atoms in said chain. Suitable fatty acid compounds which are available commercially are, for example, coconut oil fatty acids, peanut oil fatty acids, palm oil fatty acids, stearic acid, oleic acid, palmitic acid, and the like.

While the salts of fatty acids are in general suitable bodying agents for producing a suitable viscosity in the hydrocarbon, I employ a metallic soap preferably a hydroxy aluminum soap bodying agent which has the ability to form hydrocarbon gels at ordinary temperatures. A suitable soap of this type can be considered as compounded from two distinct components. One is aluminum laurate or a saturated fatty acid soap containing at least 40–50% of this substance or of a functionally related acid soap; this component is a relatively high-melting solid that, by itself, produces only thin and unstable gels. The second component is an aluminum soap or soaps selected from the group including soaps of cycloaliphatic and unsaturated acids—that is, an aluminum naphthenate, oleate, oleate-linoleate or the like. The combination of an aluminum soap of the laurate type with one or more soaps of the naphthenate-oleate type give a thickening or bodying agent of distinctive and superior properties not found in either component and when prepared by the precipitation process, a solid is produced which withstands ordinary handling and storing conditions and which is readily soluble in the oily liquid to produce a highly viscous liquid or gel. I have found that at about 75° F., for example, from about 3% to about 10% of this type soap disperses in gasoline in from about 15 seconds to about 10 minutes and that gels having a suitable filtrate rate and viscosity are produced within from about 30 seconds to about 20 minutes.

I have found that from about 0.5% to about 10% by weight relative to the oily liquid of this hydroxy aluminum soap, preferably between about 3% and about 6%, produces a suitable gel for fracturing most formations in accordance with this invention. Where the soap may be deteriorated as by weathering or contaminated as by moisture, it is sometimes desirable to use even more than 10%. In accordance with the preferred embodiment of this invention, the oily liquid is weighed or otherwise measured and the soap is added in a tank as the liquid is stirred. Sometimes the liquid may be heated to advantage. A flow-type mixer for the soap and the oily liquid may be used at the well head with soap which reacts readily to produce a gel in the oily liquid. I have found that the gel will develop in the well. Therefore, since the more viscous gels are difficult to pump, the soap-liquid dispersion may be introduced into a well before the maximum viscosity is reached. Accordingly, when the gellation has proceeded to a point at which the viscosity is sufficient to maintain substantially all the particles of undispersed soap in suspension, the dispersion is pumped into the well. Fluid in the tubing ahead of the bodied fluid may be displaced into the annulus 33 before the packers are set or it may be displaced through a circulation port above the straddle packer or it may be left in the tubing. In any case, a pressure herein referred to as the bursting pressure is built up by pump 31. When the casing is ruptured, the bodied fluid or gel may be injected immediately into the formation or it may be allowed to stand in the well until the maximum gellation has developed as indicated by a sample retained at the surface. By this means, high viscosity liquids are available for producing

a fracture in the strata 15 adjacent perforation 32 after the perforation has been produced.

Any amount of the viscous liquid may be injected into a formation fracture 34 depending upon the size of fracture desired. A filler fluid, i. e., an inert fluid such as crude oil or a refined oil such as gasoline or kerosene which has no effect upon the gel may be injected into the well after the injection of the viscous liquid to force the viscous liquid further into the strata. When the viscous liquid reaches the strata 15, due to its retarded tendency to filter therethrough, it not only produces a fracture in the strata, but extends the fracture back from the well into the selected rock strata a substantial distance. Hard formation props such as sand may be incorporated in the gel to support the overlying rocks and maintain a permeable channel to the well after the gel is removed.

Inasmuch as this viscous liquid tends to obstruct the flow of the interstitial fluids from the fractured formation into the well, it is removed therefrom after it has produced a fracture of suitable proportions. A peptizer or viscosity breaker for the gel may be incorporated in the viscous liquid and become effective after a time delay. For example, from about 1% to about 3% by volume of water which becomes effective several hours after the viscous liquid has reached the fracture may be incorporated in the viscous liquid as, for example, by emulsification or the like. Likewise other gel breakers which become effective at the temperature of the formation may be incorporated in the viscous liquid. In some cases, particularly in deep wells, the heat from the formation is sufficient to reduce the viscosity or gel so that the fracturing liquid may be completely removed from the interstices of the formation. Among suitable materials for breaking the gel and reducing the viscosity of soap-hydrocarbon gels, I have found the water-soluble amines such as ethanolamine or similar ammoniacal compounds and the oil soluble sulfonates to be particularly effective. Other suitable gel breakers are ammonia, alkali oxides and hydroxides and the stronger acids. Generally about 1% breaker, based upon the volume of the fracturing liquid, diluted with a suitable solvent such as gasoline is pumped into the well following the fracturing liquid to reduce the viscosity or break the gel so that when the well is produced the sol will flow out of the formation. More than 1% of the breaker is sometimes required, particularly where the soap content is high.

While, as indicated above, the breaker is preferably injected into the fracture through the well following the fracturing liquid, I have found that some of the gels, particularly those produced by the hydroxy aluminum soaps, may be broken by contact with the interstitial fluids in most formations. Breaking the gel by this means is necessarily slow since the gel must be adapted to withstand the peptization effect of the gel breaker for sufficient time to permit placement of the gel plus a reasonable safety factor. Thus, while it is not generally desirable to break the gel by the action of the interstitial fluids due to the necessary delay, such procedure is within the purview of this invention.

As pointed out above, props, preferably sand, are incorporated in the viscous liquid either during mixing or during the time it is being injected into the well. These props, due to the high suspending forces of the viscous liquid, are carried into the formation fracture with the viscous liquid. Since these liquids have only a temporary high viscosity, i. e., since this high viscosity is subsequently broken in the fracture, the props are deposited in the fracture and held there by the formation as the fracture is collapsed so there is no tendency for the props to flow back into the well as the well is produced and as the sol flows back into the well.

As an example of the operation of my invention, a 3-inch, 7.57-pound A. P. I. casing section was weakened by milling an axial groove 2 inches long and a .124 inch deep in the outer surface. This left a minimum wall thickness at the bottom of the groove of .092 inch which has a calculated bursting pressure in air of about 2700 p. s. i. This weakened casing section was then spotted in an injection well and cemented in a sandstone strata. A bottom-hole pressure of 3850 pounds was then applied with a bodied liquid, as above described, to rupture the pipe. After the pipe ruptured, the pressure on the bodied liquid dropped; 1000 gallons of the bodied liquid was injected into the sand.

From previous tests on an offset well, this sandstone strata is known to have a water injection rate of substantially less than one gallon per minute at 100 pounds per square inch bottom-hole pressure. After rupturing the casing and fracturing the formation as above described, and after breaking the bodied liquid and removing the low-viscosity liquid, this sandstone strata had a water injection of 15 gallons per minute.

It will be apparent that my invention is subject to a number of modifications and that it is not limited to the examples which are given merely for purpose of illustration. It will also be apparent that any process described is not limited by the means used to weaken the casing; and, vice versa, any type of weakened casing section may be ruptured by numerous embodiments of the process as hereafter claimed.

I claim:

1. A method of completing a well comprising placing in said well a casing having a weak section, cementing said weak section in said well and applying internally thereto by hydrostatic pressure of a bodied liquid a stress greater than the combined ultimate strength of said weak section and the adjacent formation whereby the strata adjacent said weak section may be fractured to increase its productivity.

2. A method of completing a well comprising placing in said well a casing having a weak section, cementing said weak section in said well by placing cement in the annulus above and below said weak section to isolate the formation opposite said weak section from other formations traversed by said casing, internally isolating said weak section from the remainder of said casing, and applying internally thereto by hydrostatic pressure of a bodied liquid a stress greater than the combined ultimate strength of said weak section and the adjacent formation, and subsequently applying to said bodied liquid a pressure great enough to rupture said casing and fracture said formation whereby the formation at the depth of said weak section may be fractured to increase its productivity.

3. A method of completing a well comprising placing in said well a casing having a weak section, cementing said weak section in said well by placing cement in the annulus above and below said weak section to isolate the formation op-

posite said weak section from other formations traversed by said casing, internally isolating said weak section from the remainder of said casing, applying internally thereto by hydrostatic pressure of a bodied liquid a stress sufficient to rupture said casing and produce a fracture in the strata behind said weak section, injecting said bodied liquid into said fracture, and reducing the viscosity of said bodied liquid, whereby the permeability of said strata is substantially increased.

4. A method of completing a well comprising placing a casing in said well, said casing having weak sections at the depth of potentially productive strata in said well, cementing said casing in said well by pumping cement into the annulus around said casing to an elevation above said weak sections, internally isolating one of said weak sections from the remainder of said casing, applying internally of the isolated weak section by hydrostatic pressure of a bodied liquid a stress greater than the combined ultimate strength of a weak section in said casing and the adjacent formation and sufficient to rupture said weak section and produce a fracture in said strata behind said weak section, injecting said bodied liquid into said fracture, and reducing the viscosity of said bodied liquid whereby the permeability of said strata is increased.

5. A method according to claim 4 in which said bodied liquid contains a propping agent.

6. A method of completing a well penetrating a plurality of potentially productive strata including lowering into said well a pipe containing sections of iron or steel and sections of a metal having a substantially lower tensile strength than said iron or steel, spotting said last-named sections at the level of said potentially productive strata, introducing cement slurry into the annular space between said pipe and the walls of said well in an amount sufficient to seal the annular space above the level of said last-named sections, allowing the cement to set, placing packers in said iron or steel pipe above and below one of said last-named sections to isolate same from other low tensile strength sections, applying internally of the isolated sections by hydrostatic pressure of a bodied liquid containing a propping agent a stress sufficient to rupture said low tensile strength section of said pipe and produce a fracture in the formation behind said isolated section, and reducing the viscosity of said bodied liquid in said fracture whereby a selected strata may be produced and the permeability of said selected strata is substantially increased.

7. A method of completing a well penetrating a plurality of potentially productive strata including lowering into said well a pipe containing sections of iron or steel and sections of a metal having a substantially lower tensile strength than said iron or steel, spotting said last-named sections at the level of said potentially productive strata, introducing cement slurry into the annular space between said pipe and the walls of said well in an amount sufficient to seal the annular space above the level of said last-named sections, allowing the cement to set, placing packers in said iron or steel pipe above and below one of said last-named sections to isolate same from other low-tensile-strength sections, applying internally of the isolated section by hydrostatic pressure of a bodied liquid containing a propping agent a stress sufficient to rupture said low-tensile-strength section of said pipe and produce a fracture in the formation behind said isolated section, injecting said bodied liquid into said fracture, reducing the viscosity of said bodied liquid, and producing said well through said isolated section to increase the permeability of said potentially productive strata and test the productivity thereof without contamination from other strata penetrated by said well.

8. In a method of completing a well comprising the steps of placing a casing in said well, said casing having rupturable grooves at the depth of potentially productive formation in said well, cementing said casing above and below said rupturable grooves, internally isolating a portion of the said casing embracing said rupturable grooves, disposing a body of low-penetrating liquid within said isolated section of casing, applying pressure to said body sufficient to perforate said casing at at least one of said grooves, continuing the application of pressure to said liquid to produce a fracture in said formation behind said perforated casing and reducing the viscosity of said low-penetrating liquid within said fracture whereby a high-permeability channel is produced in a formation opposite said perforated casing.

9. The method of completing a well comprising the steps of placing in said well a metallic casing having a weak section opposite a potentially productive formation, introducing into the annulus between said casing and the wall of said well a cement slurry in an amount sufficient to fill the said annulus to a point above said weak section, allowing said cement slurry to set, thereafter introducing into said casing a quantity of a low-penetrating gelled hydrocarbon, applying a hydrostatic pressure to said gelled hydrocarbon sufficient to rupture said weak section and produce a fracture in the adjacent set cement and the adjacent formation, displacing additional gelled hydrocarbon into the fracture in said formation to extend said fracture, thereafter breaking said gelled hydrocarbon and reducing its viscosity to substantially the viscosity of the well fluids, and producing said well to remove the hydrocarbon of reduced viscosity from said formation whereby a highly permeable flow channel is produced in said formation.

JOSEPH B. CLARK.


References Cited in the file of this patent

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 1,393,311 | Pendleton | Oct. 11, 1921 |
| 2,215,913 | Brown | Sept. 24, 1940 |
| 2,261,292 | Salnikov | Nov. 4, 1941 |
| 2,315,496 | Boynton | Apr. 6, 1943 |
| 2,330,144 | Powers | Sept. 21, 1943 |
| 2,354,570 | Benckenstein | July 25, 1944 |
| 2,379,516 | Garrison | July 3, 1945 |
| 2,418,343 | Garol | Apr. 1, 1947 |