

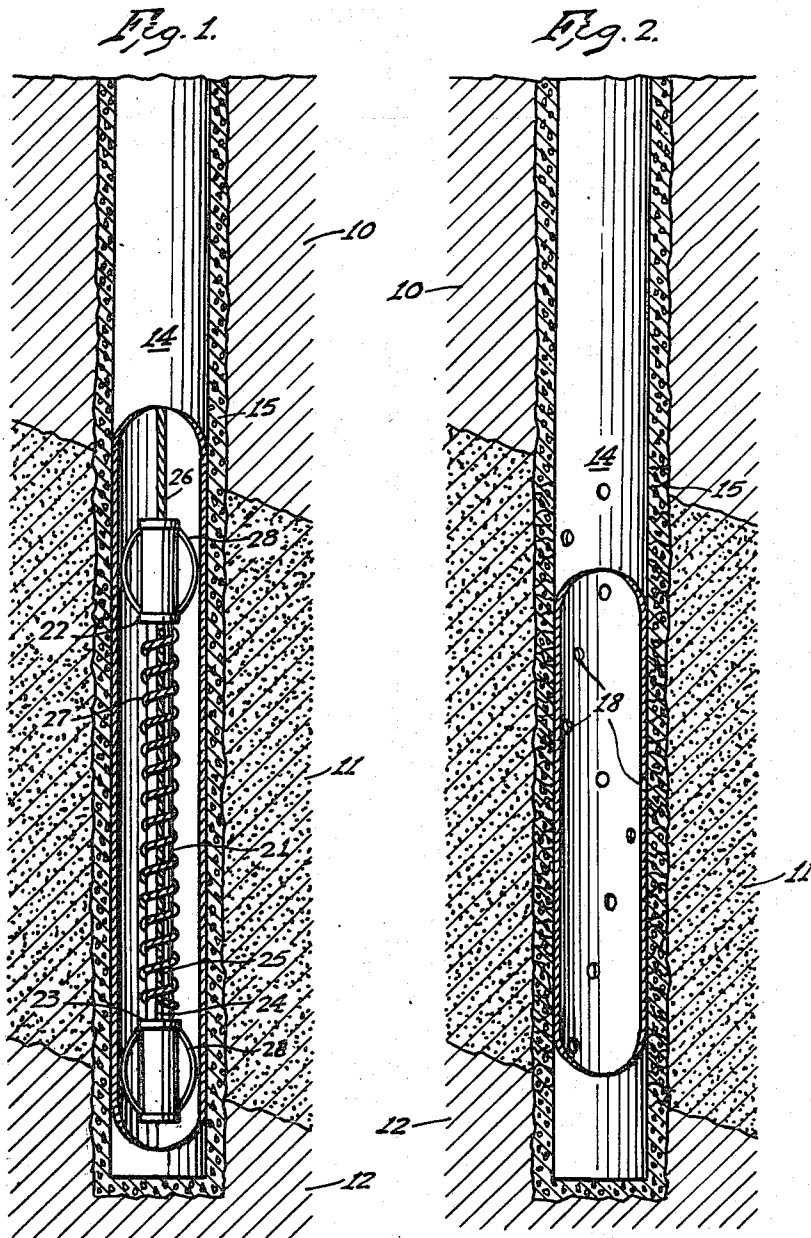
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EXPLOSIVE DEVICE

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EXPLOSIVE DEVICE

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1 Claim. (Cl. 102—21.8)

This invention relates to an explosive device which is particularly adapted for use in completing fluid-producing wells in poorly-consolidated producing formations and more particularly to such a device made with explosive cord.

In producing oil, gas, or other fluids from poorly-consolidated formations such as unconsolidated sands, it is desired to avoid the production of sand with the fluids in order to prevent costly shut-down due to clogging of the well bore and to avoid damage to pumps and other well equipment. A number of procedures for sand control have been employed including the use of various types of strainers in the producing formation; for example, wire-wrapped slotted pipes, gravel packs, and the like. The prior art means for sand control have not been entirely satisfactory. Abrasion caused by sand particles enlarges the openings in the wire-wrapped slotted pipe and allows the production of substantial quantities of sand which usually accumulates in the well bore, stopping production, and necessitating an expensive clean-out process. The openings in the pipe are also subject to clogging by sand with resulting decrease in production. Gravel packs are also subject to clogging. This is due to the fact that it is difficult to place the gravel in the well without forming voids in some places in the pack. Such voids allow shifting of the gravel during production and consequent movement of sand from the surrounding formation which clogs fluid passages in the pack and stops or reduces production.

The copending patent application of Abraham J. Teplitz, Serial No. 424,862, now abandoned, describes a new method of completing wells in unconsolidated formations which makes possible the production of fluids from unconsolidated sands without the production of substantial quantities of sand. The new method in general comprises installing in a well drilled in a poorly-consolidated producing formation a tubular casing coaxial with the bore hole, forming a cementitious sheath in the annular space between the casing and the walls of the poorly-consolidated producing formation, and applying a stress to the sheath sufficient to form fractures in the cementitious material. In one modification of the new method the stress is applied by detonating an explosive within the casing opposite the poorly-consolidated formation. The small fractures or cracks formed in the cement allow fluids to filter through the sheath and enter perforations in the well casing while sand is excluded. The fractured sheath retains its general outline and continues to support the surrounding unconsolidated sand formation.

The present invention is directed to an explosive device which is particularly adapted for use in the method of completing a well described in said Teplitz application. The explosive device of the invention in general comprises an elongated, inert core member, a longitudinal strand of explosive cord on the outside of the core member, wrappings of explosive cord attached to the core member, means for lowering the device into a well and means operable from ground level for detonating the explosive cord within the well.

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The invention can be described further by referring to the drawing, of which

Figure 1 is a diagrammatic view of an explosive device of the invention in position within the producing zone of an oil well; and

Figure 2 is a diagrammatic sectional view of the producing zone of an oil well which has been completed with the use of a device of the invention.

Figure 1 shows, by way of example, a well extending through a consolidated formation 10, an unconsolidated oil sand 11 and into a consolidated formation 12. The well is cased throughout the producing formation with a tubular casing 14, which is preferably steel casing pipe commonly used in the art. Figure 1 shows casing 14 as an unperforated pipe which is to be perforated after it is placed in the well, as will be described in more detail hereinafter. However, if desired, the pipe can be perforated before it is placed in the well. Conventional shop-perforated or slotted pipes, screen pipes and the like can be used instead of the unperforated casing shown in Figure 1.

The casing 14 is surrounded by a cementitious sheath 15, formed preferably from a slurry of neat Portland cement. Care is taken to eliminate voids or channels from the cement sheath 15 before it sets, for example, by using scratchers and centralizers in the cementing operation. After the cement has set, the well is ready for the phase of the completion method in which fractures are formed in the cement sheath with the explosive device of my invention and perforations are formed in the tubular casing if they have not been already formed.

The structure of the well after the cement sheath has been fractured and perforations have been formed in the tubular casing is illustrated diagrammatically in Figure 2. The structure comprises the casing 14 having openings 18 therein and the surrounding cementitious sheath 15 having a network of small fractures or cracks which provide passages for fluids from the producing formation 11 into the openings in the casing.

To use a device of my invention in completing a well, it is lowered into the well through the cemented casing to a level opposite the oil sand as shown in Figure 1. The preferred embodiment of the device, as illustrated diagrammatically in Figure 1, comprises an elongated inert core member which can be, for example, a length of steel drill pipe. In the preferred embodiment, the core member has a reduced diameter section 21, referred to in the claim as an explosive cord mounting section, which is adapted to receive wrappings of explosive cord. Advantageously the reduced diameter section is formed by turning the cylindrical or tubular core member on a lathe to cut away a section in which the explosive cord wrappings are protected from abrasion by the shoulders 22 and 23 which have the original diameter of the core.

In the preferred embodiment of Figure 1, the core member is provided with a shallow longitudinal groove 24 in the reduced diameter section 21. This groove is adapted to receive one or more strands of explosive cord which serve as detonating strands for the explosive cord which is wrapped about the core and presses tightly against the detonating strand.

In the preferred embodiment of the explosive device the wrappings of explosive cord are attached to the core member in the following manner. A detonating strand 25 is placed in the groove 24. To the free end of strand 25 is attached a detonating means, preferably an electric blasting cap, not shown in the drawing. The cap may be fired from ground level through an electrical conductor associated with the supporting cable 26 which is the means for lowering the device into a well. Alternatively the cap may be fired by means of a go-devil dropped from the ground level or by a time clock in known man-

ner. The rest of the explosive cord attached to the core member is wrapped as a coil or helix 27 on the core and presses tightly against the longitudinal detonating strand 25. The cord forming the helix 27 can be either a continuation of the strand of cord in groove 24 or a separate length of explosive cord.

The explosive device is advantageously provided with means for centering the device within a well. Figure 1 shows such means in the form of centralizing strips 28 disposed at each end of the device.

An explosive cord which is particularly suitable for use in the device of the invention is known commercially as Primacord. The cord is $\frac{1}{4}$ inch in diameter and comprises an explosive core of PETN (pentaerythritol tetranitrate) and a water-proofed textile covering. The explosive rate is about 20,000 feet per second. This explosive cord is tough, flexible and substantially impervious to water. It is relatively insensitive to ordinary shock, friction, fire, or to temperatures met in oil wells and therefore is safe to handle and resistant to premature explosion when used in completing a well. It is detonated by an electric blasting cap. While Primacord is the preferred explosive cord, other explosive cords having the above-described properties can also be used for the explosive device of the invention.

In completing a well the explosive cord opposite the producing formation 11 is detonated as by passing an electric current through a conductor in cable 26 which detonates the blasting cap or other detonator (not shown in the drawing) on the explosive device and which initiates detonation of the explosive cord sections 25 and 27. The amount of explosive cord is predetermined by empirical tests and when this selected amount of cord explodes within the casing 14, the resulting lateral force bulges the casing and applies a limited stress to the surrounding cement sheath 15.

When the limited stress is applied by the explosion to the cement sheath while it is confined between the well casing and the wall of the producing formation, many small fractures form in the portion of the sheath to which the stress is applied. However, the sheath retains its general outline as shown in Figure 2 and continues to support the surrounding sand formation. Consequently, the shifting of sand which results in the clogging of conventional well strainers in oil sands is prevented or greatly reduced. The small fractures in the cement allow fluids to enter the well from the producing formation but prevent the production of sand of any substantial particle size. The greatest pressure gradient during production from the resulting well structure occurs as the fluids pass through the fractures in the cement rather than, as in conventionally completed wells, in the sand formation. Consequently, the forces tending to disturb the sand formation and cause movement of sand are considerably smaller than in conventional well structures.

Following the described fracturing operation, the tubular casing 14 can be perforated if it has not already been perforated. For this purpose a conventional casing perforator, for example, a mechanical perforator of the knife type, can be lowered into the well opposite the producing formation and the fractured cement sheath. The perforator is then actuated to form holes in the casing which admit the fluids filtering through the fractures in the cement sheath. The casing perforation can also be performed before the fracturing operation if desired.

Although the structure illustrated in Figure 1 is preferred for the explosive device of the invention, the device can be modified and still produce advantageous results. For example, instead of being attached as spiral wrappings, the explosive cord can be attached longitudinally to the elongated core as a number of loops or strands, clipped or otherwise fastened along its length. It should be understood, however, that the structure of the explosive device illustrated in the drawing is greatly preferred and has important advantages in its use in com-

pleting a well. For example, the provision of a longitudinal detonating strand under the spiral wrappings of explosive cord has especially proven to have important advantages. I have found that with this structure the possibility of misfires with the device is considerably less than when the longitudinal strand is omitted.

The explosive device of the invention can vary considerably in the length and diameter of the core member, depending on such factors as the inside diameter of the casing in the producing zone and the top to bottom depth of the producing sand formation. A device of suitable size for many operations can be made using as the core member a section of $4\frac{1}{2}$ inches drill collar tubing of which a 10 foot length is turned on a lathe to form an intermediate reduced diameter section for the wrappings of explosive cord. A shallow longitudinal channel is also milled for the detonating strand.

The length of explosive cord attached to the core per linear foot must be sufficient to cause fracturing of the cement sheath in the producing formation but insufficient to cause rupturing of the tubular well casing. The amount of cord to be used will thus depend upon the thickness of the casing wall and the thickness of the cement sheath. As an example, using the $\frac{1}{4}$ inch diameter cord containing PETN, in $5\frac{1}{2}$ inch J-55 casing surrounded by a 2 to 3 inch thick sheath of Portland cement, from about 5 to 20 feet of explosive cord per linear foot will fracture the cement without rupturing the casing. Using a different type of explosive cord or a different thickness of casing or cement sheath, the amount of cord to be used might differ considerably. However, bearing in mind the result desired, i. e., without rupturing the casing to form a fractured cement sheath which retains its general outline and supports the oil sand, the amount of explosive cord required can be found by routine experiments in a test hole and the information gained used in an actual well completion.

I have carried out particular operations which illustrate the results obtainable using an explosive device of my invention. In one such operation, to simulate the structure of a completed well in a producing formation, a cement sheath was formed about a length of slotted liner assembly. This was done by centering a length of 5 inch slotted liner in a length of $8\frac{3}{4}$ inch casing. The annular space was filled with cement and after the cement had set the outer casing was removed from a 10 foot section of the assembly. The assembly, with cement exposed over a 10 foot section, was then centered within a boiler flue and the cement-flue annulus was solidly packed with damp sand. The entire assembly was lowered into a test hole and an explosive device of my invention was lowered into the slotted liner. The explosive device had wrapped about it 6 feet of Primacord per linear foot along a 32 inch length. The Primacord was detonated within the slotted liner, after which the assembly was raised to the surface and examined. It was observed that the cement opposite the 32 inch portion of the explosive device was severely fractured. The cement had both vertical and horizontal fractures, the vertical fractures on the average being about 2 inches apart and the cross-cracking appearing, on the average, about every 6 inches.

If it is found that the fractures formed in the cement by detonating the explosive device of the invention are not large enough to produce fluids as rapidly as desired, the fractures can be enlarged by any of a number of known methods, for example, by treating the well with a chemical agent such as hydrochloric acid.

Obviously many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof and therefore only such limitations should be imposed as are indicated in the appended claim.

I claim:

1. An explosive device for fracturing the cement sheath

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surrounding a well casing which comprises an essentially rigid, vertically elongate, metallic core member of substantially circular transverse configuration throughout its length, said core member having intermediate its end portions an explosive cord mounting section of reduced diameter, each of said end portions being provided with means for centralizing the core member in a well casing, said explosive cord mounting section having a straight longitudinal groove in its outer surface, a length of explosive cord, said explosive cord extending in one direction along the explosive cord mounting section and in the groove and thence extending along the explosive cord mounting section in the opposite direction wrapped tightly as a helix about both the explosive cord mounting section and the extent of the explosive cord disposed in the groove, the helical extent of the explosive cord pressing tightly against the extent of the explosive cord in the groove to afford a multiplicity of vertically spaced con-

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tacts therebetween for the transference of detonation therebetween through such contacts, a blasting cap secured to one end of the explosive cord, means for detonating the blasting cap, and means for suspending the device in a well, whereby selection of the number of turns of explosive cord in the helix per unit length of the cord mounting section can fix within a broad and continuous range the amount of explosive force to be applied per unit length of a well casing with the multiplicity of contacts reducing the possibility of a misfire.

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