Sept. 23, 1969 H. E. JOHNSON 3,468,386

FORMATION PERFORATOR

Filed Sept. 5, 1967 2 Sheets-Sheet 1

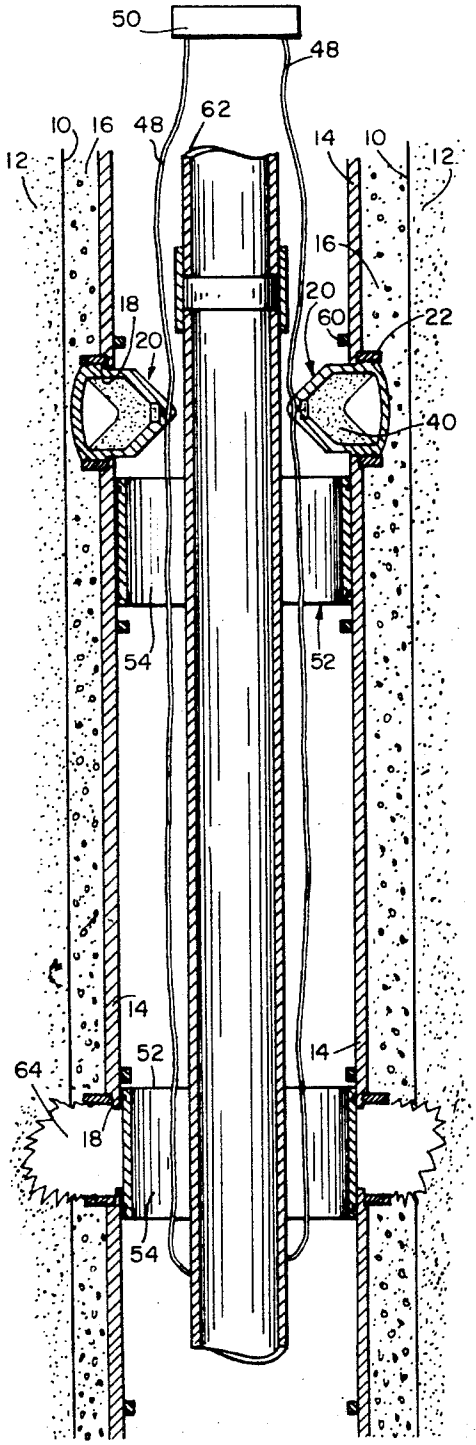


Fig. 1.

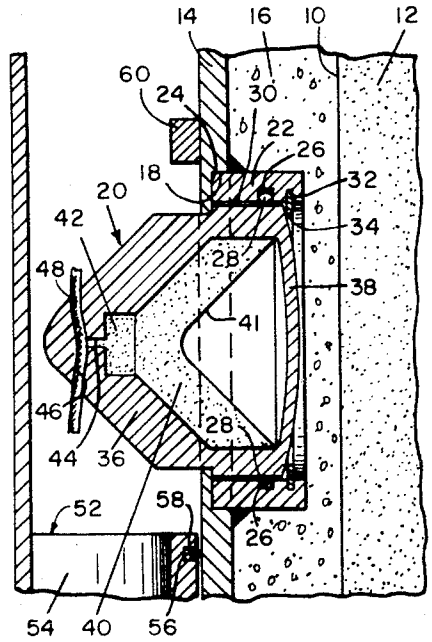


Fig. 2.

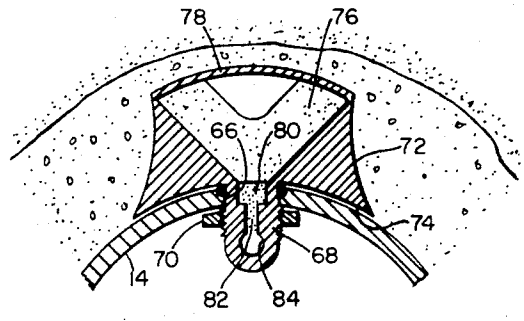


Fig. 3.

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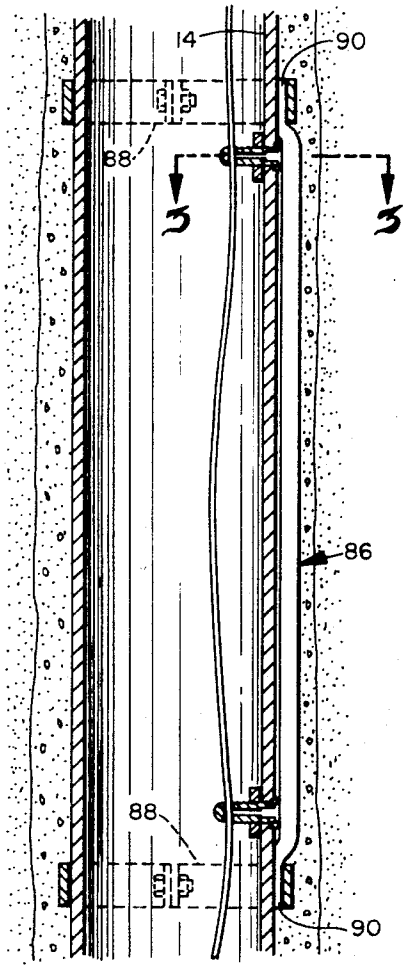


Fig. 4.

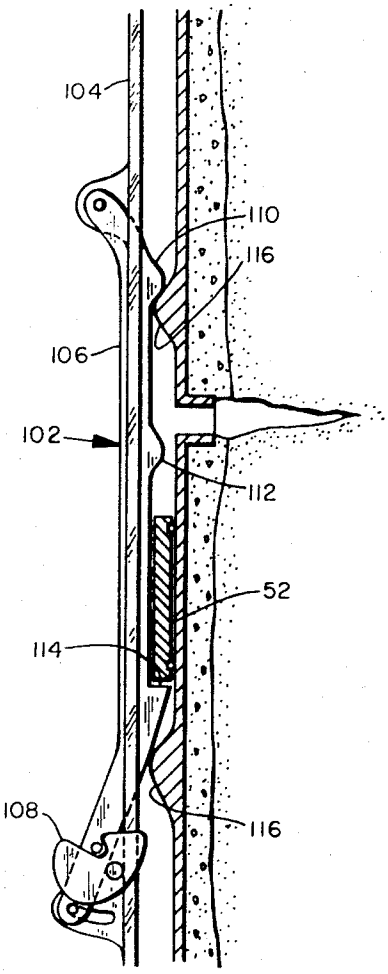


Fig. 7.

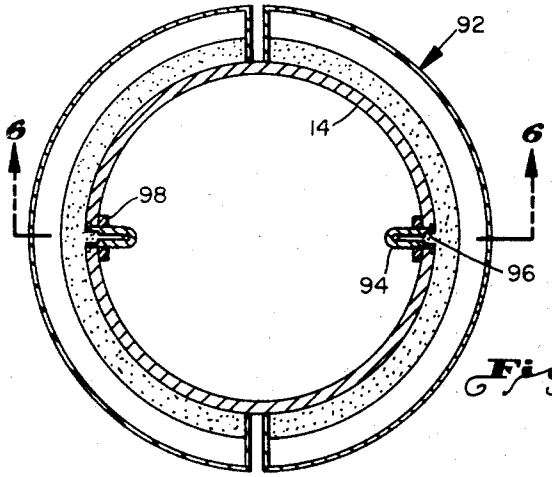


Fig. 5.

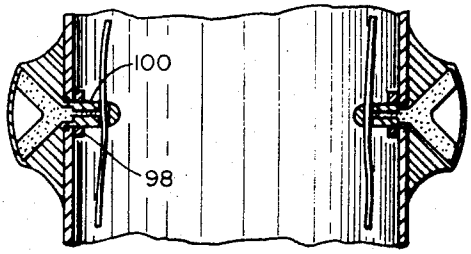


Fig. 6.

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FORMATION PERFORATOR

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Int. Cl. E21b 43/117, 33/12
U.S. Cl. 175—4.6 9 Claims

ABSTRACT OF THE DISCLOSURE

A formation perforating apparatus is secured sealingly in an opening of a casing sub in a manner that the face of the perforator is unobstructed by the casing shell so that a shaped charge or perforating bullet contained within the perforator does not have to penetrate the casing upon detonation. The perforator is detonated by Primacord or detonating wire from the surface. The perforator may be in the form of a conical section, or it may be toroidal, or it may be elongatedly trapezoidal. If conical, the perforator occupies a circular opening in the casing. If toroidal, the perforator encircles the casing. If elongatedly trapezoidal, the perforator is positioned longitudinally on the casing. The perforating apparatus includes a sliding sleeve valve which is remotely controlled to cover the opening left in the casing wall after explosion of the perforator.

This invention relates to the production of hydrocarbons and more particularly to the perforation of subterranean formations capable of producing oil or gas. Still more particularly, this invention relates to an apparatus for perforating a producing formation, such as an oil producing formation, to stimulate the production of fluid therefrom.

After a productive formation, one capable of producing oil or gas, has been drilled to the chosen depth, a casing is inserted down the length of the borehole and the space between the exterior surface of the casing and the interior surface of the borehole is filled with cement. Then, in order to produce fluid from the well, explosive charges or bullet perforators are lowered down the well to a position opposite the productive formation and the explosives are set off. The explosive charges or bullets make puncture holes through the casing and cement liner and penetrate into the formation permitting the well fluid to flow into the casing and be produced. This process is referred to as "completing" the well. The greatest disadvantage of this process is that the explosive charge or bullet must penetrate the casing and the total thickness of the cement liner before the productive formation is reached.

The primary object of this invention is to provide a more effective means for perforating a productive formation. Another object of this invention is to provide a means for the perforation of a productive formation in a manner that the perforating means does not have to first penetrate the casing.

Still another object of this invention is to provide a means for selectively closing open portions of the well casing after the perforation operation has been carried out.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings, wherein:

FIGURE 1 is a sectional view of a borehole illustrating one manner in which an apparatus of this invention may be used.

FIGURE 2 is an enlarged sectional view of a shaped charge apparatus used according to this invention.

FIGURE 3 is a sectional view of another embodiment of a shaped charge apparatus according to this invention.

FIGURE 4 is a longitudinal sectional view of still another embodiment of a shaped charge according to this invention.

FIGURE 5 is a sectional view of still another embodiment of a shaped charge according to this invention.

FIGURE 6 is a view along the lines 6—6 of FIGURE 5.

FIGURE 7 is an elevational view of a shifting tool for positioning a sleeve valve of this invention.

This invention comprises the placing of explosive devices, such as shaped charges or perforating guns sealingly in openings in the casing of a well in a manner that when the casing is put in place and the well is cemented, only a thin portion of cement is present between the explosive device and the face of the productive formation. Thus, the shaped charge or bullet need penetrate only a small thickness of cement in order to reach the productive formation. The explosive units are preferably ignited by Primacord or detonating wire in a remote manner from the surface. When shaped charges are used, the housing for the charge disintegrates after exploding, and if desired, a sliding sleeve valve may be selectively positioned over any of the openings resulting from the shot.

Referring now to the drawings in detail, a borehole **10** is shown drilled through a productive formation **12**. Conventionally, after the well is drilled, casing is set in place and the interval between the casing and the face of the borehole is filled with cement. In the figures, a section of casing **14** is shown in position down the borehole **10** and is surrounded by cement **16** which is used to seal off formation fluids from the well. Through openings **18** in casing **14** are positioned perforators **20** which are shown in the drawings to be of the type employing a shaped charge, but could also be of the type incorporating perforating bullets. It is preferred to use the shaped charge perforator since the perforator housing is designed to disintegrate upon explosion. The perforator **20** slips into an O-ring seal adapter **22** which is external of the casing, and preferably the perforator **20** and O-ring seal adapter **22** abut against a retaining shoulder **24** for increased stability. O-ring seal adapter **22** may be held in place removably as by threads, but preferably, it is generally more convenient to weld the O-ring seal adapter **22** into position on the casing. Perforator **20** is designed to fit closely into O-ring seal adapter **22**, and for holding the perforator in a sealable position a recess **26** is formed in O-ring seal adapter **22** and a compressible O-ring **28** of a material such as Neoprene fits into recess **26** and is compressed slightly by surface **30** of perforator **20**. O-ring seal adapter **22** includes a recess **32** into which a clip ring **34** is inserted after perforator **20** is in position by means of which clip ring **34** holds perforator **20** in place. Protruding through casing **14** is a conical portion **36** of perforator **20** which is of substantially thicker wall section than a front wall **38** of perforator **20**. Front wall **38** is formed purposely thin so that it will be easily frangible. Conical section **36** is given its conformation in order to provide the proper geometry for a shaped charge **40** formed within perforator **20**. Shaped charge **40** is held in position by a thin copper liner **41**. The explosive material forming the shaped charge may be any of the conventional explosives generally used in such shaped charges. At the apex of the conically shaped charge is positioned a booster charge **42** of explosive which is employed to detonate the main body of explosive. An axial passageway **44** provides communication between booster charge **42** and a transverse passageway **46** through which passageway **46** passes a detonating means such as Primacord **48** which is ignitable from the interior of the casing **14** and remotely ignitable from the surface of the ground. That is, an ignition means may be positioned within the casing

close to the perforator and may be controlled from the surface of the ground for safety. Primacord is shown as a preferred ignition means, but other ignition means such as detonating wire may be used to set off the booster charge and shaped charge.

In using the perforator of this invention the location of the productive formation should be accurately determined in order that the casing sub containing the desired number of perforating units may be properly located. Well logging and other related conventional measurements may be employed in selecting the most desirable location of the perforating units as well as the number and type of units to be employed. One manner of positioning the formation perforator casing sub is to attach a casing float collar or casing cementing adapter to the bottom of a section of casing of slightly less total length than the distance from the bottom of the hole up to the position chosen to be the lower end of the casing sub. Primacord or detonating wire is attached to each of the perforating units employed and the perforating casing sub is lowered into the hole preferably before the detonating unit **50** is attached. The detonating unit **50** may be of any conventional type usable with the explosive chosen for the perforators, that is, a mechanical, electrical, or timing device type detonator, and may also be retrievable. After proper positioning of the formation perforating casing sub a locating device such as a gamma ray logging tool having a collar locator may be run down the borehole to check the positioning of the perforating units before completing the operation. If the position of the perforating units is correct, the casing may be cemented in place and after the cement cures, the explosive perforator may be detonated.

It is preferred that the perforator **20** be made of a material which will disintegrate upon explosion of the shaped charge so that the opening **18** in the casing wall will be clean and free of debris. Such a material would be diecast aluminum or an easily frangible ceramic. After detonation, a closure device, such as a sliding O-ring sleeve valve **52** comprising a tubular section **54** having a close fit against the interior wall of the casing **14**, may be moved into position over opening **18** in which a perforator **20** has just been exploded. O-ring sleeve valve **52** includes a circumferential recess **56** near each end of the cylindrical valve into which is placed an O-ring **58** to provide sealing engagement with the interior wall of casing **14**. O-ring sleeve valve **52** is slid into position over opening **18** and in its closed position abuts a stop **60** adjacent opening **18**. In the drawing stop **60** is shown in FIGURES 1 and 2 of rectangular cross-sectional configuration for the sake of clarity. In most installations stop **60** is more suitably formed with an angular or rounded cross-sectional conformation which will facilitate the operation of a sleeve shifting tool and also cause the stops to be less subject to damage from well bore equipment. Sliding O-ring sleeve valve **52** may be operated from the surface by means of a sleeve shifting tool similar to that shown in FIGURE 7. Such a shifting tool is run on a wireline, rod string, or tubing string. Sleeve valve **52** may be operated selectively so that a chosen number of openings **18** may be covered or uncovered as desired. FIGURE 1 shows, for the purpose of illustration, how a sleeve valve **52** may be brought into a closed position over opening **18** in order to prevent communication between a perforation **64** and the interior of casing **14**. Of course, sleeve valve **52** is shown in a simplified form for the sake of illustration and suitable variations in the valve structure are within the scope of this invention. FIGURES 3, 4, 5 and 6 show additional embodiments of shaped charge apparatus prepared according to this invention. In the embodiment shown in FIGURE 3 the shaped charge device is positioned substantially exteriorly of the casing to which it is attached. A bore **66** is formed in the wall of casing **14** and a threaded mounting boss **68** is inserted through the bore **66** from the exterior of the casing and is held in place by cooperation of a retaining nut **70** threadably engaging the mounting boss. On the exterior of casing **14** the perforated device includes a thick-walled housing portion **72** preferably made integral with mounting boss **68**. Housing **72** has a concave rear surface **74** which permits abutment of the housing with the exterior wall of the casing. Inside the housing **72** is positioned a shaped charge **76** which is held in place by a thin frangible wall. **78**. Mounting boss **68** has a hollowed-out portion which is occupied by a booster charge **80** so arranged to detonate shaped charge **76**. A passageway **82** is provided to communicate with a bore portion **84**. Booster charge **80** communicates through passageway **82** with a length of Primacord which is positioned through bore **84**. Thus, in operation the shaped charge described in FIGURE 3 is ignited in the same manner as described in the embodiment of FIGURE 2.

In FIGURE 4 is shown an elongated perforating apparatus in which the shaped charge is positioned longitudinally along the casing.

An elongated perforator **86** is positioned exteriorly on the casing **14** and is supported at an upper and lower extremity by a conventional clamping band **88** which can be positioned around the casing and perforator by conventional means, such as a machine nut and bolt, and arranged to hold the perforator in position by cooperation with an extension **90** of the perforator housing. In cross-section elongated perforator **86** is similar to the cross-section of the perforator shown of FIGURE 3.

FIGURES 5 and 6 show still another variation of exteriorly positioned perforators according to this invention. In this embodiment the formation perforator is positioned around the external periphery of the casing **14**. Although a series of arcuate perforators could be positioned around the exterior periphery of the casing, the most convenient and preferred construction is to use perforators which are essentially semi-circular in shape as shown in FIGURE 5. The semi-circular perforators **92** are held in position abutting the casing **14** in the same manner as the perforators shown in FIGURE 3. That is, a mounting boss **94** is inserted through a bore **96** in casing **14** and is held in position by the cooperation of a retaining nut **98** with threads **100** on mounting boss **94**. FIGURE 6 is a longitudinal section view of the semi-circular perforators of FIGURE 5 and in cross-sectional view shows these perforators to be constructed essentially like the perforators of FIGURE 3.

FIGURE 7 shows a shifting tool **102** usable with the sliding valve **52** of this invention in positioning valve **52** after formation perforation has been accomplished. Shifting tool **102** includes a body portion **104** to which is attached a shifting dog **106** and a one-way release trigger **108**. Shifting dog **106** has protruding therefrom a cocking cam **110**, a releasing cam **112**, and a shoulder **114**. One-way release trigger **108** is spring-loaded and ratchet controlled so that the trigger is biased to rotate counterclockwise. The shifting tool is run into the casing with shifting dog **106** in a retracted cocked position. When the one-way released trigger **108** contacts upper valve stop **116** the release trigger is rotated counterclockwise to release the lease dog. The tool is then lowered until shoulder **114** approaches lower valve stop **116**. Then the direction of movement is reversed so that shoulder **114** is brought into abutment with the lower portion of sleeve valve **52** and the shifting tool raises the sleeve valve to its closed position. At this time the shifting dog is automatically released when releasing cam **112** is forced over upper valve stop **116**. Shoulder **114** then slides through sleeve valve **52** and the tool can be extracted. If, instead of raising the shifting tool when the sleeve valve is closed, the shifting tool is again moved downward, cocking cam **110** will contact upper valve stop **116** and the shifting dog can be returned to the retracted position by the rotation of release trigger **108** to its initial cocked position.

Since many different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that the specific embodiments described in detail herein are not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

What is claimed:

1. A formation perforator comprising:

a casing section positionable in a borehole adjacent a productive formation, said casing having an opening in the wall thereof opposite said productive formation,

perforator means sealingly positionable in said opening of said casing adjacent said productive formation,

means operable from within said casing for actuating said perforator means, and

a sliding sleeve valve interiorly of said casing and positionable adjacent said opening in said casing wall, said valve operable from within said casing by means controllable from the surface of the ground to position said valve to sealingly cover said opening.

2. A formation perforator as described in claim 1 in which:

said perforator means includes a housing containing a shaped explosive charge.

3. A formation perforator as described in claim 1 wherein said housing containing said shaped explosive charge is positioned substantially exteriorly of said casing.

4. A formation perforator as described in claim 3 wherein said housing containing said shaped explosive charge comprises an elongated housing positioned parallel to the longitudinal axis of said casing.

5. A formation perforator as described in claim 3 wherein said housing containing said shaped explosive charge comprises an elongated housing positioned radially around said casing substantially normal to the longitudinal axis of said casing.

6. A formation perforator as described in claim 1 wherein said housing containing said shaped explosive charge is positioned in said opening substantially interiorly of said casing.

7. A formation perforator as described in claim 6 wherein said housing containing said shaped charge includes a thin-walled front portion facing exteriorly of said casing and a thick-walled conical rear portion facing interiorly of said casing, a booster explosive charge positioned adjacent said shaped explosive charge, a transverse passageway adjacent the apex of said conical portion, and ignition means passing through said transverse passageway to set off said booster charge, said ignition means ignitable from within said casing.

8. A formation perforator as described in claim 7 in which said housing is removably positionable in said casing, said casing includes a retaining shoulder refining said opening and against which said housing abuts, an O-ring seal adapter adjacent said opening exteriorly of said casing for holding said housing in sealable alignment, and a clip-ring retainer to hold said housing in tight engagement against said retaining shoulder.

9. A formation perforator as described in claim 8 in which said ignition means includes a wire-line ignitor assembly.

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DAVID H. BROWN, Primary Examiner

U.S. Cl. X.R.

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