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[11] 3,601,196

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[73] Assignee Esso Production Research Company

[54] REMOTE PERFORATING IN DUAL COMPLETION WELLS

10 Claims, 14 Drawing Figs.

[52] U.S. Cl. 166/297, 166/250, 166/55.1, 175/4.51
[51] Int. Cl. E21b 43/119
[50] Field of Search 166/297, 313, 250, 255, 55.1; 175/4.51

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Primary Examiner—David H. Brown
Attorneys—Thomas B. McCulloch, Melvin F. Fincke, John S. Schneider, Sylvester W. Brock, Jr., Kurt S. Myers and Timothy L. Burgess

ABSTRACT: Method for perforating in a dual, parallel pipe string tubingless well. A crossover passage or port connects these pipe strings. Each pipe string is provided with a landing nipple at about the same depth below the crossover port. A radioactive source tool, which includes a radioactive pill for transmitting radiation in angular directions and a seating member for seating the radioactive source tool in the landing nipple arranged in one of the pipe strings, is pumped through the one pipe string until the seating member is landed in the landing nipple. The radioactive pill is suspended from the seating member a predetermined distance which is approximately the level at which it is desired to perforate. A perforating assembly, which includes a directional perforating gun, a directional radiation detector, a radioactivity-sensitive gun-firing mechanism including a source of electrical power for causing actuation of the perforating gun, a rotation device for causing the perforating gun to rotate, a seating member for seating the perforating assembly in the landing nipple arranged in the other pipe string, and a locomotive device for moving the perforating assembly through the other pipe string, is then pumped through the other pipe string until the seating member lands in the landing nipple. The detector of the perforating assembly is suspended a predetermined distance from the seating member so that it is positioned at the same level as the radioactive pill in the adjacent pipe string. The firing mechanism utilizes a switch which is actuated when the radioactive count detected by the radiation detector reaches a predetermined level. The directional gun is aimed so as to fire in a predetermined angular direction when the directional detector is facing the radioactive pill. The perforating assembly is rotated by circulating fluid in the pipe strings. After the perforating gun has fired, the perforating assembly is removed from the other pipe string. The radioactive source tool is then removed from the one pipe string. The perforating gun may be reloaded and the perforating procedure repeated at a different level in the well bore after repositioning the radioactive source tool and perforating assembly.

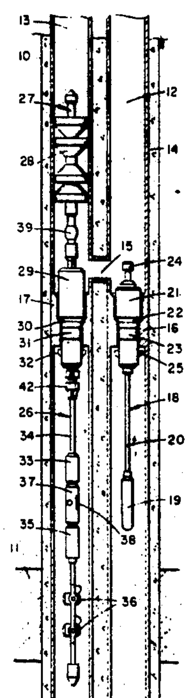

FIG. 1.

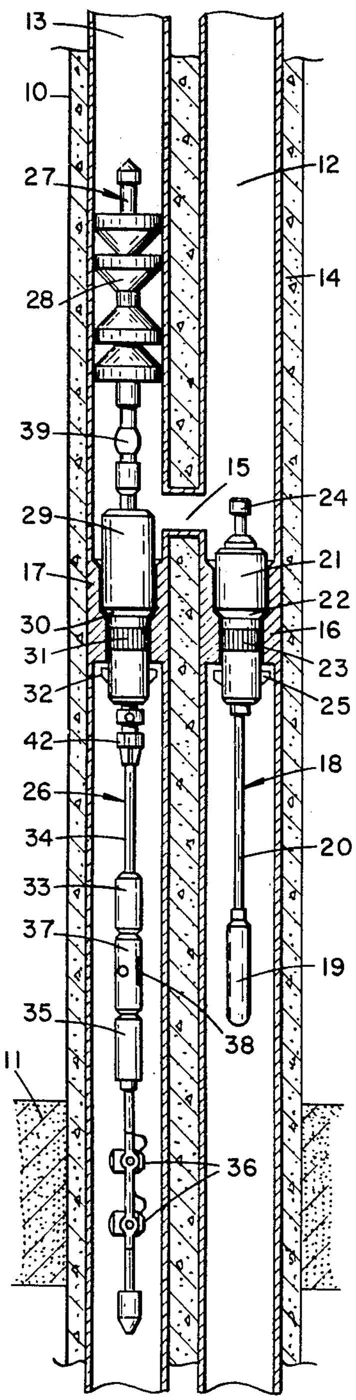

FIG. 2A.

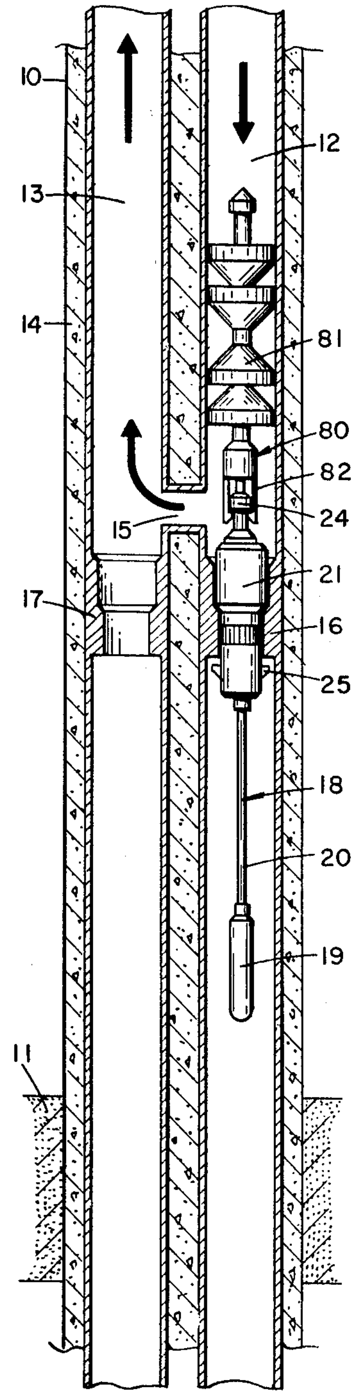

FIG. 2B.

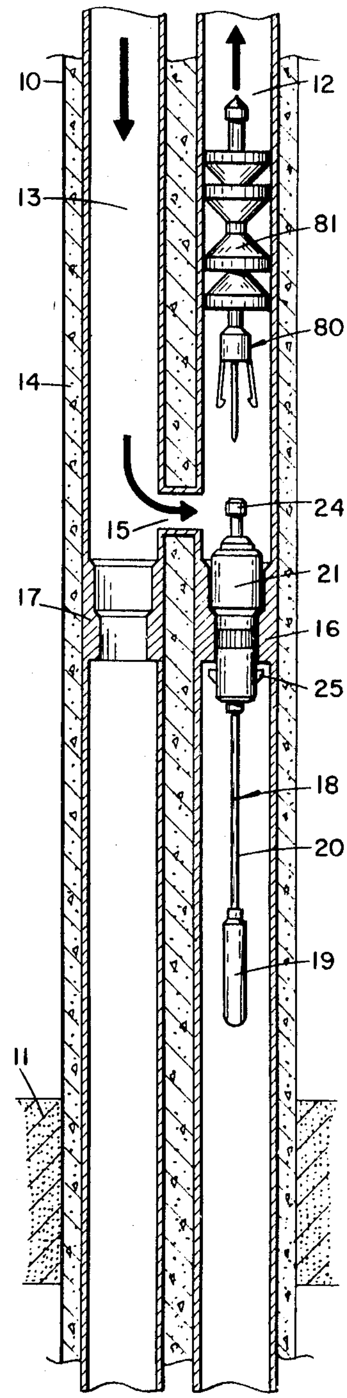

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FIG. 2C

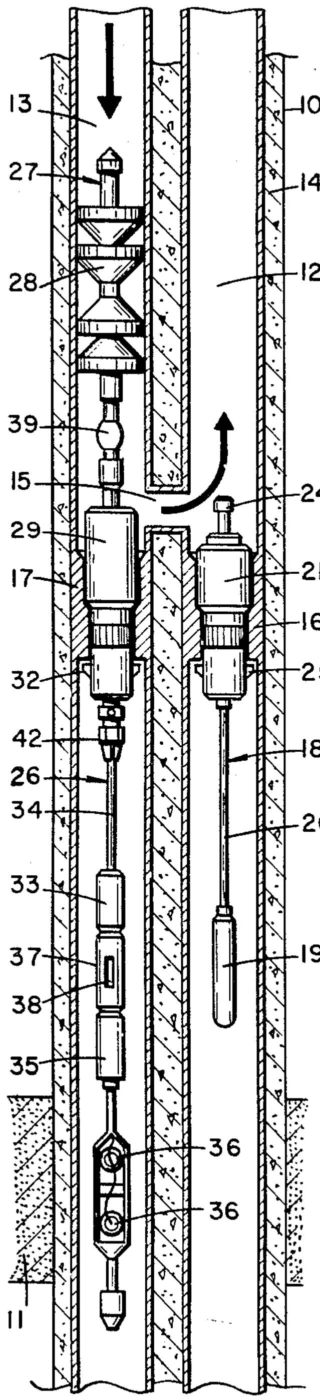

FIG. 2D

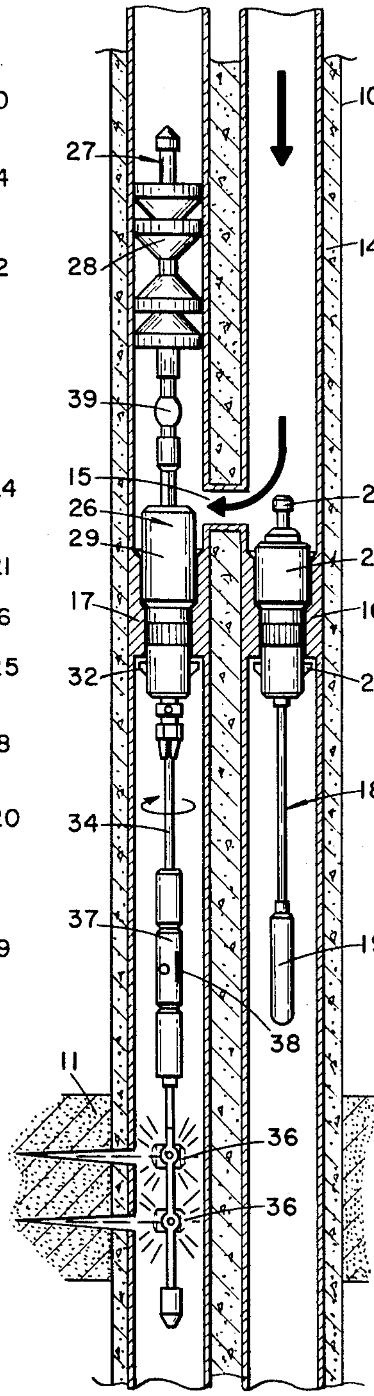

FIG. 2E

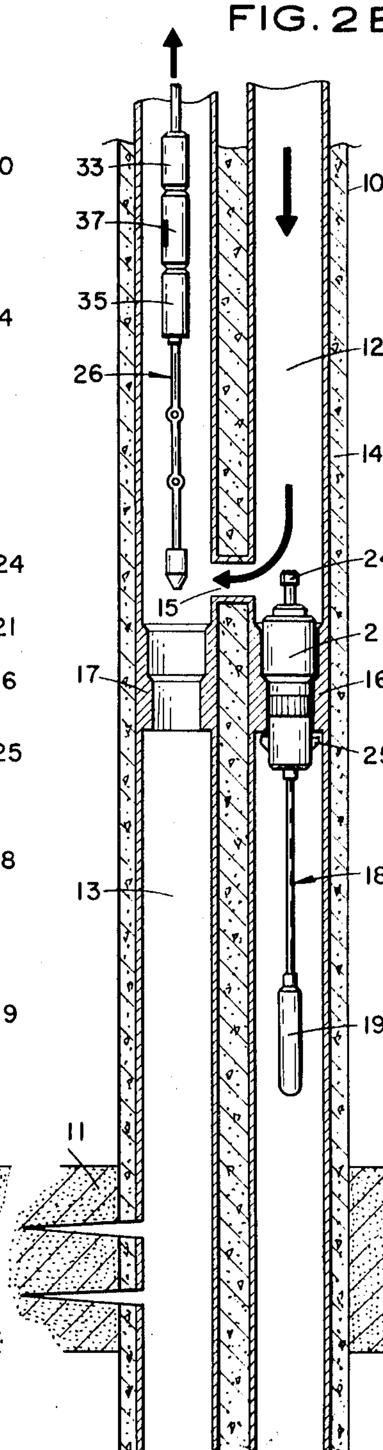

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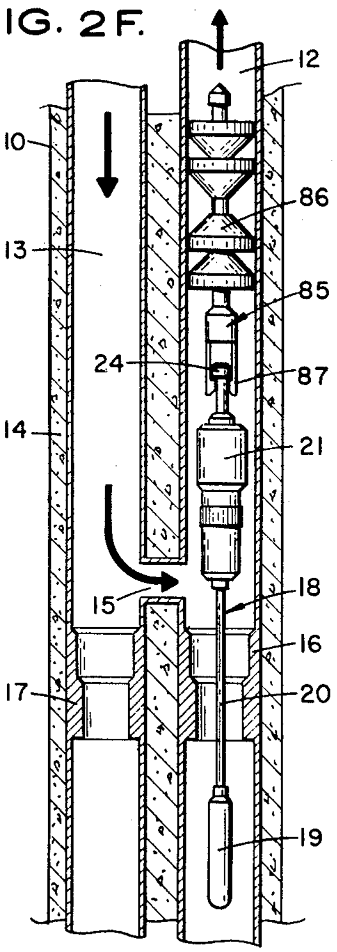
FIG. 2F.



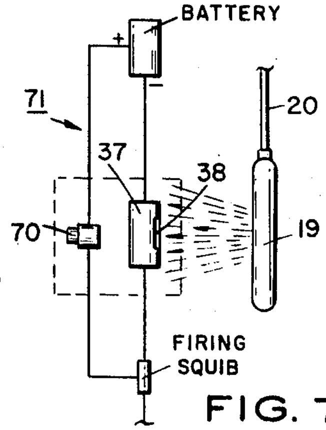


FIG. 7.

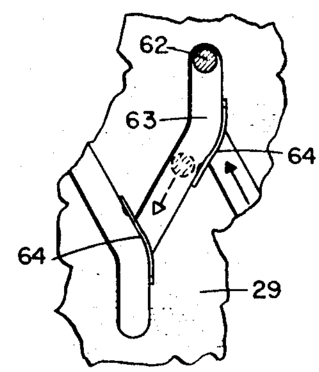


FIG. 6.

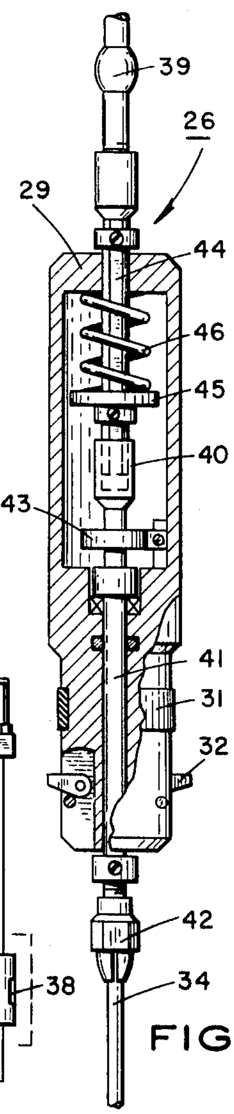


FIG. 3.

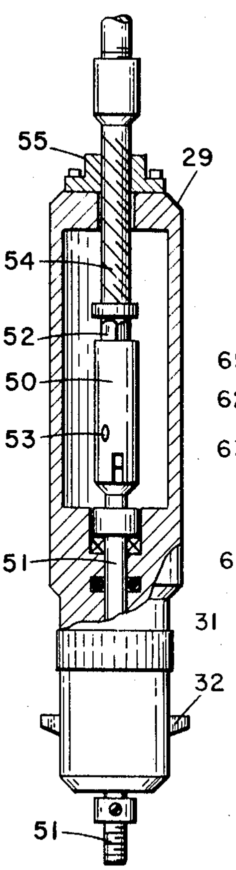


FIG. 4

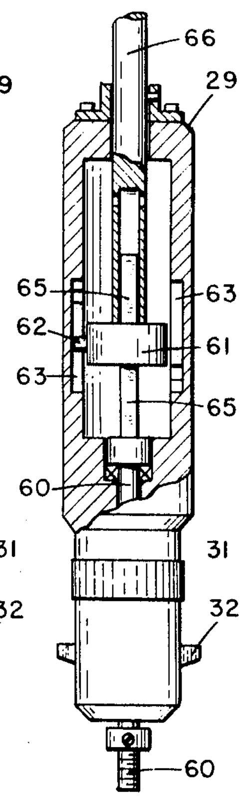


FIG. 5.

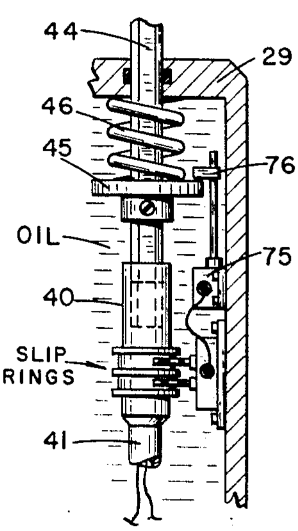


FIG. 8.

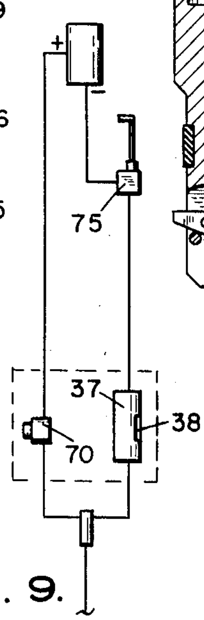


FIG. 9.

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REMOTE PERFORATING IN DUAL COMPLETION WELLS

BACKGROUND OF THE INVENTION

The present invention concerns method and apparatus for completing parallel, dual-string tubingless oil and/or gas wells which have through flowline (TFL) servicing capability. Tubingless TFL completions have application to underwater wells, highly deviated offshore wells drilled from platforms, deviated wells drilled from urban drill sites or deviated wells drilled from land to adjacent underwater reservoirs. One of the problems in completing such wells is to orient properly a perforating gun in one of the pipe strings so as not to shoot in the adjacent parallel pipe string. The ability to perforate using pumpdown techniques facilitates completion of subsea wells, as well as future workovers. In such wells, it is possible to move the drilling rig off location several days earlier than would be the case if the drilling rig were required to perform well-completion operations.

SUMMARY OF THE INVENTION

A method for perforating in a tubingless TFL well containing two spaced-apart parallel pipe strings comprising launching into one of said pipe strings a radioactive source; pumping said radioactive source through said one pipe string to adjacent a level therein at which it is desired to perforate; launching into said other pipe string a perforating tool provided with a perforating gun having a selected direction of perforation, a detector of radiation having a selected direction of radiation detection relative to said direction of perforation, means for rotating said perforating gun when the perforating tool is caused to move by hydraulic pressure, a locomotive device for causing the perforating tool to move through and in the other pipe string by hydraulic pressure, a radioactivity sensitive firing mechanism including a source of electrical power for actuating the perforating gun and a switch actuated when the radioactive count detected by the radiation detector reaches a predetermined level; pumping the perforating tool through the other pipe string until the radiation detector is at the level of the radioactive source; moving the perforating tool by circulation of fluid through said pipe strings to cause said perforating gun to rotate until at one horizontal angular position of said perforating gun the detected radiation reaches a preselected level to indicate that the direction of detection of radiation is toward said radioactive source and said direction of perforation is in a preselected direction, the perforating gun automatically firing or actuating when in such position. After the perforating gun has fired, the perforating tool is first circulated out of the well and then the radioactive source is circulated out of the well.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view of the earth's surface showing a subsea borehole having arranged in it two pipe strings, one of which contains a perforating tool assembly and the other one of which contains a radioactive source tool positioned in accordance with the teachings of the invention;

FIGS. 2A–2F illustrate stepwise the perforating procedure for use in tubingless TFL completed wells;

FIG. 3 is a partly sectional view illustrating one embodiment of a perforating tool assembly rotating device;

FIG. 4 is a partly sectional view illustrating another embodiment of a perforating tool assembly rotating device;

FIG. 5 is a partly sectional view of still another embodiment of a perforating tool assembly rotating device;

FIG. 6 is a more detailed view of the rachet-type rotating device shown in FIG. 5;

FIG. 7 schematically illustrates the firing mechanism circuit in which a pressure switch is included;

FIG. 8 is a partly sectional view illustrating use of an overtravel switch in the rotating device shown in FIG. 3; and

FIG. 9 schematically illustrates the firing mechanism circuit in which an overtravel switch is included.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a borehole **10** penetrating a subsurface oil- or gas-productive formation **11**. Two eccentric parallel spaced-apart pipe strings **12** and **13** are arranged in borehole **10** and cemented therein by means of cement **14**. Pipe strings **12** and **13** are connected together by crossover port **15**. Pipe string **12** is provided with a landing nipple **16** below crossover port **15** and pipe string **13** is provided with a landing nipple **17** at about the same level. A radioactive or nuclear source tool **18** is located in pipe string **12**. The components of this tool include a radioactive pill **19** suspended at a preselected depth from landing nipple **16** to near formation **11** on a line or small-diameter flexible tubing **20** attached to a locating lockdown mandrel **21** provided with a seating shoulder **22** for seating in landing nipple **16**, a packoff **23** for sealing off the space between the interior surface of the landing nipple and the outer surface of the locating-locking device, a setting and retrieving head **24**, and retractable, shearable lugs **25** for locking mandrel **21** in landing nipple **16**. A perforating tool assembly **26** is located in pipe string **13**. The components of this tool include a locomotive device **27** which suitably may be sets of oppositely facing swab cuts **28** and a locating-lockdown mandrel **29** having a seating shoulder **30** for seating in landing nipple **17**, a packoff **31** for sealing off the space between the interior surface of the landing nipple and the outer surface of mandrel **29**, and retractable, shearable lugs **32** for locking mandrel **29** in landing nipple **17**. Mandrel **29** also contains the rotating mechanism which in this instance is the embodiment shown in FIG. 3 and described later herein. Perforating tool assembly **26** also includes a battery case **33** which is suspended from mandrel **29** by means of a line or small-diameter line flexible tubing **34**. Battery case **33** contains electrical power to actuate firing head **35** which in turn detonates fixed directional perforating gun elements **36**. A nuclear or radioactive source (radiation) detector **37** is positioned between the electrical power in battery case **33** and electrical firing head **35**. Tubing **34** and tubing **20** are cut to suitable lengths to locate radiation detector **37** and radioactive source pill **19** at the same depth level in the well. Radiation detector **37** has a shielded window **38** which allows the radiation detector mechanism only to investigate in effect the radioactive count in a small horizontal angular range when battery case **33**, radiation detector **37**, firing head **35** and directional perforating gun elements **36** are rotated in a circle by means of the rotating mechanism. The function of the radiation detector **37** is to investigate the level of radiation of the borehole as it is being rotated around in a circle; and when the radioactive count reaches a preset level, indicating that the radiation detector window is directly facing radioactive source pill **19**, a switch makes electrical connection between battery case **33** and firing head **36**, which in turn detonates directional perforating gun elements **36** which are shown facing directly away from pipe string **12**. A swivel **39** connects locomotive device **27** to the other components of the tool.

Any desired radioactive substance may be employed as the radioactive pill, such as radon, radium bromide, radium chloride, uranium bromide, uranium tetrabromide, etc. These are naturally radioactive substances; however, other artificial radioactive substances also may be employed.

Radiation detector **37** may be any device capable of converting radiation energy transmitted from the radioactive source to electrical pulses and which transmits said electrical pulses only when the radiation detected by said detector reaches a specified predetermined level. Suitable for use is a Gieger-Mueller counter or an ionization chamber or a proportional counter, each modified to transmit electrical signals only when the predetermined radiation peak is reached.

The shielding material on the detector is formed of radiation absorbing or moderating substances, such as lead, tungsten, paraffin, boron, cadmium, etc., which substances are capable of absorbing or moderating the detected radiation.

One type of mechanism for rotating the perforating gun elements **36** is illustrated in FIG. **3**. Referring to FIG. **3**, there is shown a splined keyway **40** connected through mandrel **29** by means of shaft **41** and chuck **42** to flexible tubing **34**. A coiled band spring **43** is connected to shaft **41**. A splined shaft **44** is initially arranged in splined keyway **40**. A support **45** is attached to splined shaft **44** and a compression spring **46** is attached at one end to the support and at the other end thereof to the upper interior end of mandrel **29** to inhibit upward movement of splined shaft **44**. The upper end of splined shaft **44** is connected to locomotive device **27** through swivel **39**. This rotating mechanism operates as follows. Mandrel **29** is set in landing nipple **17** and fluid is circulated down pipe string **12** through crossover port **15** and up pipe string **13**. Swab cups **28** are forced upwardly which causes connected splined shaft **44** to move upwardly against the bias of spring **46** until splined shaft **44** is no longer engaged in splined keyway **40**. Coiled band spring **43** then causes slow rotation of shaft **41** which in turn rotates tubing **34** and radiation detector **37** and gun elements **36** in one or more complete revolutions.

Another embodiment of the rotating mechanism, illustrated in FIG. **4**, includes a splined keyway **50** connected to the rotatable components by means of shaft **51**. A splined shaft **52** is keyed into splined keyway **50** and is initially prevented from vertical movement in the keyway by shear pin **53** which connects keyway **50** and shaft **52**. A threaded shaft **54** connects shaft **52** to swivel **39** and locomotive device **27**. Shaft **54** extends through a threaded headnut **55**. In operation of this embodiment, fluid is circulated down pipe string **12** through bypass **15** and up pipe string **13** to force swab cups **28** upwardly. Movement of swab cups **28** upwardly moves shaft **54** upwardly through threaded headnut **55** to cause shear pin **53** to shear and permit shaft **52** to rotate keyway **50** and shaft **51** connected to keyway **50** through one or more revolutions.

The rotating mechanism shown in FIGS. **5** and **6** is a racheting "sawtooth" arrangement. As seen in these figures, a rotatable shaft **60** extends through the lower end of mandrel **29** and connects to the rotatable gun elements. The upper end **65** of shaft **60** which is square shaped extends through a collar or sleeve **61** and is slidably arranged within a hollow square-shaped rod **66** attached to collar **61**. Rod **66** extends through the upper end of mandrel **29** and connects to swivel **39**. Collar **61** is provided with a cam follower **62** which engages in a "-sawtooth" or Y-shaped cam surface or track **63** formed in the inner wall of mandrel **29**. As seen particularly in FIG. **6**, track **63** is provided with hinged leaf springs **64** at each juncture of the vertical paths of track **63** to permit cam follower **62** to travel and shaft **60** operably attached thereto to rotate, in only one direction, as indicated by the arrow. In the operation of this embodiment, fluid is circulated down pipe string **12** through bypass **15** and up pipe string **13** to move swab cups and shaft **66** and collar **61** and cam follower **62** upwardly until cam follower **62** travels up to the upper portion of track **63**. Then by gravity or by reverse circulation of fluid down pipe string **13** through bypass **15** and up pipe string **12**, swab cups and collar **61** and cam follower **62** move down and into the next succeeding leg of each Y section as indicated. As collar **61** is rotated by the travel of cam follower **62**, rod **66** is rotated which in turn rotates shaft **65** and shaft **60** attached to shaft **65**.

As shown in FIG. **7** a pressure switch **70** is connected into the detector-battery-gun circuit, generally designated **71**, to ensure that the gun is only armed for firing at the depth at which it is to be used. Pressure switch **70** is preset for a selected hydraulic pressure in the pipe string.

Another safety precaution is shown in FIGS. **8** and **9**. An overtravel switch **75** is provided with a rod contact **76** which engages support member **45** upon movement of that support member upwardly. It is designated to actuate just prior to separation of the splined keyway **40** and key shaft **44** described with reference to FIG. **3**. Housing **29** may be filled with a nonconductive liquid when a slipring-type conductor is used. The circuit shown in FIG. **9** includes the pressure switch **70**.

OPERATION

The perforating operation is illustrated in FIGS. **2A–2F**. In FIG. **2A**, radioactive or nuclear source tool **18** to which has been connected a running tool **80**, having oppositely facing swab cups **81** and releasable prongs **82** connected to running and retrieving head **24** of nuclear source tool **18**, is launched in pipe string **12** and pumped through that pipe string until mandrel **21** is landed in landing nipple **16** to position radioactive pill **19** at a predetermined level.

As shown in FIG. **2B**, locomotive running tool **80** is retrieved by reverse circulating fluid down pipe string **13** through bypass **15** and up pipe string **12**.

As shown in FIG. **2C**, perforator tool **26** has been launched in pipe string **13** and pumped through that pipe string until mandrel **29** is landed in landing nipple **17** by circulating fluid down pipe string **13** through bypass **15** and up pipe string **12** as indicated. Radiation detector **37** is then located at a preselected depth at the same level as radioactive pill **19**.

When it is desired to cause perforation of formation **11** fluid is pumped down pipe string **12** through bypass **15** and up pipe string **13** to move locomotive device **27** upwardly and cause radiation detector **37** to rotate in accordance with the operation described with respect to FIG. **3**. Either of the other two techniques illustrated and described with respect to FIGS. **4** and **5** may also be used to cause rotation of detector **37**. As illustrated in FIG. **2D**, when detector window **38** is facing radioactive pill **19**, electrical power is applied to firing head **35** to cause gun elements **36** to fire. As indicated by the simple circuits shown in FIGS. **7** and **9**, sufficient pressure must exist to actuate pressure switch **70** to complete the circuit (FIG. **7**) and if the overtravel switch is used, then that switch **75** must also be actuated to complete the circuit as illustrated in FIG. **9**.

As illustrated in FIG. **2E**, perforator tool assembly **26** is circulated from pipe string **13** by pumping fluid down pipe string **12** through bypass **15** and up pipe string **13**.

Nuclear source tool **18** is then retrieved by pumping a retrieving tool **85**, having oppositely facing swab cups **86** and prongs **87** for latching onto retrieving head **24** of nuclear source tool **18**, is pumped through pipe string **12** until it latches onto nuclear source tool **18**. Then, as illustrated in FIG. **2F**, fluid is pumped down pipe string **13** through bypass **15** and up pipe string **12** under sufficient pressure to cause shearable lugs **25** to shear to permit removal of nuclear source tool **18** from pipe string **12**.

Having fully described the apparatus, advantages, objects and method of our invention, we claim:

1. A method for perforating in a tubingless TFL well containing two spaced apart, parallel pipe strings comprising:

launching a radioactive source into one of said pipe strings;

pumping said radioactive source through said one pipe string to adjacent a level therein at which it is desired to perforate;

launching into said other pipe string a perforating tool provided with a perforating gun having a selected direction of perforation, a detector of radiation having a selected direction of radiation detection relative to said direction of perforation, means for rotating said perforating gun when said perforating tool is caused to move by hydraulic pressure, a locomotive device for causing said perforating tool to move through and in said other pipe string by hydraulic pressure, a radioactivity-sensitive firing mechanism including a source of electrical power for actuating said perforating gun, and a switch actuatable when the radioactive count detected by said radiation detector reaches a predetermined level;

pumping said perforating tool through said other pipe string until the radiation detector is at the level of said radiation pill; and

moving said perforating tool by circulation of fluid through said pipe strings to cause the perforating gun to rotate until at one angular position of said perforating gun the detected radiation by said radiation detector reaches a preselected level to indicate that the direction of detection of radiation is toward said radioactive pill and said direction of perforation is in a selected direction, said perforating gun automatically firing when in such position.

2. A method as recited in claim 1 in which said direction of perforation is away from said one pipe string.

3. A method as recited in claim 1 in which said direction of perforation is toward said one pipe string.

4. A method as recited in claim 1 in which said perforating gun automatically firing when in said one angular position when well pressure adjacent said perforating tool is at a predetermined level.

5. A method as recited in claim 4 in which movement of said perforating tool by circulation of fluid to cause the perforating gun to rotate also actuates a switch to permit said perforating gun to fire.

6. A method as recited in claim 1 including the step of reverse circulating said perforating gun out of said other pipe string after firing of said perforating gun.

7. A method as recited in claim 6 wherein said perforating tool is moved upwardly to cause said perforating gun to rotate.

8. A method as recited in claim 6 including moving said perforating tool upwardly and downwardly to cause said perforating gun to rotate.

9. Apparatus for perforating in a tubingless TFL well containing two spaced apart, parallel pipe strings connected together through a crossover port comprising:

a pumpable perforating tool adapted to be pumped into and out of one of said pipe strings and provided with a perforating gun having a selected angular direction of perforation and a detector having a selected angular direction of radiation detection relative to said direction of perforation, locomotive means for causing said perforating tool to move vertically in one of said pipe strings when acted upon by hydraulic pressure, rotating means for rotating said perforating tool when said perforating tool is moved vertically in said one pipe string by hydraulic pressure, and means for automatically firing said perforating gun when the level of radiation detected is at a preselected value; and a radiation source adapted to be pumped into and out of said other pipe string.

10. Apparatus as recited in claim 9 including means arranged on said perforating tool adapted to prevent firing of said perforating gun until a predetermined pressure is reached in said one pipe string at the level of said perforating tool.