Dec. 5, 1961 J. W. KENNEDAY 3,011,550

APPARATUS FOR PERFORATING PIPE STRINGS

Filed Aug. 22, 1958 2 Sheets-Sheet 1

FIG. 1.

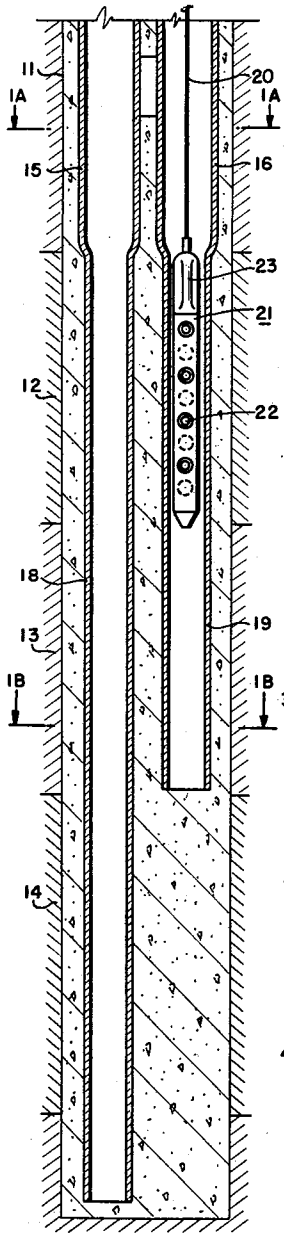
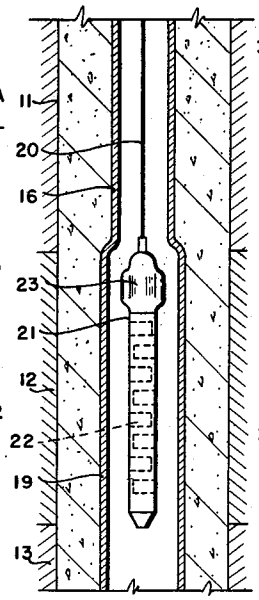


FIG. 2.



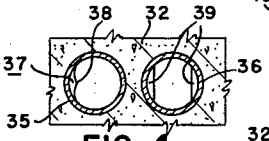


FIG. 4.

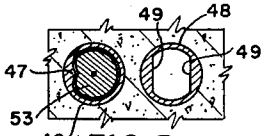


FIG. 5a.

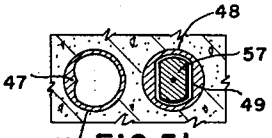


FIG. 5b.

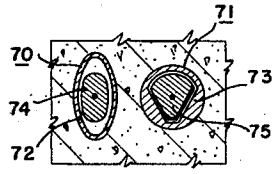
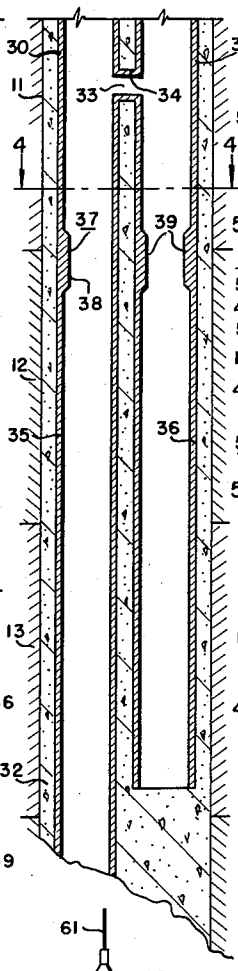


FIG. 7.

FIG. 3.



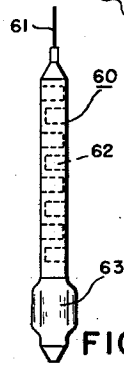
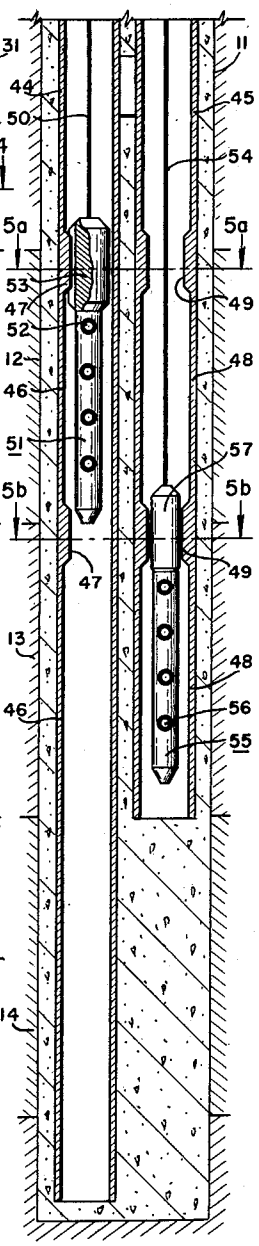


FIG. 6.

FIG. 5.



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APPARATUS FOR PERFORATING PIPE STRINGS

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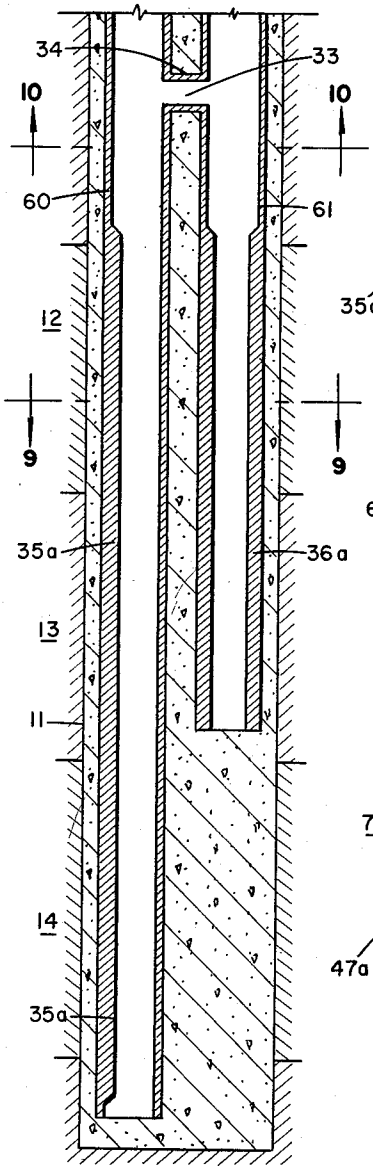


FIG. 8.

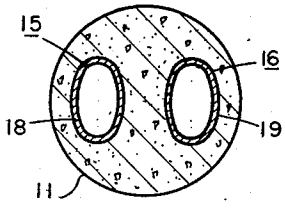
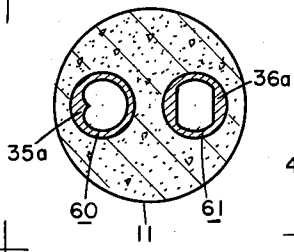


FIG. 1B.

FIG. 9.



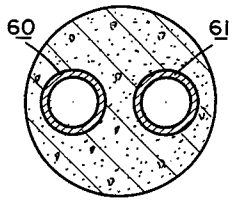


FIG. 10.

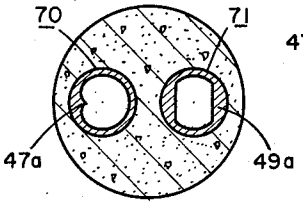


FIG. 12.

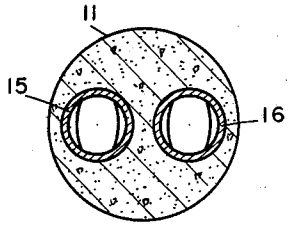


FIG. 1A.

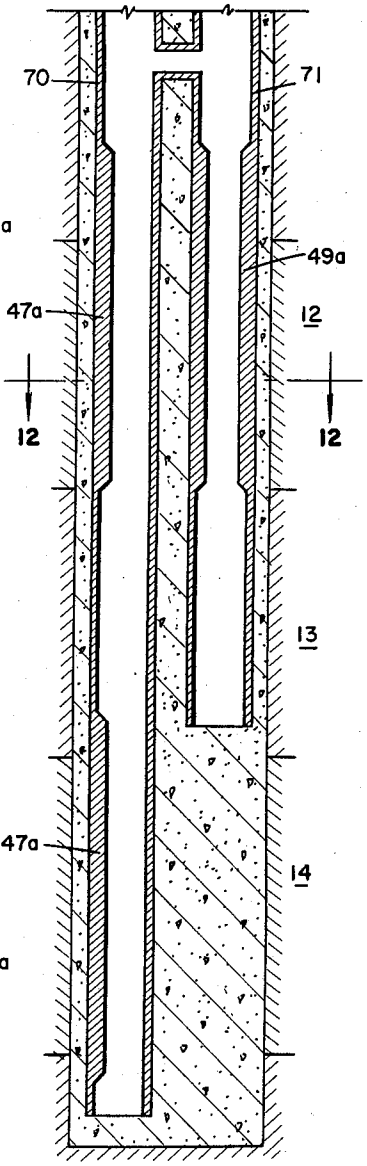


FIG. 11.

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APPARATUS FOR PERFORATING PIPE STRINGS

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12 Claims. (Cl. 166—55)

The present invention is directed to apparatus for perforating pipe strings. More particularly, the invention is directed to apparatus for perforating a selected pipe string in a well having a plurality of pipe strings therein. In its more specific aspects, the invention is concerned with perforating at least one of a plurality of eccentrically placed pipe strings in a well bore.

The present invention may be briefly described as apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein for penetrating one of the pipe strings at a time, which includes a pipe string arranged in and forming part of one of said pipe strings at a point adjacent a hydrocarbon productive zone to be penetrated. The section has an interior configuration different from the interior configuration of the greater portion of said one pipe string and is arranged relative to the other pipe string such that the interior configuration of said section is oriented away from said other pipe string. An elongated perforator provided with perforating means is movable through said one pipe string, the perforator having a dimension only sufficiently smaller than said section such that it is movable therethrough and has at least a portion of its exterior conforming to the interior configuration of said section whereby said perforator on moving through said section is oriented to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string.

It is contemplated in the practice of the present invention that the cross-sectional interior configuration of said pipe section may be rectangular, triangular or substantially triangular, elliptical, ovoid, or provided with any shape which will allow a conforming shape on a perforator to be oriented in a predetermined selected direction. For example, the interior surface configuration of said pipe section may be irregular with a conforming irregular shape or surface provided on the gun perforator.

In the present invention, the pipe section may be provided with means which provides an interior configuration different from the interior configuration of the greater portion of the pipe string. The means may be arranged in or inserted in the section such that the perforator on moving through the means is oriented properly so that it perforates only the pipe string through which it is moving.

It is also contemplated that a plurality of pipe sections may be provided in one or more of the parallel pipe strings with each section oriented relative to the other pipe string such that the perforator on moving through said section is oriented to position the perforator such that on firing the perforating means carried by the perforator the pipe section is penetrated and the other pipe string is not penetrated. It is also contemplated that each of the several pipe strings may be provided with pipe sections or means in pipe sections for orienting a gun perforator having a conforming shape to the pipe sections to penetrate only the pipe string through which the gun perforator is moving. In the present invention, it is further contemplated that the interior configuration of the pipe sections in one pipe string may be similar to or different from the interior configuration of the pipe sections in the other pipe strings, with the gun perforator movable through the pipe strings also having exterior configurations conforming to the interior configuration of the respective pipe string through which it is moved.

The present invention will be further illustrated by reference to the drawing in which

FIG. 1 is a front view of parallel casing strings cemented in a well bore with a gun perforator arranged in a pipe section having a special configuration;

FIG. 1A is a sectional view taken along the line 1A—1A of FIG. 1;

FIG. 1B is a sectional view taken along the line 1B—1B of FIG. 1;

FIG. 2 is a side view of FIG. 1;

FIG. 3 is a front view of a modified embodiment of the present invention in which pipe sections are provided with means therein providing a different configuration from the interior configuration of the rest of the pipe;

FIG. 4 is a view taken along the lines 4—4 of FIG. 3;

FIG. 5 is a further modification of the present invention showing spaced apart means and pipe sections of parallel eccentrically positioned coextensive pipe string;

FIG. 5*a* is a view taken along the lines 5*a*—5*a* of FIG. 5;

FIG. 5*b* is a view taken along the lines 5*b*—5*b* of FIG. 5;

FIG. 6 is a modified gun perforator with means on its lower end;

FIG. 7 is a cross-sectional view of parallel pipe sections having perforators of different shapes arranged therein;

FIG. 8 is a sectional view, similar to FIG. 3 showing a further modification of the present invention;

FIG. 9 is a view taken along the line 9—9 of FIG. 8;

FIG. 10 is a view taken along the line 10—10 of FIG. 8;

FIG. 11 is a sectional view, similar to FIG. 5, showing a further modification of the present invention; and

FIG. 12 is a sectional view taken along the line 12—12 of FIG. 11.

Referring now to the drawing and particularly to FIGURES 1 and 2, numeral 11 designates a well bore which has been drilled to penetrate a plurality of subsurface earth formations, zones, sands, strata, horizons 12, 13 and 14, which may be productive of hydrocarbons. Arranged in the well bore 11 are parallel pipe strings 15 and 16, which are cemented in the well bore 11 by cement 17. The pipe strings 15 and 16 are each provided with sections 18 and 19, respectively, which for purposes of description only may have a shape as mentioned before but which is preferably oval or elliptical in cross section. Run in through the pipe string 16 on a wire line or flexible lowering means such as cable 20 and attached thereto is an elongated perforator 21 which may be a bullet gun or shaped charge perforator or may be a chemical or mechanical type perforator. Preferably, however, perforator 21 is a shaped charge perforator provided with a plurality of shaped charges 22. The perforator 21 is provided with at least its upper end 23 shaped to conform with the interior configuration of the section 19 such that when the perforator 21 is lowered on wire line 20 to within the section 19, it has to be rotated or oriented to pass freely therethrough and will only pass therethrough when in its proper position. This allows the shaped charges 22 to be positioned to fire in a predetermined or selected direction such that the pipe section 19 will be perforated in the zone 12 as may be desired without perforating the pipe section 18 of the pipe string 15. By providing pipe sections of selected interior configuration and with perforating means of corresponding or conforming shape but smaller in dimension, it is possible to perforate a hydrocarbon productive zone and produce therethrough without perforating another parallel pipe through which simultaneous produc-

tion may be had from a vertically spaced apart hydrocarbon productive zone penetrated by the well bore.

Referring now to FIGURES 3 and 4, the well bore **11** has parallel pipe strings **30** and **31** arranged therein and cemented into place with cement **32**. Like in FIGURES 1 and 2, the well penetrates the horizons or zones **12**, **13** and **14**, which may be productive of hydrocarbons such as oil and gas. In this embodiment of the present invention, the pipe strings **30** and **31** are fluidly interconnected by a passageway **33** formed by an interconnecting means **34**. Also in this embodiment pipe sections **35** and **36**, respectively, are provided in pipe strings **30** and **31**. The interior of the pipe section **35** is provided with a means **37** which defines an irregular shape or surface **38** shown more clearly in FIGURE 4. The pipe section **36** in pipe string **31** is provided with means **39** which provides a rectangular or oval shape such that when a gun perforator or perforators having exterior surfaces corresponding to the irregular shape **38** or to the opening defined by the means **39** are moved through the respective sections **35** and **36**, the gun perforators are oriented such that the perforating surface is pointed away from the other pipe string, the perforating surface of each of the perforators being arranged relative to the orienting surface such that the perforating surface is always pointed away from the other pipe strings when moved through the respective section having a configuration to which its outer surface conforms.

Referring now to FIGURES 5 to 5*b* inclusive, a modified embodiment is shown in which there is positioned in well bore **11** a plurality of parallel pipe strings **44** and **45** with the pipe string **44** being provided with sections **46**, each being provided with means **47** providing an interior configuration for the sections **46** different from the interior configuration of the rest or greater portion of the pipe string **44**. The pipe string **45** also has arranged thereon pipe sections **48**, each of which is provided with means **49** providing an interior configuration for the sections **48** different from the interior configuration of the rest or greater portion of the pipe string **45**.

Suspended by a wire line or other suspending means such as a cable **50** in pipe string **44** is a perforator **51** provided with perforating means **52** which has an upper end, portion **53**, having a configuration conforming to the configuration of the means **47** in the sections **46** of pipe string **44** such that when the perforator **51** is lowered or moved therethrough, the perforator **51** is oriented such that the means **52** are pointed away from the pipe string **45** to allow the means **52** when operated to perforate only the pipe string **44**.

Arranged in pipe string **45** and suspended therein by a wire line or other suspending means **54** is a perforator **55**, which, like perforator **51**, is provided with perforating means **56**. Perforator **55** has its upper end **57** shaped to conform with the interior configuration of means **49** such that when the perforator **55** is moved through the means **49** in the sections **48**, it is oriented such that the perforated means **56** is pointed in a direction away from the pipe string **44** such that only the pipe string **45** is perforated when the means **56** are operated or fired.

In FIGURES 1, 2, and 5–5*b* inclusive, the upper end of the perforator is shaped or conformed to a configuration similar to that of the interior of the pipe section. FIGURE 6 shows a modified embodiment of a gun perforator such as **60**, lowerable on a wire line **61** and which is provided with perforating means **62**. In this embodiment the lower end **63** of the gun perforator has an exterior surface with a configuration conforming to the configuration of a selected pipe section of one of the pipe strings as shown in the several figures of the drawing. Thus when the perforator **60** is lowered or moved through the pipe string, it may have its lower end **63** positioned in one of the pipe sections or means below or adjacent a zone to be perforated such that the pipe string or section in that zone may be perforated without piercing the other pipe string.

Referring now to FIGURE 7, a cross-sectional view is shown of parallel pipe strings **70** and **71**, having pipe sections **72** and **73** of different configurations and having perforating means **74** and **75** of conforming configurations arranged therein. Thus the cross section of pipe section **70** is elliptical or oval while the cross section of pipe **71** is substantially triangular. In the showing of FIGURE 7, the perforating means would be arranged in the perforator **74** such that the pipe **71** would never be perforated, while in the perforator **75**, the perforating means would be located such that the pipe string **70** would never be perforated.

It will be clear from the several figures of the drawing that one pipe string is so arranged relative to another pipe string such that the section of different internal configuration has a cross-sectional dimension oriented in a direction away from the periphery of an adjacent pipe string. Thus, when the portion of the perforator is lowered into the section, to enter the section, it must be oriented to conform that portion of its surface with the cross-sectional dimension of the section.

In the showing of FIGURE 3, especially, where the pipe strings **30** and **31** are fluidly interconnected by passageway **33**, the parallel pipe strings **30** and **31** may suitably be used for simultaneous production from a plurality of perforated zones and also the two pipe strings **30** and **31** may be used for workover and servicing operations. This may conveniently be accomplished by lowering and seating a tubular member in one of the pipe strings above the fluid passageway **33** and sealing same in the sealed pipe string such that production may be had through one pipe string and through the other pipe string. When workover operations are to be performed, the tubular member would be sealed above the passageway **33** such that fluid might be circulated through the passageway **33** from one pipe string to the other and then flowed through the other pipe string through a tubular member sealed above the passageway **33** in said other pipe string.

Referring now to FIGS. 8, 9, and 10, the showing of which is similar to FIG. 3, parallel pipe strings **60** and **61** are provided with pipe sections **35***a* and **36***a* having cross-sectional configurations the same as shown in FIG. 3, excepting that the configurations are continuous and extend the entire length of the pipe section.

The modification shown in FIGS. 11 and 12 illustrates parallel pipe strings **70** and **71** which are provided with pipe sections having internal configurations which are the same shape as that of FIG. 5. As shown, pipe string **70** is provided with pipe sections **47***a* which are vertically spaced apart and extend a greater length than the sections shown in FIG. 5. Pipe string **71** is provided with a pipe section **49***a* which is the same as that of FIG. 5 excepting that it is of greater length.

It will be understood that it is necessary to attach the two pipe strings together such as by strapping so as to retain their relative position as they are being placed in the borehole.

The present invention is of considerable importance and utility in that it is possible to complete a well in a plurality of hydrocarbon productive zones without using tubing and perforating the pipe strings in said well separately without perforating other of the parallel pipe strings. If apparatus were not provided for orienting the perforator for perforating only one pipe string, it would not be possible to obtain fluid simultaneously from separate spaced apart hydrocarbon productive zones.

The nature and objects of the present invention having been completely described and illustrated, what I wish to claim as new and useful and secure by Letters Patent is:

1. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein for

penetrating one of said pipe strings at a time which comprises, in combination, a pipe section arranged in and forming part of one of said pipe strings at a point adjacent a hydrocarbon productive zone to be penetrated, said section having its interior surface of a configuration different from the interior configuration of the greater portion of said one pipe string, said one pipe string being arranged relative to another of said pipe strings such that said section has a cross-sectional dimension oriented away from the periphery of said another pipe string and an elongated perforator provided with perforating means and movable through said one pipe string, said perforator having a cross-sectional dimension only sufficiently smaller than said section to be movable therethrough and having at least a portion of its exterior surface conforming to the interior configuration of said section, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and moving through said section is oriented to conform said portion of its exterior surface with said cross-sectional dimension of said section to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

2. Apparatus in accordance with claim 1 in which the cross-sectional interior configuration of at least a portion of said section is rectangular.

3. Apparatus in accordance with claim 1 in which the cross-sectional interior configuration of at least a portion of said section is substantially triangular.

4. Apparatus in accordance with claim 1 in which the cross-sectional configuration of at least a portion of said section is elliptical.

5. Apparatus in accordance with claim 1 in which the cross-sectional interior configuration of at least a portion of said section is irregular.

6. Apparatus in accordance with claim 1 in which the cross-sectional interior configuration of at least a portion of said section is ovoid.

7. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein in penetrating one of said pipe strings at a time which comprises, in combination, a pipe section arranged in and forming part of one of said strings at a point adjacent a hydrocarbon productive zone to be penetrated, said section having its interior surface of a configuration different from the interior configuration of the greater portion of said one pipe string, said one pipe string being arranged relative to another of said pipe strings such that said section is oriented away from the periphery of said other pipe string and an elongated perforator provided with perforating means and movable through said one pipe string, said perforator having a cross-sectional dimension only sufficiently smaller than said section to be movable therethrough and having an exterior surface conforming to the interior configuration of said section, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and moving through said section is oriented to conform said portion of its exterior surface with said cross-sectional dimension of said section to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

8. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein in penetrating one of said pipe strings at a time which comprises, in combination, a pipe section arranged in and forming part of one of said pipe strings at a point adjacent a hydrocarbon productive zone to be penetrated, said section having means arranged therein providing an interior surface of a configuration different from the configuration of the rest of said one pipe string, said means

being positioned in said one pipe string relative to another of said pipe strings such that said means has a cross-sectional dimension oriented away from the periphery of said another pipe string and an elongated perforator provided with perforating means and movable through said one pipe string, said perforator having a cross-sectional dimension only sufficiently smaller than the interior configuration means in said section to be movable therethrough and being provided with means having an exterior surface conforming to the surface of the interior configuration means, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and moving through said interior configuration means is oriented to conform said exterior surface means with said cross-sectional dimension of said interior surface means to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

9. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein in penetrating one of said pipe strings at a time which comprises, in combination, a pipe section arranged in and forming part of one of said pipe strings at a point adjacent a hydrocarbon productive zone to be penetrated, said section having its interior surface of a configuration different from the interior configuration of the greater portion of said one pipe string, said one pipe string being arranged relative to another of said pipe strings such that said section has a cross-sectional dimension oriented away from the periphery of said another pipe string and an elongated perforator provided with perforating means and movable through said one pipe string, said perforator having a cross-sectional dimension only sufficiently smaller than said section to be movable therethrough and having its upper end portion of its exterior surface conforming to the interior configuration of said section, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and moving through said section is oriented to conform said portion of its exterior surface with said cross-sectional dimension of said section to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

10. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein in penetrating one of said strings at a time which comprises, in combination, a pipe section arranged in and forming part of one of said pipe strings at a point adjacent a hydrocarbon productive zone to be penetrated, said section having its interior surface of a configuration different from the interior configuration of the greater portion of said one pipe string, said one pipe string being arranged relative to another of said pipe strings such that said section has a cross-sectional dimension oriented away from the periphery of said another pipe string and an elongated perforator provided with perforating means and movable through said one pipe string, said perforator having a cross-sectional dimension only sufficiently smaller than said section to be movable therethrough and having its bottom end portion of its exterior surface conforming to the interior configuration of said section, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and moving through said section is oriented to conform said portion of its exterior surface with said cross-sectional dimension of said section to position the perforating means to perforate said one pipe string only in a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

11. Apparatus for use in a well having parallel eccentrically positioned coextensive pipe strings therein in pene-

trating one of said pipe strings at a time which comprises, in combination, pipe sections arranged in and forming part of each of said pipe strings to a point adjacent a hydrocarbon productive zone to be penetrated, each of said sections having its interior surface of a similar configuration to each other but different from the interior configuration of the greater portion of the pipe string in which the sections are arranged, said sections in one pipe string being arranged relative to the other pipe string such that each of said sections has a cross-sectional dimension oriented away from the periphery of the other of said pipe strings and an elongated perforator provided with perforating means and movable through said pipe strings, said perforator having a cross-sectional dimension only sufficiently smaller than each of said sections to be movable therethrough and having at least a portion of its exterior surface conforming to the interior configuration of said sections, said perforating means being arranged relative to said portion of said exterior surface such that said perforator on entering and

moving through said sections is oriented to conform said portion of its exterior surface with said cross-sectional dimension of said section to position the perforating means to perforate only in said one pipe string through which it is moved a direction away from said other pipe string, said perforator being movable through said section only in said oriented position.

12. Apparatus in accordance with claim 11 in which the interior configuration of said sections in one of said pipe strings is different from the interior configuration of said sections in another of said pipe strings.

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