Sept. 24, 1963 J. W. KENNEDAY ET AL 3,104,709

WELL PERFORATING APPARATUS

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FIG. 1.

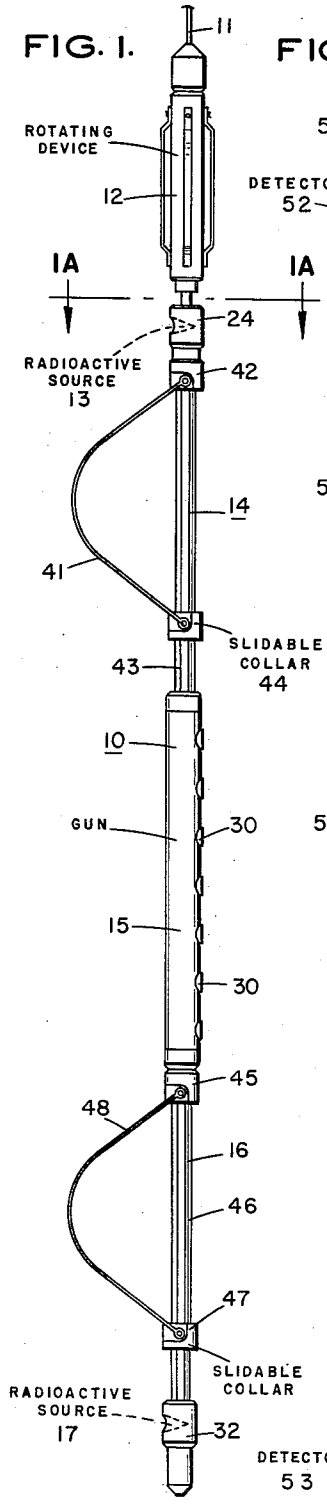


FIG. 2.

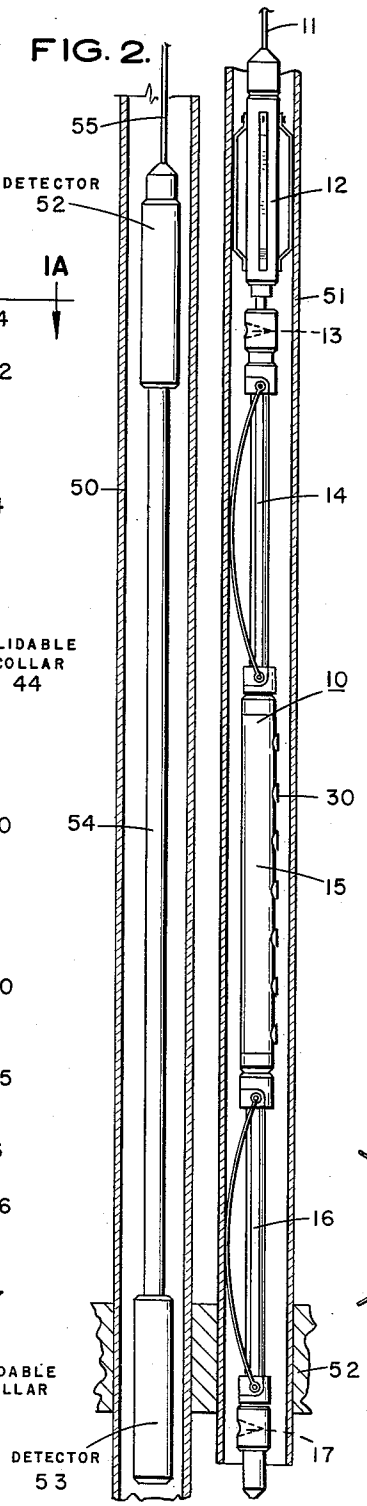


FIG. 3.

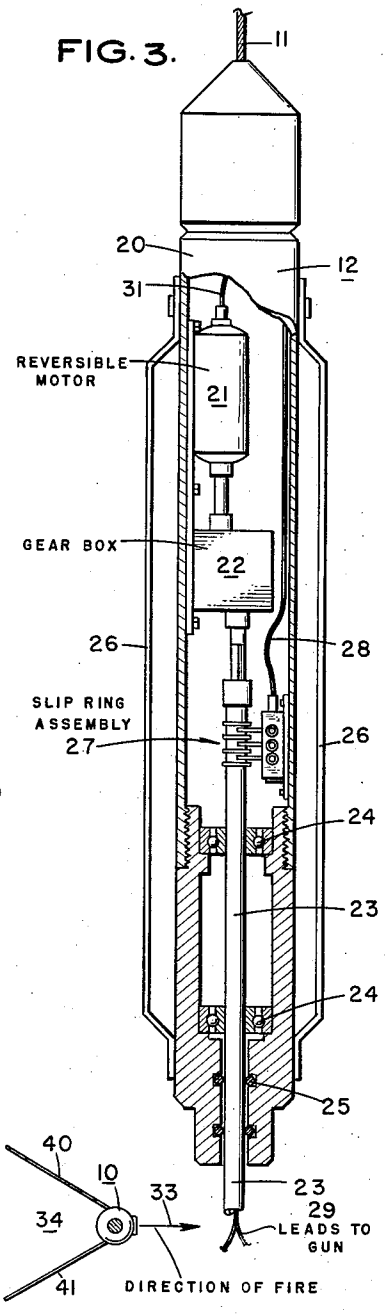


FIG. 1A.

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FIG. 5.

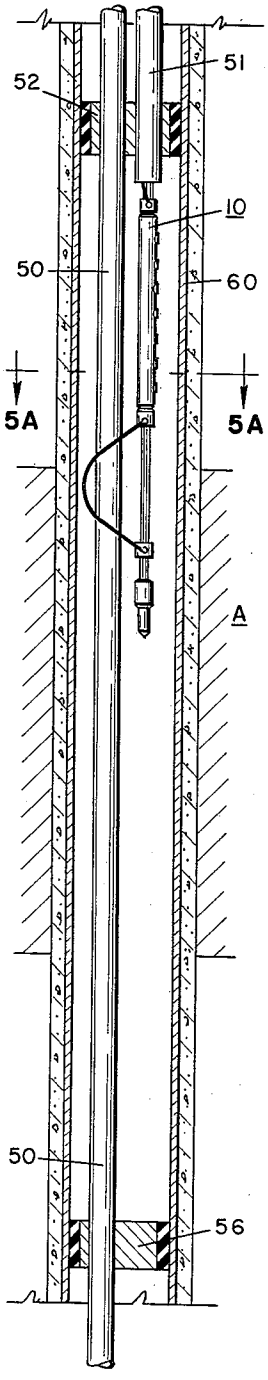
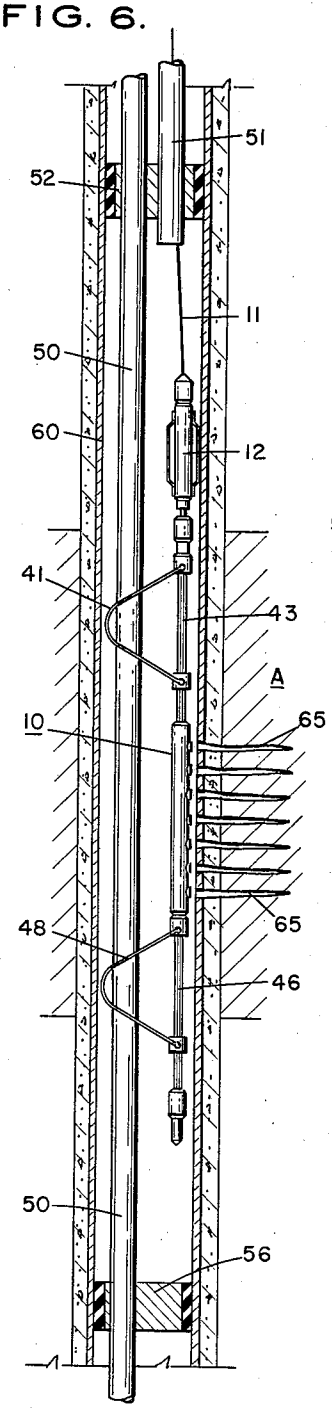


FIG. 6.



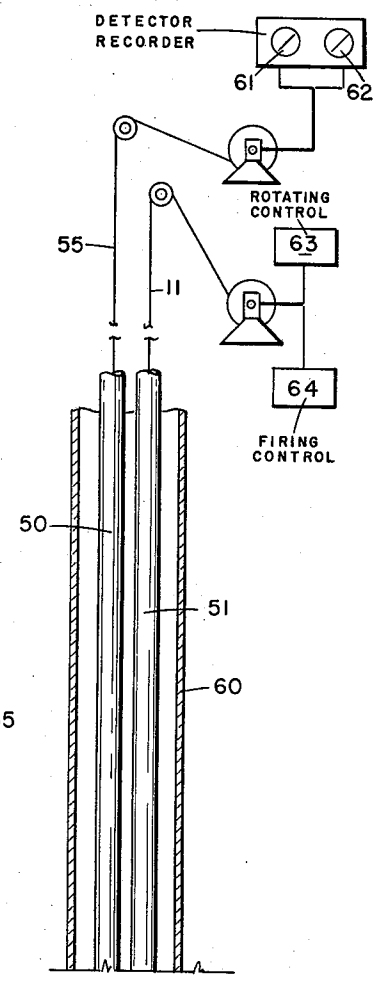


FIG. 4.

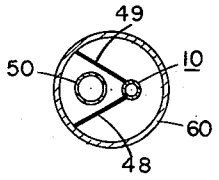


FIG. 5A.

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WELL PERFORATING APPARATUS

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Filed Mar. 1, 1960, Ser. No. 12,047
2 Claims. (Cl. 166—55.1)

This invention concerns a method of orienting through tubing perforating guns to perforate the upper zones of conventionally cased multiple completions having two or more tubing strings and apparatus for performing the method.

Objects of the invention include a technique and apparatus for use therewith for properly orienting guns to perforate or reperforate the upper zones of conventionally cased multiple completions producing through two or more strings of tubing that avoid damage to the lower zone tubings and that eliminate the need for using offset orienting mandrels.

For the purpose of illustrating the invention in a simple, clear manner in the description of the invention to follow the use thereof is described with regard to only two tubing strings. It will be apparent from the description that the invention is adaptable for use with more than two tubing strings. Consequently, the invention is not to be considered limited to use with only two tubing strings. The V-shaped centralizers may be formed so as to straddle three or more tubing strings as to straddle one tubing string as will be described.

In brief, the apparatus of the invention includes a gun perforator assembly comprising perforating guns having a selected direction of fire; tubing or pipe string detecting means; V-shaped centralizer means arranged on said assembly; and means for rotating the assembly. The centralizer means are designed in a manner such that a lower zone tubing will fit within the V formed by the centralizer means and at the same time force the perforating gun against the side of the casing opposite the lower zone production tubing. The selected direction of fire of the gun perforator is opposite to or away from the direction of the V of the centralizer means. The top of the centralizer means is fixed to the assembly with the bottom free to move vertically to allow for lengthening due to compression of the centralizer means. The tubing detecting means may be any desired type; i.e., two radioactive sources, one of each located above and below the perforating guns, may be arranged on the assembly and two radioactive detectors may be run in the tubing the direction of which it is desired to detect; or detectors may be run in the tubing on the gun perforator and radioactive material may be placed in the tubing the direction of which it is desired to detect; or both a source of radiation and a detector of radiation may be arranged on the gun perforator and the induced radiation, caused by bombardment of the radioactive source on the tubing the direction of which it is desired to detect, may be detected by the detector.

In the method of the invention the assembly is run in the upper zone tubing until it is positioned adjacent the lower end thereof. The assembly is rotated with the rotating means through two or more revolutions to determine the maximum peak deflection on the detector recorder located at the earth's surface. With these readings the perforating gun is oriented with the rotating device so that the gun charges will be facing away from the lower zone production tubing. The assembly is then lowered until a centralizer means is below the lower end of the upper zone tubing. The centralizer means then expands and forces the perforating gun against the casing. The assembly then is lowered to the desired perforating interval.

The above objects and other objects of the invention will be apparent from a description thereof taken in conjunction with the drawing wherein:

FIG. 1 is a vertical view of the gun perforator assembly of the invention;

FIG. 1A is a view taken on lines 1A—1A of FIG. 1;

FIG. 2 is a cross-sectional view of two pipe strings, one of which contains the gun perforator assembly and the other of which contains two spaced-apart detectors of radiation;

FIG. 3 is a vertical partly sectional view of the rotating device portion of the gun perforator assembly;

FIG. 4 is a vertical view of the well bore containing two pipes or tubing strings and a schematic showing of the surface equipment for rotating the tool or assembly; for firing the guns; and for detecting the direction of the pipe it is desired to detect;

FIG. 5 is a vertical view of the well bore adjacent the upper zone illustrating one step of the method of the invention;

FIG. 5A is a view taken on lines 5A—5A of FIG. 5; and

FIG. 6 is a view similar to that shown in FIG. 5 except the entire tool or assembly is positioned out of the upper zone tubing string.

Referring to the drawings in greater detail, in FIG. 1 a perforator tool 10 is suspended on a multi-electrical conductor cable 11. Tool 10 includes the following component parts: A device 12 for rotating the tool (the rotating device 12 is seen in greater detail in FIG. 3 and will be described relative to that figure); an upper directional radioactive source 13 arranged below rotating device 12, an upper positioner section 14; a gun section 15; a lower positioner section 16; and a lower directional radioactive source 17.

Details of rotating device 12 will now be described. The device includes a housing 20 connected to a cable 11 in which is arranged a reversible motor 21 to which is connected a gear box 22 which, in turn, is connected to a rotatable shaft 23. Hollow shaft 23 extends through the lower end of housing 20 and connects to housing 24 containing the upper radioactive source 13. Housing 20 has arranged therein bearings 24 which permit shaft 23 to rotate relative to housing 20 and sealing means such as O-rings 25, which are adapted to prevent fluid from entering housing 20. Drag springs 26 are arranged on the exterior of housing 20 and function to prevent rotation of housing 20 and to centralize the housing in the tubing or pipe string. Shaft 23 may be provided with a slip ring assembly 27 for conducting electrical signals transmitted through a conductor 28 which is connected to cable 11 to conductors 29 which connect to gun elements 30 of the gun section 15. A conductor 31 connects cable 11 to motor 21.

Radioactive source 13 contained in housing 24 and radioactive source 17 contained in a housing 32 are provided with shields configured so as to collimate the emanating radiation to confine the area of detection to a limited arc, as for example, an arc of 45° of the well bore. This limited arc of investigation is more clearly seen in FIG. 1A.

As seen in FIG. 1A, the direction of fire 33 of gun elements 30 is away from the direction of the arc of detection 34.

Any desired radioactive substance may be employed as the radioactive source. Examples of such materials are radon, radium bromide, radium chloride, uranium bromide, uranium tetrabromide, etc. These are naturally radioactive substances; however, known artificially radioactive substances also may be employed.

The shielding material for collimating the emanating radioactive beam may be formed of radiation absorbing or moderating materials, such as lead, tungsten, paraffin, boron, cadmium, etc., which material is capable of absorbing or moderating the radiation being detected.

Positioning section **14** includes spaced-apart spring arms **40** and **41** connected at their upper ends to a collar **42** which is secured to a mandrel **43** which, in turn, connects to housing **24**. The lower ends of spring arms **40** and **41** are secured to a sliding collar **44** which is mounted for vertical movement on splined mandrel **43**. As seen clearly in FIG. 1A, spring arms **40** and **41** form a V.

Lower positioning section **16** is similar to upper section **14** in that an upper collar **45** is secured to a mandrel **46** which, in turn, is connected to gun housing **15** in which are arranged gun elements **30**. A lower collar **47** is slidably arranged on splined mandrel **46**. Lower spring arms **48** and **49**, which are shown in FIG. 5A, are connected at their upper ends to stationary collar **45** and at their lower ends to movable collar **47**.

In FIG. 2, two spaced-apart pipe strings **50** and **51** are shown. In pipe string **50**, upper and lower radiation detectors **52** and **53** interconnected by rod **54** are suspended on a multi-electrically conductive cable **55**. The detectors **52** and **53** are spaced so that the sources of radioactivity **13** and **17** are positioned at their respective levels. In pipe string **51**, the gun perforator tool **10** is arranged.

Detectors **52** and **53** may be any devices responsive to radiation produced by the radioactive material; for example, they may be Geiger-Mueller counters, ionization chambers, or proportional counters.

The surface equipment is shown in FIG. 4. Tubing **50** extends to the lower zone and tubing or pipe string **51** extends to the upper zone. Both tubings are shown arranged in a casing **60**. Cable **55** connected to the detectors **52** and **53** arranged in pipe string **50** connects to detector recorders **61** and **62** which record the detected radiation of detectors **52** and **53**, respectively.

Cable **11** connected to the gun perforator tool **10** connects to a control **63** for the reversible motor **21** and to a firing control **64** for the gun elements **30**.

The operation of the invention is illustrated in FIGS. 5, 5A, and 6. As seen in FIG. 5, both tubing strings **50** and **51** extend through a dual bore packer **52**, which is positioned above upper zone A. Tubing string **50** extends through a single bore lower casing packer **56** and adjacent a lower zone, not shown. In operation, tool **10** is lowered through pipe string **51** until the lower end of tool **10** is adjacent the lower open end of pipe string **51**. Then, detectors **52** and **53** are lowered on wire line or cable **55** in pipe string **50** until they are positioned adjacent the perforator tool **10**, as seen in FIG. 2.

Then readings are registered on the recorders **61** and **62** in order to determine whether the gun is properly oriented; i.e., that its direction of fire is away from pipe string **50** or stated another way that positioning spring arms will straddle pipe string **50** when the perforator tool **15** is lowered through the lower open end of pipe string **51**. If the gun elements are not properly oriented, the gun perforator tool **15** is rotated by operating motor **21** from rotation control **63**. When the detector readings indicate that the gun elements are properly oriented, rotation is stopped and the perforator tool **15** is lowered

out the lower end of tubing string **51** until only upper positioning section **14** remains within the confines of tubing string **51**. Then, another reading is taken on detector recorder **61** and **62** to check the position of the gun elements. If for some reasons the gun elements are not properly positioned at this time, the perforator tool is pulled back up into tubing string **51** and the step of rotating the gun perforator until the gun elements are properly positioned is repeated. If the gun elements are properly oriented, then the assembly is lowered entirely out of tubing string **51** to the depth for perforation. As seen in FIG. 6, firing of gun elements **30** cause perforations **65** in upper zone **53**.

It is noted that the sliding collars **44** and **47** move upwardly once the spring arms are free from compression within tubing string **51**. Also, as seen in particular in FIG. 6, once the centralizer arms are freed, they are designed to force the gun perforator tool **15** against the side of casing **60**. Of course, the centralizers also are designed so that the lower zone tubing **50** is straddled by or fixed with the V formed by the arms.

Two detectors are used to illustrate the invention; however, it is possible to use but one detector and shift its position when readings are desired. Additionally, other type pipe detecting means may be employed. For example, the source of radiation may be located in the lower zone tubing string and focused or collimated detectors used on the gun perforator tool; or both the source of radiation and the detector may be mounted or arranged on the gun perforator tool.

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

1. Apparatus for perforating in a cased well bore having at least two eccentric, spaced-apart pipe strings arranged therein, one of said pipe strings being shorter than the other comprising a well tool adapted to be lowered in said one pipe string and including a perforator having a selected radial direction of perforation, resilient expansible, retractable V-shaped centralizer means adapted to expand and straddle said other pipe string and force said well tool against the wall of said casing when said centralizer means is lowered through the lower end of said one pipe string, means for rotating said well tool within said one pipe string, and a source of radiation having a selected radial direction of bombardment; radiation detector means arranged in said other pipe string adapted to detect rays emitted by said radiation source; said direction of perforation and said direction of bombardment and said direction of expansion of said centralizer means being fixed relative to each other with the direction of perforation being in a direction other than in the direction of expansion of said centralizer means.

2. Apparatus as recited in claim 1 wherein said centralizer means includes two spring arms extending spaced-apart in a V-shape in a radial direction, one end of each arm being immovably secured to said well tool and the other end of each arm being movably secured to said well tool.

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