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WELL OPERATION DEPTH CONTROL METHOD

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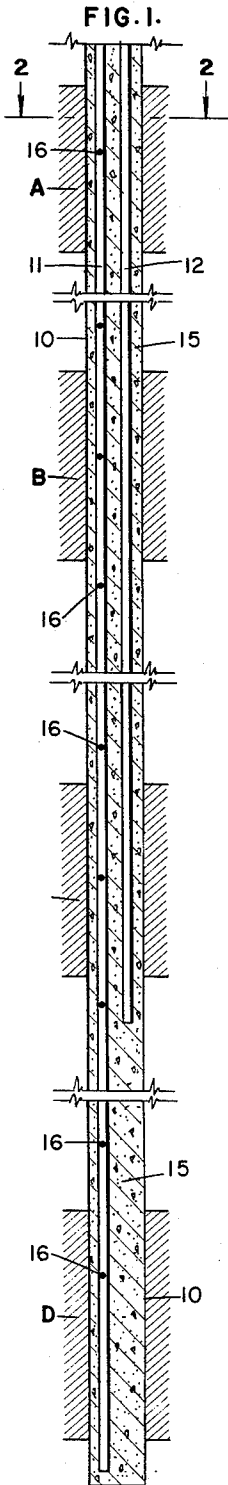
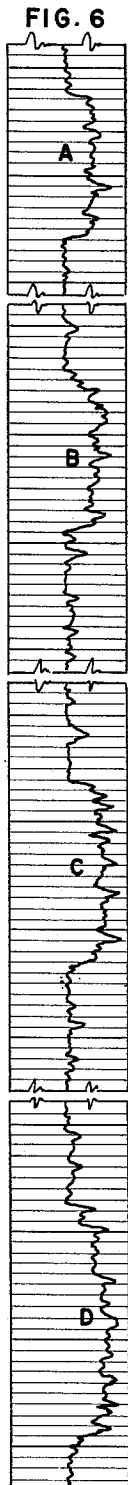
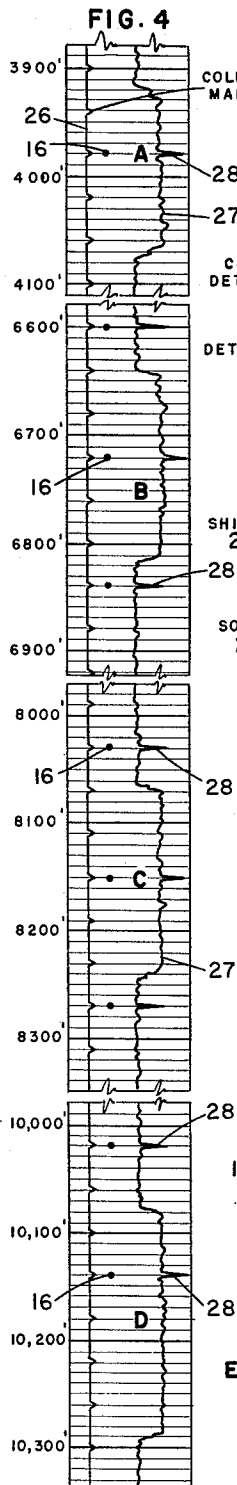
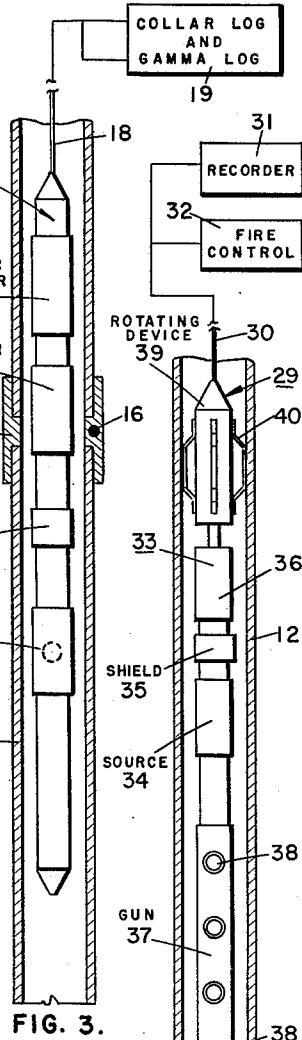


FIG. 3.

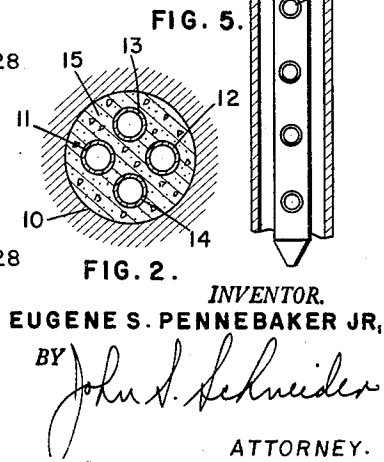


FIG. 2.

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1

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WELL OPERATION DEPTH CONTROL METHOD
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The present invention concerns a method of depth control in well operations and particularly in operations in wells containing a multiplicity of pipe strings. It is especially applicable in multiple tubingless completions. In these type completions a plurality of pipe strings are set in a well bore, the pipe strings and productive formations penetrated by the well bore are perforated, and each formation's fluids are produced independently through the individual pipe strings.

In order to obtain accurate depth control in completions, recompletions, or work-over operations conducted in wells, it is conventional practice to make a radioactivity survey of the well to locate positions of subsurface productive formations along with a pipe string collar locator log to indicate positions of the pipe string collars. Correlating positions of the pipe string collars and the positions of the productive formations in this manner permits accurate positioning of work tools, e.g., perforator guns, in the well adjacent any particular productive formation by lowering the work tool, together with a pipe string collar locator logging device, a depth determined by the number of pipe string collar indications found between the surface of the earth and the particular formation as established by the original pipe string collar locator and radioactivity survey correlation log. In wells containing two or more spaced-apart, parallelly extending pipe strings, it is necessary to obtain the correlating pipe string collar locator and radioactivity survey log for each pipe string to accurately establish locations of the productive formations relative to locations of the pipe string collars, because the conventional pipe string collar locator device detects only the collars of the pipe strings through which it is run. On the other hand, if the collar locator device detected the collars of adjacent pipe strings, there would be no way to distinguish the collars of one pipe string from those of the others. Therefore, it is necessary to restrict detection of the collars to the pipe string through which the pipe collar locator device is run.

When operating in these type wells, it is expensive and time-consuming to obtain the required radioactivity survey and pipe string collar locator logs for each pipe string. A procedure which minimizes cost and time consumed in operations of this nature is provided by the present invention. In the technique covered by the method of the invention, at least one indicator, e.g., a radioactive substance, is positioned a desired place (or places) along the length of the pipe string in which the correlation collar locator and radioactivity survey log is to be run. Then, when the radioactivity survey is made, the location or locations of the spotted radioactive material are correlated with the locations of the producing formations. To accurately locate the producing formations when operating in the pipe strings other than the pipe string in which the marker has been placed, it is only necessary to use a tool capable of locating the marker and then raise or lower the marker pickup apparatus to the desired formation the distance shown on the radioactivity survey log. When pipe strings of different lengths are employed, it is preferable to place the markers in the longest pipe string.

The technique is especially useful for completion and recompletion operations in which the perforating gun

2

itself carries a detector of radiation or a source and detector of radiation. Thus, the gun perforator orienting apparatus, whether of the induced radioactivity detector type or of the direct or natural radioactivity detector type, serves the dual function of orienting the gun perforator and detecting the location of the marker. Once the marker has been established, the gun perforator assembly is moved upwardly or downwardly the measured distance from the marker as determined from the radioactivity survey log, oriented according to known techniques, and fired. Orientation of the gun perforator assembly in completion operations when more than one pipe string is positioned adjacent a productive formation it is desired to perforate is necessary in order to direct the fire of the gun elements in a direction so as to avoid striking and damaging one or more of the pipe strings extending parallel to the pipe string through which the gun perforator assembly is lowered. One method for directing the fire of gun perforator elements, i.e., for orienting the gun, utilizes radioactivity detection techniques as mentioned supra. In one of these a radiation detector and a source of bombarding radiation are positioned in the pipe string through which the production fluids are to be conducted to the surface, and the radiation resulting from bombardment by the source radiation is detected, as described and claimed in U.S. patent application Serial No. 780,524, filed December 15, 1958, by Harry S. Arendt, entitled "Method and Apparatus for Operating in Wells." It is this technique that is described relative to the operation of the method of the invention. Other gun orienting techniques of this type may be employed for orienting a gun, as for example, the technique is which a radiation detector is arranged in the pipe string to be detected, and a radiation source is positioned in the pipe string through which the fluids are to be produced, and the direct focused primary radiation of the source is detected by the detector. U.S. patent application Serial No. 780,517, filed December 15, 1958, by James T. Brumble, Jr., entitled "Method and Apparatus for Well Operations," shows and describes this orienting technique.

A primary object of the present invention is to provide an improved method for more accurately maintaining depth control in wells containing multiple tubing strings.

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

FIG. 1 is a cross-sectional view of the earth's subsurface showing a well bore penetrating a plurality of producing formations and containing a plurality of pipe strings, one of which is provided with markers;

FIG. 2 is a view taken on lines 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view of one pipe string, showing arranged in it pipe collar detector and induced gamma ray logging apparatus;

FIG. 4 illustrates representative pipe collar and radioactivity survey logs taken following placement of radioactive material in one of the pipe strings;

FIG. 5 is a cross-sectional view of one pipe string showing arranged in it a gun perforator assembly including radioactivity orienting elements; and

FIG. 6 illustrates a representative electrical resistivity log.

Referring to the drawings in greater detail, in FIGS. 1 and 2 is shown a borehole 10, which penetrates a plurality of subsurface productive formations A, B, C, and D. Four pipe strings 11, 12, 13, and 14, only two of which, 11 and 12, are shown in FIG. 1, are arranged in borehole 10 and cemented therein by means of cement 15. Each pipe string terminates adjacent one of the producing formations. Thus, as seen in FIG. 1, pipe

string 11 extends to adjacent the lowermost or deepest productive formation D, and pipe string 12 extends to adjacent the next lowest productive formation C. Although this particular arrangement has been used to illustrate the invention, if desired, all the pipe strings may be run to the bottom of the borehole.

Radioactive markers 16 are shown spotted along the length of the longest pipe string 11. The markers are preferably spaced apart a few hundred feet and positioned at points or places other than adjacent the productive formations in order to avoid possible confusion during subsequent gun orienting operations. One radioactive marker should be sufficient; however, to increase the accuracy of the depth control, particularly in deep wells, more than one may be employed.

Placing or spotting radioactive material in pipe string 11 may be carried out in any desired manner; e.g., marker 16 may be placed in a pipe collar, or it may be placed on a short joint of casing or pipe which has been treated such that it will radiate radioactive energy of sufficient magnitude to be readily detected by the detector used in conjunction with the single line, self-orienting perforator. Therefore, the radioactive marker may be in the form of radioactive paint on a collar or joint or radioactive thread dope placed in the pipe threads or a radioactive capsule or pill placed in a collar or joint. Any suitable technique may be employed, so long as it is compatible with the instrumentation employed with the perforator-orienting equipment. When operating in wells containing multiple pipe strings, it is customary to insert a short joint of pipe in the lower part of each pipe string to provide a readily distinguishable marker on the collar locator log. This short joint of pipe may be treated and used as the radioactive marker. Also, the markers may be temporarily positioned in one or more of the pipe strings. For example, radioactive markers may be retrievably placed by wire line tools in conventional, offset mandrels run at various depths on the pipe strings. The radioactive material constituting the marker may have a short or relatively short half-life; as for example, iodine 131, 8.04 days; tantalum 182, 115 days; thorium 228, 1.9 years; antimony 126, 9 hours; antimony 119, 39 hours; or longer half-life materials such as uranium 238, 4.498×10^9 years; radium series 226, 1620 years; actinium 227, 27.7 years; thorium 230, 8×10^4 years; and potassium isotope 40, 1.4×10^9 years.

The collar locator and induced radio-activity survey correlation apparatus is shown in FIG. 3. As seen therein, this equipment, generally designated 17, is suspended on a wire line 18, which extends to collar log and gamma-ray log recorder apparatus 19 at the surface of the earth. Assembly 17 includes a conventional, magnetic collar locator device 20 connected to the radioactivity survey equipment, which includes a gamma ray detector 21 shielded by shield 23 from a radiation source 22. Assembly 17 is suspended in pipe string 11, one collar of which 24 has located therein a radioactive capsule 16.

A representative correlation log obtainable by the equipment or assembly of FIG. 3 is illustrated in FIG. 4. The collar locator log, designated 26, is positioned on the left-hand side of the record; whereas the radioactivity log, designated 27, is positioned on the right-hand side of the record. The various radioactive markers 16 on the collar locator log, as well as their indications 28, on the gamma ray log are shown.

The apparatus for perforating the subsurface formations, orienting the gun perforator to direct the fire thereof in a particular or selected direction and for locating positions of marker 16, designated in general 29, is shown in FIG. 5 arranged in a pipe string; e.g., pipe string 12, and suspended on a wire line 30, which extends to the surface of the earth and connects to a gamma ray recorder 31 for recording the gamma ray indications, and a fire control 32, which is adapted to control the firing of the gun perforator. Tool 29 includes a pipe locator and radioactivity marker locator section 33, which

comprises a source of focused bombarding radiation 34; a radiation shield 35; a radiation detector 36; a gun section 37, which comprises a plurality of gun elements 38, which may be suitably of the jet or bullet types; and a tool positioner section 39, which includes a plurality of centralizers or restrainers 40.

In practice, borehole 10 is formed to penetrate producing formations A, B, C, and D. Then, an electrical resistivity log is run in the open hole to establish locations of the productive formations A, B, C, and D, as illustrated by the representative electrical resistivity log shown in FIG. 6. Pipe strings 11, 12, 13, and 14 then are run and set in borehole 10. The longest pipe string 11 being treated or spotted with radioactive material, such as the positioning of a radioactive capsule in selected pipe collars thereof, prior to running and setting of this pipe string. The pipe strings then are cemented in place by means of cement 15. At this time the apparatus shown in FIG. 3 is run in pipe string 11, and the various formations are indicated on the log relative to the various pipe collars of pipe string 11 and relative to the positions of the radioactive markers 16, as seen in FIG. 4. The radioactivity log 27 of FIG. 4 also is correlated with the electrical resistivity log of FIG. 6.

When it is desired to perforate the lowest producing formation, i.e., formation D, it is only necessary that the gun 37 be lowered on a wire line to the depth of formation D, as established by the correlative radioactivity log 27 and pipe collar locator log 26. The depth to which the perforator is lowered is determined by the number of collars and the distance between the collars, and sufficient cable is played out until that depth is reached. Since there are no intervening pipe strings in any direction surrounding pipe string 11 adjacent formation D, it is not necessary to orient the gun perforator.

However, when it is desired to perforate any one of the upper formations A, B, or C, it is necessary to orient the gun perforator to direct the direction of fire thereof to avoid striking one or more of the adjacent pipe strings. Thus, if it is desired to perforate formation C, it is necessary for the direction of fire of the gun perforator to be directed away from the direction of pipe strings 11, 13, and 14. Also, the exact locations of the formations A, B, and C relative to the locations of pipe collars of each of these pipe strings is not known. To perforate formation C, the equipment shown in FIG. 5 is lowered in pipe string 12. During the lowering operation, the one or more markers 16 are detected by the detector 36. Also, detector 36, in conjunction with source 34 and shield 35, may if desired provide another radioactivity log 27 of the borehole. The gun 37 is raised and lowered on wire line 30 above or below a particular marker 16 a desired measurable amount until it is accurately positioned adjacent formation C as determined by the initial radioactivity log or survey run in pipe string 11. As illustrated, formation C as established by the radioactivity survey 27 taken in pipe string 11 is located between 8060 and 8240 feet. One marker 16 is located at 8030 feet, and when this marker is detected by detector 36, gun 37 is lowered 30 to 210 feet for proper positioning. When gun 37 has been properly positioned, it is oriented according to conventional techniques, and when in proper position, it is fired.

Source of radiation 22 or 34 may be fast neutrons or gamma rays. Thus, the source may be an alpha neutron (α , n), deuteron neutron (d, n), or proton neutron (p, n) reactions wherein the alpha particle, deuteron or proton, is accelerated by an electric field and thereby caused to interact with selected target materials in order to produce neutrons of various energies within the confines of source 22; or the radiation source may be neutrons originating from a radium beryllium or polonium beryllium source. Sources of high energy gamma radiation which may be employed are radioactive Na 24, LA 140, Sb 124, Co 60, or high energy gamma rays produced by various reac-

5

tions in high energy particle machines in a manner well-known to the art in nuclear physics. For example, the bombardment of lithium by protons produces high energy 17 mev. gammas.

Detectors 33 or 21 detect slow neutrons or gamma rays or fast neutrons, and for detection of this radiation ionization chambers, Geiger-Muller tubes, and scintillation counters may be used. The shields 35 and 23 are formed of radiation absorbing or moderating materials, such as lead, tungsten, paraffin, boron, cadmium, etc., which materials are capable of absorbing or moderating the induced radiation.

Having fully described the method, apparatus, and objects of my invention, I claim:

1. A method for perforating in a well penetrating at least two vertically spaced, upper and lower productive formations and containing at least two juxtaposed pipe strings, one of which contains at least one radioactivity marker positioned along the length thereof comprising running in said one pipe string a radioactivity survey tool together with a collar locator tool, and preparing therefrom a correlation log showing the locations of said productive formations, the locations of the pipe collars of said one pipe string, and the position of said radioactivity marker relative to each other; lowering in said other pipe string a device provided with a perforator having a selected direction of perforation, and with radiation means having a selected direction of pipe detection including a source of radiation and a detector of both radiation resulting from interactions of said source radiation and direct radiation emanating from said marker, and with means for causing rotation of said device, to the depth of said radioactivity marker by detection of said radioactivity marker by said detector; moving said device the distance between said radioactivity marker and said upper formation as shown on said correlation log to position said device adjacent said upper formation; rotating said device, to locate the position of said one pipe string relative to a reference position of said device, and accordingly, to said direction of pipe detection and said direction of perforation, with said radiation means; further rotating said device to direct the direction of perforation away from said one pipe string; and then actuating said perforator to perforate said upper formation.

2. A method as recited in claim 1 including following making of said correlation log, lowering a perforator in said one pipe string to the depth of said lower formation as determined by said correlation log; and actuating said perforator to perforate said lower formation.

3. A method for perforating in a well penetrating at least two vertically spaced, upper and lower productive

6

formations and containing at least two juxtaposed pipe strings comprising positioning along the length of one of said pipe strings at least one radioactivity marker; running in said one pipe string a radioactivity survey tool together with a collar locator tool and preparing therefrom a correlation log showing the locations of said productive formations, the locations of the pipe collars of said one pipe string, and the position of said radioactivity marker relative to each other; lowering in said other pipe string a device provided with a perforator having a selected direction of perforation, and with radiation means having a selected direction of pipe detection including a source of radiation and a detector of both radiation resulting from interactions of said source radiation and direct radiation emanating from said radioactivity marker, and with means for causing rotation of said device, to the depth of said radioactivity marker by detection of said radioactivity marker by said detector; moving said device the distance between said radioactivity marker and said upper formation as shown on said correlation log to position said device adjacent said upper formation; rotating said device, to locate the position of said one pipe string relative to a reference position of said device, and accordingly, to said direction of pipe detection and said direction of perforation, with said radiation means; further rotating said device to direct the direction of perforation away from said one pipe string; and then actuating said perforator to perforate said upper formation.

4. A method as recited in claim 3 including following making of said correlation log, lowering a perforator in said one pipe string to the depth of said lower formation as determined by said correlation log; and then actuating said perforator to perforate said lower formation.

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