Jan. 12, 1965 C P. LANMON 3,165,153

METHODS AND APPARATUS FOR WELL COMPLETIONS

Filed May 2, 1960

2 Sheets-Sheet 1

Fig. 1

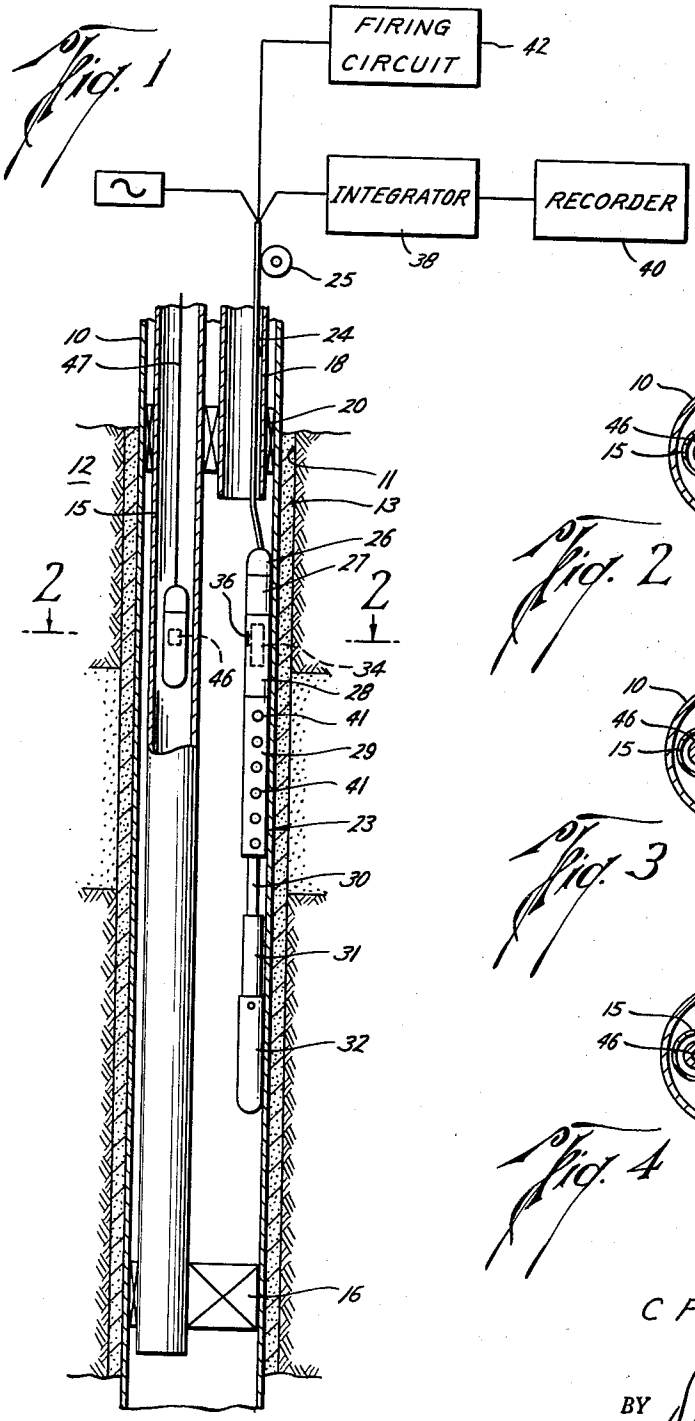


Fig. 2

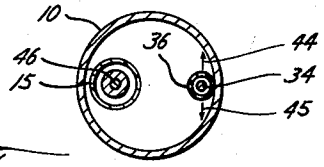


Fig. 3

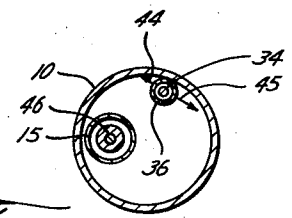
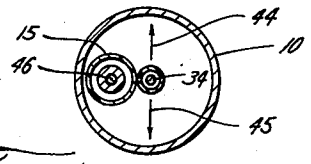


Fig. 4



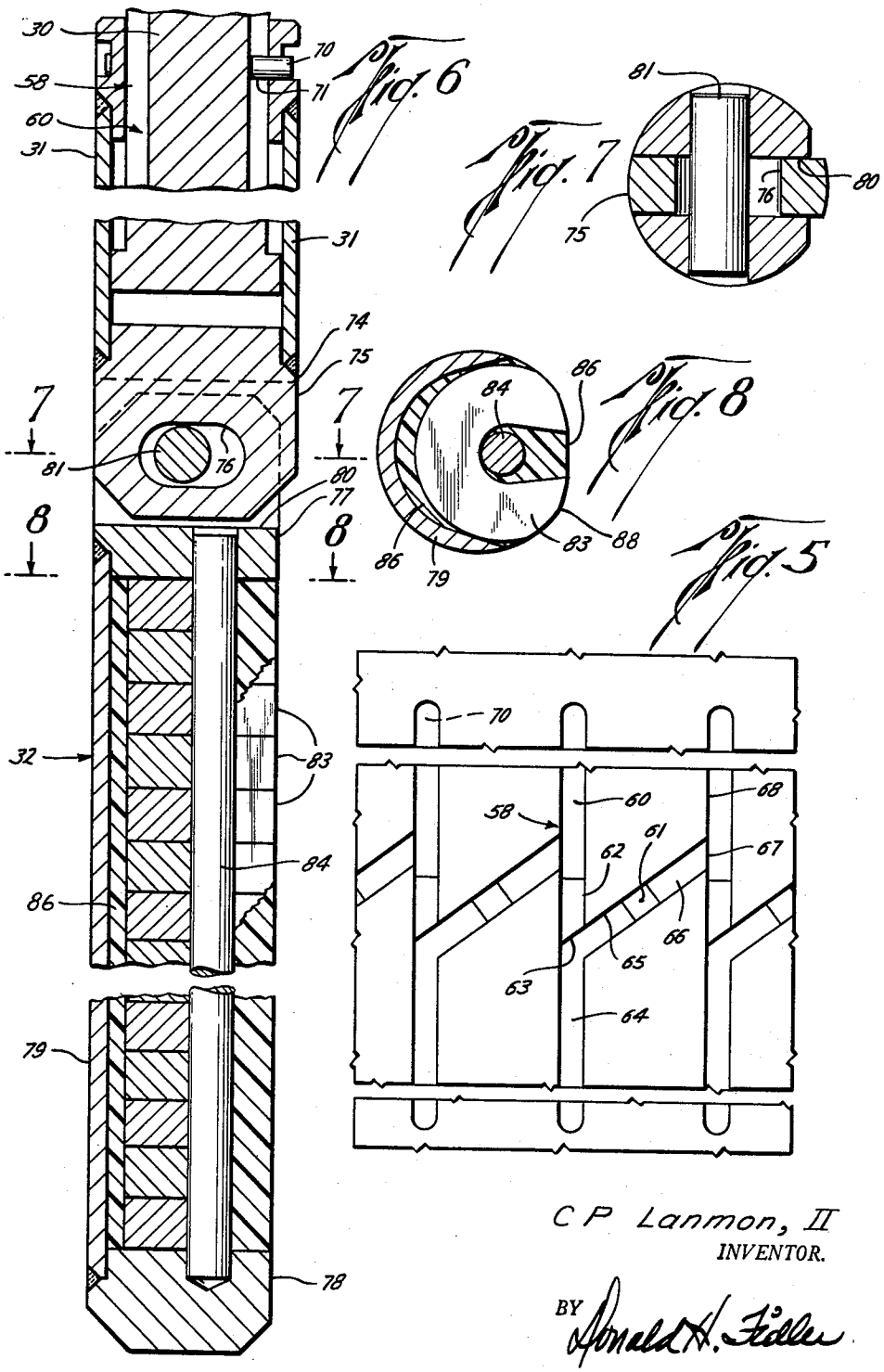
C P Lanmon, II
INVENTOR.

BY Donald A. Tidlow
ATTORNEY

Jan. 12, 1965 C P. LANMON 3,165,153

METHODS AND APPARATUS FOR WELL COMPLETIONS

Filed May 2, 1960 2 Sheets-Sheet 2



C P Lanmon, II
INVENTOR.

BY Donald A. Fidler

ATTORNEY

United States Patent Office 3,165,153
Patented Jan. 12, 1965

3,165,153
METHODS AND APPARATUS FOR WELL COMPLETIONS

C P. Lanmon, Friendswood, Tex., assignor to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Filed May 2, 1960, Ser. No. 25,997
9 Claims. (Cl. 166—4)

This invention relates to well tools and, more particularly, to methods and apparatus for completing a well wherein it is desired to orient a perforating apparatus relative to a string of pipe.

In conventional multiple well completion, after a casing has been cemented to the borehole, there are usually two or more production zones located at different depths from which production is desired. It is customary, in this type of production, to have a string of tubing within the casing which extends to the lowermost zone and is suitably packed off in the casing from the upper zone. The upper zone may be produced directly through the annulus between the tubing and the casing or, alternatively, the upper zone may be produced through another string of tubing which terminates short of the upper zone and is packed off in the casing. While both zones can be perforated with ease when the strings of tubing are not in the well, it is desirable from an economical and practical production viewpoint, in many instances, to perforate the zones after the strings of tubing have been set in the casing.

Accordingly, it is an object of the present invention to provide new and improved apparatus for orienting a well tool which is preferably a perforating apparatus in a string of pipe. It is a further object of the present invention to provide new and improved systems for achieving perforation of a production zone adjacent to a string of tubing extending through the zone. A still further object of the present invention is to provide apparatus for use in a multiple well completion in a cased well bore.

Apparatus in accordance with the present invention includes first and second longitudinally aligned members arranged for indexing or relative rotation therebetween. The first member is arranged for coupling with a cable while the second member includes magnetic attaching means. The first member further includes a directional radiation device having a predetermined orientation with respect to perforating means so that the perforating means may be oriented to fire in a selected direction.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by way of illustration and example of a certain embodiment when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a view of apparatus embodying the present invention as employed in a multiple well completion;

FIGS. 2–4 are cross sections taken generally along the line 2—2 of FIG. 1, illustrating various locations the tool may assume in a cased bore;

FIG. 5 is a plan view of an indexing system;

FIG. 6 is a cross-sectional view of the anchor device for the tool;

FIG. 7 is a cross-sectional view taken along line 7—7 of FIG. 6; and

FIG. 8 is a cross-sectional view taken along line 8—8 of FIG. 6.

In FIG. 1, a casing 10 is disposed in a borehole 11 which traverses the earth formations 12, and a customary column of cement 13 is between the casing and the

borehole. A first tubing 15 in the casing 10 extends therethrough and is packed off at its lower end by means of a conventional packing means 16 so that the lower production zone (not shown) opens to the interior of tubing 15. A second tubing 18 in the casing 10 terminates short of an upper production zone in which perforations are desired. The first and second tubings 15 and 18 may be packed off in the casing by conventional packing means 20 above the upper production zone so that fluid entering the section of the casing between the upper and lower packers 16 and 20 may flow through the second tubing 18 to the earth's surface.

A well perforating tool 23, in accordance with the present invention, is adapted to be passed through the tubing string 18 by means of a cable 24 and winch 25 in the customary manner. The perforating tool 23 includes a conventional casing collar locator 26, an electrical assembly 27 and a gamma ray detector assembly 28 combined with a perforating gun 29. The gun 29 has secured to its lower end, a depending, indexing mandrel 30, which is slidably and rotatably received in a tubular, indexing sleeve 31. The sleeve 31 is, in turn, connected to an anchor member 32. The perforating tool, as will become apparent from the discussion to follow, is arranged so that the anchor member 32 and indexing sleeve 31 are fixed relative to the casing 10 while the gun 29 may be moved longitudinally and, in so doing, the indexing mandrel 30 and a follower on the indexing sleeve 31 cooperate to rotate the gun 29 in discrete angular steps.

The gamma ray detector assembly 28 includes a conventional detector 34 for gamma rays which is suitably shielded except for a narrow, elongated opening 36 extending lengthwise of the assembly, thereby being a direction sensitive device. The electrical assembly 27, of conventional design, performs the function of converting the gamma ray response of the detector 34 into electrical pulses which may be supplied up the cable to an integrator 38. While the above described type of apparatus is well-known, further reference may be made to Patent No. 2,316,361 for typical details. The integrator then supplies a signal to the recorder 40, which records the intensity of the radiation received by the detector 34 in a well known manner.

The perforating gun 29 includes a hollow, tubular housing which receives shaped charges 41, the shaped charges 41 being detonatable in a well known manner by the application of a firing current from a surface firing circuit 42 to a primacord (not shown). The arrangement of the directions of firing of the shaped charges is controlled or oriented with respect to the opening 36 of the detector so that the directions of firing may be ascertained prior to detonation. While there are many ways of arranging the direction of firing for orientation, one system, shown in FIGS. 2–4, is such that the perforating axes, typically shown by arrows 44, 45 lie in a longitudinal plane and fire in directions disposed at 180° with respect to one another. With this arrangement, the opening 36 in the radioactivity detector is disposed perpendicular to the longitudinal plane.

In the tubing 15, a source of radioactivity 46, which emits gamma rays, may be positioned adjacent to the radioactivity source by means of a wire line 47. Hence, if the detector 34 is rotated relative to the source 46, the intensity of radiation admitted through the opening 36 to the detector 34 will vary, depending upon the position of the opening 36 relative to the source 46. That is, when the opening 36 directly faces the source 46, a maximum number of gamma rays would be intercepted by the detector 34, whereas, when the opening 36 is facing directly away from the source 46, a minimum number of gamma rays would be received by the detector 34. Thus,

it will be appreciated that, if the perforator is rotated in discrete, angular steps, a plot or recording may be made of the intensity of radiation at each of the steps and, hence, it can be very accurately determined what the position of the opening 36 is relative to the radioactive source 46.

As shown in FIGS. 2–4, the perforating tool 23 is adapted to be brought into very close contact with respect to either the casing 10 or tubing 15 and the perforating gun 29 rotated relative to either the casing or tubing. Thus, when the position is reached, wherein a maximum intensity of radiation is recorded, the directions of the firing axes are such that they will not intercept the tubing 15. To achieve the rotation of gun 29, the indexing mandrel 30, which is slidably and rotatably received within indexing sleeve 31, has, about its periphery, a slot system 58 (FIG. 7) which is best shown in plan view in FIG. 5. The slot system 58 includes a number of longitudinal slots 60 which are connected to one another intermediate of their length by transverse, inclined slots 61. As will be readily appreciated, the number of longitudinal slots on the mandrel will determine the number of rotative steps through which the mandrel can be rotated through. Each of the longitudinal slots 60 is provided with an inclined surface 62 extending towards the outer surface of the mandrel and terminating at a shoulder 63 formed between a bottom wall 64 of a slot 60 and the inclined surface 62. The shoulder 63 is generally aligned with a sidewall 65 of an inclined slot 61. The inclined slots 61 are similarly provided with inclined surfaces 66 extending towards the outer surface of the mandrel which terminate at shoulders 67 aligned with the sidewalls 68 of the longitudinal slots 60.

The indexing sleeve 31 includes a follower 70 in the form of an arcuate ring received in an annular groove in the sleeve 31, one end 71 of the follower being passed through an opening in the sleeve into register with the slot system 60. Follower 70 is constructed of resilient or spring material. The end 71 of the follower 70 is thus arranged to move radially outwardly relative the indexing mandrel 30 in response to changes in depth of the slot system. Thus, when the mandrel 30 and sleeve 31 are moved relative to one another in one direction, end 71 of follower 70 will be biased outwardly by the inclined surface 62 until it rides over the shoulder 63, whereupon it moves inwardly into the slot system towards bottom surface 64 to a point below the shoulder 63. Relative movement in an opposite direction will cause the follower to enter the inclined slot 61 and, with the sleeve 31 being fixed relative to the casing 10, the mandrel 30 will rotate and the end 71 of the follower 70 will be biased outwardly by the inclined surface 66 and irreversibly transferred over the shoulder 67 formed in the sidewall of a longitudinal slot 60. In this manner, the end 71 of the follower 70 is irreversibly moved between the longitudinal slots 60 and thereby continuously rotates the mandrel 30. As is obvious from the disclosure, the mandrel 30, gun 29, detector 28, assembly 27 and casing collar locator 26 are moved longitudinally by movement of the cable 24.

The indexing sleeve 31 is secured at its lower end to a cylindrical block member 74 having a depending tongue 75, the tongue 75 having an elongated opening 76 extending transversely to the central axis of the block member 74. The anchor member 32 includes upper and lower block members 77 and 78 held in spaced relationship to one another by a semi-tubular shell member 79 welded to the block members. The upper block member 77 has an upper groove or slot 80 to receive the depending tongue 75 and a pin 81 passing through the upper block member 77 and transverse slot or opening 76 loosely couples the anchor member 32 to the cylindrical block member 74 and sleeve 31. By virtue of the transverse opening 76, the anchor member 32 may move laterally of the cylindrical block member 74 thereby insuring contact of the anchor member 32 with a well casing.

The shell member 79 is preferably constructed of non-magnetic material such as a chromium-nickel austenitic stainless steel and recieves a number of permanent horseshoe magnets 83 stacked vertically of one another in the shell member 79 with a non-magnetic rod member 84 received by bores in the block members 77, 78 and disposed between the U of the magnets 83 to retain them in the shell member 79. A filler material 86, such as an epoxy resin, is employed to fill up the vacant spaces between the magnets 83 and shell member 79. The ends 88 of the magnets may be ground to conform generally with a cylindrical profile of a casing to improve the match of the magnets to the casing wall. The strength of the magnets, of course, is related to the weight of tool so that the magnets grip the casing with sufficient force to permit indexing yet are slidable along the casing under the influence of the weight of the tool. While members 79 and 84 are preferably non-magnetic, it will be appreciated that magnetic materials would not appreciably affect the magnetic characteristics of the device.

In operation, the radioactive source 46 is located in the longer length of tubing 15 at the level where the orientation of the perforating tool 23 is desired. Thereafter, the perforating tool 23 is lowered through the shorter length of tubing 18 to the level corresponding to the location of source 46. While the tool 23 is passing through the tubing 18, the anchor member 32 thereon will be magnetically attached to the tubing; however, the weight of the tool is sufficient to overcome the magnetic force and slide the anchor 32 along the tubing. It will be appreciated that, when the downward movement of the tool is stopped, limited longitudinal movement of the cable for a short distance not greater than the length of longitudinal slots 60 in the indexing mandrel 30, first upwardly and then downwardly in succession, will move the mandrel 31 relative to the magnetically attached anchor member 32. Thus, the indexing and orientation of the perforating gun 29, as above described, may be accomplished.

FIGS. 2–4 are typical of positions that the tool may assume when the tool is in a section of casing having a length of tubing passing therethrough. Of course, when the tool 23 emerges from the end of tubing 18, the natural inclination of the borehole and casing which bring the tool into contact with the casing and slight rotational torque on the cable will bring the magnets into contact with the casing. It will thus be appreciated that the tool may attach to either the tubing string or casing and the loose pin connection between the anchor 32 and indexing sleeve 31 facilitate the indexing operation to orient the perforating gun 29 of the tool.

From the foregoing, it will be appreciated that a well tool is disclosed which may basically consist of a first member, which may include the casing collar locator 26, the detector 28 and the gun 29, and is adapted for coupling to a cable, and a second member including a magnetic anchor means 32 while indexing mandrel 30 and indexing sleeve 31 couple the two members to one another.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A well tool for use in a well string of ferromagnetic material comprising: first and second elongated members adapted to be passed along a well string by a cable; said first and second members being disposed in longitudinal alignment and in an end-to-end relationship; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; said second member including magnetic anchor means for magnetically attaching said second member to the well string.

2. A well tool for use in a well string of ferromagnetic material comprising: first and second elongated members adapted to be passed along a well string by a cable; said first and second members being disposed in longitudinal alignment with end portions telescopically mounted relative to one another; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; said second member including anchor means comprised of permanent magnets having a resultant force of magnetic attraction for magnetically attaching said second member to the well string.

3. A well tool for use in a well string of ferromagnetic material comprising: a first member adapted to be passed along a well string by a cable; a second member telescopically mounted relative to said first member; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; anchor means comprised of permanent magnets having a resultant force of magnetic attraction for magnetically attaching said second member to the well string, and means connecting said anchor means and said second member to one another to permit limited lateral movement therebetween.

4. A well tool for use in a well string of ferromagnetic material comprising: a first member including perforating means adapted to be passed along a well string by a cable, said perforating means having predetermined directions of firing; a second member telescopically mounted relative to said first member; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; anchor means comprised of permanent magnets having a resultant force of magnetic attraction for magnetically attaching to the well string, and a slot and pin connection between said anchor means and said second member, said slot being elongated to permit limited lateral movement therebetween.

5. A well tool sized for passage through a string of tubing and for use in a well casing of ferromagnetic material below the end of the tubing string comprising: a first member including perforating means adapted to be passed through a tubing string by a cable, said perforating means having predetermined directions of firing, said first member further including a direction sensitive radioactivity device; a second member telescopically mounted relative to said first member; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; anchor means comprised of permanent magnets having a resultant force of magnetic attraction for magnetically attaching to the well string, and means connecting said anchor means and said second member to one another to permit limited lateral movement therebetween.

6. A well tool sized for passage through a string of tubing and for use in multiple completions where a string of tubing comprised of ferromagnetic material extends through a section of casing of ferromagnetic material where production is desired, including a first member adapted to be passed into the section of casing by a cable; a second member telescopically mounted relative to said first member; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; anchor means comprised of permanent magnets having a resultant force of magnetic attraction for magnetically attaching to the ferromagnetic material and means connecting said anchor means and said second member to one another to permit limited lateral movement therebetween.

7. A well tool sized for passage through a string of tubing and for use in multiple completions where a string of tubing comprised of ferromagnetic material extends through a section of casing of ferromagnetic material where production is desired, including first and second members adapted to be passed through a tubing string into the section of casing by a cable; said first and second members being disposed in longitudinal alignment with end portions telescopically mounted relative to one another; means coupling said first member to said second member and including indexing means for rotating said members relative to one another; said second member including magnetic anchor means for magnetically attaching said second member to the ferromagnetic material.

8. A method of perforating a cased well intermediate of the length of a tubing string disposed within such a cased well, comprising the steps of: lowering a first radioactive device in the tubing string to a position intermediate the length of the tubing string, lowering into the cased well a tool having a second directional radioactivity device, a well perforator, an indexing device and wall anchor means where the second directional radioactivity device has a fixed angular orientation relative to the direction of firing of the well perforator and the indexing device connects the perforator to the wall anchor means and where said first and second radioactivity devices emit and detect radioactivity, positioning the second radioactivity device and perforator at a level corresponding to the position to the first radioactivity device, attaching the wall anchor means in the cased well relative to the wall of the cased well in a fixed non-rotatable position, indexing the perforator and second radioactivity device with respect to the fixed position of the wall anchor means through a 360° arc while deriving indications of the indexed position of the second radioactivity device relative to the radioactivity intercepted by the detecting radioactivity device, and further indexing the perforator in accord with derived indications to a position where its direction of firing is arranged to avoid interception with the tubing string in the cased well.

9. The method of claim 8 and further including the step of firing the perforator.

References Cited in the file of this patent

UNITED STATES PATENTS

2,618,342	Meyer	Nov. 18, 1952
2,631,671	Krasnow et al.	Mar. 17, 1953
2,785,754	True	Mar. 19, 1957
2,796,023	Abendroth	June 18, 1957
2,938,584	Tausch et al.	May 31, 1960
2,998,068	True	Aug. 29, 1961
3,036,641	Nutter	May 29, 1962