Sept. 12, 1939. A. L. ARMENTROUT ET AL 2,173,033

METHOD AND APPARATUS USEFUL IN THE PRODUCTION OF WELLS

Filed Feb. 16, 1938 3 Sheets-Sheet 1

Fig. 1.

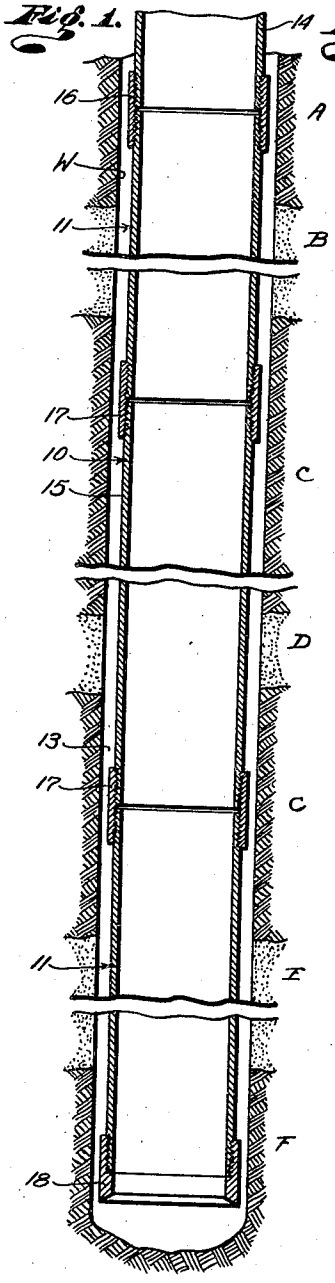


Fig. 2.

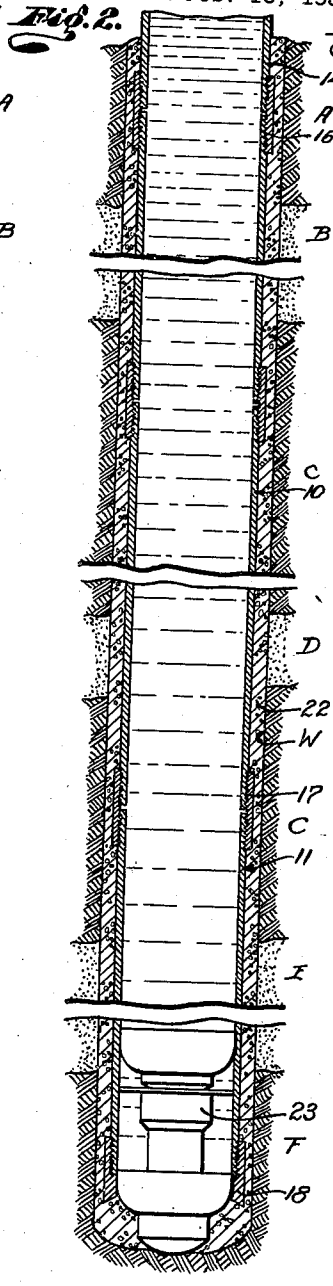
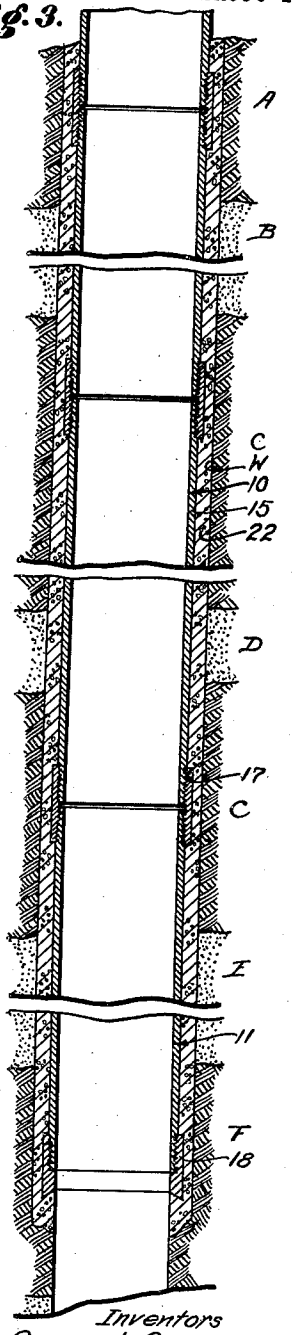


Fig. 3.



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Fig. 4.

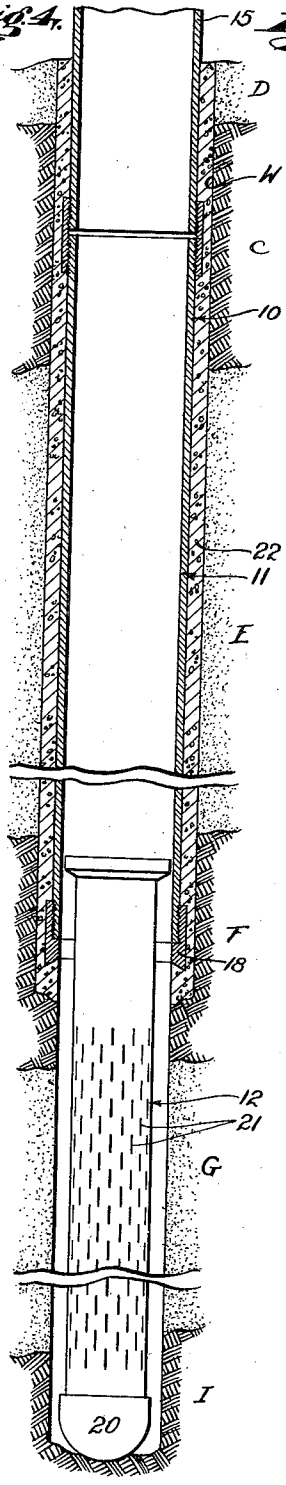


Fig. 5.

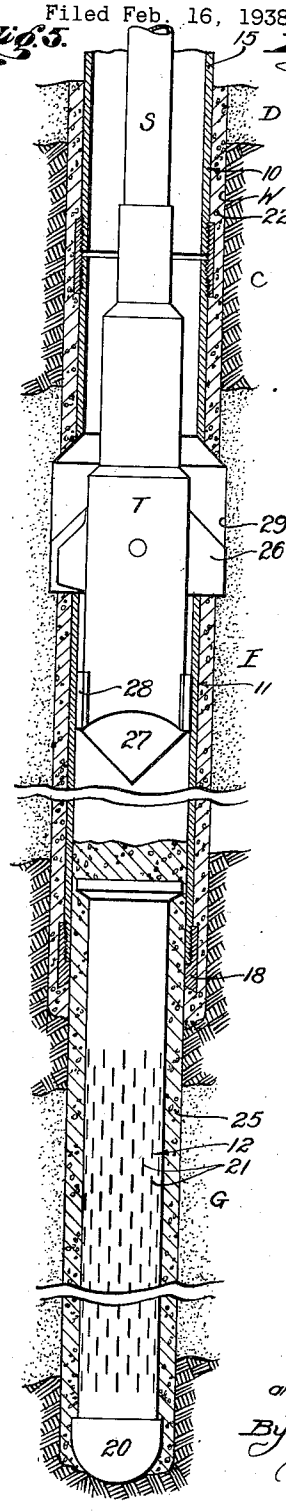
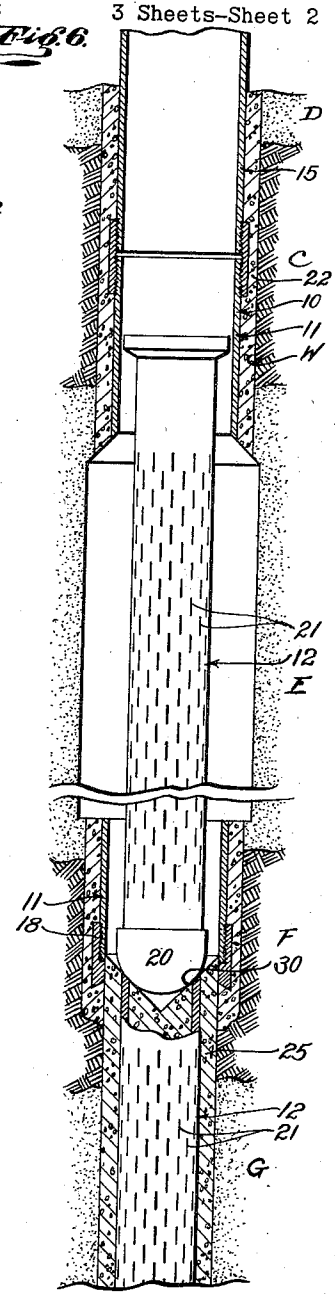


Fig. 6.



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METHOD AND APPARATUS USEFUL IN THE PRODUCTION OF WELLS

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Fig. 7.

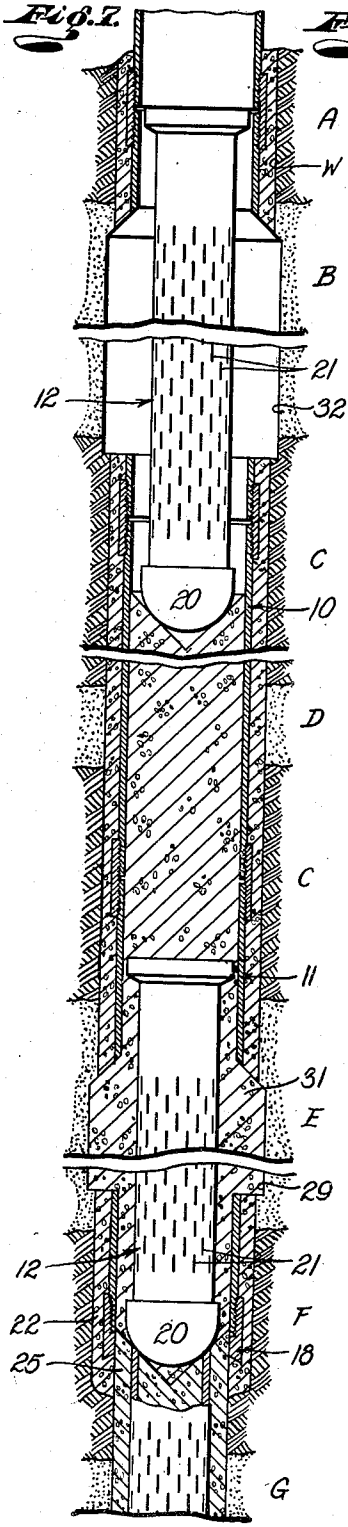


Fig. 8.

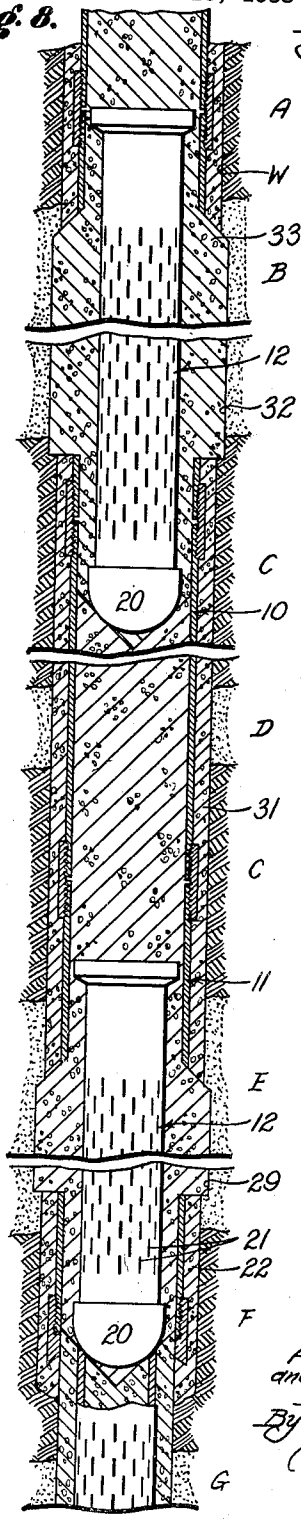
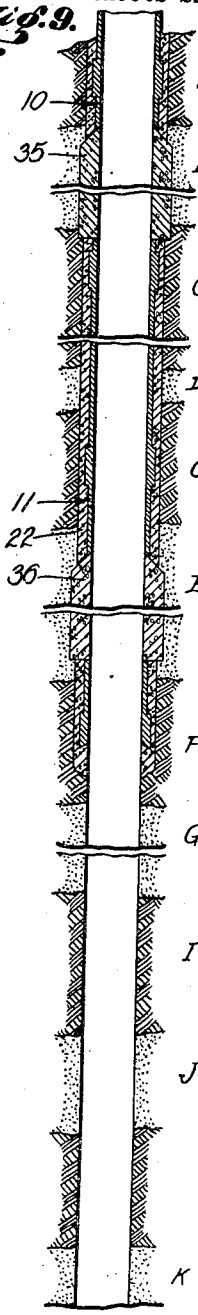


Fig. 9.



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Patented Sept. 12, 1939 2,173,033

UNITED STATES PATENT OFFICE

2,173,033

METHOD AND APPARATUS USEFUL IN THE PRODUCTION OF WELLS

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Application February 16, 1938, Serial No. 190,741

21 Claims. (Cl. 166—1)

This invention has to do with the conditioning of wells for the production of fluid therefrom and has particular reference to methods and apparatus useful in producing fluids from deep wells such as oil wells, gas wells, etc. A general object of this invention is to provide a practical, effective method, and simple, inexpensive apparatus for facilitating the production of fluid from the productive strata in a well.

Another object of this invention is to provide a method whereby fluid may be produced either simultaneously or successively from the several productive zones or strata penetrated by, or encountered in a well.

Another object of this invention is to provide a method for producing a well that provides for the sealing off of the various productive strata, and the strata, if any, bearing unwanted fluid that have been logged or recorded during the drilling of the well, the subsequent successive exposing of individual productive strata or groups of adjacent productive strata for production of the fluids therefrom and the sealing off of the said exposed strata when the same become depleted or adversely affect successive exposure of the other productive strata. In accordance with the method provided by this invention fluids from the several productive strata may be separately or individually produced or allowed to produce while the depleted strata and the other strata bearing the desired fluid, as well as strata bearing unwanted fluid, remain sealed off, thus promoting the economical and complete production of the wanted fluid from the several paying strata penetrated by the well.

Another object of this invention is to provide a method for producing a well that allows the operator or driller to drill through productive or potentially productive strata, then case the well and deepen the well in an attempt to reach other productive strata with the assurance that the productive strata already penetrated may be placed on production at will.

Another object of this invention is to provide a method of the character mentioned that permits or provides for the subsequent deepening of the well to lower productive strata after the several productive strata penetrated during the original drilling operation have been depicted and sealed off.

Another object of this invention is to provide a method of the character mentioned in which only a single water string or casing is required for the production of fluid from the several individual strata.

Another object of this invention is to provide a method of the character mentioned that does not necessitate the pulling or the withdrawal of the liners, the casing, or similar equipment from the well.

Another object of this invention is to provide a method of the character mentioned that precludes the possibility of water or unwanted fluid entering a producing stratum from an adjacent stratum by way of the well, and precludes the loss of the wanted fluid into a low pressure or "thief sand".

Another object of this invention is to provide a method of the character mentioned that does not necessitate the employment of special cementing equipment, drilling equipment, or the like.

Another object of this invention is to provide a simple, durable water string or well casing for use in the method referred to above, that provides for the easy successive exposure of the several productive strata as the productive strata from which the fluids are withdrawn are successively depleted and sealed off.

A further object of this invention is to provide a well lining or well casing embodying a plurality of drillable portions or sections to be arranged in the portions of the well penetrating the productive strata, said portions being such that they may be readily drilled up to expose or open their respective strata for production purposes.

The various objects and features of our invention will be fully understood from the following detailed description of a typical preferred manner of carrying out the method and a typical preferred form of apparatus of the invention, throughout which description reference is made to the accompanying drawings, in which:

Fig. 1 is a fragmentary vertical sectional view of the lower portion of a well showing the casing provided by the invention in position therein. Fig. 2 is a view similar to Fig. 1 showing the cement encasing the lower portion of the casing. Fig. 3 is a view similar to Fig. 2 illustrating the well deepened. Fig. 4 is a view similar to Fig. 3 illustrating a liner arranged in the open lower portion of the deepened well for the purpose of producing. Fig. 5 shows the open lower portion of the well cemented up and illustrates a tool drilling away a drillable section of the casing. Fig. 6 is a view similar to Fig. 5 showing a liner arranged in position to receive the fluid from a stratum exposed by drilling up a portion of the casing. Fig. 7 is a view similar to Fig. 6 showing the two lower depleted productive strata cement-

ed off and illustrating a portion of the casing drilled away to expose a higher stratum for production through a liner. Fig. 8 is a view similar to Fig. 7 showing all of the exhausted productive strata cemented off and Fig. 9 is a reduced diagrammatic view of the lower portion of the well showing the cement and equipment drilled out of the casing and showing the well deepened to penetrate lower productive strata.

The method and apparatus of the invention may both be modified or varied somewhat to adapt them for employment under different conditions that may be encountered in the wells to be developed or produced. In the following detailed disclosure we will describe the method and apparatus of the invention in connection with the production of fluid from a typical oil well or gas well, a portion of which is illustrated in the drawings, it being understood that the invention is not to be construed as limited or restricted in any way to the particular application or details about to be described.

In the drawings we have illustrated a well W penetrating or passing through a non-productive stratum or zone A, a productive stratum B underlying the stratum A, a non-productive zone C underlying the stratum B and including a water sand or stratum D, a productive stratum E underlying the stratum D and a non-productive stratum F underlying the stratum E. A productive or oil bearing stratum G lies below the stratum F and overlies a stratum I that may be considered as non-productive. The well as initially drilled or as illustrated in Figs. 1 and 2 reaches or enters the non-productive stratum F. Where we herein refer to non-productive strata we mean strata of earth formation that do not bear fluid, that bear the wanted fluid in small quantities or mixed with a high percentage of unwanted fluid, or that carry only unwanted fluids. Further, where we herein refer to productive strata we mean strata of earth formation that bear the desired fluid or fluids in sufficient quantities to be profitably produced.

The apparatus of the invention employed in carrying out the method is characterized by its simplicity and the apparatus will be first described to facilitate the description of the method. The apparatus of the present invention comprises a lining or casing **10** for the well W having a plurality of drillable portions or sections **11** and drillable liners **12** to be arranged in the well W and in the casing **10**.

The casing **10** is provided to line the well W to exclude or assist in excluding unwanted fluid such as water, etc., to exclude the fluid from the productive strata B and E until it is desired to produce from such strata, to prevent caving of the well, and to perform the other functions of a well casing. It may be assumed that the casing **10** is constructed to extend from the upper end of the well into the lower portion of the well and that the casing is to be landed at the ground surface in the usual manner. The casing **10** may be of uniform diameter throughout its length and may be made up of a number of sections connected by threaded couplings or collars. The casing **10** is placed in the well W with substantial clearance leaving a space **13** around the casing.

In accordance with the invention the casing **10** is characterized by the inclusion therein of one or more drillable sections **11**. The drillable sections **11** are located or assembled in the casing **10** to extend either partially or entirely through the productive stratum or strata penetrated by the well W. Thus in the simple illustrative case shown in the drawings the casing **10** embodies a drillable section **11** to be located in or to extend through the portion of the well penetrating the productive stratum B and a drillable section **11** to be located in or to extend through the portion of the well penetrating the productive stratum E. It is to be understood that where the well as initially drilled (see Figs. 1 and 2) penetrates productive or potentially productive strata in addition to the strata B and E that the casing **10** may include drillable sections for arrangement in the parts of the well penetrating such additional strata.

The drillable sections **11** of the casing **10** are tubular members or structures and their lengths are determined by the vertical extent of their respective productive strata B and E. Thus if a productive stratum B or E is of substantial vertical extent, the section **11** for arrangement in that part of the well W may be made up of a number of tubular sections or parts connected by threaded couplings or the like. In accordance with the invention the casing portions or sections **11** are formed of a material that may be readily drilled up or reduced to fragments or cuttings by a tool operated in the well W. It is preferred to form the sections **11** of aluminum or an aluminum alloy as such material has the required strength and is resistant to the action of the fluid in the well and yet is readily drilled up by a tool operated in the well. Further, where the sections **11** are formed of aluminum or an aluminum alloy their cuttings have a low specific gravity whereby the cuttings may be flushed from the well with circulating fluid, if desired, during or following the drilling operations. It is to be understood that the invention contemplates the manufacture of the sections **11** of various drillable materials. For example, the sections **11** may be formed of cement, glass, Bakelite, fibrous compositions, etc. When the sections **11** are formed of several parts connected by couplings or collars their several parts and connecting elements are preferably formed of the same or a similar drillable material.

The casing **10** with the exception of its sections **11** may be formed of steel to reduce its cost. The upper casing portion **14** is connected with the uppermost drillable section **11** by a threaded collar **16**. The casing section or portion **15** is connected with the spaced drillable sections **11** by suitable threaded collars **17**. The collars **16** and **17** may be formed of steel. The collars **16** and **17** are preferably treated, coated, insulated or otherwise constructed to prevent the development of an electrolytic action between the various portions of the casing **10** and the non-ferrous sections **11**. For example, the collars **16** and **17** may be formed of a di-electric material or may be formed of steel and coated with a di-electric material to prevent direct physical contact between the surfaces of the various collars and the non-ferrous sections **11**. In practice the collars **16** and **17** when formed of steel may be coated with a hard rubber composition, fibrous compounds, etc. It has also been found practical to plate the steel collars with cadmium to prevent galvanic or electrolytic action between the aluminum and the steel. Where a drillable section **11** is at the lower end of the casing **10**, as illustrated in the drawings, a suitable shoe **18** may be threaded on the lower end of said section. The shoe **18** may be of the same material as the lowermost section **11** or may be formed of steel, in which case it is

treated or insulated in the same manner as the collars 16 and 17 to prevent the development of an electrolytic action.

The liners 12 are intended to be located in the casing 10 at or within the drillable sections 11 after the same have been drilled up or partially drilled away, as will be subsequently described. One or more liners 12 may also be arranged in the open lower portion of the well W in the event that the well is deepened to extend beyond the lower end of the casing 10. The liners 12 are in the nature of screens to prevent sand and other solid matter from flowing upwardly in the well and casing 10 with the produced fluid and may be perforate to admit the desired well fluid. Where the casing 10 has several drillable sections 11 or the well W penetrates a plurality of potentially productive strata, a corresponding number of liners 12 may be employed, as will be described in connection with the method of the invention.

The several liners 12 may be similar in construction, although the lengths of the liners may depend upon the vertical extents of the respective productive zones in which they are arranged, and the lengths of the drillable casing sections 11 in which they are to be arranged. The liners 12 are elongate tubular members or structures adapted to be passed into and through the casing 10 with suitable clearance. The liners 12 may be provided at their lower ends with suitable plugs or shoes 20. When the liners 12 are of substantial length they may be made up of several pieces or tubular sections connected by suitable couplings. The screens or liners 12 may be provided with suitable perforations for the admission of well fluids. In the particular case illustrated in the drawings the liners 12 are provided with longitudinally and circumferentially spaced slots 21 that serve to admit the fluids from the productive strata and that screen out or prevent the entrance of sand, etc. The liners 12 may be supported or suspended in the well W and the casing 10 in any of the well known manners. For example, the liners 12 may be provided with liner hangers or the like, if desired. As liner hangers are well known to those skilled in the art they have been omitted from the present disclosure.

The liners 12 are preferably, though not necessarily, drillable. For example, where it is anticipated that there is a productive stratum below the lower end of the well W as originally drilled (see Figs. 1 and 2) or where it may be desired for any reason to deepen the well, the liners 12 are preferably formed of drillable material. On the other hand, where the well is not to be deepened following the landing and cementing of the casing 10 the liners 12 need not be formed of drillable material. In the typical instance illustrated in the drawings where the well W is to be deepened to reach the productive or potentially productive stratum G, it will be considered that the liners 12 are formed of a readily drillable material that may be reduced to fragments or cuttings by a tool operated in the well W. The liners 12 may be formed of the same material as the casing sections 11 and it may be preferred to form the liners of aluminum or an aluminum alloy. If desired, however, the liners 12 may be formed of other drillable materials. For example, they may be formed of glass, cement, Bakelite, fibrous materials, etc. It is to be understood that where the liners 12 are formed of a non-ferrous metal and are liable to contact ferrous portions of the casing 10 or other equipment, they are to be protected against the development of a galvanic action in the same manner as the casing sections 11 described above.

For the purpose of disclosing the invention it will be assumed that the well W is first drilled to the depth illustrated in Figs. 1 and 2 of the drawings to penetrate the productive strata B and E and to have its lower end entering the non-productive stratum F. As the various forms of drilling tools and the well drilling methods are well known to those skilled in the art, the drilling tools and the drilling operation have been omitted from the drawings. During the drilling of the well W to the depth illustrated in Figs. 1 and 2 of the drawings the locations and the extents of the productive strata B and E are made known to the drillers by means of core samples or otherwise, and the positions and extents of the productive strata B and E are logged or recorded.

Following the drilling of the well W to the depth illustrated in Figs. 1 and 2 of the drawings, the casing 10 is made up and run into the well. The casing 10 is assembled or constructed so that its drillable sections 11 occur at or occupy the portions of the well W penetrating the productive strata B and E when the casing is landed. The casing 10 is suspended or landed so that its lower end or the shoe 18 on its lower end is spaced above the bottom of the well W. The well casing 10 may be landed or suspended at the ground surface in the well known manner.

The next phase or step of the method is the cementing of the casing 10. In accordance with the invention the casing 10 is cemented in the well W from the bottom of the well to a plane above the uppermost productive stratum B. Cement in a plastic state is introduced into the well W to occupy the space 13 around the casing 10 within the limits just mentioned. In carrying out this operation the cement slurry, which is a mixture of water and Portland cement and which we will herein designate cement 22, is passed, pumped, or otherwise delivered downwardly through the casing 10 and is forced upwardly around the lower end of the casing into the space 13. In practice the volume or capacity of the portion of the space 13 to be occupied by the cement 22 is determined or estimated and the cement slurry or cement in the necessary quantity is mixed and introduced into the upper end of the casing 10. The mass or body of cement 22 may be forced down through the casing 10 under pressure by pumping liquid downwardly after it. A plug 23 may follow the body of plastic cement 22 downwardly through the casing 10 to prevent the mixture of the cement with the liquid following it. The plug 23 is such that it may be drilled up by a drilling tool operated in the well. When substantially all of the cement 22 has been forced into the space 13 around the casing 10 the plug 23 engages the bottom of the well. The cement 22 is then allowed to set and harden. It will be observed that the cement 22 forms a sheath or shell entirely surrounding the casing 10 from its lower end to a plane above the uppermost productive stratum B to fully seal off the productive stratum B and E and the water bearing strata D to prevent the entrance of fluid therefrom into the well, and to prevent the passage of fluid from one stratum to another on the exterior of the casing 10.

When the cement 22 has hardened the well W may be deepened in an attempt to reach a productive stratum underlying the non-productive stratum F. For example, if surveys, etc. have indicated that the stratum G underlies the stratum

F the well may be deepened to reach the stratum G for the purpose of producing from the same. However, it is to be understood that the well may be produced from the strata B and E already penetrated, if this course is desired. The deepening of the well W may be performed by suitable drilling tools; for example, a rotary well drilling string may be operated through the casing 10 to deepen the well. The drilling tool drills up the plug 23 and any cement 22 that may be in the lower portion of the casing 10 and the lower part of the well W. In Figs. 4 to 8, inclusive, of the drawings, we have shown the well W deepened to penetrate the productive stratum G and to enter the non-productive stratum I. It is to be understood, of course, that the well W may be deepened to penetrate a number of productive strata.

In the event that the stratum G or the other strata encountered in deepening the well W, as above, are found to produce in paying quantities, the invention provides for the production of the wanted fluid from such strata. In Fig. 4 of the drawings we have illustrated a drillable liner 12 arranged in the open lower portion of the well W to receive the desired fluid from the stratum G and to deliver the same upwardly into the casing 10. The liner 12 may be run down through the casing 10 and set or hung in any selected manner. In the typical case illustrated the liner 12 is supported on the bottom of the well to extend upwardly through the stratum G and enter the lower portion of the casing 10. It will be obvious that the liner 12 may be suspended from the casing 10 by a suitable liner hanger, if desired. Following the setting of the liner 12 the stratum G is allowed produce through the liner and the casing 10 and, if necessary, the well may be pumped to obtain the fluid from the stratum G. The stratum G may be produced until depleted of the wanted fluid or until it is abandoned for other reasons.

Upon depletion of the stratum G, it will usually be desired to seal off or cement off that stratum to prevent water or other unwanted fluid produced by said stratum from entering the well and to prevent the fluid produced from other strata from flowing into the stratum G. In accordance with the invention a body or mass of cement slurry or plastic cement 25 is passed or pumped down through the casing 10 to close off the stratum G. In practice it may be preferred to fill the entire open lower portion of the well W with cement 25. If the liner 12 is drillable, as described above, it may be left in the well to be encased in the cement 25. However, if the liner 12 arranged in the stratum G is non-drillable it is preferred to remove the liner from the well before delivering the cement 25 to the stratum G to close off the same. The body of cement 25 occupying the open lower portion of the well W may completely encase the liner 12 and in any case completely seals off the stratum G. The cement 25 is allowed to set and harden.

The strata E and B and any other productive strata penetrated by the well W, as initially drilled, may now be produced. It is a feature of the invention that the strata E and B may be individually and successively exposed or opened to the interior of the casing 10, produced, and then individually sealed off whereby the strata are separately produced for the fullest possible recovery of oil or wanted fluid. In this connection it is to be understood that the following operations for the successive individual production of fluid from the strata E and B may be carried out without having first deepened the well W to produce from the stratum G, as described above. In other words, in the event the well is not deepened to the point illustrated in Figs. 3 to 8 of the drawings the following operations may be performed to produce or recover fluid from the productive strata E and B.

The first step in producing the desired fluid from a stratum E or B subsequent to the landing and cementing of the casing 10, as described above, is the opening of the selected stratum or the exposure of the selected stratum to the interior of the casing 10. Reference will now be made to Figs. 5 and 6 of the drawings. To open or expose the stratum E an expanding type tool T is run into the casing 10 to a point within the drillable section 11 opposite the stratum E. In practice the tool T may be any suitable form of underreamer, wall scraper, or expansible well drilling tool. In the case illustrated in Fig. 5 the tool T is secured to the lower end of a rotary well drilling string S and has blades 26 for cutting away the drillable section 11 and the cement 22 encasing the same. The tool T is lowered to a point in the section 11 that extends through the stratum E and the tool T is controlled or manipulated so that its blades 25 expand. During the outward movement or expansion of the blades 26 the string S is rotated so that the blades cut through the drillable casing section 11 and the cement 22 around the same. The section 11 being formed of aluminum, an aluminum alloy or other drillable material is readily drilled up or reduced to small cuttings by the blades 26 and the blades are operable to quickly cut away the cement 22. The cuttings from the drillable section 11 and the cement 22 may be washed or flushed to the ground surface by circulation fluid discharged from the tool T.

The tool T is fed longitudinally as it is rotated so that the blades 26 drill away a substantial portion of the drillable section 11 and expose a substantial portion of the stratum E. It is preferred to employ a tool T that is capable of not only drilling up the section 11 and the enclosing cement 22, but is also operable to cut into the stratum E to clean the wall of the portion of the well penetrating said stratum. The tool T may carry a diamond point bit 27 and may have guides 28 cooperating with the interior of the casing 10. It is preferred to operate the tool T to drill up a substantial part of the section 11 and the adjacent cement 22 and form a cavity 29 of substantial length or vertical extent. The cavity 29 exposes a considerable portion, or the entire vertical part, of the stratum E to the interior of the casing 10. When a cavity 29 of the desired length has been formed the tool T is removed from the well and, if desired or necessary, the well may be cleaned or bailed to remove cuttings, etc. from the casing 10.

The next step of the method is the arrangement or setting of a drillable liner 12 in the casing 10 to extend through the annular cavity 29 or the portion of the well penetrating the stratum E. The liner 12 may be set, suspended or supported in any selected manner. Fig. 6 of the drawings illustrates the lower end or plug 20 of the liner 12 received in the cut 30 made by the bit 27 in the cement 25 during the formation of the cavity 29. The plug 20 serves to support the liner 12 so that the liner extends vertically through the cavity 29. The wanted fluid is then allowed to produce from the stratum E or is caused to produce from the stratum E to pass

through the perforate liner 12 and flow upwardly through the casing 10. It is to be observed that the cement 22 around the casing 10 fully seals the stratum D from the stratum E to prevent the contamination of the wanted fluid by water from the stratum B and prevents the loss of the fluid from the stratum E to the adjacent strata of earth formation. The stratum E may be allowed to produce or the well may be pumped until the stratum E is depleted or abandoned for other reasons.

The method of the invention then provides for the sealing off or cementing off of the depleted stratum E. A body of cement slurry or cement 31 is pumped or otherwise delivered to the lower portion of the casing 10 to occupy the cavity 29 (see Fig. 7). The casing 10 and the cavity 29 may be completely filled with the cement 31 from the upper end of the cement 25 to a plane above the upper end of the stratum E or to a plane above the upper end of the drillable section 11 extending through the stratum E. In practice the cement 31 may extend upwardly through the casing portion 15 to a position adjacent the drillable section 11 extending through or opposite the productive stratum B. If desired the liner 12 at the stratum E may be removed from the casing 10 before the cementing off of the stratum E. However, when a drillable section 12 is employed at this point it may be permitted to remain in the well and to be embedded in the cement 31. Figs. 7 and 8 of the drawings illustrate the cement 31 sealing off the stratum E and encasing the drillable liner 12 as just described. The cement 31 is allowed to set and harden.

The method now provides for the production of the wanted fluid from the stratum B. The stratum B may be produced in substantially the same manner as the stratum E. That is, a suitable tool is operated in the casing 10 to drill up the drillable casing section 11 opposite the stratum B and to drill up the cement 22 about the same, and a liner 12 is arranged in the casing 10 to receive the fluid from the stratum B thus exposed. Fig. 7 of the drawings illustrates a cavity 32 formed in the well by the drilling up of the section 11 and the cement 22 as just described, and shows a liner 12 in position in the casing 10 to receive the fluid from the stratum B. The plug 20 on the lower end of the liner 12 may rest on the upper end of the cement 31 to support the liner, it being obvious that the liner 12 may be suspended from the casing 10 by a liner hanger, if desired. The fluid may be produced from the stratum B or may be pumped until the stratum is depleted or fails to produce for other reasons.

If there are productive strata above the stratum B the depleted stratum B is sealed off and the higher strata are successively produced in the same manner as the strata B and E. If, on the other hand, the stratum B is the uppermost producing stratum as illustrated in the drawings it may be desired to deepen the well W beyond the point illustrated in Figs. 4 and 5 of the drawings in an attempt to reach lower productive strata. Preparatory to carrying out either of the procedures just mentioned cement slurry or plastic cement 33 is introduced into the casing 10 to seal off the stratum B. The cement 33 preferably completely occupies the cavity 32 and may extend some distance upwardly in the casing 10 from the cavity. Where a drillable liner 12 is employed for the production of the stratum B it may be left in the casing to be enclosed in the body of cement 33. The cement 33 is then allowed to set and harden.

If there is reason to believe that there may be productive strata below the stratum G or below the lower end of the well W as initially drilled, or if it is desired to explore the earth formation beyond the horizon or depth to which the well has been drilled, the method of the invention contemplates the deepening of the well. To carry out this well deepening operation a suitable well drilling tool (not shown) is operated in the casing to drill up the cement 33 and the liner 12 therein, the cement 31 and the liner 12 therein, and the cement 25 and the liner 12 therein. The liners 12 being formed of aluminum, an aluminum alloy or other drillable material are readily drilled up or reduced to cuttings when the drilling tool is operated in the casing to drill up the cement. This drilling operation clears the casing 10 leaving the same open for drilling operations and producing operations, but leaves tubes or shells 35 and 36 of cement in the cavities 29 and 32, respectively (see Fig. 9). These cement shells 35 and 36 seal off or close the strata B and E, respectively, from the interior of the casing 10 so that unwanted fluids that may be in these strata are prevented from entering the well.

The drilling operation may be continued to deepen the well to any desired point. In Fig. 9 of the drawings we have shown the well W deepened to penetrate productive strata J and K spaced below the previously produced productive stratum G. In accordance with the invention the desired fluid may be produced from the strata J and K by the same method employed in producing from the strata B and E to permit a subsequent deepening of the well. That is, a casing similar to the casing 10 may be arranged in the well W having drillable sections at the strata J and K so that the strata J and K may be exposed and produced at will, and so that the well may be deepened following the setting of such a casing in an attempt to reach lower productive strata.

The method of the present invention provides for the successive and complete recovery of the wanted fluid from a number of productive strata encountered in a well and permits the subsequent deepening of the well when occasion requires. The method may be carried out without the employment of special cementing equipment or special drilling equipment. After the several available productive strata have been depleted of the wanted fluid the shells 35 and 36 of cement sealing off the depleted strata may be broken out or drilled away to again expose the strata to determine if their productivity has been restored. It is to be particularly noted that the method permits the drilling and the casing of a well, that penetrates a number of productive strata, with the assurance that the several productive strata may be selectively or individually made to produce at any time.

Having described only a typical preferred form of apparatus and manner of carrying out the method of our invention, we do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims.

Having described our invention, we claim:

1. The herein described method comprising drilling a well to penetrate a productive stratum,

arranging a casing in the well having a readily drillable portion at said stratum, drilling up said portion to leave an open uncased zone at said stratum and to expose said stratum for producing, and then allowing the stratum to produce.

2. The method of operating a well having a plurality of productive strata comprising arranging a casing in the well having readily drillable portions at said strata, and then operating a drilling tool in the well to drill up said portions to expose the respective strata for production.

3. The method of operating a well having a plurality of productive strata comprising providing a casing having readily drillable portions, arranging the casing in the well to have its drillable portions at said strata, encasing the part of the casing passing through said strata with cement, and then drilling up said drillable portions of the casing and the cement surrounding the same to leave open uncased zones at said strata and thus expose the strata for free production.

4. The method of operating a well having a plurality of productive strata comprising providing a casing having readily drillable portions, arranging the casing in the well to have its drillable portions at said strata, and then successively producing from said strata by first drilling up a drillable portion at one stratum to leave an open uncased zone in the well at said stratum, allowing said stratum to produce, drilling up the drillable portion at another stratum to leave an open uncased zone in the well at said stratum, and then allowing the last mentioned stratum to produce.

5. The herein described method comprising drilling a well to penetrate a productive stratum, providing a casing having a readily drillable portion, arranging the casing in the well to have said drillable portion at said stratum, encasing said portion of the casing and the adjacent parts of the casing with cement, and operating a tool in the well to drill up said drillable portion and the cement about the same to provide an open uncased zone at the stratum to allow the stratum to freely produce into the casing.

6. The method of operating a well having a plurality of productive strata comprising providing a casing having readily drillable portions, arranging the casing in the well to have its drillable portions at said strata, encasing the casing with cement from its lower end to above the uppermost productive stratum, operating a tool in the well to drill up one of said drillable portions and the cement around the same to expose its respective stratum for free communication with the casing, allowing said stratum to produce, operating a tool in the well to drill up another of said drillable portions and the cement around the same to expose another productive stratum for free communication with the casing, and producing from the last mentioned stratum.

7. The method of operating a well having a plurality of productive strata comprising providing a casing having readily drillable portions, arranging the casing in the well to have its drillable portions at said strata, encasing the casing with cement from its lower end to above the uppermost productive stratum, operating a tool in the well to drill up one of said drillable portions and the cement around the same to expose its respective stratum for free communication with the casing, allowing said stratum to produce, cementing off said stratum when the same is depleted, operating a tool in the well to drill up another of said drillable portions and the cement around the same to expose another productive stratum, and producing from the last mentioned stratum.

8. The method of operating a well comprising drilling the well to penetrate a productive stratum, arranging a casing in the well having a readily drillable portion in that part of the well penetrating said stratum, deepening the well beyond the lower end of the casing to reach another productive stratum, producing the desired fluid from the last mentioned stratum, sealing off said last mentioned stratum when the same is depleted, and then drilling up said drillable casing portion to expose the first mentioned stratum for production.

9. The method of operating a well comprising drilling the well to penetrate a productive stratum, arranging a casing in the well having a readily drillable portion in that part of the well penetrating said stratum, cementing the casing in the well from the lower end of the casing to a plane above the said stratum, deepening the well to reach another productive stratum below the casing, producing from the last mentioned stratum, cementing off said last mentioned stratum, and operating a tool in the well to drill up said drillable portion of the casing and the cement around the same to expose the first mentioned stratum for production.

10. The method of operating a well comprising drilling the well to penetrate a productive stratum, arranging a casing in the well having a readily drillable portion in that part of the well penetrating said stratum, deepening the well beyond the lower end of the casing to reach another productive stratum, producing the desired fluid from the last mentioned stratum, sealing off said last mentioned stratum when the same is depleted, operating a tool in the casing to drill up said drillable portion and expose the first mentioned stratum, producing from said first mentioned stratum, cementing off said first mentioned stratum, and then again deepening the well to reach lower productive strata.

11. The method of operating a well comprising drilling the well to penetrate a productive stratum, arranging a casing in the well having a readily drillable portion in that part of the well penetrating said stratum, deepening the well beyond the lower end of the casing to reach another productive stratum, arranging a readily drillable liner in the portion of the well entering the last named stratum to produce from the same, producing from said last named stratum, filling the portion of the well entering said last named stratum with cement to close off the stratum, drilling up said drillable portion of the casing to expose the first named stratum, arranging a drillable liner in the casing to produce from said first named stratum, and then drilling out the liners and cement in the casing and well and deepening the well.

12. The method of operating a well comprising drilling the well to penetrate a productive stratum, providing a casing having a readily drillable portion, arranging the casing in the well to have said drillable portion in that part of the well penetrating said stratum, deepening the well beyond the lower end of the casing to reach another productive stratum, arranging a readily drillable liner in the portion of the well entering the last named stratum to produce from the same, producing from said last named stratum, filling the portion of the well entering said last

named stratum with cement to close off the stratum, drilling up said drillable portion of the casing to expose the first named stratum for free production, arranging a readily drillable liner in the casing to produce from said first named stratum, producing from said first named stratum, filling the portion of the well and casing penetrating said first named stratum with cement to seal off the stratum when the same is depleted, and then drilling out the liners and cement in the casing and well and deepening the well.

13. The herein described method comprising drilling a well to penetrate a productive stratum, arranging a casing in the well having a readily drillable portion at the said stratum, drilling up the said portion to expose said stratum, arranging a readily drillable liner in the casing to produce from said stratum, delivering cement to the casing to seal off said stratum from the casing, and then operating a drilling tool in the casing to drill up the liner and cement therein and to deepen the well.

14. The herein described method comprising drilling a well to penetrate productive strata, setting a casing in the well, and then successively producing from said strata by drilling out the casing to freely expose a stratum, allowing the stratum to produce and then cementing off the stratum when depleted and repeating these operations at the other strata.

15. A casing for a well having spaced productive strata comprising an elongate assembly of connected tubular sections, the sections in the portions of the well penetrating said strata being formed of readily drillable material, the other sections being formed of steel.

16. A casing for a well having spaced productive strata comprising an elongate assembly of connected tubular sections, the sections in the portions of the well penetrating said strata being formed of aluminum, the other sections being formed of steel.

17. A method of operating a well comprising lowering into the well a string of casing made up of sections of normal casing and sections of drillable casing, so that the sections of normal casing are substantially opposite portions of the well from which no production is desired and the sections of drillable casing are substantially opposite portions of the well from which production is desired, cementing such string of casing in the well, drilling away the sections of drillable casing from portions of the well from which production is desired, and baring the surfaces of the portions of the well from which the drillable casing has been removed and from which production is desired.

18. A method of operating a well comprising lowering into the well a string of casing made up of sections of normal casing and sections of drillable casing, so that the sections of normal casing are substantially opposite portions of the well from which no production is desired and the sections of drillable casing are substantially opposite portions of the well from which production is desired, cementing such string of casing in the well, drilling away the sections of drillable casing from portions of the well from which production is desired, baring the surfaces of the portions of the well from which the drillable casing has been removed and from which production is desired, and lowering through the remaining sections of normal casing a perforated inner string seated opposite portions of the well from which production is desired.

19. A casing for a well comprising an elongate assembly of connected tubular sections, the major number of the sections being formed of steel and the balance being formed of readily drillable material, the readily drillable material sections being interposed between steel sections and so arranged that on removing portions of them the well walls may be exposed thereby.

20. The method of operating a well comprising positioning in the well a casing having readily drillable portions interposed between steel portions, producing the well through the casing and subsequently removing at least a portion of the readily drillable portion of the casing.

21. The method of operating a well comprising positioning in the well a casing having readily drillable portions interposed between steel portions, and encasing at least the readily drillable portion of the casing with cement, producing the well through the casing and subsequently removing at least a portion of the readily drillable portion of the casing and the encasing cement.

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