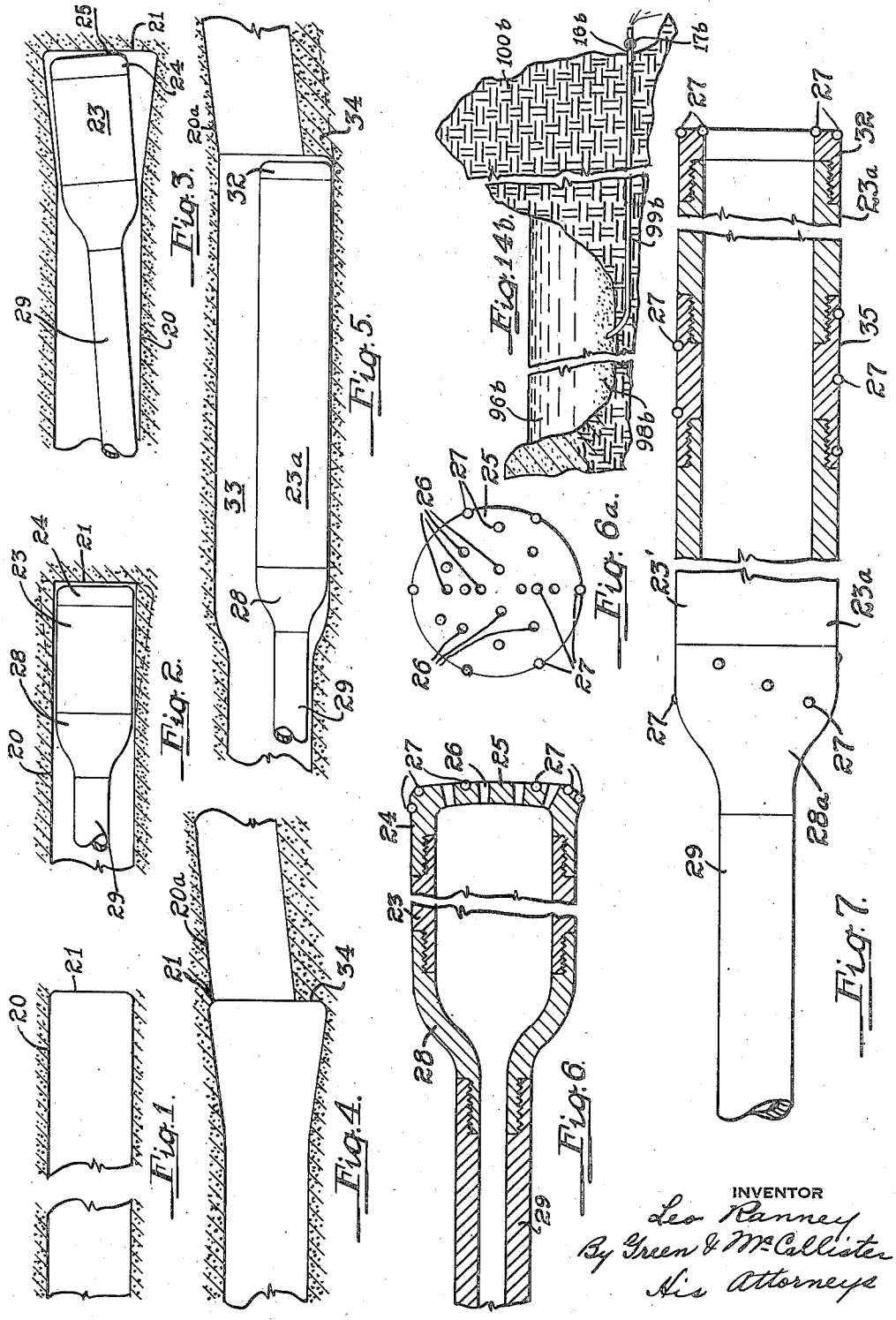
April 28, 1942. L. RANNEY 2,280,851

METHOD OF WELL DRILLING

Filed Jan. 12, 1939 4 Sheets-Sheet 1




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METHOD OF WELL DRILLING

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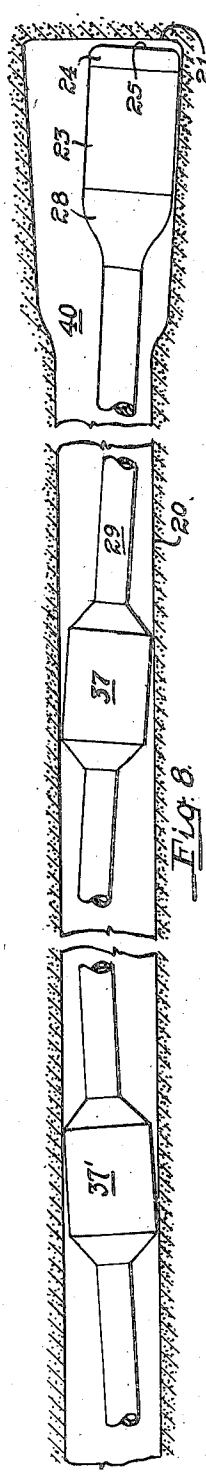



Fig. 8.

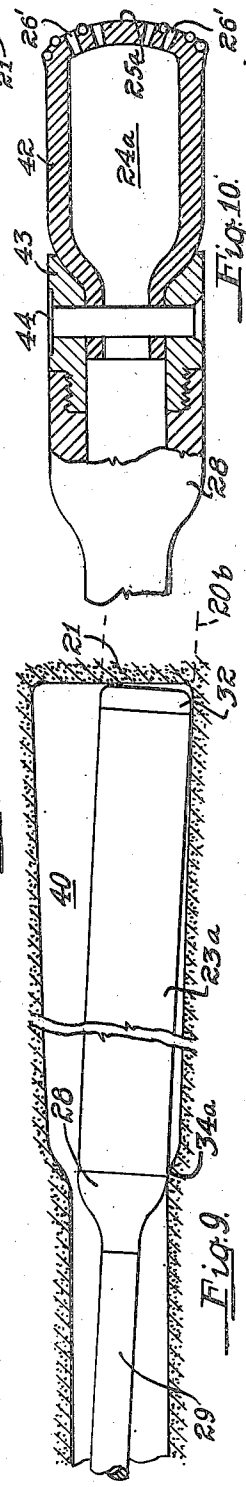



Fig. 9.

Fig. 10.

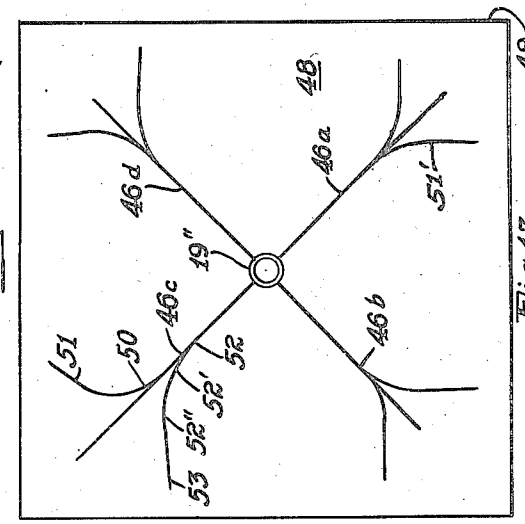



Fig. 13.

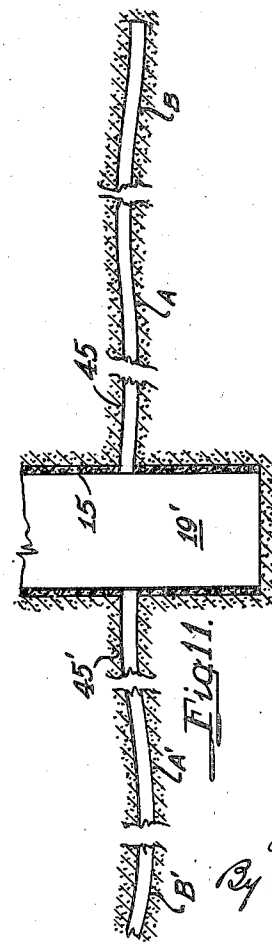



Fig. 11.

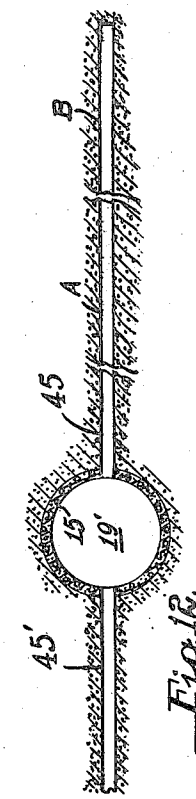



Fig. 12.

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METHOD OF WELL DRILLING

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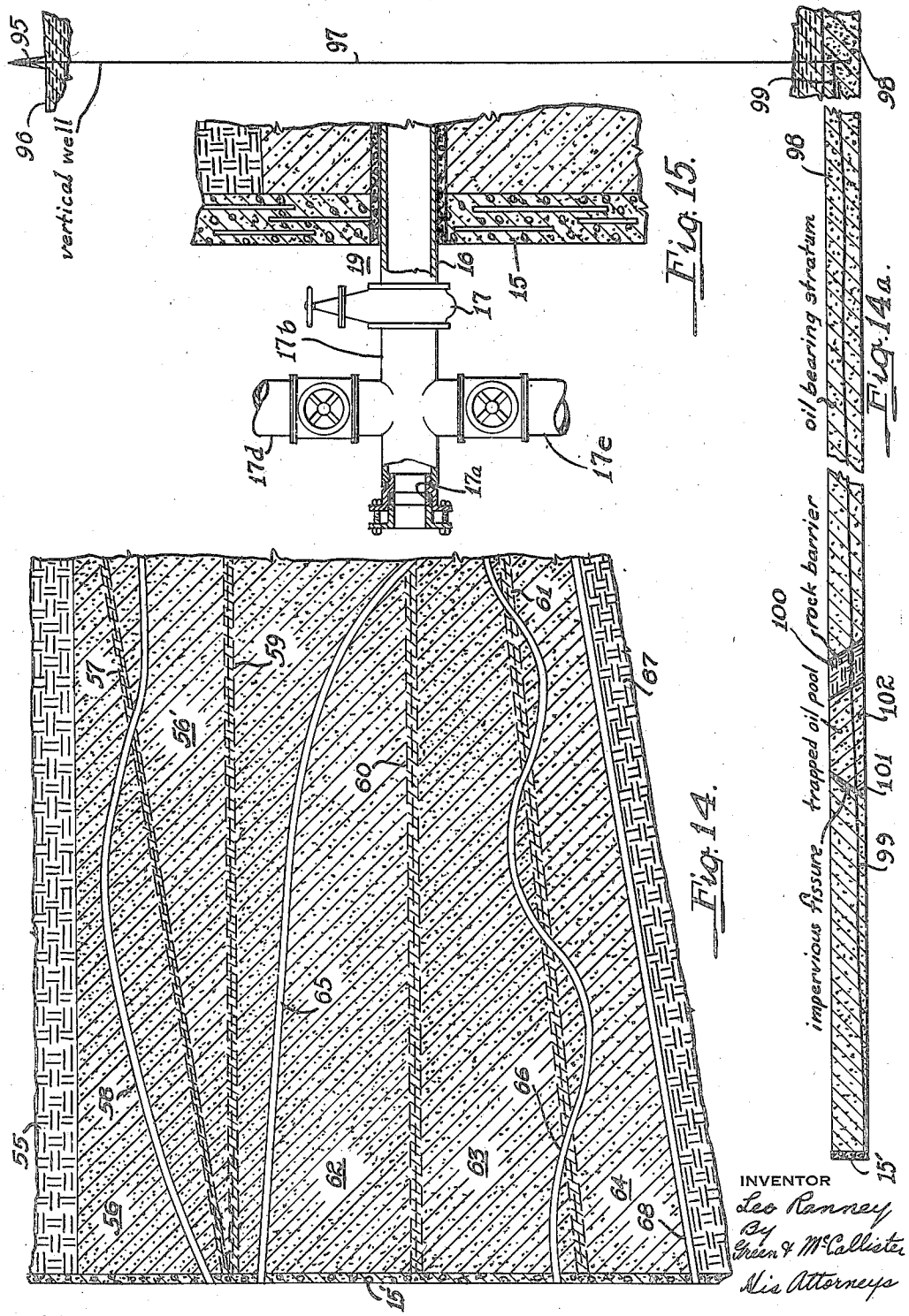



Fig. 15.

Fig. 14a.

Fig. 14.

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METHOD OF WELL DRILLING

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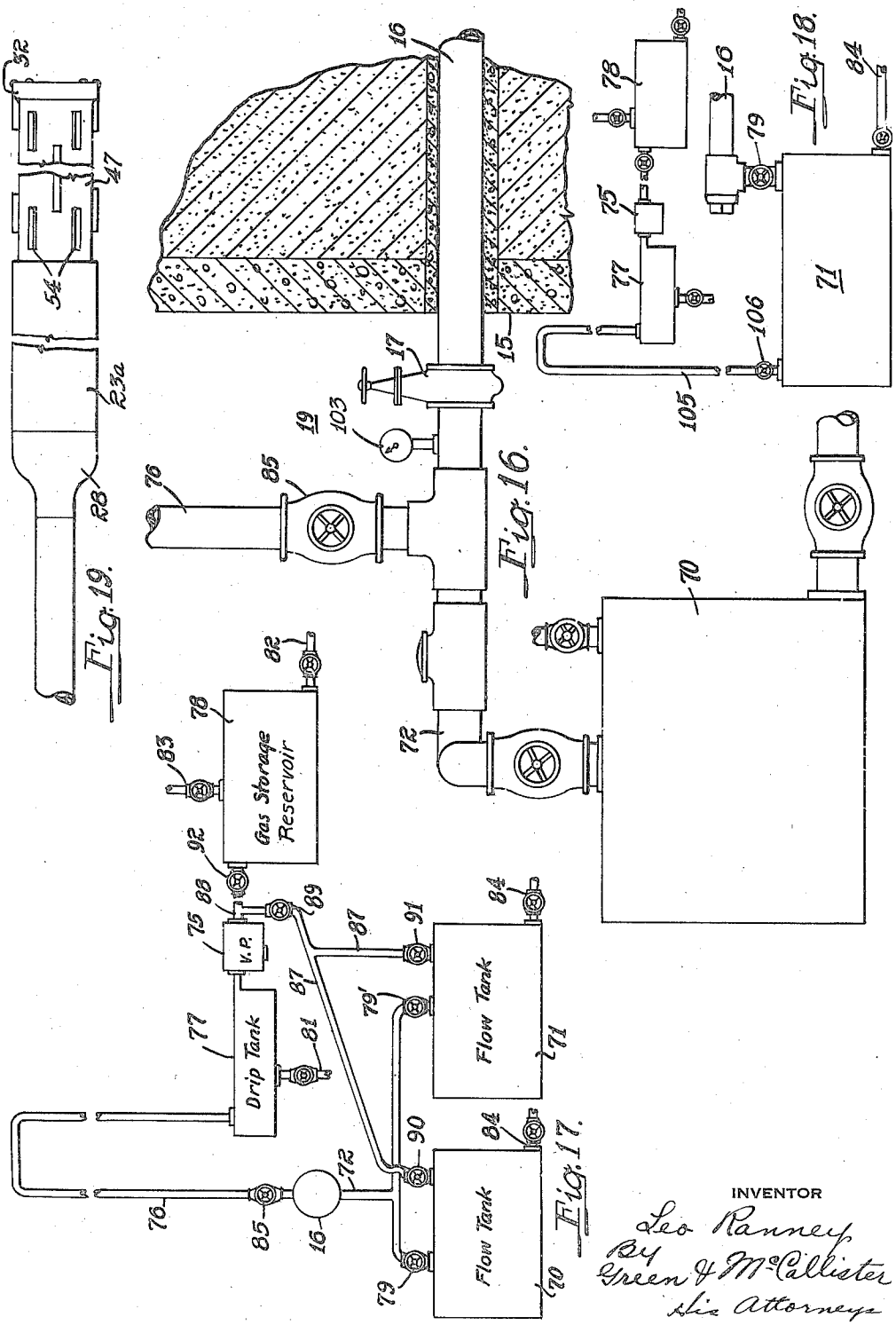



Fig. 19.

Fig. 16.

Fig. 18.

Fig. 17.

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# UNITED STATES PATENT OFFICE

2,280,851

## METHOD OF WELL DRILLING

Leo Ranney, McConnelsville, Ohio

Application January 12, 1939, Serial No. 250,569

39 Claims. (Cl. 255—1.8)

This invention relates generally to well-drilling operations and specifically to a drilling procedure of such character that substantially all of the drilling operation is accomplished within a productive stratum and under conditions such that a substantial portion of the well surface is either productive surface or has the potentiality of being rendered productive.

Natural products, such as oil or gas, are obtainable from the earth by drilling operations because they are ordinarily located in earthy material through which they are capable of flowing. This fluid-bearing material is usually a sedimentary deposit and is usually of such character that it may be defined by the geologic term "stratum." Commercial drilling for such natural products has largely been accomplished from the earth surface with the result that practically all of such operations involve substantially vertically driven wells where almost the entire length of each well is located in non-productive material and only relatively short portions are cut through a productive stratum, thus exposing a very small length area of such stratum within the well and from which a flow may take place.

Vertical wells are frequently driven to a depth of from 6,000 to 10,000 feet and all for the purpose of exposing a productive stratum which may not exceed 20 feet in thickness and it may be said that of the vertical wells now driven less than two (2) per cent of the total length of the well is located within a productive stratum, with the result that at least 98 per cent of the well is cut through non-productive strata. A productive stratum may outcrop or extend close to the surface of the ground and under such conditions surface drilling may be simplified but, in general, only a short length of the well is formed within or cut through productive material, consequently the well provides only a relatively small area of surface through which a flow is possible.

A broad and fundamental object of this invention is to produce a well-drilling procedure for producing wells which are from several hundred to several thousand feet in length and in which approximately 98 per cent of the well length is located within a productive stratum.

Experience teaches that oil bearing strata, for example, vary considerably in form and density. Such a stratum may be hard and tight as building stone or it may be in the form of well consolidated or even open sand. All such formations may occur in the same locality, and in many cases at one level. In addition, each such formation may be traversed by non-productive material which may be in such form as to impede or even prevent the flow through the productive stratum.

Practically all oil bearing sands were water-laid; consequently, are layer-like in form, and usually extend over large areas, although they are relatively thin. Floods, shifting currents, upheavals of nature and the varying contour of the then sea bottom all had an effect on the character and form of such strata. Oil productive layers are often a part of a horizon including shale, clay deposits and limestone deposits, all in layer formation with the layers either in parallel relation to the horizon or at widely varied angles thereto and in some cases in the form of lenses wherein a particular sub-stratum tapers from the center to disappearing thin edges. From the foregoing, it is apparent that productive horizons generally extend over large areas in approximately horizontal direction; are relatively thin with reference to their extent; and that even where a productive sub-stratum may be readily and easily reached by a vertically driven well, the length of the portion of the well which is actually located within the productive sub-stratum will necessarily depend upon the vertical thickness of the sub-stratum and in no way upon its extent. This is true, even where a productive stratum outcrops and even though the surface drilling operation is controlled in accordance with now known procedure, in an effort to extend the length of that portion of the well which is actually located within the outcropping productive material.

In this connection, it should be noted that the various strata in an oil bearing horizon are usually irregular and are often undulating in shape with the result that an oil bearing sub-stratum may be irregular or even of wavy formation but, in any event, will be of such shape that it cannot be followed by such well drilling procedures as were known prior to my present invention. Then too, a stratum which was laid in the form of open or even loose sand is often subjected to the percolation of heavily mineralized waters with the result that at least portions of such stratum are permeated with silicon or calcium deposits to such an extent that they are rendered tight or even impervious with the result that they are non-productive although located in, and forming a part of a productive horizon or stratum. This accounts for the fact that many vertical wells drilled in a producing field result in what are termed "dry holes."

An object of my invention is to produce a form of well and a method of drilling the same which makes it economically feasible to rework, by redrilling, oil or gas fields which are now unprofitable or have been abandoned because such oil and gas as is contained therein is not readily available by present drilling procedures.

A fundamental object of my invention is to perfect a well-drilling operation such as to make it commercially practical and economically feasible to produce drilled wells in which all or the major portion of the length of the well is located within a productive sub-stratum. In this connection, it might be noted that I use the term "productive sub-stratum" to mean a stratum containing the fluid (oil, water or gas) sought by the drilling operation.

A further object of my invention is to produce drilled wells in oil bearing horizons wherein each well is so located that it is either self-draining under the action of gravity or in response to syphonic action or atmospheric pressure.

A further object is to provide an improved procedure for drilling wells in a generally horizontal direction and for controlling, at a point remote from the point of application of the drilling force to the material being drilled, the direction in which the drilling proceeds.

A further object is to produce a new and improved drilling procedure wherein the drilling operation may be so controlled, throughout substantially each length portion of the well, as to cause the well to substantially follow a productive sub-stratum dissolved, for example, by prior exploratory drilling operations.

A further object is to produce a form of well and method of producing the same such that the well may lie wholly within a productive horizon, but cross and recross known nonproductive material or sub-strata within the horizon, thus tapping productive sub-strata and pockets which could not readily be tapped or explored by surface drilling operations.

These and other objects which will be made more apparent throughout the further description of my invention are attained by means of procedure hereinafter described and apparatus such as is illustrated in the accompanying drawings, wherein:

Figure 1 is a diagrammatic illustration of a horizontal well of indeterminate length.

Figure 2 is a view corresponding to Figure 1 and diagrammatically illustrates a special drilling tool within the well and preliminary to changing the direction of the drilling operation;

Figure 3 is a view corresponding to Figures 1 and 2 and diagrammatically shows the result of the operation of the special tool and its position preliminary to accomplishing a "rise" in the drilling operation;

Figure 4 is a view corresponding to Figure 3 and diagrammatically illustrates the results accomplished by the special tool in enlarging the end of a drilling and then continuing the drilling at an angle to the axis of the enlarged portion of the hole or drilling;

Figure 5 is a view corresponding to Figure 4 but diagrammatically illustrates results of the drilling procedure preliminary to a "rise" and illustrates a core barrel and drill bit in place within the enlarged portion of the well and as a preliminary to continuing the drilling operation;

Figure 6 is a diagrammatic sectional view of a special form of drilling assembly, termed a "beezer," and shown associated with a sub and the drill rod;

Figure 6*a* is a front elevation of the drilling face of the beezer illustrated in Figure 6;

Figure 7 is a diagrammatic view of a special drilling tool shown partially in section and partially in side elevation and also shown as having parts broken away to indicate that the tool may be of considerable over-all length;

Figure 8 diagrammatically illustrates a horizontally drilled hole in which the end of the hole has been enlarged preparatory to changing the direction of the drilling operation and special drilling equipment is diagrammatically illustrated as located within the hole, as a preliminary to occasioning a "fall" in the drilling operation;

Figure 9 is a view corresponding to Figure 8 and diagrammatically discloses a drilling tool within the hole and the relationship of tool and hole after the hole-enlarging operation has been completed;

Figure 10 is a fragmental sectional view diagrammatically illustrating a special form of drilling tool;

Figure 11 is a diagrammatic vertical sectional view illustrating a shaft sunk into a productive horizon and horizontal wells extending therefrom;

Figure 12 is a digrammatic horizontal sectional view of the shaft and the wells illustrated in Figure 11;

Figure 13 is a diagrammatic illustration of a property in which a shaft has been sunk and from which horizontal wells are drilled;

Figure 14 is a diagrammatic sectional view of a possible productive horizon and illustrates various forms of horizontal wells which may be drilled in accordance with my invention;

Figure 14*a* is a diagrammatic carrying forward of a portion of the sectional view of Figure 14 and illustrates both a horizontally drilled and a vertically drilled well under conditions such that each well cuts into the oil-bearing stratum there shown;

Figure 15 is a fragmental sectional view of a portion of the wall of a shaft or chamber and illustrates apparatus which may be employed in the operation of drilling a horizontal well from such a shaft or chamber;

Figure 16 is a view corresponding to Figure 15 but diagrammatically illustrates piping and a flow tank such as may be employed for the purpose of receiving a liquid such as oil from a "self-draining" well;

Figure 17 is a diagrammatic view corresponding to Figure 16 and more fully illustrating producing apparatus such as may be employed in connection with a horizontal well; and

Figure 18 is a diagrammatic view illustrating a variation in the apparatus of Figure 17.

Fig. 19 is an elevational view of another modification of the drilling tool.

While my invention broadly involves the drilling of wells in a substantially horizontal—as distinguished from a vertical—direction, an important feature thereof is what may be termed "elevation control" wherein drilling procedure is employed for varying the direction of drilling so that different portions of the hole are inclined more or less to the horizontal and under the control of the driller. This elevation control is different and distinct from lateral control and makes it possible to drill a substantially horizontal well wherein different length portions thereof

extend at an angle to each other and at various inclinations to the horizontal but wherein the average direction of the entire well is substantially horizontal and all directional changes are accomplished in such a way that substantially all portions of the well are curved but curved on such diameters as to accommodate the ready introduction, effective operation, and ready withdrawal of well drilling, well shooting, well cleaning, well producing and other similar equipment.

The drilling of horizontal holes or taps is not new. Such prior patents as Casamajor 50,902 of November 14, 1865, Wright 1,520,737 of December 30, 1924, and my Patent 1,811,560 of June 23, 1931, disclose that the idea of gaining access to productive strata by means of horizontal drillings is old, but no one has heretofore been able to drill a well in a substantially horizontal direction and at the same time control the drilling operation in such a way as to cause the well to proceed in upwardly inclined and downwardly inclined directions at the will of the driller and for the purpose of following a productive sub-stratum, or for the purpose of moving from a non-productive to a productive sub-stratum. That is to say, the thought of drilling short horizontal taps is old as disclosed by the patent to Casamajor and the other patents above mentioned, but prior to my present invention no one had produced or even contemplated a procedure for drilling horizontal wells which approximated the length of vertically drilled wells. In addition, no one has contemplated a well drilling procedure for producing a horizontal well wherein each length unit of the well is located in a predetermined position and is drilled under conditions such that its direction is under the control of the driller.

I have actually drilled horizontal wells of a length approximating that of the modern vertical wells and in addition I have so controlled the drilling of each such well that each length unit of well was elevationally positioned to correspond to a predetermined plan of drilling procedure and for the purpose of effectively locating well lengths within a productive horizon.

Except where an outcrop is involved, the first step in my procedure is to sink a shaft of substantial size to a point within, or adjacent to, a productive horizon. The shaft will ordinarily be of such size as to approximate a cylindrical chamber of about 20 feet in diameter except under conditions where the horizon involved is located a long distance below the surface. Under such conditions, the shaft will approximate a mine shaft in that it will be of sufficient size to accommodate an adequate elevator and it will terminate in a chamber of approximately 20 feet in diameter located within, or adjacent to, the productive sub-stratum. As soon as the shaft or chamber is completed, I seal over the surface, particularly where the shaft or chamber is formed within a productive sub-stratum, and this is ordinarily done by lining the chamber with a concrete wall formed in such a way as to prevent an inflow of fluid (water, oil or gas) into the chamber thus produced and so as to resist external pressure. The concrete wall may be reinforced as desired or as is necessary to prevent caving and to insure the safety of the drillers and the drilling and producing apparatus.

The point of initiating the drilling operation with relation to the productive sub-stratum will depend upon the character of the horizon. In many cases, oil sands lie in well-defined layers, each sub-stratum having texture and characteristics of its own. Productive and non-productive sub-strata often alternate and some such strata may contain water, or the oil of the productive sub-stratum may contain gas. As a result, exploratory drills and/or experience will designate the position of the initial opening (through the concrete wall) into the productive stratum. For example, in Figures 11 and 12, I have diagrammatically shown two wells, both drilled from the same chamber and both traversing the same productive horizon.

I initiate the drilling operation by either drilling through the concrete wall (Figure 15) as a preliminary to setting a pipe 16 in place therein, or by setting the pipe in place during the operation of forming the wall. In any event, the pipe is sealed in an opening in the wall in such a way as to provide a water-tight and gas-tight joint with the wall. As shown in Figure 15, this pipe is provided with a gate valve 17 and the pipe may be extended beyond the gate valve so as to receive a stuffing box 17*a* where conditions are such that the productive stratum involved contains gas under pressure. Where such a condition is encountered, the pipe will also be provided with a cross 17*b* so located that one branch 17*d* may be connected with piping for the purpose of leading the gas away from the drilling operation and the other branch 17*e* is so equipped or positioned as to readily dispose of the drill water and the drillings from the pipe. Where a low degree of gas pressure is encountered the gas may be effectively disposed of by subjecting the branch 17*d* to vacuum and under such conditions that the packing gland 17*a* may be dispensed with.

The diameter of the pipe 16 and of the gate valve, stuffing box, etc., associated with it, will be sufficient to accommodate a drill bit of the desired diameter and the chamber 19 into which the pipe projects, will be of sufficient size to accommodate the handling of such drill rods and core barrel sections as will be employed during the drilling operation.

For the purpose of description, it will be assumed that the drilling is to be conducted in consolidated sand; and that the conditions of drilling are such as to designate a drilled well which starts in a horizontal direction at its point of initiation. Under such conditions the pipe 16 will extend horizontally through the wall 15 and into the productive substratum. The drilling may be, and preferably is, accomplished with a diamond drill bit which, as is well known, is rotated about its longitudinal axis by the drill rod for the purpose of accomplishing the drilling operation, and during the drilling operation cuts a cylindrical core out of the material on which it operates.

The conditions encountered in each well drilling operation will, of course, designate the procedure to be employed but, for the purpose of simplifying the description, I will first describe a drilling operation wherein elevation control is employed in such a way as to accomplish a "rise" in the hole being drilled. By the term "rise" I mean a change in direction in a drilled hole or well which is upward with relation to the direction of an immediately preceding length portion of the well. For example, the term "rise," as employed herein, may define a "lift" in the well drilling operations wherein the lifted portion of the hole extends more nearly horizontal than

the immediately preceding portion and even though the lifted portion is in fact inclined downwardly away from the horizontal. In this connection, it might also be noted that I employ the term "fall" to indicate a drilling procedure producing a length portion of the hole or well which is downwardly inclined with reference to an immediate preceding portion of the well. That is tc say, a drilling operation which changes the direction of a drilled hole from a horizontal direction to a downward incline, comes within the contemplation of the term "fall." Likewise, a drilling operation which produces a portion of a well of greater downward inclination than the immediately preceding portion and a drilling operation which produces a portion of a well of less upward inclination than the portion immediately preceding it, both are included within the contemplation of the term "fall."

Horizontal holes drilled in sand or another oil-bearing stratum have a tendency to fall and I take advantage of this in connection with all wells drilled in accordance with my invention and so control the drilling operation that substantial length portions of every well are curved but under conditions such that the well extends generally in a horizontal direction. By employing such procedure I am able to so control the drilling operation that substantially the entire length of the well is located in a productive substratum, or I am able to so control the drilling operation that the well extends from one stratum to another and in such a way as to take advantage of natural conditions encountered and, independently of the relation of the well of the sub-strata pierced by it, I am able to so locate the well that it is self-draining either by gravity alone or under the influence of atmospheric pressure. I employ the term "self-draining" with respect to a well for the purpose of indicating a well which is so located with relation to the horizontal that liquid collecting therein may be discharged therefrom by the action of gravity alone; by the action of fluid pressure so applied back of liquid within a length portion of the well that it occasions a substantially free flow of the liquid throughout length portions of the well and toward the outlet of the well; by the action of vacuum applied to the interior of the well under conditions such as to create a barometric column of liquid moving toward the mouth of the well; and by syphonic action.

In describing elevation control in detail, I will first describe the procedure for accomplishing what I have heretofore termed a "rise" and under conditions where the portion of the well immediately preceding the point of the desired rise, is horizontal. In Figure 1 I have diagrammatically illustrated a portion of a drilled hole of indefinite length wherein the last drilling operation was in a horizontal direction so as to produce a horizontal portion of substantial length. The cylindrical wall of the well is there designated by the reference character **20**, whereas the unfinished end of the hole or drilling constitutes a substantially vertical face and is designated by the reference character **21**. In order to occasion a rise, the drill head and the core barrel (where a core barrel is employed as a part of the drilling assembly) are withdrawn from the hole and a short core barrel **23** equipped with a so-called "beezer" **24** (see Figures 2, 6 and 7) is substituted for the ordinary and usual drilling assembly and the substitute equipment is introduced into the hole. A beezer is a cutting tool, which in an operation such as is here being described, takes the place of the ordinary core cutting bit. It is screwed onto the forward end of the short core barrel **23** and is provided with a forward end **25** which is closed except for water-delivery apertures **26** and, as illustrated in Figures 6 and 6*a* is provided with two series of diamond cutters or their equivalent, one being located on the periphery and the other on the forward end **25** of the beezer.

As previously stated, the beezer **24** is secured to the forward end of a short core barrel. This barrel is, in turn, secured to a sub **28** and the sub is secured to the forward end of the drill rod **29**. The diamond cutters or other abrasives of the beezer are so located that the beezer assembly described may be employed for forward drilling and also for the purpose of reaming out, i. e., increasing the diameter of a portion of a drilled hole.

In the operation under discussion, the drill rod **29**, with a beezer assembly secured to the forward end thereof, is introduced into the drilled hole to a point such that the forward end **25** of the beezer engages the face **21** of the unfinished hole, as shown in Figure 2. If the combined length of the assembly (sub **28**, short barrel **23** and the beezer **24**) is three feet, then the drill rod is withdrawn an amount closely approximating 2½ feet (i. e., an amount approximating but appreciably less than the over-all length of the assembly), whereupon it is rotated rapidly and advanced slowly so that the beezer will, in effect, gyrate in the end of the hole and enlarge the hole more or less conically with the base of the cone directed toward the unfinished end **21** of the well (see Figures 2 and 3). During this operation the usual amount of drill water is delivered through the rod **29** and apertures **26** of the beezer, thus washing the cuttings out through the drilled hole. Throughout this reaming operation, the advancing beezer is carefully controlled so that its forward end **25** is not forced against the end face **21** of the hole until after the first step in the hole enlarging operation has been completed.

When an enlargement such as shown in Figure 3 has been accomplished, the speed of rotation of the drill stem is reduced and reduced to a speed substantially below that employed during normal drilling operations. It should be noted that this reduction in rotative speed is effected when the forward face of the beezer is barely in contact with the unfinished end face **21** of the hole, as indicated in Figure 3, and consequently when the rear end of the beezer assembly (sub, short core barrel and beezer) is resting on the portion of the drilled hole of normal diameter, i. e., the forward end of that portion of the hole which has not been enlarged by the operation of the beezer. Under such conditions, the weight of the drill rod **29** back of the beezer assembly will cause it to sag, thus cocking the beezer assembly upwardly at its forward end, as shown in Figure 3. That is to say, the beezer assembly and the sagging drill rod **29** function as a lever of the first class wherein the weight of the drill rod constitutes the power, the bottom of the drilled hole immediately adjacent the enlarged portion thereof, constitutes the fulcrum and the beezer **24**, in effect, constitutes the load.

With the tool in the position described and indicated in Figure 3, and while continuing the abnormally slow rotation of the drill rod **29**, the

beezer assembly is pressed forwardly by the hydraulic or equivalent apparatus with a pressure far in excess of the usual drilling pressure exerted on the drill rods during normal drilling operations. Under such conditions the sag of the drill rod 29 will be somewhat accentuated by the pressure. Then, too, the angular relation between the end face 21 of the hole and the beezer assembly will also tend to accentuate the upward cock or inclination of the beezer assembly with the result that the combined forces acting on the beezer assembly cause it to move forward into the earth material and drill a hole 20*a* of substantial normal diameter, as shown in Figure 4, but which is inclined upwardly with relation to the portion of the hole immediately preceding it and illustrated in Figure 1. In this way I accomplish a "rise" under conditions such that the direction of the drilled hole is changed with relation to the horizontal. The operation of accomplishing this rise is, however, not completed until the usual drilling equipment can be again employed in the drilling operation.

The next step of the operation is, therefore, in preparation for the normal drilling equipment and involves withdrawing the beezer assembly from the new and "rise" portion 20*a* of the hole and a short distance back from the face 21 of the hole as a preliminary to a further reaming or hole-enlarging operation. If the drilling assembly (core barrel and drill bit) to be used in the next drilling operation is 10 feet long, then the beezer assembly is moved back from the face 21 a distance somewhat greater than 10 feet, i. e., a distance of approximately 11 feet and the drill rod is again rotated at a high rotative speed for the purpose of threshing out or enlarging the diameter of the hole. During this enlarging operation the beezer assembly is advanced slowly as before and to a point such that the diameter enlarging operation overlaps the prior enlarging operation with the result that the bore of the horizontal portion of the hole is increased for a distance of approximately 11 feet back from the face 21, as shown in Figure 5.

The drill rod and the beezer assembly are now withdrawn from the drilled hole and usual drilling equipment is substituted for the beezer assembly. That is to say, a 10-foot core barrel 23*a* equipped with a drill bit 32 is attached to the forward end of the drill rod and the drill rod is again introduced into the hole and to a point such that the drilling assembly will lie within the enlarged portion of the drilled hole with the drill bit 32 in effect contacting the face 21 of the hole. This relationship is illustrated in Figure 5, wherein the enlarged portion of the hole is designated by the numeral 33. It will be noted that the drilling assembly lies on the bottom of the enlarged cavity 33 and that the adjacent portion of the drill rod 29 is in effect supported by the portion of the hole 20 of normal diameter. The drill rod is next rotated at the normal drilling speed and pressure is applied thereto for the purpose of advancing the drilling assembly. This pressure is preferably somewhat greater than the normal drilling pressure but, in any event, the upwardly inclined portion 20*a* of the hole will in effect define a path of least resistance for the drill bit 32 and its associated assembly with the result that the bit will cut away or round off the shoulder 34 formed between the remaining portion of the temporary end face 21 and the upwardly inclined portion 20*a* of the hole.

Ordinarily, the normal drilling assembly (sub 28, long core barrel 23*a* and bit 32) may be forced into the upwardly inclined portion 20*a* with little or no rotative movement being imparted to the drill rod 29, but the operation above described insures the proper positioning of the assembly for continuing the upward rise started by the beezer assembly. When it is necessary to apply rotative force to the normal drilling assembly for the purpose of causing it to enter the upwardly inclined portion 20*a* of the hole, it is driven forward at greater than normal speed while being rotated at less than normal speed. This insures the forward end of the cutting assembly moving along the line of least resistance as above described and insures its entering the upwardly inclined portion 20*a* of the hole.

Where the drilling is carried forward under conditions such as to cut cores, the drilling operation will be continued with the core barrel and drill bits such as is diagrammatically illustrated in Figure 5, and until that assembly has been advanced a sufficient distance to fill the barrel. The drill rod 29 and assembly are then withdrawn and a 20 foot core barrel is substituted for the 10 foot barrel and the substituted assembly is introduced into the hole. This substitution ordinarily involves removing the drill bit 32, securing a 10 foot section of core barrel to the core barrel then secured to the drill rod and then screwing the drill bit to the forward end of the assembly. Where the change in elevation is quite marked, it may be necessary to employ special accessories for insuring the successful introduction of the longer drilling assembly. In Figure 7, I have illustrated special drilling equipment wherein a so-called broozer 35 is located at a point intermediate the ends of the drill assembly. As there illustrated, a sub 28*a* is secured to the forward end of the drill rod 29 and is attached to a core barrel 23′ which is preferably of the usual length, i. e., is a 10-foot section of core barrel. The broozer 35 is secured to the forward end of this section and between it and another core barrel section 23″ which carries the drill bit 32.

As illustrated, the broozer 35 is a short cylindrical pipe-like section of substantially the same internal and external diameter as a core barrel section but is provided on its outer periphery with a series of diamonds 27 or equivalent abrasive devices which are preferably located in staggered relationship. In Figure 7, I have also shown a special form of sub 28*a* which I term a trimmer in that its peripheral face is provided with a series of abrasive devices, such as diamonds 27. The diamonds are located on the portion of the peripheral face which is cylindrical and they are arranged in staggered relationship.

It will be apparent to those skilled in the art that the character of the formation being drilled will determine whether or not a drilling assembly provided with both a broozer and a trimmer is necessary in accomplishing a rise or fall in the drilled hole. That is to say, if the formation is relatively soft or friable, the probability is that a drilling assembly of approximately 20 feet in length can be readily introduced into the hole even after a substantially abrupt rise or fall has been accomplished. In harder formations it may be desirable to employ both the trimmer 28*a* and the broozer 35 in the longer drilling assemblies. A drilling assembly including a broozer or a trimmer or both such accessories will cut away the drilled material in such a way as to accommodate the entrance and easy

passage of the drilling assembly of the desired length and will have the effect of increasing the radius of curvature of that portion of the hole between portions thereof extending in different angular directions. It will, of course, be apparent that where the drilling assembly includes several core barrel sections, a broozer may be included in that assembly between each pair of adjacent core barrel sections and in this way the drilled hole is made elliptical in cross section either at a rise or a fall and in the portion of the hole which intervenes between portions of usual diameter extending at an angle to each other.

It will also be apparent that the character of the abrasive devices forming a part of such special equipment will be to some extent designated by the character of the formation. For example, I have found that in many formations short pieces of superhard metal may be substituted for the diamonds **27** and may be welded to the surface of the broozer and/or the trimmer.

After a 20 foot core is cut by a drilling assembly, such as illustrated in Figure 7, the assembly is withdrawn and an additional section of core barrel may be added to it before it is returned to the hole. As above noted, it may be desirable to employ both a trimmer and a broozer in the drilling assembly for the purpose of assuring the safety of the tools as they pass through the different parts of the drilled hole.

When it is desired to accomplish a fall as indicated in Figure 9, a beezer and a short core barrel are again employed as the drilling assembly or, as I have previously termed it, the beezer assembly. In this case, however, the drill rod is provided with one or more appropriately located guides for the purpose of preventing a sagging of the drill rod such as is utilized in the operation of accomplishing a rise. As shown in Figure 8, two guides **37** are placed in the drill rod **29**, the first being located at least 10 feet (one drill rod section) back of the beezer assembly, and the second located at least 10 feet back of the first. The beezer is then advanced, as previously described in connection with Figure 1, until its face is in contact with the end **21** of the unfinished hole. It is then withdrawn an amount slightly less than the length of the next drilling assembly to be employed in lengthening the hole. The drill rod is then rotated at a high speed and advanced slowly so as to enlarge the end of the unfinished hole, all as previously described in connection with Figures 2 and 3.

After the enlarging operation, the drill rod and the beezer are withdrawn and a drilling assembly of intermediate length such, for example, as a sub, a 10-foot core barrel and drilling bit, is secured to the forward end of the drill rod. The guides heretofore mentioned are left in place on the rod. The rod is then inserted into the drilling or hole so that the forward end of the assembly lies within the enlarged portion of the hole with the drill bit immediately adjacent the end face **21** of the hole, as shown in Figure 9. Under such conditions the back end of the drilling assembly rests on the shelf or shoulder **34***a* occasioned by the enlarging operation, whereas the forward end of the assembly rests at the lowermost point of the enlarged portion of the hole. The drilling assembly is therefore pointed in a direction such as to occasion a fall, i. e., lies at an appreciable angle to the portion of the drilled hole immediately preceding the enlarged portion **40**, and is therefore in the position for turning the hole downwardly with relation to the longitudinal axis of that portion of the hole.

The drill rod is now rotated slowly and is advanced slowly with the result that the drilling operation will be continued along the line designated by the axis of the drilling assembly as it is positioned in Figure 9. It will also be understood that by proceeding in this way it is possible to maintain the continuity of the cores taken. The dotted lines **20***b* indicate the new direction, i. e., the "fall."

If it is desirable to turn the hole downwardly more rapidly than can be accomplished by the procedure just described, I employ a beezer assembly (Figure 6) in starting the down-turned portion of the hole and I employ it in much the same way that it is employed in starting a rise. That is to say, immediately after enlarging the diameter of the hole, as shown in Figure 8, the rotation of the drill stem may be practically stopped while the beezer is occupying the forward end of the enlarged portion of the hole. Under such circumstances, the sagging of the drill rod **29** back of the second guide **37'** will in effect occasion a bowing of the portion of the drill rod between the two guides, **37—37'** with the result that the forward end of the drill rod will be inclined downwardly with relation to the axis of the drilled hole and this inclination will be in response to both the sagging and bowing of the drill rod here mentioned, and also the weight of the beezer assembly. The drill rod is now rotated at about the normal drilling speed or preferably somewhat faster, and is advanced so that the beezer enters the undrilled portion of the substratum. Under such conditions, this drilling operation with the beezer assembly may be continued for several feet before the beezer assembly is withdrawn and replaced by an ordinary 10-foot core barrel and drill bit. The further operation of completing a fall will be in effect as described in connection with Figures 1–5, and a drilling assembly equipped with broozer **35** and trimmer **28***a* may be employed if circumstances indicate the necessity for it.

While Figures 1–5, 8 and 9 and the operation described in connection with them contemplate an elevation control under conditions such that the change in direction is made from the horizontal, it will, of course, be understood that a drilled hole which is substantially horizontal but which, at the same time, is inclined below the horizontal, may be lifted in accordance with the procedure here described, so as to effect a drilling in a horizontal direction. Conversely, elevation control may be employed to so change the direction of drilling that an upwardly inclined portion of a well is followed by a downwardly inclined portion or a horizontal portion and that various such combinations may be produced in accordance with procedure here described. It will, therefore, be apparent that without employing any equipment other than here described, and by effectively utilizing the force of gravity I can so control the drilling as to produce a substantially horizontal well while at the same time occasion a rise or fall throughout predetermined lengths thereof.

Figure 10 diagrammatically illustrates a modified form of beezer **24***a* shown in association with a sub **28** of the usual form. As illustrated, the drilling face **25***a* extends across one end of a substantially barrel-shaped portion **42** which is pivotally secured to a carrier **43** by a pin **44**. The carrier is provided with a standard screw

thread at its rear end and is arranged so that it may be secured to a standard sub or core barrel in the usual manner of securing such parts together. The forward end of the carrier overlaps the portion 42 of the beezer which, as shown, is hollow and is in open communication with the hollow interior of the carrier for the purpose of delivering drill water to the apertures 26' formed in the drill face 25a. The relationship of carrier 43 and barrel portion 42 is such as to permit the beezer to swing through a relatively small angle about the pin 44 and in this way facilitates hole-enlarging or reaming operations such as are described in connection with Figures 1–5 and Figures 9 and 10.

The elevation control herein described makes it possible to, in effect, ferret out highly productive sub-strata and even highly productive pockets in the horizon being drilled. It also makes it possible to follow a predetermined plan of drilling adopted for the purpose of taking advantage of information gained by the drilling of previous wells or exploratory holes. The ability to drill wells which are in effect self-draining is of material advantage in connection with the reworking of fields which have previously been developed by the drilling of vertical wells.

During horizontal drilling operations, such as are here described, conditons are sometimes encountered where it is desirable to prevent substantial penetration of the earth material by the drill water employed during the drilling operation. Under such conditions, I employ some such material as calcium carbonate or lime in the drill water and in such proportions as to produce a thin grout which is carried into the surface pores and interstices of the side wall or surface of the drilled hole under the pressure of the drilling water, thus clogging the same and rendering the side wall of the hole substantially impervious to the flow of fluid (gas or liquid). After the drilling operation is completed and the drilling equipment is withdrawn from the hole, I may destroy the effectiveness of the substantially impervious barrier so produced by either shooting the hole and thus disrupting the barrier, or by subjecting the interior of the hole to the action of a liquid such as will dissolve the barrier material and thus remove it from the pores and interstices of the earth material so that the side wall of the well is no longer impervious. Where calcium carbonate or similar material is employed as a constituent of the grout, it may be readily dissolved out of the pores and interstices by a suitable acid solution, thus opening them for the passages of both gas and liquid.

In the drilling of horizontal wells, such as are here contemplated, loose sand or unconsolidated material is sometimes encountered, thus presenting a condition under which the wall of the drilled hole may cave. Under such conditions, it is also desirable to employ pore-plugging material in the drill water and in such proportions as to produce a thin grout. Where wall strength is desired, it may be necessary or desirable to employ a cementitious material in the drill water. Here the consistency of the grout should be such as will favor pore penetration with the result that the loose sand or unconsolidated material subjected to the pentrating grout will, in effect, filter out the solid material, thus forming a hole-encasing structure which is not only impervious to fluid flow but which adds strength to the side wall of the hole. Where the hole is so treated, I may insert a perforated pipe as a lining for the hole after the drilling is completed and the drilling tools are removed, it being understood that the perforated pipe will be so inserted as to completely line the well or the portions thereof which require lining to prevent caving. A chemical reagent (a suitable acid) may then be delivered to the interior of the well where it has access to the pore-filling cementitious material, with the result that the material is dissolved and the impervious barrier to the flow of liquid or gas is thus removed from the pores of the side wall of the well.

It will, of course, be understood that the drilling operation will be carried forward as usual under conditions where the drill water is converted into a thin grout and that cores may be taken if desired. That is to say, the drilling water is delivered through the drilling equipment in such quantities as insure the washing away of the grit and fine particles which result from the drilling operation. I have used the term "side wall" herein to designate surface of the well which extends longitudinally thereof and for the purpose of distinguishing that surface from the "end face," i. e., the inner end of the well.

As shown in Figures 11 and 12, a shaft or chamber may be located in a productive horizon and horizontal wells may be drilled in substantially all directions from the shaft, thus opening up a large section of productive property in such a way that all recoverable oil can be stripped from a productive horizon without resorting to expensive pumping operations and, in many cases, without resorting to repressuring operations. That is to say, wells embodying my invention can be so located and so controlled in drilling as to penetrate those portions of the horizon which former drilling (either vertical or horizontal) discloses to be highly productive and the successive length portions of each well can be so located with relation to each other as to produce what I have termed a self-draining well, thus facilitating recovery of the available oil.

In Figures 11 and 12, I have diagrammatically illustrated a drilling procedure which I preferably employ when drilling from a shaft or submerged chamber 19'. It will, of course, be understood that the shaft or chamber is of limited dimensions and that, therefore, it would be necessary to disassemble not only the drill rod sections but also the core barrel sections in order to remove core from the well being drilled. I am here referring to the fact that drill rod and core barrel sections are ordinarily about 10 feet in length and that, therefore, the operation of withdrawing the core and of again introducing the drilling apparatus into the well would involve a large amount of time and labor if it were necessary to disconnect each section of drill rod and core barrel during the operation of withdrawing the core, and to again connect the sections together, during the operation of re-entering the well with the drilling equipment.

I avoid this difficulty by so locating the shaft or chamber within the productive horizon that horizontal wells may be drilled in several directions from the shaft or chamber in developing the potentialities of the particular portion of the horizon involved. I then proceed in such a way that the drilling operations in connection with two wells are so correlated as to be, in effect, a single operation. The drilling operations for two such wells are initiated at diametrically opposed

points in the vertical surface or wall of the chamber or shaft and the drilling of each well is so continued that the two are substantially axially aligned.

In Figures 11 and 12, I have illustrated a shaft or chamber 19' which is substantially cylindrical and I have also illustrated horizontal wells radiating from that chamber. The chamber is preferably about 20 feet in diameter and preferably extends about 20 feet below the point where drilling operations are to be initiated. The drilling machine is located at about the center of the shaft and at a height about the bottom thereof convenient for the desired drilling in the productive horizon.

In carrying forward what I have termed a co-related drilling operation, I initiate the drilling of the horizontal well 45 from the interior of the shaft 19 and continue the drilling operation for a relatively short distance, i. e., for example, to a point A. I then rotate or reverse the hydraulic (rod-carrying and rod-turning mechanism) of the drilling machine and initiate the drilling of a well 45' at a point in the opposite wall of the shaft substantially diametrically opposed to the point of initiating the well 45. I continue this drilling operation to a point A' which is equal to the distance A plus the drilling assembly (core barrel and drill bit) employed in drilling the well 45' to the depth A'. With this arrangement the well 45 may be employed for rod storage purposes during the operation of withdrawing the drill rod from the well 45' as a prelinimary to removing the core from the drilling equipment employed in that well. A drilling assembly will, however, be connected to the rear end of the rod being withdrawn from the well 45' so that the operation of withdrawing drill rod from the well 45' and moving it into the well 45 will, in effect, accomplish a setting of the drilling equipment in the last-named well.

After the drill rod is withdrawn from the well 45' and the rear end of the drilling assembly is exposed within the shaft or chamber 19' the drill rod is disconnected from that drill assembly preparatory to continuing the drilling operation in the well 45. Such drill rod sections as may be necessary are then connected to the drill rod (now extending into the well 45) and after the hydraulic has been rotated and reversed and the water swivel connections made to the drill rod the operation of drilling the well 45 is continued and to the extent that the core barrel there employed will permit.

It will be apparent that, during the withdrawal of the core barrel from the well 45, drill rod and well-drilling equipment are being simultaneously introduced into the well 45'. From this it is apparent that the two well drilling operations overlap in part; that, during the overlapping procedure, the drill rod is equipped at both ends with drilling equipment; and that as the drilling equipment is in effect removed from the one well corresponding drilling equipment is in effect set in drilling position in the other well. Thus it will be apparent that where my co-related procedure is employed two complete wells can be drilled from one shaft or chamber such as the shaft 19', in less than one-fourth the time that it would take to drill one such well from a similar shaft. It will also be apparent that where a single well 3000 feet in length is drilled from a shaft approximating 20 feet in diameter 300 rod uncoupling operations must be resorted to in withdrawing the last core, but that two such wells can be drilled as described and the cores can be removed from each well and independently of the depth of the well by employing not more than one rod uncoupling operation. It will, of course, be understood that where jointed core barrels 50 feet in length are employed in each of the well drilling operations it will be necessary to employ at least five rod coupling operations in each continuation of the drilling operation in order to provide for the taking of a fifty foot core.

In Figure 13 I have diagrammatically illustrated a further procedure which may be employed in the operation of stripping oil from a productive horizon or a predetermined portion thereof. Here again, I locate the vertical shaft or the drilling chamber 19'' in such relation to the boundaries of the property involved so as to facilitate drilling operations such as I have just described wherein wells extending into substantially opposite directions are, in effect, simultaneously drilled.

The property 48, diagrammatically illustrated in Figure 13, is approximately square and is bounded by property lines 49. The drilling chamber 19'' is located at about the center of the property and four horizontal wells 46*a*, 46*b*, 46*c* and 46*d* are drilled therefrom. As illustrated, the wells may be so located as to extend substantially diagonally with relation to the property, i. e., each well may extend from the central chamber 19'' toward one corner of the property. In addition, the wells are preferably located in opposing pairs and so arranged that the co-related drilling operations described may be employed in drilling the wells 46*a* and 46*c* and also in the drilling of the wells 46*b* and 46*d*.

After each of the wells is drilled to a desired length by a procedure involving elevation control as herein described, I may drill branch holes therefrom which drift laterally with relation to each parent or trunk well. As shown in Figure 13, each of the four main wells is provided with two branch wells, one located to the right and the other located to the left of the parent or trunk well, and in this way substantially the entire property is covered by the drilling operation. The drilling of each branch is initiated by the use of a whipstock and one or more additional whipstocks may be employed in the operation of completing each branch. It will be understood that the branches are also substantially horizontal and are drilled in accordance with a procedure involving elevation control.

After the main drilling operation in connection with each pair of wells 46*a* and 46*c* or 46*b* and 46*d* is completed, a whipstock is located within the hole, for example, at the point 50 in the well 46*a*, as a preliminary to drilling a lateral branch. The whipstock may be in all respects similar to whipstocks such as are employed in vertical drilling operations and the operation of locating it at the desired point in the well is substantially similar to the operation of locating a whipstock in a vertical well. There is, however, this difference, viz., the whipstock has to be pushed into the horizontal well by the drill rod and as it moves into the well it necessarily moves along and is supported by the lower portion of the well surface.

After the whipstock is in position, the lateral branch is initiated in substantially the same manner as in the drilling of vertical wells and where the lateral deviation of the branch is relatively large, it may be necessary to employ two

or more whipstocks to accomplish the desired drift. During the drilling of each such branch I employ what I have heretofore termed elevation control and thus combine that procedure with procedure for accomplishing a drift for the purpose of controlling both the horizontal and the vertical positioning of substantially each length unit of the well.

An operation such as described may be employed in completing a branch 51 which may extend at a substantial angle to the parent well. The drilling of each such branch of the well 46c may be, and preferably is, co-related with the drilling of the branch 51' of the well 46a but whether it is or not, the well 46a may be employed in receiving the drill rod as it is withdrawn from the well 46c for the purpose of core removal during the branch hole drilling operation.

After the branch 51 is completed, the whipstock or whipstocks are removed and a whipstock may be located at a point such as the point 52 in the well 46c as a preliminary to drilling the branch 53. Those skilled in the art will realize that a branch hole involving a drift, such as indicated in connection with the branch 53, will probably require the use of two additional whipstocks located at approximately the points 52' and 52''.

The drilling of one or more branches for each of the wells 46a, 46b and 46d will be substantially as herein described and will be conducted in such a way as to produce substantially horizontal branches which are preferably self-draining wells in the broad sense that I employ that term.

From the foregoing, it is apparent that drilling procedure such as here described not only makes it possible to completely cover a property which may include many acres and involve the drilling of horizontal wells several thousand feet in length, but it also enables the drilling of branch or tributary wells which function as feeders to the main or trunk wells. Under such conditions, such oil removal and storage apparatus as is employed can be effectively utilized with each trunk well and labor and expense are therefore saved in connection with resetting the same.

This lateral drifting, such as is diagrammatically shown in connection with the branch wells, may also be accomplished by a specially formed drilling assembly such, for example, as disclosed in Figure 19 wherein I employ as a part of that assembly a so-called drift barrel 47 which takes the place of the ordinary core barrel throughout part or all of the length of the core barrel portion of the assembly. As there shown, the drilling assembly includes the ordinary sub 28 and one or more core barrel sections 23a, a drift barrel 47 and a drill bit 32. The drift barrel is located at the forward end of the assembly and carries the drill bit 32. It is so screw threaded at its ends that it may be coupled to the usual form of barrel sections and drill bit but it is preferably of reduced outside diameter and is provided throughout its length with externally located longitudinally extended ridges 54 which may be located in staggered relationship as shown, or which may be in the form of external corrugations. Where a drilling assembly includes in its make-up such a barrel—and the barrel is located as illustrated immediately back of the drill bit, a clockwise rotation of the assembly will cause a lateral drift to the right and a counterclockwise rotation will consequently cause a lateral drift to the left. It will, however, be understood that where it is desired to employ such an assembly in accomplishing a lateral drift to the right the ordinary or right-hand threaded drill rods and other equipment will be employed, and where a left-hand drift is desired then the equipment must be of special character in which each part thereof is provided with left-hand screw threads so that the impelling force imposed on the drill rod will not unscrew the connections involved.

In Figure 14, I have diagrammatically illustrated wells such as I have drilled in accordance with procedure here defined. That is to say, an outcrop may be faced up as illustrated in Figure 14 and in such a way as to expose productive as well as non-productive or offending sub-strata. The upper layer 55 is intended to indicate a non-productive stratum such, for example, as impervious rock. Below this I have indicated a productive sub-stratum 56 of considerable vertical depth, but which is intercepted by an inclined stratum of impervious rock 57 and is, therefore, separated into an upper and lower portion, the lower portion 56' of which may be lens shape. Under such conditions, it may be desirable to initiate the drilling of the well in an upward direction and I have illustrated this by diagrammatically illustrating a well 58 which enters the productive sub-stratum at a point near its bedding plane and extends upwardly for a substantial distance (possibly several hundred feet) and then is diverted so that it cuts through the offending sub-stratum 57 and thus opens up the productive lens 56'.

In Figure 14, I have also diagrammatically illustrated non-productive sub-strata 59, 60 and 61 which are vertically spaced and which separate productive sub-strata 62, 63 and 64. I have assumed conditions in connection with the sub-stratum 62 which render it advisable or at least desirable to start a horizontal well 65 at a point near the non-productive sub-stratum 59 and then to continue the well in such a way that it moves downwardly along a gradually increasing curve, substantially as shown.

It will be understood that the rate of fall in such a drilling operation may be controlled so as to cause the well to move downwardly at a relatively great angle or at a relatively small angle to the horizontal. This is accomplished by employing drilling assemblies in which the number of core barrels involved is varied. For example, if it is desired to accomplish a rapid fall in drilling operations such as is here under consideration, the drilling assembly will preferably include but one core barrel and it may be desirable to employ a core barrel of substantially less length than the normal core barrel. On the other hand, where a relatively slow fall is desired, the drilling assembly will include several core barrel sections or will be so fabricated as to produce a long drilling assembly. It will be apparent that the core barrel sections are the stiffest portion of the drilling equipment employed in well drilling operations and that, therefore, where the guiding action of a long stiff section is desirable or necessary, this can be accomplished by employing an assembly built up of a number of stiff core barrels and even under conditions where it may not be desirable to take long cores. From this, it is apparent that the rate of fall may be controlled by the type of drilling assembly employed and that by varying the length of the drilling assembly the operator may control the rate of fall in each length unit of the

well and in this way produce a well which is continuously receding from the horizontal but which may be undulating or wavy at least along portions of its length.

The sub-stratum 61 is similar to the offending sub-stratum 57 in that it extends at an angle through a productive horizon and separates two productive sub-strata. Under such conditions, it may be economically desirable to drill a single well 66 which serves both sub-strata 63 and 64 and which is so controlled during the drilling that it is, in effect, threaded through the offending stratum 61 in such a way that alternate length portions of the well are in the productive sub-strata 63 and 64. It will also be noted that while the well 66 substantially follows the offending sub-stratum 61, it is so positioned with relation thereto that each turn in the well occasions a relatively short length of hole within the offending stratum with the result that the major portion of the well surface is located in a productive stratum such as oil-bearing rock or sand, with the result that a substantial portion of the surface of the well is at least potential oil delivery surface. The well 66 also illustrates the possibility of so taking advantage of a situation involving productive and non-productive sub-strata that a single well will serve two adjacent productive sub-strata but at the same time be so positioned as to be self-draining, within the broad meaning of that term.

It will be understood that the horizontal scale of Figure 14 is greatly contracted with relation to the vertical scale and that each of the wells there illustrated is at least a thousand feet in length.

The sub-stratum 67 of Figure 14 may constitute impervious material such as a limestone layer but, in any event, I have disclosed a well 68 which is so drilled that it follows the bedding plane between the sub-strata 64 and 67. I have found that conditions such as illustrated in connection with the sub-strata 64 and 67 make it possible to simplify the procedure of drilling substantially horizontal wells and particularly where the bedding plane between the productive substratum and a hard, non-productive sub-stratum is inclined upwardly in the direction of the drilling operation. Under such conditions, a drilling tool may be employed which will not readily cut into the offending sub-stratum and which will, therefore, be guided by the surface of that sub-stratum. The well will, therefore, follow the contour of the bedding plane and where the bedding plane is favorably located the entire length of the well may be self-draining.

It will, of course, be understood that where conditions are favorable for following the bedding plane throughout a portion of the well length but unfavorable throughout the remaining portion of the well, drilling procedure involving elevation control as herein defined may be employed in connection with what may be termed "supported tool" drilling, wherein the drilling tool employed tends to follow the surface of a hard sub-stratum, as is diagrammatically illustrated in connection with the well 68.

This reference to the desirability of employing various drilling procedures throughout the length of a single well is primarily for the purpose of disclosing that preliminary surveys of a field or property may disclose natural conditions which will favor one or another form of drilling, and that my invention makes it possible to combine various procedures for the purpose of taking full advantage of natural conditions. It will also be apparent that my invention makes it possible to take full advantage of natural conditions and at the same time produce wells that are self-draining.

It will, of course, be apparent that the wells illustrated in Figure 14 need not necessarily be drilled from an outcrop exposure. To accentuate this and to indicate that Figure 14 may equally well illustrate a situation in which a shaft is sunk into the productive horizon for the purpose of facilitating the well drilling operation, I have shown a concrete wall 15' which corresponds in structure and function to the wall 15 heretofore described and serves to seal the severed productive sub-stratum involved.

In Figure 14*a*, I have attempted to pictorially illustrate the relationship of well surface to productive sub-strata in a horizontal well embodying my invention and also in a vertical well such as is usual in the well-drilling industry. In the drawing, a derrick 95 is diagrammatically illustrated as located on the surface 96 of the ground and as associated with a vertical well 97 which extends through non-productive material and terminates in a productive sub-stratum 98 which is relatively shallow (vertically) with relation to its extent. A well 99 embodying my invention is so drilled that its entire length is located within the productive sub-stratum 98, thus comparatively illustrating the difference between horizontally and vertically drilled wells. The well 97 is characteristic of almost all vertically drilled wells in that a relatively small percentage of the well length is located within a productive stratum and consequently a relative small percentage of the well surface is composed of productive or oil delivering material. On the other hand, the well 99 is illustrative of wells embodying my invention in that substantially its entire length is in productive material and substantially its entire surface is formed of productive material.

Figure 14*a* also illustrates one of the advantages resulting from the use of my well-drilling procedure. I have there illustrated a rock barrier 100 which intercepts or crosses the productive sub-stratum 98 and which is so associated with an impervious fissure 101 as to segregate a substantially large volume of the sub-stratum and thus produce a pocket 102 in which a pool of oil is trapped. It is well known that such pockets and pools exist and it is apparent that while a vertical well drilling operation might reach the oil thus pocketed, nevertheless a vertical well extending into the pocket would have no effect whatever in draining available oil from the portion of the sub-stratum 98 on either side of the pocket. A horizontal well which is so driven that it follows a productive sub-stratum will necessarily pierce fissures and barriers such as illustrated in Figure 14*a* and will, therefore, not only open up pockets such as there illustrated but will also be effective in opening up adjacent portions of the sub-stratum.

The diagrammatic wells 66 (Figure 14) and 99 (Figure 14*a*) illustrate another characteristic of my improved well drilling procedure and the wells produced thereby, in that they disclose that the direction of drilling is continuously changing; that each length unit of the well occupies a different relationship to the horizontal from that of the length unit adjacent thereto; and that widely spaced length units are recurrently horizontal. Then, too, they disclose that substantially the entire weight of the drilling equip-

ment (drill rods and drilling assembly) is carried by the lower faces of the drilled hole.

Figure 14b is a diagrammatic illustration of a well which is so drilled and located as to render a mountain lake or river available as a source of water supply. As there shown, a well 99b is drilled in a substantially horizontal direction from the face of a cliff and through some such earth material as solid rock 100b. As shown, substantially the entire well is upwardly inclined at a small angle to the horizontal but the inner end is abruptly turned upwardly so that the well terminates in porous material 98b located immediately below or in communication with a lake or river 96b, and which is therefore permeated with a substantially inexhaustible supply of water.

From the foregoing, it will be understood that elevation control, as herein described, may be employed for the purpose of, in effect, drilling an upwardly inclined well which extends from below into a sub-stratum and thus assure a free delivery of liquid from the sub-stratum and to a point below it. In Figure 14b the water supply illustrated may, of course, be a subterranean lake or stream but the illustration is primarily to disclose the effectiveness of drilling procedure embodying my invention in reaching a productive sub-stratum and under conditions such that the pressure within the sub-stratum occasions a flow of earth liquid and under conditions such that the flow may be effectively controlled. In Figure 14b, I have diagrammatically illustrated the well 99b as provided with a delivery pipe 16b which is provided with a valve 17b corresponding to the gate valve 17 of Figure 15.

In Figures 16 and 17 I have diagrammatically illustrated means which may be employed for receiving the oil from and also for working wells embodying my invention. After the well drilling operation is completed, the tools are withdrawn from the well and the valve 17 in the pipe 16 (Figures 15 and 16) is closed so as to facilitate coupling the pipe to one or more flow tanks 70—71 (Figure 17) and to such other equipment as may be necessary or desirable.

As shown, the flow tanks are located below the pipe 16 so that oil or other liquid issuing therefrom will drain into the reservoirs by gravity and piping 72 is provided for accomplishing this result. In addition to the flow tanks 70—71, I have provided means for subjecting the interior of the well to a substantial vacuum in order to facilitate draining the oil from the porous sub-stratum exposed by the well-drilling operation. As diagrammatically shown in Figure 17, a vacuum pump 75 is so coupled to the pipe 16 as to effectively reduce the air pressure within the well communicating with the pipe but at the same time avoid the possibility of drawing appreciable amounts of liquid from the pipe into the pump. This is accomplished by connecting the pump to the pipe 16 by means of a long loop of pipe 76 which extends upwardly, in hairpin formation, from the pipe 16 to a height of 40 feet or more and then downwardly to a drip tank 77 which is in direct communication with the intake of the pump 75. The pipe 16 may be provided with a vacuum gage 103. The outlet of the pump may communicate with a gas reservoir 78 which may be located at any convenient point with relation to the pipe 16 and, under usual conditions, will be located at the surface of the ground.

As shown in Figure 17, the piping connections are such that the one or more flow tanks 70—71 employed may be in open communication with the interior of the pipe 16 and consequently may be subjected to the reduction in pressure occasioned by the vacuum pump 75. It will also be noted that communication between each such reservoir and the pipe 16 is controlled by a separate valve 79—79' and that the first-mentioned valve is associated with the tank 70, whereas the valve 79' is associated with the tank 71. The drip tank 77 is provided with valve controlled drain 81; the gas storage tank is provided with a valve controlled drain 82 and a valve controlled vent 83; each of the tanks 70 and 71 is provided with a valve controlled delivery vent 84; and a valve 85 is located in the piping 76 between the pipe 16 and the vacuum pump 75.

Under usual conditions, one or more tanks (70—71) will be located in the bottom of the shaft 19 (Figure 11) in which the well terminates and below the outlet of the well, i. e., below the outlet of the pipe 16, so that oil or other liquid draining from the well will flow by gravity into one or the other of the storage tanks. As long as a substantial gravity flow continues from a well, the vacuum pump is not necessary but the application of a vacuum to the interior of the well facilitates the stripping of available oil from the field involved and particularly where the field is devoid of gas pressure. Where there is a substantial flow of liquid from the well, the valve 17 and one or both of the valves 79—79' are opened, it, of course, being understood that the valves in the drainage connections 84 are closed.

Where the liquid flow conditions from the well are such as to make it desirable to operate the vacuum pump, the valve 85 is fully opened, care being taken to close all valves such as those in the pipe connections 81 and 84, which might occasion air leakage into the system. The vacuum pump is then started and its operation is continued at such a rate and for such a period as may be necessary to establish and maintain the desired reduction in pressure within the pipe 16, the associated well and the tanks 70 and 71. The reduction in pressure will be felt throughout the entire length of the well and will cause a movement of the oil through the porous oil bearing material and toward and into the well. Under usual conditions this movement and flow into the well will vary with the intensity of the vacuum employed.

While the vacuum pump is in operation, it is in effect exhausting into the gas storage tank 78 and where the application of vacuum causes a substantial flow of natural gas it may be desirable to store the gas for power or other purposes. It will, of course, be understood that the gas storage facilities must be such as to avoid subjecting the vacuum pump to an objectionable amount of back pressure.

Where conditions are such as to create sufficient frothing to occasion the delivery of appreciable quantities of oil through the hairpin pipe connection 76, it may be desirable to apply heat to the piping 76 at a point near pipe 16, or to the pipe 16, since this will aid in liberating the gas from the oil and will prevent objectionable frothing.

In Figure 18 I have shown a simplification of the apparatus illustrated in Figure 17. A single flow tank 71 is illustrated as being located below the well pipe 16 and connected thereto by means of piping including a valve 79. The interior of

the tank 71 is then connected to the drip tank 77 by means of a hairpin 105 which is provided with a valve 106. The equipment also includes the vacuum pump 75 and the gas storage tank 78. It will be apparent that the application of vacuum to the interior of the well is accomplished by exhausting the interior of the storage tank while the valve 79 is open. Such an arrangement of apparatus not only simplifies the piping connections but also tends to minimize the amount of oil or other liquid carried over into the drip tank as a result of such frothing as may occur.

In Figure 17 I have diagrammatically illustrated piping 87 between the discharge pipe 88 of the pump 75 and each of the flow tanks 70—71. The piping is illustrated as provided with valves 89, 90 and 91, and the discharge pipe 88 is provided with a valve 92. With such an arrangement of piping, the vacuum pump 75 may be employed for discharging oil from the flow tanks 70 and 71, it being understood that the piping 87 communicates with the top of each tank and that the drainage connections 84 communicate with the bottoms of the tanks. Where it is desired to so employ the vacuum pump in discharging the tank 70, for example, the valves 79, 91 and 92 are closed, whereas the valyes 89, 90 and 79' are opened. The opening of the last-mentioned valve permits the delivery of oil from the well to the reservoir 71, whereas the vacuum pump delivers fluid pressure to the tank 70 and on opening the drainage valve 84 of that tank the oil will be forced therethrough. It will, of course, be understood that the displacement of oil from the tanks 70—71 is occasioned by building up back pressure on the pump 75 and where the tanks are located a substantial distance below the surface of the ground, auxiliary means may be necessary for forcing the oil upwardly through the pipe connections 84 and into a tank at the surface of the ground.

The interior of a well and the porosity of the sub-stratum through which the well is drilled provides a tremendous volumetric capacity which, when maintained at a sub-atmospheric pressure, has a substantial effect in creating a flow of liquid through the productive zone into the well. It will be apparent that because of the large volumetric capacity thus subjected to the reduced pressure, an ordinary short time infiltration of oil, gas, air and water into the vacuum system will occasion a minimum and almost inappreciable reduction in the vacuum involved. An inflow of liquid or fluid in quantities which are substantially great with relation to the volumetric capacity involved will, of course, reduce the vacuum. Under ordinary conditions, flow tanks such as the tanks 70 and 71 can be emptied, after having been filled by a vacuum induced flow of liquid from the well, and then re-established within the vacuum system without occasioning an appreciable rise in pressure within that system. It should also be noted that where a well is thus subjected to a high vacuum, the effect of the vacuum—in producing a flow of liquid toward the well—will be felt in some cases as much as 200 feet away from the well and with the result that one such application of vacuum may more or less effectively strip all available oil from a substantial portion of the producing horizon involved, and that this stripping effect may be extended by successive applications of vacuum to the well. It will also be apparent to those skilled in the art that even where the well involved constitutes a part of a field-reworking operation and even though the residual oil in the field appears to be "dead" from the standpoint of dissolved gas, the application of vacuum as above described will, in effect, upset a condition of equilibrium existing within the sub-stratum, and occasion a release of gas absorbed by such oil as is present and the free gas trapped within the pores of the sub-stratum, and thus render the same available as the expulsive medium for the forcing of the oil—or other liquid—toward and into the well. In oil field parlance, this would be explained as so building up a vacuum in the flow tanks, the well and the oil bearing horizon adjacent the well, that the vacuum will suck the oil from the oil bearing sand or rock into the well and the sucking action will be effective for a distance of approximately 200 feet on both sides of the well.

In connection with the application of vacuum to a well embodying my invention and its continuing effect on the portion of the oil bearing horizon after the vacuum pump has been shut down, it might be noted that I have applied a vacuum to a horizontal well of more than 1,000 feet in length, shut down the vacuum pump and that a substantial degree of vacuum remained within the enclosed system (well and communicating strata) at the end of six weeks during which entire period flow from the well was maintained and the flow tanks, forming a part of the vacuum system, were repeatedly drained. It will be apparent that this, in itself, is a characterizing feature of my invention and that nothing comparable to it has been, or can be accomplished in connection with a vertical well, primarily because a vertical well is not self-draining and in addition the application of vacuum to a vertical well would not be felt a sufficient distance back of the surface of the well to have any appreciable effect in creating a flow of oil or liquid into the well. This is because there is ordinarily a column of fluid within the well itself, which occasions a back pressure thereon, on the productive sand around and adjacent to the well.

In addition to the above, I desire to further outline beneficial results and features.

In the drilling of vertical wells, it is customary to drill one well for approximately each five acres of extent of productive sand and where the productive stratum is, say, 15 feet thick (vertically) then the exposed length of the well which is actually located within and cut through productive stratum is 5 feet or approximately 3 feet for each acre of horizontal extent involved. On the other hand, a well embodying my invention and, for example, having a length of 3,000 feet will effectively drain recoverable oil from a tract having a horizontal extent of approximately thirty acres. That is to say, such a well will drain recoverable oil for a distance of 200 feet in each direction from the well with the result that each hundred feet of well length provides an effective outlet for the oil contained in approximately one acre (horizontal extent) of productive stratum. It, therefore, follows that a well of ordinary length—3,000 feet—and embodying my invention, will effectively strip the recoverable oil from a stratum approximating 30 acres in extent and that the well length for each such acre will approximate 100 feet as compared to 3 feet in an ordinary vertical well.

Thus it is apparent that a well embodying my invention has a potential advantage over an ordinary vertical well of about 3300 per cent, in connection with the recovery of available oil.

This, of course, assumes usual or average conditions within the productive stratum involved. It might also be noted that ordinary vertical well drilling operations in the past have extracted only about 16 per cent of the original oil content from oil bearing strata subjected to such operations, whereas operations carried forward in accordance with my invention are capable of being so employed as to recover at least twice as much residual oil from a depleted field as was obtained by the original vertical well drilling operations under the virgin field pressure then existing. It might also be here noted that the reasonable expectation under normal conditions is that the residual oil recovered, by procedures embodying my invention, is approximately three times the amount of the original recovery by vertical drilling operations. In this connection, I am also noting that the recovery of residual oil from a depleted field by my process is generally accomplished without the benefit of any substantial residual pressure within the field.

It will also be apparent to those skilled in the art that wells embodying my invention have a material advantage over ordinary vertical wells from the standpoint of flow conditions encountered within the productive horizon. That is to say, the oil drainage through a productive substratum and toward a vertical well takes place along lines of flow which necessarily converge in all directions toward the well with the result that resistance to flow necessarily increases toward the well. The rate at which the resistance increases is quite rapid and involves a function of the velocity of flow and the amount of convergence. This is true whether the vertical wells are drilled from the surface of the ground or in accordance with the procedure outlined by me in my so-called oil mining patents. By the use of my present invention the lines of flow of oil moving toward the horizontal well are substantially parallel throughout their entire length, thus occasioning an absolute minimum of resistance to flow. In addition to the above, the accumulation of liquid in an ordinary vertically drilled well sets up a back pressure which resists further flow unless pumping of the well is continuously resorted to, whereas in wells embodying my invention gravity itself aids not only the flow to the well but also the delivery from the well.

Inventions disclosed but not claimed herein constitute the subject matter of copending divisional applications for patents as follows: applications Serial Numbers 428,398 and 428,399, filed January 27, 1942; application Serial Number 428,448, filed January 28, 1942; and application Serial Number 428,750, filed January 29, 1942.

It will be apparent to those skilled in the art that additions to, omissions from and changes in the procedural steps herein set forth as involving my improved well drilling procedure may be made; that, likewise, various modifications, additions and omissions may be made in connection with the apparatus herein set forth; and that horizontal wells herein illustrated and described may be varied materially and all without departing from the spirit and scope of my invention as defined by the appended claims.

What I claim is:

1. A well drilling procedure which includes drilling in a substantially horizontal direction while supporting the drilling tool on the side face of the drilled hole, and while continuously controlling the direction of drilling so that successive length units of the drilled hole extend in a substantially horizontal direction but each has a relationship to the horizontal different from that of a similar unit immediately adjacent thereto.

2. The method of drilling a well, such as an oil or gas well, which includes drilling in a substantially horizontal direction while substantially continuously changing the direction of drilling so that each length unit of the drilled well occupies a position with relation to the horizontal different from that of the length unit adjacent thereto and so that widely spaced length units extend in substantially horizontal directions.

3. A well drilling procedure which includes driving the drilling equipment in a substantially horizontal direction while supporting the same on the side wall of the resulting hole and in utilizing a portion of the weight of such equipment to change the elevational direction of the drilling operation.

4. A method of drilling a well, such as a gas or oil well, which consists in so controlling the drilling operation that substantially the entire length of the well extends in an approximately horizontal direction, while continuously changing the direction of the drilling operation so that each length unit of the well occupies a position with relation to the horizontal different from that of the length unit adjacent thereto, and while supporting substantially all of the weight of the drilling equipment on the face of the drilled hole during the drilling operation.

5. A method of drilling a well, such as an oil or gas well, which consists in driving drilling equipment in a substantially horizontal direction, utilizing the weight of the drill rod constituting a part of the equipment to occasion a rise in the drilling operation and utilizing the weight of the drilling assembly constituting a part of the equipment to occasion a fall in the drilling operation.

6. A method of drilling a well, such as a gas or oil well, which consists in impelling drilling equipment in a substantially horizontal direction while washing the drillings from the hole thus formed, enlarging the bore of the hole so formed for a short distance from the end thereof, utilizing the enlarged bore thus formed to cock the drilling assembly constituting a part of the drilling equipment, and then continuing the drilling into the end of the enlarged portion of the hole while the drilling assembly is so cocked.

7. The method of changing the direction of a substantially horizontally drilled hole, which consists in enlarging the hole for a short distance from the end thereof, utilizing the weight of a portion of the drilling equipment to cock the drilling assembly projecting into the enlarged portion of the hole and then continuing the drilling through the enlarged end of the hole while the drilling assembly is so cocked.

8. A method of occasioning a rise in a substantially horizontal drilled hole which consists in inserting a relatively long drill rod and a relatively short drilling assembly into the hole, forcing the assembly against the end of the hole with sufficient pressure to cock the same within the hole and then rotating the rod and the assembly while continuing to subject the same to such cocking pressure.

9. A method of occasioning a rise in a substantially horizontal drilled hole which consists in enlarging the unfinished end of the hole, so locating a drilling assembly and the operating

drill rod therefor within the hole that the assembly projects into the enlarged portion of the hole while being supported on a portion of the hole of normal bore, then forcing the drilling assembly against the enlarged end of the hole with greater than usual drilling pressure and while so supported and while rotating the drill rod at less than normal drilling speed, and continuing such rotation and pressure while continuing the drilling beyond the end of the enlarged portion of the hole.

10. A method of occasioning a fall in a horizontally drilled hole which consists in enlarging the unfinished end of the hole, so positioning a drilling assembly and actuating drill rod therefor in the hole that the assembly is supported on both the portion of the hole of normal bore and the enlarged portion of the hole, then forcing the assembly against the enlarged end of the hole while rotating the same.

11. A method of exploiting a productive horizon which consists in determining the location of a productive sub-stratum within such horizon, exposing a substantial section of such sub-stratum and then drilling a well in a substantially horizontal direction within such substratum while employing elevation control during the drilling operation to cause successive length portions of such well to substantially conform in positional elevation to that of such sub-stratum.

12. A method of drilling in earth material which includes driving a drilling assembly in a substantially horizontal direction through such material, from time to time employing the weight of a portion of the drilling equipment to occasion a rise in the drilling operation and utilizing the guiding action of the drilling assembly to control the rate of elevational change in the drilled hole intermediate such rises.

13. A method of drilling in earth material which consists in driving a drilling assembly in a substantially horizontal direction through such material, periodically employing the weight of a portion of the drilling equipment to occasion a rise in the drilled hole and controlling the rate of fall intermediate such rises by apportioning the length and stiffness of the drilling assembly to the desired rate of fall.

14. A method of drilling in earth material which includes driving a drilling assembly in a substantially horizontal direction through non-productive earth material employing elevation control to maintain the drilling in a substantially horizontal direction and in lifting the inner end of the hole so produced to penetrate productive material located above such non-productive material.

15. A well drilling procedure which includes driving a drill bit and associated core barrel through earth material in a substantially horizontal direction while supporting the weight of the bit and core barrel on the side wall of the hole so formed and while taking a core from such earth material, utilizing the weight of a portion of the drilling equipment to occasion a rise in such hole and in continuing the drilling along such rise while supporting the drilling equipment on the side wall of the resulting hole and while taking a core of earth material.

16. A well drilling procedure which includes driving well drilling equipment in a substantially horizontal direction while substantially continuously changing the elevational position thereof by occasioning rises and falls therein and while maintaining the drilling operation in substantially the same horizontal direction, and then occasioning a lateral drift in such well drilling operation while substantially continuously changing the elevational position thereof by occasioning rises and falls therein.

17. A well drilling procedure which includes penetrating a productive sub-stratum, driving well drilling equipment in a substantially horizontal direction within said sub-stratum, from time to time occasioning a rise in the drilling operation to elevationally position length units of the well being drilled, occasioning a lateral drift in such well and from time to time occasioning a rise in the laterally drifting portion thereof.

18. A well drilling procedure which includes driving well drilling equipment in a substantially horizontal direction while rotating the same, from time to time utilizing the weight of a portion of such equipment to occasion a rise in the drilling operation and employing the rotation of the drilling assembly to occasion a lateral drift in such drilling operation.

19. A method of well drilling which consists in drilling through earth material at a point below the surface thereof and in a substantially horizontal direction, while substantially continuously changing the elevational direction of the drilling operation and while utilizing the weight of different portions of the drilling equipment to accomplish an elevation control in such drilling operation.

20. A method of well drilling in a substantially horizontal direction which consists in forcing drilling equipment in a substantially horizontal direction while washing the drillings from the hole thus formed, from time to time enlarging the diameter of the hole at the forward or inner end thereof during such drilling operation and utilizing the portion of enlarging diameter to occasion a rise in the drilling operation.

21. A method of drilling a substantially horizontal well in earth material which consists in rotating well drilling equipment while forcing the same in a substantially horizontal direction through such earth material to form a well hole of substantially uniform diameter, then increasing the diameter of such well hole adjacent the end thereof and then changing the elevational direction of the drilling by exerting abnormal pressure on the drilling equipment while rotating and forcing the same into the earth material beyond the portion of increased diameter.

22. A method of exploiting a productive horizon which consists in penerating a productive sub-stratum thereof, drilling through such substratum in a substantially horizontal direction to form a well hole therein of substantially uniform diameter and extending substantially parallel to the bedding planes thereof, increasing the diameter of such well hole at a point adjacent the inner end thereof and then continuing the drilling operation beyond the portion of the well hole of increased diameter at a different elevational direction from that of the portion of the well hole preceding such portion of increased diameter.

23. A method of exploiting a productive horizon which consists in penetrating a productive sub-stratum thereof, then drilling into said substratum along a line substantially parallel to the bedding planes thereof and occasionally changing the elevational direction of such drilling operation to cause a portion of the drilled hole to extend in a horizontal direction.

24. A method of exploiting a productive hori-

zon which consists in penetrating a productive sub-stratum thereof, drilling in said sub-stratum to produce therein a well hole extending substantially parallel to the bedding planes thereof and from time to time occasioning a rise in the drilling operation to cause spaced length portions of such well hole to extend in a horizontal direction.

25. A method of changing the elevational direction of a substantially horizontal well hole, which consists in enlarging the bore at the inner end of such hole, inserting well drilling equipment into said well so that the drilling assembly thereof extends at an angle to the longitudinal axis of the portion of said well of enlarged bore forcing the forward end of such assembly against the end of the enlarged portion of the hole under a pressure greater than normal drilling pressure and rotating the same while subjected to such pressure to thereby continue the well hole beyond such portion of enlarged bore.

26. A method of drilling a well, such as an oil or a gas well which consists in forcing drilling equipment in a substantially horizontal direction through earth material while rotating the same, increasing the bore of the hole so produced at the unfinished end thereof, supporting the drilling equipment in the portion of the hole of normal diameter while forcing the drilling end thereof into engagement with the end of the hole of increased diameter and rotating such equipment while so supported to continue the drilling operation beyond such portion of increased diameter.

27. A method of drilling a well which consists in forcing drilling equipment in a substantially horizontal direction through earth material, occasionally changing the elevational direction of such drilling operation to cause spaced portions of the resulting well to extend in a horizontal direction, locating a whipstock in such well and continuing the drilling operation past such whipstock in a substantially horizontal direction to produce a branch well, and in causing occasional changes in the elevational direction of such drilling operation to cause spaced portions of said branch well to extend in a horizontal direction.

28. A method of drilling a well which consists in forcing drilling equipment in a substantially horizontal direction through earth material, employing elevation control to cause spaced length portions of the resulting well to extend in parallel directions, locating a whipstock in such well and continuing the drilling operation past such whipstock and in a substantially horizontal direction to form a branch well, and in employing elevation control to cause spaced length portions of said branch well to extend in parallel directions.

29. A method of drilling a well which consists in forcing drilling equipment in a substantially horizontal direction through earth material occasionally causing a rise in the drilling operation to produce spaced portions of the resulting well hole extending in parallel directions, locating a whipstock in such hole and continuing the drilling operation in a substantially horizontal direction past such whipstock while causing occasional rises in such operation.

30. The method of drilling a well which consists in driving drilling equipment in a substantially horizontal direction through earth material to produce a substantially horizontally extending well hole, locating a whipstock in said hole, continuing the drilling operation by driving drilling equipment in a substantially horizontal direction past said whipstock to form a branch hole and in causing an occasional rise in the drilling operation to produce spaced length portions of such branch hole extending in parallel directions.

31. A method of exploiting a productive horizon which consists in determining the location of a productive sub-stratum thereof, penetrating said sub-stratum and drilling a well hole in a substantially horizontal direction therein while employing elevation control during the drilling operation to cause spaced length portions of such well hole to extend in parallel directions, locating a whipstock in such well hole, continuing the drilling operation past such whipstock and in a substantially horizontal direction to form a branch well on one side of said well hole and then locating a second whipstock within said well hole and continuing the drilling operation past said second whipstock and in a substantially horizontal direction to form a branch well on the other side of said well hole.

32. A method of exploiting a productive horizon which consists in penetrating a productive sub-stratum thereof, then driving drilling equipment in a substantially horizontal direction within said sub-stratum, locating a whipstock in the resulting well hole within said sub-stratum, continuing the drilling operation in a substantially horizontal direction past said whipstock to produce a branch well on one side of said well hole and occasionally causing a rise in such drilling operation to cause spaced length portions of the branch well to extend in horizontal directions, locating a second whipstock within said well hole, continuing the drilling operation past the second whipstock and in a substantially horizontal direction to form a second branch well on the other side of said well hole and in occasioning an occasional rise in such drilling operation to cause spaced length portions of said second branch well to extend in a horizontal direction.

33. A method of drilling substantially horizontal wells in earth material which consists in driving a drilling assembly in a substantially horizontal direction through such material, from time to time occasioning a rise in the drilling operation and to cause spaced length portions of the well to extend in horizontal directions and in controlling the rate of fall of the drilling operation by apportioning the length and stiffness of the drilling assembly to the desired rate of fall.

34. A method of drilling a well, such as an oil or gas well, which includes drilling in a substantially horizontal direction while from time to time occasioning a rise in the drilling operation and while supporting substantially all of the weight of the drilling equipment on the side of the drill hole.

35. A method of exploiting a productive horizon which consists in sinking a shaft into such horizon, drilling from said shaft into a productive sub-stratum of said horizon and in a substantially horizontal direction within said substratum, and from time to time enlarging the bore of a portion of the resulting drilled hole and utilizing the weight of a portion of the drilling equipment and the portion of enlarged bore to accomplish a control in the elevational direction of such drilling operation.

36. A method of exploiting a productive horizon which consists in sinking a shaft into such horizon, drilling from said shaft into a productive sub-stratum of such horizon and drilling in a substantially horizontal direction within such

sub-stratum to form a self-draining well terminating in said shaft, and from time to time during such drilling operation utilizing the weight of a portion of the drilling equipment to occasion a rise in the drilling operation to cause spaced length portions of the resulting well to extend in a horizontal direction.

37. A method of exploiting a productive horizon which consists in sinking a shaft to a productive sub-stratum thereof, drilling from said shaft into such sub-stratum and in a substantially horizontal direction within such sub-stratum to form a self-draining well terminating in said shaft, and from time to time during such drilling operation enlarging the bore of the resulting well hole at the unfinished end thereof and employing the weight of a portion of the drilling equipment to occasion a rise in such drilling operation.

38. A method of exploiting a productive horizon which consists in sinking a shaft into such horizon, drilling from said shaft into a productive sub-stratum of such horizon and in a substantially horizontal direction within said sub-stratum to form a self-draining well terminating in said shaft, from time to time during such drilling operation enlarging the bore of the resulting well hole at the unfinished end thereof, employing the weight of a portion of the drilling equipment to occasion a change in the elevational direction of such drilling operation, and continuing the drilling operation in such changed direction beyond such portion of the well hole of the enlarged bore.

39. A method of exploiting a productive horizon which consists in sinking a shaft into such horizon, drilling a self-draining well from said shaft into a productive sub-stratum of said horizon by driving a drilling bit and associated core barrel from said shaft into said sub-stratum in a substantially horizontal direction within such sub-stratum, taking cores during such drilling operation, from time to time during the drilling operation enlarging the bore of the resulting well hole at the unfinished end thereof and employing the weight of a portion of the drilling equipment to occasion a rise in the drilling operation immediately beyond the portion of the well hole of the enlarged bore.

LEO RANNEY.

CERTIFICATE OF CORRECTION.

Patent No. 2,280,851. April 28, 1942.

LEO RANNEY.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 36, for "well of" read --well to--; page 5, second column, line 38, for "drill assembly" read --drilling assembly--; page 8, first column, line 13, for "height about" read --height above--; and line 33, for "prelinimary" read --preliminary--; page 12, second column, line 53, for "5 feet" read --15 feet--; page 15, second column, line 25-26, claim 32, for "equlpment" read --equipment--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of June, A. D. 1942.

Henry Van Arsdale,

(Seal) Acting Commissioner of Patents.