

Dec. 5, 1961

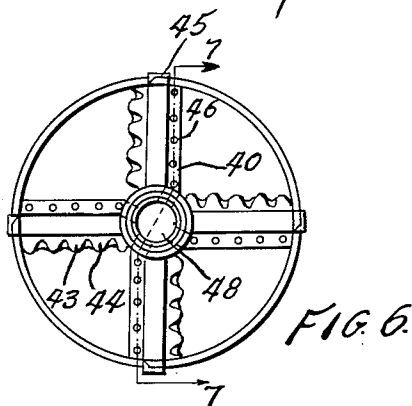
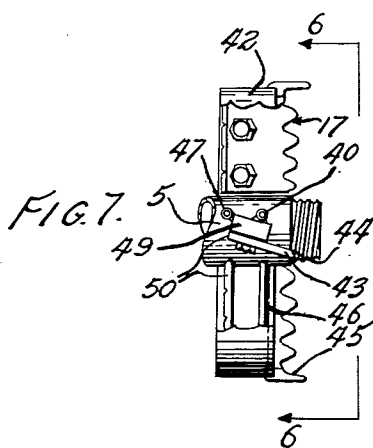
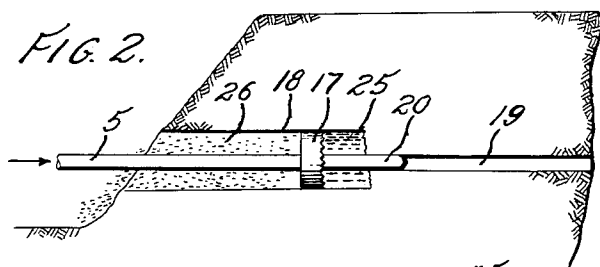
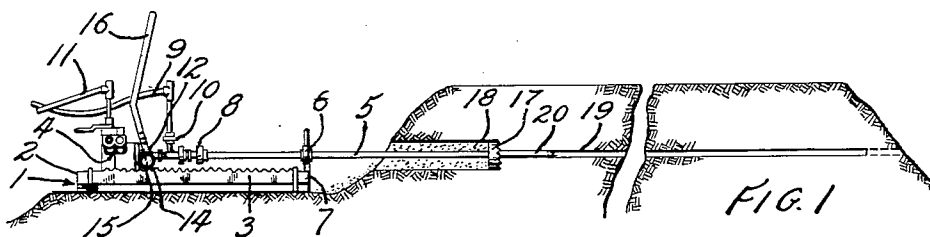
G. M. TURNER

3,011,567

METHOD OF DRILLING HORIZONTAL BORES EMPLOYING A
GEL-FORMING COLLOIDAL DRILLING FLUID

Filed Nov. 26, 1956

3 Sheets-Sheet 1



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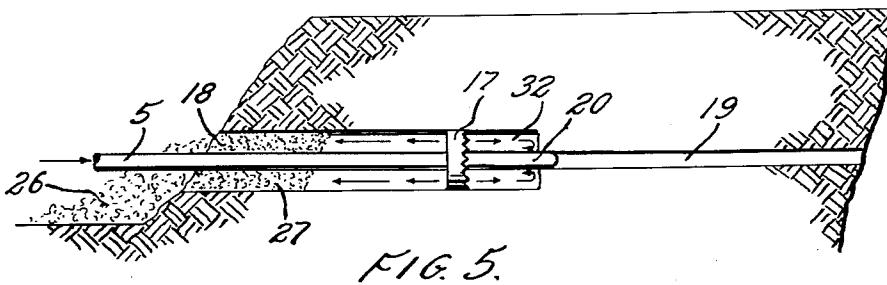
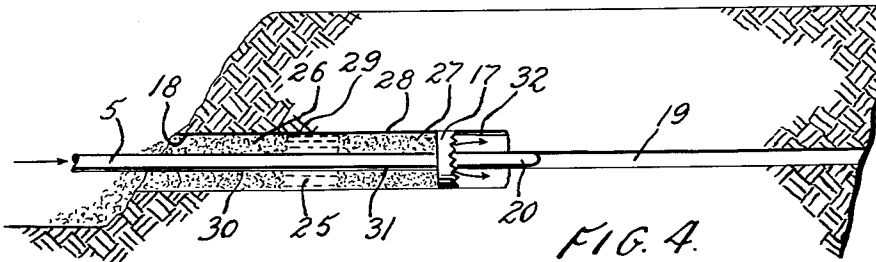
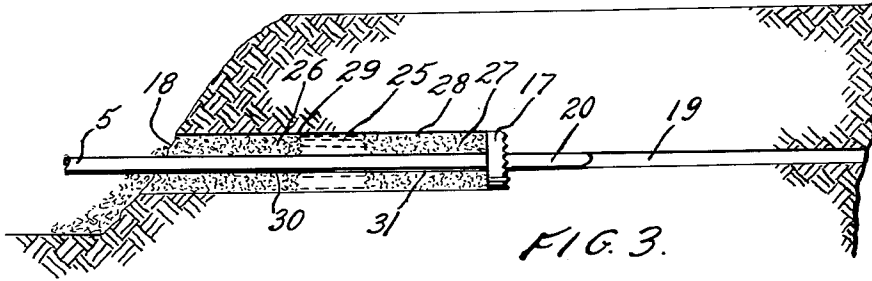
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3 Sheets-Sheet 2



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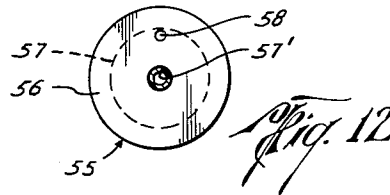
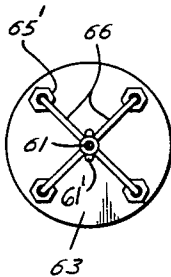
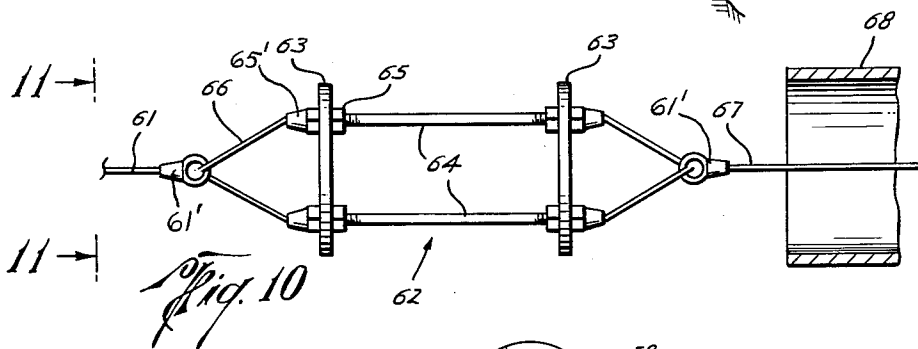
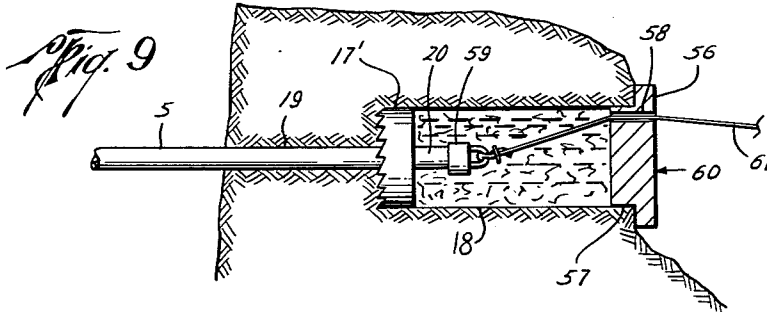
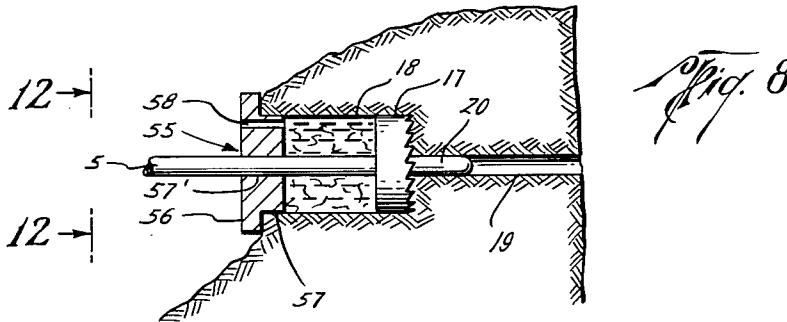
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3 Sheets-Sheet 3



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METHOD OF DRILLING HORIZONTAL BORES EMPLOYING A GEL-FORMING COLLOIDAL DRILLING FLUID

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Filed Nov. 26, 1956, Ser. No. 627,923
8 Claims. (Cl. 175—53)

This invention relates to a method of horizontal excavation in which a gel-forming, colloidal material, as particular clays, in dilution with liquids, as water, is employed as a lubricating medium to lubricate the cutters or reamers, is employed as a fluid binder to bind the cuttings, is employed as a filter cake to hold up the bore wall against cave in or spalling, and to maintain arching, and also to lubricates the bore for easy removal of masses of cuttings from the bore and in cases to circulate the cuttings from the well bore.

It is a primary object of this invention to use a gel-forming, colloidal material of the type hereinabove described in horizontal drilling in a manner that the end of the bore from whence reaming commences is plugged to hold in the cuttings while the colloidal material, as drilling mud, serves to hold the cuttings in a mud mixed mass, forms a filter cake on the bore wall to prevent cave in and spalling, and to lubricate the bore for the easy withdrawal of the masses of cuttings to be removed.

It is also an object of this invention to use a gel-forming, colloidal material of the type hereinabove described in horizontal drilling to circulate the cuttings from the bore while preventing cave in and spalling by forming a filter cake on the bore wall.

It is also an object of this invention to use a gel-forming, colloidal material of the type hereinabove described in horizontal drilling in combination steps to hold the cuttings massed and the bore wall lubricated and caked so that the masses of cuttings may be removed by compressed air.

Other and further objects will be apparent when the specification herein is considered in connection with the drawings in which:

FIG. 1 is a sectional elevation showing a typical horizontal drilling machine and the first step of its employment in carrying out the method of one form of this invention;

FIG. 2 is a sectional elevation showing the drill stem of the machine shown in FIG. 1 in position as carrying out the second step of this form of method.

FIG. 3 is a sectional elevation showing the drill stem of such machine in position as carrying out the third step of such method;

FIG. 4 is a sectional elevation showing such drill stem in position as carrying out the fourth step of such method;

FIG. 5 is a sectional elevation showing such drill stem in position as carrying out the fifth step of such method;

FIG. 6 is an end view, taken along line 6—6 of FIG. 7, showing a form of reamer employable in this invention;

FIG. 7 is a side elevation of such reamer taken along line 7—7 of FIG. 6;

FIG. 8 is a sectional elevation showing the drill stem of the machine shown in FIG. 1 in process of carrying out another method form of the invention;

FIG. 9 is a sectional elevation showing such drill stem in process of carrying out a variation of the method shown in FIG. 8;

FIG. 10 is a sectional elevation showing the swab and casing employed in the exercise of the invention;

FIG. 11 is an end view taken along line 11—11 of FIG. 10; and

FIG. 12 is an end view taken along line 12—12 of FIG. 8.

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Referring to the drawings, FIG. 1 shows diagrammatically one machine adapted to carry out such methods, but it is herein pointed out that a number of machines and devices can fulfill the same function. Such a machine 1 has a frame 2 which supports racks 3. The engine 4 is mounted on a guide base, not shown, which is adapted to slide along the racks 3. The engine 4 is connected to rotate the drill stem 5, and the steady rest 6 on the frame 2 supports the drill stem 5 at the end 7 of the frame, while the bearing member 8, also mounted on the frame, supports the drill stem centrally of the frame.

The drilling fluid or mud supplied to the drill stem bore by means of the hose 9 and swivel 10 and compressed air may enter the engine 4 by way of the air hose 11 and pass through the hollow drive kelly 12 to the drill stem 5 connected thereto.

Pinions 14 on the shaft 15 mesh with the racks 3 and the shaft 15 is journaled in a bearing member, not shown, which is rigidly connected to the engine 4. The handle 16 is adapted to be removably connected to the shaft 15 or to a pinion 14 so that the engine 4 may be moved along the racks 3 as the drill stem rotates to ream the bore 18 by rotating its affixed cutter or reamer 17 of the conventional type having openings between its radial supports or spokes through which the cuttings are directed outwardly the bore 18. In the view of FIG. 1 a pilot bore 19 has previously been drilled, and the guide 20 is connected to the drill stem ahead of the reamer 17 and moves in the pilot bore.

FIGS. 6 and 7 show one form of cutter or reamer for carrying out the functions of this invention. Such form is not all inclusive, and other constructions of reamers are applicable as well, and this invention is submitted to encompass a variety of such reamers. In the conventional disclosure shown, the rim 42 of the reamer 17 is supported from the drill stem 5, by means of spokes, arms or radial support bars 49, which rigidly connect the rim and drill stem. Pipes 40 and 41 are included as part of the support bars 49, and are affixed thereto, and extend from the drill stem 5, with which they establish inner fluid communication, radially outwardly to the rim. Blades 43 are connected to the arms 49, and each blade consists of a plurality of teeth 44. The blades 43 thus form rows extending from the drill stem 5 to the rim 42, and are topped by a tooth 45 at the rim, so that the tooth 45 over-extends the other teeth 44 of each blade, as shown in FIG. 7. The pipes 40 and 41 have orifices 46 therein so that fluid may be pumped down the drill stem to pass outwardly through such orifices 46 for purposes to be hereinbelow described.

This invention is directed to methods of horizontal excavation, and a type of machine will serve which has the following characteristics. The machine must have a hollow drill stem, must be movable in a direction axially of the drill stem, must be able to rotate the drill stem, and deliver the drilling mud to pass down the drill stem bore and out through the cutter or reamer thereon. Additionally a means to deliver compressed air is required to practice the third method hereinabove set forth. As there are many types of devices that can carry out these requirements, the machine hereinabove described is stated to be only one of the wide variety of the structures which may carry out the methods of this invention.

Heretofore machines of the type hereinabove described have used water as a circulating medium to lubricate the bore and to mix with the cuttings. However it has been found preferable to use a gel-forming colloidal drilling clay, which, when not exceedingly diluted, acts as a combination sealing agent, lubricating agent, and consolidating agent. The use of this drilling mud makes it possible to use the machinery hereinabove described and the drilling or boring methods which such machinery

accomplishes in drilling or boring in sandy sub-soils which heretofore have required more expensive equipment or methods, as the tunneling method. This invention thus provides a method which permits drilling in unconsolidated materials, as in fine sands, for example, which melt, as quicksand, in the presence of liquid, and in other formations of material which easily spall and cave in. It is possible to drill in such formations when the cuttings remain in the bore as drilling progresses so as to consolidate them to support the bore wall, and this may be done in cases without plugging the bore to retain the cuttings.

Under such conditions, making reference to FIG. 8, a pilot bore 19 may be drilled through beneath a roadbed from the near side or side on which the drilling machine is located. A plug 55 is shown as having been installed upon the drill stem 5 which extends through a bore 57' through the plug. Then with a forward toothed reamer 17 installed on the drill stem 5 the reamed bore 18 is developed as the drilling mud or circulating fluid is supplied therethrough, while the plug body 57, of diameter to fit snugly to the reamed diameter, is installed in the entrance to the bore, while the flange 56 of the plug bears on the side face of the roadbed. The plug is then firmly propped against outward displacement, any conventional props being suitable for this purpose. As drilling progresses the drill stem 5 slides through the plug bore 57', and as fluid is circulated down the drill stem 5 and out of the reamer 17, it acts as a binder or adhesive between the cuttings and formation particles to consolidate them and hold them together as a core which substantially fills the bore 18, and thereby prevents spalling and cave ins.

Since more circulating fluid or drilling mud may be required than the necessary minimum to maintain the cuttings in core form, a drainage outlet 58 is provided through the plug 55 so that the excess fluid may run out this outlet, carrying therewith some small amount of the smaller formation particles, while the great mass of the cuttings remain in the bore 18 to support it. In this method the pilot bore 19 is reamed to the size of the bore 18, and when the reamer 17 has been advanced all the way through the roadbed, the plug 55 is removed from the bore inlet and slid outwardly on the drill stem.

Then the reamer 17 may be removed at the far side and a swab 62 as shown in FIGS. 10 and 11 is connected on the far end of the drill stem 5 as by a cable 61 connected to the guide end 20, and pulled through the bore 18.

As shown in FIGS. 10 and 11, the swab 62 is simply constructed of two spaced apart plates 63 connected by rods 64 having threaded ends which extend through holes in the plates 63. Firm interconnection is made between the rods 64 and plates 63 by means of nuts 65. 65' threaded on the rods 64 on either side of the plates 63.

Bridle lines 66 on either end of the swab 62 are firmly connected into the nuts 65' and are tied together at their outer ends in a connection ring 61'. The cable 61 is connected to the connection ring 61' at one end of the swab 62 and the cable 67 is connected to the connection ring 61' at the other end of the swab 62.

Since the drilling mud has so well held the cuttings in core shape by its binding qualities, and has also lubricated the outer periphery of the core of cuttings, the exertion of an endwardly acting force on the core may easily force it along the bore within the filter cake formed on such bore wall, so that the core may be moved with slight effort out of the bore 18. Also, as the core tends to maintain its consolidated form as it emerges from the bore, it may be broken up in segments and handled with ease, whereas cuttings removed in other than consolidated and cohesive segments tend to form muck in the ditch beside the roadbed and must be removed with difficulty.

A variation of procedure is shown in FIG. 9 in which

a reamer 17' with teeth facing reversely to the reamer 17 shown in FIG. 8 is employed. In this case, after the pilot bore 19 has been drilled through to the far side of the road bed the reamer 17' is installed thereon, and a conventional swivel 59 is installed on the guiding end 20, and the cable 61 connected to the part thereof which does not rotate with the rotation of the drill stem. The cable 61 is extended through an opening in the plug 60 which is of identical construction as the plug 55 except that there is no central bore 57' therethrough. With this plug 60 in the end of the bore 18, and firmly propped from the outside against being forced out under pressure, all of the cuttings are retained in the bore 18 as the reverse reamer 17' reams back through to the near side, the drilling mud being circulated therethrough at a rate to abet drilling without building up back pressure in the drilled bore. Such rate must be a rate which will supply the drilling mud no faster than it can follow the reamer, be absorbed into the cuttings, and form a filter cake on, and flow into the bore wall formation. Such method works equally as well in unconsolidated formations as the method hereinabove described and demonstrated by FIG. 8.

In this method the plug 60 is removed from the far end of the bore 18 when the bore 18 has been reamed through to the near side, and the cable 61 is removed from the opening 58 through the plug 60 and connected to the swab 62 as at the bridle ring 61'. Then the swab 62 is drawn through the bore 18 to remove the core which slides out with ease as hereinabove described.

In all of the methods hereinabove described the swab 62 used to clear the bore 18 may be connected to draw thereafter a casing 68. Such a casing 68 is shown in FIG. 10. The cable 67 is shown extending therethrough for connection to the other end of the casing 68 but also connection to the adjacent end of such casing 68 may be made. The use of the drilling mud, especially in unconsolidated formations, insures that the casing 68 may be drawn into the bore 18 without danger of stoppage, as by caved-in parts of the bore.

It is not necessary when employing the method set forth hereinabove to use the plugs 55 or 60 in certain formations to maintain the cuttings in the bore where such formations permit the use of a quantity of drilling mud in such proportion to the cuttings as to form a consolidated adhesive core which will not be broken up or in part forced out of the bore as a result of the fluid circulation. In such cases the circulated mud goes into the cuttings in such proportions as not to wash therethrough and wash out the outer end of the bore, but rather the drilling mud is sufficient in quantity to bind the cuttings together.

As a second method of employing the invention, the drilling mud may be circulated in sufficient quantities and under sufficient pressure to circulate the cuttings out of the bored hole. This condition is shown in FIG. 1, which figure may also serve to demonstrate the first step in a method to be hereinbelow described.

This process of employing the drilling fluid to circulate the cuttings out of the bore is best employed when boring in such formations as sandstone, since sandstone and similar formations are so consolidated in nature that the formation defining the bore wall will not cave in in any event. Also the nature of a sandstone material is such that the cuttings thereof are readily suspended in, and carried along with a drilling fluid such as hereinabove described, reference being made to as an example material used in vertically drilling wells, as oil and/or gas wells Aquagel, a pioneer bentonite, as described in section 2100, Baroid Drilling Mud Data Book, copyright 1953 by Baroid Sales Division, National Lead Company, Houston, Texas.

In this method the cuttings are circulated out the entrance of the bore, and the bore is thus kept open so

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that the cuttings do not tend to bind the drill stem 5 in rotation, while in the meantime, the bore wall stands up and does not wash away due to such circulation because of the compact nature of sandstone and similar soils. On the other hand the use of such method of circulating the cuttings from the bore would be impractical in an unconsolidated formation where it might cave in, and where, because of such unconsolidated nature of the formation the circulation of the mud in quantity to carry the cuttings, along might result in washing away the wall of the bore. In such formation the first method described hereinabove is recommended.

The advantage obtained by the employment of a gel-forming colloidal drilling fluid in horizontal drilling offer particular benefits when such drilling fluid is used in conjunction with the method steps disclosed in Patent No. 2,702,180, issued Feb. 15, 1955 to William M. Horner for Method of Excavation since such fluid obtains a much higher degree of lubrication than water, a higher degree of consolidation than water, and accomplishes a benefit which water cannot accomplish in that it forms a filter on the bore wall to prevent the loss of the liquid phase of the drilling fluid into the formation and strengthens the bore wall against spalling and cave-in.

FIGS. 1-5 illustrate the method steps of employing this third form of the invention. In operation, the machine is actuated to ream for a distance of about three feet. Then the drilling mud is supplied into the drill stem bore, after, or as, the drill stem is withdrawn outwardly for a short distance, as shown in FIG. 2, to supply the space 25 into which the mud is injected. When the drill stem is drawn outwardly to provide this space 23, rotation of the drill stem is continued in the direction of drilling, with the result that the mass of formation cuttings 26 is substantially consolidated and compacted behind the cutter or reamer since the inclination or pitch of the rear end or edge of the reamer teeth 44 is such as to tend to direct the cuttings outwardly when the reamer 17 rotates.

Meanwhile the mud passes out through the orifices 46 in forced volume, to fill the space 25, and being under pressure, part of the mud will obviously enter into the surrounding formation and into the consolidated and compact mass of cuttings 26 behind or outwardly of the space 25. It is also obvious that part of this mud will pass into the surface separating the mass 26 from the surrounding formation.

As shown in FIG. 3, the drill stem and reamer are then advanced through the space 25 and drilling has been continued for another distance of say three feet. In point of time this drilling ahead an additional distance is calculated to be accomplished before there can be any substantial dissipation of the mud in space 25 either into the mass 26, into the surrounding formation, or into the new cuttings 27.

Then as shown in FIG. 4, the drill stem is again withdrawn a short distance as rotation continues in the direction of drilling with the result that a second mass of formation cuttings 27 is compacted behind the reamer or cutter. This exertion of force against the mass 27 also exerts pressure on the mud remaining in the space 25 and forces such mud into such masses 26 and 27 as well as along the periphery 28 of the mass 27 and along the periphery 29 of the mass 26, and also along the drill stem periphery portion 30 within the mass 26, and the drill stem periphery portion 31 within the mass 27.

As the second mass 27 has been compacted by the withdrawal of the reamer for a short distance, such withdrawal has provided the space 32. The mud supplying means is now disconnected from the machine, and a fluid as compressed air, is supplied through the machine and drill stem bore and forced into the space 32. After this the mud under pressure in the bore, must exert force on the mass 27 to move it outwardly. In this outward motion it must further press upon any mud in

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the space 25, and takes up this space as it moves outwardly into contact with the mass 26. The mud must consequently be forced into the masses 26 and 27 to a greater degree to thereby oppose the outward escape of the compressed fluid, as air. Also, the mud must pass between the formation and the peripheral surfaces of the masses 26 and 27, so that it acts as a lubricant along such surfaces, as well as along the surface of the drill stem, and thereby this effect abets the fluid pressure in enabling it to more easily force the masses 26 and 27 from the bore hole, as shown in FIG. 5.

For boring and reaming work on clay subsoils the operation is begun with the reamer, and after an initial few feet of travel the further advance of the reamer is temporarily discontinued and the reamer is retracted. During reamer advance and to assist cutting action mud is fed in sufficient quantity to the cutting area for softening the clay being cut and for lubrication to minimize wear. The mud wets and consolidates the cuttings and also wets the surrounding bore wall surface. The latter is troweled smooth and made more dense by the rotating wide peripheral rim or band of the reamer so that the clay surface of the bore becomes hard, smooth and slick. The bore wall becomes a slippery slide surface. In addition to wetting the wall surface and the cuttings, the mud fills the voids between the cuttings and also consolidates the cuttings; and upon retraction of the reamer the mass of goeey and mucky cuttings is compacted, consolidated and merged or molded into a solid cylindrical core filling the core and being slidable on the slick cylindrical surface of the bore. If the reamer is fully retracted, the compacted and consolidated round unit will be completely ejected as a solid, plug-like mass or core to be broken up and manually shoveled to one side.

Instead of complete retraction, the reamer is usually brought back (see FIG. 2) only far enough to insure sufficient consolidation, compaction and molding of the cuttings, particularly at their inner face, and only partially to project the core from the bore. This initial retraction consolidates and molds the clay into a unit with no tendency to bond it to the slick bore wall surface, and the additional cutting can proceed with minimum delay. The mud tends to swell the compacted cylinder into a close sliding fit with the bore wall, and also to swell the surface around the pilot 20, and thus seals against excess leakage of compressed air which may now be introduced at the front of the retracted reamer. Air under relatively light pressure pushes the slippery, solid plug outwardly. In practice, it is not necessary that the plug be blown entirely out of the bore at one time, and especially in the initial stages. The bore can be cleaned out in steps of reamer advance and retraction. Thus if the first push-out terminates with the mass 26 partially ejected, as seen in FIG. 3, the following advance of the reamer leaves the space 25 between the partially ejected mass 26 and the second mass of cuttings 27 behind the reamer 27 as it advances. Then, since the end face of the first core 26 has been solidly compacted and consolidated as has been the bore wall surface by reason of the troweling band of the reamer, these wetted and packed faces are somewhat resistant to quick soaking of a further copious mud supply, and the mud supply backs up in the space 25 and at the same time is taken up by the new cuttings and the newly reamed bore wall surface. Excess mud cannot readily escape, but it tends to form a more or less solid force-transmitting body in so far as it is not absorbed by the hard clay.

Now, after the second increment of reaming, the reamer is again retracted to compact and consolidate the second mass of cuttings, with the compacting and consolidating beginning at the front end and moving on back until the mass is molded into the slidable cylinder or core. When pressurized air acts against its forward solid face, it is displaced bodily rearwardly as a unit. Its sliding travel

is transmitted to the first core, either directly or through any drilling mud trapped within the intervening space. The blowout can continue to completion or only partially, as the working crew desires. FIG. 5 illustrates the relation of the second plug still partly in the bore after the first plug has been completely ejected.

These steps are repeated until the hole reaches completion, but just before the final reaming operation it is customary to fully blow out all previously cut, compacted consolidated cores. Because of the slippery slide surfaces and the relatively close fit, high pressure air is not needed to blow out the plugs, and they are ejected easily with no danger of blowing up the embankment.

It is herein pointed out that hereinabove pilot bores have been described as having been drilled before the reaming operation, however such may not be necessary in certain formations, in which case open type cutters may be used, or a succession of such cutters of increasing diameters, and in the absence of initial pilot bores.

An advantage obtained by the formation of the filter cake on the bore wall by the drilling mud is that of retaining the fluid content of the mud from passing outwardly through the bore wall and being lost in the surrounding formation. Thus the use of the gel-forming colloidal drilling clay diluted with water serves to reduce the amount of such circulating medium as compared with the use of water alone for this purpose, since with no such filter cake, the circulated water can easily be lost in porous formations, cavities, or voids. However in soils where the contexture of the formation may be known to be sufficiently cohesive to permit the use of water, such may be used in the place of the drilling mud, and circulated in either the method shown in FIG. 8 or in the method shown in FIG. 9, and the use of water in such methods is included as a variation of the practice of this invention.

The invention broadly considers various method steps employed in horizontal drilling, such as employing a drilling mud, as, for instance, a circulating fluid comprising a gel-forming colloidal material, as a clay, in drilling horizontal bores in a manner to maintain a substantially smooth bore, also the invention includes employing such a drilling mud or also water while maintaining the bore plugged, and in summary the invention is not limited to the particular method step sequence or number of steps described in the methods herein set forth, but other modifications and variations are considered as well, as such may fall within the broad spirit of the invention and within the broad scope of interpretation claimed and merited for the appended claims.

What is claimed is:

1. A method of horizontal earth excavation comprising the steps of drilling a pilot bore, installing an open type reverse reamer on the drill stem on the far side, connecting a cable to the drill stem and extending the cable through a plug, reaming the pilot bore from the far side with the open type reverse reamer far enough to make room for the plug, inserting the plug in such reamed bore to seal it, the cable extending outwardly of the plug, and maintaining the plug in the reamed far end of the bore being reamed and continuing reaming it toward the near end while lubricating it by supplying during reaming a diluted, gel-forming, colloidal material which also tends to bind the cuttings, the cuttings thus held in the plugged bore being reamed being adhesively held together to fill the bore against spalling and cave in, and the fluid forming a filter cake to reenforce, lubricate and seal the bore wall against fluid loss, and removing the plug to permit a cuttings removing means connected to the cable to be pulled into the reamed bore as the reamer stem is withdrawn from the near side and shortened, and continuing to withdraw and shorten the reamer stem, the cable thereby pulling the cuttings removing means through the reamed bore.

2. A method of horizontal earth excavation comprising

the steps of employing a horizontal drilling machine in drilling a pilot bore and in reaming the pilot bore with an open type reamer for a distance, maintaining a plug fitted in the bore distance reamed while continuing reaming and while lubricating the bore by supplying during reaming a fluid carrying diluted, gel-forming, colloidal material to bind, adhesively hold together and consolidate the cuttings to fill the reamed bore against spalling and cave in and to form a filter cake on the reamed bore surface to reenforce, lubricate and seal the bore against fluid loss, removing the plug together with connecting a cuttings removing means to the reamer stem reaming end by means of a cable, and pulling the cuttings removing means through the reamed bore to remove the cuttings out the drilling machine end of the reamed bore as the reamer stem is progressively shortened from the drilling machine end thereof.

3. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a bore with an open type cutter for a distance from the machine side, maintaining a plug around the drill stem and fitted in the bore distance drilled while continuing drilling and while lubricating the bore by supplying during drilling a fluid carrying diluted, gel-forming colloidal material to bind, adhesively hold together and consolidate the cuttings to fill the drilled bore against spalling and cave in and to form a filter cake on the drilled bore surface to reenforce, lubricate, and seal the bore against fluid loss, removing the plug together with connecting a cuttings removing means to the drill stem drilling end by means of a cable, and pulling the cuttings removing means through the drilled bore to remove cuttings out the drilling machine end of the drilled bore as the drill stem is progressively shortened from the drilling machine end thereof.

4. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a pilot bore and in reaming the pilot bore with an open type reamer for a distance from the drilling machine end, maintaining a plug about the reaming stem and fitted in the bore distance reamed while continuing reaming and while lubricating the bore by supplying during reaming a fluid carrying diluted, gel-forming, colloidal material to bind, adhesively hold together and consolidate the cuttings to fill the reamed bore against spalling and cave in and to form a filter cake on the reamed bore surface to reenforce, lubricate and seal the bore against fluid loss, removing the plug together with connecting a cuttings removing means to the reamer stem reaming end by means of a cable, and pulling the cuttings removing means through the reamed bore to remove the cuttings out the drilling machine end of the reamed bore as the reamer stem is progressively shortened from the drilling machine end thereof.

5. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a bore with an open type cutter installed on the drilling end of a drill stem rotated by the drilling machine and thereby drilling for a distance from the machine side, maintaining a plug around the drill stem and fitted in the bore distance drilled while continuing drilling and while lubricating the bore by supplying during drilling a fluid carrying diluted, gel-forming colloidal material to bind, adhesively hold together and consolidate the cuttings to fill the drilled bore against spalling and cave in and to form a filter cake on the drilled bore surface to reenforce, lubricate, and seal the bore against fluid loss, continuing rotation of the drill stem in direction of drilling while moving the drilling machine equipment rotating the drill stem in direction away from the bore to withdraw the drill stem and cutter to compact a mass of formation cuttings behind the cutter, injecting the drilling fluid through the drill stem and cutter into the space provided inwardly of the withdrawn cutter, advancing the cutter through the space and employing the

drilling fluid in continuing drilling for another distance, continuing rotation of the drill stem in the direction of drilling while withdrawing the drill stem outwardly to compact another mass of formation cuttings behind the cutter, and injecting compressed air through the drill stem and cutter into the space inwardly of the cutter to force against the inner compacted mass and move the masses outwardly as the drilling fluid lubricates the drilled bore and tends to bind the cuttings in an adhesive, easily slidable mass.

6. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a pilot bore and in reaming the pilot bore with an open type reamer for a distance from the drilling machine end, maintaining a plug about the reaming stem and fitted in the bore distance reamed while continuing reaming and while lubricating the bore with water to bind and adhesively hold together the cuttings to fill the reamed bore against spalling and cave in and to reenforce, lubricate and seal the bore against fluid loss, removing the plug together with connecting a cuttings removing means to the reamer stem reaming end by means of a cable, and pulling the cuttings removing means through the reamed bore to remove the cuttings out the drilling machine end of the reamed bore as the reamer stem is progressively shortened from the drilling machine end thereof.

7. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a bore with an open type cutter for a distance from the machine side, maintaining a plug around the drill stem and fitted in the bore distance drilled while continuing drilling and while lubricating the bore with water to bind and adhesively hold together the cuttings to fill the drilled bore against spalling and cave in and to reenforce, lubricate, and seal the bore against fluid loss, removing the plug together with connecting a cut-

tings removing means to the drill stem drilling end by means of a cable, and pulling the cuttings removing means through the drilled bore to remove cuttings out the drilling machine end of the drilled bore as the drill stem is progressively shortened from the drilling machine end thereof.

8. A method of horizontal earth excavation comprising the steps of employing a horizontal drilling machine in drilling a pilot bore and in reaming the pilot bore with an open type reamer for a distance, maintaining a plug fitted in the bore distance reamed while continuing reaming and while lubricating the bore with water to bind and adhesively hold together the cuttings to fill the reamed bore against spalling and cave in and to reenforce, lubricate and seal the bore against fluid loss, removing the plug together with connecting a cuttings removing means to the reamer stem reaming end by means of a cable, and pulling the cuttings removing means through the reamed bore to remove the cuttings out the drilling machine end of the reamed bore as the reamer stem is progressively shortened from the drilling machine end thereof.

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