July 9, 1968 G. T. SWEENEY ET AL 3,391,543

MEANS AND TECHNIQUE FOR INSTALLING ELONGATED RODS IN UNSTABLE EARTH FORMATIONS

Filed June 23, 1966 2 Sheets-Sheet 1

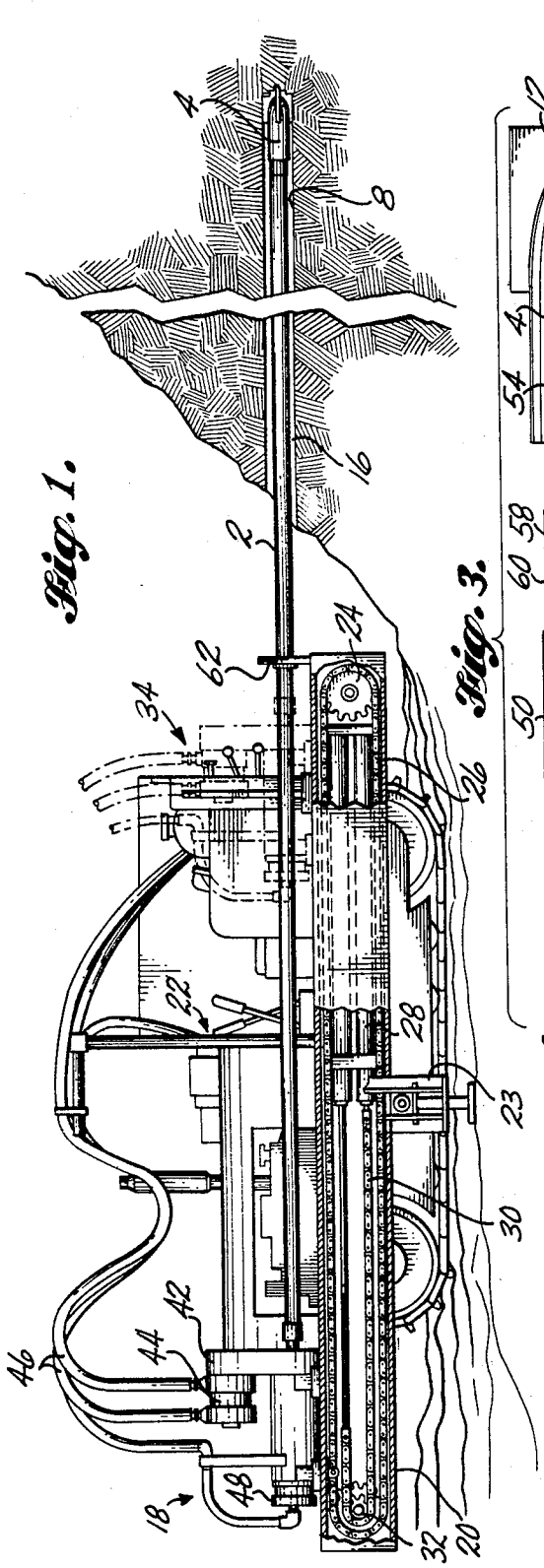


Fig. 1.

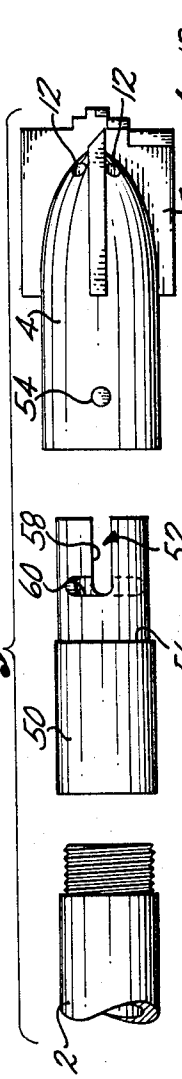


Fig. 3.

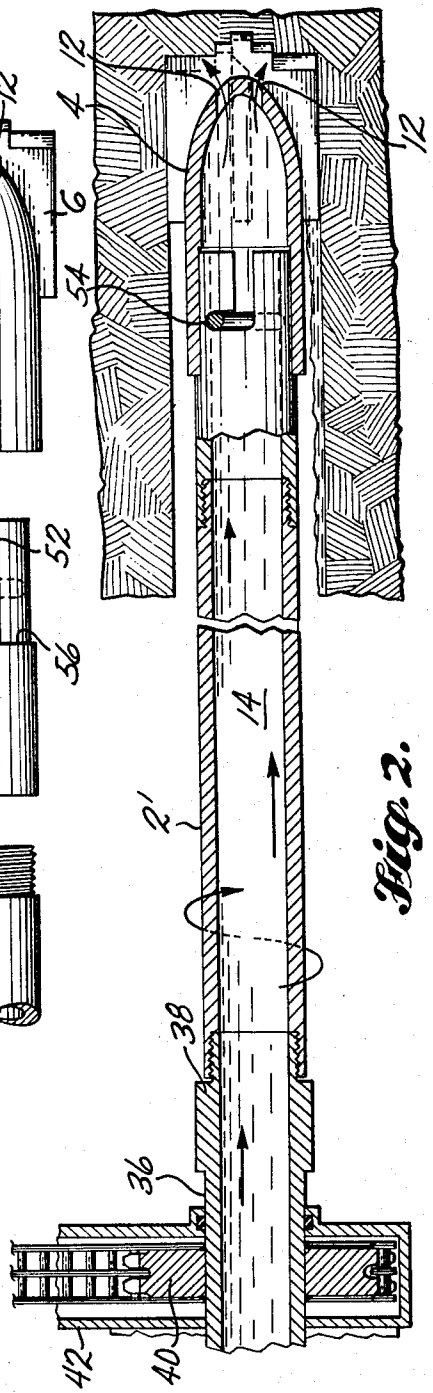


Fig. 2.

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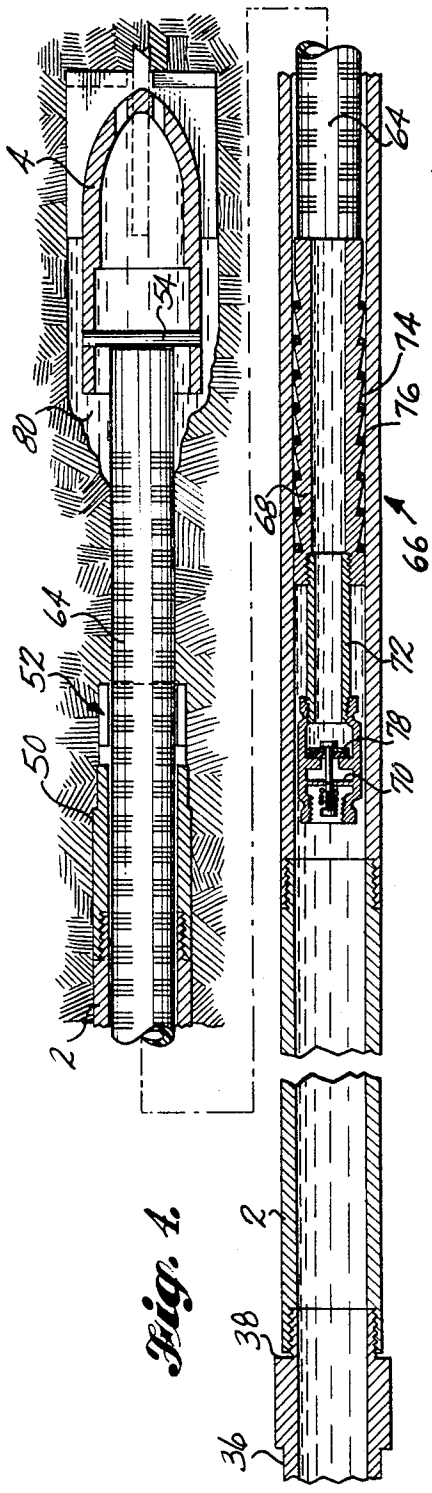


Fig. 4.

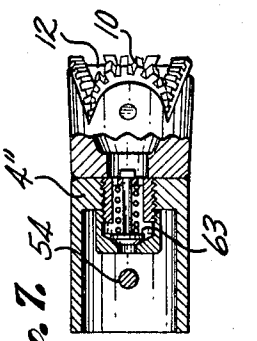


Fig. 7.

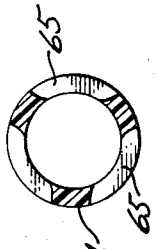


Fig. 6.

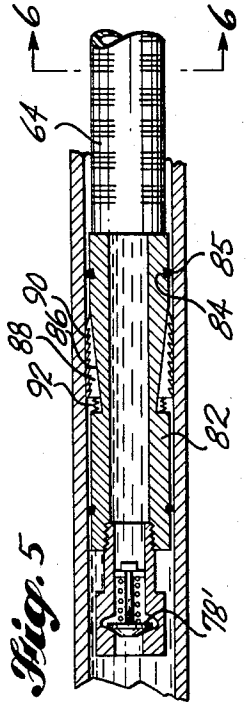


Fig. 5

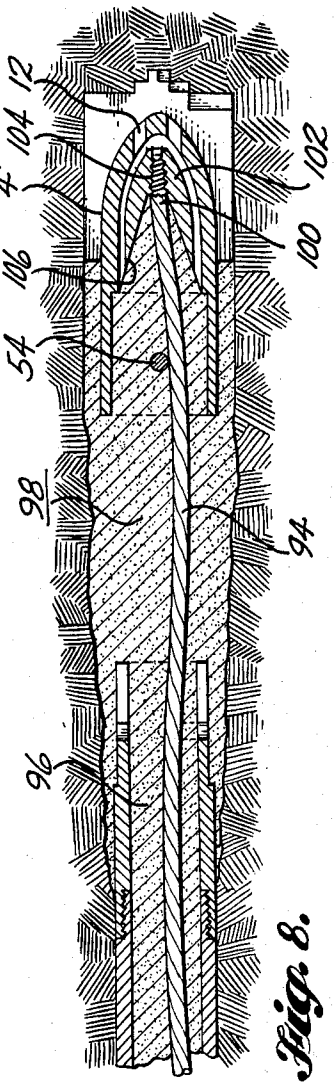


Fig. 8.

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MEANS AND TECHNIQUE FOR INSTALLING ELONGATED RODS IN UNSTABLE EARTH FORMATIONS

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19 Claims. (Cl. 61—53.64)

ABSTRACT OF THE DISCLOSURE

A method and apparatus are disclosed for installing an elongated rod in the earth. According to the method a tubular casing having a plurality of detachable sections along the length thereof, is installed in a tunnel in the earth and the rod is inserted therein. Then, the rod is "dumped" in the tunnel by charging a liquid medium into the casing about the rod, and retracting the casing from the tunnel in successive stages after each of which the section at the end of the casing adjacent the mouth of the tunnel is detached and removed from the casing. To retain the rod in the tunnel and to maintain the charge about the rod, a piston is slidably engaged in the casing between the rod and the aforesaid end of the casing, and is advanced from one end section to the next during each retraction stage, and locked in the latter section of the casing between stages, while the one end section is detached and removed therefrom.

This invention relates to a means and technique for installing elongated rods in earth formations, and in particular to the installation of such rods in unstable earth formations, that is, ones which tend to collapse and fill any excavation which is made in them.

The invention is applicable to the installation of all types of elongated rods, including those which are hollow and those which are solid, those which are perforate and those which are imperforate, and those which are formed in the earth, as with a cure-hardenable grout, as well as those which are formed outside of the earth and thereafter inserted into it. For example, the invention is applicable to the installation of horizontal drains in an aquifer for purposes of relieving it of the water. In such a case the "rod" is both perforate and hollow to collect and drain the water to some point outside of the aquifer. On the other hand, the invention is also applicable to the installation of so-called "soil anchors." A soil anchor consists essentially of a block of concrete or similar material which is installed in an earth formation about a cable for purposes of anchoring a retaining wall or other artificial structure to the formation. In this instance, of course, the "rod" is both solid and formed in situ.

In installing rods of this nature, it will be appreciated that it is seldom possible to use the rod itself in penetrating the earth formation. To the contrary, some means and/or technique is generally required whereby the rod can be protected from its surroundings until the formation is brought into a state of equilibrium around it. It is a principal object of the invention to provide such a means and technique, and in particular one whereby the rod may be installed at great distances into the earth; for example, at distances of three to five hundred feet or more. Still another object is to provide a means and technique of this nature whereby the rod may be installed in lateral directions as well as vertical directions, and whereby it may be installed in a straight line from the point of entry, notwithstanding the nature of the earth material which may lie in its path. Additional objects include the provision of a means and technique of this nature for

installing rods of light weight and relatively low strength material, such as plastic material. Still further objects will become apparent from the description which follows.

These objects are realized in accord with the invention by a means and technique of our invention wherein the operation is carried out in two stages, the first of which involves the installation of the rod in a protective "sheath" and the second, the "dumping" of the rod from the sheath. Initially, we install an imperforate tubular casing in the earth which has a substantially earth-free interior condition. The rod is loosely inserted in the casing either in advance of the casing's installation in the earth, or at a subsequent time. Then, the casing is retracted in relation to the rod—to "dump" the rod—while a liquid pressure medium is pumped into the annular space between the rod and the casing to prevent the earth from infiltrating the space with debris and effectively locking the two against relative movement.

When installing horizontal drains and the like, we use a watery medium such as seepage from the aquifer, which is displaced by the earth when the operation is completed. On the other hand, when installing soil anchors and the like, we use a cure-hardenable grout such as concrete, which is non-displaceable by the earth and remains about to rod to add to the body of the same. If the grout is highly viscous, it is preferable to use a low friction material for the casing, or to insert a low friction liner in the casing, to reduce the drag as it is withdrawn.

Our present practice for installing the casing in a substantially earth-free interior condition, is to drive it into the earth behind a relatively enlarged tunneling tool, and to pump a liquid wash into the tunnel at a point ahead of the casing to flush the displaced earth material out of the formation through the annular space between the casing and the wall of the tunnel. The liquid wash also operates to lubricate and cool the head of the tool, which may be equipped with a drill bit and rotated into the earth for purposes of displacing the material.

The particulars of these techniques will become more evident by referring to the accompanying drawings wherein we have illustrated two embodiments of the invention, both of which make use of the casing as a drill rod and water swivel for the tool, which is in the form of a ported detachable bit.

In the drawings, FIGURE 1 is a side elevational view of a tractor-mounted device for installing horizontal drains and the like, there being part of the device removed to illustrate a linear drive mechanism for the drill rod;

FIGURE 2 is a part cross-sectional view along the length of the rod and through part of a rotary drive mechanism for the rod.

FIGURE 3 is an exploded view of a coupling arrangement by which the bit is detachably connected to the rod;

FIGURE 4 is another part cross-sectional view along the length of the rod, illustrating the manner in which the drain is "dumped from the rod" by pumping a piston device through the rod while the rod is being withdrawn from the earth;

FIGURE 5 is a similar view of an alternative piston device for installing the drain in the manner of FIGURE 4;

FIGURE 6 is a cross-sectional view through the drain along the line 6—6 of FIGURE 5;

FIGURE 7 is an alternative form of bit for penetrating exceptionally hard material, such as rock, and withstanding high artesian heads; and

FIGURE 8 is a part cross-sectional view in the manner of FIGURE 4, but illustrating a third form of bit and a scheme for installing soil anchors and the like.

The drill rod 2 is assembled from ten foot sections 2' of steel tubing which are threaded at their ends to be

flush coupled with one another into the necessary length of rod. The bit 4 in FIGURES 1–4 is equipped with longitudinally extending cutting blades 6 which make it suitable for excavating a tunnel 8 in relatively loose material, such as sand or gravel. The modified form of bit 4' in FIGURE 8 is also equipped in this fashion. However, the form 4'' seen in FIGURE 7 is equipped with roller teeth 10 that turn against the surface of rock and other similarly hard material, and progressively abrade away the surface.

All three bits have tubular bodies that are ported at 12; and in addition, each has an enlarged diameter relative to the diameter of the drill rod, so that in the course of the excavation step, water 14 can be pumped along the length of the rod and discharged through the ports to flush the displaced earth material back out through the annular space 16 between the rod and the wall of the tunnel.

The rod and bit are run in by a travelling drillstock 18 which is slidably supported on the rim of a horizontal forklift cradle 20 that is adjustably cantilevered from one side of a heavy construction tractor 22 and supported on a hydraulic jack 23 at the base of the cradle. The length of the cradle 20 approximates the length of each section 2' of the rod, so that the sections can be progressively added by running in the rod the length of a section, retracting the drillstock to the opposite or left-hand end of the cradle, inserting an additional section, and then advancing the drillstock in the right-hand direction once more.

The alternate action of the drillstock is produced through the medium of a chain drive mechanism housed in the cradle 20. This mechanism includes a pair of driven sprockets 24 at the ends of the cradle, a continuous chain 26 about the sprockets, and a hydraulically driven pulley-chain drive mechanism connected with the left-hand driven sprocket 24. This latter mechanism includes a pair of hydraulic rams 28 which are connected with the opposite ends of a pulley chain 30 that extends about a drive sprocket 32 affixed on the shaft of the left-hand driven sprocket 24. The hydraulic rams 28 are driven by a pair of hydraulic pumps in a hydraulic transmission connected to a power take-off shaft at the rear 34 of the tractor. Each ram 28 is single acting and the transmission pumps have relatively high and low speeds. The low speed pump is used in advancing the drillstock on the run-in step and then the two pumps are added together in reversing the drillstock on the retraction step. This makes it possible to advance the drillstock at a rate which will not overheat the hydraulic system, yet rapidly reverse the drillstock on the retraction step. In a typical case we use 10 and 40 gallon per minute pumps to power the rams, and a 2 to 1 ratio between the drive sprocket 32 and the left-hand driven sprocket 24. The controls for operating the rams are also at the rear 34 of the tractor.

The drillstock 18 houses a chain-driven drill spindle 36 which has an externally threaded chuck 38 for receiving the internal threads at one end of each new section 2' of drill rod. The chain drive mechanism for the spindle 36 includes a pair of sprockets, one 40 of which is fixed on the spindle and can be seen in FIGURE 2. The two sprockets are housed in an oblong jacket 42, one over the other, at the forward end of the drill stock. The upper sprocket (not shown) is driven by a hydraulic transmission, the pump 44 of which is housed at the upper back of the jacket in FIGURE 1. Dual flexible hydraulic connections for the pump can be seen at 46.

The water 14 is pumped into the drill rod 2 through the drillstock 18. As is evident in FIGURE 2, the spindle 36 has a hollow bore which provides a passage for the entry of the water into the rod from a pump 48 at the back of the drillstock. The pump controls are at the rear 34 of the tractor, together with the other controls.

The bit 4 is detachably connected with the drill rod through the medium of a slotted adaptor 50 at the forward end of the rod. The adaptor 50 has a tubular body which is threaded and flush coupled to the forward end of the first section 2' of rod. In the forward end of the adaptor are two diametrically opposed but commonly oriented L or J slots 52. These slots are adapted to receive a pin 54 which is secured across the bore of the bit. The forward end portion of the adaptor 50 is relieved to slide within the bit and the connection is made by inserting the adaptor into the bit until the shoulder 56 of the adaptor abuts the rear of the bit. In such a case, the pin 54 must engage in the longitudinal legs 58 of the slots and having done so, any rotation given to the adaptor in the clockwise direction engages the pin in the transverse legs 60 of the slots and prevents the release of one from the other in the longitudinal direction.

Preferably, a sealing ring (not shown) is installed between the interfitting parts of the adaptor and the bit.

In FIGURES 1 and 2 the drill rod, the adaptor, and the bit are assembled in a string and shown in use for the excavation step. Beginning with the connection between the adaptor and the first section of rod, each joint is tightly torqued into the string. As seen in FIGURE 1, there is a bearing guide 62 for the string at the forward end of the cradle. When each new section of rod is added to the string, the joint is made at a point just to the rear of the bearing guide 62. For a moment while the new section is spun onto the threads of the last, the string is inactivated in the guide with a pipe wrench (not shown) so that the torque of the drill chuck 38 may be used to tighten the new section onto the string. The added length is then advanced into the earth with the string for the length of the cradle. Throughout the pump 48 applies pressurized water to the rod and the excavated debris is flushed back along the length of the rod to the mouth of the excavation. Ultimately, when the drill chuck reaches a point just short of the bearing guide, the pipe wrench is applied once more, but in the opposite sense, and the operator simultaneously reverses the rams and the rotation of the drill spindle, and after disengaging the drill chuck, adds in the 40 gallon pump to quickly reverse the drillstock along the length of the cradle. A new section is added as before and the process is repeated until a string of the desired length is installed in the earth. Of course, the pipe wrench prevents the drill from uncoupling the adaptor each time the chuck is uncoupled from the string.

FIGURE 4 illustrates the process of "dumping" the drain in the excavation. The drain is formed from circumferentially slotted lengths of polyvinyl chloride tubing 64 which are end-rabbeted and flush coupled with one another by means of an adhesive spread between their overlapping ends. The lengths may be assembled one after another in the rod at the time the rod lengths are added to the string, or they may be assembled in the completed rod after it is installed. In all events, the tubing is inserted into the rod until the forward end of the same abuts against the pin 54 in the bit. Assuming that there is no great delay in inserting the tubing, the amount of ground water and debris which bleed in through the ports 12 is not of any significance. In areas of high artesian head, a check valve 63 can be used in the bit, as in FIGURE 7.

The "dumping" step is possible only if the clearance between the drain and the rod is kept free of debris. It is also important that there is no opportunity for the debris to enter the slots 65 in the drain until the hydrostatic head in the earth formation has reached a state of equilibrium around the drain. We have found that it is possible to successfully "dump" the drain by "bathing" the drain in a charge of pressurized water while the rod is being retracted. After the drain is in place in the rod, we insert a so-called "floating locking piston device" 66 in the rod behind the drain. An example of such a device can be seen abutted up against the drain in the lower half of FIGURE 4. It has an elongated tubular body which is divided into forward and rearward sections 68 and 70, respectively, joined together by a nipple 72. The forward section 68 makes a close sliding fit within the rod and is characterized with a series of circumferential grooves 74 that extend

about its exterior surface and each contain a neoprene O-ring **76**. The grooves **74** are inwardly tapered in the front to rear direction, and due to the taper the rings **76** are retained against the shoulder at the rear of each groove when the device is urged in the opposite direction. On the other hand, when it is urged in the front to rear direction, they engage in the taper of the grooves and seal the device against the passage of water.

The rearward section **70** makes a looser fit within the rod and houses a spring loaded check valve **78** which opens under pressure from the drillstock. Accordingly, water **14** can be pumped into the forward end of the rod to place it under pressure, yet the captive charge **80** cannot escape to the rear of the rod because of the sealing action of the O-rings **76**.

An alternative form of the device is seen in FIGURE 5. In this instance, the forward section **82** of the device is characterized with two exterior grooves **84** for O-rings **85**, and these grooves are interspaced by a pair of tapered dovetail notches **86** which are disposed at diametrically opposed points on the exterior surface of the section. Each of the notches **86** contains a spring biased wedge **88** which is sized to dovetail within the notch and to conform with the inside diameter of the rod. The curved outside surfaces of the wedges are serrated so that there are teeth **90** on the surfaces which tend to grip the wall of the rod when the wedges are urged against their springs **92** in the rearward or left-hand ends of the notches.

When the piston device is in place in the rod, the drillstock **18** is brought up and torqued onto the last section. The pump **48** is turned on and the water **14** is pumped through the piston device into the rod until a gauge (not shown) in the rod indicates that a charge of predetermined pressure has been attained in the rod. Ordinarily, this charge is of the order of 40–50 lbs. per square inch gauge pressure. Then the pump **48** is turned off for a brief time while the rod is run a short distance into the earth to plug the ports **12** in the bit. Whereupon, the pump is turned on again and the fact that the bit is plugged is confirmed by a sharp increase in the gauge pressure. This being the case, the drill spindle **36** is reversed momentarily in the counterclockwise direction, and the drillstock is given a slight "jerk" in the rearward direction. The act of reversing the spindle brings the pin **54** into alignment with the longitudinal legs **58** of the adaptor slots, while the reversal of the drillstock slips the pin out of the slots and frees the adaptor from the bit. The forty gallon pump is then used to retract the drillstock along the length of the cradle until the last section of rod is exposed at the mouth of the excavation. It is removed from the string, the drillstock is engaged with the next section, reversed, and so on. Section by section the drill rod is retracted from the tunnel. Meanwhile, the piston device **66** is pumped up the length of the rod from one section to the next to hold the charge in the rod about the drain. Each time the pressure of the charge drops below the pressure of the pump **48**, the check valve **78** opens and admits more water to the charge to restore the pressure. Of course, when the adaptor **50** is at first withdrawn from the bit, there is a sudden surge of earth material into the space vacated by the rod. However, at this time the charge is at its most effective pressure level. As more and more of the rod is withdrawn, it becomes less effective; but at the same time the water in the excavation achieves a more stable condition and, therefore, one factor compensates for the other. Ultimately, the whole of the rod is withdrawn and the drain is encapsulated by the surrounding earth. The bit, of course, remains in the excavation. The adaptor and the piston device are reusable together with the rod.

FIGURE 8 illustrates the installation of a soil anchor. In this case a length of high tensile strength cable **94** is inserted into the drill rod **2**, rather than the drain **64**. In addition, a concrete grout **96** is used to form the charge **98**, in lieu of the water **14** used in the embodiment of FIGURES 1–7. Otherwise, the installation process remains the same.

There is one important departure from the earlier embodiment, however. Of course, the cable **94** does not have the same stiffness as the tubing. Moreover, the grout **96** exerts considerable drag over all surfaces to which it is exposed. Therefore, to facilitate the operation, we use a modified form of bit **4'** which is adapted to grip the leading end **100** of the cable for purposes of retaining the cable in a strung out position over the length of the tunnel during the retraction step. The forward end of the bit **4'** has a filleted core **102** which is longitudinally recessed to the tip of the core where there is a threaded hole **104** that is adapted to receive the end of the cable. The recess **106** is progressively tapered toward the hole so that it leads the end of the cable into the hole when the cable is probed into the core. Thereafter, the threads in the hole take hold of the cable and prevent it from being released without considerable force.

There are several ways of developing the anchor. The drill rod may be withdrawn in one continuous step while the grout **96** is in a readily flowable condition. Or it may be held at an intermediate point until the grout has assumed a partially set condition so as to "bell" the bottom of the anchor. By terminating the operation at an appropriate point, the trailing end (not shown) of the cable can be exposed for use in attaching the anchor to the structure to be supported.

Preferably, an expansion agent such as aluminum dust is added to the grout to aid in filling the tunnel.

If desired, it is also possible to engage the screen with the bit. For example, the forwardmost section of the screen can be provided with J or L slots to engage the pin **54** in the manner adopted for the adaptor. Furthermore, if desired, the springs in the various check valves can also be used to facilitate other aspects of the operation. For example, the spring loading of check valve **78'** in FIGURE 5 can be used in connection with the wedges **88** to expand and contract the wedges in accord with the opening and closing of the valve. Or, in a reverse situation, the spring loading of the check valve **63** in FIGURE 7 can be adjusted by the application of the rod to the pin **54**, to the effect that the loading is increased when the rod is withdrawn. It is also our intention that other modifications and additions can be made in and to the invention without departing from the scope and spirit of the invention as defined in the following claims.

We claim as our invention:

1. A method of installing an elongated rod in the earth, comprising installing a tubular casing in a tunnel in the earth, said casing having a plurality of detachable sections along the length thereof, and the rod inserted therein, charging a liquid medium into the casing about the rod, and retracting the casing from the tunnel in successive stages after each of which the section at the end of the casing adjacent the mouth of the tunnel is detached and removed from the casing, there being a piston slidably engaged in the casing between the rod and the aforesaid end of the casing, which is advanced from one end section to the next during each retraction stage, and locked in the latter section of the casing between stages, while the one end section is detached and removed therefrom.

2. The method according to claim **1** wherein the piston is advanced from one end section to the next by pumping a liquid medium into the aforesaid end of the casing during each retraction stage.

3. The method according to claim **2** wherein the piston is locked in the aforesaid latter section of the casing by generating a hydraulic pressure differential thereacross.

4. The method according to claim **1** wherein the liquid medium is charged into the casing about the rod before the casing is retracted from the tunnel.

5. The method according to claim **4** wherein the liquid medium is a cure-hardenable grout which is nondisplace-

able by the earth and which remains about the rod when the operation is terminated, to add to the body of the same.

6. The method according to claim **1** wherein the liquid medium is charged into the casing about the rod during each retraction stage.

7. The method according to claim **6** wherein the liquid medium is a watery medium which is displaced by the earth when the operation is terminated.

8. The method according to claim **6** wherein the liquid medium is charged into the casing through the piston.

9. The method according to claim **6** wherein a portion of the liquid medium is also charged into the casing about the rod before the casing is retracted from the tunnel.

10. The method according to claim **9** wherein the end of the casing remote from the mouth of the tunnel is temporarily closed to the passage of liquid therethrough, to confine the aforesaid portion of the charge to the casing until the first retraction stage is begun.

11. The method according to claim **1** wherein there is a tunneling tool disposed in the tunnel adjacent the end of the casing remote from the mouth of the tunnel, and the rod is secured to the tool.

12. Apparatus for installing an elongated rod in the earth, comprising means for installing a tubular casing in a tunnel in the earth, said casing having a plurality of detachable sections along the length thereof, and means for "dumping" the rod in the tunnel from an inserted position within the casing, including means for charging a liquid medium into the casing about the rod, and means for retracting the casing from the tunnel in successive stages after each of which the section at the end of the casing adjacent the mouth of the tunnnel is detached and removed from the casing, including a piston which is slidably engageable in the casing between the rod and the aforesaid end of the casing, means for advancing the piston from one end section to the next during each retraction stage, and means for locking the piston in the latter section of the casing between stages, while the one end section is detached and removed therefrom.

13. The apparatus according to claim **12** wherein the piston advancing means includes means for pumping a liquid medium into the aforesaid end of the casing during each retraction stage.

14. The apparatus according to claim **13** wherein the piston locking means includes means on the piston responsive to a hydraulic pressure differential thereacross to interlock the piston with the walls of the casing.

15. The apparatus according to claim **13** wherein the piston has a passage therethrough to admit liquid medium about the rod, and valve means therein which are responsive to a predetermined pressure differential across the piston to open the passage to flow.

16. The apparatus according to claim **12** wherein the casing retraction means is operable to rotate the casing, and the casing sections are rotatably engaged and disengaged to and from one another.

17. The apparatus according to claim **12** wherein the casing installation means includes a tunneling tool and means for driving the casing into the earth behind the tunneling tool.

18. The apparatus according to claim **17** wherein the tunneling tool is equipped with a rotary drill bit and the casing drive means is operable to rotate the casing, and wherein the casing installation means further comprises an adaptor for detachably engaging the casing with the tool to drive the bit into the earth.

19. The apparatus according to claim **17** wherein the tunneling tool has means thereon for securing the rod to the tool.

References Cited

UNITED STATES PATENTS

890,765	6/1908	Gilbreth	61—53.64
2,146,645	2/1939	Newman	61—53.6 X
2,383,496	8/1945	Nebolsine	166—50 X
2,798,692	7/1957	Thomas	175—62 X
2,956,626	10/1960	Hall	166—153 X
3,184,924	5/1965	Staunau	61—53.68 X

FOREIGN PATENTS

1,243,359	8/1960	France.

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