

Jan. 21, 1969

D. SILVERMAN
METHOD AND APPARATUS FOR DRIVING AND LINING AN
UNDERGROUND CONDUIT

3,422,631

Filed Nov. 16, 1966

Sheet 1 of 4

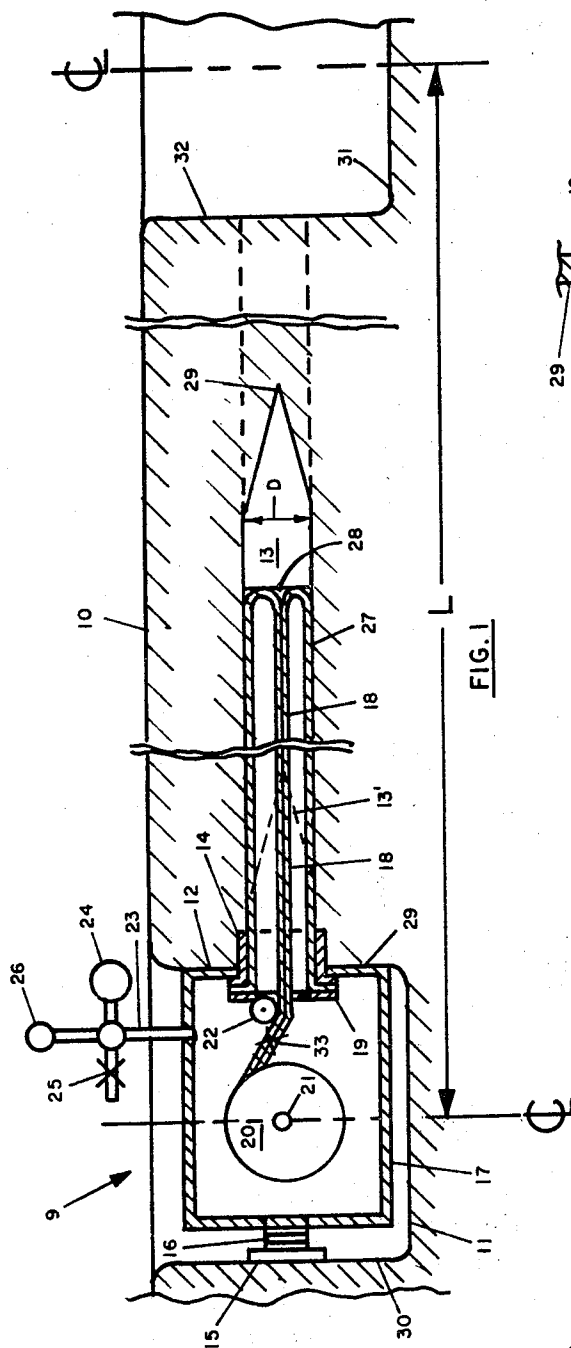


FIG. 1

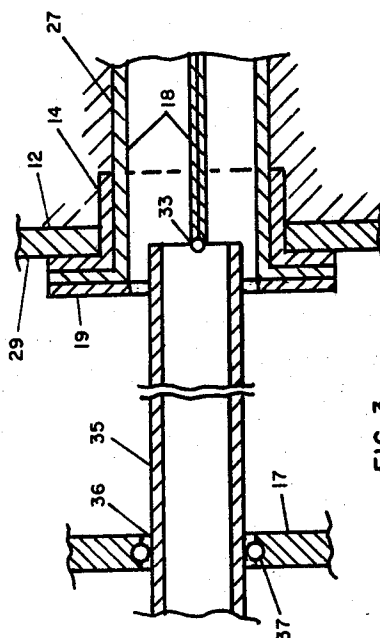


FIG. 3

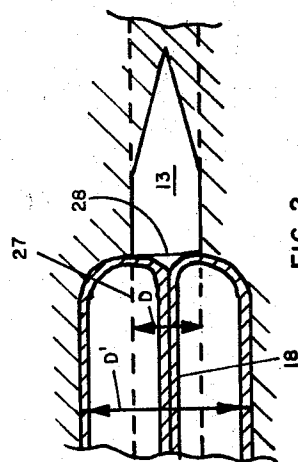


FIG. 2

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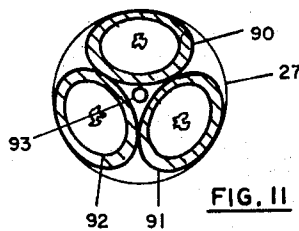
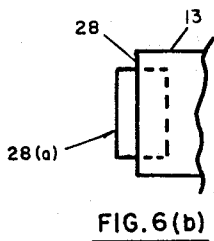
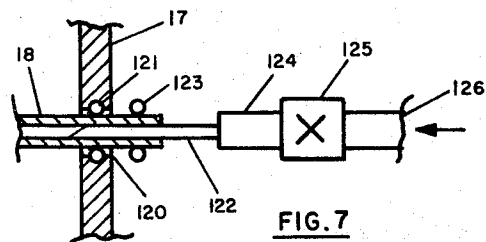
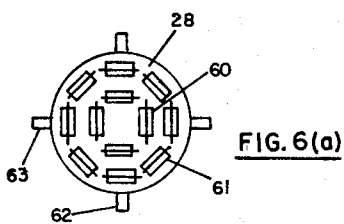
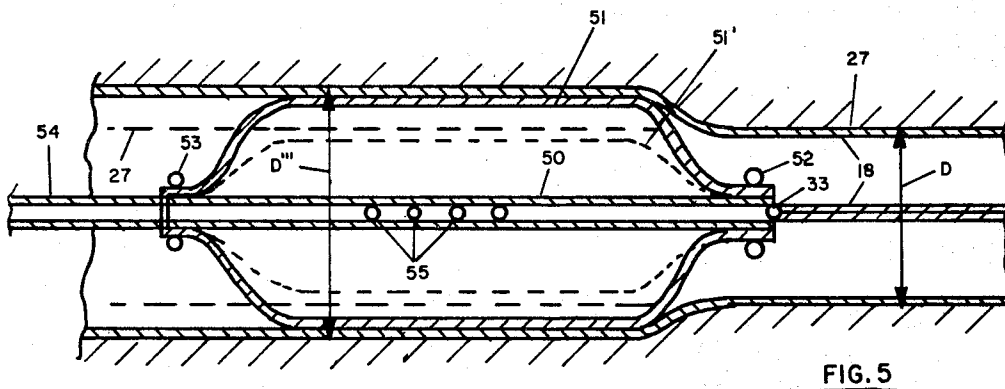
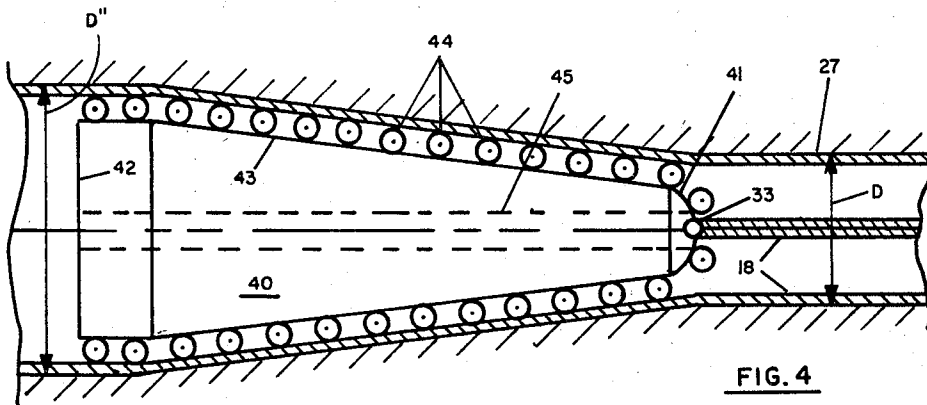
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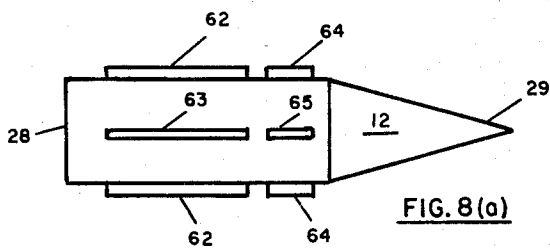


FIG. 8(a)

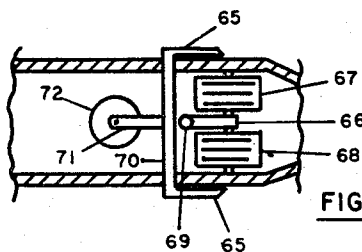


FIG. 8(b)

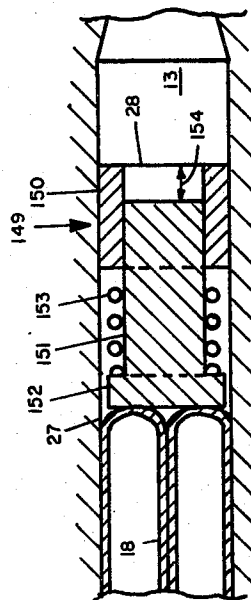


FIG. 15

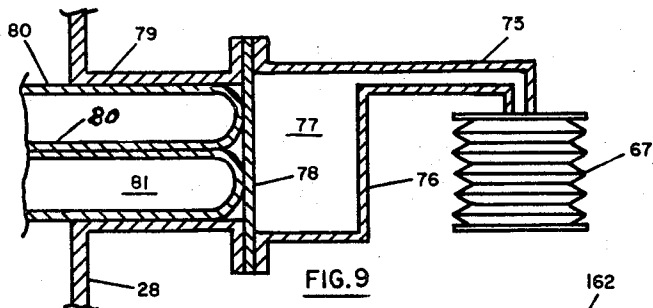


FIG. 9

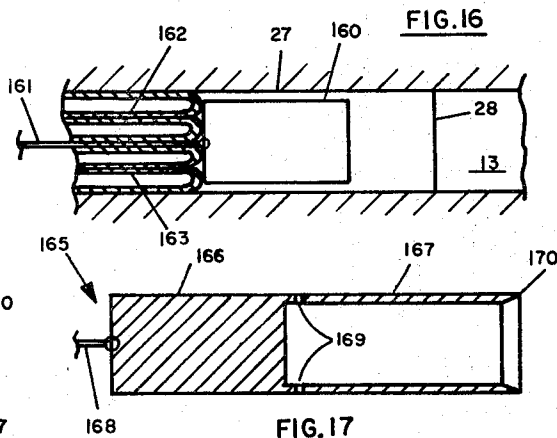


FIG. 16

FIG. 17

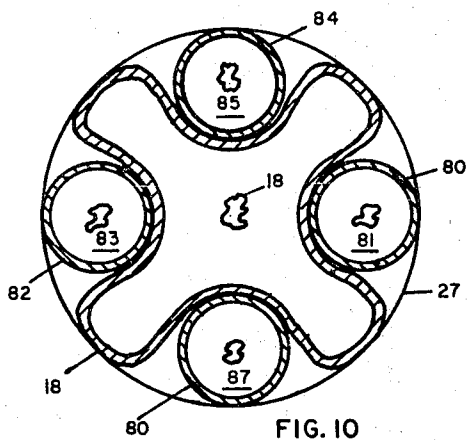


FIG. 10

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3,422,631 METHOD AND APPARATUS FOR DRIVING AND LINING AN UNDERGROUND CONDUIT

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36 Claims

Int. Cl. E01g 3/00; 5/00; E21b 17/00

ABSTRACT OF THE DISCLOSURE

The method relates to using fluid pressure in everting a flexible tubing forwardly to force a driving head through earth to form a conduit or to move an object through a conduit already provided. The conduit may be lined by the tubing or by cement placed between the walls of the tubing and the conduit. The apparatus has a fluid pressure chamber connected by an earth anchored body having an opening to which one end of the tubing is attached peripherally and through which the flattened portion of the tubing passes to be eversed in the earth or inside of a conduit provided. A driving head is provided forwardly of the leading end of the portion of the eversed tube. The driving head may depend from a plow and lead the way for the tubing or the tubing itself forces the head forwardly.

This invention concerns the forming, enlarging, lining, and consolidating a cylindrical tunnel or conduit in the earth in the unconsolidated formations near the surface thereof. More particularly, it concerns the use of the pressure of the fluid in an everting tubing to provide the force with which to drive a bullet-shaped driving head to form the tunnel, channel or conduit, and at the same time, to provide an expansive force to enlarge the diameter of the conduit as formed, and also to line the conduit with the material of which the tubing is constructed. This invention also contemplates forming the conduit by mechanical means with the everting tubing following behind such means. It also contemplates the placement of a polymerizing composition or cement slurry in the annulus between the tubing and the earth to consolidate the earth materials and cement the tubing thereto, the internal fluid pressure in the everted tubing serving to press such cementing material into contact with the earth and maintain the cylindrical form of the tubing, which will form the internal surface of the conduit or tunnel.

In general, my invention involves the eversion of a flexible tubing from a closed chamber by fluid pressure so as to drive the everting end of the tubing into the earth, preferably in a more or less horizontal direction. The forward movement of the everting end of the tubing through the earth is facilitated by the use of a pointed cylindrical driving head, against the back of which the tubing presses. The pressure of the tubing against the driving head is a function of the fluid pressure inside the tubing. This pressure can be appreciable since the tubing is confined on the circumferential surface by the earth wall, and the only direction in which the tubing can have appreciable movement is in the longitudinal everting direction, by forcing the driving head forward.

By using sufficient fluid pressure the tubing also can be expanded radially, forcing the earth outward and enlarging the diameter of the opening, tunnel, or conduit.

Also, the end of the collapsed uneverted tubing can be used to pull forward, through the everted tubing in the tunnel, an oversize bullet-shaped device that will enlarge the diameter of the tunnel as it advances.

In the case the volume of the earth through which the tunnel is to pass is too hard or compacted, I contemplate

the use of a plowlike device comprising a bullet-shaped metal driving form supported by means of a vertical thin bladeliike vane or fin from a vehicle on the surface of the earth. This vehicle supports the metal driving form at an adjustable distance below the surface of the earth. The vehicle is driven along the surface of the earth carrying with it the metal form. This driving form contains a tubular extension on its back wall which forms a cup. The everting tubing expands into this cup and everts as the driving form moves forward through the earth. As in the case of the driving head forced by the everting tubing, the expanded everted tubing by its internal fluid pressure supports the earth wall and maintains the tunnel or conduit in cylindrical form.

I envision also means on the vehicle for supplying a volume of polymerizing composition or cement slurry and delivering this composition by conduit means to the metal driving form, where it can be discharged around the periphery of the cup on the rear of the driving form. This would be on the outside of the everted inflated tubing. Thus the polymerizing composition serves to cement together and consolidate the earth material forming the wall of the conduit, and cement the tubing to this consolidated earth conduit, thus forming a strong-walled-lined conduit in the earth that can be used for the transport of fluids, or to encase and protect wires, pipes, or other devices that might be inserted into the conduit.

It is therefore an important object of this invention to provide apparatus for and a method of driving or forming a lined tunnel or conduit in the earth. It is a further object of this invention to form this conduit without having to dig a trench from the surface down to the depth of the conduit. It is a further object to provide a consolidating material and a lining material so that a strong rigid conduit will be formed.

These and other important objects, features and advantages of this invention will become apparent from the following detailed description in conjunction with the accompanying drawings, in which:

FIGURE 1 is a general schematic elevation view of the apparatus of this invention.

FIGURE 2 is a partial view of the embodiment of FIGURE 1 in which the enlargement of the tubing is shown increasing the diameter of the conduit.

FIGURE 3 illustrates how the advancing tubing can be used to pull into the everted tubing a semirigid tube.

FIGURES 4 and 5 illustrate two methods of enlarging the diameter of the conduit after it is formed. FIGURE 4 illustrates a mandrel of diameter greater than that of the conduit, while FIGURE 5 illustrates an expandible packer.

FIGURES 6a and 6b illustrate two means by which the friction of the everting tubing against the back of the driving head can be minimized.

FIGURE 7 indicates one way in which fluid can be introduced into the space between the back of the driving head and the everting tubing, and also in the annular space between the tubing and the earth wall of the conduit.

FIGURES 8a, 8b, 9, 10, and 11, illustrate means by which the driving head can be controlled and steered hydraulically or pneumatically.

FIGURE 12 indicates means by which the driving head can be controlled electrically.

FIGURES 13a and 13b indicate how a polymerizing composition or cement slurry can be continuously positioned outside of the advancing everted tubing so as to cement the tubing to the earth and consolidate the earth particles to a substantial depth radially from the tubing.

FIGURE 14 indicates apparatus means for anchoring the tubing at the mouth of the conduit, and,

FIGURES 15, 16, and 17 indicate different embodiments of driving heads.

Referring now to the drawings, and in particular to FIGURE 1, the method of forming such a conduit in the shallow earth is illustrated. The description will be started from the condition in which the conduit is already partly formed, and is being extended.

The surface of the earth is represented by the numeral 10. A hole 11 is dug to an appropriate depth, or an appropriate wall 12 is found. A driving head, which is a conical or bullet-shaped metal assembly 13 having a sharp-pointed end 29 and a more or less flat back end 28, is pressed into the wall of the hole, at the proper depth and in the desired direction, until its back surface 28 is slightly forward of the wall 12. This is shown dotted as 13'. The instrument assembly 9 is lowered into the hole and the tubular extension 14 is in the conduit at the back end of 13 and is pressed into the earth until the front wall of the instrument 29 is in contact with the wall 12 of the hole. The pressure to force the extension 14 into the earth is applied by means of plate 15 bearing on the back wall 30 of the hole, by force mechanism 16 of conventional type, hydraulic, mechanical, etc. Of course, if there is no back wall 30, other means of bracing the instrument assembly 9 are required. This bracing is also needed when, as will be described, the tubing is everted and internal pressure is forcing it against the back of the driving head.

A flexible eversible tubing 18 is placed in collapsed form, for example, on reel 20 journaled on shaft 21, or is held by other means, within the instrument case 17. This tubing 18 is sealed circumferentially over the opening 14 by means 19. Fluid pressure (liquid or gas) is applied by pump 24 through pipe 23 into the chamber 17. This causes the tubing 18 to be extruded out of the opening of extension 14 and everted. This tubing tends to advance by eversion at its leading edge, where it presses against the surface 28. Since the tubing is confined laterally by the wall 27 of the hole or conduit, the fluid pressure in the tubing is exerted against the driving head 13, forcing it farther into the earth.

When the head 13 has progressed to slightly beyond the distance $L/2$ where L is the distance from hole 11 to the next hole 31, the tubing 18 can be cut at the reel 20, and the free end of the tubing sealed, as at 33. Then further increase of fluid pressure in the chamber 17 will drive the head 13 forward and the sealed end 33 will advance until it will reach the position against the back surface 28, which will be at the time that the driving head 13 breaks through the wall 32, of the next hole 31. The conduit will then be complete and will have been lined by the tubing 18.

If the tubing 18 is extensible, or if the diameter of the tubing is greater than the diameter D of the driving head, the fluid pressure inside the tubing will cause it to expand radially, enlarging the conduit by compression of the earth, to a diameter larger than D . This is shown in FIGURE 2, where the driving head 13 has created a conduit of diameter D , shown dotted, as 27, while the subsequent expansion of the tubing 18 has enlarged this conduit to the diameter of D' .

The tubing 18 is necessarily fairly thin since it must be flexible enough to be eversible. If it is desired to line the conduit with a heavier walled tubing or a semi-rigid walled tube, they can be pulled into the tubing 18 by the advancing end 33 of the tubing 18. This is shown in FIGURE 3 where the tube 35 is shown attached to the end 33 of the tubing 18. The tube 35 is sealed through a pressure gland 36 with seal 37 in a wall of the chamber 17.

If it is desired to enlarge the diameter D of the conduit larger than that shown in FIGURE 2 as D' , it is possible to use the advancing end 33 of the tubing 18 to pull into the conduit a bullet-shaped conical structure 40 of suitable size. As shown in FIGURE 4, this can have a pointed head end 41 fastened to tubing end 33, with tapered wall

43. If desired, the conical section 43 can carry a multiplicity of rollers 44 which minimize the friction involved in moving the device 40 through the conduit. It will be desirable to have one or more openings 45 through the device 40 to ensure passage of the fluid which is driving the leading end of the tubing 18. As the device 40 moves through the conduit, it expands the diameter to D'' , the diameter of the outer edges of the rollers 44.

It is possible to apply greater pressure to expand the diameter of the conduit, by the use of a hydraulic packer, as shown schematically in FIGURE 5. This comprises a tube structure 50 about which is placed and sealed at 52, 53, a cylindrical expansible boot 51 made of rubber or similar expansible material. A hydraulic hose 54 is attached to the packer, and the pressure of fluid in this hose can enter the boot through openings 55 to expand the boot from nominal diameter D to diameter D'' , enlarging the conduit to this diameter. This packer can be pulled into the conduit by the advancing end 33 of the tubing 18. In this use of the packer system, the packer is moved ahead, stopped, enlarged, relaxed to normal diameter, advanced, enlarged, etc., in a step-by-step process.

In FIGURE 1, the everting end of the tubing 18 is shown pressing against the base 28 of the driving head 13. Since the movement of the tubing 18 at this point is in a radial direction along the back surface 28 of the head 13, this movement will be facilitated by rollers 60, 61, etc., mounted on tangentially arranged shafts on the back surface 28. This is shown in FIGURE 6a. In FIGURE 6b is shown an alternative construction in which a block of lubricating material 28a is inserted into the back surface 28 of the head 13. This can be a hard wax or similar material which will provide a film of lubricating material to facilitate the radial movement of the tubing 18 on the back surface of the driving head.

It is possible also to inject into the inside of the collapsed tubing 18, a lubricating material such as oil, grease, etc., so that after the tubing is everted, this film of lubrication will be in a position between the outer surface of the tubing and the back surface of the driving head. This is illustrated in FIGURE 7 in which 17 indicates one wall of the chamber 17. The tubing 18 is inserted through openings 120 and sealed by means 121. A small diameter tube 122 is inserted into the end of the tubing 18 and sealed by means 123. The tube is attached to pipe 124, valve 125, and pipe 126. The lubricating means is pumped into the pipe 126, through the valve, tube and tubing to the everted end of the tubing. As will be discussed later, other compositions of matter, such as cement slurry or polymerizing plastic can be pumped through tubing 18, out through the everting end, between the head and the tubing and then into the annulus between the tubing and the earth wall of the conduit, where it can harden and form a rigid wall for the conduit.

In forcing the conduit creating driving head through the earth, it is desirable to know where it is at any given time, and to be able to alter its direction as desired. There are many well known methods of determining the position of an object, particularly a metallic object, in the earth. This is not a critical part of this invention and will not be discussed further. What is an important part of this invention is the ability to change the direction of motion of the driving head as desired.

In FIGURES 8a and 8b are shown two partial views, exterior (FIGURE 8a) and interior (FIGURE 8b) of the driving head. This head has narrow guides, fins, or vanes 62, 63, fastened longitudinally to the outer surface. These are for the purpose of preventing changing direction and rotation of the driving head. These are also short segments of these vanes 64, 65, which can be rotated through a small angle. While these are shown at the front end of the vanes 62, 63, they could equally well be at the back end, etc.

Consider the vanes 64, for example. They are fastened to shaft 69 journaled through the wall of the cylinder. Inside the cylinder is an arm 66 fastened to the shaft 69.

The position of arm 66 is controlled by the two bellows, cylinders, or equivalent fluid control means 67, 68. These can control the position of the arm 66 and thus the vanes 64, by the differential force, that is by the relative magnitude of force exerted by each cylinder or bellows. In a similar way, the vanes 65 are fastened to shaft 70, as is arm 71, which is acted upon by cylinder or bellows 72, etc. It will be clear that electric motors or solenoids placed inside the driving head could be used to control the position of the vanes 64, 65, in place of the hydraulic or pneumatic means illustrated, as is well known in the art.

In FIGURE 9 is shown one way that the pressure in cylinder or bellows 67, for example, can be changed or controlled. Consider 28 to be part of the back surface of the head 13. There is a cylindrical depression 79 into which is headed a small diameter eversible tubing 80, having internal pretssure 81 in the fluid inside the tubing 80. If the driving head 13 is restrained against forward movement, then the pressure 81 is exerted against the diaphragm 78, and against fluid 77 in the system comprising chamber 76, tube 75, and bellows 67.

In FIGURE 10 is shown an embodiment in which four small diameter eversible tubes 80, 82, 84, and 86, are shown, with a large eversible tube 18 filling the space between them. The pressures 81, 83, 85, and 87 in the tubings must be higher than that in the central tubing, so that they will not be collapsed by the pressure in 18. They are not extensible and so cannot enlarge to the point where they will collapse the tubing 18. Each of the four small tubings is centered in a cavity like 79 against a diaphragm like 78. They operate in pairs, 80 and 82, for example, controlling the pressures in a pair of opposing bellows. So long as the pressures 81 and 83 are equal, the vane they control will have no deflection. If pressure 81 or 83 is made greater than the other, then the vane will be deflected, and so on.

Now, the total force of the four small tubings against the head is not enough to drive it forward, and the contribution of the force due to the tubing 18 is required to drive the head. Although the pressures in all five tubings can be controlled separately, it is possible to have the pressures in the small tubings created by adding a controllable incremental pressure to the pressure in 18. Each of the eversible tubings comes from a separate chamber, or a separate part of chamber 17 in which the pressure can be controlled independently of the others. Also there are separate openings for each of the tubings and common means to guide the five tubings into the conduit.

Also, it is possible to make the tubings 80, 82, 84, 86, larger so that without tubing 18, they can together provide enough force to drive the head 13 to form the conduit. Also, it is possible, instead of using only one tubing 18 as in FIGURE 1, to use 3, 4, or more, all supplied with the same pressure, and operating against the wall 28. This is shown in FIGURE 11. In that case, a control cable 93 can be connected to the head 13, which cable will be pulled behind the head in the interstice between the three or more tubings, 90, 91, 92, etc. This control cable can be used, in well known ways in conjunction with motors or solenoids inside the head 13 to control the angle of the vanes 64, 65. These particular details do not form part of this invention and will not be discussed further, since they are well known. The cable 93, or other control means alternatively can be reeled onto a suitable reel structure inside the head 13, and payed out as the head advances. Such reel means can be of conventional design and is shown schematically in FIGURE 12 as reel 96 on shaft 97 with cable 95 passing out of the head through opening 98 in back wall 28 of head 13.

The material of which the tubing is made is not critical. It can be made of the many commercial types of plastics or elastomers, such as polyethylene polyesters, either reinforced or not, as desired. However, the tubing must be

able to withstand the internal pressure of the fluid in the housing without bursting.

While I have shown how the advancing eversible tubing can be made to press against the back of the driving head 13, a second such tubing can be used to force a larger driving head through the conduit previously formed by the smaller head 13 to enlarge the diameter of the conduit, and so on. More generally, the advancing eversible tubing can be used to drive or force any type of structure through a conduit after it has been formed.

In the event that the top layer of the earth is too compacted to be perforated by the driving head 13 of FIGURE 1 driven by the everting tubing 18, it is possible to mechanically force the driving head through the earth with the everting tubing following behind. This is shown schematically in FIGURES 13a and 13b. Again I show the earth surface at 10, the hole 11, the pressure instrument casing 17 with tubing 18 fastened over the opening in the wall 29 and the tubing guide 14 penetrating the earth as shown. The metal forming or driving head 100 has a front pointed end 101 and a rear cup-shaped end 102 with cylindrical wall 103. The forming head is shown supported by a thin vertical metal wall or vane 104, which is itself supported from a platform 105. Four wheels 106 are shown supporting the platform. Means (not shown) may be provided for adjusting the vertical spacing between the head 100 and the platform, so as to place the conduit at the desired depth below the surface of the earth. Means 107 are provided to attach the wheel-supported platform to a tractor or similar device to drive the vehicle forward and carry the forming head forward. Of course, other constructions may be used to support and drive the forming head through the earth, as is well known in the art.

As the forming head moves forward, spreading the earth, the tubing 18 everts at its forward end within the cup 102 on the rear wall of the head 100. The internal fluid pressure in the everted tubing keeps the earth from falling back to collapse the tunnel or conduit.

I have shown in FIGURE 13 a pipe 111 leading to an internal conduit inside the web 104, leading to an annular passage 120 within the wall 103 of the cup. The purpose of this pipe and conduit is to force a settable composition down into the cup and out and around the tubing 18. To facilitate this, I have shown an enlarged portion 110 of the head 100. This creates a slightly larger diameter conduit in the earth than the diameter of the tubing 18. This radial annulus is filled with the settable composition. The inflated tubing keeps the internal opening of the desired diameter, and the composition seals the tubing to the surrounding earth which is itself cemented and consolidated by the composition. Thus a stronger, more rigid conduit can be constructed than would be possible by the use of the tubing 18 alone.

There are many settable compositions that can be used for this purpose such as those used for the manufacture of plastic pipe and similar articles, and for the consolidation of sand in oil wells. An example would be an epoxy resin or similar time hardening material. Also, a cement slurry can be used, etc. The particular composition would be at the choice of the user so long as it will set up to a substantially rigid shape. Further discussion of this choice is not believed to be required at this time, since the art of such materials is well known. The means to carry the reservoir of plastic composition on the platform 105 and force it down the pipe 111 can be quite conventional and need not be discussed further at this time. However, it may be desirable to have the pump, shown schematically as 114, which forces the composition into the pipe, be driven by means 113 from the wheels 106 so that the volume of composition is proportional to the displacement of the head 100, or the length of the conduit filled. Also, I have shown pressure gauge 115 on the composition input pipe and gauge 116 on the fluid chamber 17. It will be clear that the fluid pressure 116 should be at all times greater than the pressure 115 so as to maintain a true cylindrical conduit. It will probably be most effective if

the fluid that is being used to exert the tubing 18 is a liquid rather than a gas.

In FIGURE 14, I show further detail for a termination of the conduit and a fixture for the fluid chamber to seal the conduit. The earth is represented by 152, with a vertical wall 153 corresponding to the wall 12 of FIGURE 1, and the mouth of the conduit 155. Into this mouth is inserted a tubular fixture 133 with a circular flange 132 which is pressed against the wall 153. This fixture has a tapered nose portion 131, and a corresponding tapered ring 142, adapted to seal the tubing in between the tapered surfaces. The ring 142 is pressed tightly onto the nose by flange 146 and nut 148 which is screwed onto the fixture by threads 149. A seal ring 143 is placed in the wall of the ring 142.

Flange 146 can be a circular plate that will close the conduit 154. Or it can have a threaded opening to accept a correspondingly threaded pipe. Or, as shown, it can be part of the pressure chamber 145 corresponding to 17 of FIGURE 1.

The fixture has in its cylindrical portion an annular passage 134, with ports 135 leading radially outward. The annular cavity 136 leads to 134 and to pipe 137, thence to pipe 138, valve 139, line 149, pump 149, and pump input 141. Pump 140, as is well known in the art, can force a fluid composition into the fixture and out through openings 134, 135, etc. This fluid can be a settable material capable of hardening to a rigid shape. This can be cement slurry, gel, polymerizing plastic, etc. With the tubing 18 in the position shown (only one-half of the drawing is shown, most of the parts are symmetrical about the centerline 150), cement, for example, pumped in through 137, would flow out 134 and fill the annular space between the tubing and the earth conduit 155.

Let us consider how this equipment would be used. The conduit is started by pressing the driving head (not shown) to the left into wall 153, forming the mouth 155 of the conduit. The tubing 18 is placed inside the chamber 145 with portion 18" extending out through flange 146. (The nut 148 is loosened and parts 130 and 142 are separated.) Ring 142 is slipped over the end of the tubing 18, and the tubing end 18' slipped over the nose 131 of the fixture 130. The ring 142 is replaced and nut 147 is then slipped over the threads 149 and tightened. The assembly including the fixture 130 is then placed at the mouth of the conduit as shown, with the tubular portion 133 inside the conduit. Pressure is increased in the chamber 145, and the tubing is extruded out of the chamber and into the conduit, pressing on the back surface of the driving head.

Cement slurry, or settable plastic composition 151 can be pumped into the annulus between the tubing 18 and earth wall 155 of the conduit, through valve 139, pipe 137, and openings 134, 135. By maintaining the pressure inside the tubing 18 greater than the pressure in the slurry or composition in the annulus, the tubing will retain a smooth cylindrical contour, and provide a form or mold for the settable material in the annulus.

When the tubing and driving head have reached the distant end of the conduit, and the settable material has hardened, a fixture similar to 130 can be placed in the distant end of the conduit, and the tubing anchored thereto, as at 18'.

In FIGURE 15, I show another embodiment in which a hammer device is used in conjunction with the driving head 13, to use percussive force to drive it through the earth. This hammer can be part of the driving head itself, or a separate assembly placed in back of the head, between the head and the everting tubing. In this figure, I show a tubular cylinder 150 adapted to seat against the back wall 28 of the driving head 13. Inside of this cylinder is a slidably fitted piston 151 with head 152 against which the tubing presses. The piston is forced by means of spring 153 to a position remote from the back surface 28. As the pressure in the tubing increases, the tubing everts, press-

ing on the piston 151, driving it forward until it strikes the driving head. This causes a forward movement of the head. The pressure in the tubing can then be reduced, permitting the spring 153 to separate the piston from the surface 28. Then when the pressure in tubing 18 is again increased, the piston again moves forward to strike a blow against the head. If desired, the tubing 18 can be retracted or inverted by pulling on the uneverted portion. Some fluid will have to be removed from the tubing to permit this shortening of the everted tubing. Then when fluid is again forced into the tubing, it moves forward rapidly against the piston and so on, as before.

In FIGURE 16, I show another embodiment of a percussive device to drive the driving head by means of percussion blows. This comprises a cylindrical mass of metal 160, of slightly less diameter than that of the head 13. This has a retrieval tension member 161 attached to its back surface. Instead of a single large diameter tubing, a grouping of perhaps three or more tubings (as in FIGURE 11) would be used to permit passage of the retrieval member down the axis of the conduit. In operation, the pressure in the tubings is reduced, the retrieval member is pulled back a sufficient distance, and released and the pressure increased, driving the mass 160 rapidly toward the head until it strikes the head, and drives it forward.

In FIGURE 17, I show a modification of FIGURE 16, in which the mass 166 (or the driving head 13 itself) has a thin cylindrical shell 167 on the front end. This device is used without a driving head. The leading edge 168 is sharpened and serves as a core cutter, when driven against the earth. Vents 169 permit the shell to fill with earth, after which the tubings are inverted and the retrieval means 168 used to pull the unit 165 out of the conduit. The shell is emptied of earth and again driven into the conduit and the front wall where it again picks up a load of earth, etc.

Thus, the everting tubing can push the driving head by steady pressure, or by the use of the hammer, and pulsating pressure, it can drive the head percussively. Or it can drive a core cutter into the earth to cut out a cylinder and so lengthen the conduit.

While I have described my invention in terms of the foregoing specific details and embodiments thereof, and have omitted some of the detail on the basis that it is well known in the art, it will be understood that these are by way of illustration only and do not limit, in any way, the choice of equivalent units or systems as might be chosen by one skilled in the art, and the scope of the invention is properly to be ascertained by reference to the appended claims.

I claim:

1. Apparatus for forming and lining a cylindrical conduit in the earth by forcing a bullet-shaped driving head through the earth and everting a tubing to line said conduit, comprising,

(a) driving head means comprising a bullet-shaped metal object of diameter D adapted to be placed in and forced through the earth to displace the earth, and to form said conduit,

(b) annular anchoring means at the mouth of said conduit,

(c) flexible everting tubing means with one end in circumferential attachment to said anchoring means,

(d) means to apply fluid pressure to said tubing across said anchoring means, whereby said tubing is progressively forced through said anchoring means and the attached end of said tubing, into said conduit, and caused to evert as it progresses through said conduit in contact with said head.

2. The apparatus as in claim 1 in which said means to apply fluid pressure to said tubing comprises a pressure-tight chamber, said tubing placed inside said chamber, an opening in the wall of said chamber, and said anchoring means in operating relation to said opening, whereby said tubing is in circumferential sealing engagement over said opening.

3. The apparatus as in claim 2, in which the pressure of the fluid in said chamber and in said everted tubing, causing said tubing to press on the back surface of said head means, is sufficient to drive said head means through the earth.

4. The apparatus as in claim 3, including means between said everting tubing and the back wall of said head means to reduce the friction between said tubing and said head means.

5. The apparatus as in claim 2, in which said head means includes a sharp-edged tubular extension attached to the front end thereof, and retrieval means attached to the back end thereof, said tubular extension adapted to be driven into the earth and to cut a cylindrical core of earth material.

6. The apparatus as in claim 1, including means to position a material composition in the annulus between said tubing and the earth wall of said conduit, said composition capable of hardening to a substantially rigid shape.

7. The apparatus as in claim 6, in which said means to position said composition includes means to inject said composition into said annulus adjacent the mouth of said conduit.

8. The apparatus as in claim 1, including surface vehicle means, means to support said driving head means from said vehicle means, and means to transport said vehicle means and with it, said head means.

9. The apparatus as in claim 8, including pipe means from said vehicle means to said driving head means and through openings in the rear wall of said head means, and means to force a material composition through said pipe means to and through said head means into the annulus between said tubing and the earth wall of said conduit.

10. The apparatus of claim 1, including means attached to the collapsed uneverted tubing and adapted to be drawn into said everted tubing in said conduit.

11. The apparatus as in claim 10, in which said means attached to said tubing comprises a tapered cylindrical device of diameter greater than D.

12. The apparatus as in claim 10, in which said device comprises an extensible hydraulic packer, the collapsed diameter of which is less than D and the expanded diameter is greater than D.

13. The apparatus of claim 1, in which said driving head includes at least one longitudinal fin attached to the outer surface of said head, a terminal portion of said at least one fin capable of being deflected by means inside of said head.

14. The apparatus as in claim 13, in which said deflecting means is hydraulic, and including hydraulic control means comprising a plurality of small eversible tubings pressing on the back of said head.

15. The apparatus as in claim 13, in which said deflecting means is electromechanical, said electromechanical means controlled through conductor means mounted inside of said head and trailing out behind said head as said head moves through the earth.

16. The apparatus as in claim 1, including means to inject a fluid under pressure into the collapsed uneverted tubing whereby said liquid will flow through said tubing to the everting portion of said tubing, then will flow between the tubing and the back wall of said head means and then into the annulus between said tubing and the wall of said conduit.

17. The apparatus as in claim 1, in which the diameter of said tubing is smaller than D, whereby an annular space is formed between said tubing and the earth wall of the said conduit.

18. The apparatus as in claim 1, in which the inflated diameter of said tubing is greater than D, whereby the pressure inside said everted tubing will force the tubing radially outward, displacing the earth outward and forming a conduit of larger diameter than D.

19. The apparatus as in claim 1, including hammer means placed behind said driving head means in said conduit, and including means to move said hammer means away from said head means, whereby when an increasing pressure is applied to said tubing, the pressure in said tubing acting on said hammer means will cause it to move forward and strike said head means a percussive blow.

20. The method of forming and lining a cylindrical conduit in the earth by forcing a bullet-shaped driving head through the earth and everting a flexible tubing to line said conduit, comprising,

(a) placing in the earth at a desired depth a bullet-shaped driving head of diameter D,

(b) moving said head through the earth to displace the earth and to form said conduit,

(c) attaching one end of a collapsed flexible evertible tubing circumferentially to annular anchoring means at the mouth of said conduit,

(d) progressively forcing the tubing through the anchoring means and the attached end of said tubing into said conduit, by means of fluid pressure applied to said tubing,

(e) continuing to apply fluid pressure to said tubing causing it to progressively evert as it moves down the conduit until the everting portion of said tubing reaches said driving head, and,

(f) continuing to apply fluid pressure to said tubing to keep the everting end of said tubing at the driving head as said driving head moves through the earth.

21. The method as in claim 20, including the step of placing in the annular space between the outer surface of said tubing and the earth wall of said conduit a material composition capable of hardening to a substantially rigid shape.

22. The method as in claim 21, including the step of maintaining the pressure of said composition in said annulus at a lower pressure than the pressure in the everted tubing.

23. The method as in claim 21, in which said material composition is a cement slurry.

24. The method as in claim 21, in which said material composition is a polymerizable plastic composition.

25. The method as in claim 20, including the step of increasing the fluid pressure applied to said tubing until the pressure of said everted tubing on the back surface of said driving head is sufficient to force said head through the earth.

26. The method as in claim 25, including the step of reducing the friction between the everting tubing and the back wall of said driving head.

27. The method of claim 20, including the steps of supporting said driving head from a vehicle on the surface of the earth and moving said vehicle along a predetermined path on the surface of the earth, whereby said head will move forward along said same path and said tubing will evert at its back surface.

28. The method as in claim 27, including the steps of forcing a material composition through tubular means from said vehicle to said driving head, and through openings in the rear wall of said driving head into the annular space between said tubing and the earth wall of said conduit, said composition capable of hardening to a substantially rigid shape.

29. The method as in claim 20, including the step of injecting a fluid into the interior of the collapsed uneverted tubing whereby said fluid will flow through the collapsed tubing to the point of eversion, then between the back wall of said head and said tubing, and then into the annular space between said tubing and the earth wall of said conduit.

30. The method as in claim 20, including the step of cutting the collapsed uneverted tubing, and sealing the end connected to the everted tubing.

31. The method as in claim 20, including the step of attaching an object to the collapsed portion of said tubing, whereby as the tubing is forced into the conduit,

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said object will be carried along inside of said everted tubing in said conduit.

32. The method as in claim 20, including the additional steps of placing hammer means behind and moveable with respect to said driving head, and applying a pulsating fluid pressure to said tubing, whereby said everting tubing will apply a pulsating force to said hammer means causing it to strike repetitive percussive blows to said driving head.

33. The method of claim 20, including the additional steps of attaching a sharp-edged cylindrical tube to the front end of said driving head, driving said tubing and said head forward in said conduit until said head strikes the earth, whereby a core of earth will be cut and positioned in said tube, removing said fluid pressure from said tubing, retrieving said tubing and said head, and removing the earth core from said head.

34. The method of transporting an object of diameter d along a prepared cylindrical conduit of diameter D , where d is less than D , comprising,

- (a) inserting said object into the mouth of said conduit,
- (b) attaching one end of a collapsed flexible evertible tubing circumferentially to annular anchoring means at the mouth of said conduit,
- (c) progressively forcing said tubing through the anchoring means and the attached end of said tubing into said conduit by means of fluid pressure applied to said tubing,
- (d) continuing to apply fluid pressure to said tubing, causing it to progressively evert as it moves down the conduit until the everting portion of said tubing reaches said object, and

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(e) continuing to apply fluid pressure to said tubing to keep the everting end of said tubing in contact with said object,

whereby as said tubing continues to evert and extend itself along said conduit it will force said object ahead of it along said conduit.

35. The method as in claim 34 in which said object has an attached retrieval means and including the additional step of retrieving said object by pulling back on said retrieval means.

36. The method as in claim 34 in which said object has an attached retrieval means comprising a small diameter flexible means threaded through the collapsed un-everted portion of said tubing, and including the additional steps of pulling back on said retrieval means and pulling back on said uneverted tubing.

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