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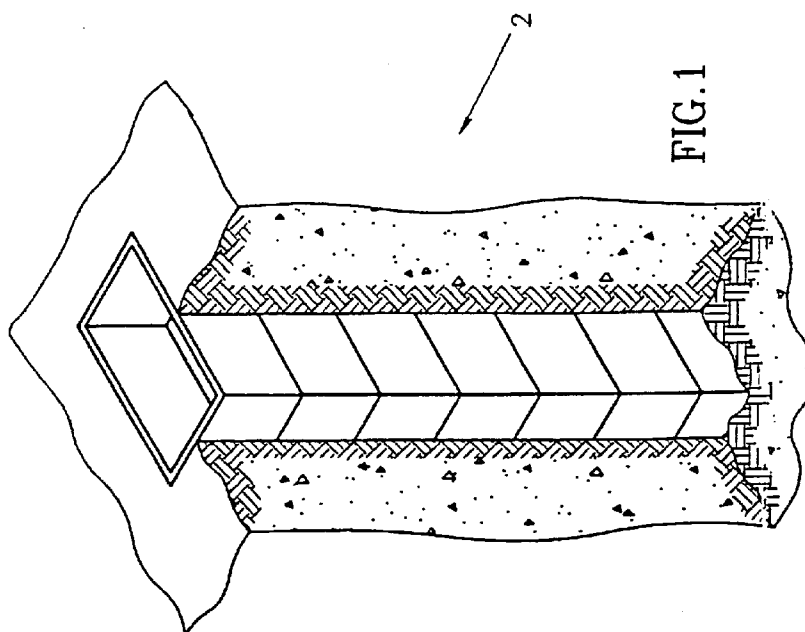
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### (54) Construction of holes and tunnels having support walls

(57) A method for constructing an underground construction comprising a hole or tunnel having support walls, the method comprising the steps of excavating an initial hole or tunnel segment, forming at least a portion of the initial segments so that its walls assume a final shape and size corresponding to the external shape and size of the support walls, inserting at least a leading support wall element into a the

segment, excavating a further hole segment, forming the further hole segment so that its walls assume a final shape and size corresponding to the external shape and size of the support walls, allowing the at least first support wall element to translocate into the further segment and introducing one or more trailing support wall elements into the initial segment, repeating necessary steps until constructing the entire hole.



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## Description

### FIELD OF THE INVENTION

The present invention is generally in the field of excavations, e. g. construction of foundation elements, retaining walls and tunnels.

### BACKGROUND OF THE INVENTION

Excavation of holes with support walls is required in several cases, particularly in loose soil or at excavations performed at watery environments, such as underwater excavations or excavations performed at high water tables. Holes with support walls may be useful also for obtaining higher strength of foundation elements or retaining walls.

One method for constructing a hole with support walls is by first excavating the hole, placing an insert into the hole and then casting concrete into the space between the insert and the walls of the hole. This method is not suitable for excavating in a watery environment unless, the excavation is constantly filled with a substance such as Bentonite or suitable polymeric substances, which must then be subsequently pumped out during the concrete casting procedure.

This is a time consuming procedure requiring special equipment and is relatively expensive. A further disadvantage of such a method lies in that the surface quality of the casted foundation elements or retaining walls (after removing the surrounding soil) is rough and for obtaining a smooth surface finish, treatment of the surface is necessary which again is a time and labor consuming procedure.

Another known method for excavating holes with support walls is by excavating an opening in the ground of a size substantially larger than the size of the actual required size of the hole, then inserting precast reinforcing wall elements into the excavation and then filling back the removed soil into the gap between the walls of the excavation and the external faces of the reinforcing elements and pressing it. This method is complicated and time consuming and is restricted to substantially short and vertical excavations.

It is an object of the present invention to provide a novel method for constructing holes or tunnels with reinforcing walls in which some of the above-noted disadvantages are substantially reduced or overcome.

### SUMMARY OF THE INVENTION

According to the present invention there is provided a method for constructing an underground construction comprising a hole or tunnel having support walls, the method comprising:

- (a) excavating an initial hole or tunnel segment;
- (b) forming at least a portion of said initial segments

so that its walls assume a final shape and size corresponding to the external shape and size of the support walls;

(c) inserting at least a leading support wall element into a said segment;

(d) excavating a further hole segment;

(e) forming said further hole segment so that its walls assume a final shape and size corresponding to the external shape and size of the support walls;

(f) allowing said at least first support wall element to translocate into said further segment and introducing one or more trailing support wall elements into said initial segment;

(g) repeating steps (d) - (f) until constructing the entire said hole.

According to one embodiment of the method according to the present invention, the excavation is substantially vertical and the construction, which comprises a hole having support walls, serves as a foundation element. According to another embodiment, the method comprises constructing a plurality of substantially vertical holes having support walls adjacent one another, these constructions serving as members in a retaining wall.

According to still another embodiment of the present invention, the excavation is horizontal or slanted, to construct a tunnel with support walls, useful as ducts, as pipes for protecting cables, e.g. telephone or electric cables, contained therein, etc.

At times, the method according to either of the above embodiments may comprise also filling the space confined within the walls of the holes with a filler substance, such as concrete, reinforced concrete, gravel, soil, etc. This is particularly the case where the construction is a vertical hole serving as a foundation element or a member in a retaining wall. Where the method involves filling the confined space with a filler substance, particularly concrete, the wall elements may comprise apertures for introducing concrete or the like into the interstice between the inner walls of the excavations and the external faces of the support walls. Alternatively, or in combination, contact grout or concrete may be applied into the interstice directly by injecting it through tubes inserted therein.

Where the constructions form part of a retaining wall, one side of all wall elements may have a shape or patents so that all such sides together form a uniform wall. The wall elements may consist of several elements which together form a tubular, e.g. cylindrical or prismatic, wall element. For example, each wall element may consist of two members with a substantially U-like cross-sectional shape, which together form a tubular wall element.

In accordance with one embodiment of the invention, at least one side of the wall elements is removable. In another embodiment, an inner surface of at least one side of the wall element is covered with a polymer sub-

stance.

The leading wall element may be identical or different to the other wall elements. According to a preferred embodiment of the invention, the leading wall element comprises a wedge-like leading edge on at least one side thereof.

According to a preferred embodiment of the invention, the excavation is performed by an excavating equipment comprising pressure members adapted for applying force in a radial direction. Where the excavation is a tunnel, the wall elements may be inserted and translocated within the hole by the use of such an excavation equipment.

Also provided by the present invention are prefabricated wall elements for use in conjunction with the method of the invention.

For better understanding, the invention will now be described, by way of example only, with reference to specific embodiments illustrated in the accompanying drawings.

## DESCRIPTION OF THE DRAWINGS

**Fig. 1** is an isometric view partially cut-out of a rectangular foundation element constructed according to the method of the present invention;

**Figs. 2a - 2g** illustrate the steps of constructing the foundation element of Fig. 1, each figure showing a front and a side cross-sectional view;

**Fig. 3** is an isometric view partially cut-out of a cylindrical foundation element constructed according to the method of the present invention;

**Figs. 4a - 4g** illustrate the steps of constructing the foundation element of Fig. 3;

**Figs. 5a - 5h** illustrate the steps of constructing a tunnel according to the method of the present invention;

**Fig. 6** is an isometric view partially cut-out of a retaining wall constructed according to the method of the present invention;

**Fig. 7** is an isometric view illustrating a male-female connection of two consequent cylindrical wall elements of a foundation element according to the present invention;

**Fig. 8** is a top cross-sectional view illustrating one way of locking two adjacent wall elements of a retaining wall constructed according to the method of the present invention;

**Fig. 9** is an isometric view of a rectangular leading wall element according to the present invention;

**Fig. 10** is a cross-sectional view along line X-X in Fig. 9;

**Fig. 11** is an isometric view of a wall element comprising a removable side wall;

**Fig. 12** is an isometric view of a wall element formed of two U-shaped wall elements;

**Fig. 13** is an isometric view of a wall element according to the present invention comprising apertures; and

tures; and

**Fig. 14** is an isometric view partially cut-out of a foundation element illustrating how contact grout is injected into the interstice between the inner walls of the hole and the external walls of the reinforcing elements.

## DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Attention is first directed to Figs. 1 and 2a-2g showing how a rectangular foundation element **2** is constructed according to the present invention.

At a first step, an initial hole segment **4** is excavated, for example by an excavating equipment **6**, such as that disclosed in PCT Patent Application WO 94/19272, comprising an excavating clamshell buckets **8** and surface clamping plates **10**, adapted for lateral extraction and retraction, the excavating equipment being operated and displaced into and out of the excavation by cables **12** and **13**. In addition, various other excavating equipment may also be used.

After the initial hole segment **4** is excavated, the surface clamping plates **10** apply lateral pressure on the inner wall of a portion **14** of the initial hole segment **4**, as can be seen in Fig. 2B, whereby the walls of the portion **14** assume a final shape corresponding to the external shape and size of a rectangular leading reinforcing wall element **16**. After hoisting the excavation equipment **6**, from the hole, a leading wall element **16** is inserted into the formed portion **14**, as shown in Fig. 2C. The wall elements are typically prefabricated elements, the nature of which will be explained in more detail below.

The next step in constructing the foundation element, as illustrated in Figs. 2D, is digging a further hole segment **18** and then the pressure plates **10** expand and form the walls of segment **18** so that they assume a shape and size corresponding to the external shape and size of the reinforcing wall elements.

Upon retraction of the pressure plates **10**, after forming the further segment **18**, the leading wall elements **16** drops into the further segment **18** and after withdrawing the excavating equipment **6**, a trailing reinforcing wall element **20** is introduced into the initial hole segment **4** as shown in Fig. 2E.

The above procedure is repeated as illustrated in Figs. 2F and 2F until a foundation element **2** of a required depth is obtained, illustrated in Fig. 1.

Reference is now made to Figs. 3 and 4A-4G of the drawings, illustrating how a cylindrical hole **30** with a support wall is constructed according to the method of the present invention.

At a first step, an initial bore segment **32** is drilled, for example by using the drilling equipment **34** as disclosed in GB Patent No. 2176519, comprising a drilling tool such as an auger **36** connected to a drive (not shown) and further comprising clamping shells **38** hav-

ing the shape of cylindrical segments, adapted for applying radial pressure on the walls of the bore and pressing the ground. As an alternative to auger **36**, also a bucket or any other drilling tool adapted to the soil conditions may be used. The drilling equipment is introduced and removed from the bore by a hoisting cable **40**.

After drilling the initial bore segment **32**, at least a portion of its wall are pressed by clamping shells **38** and the walls of the hole then assume a shape and size corresponding to the external shape and size of an initial leading cylindrical wall element **42**. Then, the drilling equipment is hoisted from the bore and the leading wall element **42** is inserted into the initial segment **32** as shown in Fig. 4c.

Thereafter, the drilling equipment **34** is again lowered into the bore through the confined space of leading wall element **42** and a further hole segment **44** is then excavated as shown in Fig. 4D. Then, the further hole segment **44** is formed by the clamping shells **38** to the shape and size corresponding to the external shape and size of the reinforcing wall elements **42** (Fig. 4D). Upon retraction of the clamping shells **38**, the leading wall element **42** drops into the further hole segment **44** and after the drilling equipment **34** is withdrawn from the bore, a trailing wall element **46** is inserted into the initial bore and over the leading wall element **42**, as shown in Fig. 4E.

The above steps are repeated (Figs. 4F and 4G) until constituting a complete hole with reinforcing walls **30** of the required depth, as seen in Fig. 3.

Referring now to Figs. 5A - 5H, it will be explained how a horizontal tunnel with support walls may be constructed according to the present invention. However, it should be obvious that tunnel construction in accordance with the invention is not restricted to horizontal and may obviously also be diagonal.

The principle difference between tunnelling and constructing foundation elements is that tunnels are substantially horizontal holes in which gravitation forces do not assist in excavating or in inserting the wall elements and thus, specialized equipment is required.

Drilling equipment **60** comprises a drilling end **62** (which may be for example a drilling bit, an auger or a bucket drill or any other drilling tool adapted to the specific ground conditions; in case of a drilling bit continuous drilling operations may be obtained by the aid of a flushing system) attached by a first shaft **64** to a drive (not shown) and further comprising a first set of clamping shells **66** linked by a second shaft **68** to a second set of clamping shells **70**, both sets of clamping shells capable of radially expanding and retracting. The shafts **64** and **68** are axially retractable.

At a first step, an initial hole segment **74** is drilled (Figs. 5A, 5B). Then the first set of clamping shells **66** are radially expanded whereby they clamp against the inner wall of the hole, followed by extraction of the first shaft **64**, whereby the drilling end **62** is urged into the

soil and further drilling is performed (Fig. 5C). Then clamp shells **66** contract and shaft **64** retracts. Subsequently, clamp shells **70** radially expand and clamp against the wall of the hole and the second shaft **68** extracts (Fig. 5D).

After forming the initial hole segment **74** by the clamp shells **66** and **70**, the drilling equipment is removed from the hole and a leading wall element **78** is inserted into the initial hole segment **74**.

The drilling equipment is then inserted through said leading element **78** and the above procedure is repeated (Figs. 5E-5G), whereby the tunnel is lengthened and trailing wall elements **80** are inserted following the leading wall element **78**, until completing the tunnel (Fig. 5H).

The design of the clamp shells **66** and **70** is such that inserting the wall elements **78** and **80** may be performed by the aid of the clamp shells clampingly gripping the wall elements at their inner surfaces and advancing them into the hole (as illustrated in Fig. 5G).

Fig. 6 of the drawings illustrates a retaining wall **90** constructed of plurality of vertical reinforced holes **92**, each consisting of a plurality of wall elements **94** and constructed as explained in connection with Figs. 1 and 2A-2G.

In order to assure aligning of the holes **92** and of wall elements **94** with one another, adjacent wall elements **94** above one another are fixed to one another by a male-female arrangement **96**, whereas adjacent wall elements near one another are fixed by other male-female arrangement **98**.

Turning now to Fig. 7, it is shown that a male-female arrangement **100** is also suitable for fixing two cylindrical wall elements **102** and **104** above one another, each such wall element comprising at a bottom edge thereof several cut-outs **106** whereas the opposed, top end of each of the elements comprises projections **108** of a shape and size adapted to blend with the cut-outs of a trailing wall element.

Fig. 8 of the drawing illustrates another method for fixing adjacent, neighboring wall elements of a retaining wall. According to this method, each of the wall elements **112** and **114** of holes **116** and **118**, respectively, has U-like shaped sides **120**, whereas when the two neighboring wall elements are constructed adjacent one another with the U-shaped edges facing one another, there is created a cavity **122**. This cavity may be reinforced by cement cast or by soil, rocks, etc., whereby lateral movement between the adjacent reinforcement holes **116** and **118** is prevented.

Figs. 9 and 10 show a rectangular leading wall element **128** comprising a wedge-like edge **130** at two opposed edges thereof. This arrangement is useful in blazing the trail of the leading wall element by scraping the soil projecting into a hole segment which may obstruct the advancing of the wall elements. The wedge-like edge is also operating as a guide for the excavating tool while being extracted from the hole.

The confined space within the walls of the hole may be filled with a filler substance which may be, for example plain or reinforced concrete, soil which has been removed during excavating the hole, rocks, etc.

If a foundation element or a retaining wall is later to be exposed by removing the surrounding soil, it may at times be desired to have one or more sides of the construction with a decorative pattern or design, or simply obtain a good surface quality which will require no further operations thereon.

The rectangular wall element **138** of Fig. 11 comprises a removable wall **140** secured to the element by locking nuts **142**, the inner surface of the wall **140** comprising a molding pattern. The arrangement is such that after constructing the hole and casting concrete in it, the ground surrounding the foundation element or retaining wall is excavated and the removable walls **140** (all facing the same side) are removed, exposing a concrete wall having the negative design of the decorative pattern of the inner surface of the removed wall.

In order to obtain still a better surface quality, the inner surface of at least the removable wall **140** may be coated with a polymeric substance, which will ensure a smooth concrete surface.

Fig. 12 illustrates how a tubular wall element **146** may be constructed of several segments, in the present case of two substantially U-like shaped elements **148** and **150**, with locking members **152** for attaching the elements to one another. Such elements are useful for example for constructing a retaining wall, where the partitioning walls between neighboring wall elements are removed, whereby a continuous wall is obtained.

Where it is required to improve contact between a foundation element or retaining wall and between the ground, e.g. in cases of extreme loads to be applied on the construction, or at watery environments, it is at times useful to introduce concrete or a contact grout in the interstice between the inner wall of the hole and between the external faces of the wall elements. For that purpose, for example, wall elements **160** as seen in Fig. 13 may be used, such elements comprise a plurality of side apertures **162**. After inserting the wall elements into the hole, concrete is introduced into the space confined within the walls, which then penetrates into said interstice through the apertures **162**.

In addition or in the alternative the contact between the construction and the surrounding ground may also be improved by applying contact grout directly into the interstice **166** as shown in Fig. 14, by a plurality of injecting tubes **168** introduced into the interstice **166**, each tube comprising a plurality of nozzles **170**. The tubes **168** are connected to a central tube **172** receiving pressurized contact grout from a pressure unit **174** whereby the contact grout is forcefully injected into the interstice **166**.

Excavations for constructing the holes according to the present invention may be performed by a variety of excavating means, however, it should be noted that an

important feature of the excavating equipment is its ability to apply lateral pressure onto the walls of the hole for forming them into the shape and size corresponding to that of the external shape and size of the reinforcing walls, whereby the walls of the hole are pressed.

It should be obvious to a person versed in the art that the wall elements are prefabricated elements manufactured at a large variety of sizes and of various materials, e.g. plain or reinforced concrete, polymers, metal or various combinations thereof.

It would also be obvious to a person versed in the art that other locking means may be used for obtaining linkage between adjacent wall elements in order to ensure their alignment.

## Claims

1. A method for constructing an underground construction comprising a hole or tunnel having support walls, the method comprising:
  - (a) excavating an initial hole or tunnel segment;
  - (b) forming at least a portion of said initial segments so that its walls assume a final shape and size corresponding to the external shape and size of the support walls;
  - (c) inserting at least a leading support wall element into a said segment;
  - (d) excavating a further hole segment;
  - (e) forming said further hole segment so that its walls assume a final shape and size corresponding to the external shape and size of the support walls;
  - (f) allowing said at least first support wall element to translocate into said further segment and introducing one or more trailing support wall elements into said initial segment;
  - (g) repeating steps (d) - (f) until constructing the entire said hole.
2. A method according to Claim 1, wherein the wall elements are made of concrete.
3. A method according to Claim 1, comprising excavating a substantially vertical hole and inserting said wall elements into the hole.
4. A method according to Claim 3, comprising filling the space confined within the walls of the hole by a filler substance.
5. A method according to Claim 3, wherein the hole with reinforcing walls serves as a foundation element.
6. A method according to Claim 3, comprising constructing a plurality of substantially vertical holes

with reinforcing walls adjacent one another, the constructions serving as members in a retaining wall.

7. A method according to claim 5, wherein one side of the retaining wall has a shape or pattern so that all such sides together form a uniform wall. 5
8. A method according to claim 1, comprising excavating a substantially horizontal hole and inserting said wall elements into the hole, the construction serving as a tunnel. 10
9. A method according to Claim to claim 1, wherein adjacent wall elements are fixed to one another by locking means. 15
10. A method according to Claim 9, wherein said locking means comprise a male-female arrangement.
11. A method according to Claim 1, wherein the wall elements comprise two members with a substantially U-like cross-sectional shape which together form a tubular wall element. 20
12. A method according to Claim 1, wherein one or more wall elements comprise apertures. 25
13. A method according to Claim 1, wherein said leading wall element comprises a wedge-like leading edge on at least one side thereof. 30
14. A method according to Claim 1, wherein one side of the wall elements is removable.
15. A method according to Claim 1, wherein an inner surface of at least one side of the wall element is covered with a polymeric substance. 35
16. A method according to Claim 1, wherein the excavating is performed by excavating equipment comprising pressure members adapted for applying force in a radial direction. 40
17. A method according to Claim 15, wherein the wall elements are inserted and translocated within the hole by said pressure members of said excavating equipment. 45
18. A method according to any one of the preceding claims, wherein a contact grout is applied into an interstice between inner walls of the hole and between external sides of the reinforcing walls. 50
19. For use in a method according to Claim 1, a prefabricated tubular wall element. 55

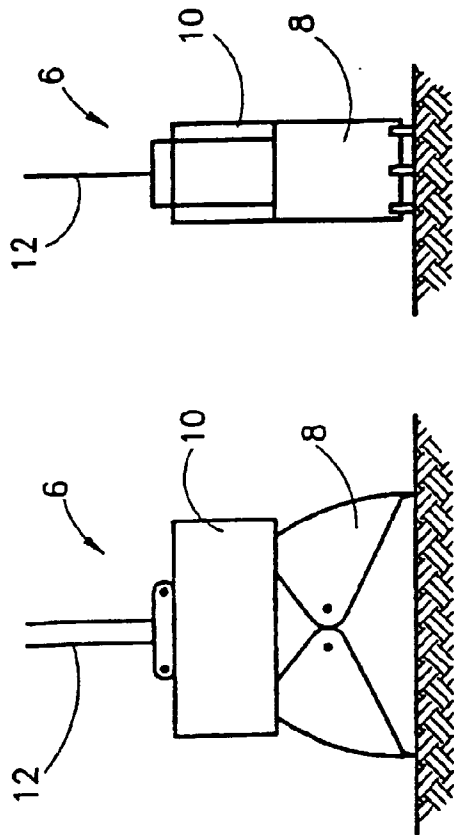
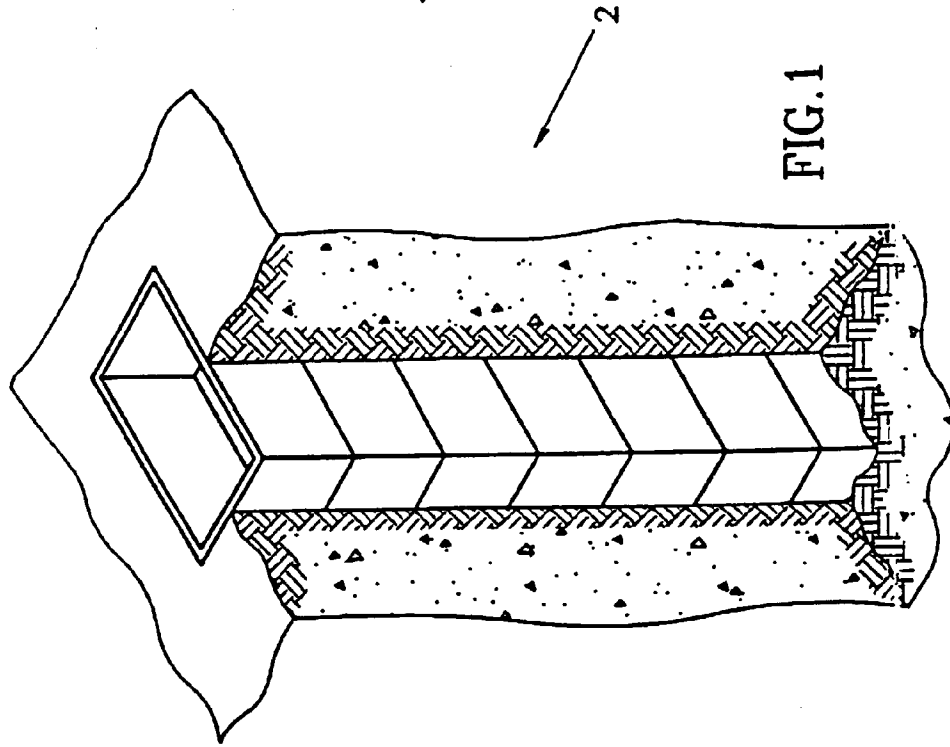


FIG. 2A

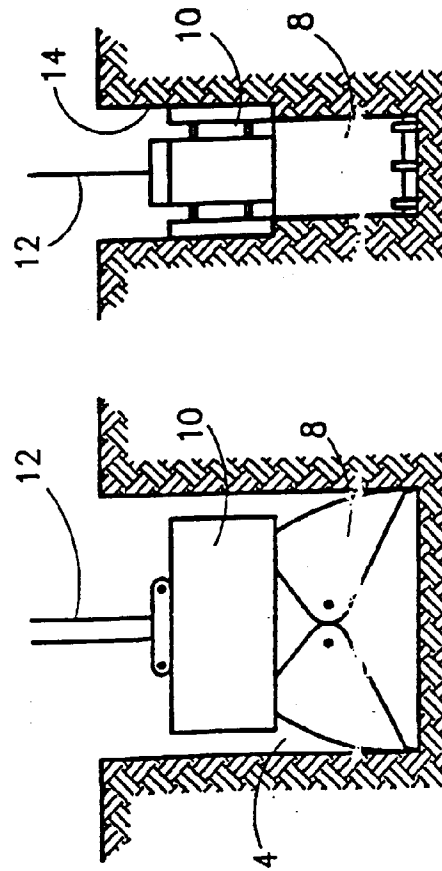


FIG. 2B

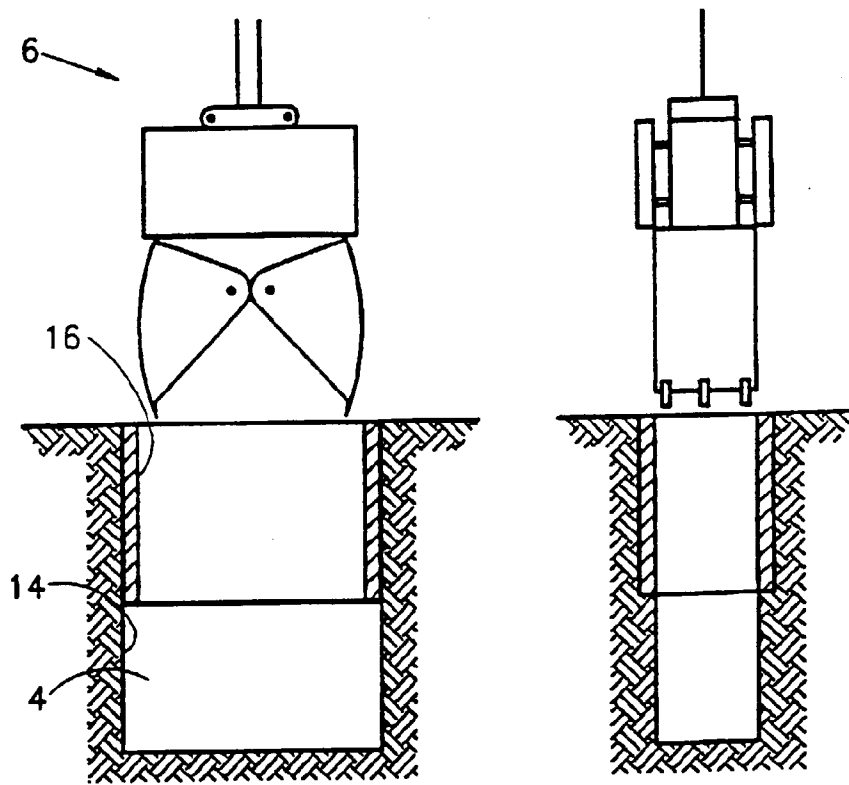


FIG. 2C

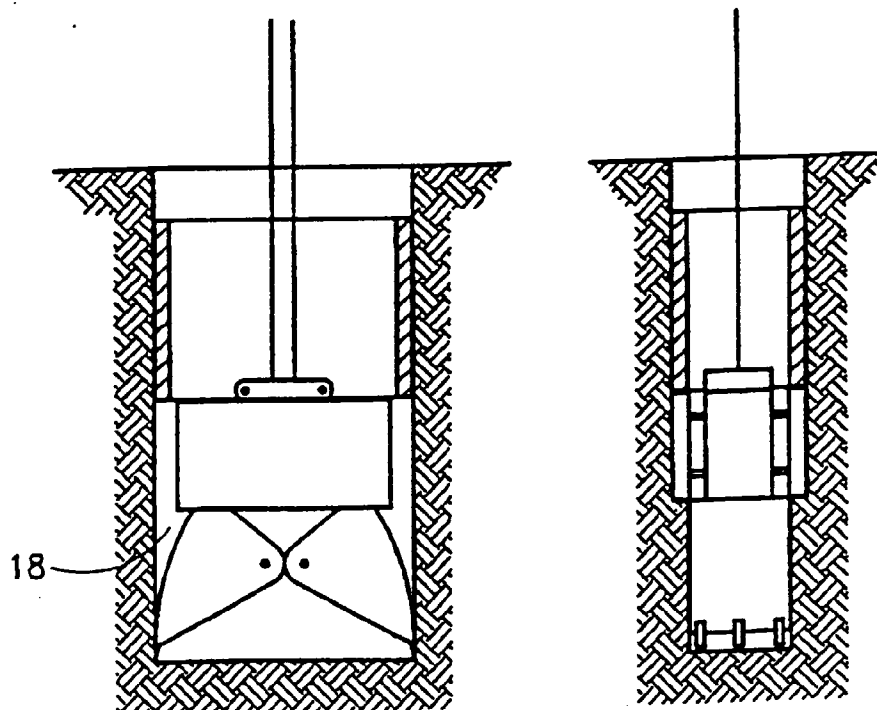
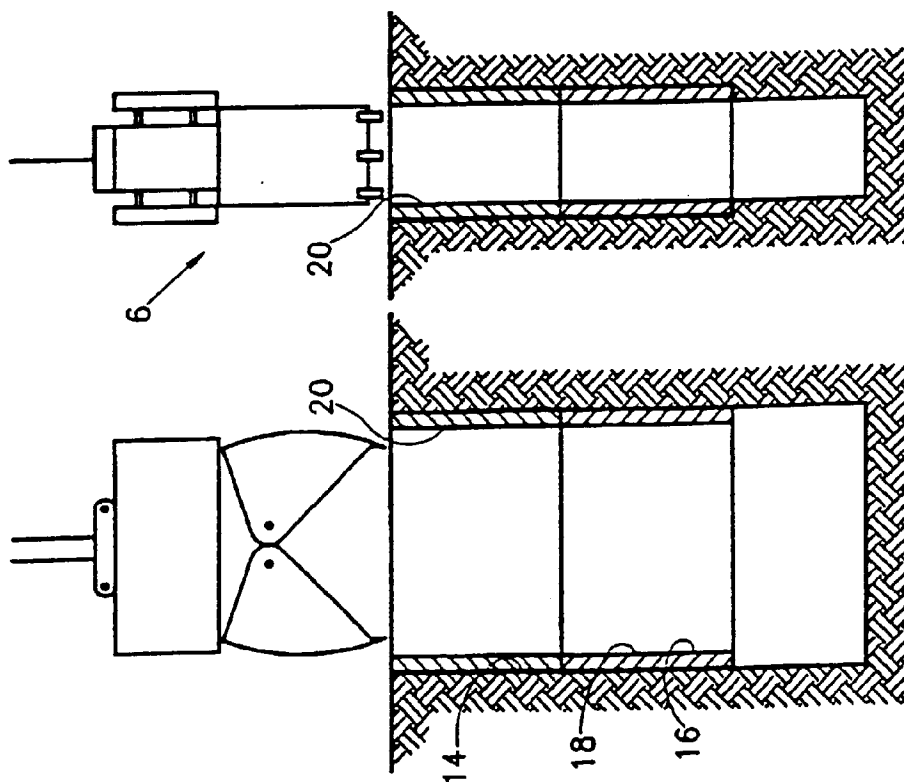
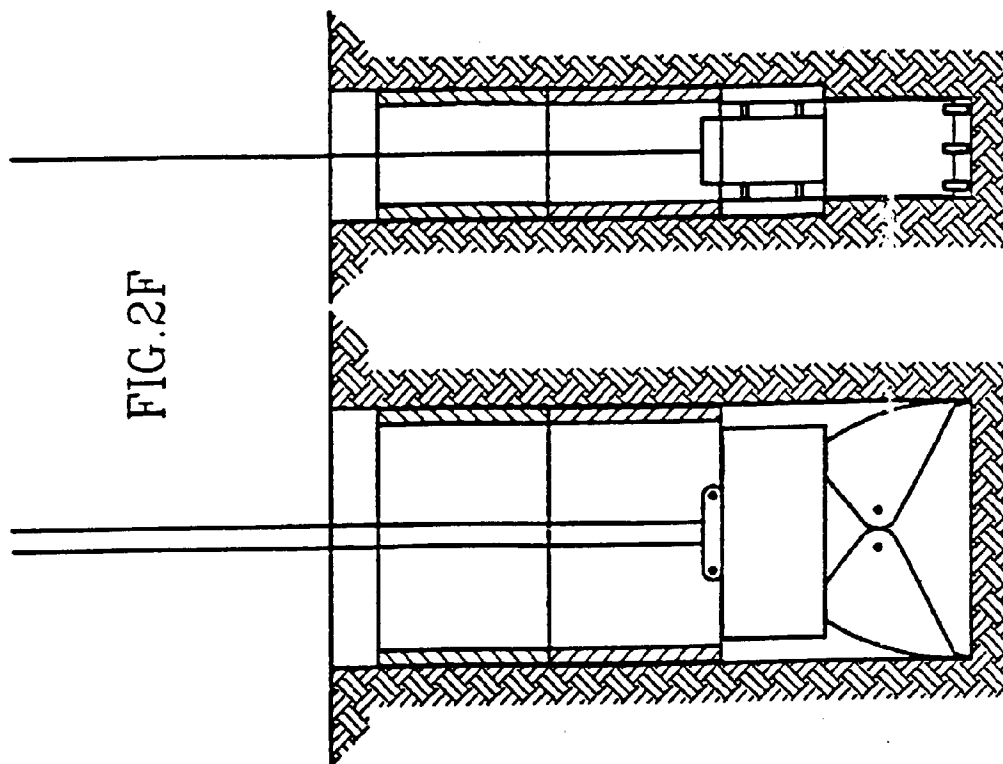


FIG. 2D





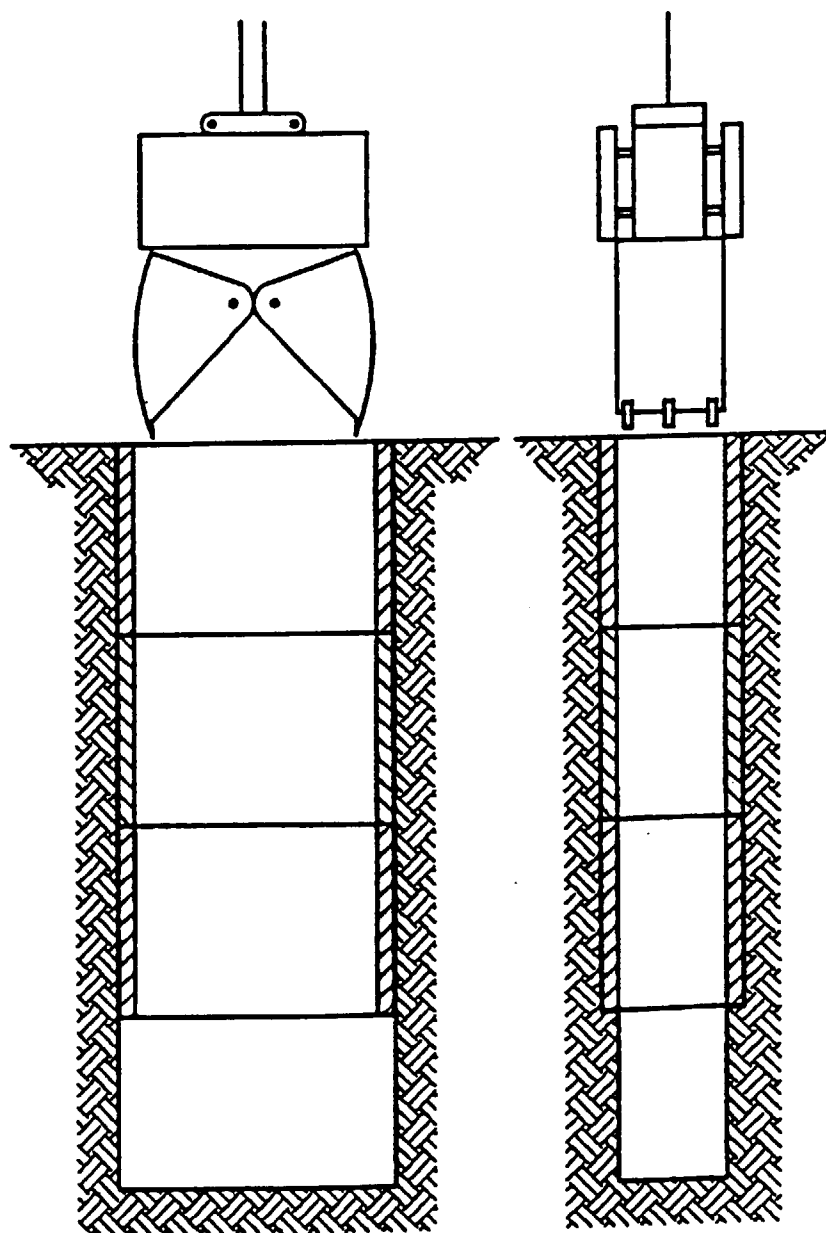
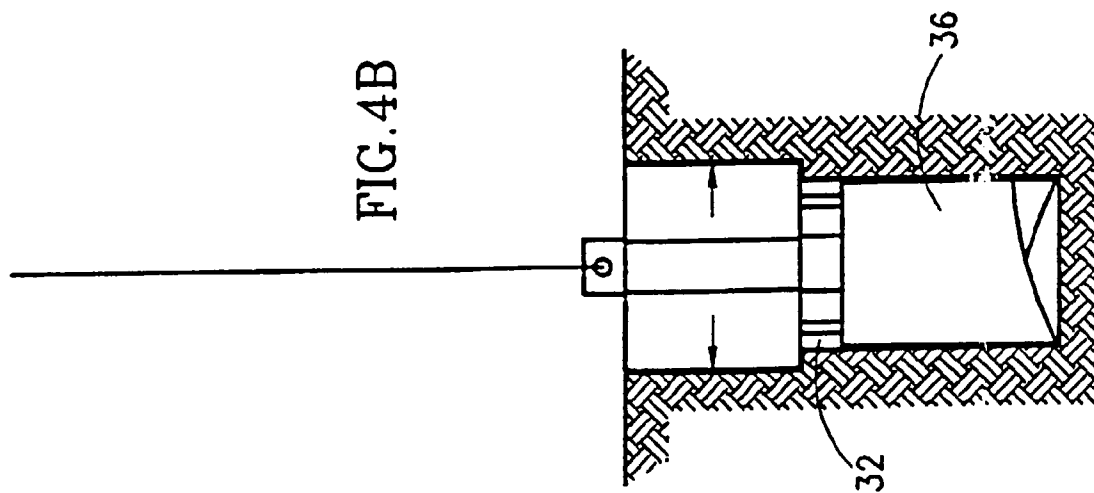
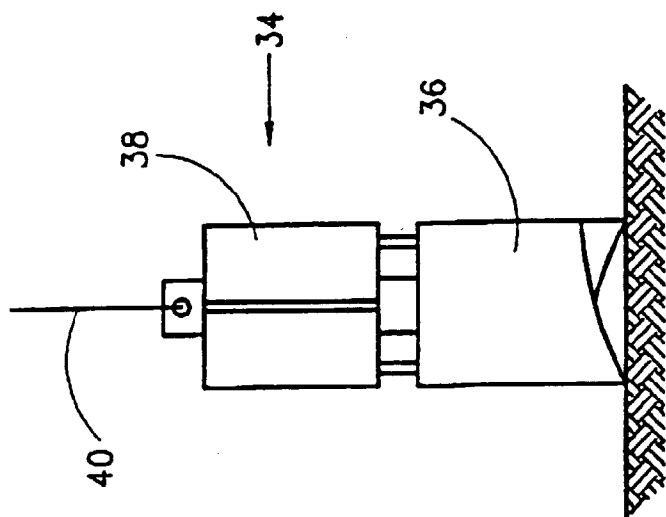
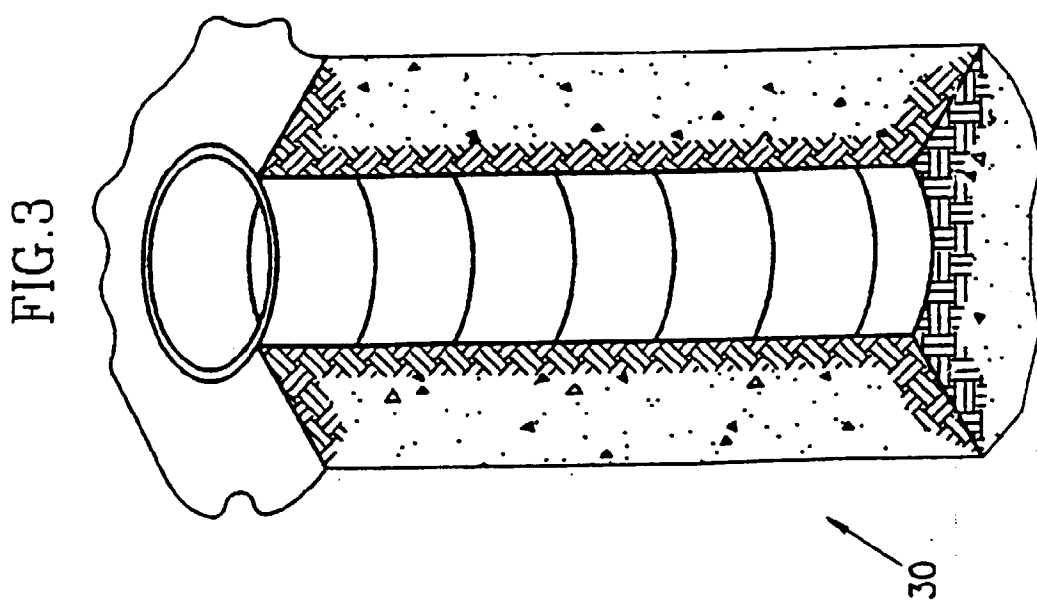


FIG.2G



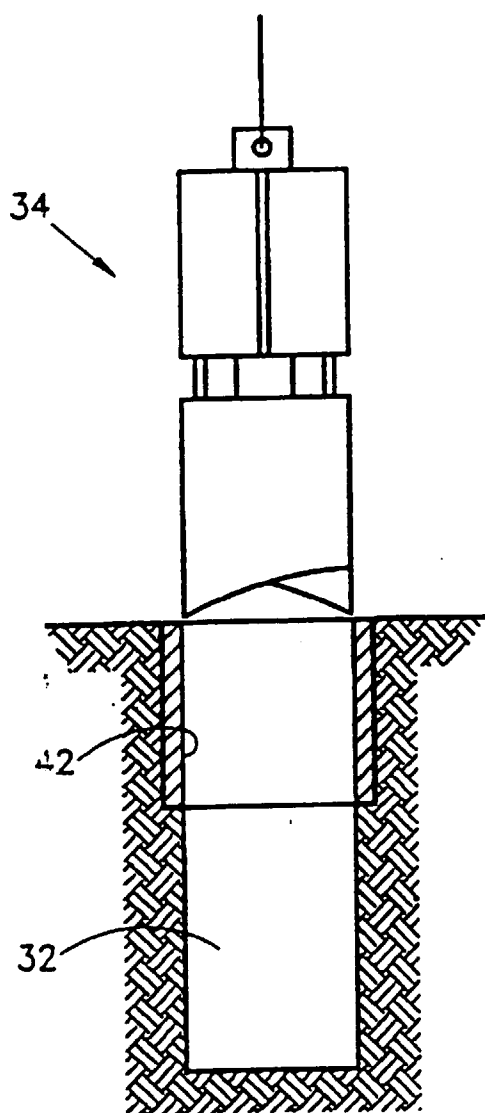


FIG. 4C

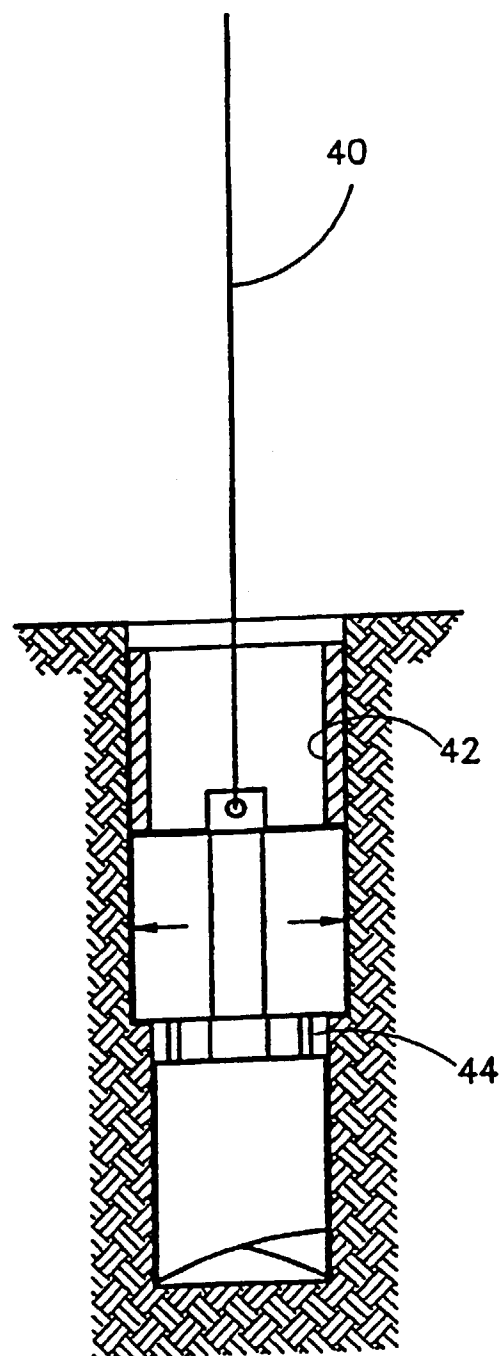


FIG. 4D

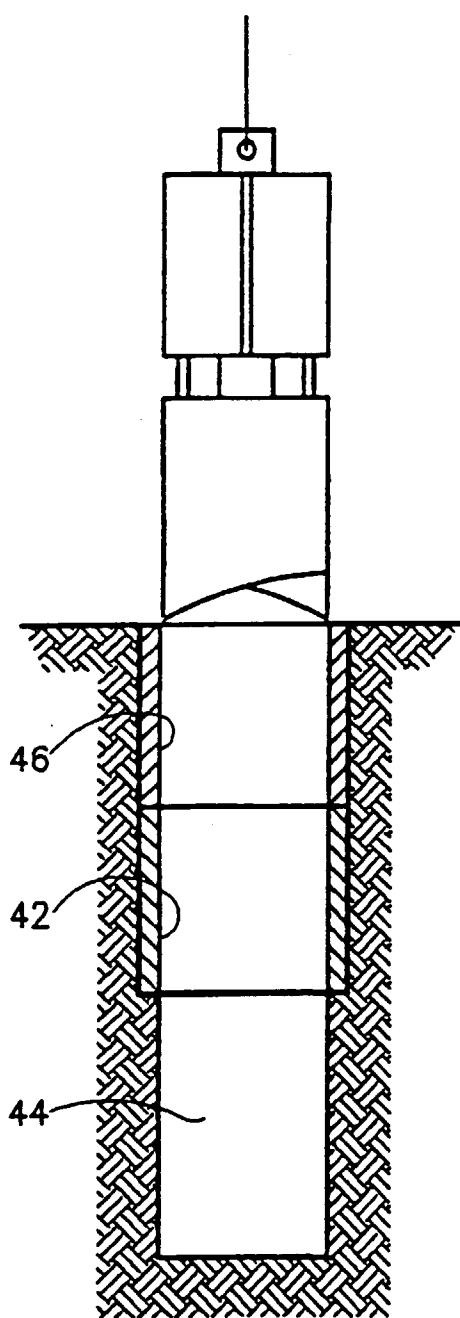


FIG. 4E

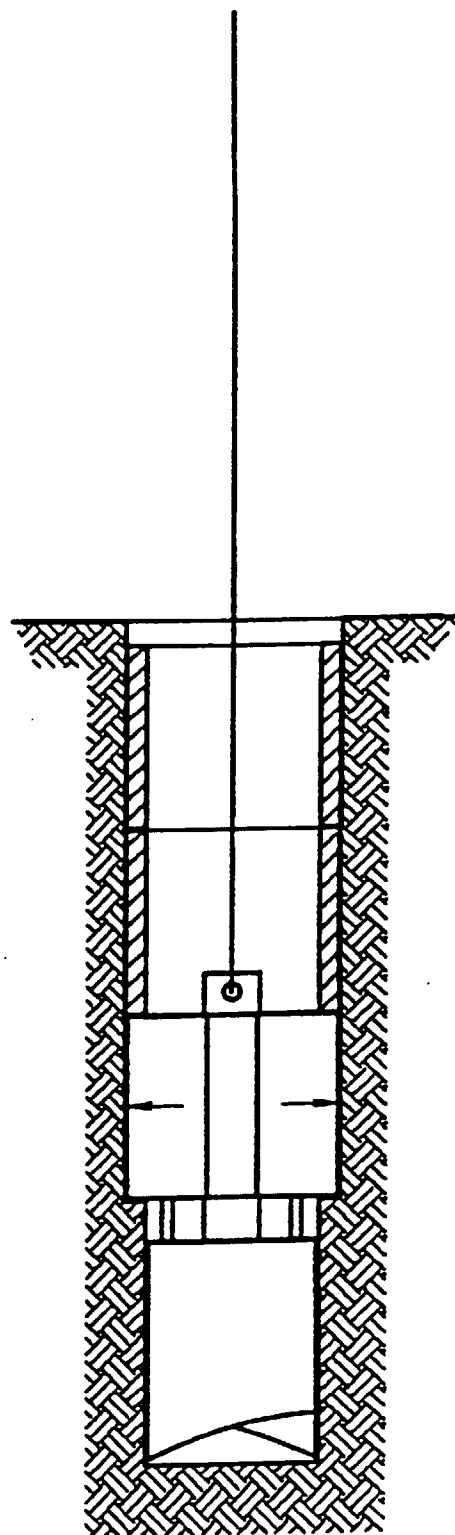


FIG. 4F

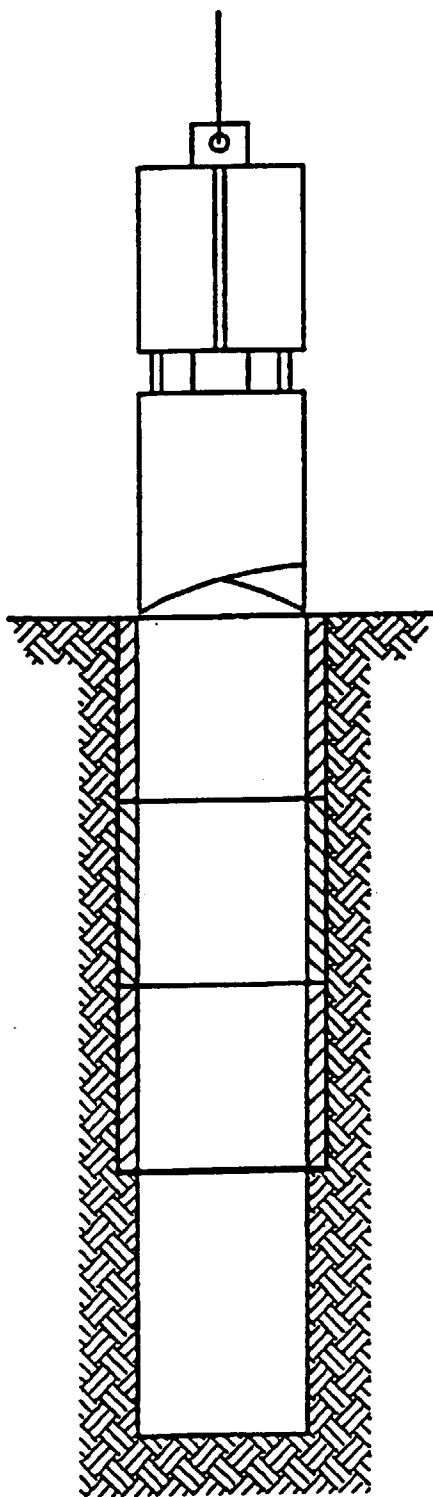
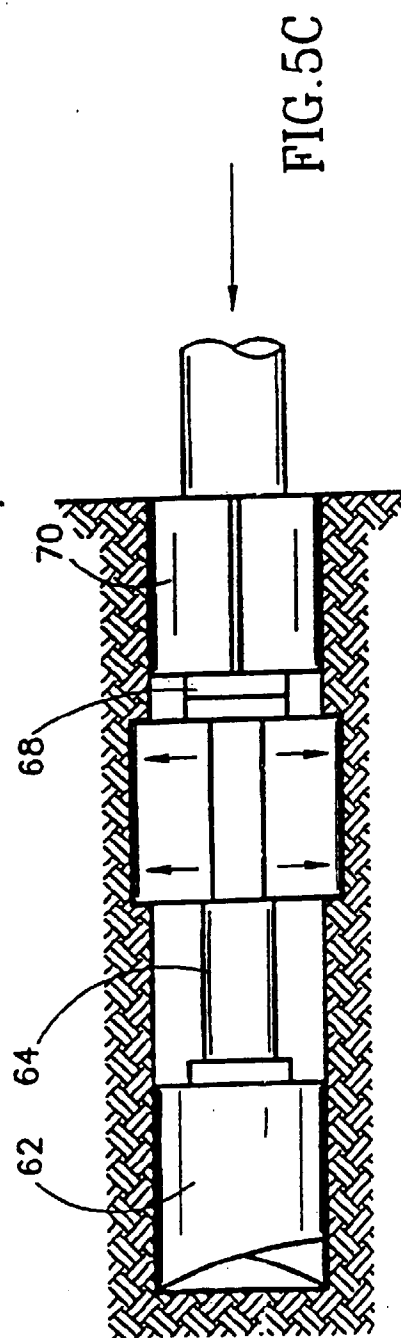
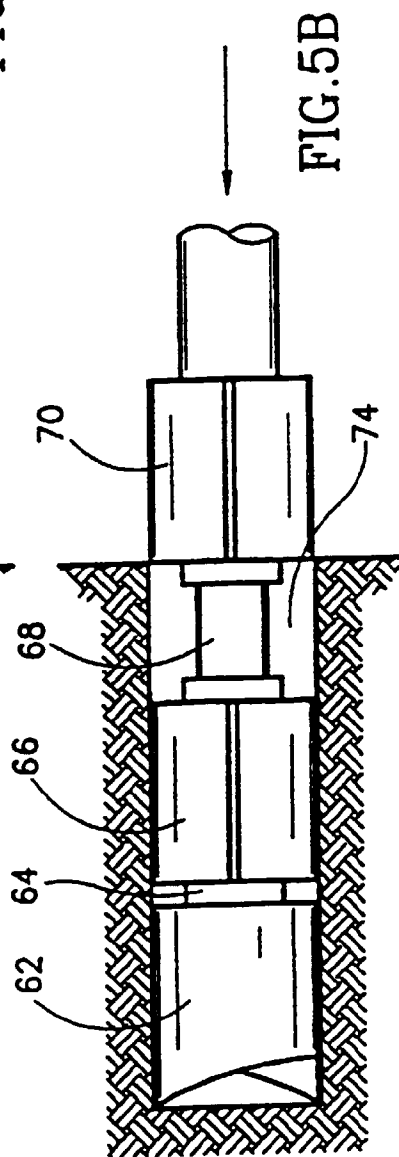
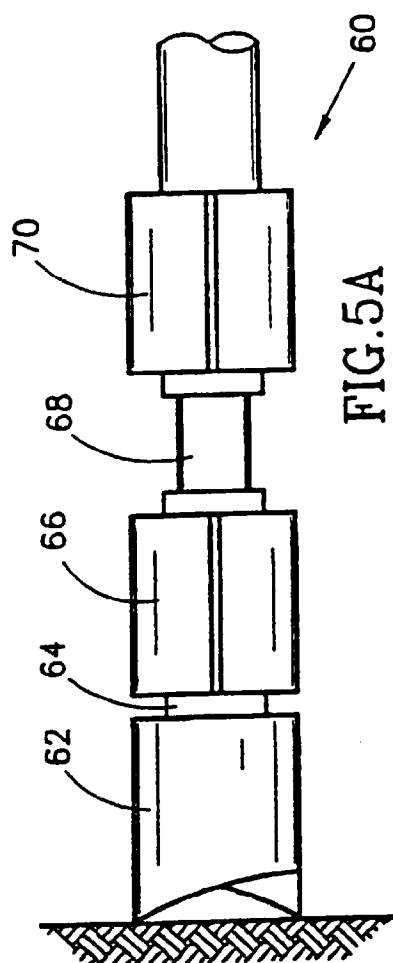
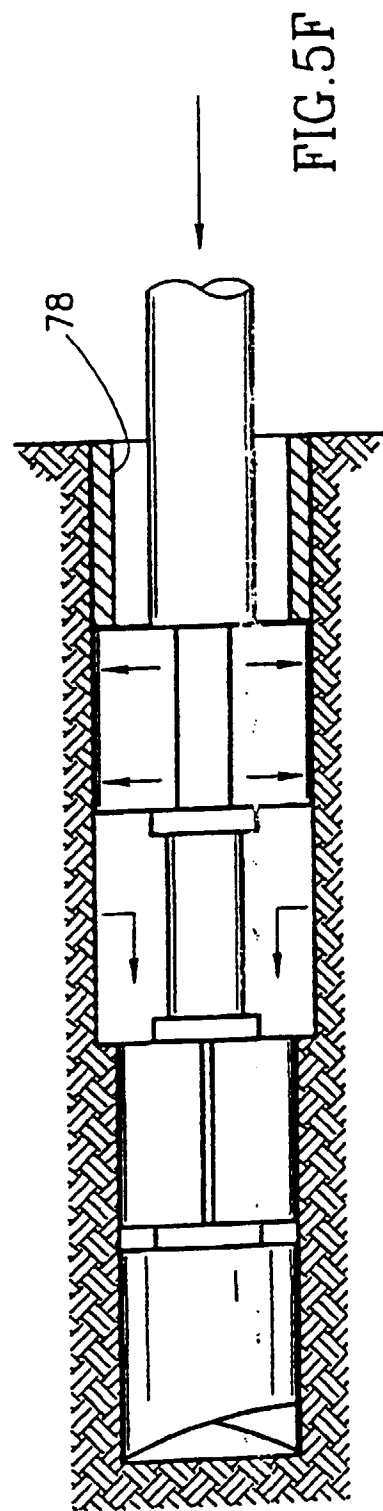
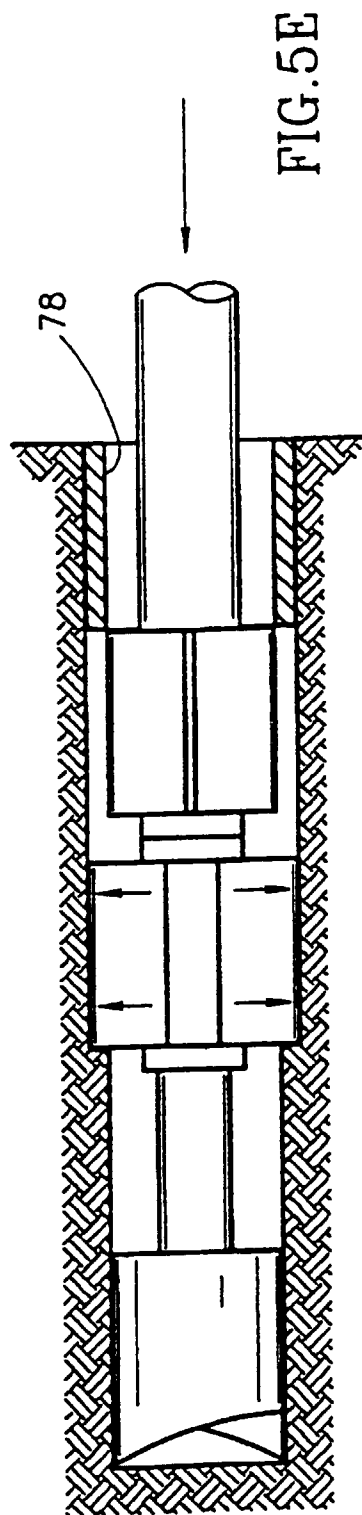
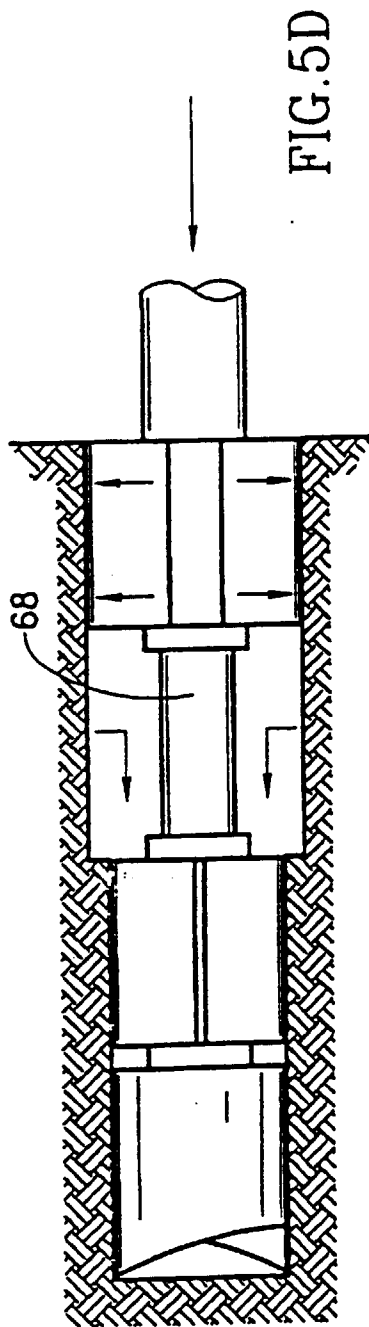
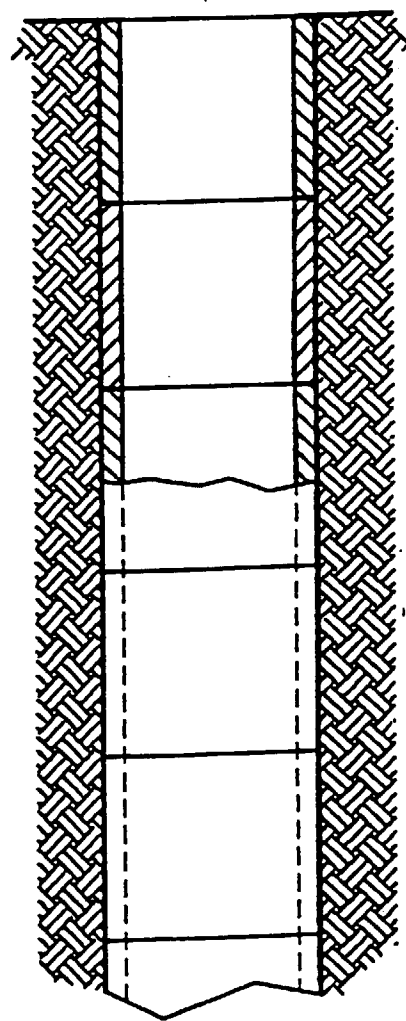
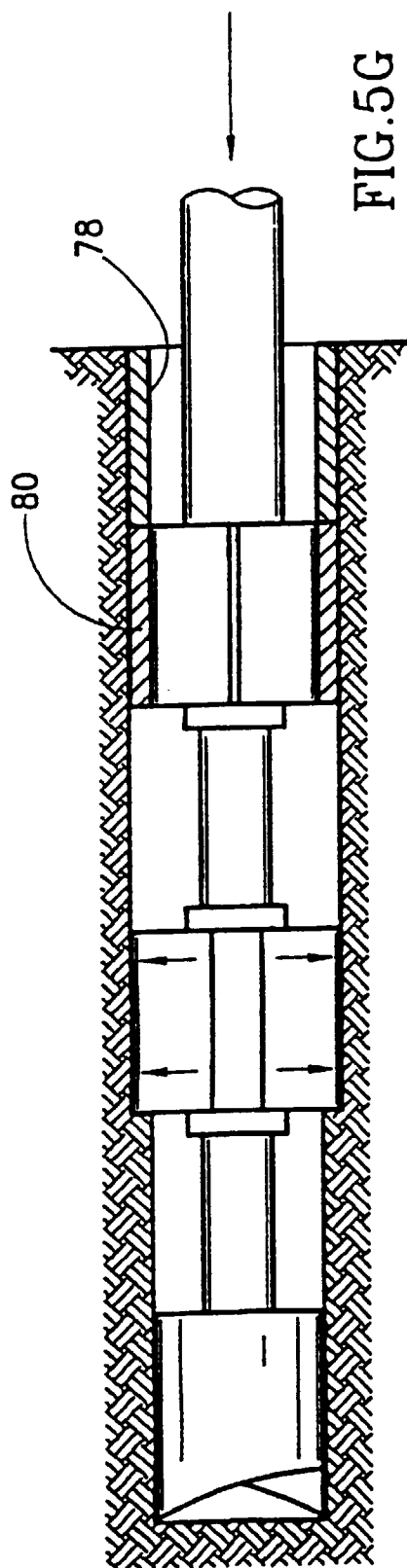


FIG.4G









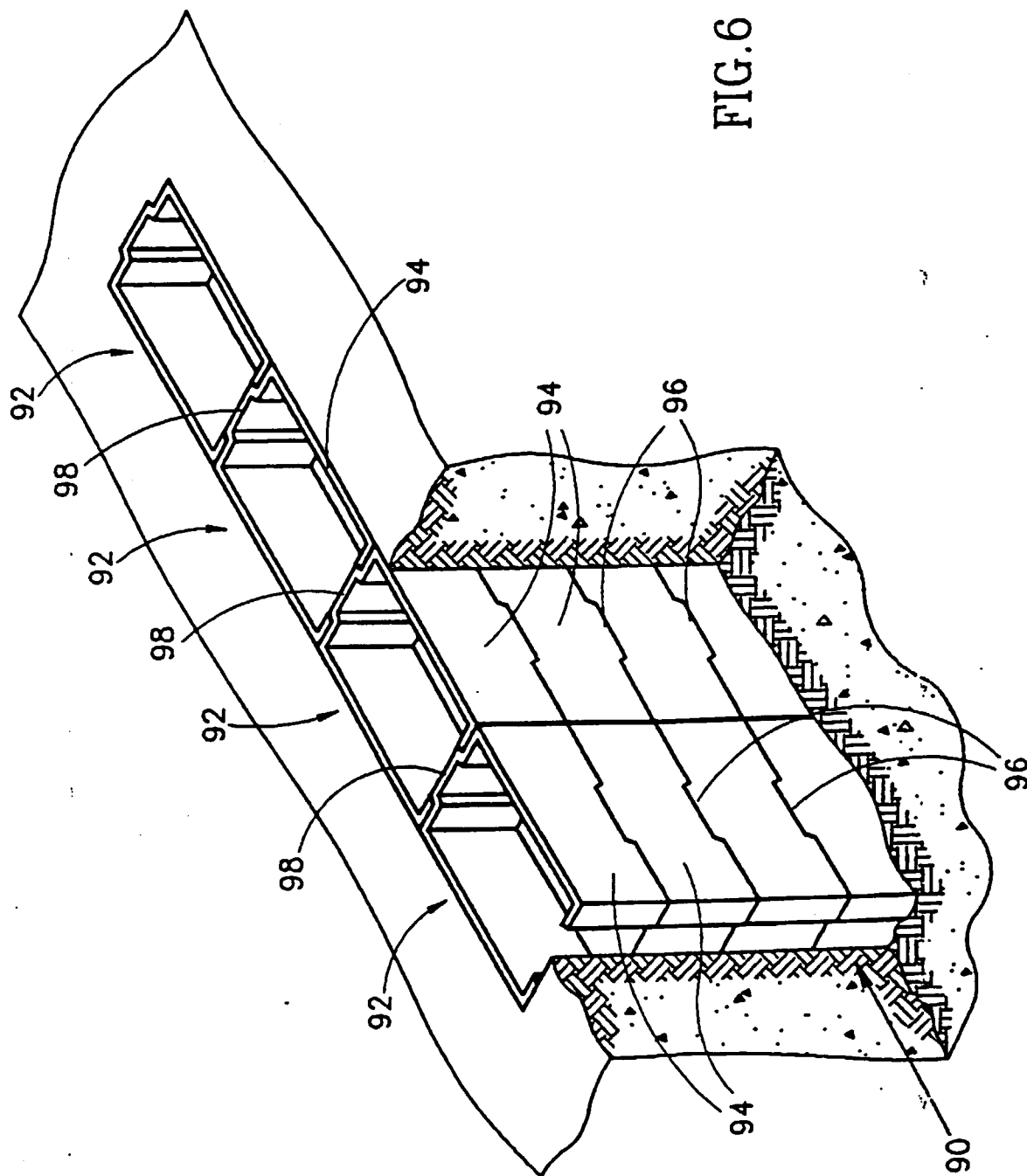


FIG. 6

FIG.9

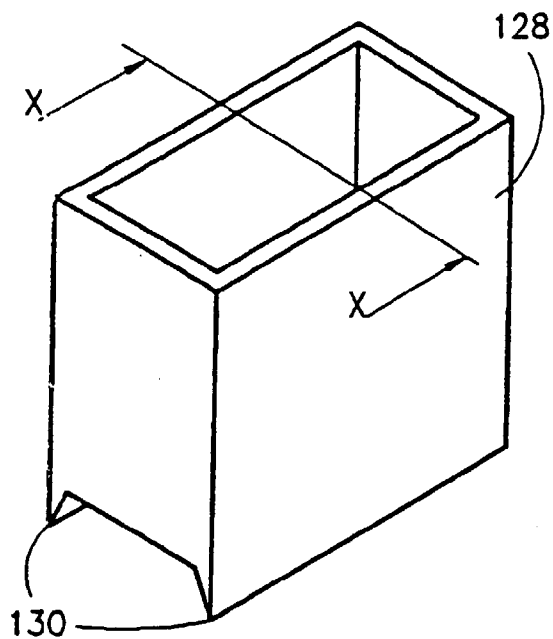


FIG.7

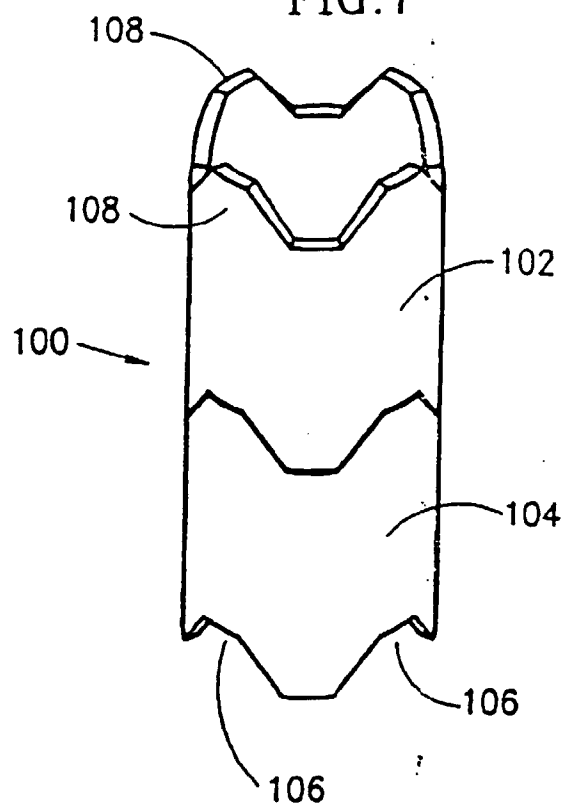


FIG.10

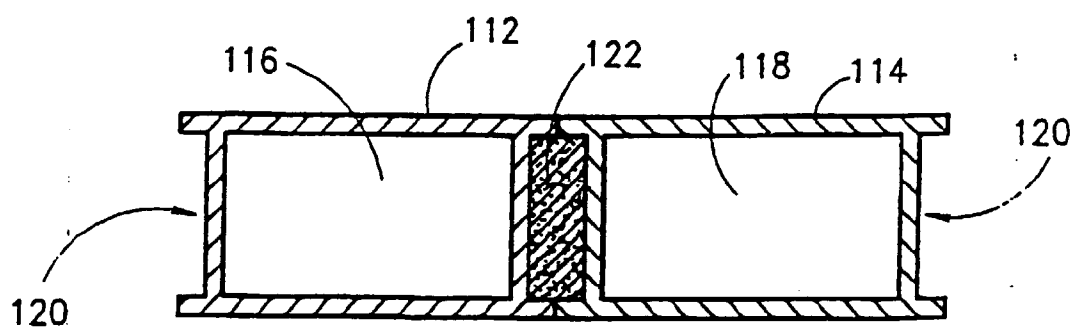
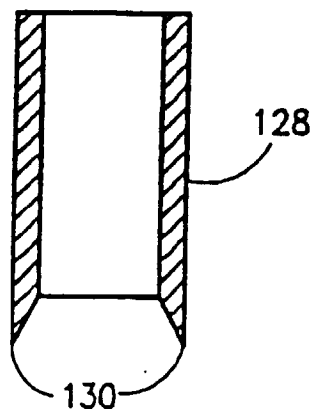


FIG.8

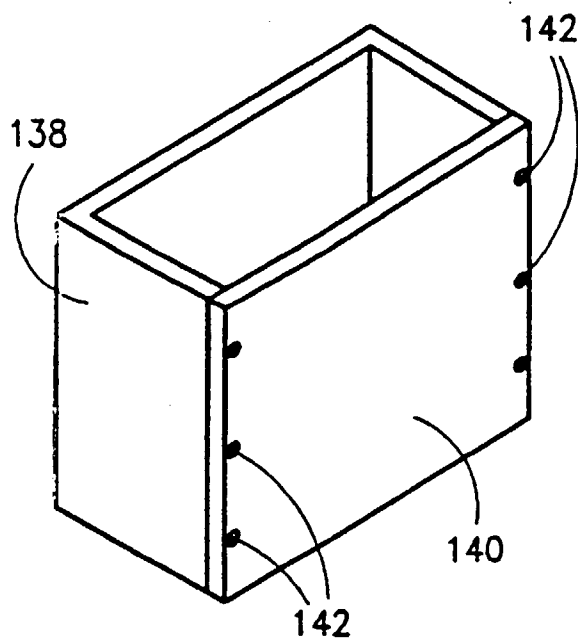


FIG. 11

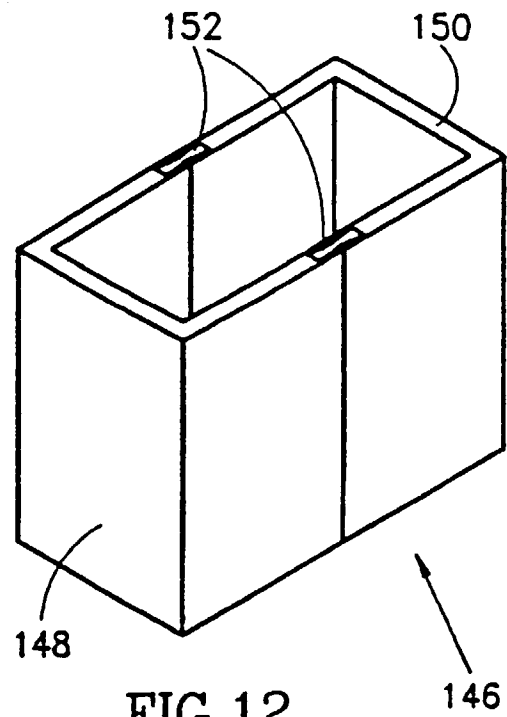


FIG. 12

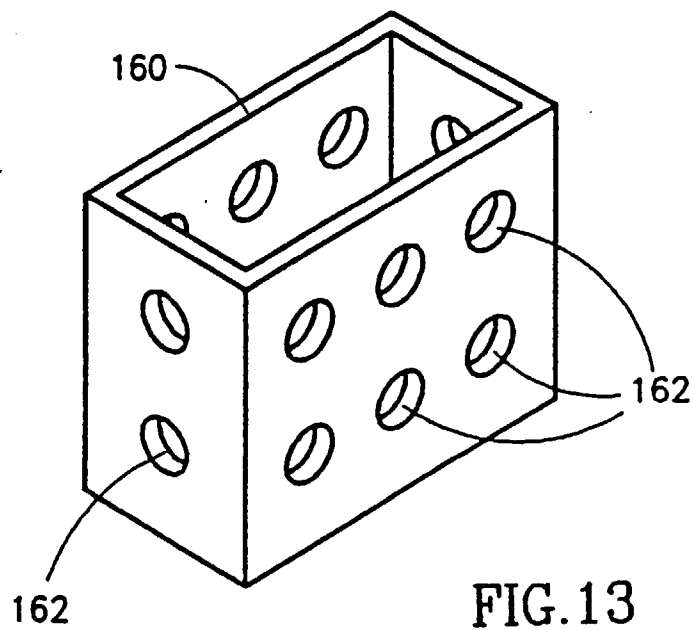


FIG. 13

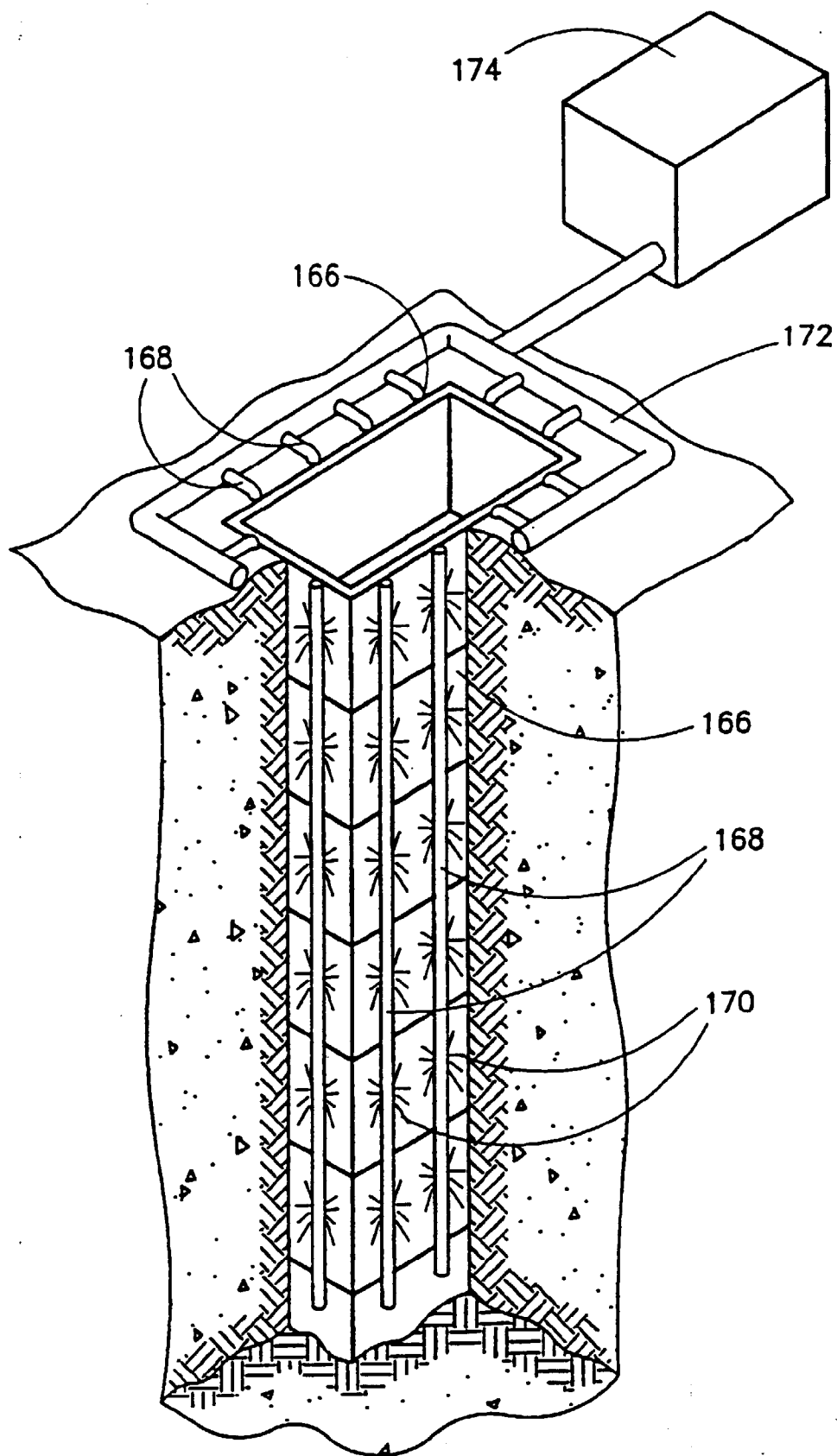


FIG.14