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Geis et al.

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[54] **EARTH BORING METHOD AND APPARATUS**

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[52] **U.S. Cl.** **175/24**, 175/61, 175/62, 175/173

[51] **Int. Cl.** **E21b 7/08**, E21c 9/00, E21c 19/00

[58] **Field of Search** 175/24, 45, 61, 62, 175/73, 171, 173, 258

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[57] **ABSTRACT**

A method and apparatus for boring a hole in the earth utilizing a rotary auger extending through a casing member which guides the lateral cutting direction of the auger as it rotates. During auger advancement through the earth, the boring machine applies axial thrust to the casing member for advancing it through the bored hole directly behind the auger. The casing member is adapted to bend longitudinally whenever the hole deviates from a straight path. The casing member includes circumferentially spaced rods mounted longitudinally within the casing and associated sensor devices for detecting the degree and direction of casing member bending. Movable shoes are mounted adjacent to the exterior of the casing member and are actuated by a control device responsive to signals received from the sensor devices to guide the casing member and auger back toward the desired path.

20 Claims, 4 Drawing Figures

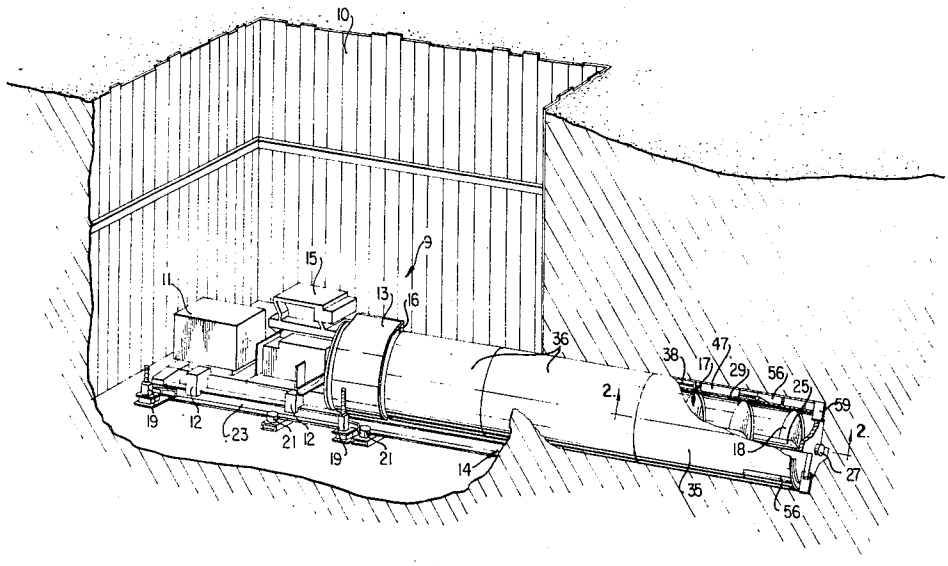
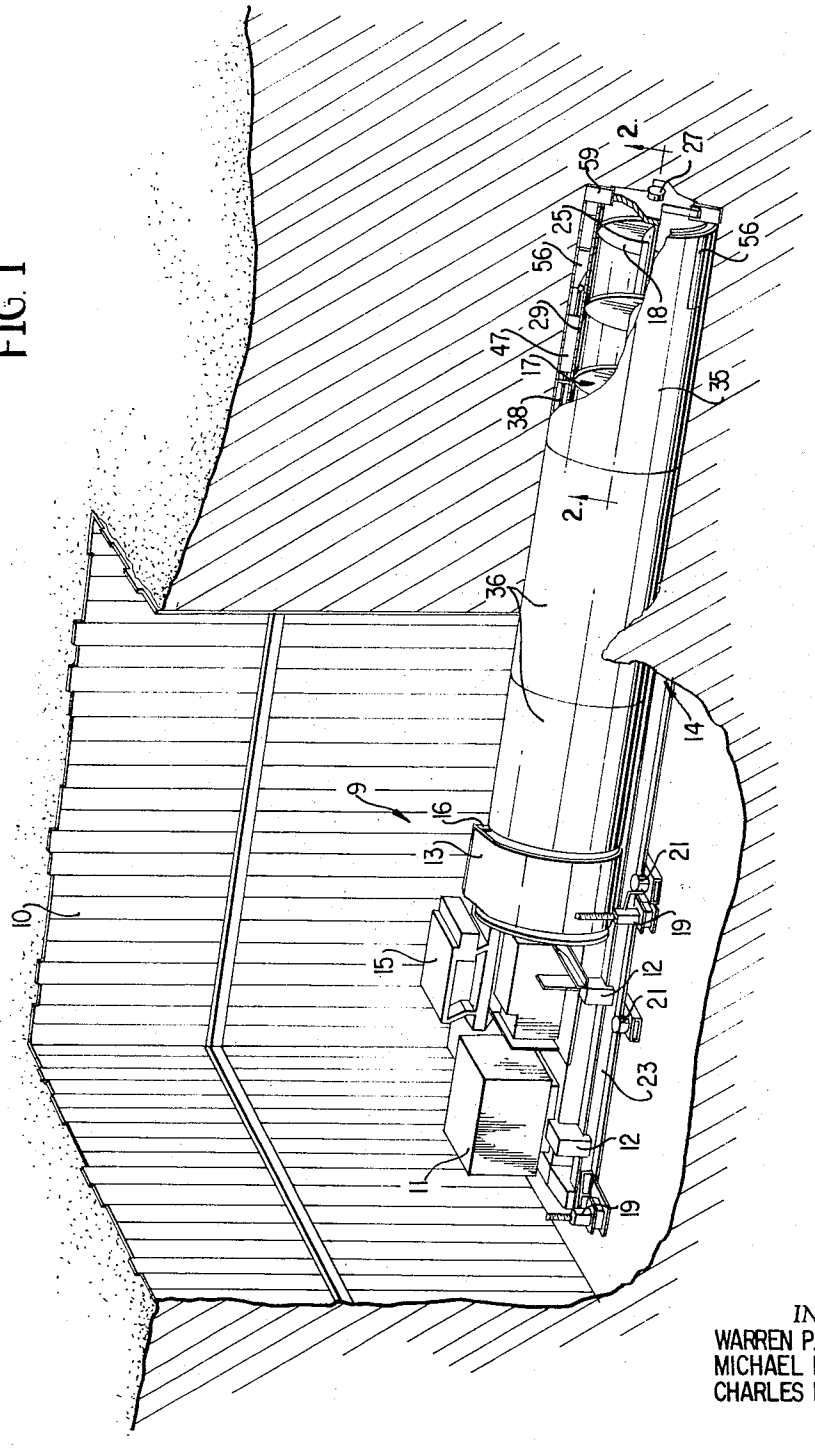


FIG. 1



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FIG. 2

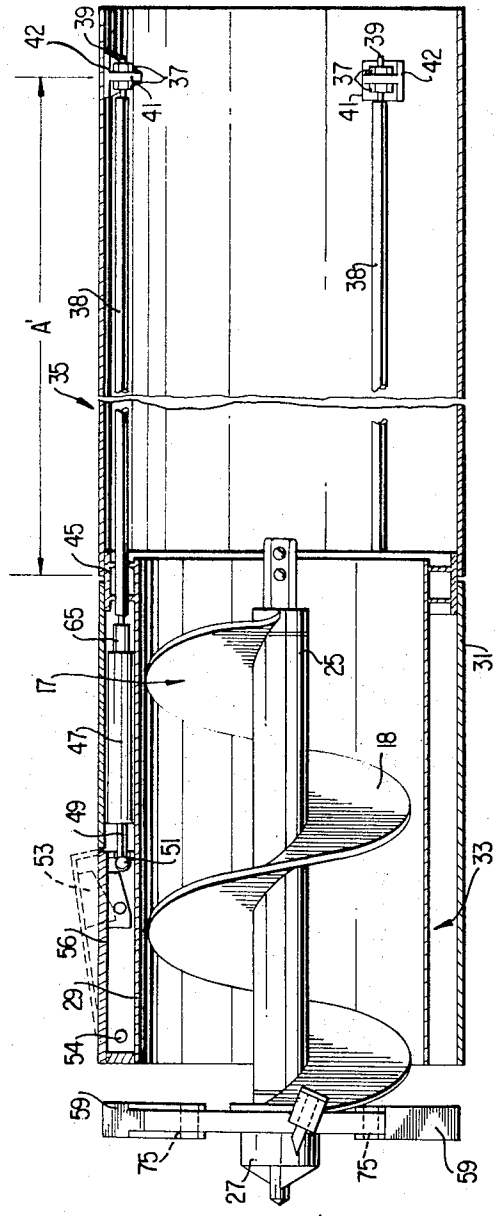


FIG. 3

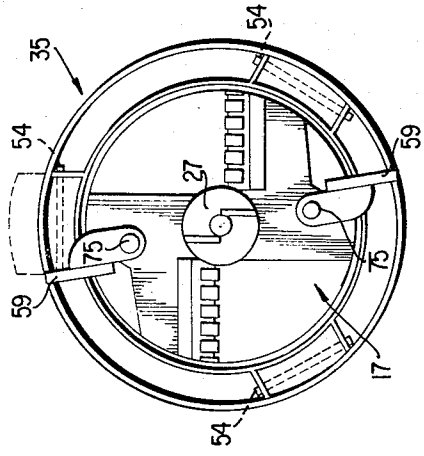
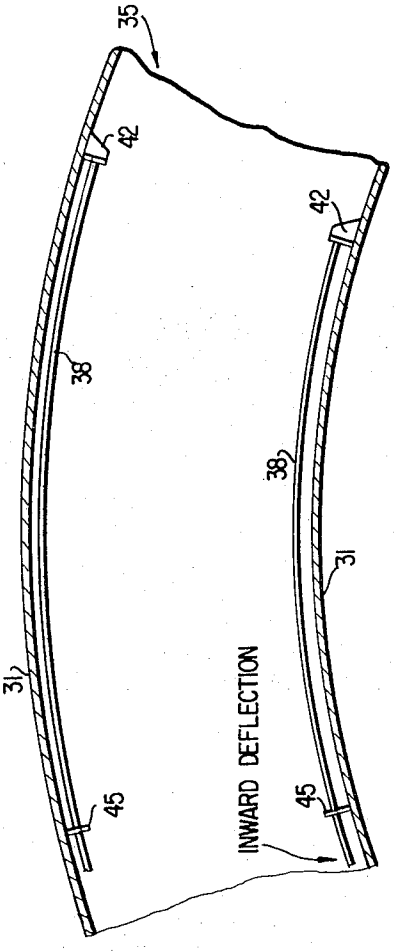


FIG. 4



EARTH BORING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to earth boring, and more particularly to methods and apparatus for boring a hole in the earth with an auger, while simultaneously advancing a casing behind the auger.

Horizontal earth boring equipment has long been used to bury pipes or conduits under the earth, without the necessity of there being an open trench. This method is particularly useful in traversing roads and other obstacles where trenching would be extremely costly and would require temporary interruption of use of the ground surface.

Conventional horizontal earth boring machines include a horizontal frame which supports a carriage for movement along the frame. The carriage supports a source of power, such as an internal combustion engine, for rotating the auger and to provide power for pushing the casing behind the auger. Typically, a casing is supported on the frame and a cylindrical pusher is movable with the carriage and has a circular abutment which engages the rearward end of the casing. The auger extends through the pusher and through the casing and has a cutting head for boring through the earth. As the auger advances, the pusher applies an axial thrust to the casing which causes the casing to advance behind the auger. When the casing has reached the end of the machine frame, the carriage is moved away from the casing, after being disconnected from the casing and from the auger, and another section of the auger is coupled to the first section and another section of casing is welded or otherwise secured to the first section. The carriage is then advanced to position the pusher against the rearward end of the second casing section and the auger is recoupled to the source of power. Boring then continues and additional casing sections and auger sections are added as necessary.

These conventional earth boring machines are capable of producing holes up to 200 feet in length with small diameter casings, and holes of shorter length with casing of as much as 4 feet in diameter.

Since the axial thrust is applied to the casing and the auger at the entrance to the bore hole, as the length of the bore hole increases, there is a tendency for the auger to wander off of the desired straight path. This tendency is further enhanced by uneveness in the resistance to penetration across the width of the bore hole. The presence of rock, for example, on one side of the bore hole may cause the auger to be deflected laterally. If correction is not made for lateral deflection, the bore hole may become so far deviated that additional drilling or reaming operations are necessary to cure the defects in the resulting bore hole.

Various attempts have been made to overcome the lateral deflection experienced by these earth boring machines. For example, one proposed solution has been to provide a radially movable cutter blade on the cutting head of the auger and to move the cutting head outwardly as the auger rotates to enlarge the bore hole in a direction which will return the auger to the desired straight path. Deviation according to this proposed system is measured by flexing of the auger shaft. However, since the auger rotates, it is necessary to provide an elaborate system for expanding and retracting the reaming cutter during each rotation of the auger. Also, if this proposed system were employed while advancing a casing simultaneously with the auger, the reaming cutter would have to extend radially a substantial distance from the periphery of the cutter head to have a significant effect on the direction of advancing movement of the casing. Apparatus of this type is disclosed in U.S. Pat. Nos. 3,554,301 and 3,554,302.

SUMMARY OF THE INVENTION

In view of the deficiencies of prior methods and apparatus for boring and casing holes in the earth, it is an object of this invention to provide a method and apparatus for correcting deviations from a predetermined straight path as the auger and casing advance through the earth.

It is a further object of this invention to provide a method and apparatus for earth boring which is capable of responding rapidly to deviations from the desired path of the bore hole and of guiding the casing and auger toward the desired direction.

It is another object of this invention to provide apparatus for boring straight holes in the earth while advancing casing with the auger and which effectively corrects for deviations from the desired straight path, and which apparatus performs effectively and reliably.

A still further object of this invention is to provide a method and apparatus for continuously sensing and correcting for deviation from the desired straight path as the auger and casing advance through the earth.

These objects are accomplished in accordance with a preferred embodiment of the invention by providing a casing member or section through which the auger extends and which has a sleeve in which the auger is journalled. The cutting head at the end of the auger is spaced from the forward end of the casing member. The casing member is provided with a plurality of shoes at spaced intervals around the circumference of the casing adjacent the forward end. The forward end of each shoe is pivoted on the casing, so that the rearward end of the shoe swings outwardly away from the exterior of the casing, thereby engaging the earth surrounding the casing and applying a lateral thrust to the casing. The shoes are individually actuated by control rods which extend longitudinally of the casing member and which are spaced apart from each other around the circumference on the interior of the casing member. One end of each control rod is secured to the casing member and a sensor is positioned adjacent the opposite end of each control rod. As the casing member bends about a longitudinal axis, the longitudinal movements of the free ends of the respective control rods are sensed by the respective sensors to determine the direction and magnitude of bending. A power device individually operates the guide shoes on the casing and a control device actuates the shoe on the side of the casing that is closest to the direction of bending, causing the shoe to move outwardly from the wall of the casing, thereby deflecting the casing in a direction tending to straighten the casing. The lateral force on the casing is transmitted to the auger, thereby deflecting the auger toward the desired path. As the boring process continues, the control rods and the sensors continuously monitor bending of the casing member to provide the necessary correction by means of the guide shoes as the casing and the auger advance through the earth.

DETAILED DESCRIPTION OF THE DRAWINGS

This preferred embodiment is illustrated in the accompanying drawings in which:

FIG. 1 is a perspective view of an earth boring machine including the guidance casing of the invention;

FIG. 2 is a cross-sectional view of the automatic guidance casing of the invention taken along lines 2—2 of FIG. 1;

FIG. 3 is a front elevational view of the automatic guidance casing of the invention; and

FIG. 4 is a schematic operational view of the control rods in their deflected position.

DETAILED DESCRIPTION

Referring now to the drawings, there is shown a preferred embodiment of the invention. FIG. 1 shows an earth boring machine employing the guidance casing of the invention. This earth boring machine **9**, positioned for horizontal boring, is shown within an open trench **10**. The earth boring machine comprises an internal combustion engine **11** and throttle controls **15** for imparting rotational movement to a drilling auger **17**. The internal combustion engine **11** and throttle controls **15** are secured to a track assembly **23** at **12**. A casing pusher member **13** is slidably mounted on the track assembly forward of the controls **15**. The track assembly **23** in anchored to the ground at the bottom of the trench **10** by means of the anchor pins **21**. Prior to final positioning of the earth boring machine, levelling jacks **19** are utilizable to generally align the track assembly in the desired direction of drilling.

The auger **17** includes a conveyor **18** convoluted about a shaft **25**. The shaft **25** is rotatably coupled to the internal combustion engine **11**. At the forward end periphery of the pusher member **13** there is an annular surface **16** which is positioned to engage the rearward end either of a guidance casing **35** or casing members **36** mounted between the casing **35** and the pusher member **13**.

The guidance casing **35** comprises the longitudinally extending outer cylindrical wall **31** which extends for the entire length of the casing **35**. The front section of this casing, as previously discussed, comprises an inner cylindrical casing wall or guide sleeve **29** which performs a guidance function on the auger **17**. An annular chamber or channel indicated at **33** is formed between the two casing walls at a forward section of the casing **35**.

The foremost portion of the auger assembly includes, in the preferred embodiment, a plurality of rotatable cutting blades **59** which extend outwardly beyond the outer periphery of an outer cylindrical casing wall **31**. An outwardly protruding guide **27** which rotates with the auger shaft **25** is shown at a foremost central portion of the auger assembly. This guide aids in generally centering the auger **17** during the drilling operation. The outwardly extending blades **59**, of a conventional type, are hinged at **75** so that reverse, or noncutting, rotation will cause them to pivot inwardly and allow the removal of the auger blade **17** through the casing **35**.

The front end of the auger **17** extends somewhat ahead of the casing **35**, during the drilling operation. The cutters **59** rotate to cut a bore of sufficient diameter to allow the casing members **35** and **36** to advance as the boring progresses. During the cutting operation, the material being cut from the earth falls downwardly and toward the inside of the casing. This loose material is conveyed through the casing sections, by the conveyor portion of the auger **17**, until the material reaches the pusher member **13**, where it is removed. As the drilling operation continues, the casing is pushed into the augered hole until it reaches the end of the track section shown at **14**. When in that position, the pusher **13** is backed off and a new casing section is inserted behind the guidance casing. It can be appreciated that extendable shaft sections could be continually inserted behind the auger cutter so that drilling may continue for relatively long distances through the earth.

The annular surface **16** at the outer periphery on the casing pusher member **13** engages the rear of the guidance casing **35** and each subsequently added casing member **36** to hold the casing in place and provide a reaction surface.

The cylindrical sleeve **29** has a radius slightly larger than that of the auger **17**. This difference in radii, however, is small enough so that longitudinal deflection of the casing causes the sleeve **29** to apply a lateral force on the auger. The sleeve **29** then generally guides the auger **17** rotating therein. Sections of the auger behind the guidance casing **35** may be supported by the rear casing members **36** if desired. This result may be accomplished in any convenient manner, such as, for example, by providing the rear casing members **36** with internal sleeves comparable to the sleeve **29** on guidance casing **35** or by using rear auger sections having diameters conforming to the internal diameters of the rear casing members **36**.

Guidance means or pusher shoes **56** are disposed at the forward end of the casing **35** within the chamber **33**. Three generally equidistant pusher shoes or wings **56** are shown disposed circumferentially about the casing wall. The pusher shoes **56** have an outer periphery or guide surface which conforms generally to the cylindrical shape of the outer casing **31**. Thus, when the shoes **56** are inoperative they lie flush with the outer surface of the casing **35** and do not interfere with the surrounding earth. When activated, however, they pivot outwardly about a pin **54** with the guide surfaces engaging the bore hole wall thereby passing off of that wall and reorientating the casing **35** and the auger **17**. This outward movement may be maintained at various degrees of inclination from the casing **35**. The shoes **56** are also provided with an inclined cam block **53** which normally extends within the area **33**. The cam block **53** when acted upon by the control means **47** causes the shoes **56** to pivot outwardly and engage the earth surrounding the casing.

The guidance casing **35** includes means **38** for sensing bending or deflection from a straight line path, guide means **56** for changing the direction of advancement of the auger and control means **47** for adjusting the guide means in response to a sensed deviation.

The sensing means employed in the preferred embodiment comprises axially extending control rods **38** which have one end thereof anchored to the outer wall **31** of the casing **35**. These anchoring points are shown generally at **42**. A support bracket or anchor **41** is secured to the casing, by welding or other suitable means and is used to secure a rearward end of the rod **38** to the casing **35**. The rod **38** is preferably provided with a threaded end, shown generally at **39**, which fits within the support **41**. Locking nuts **37** are provided on either side of the support **41** to secure the rod **38** to the an-

chors. The anchors also serve to space the rods from the wall **31** so that interference between the rods **38** and a bending casing **35** will be avoided.

The foremost end of the rod **38** includes a measuring rod **65** mounted coaxially therewith. The forward section of the rod **38** is slidably received with a sleeve member **45** within the area **38.** A distance A' which extends from the support **42** to the sleeve **45,** as can be appreciated, will experience bending when drilling varies from a straight line path. This distance indicated at A' may be, for example, as much as seventeen feet.

The measuring rod **65** is shown having a forward end thereof extending within the control means **47.** This control means may, for example, comprise a proportional error device or position sensor which translates deflections of the control rod **38** into proportional movement of an axially movable shaft **49.** The particular structure of the control means **47** is not important as far as the present invention is concerned, because one may use any of the known electrical, hydraulic and pneumatic systems for translating a certain amount of movement of an input element into a proportional amount of powered movement of an output element. Of course, in selecting a particular systems, one should bear in mind the usual engineering criteria of space availability, component sizes, power capabilities, etc. if an optimized installation is to be achieved. The shaft **49** has a cam follower roller **51** rotatably disposed thereon. The roller **51** and shaft **49** are shown drawn inwardly by the control means **47.** In phantom, however, there is shown the activation of the shaft **49** which may be caused to move outwardly and cooperate with the cam block **53** on the shoe **56.** This outward movement of the shaft **49** will cause the block **53** to ride upwardly upon the follower **51** thus outwardly pivoting the shoe **56** about pin **58.**

Normally, each guide means **56** will have associated therewith a sensing means **38** and a control means **47.** In the preferred embodiment three such guide means and associated assemblies are provided. It can be, however, appreciated that more or fewer guide means may be employed, depending on the system requirements. Other known sensing means or guide means may be employed in carrying out the invention.

The straight line and deflected positions of the guidance casing **35** are shown in FIGS. **2** and **4,** respectively. It should be noted that in FIG. **4** deflection of the casing is shown somewhat exaggerated and schematically so that the automatic guidance features of the invention can be more clearly understood. The control rods **38** are shown in FIG. **4** as being anchored to a rear portion of the casing inner wall at **42.** Their forward ends being slidably received in sleeves **45.** Longitudinal flexing of the casing wall **31** will cause the control rods **38** to move longitudinally in and out of the collars **45** depending upon the direction of deflection.

FIG. **4** shows deflection of the casing **35** in the downward direction. This downward deflection causes the upper control rod **38** to retract at the collar **45** while the lower control rod moves inwardly. This movement of the control rods **38** relative to the casing wall **31** occurs at the three locations around the casing. Arching or bending of the casing as shown in FIG. **4** then causes all of the control rods to move longitudinally but only the pusher shoes associates with an inwardly deflecting control rod will be caused to actuate, in the preferred embodiment. The rods **38** tend to maintain their straight configuration due to the slidable movement of their free ends within the sleeves **45.** The sleeves, however, which are secured to the casing move according to the radius of the bending experienced by the casing.

The system, in the preferred embodiment, has been so designed as to hold the pusher shoes inwardly against the outer side walls of the cylindrical casing **35** until an appropriate inward deflection of the rods **38** is sent through control means **47** to the guide means **56,** that is, until a movement of a measuring rod **65** on the forward end of a rod **38** signals a need for corrective action and such signal is acted upon by the associated control means **47** to effect a forward movement of an output rod **49** to cam the associated guide means or shoe **56** outwardly. The outward movement of a lower pusher shoe due to the deflection shown in FIG. **4** would cause the casing **35** to move upwardly, thereby applying an upward force on the auger **17** by means of the sleeve **29** urging the auger to reassume its straight line position. Thus, it can be seen that slight deflection in the control rods can cause automatic movement of the appropriate pusher shoe to correct any deviation from the straight line path.

In operation, the jacks **19** shown adjacent the track **23** are adjusted to level the track prior to actual boring. Once the track and associated machinery have been levelled, the anchor pins **21** may be driven into the trench floor to positively secure the earth boring machine **10.** The guidance casing **35** is positioned on the machine with the rearward end of the casing in engagement with the surface **16** of the pusher member **13.** The auger shaft is connected with the engine to be driven thereby.

As the auger **17** advances through the earth, the guidance casing **35** is advanced into the bore hole closely behind the auger. As the casing and auger advance into the earth, additional casing members **36** are inserted between the preceding casing member and the pusher member **13.** Bending of the casing **35** caused by deviations from a selected path is detected by the relative flexing of the control rods **38.** The measuring rods **65** cooperate with the respective control means **47** to cause a proportional outward movement of the shoe **56** on the side of the casing **35** that will cause the auger **17** to be disposed laterally toward the desired path. This correcting action continues until the auger **17** and the casing **35** return to the desired drilling path.

It should be noted that remote guidance means may be used wherein a signal sent from the boring machine **10** can remotely cause the casing to deflect in any desired direction. Thus, an upwardly curved shaft or bore may be drilled as well as in other desired directions. It should also be noted that while the control means **47** is disclosed as only causing pusher shoe operation through inward deflection of the control rods, it is possible to interconnect the control means so that movement of one control rod may actuate a non-associated pusher shoe. Also, various sensing means may be utilized with the invention, other than linear deflection of a control rod of the preferred embodiment.

Particularly significant is the fact that deflections may be accurately and easily measured within a non-rotating longitudinally insertable guidance casing which changes the direction of drilling to be followed by a rotating auger. By sensing deflections of the casing wall, which is at the greatest radius from the center of the bore hole, accurate directional control can be

achieved without requiring extremely sensitive equipment. Additionally, the guiding means in the casing does not interfere with the operation of the auger.

Although the invention has been described with reference to a preferred embodiment and method, additions, not specifically described, as well as modifications, substitutions and deletions may be made without departing from the invention, as claimed.

What is claimed is:

1. An earth boring machine comprising:
a non-rotatable cylindrical casing;
a rotary auger extending through said casing and having a rotary cutting element adjacent the end thereof;
power means for rotating the auger and for advancing the auger and casing axially along a selected path;
sensing means on the casing for sensing deviations from the selected path;
outwardly movable guide means on the casing cooperating with earth adjacent the casing for changing the direction of advancing movement of the casing, said guide means being movable outwardly for varying the degree of change of direction relative to advancing movement; and
control means for adjusting the guide means in response to the degree of deviation sensed by said sensing means.

2. An earth boring machine according to claim 1 including a guide sleeve in said casing, said auger being received in said guide sleeve and journalled thereby, whereby deflection of said casing is transmitted to said auger by said sleeve.

3. An earth boring machine comprising:
a cylindrical casing;
a rotary auger extending through said casing and having a rotary cutting element adjacent the end thereof;
power means for rotating the auger and for advancing the auger and casing axially along a selected path;
plural guide means spaced circumferentially around the casing cooperating with earth adjacent the casing for changing the direction of advancing movement of the casing, said guide means being adjustable for varying the degree of change of direction relative to advancing movement;
plural sensing means spaced circumferentially around said casing for sensing deviations from the selected path; and
control means for adjusting the guide means in response to the degree of deviation sensed by said sensing means, said plural sensing and guide means cooperating to control the change of direction of advancing movement.

4. An earth boring machine according to claim 3 wherein said plural sensing means include a plurality of rods extending axially of said casing and spaced apart from each other around the circumference of said casing, said rods being secured at one end to said casing, and including position sensors on said casing adjacent the opposite ends of the respective rods for measuring the change in position of the ends of the respective rods in response to bending of said casing between opposite ends of said rod, said control means adjusting said guide means in proportion to the degree of movement of the respective rods relative to the casing.

5. An earth boring machine according to claim 3 wherein said guide means includes a plurality of pusher shoes, said shoes being pivotally mounted on the exterior of said casing for swinging outwardly in response to said control means.

6. An earth boring machine according to claim 5 wherein said pusher shoes extend axially of said casing and are pivotally mounted to allow the rearward end of the respective pusher shoes to swing outwardly from the casing a greater distance than the forward end of the shoes upon actuation of the adjusting means.

7. An earth boring machine comprising:
a rotary auger;
power means for rotating the auger;
a cylindrical casing;
power means for advancing the casing axially, said auger extending through said casing and being journalled therein, said auger including a cutting head extending outwardly from the forward end of the casing; and
guide means on the casing having a guide surface movable relative to said casing in a direction having a radial component for cooperation with earth adjacent the casing to deflect the auger toward a selected path in response to deviations from the path.

8. An earth boring machine according to claim 7 including sensing means cooperating with said casing for sensing deviations from a selected path and causing the actuation of said guide means to correct said deviations.

9. An earth boring machine according to claim 7 including plural guide means spaced circumferentially around the casing, said guide means being selectively actuated by and cooperating with plural sensor means disposed within said casing.

10. An earth boring machine according to claim 9 wherein said plural guide means includes pusher shoes positioned at a forward advanced end of said casing, said shoes being pivotally mounted on the outer periphery of said casing for swinging outwardly and engaging the surrounding earth.

11. An earth boring machine according to claim 9 wherein said plural guide means includes at least three pusher shoes equally positioned about said casing for engaging the earth thereabout.

12. An earth boring machine according to claim 9 wherein said plural sensing means include a plurality of rods extending axially of said casing and spaced apart from each other around the circumference of said casing, said rods being secured at one end of said casing, and including position sensors on said casing adjacent the opposite ends of the respective rods for measuring the change in position of one end of the respective rods in response to bending of said casing between opposite ends of said rod.

13. An earth boring machine comprising:
a rotary auger;
power means for rotating the auger;
a cylindrical casing;
power means for advancing the casing axially, said auger extending through said casing and being journalled therein, said auger including a cutting head extending outwardly from the forward end of the casing; and
plural guide means spaced circumferentially around said casing and plural sensing means spaced cir-

cumferentially around said casing, said guide means on the casing cooperating with earth adjacent the casing for deflecting the auger toward a selected path, said plural sensing and guide means cooperating to control the path of augering in response to deviations from the selected path.

14. A casing for use in earth boring machines for correcting deviations from a selected path of advancing movement of the casing and associated auger comprising:

an outer casing member;

an auger guide sleeve secured in said casing member;

a plurality of pusher shoes each pivotally mounted on an end portion of said casing member for pivotal movement in a radial direction, said pusher shoes being spaced around the circumference of said casing member and each of said shoes having a guide surface that is movable relative to the casing member to various degrees of inclination to the surface of said member;

means in said casing for detecting the degree of longitudinal bending of said casing member and the direction of said bending; and

control means for operating selected ones of said shoes in response to conditions sensed by said detecting means.

15. A casing according to claim **14** wherein said means in said casing for detecting the degree of longitudinal bending of said casing member includes a plurality of rods extending axially of said casing and spaced apart from each other around the circumference of said casing, said rods being secured at one end to said casing and at the other end cooperating with said control means for measuring the change in position of the ends of the respective rods in response to bending of said casing between opposite ends of said rod, said control means adjusting said pusher shoes in proportion to the degree of movement of the respective rods relative to the casing.

16. A casing according to claim **14** including at least three pusher shoes evenly spaced about the periphery of said casing member, said pusher shoes being pivotally mounted to allow the rearward end of the respective pusher shoes to swing outwardly from the casing member a greater distance than the forward end of the shoes upon actuation of said control means.

17. A casing according to claim **16** wherein said pusher shoes further include cam follower means at said rearward end thereof, said follower means cooperable with cam means associated with said control means for individually activating said pusher shoes in reponse to bending of said casing member.

18. An earth boring machine comprising:

a cylindrical casing;

an auger means extending within said casing and having a cutting head on the forward end thereof;

means for rotating said auger to bore a hole along a desired path;

means for advancing said casing axially within the hole being bored; and

guide means operatively associated with said casing and the hole being bored for selectively moving said casing to guide said auger and said cutting head along the desired cutting path, said guide means including a plurality of shoes each having an external surface normally forming a continuation of the external surface of a forward end portion of said casing and each being mounted on said casing for pivotal movement in a direction such that the rear end portion of each shoe may be positioned radially outwardly from the exterior surface of the casing.

19. A method of boring a cased hole in the earth along a straight path comprising:

assembling an auger in a casing with the cutting head of the auger spaced outwardly from the forward end of the casing;

applying axial thrust to said casing and said auger while rotating said auger;

said casing having external guide shoes adjacent the forward end thereof, said guide shoes being movable relative to said casing to provide reaction against the adjacent earth to deflect the casing and auger;

sensing the degree of longitudinal bonding of the casing and the direction of said bending when the auger and casing are deviating from a straight path;

adjusting the position of at least one of said guide shoes in response to the degree and direction of deviation that is being sensed, wherby movement of the guide shoe urges the casing and auger to return to a straight path.

20. A method of boring a cased hole in the earth along a straight path comprising:

assembling an auger in a cylindrical casing with the cutting head of the auger spaced outwardly from the forward end of the casing;

positioning power means coupled to said auger and said casing within an open trench;

simultaneously rotating said auger while applying lateral thrust to said casing;

sensing deviations from a straight drilling path by means cooperating with said casing;

generating a proportional response to said sensed deviations;

coupling said response to guide means including plural guide shoes mounted in spaced relation about said casing for movement to positions radially beyond the exterior of said casing; and

adjusting the position of said casing by selectively activating at least one guide shoe to correct said casing for said sensed deviations from a straight line path.

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