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CORE FORMING TYPE HORIZONTAL BORING MACHINE
WITH EXPANSIBLE ROLLING CUTTERS
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CORE FORMING TYPE HORIZONTAL BORING MACHINE WITH EXPANDIBLE ROLLING CUTTERS

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ABSTRACT OF THE DISCLOSURE

Underground boring apparatus comprising two relatively rotatable members mounted coaxially with one another by means of tapered roller bearings, one of which supports a plurality of cutter elements on the end thereof mounted on cutter blocks which are slideable radially in grooves the cutters being dimensioned and positioned, such that upon rotation and axial movement of the cutter support, the cutters will radially expand to describe an annularly shaped passage accommodating the entire support means.

This invention relates to the boring of holes, and more particularly it concerns a novel method and apparatus for forming underground passages and for laying underground pipe in such passages.

Because of the heterogeneous composition of the earth's surface, and because of its weight and consistency, great difficulty has been experienced in boring underground tunnels and passageways for the laying of pipes and other conduits. In digging an open pit or trench, of course, large machinery and great amounts of power are readily and easily applied to the desired area. However, the limited space available in an underground tunnel severely limits the size, and therefore the power capacity of available machinery.

According to one feature of the present invention, an underground hole is bored in a very efficient manner by means of a planetary cutter arrangement which curtails the available power so as to cut an annularly shaped tunnel from which the core thereof is later removed in a relatively simple operation.

It has not heretofore been possible to exploit the power concentration principle mentioned above with any degree of success. Where, for example, one or more cutters are mounted on a central rotating disk and spider and extend outwardly therefrom in cantilever fashion to cut an annularly shaped hole, the maximum depth of the annularly shaped hole which can be cut is limited by the cantilevered length of the cutters. Once this depth is reached, the tool must either be completely taken out of the tunnel so that the short core formed by cutters may be broken off and removed, or else the core must continually be broken up and washed or otherwise conveyed out around the cutter supporting structure. The cantilevered length of the cutters is also quite severely limited for the further out they extend from their supporting structure the more prone they are to bending under pressure of the surrounding earth. This situation becomes aggravated so that a tapered hole is formed and the cutters seize and become locked into the earth.

The present invention eliminates all of the above difficulties while permitting the concentration of all available digging power into the formation of an annularly shaped hole of constant diameter and infinite length, without any danger of tool seizure. Moreover, according to the present invention, cutter tools may be removed and replaced in far less time and with far less expense and difficulty than has heretofore been possible with known machinery.

According to the present invention, cutting tools are mounted in planetary fashion and driven about an imaginary center, the supporting and driving means being arranged entirely within the annular region generated by the cutters. The supporting means move along immediately behind the cutters so that they are not subjected to excessive cantilever effects and thereby maintain a constant diameter cut without seizure. At the same time, the core thus formed may extend without interference by machinery or other apparatus so that the annular hole may be extended indefinitely.

More specifically, apparatus according to the present invention includes a pair of ring or tubular shaped elements held in coaxial relationship by intermediate boring means which permit relative rotation between them and at the same time transmit longitudinal forces from one element to the other. Motor means are located in the annular region defined by the two tubular elements, and these motor means are connected to produce relative rotation between the elements. Means are provided whereby the longitudinal motion is transmitted on one end of the tubular elements and cutter means are mounted on the opposite end of the other tubular element. The cutter means are arranged to generate an annular surface, the smaller diameter of which is at least as small as the inner diameter of the inner tubular element, and the larger diameter of which is at least as large as the outer diameter of the outer tubular element.

Where the apparatus is used for the laying of pipe, the outer tubular element may be attached immediately inside one end of the pipe and the longitudinal forces transmitted to it from the other end of the pipe. As the device proceeds into the earth, additional lengths of pipe may be added from its other end. Of course, in such instance the cutters would be mounted to the inside tubular element and would cut a major diameter at least as great as the outside diameter of the pipe.

Two embodiments are shown and a detailed description of each is given hereinafter. In both embodiments, the cutters are removable from their mounting means for replacement. Also, the cutters may be moved radially inward or outward on their respective mounting means to free them from the surrounding earth for retracting the machine. This radial adjustment feature permits the cutters to be retracted to within the inside diameter of the pipe being laid, thus allowing the machine and cutters to be removed without removal of any of the pipe which has already been laid.

The boring machine of the first embodiment is designed to cut an annular passageway having a 48 inch outer diameter and a 24 inch inner or core diameter. The cutters of the machine are mounted on cutter blocks which slide in radial grooves in a cutter mounting ring. They are held in place by means of arcuate locking segments which are bolted to the inside edge of the ring. When the cutters are to be replaced, the core of the annular passageway formed by the machine is removed and a man crawls through the passageway to the inner tubular element which he reaches through to unbolts the locking segments and releases the cutters. New cutters may be inserted and locked in place without otherwise disturbing or moving the machine.

In the second embodiment, the machine is designed to cut an annular passageway having a 36 inch outer diameter and a 12 inch inner diameter. Because of the restricted size of the passageway, it becomes impractical to release and remove the cutters manually. In this second embodiment, means are provided whereby the cutters automatically becomes retracted radially inward upon reversing the direction of rotation of the drive motor.

This is accomplished by mounting the cutters on slide blocks having extensions and pins which fit into differently configured openings in two adjacent rotationally rotatable rings. The first, or slide block ring, has radial
openings which permit the slide blocks and associated cutters to move only in a radial direction. The second, or cutter retraction ring, has circumferentially extending slot-like openings, one of each being further displaced from the ring center than the other. Because each slide block extension with its associated pin extends through the openings in both the slide block ring and the cutter retraction ring, it will move radially as these rings are rotated with respect to each other. The cutter retraction ring is keyed to the inner rotating tubular element of the machine plate therewith. As the inner tubular element begins to rotate in a cutting direction the cutter elements, in resisting rotational movement, are urged radially outwardly until their respective slide block pins reach the ends of the slots in the cutter retraction ring. The cutters then rotate with the inner tubular element in fully extended cutting positions. When the direction of rotation is reversed, the cutter retraction ring and the slide block ring undergo reverse relative rotation thus urging the slide blocks and cutters radially inwardly. The machine can then be withdrawn for cutter replacement.

In certain instances it may be desired to operate the cutters in a reverse direction without retraction. This is achieved by means of a slot in the inside edge of the slide block ring which comes into alignment with the key slot of the cutter retraction ring when the cutters are fully extended. Means are provided to move the key securing the cutter retraction ring to the inner tubular element in a forward direction also to key the slide block ring. When this occurs relative rotation of the rings is prevented and the cutters are maintained in radially extended position irrespective of their direction of rotation.

There has been outlined rather broadly the more important features of the invention in order that the Detailed Description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto. Those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures for carrying out the several purposes of the invention. It is important, therefore, that the claims be regarded as including such equivalent constructions as do not depart from the spirit and scope of the invention.

Specific embodiments of the invention have been chosen for purposes of illustration and description, and are shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a diagrammatical representation illustrating the embodiment of the present invention as used to install an underground pipe;

FIG. 2 is a sectional view, taken in elevation, along the longitudinal axis of a first embodiment of the present invention;

FIG. 3 is a cross section view taken along lines 3—3 of FIG. 2;

FIG. 4 is a fragmentary perspective view illustrating a portion of the cutter arrangement of the first embodiment;

FIG. 5 is a fragmentary cross section view taken along lines 5—5 of FIG. 2;

FIG. 6 is a sectional view, taken in elevation, along the longitudinal axis of a second embodiment of the present invention;

FIG. 7 is a cross sectional view taken along lines 7—7 of FIG. 6;

FIG. 8 is a fragmentary cross section view taken along lines 8—8 of FIG. 6;

FIG. 9 is a perspective view illustrating the configuration of one number of the assembly of the second embodiment; and

FIG. 10 is an enlargement of a portion of FIG. 6 illustrating the shifted portion of certain elements thereof.

FIG. 1 shows schematically one application of the present invention for boring a horizontal tunnel in the earth. Prior to boring the tunnel a vertical entrance opening 10 is first excavated to a depth at least equal to the depth of the tunnel to be bored. A boring machine 12, to be described more fully hereinafter, is driven in a horizontal direction from one of the walls of the entrance opening 19 to form a horizontal tunnel 14. A boring machine 12 is attached to the forwardmost of a series of pipe segments 16 which are aligned along the tunnel 14. The last of these pipe segments 16 is guided by means of the pressure plate 18 in a forward direction, this force being transmitted to the boring machine 12 for urging it forward to excavate and elongate the tunnel 14.

The pressure plate 18 is actuated by a pair of hydraulic piston and cylinder assemblies 20 which are fitted inside the entrance opening 10 by means of support members 22. The piston and cylinder assemblies 20 are guided by means of upper and lower guide rods 24 so that the pressure plate 18 acts in proper alignment against the pipe segments 16.

A pump and hydraulic reservoir 26 is provided outside the tunnel 14 and is connected via hydraulic lines 28 and a force control valve 30 to the hydraulic piston and cylinder assemblies 20. By operating this valve, the hydraulic piston and cylinder assemblies 20 are caused to act upon the pipe segments 16 and the boring machine 12, driving the latter further along the tunnel 14. When the last of the pipe segments 16 is driven to the full extent of the hydraulic piston and cylinder assemblies 20, the force control valve 30 is reversed and the hydraulic piston and cylinder assemblies 20 are retracted. A new pipe segment 16 is then inserted into place behind the last pipe segment and the force control valve 30 is switched back to cause the hydraulic piston and cylinder assemblies 20 to force the pressure plate 18 against this new pipe segment to continue the boring operation.

Further hydraulic lines 32 are connected to the hydraulic lines 28. These further lines supply high pressure hydraulic fluid through the pipe segments 16 to the boring machine 12 for operating the various mechanisms thereof.

Electrical control lines 34 also extend through the pipe segments 16 to the boring machine 12 and are connected to various solenoids within the boring machine 12 for controlling the various hydraulic valves thereof. A slurry reservoir 36 is connected via a slurry pump 38 and a line 40 in through the pipe segments 16 to the front of the boring machine 12 to aid in the cutting operation and to flush out the grindings and cuttings produced by the boring machine. These cuttings are caused to flow back along the surface of the pipe segments 16 and to discharge into a sump 41 at the bottom of the entrance opening 10.

Referring now to FIG. 2, it will be seen that the boring machine 12 of the first embodiment extends telescopically out from the forward end of the first pipe segment 16, and is of generally annular or tubular overall configuration. The forward end of the boring machine 12 is provided with a plurality of cutters 42 which move in planetary fashion about the longitudinal axis of the tunnel 14. These cutters, as shown in FIG. 3, include groups of inside cutters 42a, intermediate cutters 42b and outside cutters 42c and during their planetary movements, they describe an annularly shaped path, the major diameter of which is larger than the outer diameter of the pipe segments 16 and the minor diameter of which is smaller than the inner diameter of the boring machine 12 itself.

It will be noted that the entire mechanism of the boring machine 12, including its electrical hydraulic and the slurry supply lines, are all located within the annular region described by the rotating cutters 42. Consequently, the machine 12 and the pipe segments 16 may move along for an indefinite distance while producing an annularly shaped passageway 46 and leaving an earth core 48 of any desired length without being affected by the core 48. At any desired time, during or after the boring operation, the
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core 48 may be broken off into one or several large chunks or segments and removed out through the entrance opening 10 thus forming the complete tunnel 14.

Basically, the boring machine 12 comprises a pair of coaxially arranged tubular elements such as an internal mounting ring 50 and an external mounting ring 52. The internal mounting ring is surrounded by an internal bearing race 54 while the external mounting ring is lined with an outer bearing race 56. Tapered roller bearings 58 ride in these races and serve to maintain the internal and external mounting rings 50 and 52 in proper coaxial relationship for permitting relative rotation therewith between while at the same time serving to transmit longitudinal forces from one ring to the other.

An internal ring gear 60 is bolted to the rear of the internal mounting ring 50. This internal ring gear is driven by means of a plurality of drive gears 62 distributed about the annularly shaped passageway 46. Each drive gear 62 is turned by means of a hydraulic drive motor 64 operating through a planetary type drive transmission 66. The motors and transmissions are, of course, themselves mounted within the annularly shaped passageway 46. The hydraulic drive motors 64 are each bolted to their respective drive transmissions 66 and this portion is bolted to a ring shaped power unit base plate 68 attached to the external mounting ring 52. The hydraulic motors 64 are driven from the pump and hydraulic reservoir 26 supplying hydraulic fluid under pressure through the lines 28 and 32.

An internal clamp ring 70 is bolted to the forward end of the internal mounting ring 50 and onto this internal clamp ring 70 is bolted a cutter mounting ring 72. The cutter mounting ring 72, which is shown in full face view in FIG. 3, is provided on its forward face with twelve radially extending undercut dovetail type grooves 74. Each of these grooves accommodates a cutter block 76 on which the various cutting tools 42 are mounted. A typical cutter block 76, along with its cutting tools, is shown most clearly in the perspective view of FIG. 4. The cutter block 76 itself has slanted sides which fit closely within the grooves 74 in the cutter mounting rings 72. The rear portions of the sides of the cutter block 76 however, are straight rather than slanted and serve to define an abutment 78 which engages with the inner surface of the cutter mounting ring 72 for preventing the cutter block from sliding radially outward from the ring. Each cutter block 76 has mounted thereon in cantilever fashion at least one cutter 42. These cutters are frusto-conical in overall configuration and their outer surfaces are knobbled to augment their cutting action. They are mounted for free rotation about an axis canted with respect to the longitudinal axis of the tunnel 14. On certain of the cutter blocks 76, there is also provided an outwardly extending reamer 82 also mounted in cantilever fashion to rotate freely about an axis parallel to the longitudinal axis of the tunnel 14. As illustrated in FIG. 3, the various cutters 42 and reamers 82 are arranged about the cutter mounting ring 72 in such a fashion as to provide a smoothly reamed outer or major diameter surface and a full cut throughout the region between the major and minor diameters of the annularly shaped passageway 46 being cut.

The cutter blocks 76 slide into the groove 74 of the cutter mounting ring 72 as illustrated in FIG. 3 and are secured in place by means of an arcuate shaped locking segments 84 which are bolted to the inside top face of the cutter mounting ring 72. In removing a cutter or reamer for replacement, the locking segment 84 associated with its particular cutter block 76 is merely unbolted from the cutter mounting ring 72 and the cutter block is slid radially inward from the cutter mounting ring 72. A new cutter block with a cutter or reamer is then slipped into place and secured by the locking segment 84.

In order to reduce skin friction between the core 48 and the various operative elements of the boring machine 12, there is provided an inner casing 90 which extends longitudinally from a point immediately behind the cutter mounting ring 72 to a point behind the hydraulic drive motors 64. This inner casing 90 is welded or otherwise affixed to the power base plate 68 and to a rea mounting ring 92 behind the hydraulic drive motors 64.

There is also provided an outer casing 94 which extends from a point immediately behind the power base plate 68 and back beyond the rea mounting ring 92. A retaining ring 96 is welded about the inner surface of the rearward end of the outer casing 94 and the casing and retaining ring are slotted or notched at 98 to receive temporary lugs 100 which are welded or otherwise affixed to the inside of the forward pipe segment 16. The forward movement of the pipe segments 16 is aided by the action of the pressure plate 18, is thus transmitted via the lugs 100 and the outer casing 94 to the external mounting ring 52 of the boring machine. This forward force is then transmitted through the tapered roller bearings 58 to the internal mounting ring 50, and from there through the cutter mounting rings 72 and cutter blocks 76 to the various cutters 42 and reamers 82.

In order to protect the tapered roller bearings 58 from accumulation of dirt and grindings, there are provided a rear seal retaining ring 102, attached to the power unit base plate 68, and an external clamp ring 104 which is attached to the front of the external mounting ring 52. The seal retaining ring and the external clamp ring form seal enclosures with the inner mounting ring 50 and the internal clamp ring 70, respectively, and into these enclosures are provided a rear seal 106 and a forward seal 108.

During operation of the system, slurry is pumped by means of the pump 38 from the reservoir 36 through the line 40 and into a slurry header 110 which distributes it out through slurry header lines 112 and into the region between the outer casing 94 and the pipe segments 16. This slurry passes up toward the end of the casing and into the region of the cutters 42 and reamers 82. It is thereafter washed back along the outside of the pipe segments 16 and back into the sump 41 at the bottom of the entrance opening 10.

Also, during this time, the pump and hydraulic reservoir 26 supply high pressure hydraulic fluid to operate the hydraulic piston and cylinder assemblies 20 for urging the pipe segments 16 and consequently the boring machine 12 forwardly into the tunnel 14. This hydraulic fluid is supplied from a hydraulic header 116 to the various hydraulic drive motors 64. These motors cause their respective drive transmissions 66 to turn their drive gears 62 for rotating the inner ring gear 70. This causes the internal mounting ring 50 to rotate along with the internal clamp ring 70 and its cutter blocks with their associated cutters and reamers 42 and 82. The manner of distribution of the slurry and hydraulic fluid through the headers 110 and 116 about the annular space 46 is illustrated in FIG. 5.

At any given time, the operation may be stopped and the core 48 removed from the annularly shaped passageway 46 without requiring removal of the boring machine 12 or any part thereof. Also, once this core 48 is removed, any of the cutters may readily be replaced simply by removing their associated locking segments 84 and sliding them out from the cutter mounting ring 72. This, of course, may be done manually without retraction of the machine simply by sending a man down into the area vacated by the now removed core 48 and having him perform the afore-described cutter replacement operations.

While the above described embodiment is suitable for operation when boring holes of such a size as to permit a man to crawl in through the tunnel 14 and inside the inner casing 90 to remove the cutters 42, it is, of course, not possible to do this where the tunnel 14 is to be of a smaller diameter. The alternate embodiment shown in FIGS. 6–10 however, permits this to be accomplished in a much smaller size tunnel opening. With this alternate
embodiment, the cutters which form the outer periphery of the tunnel 14 may be retracted radially inward simply by reversing the rotation of the hydraulic drive motors. With the cutters thus retracted, the entire machine may easily be slipped out through the tunnel 14 without having to remove the various pipe segments 16 which have been laid in place.

The basic construction of this second embodiment is physically similar to that of the first embodiment described above. Thus the alternate embodiment, like the first, includes a pair of coaxially exposed tubular elements such as an internal mounting ring 120 and an external mounting ring 122. Inner and outer bearing races 124 and 125 are attached respectively to the internal and external mounting rings 120 and 122 and these bearing races serve to guide tapered roller bearings 128 as described above. An internal ring gear 130 is attached to the internal mounting ring 120 and is driven, as in the first embodiment, by means of a plurality of drive gears 132, each of which is connected via a drive transmission 134 to a hydraulic drive motor 136. Ring type mounting means (not shown) are used to support the hydraulic drive motors 135 and drive transmissions 134 within the annular space defined by the cutters as in the first embodiment.

At the forward end of the external mounting ring 122, there is attached a forward clamp ring 140 and a forward seal ring 142. A forward seal ring 144 is located between the forward seal ring 142 and the internal mounting ring 120.

Immediately ahead of the forward seal ring 142, there is provided a cutter retraction ring 146. The cutter retraction ring, as shown most clearly in the face view of FIG. 7, is formed with six elongated slots 148. It will be seen that these slots do not extend exactly tangentially of the ring but rather are angled slightly so that in moving in a clockwise direction about the ring, the surfaces of each slot become more radially displaced from the center of the retraction ring 146. Thus the slots effectively spiral outwardly in a clockwise direction about the ring. A pair of diametrically opposed locking dog notches 150 are cut into the inner surface of the cutter retraction ring 146. These slots accommodate locking dogs as will be explained hereinafter to control the retraction of certain of the cutting elements.

Immediatedly beyond the cutter retraction ring 146, there is provided a slide block ring 154. This ring, as shown in the face view of FIG. 8, has inner and outer diameters which coincide with the inner and outer diameters respectively of the cutter retraction ring 146. However, instead of the slots 148 which are formed in the cutter retraction ring 146, the slide block ring 154 is provided with a plurality of radially extending lug slots 156 which open out peripherally of the slide block ring 154. The slide block ring is also provided with a pair of diametrically opposed locking dog notches 158 which are formed along its inside surface.

It is important to note that the locking dog notches 158 of the slide block ring 154 are in direct alignment with a pair of its lug slots 156, while the locking dog notches 150 of the cutter retraction ring 146 are in direct alignment with the most radially displaced ends of a pair of its slots 148.

An inside cutter mounting ring 160 is attached to the slide block ring 154 by means of six equally spaced studs 161 which serve to hold it out forward of the slide block ring, thus defining a slot or space 163 therebetween. As illustrated in FIGS. 6 and 8, six inside cutters 165 are bolted about the inside cutter mounting ring 160.

Six slide blocks 162 are distributed about the machine in the vicinity of the slide block ring 154. These slide blocks 162 are provided with wings or flanges 164 which fit closely in the slot or space 163 between the inside cutter mounting ring 160 and the slide block ring 154.

Also, each slide block 162 is provided with a lug 166 which fits closely but slidably within the peripheral lug slots 156 in the slide block ring 154. Thus the slide blocks 162 are guided for radial movement relative to the slide block ring 154, but are caused to rotate along with the slide block ring. Each slide block 162 has bolted to its forward end an outside cutter 167. As illustrated in FIG. 8, the outside cutters 167 are arranged to fit in an interrelated way with the inside cutters 165. The inside cutters 165, however, are mounted at a fixed radial displacement from the center of the machine on the inside cutter mounting ring 160, while the outside cutters are mounted on the radially displaceable slide blocks 162 and may move in and out radially with these blocks.

A slide block 162 extends through each of the slots 154 in the cutter retraction ring 146 and is pinned to a corresponding one of the slide blocks 162. As the cutter retraction ring 146 rotates relative to the slide block ring 154, the slide block studs move along the slots 156 and are urged either radially outwardly or radially inwardly depending upon the direction of relative rotation of these two rings. Accordingly the outside cutters are thus moved inwardly or outwardly depending upon this relative rotation.

In place of the inner casing 90 of the first embodiment, there is provided in this alternate embodiment a tubular locking sleeve 170. This locking sleeve, which is shown most clearly in the perspective view of FIG. 9, has located near its forwardmost end at diametrically opposed points on its outer periphery, a pair of locking dogs 169. As the locking sleeve rotates, these locking dogs 169 rotate therewith and, accordingly, rotate any rings having notches which happen to be accommodating them.

The locking sleeve 170 is shiftable back and forth in a longitudinal direction by means of a pair of hydraulic jacks 172 operating a shift plate 174 which engages a peripheral slot 176 at the rearward end of the locking sleeve 170. The hydraulic jacks 172 are affixed to the power unit base plate; and the shift plate and peripheral slot combination allows the locking sleeve 170 to be shifted longitudinally even though it may at the time be rotating.

When the locking sleeve 170 shifts longitudinally, the locking dogs 169 move from a rearward position as shown in FIG. 6, to a forward position as shown in FIG. 10. In their rearward position, the locking dogs engage corresponding locking dog notches in the internal mounting ring 120 and in the cutter retraction ring 146. When the locking sleeve 170 is moved forward, the locking dogs 169 also move forward, the locking dogs 169 additionally engage the notches 158 in the slide block ring 154.

During the cutting operation, the hydraulic jacks 172 are extended to move the locking sleeve 170 rearwardly thus disengaging the locking dogs 169 from the slide block ring 154. The hydraulic motors 136 normally operate through the drive transmissions 134 to turn the drive gears 132 and the internal mounting ring 120 in a counterclockwise direction. The internal mounting ring, which is keyed by means of the locking dogs 169 to the cutter retraction ring 146, causes this ring also to rotate in a counterclockwise direction. The outside cutters 167, being engaged with the earth, tend to resist this rotation so that initially the cutter retraction ring 146 turns in a counterclockwise direction relative to the slide block ring 154.

This urges the slide blocks 162 and the outside cutters attached thereto in a radially outward direction until the slide block studs 168 reach the ends of the slots 156 in the cutter retraction ring. In this event, rotation of the cutter retraction ring causes the studs also to rotate along with the slide blocks 162 and the slide block ring 154.

Thus all of the cutters rotate under the influence of the hydraulic drive motors 136.

After a desired length of tunnel is cut, and the core thereof is removed, the outside cutters 167 may be retracted and the boring machine withdrawn simply by
reversing its direction of rotation. This reversal of direction of rotation causes the cutter retraction ring 146 to rotate in a clockwise direction relative to the slide block ring 154 whose rotation is resisted by means of the outside cutters in engagement with the earth. This relative rotation causes the slide block studs 168 to move to the opposite ends of the slots 148 in the cutter retraction ring thus producing an inward radial movement of the studs and slide blocks with a corresponding inward radial movement of the outside cutters 167. When the cutters have been retracted to a point where their outer peripheries are within the inside diameter of the pipe segments 16, the boring machine may then be withdrawn for replacement of the cutters or such other adjustments and repairs as may be necessary.

In certain instances, it may be desired to reverse the direction of rotation of the hydraulic motors 136 without retracting the outside cutters so as to produce a cutting action in the opposite direction. This is accomplished simply by causing the hydraulic jacks 172 to retract, thus moving the locking sleeve 176 in a forward direction so as to bring the locking dogs 169 into engagement also with the locking dog slots 158 on the slide block ring 154. This locks the slide block ring from relative rotation with either the cutter retraction ring 146 or the internal mounting ring 120. In this condition, the hydraulic drive motors 136 may be driven in either direction without radial displacement of the outside cutters 167 since no relative rotation may now take place between the cutter retraction ring 146 and the slide block ring 154. However, the hydraulic jacks 172 at any time may be extended to bring back the locking sleeve 176 so that the locking dogs 169 come out of engagement with the slide block ring 154. Clockwise rotation of the hydraulic drive motors 136 will thereafter cause retraction of the outside cutters as illustrated in FIG. 10.

Having thus described my invention with particular reference to the preferred forms thereof, it will be obvious to those skilled in the art to which the invention pertains, after understanding my invention, that various changes and modifications may be made therein without departing from the spirit and scope of my invention, as defined by the claims appended thereto.

What I claim is:
1. Boring apparatus comprising a pair of elongated tubular elements, one disposed inside the other, bearing means disposed about the space between said elements and maintaining them in coaxial alignment, said bearing means being configured to permit relative rotation between said elements and to transmit longitudinal forces from a first of said elements to the second of said elements, a plurality of cutter elements distributed out beyond one end of said tubular elements and mounted to rotate with said second element, said cutter elements being dimensioned to describe an angularly shaped passageway upon the rotation and forward longitudinal movement of said second tubular element such as to accommodate both said tubular elements, at least one drive motor attached to said first tubular element and connected to rotate said second tubular element, said motor also being located entirely within said angularly shaped passageway and longitudinal force transmitting means extending along within said angular passageway and arranged to effect longitudinal movement of said first tubular element during rotation of said second tubular element, said longitudinal force transmitting means being resistive to rotational forces whereby said cutter elements are maintained in a fixed longitudinal relationship with respect to said bearing means so as to avoid increasing cantilevering effects upon said cutter elements during their cutting action.
2. Boring apparatus as in claim 1, wherein said longitudinal force transmitting means comprises an elongated pipe configured at its inner end to abut said first tubular element.

3. Boring apparatus as in claim 1, wherein said bearing means comprises tapered bearing races formed on the facing surfaces on said tubular elements, and tapered roller bearings fitted between said races.
4. Boring apparatus as in claim 1, wherein said cutter elements are mounted in a manner to be withdrawn radially inward toward the axis of rotation of said second tubular element.
5. In a boring machine, tubularly configured cutter support means, at least a portion of said support means being rotatable about a given axis, the rotatable portion of said tubularly configured cutter support means being ring shaped at the forward end thereof and formed with radially extending undercut grooves about its forward face, a plurality of cutters, each affixed to a cutter block, said cutter blocks being slideable radially into said grooves, means for locking said cutter blocks in place in said grooves, said cutters being dimensioned and positioned on said support means such that upon rotation and axial movement of said rotatable portion of said cutter support means said cutters describe an annularly shaped passage accommodating the entire cutter support means, and motor means positioned entirely within said annularly shaped passage and connected to rotate said portion of said cutter support means.
6. In a boring machine, tubularly configured cutter support means, at least a portion of said support means being rotatably about a given axis, the rotatable portion of said tubularly configured cutter support means being ring shaped at its forward end and formed with a plurality of undercut grooves which extend radially about its forward face and open on the inner periphery thereof, a plurality of cutters each affixed to a cutter block, said cutter blocks being slideable radially into said grooves, at least one ring locking segment bolted to said rotatable portion, said locking segment being accurately shaped and fitted up against the inner peripheral surface of said ring shaped forward end to close the inner ends of said slots for locking said cutter blocks in place, said cutters being dimensioned and positioned on said support means such that upon rotation and axial movement of said portion of said cutter support means said cutters describe an annularly shaped passage accommodating the entire cutter support means, and motor means positioned entirely within said annularly shaped passage and connected to rotate said portion of said cutter support means.
7. In a boring machine a plurality of cutter elements, slide blocks mounting said cutter elements, a slide block ring having radially extending surfaces accommodating said slide blocks, a cutter retraction ring mounted in coaxial alignment with and adjacent to said slide block ring and having generally spiral surfaces accommodating extensions of said slide blocks, means for controlling the relative rotational positioning of said slide block ring and said cutter retraction ring and means operative to rotate said rings.
8. In a boring machine a plurality of cutter elements, slide blocks mounting said cutter elements, a slide block ring having radially extending slots accommodating said slide blocks, a cutter retraction ring mounted in coaxial alignment with and adjacent to said slide block ring and having generally spirally extending slots of limited length accommodating extensions of said slide blocks and means operative to rotate said rings.
9. In a boring machine a plurality of cutter elements, slide blocks mounting said cutter elements, a slide block ring having radially extending slots accommodating said slide blocks, a cutter retraction ring mounted in coaxial alignment with and adjacent to said slide block ring and having generally spirally extending slots of limited length accommodating extensions of said slide blocks, means operative selectively to permit and oppose relative rotation between said rings and means operative to rotate one of said rings.
10. In a boring machine a plurality of cutter elements,
slide blocks mounting said cutter elements, a slide block ring having radially extending slots accommodating said slide blocks, a cutter retraction ring mounted in coaxial alignment with and adjacent to said slide block ring and having generally spirally extending slots of limited length accommodating extensions of said slide blocks, a key element movable between a first position out of engagement with at least one of said rings and a second position engaging both said rings in a manner interlocking them rotationally and means operative to rotate the other of said rings, means operative selectively to permit and oppose relative rotation between said rings and means operative to rotate one of said rings.

11. In a boring machine a plurality of cutter elements, slide blocks mounting said cutter elements, a slide block ring having radially extending slots accommodating said slide blocks, a cutter retraction ring mounted in coaxial alignment with and adjacent to said slide block ring and having generally spirally extending slots of limited length accommodating extensions of said slide blocks, each of said rings further being formed with internal peripheral key notches, a tubular locking sleeve closely fitting into each of said rings, at least one locking key attached to the outer surface of said locking sleeve and dimensioned to fit into said key notches, means operative to move said locking sleeve longitudinally between a first position with said locking key out of engagement with at least one of said rings and a second position engaging the locking slots of both said rings for locking them together rotationally and means operative to rotate the other of said rings, means operative selectively to permit and oppose relative rotation between said rings and means operative to rotate one of said rings.

12. In a boring machine a tubular mounting ring, means for rotating said mounting ring, a tubular locking sleeve closely fitting inside said tubular mounting ring and extending out beyond said mounting ring, a pair of further rings mounted on said tubular locking sleeve adjacent to said tubular mounting ring, one of said rings being formed with radially extending slide block notches and the other being formed with generally spirally extending slots of limited length, a plurality of slide blocks dimensioned to be guided in said radially extending slots and having extensions protruding into said spirally extending slots, cutter elements mounted on said slide blocks, each of said rings and said tubular locking sleeve being formed with internal peripheral key notches, at least one locking lug attached to the outer surface of said locking sleeve, said locking lug being dimensioned to fit into each of said internal peripheral key notches, and means for moving said locking sleeve longitudinally between a first position with said locking key engaging said tubular mounting element and one of said rings and a second position with said locking key engaging said tubular mounting element and both said rings.

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ERNEST R. PURSER, Primary Examiner.