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Winberg et al.

[11] **3,859,810**

[45] **Jan. 14, 1975**

[54] **TUNNEL BORING MACHINE**

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[52] **U.S. Cl.** **61/84,** 299/31, 61/42

[51] **Int. Cl.** **E21d 9/00,** E21d 11/08

[58] **Field of Search** ..... 61/84, 85, 42, 45 R, 63; 299/31, 33, 11

[56] **References Cited**

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[57] **ABSTRACT**

The present invention relates to tunnel boring machines of the type generally comprising a cutterhead assembly rotatably supported on a cutterhead support assembly, a main frame fixed to the cutterhead support assembly, a gripper assembly slidable on the main frame, and drive means. The invention encompasses a novel erector assembly which may be fixed to the gripper assembly so that the machine can be engaged in active drilling operation simultaneous with the erection of a tunnel lining by said erector assembly.

24 Claims, 4 Drawing Figures

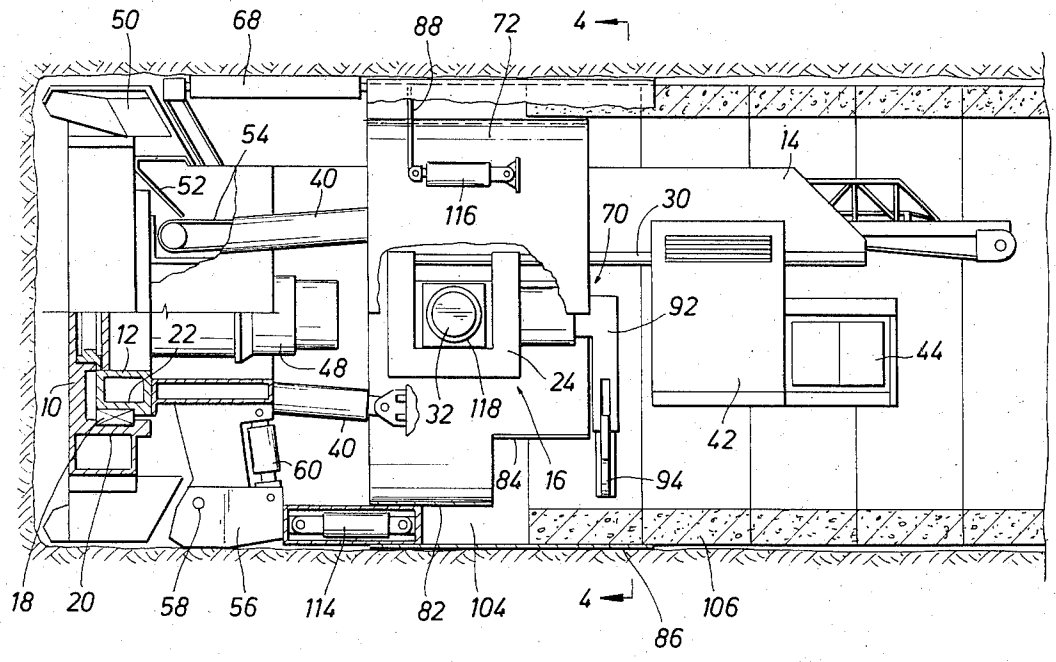

FIG. 1

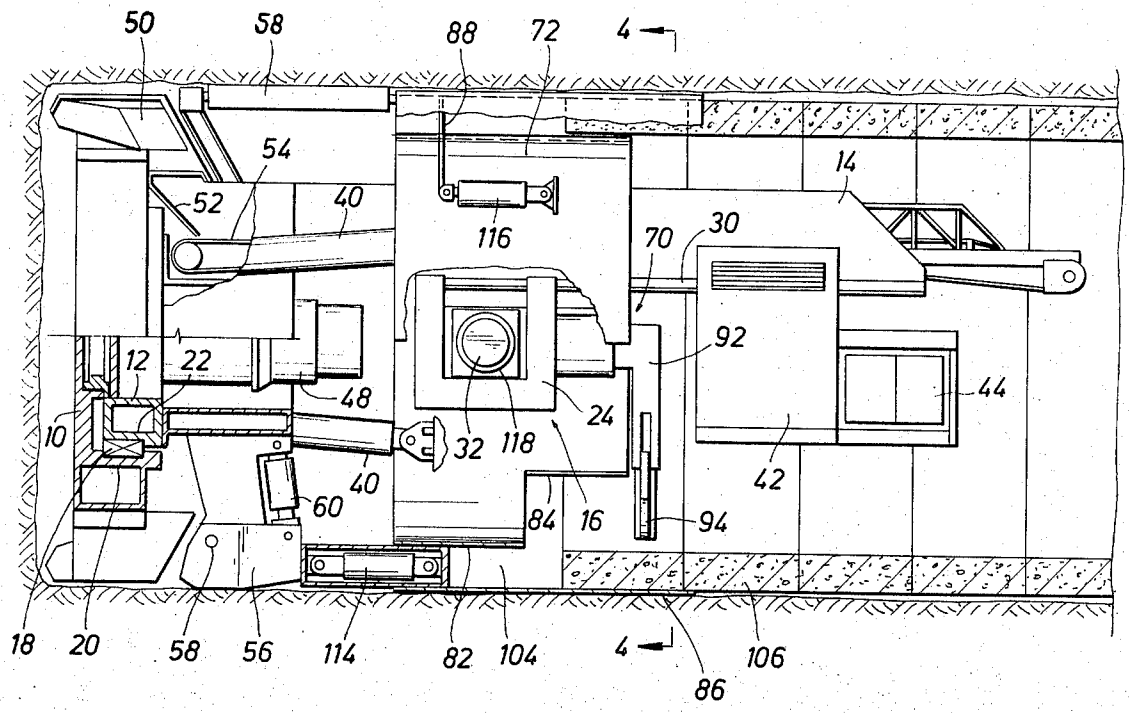
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FIG. 2

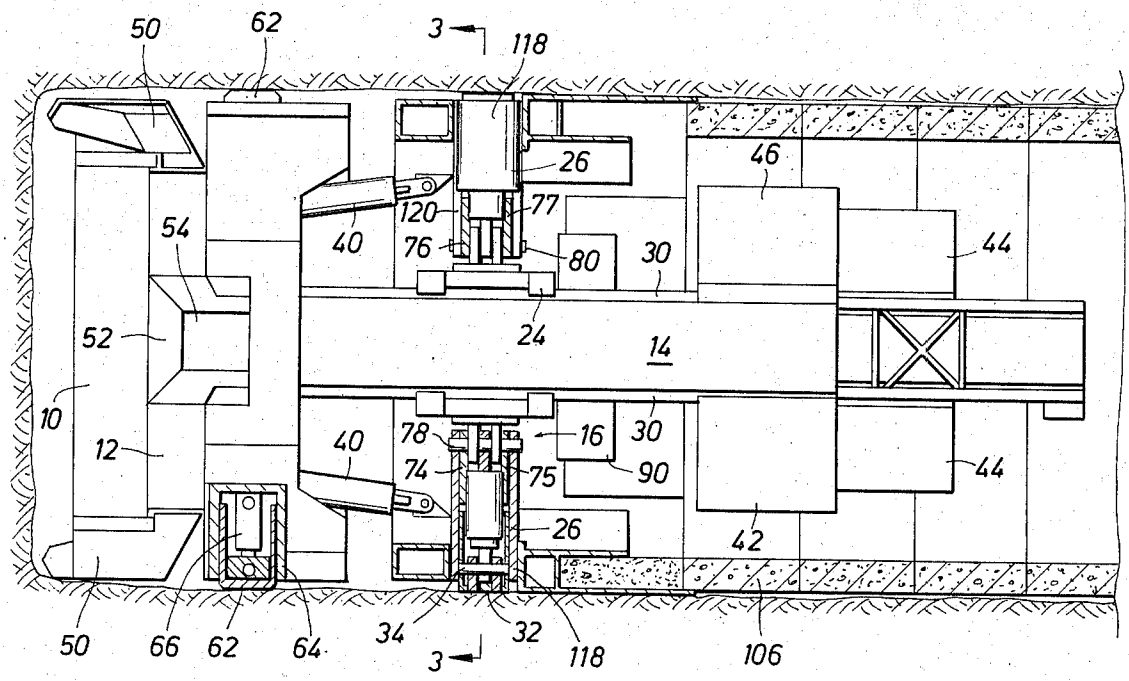
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FIG. 3

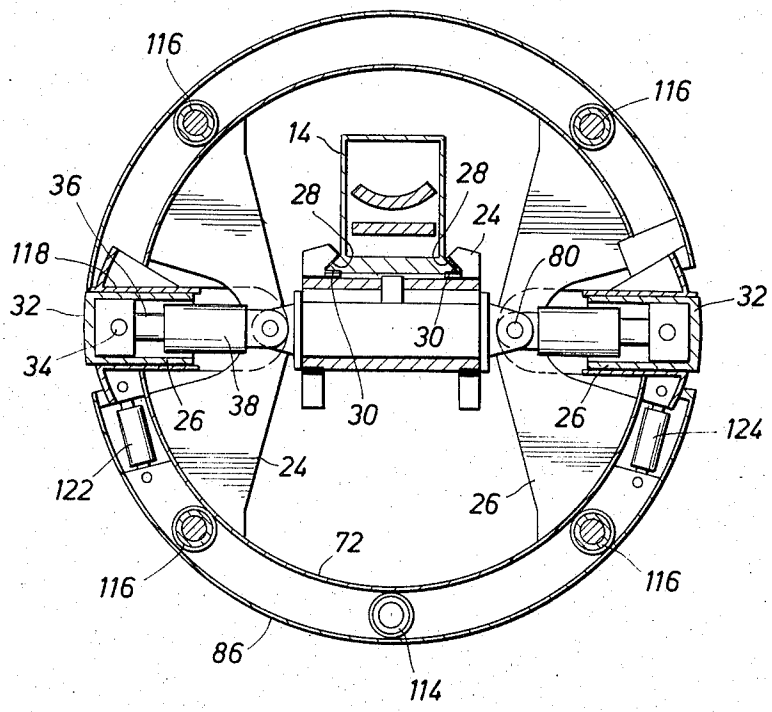
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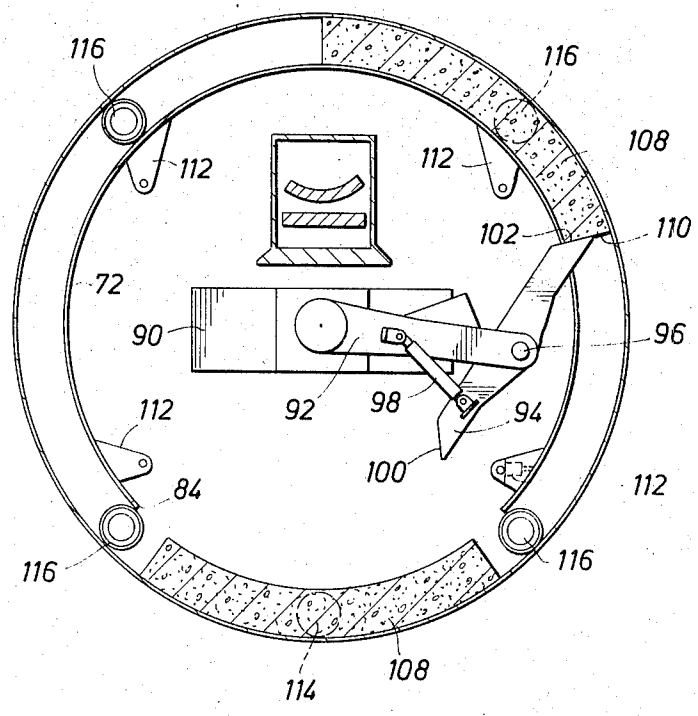
FIG. 4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TUNNEL BORING MACHINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the drilling of tunnels through earth or rock formations and the construction of linings in such tunnels to support the formation after drilling.

The particular type of tunnel boring machine to which the invention pertains is designed to move pregressively forward in a tunnel while boring the same. It comprises a cutterhead assembly including a plurality of cutters mounted on its forward face for contacting the earth formation. The cutterhead assembly is rotatably mounted on a cutterhead support assembly. The cutterhead support assembly is in turn fixed to a main frame which extends axially away from the cutterhead support in a rearward direction. A gripper assembly is mounted on the main frame so that it can slide longitudinally therealong.

The gripper assembly includes a pair of grippers mounted on a carriage which is non-rotatable to the main frame. The grippers are radially extensible to engage the tunnel wall. When the grippers are engaged with the tunnel wall, the main frame, cutterhead support and cutterhead are driven forward relative to the grippers by the drive means thus urging the cutters against the tunnel face. Simultaneously the cutterhead is rotated, moving the cutters across the face of the tunnel. The grippers remain fixed against the tunnel wall to provide reaction for the drilling forces. Buckets mounted along the periphery of the cutterhead, scrape along the invert of the tunnel and pick up the fragments of rock and dirt which have been broken from the tunnel face by the cutters. When the buckets reach the top of their circular path, they drop these cuttings onto a conveyor which transports them to the rear of the machine whence they are removed from the tunnel.

Drilling proceeds in this manner until the main frame reaches the end of its travel with respect to the gripper assembly. At this time the grippers are retracted from the tunnel wall and the drive means is reversed to pull the gripper assembly forward along the main frame. Then the grippers are once again extended into engagement with the tunnel wall, and drilling begins again. A basic tunnel boring machine, such as is described above, is exemplified in U.S. Pat. No. 3,598,445.

2. Description of the Prior Art

Several different types of erector assemblies for constructing tunnel linings are known in the prior art. In many instances, a tunnel boring machine having an erector assembly is modified to eliminate the gripper assembly. The machine is then forced to operate in cycles in which: 1) a ring of lining is constructed by the erector assembly; 2) use of the erector assembly is stopped and drilling progresses with the drive means of the machine thrusting directly against the axial edge of the previously constructed ring of lining. A machine of this type is disclosed in U.S. Pat. No. 3,247,675. In such cyclic operations, drilling and lining construction cannot occur simultaneously. This is one of the major disadvantages of such machines since it considerably slows the progress of the tunnel.

At least one system for simultaneous drilling and lining construction has been devised, as shown in U.S. Pat. No. 3,678,694. However, this system involves an extremely complicated erector system which is separate from the tunnel boring machine per se.

Another disadvantage of prior erector mechanisms is that they have been mechanically complicated and have included many moving parts. Typically they have included erector arms whose ends were adapted for gripping segments of the lining. It is generally necessary for these arms to be movable longitudinally and circumferentially as well as being telescopic or otherwise radially reciprocating. U.S. Pat. No. 3,247,675, cited above, discloses such an assembly. It can readily be appreciated that such mechanisms were difficult and expensive to manufacture, repair and operate. Furthermore they take up relatively large amounts of room on the tunnel boring machine. This is a major disadvantage since space is at a premium in such machines. Indeed this probably is one of the reasons for the elimination of the gripper assembly in prior tunnel boring machines including erector assemblies.

Another modification of the basic tunnel boring machine described above has an arrangement by which the gripper assembly can be used to correct for "roll," i.e. rotation of the tunnel boring machine about its own longitudinal axis, so as to misalign it from its proper level position. Such modification is exemplified in U.S. Pat. Nos. 3,061,287 and 3,203,737. Such roll usually occurs because of gradual creeping of the gripper shoes circumferentially along the tunnel wall. The prior arrangements for correcting such roll are either limited in application or involve complicated mechanisms with many parts and the inherent disadvantages of such mechanisms.

SUMMARY OF THE INVENTION

One of the principal objects of the present invention is to provide a tunnel boring machine, including an erector assembly, capable of simultaneous drilling and lining construction. Accordingly, a gripper assembly is slidably mounted on the main frame of the machine and the erector assembly is fixed to the gripper assembly. The drive means of the machine is operative between the gripper assembly and the cutterhead support assembly to drive the cutterhead support, together with the cutterhead and main frame, forward relative to the gripper assembly which remains fixed by its grippers to the tunnel wall.

Another object of the invention is to provide a simple, economical erector assembly having only a small number of moving parts and effectively occupying only a small amount of space on the machine. The erector assembly includes an arcuate inner shell supported on the gripper assembly so that its outer surface is everywhere equidistant from the tunnel wall. An erector arm, rotatable about the axis of the inner shell, engages segments of the lining such that they partially axially overlap the inner shell and moves these segments circumferentially along the inner shell to their selected positions. Holding means on the erector assembly temporarily holds the segments in place while other segments are positioned to form a broken ring around the inner shell. A key segment is then inserted in the break in the ring, preferably from a storage receptacle located forward of the ring, and the holding means is released.

To further simplify the erector mechanism, the erector arm preferably comprises a boom rotatable about the inner shell axis and a foot at the outer end of the

boom mounted to pivot in the plane of rotation of the boom. The foot need not grip the segments, but can simply push them along the outer surface of the inner shell.

Another object of the invention is the provision of auxiliary drive means in a tunnel boring machine. Such may be connected to the gripper assembly and extensible to engage and thrust against the axial edge of the lining. The auxiliary drive means can be used independently of the main drive means if means are provided to fix the gripper assembly relative to the cutterhead support. In any event, the auxiliary drive means can be used in conjunction with the main drive in various modes of operation.

Other features, objects and advantages of the present invention will be made apparent by the following detailed description of the preferred embodiments and by the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of a tunnel boring machine according to the invention with parts broken away and parts shown in section;

FIG. **2** is a top plan view of the machine of FIG. **1** with parts broken away and parts shown in section;

FIG. **3** is a transverse cross section taken along lines 3—3 of FIG. **2.**

FIG. **4** is a transverse cross section taken along lines 4—4 of FIG. **1.**

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is considered helpful in the understanding of the present invention to present here a brief general description of a type of tunnel boring machine with which the invention may be employed. Referring to FIGS. **1** and **2,** it can be seen that the tunnel boring machine generally comprises a cutterhead assembly **10,** a cutterhead support assembly **12,** a main frame **14,** and a gripper assembly **16.** The cutterhead **10** is rotatably mounted on the cutterhead support **12** by means of a bearing assembly **18** disposed between a rearward extension **20** on the cutterhead **10** and a mating hub **22** on the cutterhead support **12.** The cutterhead support **12** is in turn rigidly mounted on the forward end of the main frame **14** so that the cutterhead, cutterhead support and main frame will move forward and backward as a unit.

The gripper assembly **16** (see also FIG. **3**) comprises a carriage **24** and two grippers **26.** A pair of rails **30** are integrally formed on opposite sides of the lower part of main frame **14.** Raceways **28** on the carriage **24** are configured to fit and ride on the rails **30** so that the gripper assembly **16** can move longitudinally relative to the main frame **14** and its connected parts. However, it will be seen that the fit and configuration of rails **30** and raceways **28** prevent lateral movement and rotation of the carriage **24** relative to the main frame **14.**

The grippers **26** are mounted on the carriage **24** on opposite sides thereof. Each of the grippers **26** comprises an integral shoe **32** pivotally connected at **34** to the outer end of a hydraulic ram **36.** The ram **36** is mounted in a cylinder **38** and is selectively radially extensible and retractable therein. When the rams **36** are extended, the shoes **32** contact the side walls of the tunnel in which the machine is disposed and which it is progressively drilling.

Main drive means comprising hydraulic cylinder assemblies **40** are disposed between the cutterhead support assembly **12** and the gripper assembly **16.** In some machines the hydraulic cylinder assemblies may be connected directly to the gripper assembly. In the exemplary embodiment described herein, it is connected to the gripper assembly through related apparatus, shell **72,** to be described hereafter. On the rear of the main frame **14** on opposite sides thereof are a cab **46** for the machine operator and a compartment **42** for housing various equipment such as electrical equipment, pumps for the hydraulic fluid, etc. Auxiliary storage compartments such as **44** may also be provided in this vicinity.

Drilling generally proceeds as follows. The grippers **26** are extended and firmly engaged with the tunnel wall. This provides reaction for the forces of the hydraulic cylinders **40.** The hydraulic cylinder assemblies **40** are extended to urge the cutterhead assembly **10** against the face of the tunnel. Simultaneously, rotary drive means, such as a motor **48,** is operated to rotate the cutterhead assembly **10** on the cutterhead support assembly **12.** A plurality of cutters (not shown) are mounted on the front of the cutterhead assembly **10** to engage the formation. These cutters are pressed into and dragged along the face of the tunnel by the forward and rotary drive of the cutterhead assembly. The cutters thus break away the formation and fragments fall to the floor of the tunnel.

A plurality of buckets **50** are mounted on the outer edge of the cutterhead assembly **10** and rotate therewith. These buckets **50** are configured to scrape the invert of the tunnel as they pass along the bottom of their arc of travel and collect the fragments which have been broken from the formation. When the buckets **50** reach the top of their arc, they dump these fragments into a chute **52** in the cutterhead support assembly **12.** The chute **52** directs the fragments onto an endless belt type conveyor **54** which runs longitudinally through the main frame **14** and carries the fragments to the rear of the machine whence they can be removed from the tunnel.

Drilling proceeds in this manner until the main frame **14** has reached the end of its forward travel on the gripper carriage **24** (or until it has reached any other desired point in its travel). At this time the grippers **26** are retracted from the tunnel wall and the cylinder assemblies **40** are reversed to pull the gripper assembly **16** forward along the main frame **14.** The grippers **26** are again extended to anchor the gripper assembly relative to the tunnel wall and the drilling is resumed.

The tunnel boring machine shown is of the "fixed head" type, i.e. the cutterhead support assembly **12** does not move relative to the main frame **14.** To steer this type of machine, a plurality of shoes are provided on the cutterhead support assembly. These can be urged against the tunnel wall to shove the cutterhead support assembly **12** in any desired direction. The bottom shoes **56** (only one of which is shown) effect the vertical steering. The shoe **56** is pivoted at **58** to swing in a vertical plane and a hydraulic ram assembly **60** is provided to pivot the rear end of shoe **56** about the pin **58.** Because the cutterhead support assembly **12** always rests on the shoe **56,** a downward motion of the rear end of the shoe moves the cutterhead support assembly **12** upwardly. Similarly, upward motion of the rear end of the shoe **56** moves the cutterhead support assembly **12** downwardly.

For horizontal steering, a pair of shoes **62** are provided on opposite sides of the cutterhead support assembly **12.** The shoes **62** are mounted in slideways **64** in the cutterhead support assembly **12** and can be urged radially outwardly by hydraulic ram assemblies **66.** Extension of the shoe **62** on the left hand side of the machine, for example, turns the machine to the right by shoving it away from the left hand tunnel wall.

In another type of tunnel boring machine known as the "swivel head" type, the cutterhead support assembly is mounted on the main frame by means of a ball joint or the like so that it can swivel relative to the main frame. In this type of machine, the steering is accomplished by a plurality of hydraulic cylinder assemblies or the like operative to pivot the cutterhead support assembly to various attitudes on the main frame. Although the "fixed head" type machine is shown and described here as exemplary, it should be understood that the invention is equally applicable to the "swivel head" type machine and to machines having various other modifications.

In addition to the basic equipment described above, a tunnel boring machine according to the invention may also include features such as the shield **68** which extends over the top part of the machine rearwardly of the cutterhead support assembly **12** and prevents large rock fragments from falling from the crown of the tunnel and injuring personnel or damaging the equipment.

Turning now to a more detailed description of the invention, the machine includes an erector assembly indicated generally at **70** which is fixed to the gripper assembly **16.** The erector assembly **70** comprises an inner shell **72** supported by transverse gusset plates **74, 75, 76,** and **77.** The gusset plates **74, 75, 76,** and **77** are supported on the gripper carriage **24** by respective pivot pins **78** and **80.** The inner shell **72** is arcuate and is positioned on the carriage **24** so that its outer surface is everywhere equidistant from the tunnel wall, i.e. it is spaced from the tunnel wall and generally follows its contour. The forward part **82** of the inner shell **72** is cylindrical, while the rear part of the inner shell **72** has an opening **84** therein along the invert or floor of the tunnel. The inner shell **72** overlies the gripper assembly **16** and extends rearwardly beyond the gripper assembly a slight distance.

A cylindrical outer shell **86** is supported on the inner shell **72** by an annular gusset **88** between the forward ends of the two shells **72** and **86.** The outer shell **86** is coaxial with the inner shell **72** and extends axially beyond the inner shell a short distance. The shells **72** and **86** are spaced apart a distance slightly greater than the thickness of the segments of which the tunnel lining is to be formed, and the shells are sized so that the outer surface lies adjacent the tunnel wall. The shells **72** and **86** support and guide the segments of the tunnel lining as they are being positioned in a manner to be described more fully below.

Another main part of the erector assembly **70** is the erector arm comprising base **90,** boom **92** and foot **94.** The base **90** is attached to the rear of the carriage **24.** The boom **92** is rotatably mounted on the rear of the base **90** and extends in a radial direction. The base **90** contains an actuator for rotating the boom **92** in a transverse plane about the axis of the shells **72** and **86.** The radially extending part of the boom **92** is located just rearwardly of the rear edge of shell **72** so that the boom **92** can swing clear of the shell **72.**

The foot **94** is pivotally mounted by pin **96** on the outermost end of the boom **92** so as to pivot in the place of rotation of boom **92.** A piston and cylinder assembly **98** is provided for pivoting foot **94.** The foot **94** is elongated and has segment engaging means on each end thereof. In the preferred embodiment shown the segment engagement means comprises a pair of non-gripping pushing surfaces **100** and **102.**

Referring to FIG. **1** it can be seen that the outer shell **86** and the cylindrical part **82** of the inner shell **72** form a receptacle **104** adjacent the invert of the tunnel and forward of the erector arm.

In describing the operation of the erector assembly **70,** it will be assumed that a section **106** of tunnel lining has been previously constructed by the erector assembly. The section **106** is comprised of a plurality of rings of concrete or other suitable material disposed end-to-end. Each of the rings includes a plurality of arcuate segments such as **108.**

To construct the next ring of lining, the gripper assembly **16** is positioned on the main frame **14** so that the attached erector assembly **70** is forward of the section **106** of lining previously constructed. A first segment, known as the key segment, is lowered through opening **84** to the bottom of the outer shell **86** and then pushed into the key storage receptacle **104.** Next another segment **108** is placed through opening **84** on the bottom of the outer shell **86** below the erector arm in such a position that it can be engaged by the foot **94** and so that it also axially overlaps the inner shell **72.** The boom **92** and foot **94** are then pivoted until one of the surfaces **100, 102** engages the edge **110** of the second segment **108.** The boom **92** is then rotated to move the segment circumferentially between the inner and outer shells **72** and **86** to a desired position adjacent the crown of the tunnel. Because of the presence of the inner shell **72** which supports and guides the segment, the foot **94** does not need gripping means per se but only the pushing surfaces **100** and **102.** When the first segment has been positioned, it is held in place by suitable holding means so that the erector arm will be free to position another segment.

As shown, the holding means comprises a plurality of ram assemblies **112** having parts radially extensible through holes (not shown) in the inner shell **72** to engage the segments **108** and hold them against the outer shell **86.** While the second segment is being positioned, a third segment may be placed on the bottom of the outer shell **86** ready for engagement by the foot **94.** By positioning segments on alternating sides of the tunnel wall, the necessary movement of the boom **92** and the foot **94** is minimized. It will be noted that for positioning of the lower segments in the ring, it might be necessary to place the segments slightly off center on the bottom of the outer shell **86** so as to allow room for the appropriate surface **100** or **102** to engage their edges, i.e. a segment can not be placed too close to another segment already positioned because the end of the foot **94** must be placed between the two in order to engage the segment. It will also be appreciated that while the provision of an elongated foot with a pushing surface at each end simplifies the erection process, a single pushing surface could be employed. The foot **94** can always be pivoted until it lies perpendicular to the boom **92.** In this position, the boom can be rotated to any position past segments already positioned in the ring being

constructed or a segment lying on the bottom of the outer shell awaiting positioning.

Segments are positioned in the manner described above until a broken ring is formed with the break in the ring lying to the rear of the key storage receptacle and being of slightly larger dimension than the key segment. The key segment is then pushed rearwardly from the receptacle **104** into the ring by key placement means comprising the key thrust assembly **114.** The key supports the other segments in the ring so that the holding rams **112** can be released.

Hydraulic segment thrust assemblies **116** are mounted on the outer surface of the inner shell forward of the locus of the ring being constructed. These assemblies have extensible parts for axially packing the newly formed ring against the section **106** of previously constructed tunnel lining. The key thrust assembly **114,** while located forward of the assemblies **116** has a telescoping cylinder extensible toward the key segment for placement of the key segment and further extensible for axially packing the key segment against the section **106.**

It will be appreciated that the unique construction of the erector assembly provides many advantages over the prior art. One of these is the simplification of the erector arm. It has been stated that with the arrangement of the present invention, no segment gripping mechanism is needed, rather the non-gripping pushing surfaces **100** and **102** are employed. Additionally, it can be seen that the erector arm does not move longitudinally, nor does it reciprocate radially. The only movement required for placement of the segments is the rotation of the boom **92** and the pivoting of the foot **94,** both of which occur in one transverse plane. This not only simplifies the mechanism, reducing the number of moving parts, but also causes the erector arm to occupy less space on the tunnel boring machine. This is an important advantage since space is at a premium in tunnels and boring machines used therein. Additionally, the simplified mechanism reduces the cost of manufacture and makes the assembly easier and cheaper to operate and repair.

Much of the simplification of the erector arm and the related advantages is made possible by the use of the shell, particularly the inner shell **72.** Yet the shells **72** and **86,** even though quite large, effectively take up very little space in the machine since they lie close to the tunnel wall. Furthermore, the shells serve as shields to protect the personnel and machinery from debris which would otherwise fall from the unlined portion of the tunnel wall.

The thrust assemblies **114** and **116** also provide an auxiliary drive means for the tunnel boring machine which may be used with or instead of the main drive means **40.** Under good drilling conditions, the grippers **26** provide adequate reaction for the drilling forces so that a ring of the tunnel lining can be constructed while drilling is taking place.

However if drilling conditions are such that the grippers can not provide adequate reaction, alternate modes of operation may be employed. In one such mode, the gripper assembly **16** is fixed relative to the cutterhead support assembly **12,** and thus to the cutterhead assembly **10** and main frame **14,** by locking the hydraulic cylinder assemblies **40.** The assemblies **114** and **116** can then be used to advance the machine against the tunnel face by thrusting against the axial edge of the tunnel lining.

In another mode, the grippers might be engaged with the tunnel wall to provide part of the reaction force and backed up by the assemblies **114** and **116** locked in position against the edge of the tunnel lining.

Other variations are possible. For example if an especially long drilling stroke were desired, both the cylinder assemblies **40** and the auxiliary drive means **114** and **116** could be used, either simultaneously or consecutively.

Turning now to a more detailed discussion of the gripper assembly **16,** it will be seen that the grippers **26** are pivotally mounted on opposite sides of the carriage **24** by spaced apart pins **78** and **80.** These same pins **78** and **80** also pivotally mount the gusset plates **74, 75, 76** and **77** which support the shells **72** and **86.** Each of the grippers **26** rides in a slideway **118,** and the slideways **118** each have at their radially inner ends a pair of ears **120** which extend radially inwardly for pivotal connection to one of the pins **78** or **80.**

Gripper piston and cylinder means **122** and **124** are mounted on opposite sides of the gripper assembly, each of the assembies **122** and **124** having one part attached to the adjacent slideway **118** and the other part attached to the shells **72** and **86.**

When the grippers **26** are not in engagement with the tunnel wall, the piston and cylinder means **122** and **124** can be used to pivot the grippers **26** about their respective pins **78** and **80** so as to align them properly with the tunnel wall. When the grippers **26** are in engagement with the tunnel wall, the piston and cylinder means **122** and **124** can be used to correct for "roll" of the tunnel boring machine, i.e. rotation of the machine about its longitudinal center caused by gradual creeping of the gripper shoes **32** along the tunnel wall. If, for example, the machine has rotated clockwise, the piston and cylinder **122** are extended and the piston and cylinder **124** are contracted. This rotates the shells **72** and **86** in a counterclockwise direction. When the shells rotate, the pin **78** moves downwardly and the pin **80** moves upwardly straightening the carriage **24.** Because the rails **30** and slideways **28** prevent relative rotation of the carriage **24** and the main frame **14,** the entire machine is straightened by this movement of the pins **78** and **80.** The fact that the outer shell **86** lies closely adjacent the tunnel wall and bears against it, insures that the pins **78** and **80** will move as described above when the shells **72** and **86** are rotated. After the machine has been straightened, the grippers **26** can be retracted from the tunnel and realigned by means of the piston and cylinder means **122** and **124.** This unique roll correction means is enhanced by the shells, particularly the outer shell **86.**

In addition to serving as a means for roll correction, the pistons and cylinders **122** and **124** may be used in combination with grippers **26** to raise or lower the main frame at the location of the gripper assembly **16.** This is permissible since the grippers are mounted for independent pivoting about pins **78** and **80.** For example to raise the main frame **14,** both pistons and cylinders **122** and **124** may be extended, while grippers **26** are in engagement with the tunnel wall, raising pins **78** and **80** and thus the main frame. Similarly, contraction of both pistons and cylinders **122** and **124** lower pins **78** and **80** and main frame **14.** Since this movement requires counter-pivoting of the grippers about their respective

pins, it can be seen that independent mounting of the grippers is required. Prior art machines were provided with roll correction apparatus do not provide such independent mounting, limiting their flexilibity.

From the foregoing it will be appreciated that the tunnel boring machine shown and described above provides a novel erector assembly, connected to the gripper assembly, whereby erection of tunnel lining and drilling of the tunnel can proceed simultaneously. The shell means, while large, is disposed in an "out of the way" location along the periphery of the tunnel and overlies other parts of the machine. Thus it does not effectively take up a large amount of the available space in the tunnel, yet it helps to make possible the simplification of the remainder of the erector assembly whereby additional space is saved. The invention also provides an erector assembly with relatively few moving parts which is relatively inexpensive and easy to manufacture, operate and maintain.

Additionally the invention provides both main drive means and auxiliary drive means for the machine, which drive means can be used either individually or together to achieve various modes of operation, thus enhancing the adaptability of the machine. Finally the invention provides a unique mechanism for correction of "roll."

The above description and the drawings represent preferred embodiments of the invention. Many modifications of the invention may be made without departing from the spirit of the invention, and it is intended that the scope of the invention be limited only by the appended claims.

We claim:

1. A tunnel boring machine comprising:

a cutterhead support assembly;

a cutterhead assembly rotatably mounted on said cutterhead support assembly;

a main frame connected to said cutterhead support assembly and extending in a generally rearward axial direction therefrom opposite said cutterhead assembly;

a gripper assembly slidably mounted on said main frame rearwardly of said cutterhead support assembly for axial movement relative to said main frame, said gripper assembly comprising a gripper carriage slidable on said main frame, a pair of grippers carried by said carriage and radially movable relative to the wall of a tunnel in which said machine is employed for engagement therewith, and means for selective radial projection and retraction of said grippers relative to said wall for engagement and non-engagement therewith;

an erector assembly connected to said gripper assembly and operative to construct a lining along the wall of said tunnel; and

drive means connected to said gripper assembly for driving said cutterhead support assembly forward relative to said gripper assembly when said grippers are engaged with the wall of said tunnel and thereby advancing said cutterhead assembly.

2. A tunnel boring machine as recited in claim **1** wherein said erector assembly comprises an arcuate inner shell, supported on said gripper assembly, an outer surface of which is everywhere substantially equidistant from said tunnel wall; an erector arm located adjacent to said inner shell and mounted for rotation about the axis of said inner shell, said erector arm including segment engagement means at its outermost end for engaging a segment of said tunnel lining such that at least a portion of said segment axially overlaps said inner shell; means for rotating said erector arm about said axis so as to move such segment circumferentially along the outer surface of said inner shell to a desired position in a section of said tunnel lining being constructed between said inner shell and said tunnel wall; and holding means engageable with such segment for temporarily holding such segment in said position during construction of the remainder of said section.

3. A tunnel boring machine as recited in claim **2** wherein said holding means comprises a plurality of ram assemblies mounted on said inner shell, each of said ram assemblies including an extensible and retractable holding foot engageable with the inner surface of said segment and also including means for extending and retracting said foot.

4. A tunnel boring machine as recited in claim **2** wherein said erector arm comprises a boom mounted for rotation about said axis and extending radially outwardly therefrom, an erector foot pivotally mounted on the outer end of said boom for pivotal movement in the plane of rotation of said boom, said erector foot being elongated and having such segment engagement means on at least one end thereof, and means operative to pivot said erector foot relative to said boom.

5. A tunnel boring machine according to claim **4** wherein said segment engagement means comprises a non-gripping segment pushing surface formed on the end of said erector foot.

6. A tunnel boring machine according to claim **2**, said section comprising a plurality of said segments arranged in a ring around said inner shell, and said section including a key segment operative to support other of said segments in said ring, whereby said holding means can be released.

7. A tunnel boring machine according to claim **6** wherein said key segment is located adjacent the invert of said tunnel.

8. A tunnel boring machine according to claim **7** wherein said erector assembly further includes a key storage receptacle located axially forwardly of said erector arm for storing said keys during positioning of said other segments and wherein said tunnel boring machine further includes a key placement mechanism for moving said key segment from said receptacle rearwardly into axial alignment with said other segments.

9. A tunnel boring machine according to claim **8** further comprising a plurality of segment thrust assemblies, each of said segment thrust assemblies including a fixed part rigidly mounted on the radially outer surface of said inner shell between said cutterhead support assembly and said other segments and a ram telescopically mounted on said fixed part and extensible toward and engageable with said segments for packing said segments against a completed part of the tunnel lining; and wherein said key placement mechanism comprises a fixed part and a ram, said ram being extensible through said receptacle to push said key segment rearwardly from said receptacle into axial alignment with said other segments and being further extensible to pack said key segment against said completed part of the tunnel lining.

10. A tunnel boring machine according to claim **6** further comprising a plurality of segment thrust assemblies, each of said segment thrust assemblies including

a fixed part rigidly mounted on the radially outer surface of said inner shell between said cutterhead support assembly and said segments and a ram telescopically mounted on said fixed part and extensible toward and engageable with said segments for packing said segments against a completed part of the tunnel lining.

11. A tunnel boring machine according to claim **2** wherein said inner shell has an opening therein adjacent the invert of said tunnel through which said segments can be passed.

12. A tunnel boring machine according to claim **11** wherein said erector assembly further comprises a cylindrical outer shell coaxially surrounding said inner shell and rigidly mounted relative thereto, said outer shell being spaced from said inner shell by a distance slightly greater than the thickness of said segments.

13. A tunnel boring machine according to claim **12** wherein said outer shell extends axially rearwardly beyond said inner shell to a completed part of said tunnel lining.

14. A tunnel boring machine according to claim **9** wherein said segment thrust assemblies and said key thrust assembly form auxiliary drive means for advancing said cutterhead assembly by extending said rams against said tunnel lining.

15. A tunnel boring machine according to claim **14** further comprising means for selectively longitudinally fixing said gripper assembly relative to said cutterhead support assembly.

16. A tunnel boring machine according to claim **15** wherein said first mentioned drive means comprises a plurality of hydraulic cylinder assemblies mounted between said gripper assembly and said cutterhead support assembly, said cylinder assemblies further serving as said fixing means.

17. A tunnel boring machine according to claim **1** further comprising auxiliary drive means for advancing said tunnel boring machine by thrusting against said tunnel lining.

18. A tunnel boring machine according to claim **17** further comprising means for fixing said gripper assembly relative to said cutterhead support assembly.

19. A tunnel boring machine according to claim **18** wherein said first mentioned drive means comprises a plurality of hydraulic cylinder assemblies mounted between said gripper assembly and said cutterhead support assembly, said cylinder assemblies further serving as said means for fixing said cutterhead support assembly relative to said gripper assembly and wherein said auxiliary drive means comprises a plurality of thrust assemblies mounted on said erector assembly, each of said thrust assemblies having a ram extensible toward and engageable with said tunnel lining.

20. A tunnel boring machine according to claim **1** wherein each of said grippers is pivotally connected to said carriage so as to pivot in a plane transverse to said tunnel; said machine further comprising gripper piston and cylinder means connected to each of said grippers and operative to pivot said gripper means in said transverse plane.

21. A tunnel boring machine according to claim **20** wherein said erector assembly comprises arcuate shell means lying adjacent said tunnel wall and connected to said carriage, and wherein said gripper piston and cylinder means are connected to said shell means.

22. A tunnel boring machine according to claim **20** wherein the longitudinal centerline of said tunnel is substantially coincident with a longitudinal axis of said machine, wherein said carriage is non-rotatable on said main frame and said shell means is non-rotatable on said carriage such that said gripper piston and cylinder means are further operative to rotate said machine about said machine axis when said grippers are engaged with the wall of said tunnel.

23. A tunnel boring machine according to claim **20** wherein each of said grippers comprises a gripper shoe pivotally connected to the radially outer end of said gripper so as to pivot in said transverse plane.

24. A tunnel boring machine according to claim **20** wherein the pivotal connections of said grippers are radially spaced from the longitudinal axis of said tunnel and also spaced from each other.

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