Feb. 18, 1969 E. W. HAYES 3,427,813

SHIELD TUNNELING APPARATUS

Filed Feb. 8, 1967

Sheet 1 of 4

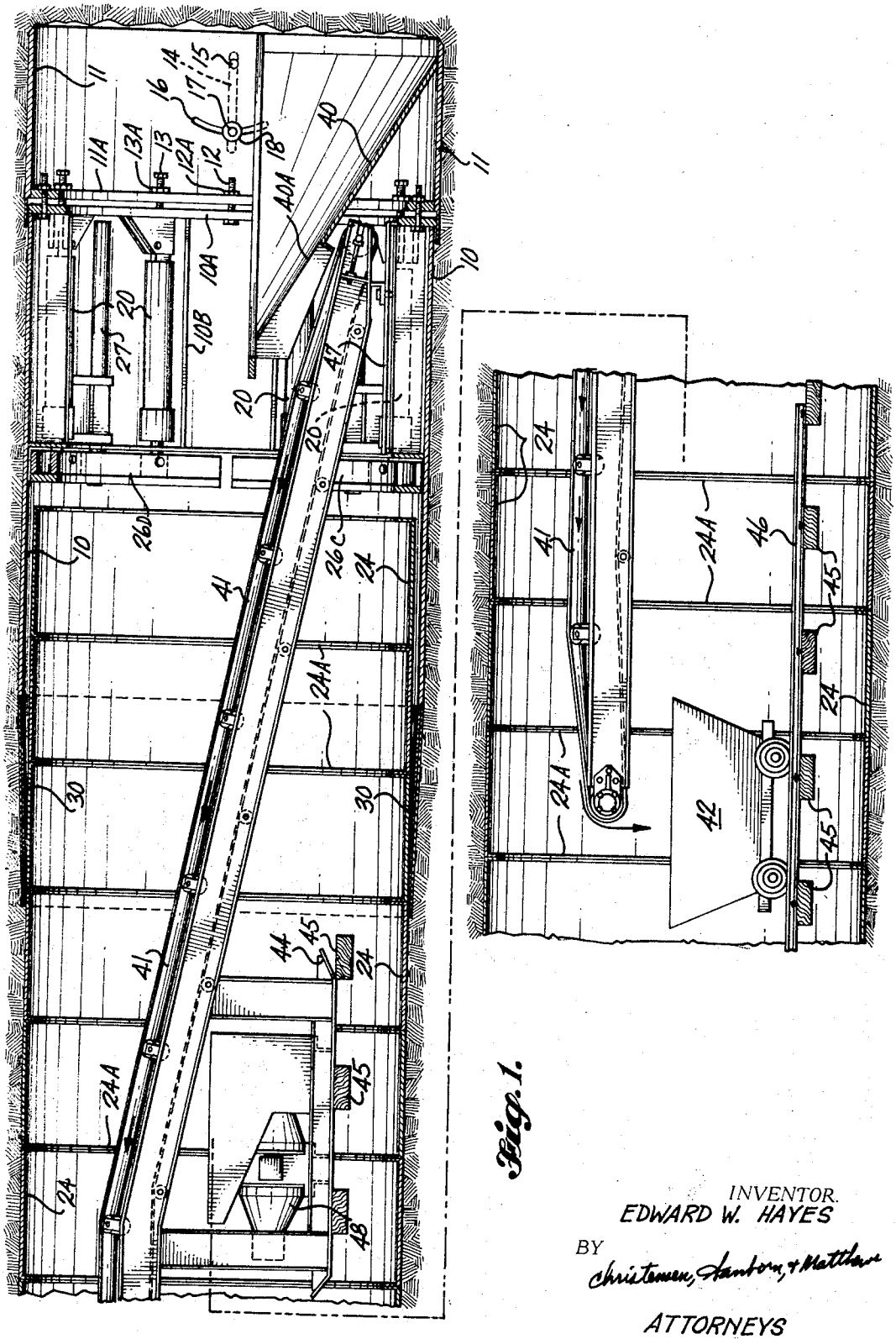


Fig. 1.

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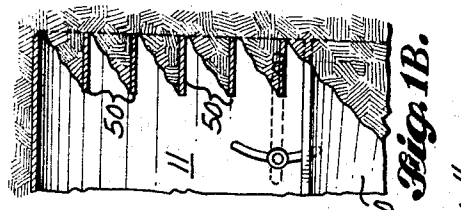


Fig. 1B.

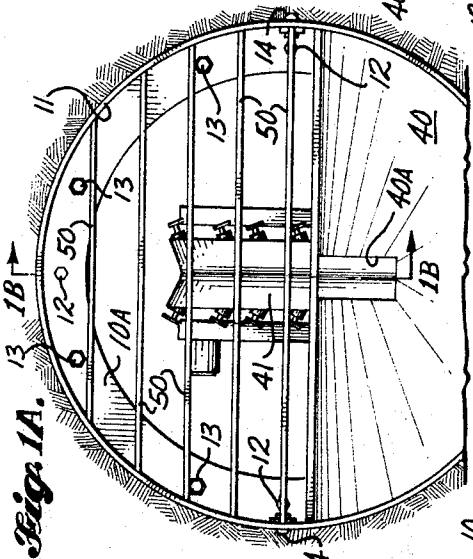


Fig. 1A.

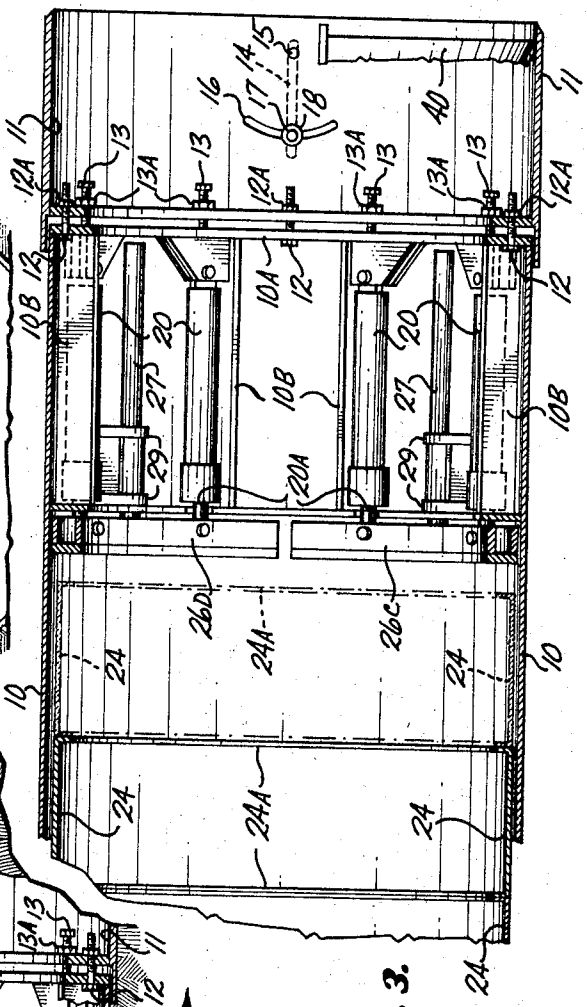


Fig. 3.

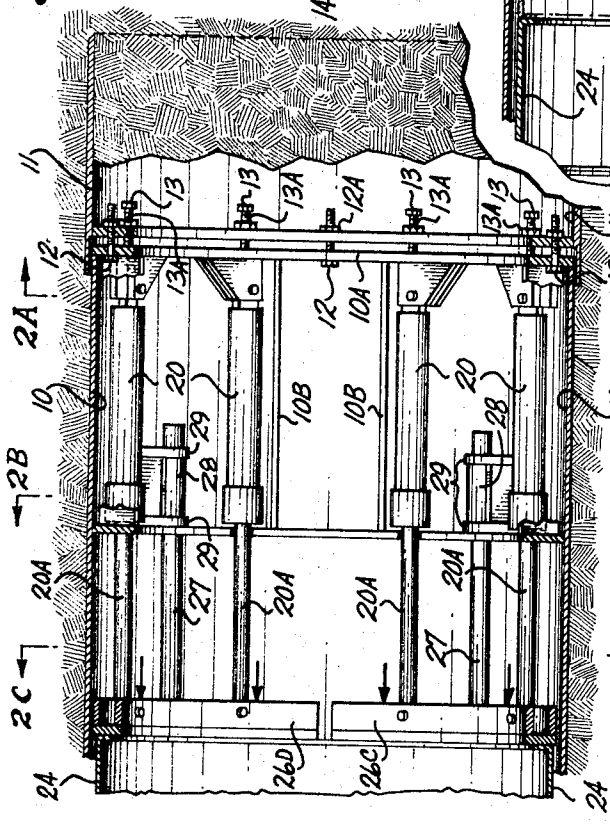


Fig. 2.

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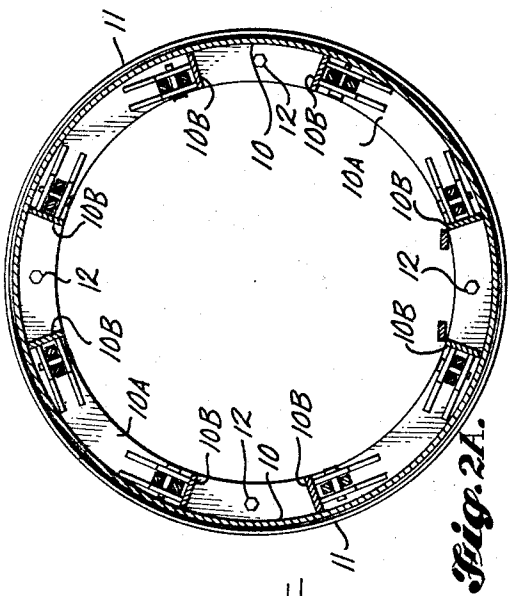


Fig. 2A.

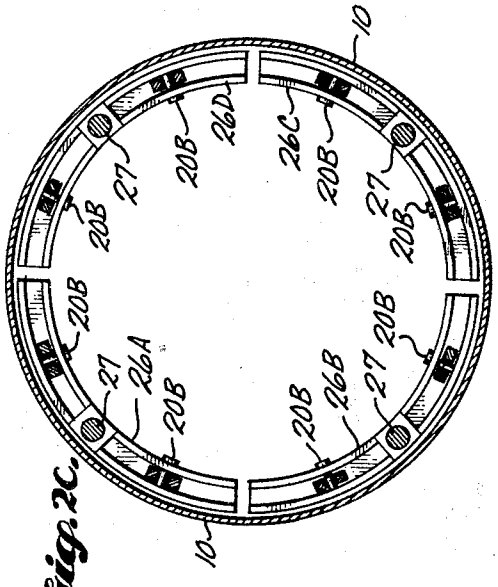


Fig. 2C.

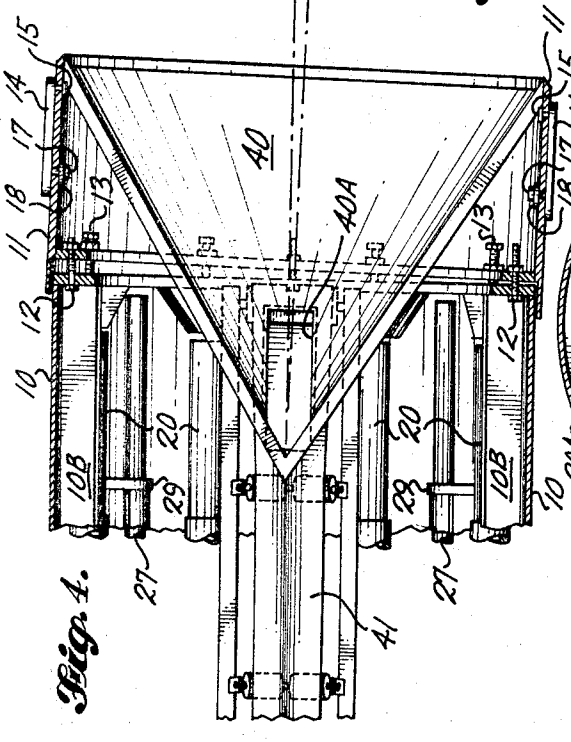


Fig. 4.

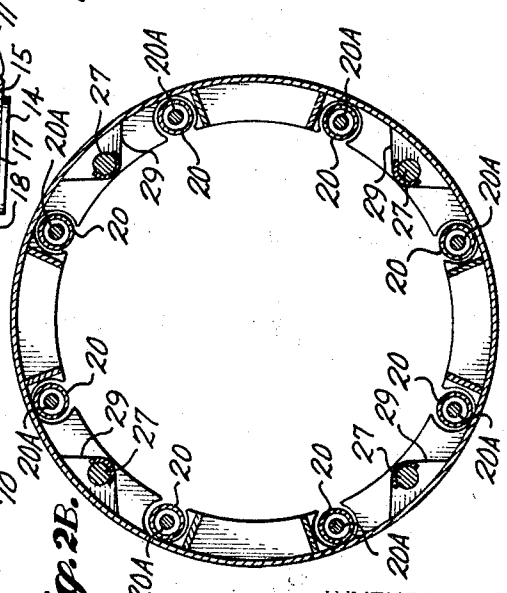


Fig. 2B.

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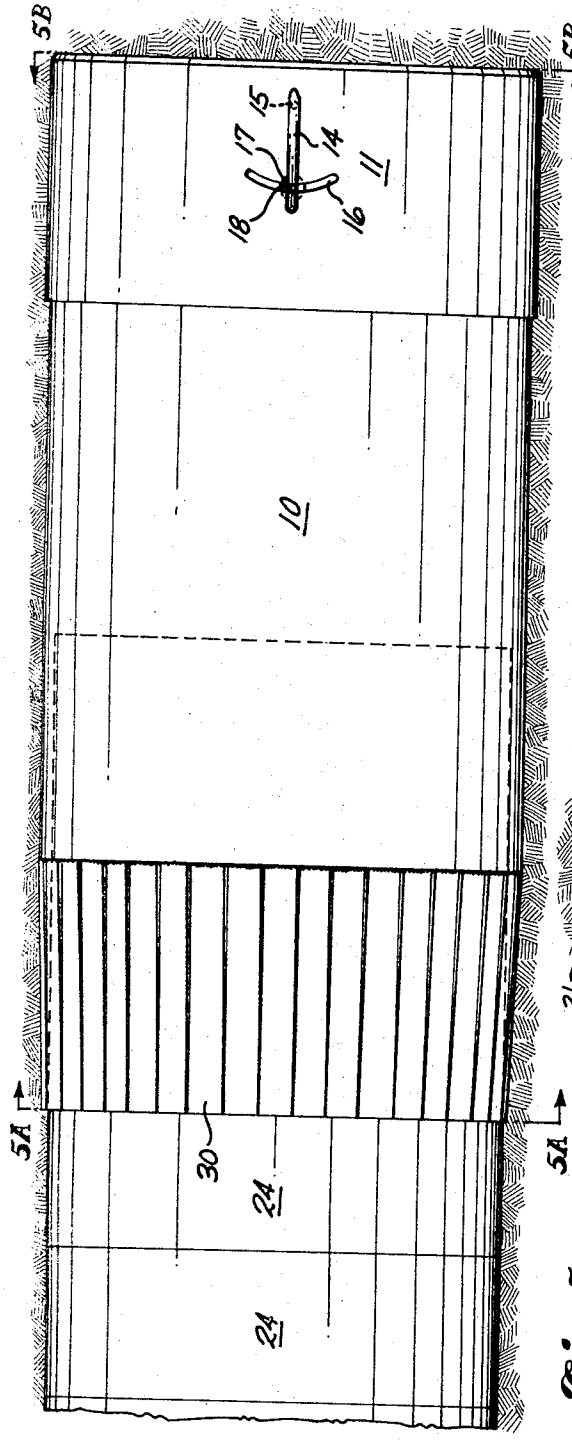


Fig. 5

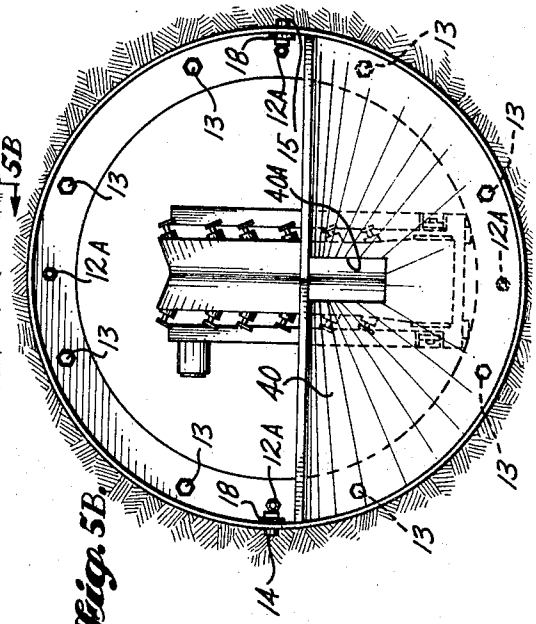


Fig. 5B

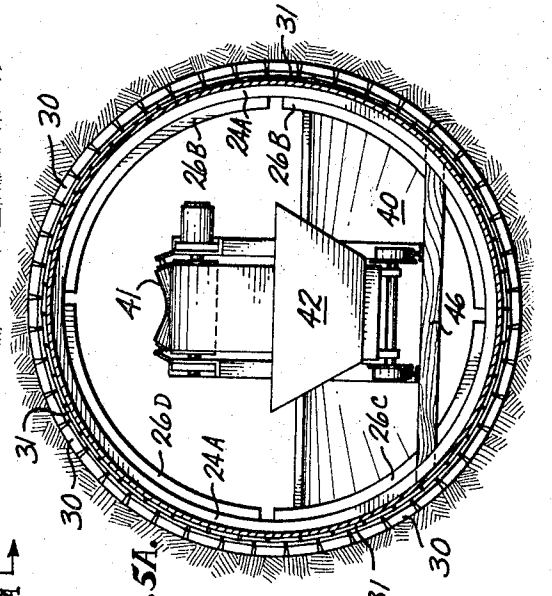


Fig. 5A

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SHIELD TUNNELING APPARATUS

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Filed Feb. 8, 1967, Ser. No. 614,706
U.S. Cl. 61—85 8 Claims
Int. Cl. E01g 5/14

ABSTRACT OF THE DISCLOSURE

A tunneling system is disclosed which includes a hydraulic tunneling shield having an adjustable front cutting edge which permits control over the direction of shield movement. The trailing end of the assembly is provided with overlapping and spaced apart sections which overlie the tunnel liners as the same are assembled inside of the rear section of the shield. Anti-rotation devices secured to the exterior of the shield prevent shield rotation.

The present invention relates to apparatus for tunneling and more particularly to an improved shield and earth removal system for use in shield-tunneling. Shield-tunneling in general involves the use of a steel box or ring, typically of circular cross section and having a forward end which projects into the earth to be excavated. Hydraulic jacks carried in the shield are adapted to force the shield forwardly through the earth by pushing against the tunnel lining plates installed behind the shield. The internal diameter of the shield is slightly greater than the outer diameter of the tunnel liners so that the tunnel lining can be assembled within the confines of the tail section of the shield. Then when the shield is jacked forwardly the tunnel lining is left in position to support the surrounding earth. Suitable grouting material is typically utilized to fill the void existing between the tunnel lining plates and the surrounding ground due to the diameter differentials between the shield and the lining plates. Historically, one of the reasons for using cylindrical shields of circular cross-section is that shields show a tendency to spiral as they advance, and thus it has been found that a circular shield tends to minimize adverse effects of such rotation on the primary lining plates being erected within the tail section.

It has been found in practice that during the driving of a tunnel using a shield there is a tendency for the tunnel to drift. Heretofore the direction of the shield movement has been primarily controlled through the use of differentials in the pressure applied to the various hydraulic jacks located around the periphery of the shield and adapted to drive against the previously installed tunnel lining plates. It is not uncommon to find in practice that the tail of the shield becomes "iron-bound" due to the tail binding on opposite corners or edges of the last installed lining plates as steering is attempted. It would be advantageous to have a tunneling system including a shield assembly having increased steering capabilities as well as an improved tail section to facilitate the driving of a tunnel in an accurate path without encountering the various binding problems heretofore encountered in the art.

Accordingly, it is an object of the present invention to provide an improved tunneling shield assembly. Another object of the present invention is to provide a tunneling shield having a simple but extremely rugged steering control assembly. Another object of the present invention is to provide selectively positionable steering members for controlling the rotation of a tunneling shield. An additional object of the present invention is to provide a tunneling shield having flexible overlapped sheets on the tail section thereof for protecting the workers during assembly of liner plates and reducing binding problems heretofore encountered. Another object is to provide a tunneling shield having a plurality of horizontal plates extending across at least part of the leading open end to permit use of the shield in soft ground.

The apparatus of the present invention includes a tunneling shield having a cylindrical front section adjustably secured to a tube-like main body portion. The arrangement is such that the adjustable section can be selectively positioned at an angle with respect to the longitudinal axis of the main shield body. In one preferred embodiment the nose section is adjusted by means of a bolt and lock-nut arrangement whereby very small and accurate adjustments can be made. A pair of guidance fins are secured to the exterior of the shield assembly and act to prevent rotation of the shield as it is driven through the earth. A plurality of jacks are carried within the shield and are adapted to exert pressure against the tunnel liners which have been installed behind the shield during the tunneling operation. The rearwardly extending portion of the shield overlies the assembled liners by a sufficient amount to permit assembly of the liners by the workmen while within the confines of the shield. Thus the workmen are protected and speed of the tunneling operation is increased since the liner plates can be assembled in the rear portion of the shield while simultaneously the earth in the front portion of the shield is being "mucked" onto a conveyor for automatic car loading.

The rear end of the shield is provided with a multiplicity of overlying plate members secured to the tail end of the main shield body. The arrangement is such that a flexible tail section is provided which permits limited movement of the shield in a direction transverse to its longitudinal axis without binding occurring. Furthermore the articulated skirt assembly on the rear of the shield assists in filling of the void created between the shield and the liners due to diameter differentials between the liner plates and the shield asembly.

In one embodiment of the invention the upper portion of the leading end of the shield is provided with horizontal plates so that multiple angles of repose exist in the earth being tunneled and thus the assembly can be utilized in earth which normally would be too soft to permit safe shield-tunneling. The overall arrangement of the apparatus is such that one crew can be working on the earth face, another crew can be engaged in assembly of liners, and a third can be removing the earth via a rail system.

The above as well as additional advantages and objects of the invention will be more clearly understood from the following description when read with reference to the accompanying drawings wherein,

FIGURE 1 is a cross-sectional view showing the arrangement of various components within the improved shield assembly and including the improved earth loading system extending backwardly from the shield assembly into the already lined portion of a tunnel.

FIGURE 1A is a right end view of an alternative embodiment having a plurality of lateral plates across the upper part of the front of the nose section.

FIGURE 1B is a cross section of part of a shield such as shown in FIGURE 1A illustrating the manner in which multiple angles of repose are provided.

FIGURE 2 is a cross-sectional view showing the shield assembly with the jacks extended after having moved the shield forwardly in the advancing operation.

FIGURES 2A, 2B, and 2C are respectively cross-sectional views along the lines A—A, B—B, and C—C of FIGURE 2.

FIGURE 3 is a view similar to FIGURE 2 but showing jacks retracted after the advancing operation of

FIGURE 2 and including in dashed lines the liner assembly being installed following the shield advancing operation.

FIGURE 4 is a top view partially in section showing the manner in which earth is fed onto the endless belt assembly and with the leading end of the shield adjusted for changing the direction of travel of the assembly.

FIGURE 5 is an elevation of the complete shield assembly showing in particular the articulated tail assembly and its relationship to the assembled liner plates.

FIGURE 5A is an end elevation along the lines A—A in FIGURE 5 to further illustrate details of the tail assembly and the relationship of the earth moving apparatus.

FIGURE 5B is a view of the front end of the apparatus in FIGURE 5 along the lines B—B.

Turning now to the drawings and in particular to the cross sectional view of FIGURE 1, there is shown a preferred embodiment of the improved tunneling shield assembly and earth moving apparatus of the present invention. The shield includes a main tubular or cylindrical body section **10** of circular cross-section and having an adjustable leading end **11** held thereto by means of the bolts **12**. Bolts **13** threaded through the nuts **13A** which are welded to the circumferential flanges **11A** of the leading end of the shield engage the circumferential flange **10A** of the main body **10**. The arrangement is such that by simultaneously loosening or tightening the nuts **12A** and adjusting the bolts **13** the angular relationship of the leading end **11** with respect to the main tubular body **10** can be altered for accurate steering of the shield. As seen most clearly in FIGURE 5B the embodiment illustrated herein utilizes four nut and bolt assemblies **12–12A** and eight nut and bolt assemblies **13–13A** for holding the earth engaging leading edge section **11** in accurate position on the main body **10**. The arrangement is such that control is possible in both vertical and horizontal directions, as well as combinations thereof.

It is well known in the shield-driving art that there is a tendency for a tunneling shield to rotate as it is being driven through the earth. Such rotation gives rise to many problems and accordingly the shield of the present invention includes a pair of fin-like guidance members **14** and **15** (FIGURE 5B) which are of an elongated rectangular cross sectional form as seen in FIGURE 5. Each guidance fin is supported for rotation on the exterior of the assembly by means of the bolt **15** which passes through the wall of the leading end section **11** and is threaded into a threaded hole in the forward end of the guidance fin. Arcuate slots **16** are provided in diametrically opposed relationship on the end section **11** in a manner such that threaded pins **17** having enlarged washers **18** disposed thereabout can pass through the arcuate slot **16** and into threaded holes in the associated guidance fin. Thus the workmen within the shield can adjust the angular relationship of the fins with respect to the longitudinal axis of the shield to thereby aid in guidance of the assembly and counteract rotational tendencies. By having the pivot pin **15** and the adjustment pin **17** threaded into appropriate openings in the guidance members **14** and **15** it is possible for the workmen to release the guidance members should there be any need to do so during a tunneling operation (as for example by engagement thereof with an unusually rigid obstruction). In such event the fins would merely be left behind as the shield continued in its movement through the earth.

In the embodiment of the invention shown herein eight hydraulic jack assemblies **20** are carried within the main shield body **10** with the front end of each jack **20** being secured by a pin **21** (FIGURE 2) to an associated bracket **23** welded to the internal circumferential flange **10A** and to longitudinal flanges **10B**. Each jack has a piston rod **20A** extending rearwardly (i.e. to the left in the drawings) of the piston body for exerting a driving force on the tunnel lining members **24**. While various types of lining members can be utilized, there is illustrated in FIGURE 1 a plurality of segmented steel lining members **24** each having internal circumferential ridges **24A** which abut the corresponding ridges of an adjacent lining member. Bolts are passed through these flanges to rigidly secure each adjacent pair of the lining members in place. Each lining member **24** is made from a plurality of segments of a right circular cylinder so that the individual segments can be carried through the tunnel, into the shield, and then assembled in the tail section of the shield. The internal circumferential ridges **24A** not only serve for interconnection of adjacent liners but also provide an enlarged area against which the thrust plates on the ends of the jacks exert the necessary force for driving the shield through the earth.

In the embodiment illustrated herein four thrust plates **26A–26D** (FIGURE 2C) are used with each forming a quadrant of the total circumference of the shield assembly. The pressure plates are guided in their movement by the guidance rods **27** secured to the center of each pressure plate and with each passing through an associated guidance cylinder or support **28** held in position on the interior of the shield body **10** by means of the brace members **29** welded thereto and to the shield body. As seen most clearly in FIGURES 2 and 2C each piston **20A** is held by a pin **20B** to an associated one of the pressure plates **26A–26D** in a manner such that uniform pressure can be applied around the entire circumference of the previously installed tunnel lining members. The hydraulic jacks are arranged in pairs with two jacks being connected to each of the pressure plates **26A–26D** in the manner illustrated in FIGURE 2C.

The manner in which the shield is advanced is illustrated most clearly in FIGURES 2 and 3. In FIGURE 2 it will be seen that the jacks are in their extended position after having driven the shield assembly forwardly by means of pushing against the previously installed tunnel lining members. In FIGURE 3 the jacks are illustrated in their retracted positions to make room for the insertion and assembly of the next section of tunnel lining illustrated in dashed lines.

It should be noted in FIGURES 1 and 3 that the rearward (i.e. leftward) portion of the shield body **10** extends over approximately three of the installed tunnel liners. This permits the workmen to assemble the liner plates within the confines of the shield and thereby obtain the protection of the shield during assembly of the tunnel lining. This of necessity requires that the internal diameter of the shield be slightly larger than the outer diameter of the lining members. Thus as the shield advances through the earth a small void exists about the periphery of the tunnel lining plates and the surrounding ground. Depending upon the type of earth through which the tunnel is being driven it may be desirable to fill this void with any one of a number of well known filler materials. Thus button-head or Zert type pressure fittings are provided in the walls of the shield for the receipt of pressurized filler material. It has been found in practice that bentonite works well in sandy ground and serves to not only seal the exterior of the liners but also to lubricate the exterior of the shield and facilitate movement thereof through the earth.

As the tunneling operation continues the earth tends to settle around the installed liner plates and also exerts pressure on the shield. Flow of the dirt and/or filler material around the liner is facilitated with the shield assembly of the present invention by virtue of the two circumferential rows of overlapping rectangular steel plates **30** and **31** welded to the trailing end of the main shield body **10**. These layers are so arranged that the openings between the plates **30** overlie the approximate center of an associated plate **31** in the inner layer of the members, and the openings between adjacent plates **31** are covered by the plates **30**. Thus the plates provide an articulated tail section of

longitudinal flaps which protect the workmen and yet permit the outer diameter or circumference of the tail section of the shield to contract under the pressure of the surrounding earth. Thus a smooth flow of earth back into position around the tunnel liners after the shield has passed a given point is facilitated. The plate members **30** and **31** thus form what can be described as an articulated sheath reminiscent of a Roman skirt. It is found in practice that binding of the shield is thus avoided or reduced, and yet the workmen are protected without the need of an unduly long and high section modulus shield.

As is known in the art, during a shield-tunneling operation the working face is mucked by the workmen standing in the leading portion of the shield. In the embodiment of the invention illustrated herein a conical member **40** (FIGURES 1 and 5B) having it apex re-entrant within the shield is disposed across the lower half of the front end of the shield (within section **11**). An opening **40A** is provided near the upper left center of the conical member **40** so that the workmen can easily move the earth up the conical member **40** and through the opening **40A** onto the endless belt **41**. The belt is driven by a suitable source, such as an air or electric motor, in the direction indicated by the arrows so that the dirt is moved away from the working face. As seen in FIGURE 1 the endless belt **41** first extends upwardly and then rearwardly by a distance sufficient to permit a spare car **42** to be positioned beneath the extended end thereof while an active car is being loaded with earth. The arrangement is such that relatively small cars **42** can be utilized in a small diameter tunnel and yet by having space for more than one car beneath the end of the belt it is possible for the earth in a given cylindrical section (corresponding to the space occupied by one set of liner plates) to be accommodated by the cars. Thus a rapid and continuous tunneling operation can take place since earth can be hauled from the tunnel by one crew while another crew is assembling liner plates and a third crew is operating the shield assembly and actually working the face of the tunnel.

As seen in FIGURE 1 the endless belt assembly **41** is carried by the skids **44** which are adapted to ride along the wood ties **45** positioned across the liner plates **24** and adapted to receive the rails **46** on which the cars **42** ride. The front lower end of the conveyor assembly is secured to the plate **47** extending across the shield **10** and secured thereto. Thus it will be seen that as the shield **10** is driven forwardly the entire earth moving apparatus including the endless belt **41** and the hydraulic control and drive assembly **48** for the jacks is pulled along with the shield.

In some cases it is found that the earth is prone to "run" and assume an angle of repose such that shield tunneling therethrough is difficult if not impossible without the use of breast boards. Thus in the alternative embodiment of FIGURE 1A a plurality of horizontal rectangular plates **50** extend across the front end of the shield so that multiple angles of repose of relatively short vertical distance are provided (FIGURE 1B). The danger of the face collapsing is thus minimal and the operation can continue in relatively "loose" earth. Due to the small cross-sectional area of the plates **50** in the vertical plane no undue loading is imposed on the system as the shield is driven through the earth.

There has thus been disclosed an improved shield tunneling assembly having a rugged steering section on the forward end and an articulated or sheathed trailing end. The system is so arranged that "down" time is substantially eliminated and rapid tunneling safely accomplished. In the use of one system it was found that even in a small diameter tunnel one crew was able to dig the earth face while protected by section **11** at the same time that the mine cars were being emptied and liner plates installed.

While the invention has been described by reference to presently preferred embodiments thereof, it is to be understood that the same was done only for purpose of teaching the invention and that those changes and modifications which become obvious to one skilled in the art as a result of the teachings hereof are encompassed by the following claims.

What is claimed is:

1. A tunneling apparatus comprising in combination: an elongated cylindrical tunneling member having a longitudinal axis and first and second ends, and a plurality of plate means secured to the said second end of said member in overlapping relationship to define an articulated tail section having a variable diameter said plate means including a first circumferential row of elongated plate members each having one end secured to said second end of said first tunneling member and defining a space between adjacent plate members, said plate members extending from said second end substantially parallel to said longitudinal axis, and a second circumferential row of elongated plate members each having one end secured to said second end of said first member with said second row being disposed about said first circumferential row with each of said second plurality of plate members overlying the spaces between adjacent ones of said first plurality of plate members.

2. The apparatus of claim **1** and including a second cylindrical tunneling member; and adjustable attachment means engaged with said first and second tunneling members and holding said second member on the first end of said first member and permitting selective adjustment of the longitudinal axis of said second member with respect to the longitudinal axis of said first member to thereby permit control over the direction of movement of the apparatus through the earth, said attachment means including a first plurality of bolt means threaded into one of said tunneling members and having bolt heads frictionally engaging the other tunneling member for adjustably interconnecting said first and second members and preventing relative movement of said members away from each other; and a second plurality of bolt means threaded into one of said members and having bolt ends engageable with the other member and preventing relative movement of said members toward each other.

3. The apparatus defined in claim **1** and including guidance means adjustably secured to the exterior of one of said tunneling members and including guidance surfaces positionable at selected angles with respect to the longitudinal axis of the member to which said guidance means is secured.

4. The apparatus defined in claim **3** wherein said guidance means includes first and second elongated guidance fins each pivoted at one of its ends to the exterior of one of said shield members and each including lock means for holding the fin in a selected angular relationship on the shield member.

5. A shield tunneling system comprising in combination: a first elongated cylindrical shield member having a leading and a trailing end; a second cylindrical shield member having a first end of a diameter and cross section substantially the same as and adapted to mate with the leading end of said first member; adjustable connection means interconnecting said first and second members for adjustment of the longitudinal axes of said members to control the direction of movement thereof through the earth; hydraulic jack means secured to said first member and operative to move within said trailing end to force said members through the earth; a first plurality of plate members secured to the trailing end of said first shield member and arranged around the circumference thereof with each plate member being separated from the adjacent plate member by a predetermined distance; a second plurality of elongated plate members secured to said trailing end of said first member with said second plurality of plate members being disposed over said openings between adjacent ones of said first plurality of plate members to define an articulated protective tail section on the tail end of said first member; and guidance means including first and second anti-rotation members pivotally secured to the exterior of one of said shield members.

6. The apparatus defined in claim 5 wherein said anti-rotation members include first and second elongated fin members each having a threaded opening in one end thereof, and bolt means extending through the wall of one of said shield members and into the threaded opening of the associated fin for holding the same in a removable manner on the exterior of the associated shield member.

7. The apparatus defined in claim 5 wherein said plate members are welded to the tail end of said first shield member.

8. The apparatus defined in claim 5 and including a plurality of horizontal plate members secured to and extending across the leading end of said second shield member in spaced apart vertical position.

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