United States Patent [19]

Fink

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[54] **SMALL DIAMETER HORIZONTAL TUNNELING MACHINE**

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[52] **U.S. Cl.** **175/73;** 175/62; 175/171; 175/334; 175/336

[51] **Int. Cl.²** **E21B 7/04;** E21B 9/34; E21B 3/02

[58] **Field of Search** 175/62, 162, 73, 334, 171, 175/336; 299/55, 31, 33, 56, 57; 61/85

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[57] **ABSTRACT**

A method and apparatus for continuously drilling and lining a small diameter horizontal tunnel are disclosed. A head assembly of the tunneling machine includes a support section and a rotatable section which is rotatably journaled on the support section. The rotatable section includes at least one roller cutter which engages the end face of the tunnel for removing material from the end face. A rotatable drive shaft extends through the tunnel and is connected to the rotatable section for providing the sole means for rotating the rotatable section. A thrust unit at the portal of the tunnel is connected to the tunnel liner and applies a force solely through the tunnel liner to axially advance the head assembly.

8 Claims, 6 Drawing Figures

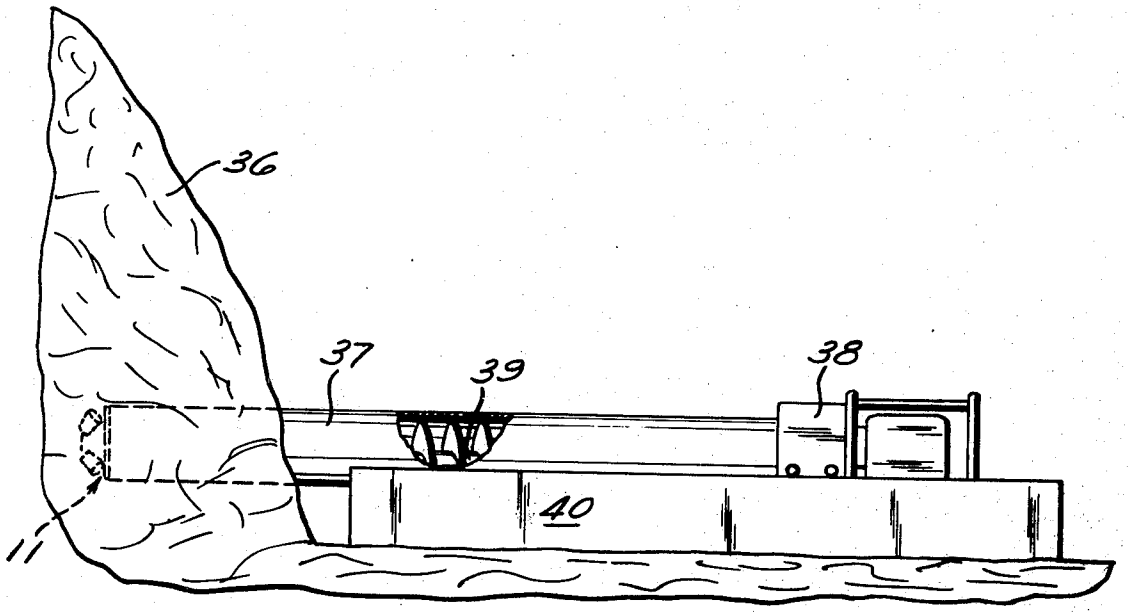
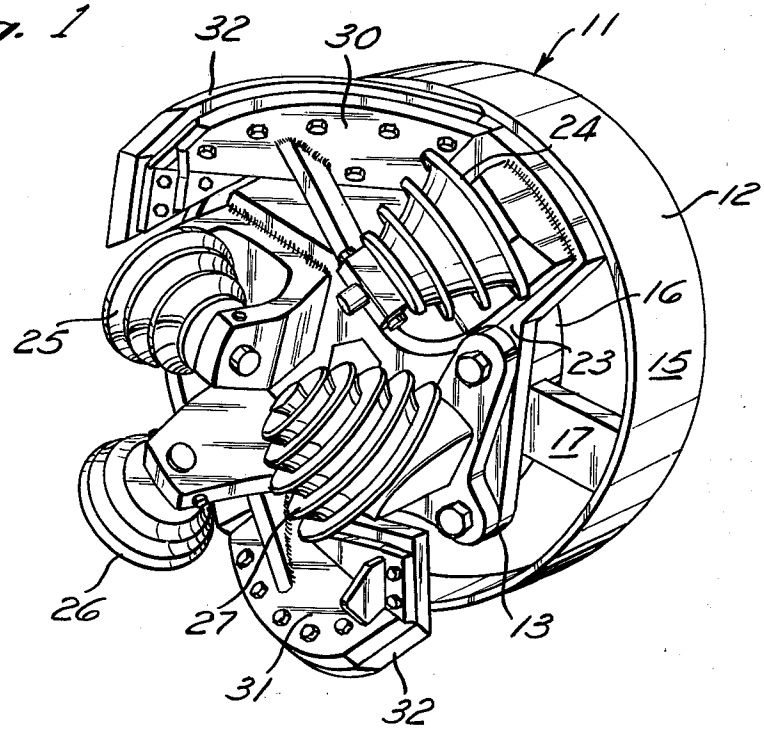


Fig. 1



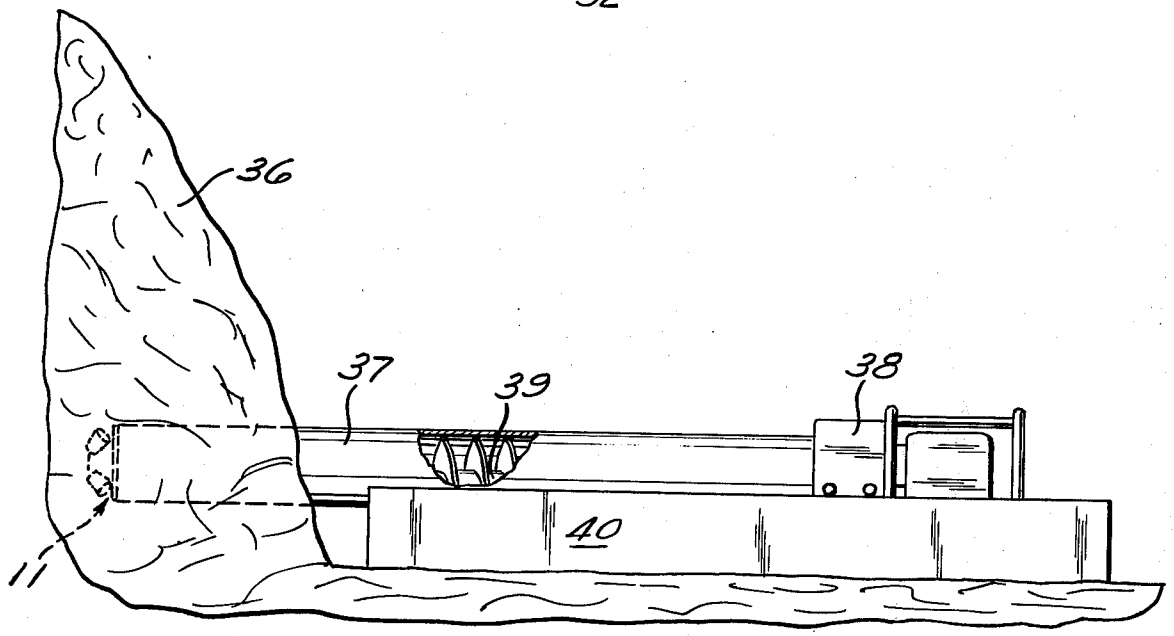


Fig. 2

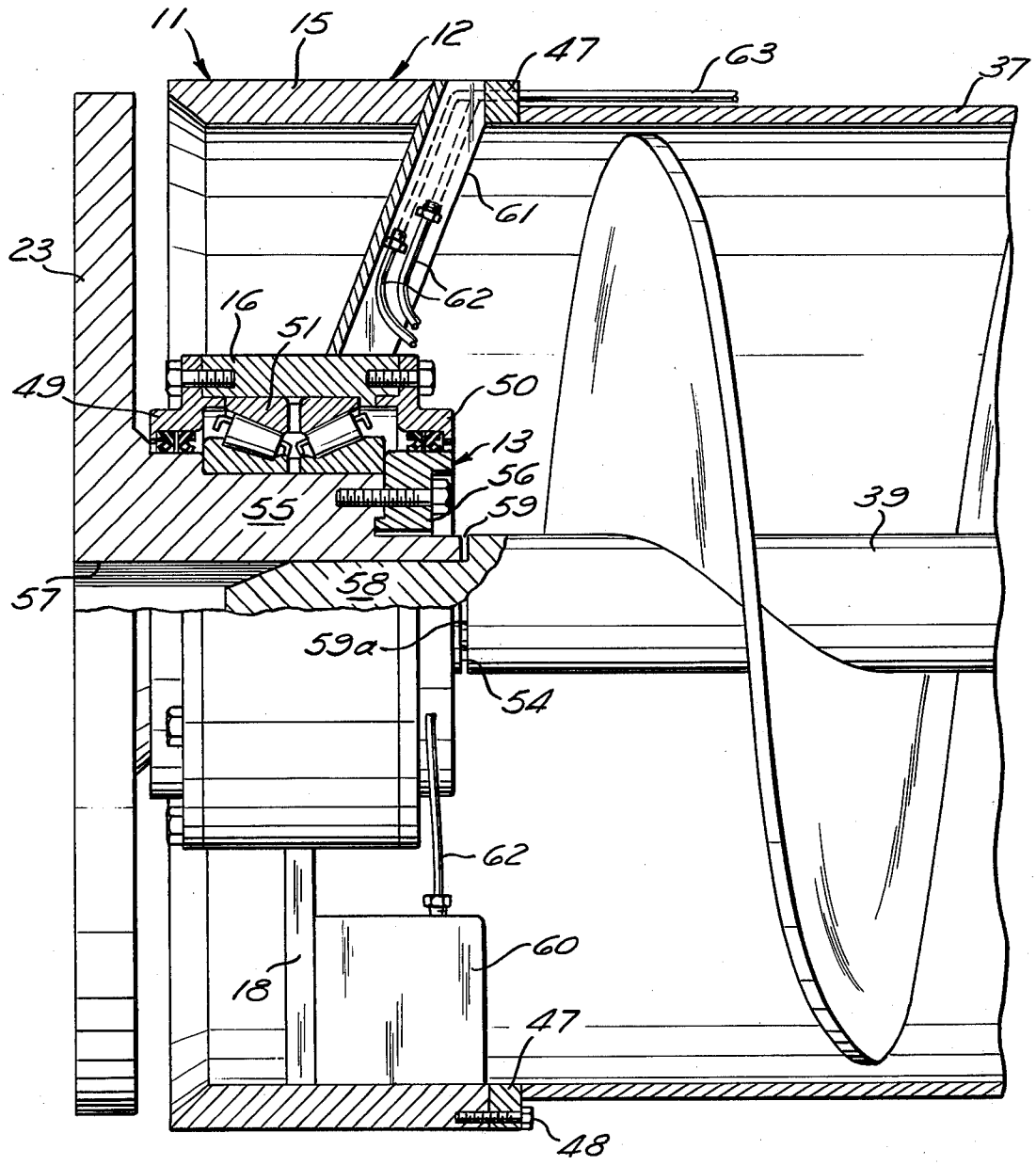

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Fig. 3

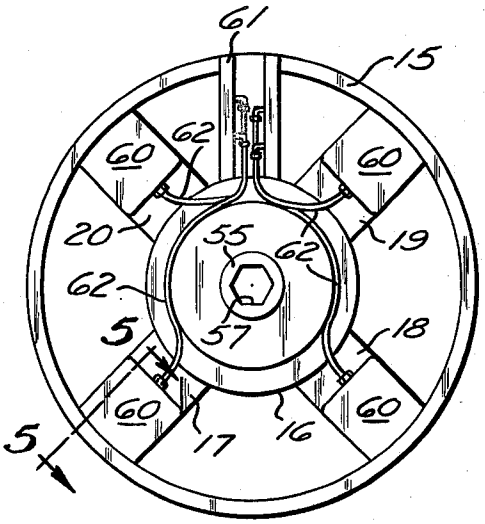


Fig. 4

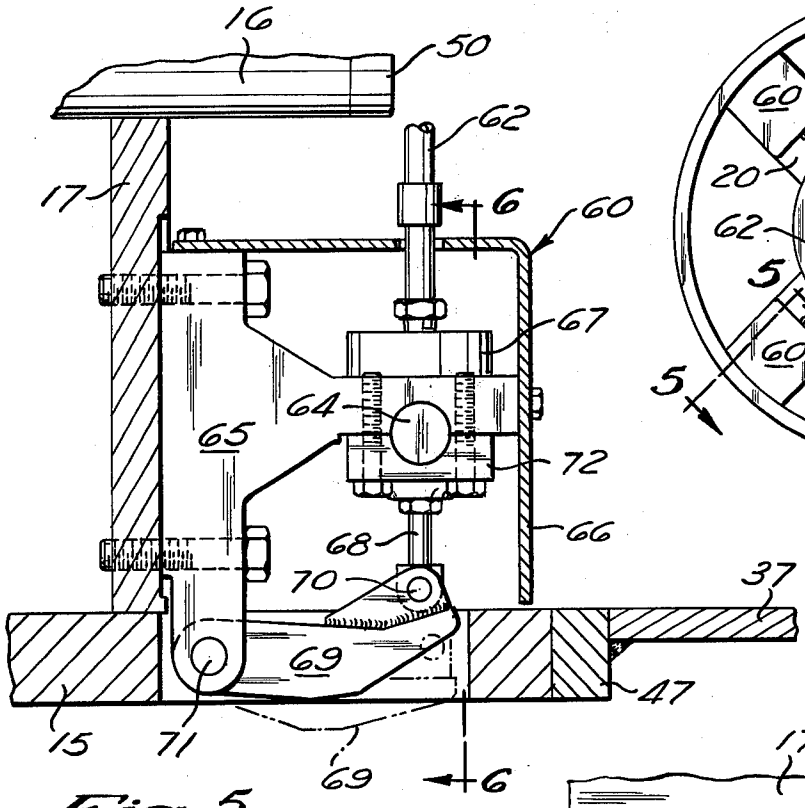


Fig. 5

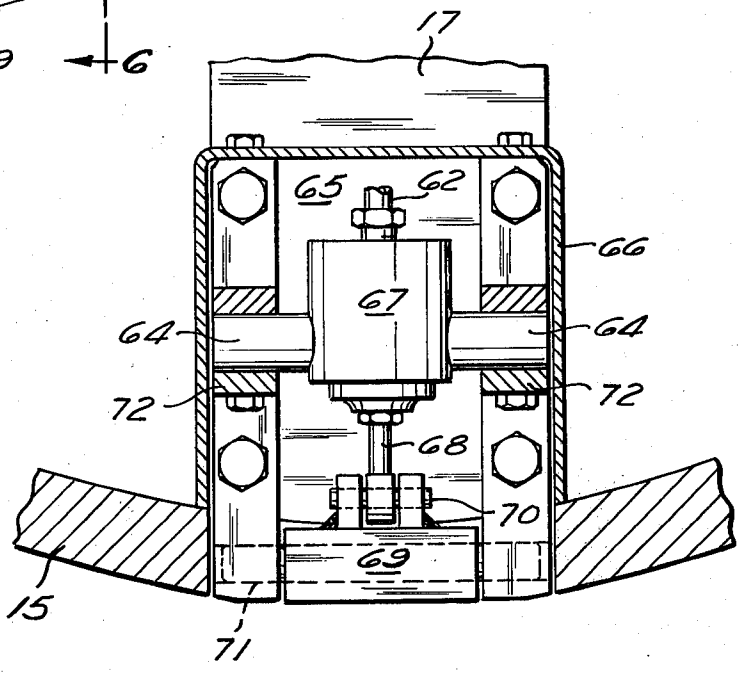


Fig. 6

SMALL DIAMETER HORIZONTAL TUNNELING MACHINE

BACKGROUND AND SUMMARY OF THE INVENTION

Small diameter horizontal tunneling machines are used for drilling or boring tunnels less than 5 feet in diameter through various types of earth formations. Such machines are used where it is either impractical or impossible to excavate a trench from the surface of the ground, such as when drilling through hills or mountains or when drilling transversely beneath highways.

Commercially used prior art tunneling machines for such purposes include an auger which carries materials from the end face of the tunnel to the portal of the tunnel, and teeth or scrapers which are mounted on the end of the auger and are rotated by the auger and pushed by the auger against the end face of the tunnel. A cylindrical tunnel liner is also inserted into the tunnel as it is being drilled, and the auger rotates inside the tunnel liner. A diesel engine powered hydraulic thrust unit is located at the portal of the tunnel to provide the force to rotate and push the auger with its associated teeth or scrapers during drilling and to push the tunnel liner into the tunnel. The entire axial force to push the teeth or scrapers against the tunnel end face as they are being rotated is applied through the auger, and there is no mechanical connection between the teeth or scrapers and the tunnel liner. These prior art machines are available from Richmond Manufacturing Co., P.O. Box 188, Ashland, Ohio 44805, U.S.A.

Other tunneling machines include those shown in U.S. Pat. Nos. 3,763,657 to Colson and 3,778,107 to Haspert. Devices for steering prior art tunneling machines are shown in U.S. Pat. Nos. 3,413,033 to Clark, 3,411,826 to Wallers, and 3,382,002 to Tabor.

The present invention improves over these prior art methods and machines by providing a method and apparatus in which a force applied axially to the tunnel liner at the portal provides the sole force for axially advancing the cutter head, while the auger rotates the cutter head.

According to the principles of the invention, a head assembly includes a support section and a rotatable section rotatably journaled on the support section. The rotatable section includes at least one roller cutter, and an auger is connected to the rotatable section for providing the sole means for rotating it. A thrust unit at the tunnel portal is connected to the tunnel liner and applies a force solely through the tunnel liner to axially advance the head assembly.

The support section includes a radially outer ring, a radially inner hub, and at least two spokes fixedly connecting the inner hub to the outer ring. Steering wedges are located on the outer ring at the location of the spokes, and the space between the spokes is open so that material removed from the tunnel end face is transmitted rearwardly to the portal of the tunnel through the space between the spokes.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention are incorporated in the preferred embodiment of the invention shown in the drawings, wherein:

FIG. 1 is a perspective view of a head assembly according to the principles of the invention;

FIG. 2 is a schematic side elevational view showing the head assembly of FIG. 1 being pushed against a tunnel end face by a thrust unit;

FIG. 3 is a cross-sectional side elevational view of the head assembly and tunnel liner and auger, but with the roller cutters and scrapers removed from the head assembly;

FIG. 4 is a rear view of the head assembly shown in FIG. 1;

FIG. 5 is a cross-sectional view of a steering wedge for the head assembly taken along reference view line 5—5 of FIG. 4; and

FIG. 6 is a cross-sectional view of the steering wedge taken along reference view line 6—6 of FIG. 5.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in greater detail, FIG. 1 shows a head assembly 11 according to the principles of the invention. The head assembly 11 includes a support section 12 and a rotatable section 13 which is rotatably journaled on the support section 12. As will be explained in greater detail below, the support section 12 includes a radially outer ring 15, a radially inner hub 16, and four spokes 17, 18, 19 and 20 (only one of which may be seen in FIG. 1) fixedly connecting the inner hub 16 to the outer ring 15.

The rotatable section 13 of the head assembly 11 includes a generally flat mounting plate 23 which has secured thereto in a suitable manner such as by welding or by bolting two gage or outside roller cutters 24 and 26 and two inside roller cutters 25 and 27. Each of the cutters 24–27 is journaled on the mounting plate 23 for rotational movement, and each of the cutters 24–27 engages the end face of the tunnel with rolling contact to remove materials therefrom.

Still referring to FIG. 1, two material deflector carriers 30 and 31 are also welded to the mounting plate 23, and each of the deflector carriers 30 and 31 is provided with a suitable reinforcing rib to prevent bending or breakage. A material deflector 32 is bolted to each of the deflector carriers 30 and 31. As the rotatable section 13 rotates, the deflectors 32 deflect materials which are removed from the end face of the tunnel by the cutters 24–27 axially rearwardly through the spaces between the spokes 17–20 so that such materials can be removed from the tunnel. When the deflectors 32 become worn, they may be removed from their carriers 30 and 31 for replacement.

Referring now to FIG. 2, the tunneling machine including the head assembly 11 shown in FIG. 1 is illustrated schematically in relation to an earth formation 36 which may include hard rock through which a tunnel is to be drilled or bored. The head assembly 11 is bolted in a manner described below to a multiple section tunnel liner 37. The tunnel liner 37, in a well-known manner, is a cylindrical steel pipe which is provided in relatively short lengths which are welded together to increase the length of the liner 37 as the tunnel progresses into the earth formation 36. A diesel engine powered hydraulic thrust unit 38 is also provided at the portal of the tunnel for axially advancing the tunnel liner 37 and for rotating a drive shaft 39 which extends axially through the tunnel liner 37. As described in detail below, the drive shaft 39 is operatively connected to the head assembly 11 for providing the sole means for rotating the rotatable section 13. The thrust unit 38 is movable back and forth along a suitable base

40 for axially advancing the tunnel liner 37 as the tunnel progresses. When the thrust unit 38 approaches the portal of the tunnel, it is moved back along the base 40 away from the portal and a new section of the tunnel liner 37 is welded in place to extend the length of the tunnel liner 37. A new section of drive shaft 39 is also added to extend the length of the drive shaft 39. The thrust unit 38 is then advanced again toward the portal of the tunnel to further advance the tunnel liner 37 and head assembly 11. The structure of the thrust unit 38 is well-known in the art, and suitable thrust units are available from Richmond Manufacturing Co., P.O. Box 188, Ashland, Ohio 44805, U.S.A.

Turning now to FIG. 3, the structural details of the head assembly 11 and drive shaft 39 and liner 37 are shown in detail. For purposes of clarity, the roller cutters 24–27, deflector carriers 30 and 31, and deflectors 32 have been removed from the mounting plate in FIG. 3. The drive shaft 39 includes an auger which conveys materials from the head assembly 11 to the tunnel portal for removal. The drive shaft 39 is a multiple section drive shaft which is made in short lengths which are secured together to lengthen the drive shaft as the tunnel progresses, as described below.

Referring still to FIG. 3, an annular adapter ring 47 is welded to the free end of the tunnel liner 37 (that is, the end of the tunnel liner 37 away from the thrust unit 38), and the adapter ring 47 is bolted by a plurality of circumferentially spaced bolts 48 to the ring 15 to mechanically connect the head assembly 11 to the tunnel liner 37.

The hub 16 includes a forward bearing retainer 49 for securing the outer race of a roller thrust bearing 51 against movement relative to the hub 16 and a seal retainer 50. The rotatable section 13 includes an axle portion 55, and a bearing retainer 56 secures the inner race of the bearing 51 on the axle portion 55. Although the mounting plate 23 and axle portion 55 are shown as a single piece in FIG. 3 for purposes of clarity, these parts of the rotatable section 13 are preferably made of separate pieces which are welded together. In this manner, the rotatable section 13 is journaled on the support section 12 for rotational movement relative thereto by the bearing 51 which transmits axial forces between the support section 12 and the rotatable section 13.

A passage 57 extends from end to end through the mounting plate 23 and axle portion 55. The passage 57 is of hexagonal lateral cross-section, and a hexagonal end portion 58 of the drive shaft 39 is received within the passage 57 so that rotation of the drive shaft 39 rotates the rotatable section 13. Although the thrust unit 38 advances both the liner 37 and drive shaft 39 as it moves toward the tunnel portal, the drive shaft 39 does not transmit a force in the axial direction from the thrust unit 38 to the movable section 13. This is because the drive shaft 39 is dimensioned axially so that it cannot simultaneously axially engage both the thrust unit 38 and the rotatable section 13. This is accomplished by providing a gap 59 between shoulder 59*a* on drive shaft 39 and end face 54 on axle portion 55. In this manner, the entire axial force applied to axially advance the rotatable section 13 is applied to the end of the tunnel liner 37 at the portal, and excessive axial forces on the drive shaft 39 that might bend or break the drive shaft 39 are avoided.

Referring now to FIGS. 3 and 4, it is seen that the four spokes, 17, 18, 19 and 20 are equally spaced apart about the ring 15 and hub 16. A steering wedge 60 is secured on the head assembly 11 in axially aligned relation to each of the spokes 17, 18, 19 and 20 to steer the head assembly 11 as the tunnel is cut. This arrangement leaves the spaces between the spokes 20 and 17 and between the spokes 17 and 18 and between the spokes 18 and 19 unobstructed for the passage of material through such space for removal from the tunnel. A U-shaped channel 61 extends from the outer ring 15 to the hub 16 to convey hydraulic fluid from four hydraulic lines 63 (only one of which is shown in FIG. 3) on the outer surface of the tunnel liner 37 to each of the steering wedges 60. If desired, a suitable cover or enclosure can be provided for the hydraulic lines 63 on the outer surface of the tunnel liner 37 to prevent damage to the lines 63. The U-shaped channel 61 includes suitable passages drilled in its sides, and the hydraulic lines 63 are each connected to the portion of the channel 61 adjacent the outer ring 15 while other hydraulic hoses 62 are connected to the passages in the channel 61 for connection to the steering wedges 60. As shown in FIG. 4, each of the steering wedges 60 is provided with a separate hydraulic hose 62 so that the steering wedges 60 are each individually actuatable.

As best seen in FIG. 5, each steering wedge 60 includes a cylinder mounting bracket 65 which is bolted to its associated spoke, which is the spoke 17 for the steering wedge 60 shown in FIG. 5. A suitable cover 66 is bolted to the cylinder mounting bracket 65 to protect the steering wedge 60 from foreign materials. The steering wedge 60 also includes a single acting spring returned hydraulic cylinder 67 having a rod 68 pivotally connected to a steering shoe 69 at a pivot 70. The other end of the steering shoe 69 is connected to the cylinder mounting bracket 65 at another pivot 71. When the cylinder 67 is in its deactuated or spring returned position shown by solid lines in FIG. 5, the steering shoe 69 is in its retracted position so that it does not project beyond the outer peripheral surface of the ring 15. When hydraulic fluid is supplied to the cylinder 67, the rod 68 pushes the shoe 69 to its actuated position shown in phantom in FIG. 5 to steer the head assembly 11 as the tunnel is drilled.

The manner of supporting the cylinder 67 is best shown in FIG. 6. Cylinder trunnions 64 are secured to the cylinder 67 by welding or by a suitable bracket (not shown) and are retained on the cylinder mounting bracket 65 by trunnion caps 72. This pivotal mounting of the cylinder 67 on the mounting bracket 65 permits the cylinder 67 to rotate slightly when the shoe 69 moves between its retracted position and its extended position to accommodate movement of the pivot point 70 as shown in FIG. 5.

Turning now to the operation of the tunneling machine shown in the drawings, the thrust unit 38 including the support 40 is installed in a well-known manner with the thrust unit 38 in its start-up position spaced away from the portal of the tunnel to be drilled as shown in FIG. 2. The head assembly 11 is bolted to the adapter ring 47 on the free end of the tunnel liner 37, and the drive shaft 39 with its associated auger are rotated by the thrust unit 38. The thrust unit 38 then moves to the left as shown in FIG. 2 applying an axial force to the tunnel liner 37 to urge the roller cutters of the head assembly 11 against the earth formation 36 including the hard rock through which the tunnel is to be drilled. Because the drive shaft 39 is dimensioned as

explained above so that it can transmit only rotational forces between the thrust unit **38** and the head assembly **11**, the drive shaft **39** cannot be deflected and damaged by application of an axial thrust by the thrust unit **38** exceeding the column strength of the drive shaft **39**. After the thrust unit **38** advances to the left as shown in FIG. **2** to a position adjacent the tunnel portal at the end of the support track **40**, the thrust unit **38** is retracted to the right as viewed in FIG. **2** away from the tunnel portal while the drive shaft **39** and tunnel liner **37** remain stationary. A new length of drive shaft **39** with its associated auger and a new length of tunnel liner **37** are then secured on the end of the drive shaft **39** and tunnel liner **37** adjacent the thrust unit **38**, and the operation is repeated.

When the tunnel is completed, the head assembly **11** breaks through the other side of the earth formation **36** (not shown). The head assembly **11** is removed from the tunnel liner **37** by removing the bolts **48** (FIG. **3**), the drive shaft **39** is removed, and the hydraulic lines **63** are removed. The tunnel liner **37** is left in place to provide a permanent liner for the tunnel.

What is claimed is:

1. In combination, a tunnel having an end face and a portal, and a tunneling machine; said tunneling machine comprising a head assembly, a multiple section tunnel liner, a multiple section rotatable drive shaft, and axial thrust unit means; said head assembly including a support section movable in said tunnel in the axial direction and a rotatable section movable in said tunnel in both the axial and the rotational directions, said rotatable section including cutter means for engaging said end face of said tunnel for removing material from said end face, said rotatable section being rotatably journaled on said support section by bearing means, said bearing means preventing relative axial movement between said rotatable section and said support section whereby axially advancing movement of said support section axially advances said movable section; said rotatable drive shaft being operatively connected to said rotatable section and providing the sole means for rotating said rotatable section; said thrust unit means being disposed outside of said tunnel at said portal, said thrust unit means being operatively connected to said tunnel liner and said tunnel liner being operatively connected to said support section, and said thrust unit means axially advancing said support section and said rotatable section together in said tunnel by application of an axial force to the end of said tunnel liner at said portal.

2. The combination defined in claim **1** wherein said cutter means includes at least one roller cutter engaging said end face of said tunnel with rolling contact.

3. The combination defined in claim **1** wherein said thrust unit provides the sole means for axially advancing said support section and said rotatable section together in said tunnel by application of said axial force to said end of said tunnel liner at said portal.

4. The combination defined in claim **1** wherein said support section includes a radially outer ring operatively connected to said liner, a radially inner hub, a plurality of spokes fixedly connecting said inner hub to said outer ring, and the space between said spokes being open along the entire axial extent of said spokes whereby said material removed from said tunnel end face by said cutter means is transmitted through said space.

5. The combination defined in claim **4** wherein said movable section includes at least one deflector for deflecting said materials axially rearwardly as said movable section is rotated by said drive shaft.

6. The combination defined in claim **5** wherein said drive shaft includes an auger extending from the portion of said liner adjacent said support section axially rearwardly to the portion of said liner adjacent said thrust unit for conveying said material out of said tunnel.

7. The combination defined in claim **6** wherein said outer ring includes at least two steering wedges, said steering wedges are hydraulically actuatable for steering said tunneling machine, at least one hydraulic line supplies fluid for actuating said steering wedge, and said hydraulic line extends along the outer peripheral surface of said liner between said liner and said tunnel.

8. The combination defined in claim **6** wherein said outer ring includes at least two steering wedges, said steering wedges are hydraulically actuatable for steering said tunneling machine, and each of said steering wedges is disposed in axially aligned relation with one of said spokes between said spokes and said portal whereby said steering wedges do not interfere with the flow of material through said space.

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