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 [21] Appl. No. **822,921**
 [22] Filed **May 8, 1969**
 [45] Patented **Aug. 10, 1971**

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[54] **TUNNEL-BORING MACHINE**
 19 Claims, 15 Drawing Figs.

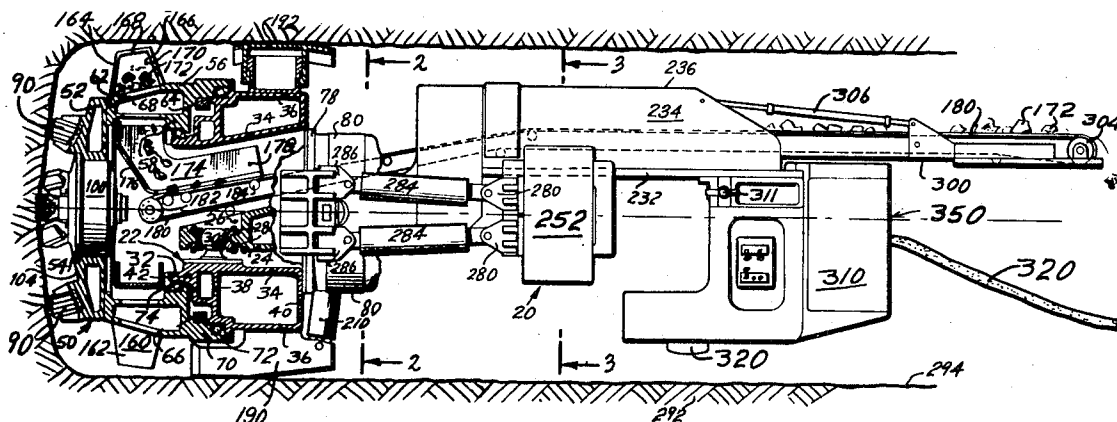
[52] U.S. Cl. 299/31,
 175/61, 175/76, 299/56, 299/60
 [51] Int. Cl. E01g 3/04
 [50] Field of Search 299/31, 33,
 56, 58, 60, 1; 175/61, 73—76, 94

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ABSTRACT: This invention is for a tunnel-boring machine which can be used for boring circular tunnels through rock. The machine comprises a rotary cutterhead, a cutterhead support, a main beam, and a gripper. On the front of the cutterhead there are mounted cutters which fracture the rock. The cutterhead support provides journal mounting for the cutterhead, and is centrally connected to the forward end of the main beam by ball and socket joint means. The ball and socket joint permits angular movement in all directions, viz., X-Y-Z axis, between the cutterhead support and the main beam. The main beam extends rearwardly and is connected by slide way means to the gripper, which permits the main beam to move in a longitudinal direction. The gripper which is a force reaction member of the machine, bridges across the tunnel, providing a rear pivoting support means about the X and Y axis for the main beam, and rigidly fixes the location of the pivot axis at the approximate center of the tunnel.



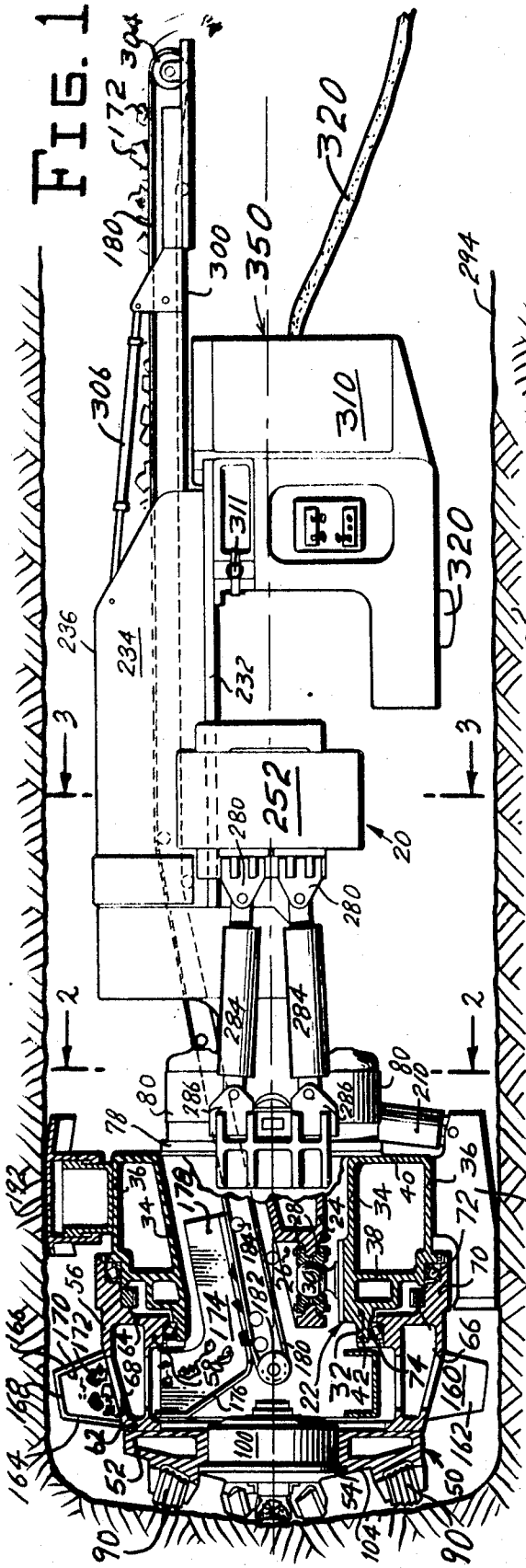


FIG. 1

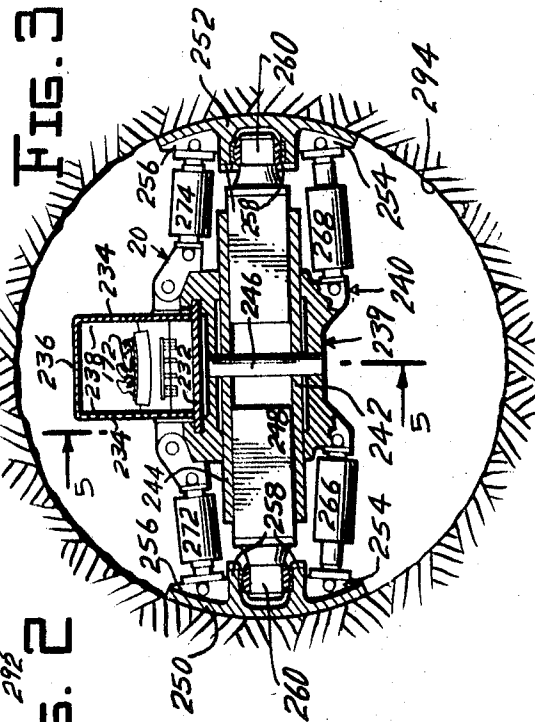


FIG. 3

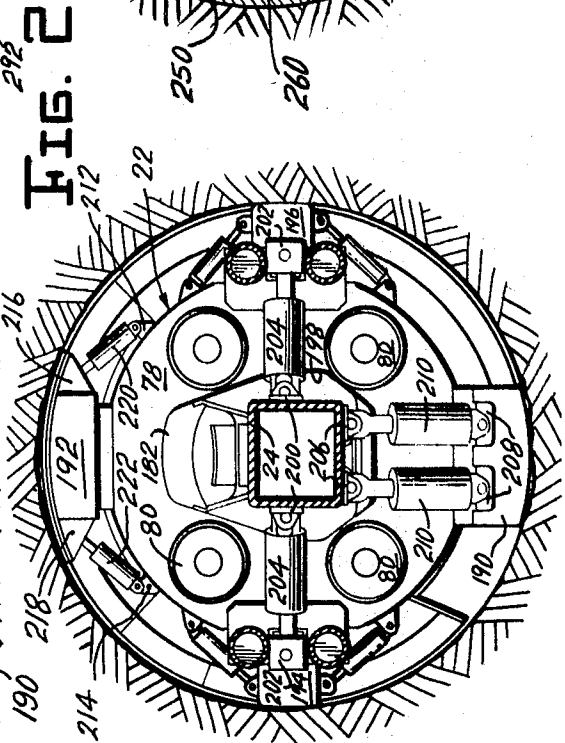
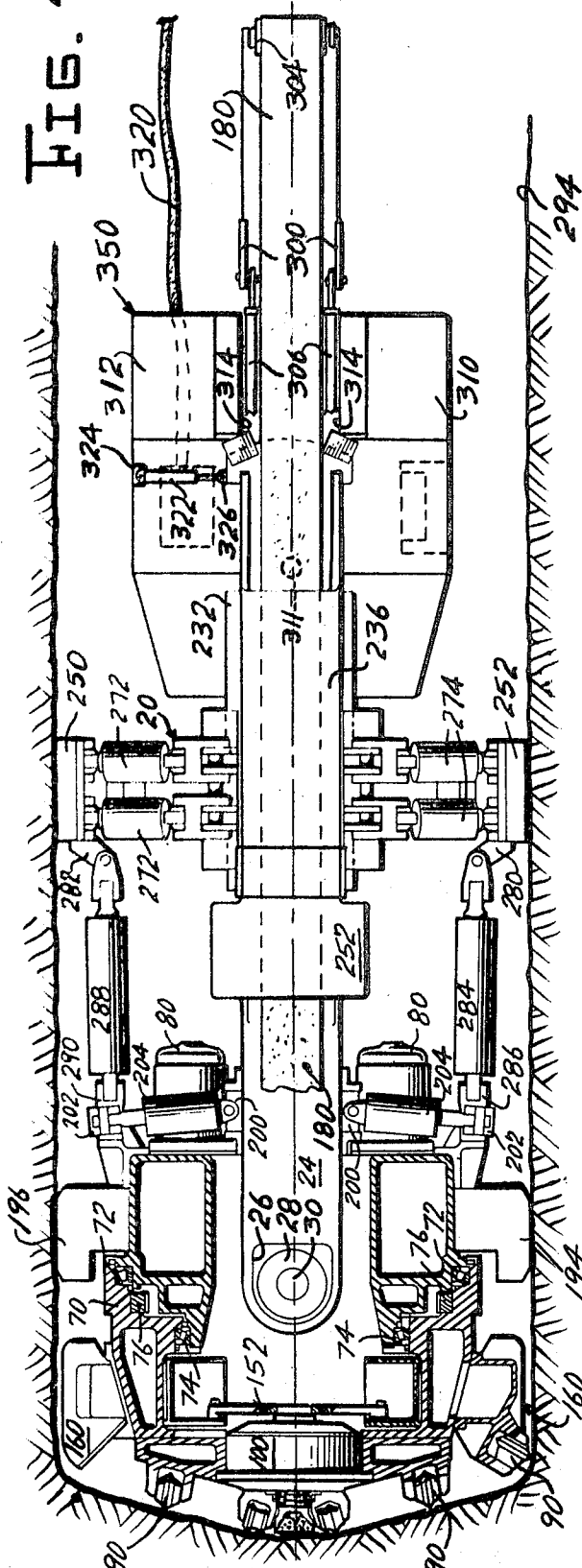


FIG. 2

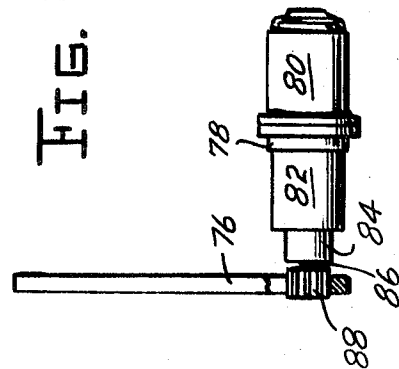
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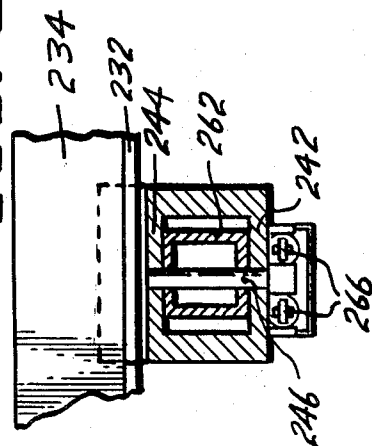
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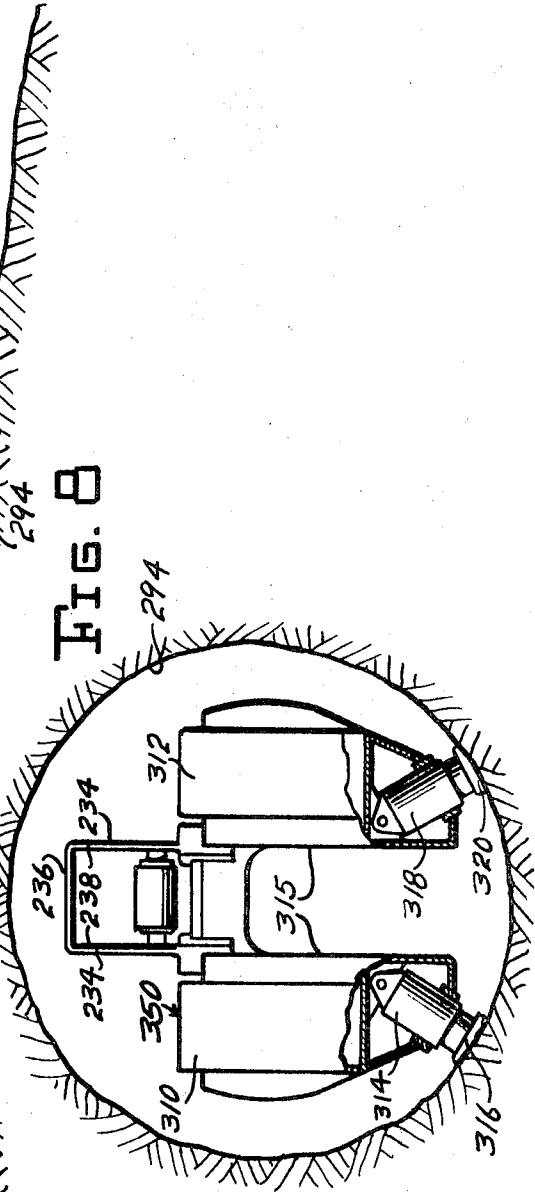
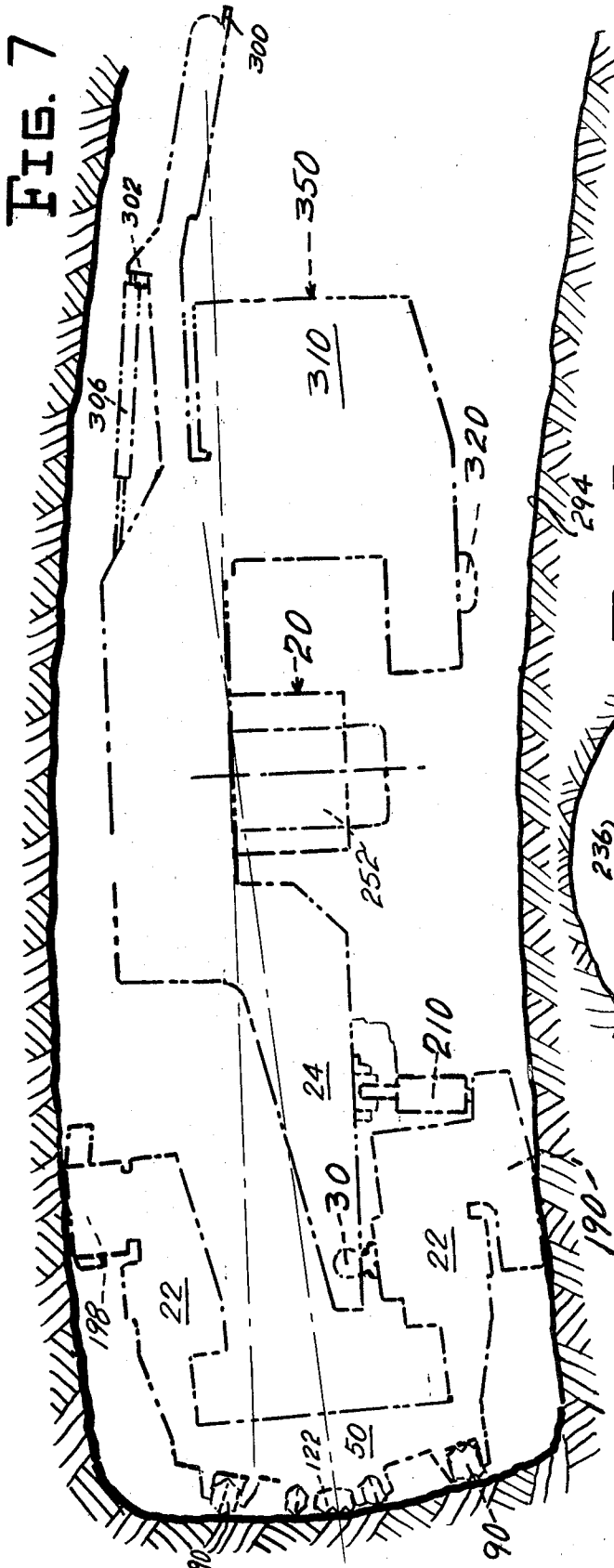


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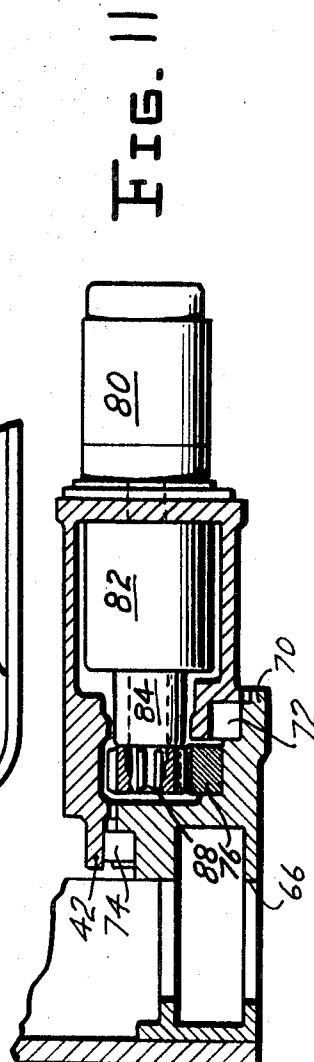
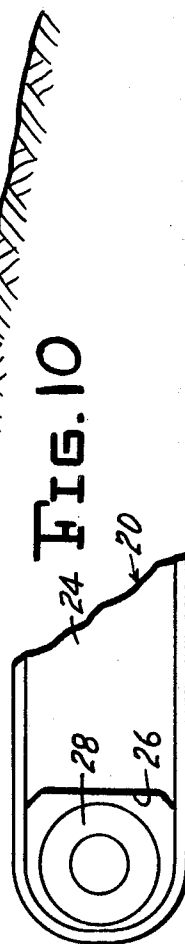
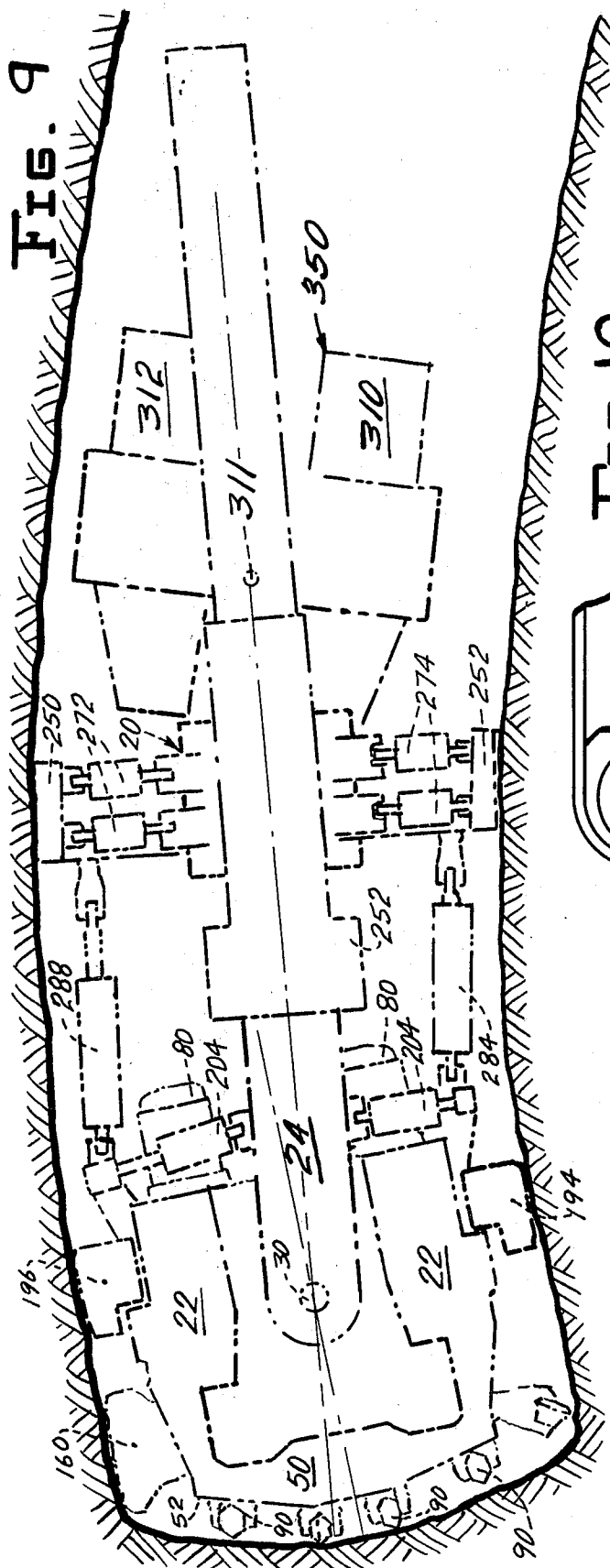


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FIG. 12

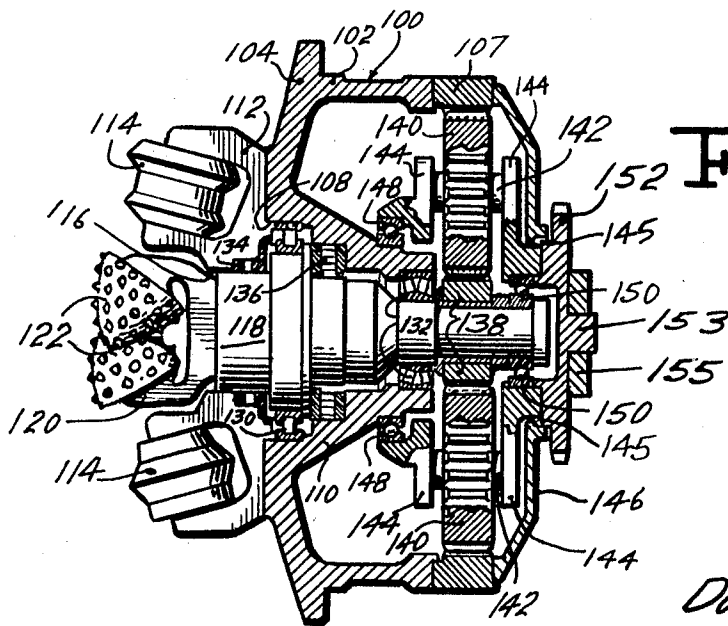
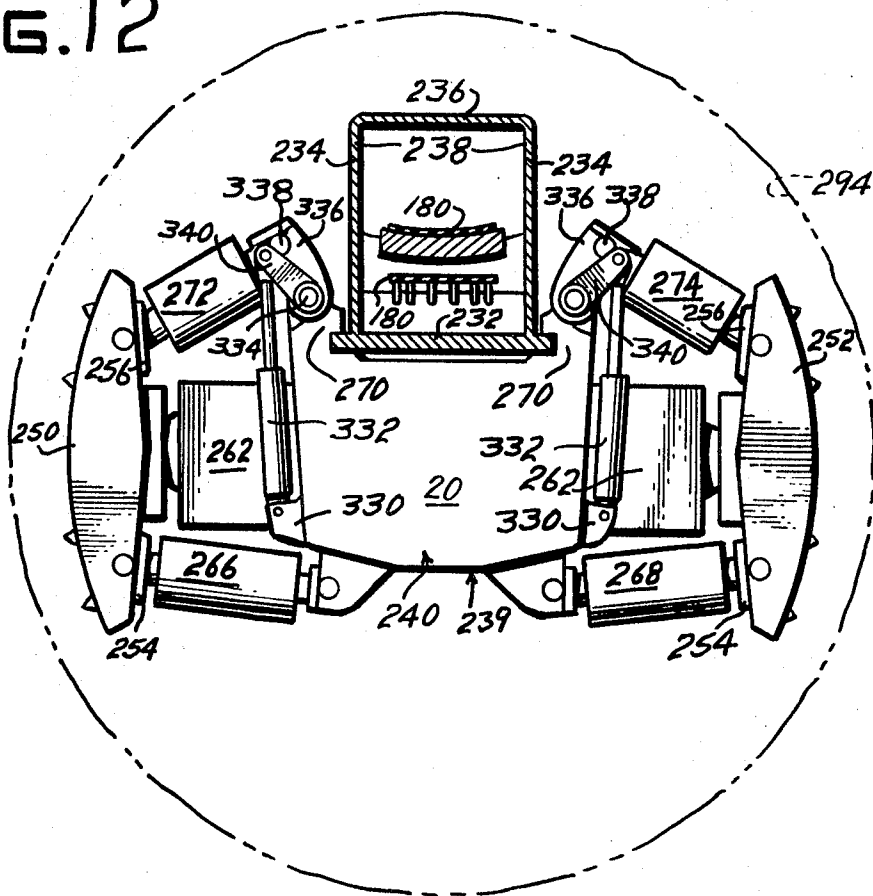


FIG. 13

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FIG. 14

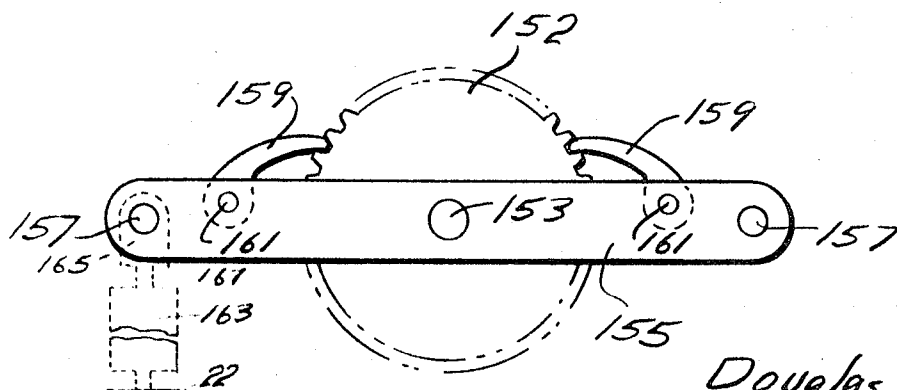
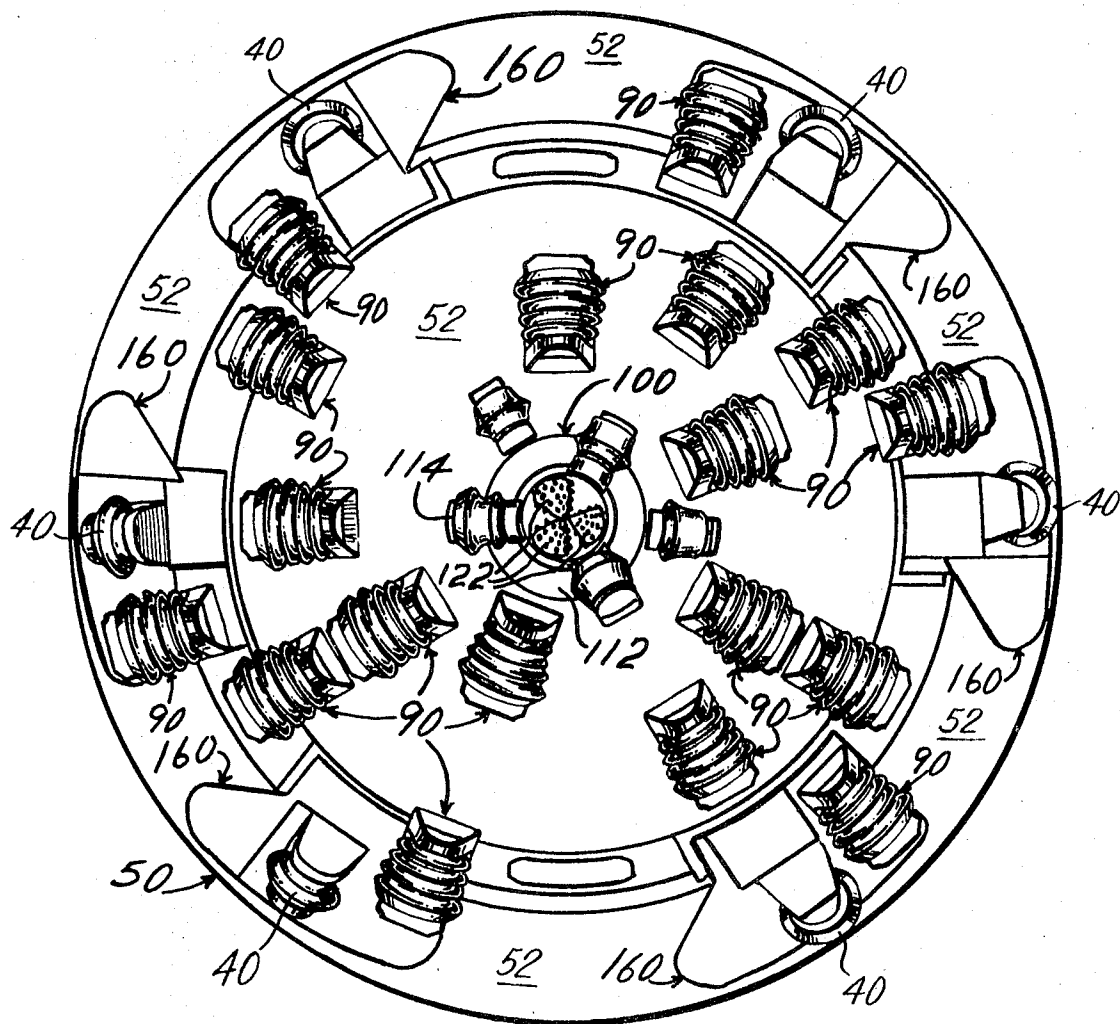


FIG. 15

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TUNNEL-BORING MACHINE

It is fast becoming apparent that a large number of tunnel-boring machines will eventually be used in the mining field.

Two of the features required for mine tunnel-boring machines are the ability to bore short radius curves in rock, and ease of access through the machine to the cutter face for cutter replacement and service. Accordingly, I have developed this particular invention having as an object to provide a tunnel-boring machine with a flexible cutterhead support and cutterhead assembly with cutters on the front thereof, and the longitudinal axis of said cutterhead and cutterhead support assembly may assume an angle with respect to the longitudinal axis of the tunnel-boring machine's main beam so as to allow the tunnel-boring machine to tunnel through short radius curves, and also having an object to provide a tunnel-boring machine having a walk-through region so that an operator or a worker may walk on the floor of the tunnel from the rear of the machine to the back part of the cutterhead support.

These and other important objects and advantages of the invention will more particularly be brought forth upon reference to the accompanying drawings, the detailed specification of the invention, and the appended claims.

FIG. 1 is a side elevational view of the tunnel-boring machine, in a tunnel, and which tunnel-boring machine is constructed in accordance with the teachings of this invention;

FIG. 2, taken on line 2-2 of FIG. 1, is a vertical, lateral cross-sectional view looking toward the cutterhead support of the tunnel-boring machine, and shows the motors for rotating the cutterhead, and also the rams for positioning the cutterhead support with respect to the main beam of the tunnel-boring machine;

FIG. 3, taken on line 3-3 of FIG. 1, is a lateral, vertical cross-sectional view of the main beam of the tunnel-boring machine and looking toward the cutterhead support of the tunnel-boring machine, and shows the gripper assembly for providing reactions for the propelling mechanism and for restraining the aft end of the main beam relative to the tunnel;

FIG. 4 is a fragmentary, horizontal, longitudinal plan view of the tunnel-boring machine, and shows the cutterhead support, the rotating cutterhead on the cutterhead support and the main beam and the gripper of the tunnel-boring machine;

FIG. 5, taken on line 5-5 of FIG. 3, is a fragmentary, longitudinal, vertical cross-sectional view of a main beam portion of the machine, and illustrates the gripper carriage and lateral outer beam connection and the sliding attachment of said carriage to the main beam;

FIG. 6 is a fragmentary view illustrating the motor, gear reducer and pinion gear in operative relationship with the ring gear of the cutterhead;

FIG. 7, in phantom, illustrates the tunnel-boring machine, in a tunnel, with the cutterhead support at a downward angle with respect to the longitudinal axis of the machine's main beam so as to make a curve or a downwardly directed arc;

FIG. 8 is a fragmentary, vertical, cross-sectional view looking at a rear of the tunnel-boring machine, and shows the supports for supporting the rear section and the rear of the main beam of the tunnel-boring machine, and with these supports being used only when the gripper is disengaged from the tunnel wall;

FIG. 9, in phantom, is an illustration of the tunnel-boring machine, in a tunnel, and with the longitudinal axis of the cutterhead support at a horizontal angle with respect to the longitudinal axis of the tunnel-boring machine's main beam so as to allow the machine to make a leftward arc or curve in a tunnel;

FIG. 10, on an enlarged scale, is a fragmentary plan view illustrating the ball and socket connection between the cutterhead support and the main beam of the tunnel-boring machine;

FIG. 11 is a vertical, longitudinal, fragmentary cross-sectional view illustrating a motor, a gear reducer, and a pinion gear in contact with the ring gear, said ring gear being positioned in the housing of the cutterhead;

FIG. 12 is a fragmentary, vertical, cross-sectional view of the tunnel-boring machine, and illustrates the gripper rams in a retracted position and gripper shoes in disengaged position from the tunnel wall, and also illustrates the sliding connection between the gripper carriage and the main beam;

FIG. 13, on an enlarged scale, is a vertical, longitudinal, fragmentary cross-sectional view illustrating the center of the cutterhead, and which center illustrates a multiplicity of rolling cutters and the center cutter, and with the gears shown inside which rotate the center cutter at a speed different from the speed of the rest of the rotating cutterhead;

FIG. 14 is a front view illustrating the front face of the cutterhead and the rolling cutters, the rolling cone cutters, and the center cutter on the front of said head.

In the drawings it is seen that the tunnel-boring machine may be considered to consist of four main components: a gripper 20, a main beam 24, a cutterhead support 22, and a cutterhead 50.

The primary function of the cutter head support 22 is to support the cutterhead 50. Structurally, the cutterhead support 22 comprises an outer cylindrical shell 36 and an inner cylindrical shell 34, and annular diaphragm plates 38 and 40. The plates 38 and 40 connect to the cylindrical shells 36 and 34. The forward parts of the shells are shaped to provide seats for the bearings 72 and 74 and for the seals that protect these bearings. There is a central mounting plate 182 through which the base 24 projects and extends.

The inner shell 34 of the cutterhead support 22 is shaped to form a suitable passage in which the front end of the muck or rock removal conveyor is positioned. Also, the ball 30 of the ball-socket joint, which connects the cutterhead support 22 with the main beam 24, is mounted in the inner shell 34, see FIG. 1. The outer shell 36 is formed to provide a mount for the front support 190, the side guides 194, and the top shield 192. On the circular mounting plate 78 there are two spaced apart brackets 212 and 214. On the rotary mount top shoe 192 there is a bracket 216 and a bracket 218. A ram 220 connects the brackets 212 and 216. A ram 222 connects the brackets 214 and 218. It is seen that by means of these rams and brackets that it is possible to rotate the rotary mount to the right or to the left and up or down. The aft diaphragm provides support for the gear reducers and drive motors, also mounted on it are the universal-type joint connections to the front end of the propelling rams. Similar brackets and universal joints are provided on the rear face of the cutterhead support which connect the respective ends of the vertical and horizontal attitude control rams with the main beam.

On each side of the main beam 24 there is a universal-type joint, mount 200. On each side of the cutterhead support there is a universal-type joint, mount 202. On one side of the main beam 24 a ram 204 connects a mount 200 and a corresponding mount 202 on the cutterhead support and a ram 204 connects a mount 200 and a mount 202 on the cutterhead support on the opposite side of the main beam 24.

On the bottom of the main beam 24 there is a universal-type joint, mount 206. On the cutterhead support bottom shoe 190 there is a universal-type joint, mount 208. Ram 210 connects the mounts 206 and 208. It is seen that by means of rams 204 and 210 and their corresponding mounts, it is possible to turn the cutterhead support to the right or to the left or up or down or a combination of these movements, providing an angular attitude between the cutterhead support and main beam.

One of the functions of the main beam 24 is to support the gripper 20. The main beam 24, aft section at the gripper mounting, see FIGS. 1 and 3, comprises a horizontal plate 232, spaced apart sides 234, and a top plate 236. The bottom plate 232, sides 234, and the top plate 236 define a housing or passageway 238.

The main function of the cutterhead 50 is to hold the cutters in their circular paths.

Structurally, the cutterhead 50 consists of an inner cylindrical shell 58, an outer cylindrical shell 56, a face structure 52, and annular braces 62 and 64 connecting the shells 56 and 58. There are openings or passageways 66 and 68 in the shells to allow the cuttings to pass through the cutterhead from the outside area of the outer shell into the inside area of the inner shell.

The rear end of the cylindrical shells is formed to house the outer races of the bearings 72 and 74, with their respective seals. Also, the ring gear 76, which engages the pinion of the drive motors, is mounted on the rear part 70 of the outer shell. On the front face 52 there are mounted a number of cutters 40, see FIG. 14. The cutters 40 are so positioned on the front face 52 that their circular paths cover the entire tunnel face when the cutterhead is rotating.

There is a large opening or passageway in the center of the face 52, but with suitable structural support immediately behind the passageway and which structural support defines a receptacle. This receptacle houses the central cutterhead assembly. The front face 104 of this assembly is a continuation of face 52 and supports several cutters 90. As shown in FIG. 13, a closed housing 100 is joined to face 104. The closed housing 100 contains planetary gear drives 107 and 140. The central cutterhead assembly rotates with the head 50. However, at the end of the central cutter end assembly, there is a shaft extension 153. The shaft extension 153 is fastened to a gear 152 of the nonrotating cutterhead support. As a result, when the cutterhead 50 and the housing 100 are turning, the nonrotating shaft energizes the planetary gear system and causes another shaft 118 of this gear system to turn at a higher rate of speed than that of the rotating head 50. The central cutter 122 is mounted on the front end of the shaft 118 and protrudes outwardly and forwardly of the front face 104.

On the outer radial wall 56 and overlying the opening 66 there are mounted a number of buckets or scoops 160 and which scoops 160 have backwalls 162, sidewalls 164 and 166 and top walls 168. Also, the scoop or bucket 160 has an opening 170. In FIG. 14 it is shown that cutterhead 50 rotates in a clockwise direction as the scoops 160 scoop up bits of earth and rock from the bottom of the tunnel. Then, when the cutterhead 50 rotates and the scoop 160 or bucket 160 rotates, the rock and earth fall through the openings 66 and fall through the openings 68. It is to be realized that there are a plurality of scoops or buckets 160.

The broken rock or earth 172 fall through the openings 66 and 68 and into a collector 174. The collector 174 has a front wall 176 and sidewalls 178. The collector 174 does not have a bottom. The earth and broken rock 172 fall on an endless belt 180. The endless belt 180 runs around a front pulley 182 and is supported by spaced-apart rollers 184. The endless belt 180 terminates in the front of the ball and socket.

The front end or forward part of the main beam holds the socket 28 of the ball joint 30. The ball and socket join the cutterhead support and the main beam. To recapitulate, the ball and socket joint 28 and 30 are an important part of this invention. This ball and socket connection make it possible for the longitudinal axis of the cutterhead support to be at an angle with respect to the longitudinal axis of the body. As a result, the cutterhead support and the cutterhead can cut or tunnel through an arc or a curve of a smaller radius than could be realized with the tunnel-boring machine of the prior art.

The middle section of the main beam is suitably shaped to support an enclosed muck removal conveyor or the conveyor for removing pieces of earth and broken rock and to provide a sliding connection with the gripper carriage 239, see FIG. 3. The rear end of the main beam supports the control equipment, operator's cab, and the rear end of the muck removal conveyor.

In FIG. 8 it is seen that in the rear of the main beam that there are two spaced-apart depending housings 310 and 312. These housings 310 and 312 define a walk-through passage 315.

The housing 310 is for housing transformers and the housing 312 is a control cab for the operator. There is attached to

the lower part of the housing 310 a ram 314 and which ram is directed downwardly and outwardly. The ram 314 has a shoe 316.

There is attached to the lower part of the control cab 312 a ram 318. On the lower part of the ram 318 there is a shoe 320. The ram 318 is directed downwardly and outwardly.

The walk-through portion 314 between the housings 310 and 312 make it possible for a party or a worker to walk on the floor of the tunnel, through the rear part of the tunnel boring machine and to the back part of the cutterhead support or near the circular mounting plate 78.

Both the equipment housing 310 and the operator's cab 312 are attached to the main beam in a special way. A pinned joint 311 allows the cabs to turn relative to the main beam around a vertical axis. This movement can be controlled by a variety of means, such as hydraulic, electrical, manual, etc. This angular freedom of the cabs relative to the main beam facilitates the negotiation of sharp curves and access to the rear passageway. This main objective of this invention was outlined in the opening paragraphs. Similarly, the aft end of the conveyor can be tilted downwardly around a horizontal axis to facilitate the travel through curves.

The main function of the gripper 20 is to provide reaction to the propelling cylinders or the propelling rams. The gripper 20 also controls the position of the aft part or rear part of the main beam. The gripper provides a special position control. In the vertical cross-sectional center plans of the gripper assembly, see Section 3-3 of FIG. 1 and also FIG. 3, the main beam is restrained from moving in any direction or from rotating around the longitudinal axis when the gripper is functioning. While partially so restrained, the main beam is free to move in the fore or aft direction or to turn around the vertical centerline of plane 3-3 or to tilt around the horizontal centerline of plane 3-3, again, see FIG. 3. The gripper assembly comprises a carriage on the outer beam assembly, two gripper beams, two gripper shoes, four lower rams, four upper rams, two crank assemblies, two crank actuator rams, and four propelling rams.

The carriage is basically a tubular frame with its axis in the lateral direction and its upper part matching the guide surface of the main beam 24 so that a spline like fore-aft relative sliding motion is possible. The outer beam assembly is also a tubular frame positioned inside of the carriage. The connection between the carriage and the outer beam is done by a vertical pin 246. The outer beam has a limited freedom to pivot around the pin 246. The gripper beams and another tubular frame match inside of the outer beam and are free to move only along the horizontal axis in the plane 3-3, again, see FIG. 3.

The gripper shoes are rigid pads with their outer faces matching the circular tunnel walls. They are ball-joint mounted on the outer ends of the gripper beams. This mounting allows the aforementioned tilt around the horizontal axis of the plane 3-3. Also, this mount provides limited freedom so that the gripper shoes will be evenly seated on uneven or broken tunnel walls.

The lower rams connect the gripper shoes with the carriage. They are universal mounted on each of their mountings.

The upper rams connect the gripper shoes with a crank which is positioned on the upper part of the carriage. They also have universal-type end connections. The crank assemblies connect to the inboard ends of the upper rams. The main crankshaft is supported by bearings in the carriage. When the gripper shoes are pressed against the wall by the rams, the cranks are rotated in their "out" positions and are locked against further rotation. If more substantial retraction of the gripper shoes is required, the cranks can be rotated in their "in" positions. FIG. 3 shows the cranks in their "out" position and FIG. 12 shows the cranks in their "in" position. This crank arrangement is not necessary for the lower gripper rams since they can have a longer stroke due to the configuration of the gripper carriage. The crank actuator rams are one of many means suitable to rotate the cranks. These are shown in FIG. 12.

The propelling rams are shown in FIG. 1. They connect to the right and left aft ends of the cutterhead support 22 with the respective gripper shoes. Their ends have universal-type mountings.

The operation of the gripper system starts with the retracted propelling rams. Then, the gripper shoes are pressed against the walls by the gripper rams. Starting the rotation of the rotating head and simultaneously extending the propelling rams will result in advancing the machine. At the end of the propelling stroke, the gripper rams are relaxed, the gripper shoes retracted, the propelling rams retracted and the cycle started again.

By way of recapitulation, it is called to the attention of the reader that the gripper functions to provide a reaction. The gripper shoes are positioned on the tunnel wall. In this manner, the gripper provides a reaction for longitudinal forces necessary to advance the cutterhead into the rock face or into the earth formation. Similarly, the gripper shoes provide a reaction for longitudinal forces when retracting the cutterhead from the rock face for servicing the cutterhead face or for changing the rotary cutter. The gripper also functions to provide reaction forces for horizontal forces, vertical forces and torsional forces transmitted by the main beam. The gripper positions the sliding main beam firmly at approximately the geometric center of the tunnel. The vertical pin 246 at the center of the gripper carriage allows the main beam to pivot, with no restriction, in the horizontal plane. The spherical bearings in the gripper shoes or the ball and socket connection in the gripper shoes allows the main beam to pivot with no restriction in the vertical plane. Since there is no freedom of movement in the gripper assembly about the Z-axis, when the gripper shoes are anchored on the walls of the tunnel, the torsional forces from the main beam are transmitted through the slide ways, through the gripper assembly and reacted onto the tunnel wall. An analogy for the above would be a universal joint with a sliding spline or a square shaft.

In regard to the function of the main beam, it is pointed out that the main beam provides means for attitude control of the cutterhead and the cutterhead support assembly or the rotating head, with respect to the tunnel. Actually, the attitude of the cutterhead and cutterhead support with respect to the main beam is controlled to provide desired positioning about the X-axis, Y-axis and the Z-axis. Further, the main beam functions to provide reaction means for forces through the ball and socket connection between the cutterhead support and the main beam, and the attitude positioning actuators, hydraulic rams connecting the cutterhead support and the main beam. Further, the main beam functions to provide means for transmitting forces such as from steering, eccentric face loads, torsional forces due to rotational power drive and the like from the cutterhead support to the gripper assembly. Also, the main beam functions to provide means for supporting the gripper assembly when the shoes are retracted and the gripper is being positioned during intermittent advance cycle of the tunnel-boring machine. The main beam also supports the rear section of the machine such as the operator's cab, the electrical and hydraulic control housing and the like. Finally, the main beam provides means for mounting the conveyor for removing the muck and broken rock from inside the cutterhead support and behind the cutterhead to the rear of the machine so that this material may be moved outside the tunnel.

In this tunnel-boring machine, as previously stated, there is a main beam 20. In FIG. 1, it is seen that the main beam 20 upon going from the left to the right increases in thickness or tapers outwardly to become thicker. Further, the main beam member continues to be the same width, see FIG. 4. At the left of the main beam member 24 there is an eye or an opening 26. There is positioned in the eye or opening 26 a socket 28. The socket 28 receives a ball 30.

The ball 30 is attached to the base member 32 of the cutterhead support 22. Actually, the base member 32 is part of the inner cylindrical wall 34. The inner cylindrical wall 34 defines

a throat through which the rock and earth is moved from the front of the rotary mount to the rear of the body.

There surrounds the inner cylindrical wall 34 an outer cylindrical wall 36. The inner cylindrical wall 34 and the outer cylindrical wall 36 are connected by annular braces 38 and 40. In FIG. 1 and in FIG. 4 it is seen that the inner cylindrical wall 34, the outer cylindrical wall 36 and the annular braces 38 and 40 define a circular chamber.

The forward part of the inner cylindrical wall 34 projects into a radial lip 42.

The cutterhead support 22 provides mounting means for the cutterhead 50 and which cutterhead 50 has a front wall or face structure 52 and with a central opening or passageway 54 therein. In FIG. 1 it is seen that the face structure 52 slopes away from the central passageway 54 so as to give the appearance of a frustum of a cone.

The cutterhead 50 has an outer radial wall 56 and an inner radial wall 58. The inner radial wall 58 and the outer radial wall 56 are connected by suitable annular braces 62 and 64. In the outer radial wall 56 there is an opening or passageway 66 and in the inner radial wall 58 there is an opening or passageway 68.

The outer radial wall 56 extends in radial lip 70. It is seen that the radial lip 42 is of less diameter than the radial lip 70 and that the radial lips 42 and 70 overlies each other.

There is positioned between the outer radial wall 36 and the radial lip 70 a bearing 72. There is positioned between the inner radial wall 58 and the radial lip 42 a bearing 74.

There is positioned on the inner surface of the radial lip 70 the ring gear 76.

On the rear of the annular brace 40 there is a circular mounting plate 78. There is positioned on this circular mounting plate 78 four motors or four electric motors 80. Each of the motors 80 is coupled to a gear reducer 82. The gear reducer 82 is coupled to a housing 84 for an output shaft 86. On the end of the output shaft 86 there is a pinion gear 88. The pinion gear 88 meshes with the ring gear 76.

From the structure of the pinion gears 88 and the ring gears 76, it is seen that the cutterhead 50 is driven or rotated with respect to the inner cylindrical wall 34 and the throat defined thereby and also with respect to ball and socket connections 24 and 28. Further, the cutterhead 50 is rotated with respect to the circular mounting plates 78 and the motors 80.

On the face structure 52 there are positioned a number of rolling cutters 90, see FIG. 14. These cutters are so positioned on the face structure 52 that they are in an overlapping relation when the cutterhead and the face structure 52 rotate.

There is positioned in the central passageway 54 in the face structure 52 a central cutter housing 100. The central cutter housing 100 has a radial wall 102, a face wall 104 and a rear wall 106.

In the face wall 104 there is an opening 108 and which opening is surrounded by an inner cone-shaped central housing 110.

There is mounted on the front of the face wall 104 an inner face ring 112. The inner face ring 112 carries a number of rolling cutters 114. In the inner face ring 112 there is an opening 116. There is positioned in the opening 116 an inner shaft structure 118. The inner shaft structure 118 on its forward end carries an inner rolling cone structure 120. This inner rolling cone structure 120 mounts three rolling cones 122.

In FIGS. 13 and 1 it is seen that the inner rolling cones 122 project in front of the rolling cutters 114. Further, the face structure 52 slopes away from the face wall 104 and the rolling cutters 114 project in front of the rolling cutters 90 mounted on face structure 52.

The inner shaft structure 118 is positioned in a bearing 130. The bearing 130 is positioned in the outer part of the inner cone-shaped central housing 110. Further, the inner shaft structure 118 is radially positioned in a bearing 132 in the inner part of the inner cone-shaped central housing 110. A seal is positioned between the inner shaft structure 118 and the face ring 112 so as to seal out dirt and extraneous matter.

Further, a thrust bearing 136 is positioned between the inner shaft shoulder structure 118 and the inner cone-shaped central housing shoulder 110. A seal 145 is positioned between the planet carrier hub and the housing cover 146 to seal out dirt and extraneous matter.

The inner shaft structure 118 carries a pinion gear or a sun gear 138. The sun gear 138 meshes with planetary gears 140. The planetary gears 140 mesh with the inner ring gear 107.

The planetary gear 140 is carried by a shaft 142 having a planet carrier 144. There is positioned between the outer wall of the inner cone-shaped central housing 110 and the planet carrier 144 a bearing 148. There is positioned between the planet carrier 144 and the inner shaft structure 118 a bearing 150. The planet carrier 144 connects with a circular gear 152. The gear 152 has an outwardly directed shaft 153. There is rotatively positioned on the shaft 153 a crossarm 155. This will be more completely discussed in a later portion of the specification.

There is attached and connected to the outer cylindrical wall 36 a front support bottom shoe 190, a cutterhead support top shield 192, and front side steering shoes 194 and 196.

In the central mounting plate 78 there is an opening 182 through which the base 24 projects and extends.

There is carried on the bottom plate 232 a gripper carriage 240. The gripper carriage 240 has a lower plate 242, an upper plate 244. The plates 242 and 244 are spaced apart. It is seen that the plates 242 and 244 with gripper carriage fore and aft side plates define a guide or a passageway.

In FIG. 3 it is seen that there is a left gripper shoe 250 and a right gripper shoe 252.

Each of the gripper shoes 250 and 252 has a lower bracket 254 and an upper bracket 256. Also, each of these gripper shoes has a socket 258 for receiving a ball 260. Each ball 260 is connected to a sliding beam 248, which beam is slidably mounted within the square tubular outer beam 262. The outer beam 262 is connected by a vertical pin 246 to the gripper carriage plates 242 and 244 at the center of the gripper 20. The outer beam is permitted to pivot in a horizontal plane and is restrained vertically by the lower plate 242 and upper plate 244.

A ram 266 connects with the bracket 254 and the shoe 250 and the frame 240. A ram 268 connects with the bracket 254 and the shoe 252 and the carriage 240. There is attached to the upper plate 244 a frame 270. A ram 272 connects with the bracket 256 of the shoe 250 and the lever arm 336. A ram 274 connects with the bracket 256 and the shoe 252 and the lever arm 336.

It is seen that by extending the rams 266, 268, 272, and 274 that the shoes 250 and 252 are pressed against the sides of the tunnel and thereby stationarily position the gripper carriage 240.

In FIG. 4 it is seen that there is a bracket 280 attached to the gripper shoe shoe 252 and the bracket 282 attached to the gripper shoe 250. A ram 284 connects by means of universal-type mounting with the bracket 280 and with a universal-type mount 286 on the cutterhead support.

A ram 288 connects by means of universal-type mounting with the bracket 282 and with the universal-type 290 on the cutterhead support.

In FIGS. 1 and 4 it is seen that there is a support means for the endless belt 180. This support means comprises a stationary support frame and an actuated support frame 300. On the rear of the actuated support frame 300 there is a drive pulley 304 and around which drive pulley 304 runs the endless belt 180. The actuated support frame 300 is connected to the sides 234 by a ram 306.

In FIG. 4 it is seen that an electrical power cable 320 connects with the main disconnect switch and then to the transformers. The output of the transformer is then fed to the electric motors and other equipment.

Also, in FIG. 4, there is illustrated a ram 322. On the housing there is a bracket 324 and on the right side of the rear part of the beam, looking forward, there is a bracket 326. The ram

322 connects with the bracket 324 and also with the bracket 326 for rotating the control cab and the housing around the vertical pin 311.

In FIG. 12 there is illustrated, in more detail, the gripper section 20. On the lower part of the gripper carriage 240 there are brackets 330. Also, a ram 332 connects with each of the brackets 330.

On the upper part of 270, there is attached by a pin 334, a lever arm 336. In FIG. 12 it is seen that there are two pins 334 and two lever arms 336, one on each side. The ram 272 is attached by a pin 338 to the lever arm 336. The ram 274 is attached by a pin 338 to the lever arm 336.

There is rigidly attached to the pin 334 a lever arm 340. The ram 332 connects with the end of the lever arm 334 so upon the extension of the ram 332 the lever arm 340 is rotated upwardly. Likewise, the lever arm 336 is rotated downwardly and the ram 272 is rotated upwardly to assist in withdrawing the shoes 250 and 252 away from the wall of the tunnel. Likewise, with the retraction of the ram 332, the lever arm 340 is rotated downwardly, the lever arm 336 is rotated downwardly, and the ram 272 is rotated downwardly to assist in moving the shoes 250 and 252 toward the wall of the tunnel. As previously explained, the use of the ram 332, arms 340 and 346 and the ram 272 is necessary because of the small working distance and the short throw of the rams 272 and 274 for moving the shoes 250 and 252 with respect to the wall of the tunnel.

The housing for the transformers 310 and the control cab for the operator 320, identified by reference numeral 350, in another version, may be provable along the bottom beam 232, in a manner similar to the grippers 20 movable along the bottom 232. This will necessitate the use of a guide way for 350. Also, this will necessitate the use of an actuating means for moving 350 along the guide 232. For example, there may be used a flexible connection means between the gripper 20 and the housing 350. The flexible connection means may be a ram or two rams. With the movement of the gripper along the beam 232, the housing 350 may likewise move along the beam 232. This will mean that it is possible to have a close proximity between the gripper 20 and the housing 350. For example, the gripper 20 and the housing 350 may be separated by only 3 or 4 inches, it is conceivable to have even a smaller separation. With this arrangement there is provided greater flexibility in the movement of the tunnel-boring machine in the tunnel. It is conceivable that it is possible to have an arc or a curve of a less radius with this arrangement of the housing 350 being closely positioned behind the gripper 20. In this arrangement gripper 20 and the housing 350 will substantially simultaneously move along the beam 232.

From the foregoing, I believe that I have invented a tunnel-boring machine which is successful in soft and medium-hard rock and will also be successful in hard rock fields wherein the cutting is in the range of 40,000 p.s.i. In fact, boring in this hard rock has seldom been attempted because machinery has not been available to do the boring.

One of the main advantages of this tunnel-boring machine is that continuous steering while boring is provided by directional attitude control of the cutterhead and cutterhead support with reference to the main beam, and hydraulic actuation of side steering shoes. The center section of the main beam slides in a channel in the gripper carriage and pivots both horizontally and vertically about the gripper beam at the geometric center of the tunnel. The forward end of the main beam is connected to the cutterhead support by the described ball and socket connection. Vertical and horizontal hydraulic actuators mounted at the rear base of the cutterhead support, and connected to the main beam, provide stabilization and directional attitude control between the main beam and the cutterhead support. The side steering shoes and the bottom shoe react with the tunnel wall and provide steering forces when the longitudinal travel cylinders are actuated. By controlling the hydraulic pressure in the cylinders, which provide attitude control between the cutterhead support and main beam, maximum eccentric cutter face loads are more readily

controlled with readouts available at the time they occur. Also, by controlling the cutterhead support and main beam attitude cylinder pressures, no uncontrolled forces are transmitted to the gripper shoes to cause slipping. The horizontal steering cylinders are positioned to place the cutterhead at such an attitude that the cutter face, at its periphery, is radial to the tunnel curve. The outboard steering shoe is positioned to follow and react on the outboard curve. The outboard travel cylinder is extended to accommodate the required cutterhead steering attitude. The inboard travel cylinders are in a retract position. The rear section is positioned to provide maximum tunnel wall clearance. The conveyor drive pulley is vertically positioned to provide maximum tunnel wall clearance. Shorter radii may be obtained by moving the pivot point on the gripper beam inboard and boring with a nonradial cutter face attitude. Vertical steering cylinders are positioned to place the cutterhead at an attitude whereby the cutter face at its periphery is radial to the tunnel curve. The gripper is normally positioned at the geometric center of the tunnel. Shorter radii may be obtained by operating with a shorter travel stroke, and with the gripper assembly at the rear portion of the main beam slide way. Shorter radii may also be obtained by positioning the gripper beam pivot point below the tunnel centerline, and boring with a nonradial cutterhead attitude.

Access to the cutter head is along the tunnel bottom, walking or proceeding in a crouched position. Access to the tunnel face is through a crawl space at the left side of and adjacent to the bottom shoe. A power actuated shield is retracted to provide a passageway for personnel and cutter handling. An alternate passage to the cutter face is through the conveyor chute in the cutterhead support and then through an opening in the cutterhead periphery. Access to the back of the cutterhead and front conveyor pulley area is through an opening in the cutterhead periphery when positioned at the bottom of the tunnel.

FIG. 15 is an elevation view showing the rear of the cutterhead and a crossarm connecting with the crosshead support.

The crossarm 155 connects to the cutterhead support 22 by pins 157. There is mounted on the crossarm 155, and on each side of the shaft 153, a detent pawl 159. The detent pawl is rotatively mounted on the pin 161 which connects to the crossarm 155. As is seen in FIG. 15, the detent pawls 159 prevent the rotation of the gear 152. In turn, through the gear turn comprising the planetary gears 140 and the sun gear 138 the rolling cones 122 rotate at a different speed than the rolling cutters 114, and which rolling cutters are rotated through the gear train comprising the planetary gears 140 and the inner circular gear 107. Also, the rolling cones 122 and the rolling cutters 114 rotate at a different speed than the rolling cutters 90 on the face of the cutterhead. As a result of the differential rotational speeds of these cones and rolling cutters there results greater cutting forces on the earth and rock.

When in use the bar 155 and the pawls 159 prevent the rotation of the gear 152. If repairs or an adjustment is to be made the pawls 159 can be taken out of engagement with the gear 152 so as to make adjustments on the cutterhead.

An alternative to having the crossarm 155 connecting to the cutterhead support 22 by pins 157 is to have a fluid actuated cylinder 163 connected to one of the pins 157. There is an attachment 165 on the end of the plunger 167 of the fluid actuated cylinder, i.e., hydraulic cylinder.

The other end of the fluid-actuated cylinder connects to the cutterhead support 22 as illustrated. In this modification one of the detent pawls 159 can be disconnected from the gear 152 and then a plunger 167, of the cylinder 163 or the ram 163, can be moved longitudinally with respect to the body of the ram 163 so as to rotate the gear 152 for disconnecting the cones or central cutter 122. This is of advantage when replacing the central cutter 122. It is to be realized that in place of three rolling cones 122 that one cone of one central rolling cutter can be used.

The ratchet-and-lever system, viz., the crossarm 155 and the detent pawls 159 in connection with the circular gear 152,

provides a means for service replacement of the center cutter bit. The ratchet lever and the hydraulic actuator mechanism are used to index the cutterhead when servicing the cutter. The cutter 122 is blocked for firm position and then the crossarm 155 in connection with the detent pawl 159 is used to index or rotate the circular gear 152 so as to loosen the central cutter 122.

Having presented my invention what I claim is:

1. A tunneling machine comprising;

- a. a cutterhead, a cutterhead support assembly and a main beam;
- b. at least one sidewall gripper connecting with said main beam and movable relative thereto in a longitudinal direction;
- c. said main beam being stationary relative to said cutterhead and cutterhead support assembly in said longitudinal direction;
- d. a rear bracing structure forming part of said cutterhead support assembly adjacent the rear end thereof;
- e. said main beam extending into said cutterhead support assembly and connecting with said cutterhead support assembly by a multidirection pivot means whereby said cutterhead and cutterhead support assembly may be turned in any direction about said pivot means, said pivot means being at about a midpoint location in said cutterhead support assembly and forward of said rear bracing structure.

2. The tunneling machine of claim 1 wherein said pivot means comprises a ball and socket connection.

3. The tunneling machine of claim 1 wherein a wall ripper is disposed on each side of said main beam and a clear space passageway for workmen is beneath said main beam and said wall grippers.

4. The tunneling machine of claim 3 wherein a conveyor for recovering the rock and earth cut away by the tunneling machine extends from inside said cutterhead support assembly at least the entire length of said main beam, said main beam being between said clear space passageway and said conveyor, serving thereby to shield the clear space from the conveyor overhead thereof.

5. The tunneling machine of claim 1 wherein a control cab is pivotally mounted on said main beam to the rear of said sidewall gripper.

6. The tunneling machine of claim 1 wherein wall engaging steering shoes are mounted on the periphery of said cutterhead support assembly and are at least partially supported by the said rear bracing structure thereon.

7. A tunneling machine comprising:

- a. a cutterhead, a cutterhead support assembly and a main beam;
- b. a sidewall gripper at each side of said main beam connecting with said main beam and movable relative thereto in a longitudinal direction;
- c. said main beam being stationary relative to said cutterhead and cutterhead support assembly in said longitudinal direction;
- d. said main beam and said cutterhead support assembly being connected by a multidirection pivot means whereby said cutterhead support assembly may be turned relative to said main beam;
- e. a plurality of propelling rams with at least one ram on each side of said main beam, each ram joined at one end of the ram to a sidewall gripper and at the other end of the ram to said cutter support assembly, a controlled extension of each of said propelling rams thereby advancing the cutterhead and cutterhead support assembly relative to said sidewall gripper means, and, if desired, cause the cutterhead and the cutterhead assembly to turn about said pivot means.

8. The tunneling machine of claim 7 wherein said rams are joined to the rear of said cutterhead support assembly, wherein said main beam extends into said cutterhead support assembly, and wherein said pivot means between main beam and cutterhead support assembly is at about a midpoint in said

cutterhead support assembly and is forward of said propelling rams.

9. The tunneling machine of claim 7 wherein said pivot means comprises a ball and socket connection.

10. The tunneling machine of claim 7 wherein wall engaging support and steering shoes are mounted on said cutterhead support assembly essentially forward of where said propelling rams are joined to said cutterhead support assembly.

11. The tunneling machine of claim 7 wherein a pair of propelling rams, one above the other are disposed at each side of said main beam.

12. The tunneling machine of claim 7 wherein a clear space passageway for workmen is beneath said main beam.

13. A tunneling machine comprising;

- a. a cutterhead, a cutterhead support assembly and a main beam;
- b. at least one sidewall gripper connecting with said main beam and movable relative thereto in a longitudinal direction;
- c. said main beam being stationary relative to said cutterhead and cutterhead support assembly in said longitudinal direction;
- d. said main beam and said cutterhead support assembly being connected by a multidirection pivot means whereby said cutterhead support assembly may be turned relative to said main beam;
- e. individually controlled steering rams, one on each side of said main beam, each ram joined at one end to said main beam and at the other end to said cutterhead support as-

sembly, whereby a controlled differential extension of one said ram will cause the cutterhead and cutterhead support assembly to turn on said pivot means.

14. The tunneling machine of claim 13 including at least one steering ram at the underside of said main beam joined at one end to said main beam and at the other end to said cutterhead support assembly.

15. The tunneling machine of claim 13 wherein said pivot means comprises a ball and socket connection.

16. The tunneling machine of claim 13 wherein wall engaging support and steering shoes are mounted on said cutterhead support assembly essentially forward of where said steering rams are joined to said cutterhead support assembly.

17. The tunneling machine of claim 13 wherein said steering rams are joined to the rear of said cutterhead support assembly, wherein said main beam extends into said cutterhead support assembly and wherein said pivot means between said main beam and cutterhead support assembly is at about a midpoint in said cutterhead support assembly and forward of said steering rams.

18. The tunneling machine of claim 13 wherein a plurality of propelling rams are disposed at the sides of said main beam each joined at one end to a sidewall gripper and at the other end to said cutterhead support assembly.

19. The tunneling machine of claim 13 wherein a pair of propelling rams, one above the other, are disposed at each side of said main beam.

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