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(54) Machine for boring non-circular tunnels.

(57) A tunneling machine for boring non-circular tunnels in rock has a cutterhead rotatable about an axis parallel to the tunnel axis. The cutterhead has rollertype cutters both on the face and around a cylindrical outer periphery. The cutterhead is mounted on a cutterhead frame that is movable axially along the tunnel axis with respect to a main frame and the main frame is mounted on clamp frames removable transversely of the tunnel axis. Clamp shoes are carried by the clamp frames for engagement with the tunnel wall and hydraulic cylinders are provided both for moving the cutterhead frame along the axis of the tunnel and the main frame transversely of the tunnel axis. The tunnel is cut by moving the cutterhead forward along the tunnel axis with the face cutters lowering a distance into the tunnel. A main frame is then advanced forwardly and cross thrust means move the main frame transversely along the clamp frames so that the cutters on the cylindrical sides of the cutterhead enlarge the circular bore into an oval bore.

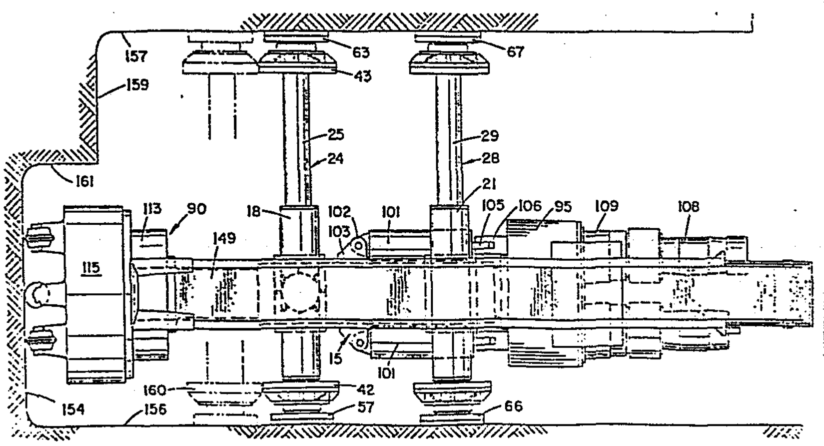

FIG. I

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Croydon Printing Company Ltd.

MACHINE FOR BORING NON-CIRCULAR TUNNELS

BACKGROUND OF THE INVENTION

This invention relates generally to hard rock tunnel boring machines, and more particularly to a hard rock tunnel boring machine using disc-type cutters mounted on a cutterhead which rotates about an axis parallel to the axis of the tunnel and is designed to cut a non-circular tunnel or entry.

Many types of tunneling machines have been devised to bore tunnels of different cross-sectional configurations through soft ground and very soft rock or soft minerals such as coal, using various types of fixed cutter bits having hard surfaces which dig into and scrape or cut away the material as the tunnel is being cut. However, such machines are not suitable for hard rock because of the rapid wear of such cutters, and it has been found that in very hard rock the only effective type of cutter is a rolling disc cutter which is forced against the tunnel face with a high force and with a rolling action. This results in forces being applied to the rock that are greater than the compressive strength of the rock, so that the material is broken away and falls away from the tunnel face, where it may be picked up and removed by suitable collecting apparatus. Because such machines require very high thrust forces against the cutting face, they must be quite rugged yet simple in construction.

One such machine is disclosed in U.S. patent No. 3,383,138, in which a fixed frame is anchored at two axially spaced points in the tunnel bore, and a movable frame having a rotating cutterhead with roller-type cutters is forced against the face of the tunnel by means of hydraulic thrust cylinders acting between the fixed frame and the movable frame supporting the rotating cutter head. With machines of this type, it is necessary that after the rotating cutterhead has advanced the full stroke length of the hydraulic cylinders providing the thrust force, the rotating action of the cutterhead is stopped and the moving frame is supported in position in the tunnel, after which the fixed or clamping frame is retracted from engagement with the walls of the tunnel, advanced forward a distance equal to the length of stroke of the thrust cylinders, and then re-anchored in position in the tunnel. After this has been accomplished, the rotation of the cutterhead is again started and thrust applied to produce a stepwise advance. Such tunneling machines make take a number of configurations, and may be reduced in size and simplified in construction, as shown in U.S. patent No. 4,189,186.

Although hard rock tunneling machines of the type described above have been quite successful in commercial operation, they have been generally somewhat limited in application because they are only able to bore tunnels which are circular in cross section, and this shape may not satisfy the requirement of a particular tunnel. As a result, if the tunnel is to have a different finished shape, such as oval or elliptical, as is common in the case of entry or access tunnels, one solution is to have the tunneling machine bore a circular tunnel with a diameter equal to the largest axis of the oval, after which the other portions have to be filled in, e.g., if a flat bottom is required. With this approach, an extra volume of rock will have to be removed, and this greatly increases the cost and time for boring the tunnel.

The alternate solution is to bore a circular tunnel having a diameter equal to the smallest dimension of the finished tunnel, and thereafter enlarge the tunnel to the desired shape. The removal of such additional rock tends to be inefficient, and reduces the efficiency provided by the operation of the circular tunnel boring machine. With this second approach, the additional material removal has been proposed in a number of ways, such as the use of additional cutterheads following behind the main cutterhead and offset therefrom, but this tends to greatly increase the cost and reduce the operating efficiency of the machine.

Still another approach has been to have the rotating cutterhead make an oscillating, traversing motion by pivoting about an axis transverse to the axis of the tunnel. Such an arrangement is shown in U.S. patent No. 4,232,905. With this type of machine, not only is the construction more complicated than with the normal machine but the stepwise advance that requires resetting of the fixed frame is quite short and the need for continually repositioning the fixed frame at each traversing stroke of the cutterhead results in a relatively slow mode of operation.

Another type of machine for boring oval tunnels is shown in West German Patent DE 2940472 C2. This machine has front and rear frames each having cylinders to grip the tunnel walls. The front frame carries a cutterhead frame that moves transversely of the tunnel axis by independent cylinders engaging the tunnel wall as well as moving axially by cylinders extending between the cutterhead and the cutterhead frame. This arrangement is complex and requires a large number of relatively moving parts and hydraulic cylinders.

SUMMARY OF THE INVENTION

The present invention provides a machine and method of operation of the machine to produce tunnels in hard rock that are oval in cross section. The term "oval" in this context refers to a shape of a tunnel having flat opposed walls that are parallel to each other and joined at the ends by semicircular wall portions. The tunnel boring machine has a cutterhead arranged to rotate about an axis parallel to the axis of the tunnel and has an outer diameter equal to the space between the parallel walls. To bore the tunnel, the cutterhead has a first set of rotating disc-type cutters on its face and it is positioned at one side in alignment with one of the semicircular wall portions and advanced to drill a circular tunnel portion against the tunnel face. After it has completed the forward stroke, it is then moved transversely to the tunnel wall while rotating, and a second set of rotating disc-type cutters mounted around the axially extending peripheral side of the cutterhead then cuts away the material under the lateral forces until it has reached the full stroke equal to the length of the straight portions of the cutter wall and reaches the other semicircular tunnel wall side. Although the cutting head could then be advanced axially in this other position, it is preferred to return it to the original side position so that all lateral cutting occurs in the same direction so that the cutterhead can be equipped with suitable scoops and scrapers to pick up the rock cuttings and transfer them to a suitable removal apparatus, such as an endless belt conveyor.

The machine itself is provided with a first or main frame which is mounted on a pair of clamp frames that are axially spaced along the tunnel and arranged so that each of the two clamp frames is locked in place by opposed clamp legs against the tunnel wall along the semicircular wall portions. Each of the clamp frames provides a cross thrust hydraulic cylinder and piston arrangement for moving the main frame laterally of the tunnel walls and parallel to the parallel walls during the side cutting action. A second frame is mounted on the main frame and carries a rotating cutterhead and drive mechanism therefor. Suitable hydraulic thrust cylinders act between the main and second frames to provide the axial thrust required when the cutterhead is making the forward cutting portion of the cycle.

The total cross or side cutting stroke can be greater than the stroke of the main frame along the two clamp frames by arranging the clamp legs so that the clamp frames are positioned adjacent one side of the semicircular tunnel walls. When the forward cutting is done from this position, at the end of the forward stroke the two clamp leg sections are repositioned by forward movement of the main frame and locked in place to provide maximum support closest to the cutterhead during the cross-cutting action. The operation of the cross thrust hydraulic cylinder means on the clamp frames then moves the main frame laterally of the tunnel wall to cut away most of the rest of the oval. However, when the cross thrust cylinder means reaches the end of the stroke, the clamp frames may be repositioned laterally by retracting the clamp legs on one side and extending the clamp legs on the other side to shift the frames laterally to the other side, and hence shift the main frame sideways on the clamp frames without moving the cutterhead laterally. After this has been done, the final amount of lateral cutting movement is produced by the movement of the main frame along the two clamp frames by the cross thrust cylinder.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of a tunneling machine according to the preferred embodiment of the present invention, showing the machine in position at the forward end of the forward cutting stroke and before the clamp legs have been repositioned forwardly for the side cutting portion of the cycle;

FIG. 2 is a side elevational view of the tunneling machine shown in FIG. 1;

FIG. 3 is a cross-sectional view through the tunneling machine, taken on line 3-3 of FIG. 2;

FIG. 4 is an end elevational view of the tunneling machine taken on line 4-4 of FIG. 2;

FIG. 5 is a fragmentary, top plan view of the front lift leg at the front clamp frame;

FIG. 6 is a cross-sectional view taken on line 6-6 of FIG. 5;

FIG. 7 is a front elevational view of the cutterhead, showing the arrangement of the cutters;

FIG. 8 is a fragmentary side elevational view of the cutterhead, with some cutters removed, showing the arrangement of the side cutters and gage cutters;

FIG. 9 is a fragmentary, schematic view looking rearwardly from the tunnel face, showing the arrangement of the clamp frames and clamp legs at the start of the side cutting portion of the cycle;

FIG. 10 is a fragmentary, schematic view similar to FIG. 9, showing the position of the main frame at the end of the first portion of the side cutting stroke;

FIG. 11 is a fragmentary, schematic view similar to FIGS. 9 and 10, showing the repositioning of the clamp legs to move the clamp frame laterally for the additional portion of the stroke;

FIG. 12 is a fragmentary, schematic view showing the arrangement of the clamp frame at the end of the side cutting stroke; and

FIG. 13 is a schematic, hydraulic diagram of the controls for the tunnel boring machine.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings in greater detail, and particularly to FIGS. 1-4, the machine has a first or main frame 15 which includes a longitudinally extending square tube portion 16. At the front end of the square tube portion 16, and by "front" is meant the end toward the tunnel face, are located upper and lower front cross thrust cylinders 18 and 19, respectively. These cylinders 18 and 19 are attached to the top and bottom of the front portion of the square tube 16 and extend transversely of the axis of the tube. Likewise, at the rear end of the square tube portion 16 are mounted upper and lower rear cross thrust cylinders 21 and 22, likewise on the top and bottom of the square tube portion and extending transversely to the axis of the tube and parallel to the axes of the front cylinders 18 and 19.

A front clamp frame 24 is mounted at the front of the square tube portion 16 to have an upper rod 25 and lower rod 26 extending through the upper and lower cross thrust cylinders 18 and 19, respectively. Likewise, a rear clamp frame 28 includes upper and lower rod portions 29 and 30 extending through the upper and lower rear cross thrust cylinders 21 and 22. As will be explained in greater detail hereinafter, this arrangement allows the first or main frame 15 to be mounted on the front and rear clamp frames 24 and 28 for lateral movement transverse to the axis of the tunnel.

It will be understood that the front and rear clamp frames 24 and 28 are substantially identical. Furthermore, the construction of the upper and lower cross thrust cylinders and rods are substantially the same and, therefore, the construction associated with the upper front cross thrust cylinder 18 and upper front rod 25 will be described in detail, it being understood that the lower cylinder of the front clamp frame and both of the cylinders of the rear clamp frame are the same in construction and mode of operation. As shown in greater detail in FIG. 3, the upper front clamp frame rod 25 has at its midpoint an enlarged piston portion 35 adapted to make a sealing fit within the cylinder bore 36 which extends from end to end through the upper front cross thrust cylinder 18. The bore 36 is closed off at the left end by a suitable seal 37 secured to the cylinder and making sealing contact with the rod 25 and a similar seal 38 at the right hand end performs the same function at that point. The engagement of the piston portion 35 with the bore 36 and of the seals 37 and 38 with the rod 25 forms a bearing arrangement for slidably journaling the main frame on the clamp frame. Since the rod 25 is smaller in diameter than the bore 36, the annular area therebetween serves as a hydraulic cylinder to produce relative movement in either direction between the clamp frame rod 25, and hence front clamp frame 24, and the main frame 15. Accordingly, a left hydraulic port 39 adjacent the left seal 37 controls fluid flow into the cylinder portion to the left of piston 35 and the right hydraulic port 40 adjacent the right seal 38 controls fluid flow to and from the cylinder portion on the right hand side of piston 35.

At their outer ends, the upper and lower rods 25 and 26 are joined together by left and right frame plates 42 and 43, respectively. The frame plates 42 and 43 are rigidly secured to the ends of the rods 25 and 26 to hold them in spaced relationship as respective pistons move through their cylinder bores and frame plates 42 and 43 also serve to mount the clamp leg cylinders for clamping the frames against the opposed sidewalls of the tunnel bore. As shown in greater detail in FIG. 3, the left frame plate 42 carries a left clamp leg cylinder 45 mounted thereon intermediate the rods 25 and 26, and the cylinder 45, which is closed off at its inner end, has a bore 46 therein. A piston 47 has an enlarged head 51 making sealing engagement with the bore 46, and extends outward through a seal member 48 which is of smaller diameter than the bore 46, to produce a differential area to allow a return action on the piston 47 to retract it for movement of the machine along the tunnel axis. The piston 47 includes a socket portion 54 adapted to receive a ball 55 which is secured to the clamp leg shoe 57, which engages the sidewall of the tunnel. The ball and socket joint 54 and 55 allows the clamping shoe 57 to make proper engagement with the tunnel wall in spite of certain irregularities that may occur because of uneven removal of material in a localized area.

Likewise, the right frame plate 43 carries a right clamp cylinder 61 having a piston 62 therein adapted to push the shoe 63 against the opposite wall of the tunnel. It will be understood that the cylinder 61 is identical in construction with the cylinder 45 and that the same structure is also repeated on the rear clamp frame 28, which likewise has left and right cylinders 64 and 65 to actuate pistons for the left and right shoes 66 and 67, as shown in FIG. 4.

In order to support the main frame 15 for purposes of steering where it is desired to raise or lower the main frame when the front and rear clamp frames are not engaged with the tunnel walls, a lifting leg is provided at the front clamp frame 24. As shown in greater detail in FIGS. 5 and 6, a plate 68 is secured to the front of the square tube portion 16 on either side of the lower front clamp frame cylinder 19, and secured to plate 68 is a lift leg cylinder 70 in alignment with the central axis of the main frame 15 and arranged to operate on a vertical axis. The cylinder 70 is held in place on the frame 68 by means of reinforcing gusset plates 71 and has a cylinder bore 72 therein. The lower end of cylinder bore 72 is closed by a seal unit 74 and a piston 76 having a head 77 operates within the cylinder bore 72 in much the same manner as in the case of the clamp leg cylinder 45. Accordingly, the piston 76 has a socket 79 therein to receive a ball 81 attached to a lift foot or shoe 82 which is engageable with the floor of the tunnel. As can be seen, whether or not the lift leg cylinder 70 is energized, it can provide either a supporting force for the front end of the main frame 15 or it can be used to raise or lower the main frame 15 at this point whenever the clamp leg shoes are not secured to the wall of the tunnel.

Mounted on the main frame 15 is a cutterhead frame 90 as shown in greater detail in FIGS. 1-3. The cutter frame 90 has a square tube central section 91 which extends within the square tube portion 16 of the main frame 15 wherein it is slidably journaled by suitable bearing plates 92. It will be understood that with this arrangement, the square tube 91 can slide axially within the square tube 16 to allow the cutterhead frame 90 to move axially along the tunnel with respect to the main frame 15. Because of the flat surfaces of the bearing plates 92, relative rotation between the two square tubes 91 and 16 is eliminated to take up the reactive torque resulting from rotation of the cutterhead, as described in greater detail hereinafter.

At the rear end of the square tube 91 is located the drive gear housing 95. At the bottom of the drive gear housing 95 are located a pair of vertically acting lift leg cylinders 97 and 98 which are connected to a support shoe 99 to allow raising and lowering of the rear or drive gear housing end of the cutterhead frame 90 for steering purposes and to support that end of the frame when the main frame is traversed along the cutterhead frame during a reset operation. The cylinders 97 and 98 have a ball and socket connection (not shown) to the shoe 99 and may be differentially actuated to provide a slight shift or twist to the frame for steering purposes and to correct for any tendency of the machine to walk in a spiral path as the result of torque reaction forces during the forward cutting operation.

The relative axial movement between the cutterhead frame 90 and the main frame 15 is provided by a plurality of axial thrust cylinders 101 which, in the present machine, are four in number and are arranged symmetrically on either side of the square tube 91. At the forward ends, the thrust cylinders 101 are secured by means of a pin 102 to an anchor mount 103 secured to the side of the square tube portion 16 of the main frame 15. The piston rods 105 extend rearwardly toward the drive gear housing 95 and are secured to suitable anchor mounts 106 on the drive gear housing 95. It will be noted that the thrust cylinders 101 are mounted so that during the forward or cutting stroke, they are pressurized on the piston rod side, even though this is of lesser cross-sectional area, to ensure that the high thrust forces are taken up on the piston rods 105 when they are in tension rather than compression.

Mounted on the rear face of the drive gear housing 95 are a plurality of electric drive motors 108 connected through individual gear transmission boxes 109 to appropriate gearing (not shown) inside the drive gear housing in a manner well known in the art. The force of all of the drive motors 108 is then transmitted from the drive gear housing 95 forwardly through a central axially positioned drive shaft 111 which extends forwardly through the square tube 91 of the cutterhead frame to the bearing housing 113, which is secured to the front end of the square tube 91. The rotary cutterhead 115 is mounted on suitable bearings 116 carried on the bearing housing 113, and drivingly connected to the drive shaft 111 by suitable means such as key 118 (see FIG. 2). The cutterhead 115 includes a shank portion 121 fitted within the inner races of the bearings 116 and has a rear radial web 123 spaced axially from the front face 125 and the outer portion of the cutterhead defines a peripheral surface 127, as will be explained in greater detail hereinafter.

The cutterhead 115, as shown in greater detail in FIGS. 7 and 8, is provided with two separate sets of disc-type cutters, one set mounted on the front face 125 for cutting during the forward thrust of the cutterhead, and a second set mounted on the peripheral surface 127 for cutting during the transverse motion of the cutterhead. The first set of cutters includes a center cutter 129 mounted on the face 125 to provide the cutting action at the central axis of the cutterhead. A plurality of face cutters 131 are spaced around the front face 125 in the well known manner to balance the forces and provide cutting action at various radial distances from the central axis. Each of these cutters is of the conventional type, including a saddle 132 mounted directly on the cutterhead and supporting an axle (not shown) on which the roller single disc cutter 133 is journaled for rotation about the axis of the axle. In the case of the center cutter 129 and the face cutters 131, these axes of rotation for the cutters are parallel to the front face 125.

The cutterhead 115 also, in the present design, has three extension portions 135 extending coplanar with the front face 125 and serving to mount the outside cutters 136 which may roll about axes that are inclined to the front face 125. Also mounted on these extensions 135 are one or more gage cutters 138 having their rollers so aligned that they define the outer periphery of the tunnel and cut the full diameter of the tunnel when the cutting head is on its forward stroke parallel to the axis of the tunnel.

The second set of cutters comprises three side cutters 141 mounted equidistantly around the peripheral surface 127 and spaced between the extension portions 135. Each of these side cutters 141 includes an extended saddle 142 supporting a plurality of rollers 143 arranged to rotate about an axis parallel to the axis of the machine and the tunnel. These rollers 143 are spaced axially so that they provide cutting over an axial length from the gage cutters 138 a distance substantially equal to the stroke of the thrust cylinders 101 and are so arranged that they function only when the cutterhead 115 is on the transverse or cross stroke when the main frame 15 is moved transversely along the front and rear clamp frames 24 and 28.

Also mounted on the extensions 135 is a plurality of scrapers 145 which serve to pick up the material broken loose from the face during both axial and transverse cutting action and transfer the material rearwardly of the tunnel face to muck buckets 146 (see FIG. 2), which in turn transfer the material to a hopper 148 from which it passes over a conveyor 149 extending across the top of the machine rearwardly to a point behind the drive motors 108, where the material is collected by suitable and well known apparatus for removal from the tunnel. It is because of the angular relationship of the scrapers 145 and the shape of the muck buckets 146 that the transverse cutting of the tunnel is always done in the same direction, since they could not function as well to remove material if the transverse cutting were done in the opposite direction. However, it is recognized that the transverse cutting could be done in both directions, as shown in West German Patent 2940472, if a muck collecting system were added which is operated independently from the cutterhead.

A schematic diagram of the general hydraulic power circuits is shown in FIG. 13. Preferably, there is a common reservoir 170 to provide an adequate supply of hydraulic fluid for all of the power cylinders in the machine, but independent pumps and drive motors are used for the axial thrust cylinders, the individual clamp leg cylinders and the cross thrust cylinders used for the transverse cutting motion. Accordingly, a first pump 171, driven by a suitable electric motor, supplies high pressure fluid through a line 173 to a single control valve 174 for all of the four cross thrust cylinders. The pressure relief valve 172 is set at a predetermined maximum pressure, which may be adjustable according to the rock formation being cut, to provide a predetermined maximum constant transverse thrust action for the cross thrust cylinders. The valve 174 is of the four-way three position reversing type, with a closed center locking position in the middle position to maintain the pressure on both sides of the cross thrust pistons. This is necessary to ensure against any lateral movement during the forward cutting action. If desired, suitable check valves and orifices may be used to control the rate of flow. It should be noted that a single control valve 174 is used so that all of these four cross thrust cylinders move in unison, since they are used only for the transverse cutting action and not for any steering or corrective action during the resetting of the machine.

The hydraulic fluid for the clamp leg cylinders is supplied by a separate pump 178 connected through a line 179 and a pressure relief valve 181 to four separate control valves, 182, 183, 184, and 185 connected in parallel and controlling the action of the four clamp leg cylinders 45, 61, 64, and 65, respectively. Again, each of these control valves is of the four-way, three-position reversing type to allow both application of the clamping force and withdrawal of the clamping pads, as required, and it is noted that each of these clamp leg cylinders can be controlled individually of the others, as required for proper operation of the machine.

Likewise, the axial thrust cylinders are supplied to a third pump 188 connected to a line 189 and a pressure relief valve 191 to a four-way, three-position control valve 192 which supplies the fluid to all four of the thrust cylinders 101 in unison. With this arrangement, the four cylinders are always supplied with fluid at the same pressure, to prevent any cocking action that might result from differential pressures in these cylinders.

Utilization of the separate supply pumps ensures independent operation of each of these three circuits and, by virtue of the separate pressure relief valves 172, 181, and 191, the pressures in each of these circuits can be adjusted independently of the others as required for optimum cutting action in a particular rock formation. Of course, separate hydraulic systems are provided, but not shown, to control operation of the front lift leg cylinder 70 and the rear lift cylinders 97 and 98, as required, since these cylinders do not require the constant supply or high pressure required for the circuits described above.

The method of operation of the machine is shown in particular reference to FIGS. 1 and 9-12. The cycle, assumed to start from the beginning of the forward cutting action, starts at the point where the front and rear clamp frames 24 and 28 are set in place and the cutterhead frame 90 is in a rearward position with respect to the main frame 15. As shown in FIG. 9, which looks rearwardly from the tunnel face, the clamp frames 24 and 28 are positioned toward the left side of the tunnel so that the left clamp leg cylinders 45 and 64 are substantially retracted and the right clamp leg cylinders 61 and 65 are substantially fully extended. This therefore positions the main frame 15 and cutterhead frame 90 to the furthest left point in the tunnel. At this point, the thrust cylinders 101 are pressurized and, with the cutterhead 115 rotating, the forward cutting action is begun, to bore a circular hole forwardly in the tunnel having a location as indicated in the phantom line 151 in FIG. 9.

The forward cutting action continues as the thrust cylinders 101 move through the full length of their stroke. At the end of the forward stroke, the tunnel has a configuration as shown in FIG. 1, in which the circular end face 154 extends forwardly adjacent the left curved face 156, while on the opposite side, the right curved face 157 terminates at the face 159, which was cut during the previous cycle of the machine.

At this point, it is then necessary to cycle the main frame 15 forwardly by releasing the clamp legs and moving the frame forwardly by reversing the action of the thrust cylinders 101. When the main frame is moved forward to the position shown in phantom lines 160 in FIG.

1, the clamp legs are then extended in the same manner as before, as shown in FIG. 9. After this has been done, the side or cross cutting portion of the cycle then begins. During this portion of the cycle, no fluid pressure is applied to the thrust cylinders 101, where the valves are held in a locked position, but the fluid pressure is then supplied to the cross thrust cylinders 18, 19, 21, and 22 to cause the main frame 15 to traverse horizontally on the clamp frames 24 and 28. As the cutterhead 115 rotates, the cutters on the front face 125 serve no significant purpose other than to provide a slight cleanup action on the tunnel face, whereas, the side cutters 141 work against the side cutting face 161 to remove the material thereon. This cutting action generates the flat, parallel top and bottom faces 152 and 153 which connect the curved side faces 156 and 157 to define the oval cross section.

At the end of the first portion of the transverse cutting stroke, the cutterhead and main frame have reached the position shown in FIG. 10, in which the cross thrust cylinders 18, 19, 21, and 22 have reached the end of their strokes, having moved through a distance 163 equal to the stroke length of the cylinders. Although this transverse distance is substantial, being equal to or greater than the radius of the cutterhead, it is possible that an even wider tunnel can be cut. To do so, it is now necessary to reposition the clamp frames 24 and 28 with respect to their clamp feet. To do this, the pressure is removed from the cross thrust cylinders 18, 19, 21, and 22 so that the main frame can, in effect, float on the clamp frames 24 and 28. When this is done, it is possible to pressurize the left clamp leg cylinders 45 and 64 while the opposite clamp cylinders 61 and 65 are depressurized, to thereby shift the clamp frame a distance indicated at 164 on FIG. 11 toward the right-hand side of the tunnel. By use of differential pressures, the actual clamping forces of the clamp shoes is not significantly reduced, and the clamp frames 24 and 28 otherwise remain in place. After the clamp leg cylinders have been shifted as indicated in FIG. 11, it is then necessary to repressurize the cross thrust cylinders 18, 19, 21, and 22 to traverse the cutterhead the additional distance 164 until the final traverse position is reached, as indicated in FIG. 12. This completes the transerse cutting portion of the cycle.

After this has been completed, it is necessary to reset the main frame 15 to the left side of the tunnel to begin the forward cutting portion of the next cycle. This again must be done in two stages by shifting the clamp legs and the clamp frames to reverse the action shown in FIGS. 10 and 11, although in this case they may be performed in either sequence as convenient, until the main frame 15 and cutterhead frame are in the position of FIG. 9. As soon as the cutterhead returns to its position, it is then possible to leave the cross thrust cylinders 18, 19, 21, and 22 in a locked position and, while the cutterhead is rotating, to now apply fluid pressure to the thrust cylinders 101 to initiate the forward cutting portion of the next cycle.

Although the preferred embodiment of the invention as described hereinabove relates to the boring of a tunnel in which the major axis of the oval is horizontal, it is recognized that the same basic arrangement, with minor modifications, may be used for boring a tunnel in which the major axis of the oval is vertical. Furthermore, if the length of the major axis is not particularly large with regard to the circuit diameter, all of the transverse cutting may be done with the use of the cross thrust cylinders for providing the transverse thrust without the need to reset the clamp frames by repositioning of the opposed clamp leg cylinders. Furthermore, it is understood that the aforedescribed preferred embodiment of the invention is only by way of example, and not as to limitation of the scope of the invention as set forth in the claims.

WHAT IS CLAIMED IS:

1. A machine for boring oval tunnels in rock comprising a clamp frame, clamp means on said clamp frame movable to engage the walls of the tunnel at two transversely opposed points to position said clamp frame in said tunnel, a main frame mounted on said clamp frame for lateral movement with respect to said clamp frame and said tunnel walls, cross thrust cylinder means to shift said main frame laterally along said clamp frame, a cutter head frame mounted on said main frame for movement along the axis of the tunnel, axial thrust cylinder means to move said cutterhead frame axially along said axis, and a rotary cutterhead mounted on said cutterhead frame for rotation about an axis parallel to said tunnel axis whereby said axial thrust cylinder means advances said cutterhead along said tunnel axis and said cross-thrust cylinder means moves said cutterhead laterally of said tunnel axis.

2. A machine as set forth in claim 1, including a second clamp frame spaced axially from said first clamp frame and clamp means on said second clamp frame movable to engage the walls of the tunnel at two transversely opposed points spaced axially from said first set of points.

3. A machine as set forth in claim 2, including second fluid cylinder means on said second clamp frame to shift said main frame laterally along said second clamp frame.

4. A machine as set forth in claim 3, including control means to operate said first and second fluid cylinder means in unison.

5. A machine as set forth in claim 1, wherein said clamp means are fluid cylinders having pistons movable transversely to said tunnel axis.

6. A machine as set forth in claim 5, wherein said clamp means are actuable to shift said clamp frame transversely to said tunnel axis to traverse said cutterhead laterally of said tunnel axis a distance greater than the stroke of said cross thrust cylinder means.

7. A machine as set forth in claim 1, wherein said cross thrust cylinder means include a pair of parallel cylinders on said main frame and said clamp frame includes a pair of parallel rods, one through each cylinder, each of said rods having an enlarged piston portion intermediate its ends making sealing engagement with the adjacent cylinder bore.

8. A machine as set forth in claim 7, wherein each of said cylinders has a seal at each end engaging the adjacent rod surface, said seals and said piston portion providing the bearing means for mounting said main frame on said clamp frame.

9. A machine as set forth in claim 8, wherein said clamp frame includes a clamp frame plate secured to the outer ends of said rods at both ends, said plate supporting said clamp means.

10. A machine as set forth in claim 9, wherein said clamp means is a fluid cylinder intermediate and parallel to said rods and a piston and clamp shoe are mounted in said cylinder.

11. A machine as set forth in claim 1, wherein said cross-thrust cylinder means are arranged to move said cutterhead laterally a distance of at least half the radius of the cutterhead.

12. A machine as set forth in any one of the preceding claims wherein:
said main frame (15) includes a square tube portion (16),
said cutterhead frame (90) includes a square tube portion (91) which is slidably journalled in said square tube portion (16) of the main frame (15),
said drive means to rotate said cutterhead comprises a drive unit (95) at the rear end of said cutterhead frame (90) and a drive shaft (111) which extends through said square tube portion (91) of the cutterhead frame, and said axial thrust cylinder means (101) is coupled between said main frame (15) and said drive unit (95).

13. A machine as set forth in any one of the preceding claims characterized in that said cutterhead has a first set of cutters operable when said cutterhead is moved by said axial thrust means and a second set of cutters operable when said cutterhead is moved by said cross thrust means.

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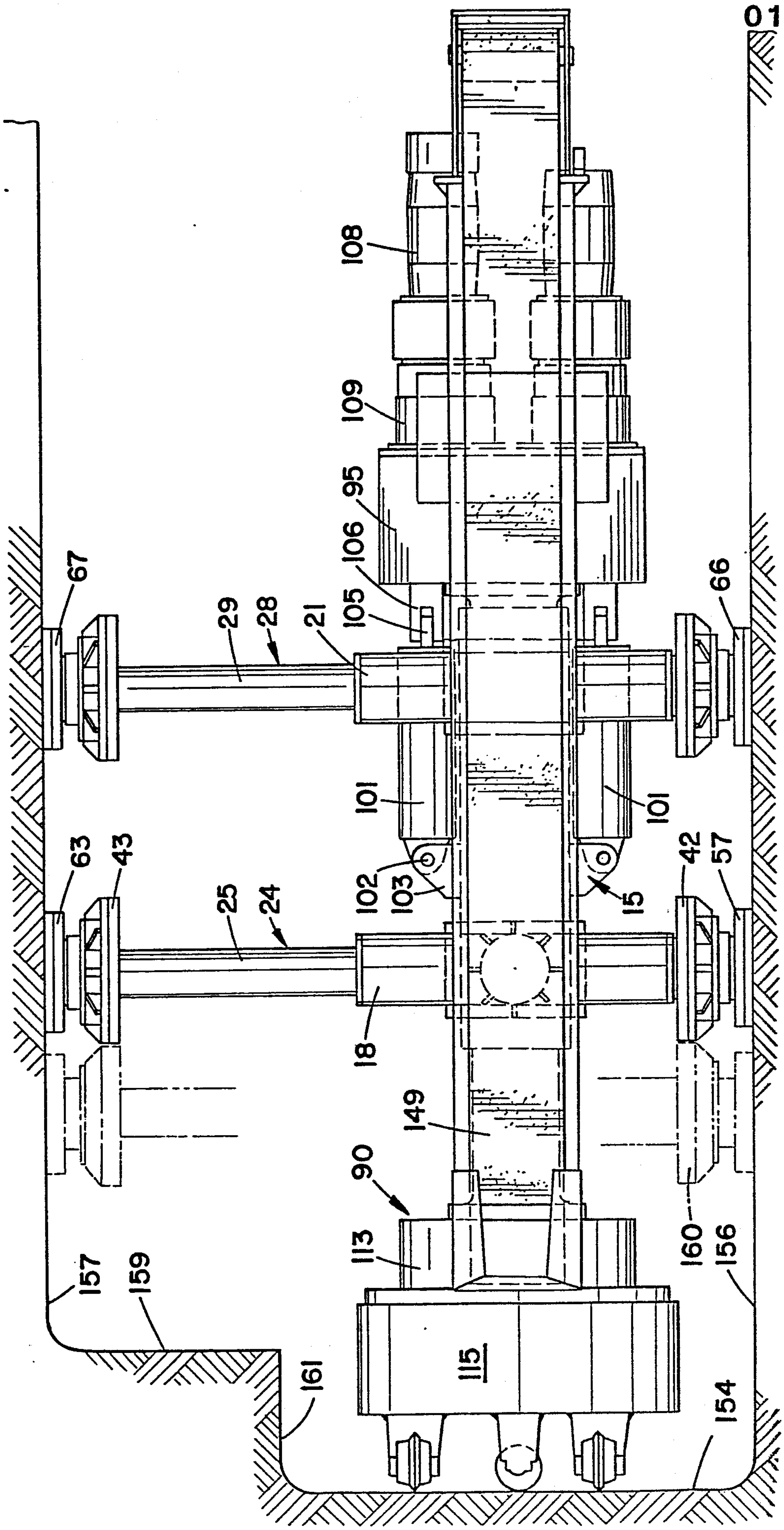

FIG. I

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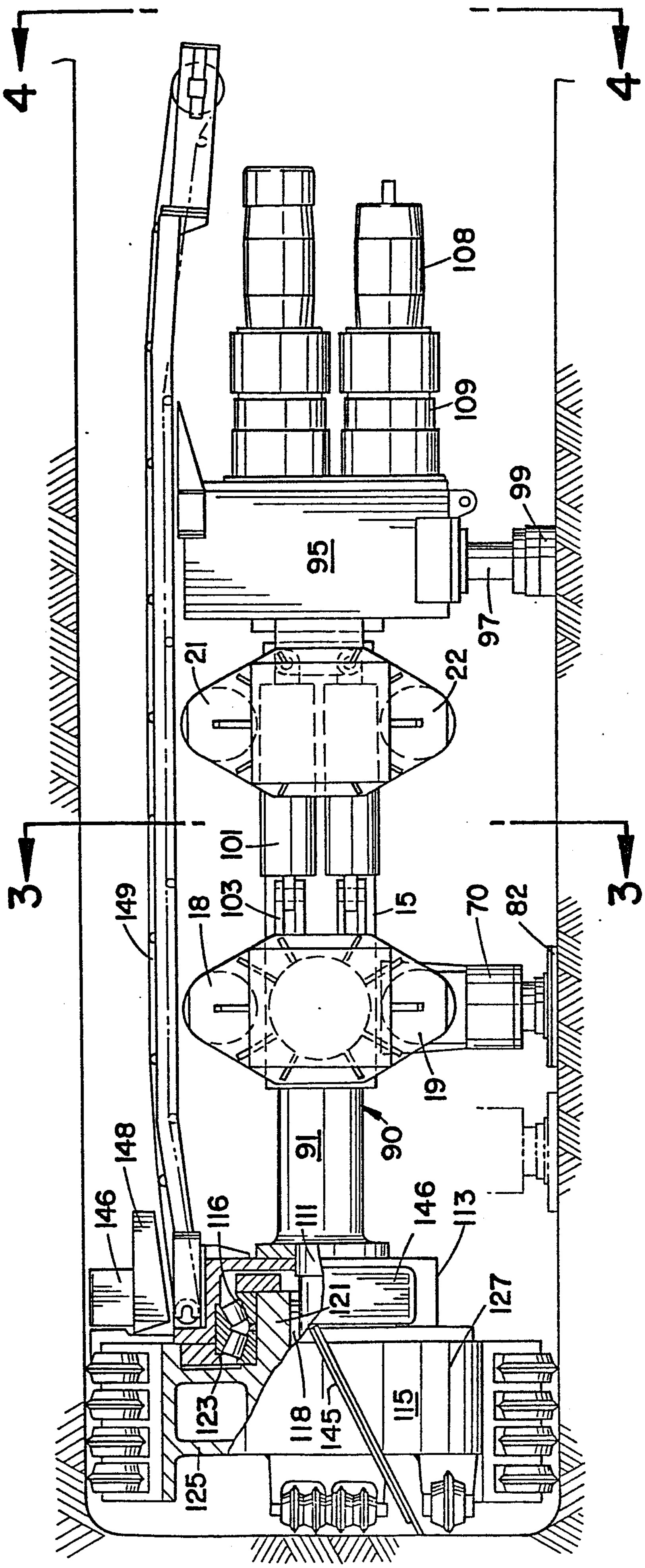

FIG. 2

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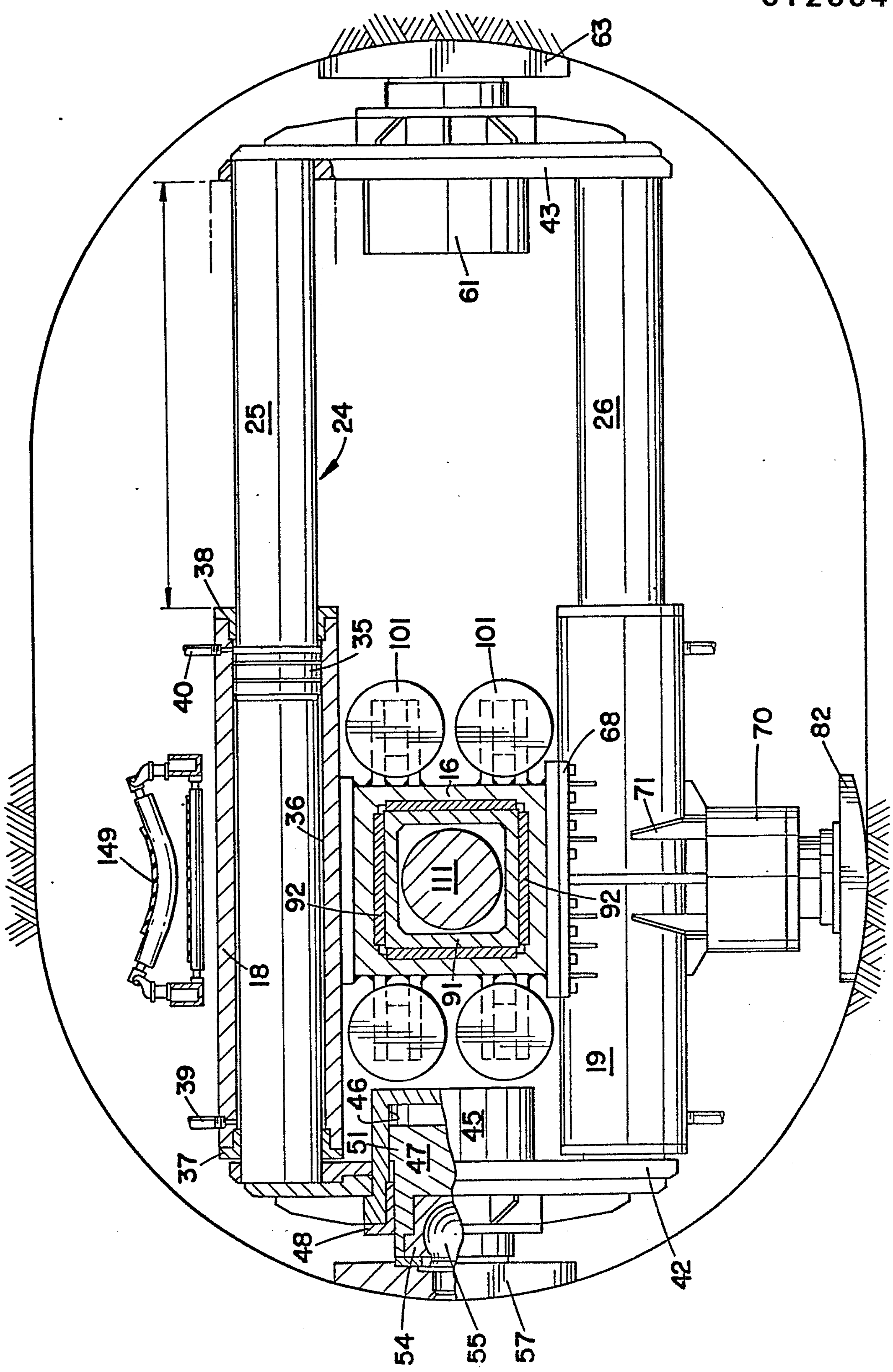

FIG.3

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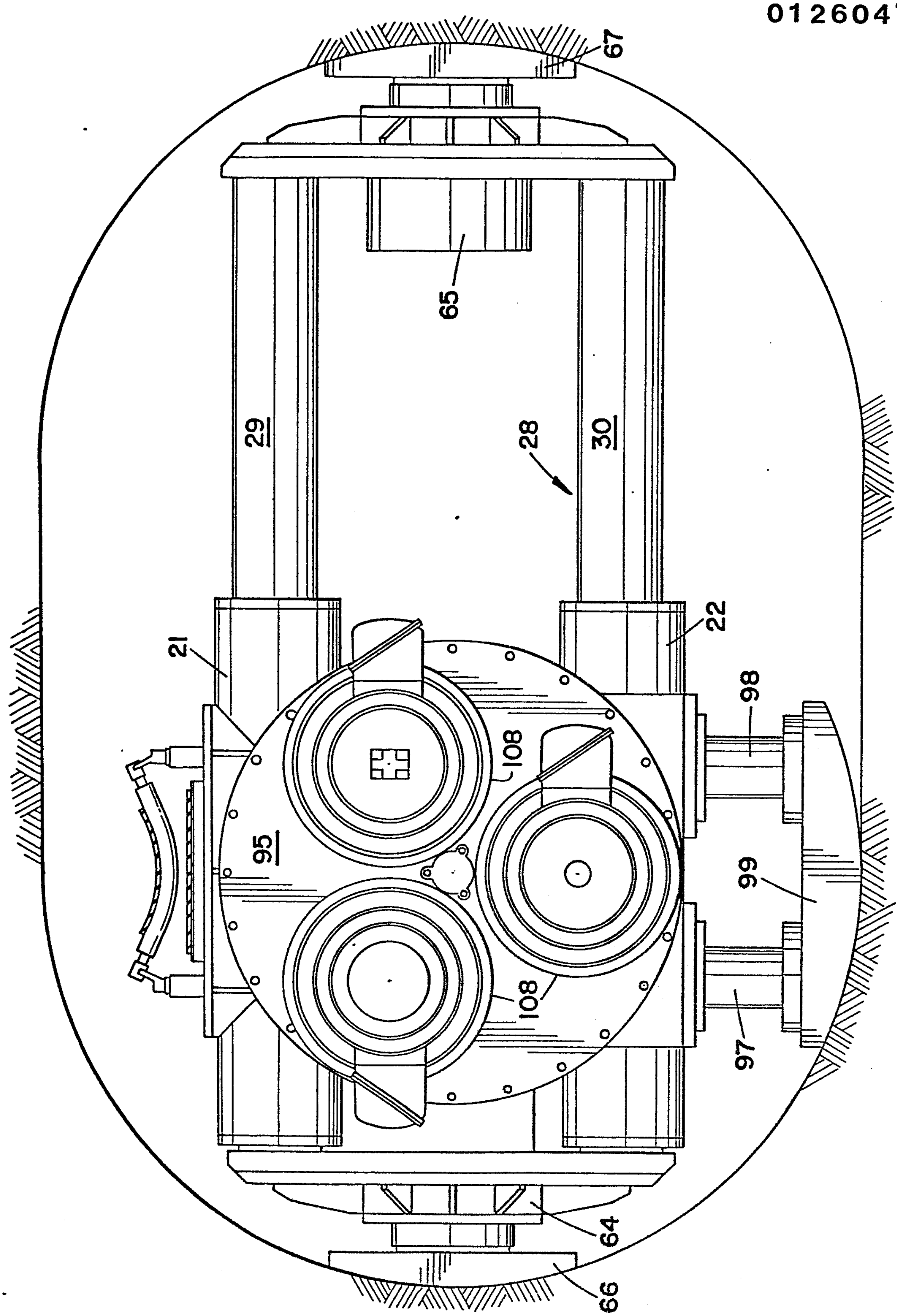

FIG. 4

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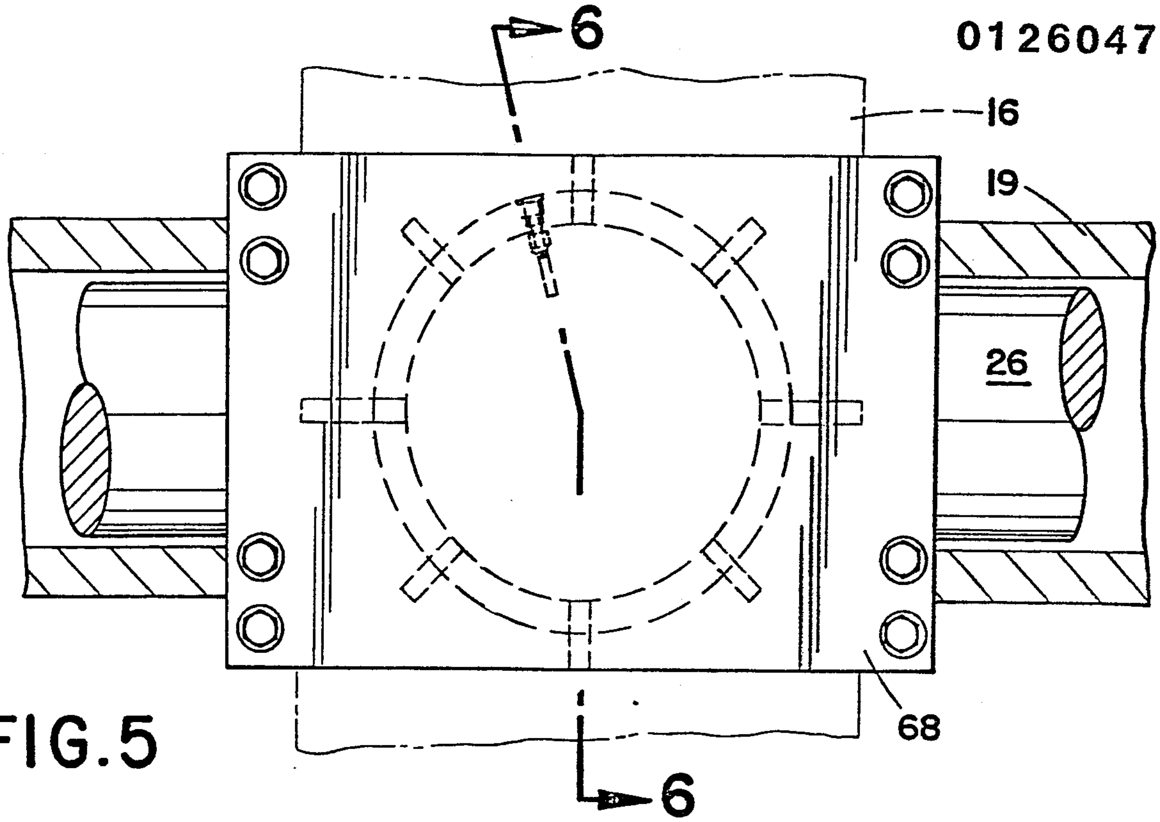

FIG.5

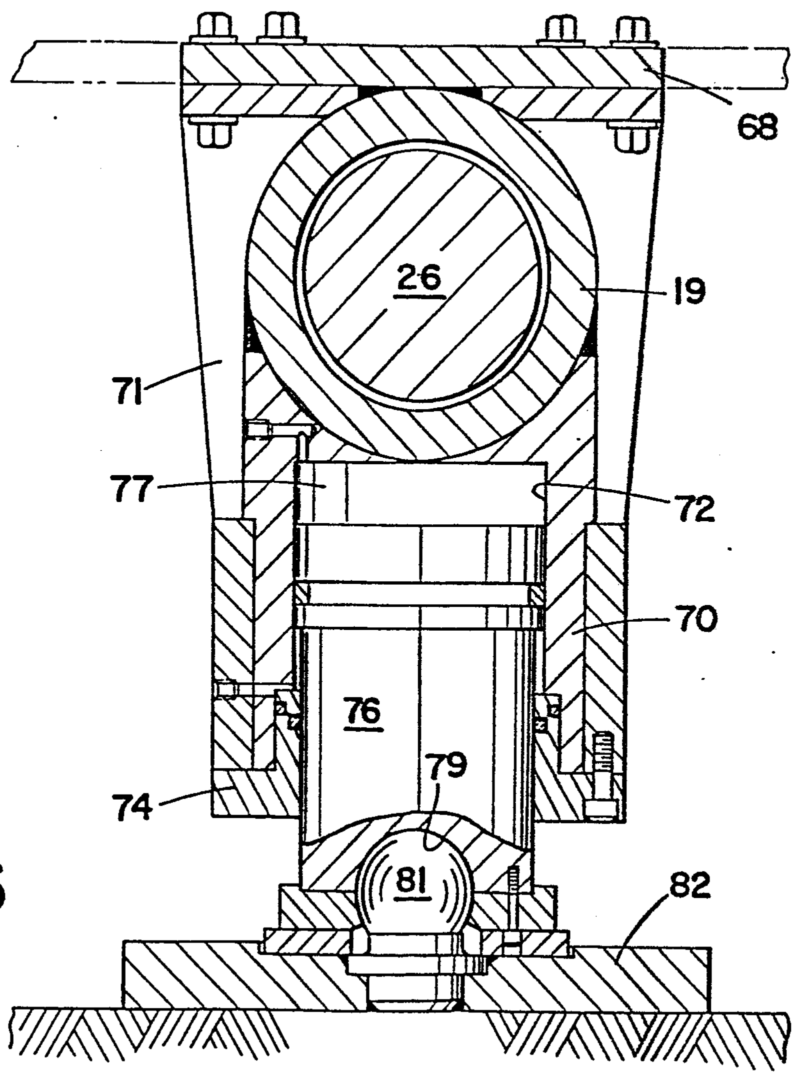

FIG.6

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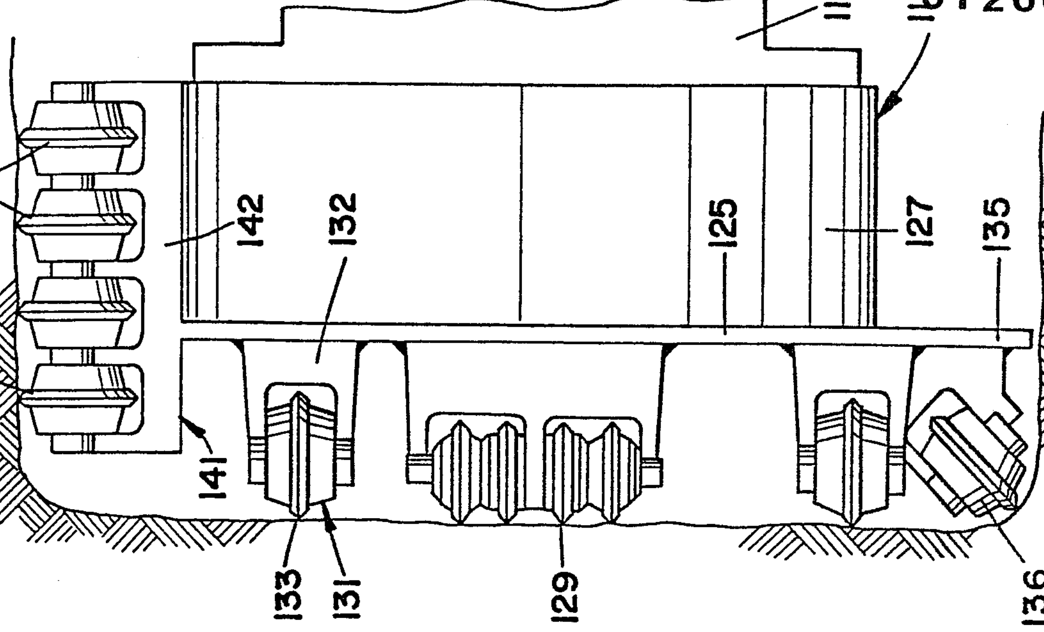

FIG.8

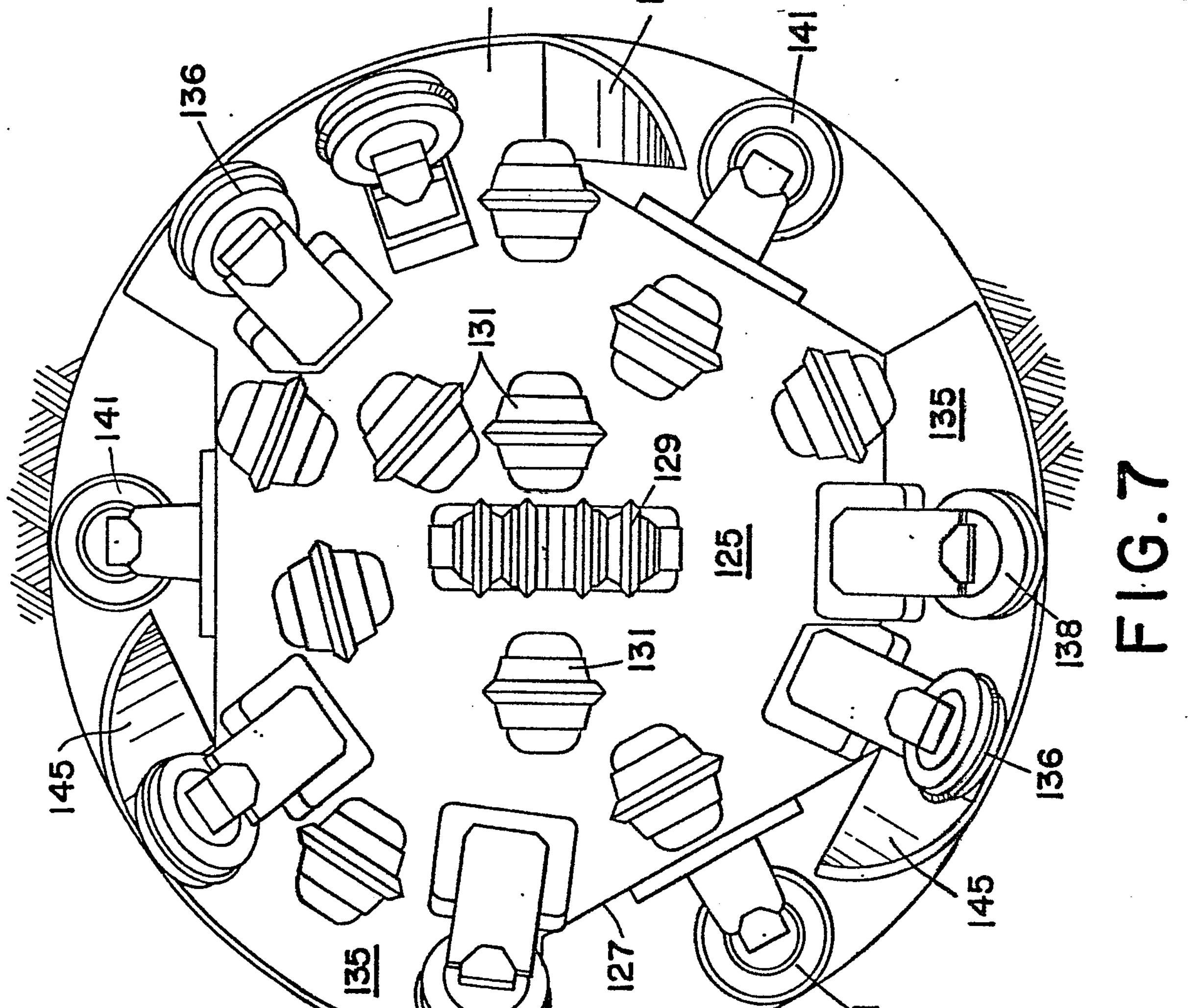

FIG.7

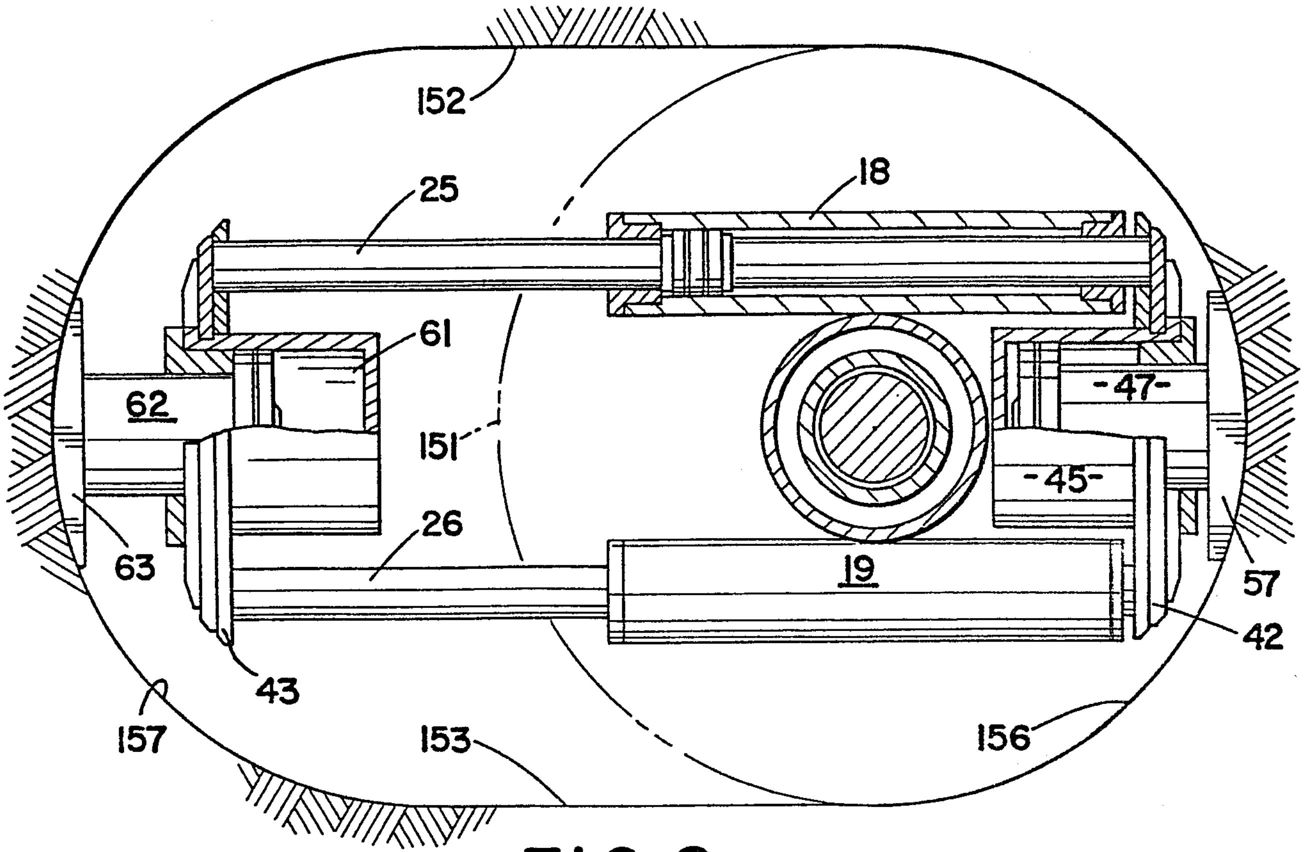

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FIG.9

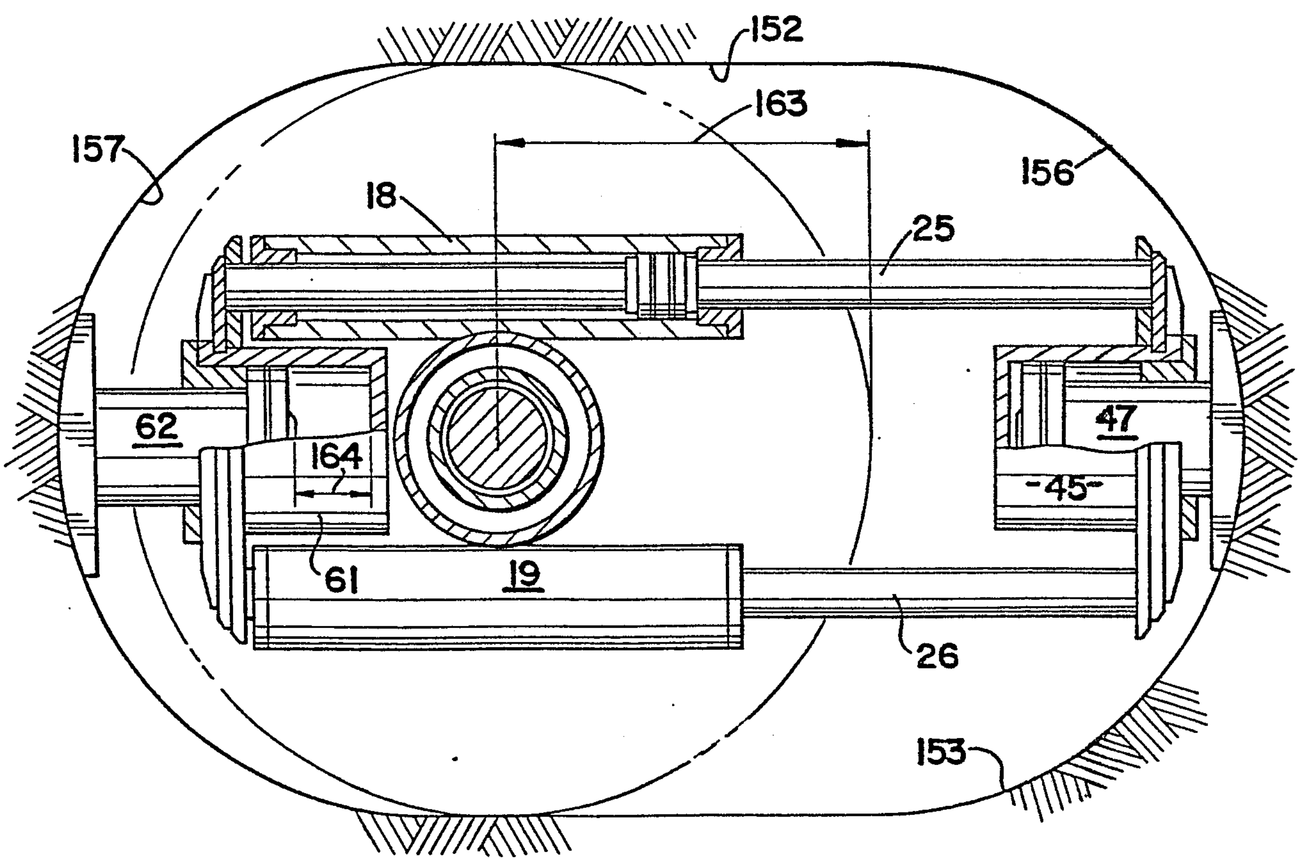

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FIG.10

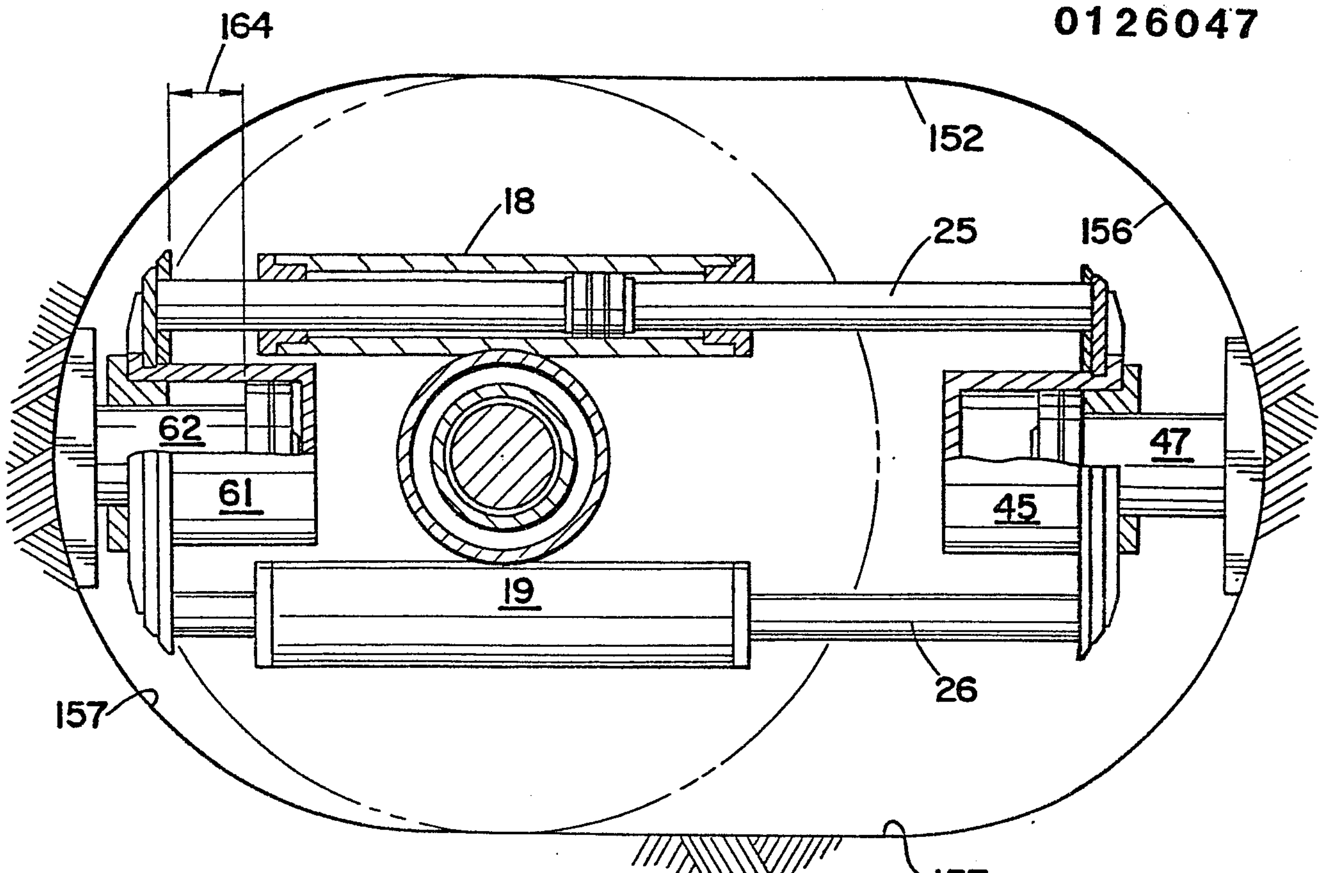
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FIG. 11

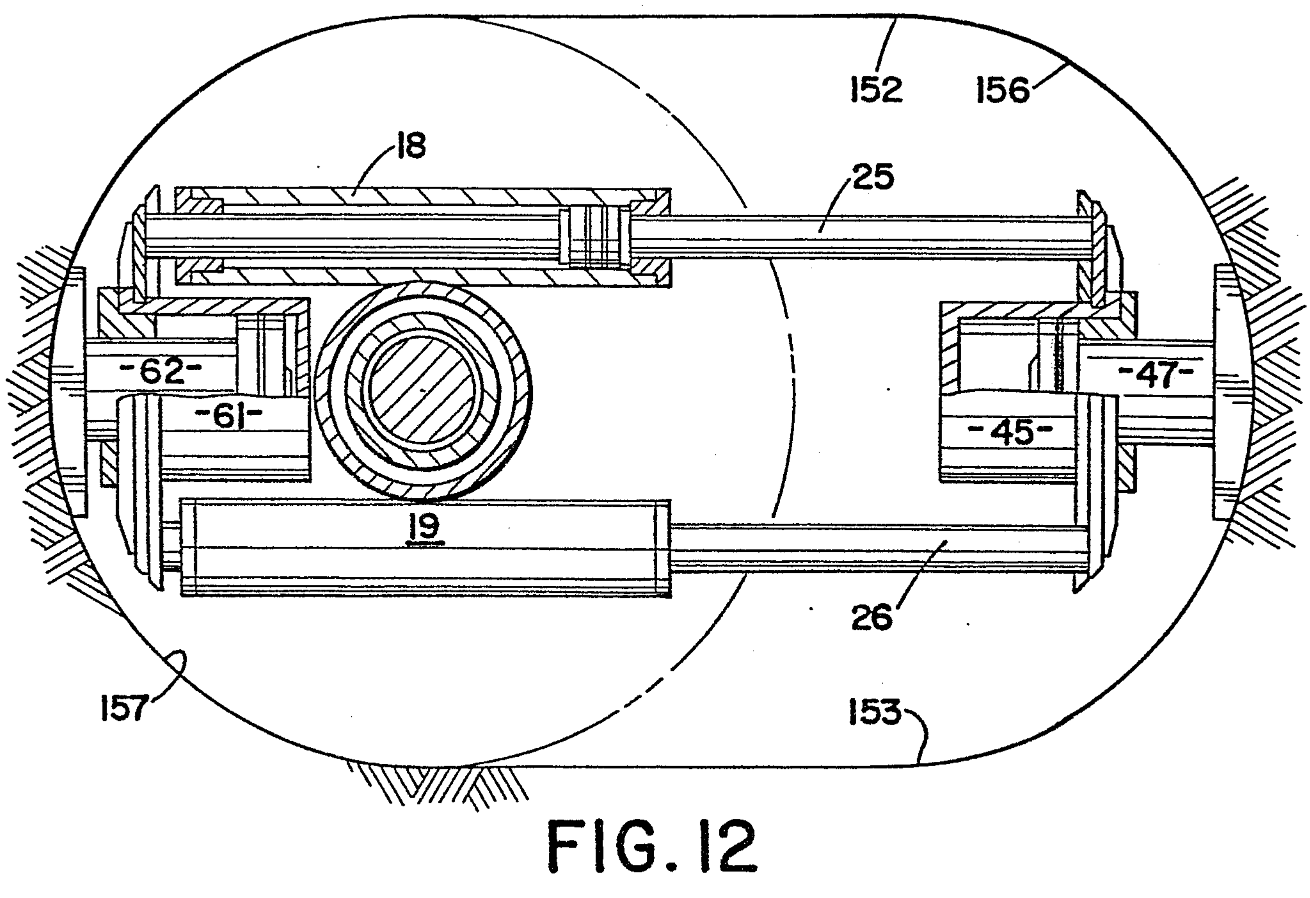
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FIG. 12

0126047

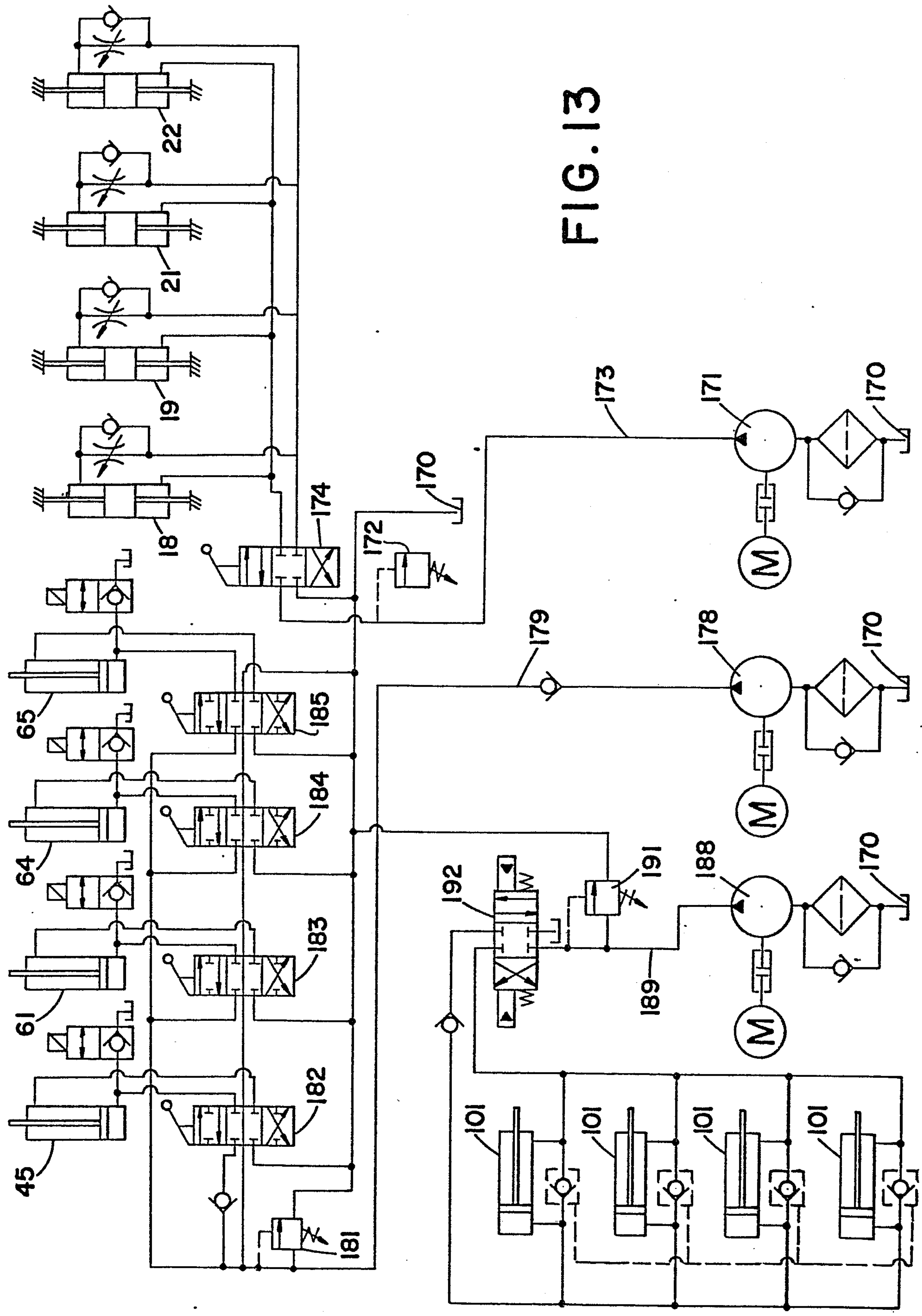

FIG.13