July 24, 1956 K. C. McINTYRE 2,756,036

EXCAVATING APPARATUS WITH RELATIVELY SLIDABLE SUPPORTING ELEMENTS

Filed Sept. 21, 1951 5 Sheets-Sheet 1

FIG. 1

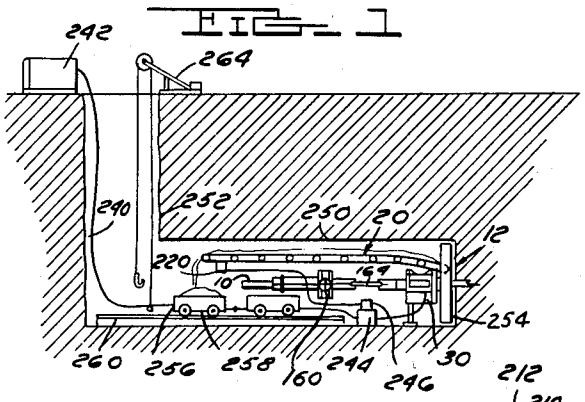


FIG. 8

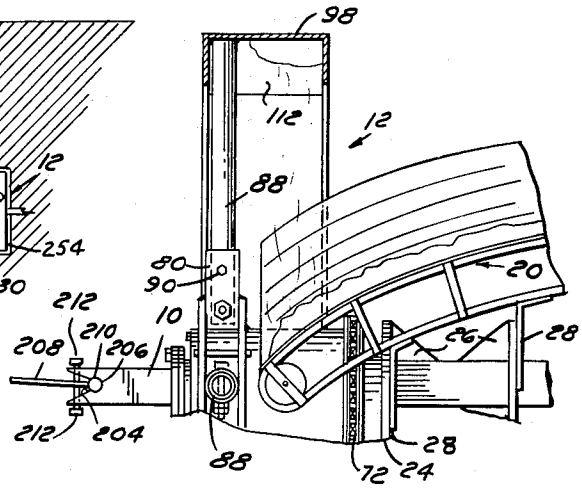


FIG. 7

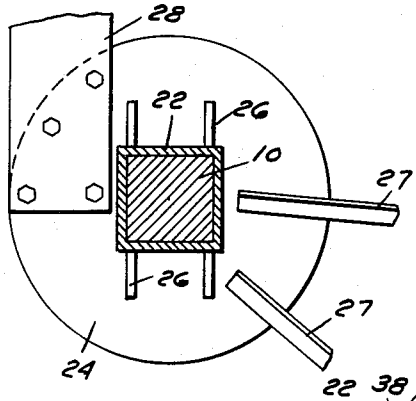
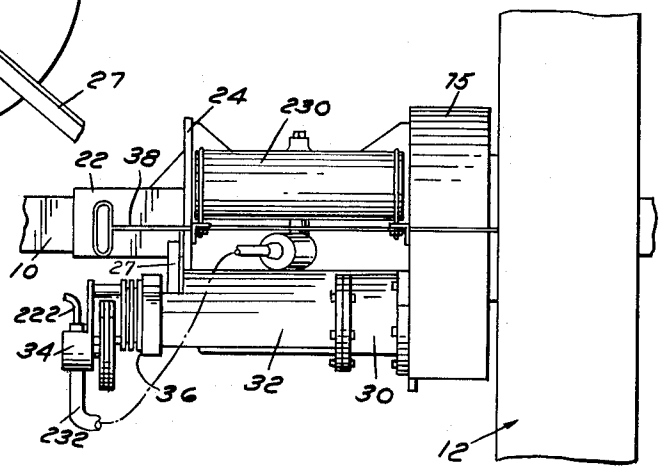


FIG. 9

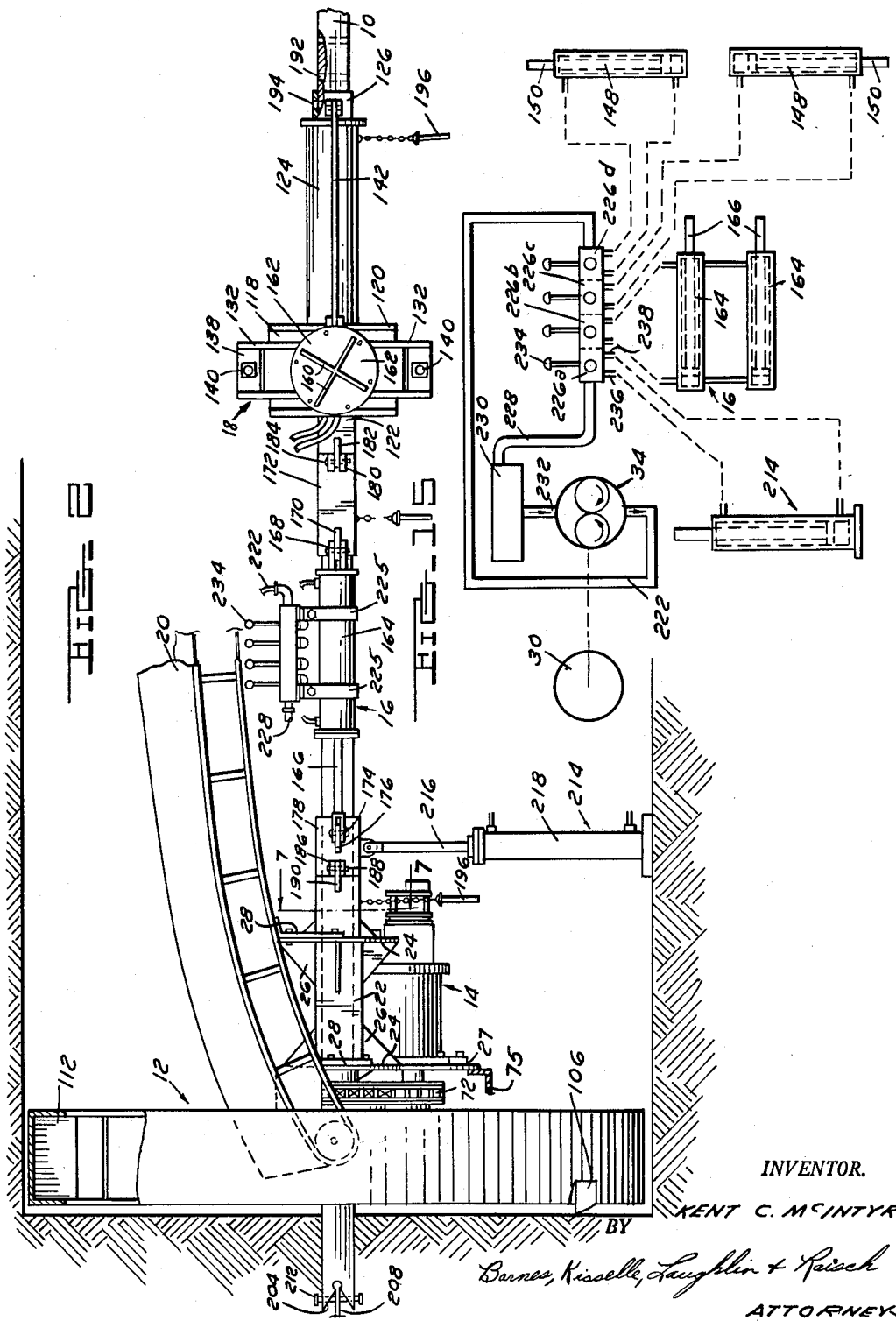


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EXCAVATING APPARATUS WITH RELATIVELY SLIDABLE SUPPORTING ELEMENTS

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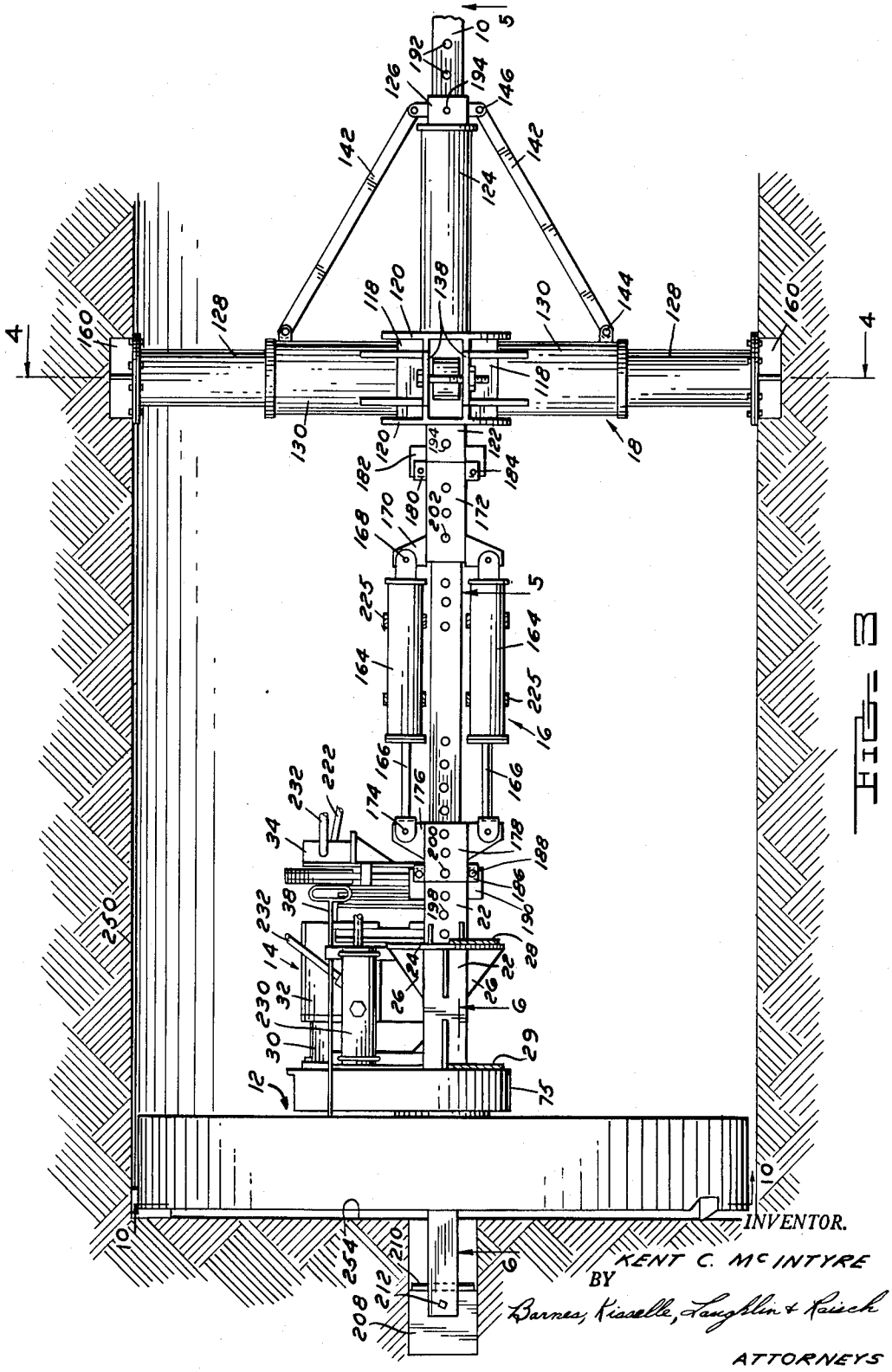


FIG 3

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FIG. 4

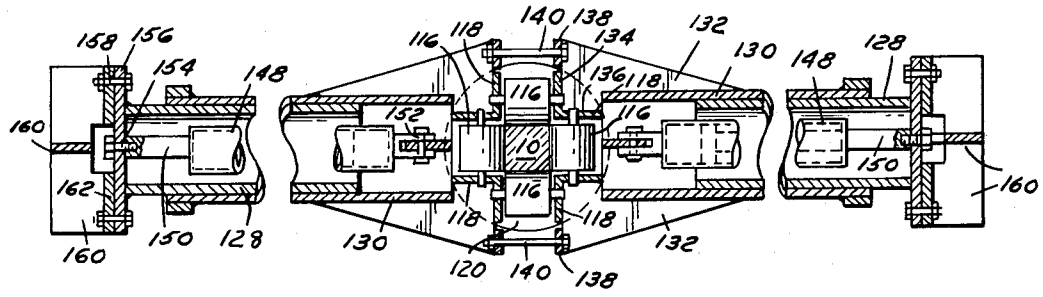


FIG. 5

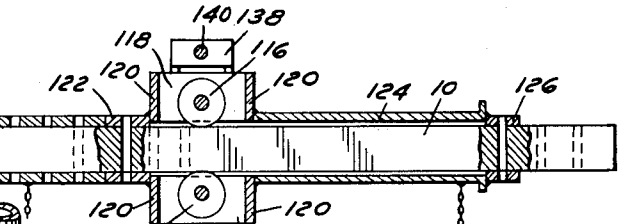
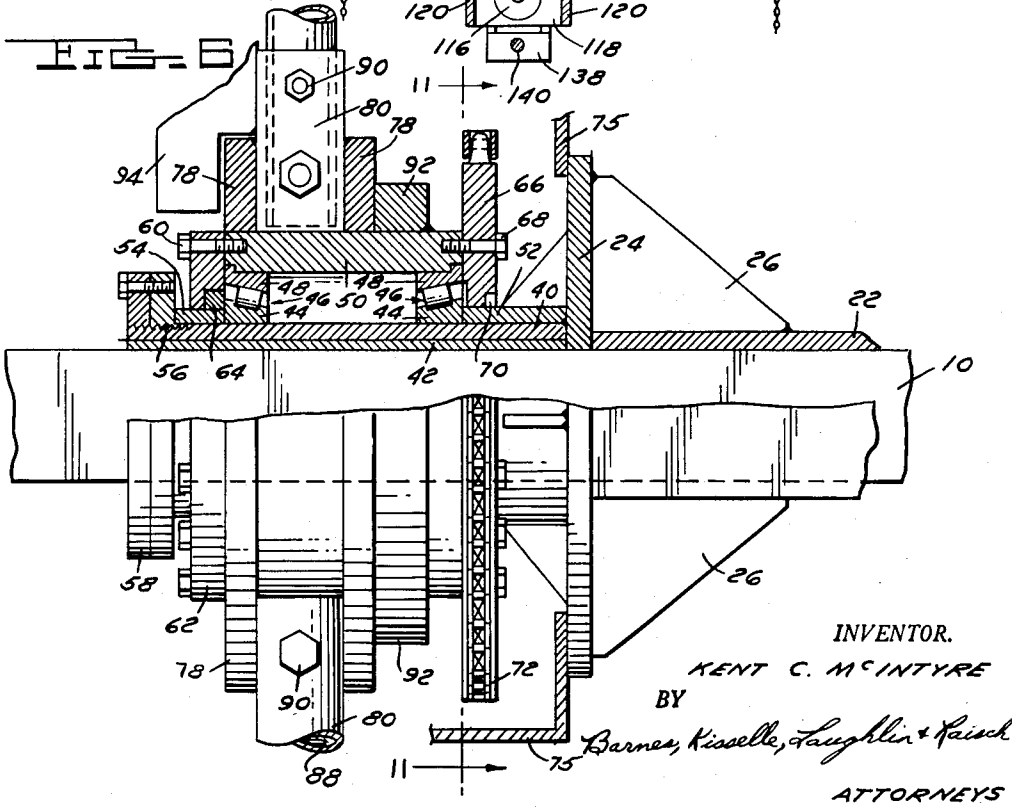


FIG. 6



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EXCAVATING APPARATUS WITH RELATIVELY SLIDABLE SUPPORTING ELEMENTS

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FIG. 10

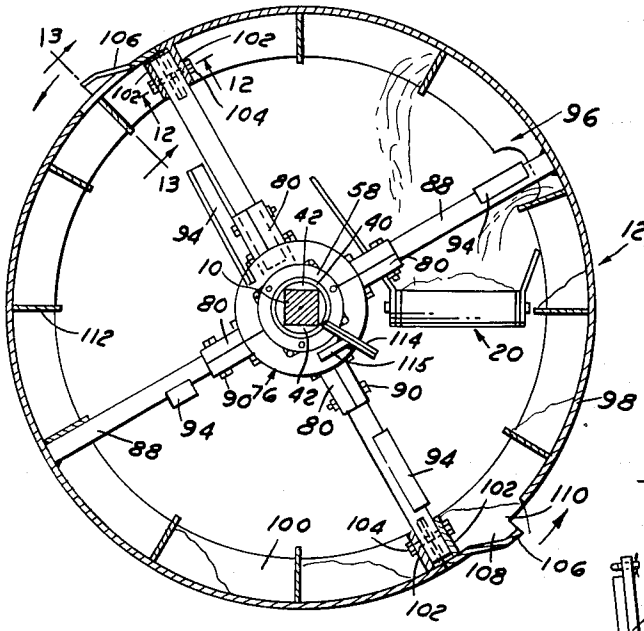


FIG. 11

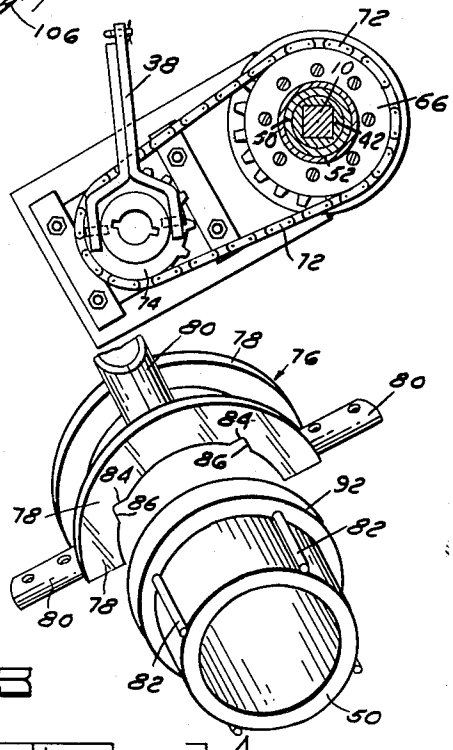


FIG. 12

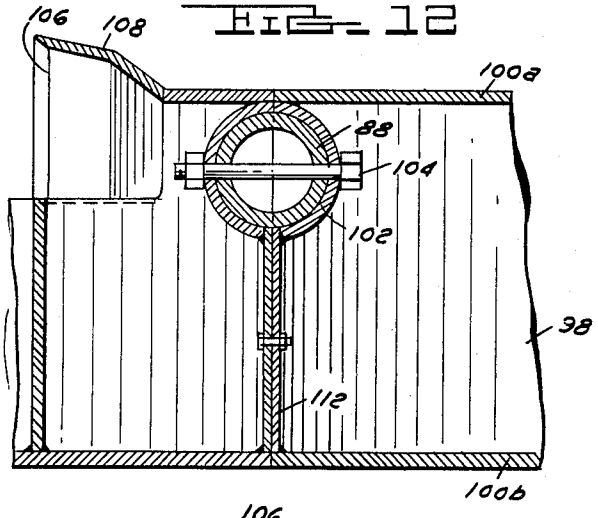


FIG. 13

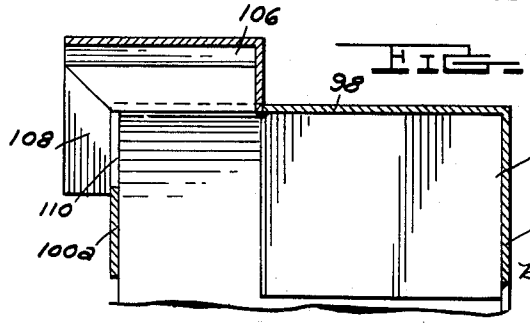


FIG. 14

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EXCAVATING APPARATUS WITH RELATIVELY SLIDABLE SUPPORTING ELEMENTS

Kent C. McIntyre, Detroit, Mich.

Application September 21, 1951, Serial No. 247,644

14 Claims. (Cl. 262—7)

This invention relates to excavating apparatus and has, more particularly, to do with a machine for digging excavations, the excavation being in the nature of a relatively large underground tunnel.

It is common practice today to excavate such tunnels by means of manually-operated air spades. This procedure is time consuming to say the least and consequently is quite costly because men qualified to do such work command very high wages. Furthermore, digging tunnels of this type by means of air spades requires a high degree of skill, and men qualified to do this type of work are not too plentiful.

One of the problems associated with the design of a machine for excavating tunnels of this type resides in the fact that the cutter on the machine must be capable of cutting a relatively large hole, and at the same time the machine itself has to be small enough and light enough to be easily manipulable in the tunnel being excavated. Another factor that enters into the design of a machine of this type is the requisite ability of the machine to accommodate itself to different soil conditions and the ability to excavate along an accurate, predetermined course. In addition, the machine must be capable of excavating tunnels which extend along a contoured path as distinguished from those which extend along a straight line.

It is an object of the invention to produce a tunnelling machine which can be operated by relatively unskilled labor to dig a tunnel accurately and very efficiently.

Another object of the invention is to produce a machine of the above described type which is of relatively simple construction and which is capable of being easily manipulated in the tunnel being excavated.

A further object of the invention is to provide a tunnel excavating machine which can be adjusted and manipulated to dig efficiently in soils which differ widely in characteristics.

A still further object of the invention resides in the provision of a tunnel excavating machine which reduces to a minimum the amount of manual labor associated with digging the tunnel and which lends itself readily for use with mechanical conveyors for handling and conveying the earth excavated to a discharging point located remately from the locus of digging.

More specifically, the invention contemplates a tunnelling machine which comprises a longitudinally extending main support shaft on which are slidably mounted one or more supports for the machine, a rotatable cutting head and the driving means therefor, and a hydraulic mechanism in the nature of a pair of jacks which may be arranged to selectively connect the shaft with the supports or with the head so that these assemblies may be moved axially with the shaft or with respect to the shaft. The head is in the nature of a large wheel having radial arms provided with radially staggered blades. At their outer ends the arms support a radially inwardly opening, circumferential trough for receiving the earth cut loose by the blades. The trough is partitioned into

a plurality of circumferentially adjoining compartments so that, as each compartment rotates to a position near the top of the wheel, the contents of the compartment are discharged by gravity into an axially extending conveyor which is in turn adapted to discharge into a dump car positioned adjacent the rear end of the longitudinally extending main support shaft.

In the drawings:

Fig. 1 is a somewhat diagrammatic view of the general arrangement of the machine of this invention in its operative position within the tunnel being excavated.

Fig. 2 is a side elevation of the machine, partly in section and with parts broken away to better illustrate certain details of construction.

Fig. 3 is a top view of the machine with certain portions thereof broken away.

Fig. 4 is a sectional view taken substantially along the lines 4—4 in Fig. 3 and showing generally the construction of the extensible torque arms on the machine.

Fig. 5 is a sectional view taken substantially along the lines 5—5 in Fig. 3.

Fig. 6 is a sectional view taken substantially along the lines 6—6 in Fig. 3.

Fig. 7 is a fragmentary sectional view taken along the lines 7—7 in Fig. 2.

Fig. 8 is a fragmentary side elevation, partly in section, of the front end of the machine.

Fig. 9 is a fragmentary side elevation of the machine generally showing the power unit thereon.

Fig. 10 is a sectional view of the cutting head of the machine taken substantially along the lines 10—10 in Fig. 3.

Fig. 11 is a detail view of the drive arrangement for the cutting head.

Fig. 12 is a fragmentary sectional view of the cutting head taken substantially along the lines 12—12 in Fig. 10.

Fig. 13 is a view similar to Fig. 12 but taken substantially along the lines 13—13 in Fig. 10.

Fig. 14 is a fragmentary perspective view of the hub assembly for the cutting head.

Fig. 15 is a diagrammatic view showing generally the hydraulic system on the machine.

Referring to the drawings and particularly to Figs. 2 and 3, the general arrangement of the machine includes a longitudinally extending main support shaft 10 on which is supported the cutting head 12, the power unit 14, the control jacks 16, the torque arm assembly 18, and the conveyor mechanism 20. Shaft 10 is of square cross section and slidably supports a sleeve 22 (see Figs. 2, 3 and 6). A pair of support plates 24 reinforced by gusset plates 26 are welded or otherwise rigidly mounted on sleeve 22. Power units 14 is slidably supported on shaft 10 by brackets 27 fixed on the support plates 24. Plates 24 also support conveyor 20 as by means of brackets 28 (see Fig. 7).

Referring now to Fig. 9, the power unit 14 includes an electrically driven motor 30, a transmission 32 connected with the motor 30, a hydraulic pump 34 driven by motor 30 through transmission 32, and a clutch mechanism 36 controlled by a clutch lever 38 for rotating head 12. The construction and operation of the various elements of the power unit 14 are generally well known and need not be described. It is sufficient to state that pump 34 is driven continuously by motor 30 and rotation of the head 12 of the machine is controlled by actuation of the clutch lever 38.

The head 12 of the machine (see Fig. 6) includes a cylindrical sleeve 40 welded to the front support plate 24 to the inner face of which are welded arcuate filler segments 42 having flat faces which slidably engage the corresponding flat faces of shaft 10. Sleeve 40 supports the inner races 44 of a pair of thrust bearings 46 the outer

races 43 of which support a hub member 50. Hub 50 is retained in an axially fixed position on sleeve 40 by means of spacer bushings 52 and 54. The front end of sleeve 40 is threaded as at 56 to receive locking rings 58 which abut against the front face of spacing ring 54 and thereby maintain the hub assembly in an axially fixed position on sleeve 40. To the front end of hub 50 there is secured, as by bolts 60, a cover plate 62 provided with a seal 64 which prevents dirt and the like from reaching bearing 46 at the front end of hub 50. A large driving gear 66 is secured, as by bolts 68, to the rear face of hub 50 and is provided with a seal 70. It will be observed that the members 48, 50, 62 and 66 rotate as a unit on sleeve 40. Gear 66 is connected as by the chain drive 72 with the driven gear 74 of the clutch mechanism 36. A shroud 75 surrounds chain drive 72.

Hub 50 in turn supports a diametrically split rim 76 (Figs. 10 and 14) and two halves of which each comprises a pair of spaced apart side plates 78 between which are welded split cylindrical socket members 80. In order to prevent relative rotation between hub 50 and rim 76, there are welded to the outer surface of hub 50 four axially extending pins 82, and each of the side plates 78 are provided with recesses 84 for interengaging pins 82. It will be observed that recesses 84 are provided with corresponding flat, substantially parallel faces 86 which enable positioning of the two portions of the split rim 76 around hub 50 by seating these rim members circumferentially on the outer face of hub 50 as distinguished from slipping these rim members axially over the front end of hub 50. This facilitates assembly and disassembly of these members, especially when the machine is disposed within the tunnel being excavated. The split sockets 80 are arranged to receive radially extending cylindrical arms 88. Arms 88 are firmly retained in sockets 80 by means of bolts 90. It will be observed that bolts 90 also serve to clamp the two half sections of rim 76 tightly around hub 50. A relatively heavy ring 92, secured around hub 50 adjacent the rear end thereof, forms a stop against which the rear side plate 78 of the rim 76 abuts. Each of the arms 88 has affixed thereto cutting blades 94. These blades are staggered radially relative to one another and are inclined to the plane of arms 88 so that, when the head 12 is rotated and advanced into the end wall of the tunnel being excavated, the blades dig into the earth and cut away slices therefrom.

At their outer ends, arms 88 support a circumferential trough 96 having a bottom or outer wall 98 and spaced apart side walls 100. The circular trough 96 is preferably divided into at least two half sections each provided with complementary socket parts 102 arranged to enclose the ends of two opposite arms 88. In the embodiment illustrated, it will be noted that the other two opposite arms 88 are welded to their respective trough sections 96. It will be appreciated, of course, that the trough may be formed as quadrant sections rather than half sections, in which case the end of each arm would be received in sockets similar to the socket illustrated at 102. Bolts 104 are employed for interengaging the socket parts 102 with the ends of the corresponding arms 88 and also for securing the two half sections of trough 96 together. In order to insure a cut throughout the radial extent of head 12 each half section of trough 96 is provided with a blade portion 106 which projects outwardly beyond outer wall 98 and a second blade portion 108 adjacent blade 106 which extends axially outwardly beyond the front side wall 100*a* of trough 96. Blades 106 and 108 in effect cooperate to form scoops around trough 96, the trough being cut away as at 110 to permit the dirt cut into by blades 106 and 108 to pass into the trough. The circumferential extent of the trough is divided into a plurality of compartments by axially extending partitions 112. As is seen more clearly in Fig. 12, it will be observed that trough 96 is supported on arms 88 such that the arms are located adjacent the front wall 100*a* and are spaced away from the rear side wall 100*b* of the trough. An additional blade 114 is mounted on one of the rim members 76, as by a bracket 115, and extends radially inwardly to a point adjacent sleeve 40 so that a maximum radial extent of cutting blades is obtained.

The torque arm assembly 18 (see Figs. 3 and 4) includes four cylindrical rollers 116 which are arranged to rollably engage the four faces of the square shaft 10. Rollers 116 are supported for rotation by four angle brackets 118. Brackets 118 extend longitudinally of shaft 10 and are interconnected so as to assume a fixed relation to one another by being welded at each end to circular support plates 120. The support plates 120 are centrally apertured to accommodate shaft 10. Front support plate 120 has welded thereto a sleeve 122 and rear support plate 120 has welded thereto a cylindrical extension 124 which carries at its rear end a sleeve 126. Sleeves 122 and 126 are of square cross section and slidably engage shaft 10. The torque arm assembly is thereby supported on shaft 10 by the rollers 116 and the sleeves 122 and 126.

The torque arms themselves are two in number one on each side of the shaft 10, and each comprises a pair of telescopically arranged cylinders 128 and 130. The outer cylinder 130 of each torque arm has four gusset plates 132 welded thereto, two on the upper side of the cylinder and two on the lower side of the cylinder. These gusset plates extend beyond the inner end of cylinder 130 and are shaped such that each cylinder 130 can be slipped endwise over and into engagement with the angles 118. The straight end faces 134 and 135 of gusset plates 132 engage with the perpendicularly related faces of angles 118. A bracket 138 extends between and is welded at each end to the gusset plates 132 on the upper portion of cylinder 130. The lower gusset plates 132 are likewise provided with a similar bracket 138. The two torque arms are clamped firmly together in position on angles 118 by means of bolts 140 one of which extends across the brackets 138 on the top-side of the torque arms and the other of which extends across the brackets 138 on the bottom-side of the torque arms. Each torque arm is provided with a stabilizing bar 142 pivotally connected at one end to cylinder 130 as at 144 and pivotally connected at the other end to sleeve 126 as at 146. Thus, the torque arms can be dismantled from the machine by simply removing bolts 140 and stabilizing bars 142 and thereafter pulling each torque arm endwise outwardly from engagement with the angles 118.

A hydraulic cylinder 148 and a piston rod assembly 150 operatively associated with cylinder 148 are mounted in each set of telescoping cylinders 128 and 130. Cylinders 148 are pivotally supported within the outer telescoping cylinders 130 as at 152, and the end of piston rod assembly 150 is connected with the inner telescoping cylinder 128 as at 154. At the outer end of each cylinder 128 there is fixed a cover plate 156 to which is attached as by bolts 158 a ground-engaging foot 160 preferably in the form of a pair of perpendicularly arranged plates which are mounted on a base plate 162. Thus, when fluid is admitted to one side of the pistons within cylinders 148, the inner telescoping cylinders 128 are extended outwardly to firmly engage the feet 160 with the side walls of the tunnel being dug; and when fluid is admitted to the other side of the pistons within cylinders 148, the inner cylinders 128 are retracted.

The longitudinal adjustment of head 12 and torque arm assembly 18 relative to shaft 10 is obtained by proper actuation of the hydraulic control jack assembly 16. This assembly includes a pair of hydraulic cylinders 164 each having an associated piston rod assembly 166. The rear ends of cylinders 164 are connected as at 168 with ears 170 fixed on a sleeve 172 slidably mounted on shaft 10. The outer ends of piston rod assemblies 166 are connected as at 174 with ears 176 fixed on a sleeve 178 which is likewise slidably mounted on shaft 10. At its rear end

sleeve 172 is provided with projecting ears 180 which are arranged to connect with ears 182 on sleeve 122 as by pins 184. Sleeve 178 is likewise provided with lateral ears 186 arranged to be selectively connected and disconnected with the sleeve 22 on head 12 by pins 188 which pass through ears 186 and cooperating ears 190 on sleeve 22. Shaft 10 is provided with a plurality of longitudinally spaced holes 192, and in order to fixedly connect the torque arm assembly 18 with shaft 10, sleeves 122 and 126 are each provided with openings 194 adapted to register with openings 192 in shaft 10 so that pins 196 may be inserted therethrough. Likewise, in order to fixedly connect head 12 with shaft 10, sleeve 22 is provided with openings 198 adapted to register with openings 192 in shaft 10 so that another pin 196 may be inserted through the registering openings. At the same time sleeve 178 is provided with openings 200 and sleeve 172 is provided with openings 202 all of which openings are adapted to register with the spaced openings 192 in shaft 10.

The arrangement just described permits the head 12 and torque arm assembly 18 to be moved longitudinally with shaft 10 or longitudinally on shaft 10. For instance, if sleeve 172 is connected with shaft 10 as by pins through openings 202 and 192 and sleeve 178 is connected with the head as by pins 188, then when the piston rod assemblies 166 are extended the whole head 12 and power unit 14 will be moved longitudinally forwardly on shaft 10. On the other hand, if the jack assembly 16 is pinned to shaft 10 as through the openings 200 at sleeve 178 and connected with the torque arm assembly by pins 184, then it is obvious that as the piston assemblies 166 are extended the torque arm assembly 18 will be moved longitudinally rearwardly on shaft 10. Thus, the head 12 and torque arm assembly 18 can be moved along shaft 10 or together with shaft 10. The importance of this operation will be described more fully hereinafter.

At its extreme front end shaft 10 is provided with a V-shaped opening 204 which terminates in a cylindrical socket 206 extending transversely through shaft 10 (Fig. 8). A guide plate 208 is mounted at the front end of shaft 10 within the V-shaped opening 204. Along its rear edge guide plate 208 has welded thereto a circular bar 210 which is received by socket 206, bar 210 being engaged with socket 206 by slipping it into the socket endwise. Guide plate 208 is thus pivotally supported at the front end of shaft 10 and may be arranged to assume a desired angle of inclination with respect to the horizontal axis of shaft 10 by means of adjusting bolts 212.

The front end of the machine is adapted to be supported by a hydraulic jack assembly 214 which includes a piston rod 216 pivotally supported on sleeve 178 and a hydraulic cylinder 218 in which the piston (not shown) at the end of rod 216 is movable. Thus, by admitting hydraulic fluid to cylinder 118 to either one side of the piston or the other, the machine may be elevated or lowered.

Conveyor 20 is of conventional construction and is driven by an electric motor 220 mounted at the rear end of the conveyor (see Fig. 1). The front end of conveyor 20 terminates just short of the path of travel of the radial arms 88 on head 12. Thus, as the trough 96 is rotated in the direction indicated by the arrow in Fig. 10, the earth cut away by the blades on the head falls into the compartments of the trough and is discharged onto the front end of conveyor 20 as the compartments rotate upwardly to a generally inverted position (see Fig. 10).

Referring now to Fig. 15, there is diagrammatically illustrated the hydraulic system for operating the various hydraulic cylinders of the machine. Pump 34 is connected as by a conduit 222 with the inlet side of an assembly of four valve blocks 226. The valve blocks 226 are mounted as a unit on cylinders 164 by brackets 225. These valve blocks are of conventional construction and need not be described in great detail. The conduit 228 connects the

outlet side of valve blocks 226 with a liquid reservoir 230, and the reservoir is in turn connected with the inlet side of pump 34 by a conduit 232. Each of the valve blocks 226 is provided with valve spools as is conventional, these valve spools being actuated by handles 234 to control the flow of fluid through the valve block. Each of the valve blocks is provided with two conduits 236 and 238 extending therefrom. When a handle 234 is actuated in one direction, the fluid is caused to travel outwardly of that particular valve block through conduit 236; and when the handle 234 is actuated in the opposite direction, the fluid is caused to travel out of that particular valve block through the other conduit 238. As was mentioned previously, the valve blocks are four in number, valve block 226*a* being connected by the conduits 236 and 238 with the hydraulic foot support 214, the valve block 226*b* being connected with the control jacks 16, and the valve blocks 226*c* and 226*d* being connected one with each of the cylinders 148 of the torque arms. As was mentioned previously, pump 34 is driven by motor 30, and the motor 30 receives its power by means of an electric cable 240 which extends from a motor generator unit 242 (see Fig. 1). Motor generator 242 also furnishes electrical energy for the conveyor motor 220. Cable 240 connects with motors 30 and 220 through suitable control switch boxes 244 and 246, respectively.

When it is desired to dig a tunnel, for instance, a sewer tunnel such as is illustrated at 250 in Fig. 1, there is first excavated a vertical shaft 252 down to the depth desired for the horizontal tunnel 250. A sufficient portion of tunnel 250 is excavated such as by means of air spades to enable positioning of the machine of this invention within the excavation. The machine is then lowered and set up for operation within the tunnel. In this connection it will be noted that the head 12 may be conveniently assembled on the machine after the machine is lowered into the tunnel. As explained previously, head 12 comprises the two half sections of trough 96 as well as the two sets of radial arms 88 associated with the split rim 76. After the trough section 96 is assembled with the radial arms 88 and the radial arms and split rims 76 in turn assembled with the hub 50 of the machine, the machine is ready for positioning within the tunnel to start the excavating operation. The shaft 10 with the torque arm assembly 18 mounted thereon is elevated to a position generally in line with the axis of the tunnel being dug by the hydraulic jack 214. After the shaft 10 is generally aligned with the axis of the tunnel being dug, the operating handles 234 controlling the operation of the cylinders 148 of the torque arms are actuated to extend the torque arms outwardly so that the foot members 160 dig into and firmly engage the side walls of the tunnel being dug. After the torque arms are thus engaged with the side walls of the tunnel, the shaft 10 can be aligned exactly with the axis of the tunnel by shifting the shaft vertically by means of the hydraulic jack 214 and laterally by selectively actuating the operating handles 234 which control the two cylinders 148.

If the ground being excavated is relatively firm, such as solid clay, I have found that the tunnel can be efficiently dug by advancing the head 12 and shaft 10 as a unit. If the excavating is to be performed in this manner, sleeve 172 is connected with the torque arm assembly as by the pins 184 and sleeve 178 is connected to the shaft 10 by inserting one of the pins 196 through a set of registering openings 192 and 200 in the shaft 10 and sleeve 178, respectively. It is assumed, of course, that at this time sleeve 178 is spaced rearwardly from sleeve 22 so that, when jacks 16 are operated, sleeve 178 is shifted forwardly such as to drive guide plate 208 and the front end portion of shaft 10 into the forward end wall 254 of the tunnel 250, guide plate 208 having previously been set at the desired inclination by adjusting screws 212. After guide plate 208 has been driven into the front wall of the tunnel a sufficient distance to provide adequate support for the

front end of the machine, the head 12 is shifted forwardly on shaft 10 to engage the forward wall 254 of the tunnel. It will be noted that head 12 and power unit 14 are in effect both supported by sleeve 22; and therefore the whole assembly of the power unit and the head can be shifted forwardly on shaft 10 by actuating the jacks 16 such that sleeve 178 abuts against sleeve 22 and pushes the whole assembly forwardly, sleeve 178 being disconnected from shaft 10 at this time. Thereafter piston rods 166 are retracted into cylinders 164 and sleeve 178 is pinned to shaft 10 in the retracted position, and at the same time sleeve 22 is pinned to the shaft 10 as by one of the pins 196 passing through a set of registering openings 198 and 192 in sleeve 22 and shaft 10, respectively.

It will be observed that, with the machine thus arranged, the shaft 10 together with the power unit 14 and the head 12 moves forwardly as a unit through the fixedly supported torque arm assembly 18 when the piston rod assemblies 166 are extended. Thus, when clutch lever 38 is actuated to cause rotation of head 12, and the operating levers 234, controlling cylinders 164, are actuated gradually and intermittently to cause the piston rod assemblies 166 to move outwardly of cylinders 164, the shaft 10 and the rotating head 12 are moved axially forwardly so that the blades 94 and 114 and scoops 108, 106 dig into the earth at the front end of the tunnel. The earth thus cut away by these blades falls into the compartments formed by the partitions 112 around the lower portion of trough 96. As these compartments rotate upwardly, the dirt accumulating therein falls onto the front end of conveyor 20. The conveyor belt moves this dirt rearwardly to the rear end of the conveyor where it discharges into a dump car 256 which is conveniently mounted on a truck chassis 258 arranged for rolling movement on tracks 260. After dump car 256 is filled, it is towed along tracks 260 to the vertical shaft 252 where it is raised to the ground surface by a hoisting mechanism such as illustrated at 264.

It will be observed that the space beneath shaft 10 to the rear of torque arm assembly 18 is unobstructed. This is quite important, since it permits the use of two cars 256 hitched one in front of the other. While the rearmost car is being filled, the forward, empty car is disposed beneath the rear end of the machine. This arrangement makes for efficient operation, since it is not necessary to wait at shaft 252 until the dump body of each car 256 is elevated, discharged and lowered again onto trucks 258.

After the piston rod assemblies 166 have been extended the limit of their travel, the pin 196 interconnecting sleeve 178 with shaft 10 is removed and the pistons retracted to permit the sleeve 178 to be pinned to the shaft 10 at a new rearward location. The shaft, together with the head 12 and power unit 14, can thus be further advanced a distance corresponding to the travel of piston rod assemblies 166. After the shaft is thus advanced through the torque arm assembly 18 a substantial distance, it then becomes necessary to move the torque arm assembly forwardly on shaft 10 to a new position. With the piston rod assemblies 166 in the extended position, sleeve 178 is pinned to the shaft and cylinder 128 is retracted to disengage the foot members 160 from the side walls of the tunnel. Thereafter jacks 16 are actuated to retract piston rod assemblies 166 and since torque arm assembly 18 is slidable on shaft 10 with sleeve 172, the whole torque arm assembly is shifted forwardly on shaft 10. At this time the machine is effectively supported in an elevated position by the hydraulic foot 214 and by reason of the fact that the front end of shaft 10 is firmly embedded in the front end wall of the tunnel. The cylinders 128 are then extended to engage the side walls of the tunnel at a new forwardly spaced location, and the excavation operation is then continued until a new setting of the torque arms is required.

When the machine is operated in this manner, it will be observed that a fixed length of shaft 10, together with the guide plate 208, advances into the ground ahead of head 12. The inclination of plate 208 is adjusted such that the weight on the front end of shaft 10 is offset by the tendency of plate 208 to elevate the front end of the machine. The extent to which plate 208 is inclined to the horizontal is, of course, determined by the firmness of the ground being excavated.

Where the ground being excavated is relatively soft, it may be necessary to operate the machine in a manner differently than described above. In excavations where the earth is not firmly packed, the ground may not provide sufficient support for the front end of the machine where only a short portion of shaft 10 is advanced ahead of head 12. Under such circumstances, the shaft 10 is driven forwardly into the front wall of the tunnel being dug a substantial distance independently of head 12 and power unit 14, and thereafter the head 12 and power unit 14 are advanced on the shaft. The shaft may be advanced through sleeve 22 by pinning sleeve 178 with a registering opening 192 in shaft 10, piston rod assemblies 166 being retracted, and operating jacks 16 to extend piston rod assemblies 166. After the shaft is advanced into the earth, say a distance of about eight feet, or even less depending upon the firmness of the soil, the ears 186 are coupled with the lugs 190 as by the pins 188 and the jack 16 actuated such as to shift cylinders 164 and sleeve 172 forwardly on shaft 10. Sleeve 172 is then coupled with shaft 10 as by one of the pins 196 passing through registering openings 202 and 192 in sleeve 172 and shaft 10, respectively. Then, by operating jacks 16, it will be observed that the head 12 and power unit 14 will be fed axially along the shaft and advanced gradually toward the leading end of shaft 10. This process can be continued by intermittently advancing jacks 16 on shaft 10 until the head 12 advances to a position adjacent the forward end of shaft 10 which necessitates the further advance of the shaft. After the available length of the shaft is consumed, that is, when the rear end portion of the shaft approaches sleeve 126, hydraulic foot 214 is actuated to assist in supporting the front end of the machine, cylinders 128 are retracted, and the torque arm assembly 18 is advanced on the shaft as previously described.

Thus, it will be seen that I have provided a sewer tunnelling machine which is of relatively simple design but which, at the same time, renders the operation of excavating sewer tunnels a very efficient one. The machine requires only a single operator and perhaps one or two helpers at the discharge end of the conveyor for insuring the proper filling of the cars 256. In addition, it will be observed that the provision of the torque arm assembly 18 and the sliding arrangement of this assembly as well as the jack 16 and of the head 12 and power unit 14 on the shaft and the simple means provided for selectively connecting these members together enables operation of the machine in various types of soil conditions. It will be further noted that the sliding arrangement of these various assemblies on shaft 10 renders the unit as a whole more or less self-propelling. The head can be advanced independently of the shaft or with the shaft through the torque arms. The torque arms in turn can be advanced independently of the shaft or with the shaft through the head. These torque arms, which may be arranged vertically instead of horizontally as shown, in addition, provide the necessary support and resist the thrust imparted to the shaft by the head. Furthermore, when it is desired to tunnel around a curve, it will be readily appreciated that the torque arms can be adjusted such that the shaft is inclined in a horizontal plane to the axis of the tunnel being dug so as to negotiate a turn. Likewise, the tunnel can be inclined along a downward or upward path at any point by adjustment of the foot support 214 so that the shaft assumes a tilted position to the horizontal. It will be observed that

support 214 is slidable with sleeve 178 along shaft 10 and therefore either the front or rear end of the machine may be elevated or lowered by means of this support 214.

I claim:

1. A machine for excavating tunnels comprising a longitudinally extending shaft, a support arm mounted on said shaft and extending transversely thereof, a sleeve non-rotatably mounted on the shaft forwardly of said support arm and slidable axially on the shaft, a head rotatably supported on said sleeve said head being provided with generally radially extending blades, means supported on said sleeve for rotating said head such that the blades thereon cut into the soil being excavated, means for optionally interconnecting said shaft and support arm to prevent relative movement therebetween, and means on said shaft for advancing said sleeve and its supported head longitudinally of said shaft.

2. A machine for excavating tunnels comprising a longitudinally extending shaft, a support arm mounted on said shaft and extending transversely thereof, a sleeve non-rotatably mounted on the shaft forwardly of said support arm and slidable axially on the shaft, a head rotatably supported on said sleeve said head being provided with generally radially extending blades, means supported on said sleeve for rotating said head such that the blades thereon cut into the soil being excavated, means for optionally interconnecting said shaft and support arm to prevent relative movement therebetween, and means on said shaft for producing relative axial movement of said shaft and said sleeve and its supported head.

3. A machine for excavating tunnels comprising a longitudinally extending shaft adapted to be positioned longitudinally within the tunnel being excavated, a sleeve non-rotatably mounted on said shaft and slidable axially on the shaft, a head rotatably supported on said sleeve and having blades thereon arranged to make a circular cut in the end wall of the tunnel being excavated, said head being movable longitudinally on said shaft with said sleeve and means for supporting said shaft in the tunnel being excavated comprising an arm mounted on said shaft and extending transversely thereof, said arm being extendable such that the opposite ends thereof may be engaged with the side walls of the tunnel being excavated to firmly support the shaft while said head is rotating and means for advancing said sleeve with its supported head longitudinally along said shaft.

4. The combination set forth in claim 3 wherein the opposite ends of said transversely extending support arm are independently extensible whereby said shaft may be positioned such that the longitudinal axis of the shaft is inclined to the longitudinal axis of the tunnel being dug.

5. The combination set forth in claim 4 wherein said arm is slidably mounted on said shaft.

6. A machine for excavating tunnels comprising a shaft member adapted to be positioned such as to extend longitudinally within the tunnel being excavated, a head member rotatably and slidably supported on said shaft member, means for optionally connecting said head and shaft members to prevent relative axial movement therebetween, said head member being provided with blade means thereon arranged such that, when the head member is rotated and advanced into the end wall of the tunnel being excavated, said blade means cut into the earth forming said end wall, a support arm member slidably mounted on said shaft member and positioned rearwardly of said head member, means for optionally interconnecting said arm and shaft members to prevent relative axial movement therebetween, said support arm member extending transversely of said shaft member and being extensible such that the ends thereof may be driven into the side walls of the tunnel being excavated whereby to support the shaft rearwardly of said head, and power means comprising a pair of extensible elements slidably mounted on said shaft member independently of said head and arm members and selectively connectable one of said elements with the shaft member and the other element with the head member to move said head member axially of the shaft member and alternatively, said other element with the shaft member and said one element with said arm member to move said head and shaft members axially as a unit relative to said arm member.

7. The combination called for in claim 6 wherein said power means comprises piston and cylinder elements and including a pair of sleeves slidably supported on said shaft, the free end of said piston being connected with one of said sleeves and said cylinder being connected with the other sleeve and means for optionally connecting one of said sleeves selectively with said shaft member or said head member and the other sleeve with said shaft member or said arm member.

8. A machine for excavating tunnels comprising a longitudinally extending shaft adapted to be positioned longitudinally within the tunnel being excavated, a support member non-rotatably mounted on said shaft for movement axially of the shaft, a head member rotatably mounted on said support member and having blades thereon arranged such that, when the head member is rotated and advanced with said support into the end wall of the tunnel being excavated, said blades cut into the earth forming said end wall, a motor on said support, a hydraulic pump on said support driven by said motor, means for operatively connecting and disconnecting said head with said motor to control the rotation of said head, a support arm slidably mounted on said shaft rearwardly of said support member, said support arm extending transversely of said shaft and having hydraulically extensible end portions which are adapted when extended to engage the side walls of the tunnel being excavated on opposite sides of said shaft, a hydraulic cylinder slidably supported on said shaft independently of said support arm and support member, a piston rod connected with a piston within said cylinder, said piston rod being slidably supported at its outer end on said shaft independently of said support arm and support member, said cylinder and piston rod being disposed between said support member and said support arm, conduit means connecting said pump with said cylinder and said hydraulically extensible end portions of said arm, and cooperating means on said shaft, support arm, cylinder, piston rod and support member for selectively connecting them one with another.

9. The combination set forth in claim 8 wherein said cooperating means comprises a plurality of longitudinally spaced openings on said shaft, said support arm, cylinder, piston rod and support member being each connected with slidable shaft mounted sleeves having openings therein adapted to register with the openings in said shaft, and including pins insertable in said registering openings to interconnect said members together.

10. A machine for excavating tunnels comprising a longitudinally extending shaft adapted to be positioned longitudinally within the tunnel being excavated, a rotatable head member slidably supported adjacent one end of the shaft and having blades thereon arranged to make a circular cut in the end wall of the tunnel being excavated, a support arm slidably mounted on the shaft adjacent the opposite end thereof, said support arm extending transversely of the shaft and being extendable such that the opposite ends thereof may be engaged with the side walls of the tunnel being excavated to firmly support the shaft while the head is rotating and a second support arm slidably mounted on the shaft between said head member and said first mentioned support arm, said second support arm being extendable and positioned generally transversely of the first support arm to engage the bottom wall of the tunnel being excavated and means for extending said second support arm whereby when the first mentioned support arm is extended to engage with

the side walls of the tunnel, said second support arm may be adjusted in length to control the angle of inclination of said shaft with respect to the axis of the tunnel being excavated and means for selectively preventing either the support arms or the head member from sliding on the shaft.

11. The combination called for in claim 10 wherein the opposite ends of said first mentioned support arms are independently extendable whereby said shaft may be supported in said tunnel by means of said support arms with the axis of the shaft inclined in a horizontal plane to the longitudinal axis of the tunnel.

12. The combination called for in claim 11 wherein said shaft is non-circular in cross section and including a pair of sleeves surrounding the shaft and slidable axially thereon, said support arms being mounted one on each of said sleeves.

13. A machine for excavating tunnels comprising a shaft member adapted to be positioned such as to extend longitudinally within the tunnel being excavated, a head member rotatably supported on said shaft member, said head member being provided with blade means thereon arranged such that, when the head member is rotated and advanced into the end wall of the tunnel being excavated, said blade means cut into the earth forming said end wall, a support arm member mounted on said shaft member and positioned rearwardly of said head member, said support arm member extending transversely of said shaft member and being extensible such that the ends thereof may be driven into the side walls of the tunnel being excavated, said head and support arm members being mounted on said shaft for movement longitudinally thereof, and means on said shaft member for moving any one of said members longitudinally of the tunnel being excavated relative to the other two members, said last mentioned means comprising a cylinder and piston assembly, a sleeve slidably supported on said shaft and connected with one end of said cylinder and piston assembly, and a second sleeve slidable on said shaft and connected with the opposite end portion of said cylinder and piston assembly, one of said sleeves being arranged to be selectively connected with either said shaft or said support arm and the other sleeve being arranged to be selectively connected with either said head or said shaft.

14. The combination set forth in claim 13 wherein said one sleeve is also arranged to selectively interconnect said shaft with said support arm and the other sleeve is also arranged to selectively interconnect said head and said shaft.

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