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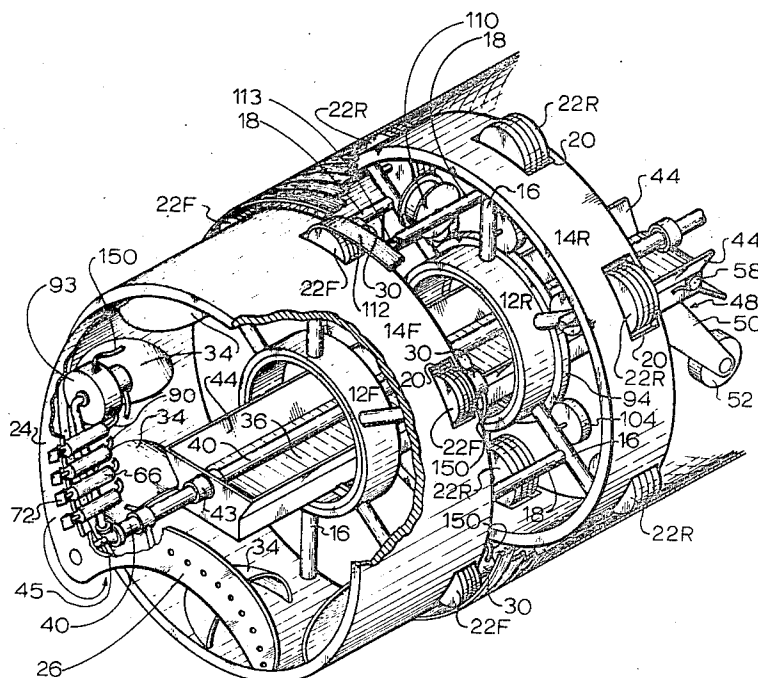
[54] **TUNNELLING MEANS AND METHOD**
 30 Claims, 14 Drawing Figs.

[52] U.S. Cl. **61/84,**
 299/11, 299/33, 299/85
 [51] Int. Cl. **E01g 3/03,**
 E01g 5/06
 [50] Field of Search **61/84, 85;**
 175/94; 299/31–33, 85, 86

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ABSTRACT: A tunnelling machine performs in such a manner that, in a cylindrical tunnel, a radial step from center to periphery advances helically about the axis of the tunnel as material is detached, to advance the locus of the step. A plurality of implements mounted on an arm have a locus corresponding approximately to the desired step direction advance the step by penetrating the material a short distance in advance of the step location and prying it toward the face of the step. Actuation of one or a small proportion of the implements at a time provides large thrust in a concentrated location. Choice of sequence of implement actuation allows compensation for the fact that radially outward parts of the arm advance farther than radially inward parts. Arm advances are alternated with cycles of implement operation. A frame, roller mounted on the walls of the tunnel has the rollers 'skew' to advance the frame helically as it rotates in the tunnel. The frame supports the implement arm and mounts a supply of permanently deformable strip material which is applied under one of the leading frame support members and corrugated thereby to overlap with preceding and succeeding layers to form temporary reinforcement for the tunnel walls. The rear of the frame may be displaced relative to the tunnel walls and the front of the frame with the implements to change the direction of the tunnel. As an incident of the implement actuation, rocks or rocklike material, too hard for the implements, may be sensed for special treatment.



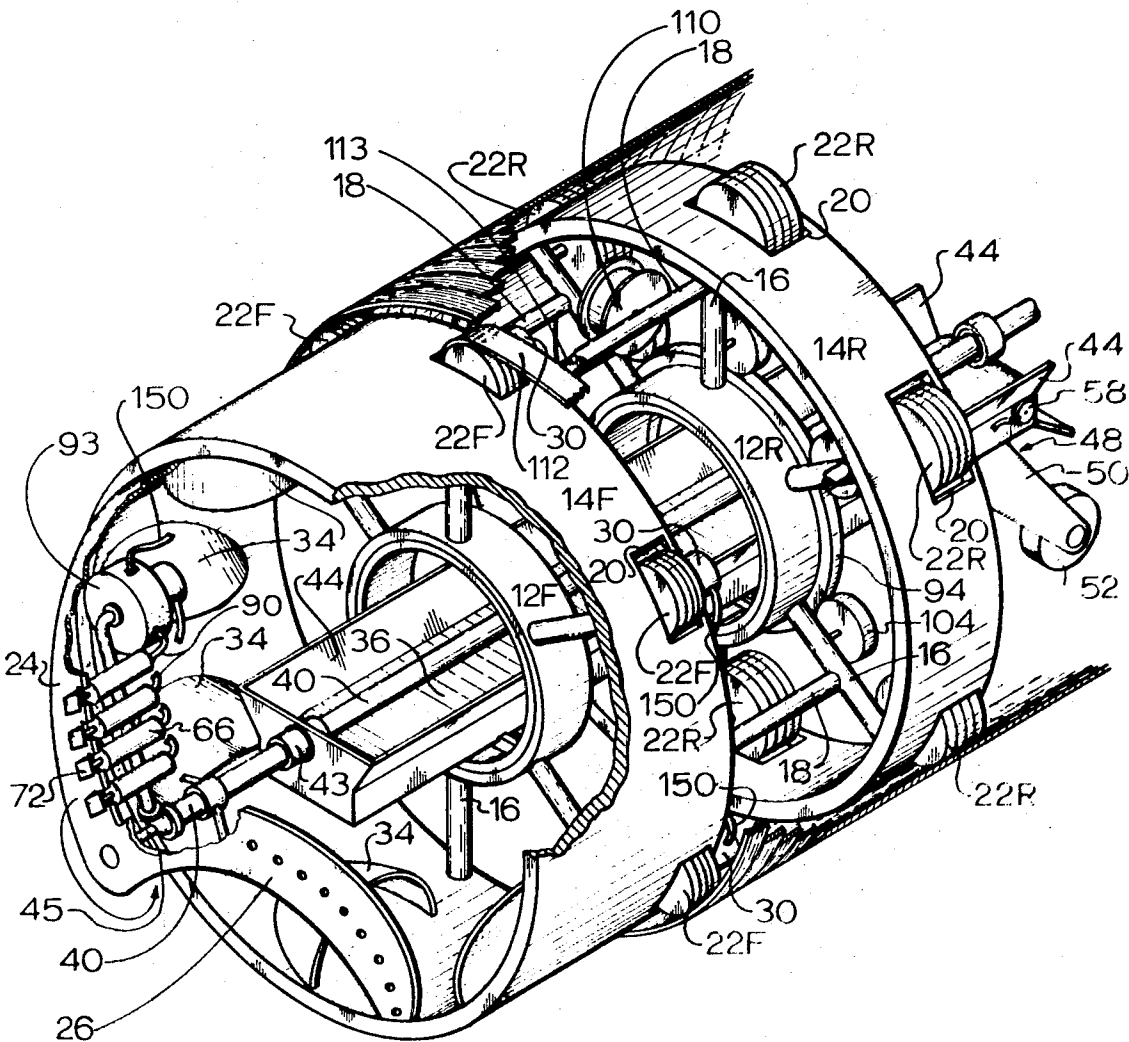


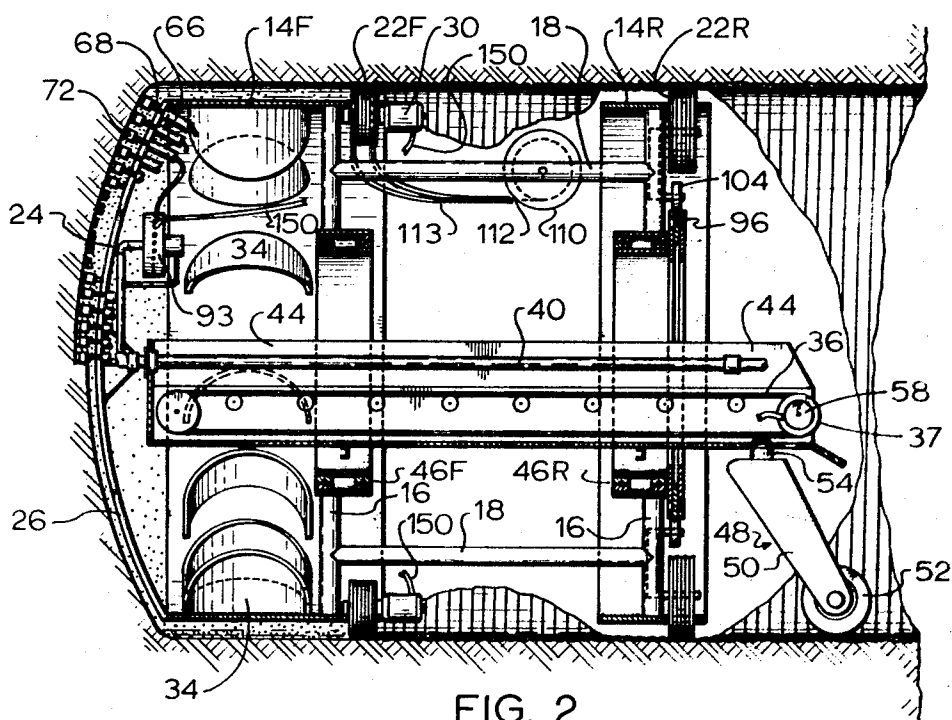
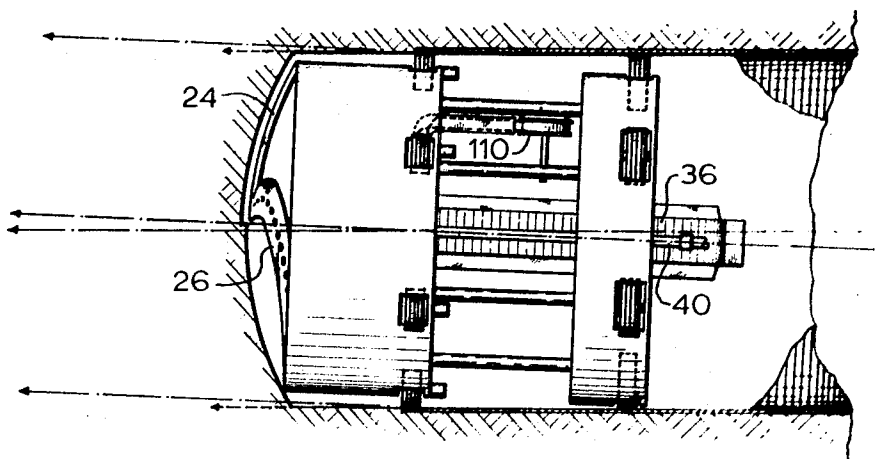
FIG. 1

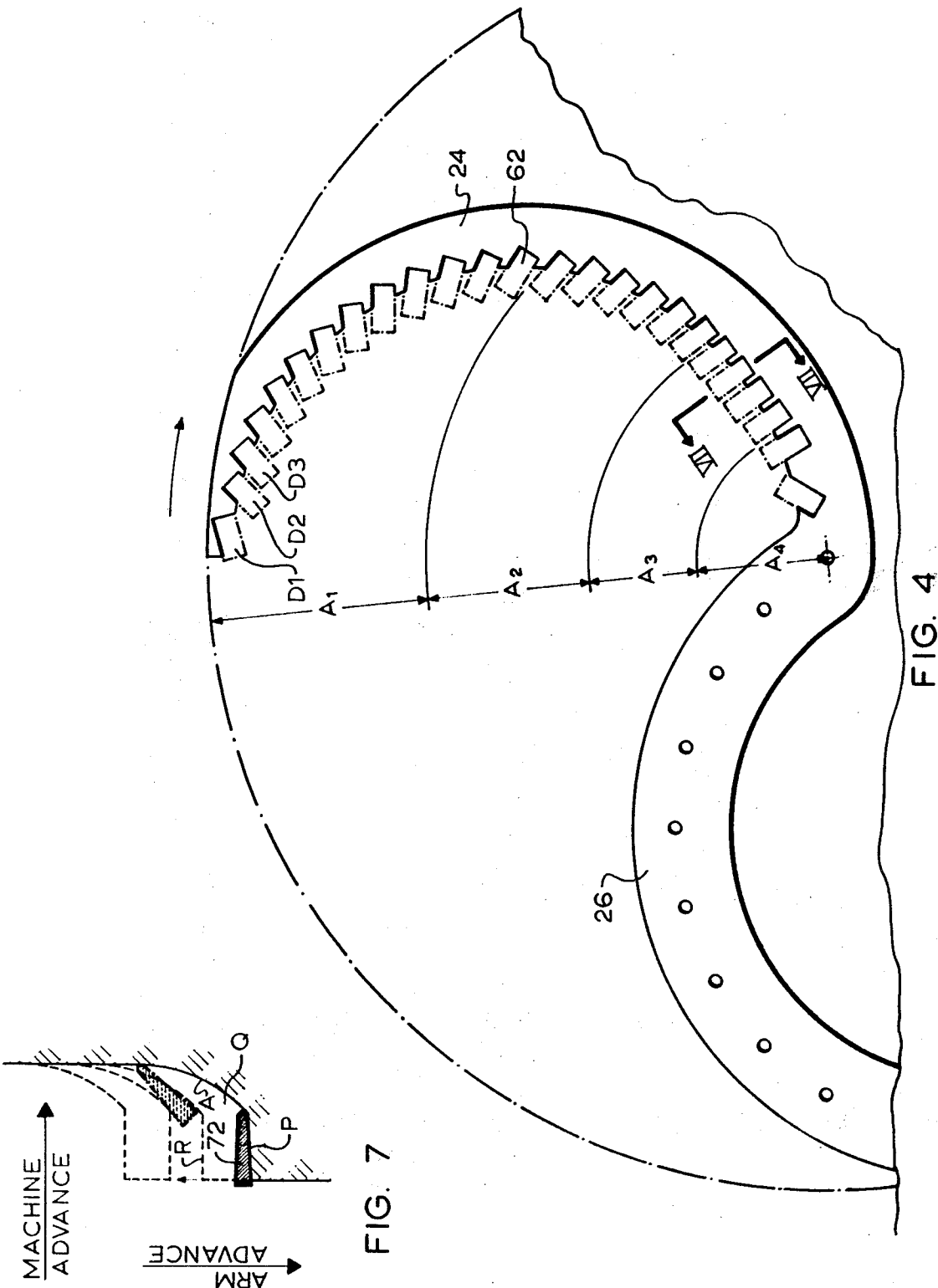
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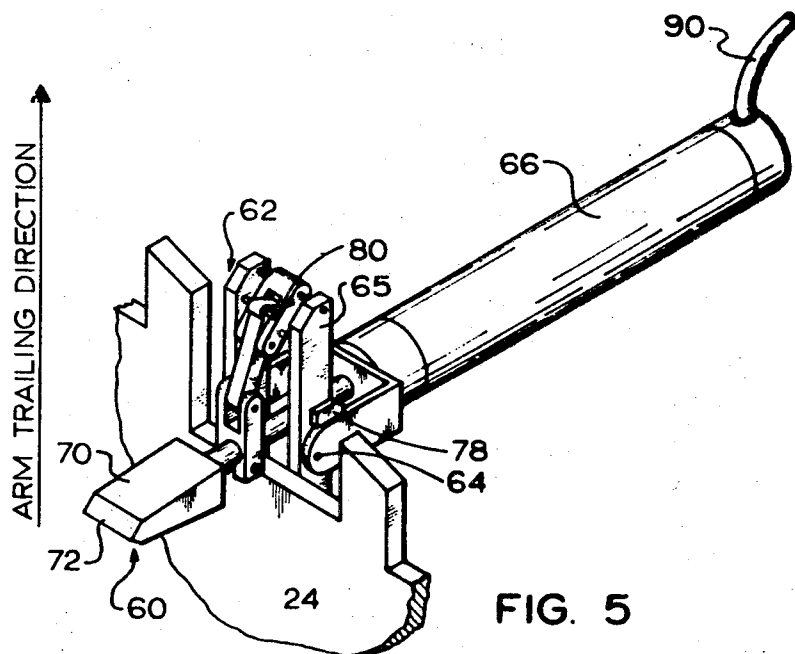


FIG. 5

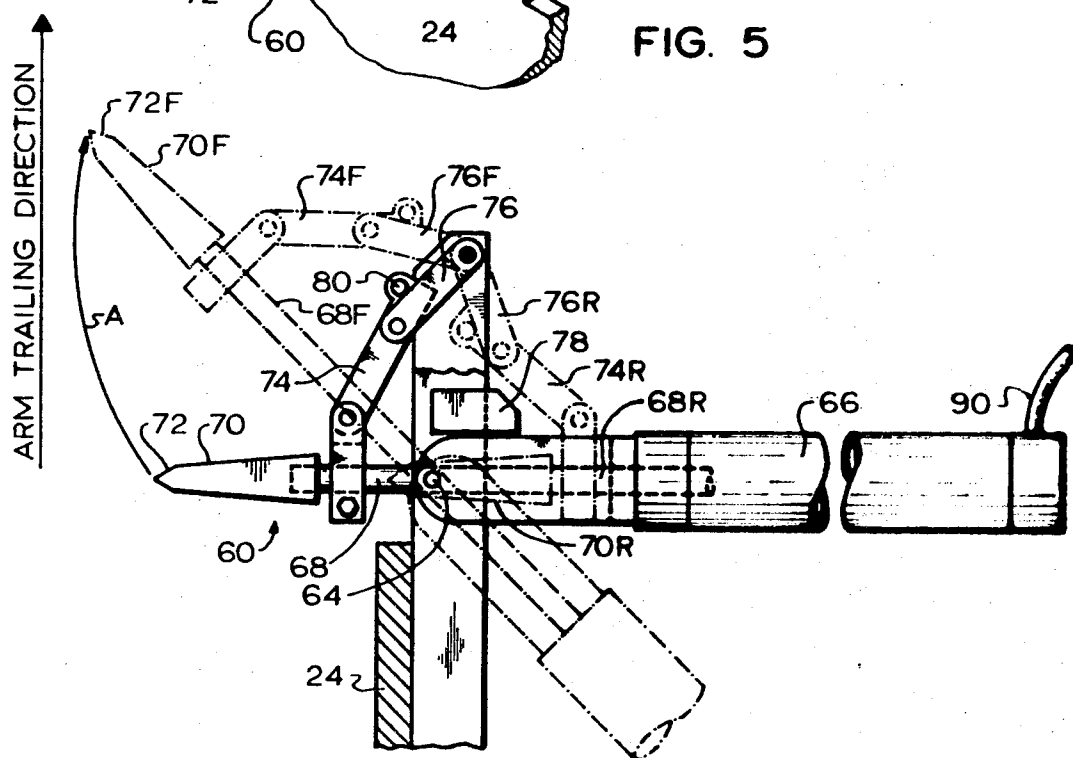


FIG. 6

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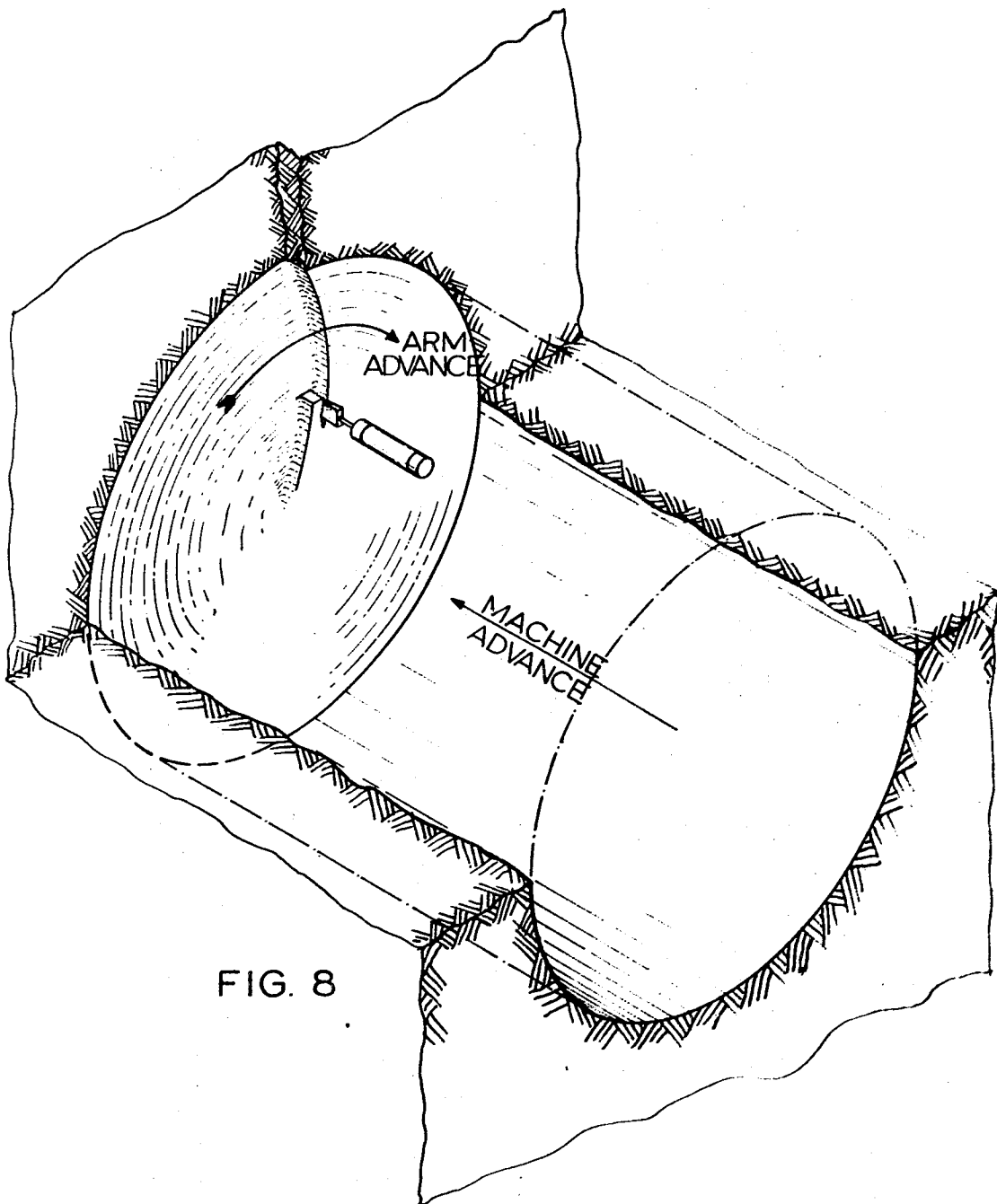


FIG. 8

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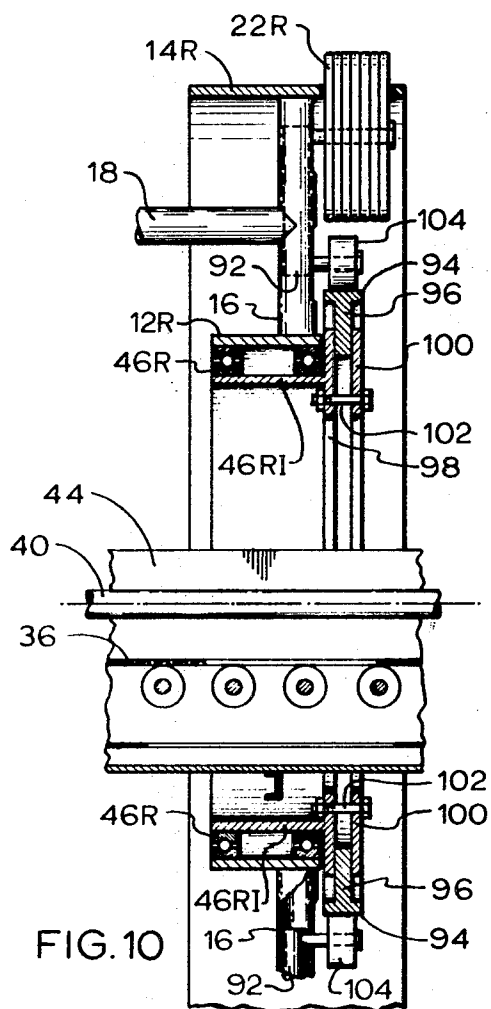


FIG. 10

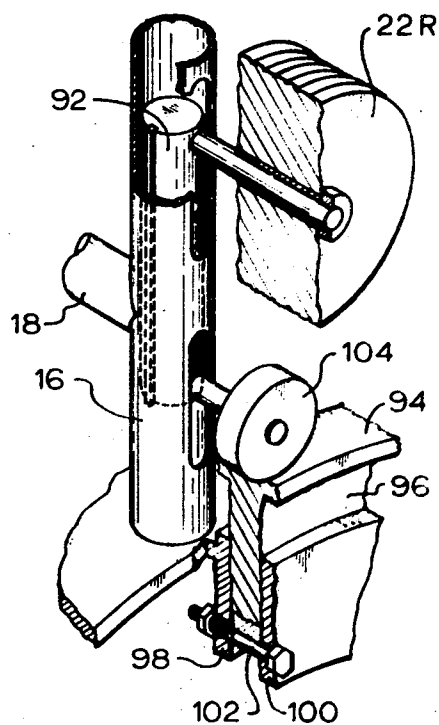


FIG. 11

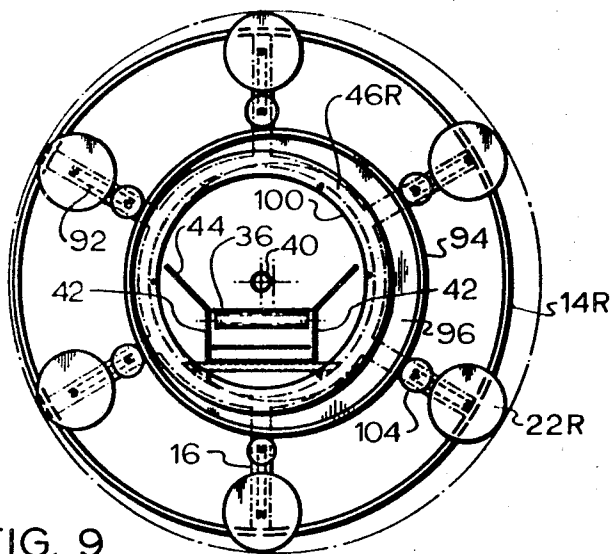


FIG. 9

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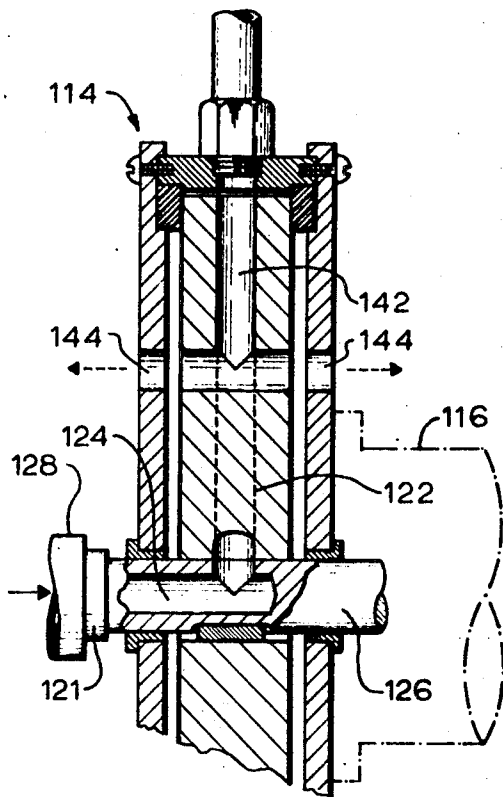


FIG. 13

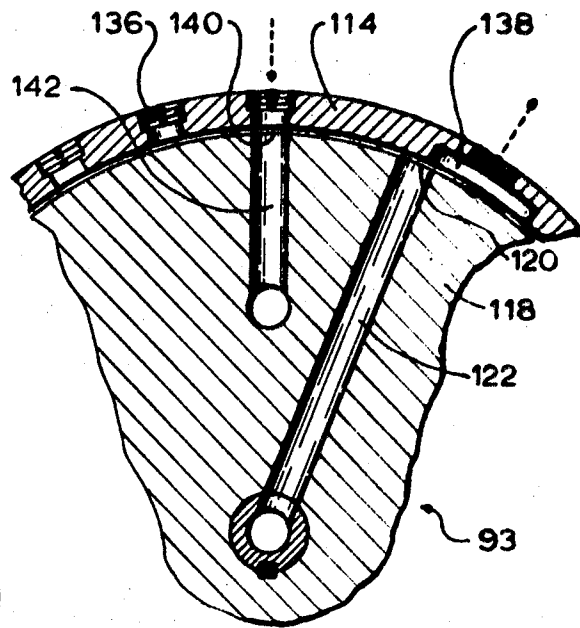


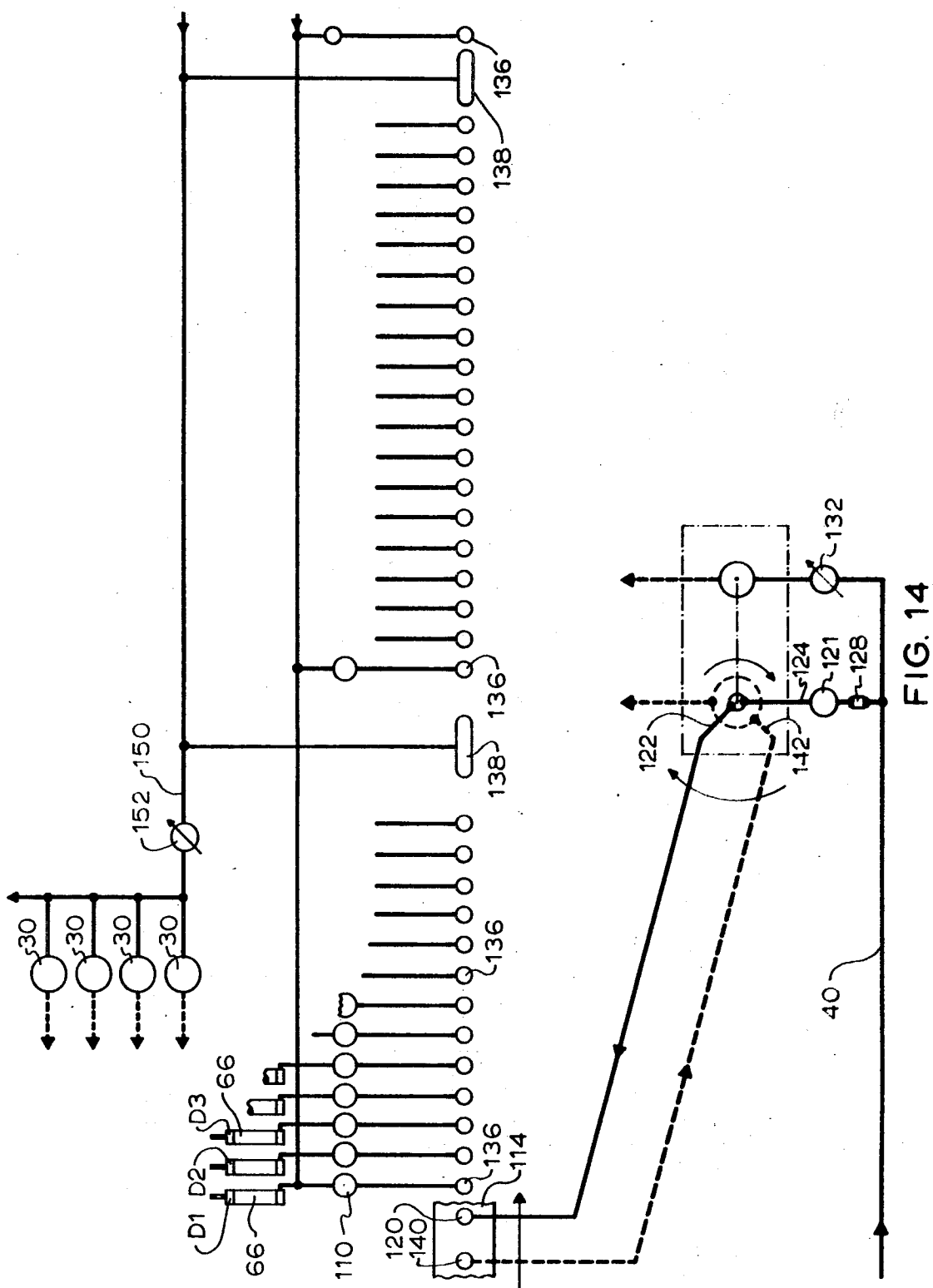
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TUNNELLING MEANS AND METHOD

This invention relates to means and a method for tunnelling.

It is a specific object of the invention to provide, in combination: means for removing material in a tunnelling direction in a manner which provides a cylindrical tunnel, a frame which supports the material removing means and advances helically on the walls of the tunnel, means for providing temporary reinforcement for the cylindrical walls, over the extent from just rearward of the material removal means to a location where more permanent reinforcing may be installed by means extrinsic to the invention.

It is an object of the invention to provide the combination described in the previous paragraph, together with means for changing the direction of the tunnel where desired, by deflection of the frame relative to the tunnel walls.

It is an object of the invention to provide the combination described in the second previous paragraph together with means available to provide for sensing the presence of rock or other material harder than that for which the normally operating earth removal means is designed.

It is an object of this invention to provide means and a method of material removal from a tunnelling face in such manner that a step divides the immediate area where the material was last removed; from the immediate area of material next to be removed, and so that the removal means is designed to detach an increment of material of predetermined width measured along the step of predetermined distance measured approximately perpendicular to the step on the side of the step with the lesser tunnelling advance and of the step depth. It will be seen therefore that material is detached where its fragmentation will be easiest, i.e. where on one side, (and sometimes on two as hereinafter described) the material is already weakened by the existence of the step. It will also be seen that the step progresses around or across the tunnelling face approximately perpendicular to the tunnelling direction. It is noted that the method and means above described are considered within the scope of the invention whether or not combined with the aforesaid frame, tunnel-reinforcing means or steering means.

It is a specific object to provide a method and means as described in the preceding paragraph wherein said material removal is performed so that the tunnel is a cylinder with a face forming one end thereof and so that the step extends outwardly along the face from the axis of the tunnel to the junction of the tunnelling face with the sidewall, where digging is performed by the removal of increments at the step, so that the step progresses about the tunnelling axis as tunnelling takes place.

The method and means of tunnelling using step progression preferably employs a plurality of removal implements extending along the step locus and movable relative thereto in the circumferential sense in which it is desired that the step advance. Thus in the cylindrical tunnel preferably, a line of implements extending from the tunnel axis to the tunnel walls provide a step which advances about the tunnelling face as tunnelling is performed by the implements.

A preferred object of the invention is to selectively actuate the material detaching implements described in the previous paragraph, along an extent of said step, so that an implement is actuated just after the implement beside it so that in fact there is a step in two directions from the material then being detached.

It is an object of the invention to provide means and a method wherein material to be tunnelled is detached from its location in a novel manner. In accord with the invention the material is detached by applying an implement in a translatory direction with the implement being shaped to enter the material in such translatory direction and then to add a rotary component to the translatory movement whereby the rotary component applied, after a penetration of the material by the implement, acts to detach the material to be tunnelled.

Detachment will take place in the direction of the previous step.

It is an object of the invention to provide a support for the material detaching operation which defines a locus along which material is detached in small increments progressing along the locus with an implement movement corresponding to each increment and whereby only one, or a small proportion of the increments, are detached at any given time so that the thrust available from the support for the implements is made available for material detachment in a small proportion of concentrated areas corresponding to the increments and not across the whole tunnelling range. In this way the force available is used to its best advantage and the material detaching is rendered efficient and by proper programming of the increment removal at varying locations a faster and more efficient tunnelling method has been achieved. Although the improvement in tunnelling speed will vary with material it will, in many cases be as much as from 50 percent to 250 percent.

It will again be emphasized, that the objects relating to: the implement manipulation, the proportion of implements used; and the use of an advancing step transverse to the tunnelling direction during tunnelling, are novel and useful whether or not combined with the helically advancing frame, the steering means or the reinforcing means elsewhere discussed.

It is an object of this invention to provide tunnelling means mounted on and operating from a frame rollably supported on the walls of the tunnel with the rollable supporting means arranged so as to helically advance the frame in the tunnel and where the frame mounts at its forward end the means for removing tunnelling material.

It is an object of the invention to provide means as described in the previous paragraph combined with means for applying, during the helical advance of the frame, temporary reinforcing strip material which is applied in a helix corresponding to the helical advance of the frame and which acts to temporarily support the walls of the tunnel pending, following the forward movement of the apparatus forming part of this invention, the provision of more permanent reinforcement.

It is an object of the invention to provide means and a method as described in the previous paragraph wherein the strip reinforcing means is made of permanently deformable material and is deformed, during its application to the walls of the tunnel, into corrugated form for added strength.

In drawings which illustrate a preferred embodiment of the invention:

FIG. 1 shows a perspective of the tunnelling device;

FIG. 2 shows a vertical cross section of the device shown in FIG. 1;

FIG. 3 shows a top view of the device tilted to cause a right curve in a tunnel;

FIG. 4 shows a disposition of individual digging implements viewed in the tunnelling direction;

FIG. 5 shows the mounting for an individual digging implement;

FIG. 6 shows the operation for an individual digging implement;

FIG. 7 demonstrates the incremental removal procedure of the material-removing implements;

FIG. 8 shows the step formed by the sequential actuation of a plurality of implements on the arm;

FIG. 9 shows a rear view of the device demonstrating the steering device;

FIGS. 10 and 11 show details of elements of the steering mechanism;

FIGS. 12 and 13 show the distributor operation; and

FIG. 14 shows schematically the overall pneumatic arrangements.

The tunnelling devices to be described are mainly (as hereinafter described) mounted on the frame first described.

The frame comprises a forward set of inner and outer cylinders 12F and 14F and a rearward set of inner and outer cylinders 12R and 14R each pair of inner and outer cylinders

rigidly jointed by spokes 16 and with the forward and rearward spokes 16 joined by longitudinally extending members 18 which, together with the spokes and cylinders, form a rigid frame. Rotatably mounted on the outer cylinders 14F and 14R to extend through slots 20 therein, are respectively, forward and rear rings of rollers 22F and 22R which are all intended to bear simultaneously on the walls of a cylindrical tunnel and to support the frame in relation thereto. The rollers 22 are set slightly off-parallel to the axis of the tunnel and all in the same sense and direction, to cause helical advance of the frame relative thereto in one sense on rotation of the frame about the tunnel axis. As shown in FIGS. 1 and 2 the tunnelling face is to the left in these drawings and the rollers 22 are tilted so that rotation of the frame clockwise looking left will advance the frame leftward. At the forward end (left in FIGS. 1 and 2) of the frame, arms 24 and 26 are mounted on the forward end of forward outer cylinder for rotation with the frame. While the outer cylinder 14R is radially outward of inner cylinder 12R the outer cylinder 14F is, for a purpose to be hereinafter specified, stepped forwardly of inner cylinder 12F. The helical advance of the frame determined by the orientation of outer rollers 22, is determined in accord with the digging rate achievable by material removing implements mounted on arm 24 and in accord with their sequence of operation.

The frame is caused to rotate, as above described, by powering at least some of the rollers 22, here the forward rings. The rollers 22F of the forward ring are individually powered by pneumatic motors 30 supplied by pneumatic lines 150 as hereinafter described.

Scoops 34 are mounted on the inner surface of the forward end of outer cylinder 14F. The scoops 34 are designed to be open upwardly on their upward travel and to dump into the forward end of conveyor 36, located centrally of a forward-rearward vertical plane approximately diametrically dividing the tunnel.

Rollers 22F are shown rearwardly disposed from buckets 34. However, it should be made clear that if desired it is an available alternative to provide (instead of the rollers 22F shown) rollers 22F (mounted to project from slots 20 and designed to be powered by pneumatic motors 30) disposed forwardly of buckets 34. This latter alternative will, in certain kinds of terrain, have advantages over the illustrated arrangement, particularly in connection with the placing of helical temporary reinforcement hereinafter referred to.

Buckets 34 are shown as having an horizontal top dumping edge and a bottom which curves approximately symmetrically to in a forward and rearward direction therefrom. Dumping therefore takes place centrally of the forward-rearward extent of the bucket. However in many applications it will be desirable to have the majority of material dumped at the rearward end of the bucket. For such application the upper (dumping) edge of each bucket will (considering a rising bucket) slope downwardly in the rearward direction, and the bottom (of a rising bucket) will be similarly sloped so that the material will slide to the rearward of a rising bucket 34 to be dumped (during its travel up and over conveyor 36) toward the rearward end due to the rearwardly sloping dumping edge. The walls of the forward cylinder 14F project forwardly of the inner cylinder 12F so that the outer cylinder 14F is forwardly axially displaced from cylinder 12F and material dumped during the upper travel of scoops 34 clears the inner cylinder 12F and may fall on the forward end of conveyor 36. It is desirable to have, on the axis of the cylinder, defined by the locus of travel of rollers 22, i.e. the axis of the cylindrical tunnel, a pneumatic supply line 40 which is attached to the junction of arms 24 and 26 for rotation therewith.

Hence the conveyor 36 is located below supply line 40 and sufficiently therebelow that material piled on said conveyor will not foul line 40. The conveyor 36 is mounted on a rectangular channel 42 which encloses, on the side and bottom, the upper and lower flights. The upward ends of the channel walls are provided with outwardly diverging wings 44 to guide material into the conveyor and maintain it thereon. The chan-

nel 42 is mounted on forward and rearward bearings 46F and 46R.

Supply line 40 which rotates relative to channel 42 is preferably supported on the channel 42 forward of the forward end of the conveyor by rotary thrust bearing 43. The junction of arms 26 and 24 is then forwardly supported by an abutment 45 from the forward elbow of conduit 40.

The conveyor channel 42 and conveyor 36 projects rearwardly of the frame and for rearward support there is provided a cradle 48 having two downwardly diverging support legs 50 which support the rearward end of the conveyor 36 and channel 42 on rollers 52 which roll on the tunnel bottom or on reinforcement laid on said tunnel wall as hereinafter described. The cradle 48 is connected to support the conveyor by a pivotal connection allowing pivoting about an approximately vertically directed axis 54. The conveyor 36 and channel 42 are intended to be stationary while the frame rotates and hence are free running on their bearings 46F and 46R on the two inner cylinders 12F and 12R. Since these members are free running, there may be a tendency on the part of the conveyor to 'creep' out of its intended horizontal orientation. This may be detected visually or by pendular means as well known to those skilled in the art but small deviations of the conveyor from the vertical axis are not critical. On detection, the situation may be corrected, again either manually or automatically by 'steering' the cradle about the vertical pivot point. There are of course other ways of maintaining the conveyor horizontal. It may for example, be keyed to the next conveyor, not shown, into which it feeds at the rearward end. The conveyor is provided with a conventional wide belt 36, supported at convenient spaced locations, along its length. As a member nonrotating about the axis of the tunnel, the conveyor 36 may be conveniently driven by a conventional drive (not shown) attached to the rearward conveyor rollers 37 or alternatively by the pneumatic motor 58, as shown. The conveyor is located to feed material dumped therein by the buckets 34 into another conveyor flight (not shown) receiving its input from the rearward end of conveyor 36 in a conventional manner.

The belt 36 is made substantially as wide as the channel 42 and any conventional means may be used to maintain the material thereon, as an alternative to wings 44.

As previously described, there are provided a pair of arms 24 and 26 which are preferably rigidly connected to each other and are here shown rigidly connected to the forward end of cylinder 14F for support thereon. The outer cylinder 14F as part of the frame is, as previously explained, mounted for helical, or for advancing rotation in the tunnel wall. The arms 24 and 26 therefore rotate substantially about the axis of the tunnel while advancing with the helix. It is noted that the arm 24 carries material-removing implements, about to be described, operating on the forward end (i.e. in the tunnelling direction) and the arm 26 is provided in case it is desired to mount manual or automatic rock digging tools thereon. The following obvious alternatives from the arrangements above described will be noted:

a. The arms 24 and 26 which are preferably also centrally supported, may be adjustably and/or rotatably mounted on cylinder 14F. The arm 24 may be mounted on the cylinder 14F for rotation relative cylinder with a different type of support means than the helically advancing frame, or for adjustment relative to such frame. Moreover the arms 24 and 26 may be made independently adjustable and may have independently actuatable drive means, but that, just as shown arms 24 and 26 to a certain extent are designed to mutually support each other.

b. Two or more arms 24 may be provided mutually extending from the center to the outside and two or more arms 26. This may be to have different radial extents on different arms or the full radial extent on two arms for symmetry or balance.

It will be seen that the arm 24 may, in any event, be caused to follow a helical path comprising mainly rotation about the tunnel axis accompanied by a smaller advance along the tunnel axis.

The arm 24 and the arm 26 are each preferably generally of a spiral shape, extending from the center of rotation outwardly and with each as it progresses outwardly increasing its trailing angle to the intersecting radial direction.

The arm 24 is provided with digging implements 60 (FIGS. 5, 6 and 1) mounted in niches 62 in the trailing side of the arm 24 and in each niche arm 24 rigidly mounts a frame 65 extending into the niche which mounts a pivot pin 64 which pivotally mounts a pneumatic cylinder 66. Pivot axis 64 has primarily a radial component but with the relevant pivotal axes 64 arranged so that at least some of the cylinders toward the outer end of the arm are oriented at an angle to the radius, in the same sense as the angle of the overall direction of the spiral arm 24. The piston 66 is mounted, as hereinafter described, in the retracted limiting position of the implement (hereinafter described) to define a piston axis approximately parallel to the axis of rotation and at its other limiting position where the forward (implement) end is located at an angle displaced from the first in the trailing direction relative to the intended rotation direction of arm 24. A piston with rod 68 is mounted for reciprocation in the cylinder 66. The piston could, within the scope of the invention, be pneumatically actuated in both directions. However, it is preferred to have the piston pneumatically actuated to move in a direction forwardly of the arm but spring biased to move rearwardly relative to the arm. Such spring return is not shown but is well known to those skilled in the art. Attached to each piston is a rod 68 projecting forwardly of the cylinder and attached to the forward end thereof is a digging implement 70 designed to penetrate earth, mixtures and most materials other than rock or rocklike substances. There will be many possible shapes for such implements, subject only to the necessity for penetration and the tunnelled material detaching motion hereinafter discussed. The shape preferred, is a chisel tip having its sharp edge 22 directed forwardly in the rearward position of the piston rod and in its preferred form having its edge 72 projecting parallel to the piston cylinder rotation axis about pivot pin 64. FIGS. 6 and 5 show the linkage controlling the implement path. The piston rod 68 is pivotally connected to one end of link 74 which at its other end is connected to one end of link 76. Link 76 at its opposite end from link 74 is connected to arm 24. All pivot points at both ends of links 74 and 76 are parallel to the pivotal mounting 64 for cylinder 66. Pivoting of the cylinder 66 so that the implement tip trails the arm 24 is referred to as pivoting in the trailing direction and pivoting in the opposite direction is referred to as pivoting toward the forward direction. Pivoting of the piston and rod toward the forward direction is limited by stop 78 attached to arm 24 and stop 78 limits pivoting of the cylinder 66 and rod 68 toward the forward position at the angular disposition where the rod and implement are directed approximately parallel to the axis of the tunnel. The links 74 and 76 have a maximum extension short of complete alignment, determined by stop 80 on link 47 which stops relative rotation of the links toward the aligned position at the angle position shown in the two counter-clockwise disposed elements. The rearward and forward positions of arm rod 68, linkage 74, 76 and implement 70 are indicated by the letters R and F. It will be seen that between the intermediate position (where no letter subscripts are used) and the rearward position, the linkage partially collapses, and on the other hand, on movement of the members forwardly of the intermediate position they are caused to follow an arc under the control of the linkage 74, 76 and the pivot 64 causing the implement tip 72 on extension motion to follow the arc A. The linkage could, on passage through its collapsed position between the intermediate and the rearward state allow the implement to pivot in the trailing direction. This will not have any practical effect since the spring driving the piston rod to its retracted rearward position will at that point have extended fully the linkage 74R-76R which is arranged to bring the cylinder and rod 68 to their piston, parallel to the tunnel axis. The rod 68 and implement could again swing toward the trailing direction on forward movement of the linkage through

the collapsed position but such deflection will normally not occur in the extension of the rod 68 from a position which is parallel to the rotation axis. It will be seen however that should such deflection occur, no serious consequence will occur although the increment removed will be somewhat narrower.

In operation, when there is no pneumatic pressure, the piston rod 68 and piston are biased toward their rearward positions 68R, 74R, 76R, 70R by the cylinder spring. When it is desired to actuate the particular digging implement, the pneumatic supply is turned on, the piston rod moves forwardly carrying with it the implement 70. Initially, the linkage is collapsed and as the implement moves forward it is restrained against deflection in a leading direction by stop 78. During the initial part of the extension stroke the orientation of the arm will be such that the implement head 72 penetrates the earth or similar material with a substantially translatory motion to substantially the depth to be removed on a particular stroke. At such depth and extent of extension stroke, the linkage 74F, 76F reaches its maximum extension so that with continued extension of the piston rod 68 the implement adds rotation in the trailing direction to its translation movement, with the linkage moving so that edge 72 describes an arc A about the arm end pivot point for the linkage. During the rotation, the implement tends to break off a portion of earth in the trailing direction relative to the implement. In FIG. 7 it will be seen that from the cross section of the material above and to the left of arc A, that a step was formed by the previous stroke of the implement at position N and that, the shape of the step remaining the same, the step intermittently advances with each stroke of the implement. Thus, and recalling that the implements are arrayed in a spiral line, it will be seen that where all or an extent of the implements are sequentially actuated, with implements spaced sufficiently close so that material is detached for substantially continuous extents along the line of the implements, that a step is created (see FIG. 8) extending, at each location, approximately parallel to the pivotal axis of the implement.

The step thus far will form a trailing (relative to arm movement) spiral as shown in FIG. 8 and conforming to the shape of the arm in FIG. 4. Although this is the preferred form it is noted that, within the scope of the invention, the arm 24 and consequent step may be straight along the radius, curved forwardly (relative to arm movement) radially outwardly or of any curve or form suitable to the tunnelling operation being performed and the sequence of actuation of and disposition of the digging implements. Thus, with the implement in position P the shear, beam or whatever combination of stresses occur in the area Q of the material resisting its detachment are minimized by the proximity of the step edge R. Thus the implement is always breaking away a small piece of material and its breaking force is exerted in a direction in which the material is unsupported on its other side. As the entire array of elements is actuated in a sense to produce a continuing step over a length in a locus corresponding generally (and qualified as hereafter described) to the spiral arm 62, it will be seen that, as digging continues, involving operation of a plurality of adjacent implements, with the arm 24 stationary; followed by an advance of the arm 24 in the leading direction with the implements retracted, followed by renewed actuation of the implements, that the step moves about the tunnelling face in the leading sense, about the axis of rotation of the arm 24.

Each of the digging implements is provided with a pneumatic line 90 arranged so that air supplied toward the cylinder 66 will cause extension of the piston rod. The lines 90 from each of the cylinders are flexible to allow pivoting of the cylinders 66 as previously described and are connected to outlets of a pneumatic distributor 93 whose location on arm 24 is indicated on FIGS. 1 and 2 and whose specific mode of operation is indicated in FIG. 14.

The step (FIG. 8) and the implements creating it have heretofore and will hereafter be referred to as extending from the center of rotation of arm 24 to the walls of the tunnel. However the anomaly of digging at zero radius prevents digging right to the center of rotation. It will therefore be real-

ized that the digging stops just short of this (although substantially at the center). This could be considered as tending to leave a central core but in fact any such core will crumble under its own weight or the effects of the nearby material removal operations. The distributor 93 is designed to operate sequences of the implements, while the arm 24 is stationary in a predetermined angular orientation and to step the arm in the leading direction, a predetermined angular amount between operations of implement sequences. The sequences are chosen particularly to compensate for the fact that angular displacement of the arm 24 makes a much greater circumferential displacement of the outer implements than the inner. Thus the sequence is chosen to ensure that outer implements are operated more often than inner to ensure that circumferential displacement and hence the circumferential thickness of the portion of material detached are approximately equal at all radial distances from the arm center of rotation. The sequences selected may vary widely with the geometry of the arm, the spacing of the elements etc. However one sequence which is considered advantageous is outlined with the understanding, that this may be differently arranged within the scope of the invention, as occasion demands.

In FIG. 4 are shown arcs dividing the implements into groups of:

A1	13 elements
A2	6 elements
A3	4 elements
A4	2 elements

The elements within a group are operated in sequence wherein each of the implements is operated once in turn here, it is assumed, from the outermost element in a group inwardly to the innermost. It will be noted that an implement operated just inwardly or just outwardly of an element which has just detached material is not only assisted in detaching material by an adjacent step in the trailing direction but also by an adjacent step on the side where the last previous element operated. Here the inwardly stepping sequential operation creates adjacent steps in the radially outward direction as well as in the trailing direction (see FIG. 8). The weakening power of the step to the locus of the last-operated adjacent element is increased when the adjacent inward digger (as illustrated on FIG. 4 on the radially outward end of the arm) deflects in a direction at an angle slightly towards the path of the adjacent outward deflection.

The preferred cycle of operation of the implements is as follows:

Sequence step	Group
1	A1
2	A1, A2
3	A1
4	A1, A2, A3
5	A1
6	A1, A2
7	A1
8	A1, A2, A3, A4

Rock removal arm 26 is supported forwardly of the frame, at its radially outer end on cylinder 14F and centrally by its junction to arm 24 and with arm 24 by the forward support 45 from pneumatic conduit 40. The rock removal arm 26 is arranged to rotate over the same locus as arm 24 but is angularly displaced therefrom. The apertures 27 schematically represent locations for the mounting of manually or automatically located and/or operable rock-treating means. Such means may be of any desired form but, for example, may be a combined rock drill followed by the application of a rock

splitter such as that merchandised by Emaco Inc. Post Office Box 176, 111 Van Riper Ave. East Paterson N.J. The rocks may be located in any desired way but location will preferably be achieved by noting the actuation of pressure level valves 110 as described in connection with the distributor 93 and the pneumatic system of FIG. 14.

There will now be described the steering mechanism, which, allows the tunnelling machine, as previously described, to have its tunnelling direction altered. As previously stated, the frame is supported on the walls of the tunnel on a forward and rearward ring of rollers 22 tilted to cause the frame to advance helically at a rate designed to match the material removal rate, as it rotates. The forward rollers 22 are preferably bearing mounted directly on the frame with the pneumatic motors drivingly connected thereto.

The rollers 22R on the rearward cylinder are mounted on the outer end of plungers 92 guided and radially slidable in spokes 16. The conveyor channel 42 is, as previously stated, connected by bearing 46R for support on and rotation relative to the frame. Connected to the stationary inner ring 46RI a circular guide rail 94 is maintained in a rigid relationship to inner bearing 46RI by clamping by any desired means such as that shown. Guide rail 94 is provided with a radially inward extending flange 96 designed to be clamped between a radially extending plate 98 rigidly connected to inner bearing 46RI and a similar annular plate 100 with the clamping here provided by bolts 102 connecting plates 98 and 100 inwardly of flange 96. Thus by loosening bolts 102 and tightening them in a new location of plates 100-98 the center of bearing 46R may be adjusted upwardly, downwardly or to the right or left relative to the center of rail 94. The adjustment of the bearing 46R relative to the center of plate 94 may of course be made much more sophisticated than the means shown.

The plungers 92 are provided, at their radially inward ends, with rollers 104 riding on the track provided by rail 94. Thus the rollers 104, plungers 92 and frame support rollers 22R describe circles about the axis of rail 94. Since the length of the plungers is selected so that there is no ambiguity in the position of the rail 94, the center of rail 94 is maintained concentric with the axis of the tunnel. Thus when the center of rail 94 is concentric with the axis of bearing 46R, the rearward end of the frame (centered about bearing 46R) is concentrically oriented relative to the tunnel. The rollers 22F on the front of the frame are located symmetrically relative to the center of the front of the frame and the digging arm 24. With the rail thus adjusted symmetrically, the overall locus of the tunneling implements is about an axis of rotation aligned with the direction of the tunnel then being encountered by the frame, and tunnelling will continue in a straight line. When it is designed to change the tunnelling direction and hence to create a curve in the tunnel, the bolts 102 used to maintain the guide rail 94 rigidly in position are loosened. If it is desired to turn the tunnel to the right, the guide rail 94 is located so that the axis of bearing 46R is eccentric relative to the guide rail and horizontally to the left thereof causing the center of bearing 46 to be eccentric relative to guide rollers 104, plungers 92 and rollers 22 in the sense that the bearings 46R representing the rear frame center is moved to the left relative to the tunnel. This tilts the forward end of the frame to the right including arm 24 causing the tunnel to deviate in this direction (see FIGS. 3 and 9).

Rollers 22F and 22R are preferably spring mounted to compensate irregularities in the surface of the tunnel.

The consequent dislocation of the position of the rearward end of conveyor 36 is easily compensated for in the next conveyor stage (not shown). From the operation described it will be seen that deflection of the center of bearing 46R relative to guide rail 94 upwardly, leftwardly or downwardly will create corresponding (opposite) changes in the tunnelling direction.

It will be obvious that, if desired, more sophisticated or more automated means of controlling the location of the guide rail for steering purposes may be provided, in the form of mechanical or physically equivalent location controls well

known to those skilled in the art. The guide rail could, within the scope of the invention be made other than circular to perform some special manipulation or operation although the need for this is not apparent.

Means are provided to apply strip material to the walls of the tunnel for temporary reinforcement of and maintenance of the position of the walls between the location where tunnelling is taking place and the provision of more permanent reinforcement. Strip material which is permanently deformable, such as steel or aluminum, is supplied longitudinally for application to the tunnel walls as hereinafter described. The supply may be in any form, but is here shown as a reel 110 of the material rotatably attached to one of the longitudinal members 18 to feed strip material 112 forwardly. The strip material extends to and through a guideway 113 which guides material 112 from the reel through the guideway and under the roller 22F of the forward ring which is the farthest advanced. As a matter of choice a roller other than the farthest advanced could be used but the first is preferred since the succeeding rollers 22F and 22R are used to increase the corrugation of the strip material. This applying roller 24F applies the strip material 112 to the tunnel walls and at the same time corrugates it (or begins its corrugation) reinforcing its strength and causing it to maintain the cylindrical shape of the tunnel wall. It is preferable that the most advanced roller 22F which is applying the reinforcing material is powered so that the reinforcing material is forced by such roller 22F into contact with the tunnel wall. This will form a firmer reinforcing wall than would occur if the lead applying motor were an idler.

Guideway 113 is preferably extended from as close to the reel as possible to as close to the lead roller 22F (i.e. the roller first applying the strip to the tunnel wall and guideway 113 is preferably designed to completely enclose the strip. These arrangements are to maintain the strip material 112 as far as possible, out of contamination with fragmented tunnelled material tumbling inside the frame. The rollers 22F following that applying the strip are shaped to maintain or enhance the corrugation. Since the rollers 22F (and 22R) are oriented to correspond to the desired advance of the frame, and the strip material 112 moves tangentially of the rollers, the strip material is laid, in corrugated form, on the tunnel at the same rate of advance as the frame. The width of the strip 112 material is such that there is a predetermined amount of overlap with the strip of the preceding or succeeding turn. The number of corrugations of overlap is thereby also determined. The overlap will be determined by the thickness of the reinforcing material and the forces to be encountered (noting that in relation to these forces, it is conventional practice to provide air pressure inside a reinforcing tunnel wall to balance the forces on the reinforcement). The thickness of the material will be at least partly determined by the reaction forces of the material tunnelled as affecting the corrugation. It will be noted that the corrugation is formed under pressure between the initial (and to varying extents) the subsequent roller pressures each as opposed by the material which forms tunnel walls. Thus better corrugation may be made (up to a point) where the material being tunnelled provides a firm reaction to the corrugating pressure. Thus a thicker material may be used for corrugation where the material being tunnelled is slightly yieldable earth than where the material is of very weak texture such as quick sand. Thus with thinner material proportionately more overlap will be required than with thicker material. Where rock or rocklike material is encountered, corrugation may be impossible, but on the other hand, reinforcement will not be required.

The reinforcement thus provided for softer than rocklike material and cooperating in its application with the motion of the frame, is not intended as the permanent reinforcement or tunnel wall, but merely to maintain the tunnelled material walls in situ until permanent reinforcement can be applied. The permanent reinforcement can of course be applied inside the spirally applied walls, immediately after the passage of the tunnelling frame and thus the length of material required to be supported by the overlapping spiral is very little more than the

length of the frame and substantially only between the forward and rearward rings of rollers 22F and 22R.

In many cases, and particularly where the material being tunnelled is soft, it will be desirable to have the temporary reinforcing material applied as close to the tunnelling face as possible. Thus, as previously mentioned, as an alternative, the rollers 22F may be placed forwardly of the buckets 34 and the lead roller 22F then will be applying the strip as near as possible to the tunnelling face. The guideway 113, totally enclosing the strip, will then extend from rearward to forward across the bucket area and as closely as possible to the inner surface of outer cylinder 14F.

The pneumatic circuit will be described in relation to FIGS. 12-14. FIG. 12 shows a portion of a cylindrical casing 114 encompassing a complete circle which, although not shown, may be considered as similar to the portion shown. The casing 114 is provided with ports as described hereinafter and rotatably mounted therein is cylinder block 118 provided with supply port 120 open to the periphery of block 118 connected by passage 122 to a bore 124 in a shaft 126. The shaft 126 projects from each end of the sidewalls of casing 114 with the end having bore 124 connected to rotary coupling 128 and, in the other direction, as a solid shaft, to connect to motor 116 by which it is driven. Rotary coupling 128 allows connection of the bore 124 in shaft 126 rotating relative to arm 24 to conduit 40 stationary relative to arm 24. Between coupling 128 and bore 124 is connected a constant pressure regulator 121 which, inter alia, controls the pressure to cylinders 66 although this will nearly be the maximum available.

The cylindrical block 118 is driven by pneumatic motor 116 of a type well known to those skilled in the art and designed to operate at constant speed when supplied under constant flow. The constant flow is assured by the constant flow regulator 132, with the supply line 40 connected through constant flow regulator 132 to the motor 116.

The constant flow regulator 132 is made adjustable since, as hereinafter described, it controls the timing cycle of the implement operation. The peripheral outer casing 114 is provided with a plurality of ports, and these are of two types. A series of ports 136 corresponding in number to all those implements to be operated in a sequence step are followed in the rotation direction by a port 138 encompassing a predetermined arc relative to the center of rotation of block 118. This is followed by a series of ports 136 corresponding in number to all those implements to be operated in the next sequence step; followed in the rotation direction by a further extended port 138. This alternation continues around the casing so that in one circuit of the casing there is encountered a series of ports 136 corresponding to each sequence step, in order of sequence, each step being spaced from the next by a port 138. Following port 120 and passage 122 in the rotation direction is an exhaust port 140 open to the periphery of the cylinder and connected to exhaust passage 142 which is connected to the exterior of block 118. Air exhausting through passage 142 may reach atmosphere through ports 144 in casing 114. The spacing between supply port 138 and exhaust 140 is made as small as possible subject to ensuring that the exhaust port 40 does not contact a port 138, before the supply port 120 has left the same port 138. As indicated in FIG. 12 the spacing of the beginning of port 138 is far enough forward in the rotation direction from the last previous port 136 that exhaustion of the cylinder 66 corresponding to said last previous port is well under way before supply to the port 138 commences. This ensures that the last implement 70 clears the material under the pressure of the cylinder before rotation of the arm commences. Since any of implements D1, D2 etc. (except those of the inner arc) will have a plurality of ports 130 connected thereto, the outer face of cylinder 118 is made a close enough fit to ports 136 to block the escape of air from all ports except those to which the port 120 or the port 140 is connected. The cylinder 118 blocks all unconnected ports 138 for the same reason. It will be appreciated that, if desired, the escape of air through unconnected ports 136 or 138 may be avoided, alter-

natively, by placing a one-way valve in the line from each such port.

FIG. 14 shows the pneumatic arrangements for the device, although only a portion of the ports from casing 114 are shown since these are sufficient to indicate the function of all such ports. The ports 136, 138 are further extended in a line instead of in their physical cylindrical form to assist in the explanation of the device. Thus the elements 128, 122, 120 140 and 114 are shown schematically with the elements 120 and 140 shown translating along the ports 138, 136 although it will be realized that the block 114 will cyclically repeat over the ports as properly physically indicated in FIG. 12.

FIG. 14 shows the first two and part of the third sequence steps (page 23). The material detaching implements are shown numbered D1, D2 etc. with D1 representing the radially outermost digger on arm 24 with increasing 'D' numbers referring to radially inward digging. It will be noted that it is preferable but not necessary to dig from the outside in, and therefore in accord with the sequence steps shown on page 23, digger D1 in group A, will be the first digger operated in each sequence step and thus will be operated eight times in a complete cycle, i.e. a complete rotation of block 118. On the other hand, the implements in the second, third and fourth groups are operated, respectively, four, two and one times per cycle.

Accordingly, the first port 136 encountered as the ports 120, 140 sweep through each sequence step, is connected to a common line to cylinder D1. Similarly the second port 136 encountered in each sequence step will be connected to implement D2 and so on through the implements in group 1. The 14th port 136 encountered in sequence steps 2, 4, 6 and 8 will be connected to the outermost elements in group 2 so that all the connections are such that each implement is actuated in accord with the sequence steps indicated on page 23 and with its location in the outward higher priority of actuation. Each port 136 may, for rock sensing, be connected through a pressure sensing valve 110 to the common line to the respective cylinder 66. The valve 110 may be set to provide an indication if the pressure expended attempting to extend the piston rod 68 is greater than the design amount for completing the stroke of piston rod 68. If the size of ports 136 and 120 is chosen to avoid the application of pressure through port 136 after the rod is extended to its predetermined amount, then an excess of pressure in the line carrying valve 110 will indicate that rock or rocklike material has been encountered. Each of the sensors 110 is characteristic of an implement position, and, as will be explained hereafter, is indicative of an angular position of arm 24. Alternatively the sensors 110 may actuate the input to a memory designed to cooperate with automatic rock-treating devices. It is noted that rock may be detected, not only by a pressure excess but by a failure, under the applied pneumatic pressure, of the implement to mechanically execute its complete operating cycle, as indicated in FIGS. 5 to 7. It will be noted that the result of any such detection may be either individual rock treatment by mounting the correct implement on the rock arm 26 as elsewhere referred to, by otherwise treating the rock or by operating automatic rock-treating equipment (not shown) on rock arm 26 under directions acquired from the memory previously referred to. No claim for automatic or manual rock removal apparatus is claimed, the above discussion being merely to indicate the use of arm 26.

As indicated in FIG. 14 a port 138 is connected between each sequence step and the port 138 is connected to a common line which in turn is connected through an adjustable constant flow regulator 152 to the motors 30 driving the powered rollers 22F and also if so connected, powered rollers 22R. By use of the flow regulator 152 roller motors 30 may be controlled to turn rollers 22 a predetermined angular amount, in a predetermined time. Since the timing, with the constant speed of rotation of port 120, is dependent on the length of port 138, the incremental advance of the frame and hence of the arm 24 between sequence steps of the implements, may be

controlled and be equal or unequal. It will however be here assumed, as here shown by the arcuate length of the port 138, that the incremental advance is equal. It should be noted that due to random differences in pressures on the rollers 22, friction of rollers on strip 112 and strip on tunnel wall; the desired incremental angular advance will not always be exactly achieved. However such variations in the advance of the frame and arm 24 will not affect the success of the tunnelling operation. Should such variations become cumulative it will be noted that this may be corrected by adjustment of constant flow regulator 152.

The operation of the device will now be described.

With the tunnelling machine in position the implements will be in the retracted position and the air will be supplied through line 40 to motor 116 to rotate at predetermined speed the distributor block 118. Air will also be supplied (through means extrinsic to the invention) to the pneumatic motor driving conveyor 36 so that this will be rotating to carry materials dumped thereon out of the frame. As the distributor block 118 rotates, it will operate cyclically the sequence step set out on page 23 interspersed with incremental advances of the frame through controlled flow for controlled periods through flow control 152 to frame roller motors 30.

During each sequence step, the individual implements 70 involved in the sequence, are operated starting from the outermost toward the inner, and hence each digs with a motion to break off an increment involving the last step to advance the step in the arm 24 rotation direction (see FIG. 8), with the step also advancing inward along the locus of the line of implements 70 as each successive implement 70 of the inwardly digging implements is actuated. An intermediate step in a digging sequence is illustrated in FIG. 8. After an individual implement has been actuated by the coincidence of port 120 with one of its ports 136, the distributor next brings ports 140 into line with the same port 136, releasing the pressure therein and allowing the retraction of the implement by the return spring in cylinder 66. It will be noted that (although difficult to show) the cylindrical wall 118 closes off all ports 136 or 138 other than those connected to pressure line 122 or exhaust line 142. Thus pressure applied through line 122 to an implement or motor 30 cannot be exhausted or weakened through one of the other ports for the same element.

When a particular digging sequence is completed, the coincidence of port 120 with a port 138 operates roller motors 30 rotating rollers 22 and advancing the frame through the angular increment determined by the length of port 138. As the frame advances the strip material 112 is drawn between the leading roller 22F and the walls of the tunnel, to be applied to the latter. The lead and to some extent following rollers 22F act to corrugate the strip material to increase its strength. Further, as the frame rotates, the buckets 34 on the rising side, will pick up material detached by the implements 70 and the buckets will dump onto the upper flight of conveyor 36 as they dump thereinto. If an implement 70 fails on actuation to execute its complete cycle as indicate in FIGS. 5-7 then rock sensing means such as valve 110 may be used to indicate the presence of rock or rocklike material. Such information will manually or automatically be used and the rock drilled and/or blasted or otherwise fragmented when convenient and preferably when, by incremental advance, the arm 26 has reached the position held by arm 24 when the rock was encountered.

As the ports 120 and 140 go through their complete cycle, all sequence steps are actuated interspersed with incremental advances. The implements involved in each sequence step are selected so that the larger circumferential advance of the arm 24 at the radially outward end is approximately compensated for by approximately proportionally more frequent operation of the implements at the correspondingly radially outward end of arm 24. Thus the step (with small and cyclically intermittent variation depending on the individual sequence step involved) advances about the tunnel as the tunnelling machine advances, along following a rotating and advancing pattern as

shown in FIG. 8. If steering is desired, then the center of the frame rear bearing axis is deflected relative to rail 94 and the rearward end of the frame is consequently deflected relative to the axis of the tunnel in the opposite sense to which the tunnelling turn is desired.

It will be noted that pneumatic actuation of the implements 70, rollers 22, the distributor 118 and the conveyor is described. It will be noted that the operation of the invention is not peculiar to pneumatic power and that such power with equivalent substitutions well known to those skilled in the art, might be performed, electrically, hydraulically or otherwise.

It will be further noted that individual features of the invention, although combining with each other are of individual value and use. For example, the implement motion described and shown in FIGS. 5-7 may be used in other applications than with arm 24 and the frame. Further the implement bearing arm 24 tunnelling by the programmed implement may be used with such rotating arm but without the rotating frame. Also the rotating frame applying temporary reinforcement may be used with other tunnelling means.

Motors suitable for use as roller motor 30 and distributor 116 are easily available from a number of sources well known to those skilled in the art. Two are mentioned here, as example only, which will be found satisfactory:

For roller motor 30—Rotor model M905,3E74 manufactured by Rotor Tool Company of 26300 Lakeland Blvd. Cleveland, Ohio 44132, U.S.A. For distributor motor 116, one of a range of motors manufactured by Atlas Copco Canada Limited 745 Montreal-Toronto Blvd. Dorval, P.Q. Canada

I claim

1. In a tunnelling machine,

a frame,

an arm supported forwardly of said frame,

for rotatable movement relative to said tunnel in a predetermined sense,

a plurality of digging implements mounted on said arm,

each of said implements being selectively actuatable to cyclically translate between an extended forward and a retracted rearward position relative to said arm, in a direction having in the initial part of the extension direction, a major component parallel to said axis of rotation,

each of said implements being controlled to rotate as well as translate toward the end of said translation extension, said rotation being directed to cause the tips of the implements to move with a component in the trailing direction relative to said predetermined arm rotation sense,

each of said implements being provided with tips directed in the extension direction to facilitate entrance by said implement into the material being tunnelled.

2. In a tunnelling machine as claimed in claim 1 wherein said tunnelling means is designed to produce a cylindrical tunnel, a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably supported by the walls of the tunnel, said rollers being mounted to produce an helical advance of said frame in the tunnel on rotation of said frame relative to the tunnel,

said rollers being divided into a group associated with the forward end of the frame and a group associated with the rearward end of the frame,

said rearward group being mounted on members radially movable relative to said frame over a predetermined range, control members for said radially movable members, a member maintained static relative to said frame, rotatably connected to said frame;

means attached to said static member providing a track connected to control the radial translation of said control members relative to said frame, means for adjusting the location of said track relative to said bearing.

3. In a tunnelling machine as claimed in claim 1 wherein said tunnelling means is designed to produce a cylindrical tunnel a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably

supported by the walls of the tunnel, said rollers being mounted and oriented to produce an helical advance of said frame on rotation of said frame relative to the tunnel, said rearward group of rollers being mounted on inwardly extending radial plungers, a static member rotatably mounted on said frame to allow relative rotation about the rotation axis, a member attached to said static member, designed to form a track for the inward end of said plungers and hence to determine the spacing of the axis of rotation of said static members from said tunnel walls, means for adjusting the location of said track relative to said rotation axis.

4. In a tunnelling machine as claimed in claim 1 wherein said tunnelling means is designed to produce a cylindrical tunnel, rollers rotatably mounted on said frame for supporting the frame while rollably supported by the walls of the tunnel,

means for supplying permanently deformable material in continuous strip form,

means for guiding said strip for longitudinal movement between one of said rollers and the wall of the tunnel, for movement tangentially of and rollably relative to said rollers,

whereby said strip material is applied to the walls in an helical arrangement,

the width of the strip material being related to the roller angular orientation to ensure that the successive strip turns overlap on the tunnel wall,

at least some of the rollers being designed to corrugate the strip material applied to the tunnel wall.

5. In a tunnelling machine as claimed in claim 1 wherein said tunnelling means is designed to produce a cylindrical tunnel, a forward and a rearward ring of rollers,

each roller being rotatably mounted on said frame, said forward and rearward rings being located to rollably support respectively, the forward and rearward ends of said frame on the cylindrical walls of said tunnel,

said roller axes being oriented to produce the helical advance of said frame in said tunnel on rotation of said frame in one direction about the tunnel axis,

the rollers in said rearward ring being mounted to be displaceable relative to said frame along radii from the axis of such cylindrical tunnel, and

a guide member maintained stationary during rotation of said frame, designed to control said radial displacement of individual rollers relative to the frame as a function of the angular displacement of each said roller about the axis of said tunnel.

6. In a tunnelling machine as claimed in claim 5 wherein at least said one of said rollers is powered to rotate relative to said frame to impel said frame to rotate in said tunnel.

7. In a tunnelling machine as claimed in claim 1 including a second arm supported forwardly of said frame for rotatable movement relative to said tunnel along the same locus as said implement mounting arm but angularly displaced therefrom, means allowing the mounting thereon of rock treating implements along radial extents relative to the axis of said rotatable movement corresponding to the corresponding radial extents where said implements are used.

8. A method of tunnelling comprising:

impelling an implement toward the material being tunnelled while mechanically limiting its movements to provide:

that the implement shall move initially in primarily a translatory direction until a predetermined amount of penetration is reached,

that the implement shall continue to move with a component in such translatory direction but providing, during said continuing movement, a predetermined rotary component about an axis transverse relative to the translatory direction whereby material on the deflection side of the penetration location of said implement is deflected in a direction transverse relative to said penetration direction, terminating said continuing movement and returning said implement to its original position.

9. A method of tunnelling comprising:

locating a plurality of material penetrating implements along a line adjacent the tunnelling face of a wall; selectively causing said implements to follow a cycle comprising:

- a. moving with primarily a translatable motion to achieve penetration of the material to be tunnelled;
- b. after achieving a predetermined degree of penetration, continuing said penetration but increasing the rotary component about an axis transverse relative to the translatable direction; whereby material on one side of said implement is deflected in a direction transverse relative to said penetration direction;
- c. returning said implements to their original position.

10. A method as claimed in claim 9 including: on completion of said cycle, moving said implement in a direction approximately opposite to said transverse direction.

11. In a tunnelling machine, a frame, means for supporting said frame on a cylindrical tunnel wall, an arm supported on said frame radially extending from and designed for rotary advancing movement in a predetermined sense about the axis of such tunnel wall; implements mounted on said arm over an extent between a radially inward and a radially outward location thereof; means for actuating said implements for extension away from said arm and retraction toward said arm, means causing said elements, during said extension movement, to translate with a major component parallel to said rotation axis; and means for causing said implements, after a predetermined translation, to rotate about an axis causing the implements to be displaced in a direction, opposite to the direction of advance of said arm relative to the translation direction; means for retracting said elements; and means for intermittently advancing said arm.

12. In a tunnelling machine as claimed in claim 11 wherein said means for supporting said frame on a cylindrical wall comprises:

- a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably supported by the walls of the tunnel, said rollers being mounted to produce an helical advance of said frame in the tunnel on rotation of said frame relative to the tunnel,

said rollers being divided into a group associated with the forward end of the frame and a group associated with the rearward end of the frame,

said rearward group being mounted on members radially movable relative to said frame over a predetermined range, control members for said radially movable members, a member maintained static relative to said frame, rotatably connected to said frame;

means attached to said static member providing a track connected to control the radial translation of said control members relative to said frame, means for adjusting the location of said track relative to said bearing.

13. In a tunnelling machine as claimed in claim 11 wherein said means for supporting said frame on a cylindrical wall comprises:

- a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably supported by the walls of the tunnel, said rollers being mounted and oriented to produce an helical advance of said frame on rotation of said frame relative to the tunnel, said rearward group of rollers being mounted on inwardly extending radial plungers, a static member rotatably mounted on said frame to allow relative rotation about the rotation axis, a member attached to said static member, designed to form a track for the inward end of said plungers and hence to determine the spacing of the axis of rotation of said static members from said tunnel

walls means for adjusting the location of said track relative to said rotation axis.

14. In a tunnelling machine as claimed in claim 11 wherein said means for supporting said frame on a cylindrical wall comprises:

rollers rotatably mounted on said frame for supporting the frame while rollably supported by the walls of the tunnel, means for supplying permanently deformable material in continuous strip form,

means for guiding said strip for longitudinal movement between one of said rollers and the wall of the tunnel, for movement tangentially of and rollably relative to said roller,

whereby said strip material is applied to the walls in an helical arrangement,

the width of the strip material being related to the roller angular orientation to ensure that the successive strip turns overlap on the tunnel wall,

at least some of the rollers being designed to corrugate the strip material applied to the tunnel wall.

15. In a tunnelling machine as claimed in claim 11 wherein said means for supporting said frame on a cylindrical wall comprises:

a forward and a rearward ring of rollers,

each roller being rotatably mounted on said frame, said forward and rearward rings being located to rollably support respectively, the forward and rearward ends of said frame on the cylindrical walls of said tunnel,

the rollers in said rearward ring being mounted to be displaceable relative to said frame along radii from the axis of such cylindrical tunnel, and

a guide member maintained stationary during rotation of said frame, designed to control said radial displacement of individual rollers relative to the frame as a function of the angular displacement of each said roller about the axis of said tunnel.

16. In a tunnelling machine as claimed in claim 15 wherein at least said one of said rollers is powered to rotate relative to said frame to impel said frame to rotate in said tunnel.

17. In a tunnelling machine, as claimed Inc. claim 11 wherein means are provided for controlling the operation of said arm and the operation of said implements, designed and constructed so that said arm is advanced between operations of said implements and said implements are operated between movements of said arm.

18. In a tunnelling machine as claimed in claim 11 wherein said frame is:

provided with rollers rotatably mounted thereon,

said rollers being designed to project outwardly beyond said frame and located and dimensioned to rollably support the frame on the walls of the tunnel,

the rotational axes of said rollers being oriented so that, on rotation of said frame relative to said tunnel, the frame will advance in an helical manner;

means for causing said frame to rotate relative to said tunnel.

19. A device as claimed in claim 18 wherein said arm is mounted on said frame for rotation therewith.

20. In a tunnelling machine, a frame provided with rollers rotatably mounted thereon, said rollers being designed and located to project outwardly beyond said frame and located and dimensioned to rollably support the frame on the walls of the tunnel,

the rotational axes of said rollers being oriented so that on rotation of said frame relative to said tunnel, the frame will advance in an helical manner,

means for mounting on one end of said frame, means for detaching material to be tunnelled;

means for causing said frame to rotate relative to said tunnel.

21. A device as claimed in claim 20 wherein said means for detaching material from one end of said tunnel is; an arm supported forwardly of said frame,

for rotatably movement relative to said tunnel in a predetermined sense thereby defining an advancing and a trailing direction;

a plurality of digging implements mounted on said arm; each of said implements being selectively actuatable to cyclically translate between an extended forward and a retracted rearward position relative to said arm in a direction, having in the initial part of the extension direction, a major component parallel to said axis of rotation;

each of said implements being controlled to rotate, as well as translate toward the end of said translation extension, said rotation being directed to cause the tips of the implements to move the component in the trailing direction relative to said arm rotation;

each of said implements being provided with tips directed in the extension direction to facilitate entrance by said implement into the material being tunnelled.

22. A digging implement mounted on a support;

means for causing said implement to start from a predetermined location and to move away from said support, initially with primarily a translatory motion,

means for causing said implement after its initial movement to describe a rotation, to return to its location in said frame,

said implement being shaped, at the end farthest from the frame, to assist its entry into subsurface material during said translatory motion.

23. Means as claimed in claim 22 wherein said implement end farthest from said support is shaped to provide a sharpened edge directed in the translatory direction.

24. In a tunnelling machine, having a frame for supporting the tunnelling means, where the tunnelling means is designed to produce a cylindrical tunnel, a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably supported by the walls of the tunnel said rollers being mounted to produce an helical advance of said frame in the tunnel on rotation of said frame relative to the tunnel,

said rollers being divided into a group associated with the forward end of the frame and a group associated with the rearward end of the frame,

said rearward group being mounted on members radially movable relative to said frame over a predetermined range, control members for said radially movable members, a member maintained static relative to said frame, rotatably connected to said frame;

means attached to said static member providing a track connected to control the radial translation of said control members relative to said frame, means for adjusting the location of said track relative to said bearing.

25. In a tunnelling machine having a frame for supporting the tunnelling means, where the tunnelling means is designed to produce a cylindrical tunnel, a forward set and a rearward set of rollers rotatably mounted on said frame for mounting the frame while rollably supported by the walls of the tunnel, said rollers being mounted and oriented to produce an helical advance of said frame on rotation of said frame relative to the tunnel, said rearward group of rollers being mounted on inwardly extending radial plungers, a static member rotatably mounted on said frame to allow relative rotation about the rotation axis, a member attached to said static member, designed to form a track for the inward end of said plungers and hence to determine the spacing of the axis of rotation of said static members from said tunnel walls, means for adjusting the location of said track relative to said rotation axis.

26. In a tunnelling machine, having a frame for supporting tunnelling means, where the tunnelling means is designed to produce a cylindrical tunnel, rollers rotatably mounted on said frame for supporting the frame while rollably supported by the walls of the tunnel,

means for supplying permanently deformable material in continuous strip form,

means for guiding said strip for longitudinal movement between one of said rollers and the wall of the tunnel, for movement tangentially of and rollably relative to said roller,

whereby said strip material is applied to the walls in an helical arrangement,

the width of the strip material being related to the roller angular orientation to ensure that the successive strip turns overlap on the tunnel wall,

at least some of the rollers being designed to corrugate the strip material applied to the tunnel wall.

27. In a tunnelling machine as claimed in claim 26 wherein at least said one of said rollers is powered to rotate relative to said frame to impel said frame to rotate in said tunnel.

28. In a tunnelling machine having a frame having a forward and rearward end supporting at the forward end thereof, the tunnelling means, where such tunnelling means is designed to produce a cylindrical tunnel, a forward and a rearward ring of rollers,

each roller being rotatably mounted on said frame, said forward and rearward rings being located to rollably support respectively the forward and rearward ends of said frame on the cylindrical walls of said tunnel,

said roller axes being oriented to produce the helical advance of said frame in said tunnel on rotation of said frame in one direction about the tunnel axis,

the rollers in said rearward ring being mounted to be displaceable relative to said frame along radii from the axis of such cylindrical tunnel, and

a guide member maintained stationary during rotation of said frame, designed to control said radial displacement of individual rollers relative to the frame as a function of the angular displacement of each said roller about the axis of said tunnel.

29. In a tunnelling machine,

a frame

an arm supported forward of said frame,

for rotatable movement relative to said tunnel in a predetermined sense,

said arm extending with a radial component relative to the axis of such rotatable movement,

a digging implement mounted on said arm,

such implement being selectively actuatable to cyclically translate between an extended forward and a retracted rearward position relative to said arm, in a direction having in the initial part of the extension direction, a major component parallel to said axis of rotation,

such implement being controlled to rotate as well as translate toward the end of said translation extension, said rotation being directed to cause the tip of the implement to move with a component on the trailing direction relative to said predetermined arm rotation sense,

such implement being provided with a tip directed in the extension direction to facilitate entrance by said implement into the material being tunnelled,

and means for causing said implement to perform its translation and rotation action at locations having different radial distances from the axis of said rotatable movement.

30. In a tunnelling machine, a frame,

means for supporting said frame on a cylindrical tunnel wall,

an arm supported on said frame and radially extending from and designed for rotary advancing movement in a predetermined sense about the axis of said tunnel wall,

an implement mounted on said arm and mounted and designed to be movable thereon between a radially inward and a radially outward location thereof;

means for actuating said implement for extension away from said arm and retraction toward said arm,

means causing said implement, during said extension movement, to translate with a major component parallel to said rotation axis;

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means for causing said implement, after a predetermined translation, to rotate about an axis causing the implement to be displaced in a direction opposite to the direction of advance of said arm relative to the translation direction, means for retracting said element;

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means for intermittently advancing said arm, means for moving said implement to various radial locations along said arm between said radially inward and radially outward locations.

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