Oct. 19, 1971 J. D. JACOBS 3,613,384

METHOD AND APPARATUS FOR ADVANCING TUNNEL SUPPORTS

Filed Feb. 10, 1969 4 Sheets-Sheet 1

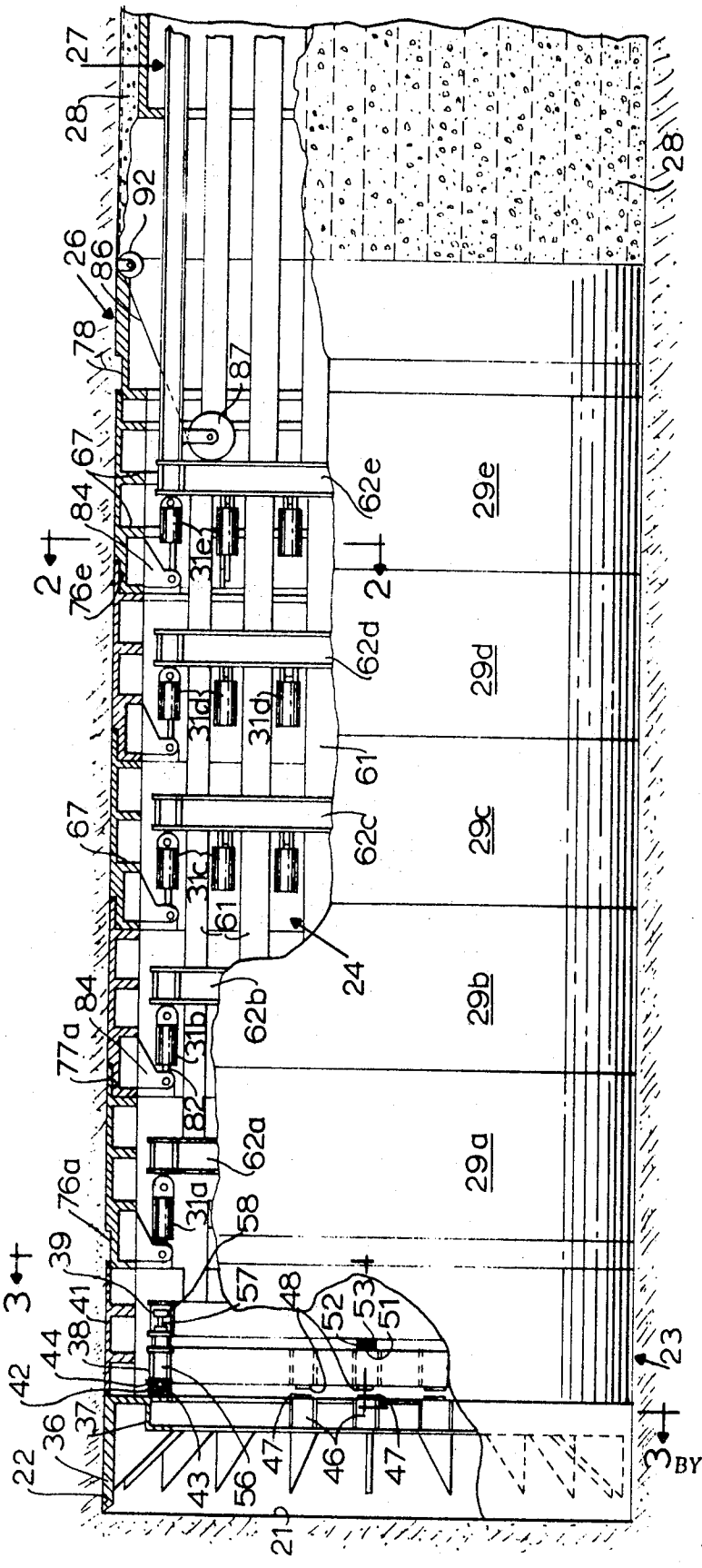


FIG. 1

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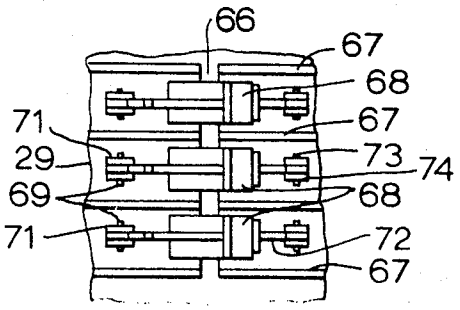


FIG. 4

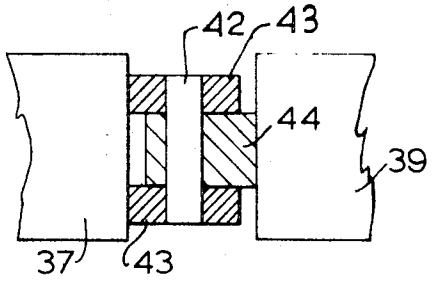


FIG. 6

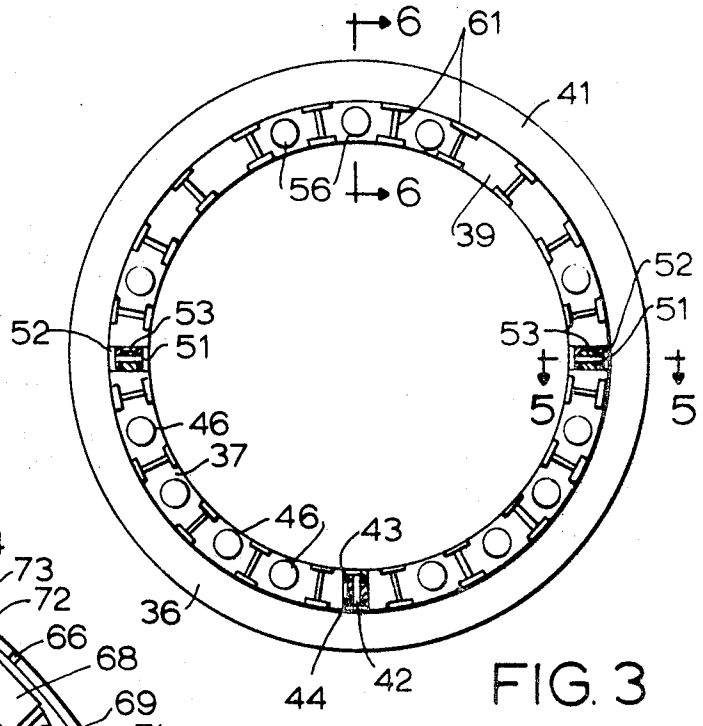


FIG. 3

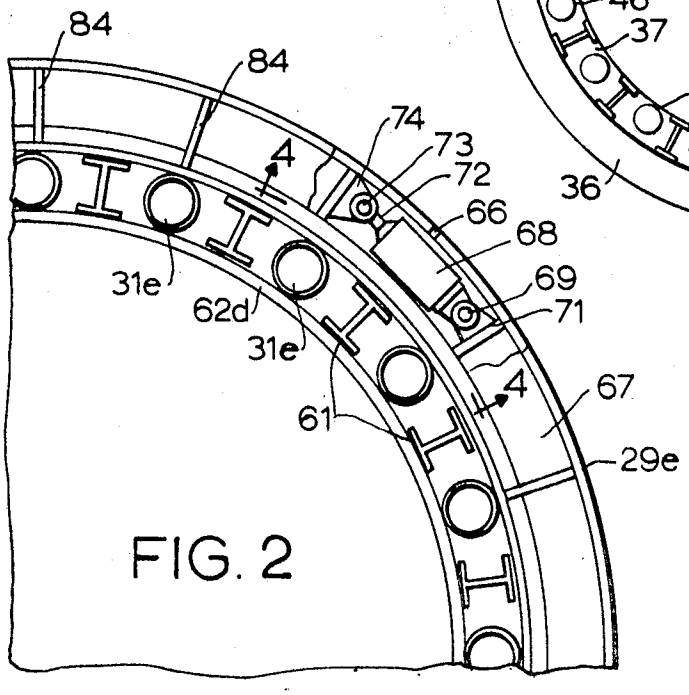


FIG. 2

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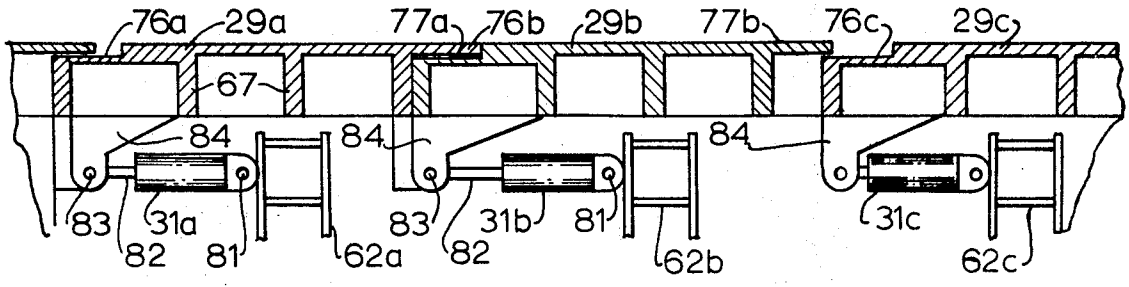


FIG. 8

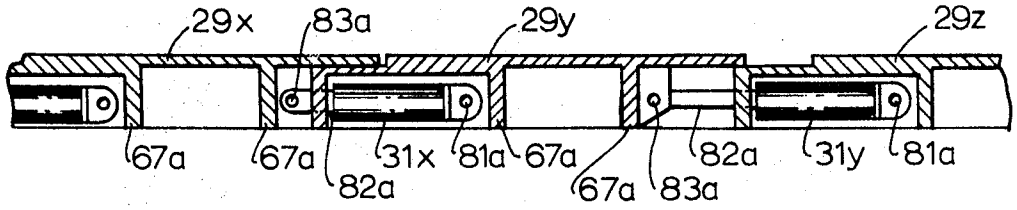


FIG. 9

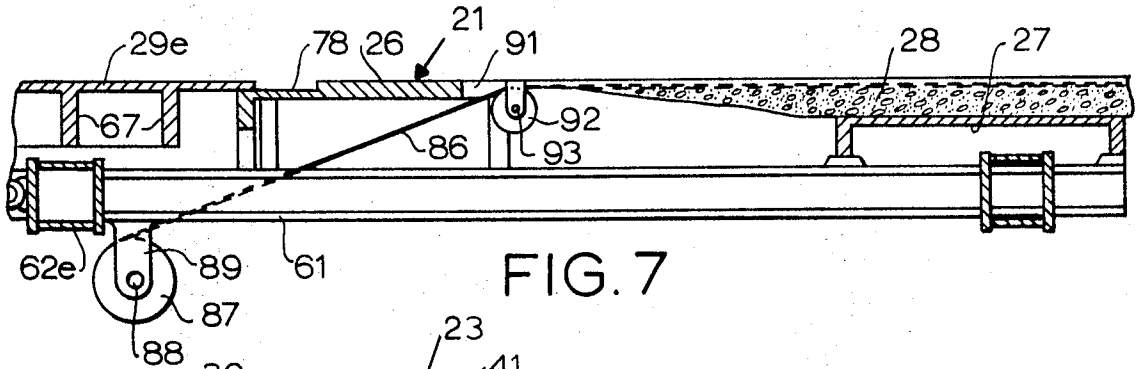


FIG. 7

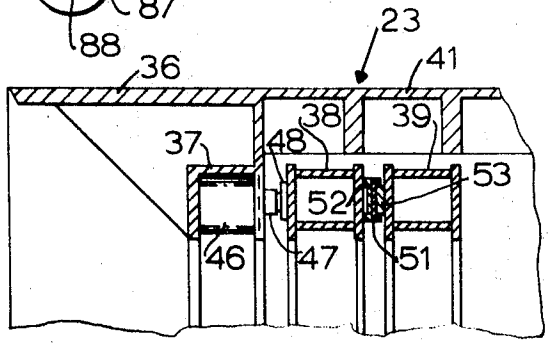


FIG. 5

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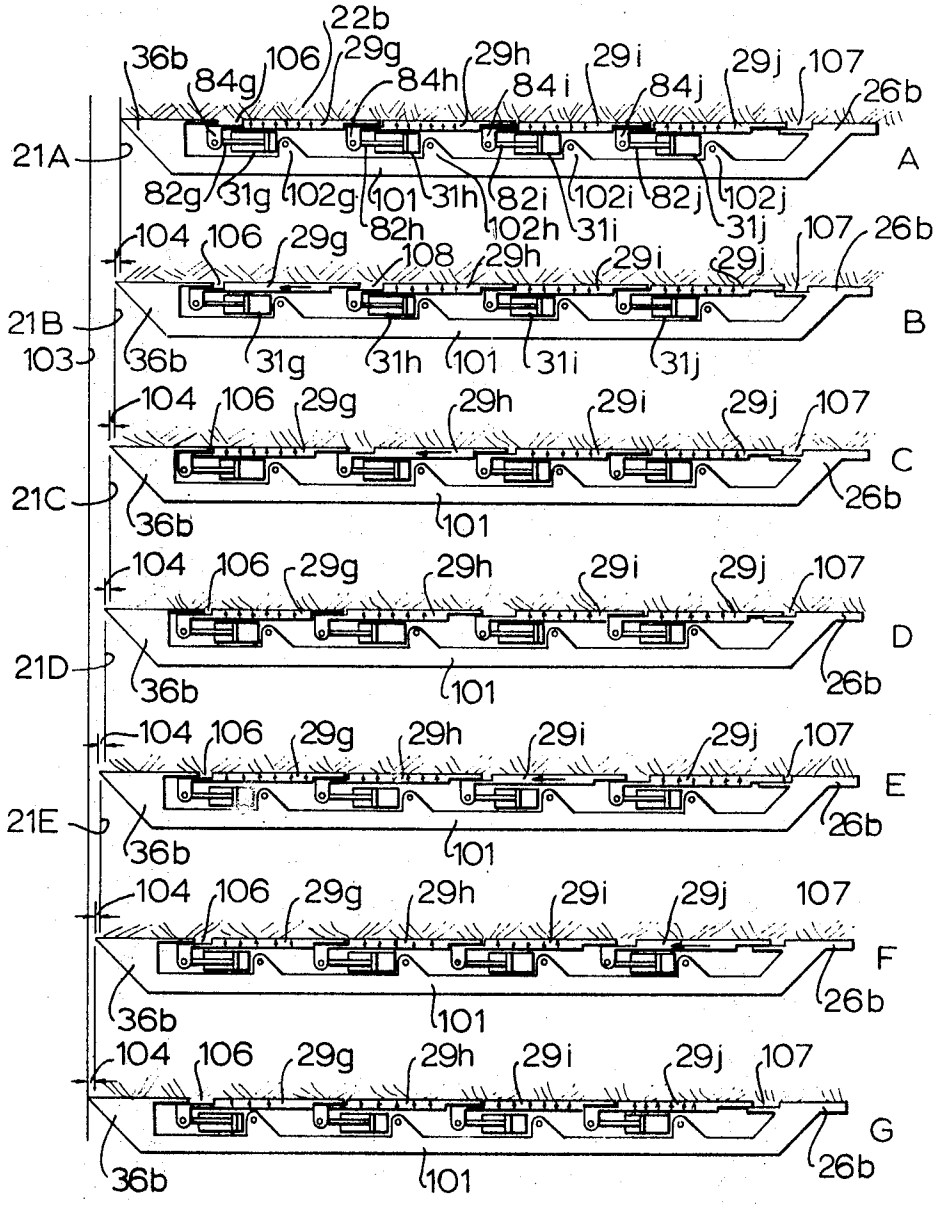


FIG. 10

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METHOD AND APPARATUS FOR ADVANCING TUNNEL SUPPORTS

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Int. Cl. E01g 3/00
U.S. Cl. 61—85 16 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and method for continuously or intermittently advancing tunnel supports against surrounding earth pressure. Cutting edge and trailing shells are interconnected by a longitudinal frame or cage structure. Intermediate the forward and trailing shell are overlapping intermediate shells which are individually connected to the cage structure by hydraulic cylinders so that each intermediate shell can be moved longitudinally relative to the others and relative to the tunnel wall while the other intermediate shells engage the tunnel wall and advance the cage as well as the forward or support and trailing shells. The intermediate shells are sequentially moved forwardly, preferably by releasing the pressure exerted against the wall, as by contracting the shell. The support may incorporate steering guidance means for adjusting the direction of the excavation device about perpendicular transverse axes. Means is also provided on the trailing shell for feeding out the rearward end wires or rods to support the tunnel walls prior to concreting and also a retainer shell which functions as a screed for the concrete and supports the concrete as it is gaining strength.

A tunnel excavation device may be of various types, one common type having a rotary cutting or boring head containing wheels or knives or blades which cut or scarify the rock or earth at the face of the tunnel causing it to fall away from the face and thus creating the tunnel bore. Such device further incorporates means for picking up the material which is loosened and discharging the material onto a conveyor for ultimate disposal. In order to operate effectively, the excavation device must be forced against the tunnel face with tremendous pressure and this requires an anchor or support for the device. Previously used supports for this purpose have certain disadvantages. A principal object of the present invention is the provision of improved means for anchoring the tunnel excavation device so that it may be forced against the face of the tunnel with the requisite pressure.

A further principal effect of the present invention is to provide a support for the tunnel wall during excavation which is capable of advancing continuously, although intermittent advance is also possible. As a result, it is not necessary to discontinue the excavating action while the support is being moved forwardly and thus the present invention reduces the time required for excavation.

Another feature of the present invention is the fact that the support may be guided so that the excavation device will dig a curved path and the direction of the curve and, within reasonable limits, the radius of the curve is subject to considerable variation under the control of the operator.

Another principal feature of the present invention is the fact that the machine may operate in relatively soft ground where other tunnel boring head advancing equipment will not adequately grip the tunnel wall or face. Thus, as hereinafter explained in detail, a plurality of shells are brought into firm engagement with the tunnel wall immediately behind the forward edge of the device

and the combined effect of a plurality of such shells engaging the wall adequately anchors the machine and enables the device to be forced forwardly with the necessary pressure. In addition, the movable shells adequately support the tunnel wall until such time as concrete may be applied to the wall and provided sufficient time to set.

Accordingly, still another principal feature of the invention is the fact that the machine supports the tunnel wall rearwardly of the excavation device against surrounding earth pressure for a sufficient distance so that a concrete lining may be applied to the tunnel bore and allowed partially to set. Thus, the invention provides structure for simultaneously advancing the excavating device and supporting in place the earth and rock behind the head.

Still another feature of the invention is the fact that a plurality of wires or rods are fed out adjacent the rear of the machine in close proximity to the tunnel walls temporarily supporting the walls until concrete can be applied.

Another feature of the invention is the provision of a space to the rear of the supporting means providing access to the tunnel wall so that concrete under pressure may be used to face the wall surrounding the wires or rods which have heretofore been mentioned.

Still another feature of the invention is the provision of a trailing shell which follows the application of concrete and functions as a screed and also supports the concrete for sufficient time to enable it to begin to set.

One of the features and advantages of the invention is the provision of a concrete support which is moved continuously at the same speed at which the boring head advances in a continuous movement immediately behind the point of application of the concrete.

Other objects of the present invention will become apparent upon reading the following specification and referring to the accompanying drawings in which similar characters of reference represent corresponding parts in each of the several views.

In the drawings:

FIG. 1 is a vertical sectional view, partially broken away to reveal internal construction, of one form of machine in accordance with the present invention.

FIG. 2 is a transverse sectional view taken substantially along line 2—2 of FIG. 1 in enlarged scale and partially broken away to conserve space.

FIG. 3 is a transverse sectional view taken substantially along line 3—3 of FIG. 1.

FIG. 4 is a fragmentary view of the intermediate shell expanding means as viewed substantially along line 4—4 of FIG. 2.

FIG. 5 is a fragmentary view of a hinge means for one of the steering rings as viewed substantially along line 5—5 of FIG. 3.

FIG. 6 is a fragmentary sectional view in enlarged scale taken substantially along line 6—6 of FIG. 3.

FIG. 7 is an enlarged fragmentary longitudinal sectional view through a portion of the rear of the machine.

FIG. 8 is a fragmentary longitudinal sectional view through a portion of the intermediate shells and surrounding structure.

FIG. 9 is a view similar to FIG. 8 of a modification.

FIG. 10 is a schematic view illustrating the method of the invention.

The machine which is the subject of the present invention is installed as part of the equipment used to dig a tunnel having a face 21 which is here shown vertical and a tunnel bore 22 which is here assumed to be horizontal and circular in cross-section. The face 21 is continuously cut away usually by an excavating device (not shown) of a type commercially available such as, for example, a

boring head disposed with the supporting structure 23 positioned immediately behind the face 21. As has heretofore been mentioned, the excavating device cuts or scarifies the tunnel face and the material displaced is collected and conveyed to the rear for disposal by means well understood in the tunneling art and not herein illustrated or described. Extending rearward from the rear of the support 23 is a cage structure 24 or frame which extends the entire length of the machine. Optionally, adjacent the rear of the cage structure 24 a trailing support shell 26 may be connected to the cage structure. It is a feature of the present invention that the support 23, cage structure 24 and trailing support shell 26 move together and it is a further feature of the invention that the same are capable of advancing continuously at a substantially uniform rate, although in some installations they may move intermittently. As an optional feature of the invention, the cage structure 24 may extend rearwardly of the support shell 26 and be connected to a concrete retainer shell 27 which is of a lesser diameter to provide for the facing of the tunnel wall with concrete 28, all as hereinafter explained.

The cage structure 24 is anchored by a plurality of intermediate shell rings, 29*a* to 29*e* shown in FIG. 1 as five in number, each overlapping the adjacent rings and movable relative thereto and each articulately connected to the cage structure 24 by a plurality of hydraulic rams 31*a* to 31*e*. In a preferred method of operation of the invention, all of the intermediate shells 29*a* to *e* but one is anchored to the tunnel wall 22 and the rams 31 of the anchored shells are energized by hydraulic pressure to continuously force the cage structure 24 and accordingly the support structure 23 forwardly. The one shell 29 which is not anchored to the tunnel wall moves forwardly to the limit of the stroke of its ram 31, whereupon it is caused to be anchored to the tunnel bore 22 by means hereinafter explained in detail, and thereupon the next rearward intermediate shell 29 is disengaged from the tunnel wall and is moved forwardly until it abuts the shell which has preceded it. Each of the intermediate shells 29 is disengaged, advanced and re-engaged sequentially until the last of the intermediate shells 29*e* has been moved forwardly, whereupon the cycle is repeated with the forwardmost intermediate shell 29*a* being moved forwardly. Inasmuch as all but one intermediate shell 29 is firmly engaged with the tunnel wall 21, an effective means for anchoring the machine is provided which enables the cage structure 24 to be forced forwardly in the manner which has been described. At the same time, inasmuch as the intermediate shell 29 is individually sequentially being moved forwardly, the entire machine gradually advances, enabling the machine to move continuously rather than intermittently. Intermittent movement is contemplated as an alternate, however. The parts of the machine will be described in order.

The excavating support 23 comprises annular rings which are the cutting ring 36 which is at the front and has a diameter equal to bore 22, smaller diameter horizontal steering ring 37, the vertical steering ring 38 and the cage attachment ring 39. Ring 37 is within ring 36. Rings 38 and 39 are enclosed within shell 41 which is of the same diameter as cutting ring 36. The horizontal steering ring 37 and vertical steering ring 38 are articulated. In the means of articulation here illustrated, at the top and the bottom of the machine is a vertically disposed steering pin 42 and eyes 43, 44 fixed to rings 37, 38 and receiving pin 42 in oversize holes to permit relative flexing of the rings, as shown in FIG. 6, the arrangement of eyes 43, 44 and pin 42 resembles an ordinary door hinge. Disposed within horizontal steering ring 37 on either side of the machine is a plurality of horizontal guidance cylinders 46, the rods 47 of which engage abutments 48 on the vertical steering ring 38. When the cylinders 46 on the right-hand side of the machine are energized to project their rods 47 while those of the left-hand side are energized to retract their rods, the horizontal steering ring 37 tilts about the vertical axis of pins 42 to the left, thereby steering the cutting ring 36 to the left. If the opposite cylinders 46 are energized, then the machine is steered to the right. If both sets of cylinders 46 are at neutral, the machine steers straight ahead.

Between the vertical steering ring 38 and the cage anchor ring 39 on either side of the machine are transverse horizontal steering pins 51 which are received in eyes 52, 53 similar to eyes 43, 44 and affixed to the rearward face of the vertical steering ring 38 and the forward face of the cage support ring 39, respectively. Mounted in vertical support ring 38 is a plurality of vertical guidance cylinders 56, some at the top and some at the bottom, the rods 57 of which engage abutments 58 on ring 39. When the cylinders 56 at the top of the machine are energized to project their rods 57 while the cylinder 56 at the bottom of the machine are energized to retract their rods 57, the machine tilts about a transverse horizontal axis through the axes of pins 51 to steer the cutting head downwardly. When the energization of the cylinders 56 is reversed, the machine steers upwardly, and when the cylinders 56 at top and bottom are equally energized, the machine advances horizontally.

It will be seen that selective energization of the various guidance cylinders 46, 56 enables the machine to be steered to left or right or up or down, or that a compound curve may be generated. The guidance cylinders 46, 56 enable the machine to be steered in accordance with a predetermined path and also to compensate for any tendency of the machine to drift out of the desired path.

Connected to cage support ring 39 is the cage structure 24. Extending longitudinally of the machine is a plurality of horizontal struts 61 equi-arcuately spaced around the perimeter of the cage structure. A plurality of transverse vertical cage rings 62*a* to 62*e* are connected to struts 61. The cage rings 62 are equi-distantly spaced longitudinally of the machine. The trailing support shell 26 is connected to the perimeter of the cage structure by brackets 63. Where a concrete retainer shell 27 is used, the struts 61 extend further rearwardly and there is at least one additional cage ring 62*f* and said shell 27 is connected to the struts 61 by brackets 64. It will be seen that ring 39, struts 61, intermediate cage rings 62 and shell 26 (and where used shell 27) are interconnected in a unitary structure.

Each intermediate shell 29 is split along at least one longitudinal element 66 and is further formed with a plurality of inwardly projecting strengthening ribs 67. Shell 29 may be made to expand and contract and in expanded condition the shell firmly engages tunnel wall 22 and movement longitudinally relative thereto is impeded by the frictional engagement of the surface of the shell with the tunnel wall. When the shell is contracted, the shell may be moved longitudinally relative to the tunnel wall. As has previously been mentioned, at any given instant, all of the intermediate shells 29 but one is expanded and in firm engagement with the tunnel wall, whereas one shell is contracted and moves relative to the wall to an advanced location. One means of expanding and contracting the shells is illustrated in detail in FIG. 4. One or more cylinders 68 is located bridging the split 66 in the shell perimeter, cylinder 68 being pivotally connected by pin 69 to bracket 71 fixed to shell 29 on one side of split 66 and rod 72 of cylinder 68 is connected by pin 73 to bracket 74 on the other side of split 66. When cylinder 68 is energized to extend rod 72, shell 29 is expanded and when cylinder 68 is energized in the opposite direction to contract the rod 72, shell 29 is contracted.

Shells 29 are formed so that they overlap. Thus the exterior of leading edge 76*a* of the forwardmost intermediate shell 29*a* is relieved at its perimeter by the thickness of the trailing edge of excavating support shell 41. At the trailing edge of the intermediate shell 29*a*

the inner surface 77*a* is similarly internally relieved. Each of the intermediate shells 29*b* to 29*e* is constructed similarly to the leading intermediate shell 29*a*. To accommodate overlapping trailing support shell 26 and the last of the intermediate shells 29*e* the outer periphery 78 of the leading edge of the trailing support shell 26 is relieved. The individual shells 29 move forwardly at any given time a distance which is slightly less than the length of relief 76; hence at any instant the shells overlap.

Movement of the intermediate shells 29 is accomplished by energization of a plurality of peripherally spaced propulsion cylinders 31*a* to 31*e*. The rearward end of each propulsion cylinder 31 is pinned by pin 81 to the adjacent cage ring 62. The rod 82 of each such cylinder is pivoted by means of pin 83 to bracket 84 fixed adjacent the forward end of each intermediate shell 29. Thus each cylinder 31 is fixed to cage structure 24 and the position of each intermediate shell 29 relative to cage structure 24 depends upon the position of its rod 82 relative to cylinder 31. Preferably, all of the cylinders associated with a given intermediate ring 29 are energized equally and at the same time. Assuming that it is desired to advance the forwardmost of the intermediate shells 29*a* relative to the cage structure 24, it is assumed that there is a gap in the overlap of said shell 29*a* relative to shell 41 of structure 23 as is seen in FIG. 1 by exposure of relief 76*a* and shell 29*a* has been contracted in diameter by retraction of its rod 72, the forwardmost cylinders 31*a* are energized to project their rods 82 and thus shell 29*a* is moved forwardly until the overlap is overcome. Thereupon shell 29*a* is expanded by projection of its rod 72 to engage the tunnel wall 22. Meanwhile the next rearward shell 29*b* has been contracted and each cylinder 31*b* is energized to advance said shell 29*b* to overcome the gap which has been created in the overlap between shells 29*a* and 29*b*. This sequential contraction of the periphery of shell 29, forward advance and expansion of the periphery of the shell is continuously repeated from front shell 29*a* to rear shell 29*e* and then renewed at front shell 29*a*. However, the energization of the propulsion cylinders 31 to advance the individual intermediate shell relative to the others is only part of the continuous cycle of energization of said cylinders. Thus each cylinder 31 which is not immediately being used to advance an intermediate shell 29 is continuously being energized to retract its rod 82 relative to the cylinder 31. Since rods 82 are connected to the intermediate shells 29 which are in turn in firm engagement with the tunnel wall 22 and since the cylinders 31 are connected to cage structure 24, the contraction of rods 82 continuously forwardly advances cage structure 24. Forward advance of cage structure 24 pushes forwardly the support 23 for the excavating device and thus applies a continuous pressure on the device.

The fit between the individual intermediate shells 29 is such that they may twist relative to the longitudinal axis of the machine and relative to each other sufficiently to follow the steering path of the steering mechanism of the boring head support structure 23. An annular gap is maintained between the underside of relieved portion 77 at the trailing edge of each shell and the outer surface of each leading edge 76. Thus when a preceding shell 29 is in contracted condition its trailing edge does not impose pressure on the leading edge of the succeeding shell which prevents the contracted shell from moving relative to the expanded trailing shell.

Directing attention to FIG. 9, an alternate means for advancing the machine is disclosed. The intermediate rings 29*x* to 29*z* are articulately connected to adjacent rings rather than to the cage structure. Thus the rearward end of the cylinder 31*x* is fixed by means of pin 81*a* to one of the reinforcing ribs 67*a* of intermediate ring 29*y*. Rod 82*a* is pivoted by means of pin 83*a* to one of the ribs 67*a* of the next forwardmost intermediate ring 29*x*. In other respects, the structure of FIG. 9, is essentially the same as that previously described and the same reference numerals followed by subscript *a* are used to designate corresponding parts. However, in this structure, the advance of the boring head support 23 is intermittent rather than continuous. During such time as the forwardmost intermediate ring 29 is being advanced, advance of the boring head support ring is discontinued. When such forwardmost intermediate ring is in forward position and expanded to engage the tunnel wall, the forward progress of the boring head support 23 is resumed.

FIG. 7 shows a preferred means for feeding a plurality of rearwardly extending heavy wires 86 or small rods from the tail of the trailing support shell 26. Thus a plurality of reels 87 of said wire or rods is mounted by means of shafts 88 which are connected by brackets 89 to struts 61. Suitable brakes (not shown) maintain the wires 86 or rods taut at all times. Longitudinal slots 91 are formed in the trailing edge of shell 26 for the egress of wires 86 and said wires are held in place near the periphery of the tunnel wall 22 by pulleys 92 mounted in brackets 93 at the slots 91. Hence the wires 86 extend rearwardly and are spaced closely enough together so that they prevent large rocks and debris falling into the tunnel behind the support ring 26. The term "supporting material" is used herein to include not only reinforcing wire 86 and rods but also ribbon, straps and flat sheets to perform a similar purpose. The space between ring 26 and screed 27 is used to apply concrete 28 to the tunnel wall and the wires support the wall 22 until the concrete 28 begins to set.

Screed 27 is of a diameter equal to the inside diameter of concrete 28 and its periphery serves to smooth the concrete as it moves forwardly. Furthermore, screed 27 supports the concrete for a period of time sufficient to enable it to gain strength.

METHOD OF OPERATION

Directing attention to FIG. 10, it will be observed that only four intermediate rings 29*g* to 29*j* are shown in order to emphasize that the number is discretionary and also to simplify explanation of the method of operation. Steering devices and other auxiliary features are eliminated for simplification. Cage 24 is represented by a single strut 101 having a cutting support member 36*b* at the front and a trailing shell 26 and four intermediate cylinder abutments 102*g* to 102*j*. The cylinders 31*g* to 31*j* bear against abutments 102*g* to 102*j*, while their rods 82*g* to *j* bear against brackets 84*g* to *j* on shells 29*g* to *j* respectively.

Vertical line 103 is a reference or datum line and does not represent the tunnel face except at the end of the completion of the cycle of operation illustrated. The cycle is shown in equal time intervals proceeding from top to bottom of the figure, the initial position being shown in sub-FIG. A and the last as sub-FIG. G; which is the same as sub-FIG. A except that the strut 101 has advanced from tunnel face 21A to reference line 103. The increment of movement of member 36*b* per time interval is indicated by numeral 104, and a feature of the invention is the capability of advance continuously in equal increments per unit of time.

In FIG. A the vertical arrows on members 29*g–j* indicate that these rings are expanded, bearing against bore 22*b*. Gap 106 exists between 29*g* and 36*b*; gap 107 between 29*j* and 26*b* (corresponding to shell 26 of FIG. 1). At this instant of time, none of the rings 29 is advancing. Note rod 82*g* is retracted, rod 82*h* projected one-fourth its travel, rod 82*i* one-half, and rod 82*j* three-fourths. Immediately after the instant of FIG. 10A, shell 29*g* is contracted (see prior description of mechanism of FIGS. 2 and 4 to perform this step).

FIG. 10B shows no vertical arrows on shell 29*g* indicating it is contracted. The horizontal arrow shows shell 29*g* is moving to the left and has about reached the limit of its movement since gap 106 is about closed, whereas a gap 108 between shells 29*g* and 29*h* has opened. In FIG. 10B rings 29*h–j* are expanded and anchored against bore 22. Rods 82*h*, *i* and *j* have retracted equal amounts—equal

to distance 104, while rod 82*g* has projected. Thus strut 101 in the interval between FIG. 10A and 10B has advanced distance 104 toward reference line 103 by action of cylinders 31*h* to *j* and shell 29*g* has advanced the length of gap 106 toward reference line 103 by action of cylinder 31*g*. Immediately after the instant illustrated in FIG. 10B, shell 29*g* is expanded and shell 29*h* contracted.

FIG. 10 illustrates, therefore, the sequential expansions and contractions of shells 29 to grip bore 22 and to relax such grip. It also illustrates gradual extension of the rods 82 connected to shells 29 which are expanded to thereby gradually advance strut 101 and cutting ring 36*b*. Finally, it illustrates relatively rapid sequential advance of shells 29 which are contracted to eliminate the gap between said shells and the shell in advance thereof. The fact that the rods 82 are projected different distances at each time interval is likewise illustrated.

During most of the cycle of movement each shell is expanded and the combined effect of the expanded shells is to anchor strut 101 against the thrust of the cylinders 31 advancing ring 36*b*. One shell 29, however, at almost every instant its contracted and is moving forward relative to the others to close the gap ahead of it. When such gap is closed, the shell is expanded and the next shell is contracted and advanced.

Referring to FIGS. 1–9, if it is necessary to change the direction of the excavating device in order to bring it back into a straight line or to cause it to travel on a curve, the guidance cylinders 46 and 56 are used in a manner which has heretofore been explained, causing pivotal movement of ring 37 relative to ring 38 about the axes of pins 42 and of ring 38 relative to ring 39 about the axes of pins 51. Because of the fact that there is not a tight engagement of ring 41 relative to intermediate rings 29*a*, the two rings may twist slightly relative to each other so that they follow the necessary curvature, and the same relationship exists between the adjacent rings 29.

Where used, the wires 86 or rods are being continuously fed out through slots 91 at the trailing edge of the trailing support shell 26, lying in close proximity to the tunnel wall 22 and protecting the interior of the tunnel from falling rocks and large lumps of dirt. Concrete 28 is applied as soon as the trailing support 26 has passed a given point. Modern pneumatic concrete sets up rather rapidly so that advance of the tunnel boring machine and the setting up of the concrete is substantially simultaneous. Screed 27 is drawn over the interior of concrete 28 to smooth the same and it also provides additional support while the concrete is gaining strength.

What is claimed is:

1. A machine for supporting earth around the periphery of a bore comprising a plurality of shells arranged end-to-end, means independently operable to advance each said shell relative to the next shell, whereby said machine advances relative to said bore, means for individually sequentially causing each said shell to grip said bore to resist sliding movement of said shell relative to said bore and then to release the grip of said shell on said bore to permit sliding movement of said shell relative to said bore.

2. A machine according to claim 1, which further comprises means for individually expanding and contracting each said shell between expanded condition gripping said bore to resist sliding movement relative to said bore and contracted condition wherein said shell is slidable relative to said bore.

3. A machine according to claim 1, which further comprises a forward support ahead of the forwardmost said shell, an articulated connection means between said forward support and said forwardmost of said shells, said connection means having hinges pivoting about an axis transverse to the direction of advance of said shells and guidance means for pivoting said support about said axis to guide the direction of advance of said support relative to said shells.

4. A machine according to claim 3 in which said connection means comprises second hinges pivoting about a second axis transverse to said direction of advance and to the axis of said first-mentioned hinges and second guidance means for pivoting said support about said second axis.

5. A machine according to claim 1 which further comprises a screed connected for movement with said shells in trailing relation to the rearmost of said shells to provide a gap for concreting of said bore.

6. A machine according to claim 1 which further comprises supporting material feed means and means adjacent the rear of said machine for mounting said feed means to apply reinforcing material to said bore rearward of said machine as said machine advances.

7. A machine according to claim 1 which further comprises a frame attached for movement with said shells inside said shells, said second means comprising a plurality of sets of activators, the number of said sets corresponding to the number of said shells, said activators attached at one end to said frame and at the other end to said shells.

8. A machine according to claim 7 in which said activators are hydraulic rams.

9. A machine according to claim 7, which further comprises a retainer shell trailing said first-mentioned shells and fixed for movement with said frame, said first-mentioned shells movable relative to said frame, said retainer shell substantially non-movable relative to said frame.

10. A machine according to claim 9, which further comprises a screed fixed to the rear of said frame with a gap between said retainer shell and said screed for concreting said bore.

11. A machine according to claim 10, which further comprises supporting material feed means mounted on said frame to discharge supporting material behind said retainer shell to the surface of said bore as said machine advances.

12. A machine according to claim 1, in which said means comprises a plurality of rams, one end of each ram attached to one shell and the other end of each ram attached to the next rearmost shell.

13. In a machine for supporting earth around the periphery of a tunnel bore, at least one shell adapted to fit within a bore, a frame connected to said shell, means for advancing said shell along said bore, supporting material feed means mounted for movement with said frame arranged to feed supporting material under tension as said shell advances rearward of said shell in close proximity to said bore and to support said bore immediately behind said shell at all times, and means associated with said feed means for maintaining said supporting material taut at all times.

14. A machine according to claim 13, wherein said feed means comprises a plurality of reels for supporting material.

15. A device for supporting earth excavation equipment comprising a plurality of earth-engaging means extending trnsversely of a tunnel bore and arranged end-to-end, a frame extending longitudinally of said bore, and a plurality of sets of activators, the number of said sets corresponding to the number of said means, each said set attached at one end to said frame and at the other end to one of said means, said activators operable to advance an individual means relative to said frame while advancing said frame relative to the remainder of said means, each of said earth-engaging means having anchoring means to cause each said earth-engaging means independently to anchor to the tunnel bore and then to disengage from the tunnel bore.

16. A device for supporting earth excavation equipment comprising a plurality of earth engaging means extending transversely of a tunnel bore and arranged end-to-end, a frame extending longitudinally of said bore, and a plurality of sets of activators, the number of said sets corresponding to the number of said means, each said set

attached at one end to said frame and at the other end to one of said means, said activators operable to advance an individual means relative to said frame while advancing said frame relative to the remainder of said means.

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