Feb. 3, 1970 G. SCHONFELD 3,493,165

CONTINUOUS TUNNEL BORER

Filed Nov. 20, 1967 4 Sheets-Sheet 1

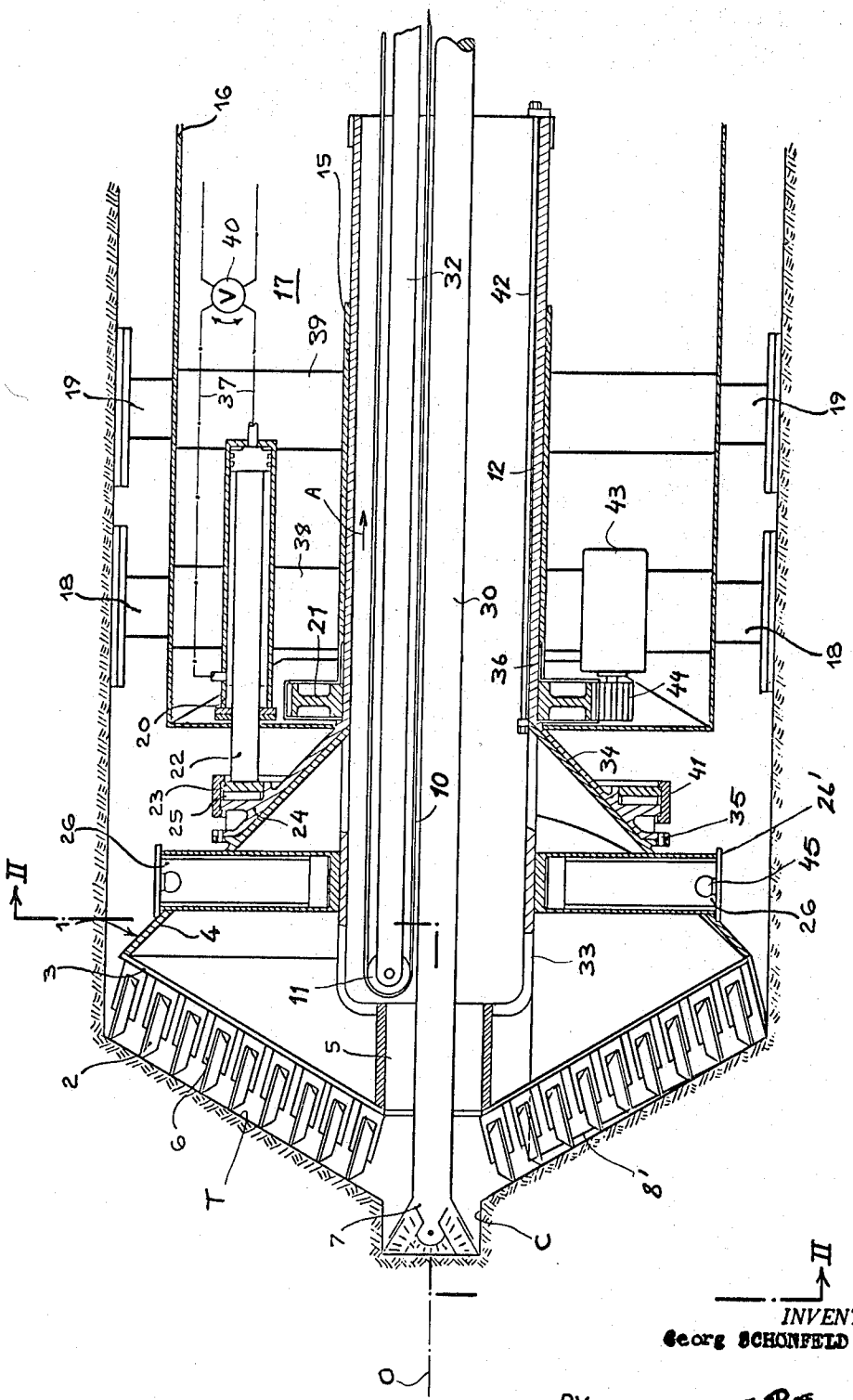

Fig. 1

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CONTINUOUS TUNNEL BORER

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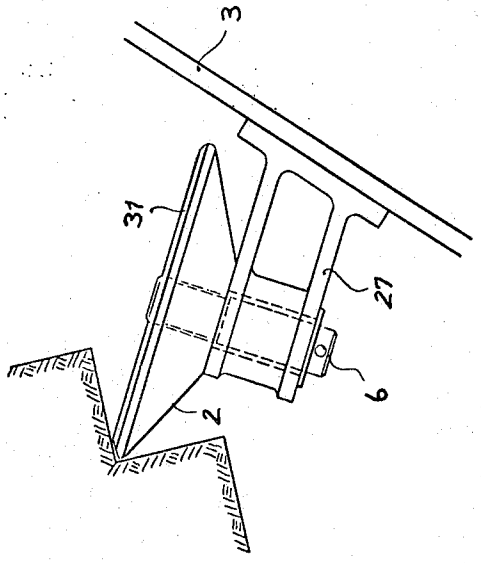

Fig. 5.

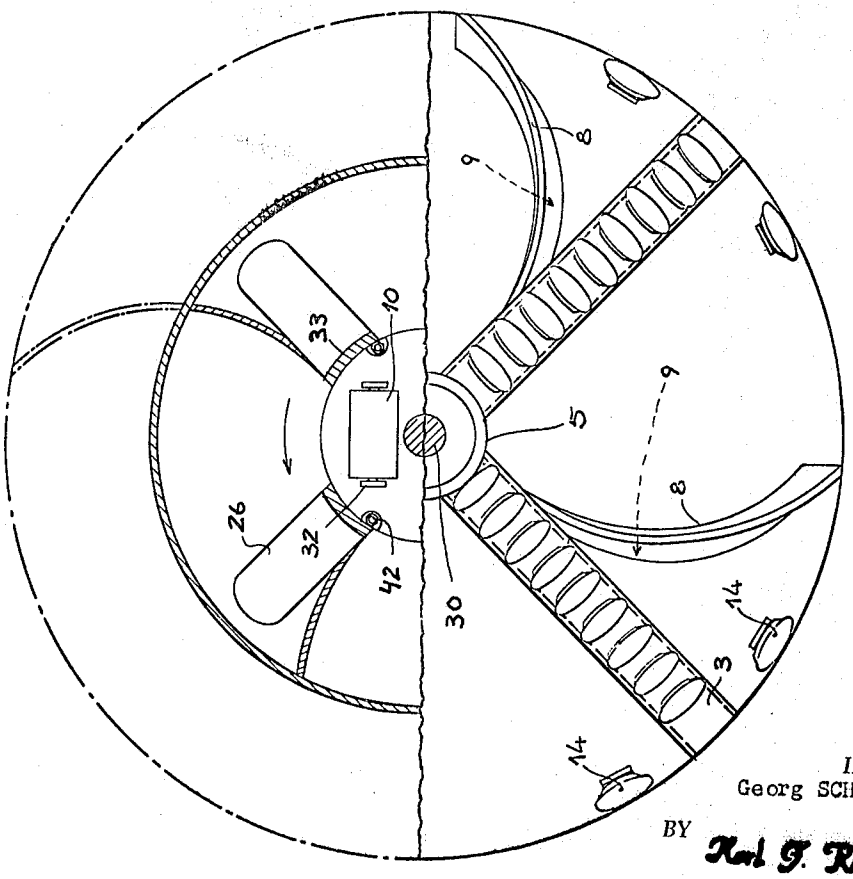

Fig. 2

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CONTINUOUS TUNNEL BORER

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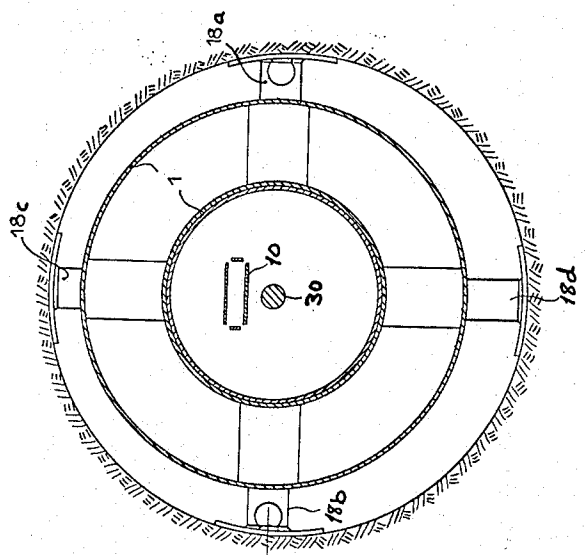

Fig. 4

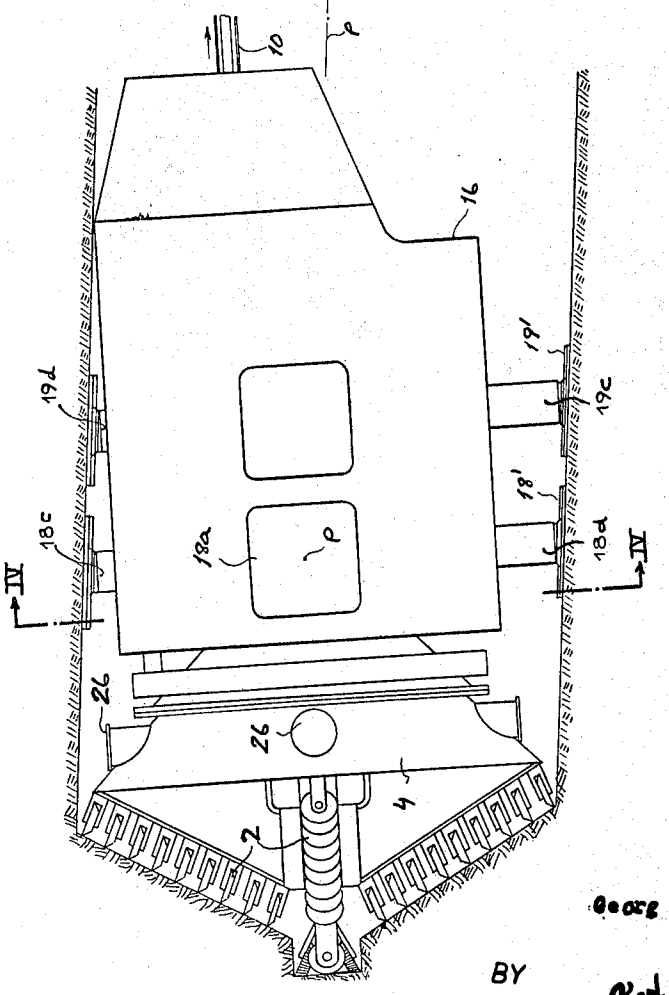

Fig. 3

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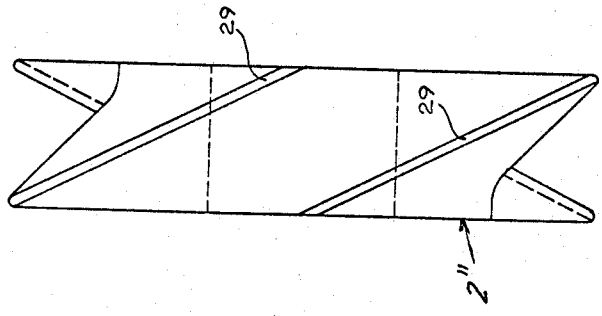

Fig. 7

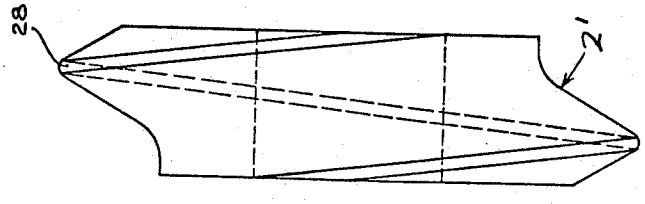

Fig. 6

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3,493,165

CONTINUOUS TUNNEL BORER

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Filed Nov. 20, 1967, Ser. No. 684,368
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Int. Cl. E21c *1/10, 13/00, 29/02*
U.S. Cl. 299—31 8 Claims

ABSTRACT OF THE DISCLOSURE

Tunnel-boring machine with a generally frustoconical rotary head spanned by one or more ribs each carrying an array of independently rotatable chisels, the head further having scoops disposed adjacent the chisels and concave in the direction of rotation for gathering muck and depositing it on a rearwardly extending conveyor passing through a tubular stem of the head slidably lodged in a cylindrical housing which is immobilizable, by a set of radial jacks, with reference to the wall of a tunnel drilled by the boring head. Axially extending thrust jacks on the housing serve for the longitudinal propulsion of the boring head and its stem with reference to the housing whereupon, by means of another set of radial jacks on the head itself, the latter may be immobilized and the housing may be pulled after it upon retraction of the first-mentioned radial jacks. The boring head may be provided with a separable neck which, upon detachment from the head, may be withdrawn from the tunnel together with the housing and with a central drill bit normally projecting beyond the boring head.

My present invention relates to a continuous boring machine to be used for excavating underground passages, such as tunnels or adits to mines, or for removing ores, coal or other minerals from subsurface locations.

Recent developments in this field, as described in an article by Thomas E. Howard (Scientific American, November 1967), include a continuous tunnel borer with a cutting or boring head rotating about a substantially horizontal axis, the head carrying a peripheral array of excavating tools working against the tunnel face under the thrust of a set of axially oriented jacks which are mounted on a two-part machine housing. The forward part of the housing, directly behind the head, is immobilized with reference to the tunnel wall by radially oriented jacks (i.e. telescoping legs) during the excavating operation, the rear part of the machine housing being simultaneously pulled forward; thereafter, the rear housing part is similarly immobilized and the front part is released in order to move up to a position just behind the head whereupon the cycle can be repeated.

An object of my present invention is to provide an improved machine of this description which, by virtue of greater compactness, operates more efficiently and is not limited to straight-line advances.

Another important object of this invention is to provide improved cutting and muck-gathering means on the boring head of such a machine in order to increase its operating efficiency, particularly when working in relatively hard rock.

It is also an object of my invention to provide means for facilitating the extraction of the greater part of the machine, minus its boring head, after the excavation of a blind underground passage.

The boring head of a tunneling machine according to the invention is of generally frustoconical, forwardly diverging configuration and is provided at its open front end with one or more radial sets of excavating tools

which are preferably mounted on radial ribs spanning this front end. The boring head also carries a plurality of angularly spaced scoops designed to gather the muck or detritus broken loose by the excavating tools and to dump it on a transport device, such as an endless band conveyor, for removal toward the rear through the generally cylindrical machine housing. This arrangement, with the large-diameter machines primarily contemplated herein, still leaves room for maintenance personnel to walk or crawl through the housing for inspection or repair work at the boring site. Advantageously, the excavating tools form a stepped array which slopes forwardly in a radially inward direction; thus, these tools may be rotary chisels independently journaled on respective axes which are parallel to the generatrices of a forwardly converging imaginary cone surface centered on the boring-head axis, the scoops extending forwardly between the tool-supporting ribs so as to terminate in the immediate vicinity of this imaginary cone surface while having their concave sides deepened in the vicinity of the peripheral wall of the boring head to form muck-receiving pockets therewith. The tool-supporting ribs and scoops end short of the boring-head axis to leave free a central area through which a drill bit extends beyond the array of excavating tools; the stem of this drill bit may be rotated jointly with the boring head, or independently thereof, to dig a central channel around which the soil and rock are removed by the revolving tools.

According to another feature of my invention, the cylindrical machine housing—whose radius is smaller than that of the array of excavating tools on the boring head—consists of a single part fitted with a first set of radial jacks for immobilizing the housing during the forward thrust of the head, another set of radial jacks being provided on the head itself whereby, upon extension of the latter jacks and retraction of the former, a reversal of the thrust-exerting plungers of an axial jack assembly pulls the housing into the tunnel after the now immobilized boring head. The latter can then again be fixed in position whereupon, after retraction of the boring-head jacks, a new forward thrust may be exerted upon the array of excavating tools. With this arrangement, given two axially spaced and independently operable sets of radial jacks on the machine housing, the latter can be limitedly tilted in any direction so that the boring head may be steered to follow the course of a coal vein or otherwise advance on a path deviating from a straight line.

By providing the boring head with a separable neck, I am able to extract the machine housing, the drill bit and the conveyor from the tunnel in a rearward direction if, for any reason, the tunnel is to remain as a blind underground passage; in this case, only the boring head with its chisels and picks is lost.

The invention will be described in greater detail with reference to the accompanying drawing in which:

FIG. 1 is a sectional elevational view of a tunnel-boring machine according to the invention, shown in its position of forward thrust;

FIG. 2 is partly an end view and partly a cross-sectional view taken on the line II—II of FIG. 1;

FIG. 3 is a side-elevational view of the machine in a position of deviation from a straight line;

FIG. 4 is a cross-sectional view taken on the line IV—IV of FIG. 3;

FIG. 5 is a detail view, drawn to a larger scale, of one of the excavating tools on the boring head of the machine; and

FIGS. 6 and 7 are enlarged side-elevational views of other forms of excavating tools usable with the machine of FIGS. 1–4.

The machine shown in FIGS. 1–4 comprises a boring head, generally designated 1, having a frustoconical peripheral wall 4 whose open front end is spanned by a set of ribs 3 serving as carriers for an array of cutting tools 2; in the specific embodiment illustrated, four such ribs extend in respective radial planes 90° apart (see FIG. 2). The ribs 3 slope forwardly, i.e. to the left in FIG. 1, toward the axis of rotation O of head 1 and terminate short of this axis at a central tube 5 which gives passage to a shaft 30 of a drill bit 7 projecting forwardly beyond the array of excavating tools 2. The latter tools are mounted in a stepped formation on the ribs 3 so that their leading edges are tangent to the generatices of an imaginary conical surface substantially coinciding with the tunnel face T being shaped by these tools. In the embodiment of FIG. 1, and as more clearly shown in FIG. 5, the tools 2 are rotary chisels provided with annular cutting ridges 31 and journaled on individual bolts 6 whose axes are more or less parallel to the associated ribs 3, on which the studs are mounted by brackets 27, and to the generatrices of the aforementioned imaginary surface represented in FIG. 1 by the tunnel face T. Thus, rotation of head 1 about its axis O will cause the chisels 2 to roll on the tunnel face T while biting ever more deeply into the soil around the central channel C produced by the bit 7.

The axial staggering of the leading edges of chisels 2 result in a terracing of the tunnel face, as best seen in FIG. 5; a set of scoops 8, whose forward edges 8′ extend parallel to ribs 3 in the immediate vicinity of the leading edges of chisels 2, help smooth the stepped tunnel face shown in FIG. 5 and also collect the rubble or muck produced by the chisels; toward the rear, the concave sides of the scoops 8 facing in the direction of rotation (counterclockwise in FIG. 2) are deepened so as to form pockets 9 with the frustoconical wall 4 of head 1. These pockets discharge, as each scoop swings above the median horizontal plane of the boring head 1, onto a conveyor 10 shown as an endless belt led around a forward roller 11 and a rear roller not shown. Belt 10 is driven, by means not further illustrated, in the direction of arrow A so as to transport the deposited detritus toward the rear from the region of head 1. The rollers are journaled between cantilevered, axially shiftable bars 32 so that the conveyor may be withdrawn from the head for purposes of access, inspection or repair; shaft 30 of bit 7 may be similarly retractable through tube 5.

A set of webs 33, respectively aligned with ribs 3, extend from tube 5 rearwardly to the narrow base of the truncated cone 4 to form supports for respective jacks 26 passing radially outwardly through the cone wall. This wall 4 is received in a frustoconical neck 34 with which it is coupled for joint rotation by a set of axial pins 35 and which is rigid with a horizontal tube 12 surrounding the shaft 30 and the conveyor 10. Tube 12 is rotatably journaled, with the aid of interposed bearings 36, in a machine housing comprising two nested cylinders 15, 16 which define an annular space 17 centered on axis O. This space accommodates the cylinders 38, 39 of two axially spaced radial arrays of jacks 18 and 19, two pairs of diametrically aligned jacks being provided in each array as illustrated in FIGS. 3 and 4. In addition, the cylinder 20 of an array of axially extending jacks 22, centered on axis O, are also mounted in the space 17 along with conduits 37 for reversibly displacing these jacks, the conduit system including a reversing valve 40 which may be oscillated at a rapid rate to impart an intermittent forward thrust to the jacks 22 and through them to a ring 23 which presses through needle bearings 25 upon an annular shoulder 24 of neck 34. A flanged outer ringer 41 embraces ring 23 to insure that a reverse actuation of jacks 22 will not disengage these jacks from the neck 34 of boring head 1. The head is furthermore shown provided with tie rods 42, e.g. three of them spaced 120° apart, by which it is removably fastened to the tube 12 so as to maintain the structural

unity of elements 1, 34 and 12. Upon disconnection of rods 42 from tube 12, housing 15, 16 with its jacks 18, 19 and 22 as well as tube 12 and neck 34 may be withdrawn from the tunnel without any interference from the coupling pins 35, leaving the head 1 in place as a lost implement.

Rotation is imparted to head 1 by means of one or more motors 43 mounted in the housing space 17, each of these motors driving a pinion 44 in mesh with a ring gear 21 which is rigid with tube 12. Bit 7 may be rotated in step with head 1, through a suitable coupling not shown, or independently thereof by drive means not further illustrated.

As shown in FIGS. 6 and 7, chisels 2 may be replaced by chisels 2′ or 2″ having a single helicoidal cutting ridge 28 or a pair of such ridges 29. Moreover, as illustrated in FIG. 2, additional chisels 14 may be disposed on the inner periphery of cone 4 between the arrays of tools 2.

In the normal operation of the system shown in FIGS. 1–4, with jacks 22 and 26 initially retracted and jacks 18 and 19 extended as illustrated in FIG. 1, bit 7 and head 1 are rotated to drill the channel C and to excavate the tunnel face T. During this operation, hydraulic or pneumatic fluid is admitted to the cylinders 20 to drive the head 1 continuously forwardly to the limit of the stroke of jacks 22. Conveyor 10 removes the oncoming debris, advancing together with head 1, shaft 30 and tube 12.

When the end of the stroke of the axial jacks 22 has been reached, the drive 43, 44, 21 of head 1 is arrested, fluid is admitted to the cylinders of jacks 26 through conduits not illustrated to extend these jacks radially outwardly against the tunnel wall whereby the head 1 is immobilized, and jacks 18, 19 are retracted whereupon valve 40 reverses the connections of cylinders 20 so that these cylinders are drawn forwardly with reference to the now stationary pistons 22. By this action, with cylinder 15 sliding on tube 12, housing 15, 16 is again brought into close juxtaposition with head 1 whereupon the aforedescribed cycle may be repeated with extension of jacks 18, 19, retraction of jacks 26 and forward actuation of jacks 22 while rotation of head 1 is resumed. If this actuation of jacks 22 occurs intermittently as set forth above, as by a rapid alternation of relatively long forward thrusts with relatively short reverse movements, the fragmentizing effect of the cutting tools 2 will be enhanced.

FIGS. 3 and 4 illustrate the manner in which my improved system can be used to dig tunnels departing from straight linearity. To this end it is merely necessary that two diametrically opposite jacks of the machine housing, e.g. jacks 18*a*, 18*b* of the forward array of jacks 18, be left extended during continuing rotation of head 1 so as to form a pivotal axis P for the swing of housing 15, 16 under the control of jacks 19*c*, 19*d* of the rear array 19 which stand skew to the extended jacks 18*a*, 18*b*. The other jacks 18*c*, 18*d* of the front array and the remaining pair of jacks of the rear array, all operable independently, are then extended beyond the tunnel wall to lock the machine housing in its tilted position; the boring operation then resumes as previously described. Tilting angles up to 45° can be readily achieved with this technique, especially if the end plates 19′, 19′ of the jacks are pivotally mounted on their pistons through suitable universal joints; such joints have been illustrated at 45, FIG. 1, for the end plates 26′ of jacks 26.

I claim:

1. A tunnel-boring machine comprising a generally cylindrical housing; a boring head supported on said housing for rotation about a substantially horizontal axis; a set of excavating tools on said boring head, said tools being distributed over a radius greater than that of said housing; first radial anchoring jack means on said housing for immobilizing same with reference to the wall of a tunnel excavated by said boring head; second radial anchoring jack means rotatively coupled with and carried on said boring head for immobilizing same with ref-

erence to the tunnel wall; retractable thrust means operatively engaging said housing and said boring head for axially advancing said boring head with reference to said housing in an extended position of said first jack means and a retracted position of said second jack means and for drawing said housing after said boring head in a retracted position of said first jack means and an extended position of said second jack means; and drive means for rotating said boring head upon retraction of said second jack means.

2. A tunnel-boring machine as defined in claim 1 wherein said head has a neck provided with an external annular shoulder centered on said axis, said thrust means including a plurality of peripherally spaced jacks, a ring engaged by said jacks confronting said shoulder, and bearing means between said ring and said shoulder.

3. A tunnel-boring machine as defined in claim 1 wherein said first jack means comprises two axially spaced radial arrays of jacks, each array including a plurality of diametrically aligned pairs of jacks, the jacks of said arrays being independently operable for enabling said housing to tilt around an extended pair of jacks of one array under the control of jacks of the other array disposed skew to said extended pair.

4. A tunnel-boring machine as defined in claim 1 wherein said thrust means includes a set of axial jacks and fluid-control means for intermittently actuating said jacks at a rapid rate.

5. A tunnel-boring machine as defined in claim 1, further comprising a shaft axially traversing said housing and said boring head, a drill bit on said shaft projecting beyond said set of excavating tools, and conveyor means

extending through said housing along said shaft into the vicinity of said boring head for the removal of muck broken loose by said tools.

6. A tunnel-boring machine as defined in claim 5 wherein said housing comprises a pair of nested cylinders defining between them an annular space centered on said axis, said first jack means and said thrust means including fluid cylinders and supply lines lodged in said annular space, said conveyor means and said shaft extending within the inner of said nested cylinders.

7. A tunnel-boring machine as defined in claim 5 wherein said boring head is provided with a detachable neck positively engaging said housing for retraction therewith from the tunnel upon separation of said neck from said boring head, said shaft and said conveyor means being withdrawable from said boring head with said housing.

8. A tunnel-boring machine as defined in claim 7 wherein said neck is rotatable with reference to said housing, said drive means including a ring gear rigid with said neck and centered on said axis.

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U.S. Cl. X.R.

175—94; 299—56, 86