United States Patent

Lauber

[15] **3,647,264**

[45] **Mar. 7, 1972**

[54] MACHINE FOR DRIVING TUNNELS, DRIFTS, RAISES, AND THE LIKE

[72] Inventor: **Ernst Abraham Lauber,** Thun, Switzerland

[73] Assignee: **Atlas Copco Aktiebolag,** Nacka, Sweden

[22] Filed: **Apr. 14, 1970**

[21] Appl. No.: **28,343**

[52] **U.S. Cl.** **299/31,** 299/75, 299/86

[51] **Int. Cl.** **E21c 29/02,** E01g 3/04

[58] **Field of Search** 299/31, 56, 75, 85, 86

[56] **References Cited**

UNITED STATES PATENTS

2,211,751	8/1940	McCarthy	299/31 X
3,498,675	3/1970	Kampf-Emden et al.	299/31
2,833,531	5/1958	Joy	299/31
1,182,453	5/1916	Buffum	299/76
2,528,748	11/1950	Greene	299/56
2,619,339	11/1952	Cartlidge	299/75 X
2,619,338	11/1952	Lindgren	299/75 X

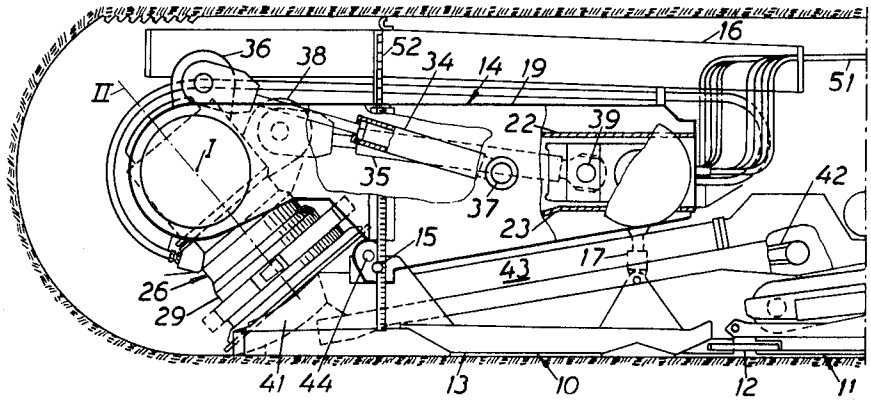
Primary Examiner—Ernest R. Purser

Attorney—Munson & Fiddler

[57] **ABSTRACT**

A tunnelling machine has a cutting unit which is mounted on a main frame to swing about a horizontal axis. The cutting unit has a rotating cutter head which cuts over the whole width of the tunnel upon the swinging of the cutting unit by means of two swing jacks. The cutting unit and the frame are braced between the sidewalls of the tunnel by means of two jacks which have their extension axes colinear with the horizontal axis of swinging. A transverse frame, slidable forwards and backwards in the main frame, can also be braced between the sidewalls by means of two colinear jacks. One of the swing jacks is mounted in the main frame and the other in the transverse frame, and the swing jacks are also used for advancing the machine in steps.

21 Claims, 7 Drawing Figures



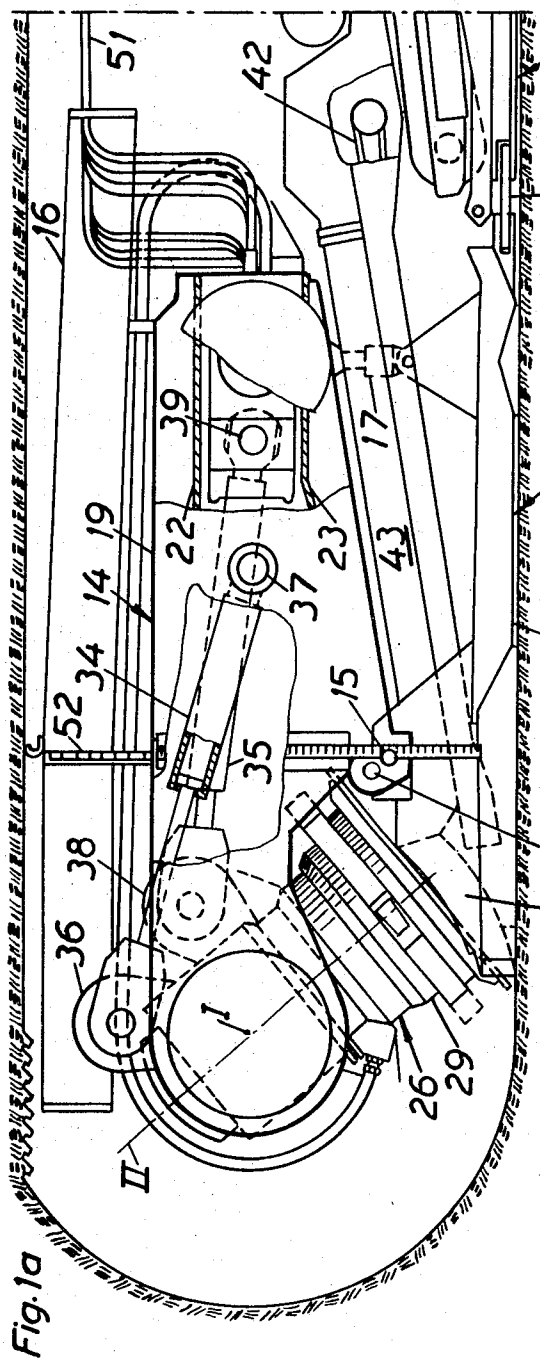


Fig. 1a

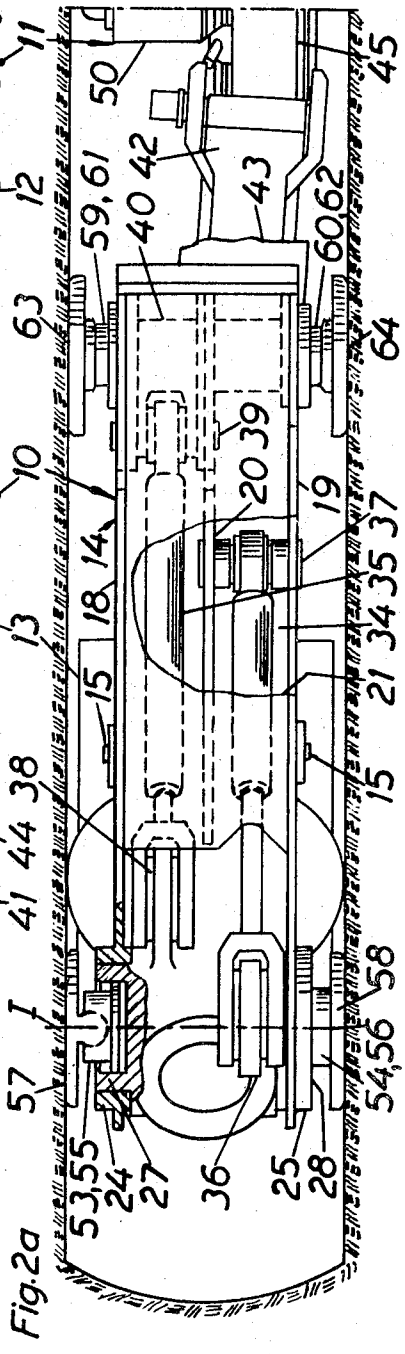


Fig. 2a

INVENTOR.
Ernst Abram Lauber
BY
Merriam & Fiddler
Attorneys

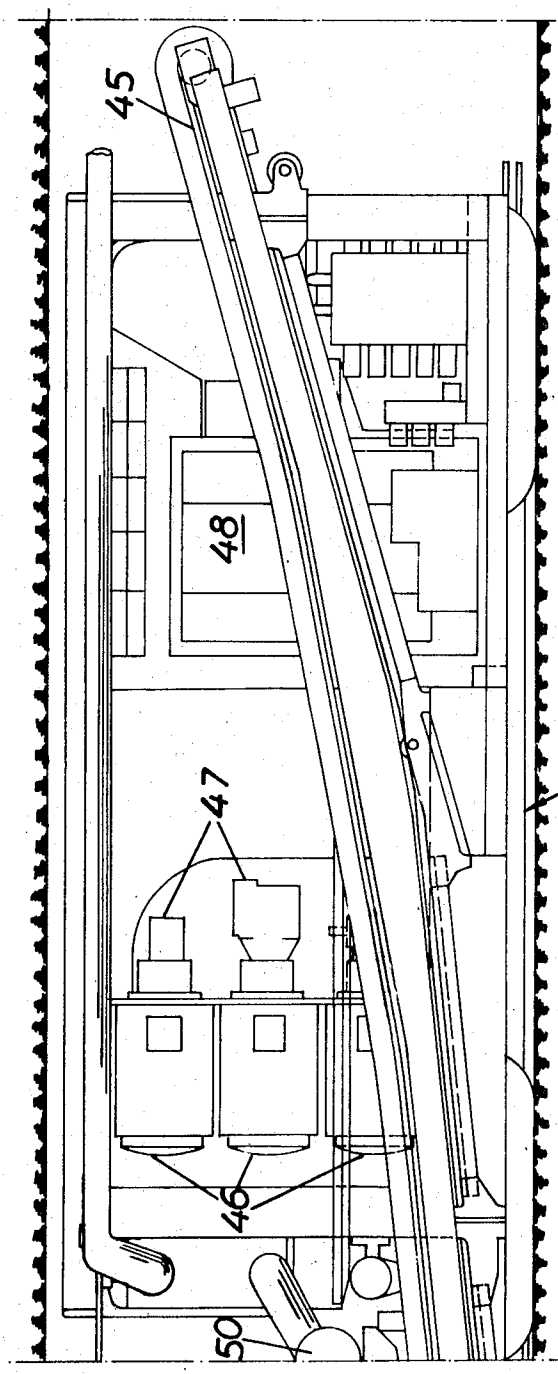


Fig. 1b

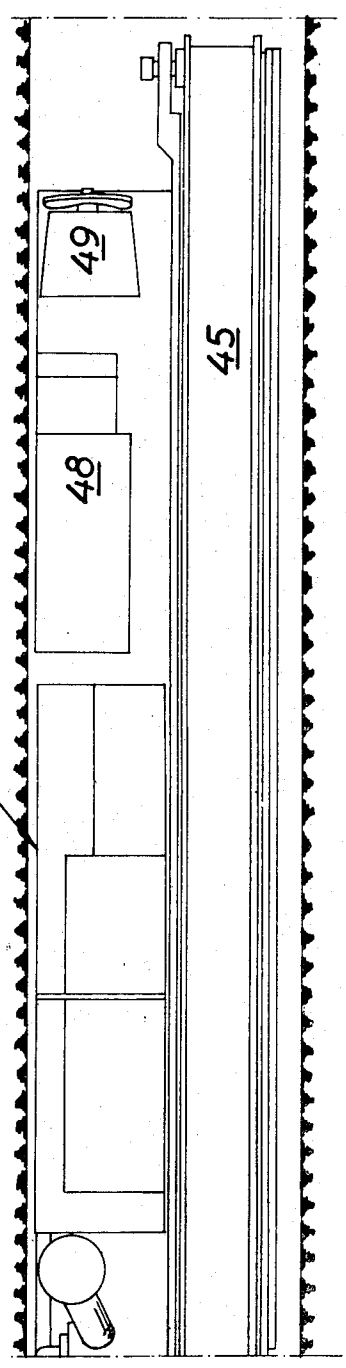


Fig. 2b

INVENTOR.
Ernst Abram Lauber
BY
Brumm & Fiddler
Attorneys

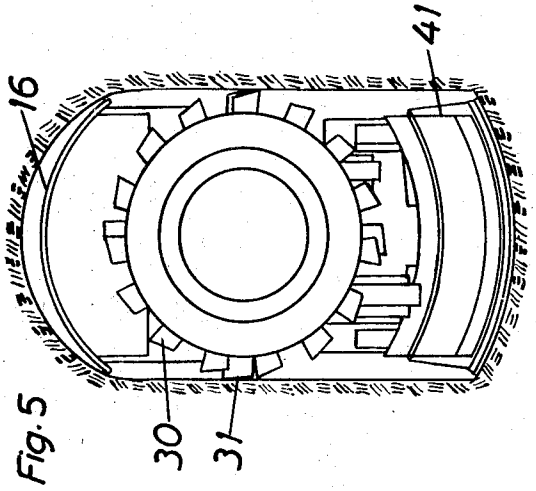


Fig. 5

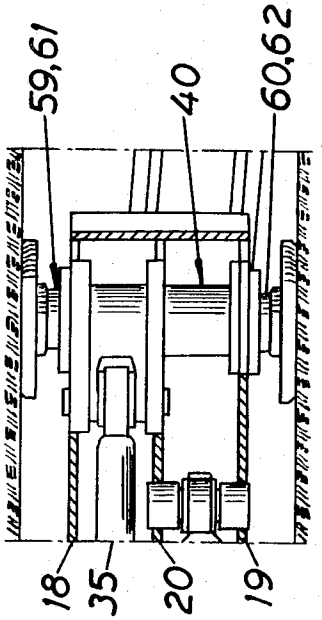


Fig. 3

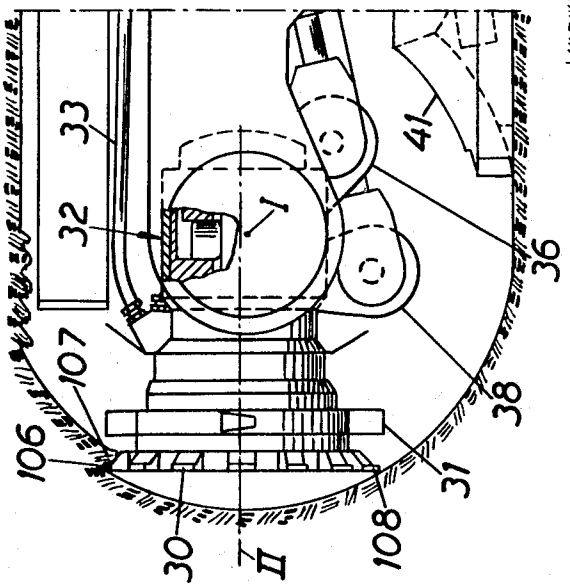


Fig. 4

INVENTOR.
Ernst Abraham Lauzes
BY
Brumm & Fiddler
Attorneys

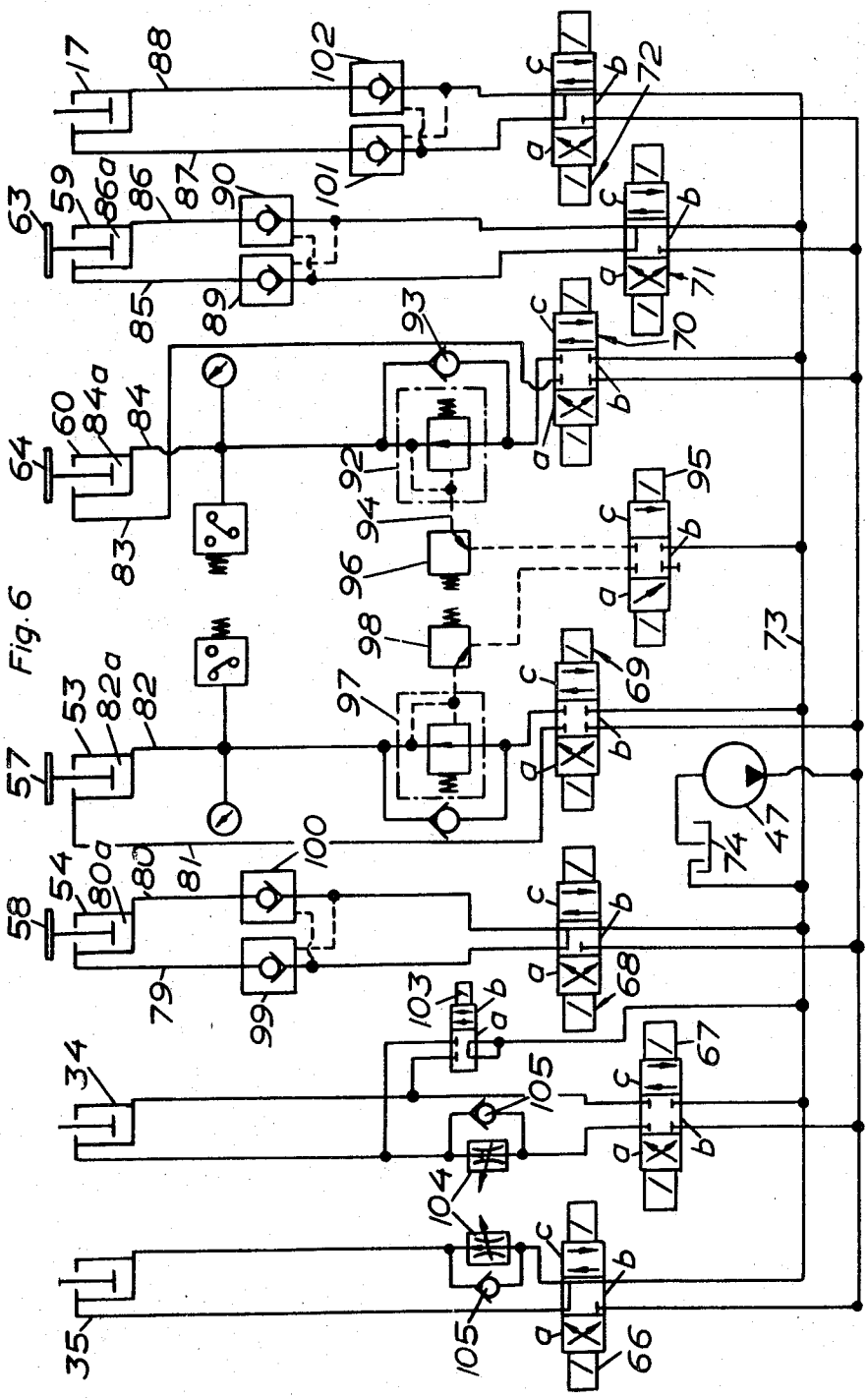


Fig. 6

INVENTOR.
Ernst Abraham Laober
BY
Munson & Fiddler
Attorneys

MACHINE FOR DRIVING TUNNELS, DRIFTS, RAISES, AND THE LIKE

This invention relates to a machine for driving tunnels, drifts, raises, and the like.

There have been suggested tunnelling machines which have a cutting device equipped with a rotating cutter head and swinging about a vertical axis. Usually, such a machine does not produce a tunnel of suitable form. However, by using a swinging frame with a number of cutter heads in accordance with the Austrian Pat. No. 271,550, a more suitable form of the tunnel is achieved. It is, however, almost impossible to make a rigid machine of this construction for producing small tunnels.

There is a need for a machine for producing small-area-tunnels, especially sewage tunnels, tunnels for supplying fresh water, and tunnels for leading off surface water; but small area tunnels are needed also in mining. It is, therefore, an object of the invention to provide a rigid machine for producing small-area-tunnels of a suitable form. Another object is to provide such a rigid machine which has improved bracing, steering and/or advancing means.

The invention is described with reference to the accompanying drawings 5 in which an embodiment of the invention is illustrated by way of example.

In the figures:

FIG. 1*a* and 1*b* are to be seen together, FIG. 1*a* being a side view, partly in section, of the forward portion of a tunnelling machine and FIG. 1*b* being a side view, partly in section, of the corresponding rear portion;

FIG. 2*a* is a top view corresponding to FIG. 1*a* and illustrated the same forward portion, some parts being removed;

FIG. 2*b* is a top view corresponding to FIG. 1*b* and illustrating the same rear portion, some parts being removed.

FIG. 3 is a fragmentary top view of a transverse frame illustrated in FIG. 1*a* in another position;

FIG. 4 is a fragmentary side view illustrating another position of a cutting device which is illustrated in FIG. 1*a;*

FIG. 5 is a fragmentary front end view of the machine, the cutting device being in the same position as in FIG. 3; and

FIG. 6 is a fragmentary hydraulic circuitry of the machine illustrated.

The tunnelling machine illustrated in the figures has a forward part 10 and a trailer 11 connected by means of a connecting plate 12. The forward part 10 has a base 13 sliding on the tunnel floor. A rigid main frame 14, the contours of which are illustrated by heavy lines in FIG. 1*a*, is pivotably mounted on the base 13 on horizontal pivots 15, and it can be limitedly pivoted by means of a jack 17 mounted between the base 13 and the main frame 14. The main frame consists of two side plates 18, 19, a central plate 20, a top plate 21, a bottom plate, stabilizing transverse plates 22, 23, and a protecting roof 16 which is removed on FIG. 2*a*.

The main frame 14 has two bushings 24, 25 at its front end, and a cutting unit 26 has a pair of trunnions 27, 28 journaled in the bushings 24, 25. The common axis of the two bushings 24, 25 is referred to as axis I. The bushing 24 and the trunnion 27 are illustrated in section but the bushing 25 and the trunnion 28 in view. The cutting unit 26 has a cutter head 29 rotatably mounted therein which has a number of cutter bits 30 (illustrated in detail in FIGS. 4, 5 only) on its peripherical circular surface and four finishing cutter bits 31. The cutter bits 30 are provided with carbide inserts and are detachable. In the housing of the cutter unit 26, there are a motor and a gearing for rotating the cutter head 29 about an axis II. The motor can be a hydraulic fluid-actuated motor 32 of the radial piston type, as illustrated in FIG. 4, which is supplied with hydraulic fluid through a hose 33. However, any other suitable type of motor may be used, for example an electric motor.

The cutting unit 26 is swingable about the axis I by means of two jacks 34, 35. One end of the jack 34 is pivotably mounted on a lug 36 on the housing of the cutting unit 26 and the other end is mounted on a pivot 37 fastened to the main frame 14. One end of the jack 35 is pivotably mounted on another lug 38 on the housing of the cutting unit 26 and the other end is

mounted on a pivot 39 fastened to a transverse frame 40 which is slidable in the main frame 14 between a rear position illustrated in FIGS. 1*a*, 2*a* and a forward position illustrated in FIG. 3. On the forward end of the base 13 there is a chute 41 formed to suit the cutter head 29 so that the cutter head acts as a scraper during swinging to its backward position illustrated in FIGS. 1*a*, 1*b*. The cutter head thus feeds a conveyor band 42 inside a drum 43 with the fragments that are cut away and broken away from the tunnel face. There are alternative holes 44 (FIG. 1*a*) in the main frame 14 for mounting the frame on the pivots 15 if a cutter head 29 with greater diameter is used. The chute 41 must then be replaced by one suiting this cutter head.

The conveyor band 42 feeds another conveyor band 45 which is fastened on the trailer 11.

On the trailer 11, there is arranged auxiliary equipment such as a hydraulic fluid tank with filters, three electric motors 46 driving hydraulic fluid pumps 47, an electric switchboard 48, the operator's seat 49, and a fan 50 with filters for sucking air from the rear part of the conveyor 42. From the trailer there are a number of hydraulic fluid hoses 51 leading to the various fluid motors on the forward part of the machine. The hoses 51 are not illustrated in FIG. 2*a*. Since there is a rubber seal 52 arranged to seal between the tunnel wall and the machine so that clean air will blow forward through the machine and dusty air will be sucked out and cleaned in the filters, there will be clean air everywhere except in front of the seal 52.

The interior of the trunnions 27, 28 form cylinders of jacks 53, 54 having pistons 55, 56 which bear universally mounted tunnel wall engaging plates or shoes 57, 58. The common axis of the pistons 55, 56 is coinciding with the axis I of swinging. The trunnions 27, 28 rotate during the swinging of the cutting unit 26 but the pistons 55, 56 do not rotate. The transverse frame 40, too, has two jacks 59, 60 with pistons 61, 62 provided with universally mounted wall engaging plates or shoes 63, 64.

In the hydraulic circuitry (FIG. 6) are illustrated the jacks 34, 35 for swinging the cutting unit 26, the forward jacks 53, 54 and rear jacks 59, 60 for bracing the machine between the sidewalls of the tunnel, and the jack 17 for swinging the main frame 14. The motor 32 for rotating the cutter head 29 and the motors for driving the conveyor bands 42, 45 are not illustrated in the circuitry. The pump 47 supplies a main supply conduit 65 with hydraulic fluid of a high and constant pressure. There are seven branches of this main supply conduit 65, each supplying an electrically remotely controlled control valve 66–72. These control valves are also connected to a branched main drain conduit 73 which leads to a tank 74. Each of the jacks 34, 35, 53, 54, 59, 60, 17 is double-acting and has two pressure chambers connected to the respective control valve by means of a combined supply/drain conduit 75–88. The jacks 54, 53, 60, 59 have their pressure chambers for extending the jacks indicated with 80*a*, 82*a*, 84*a*, 86*a*, respectively. Each of the control valves 67, 69, 70 is shown in the figure in a position *b* represented by the squares *b* for closing off the supply/drain conduits which it controls, but each of the control valves 66, 68, 71, 72 has a position represented by its square *b* in which it connects one of the two supply/drain conduits with which it is connected to the main supply conduit 65 and the other to the main drain conduit 73. The control valves have also positions represented by the squares *a* and *c* in which each valve connects one of its supply/drain conduits to the main drain conduit 73 and the other conduit to the main supply conduit 65.

The jacks 59, 60 on the transverse frame are used for steering laterally; that is, the back end of the forward part of the machine can be moved laterally by means of these jacks. The front end cannot move laterally since the cutter head has a diameter which is the width of the tunnel. When the back end has been moved laterally by means of the rear jacks 59, 60, however, the machine may have tilted sidewise a little. By means of the forward pair of jacks 53, 54 it is possible to adjust

the machine into the position in which the axis I is again horizontal.

The jack **59** is used as a steering jack and, except during steering movement, its control valve **71** is in the illustrated position in which it is locked by means of a hydraulic lock which consists of two pilot controlled check valves **89, 90**. During cutting, the control valve **70** of the jack **60** has its square a connected and, thus, the conduit **84** and the pressure chamber **84***a* are pressurized but the conduit **83** drained. An adjustable pressure regulator **92** of standard type is arranged in the supply conduit **84** so as to sense and limit the pressure in this conduit **84** to a preset value. By means of this pressure regulator **92**, an accurate holding power on the plates **63, 64** can be achieved for different types of rocks. A one-way valve **93** bypasses the pressure regulator **92** which is arranged to be remotely controlled through a pilot conduit **94**. When a valve **95** is in its closed position *b* as in FIG. **6**, the pressure in the pilot conduit **94** is the same as in the supply conduit and the pilot conduit is deactivated. When, however, the valve **95** has its square *c* connected, the pressure in the pilot conduit **94** is limited by an adjustable relief valve **96** which now controls the pressure regulator so that the pressure in the chamber **84***a* is now greatly reduced, e.g., by 80–90 percent. The forward pair of jacks **53, 54** are connected in the same way as the rear jacks **59, 60** with a pressure regulator **97** of the same type as the pressure regulator **92** arranged in the conduit **82** and controlled by a relief valve **98** when the control valve **95** has its square a connected. The jack **54** is normally locked by two check valves **99, 100**. Two check valves **101, 102** are also arranged to lock the jack **17** for swinging the main frame **14**.

When the control valve **67** of the swing cylinder **34** is in its position *b* as illustrated and a valve **103** is in its illustrated position *b* as well, then the swing cylinder **34** is locked, but when the valve **103** is in its alternative position *a* then the swing cylinder **34** can be freely moved. Restrictors **104** control the swinging speed of the cutting unit during upward/forward cutting, but check valves **105** permit fast return swinging of the cutting unit.

All the described control valves are solenoid valves which are remotely controlled by means of a nonillustrated control unit which automatically effects sequenced cutting and stepping. The operator interrupts the automatical operation only when the direction must be adjusted.

A complete sequence of cutting and stepping will now be described with reference to the FIGS. **1***a* and **6**. It will be assumed that the cutting unit just has returned to its position illustrated in FIG. **1***a* and defined by the end position of the extended jack **34**. The control valves **66, 67, 68, 71, 72**, are in the illustrated positions, and the valves **69, 70** are in positions *a*. Thus, the forward **53, 54** and rear **59, 60** sets of jacks are firmly braced between the sidewalls of the tunnel and the swing jack **34** is locked. The control valve **95** is now switched into position *c* and a power reduction of the rear jacks **59, 60** results. When, shortly thereafter, the swing jack **35** retracts upon actuation of control valve **66**, the transverse frame is advanced with the plates **63, 64** sliding along the sidewalls of the tunnel to the stop position illustrated in FIG. **3**.

Now, the control valve **95** is shifted to position a so that the forward set **53, 54** of jacks works with reduced power, but the rear set **59, 60** does so with full power. Upon actuation of the control valve **66**, the swing jack **35** extends and advances the machine as far as the relative movement between the main frame **14** and the transverse frame **40** permits because the transverse frame is in a fixed position in the tunnel. The control valve **95** is shifted back to neutral position, position *b*, and an advancing sequence is completed.

Now the control valves **66, 67, 103** are actuated in such a sequence that, at first the swing jack **34** is actuated to contract while the swing jack **35** is released hydraulically until it has passed its dead point but then actuated to extend. When the jack **34** reaches its dead point, it becomes released and stays released.

When the cutting unit reaches its top position, the jack **35** is actuated to retract so that the cutting movement of the cutting unit ends and a return movement starts. When the jack **34** reaches its dead point, it is actuated to extend until the cutting unit is returned to the position in FIG. **1***a*. The jack **35** becomes released when it reaches its dead point.

During the upward swinging of the cutting unit, the cutter bits **30**, which at the moment are on the leading half of the cutter head, cut a semicircular kerf **106** (FIG. **4**) in the tunnel face but leave a rib or core **107** which is broken down by the tapered back portion of the cutters. The axis II of rotation does not intersect the axis I of swinging, and thus, on the trailing side of the cutter head, there are small clearance gaps as indicated at **108** between the cutter bits and the rock.

Because the cutter head swings back so far at its return movement as illustrated in FIG. **1***a*, it scrapes the debris into and through the chute **41** so that the debris falls down on the conveyor band. With the cutting unit **26** in its back position, all the cutter bits **30** are off the floor and cutting is therefore avoided. However, in order to avoid jamming, the cutter head **29** is rotated during both the advancing of the machine and the return swinging of the cutting unit.

It is advantageous that the roof of the tunnel produced is elliptical and therefore very strong but the bottom of the tunnel only slightly arc-shaped. Furthermore, with a machine as described, it is possible to produce a tunnel of a shape which permits a man to walk in the tunnel even if the tunnel has an area of between two and three square meters.

It is to be understood that the invention is not limited to the embodiment described but may be varied in many ways within the scope of the claims. For example, the cutter bits **30** may be chipping bits instead of being drag bits as illustrated.

I claim:

1. A tunneling machine comprising a main frame, means for supporting said main frame in a tunnel, a cutting device pivotably mounted on the main frame for swinging about a first horizontal axis which is transverse to the longitudinal axis of the machine or of the tunnel, motor means for producing a reciprocating swinging movement of said cutting device about said first axis to effect an upward cutting stroke and a return stroke, a circular cutter head of the cutting device rotatable about an axis which is perpendicular to said first axis, motor means for rotating said cutter head, a plurality of cutter bits arranged circumferentially on the cutter head for cutting over the whole width of the tunnel face upon simultaneous rotating of the cutter head and upward swinging of the cutting device, and means for conveying debris from the tunnel face, said cutting device being mounted in said main frame by means of a pair of trunnions journaled in the frame, the interior of each trunnion forms a cylinder for a piston which is rotatable with respect to the cylinder, and said pistons are adapted to extend tunnel wall engaging members so as to brace the cutting device between the sidewalls of the tunnel but permit swinging of the braced cutting device.

2. A tunneling machine comprising a main frame, means for supporting said main frame in a tunnel, a cutting device pivotably mounted on the main frame for swinging about a first horizontal axis which is transverse to the longitudinal axis of the machine or of the tunnel, motor means for producing a reciprocating swinging movement of said cutting device about said first axis to effect an upward cutting stroke and a return stroke, a circular cutter head of the cutting device rotatable about an axis which is perpendicular to said first axis, motor means for rotating said cutter head, a plurality of cutter bits arranged circumferentially on the cutter head for cutting over the whole width of the tunnel face upon simultaneous rotating of the cutter head and upward swinging of the cutting device, and means for conveying debris from the tunnel face, said main frame including a base slidably supported on the tunnel floor, said main frame being pivotably mounted on said base for pivoting about an axis which is parallel with said first axis and motor means for lowering and raising the cutting device relative to the tunnel floor.

3. A machine as claimed in claim 2 in which said cutter bits are arranged to cut an arc-shaped kerf in the tunnel face which kerf defines an uncut rib, and means are arranged on said cutter head for breaking down said uncut rib.

4. A machine as claimed in claim 2 wherein said motor means for swinging said cutting device is arranged to swing the cutting device from a position in which the cutting half of the cutter head is behind a plane which passes through said first axis and is transverse to the tunnel to a position in which the cutting half of the cutter head is above a plane which passes through said first axis and is parallel with the tunnel.

5. A machine as claimed in claim 4 in which said motor means for swinging said cutting device is arranged to swing the cutting device less than 180°.

6. A machine as claimed in claim 2 wherein said motor means for swinging said cutting device is arranged to swing the cutter device from a position in which the cutting half of the cutter head is behind a plane which extends through said first axis and is transverse to the tunnel to a position in which the cutting half of the cutter head is so much above a plane which extends through said first axis and is parallel with the tunnel that substantially flat sidewall portions are obtained for the wall engaging members.

7. A machine as claimed in claim 2 in which said means for supporting the main frame in the tunnel includes a first power actuated pair of tunnel wall engaging members for bracing the frame between the sidewalls of the tunnel.

8. A machine as claimed in claim 7 in which a first hydraulic piston and cylinder means is arranged for extending a first one of said first pair of wall engaging members against one of the sidewalls, and a second piston and cylinder means is arranged for extending a second one of said first pair of wall engaging members against the other of the sidewalls.

9. A machine as claimed in claim 8 in which the axes of extension of said first and second piston and cylinder means are parallel to and substantially colinear with said first axis.

10. A machine as claimed in claim 7 further comprising a second frame mounted in the main frame for limited slidable movement relative to the main frame in the longitudinal direction of the machine or tunnel, motor means for moving said transverse frame relative to the main frame, a power-actuated second pair of wall engaging members mounted on said second frame for bracing the transverse frame between the sidewalls of the tunnel.

11. A machine as claimed in claim 10 in which said motor means for swinging the cutting device comprises a first double-acting hydraulic power jack pivotably mounted between the main frame and a first support on the cutting device, and a second double-acting hydraulic power jack pivotably mounted between said second frame and a second support on the cutting device.

12. A machine as claimed in claim 11 in which said first and second supports on the cutting device are displaced angularly from one another around said first axis.

13. A machine as claimed in claim 11 having means for arresting said first power jack while said second power jack is working and means for permitting actuation alternately of the first and the second pair of wall engaging members.

14. A machine as claimed in claim 13 in which said first power jack is arranged to be in its extended end position during advancing of the machine by means of said second power jack, and is locked hydraulically during advancing of the second frame by means of said second power jack.

15. A machine as claimed in claim 10, in which a first hydraulic piston and cylinder means is arranged for extending a first one of said first pair of wall engaging members against one of the sidewalls when a pressure chamber thereof is pressurized, and a second piston and cylinder means is arranged for extending a second one of said pair of wall engaging members against the other sidewall when a pressure chamber thereof is pressurized, and in which a third hydraulic piston and cylinder means is arranged for extending a first one of said second pair of wall engaging members against one of the sidewalls when a pressure chamber thereof is pressurized, and a fourth hydraulic piston and cylinder means is arranged for extending the other of said second pair of wall engaging members against the other sidewall when a pressure chamber thereof is pressurized.

16. A machine as claimed in claim 15 in which: said pressure chamber of said fourth hydraulic piston and cylinder means is connected to a control valve means which has a piston for connecting this pressure chamber to a source of hydraulic fluid, a position for connecting the pressure chamber to a drain conduit, and a position for closing off the pressure chamber from the drain conduit and from the source of hydraulic fluid; said pressure chamber of said third piston and cylinder means is connected, by means of a first conduit to a control valve means which has a position for connecting this pressure chamber to the source of hydraulic fluid and a position for connecting the pressure chamber to a drain conduit; a pressure regulator is arranged in said first conduit; and remote control means is arranged for actuating said pressure regulator to limit the pressure in said pressure chamber so as to permit said motor means for moving the second frame to move the second frame forwards while the second frame supports the main frame against the sidewalls of the tunnel by means of said second pair of supporting members and said first pair of supporting members is braced against the sidewalls of the tunnel.

17. A machine as claimed in claim 16 in which: said pressure chamber of said second hydraulic piston and cylinder means is connected to a control valve means which has a position for connecting this pressure chamber to a source of hydraulic fluid, a position for connecting the pressure chamber to a drain conduit and a position for closing off the pressure chamber from the drain conduit and from the source of hydraulic fluid; said pressure chamber of said first piston and cylinder means is connected, by means of a second conduit, to a control valve means which has a position for connecting this pressure chamber to the source of hydraulic fluid and a position for connecting the pressure chamber to a drain conduit; a pressure regulator is arranged in said second conduit; and remote control means is arranged for actuating said pressure regulator in said second conduit to limit the pressure in the respective pressure chamber so as to permit said motor means to move the main frame forwards while the main frame is supported against the sidewalls of the tunnel by means of said first pair of supporting members and said second frame is braced between the sidewalls of the tunnel.

18. A tunneling machine comprising a main frame, means for supporting said main frame in a tunnel, a cutting device pivotably mounted on the main frame for swinging about a first horizontal axis which is transverse to the longitudinal axis of the machine or of the tunnel, motor means for producing a reciprocating swinging movement of said cutting device about said first axis to effect an upward cutting stroke and a return stroke, a circular cutter head of the cutting device rotatable about an axis which is perpendicular to said first axis, motor means for rotating said cutter head, a plurality of cutter bits arranged circumferentially on the cutter head for cutting over the whole width of the tunnel face upon simultaneous rotating of the cutter head and upward swinging of the cutting device, and means for conveying debris from the tunnel face, said means for supporting the main frame in the tunnel including a first pair of power actuated tunnel wall engaging members for bracing the frame between the sidewalls of the tunnel, and said means for swinging the cutting device comprising a first double-acting hydraulic power jack pivotably mounted between the main frame and a first support on the cutting device, and a second double-acting hydraulic power jack pivotably mounted between said frame and a second support on the cutting device.

19. A tunneling machine comprising:

a. a main frame mounted for swinging movement of a horizontal axis transverse to the longitudinal axis of the tunnel and adapted to be advanced progressively into the tunnel during the tunneling operation;

b. a secondary frame mounted for limited longitudinal movement with respect to said main frame;
c. a cutting device carried by said main frame to swing about a horizontal axis substantially parallel to the swing axis of the main frame;
d. a rotatable cutter head carried by said cutting device adapted to cut into the tunnel face during the simultaneous swinging and rotary movement thereof;
e. first pressure controlled bracing device operable to maintain said main frame in contact with the opposite walls of the tunnel under pressure during the cutting operation and to permit movement thereof by release of pressure; and
f. secondary pressure controlled bracing device operable to maintain said secondary frame in contact with the opposite walls of the tunnel under pressure during the movement of said main frame.

20. A tunneling machine comprising:
a. a main frame mounted for swinging about a horizontal axis transverse to the longitudinal axis of the tunnel and adapted to be advanced progressively into the tunnel during the tunnel operation;
b. a secondary frame mounted within said main frame for limited longitudinal movement with respect thereto;
c. a cutting device carried by said main frame and adapted to swing about a horizontal axis;
d. a first pressure controlled extensibly swing jack connected between said cutting device and said main frame;
e. a second pressure controlled extensible swing jack connected to said secondary frame and to said cutting device at a point spaced from the connection with said first swing jack;
f. said swing jacks being operable to swing said cutting device into and out of engagement with the face of the tunnel;
g. said swing jacks being alternately operable to advance said frames stepwise into the tunnel.

21. A tunneling machine according to claim **20** having:
a. a first pressure controlled bracing device operable to maintain said main frame in contact with the opposite walls of the tunnel under pressure during the cutting operation and to permit advance movement thereof upon release of pressure and
b. a second pressure controlled bracing device operable to maintain said secondary frame in contact with the opposite walls of the tunnel under pressure during the advance movement of said main frame;
c. said bracing devices being actuated to provide alternate advancement of said frames into the tunnel.

* * * * *