April 12, 1949. R. D. KARR 2,466,709

TUNNELING MACHINE

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Fig. 1.

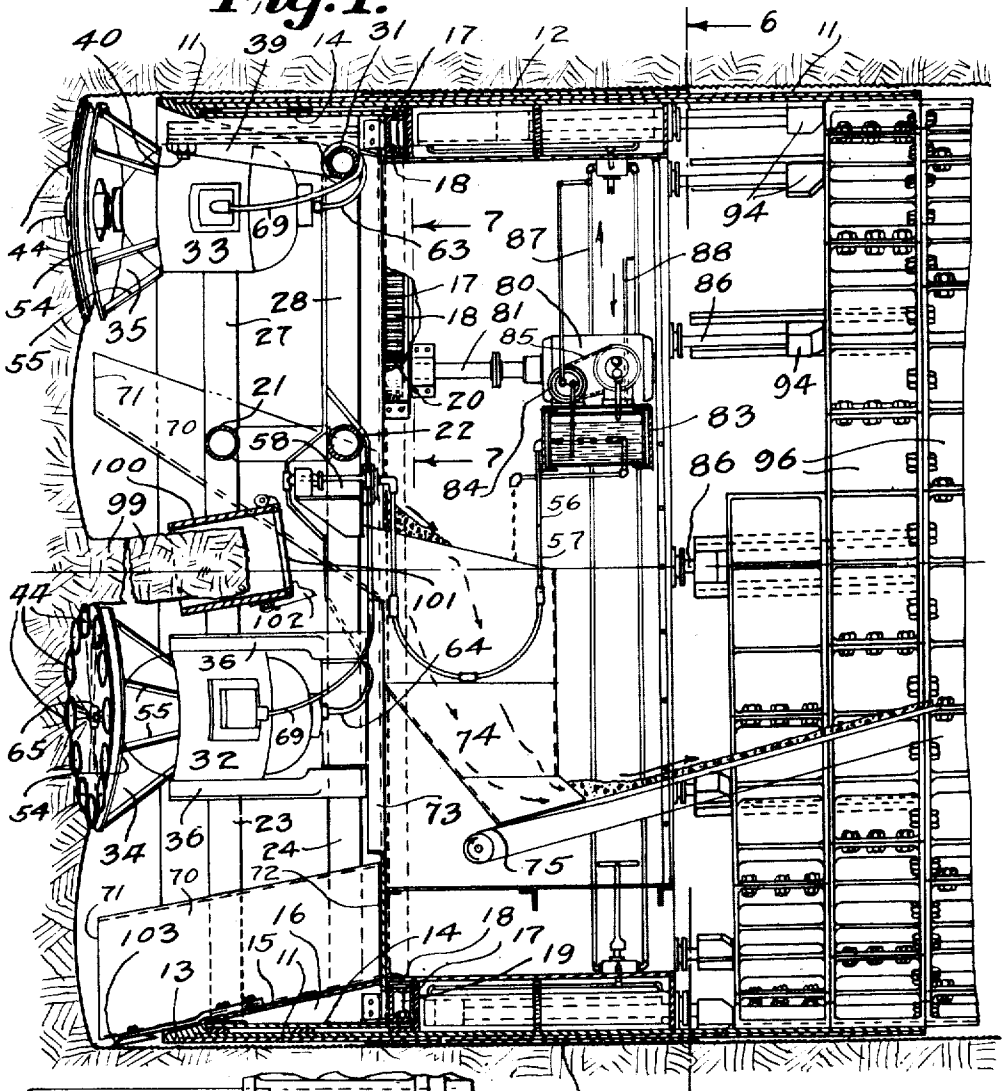


Fig. 2.

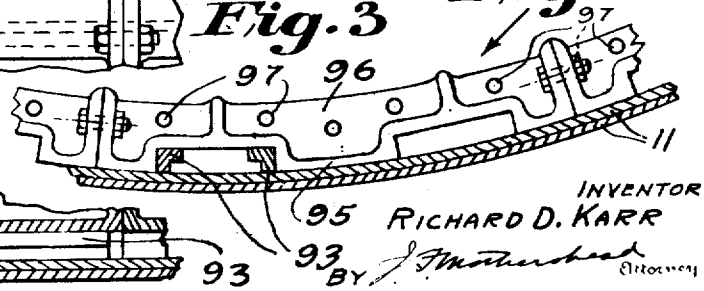


Fig. 3

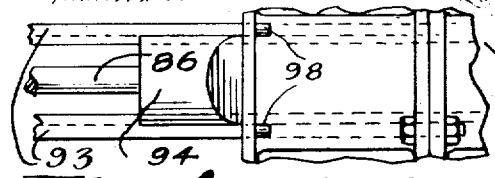
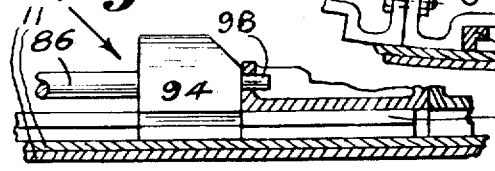


Fig. 4.



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95
93
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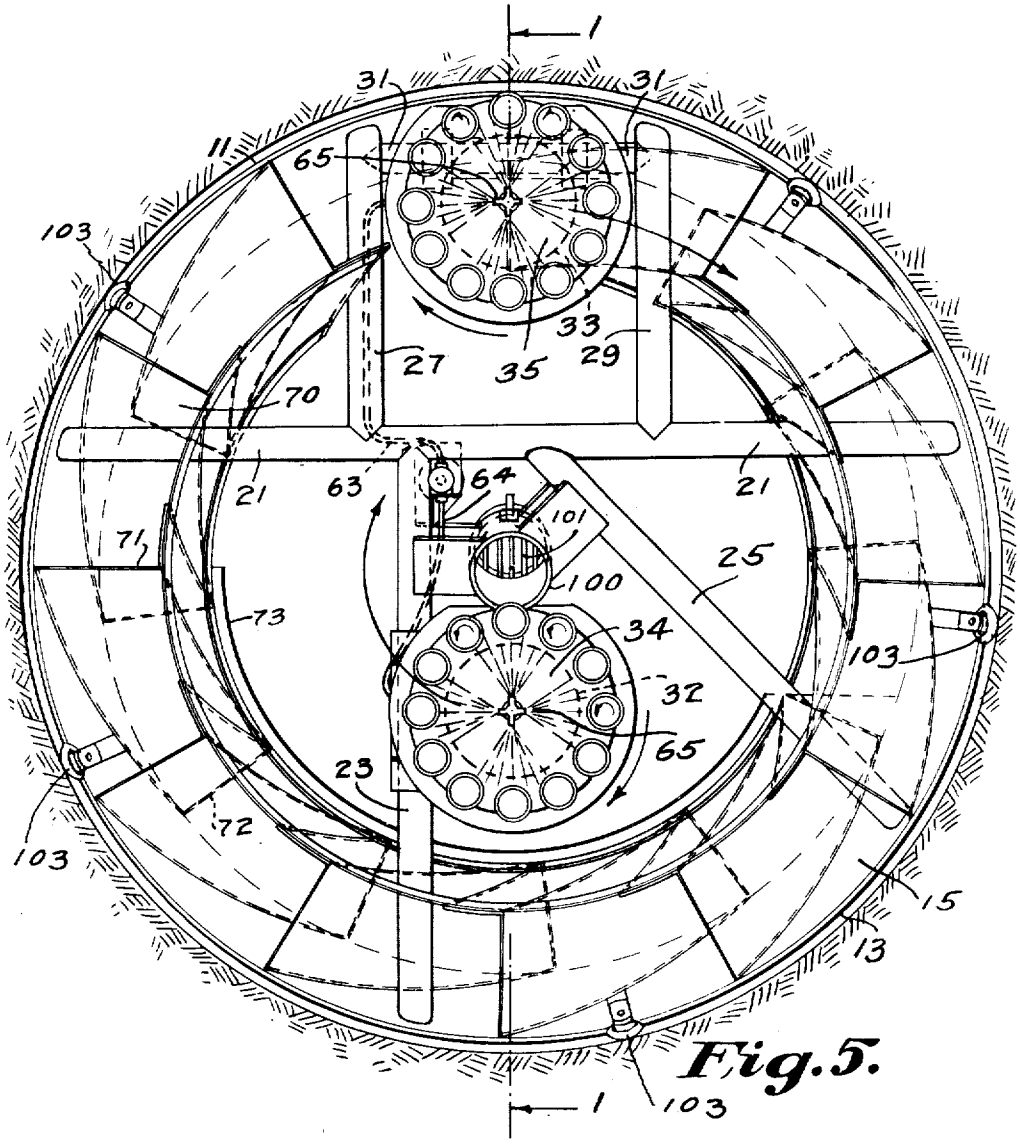


Fig. 5.

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TUNNELING MACHINE

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Fig. 6.

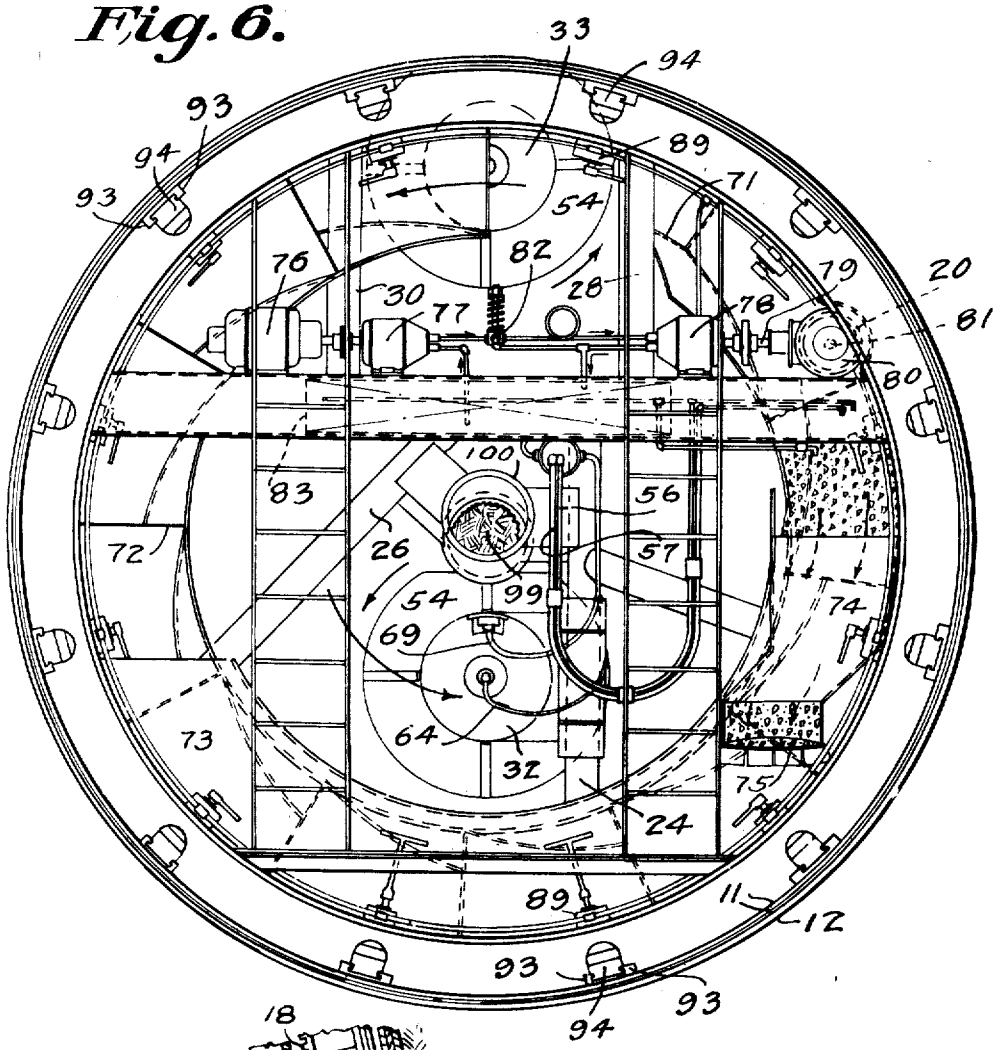
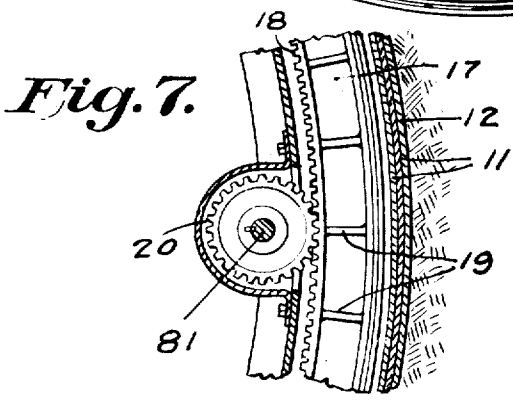


Fig. 7.



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TUNNELING MACHINE

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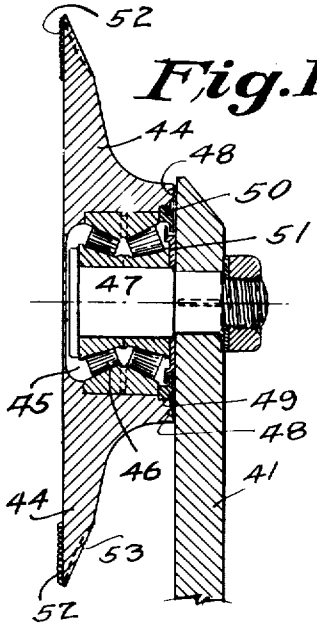


Fig. 11.

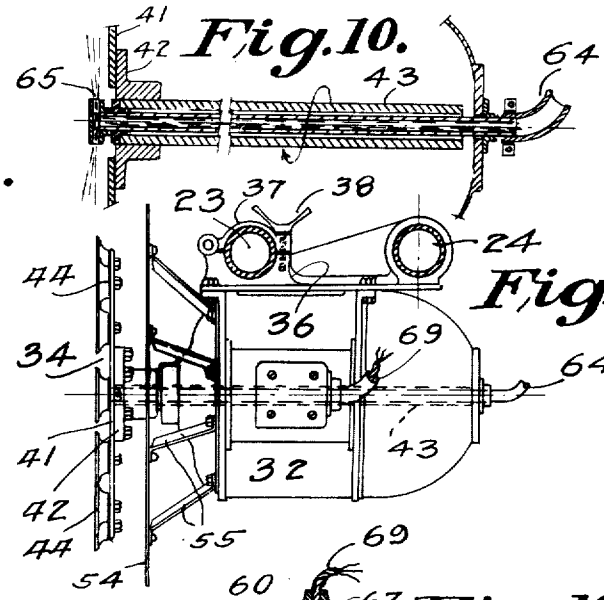


Fig. 10.

Fig. 9.

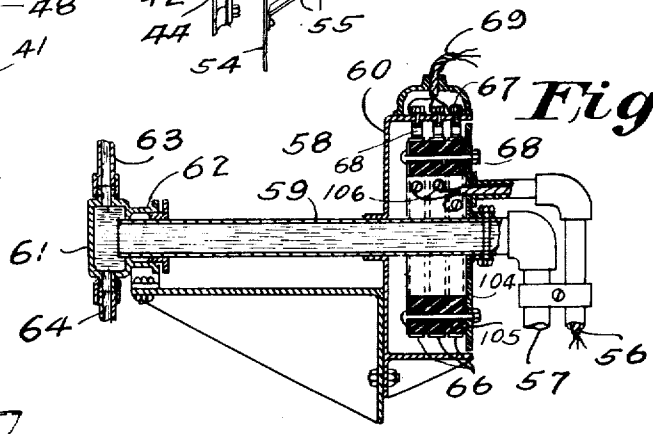


Fig. 12.

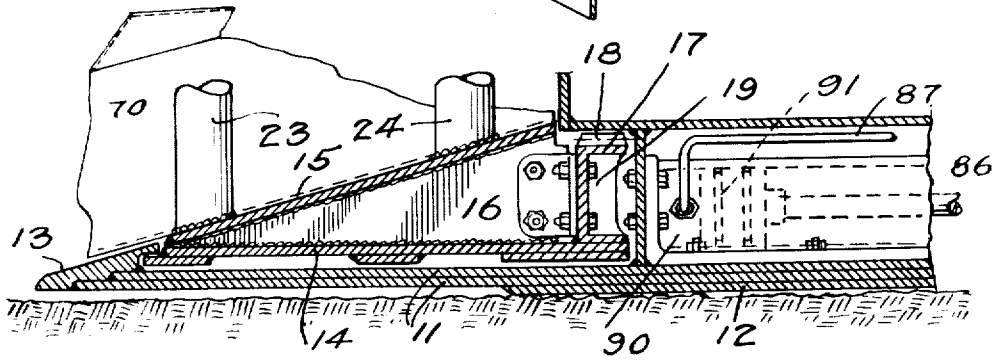


Fig. 8.

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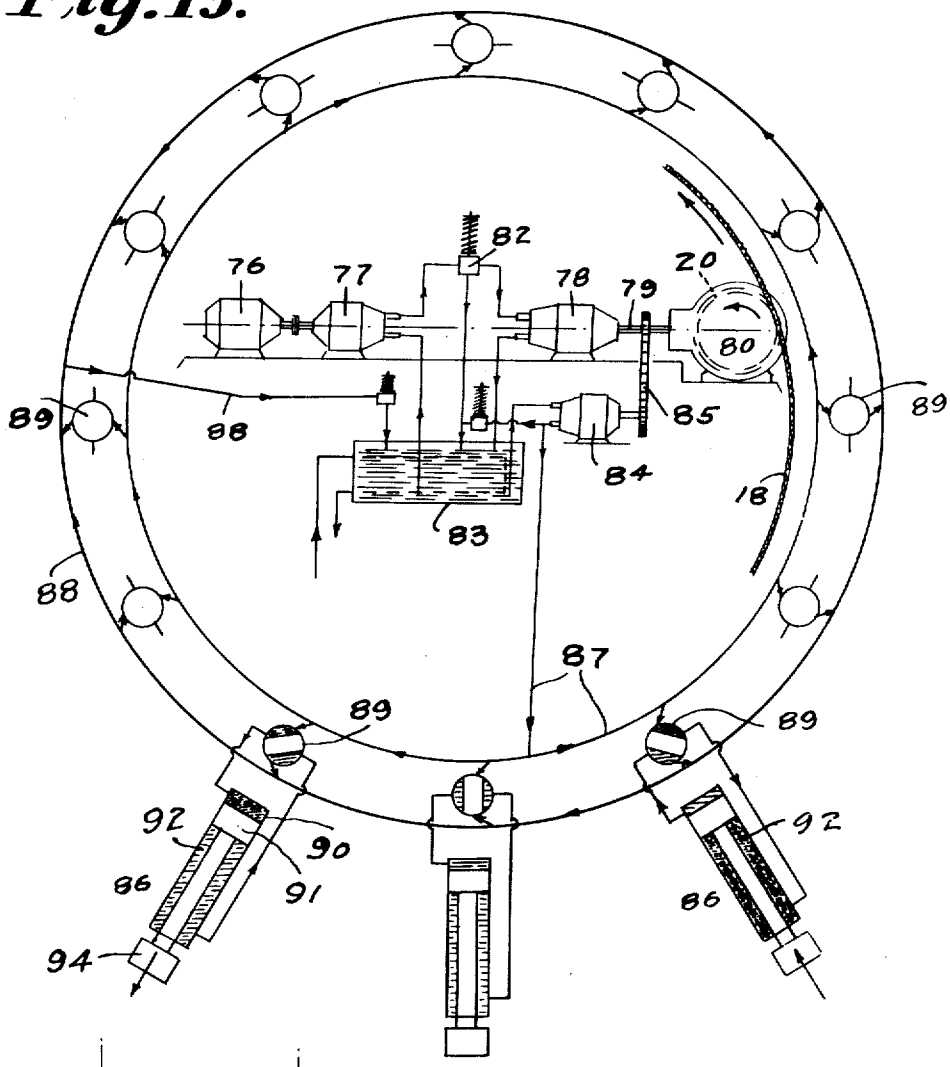
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TUNNELING MACHINE

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Fig. 13.



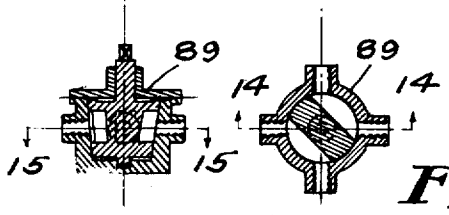


Fig. 14

Fig. 15.

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Patented Apr. 12, 1949 2,466,709

UNITED STATES PATENT OFFICE

2,466,709

TUNNELING MACHINE

Richard D. Karr, Alhambra, Calif.

Application October 2, 1944, Serial No. 556,818

6 Claims. (Cl. 262—7)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of March 3, 1883, (ch. 143, 22 Stat. L. 625) as amended by the act of April 30, 1928 (ch. 460, 45 Stat. L. 467).

My invention relates to improvements in tunneling machines in which one or more sets of rotatably mounted circular cutters are each revolved about the axes of revolution, said axes being slowly rotated about the axis of the tunnel while the entire machine is advanced axially forward.

The objects of my invention are:

First: To obtain swift revolution of each set of cutters about its own axis of revolution by the novel means of mounting each set of cutters on a circular disk, said disk being mounted directly on the shaft of an electric motor, the revolution of said motor being continuous and not dependent upon, though associated with, a slow rotational and axial advance with respect to the tunnel axis.

Second: To obtain a novel and highly efficient method of attack upon the tunnel heading because of the independent revolution of cutter assemblies associated with the controlled advance of said cutter assemblies whereby said rate of advance varies according to the resistance encountered in opposition to such advance.

Third: To provide means by which electric current for power is conveyed to the motors rotating the cutter assemblies and a similar means by which water for cooling the cutters and laying the cutting dust is conveyed to and directed upon the cutters while in operation.

Fourth: To provide an anti-friction bearing of special design for each cutter, said anti-friction bearing being considered essential to reliable operation due to elimination of friction and heat, at the same time said special design permits quick and easy removal of the cutters from their attachment to their carrying disk or plate.

Fifth: To provide an annular protection or shroud ring behind each cutter assembly so that rock fragments may be deflected from a rearward trajectory, thus protecting the operating crew.

Sixth: To provide a rapid repetition of rolling impacts at the base of a shallow ledge formed on the rock face of a tunnel heading by a plurality of chisel-edged disks set at an acute angle to the face of the heading whereby the rock face along the edge of the shallow ledges chipped off by a wedging action.

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Seventh: To provide a positive and sensitive control over the axial advance of the tunneling machine.

Eighth: To provide a hinged support for each cutter motor, by which means each cutter assembly may be independently swung rearward for demounting and renewing worn cutters.

Ninth: To provide a novel tunnel liner unit whereby a sliding tongue and groove interlocking relationship is obtained betwen the shield and the rigidly anchored tunnel lining so that the shield is restrained from rotation in a direction opposite to that of the rock cutting assemblies, and to provide improvements as later set forth by which all phases of tunneling operations including cutting the heading, removing the cuttings and advancing forward are accomplished and controlled, smoothly, continuously and with certainty by means of simple, rugged and efficient parts and mechanisms.

A preferred embodiment of my invention is illustrated in the accompanying drawings in which—

Figure 1 is a vertical longitudinal section of my machine and tunnel lining on the line 1—1 of Figure 5.

Figure 2 is a detail of one unit of my tunnel lining.

Figure 3 is a fragmentary detail plan of a section of lining and a thrust block of one of my jacks.

Figure 4 is a fragmentary radial section of the parts illustrated in Figure 3.

Figure 5 is an elevation of the cutting face of my machine showing the arrangement of the cutting and rock-fragment removing units.

Figure 6 is an elevation of the rear of the machine on the line 6—6 of Figure 1.

Figure 7 is an enlarged radial section of my drum revolving pinion and a fragment of the internal toothed ring gear on the line 7—7 of Figure 1.

Figure 8 is an enlarged fragmentary axial section of my revolving drum and attached internal toothed ring gear which rotate within the forward portion of my shield.

Figure 9 is an enlarged detail of one of the cutter assemblies, driving motor therefor, and motor mounting as for the lower of the cutters shown in Figures 1 and 5.

Figure 10 is an enlarged fragmentary axial section of one of my cutter spraying devices.

Figure 11 is an enlarged axial section of one of my cutters and roller bearing mounting therefor.

Figure 12 is an enlarged fragmentary axial section of my slip ring connection device through which electric current and water are supplied to the cutter motors.

Figure 13 is a schematic diagram of the hydraulic power system for advancing the shield and cutter assemblies mounted thereon, as the tunnel face is cut away.

Figure 14 is an enlarged axial section of my 4-way plug valve on the line 14—14 of Figure 15.

Figure 15 is a cross section of my 4-way valve on the line 15—15 of Figure 14.

In general, my improved tunneling machine comprises a cylindrical steel shield 11 which may be built of one or more laminations of sheet plate within which all the driving, cutting and advancing mechanism and controls are housed and supported. An outer plate 12, shorter than the shield 11 supports the machine and permits some tipping or axial deviation of the machine, in any direction. Secured to the leading edge of the shield 11, is a bevel edged circular shoe 13, which may be formed of cast segments bolted together. Abutting the rear edge of the entering shoe 13 is a cylindrical revoluble drum 14 with circumferential bearing rings to which is secured a conical inner drum 15 by a plurality of tapered radial webs 16 (Figure 8). To the tapered webs 16 is secured an internally toothed ring gear 17, having gear teeth 18, and reinforcing radial ribs 19. The ring gear 17 may be made of segmental sections which are bolted to the drum 14 and webs 16 or attached thereto by other suitable means, as by welding. Ring gear 17 is driven by pinion gear 20.

The drums 14 and 15 are braced internally in different directions by tubular struts 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 and 31. The struts 23, 24 and 31 also provide supports for my cutter motors 32 and 33 and the cutter assemblies 34 and 35 respectively, mounted on the shafts of said motors.

My cutter motor 32 is rigidly secured to hinging brackets 36 which are in turn revolubly mounted on the strut 24 and are held in operative position against the strut 23 by hinged clamps 37 and locking wing nuts 38 (Fig. 9). Similarly, my cutter motor 33 is fastened to a hinging bracket 39 (Figure 1) revolubly mounted on the strut 31 and detachably held in operative position by nuts 40, or the like. Conical drum 15 is recessed or discontinued as necessary for the outer cutter motor 33 and hinging bracket 39. Each revolution of my drum 14 carries the cutter assemblies 34 and 35 in concentric paths. Additional intermediate cutter assemblies may be mounted so as to cut one or more annular kerfs between those cut by the inner and outermost assemblies shown on my drawings. The innermost cutter assembly 34 leaves an uncut core 99 of convenient diameter at the axis of the tunnel, while the outermost cutter assembly 35 cuts a kerf of slightly greater diameter than the maximum diameter of my shield 11, in order to permit the easy advancing of my shield.

The cutter assembly 34 shown in detail in Figs. 9, 10 and 11 comprises a circular plate 41 bolted to a flanged hub piece 42 which is mounted on the motor shaft 43 and keyed or otherwise secured thereto. A plurality of circular bevel-edged cutters 44 (Fig. 11), each having a rearwardly open recess 45 for a roller bearing unit 46, are mounted on stud shafts 47, which stud shafts are detachably mounted on the circular plate 41. Each cutter 44 may be provided with a sealing groove 48 containing a lubricant retaining packing ring and an internal thread 49 for a threaded locking ring 50 by which a retaining washer 51 is held in place.

The design of the beveled cutter 44 is an improvement in such devices because the anti-friction bearing element is particularly well protected against the entry of dirt or water and from the loss of lubricant. The anti-friction bearing element is housed in a recess in the rear face of the thickened hub portion of the circular cutter, thereby obtaining a flush unpierced front face of the cutter which insures protection of the bearing elements at the outer end. A further novel feature of my cutter design is that by welding hard wear-resisting alloy 52 to the forward side of the cutting edge, the cutters become self-sharpening inasmuch as the softer metal body 53 of the cutting edge will wear faster than the wear-resisting allow. This self-sharpening feature has not been used in tunneling machine cutters heretofore. By means of the swinging or hinged brackets 36 the cutter motor 32 and attached cutter assembly 34 may be swung backward and away from its cutting position at the tunnel heading when in the position shown in Figure 1, for the purpose of replacing my cutter disks 44 or for removing the cutter assembly 34 for repair. Similarly, when the cutter assembly 35 is midway between the top and bottom of the heading with the supporting strut 31 vertical, the nuts 40 may be removed and the assembly 35 and motor 33 may be swung away from the tunnel heading for replacement or repairs.

My means for deflecting the rock fragments consists of a circular plate or shroud 54 which is fixedly attached by radial braces 55 to and supported by the shell of the cutter motors 32, 33 (see Fig. 9).

A flexible power cable 56 and flexible water hose 57 are run in close parallelism (Fig. 6) from their respective outlets within my shield to a novel slip ring connection device 58 (Fig. 12).

The water connection pipe 59 passes through a central bearing in housing 60 of the slip ring device 58 to a water outlet box 61, into which it fits through a water-tight stuffing box and gland nut 62 as indicated. From outlet 61 one or more distributing pipes 63, 64, carry water through the cutter motor shafts 43 (Figs. 9 and 10) and the cutter face plate 41, to a four-way nozzle 65 from which water is sprayed transversely on the cutters 44 so that the cutters may be cooled and the rock dust layed by a continuous water spray. The portion of distributing pipe 64 shown passing axially through the motor shaft 43 to 4-way nozzle 65 (Fig. 10) remains stationary within revolving shaft 43, being attached to and supported by flanged connection to the rear housing of the motor. Since water pipe 59 is rotatably mounted in housing 60 and gland 62, it serves as a shaft support for flanged disk 104 which fits rotatably spray tight into the open side of piece 60.

The electric power conduit 56 (Fig. 12) is attached to flanged disk 104 off center from pipe 59. The wires within said conduit pass through disk 104 and after separating are attached to the inner surface of insulating ring 105 by screw conductor bolts 106 which connect each wire to one of the outer distributor rings 66. As the large drum 14 and hence water and power slip ring device 58 is slowly turned by pinion 20 about the axis of the tunnel the inner parts 59, and 103 remain stationary with reference to their axis and therefore turn within the surrounding housing 60 and outlet box 61. Said fixed housing

60 is fitted with electrically insulated outlet terminals 67 which carry spring brushes 68 each in contact with one of the distributor rings 66. It is contemplated that the power current will be three-phase alternating current and thus the slip ring device 58 will have three wires of the power cable 56 leading into the housing 60, three distributor rings 66 with sets of brushes 68 and three outlet terminals 67 from which a three-wire cable will run to each cutter motor 32, 33. Necessary control switches (not shown) in the electrical power circuit and shut-off valves in the water supply (not shown) will be located at a convenient operating position in the rear portion of the shield. The length of flexible power cable 56 and water hose 57 between the fixed outlet boxes within the shield (Fig. 1) and slip ring device 58 must be sufficient to provide downwardly suspended loops in cable and hose to prevent kinking them when they are in their most extended position during the slow revolution of slip ring device 58 about the tunnel axis.

Another feature of my invention is the novel means for disposing of the rock fragments at the bottom of the heading. A convenient number of special-shaped, open-ended scoops 70 are attached to the conical drum 15 as indicated. The forward end 71 of each scoop is at an advanced position, circumferentially, with respect to the rearward end 72. During the passage of the scoops 70 through the lower portion of their circular travel the open rearward ends are closed by a stationary transverse annular bulkhead 73 which extends circumferentially around and upward on the inner side of the shield to about mid-height. A hopper 74 is mounted on the rear of said bulkhead 73 at the upper end thereof. By reason of the angularity of the scoops 70, the forward end is higher than the rear end as they pass the upper edge of the stationary bulkhead 73. Therefore, the rock fragments within each scoop fall downward and rearward into hopper 74; thence into the lower end of a suitable conveyor 75 to pass the debris farther to the rear. Disposal beyond the conveyor 75 is not considered a function of a tunneling machine.

A very important feature of my invention is the means whereby a combination electro-hydraulic and mechanical reduction gear mechanism provides the power for rotating the drum 14 and advancing the whole machine axially, both motions being inter-related automatically. An electric motor 76 (Figs. 6 and 13) drives a fluid pump 77. The pump 77 drives a fluid motor 78 which in turn drives the high speed input shaft 79 of a large ratio reduction gear unit 80. The low speed output shaft 81 turns pinion 20 and thus drum 14 and the attached cutting motors 32, 33, cutting assemblies 34, 35, scoops 70, and all other fittings or parts mounted within and supported by drums 14 and 15.

In order to properly convey an understanding of the functioning of the electro-hydraulic drive for rotating the cutting assemblies and the self-adjusting control that the resistance encountered by the cutters has upon the advance thereof, certain reasonable and correctly related values of pressures, speeds and gear ratios possible with commercially available parts will be cited while describing in detail the operation of my improvement as follows: Motor 76 and fluid pump 77 may operate at 1050 R. P. M. Pump 77 discharges fluid to fluid motor 78. A relief valve 82 between pump 77 and fluid motor 78 may be set at 2500 lbs. per sq. in. so that the torque capacity of fluid motor

78 is limited. Fluid motor 78 may have the same displacement as pump 77 and thus will revolve at the same speed, to wit: 1050 R. P. M. The gear reduction ratio of part 80 may be 350 to 1, so that the slow speed output shaft 81 and pinion 20 will turn at 3 R. P. M. A practical gear ratio between pinion 20 and ring gear 17 is 15 to 1 resulting in one revolution of gear 17; hence drum 14 every five minutes.

It is feasible to obtain a tooth load between gear teeth 18 and pinion 20 of 5000 lbs. before the relief valve on fluid motor 78 opens. It is, therefore, evident that such a maximum tooth pressure of 5000 lbs. between gear teeth 18 and pinion 20 will cause rotation of ring gear 17 as long as the resistance encountered due to (a) friction of parts; (b) work of scooping up and elevating rock fragments; (c) and resistance of the rock to the cutting elements, does not exceed the torque imparted by pinion 20. With the given load on gear teeth 18 of 5000 lbs. it is estimated that the maximum cutting presure which may be developed at the points of contact between all the circular cutters 44 simultaneously upon the rock of the tunnel heading will be about 500 pounds each. It is to be understood that this contact pressure of 500 pounds at each cutter is cited merely for discussion and explanation.

It is apparent that if the strength of the rock is such as to withstand without fracturing, the rapidly repeated rolling impacts of 500 pounds pressure from each rolling cutter, the slow transverse rotation of the cutter assemblies 34, 35, and hence of ring gear 17 will cease and fluid motor 78 will stall. However, electric motor 76 and fluid pump 77 will continue to rotate and maintain 2500 pounds pressure in the pipe to fluid motor 78 and maintain 5000 pounds tooth pressure on gear 17. The discharge of pump 77 will meanwhile escape through the relief valve 82 and return to the fluid reservoir 83 which fluid is cooled by a coil (see Fig. 1) through which water is supplied to the four-way nozzles 65.

Meanwhile, the cutter motors 32, 33 will also continue to rotate and all rock cutters 44 will continue to follow each other along the same arc of contact and subject the rock ledge to sustained, undiminished rapidly repeated vibratory shocks of 500 pounds rolling impacts, about 7200 times per minute (assuming the cutter motor rotates at 600 R. P. M. and 12 cutters are mounted on each cutter disk 41 as shown). This last characteristic of my proposed electric hydraulic drive mechanism, i. e., the ability to subject the ledge of virgin rock to a sustained repetition of sharp wedging blows especially when the advance of the cutters has been stalled without overstressing any part is the most important and novel feature of my invention. My mechanism thus automatically adjusts itself to the variations in resistance that the cutters encounter. Easy or prompt fractures of rock under the action of my rolling cutters permit steady uniform cutting advance. Tough or hard-to-cut rock slows down the speed of advance proportionately and there is automatically directed thereupon a continuous barrage of blows, of maximum intensity, for which the machine is designed. It is evident that the hardest natural rocks will soon crack and fall under the sustained swiftly repeated wedging impacts of my cutting machine. Upon fracture and removal of the rock ledge that has momentarily stalled the advance of the cutters, advance thereof starts automatically. An incidental but valuable characteristic of my hydraulic drive for

advancing the cutting elements is that the cutting edges are protected from damaging excessive pressures as would be apt to arise if there was no automatic relief against excessive pressures beyond a designed safe maximum.

Associated with the hydraulic drive by fluid motor 78 of the reduction gear 80 is the small fluid pump 84 which is driven by a chain 85 from the input shaft 79 of reduction gear unit 80. Pump 84 draws fluid from the reservoir 83 in the supporting structure of pump 84 and delivers it to the hydraulic advancing jacks 86 which are spaced for any desired number circumferentially within the shield 11 as indicated. It is obvious that pump 84 operates only as fluid motor 78 is able to turn the input shaft of the gear unit 80 and thus rotate the cutting assemblies 34, 35. Thus the amount of fluid delivered by pump 84 to advancing jacks 86 is exactly proportional to and precisely measured by the angular advance of the cutting assemblies 34, 35 in their operations upon the tunnel heading. Such inter-connection between cutting progress and axial advance maintains any desired pitch of the advancing spiral which the cutting assemblies transcribe due to the compound motion imparted to them.

The arrangement of piping and valves by which the fluid is conveyed from pump 84 to jacks 86 is made up of a common supply pipe 87 and return pipe 88. Adjacent to each jack a four-way valve 89 serves to connect the supply pipe to the driving side 90 of the jack piston 91 and the return pipe 88 to the discharge side 92. By turning the four-way valves 89, the supply and return pipe connections are reversed so that the advancing jacks may be easily and quickly retracted.

One novel feature of my improvement in tunneling machines is the recessed tracks 93 (Fig. 4) provided for each jack thrust block 94. By this means the outer ends of the jack piston rods are held in proper alignment with the cylinder barrel of the jack, reducing wear and leakage. Another result of the provision of the recessed tracks for the jack thrust block is that recesses or slots 95 on the outer surface of each piece of tunnel lining 96 (Fig. 2) may fit over said tracks 93 and thereby prevent the transverse rotation of the tunneling machine as a whole in the opposite direction to that in which the cutting elements are rotated while in operation upon the tunnel heading. The lining pieces 96 are segmental in shape having a curvature to fit loosely within the tunnel shield. All edges of the lining piece are flanged inward, each flange having suitable boltholes 97 so spaced as to line up with holes of adjoining lining pieces so as to provide means for bolting all pieces together. The face of each thrust block 94 is fitted with lugs 98 which fit into certain of the bolt-holes 97 provided in the flanges of each liner piece 96 during the period which said piece is in direct contact with said jack thrust block.

I reduce the quantity of virgin rock which is chipped off by leaving uncut a core 99 which is engaged by an axially inclined sleeve 100 eccentrically mounted in my revoluble drum 14 having a hinged grid 101 at the rear end releasably secured by a suitable catch 102.

When the sleeve 100 has advanced sufficiently to bring it in contact with the core 99, the eccentric or wobbling motion of the sleeve 100 with respect to the axis of the core will exert bending force on the core 99 until the latter breaks. The grid 101 then retains the broken core until an attendant releases the catch 102 and allows the broken core to slide out and be removed as on the conveyor 75.

I prefer to mount on my drum 15 so as to project forward in advance of shoe 13, a plurality of reaming cutters 103 substantially identical with my bevel-edged cutters 44. The rotation and axial advance of my drum 14 causes these reaming cutters to slowly advance in a helical path the pitch of which varies with the rate the jacks 94 advance the shield axially forward.

It should be understood that the foregoing disclosure is for the purpose of illustration only, and that the invention includes all modifications and equivalents which fall within the spirit and scope of the appended claims, in which it is my intention to claim all novelty inherent in my invention as broadly as possible in view of the prior art.

What I claim is:

1. A tunneling machine comprising in combination a shield, a drum revolubly mounted within said shield, a plurality of rotatable assemblies of circular beveled edged cutters supported by said drum and carried around in various orbits in an outer annulus for making an annular cut, hydraulic means for rotating said drum, electrical means for rotating said cutter assemblies at relatively high speed independently of their orbital motion about the axis of said tunneling machine; means for supplying electric current for rotating said motor and attached cutter assemblies; means for supplying water to said cutter assemblies simultaneously with their combined rotation and orbital motion; a plurality of hydraulic jacks adapted to thrust said shield forward; hydraulic driving means for said jacks controlled by the operation of the hydraulic driving means for said drum, tunnel lining means composed of identical liner units adapted to secure a sliding tongue and groove interlocking relationship with longitudinal guide bars attached to the inner surface of said shield, said guide bars adapted to guide the shield in its forward motion as well as to guide the hydraulic jack thrust blocks in axial alignment with the jack cylinders and to restrain said shield from transverse rotative movement contrariwise to that of the cutter assemblies.

2. A tunneling machine comprising a frame member, a rotatable drum mounted thereon, a plurality of polyphase electric motors carried by the drum, a cutting assembly carried by each motor, each cutting assembly comprising a plurality of disk type rock cutters, means mounted on the drum for supplying a water spray for the cutters including a distributor box having a portion rigidly attached to said drum and a companion portion revolubly mounted therein, a plurality of insulated distributor rings secured to said revolubly mounted portion and inclosed in said box, a flexible cable connecting said rings with a supply of electric current, an electrical brush member for each current phase mounted in the rigidly attached distributor box in electrical contact with one of said rings, an outlet terminal for each brush, and a suitable cable from each outlet terminal to each of said polyphase electric motors.

3. In a tunneling machine provided with an enveloping cylindrical shield, a drum revolubly mounted within said shield, an assembly of bevel-edged cutters inclined to the axis of said drum and revolubly mounted therein, a high speed

electric motor directly connected to said assembly and means for supplying electric current to said motor, the improvement which comprises means for spraying water on said cutter assembly, a plurality of hydraulic jacks for advancing said shield and drum, hydraulic driving means for said drum, a plurality of tunnel lining units provided with means for preventing the rotation of said shield while permitting the axial advance of said machine, a secondary liquid pump and means for adjusting the stroke of said pump to regulate the advance of said jacks relative to the speed of revolution of said rock cutting assembly and an exterior band of wear-resisting metal affixed to said shield for pivotally supporting the machine to provide greater ease of directional control of said cutter assembly.

4. In a tunneling machine a rotatable drum, an enveloping shield, a plurality of rock cutting assemblies, and an electric motor for each of said assemblies, the improvement which comprises a liquid pump, an hydraulic motor, a plurality of hydraulic jacks, a liquid conduit including a reservoir, a secondary liquid pump provided with stroke-adjusting means, and a heat-transmitting coil immersed in said reservoir connected to an external water supply and to means for spraying said cutting assemblies, whereby water passing through said coil serves to extract excess heat from liquid in said reservoir.

5. In a tunneling machine the combination with a shield having rotation-preventing means for engaging a tunnel lining, a drum revolubly mounted therein, a rotatable assembly of beveled edged self-sharpening cutters mounted in said drum, an electric motor for operating said assembly, a plurality of hydraulic shield advancing jacks each provided with a thrust block secured to each jack piston, and a plurality of guide bars attached to said shield parallel to the axis thereof, each having a rabbet into which a reverse rabbet of a thrust block fits.

6. In a tunneling machine of the class described having a rotary drum, an hydraulic motor for rotating said drum and a plurality of independently driven cutter assemblies, the improvement which comprises an hydraulic pump for supplying liquid to said hydraulic motor, fluid pressure regulating means for limiting the torque output of said motor, a secondary fluid pump, means for driving said secondary pump from the output side of the hydraulic motor, a plurality of hydraulic drum advancing jacks adapted to be operated by liquid from said secondary pump and means for adjusting the stroke of said secondary pump to regulate the speed of advance of said jacks.

RICHARD D. KARR.

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