Nov. 7, 1967 K. STURM 3,350,889

APPARATUS FOR DRIVING AND LINING TUNNELS IN UNSTABLE SOIL

Filed March 25, 1965 5 Sheets-Sheet 1

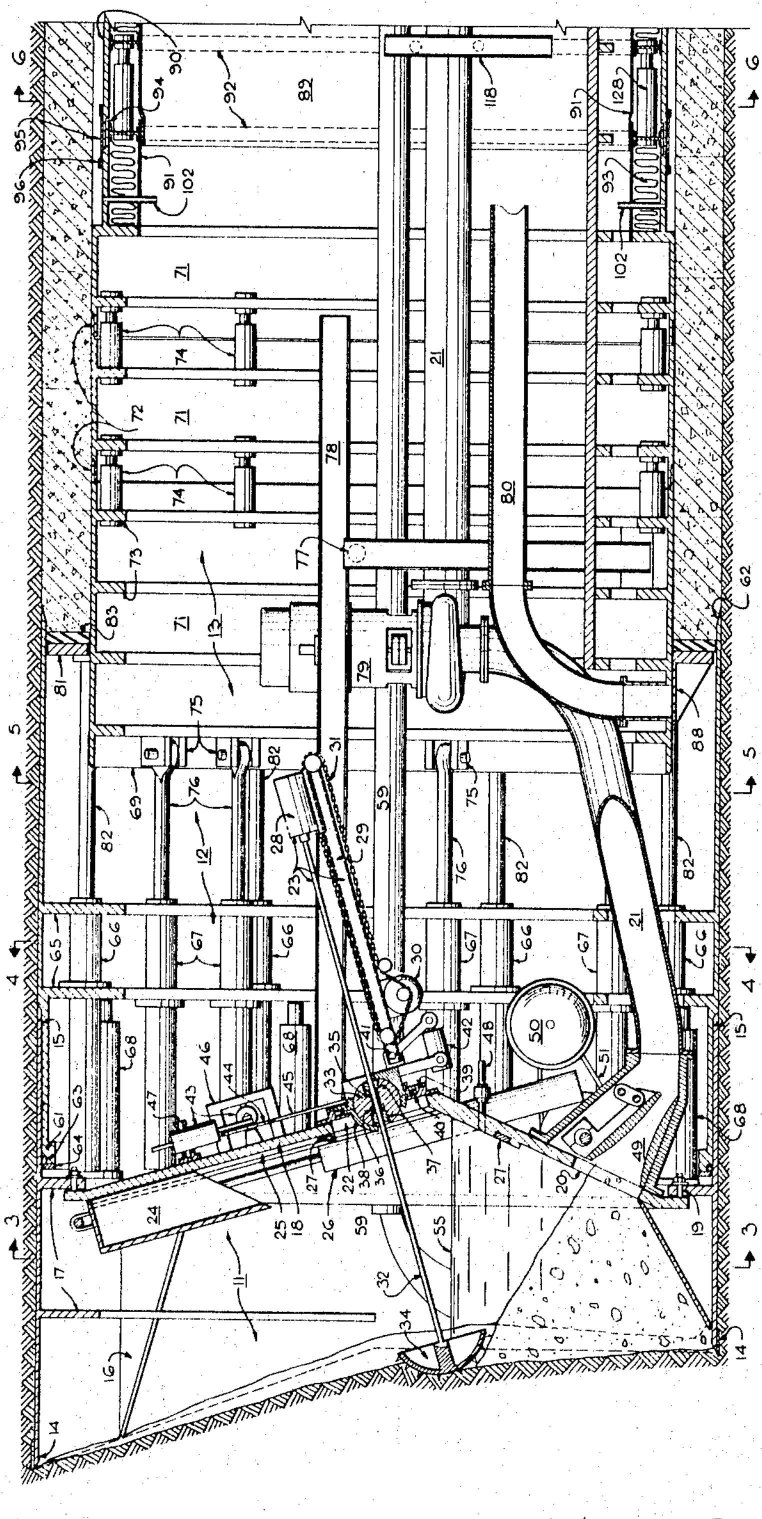

FIG. 1

Nov. 7, 1967 K. STURM 3,350,889

APPARATUS FOR DRIVING AND LINING TUNNELS IN UNSTABLE SOIL

Filed March 25, 1965 5 Sheets-Sheet 2

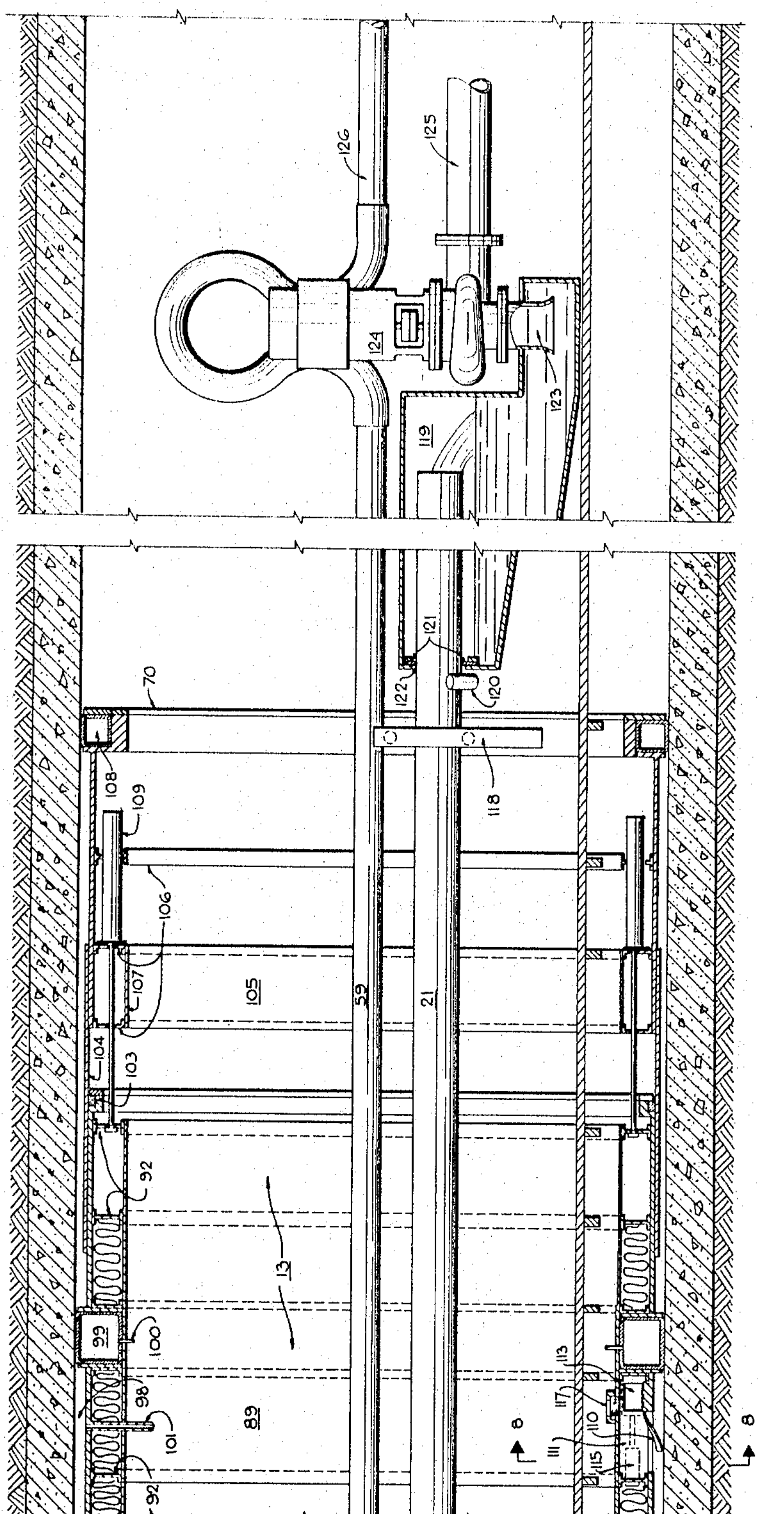

FIG. 2

APPARATUS FOR DRIVING AND LINING TUNNELS IN UNSTABLE SOIL

Filed March 25, 1965

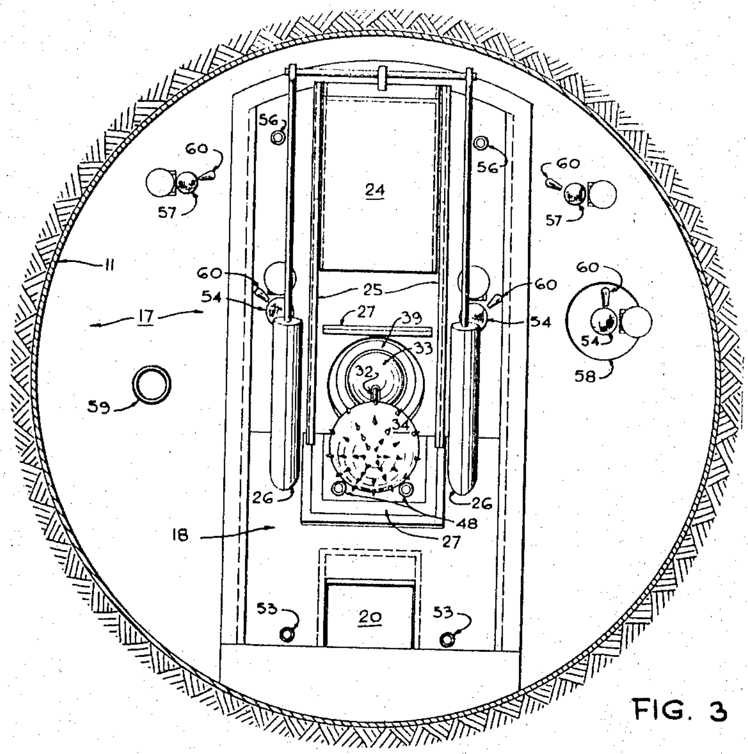

FIG. 3

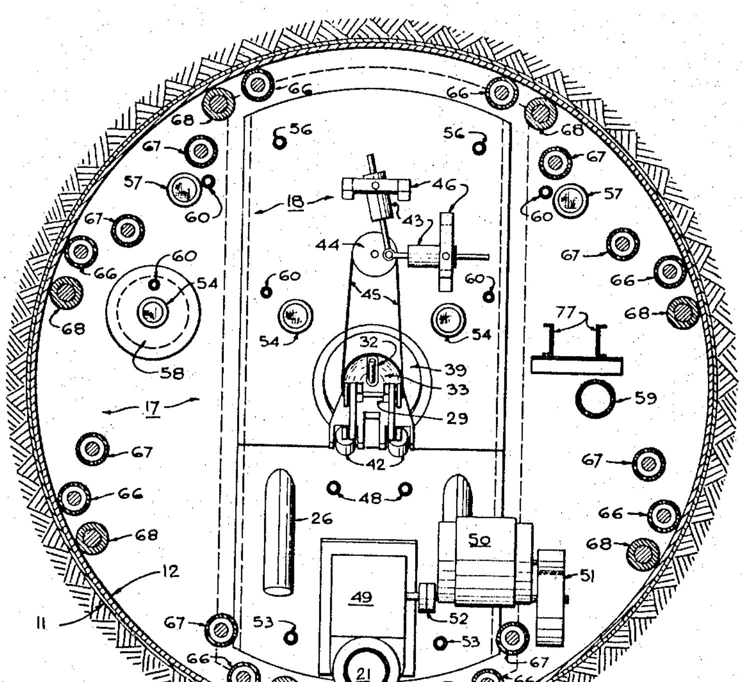

FIG. 4

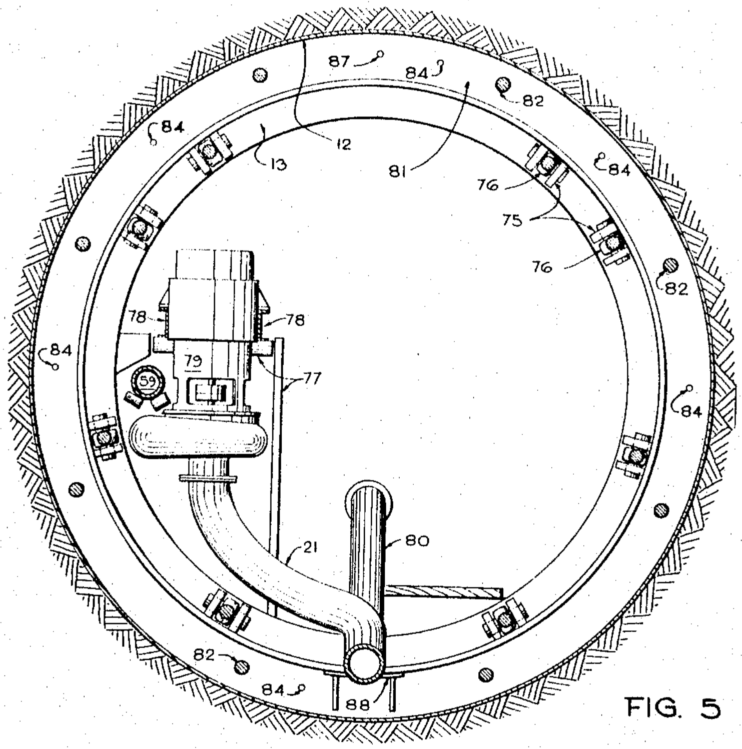

FIG. 5

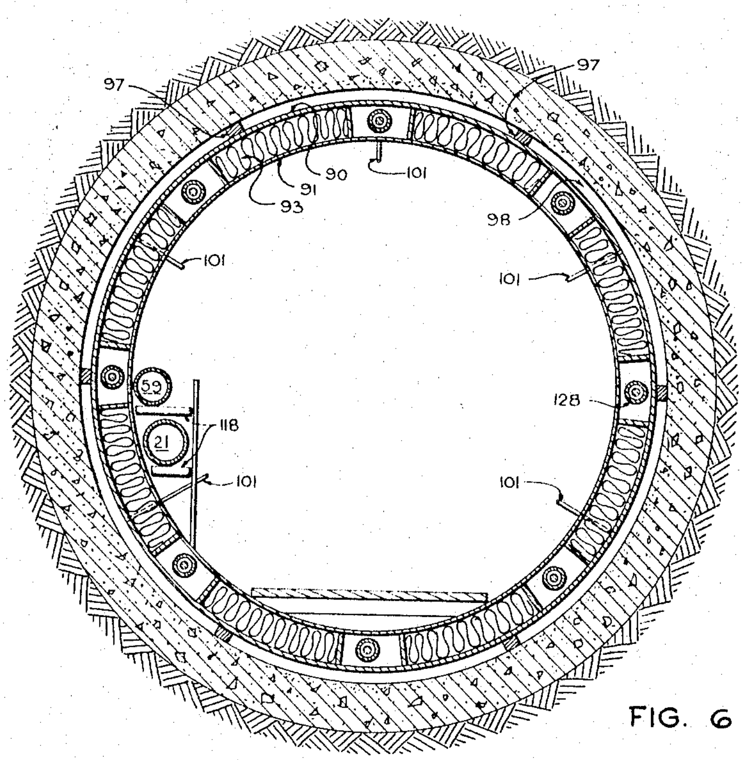

FIG. 6

Karl Sturm

Nov. 7, 1967 K. STURM 3,350,889

APPARATUS FOR DRIVING AND LINING TUNNELS IN UNSTABLE SOIL

Filed March 25, 1965 5 Sheets-Sheet 5

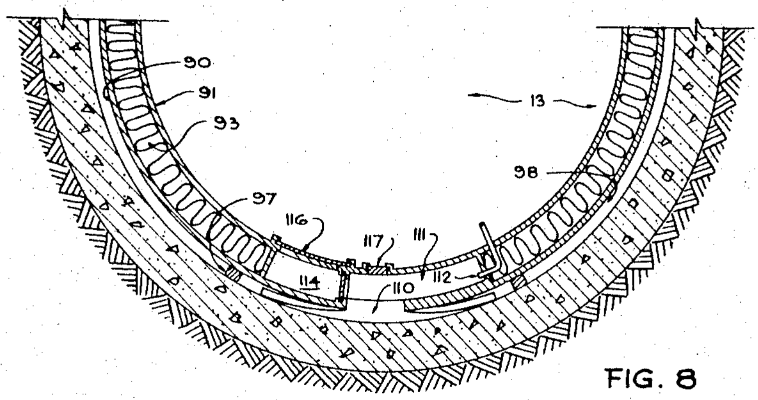

FIG. 8

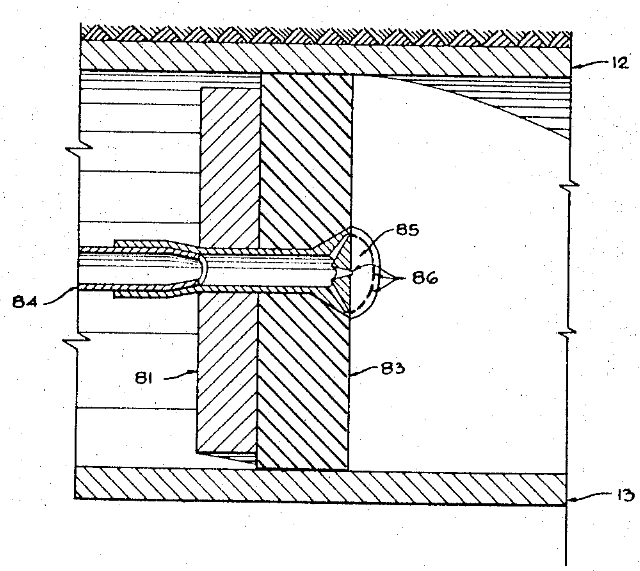

FIG. 7

Karl Sturm

United States Patent Office

3,350,889

Patented Nov. 7, 1967

1

3,350,889
APPARATUS FOR DRIVING AND LINING TUNNELS IN UNSTABLE SOIL

Karl Sturm, 499 Ventura Crescent, North Vancouver, British Columbia, Canada

Filed Mar. 25, 1965, Ser. No. 442,677
Claims priority, application Canada, Apr. 15, 1964, 900,389, Patent 715,426
18 Claims. (Cl. 61—85)

ABSTRACT OF THE DISCLOSURE

An apparatus for driving and concrete lining a tunnel in unstable ground, even in the presence of water, in a continuous operation without the aid of permanently installed supports and without pressurizing the tunnel itself, thereby reducing the hazardous conditions during tunnel driving and providing a more economical and efficient operation. This can be achieved by the described apparatus which consists of three distinct sections. The front section comprises the excavation arrangement having a closed shield near its forward end which permits the application of compressed air against the excavated face without pressurizing the tunnel itself, and which also supports various mining equipment operated from the rear and extending through the shield. Therefore, no personnel is exposed to compressed air. The second section constitutes a sliding temporary support for the surrounding soil and extends to the front face of the concrete lining. The soil on the inside of the tunnel is therefore never exposed to atmospheric pressure and its internal stress pattern is always preserved. A temporary support, permanently installed, in form of steel ribs or plates is not required. The third section comprises a slip-form for the concrete lining and has provision for steam curing to accelerate the strength gain of the concrete, thus allowing the reduction of the physical length of the apparatus. The slip-form is arranged to permit the insertion of reinforcement and other structural components. The loosened material from the tunnel face is transported hydraulically in closed pipes from the excavation face directly to the disposal area outside the tunnel. The tunnel therefore is free for the use of other operations. The concrete is placed by means of concrete pumps in a nearly continuous operation.

The invention relates to an improved method and apparatus for boring and lining of tunnels in soil, soft rock and water bearing strata.

When driving tunnels in soil or soft rock it is generally necessary to support the entire bore hole simultaneously with the excavation. This entails the use of specially formed supports made of steel, cast-iron or precast concrete, behind which grout or concrete is placed. In the case of tunnelling in water bearing strata, it is necessary to prevent soil and water from flowing into the bore hole. With present methods and equipment, this is commonly achieved by the use of a protective shield and by pressurizing the tunnel or alternatively by stabilizing the ground by freezing, grouting or chemical processes. Although these construction methods work effectively, they have the disadvantages of being slow, inefficient, very expensive and hazardous to life, in that men must work in the pressurized tunnel and at the exposed excavation face.

It is the object of this invention to overcome these disadvantages by providing an apparatus and method which will make it possible to drive and line a tunnel of any size and shape through unstable soil and soft rock, even in the presence of ground water, in a continuous operation, without the aid of permanently installed supports and without pressurizing the tunnel itself, thereby reducing

2

the hazardous conditions and providing a more economical and efficient operation. This can be achieved by a tunnelling machine having a shield close to its forward end which permits the application of pressure against the excavated face without pressurizing the tunnel itself. The tunnelling machine is provided with conventional excavating equipment capable of operating in front of the shield and with suitable means for hydraulically removing the loosened material from the excavation chamber. The rear end of the tunnelling machine serves as a continuous slip-form for the concrete tunnel lining and is so equipped to permit high pressure steam curing of the concrete. Advancement of the machine in the tunnel is accomplished by a number of jacking mechanisms acting against the forward face of the concrete lining and aiding in the consolidation of the freshly placed concrete.

For practical application the tunnelling machine may be conveniently divided into three distinct parts, namely: the front part, consisting of the leading tube and shield, mining equipment and pump sump; the intermediate part, consisting of the second tube, bulkhead, outer slip-form and jacking mechanism; the rear part, consisting of the third tube, inner slip-form and steam curing provisions.

These and other parts of the invention appear from time to time as the following specification proceeds and the advantages and objects of the invention became apparent by referring to the accompanying drawings wherein

FIGURE 1 is a longitudinal section of the front and intermediate parts of the tunnelling machine, showing the general arrangements for excavation, tunnel advancement, forming and concreting.

FIGURE 2 is a longitudinal section of the intermediate and rear parts of the tunnelling machine, showing the concrete steam curing and excavation disposal pipe arrangements.

FIGURE 3 is a cross-section through the leading tube, showing the arrangement of the front face of the shield.

FIGURE 4 is a cross-section through the leading tube, showing the arrangement of the rear face of the shield.

FIGURE 5 is a cross-section through the second tube, showing the arrangement of the slip-form and bulkhead.

FIGURE 6 is a cross-section through the third tube, showing the arrangement of the slip-form and steam curing provisions.

FIGURE 7 is a section through the bulkhead ring, showing details of the rubber air valve.

FIGURE 8 is a section through the third tube, showing details of the cleaning chamber adjacent to the concrete curing portion of the slip-form.

In the embodiment of the invention illustrated in the drawings, the tunnelling machine is shown as having a leading tube **11** at the front, an intermediate tube **12** in the middle and a third tube or inner slip-form **13** extending a substantial distance rearwards into the concrete lined section of the tunnel.

The leading tube **11** extends from its cutting edge **14** to its tail end **15** and is made out of strong durable material like steel, the outside shape of which conforms exactly to the outside dimensions of the tunnel lining. Stiffener plates **16** and stiffener rings **17** are rigidly connected to the leading tube **11** to provide additional strength. Attached to one of these stiffener rings **17** by means of bolts **19** or conventional quick couplings is a removable shield **18** having an opening **20** through which excavated material passes into the discharge line **21** and an opening **22** through which conventional mining equipment **23** is inserted and retracted. Mounted to the front face of the shield is a cover **24**, guided by tracks **25** and moved by hydraulic jacks **26** from an open position to a closed position, where it bears against rubber sealstrips **27**.

The mining equipment 23 is of commercially known type used for rotary and percussion drilling and consists of a motor 28, which is moved on guides 29 by means of chains 31 driven by an airmotor 30. The drilling rod 32 is connected to the motor 28 by conventional type couplings and extends through the ball joint 33 to the excavation face. At the forward end of the drilling rod a cutter 34 or drilling bit is attached. Alternatively, suitable hydraulic jetting equipment can be attached to the drilling rod where the material to be excavated suggests the use of such equipment. The ball joint 33 has a hole 35 through its centre with provision for the installation of seal rings 36 and bushings 37. The ball 33 is contained by a split shell 38, which can be rotated around an axis perpendicular to the shield 18 which also serves as a cover to the hole 22. The guide plate 39 has provision for the insertion of seal ring 40. The split shell 38 is so shaped to allow rotation of the drilling rod through an angle of approximately 70 degrees from the centre line to one side only, thereby providing a better sealed joint. To allow the cutter 34 to reach every part of the excavation face the ball joint 33 is rotated as previously mentioned by an open chain 45 attached to a sprocket 44 which is turned by hydraulic jacks 43. The ends of the open chain 45 are slung around the ball joint 33 and are fastened thereto by means of pins for easier disconnection. The supports 46 of the hydraulic jacks 43 are held in place by pins 47 to allow for angular movement when the sprocket 44 is being rotated.

The mining equipment 23 and guides 29 are connected to the split shell 38 by a pin 41 which allows for rotation of the said equipment when actuated by the hydraulic jacks 42.

To allow the removal or exchange of the drilling tools, the rod 32 is retracted until the bit 34 touches the ball joint, after which the cover 24 is lowered and enclosed space depressurized by opening the valves at the pipes 48. The chain 45 is then disconnected and the guide plate 39 removed together with the entire mining equipment. Installation of equipment is performed in a reverse sequence.

A crusher 49 of commercially known type is attached to the rear of the shield 18 behind the opening 20 and in line with the discharge line 21. This crusher is driven by motor 50 through a gear or belt transmission 51 and a flexible coupling 52 and reduces small boulders and oversized gravel to a size suitable for conveyance hydraulically along the discharge line. Air or water lines are connected to nozzles 53 (FIGURES 3 and 4) located at the bottom of the shield 18 to allow the accumulated loosened material in front of the opening 20 to be agitated as and when necessary for easier discharge into the crusher 49. The shield 18 is also furnished with removable windows 54 capable of withstanding high pressure and nozzles 56, installed at the highest possible location, to regulate the supply of compressed air to the excavation chamber. Adjustable spotlights 57, behind heavy duty glass, provide light for inspection of conditions in the chamber. All windows 54 and lights 57 are furnished with nozzle type window washers 60 and lids 129. A manhole 58, complete with inspection window 54, is provided to allow access to the excavation chamber when not under pressure. Penetrating the stiffener ring 17 is the main water supply pipe 59 providing water to the chamber for the hydraulic excavation process

The second tube 12, extending from its forward sealing end 61 to its tail end 62, is made out of strong durable material like steel, the outside shape of which conforms exactly with the outer shape of the leading tube 11. The first and second tubes can move independently of each other, a rubber type seal 63 being provided at the forward end of the second tube 12. Sealing is accomplished by compressing the seals 63 perpendicular to the sealing face with a ring plate 64 by means of bolts (not shown). The second tube 12 is strengthened by stiffener rings 65 which carry several jacking mechanisms 66 and 67. Further jacking mechanisms 68 are installed between the stiffener ring 17 of the leading tube and the stiffener ring 65 of the second tube.

Projecting rearwards from the second tube 12 is the third tube or inner slip-form 13 extending from its forward end 69 to its tail end 70 (FIGURE 2). The front part consists of several short sections 71, made out of strong durable material like steel, overlapping each other at joints 72 and strengthened by stiffener rings 73. The various sections 71 are connected by hydraulic or screw jacks 74 thus allowing relative adjustment of the sections. At the forward end 69 quick couplings 75 engage the piston rods 76 of hydraulic jacks 67. Between the tail end 62 of the second tube and the forward end 69 of the third tube is a bulkhead ring 81 which is attached to the piston rods 82 of hydraulic jacks 66. Rough timber boards 83, forming a tight fit between the second and third tubes 12 and 13, are secured to the bulkhead ring 81 and constitute the end form for the concrete lining. Shortly after concreting is completed the bulkhead ring and timber boards are retracted in readiness for further concreting. Several air pipes 84 with rubber type valves 85 (FIGURES 5 and 7) are installed in the bulkhead ring to permit the application of compressed air between the concrete and bulkhead ring, thereby making removal of the end form easier and cleaner. The rubber valves 85 consist of conical rubber tubes having perforations 86 along their peripheries and in their centres which open only when pressure is applied. Further attachments to the bulkhead ring 81 are plugged air and water escape openings 87 and a concrete supply line closure plate 88.

A hydraulic pump 79 rests on beams 78, fixed at their forward ends to the shield 18 and supported at the other ends on a roller support 77 (FIGURES 1 and 5). Also fixed to the shield and supported on the roller support 77 is the water supply line 59. A concrete supply line 80 is connected to the forward section of the third tube 13, the concrete being supplied by a concrete pump (not shown) rearward of the tunnel machine.

Attached to the rearmost slip-form section 71 are a plurality of ring sections 89 which are smaller in size than the concrete lining and consist of an outer tube 90, an inner tube 91, stiffener rings 92 and thermal insulation 93. The said ring sections 89 are held in position relative to each other by hydraulic or screw jacks 128 which allow adjustment in alignment of the sections. The joints 94 are sealed by a rubber seal band 95 secured to the end of each section 89 by steel bands 96. The ring sections 89 are guided by spacer bars 97 (FIGURE 6) which are off-set in the various ring sections to provide an uninterrupted space 98 between the concrete face and the outer tube 90. The space 98 is sealed at the end of the outer ring 90 by an inflatable tube 99 pressing against the concrete face when under pressure only, pressure being applied through valves 100 connected to the compressed air system. High pressure steam is constantly supplied to the space 98 from a steam plant (not shown) through pipe connections 101 and discharged through pipe connections 102. The rear end of the last ring section 89 is furnished with a seal ring 103 (similar to the seal 61 of the second tube 12) acting against the outer shell 104 of the tail end ring section 105 of the third tube 13.

The tail end ring section 105 consists of an outer shell 104, stiffener rings 106, inner shell 107 and seal 108, which is similar to seal 99. Hydraulic jacks 109 connect the tail end ring section 105 to the last ring section 89.

At the bottom of the concrete lining, and in front of the seal 99 is a scraper 110, collecting the accumulated concrete spallings into the space 111, from where they can be jetted by nozzles 112 (FIGURE 8) through holes 113 into a chamber 114. The spallings can then be removed after closing the hole 113 by means of a hydraulic jack 115 and opening a lid 116. A window 117 allows inspection of the collecting chamber 111.

The water supply pipe **59** and discharge line **21** are supported by roller supports **118** mounted at suitable intervals on the inner tube **91** of the third tube **13**. The discharge line **21** extends into a collecting chamber **119** and is supported on rollers **120** and adjacent to the chamber. The collecting chamber **119** has a rubber collar **121** at the entrance hole **122** and a mouth piece **123** to which a second hydraulic pump **124** is mounted. A fixed discharge line **125** leading to a disposal basin outside of the tunnel is mounted to the discharge end of the pump **124**. The collecting chamber **119** with second pump **124** are stationary and are relocated in steps equal to one length of discharge line **125** with the advancement of the leading tube **11**. The water supply pipe **59** is connected with the fixed water supply pipe **126** by a looped hose **127** which is successively connected to new sections of pipe, added to the water supply pipe **126**.

Having described the various members of the tunnelling machine, the method of operation is now explained.

Soil is continuously removed from the excavation face by the cutter or drilling bit **34** which is able to reach every part of the face through the rotary action of ball joint **33** and split shell **38** combined with the axial movement of the drilling rod **32**. The loosened material drops into a pool created in front of the shield **18**, the water surface **55** of the pool always being maintained well above the opening **20** by supplying water from the water supply pipe **59**. Water and exacavated material are withdrawn by the hydraulic pump **79** and discharged through the discharge line **21** into the collecting chamber **119** located to the rear of the tunneling machine. A jaw crusher **49** mounted to the rear of the shield **18** crushes small boulders and oversize gravel to a size capable of being handled by the pump. From the collecting chamber **119** the water-soil mixture is withdrawn by the hydraulic pump **124** and discharged through discharge line **125** into a settling tank or basin, preferably located outside the tunnel.

The discharge end of the discharge line **21**, following the movement of the leading tube **11**, travels toward the opening **122** of the collecting chamber **119**. When the distance traveled is sufficient to allow the installation of a new length of pipe to the stationary discharge line **125**, the collecting chamber **119** is relocated one step further into the tunnel and the new length is then added to the stationary discharge line **125**. The pump **79**, discharge line **21** and water supply pipe **59** rest on roller supports **77**, **118** and **120** to allow independent movement of the various components of the tunnelling machine.

Simultaneously with the excavation operation, the leading tube **11** is advanced by hydraulic jacks **68** mounted to the rear of stiffener ring **17** and acting against stiffener ring **65** of the second tube **12** which supports further jacking mechanisms **66** acting through piston rods **82** against the bulkhead ring **81** and therefrom against the concrete lining. While the leading tube **11** is advanced, its tail end **15** slides towards the seal **61** and on reaching its most advanced position, which is equal to the length of a new section of concrete lining, the excavation operation is temporarily interrupted to allow retraction of the piston rods **82** together with bulkhead ring **81** and timber facing **83** to a position close to stiffener ring **65** of the second tube **12**. The end face of the concrete lining can then be inspected and cleaned and reinforcement, waterstops and other structural components placed in position. The reinforcement is supplied in mats with the longitudinal bars projecting through the bulkhead ring **81** to provide sufficient lap for the following section of concrete lining. The bulkhead ring **81**, together with all attachments, is then moved to the forward end **69** of the third tube or inner slipform **13** providing a space to be filled with concrete from the concrete supply line **80**. Because of the new location of the bulkhead ring **81** the closer plate **88**, mounted thereto, clears the discharge end of the concrete supply line **80** and concrete is pumped into the section behind the bulkhead ring **81**. Concrete is delivered to the bottom of the section thereby ensuring that air and water is forced to the top where it is discharged through an escape opening **87**.

Following concrete placement, jacking mechanisms **6** force the bulkhead ring **81** against the freshly placed concrete, simultaneously advancing the second tube **12** and exposing the surrounding soil behind its tail end **62** to the pressure of the still plastic concrete. During the advancement of the second tube **12** jacking mechanisms **68** and **67** remain inactive.

It will be clear that the objects and advantages of this invention lie in the shape and arrangement of the leading tube, which allows excavation to proceed under pressure without personnel being under pressure, and in the immediate installation of the permanent concrete lining without exposing any soil face, thereby conserving the internal stress pattern of the surrounding soil, this being of considerable significance in tunnel construction. This invention also eliminates the necessity for installing costly temporary linings.

After the second tube **12** is moved to its new position, the jacking mechanisms **67** pull the third tube or inner slipform **13** forward simultaneously closing the discharge end of the concrete supply line **80**. For this operation, pressure is applied to seal **108** and reduced in seal **99**. The tail end section **105** of the third tube **13** remains fixed to the concrete lining while seal **103** slides along the outer shell **104** of tail end section **105**, the hydraulic jacks **109** being released. Following this movement the seal **99** is pressurized and the tail end section **105** is advanced by means of hydraulic jacks **109** after depressurizing seal **108**.

The space **98** between the outer shell **90** and the face of the concrete lining is kept under high pressure equivalent to the soil pressure through the medium of the high pressure steam, firstly to support the green concrete and secondly to rapidly cure it. The steam is supplied through supply pipes **101**, located at the rear end of the third tube **13**, and travels forward towards discharge pipes **102**, located near the forward end of the outer shell **90**, losing heat to the concrete during its forward motion. With the advancement of the third tube **13** the concrete is gradually exposed to hotter regions similar to the gradual increase in temperature used in standard steam curing methods. The length of the third tube **13** depends, therefore, on the rate of advance of the leading tube **11** and the required curing time of the concrete and the length of the front part of the inner slip-form **13**, consisting of ring sections **71**, depends on the rate of advance of the leading tube **11** and the initial setting time of the concrete.

All component sections of the tunnelling machine are made in short lengths compared to their diameters to allow small adjustments to be made in respect to the tunnel axis by means of jacking mechanisms **68**, **66**, **67**, **74**, **93**, **109**.

The embodiment of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A tunnelling machine adapted to cut and remove soil or soft rock, support the surrounding soil or soft rock of the unlined bore hole, airtightly isolate the face of the bore hole from the rear of the bore hole and provide forms and curing facilities for the permanent concrete lining as the tunnelling machine moves forward, the said tunnelling machine comprising a rigid leading tube shaped to the outside dimensions of the permanent concrete tunnel lining and furnished with a cutting edge at its front end, a second rigid tube shaped to the same dimensions slidably overlapped at its forward end by the tail end of the said leading tube and extending rearwardly beyond the front face of the permanent concrete tunnel lining providing temporary support for the surrounding soil or soft rock of the bore hole, a third rigid tube shaped to and constituting a slipform for the permanent concrete tunnel lining projecting forwardly from the front face of the said concrete tunnel lining and extending rearwardly into the finished lined tunnel at which the rearward portion is slightly smaller in its cross-sectional area thus providing a space between the inner face of the said concrete tunnel lining and the said slip-form for injecting high pressure steam as a curing agent, a rigid bulkhead ring slidably located between the rear end of the second tube and the forward end of the third tube constituting a form for the front face of the permanent concrete tunnel lining and providing a bearing surface for the jacking mechanisms after the said space is filled with concrete, a plurality of jacking mechanisms for the advancement of the second tube mounted peripherically thereon and detachably connected to and bearing on the said bulkhead ring, another plurality of jacking mechanisms for the advancement of the leading tube peripherically mounted thereon and bearing on the second tube while the latter is held in place by the first mentioned jacking mechanisms, a further plurality of jacking mechanisms for the advancement of the third tube, detachably connected thereon and supported by the second tube, a closed airtight shield detachably mounted near the tail end of the leading tube isolating the face of the bore hole from the rearward portion of the tunnel, a variety of mining equipment mounted to and penetrating the said shield to cut soil and soft rock in front of the said shield, a hydraulic dredging mechanism, connected to a rigid pipe penetrating and advancing with the said shield, a collecting hopper attached to a second pump located rearwardly from the tail end of the third tube receiving the effluent from the first pump the second pump being connected with a stationary discharge line leading to the disposal facilities, a water supply pipe rigidly connected to the leading tube and flexibly connected to a stationary water supply pipe rearwards of the third tube supplying water to the bore hole forward of the said shield for hydraulic removal of the excavated material, and a concrete supply line connected to the front end of the third tube for conveying concrete to the space behind the said bulkhead ring.

2. A tunnelling machine in accordance with claim 1, wherein mining equipment is detachably and movably mounted to the rear of and penetrating the shield by means of airtight ball joints.

3. A tunnelling machine in accordance with claim 1, wherein movable high pressure water nozzles are installed on the shield and project into the space in front of the shield for the loosening of the soil by means of water jets.

4. A tunnelling machine in accordance with claim 1, wherein an airtight cover operated by jacking mechanisms is slidably attached to the front face of the shield by means of guide rails to form an air lock for the removal of the mining equipment.

5. A tunnelling machine in accordance with claim 1, wherein the slip-joint, is furnished with a rubber like seal ring preferably located at the front end of the second tube bearing on the inner face of the tail end of the leading tube.

6. A tunnelling machine in accordance with claim 1, wherein the leading tube has air or water nozzles connected to the air or water system penetrating the shield from the rear close to the entrance to the discharge pipe and so directed as to agitate the settled excavated material in front of the said entrance to the discharge pipe.

7. A tunnelling machine in accordance with claim 1, wherein a portion of the third tube has the means for circulating high pressure steam from the rear end of the said portion to the front end of the said portion.

8. A tunnelling machine in accordance with claim 1, wherein the tail end of the third tube has a seal ring, preferably an inflatable rubber-like tube, confined on three sides by steel plates and pressing with its fourth side against the finished concrete lining to prevent the high pressure steam from escaping to the rear.

9. A tunnelling machine in accordance with claim 1, wherein all tubes consist of short sections slidably and airtightly overlapped and connected by a plurality of jacking mechanisms to allow an adjustment in alignment relative to the tunnel axis.

10. A tunnelling machine in accordance with claim 1, wherein the third tube has means for collecting and removal of laitance in front of the seal at the tail end of the third tube.

11. A tunnelling machine in accordance with claim 1, wherein a crusher is installed in line with the discharge line and mounted to the rear of the discharge opening in the shield.

12. A tunnelling machine in accordance with claim 1, wherein the bulkhead ring is furnished at its forming face with removable timber boards fitting between the inner face of the tail end of the second tube and the outer face of the forward end of the third tube.

13. A tunnelling machine in accordance with claim 1, wherein the bulkhead ring has means for allowing the installation of structural components such as reinforcement and water stops.

14. A tunnelling machine in accordance with claim 1, wherein the bulkhead ring has means to force air between the front face of the concrete and forming face of the bulkhead ring to aid the advancement of the bulkhead ring.

15. A tunnelling machine in accordance with claim 1, wherein the bulkhead ring is furnished with a sliding gate located in front of the discharge end of the concrete supply line, closing when the third tube advances and opening when the bulkhead ring advances.

16. A tunnelling machine in accordance with claim 1, wherein the portion of the third tube adapted for curing the concrete lining has a thermal insulation.

17. A tunnelling machine in accordance with claim 1, wherein the shield has detachable high pressure resistant windows for viewing the space in front of the shield from the rear of the shield.

18. A tunnelling machine in accordance with claim 1, wherein the shield has movable high pressure resistant spotlights to illuminate the space in front of the shield, the said spotlights being operated from the rear of the shield.

References Cited

UNITED STATES PATENTS

360,959	4/1887	Greathead	61—85
428,021	5/1890	Rothwell	175—86
438,509	10/1890	Vering	61—84
512,037	1/1894	Kraus	175—62 X
748,809	1/1904	Stone	61—85
1,026,412	4/1912	Stone	61—85 X

FOREIGN PATENTS

620,764	11/1935	Germany.
443,158	2/1936	Great Britain.

ERNEST R. PURSER, *Primary Examiner.*