Feb. 9, 1971 J. R. TABOR 3,561,223

TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

Filed July 9, 1968 7 Sheets-Sheet 1

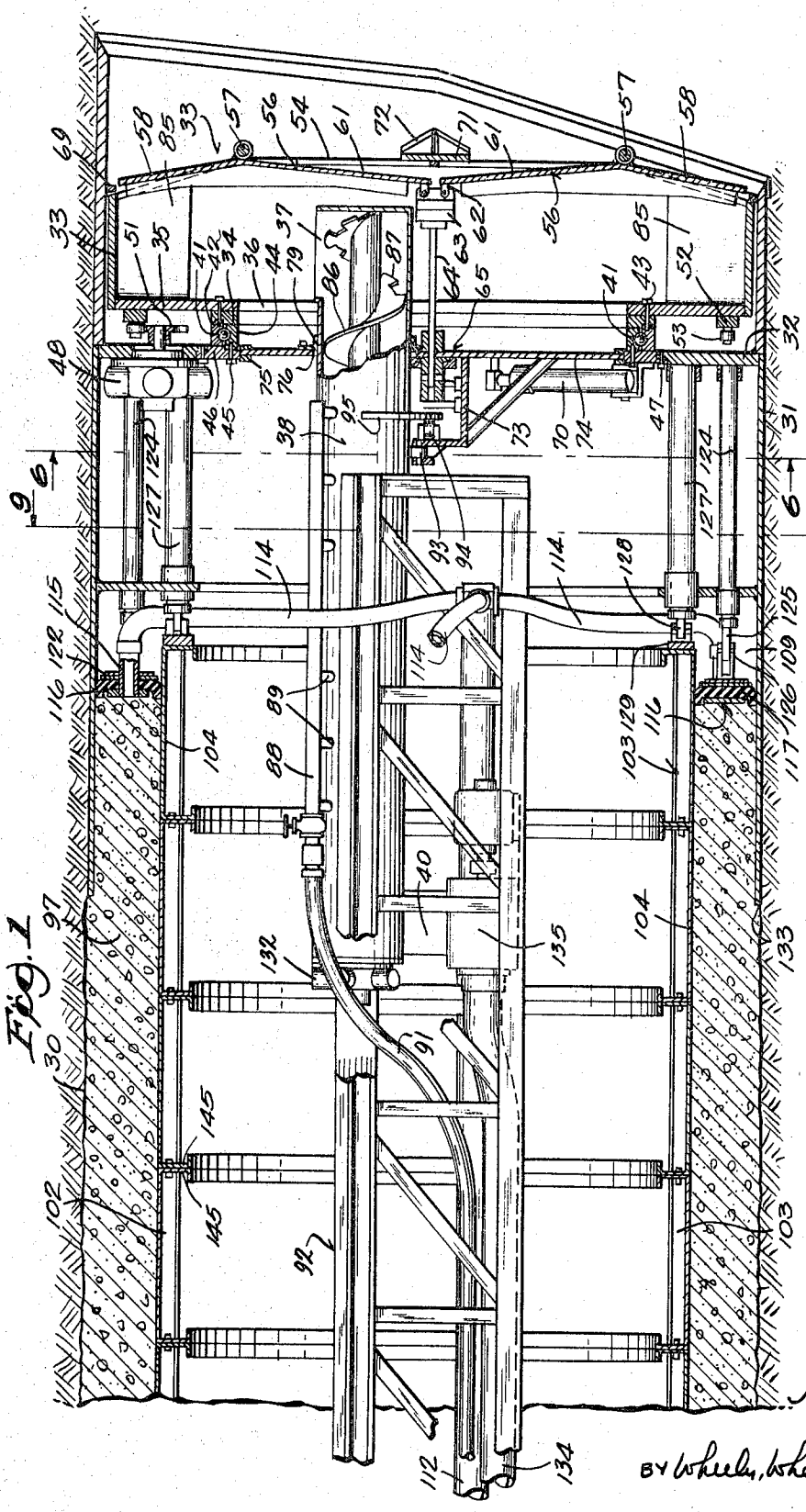


Fig. 1

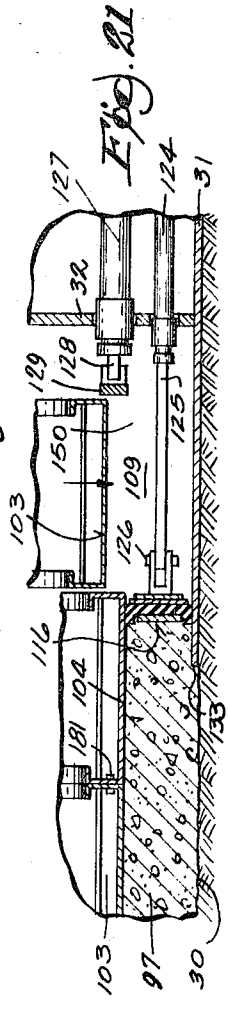


Fig. 2

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TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

Filed July 9, 1968

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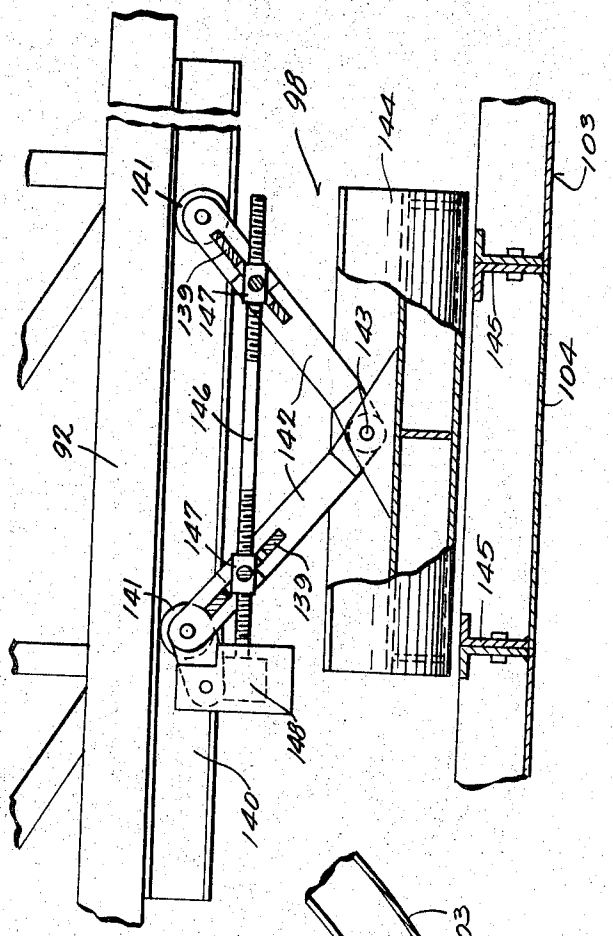


Fig. 13

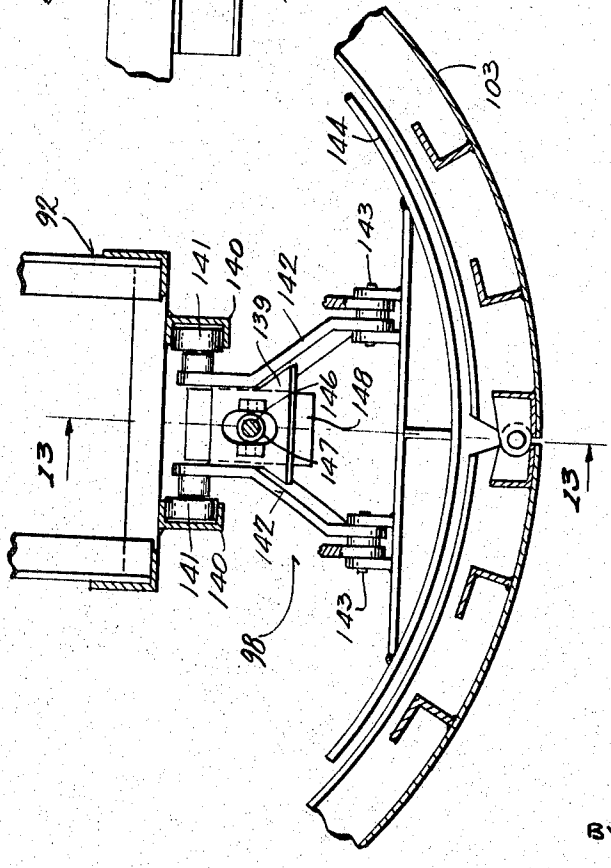


Fig. 12

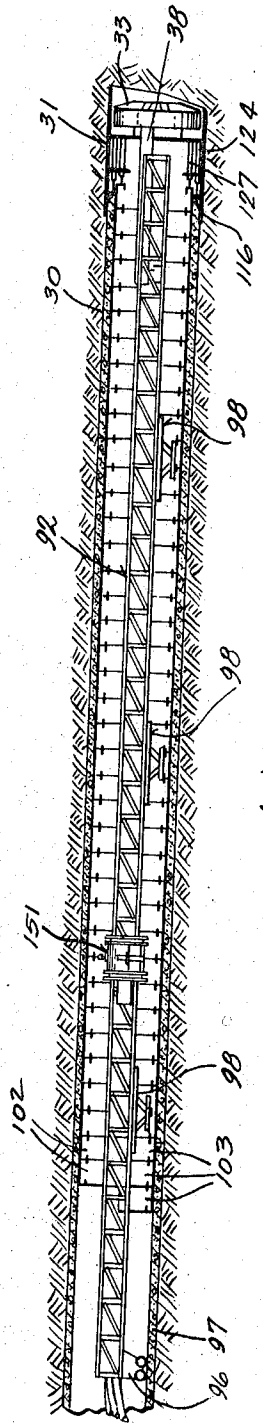


Fig. 2

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TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

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Fig. 6

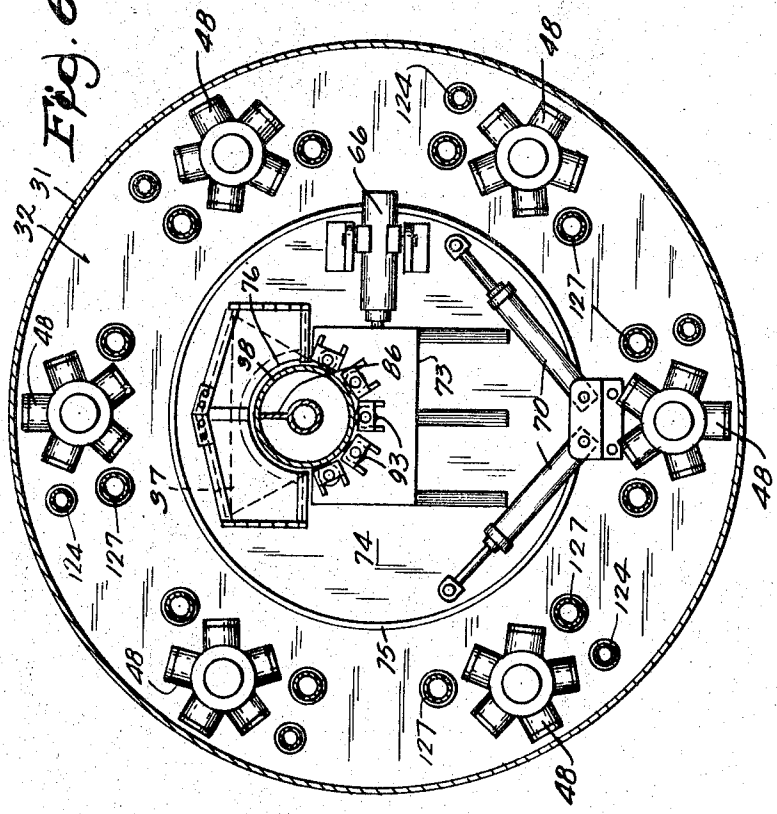


Fig. 5

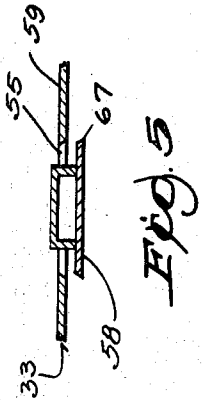


Fig. 3

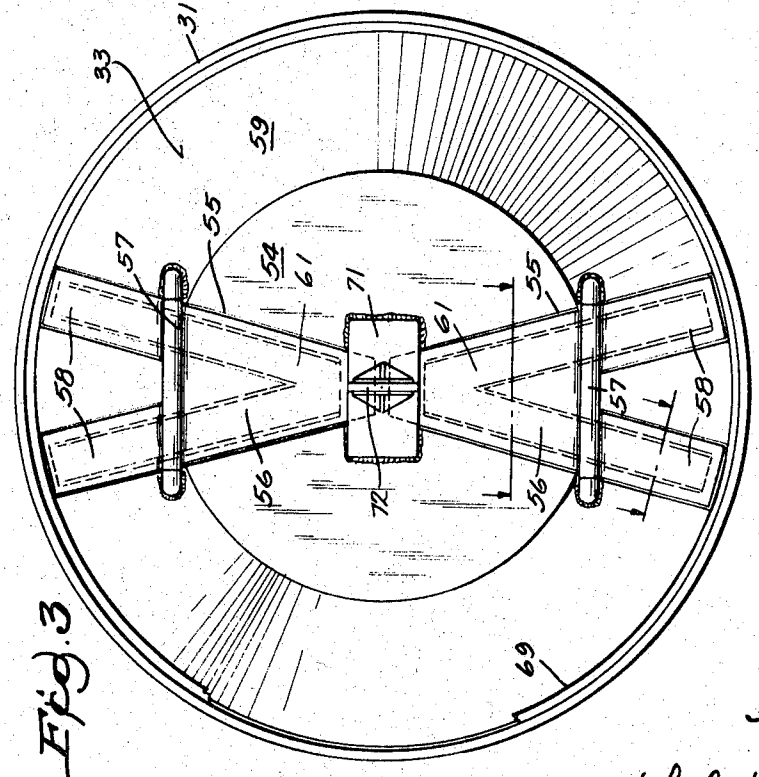
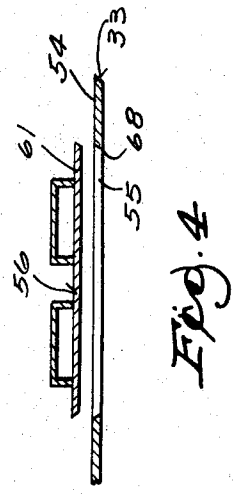


Fig. 4



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TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

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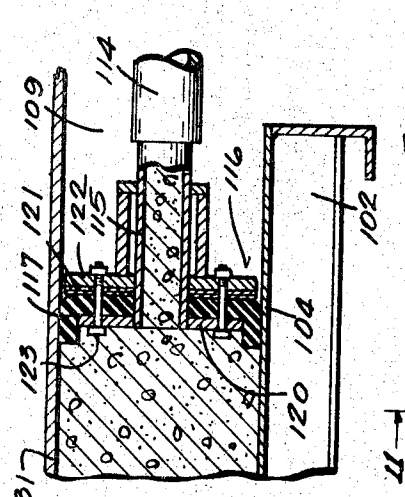


Fig. 11

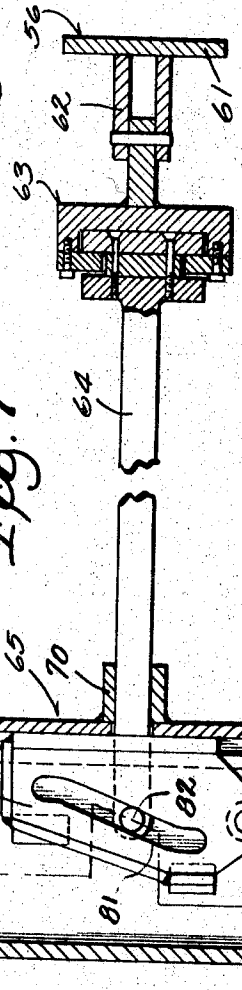
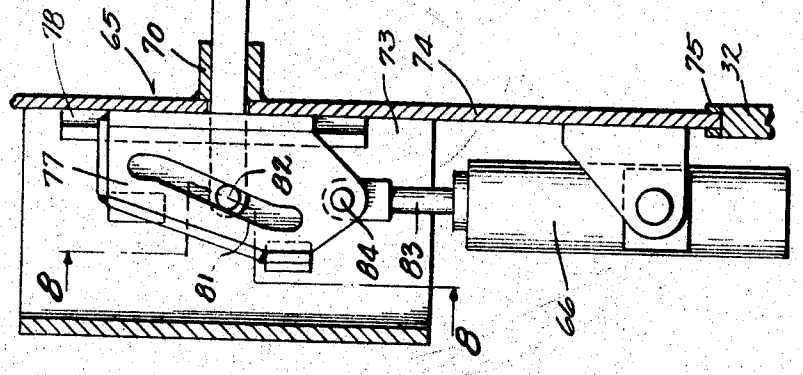
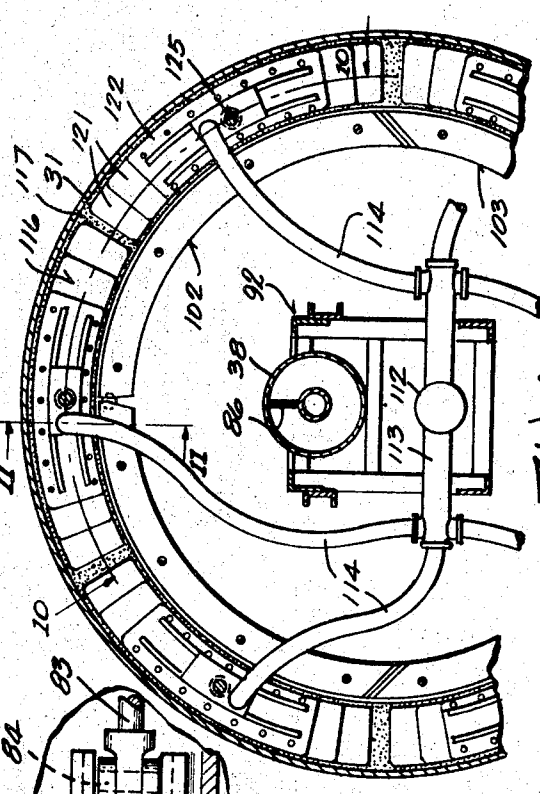


Fig. 7





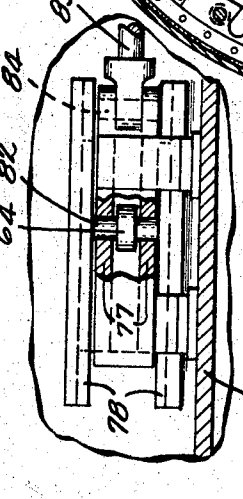


Fig. 8

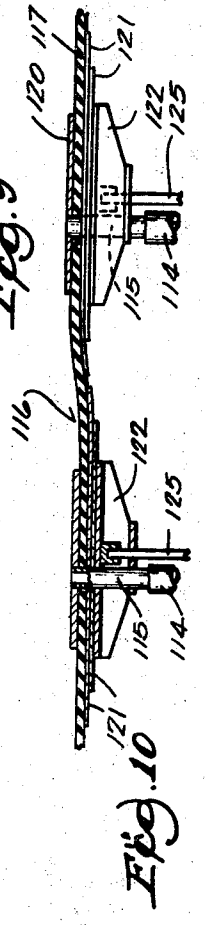


Fig. 9

Fig. 10

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TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

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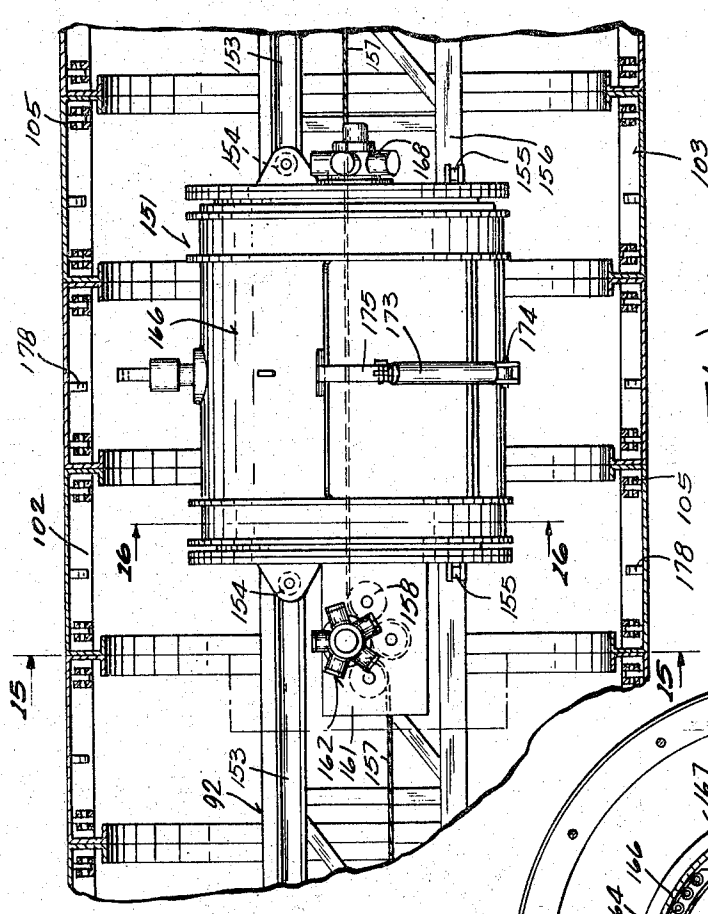


Fig. 14

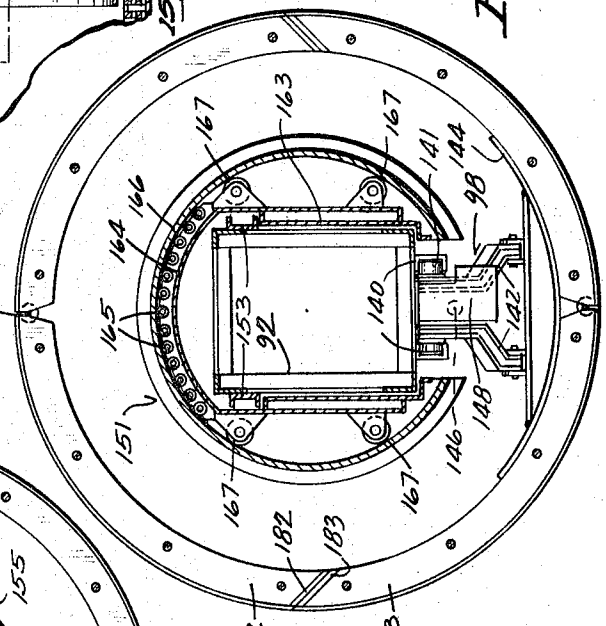


Fig. 16

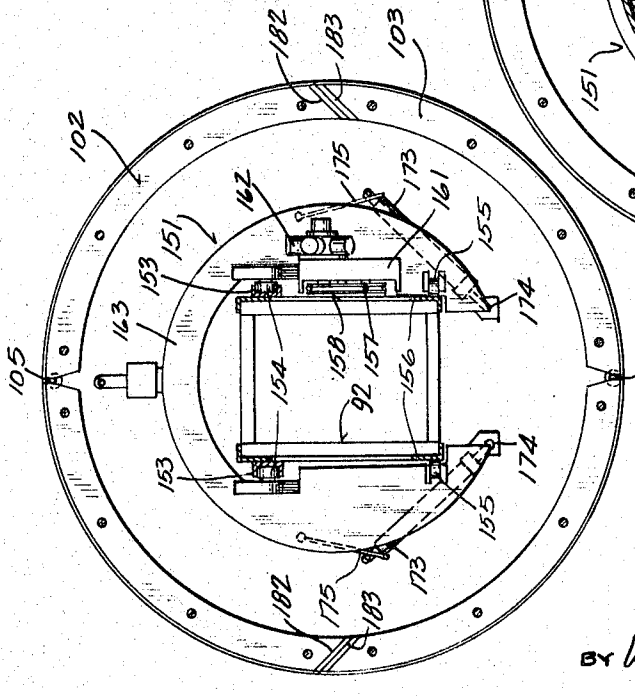


Fig. 15

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Feb. 9, 1971 J. R. TABOR 3,561,223

TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

Filed July 9, 1968 7 Sheets-Sheet 6

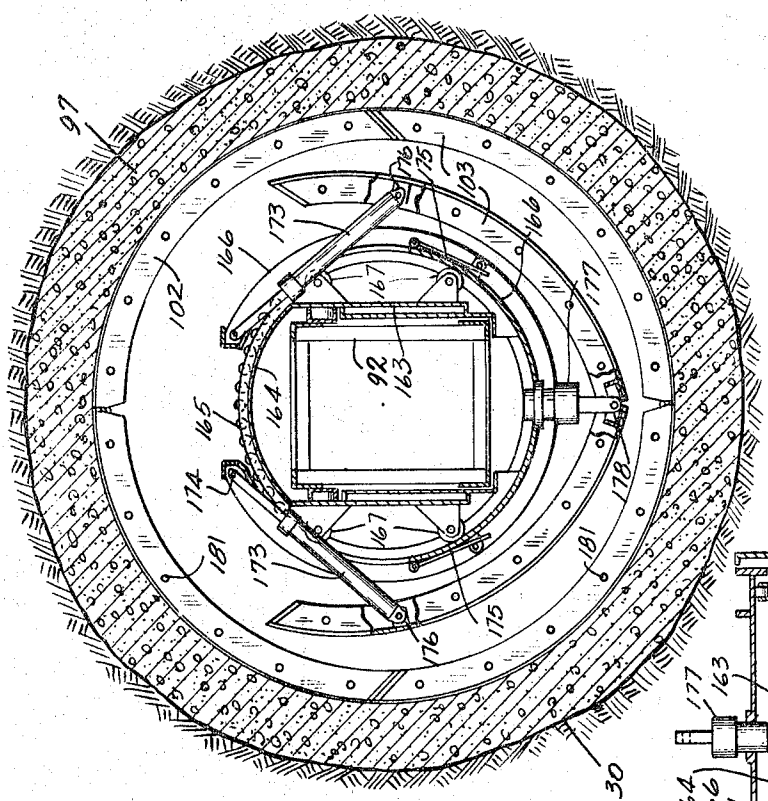


Fig. 18

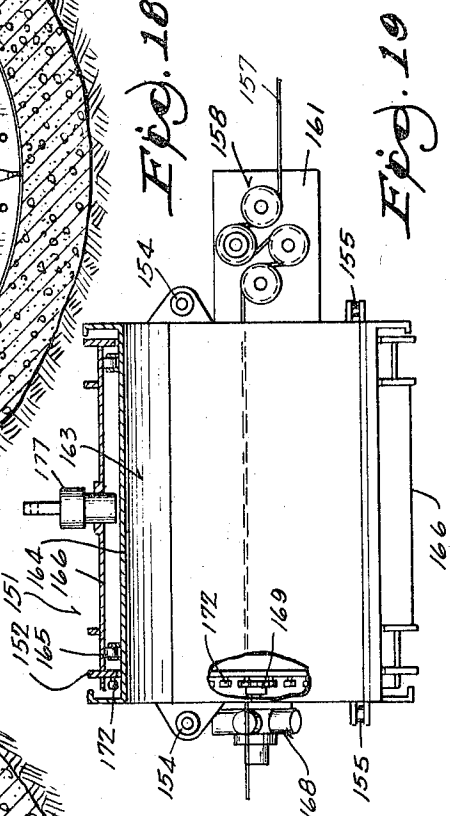


Fig. 19

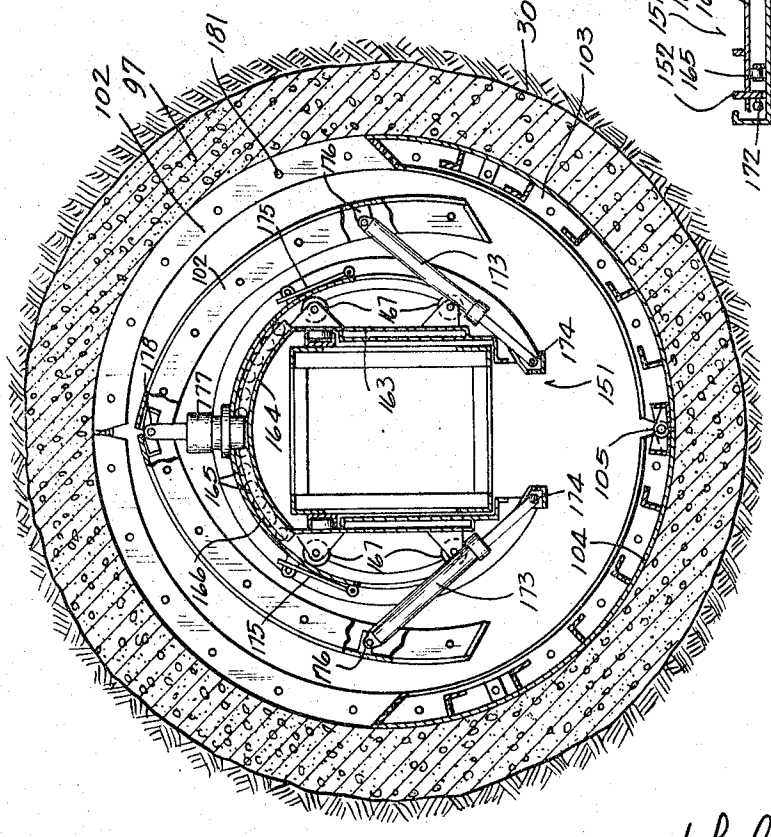


Fig. 17

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TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

Filed July 9, 1968 7 Sheets-Sheet 7

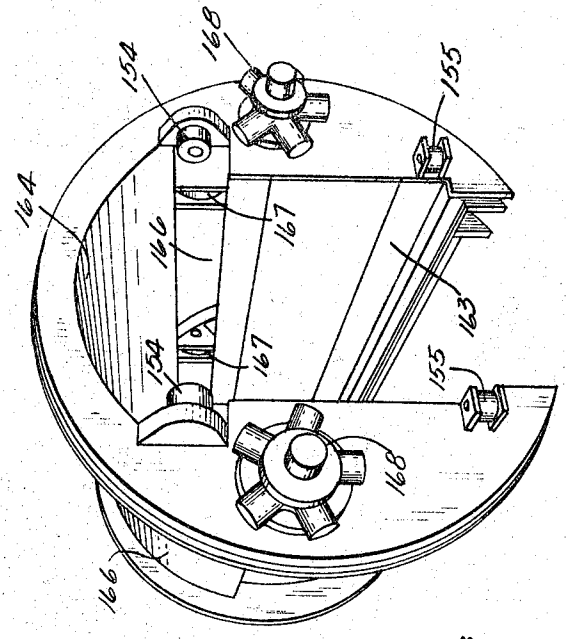


Fig. 22

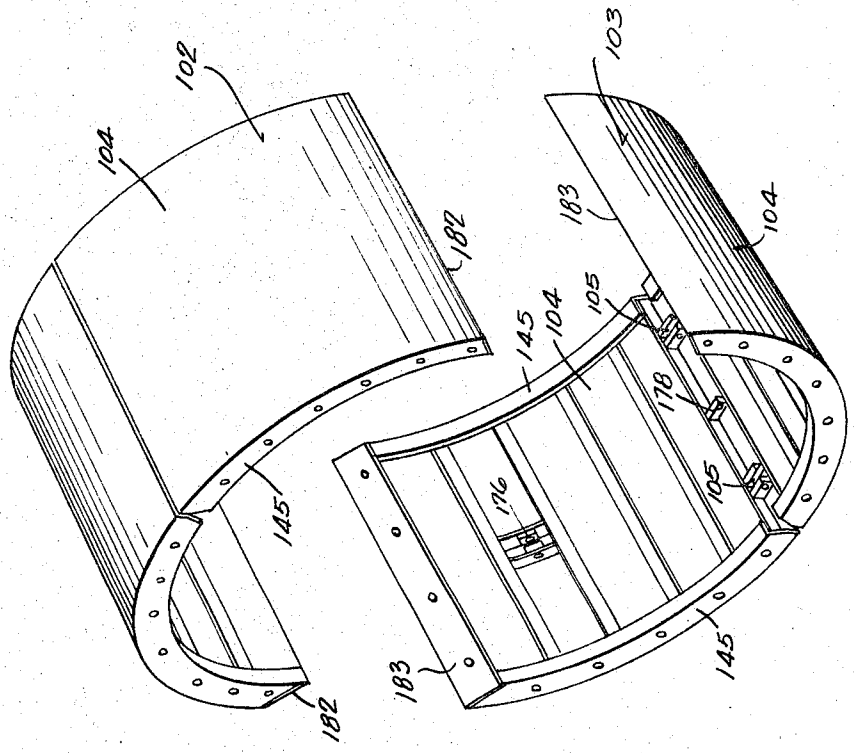


Fig. 20

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United States Patent Office 3,561,223 Patented Feb. 9, 1971

3,561,223

TUNNELING MACHINE WITH CONCRETE WALL FORMING MECHANISM

John R. Tabor, 3400 Spruce St., Racine, Wis. 53403

Filed July 9, 1968, Ser. No. 743,363
Int. Cl. E01g 3/04
U.S. Cl. 61—85 11 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure relates to a tunneling machine which has a shield with a rotary excavating wheel to excavate a tunnel, and mechanism for forming a tubular concrete tunnel lining or wall against the tunnel sides. The machine has an elongated truss which trails behind the shield and which carries a spoil removing conveyor and a fluid concrete supplying conveyor. The truss also constitutes a track for a concrete form handler for transferring forms from the tail end of the truss to the head end and for lining the tunnel with such forms.

BACKGROUND OF THE INVENTION

Tunneling machines which both excavate and form a concrete tunnel wall are known to the art. U.S. Pats. 551,042 and 1,866,416 are examples thereof. Such machines are not capable of high speed tunneling and have manpower requirements which are excessive by present day standards. The machine of the present invention satisfies a need for a high speed, largely automated tunneling machine which concurrently excavates spoil and forms a smooth concrete wall about the tunnel.

SUMMARY OF THE INVENTION

The tunnel making machine of the present invention is adapted not only to tunnel through the earth, but also to concurrently form a concrete wall in the tunnel. Forms for the concrete wall are erected by the machine at the head end thereof and are removed by the machine at the tail end thereof. The forms remain in place only long enough for the concrete to harden and are constantly reused, those from the tail end being transferred to the head end in a continuous process of form reuse. Removal of the forms at the tail end of the machine leaves the tunnel complete rearwardly of the machine with a smooth concrete wall or bore.

The machine has a shield with a rotary excavating wheel at the head of the shield and a truss which trails behind the shield. The truss carries a spoil removing conveyor and a fluid concrete supply conveyor. The truss also provides a track for a form handler which is movable along the truss to transfer forms from near the trailing end of the truss, where the concrete has hardened, to the front end of the truss for erection behind the excavating wheel. The machine is also provided with means to inject fluid concrete into the space between the erected forms and the tunnel sides.

The form handler and its coaction with the truss is unique. The form handler transfers large sections of forms longitudinally through the limited unobstructed space about the truss by partially folding or collapsing the form sections. The bottom form sections are rotated 180 degrees about the tunnel axis in the course of their longitudinal transfer to avoid confiict with the truss legs.

The excavating wheel of the disclosed embodiment is specifically adapted to excavate through relatively mucky earth strata which has sufficient moisture content to be pumped out of the tunnel under pressure or which can be fluidized by the addition of water for this purpose.

The machine has additional important features, including:

(1) Shield bulkheads which can be closed off against flow of spoil to provide 100 percent breasting at the tunnel face.

(2) A seal between the rotary wheel and shield to decrease the gap therebetween.

(3) Cutting wheel blades which are remotely controlled as to degree of opening and spoil excavating rate.

(4) A fluid concrete seal or bulkhead which can be pressed against the injected concrete to compress the concrete and eliminate voids in the concrete, fill the void behind the shield tail, fill fissures in the tunnel sides and eliminate the need for grouting operations otherwise needed to fill these voids and fissures.

(5) Fluidizing the spoil and pumping it out of the tunnel.

(6) The support for the truss by which the truss can freely advance with the shield.

Other objects, features, and advantages of the invention will appear from the disclosure hereof.

In the drawings:

FIG. 1 is an enlarged longitudinal section taken through a tunnel and the head end of a tunneling machine embodying the present invention.

FIG. 2 is a simplified longitudinal section on a reduced scale through a tunnel and showing substantially the complete length of a tunneling machine embodying the invention.

FIG. 3 is a front elevation of the machine, showing in particular the face of the cutting wheel.

FIG. 4 is a fragmentary cross section taken along the the line **4—4** of FIG. 3.

FIG. 5 is a fragmentary cross section taken along the line **5—5** of FIG. 3.

FIG. 6 is a vertical cross section taken along the line **6—6** of FIG. 1.

FIG. 7 is a fragmentary enlarged detail view of the power mechanism for actuating the gates in the cutting wheel.

FIG. 8 is a fragmentary cross section taken along the broken line **8—8** of FIG. 7.

FIG. 9 is a fragmentary cross section taken along the line **9—9** of FIG. 1.

FIG. 10 is a cross section taken along the curved line **10—10** of FIG. 9.

FIG. 11 is an enlarged cross section taken along the line **11—11** of FIG. 9.

FIG. 12 is a fragmentary cross section through the tunnel, showing the mode of supporting the truss on the concrete forms.

FIG. 13 is a section taken along the line **13—13** of FIG. 12.

FIG. 14 is a vertical longitudinal section taken through the tunnel and showing in elevation the form handler mounted on the truss.

FIG. 15 is a cross section taken along the line **15—15** of FIG. 14.

FIG. 16 is a cross section taken along the line **16—16** of FIG. 14.

FIG. 17 is a cross section taken through the tunnel and showing the form handler in the course of handling a partially collapsed top form section.

FIG. 18 is a similar cross section showing the form handler in the course of handling a partially collapsed bottom form section.

FIG. 19 is a side elevation of the form handler, a portion of this view being shown in vertical longitudinal section.

FIG. 20 is a diagrammatic view of a set of mating top section and bottom section concrete liner forms, the forms being shown in spaced apart relation.

FIG. 21 is a fragmentary view, partly in section, showing the shield advanced to open a space to receive a form section at the head end of the liner.

FIG. 22 is a perspective view of the form handler.

PREFERRED EMBODIMENT OF THE INVENTION

Although the disclosure hereof is detailed and exact to enable those skilled in the art to practice the invention, the physical embodiments herein disclosed merely exemplify the invention which may be embodied in other specific structure.

THE SHIELD AND CUTTING WHEEL

Tunnel shaft **30** is formed by a tunneling machine within a shield **31**. The shield has an annular bulkhead **32** near its head end on which an excavator such as rotary cutting wheel **33** is supported on a bearing **34**. The wheel **33** has an annular diaphragm **35** with a central opening **36** into which projects the hopper **37** of a spoil removing tubular conveyor **38**.

Bearing **34** is similar to the one shown in my copending U.S. patent application Ser. No. 474,351, filed July 23, 1965, now Pat. No. 3,382,002 in that the bearing may be removed axially as a unit from the bulkhead **32** and from the wheel **33**. Repair and replacement of the bearing **34** can thus be effectuated without having to remove the wheel itself.

Bearing **34** consists of a series of bearing balls **41** captive between an outer race **42** and an inner race **44**. Outer race **42** is releasably mounted on the wheel diaphragm **35** by a series of bolts **43**. Inner race **44** is releasably mounted on mounting ring **46** by a series of bolts **45**. Mounting ring **46** is releasably mounted on annular bulkhead **32** by a series of bolts **47**.

Upon release of the several bolts in the series of bolts **43** and **47**, the bearing structure **34**, which includes the inner race **44**, outer race **42**, balls **41** and ring **46**, can be withdrawn axially rearwardly into the shield for repair or replacement of the bearing, without requiring withdrawal of the wheel.

Wheel **33** is driven by a series of reversible hydraulic motors **48** which are clustered about the opening **36** in the bulkhead **32**. Motors **48** have drive sprockets **51** respectively engaged with a drive ring **52** mounted on the wheel diaphragm **35**. Ring **52** is provided with roller pegs **53** engaged by the sprockets **51** and by which thrust from the motors **48** is smoothly transmitted to the wheel **33** without substantial friction. Motors **48** are selectively powered to drive the wheel **33** clockwise or counter clockwise.

Most of the front of wheel **33** is closed by a face plate having a central flat portion **54** and an outer frustoconical margin **59**. The face plate is provided with radially elongated openings **55** in which radially elongated gates **56** are pivotally mounted on the pintles **57** which span laterally across the openings **55**. The gates **56** are V-shaped in front elevation and have outer portions **58** radially outwardly of the pintles **57** and inner portions **61** which are radically inwardly of the pintles **57**. The inner portions **61** have their proximate inner ends connected on swing links **62** to a rotatable coupling **63** (FIG. 7) further connected by shaft **64** to a right angle motion transmitting coupling **65** powered by fluid motor **66**. By this mechanism the gates **56** are concurrently swung about their pintles **57** to adjust the degree of opening between the gates and the wheel face **54**, **59**. When the gates **56** are closed, substantially no spoil can flow through the wheel. The tunnel face will then be substantially entirely breasted by the wheel.

From FIGS. 4 and 5, it is clear that when the gates **56** are open, the radially outward portions **58** thereof project forwardly of the wheel face portion **59**. Gate portions **61** are retracted rearwardly of the face portion **54**. In open position, gate portions **58** function as cutting blades to cut spoil from the tunnel face and bring it in through the opening **55**. The wheel face plate **54** also acts as a cutting blade to bring spoil through the opening **55** near

the center of the wheel. For cutting purposes, gate portions **58** are provided with cutting edges **67**, and the face plate portion **54** is provided with cutting edges **68**.

The center of the wheel is provided with a nose plate **71** having cutting blades **72** mounted thereon, thus to cut spoil from the tunnel face opposite the center of the wheel.

The shaft **64** which opens and closes the gates **56** is mounted on the rotating axis of wheel **33**. The rotary coupling **63** permits the shaft **64** to be non-rotatable while the wheel rotates. The right angle drive **65** is mounted on a shelf **73** (FIG. 1), in turn mounted on a second or inner bulkhead disk of plate **74** is removably disposed in the central opening in annular bulkhead **32**. The edge of plate **74** is retained on bulkhead **32** in a grooved circular bearing **75** in which the plate **74** can rotate under the power of fluid motors **70** (FIG. 6). The motors **70** are controlled to maintain plate **74** in a position to support the tube **38** and truss level and in proper centered relation in the tunnel, regardless of any tendency of the shield to roll under counter torque of the wheel **33**. It has circular opening **76** through which the spoil conveyor tube **38** extends. Disk **74** is sealed to the tube **38** about the opening **76** by flexible sealing strip **79**. When gates **56** are closed, there art two "bulkheads" in tandem to breast the tunnel. The closed face wheel **33** acts as one bulkhead and the bulkhead **32** with its closed center disk **74** acts as a second bulkhead.

To increase the effectiveness of the breasting action of wheel **33**, the shield is provided with an inwardly projecting flange or seal **69** (FIG. 1) adjacent the wheel **33**. Flange **69** overlaps the edge of wheel **33** to impede flow of mucky spoil into the wheel around its periphery. Accordingly, spoil is kept out of bearing **34** and from between the wheel drum **33** and shield wall. This prevents encrustation and spoil compaction which would interfere with wheel rotation and require increased wheel torque to rotate the wheel.

The right angle coupling **65** (FIG. 7) comprises spaced cam slides **77** which are mounted to slide on ways **78**. Respective slides **77** have corresponding inclined cam slots **81** which receive the cross pin **82** on shaft **64**. Fluid motor **66** has a piston rod **83** pivotally connected on the pin **84** to the slides **77** and by which the slides are actuated to thrust shaft **64** in either direction axially of the tunnel for the purpose of adjusting the position of the gates **56**. Shaft **64** moves axially in bearing **70** welded to bulkhead disk **74**.

THE SPOIL CONVEYOR

The wheel **33** is provided with spoil lifting flights **85** which subdivide the periphery of the wheel into a series of buckets into which spoil admitted into the wheel **33** is deposited and carried upwardly toward the top of the wheel from whence the spoil is dropped into the hopper **37**. Hopper **37** is at the front end of the tube **38** which contains an auger **86**. Auger **86** is turned under power by hydraulic motor **132**. Teeth **87** are formed in the portion of the auger flight which is in hopper **37** in order to break up clods of spoil.

The disclosed embodiment is intended primarily to tunnel through a mucky earth stratum in which the spoil will be relatively flowable. Flowability can be enhanced by injecting water into the tube **38** from a water manifold pipe **88** which has a series of outlets **89** spaced along tube **38**. Water manifold **88** receives water from the hose **91** which is supported by the elongated truss **92** which trails behind shield **31**. The fluidized spoil or "muck" is pumped by muck pump **135** out of tube **38** through down spout **40** and thence out of the tunnel through hose **134** which is carried by truss **92** and leads out of the tunnel to a place of disposal.

THE TRUSS

The forward end of the truss **92** is supported by the conveyor tube **38** which rests on a series of radial thrust

rollers **93** mounted on shelf **73**. Shelf **73** also has a series of axial thrust rollers **94** which bear axially on a thrust flange **95** fast to the tube **38** near its front end. The portion of the conveyor tube **38** embraced by portions of the truss **92** are securely fastened to the truss so that the truss is both supported at its front end by the tube **38** and is drawn forward with the tube as the shield moves forwardly in the tunnel shaft.

As best shown in FIG. 2, the truss **92** is supported at its rear end on a wheeled carriage **96** which rides on the floor of the concrete tunnel wall **97**. At several locations along its length, the truss **92** is provided with shiftable roller supports **98** which rest upon the bottom section concrete forms **103** which line the bottom of the tunnel ahead of carriage **96**.

THE CONCRETE LINER FORMS

Forms **103** are foldable or collapsible and have a novel coaction with the truss and a form handler so that the concrete wall **97** is formed continuously as the shield **31** moves forwardly in the course of excavating the tunnel.

There are also top section forms **102** which together with bottom section forms **103** completely line the tunnel shaft. A set of mating forms **102, 103** is shown in spaced apart, diagrammatic relation in FIG. 20. Each form comprises a pair of curved reinforced plates **104**, pivoted together on a hinge **105**. The plates are provided on their inner faces with a grid pattern of braces, as is conventional. When the respective top and bottom form sections **102, 103** are expanded to circular cross section and are bolted together end-to-end, they form a continuous temporary liner within the tunnel shaft and define an annular space **109** between the outer surface of the connected forms **102, 103** and the tunnel shaft wall **30** within which fluid concrete is injected to form the concrete tunnel wall **97**.

THE CONCRETE INJECTING APPARATUS

FIGS. 1, 9, 10 and 11 illustrate how the concrete is injected. The truss **92** carries a fluid concrete supply conveyor or hose **112**. This hose terminates in a manifold **113** (FIG. 9) having several flexible hoses **114** which are lead to ports **115** in a flexible annular concrete injection sealing nozzle or bulkhead **116**, details of which are best shown in FIGS. 9, 10 and 11. Nozzle **116** is made to span across the space **109** to confine the pressure of the fluid concrete injected into space **109** through the hoses **114**. Nozzle **116** includes a rubber or other elastomeric gasket or seal **117** which is reinforced at one side by a series of curved inner plates **120** about each port **115**, and on the outside by a series of progressively longer overlapping spring plates **121**, and a back-up plate **122**. These parts are held together in assembled relation by bolts **123**.

The inherent resiliency of the gasket **117** and the fact that it is not continuously reinforced throughout its circumference gives the bulkhead **116** a certain flexibility, as is indicated in FIG. 10. Accordingly, the bulkhead can yield locally to accommodate for different back pressure conditions. Each back-up plate **122** is subject to the pressure of a hydraulic jack **124**, the base end of which reacts against the fixed annular bulkhead **32** of the shield **31**. Each jack **124** has a piston **125** pivotally connected at **126** (FIG. 1) to the back-up plate **122**. The pressure existing within the jacks **124** will determine the back pressure exerted on the fluid concrete which has just been injected into the space behind the bulkhead **116**.

There is another set of hydraulic jacks **127** utilized to advance the shield forwardly in the tunnel. Jacks **127** are also seated against the bulkhead **32** at one end and have extending pistons **128** with suitable shoes **129** seated against the annular end of the last set of forms **102, 103**. Controlled pressure exerted on the jacks **127** will thrust the shield **31** forwardly in the tunnel. Controlled pressure on a pump in fluid concrete conveyor line **112** will inject concrete through the nozzle or bulkhead **116** and controlled pressure on the jacks **124** will establish the necessary back pressure on the concrete. The operator of the machine has control over all the fluid motors and the concrete pump so as to balance the various pressures to insure injection of fluid concrete at substantially the same rate as the shield moves forwardly under pressure of the jacks **127**. The operator also controls the motors **48** which turn the wheel **33**, the motor **132** which turns the screw **86**, etc.

Maintenance of control pressure on the injected concrete will insure a solid and compacted fill of the space between the forms **102, 103** and the shaft wall **30**, notwithstanding any voids or fissures adjacent said wall into which the concrete tends to leak. These voids simply fill with concrete and become part of the wall. Moreover, the void which otherwise would be formed behind the tail end **133** of shield **31** will also be filled under such pressure.

FIGS. 1 and 21 illustrate various possible positions of the parts illustrated therein, depending upon the sequence used by the operator to successively or concurrently perform various control functions. These figures are merely illustrative, as there are many other positions of the parts, depending upon the sequence selected by the operator.

FIG. 1 illustrates a sequence in which fluid concrete is injected over a newly emplaced set of head end forms **102, 103** while the cutting wheel **33** is inactive. After the concrete has filled the space **109** to the extent indicated in FIG. 1, injection of concrete is discontinued and the jacks **127** are pressurized to advance the shield and the cutting wheel **33** is rotated to excavate spoil. During this movement, pressure is maintained on jacks **124** in order to maintain pressure on the concrete, notwithstanding the forward movement of the shield.

When the parts reach the position suggested in FIG. 21 at approximately the maximum extension of jacks **124, 127**, the pistons **128** of jacks **127** are contracted to leave space for the insertion of another set of head end forms **102, 103**.

Thereafter, the concrete injecting sequence can either be concurrent or alternate with respect to the shield advancing and spoil excavating functions.

In order to provide ample time for the concrete between the forms **102, 103** and the tunnel shaft **30** to harden, the forms are left in position along a considerable length of the tunnel, as is illustrated in FIG. 2. The truss **92** is slightly longer than the over-all length of the emplaced forms. In a practical embodiment of the invention, truss **92** is 240 feet long.

THE TRUSS SUPPORT CRADLES

The head end of the truss is supported on the shield, and the tail end of the truss is supported on dolly **96**. Intermediate portions of the truss are supported on the shiftable support cradles or legs **98**. The shiftable cradles **98** have curved base pads **144** which rest by gravity on the forms **103** behind which the concrete is setting. Each pad **144** has sufficient length to span across adjacent end flanges **145** on the bottom forms **103**. Pads **144** carry upwardly projecting legs **142** with upwardly exposed end wheels **141** which provide a rolling support for the truss **92**. At spaced locations along its length, the undersurface of truss **92** is provided with sets of laterally spaced facing channel tracks **140**. Each track set extends longitudinally of the truss for a relatively short distance, for example, 20 feet. Wheels **141** of the cradles **98** are embraced by the flanges of the tracks and rollably support the truss.

Each cradle **98** has four wheels **141** and four legs **142** which have their lower ends interconnected to the pad **144** on pintles **143**. The respective front legs and rear legs are cross connected by respective front and rear brackets **139** which carry threaded sleeves **147** for the screw jack **146** which connects the front and rear sets of legs.

When the truss **92** has been drawn forwardly by the advancing movement of the shield **31** a sufficient distance so that the wheels **141** are near the rear ends of the

tracks **140**, cradles **98** are shifted ahead to a new advanced position on the floor provided by forms **103**. Only one cradle **98** is shifted at a time. While one cradle is being shifted, the truss is supported by the other cradles, the shield **31** and the dolly **96**. Shifting of any one cradle **98** is accomplished by its screw jack **146** which spans between the legs **142**. The end of the screw jack **146** is connected to an electric motor **148**. When the motor is energized to turn the screw **146** in one direction, the legs **142** will be spread, thus to lift the pad **144** to its position shown in FIGS. 12 and 13 in which it is elevated slightly above the floor of forms **103**. Wheels **141** will now suspend the cradle **98** from flanges of the channel tracks **140**. The cradle **98** is now free to be shifted forward manually. Wheels **141** will roll ahead on the tracks **140** until the cradle is repositioned at a forward location. Motor **148** is then reversed to lower the pad **144** onto forms **103** where it will again span adjacent flanges **145** thereof. Wheels **141** will again contact the upper flanges of the channel tracks **140** to rollably support the truss **92**. Each cradle **98** is shifted in turn until all have been repositioned.

THE FORM HANDLER

Form sections **102**, **103** near the tail end of the truss **92**, where the concrete has hardened and set, are periodically transferred by a form handler **151** to the leading end of the truss **92**. Form sections thus transferred are erected and repositioned ahead of the concrete injecting apparatus **116**, etc. in spaced relation to the shield wall and in endwise connection to previously erected forms. Accordingly, the form sections **102**, **103** are repeatedly reused and are continuously being shuttled from the rear end of the truss to the head end of the truss.

Form handler **151** is ensleeved over the truss **92** and is sihftable longitudinally therealong. Form handler **151** has a generally cylindrical shape (FIG. 22), except that it is open at its bottom, to clear the truss support cradles **98** as it moves along the truss **92** (FIG. 16). The truss **92** is provided with outwardly facing channel-shaped tracks **153** (FIG. 15). The form handler **151** comprises a trolley **163** with a hollow interior with flat vertical side walls to fit adjacent the sides of the truss **92**. In cross section the form handler has a horseshoe shape. Near its top, trolley **163** carries wheels **154** which ride in the truss tracks **153**. Near its bottom the form handler trolley has guide rollers or wheels **155** which bear laterally on longitudinally extending tracks **156** near the lower edge of the side walls of the truss **92** (FIGS. 14, 15).

The form handler **151** is propelled longitudinally along the truss **92** in any convenient manner. In the disclosed embodiment, cable **157** is strung along the side of truss **92**. Cable **157** is engaged by drive pulleys **158** (FIGS. 14 and 19) mounted on a power box **161** which includes a hydraulic motor **162** to turn the pulleys **158** and pull the handler **151** forwardly or backwardly along the fixed cable **157**. Motor **162** is reversible to propel the form handler selectively in both directions along the truss.

As best shown in FIGS. 16 and 17, the trolley **163** of form handler **151** includes a curved arch **164** which carries roller bearings **165** on which outer form carrier sleeve or shell **166** is rotatable. Shell **166** is generally cylindrical except where it is open along one side. Trolley **163** also carries additional wheels **167** for support and guidance of the rotatable shell **166**. Shell **166** is rotated about the rollers **165**, **167** by motor **168** (FIGS. 14 and 19) which has a drive sprocket **169** engageable with rack **172** formed on the inside of the shell **166**. Rack **172** desirably comprises a series of roller pegs extending from a drive ring **152**. Accordingly, the shell **166** can be rotated about the axis of the truss **92** between its positions respectively shown in FIGS. 17 and 18.

The purpose of rotating the shell **166** as aforestated is to shift form sections **103** from the bottom of the tunnel to the top of the tunnel and to transfer the form sections through an unobstructed space about the top and sides of the truss and thus avoid interference with the truss cradle legs **98**.

Carrier shell **166** carries two fluid cylinders **173** which are respectively anchored at one end on pins **174** near the edges of the shell. When the form handler is not carrying a form, the other ends of the cylinders **173** are secured in slings **175** (FIG. 14).

When it is desired to transfer one of the form sections, for example, top form section **102**, from the tail end of the tunnel to the head end of the tunnel, the form handler **151** is driven to a position opposite the tail end form section **102** and cylinders **173** are extended and pinned to suitable brackets **176** with which the form sections are provided. Coupling **177** is also extended and attached to bracket **178** on the form sections adjacent the hinge **105** when the curved leaf sections **104** are hinged. The end bolts **181** which attach the tail end form section to the lining are then removed. The cylinders **173**, **177** are then retracted to their positions shown in FIG. 17 in which the form section **102** is withdrawn from the concrete wall **97** and the leaf sections **104** thereof are partly collapsed or folded toward each other.

Note that the end rails **182** of top form sections **102** are slanted at **182** to facilitate sliding them off of the oppositely slanted end rails **183** of the bottom form sections **103**. This permits the leaves **104** of the upper form section to collapse radially inwardly. The form handler **151** may now be advanced to the head end of the truss **92**, carrying the form section **102** through the unobstructed top and side space about the truss **92**. Cradles **98** of the truss extend downwardly between the ends of the horseshoe opening in the form carrier **151** so that the legs do not interfere with this longitudinal movement of the form carrier and its load.

The transfer of the bottom form section **103** involves an additional manipulation inasmuch as this form is at the bottom of the tunnel and cannot be simply shifted longitudinally because the cradles **98** of the truss obstruct the space beneath the truss and would interfere with this movement. Accordingly, the form handler **151** is retracted to a position near the tail end of truss **92** and is aligned with the tailmost bottom form section **103** from which top form section **102** has previously been removed. Shell **166** is rotated 180° about trolley **163** to its bottom-most position shown in FIG. 18, and its cylinders **173**, **177** are coupled to the said form section **103**. Cylinders **173**, **177** are manipulated to collapse form section **103** inwardly, as shown in FIG. 18. Then the form carrier shell **166** is rotated through 180° again to bring it to its position shown in FIG. 17, where the form **103** will be shifted in line with the unobstructed top and side space about the truss **92**.

As shown in FIG. 2, there is one more bottom form section **103** than top form section **102**. This is because the bottom form must be emplaced at the head end of the tunnel before the top form is emplaced, in order to interlock the slanted ends **182**, **183** at the form ends. In making the longitudinal shift of forms, the extra bottom form section **103** is first shifted forwardly into its bottom position at the head of the liner and then a top form section **102** is moved to the head of the tunnel, and erected on the top of the previously emplaced bottom form section **103**.

The sequence of erecting the partially collapsed form sections at the head end of truss **92** is as follows.

Partially collapsed bottom form section **103** arrives at the end of the truss **92** after the shield **31** has been pushed forward a distance somewhat greater than the length of one form section. The pistons **128** of shield pushing jacks **127** are then retracted, as shown in FIG. 21, so that sufficient space **150** is provided ahead of the liner within which another set of form sections **102**, **103** can be received. The form carrier **151** with its lower form section **103** will be aligned with the space **150**. Cylinders **173**, **177** will be manipulated to expand the leaves **104** of the form

section **103** and erect it into place. The end rails of the form sections are then bolted to the corresponding end rails of the next adjacent form at the head end of the liner.

After the bottom form section **103** is thus erected, the form handler **151** returns to the tail end of the truss and picks up the tailmost top form section **102** and transfers it to the head end of truss as aforestated. Form handler **151** is aligned with the space **150** above the previously positioned lower form section **103**, and its cylinders **173**, **177** are manipulated to unfold and erect the form section **102** into place where it is bolted to the next adjacent top form section.

In this manner a form set comprising complementary top and bottom form sections **102**, **103** is shifted from the rear of the truss **92** to the head of the truss **92**. Pistons **128** of cylinders **127** are now placed against the most recently erected form sections. The shield advancing and concrete injecting procedure are now resumed.

What is claimed is:

1. A tunneling machine with concrete wall forming mechanism comprising:

a shield,

an excavator carried at the head of the shield,

a truss trailing said shield,

a spoil removing conveyor carried by the truss,

a fluid concrete conveyor carried by the truss,

a plurality of concrete forms for lining the tunnel in spaced relation to the wall formed by the excavator,

injecting means carried by the shield to inject concrete supplied by said concrete conveyor into the space between the forms and the tunnel wall to form a concrete wall about the tunnel,

and a form handler movable along the truss to transfer forms from near the trailing end of the truss where the concrete has hardened to the front end of the truss for erection behind said excavator.

2. The machine of claim **1** in which the spoil removing conveyor comprises means to convey mucky spoil, said excavator comprising a wheel having a face which can be substantially closed to breast said spoil.

3. The machine of claim **2** in which the shield has a substantially fixed bulkhead spaced longitudinally from said wheel and which also is substantially completely closed, whereby two spoil barriers in tandem resist flow of fluid spoil.

4. The machine of claim **1** in which said spoil removing conveyor comprises a screw auger, means for fluidizing the spoil as it is acted on by the auger and a pump to pump fluidized spoil.

5. The machine of claim **1** in which the truss has legs by which it is supported in elevated position from the tunnel floor, the space about said truss being substantially unobstructed except in the vicinity of said legs, said form handler comprising means to convey forms through said unobstructed space to avoid said legs.

6. The machine of claim **5** in which said unobstructed space is at the top and sides of the truss, said forms comprising top form sections and bottom form sections, said form handler further comprising means to transfer a bottom form section to a position at the top and sides of the truss in substantial alignment with said unobstructed space and convey it through said space to the head end of the tunnel.

7. The machine of claim **6** in which said form handler comprises an open bottom trolley having a hollow interior within which the truss is received, said truss having tracks on which the trolley is movable longitudinally along the truss, said trolley having a form carrier rotatable thereabout to shift forms from the bottom of the truss to the top of the truss.

8. The machine of claim **1** in which said truss has legs by which it is supported on said forms, and means for shifting said legs longitudinally along the truss to advance said legs with respect to the tunnel.

9. The machine of claim **1** in which said excavator comprises a wheel having a substantially closed front face with radially elongated openings, transversely extending pintles spanning said openings at a point intermediate the radial extent thereof and gates swingable on said pintles to selectively open and close said openings, gate portions at one side of the pintle moving outwardly beyond the front wall as gate portions at the other side of the pintle move inwardly of said wall.

10. The machine of claim **1** in which said injecting means comprises an annular concrete bulkhead to seal the space between the wall of the shield and the concrete forms spaced therewithin, said concrete bulkhead having ports through which concrete is pumped into said space.

11. The machine of claim **10** in further combination with means to impose back pressure on said concrete bulkhead to maintain pressure on the concrete in said space.

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U.S. Cl. X.R.

61—42; 299—33