R. T. STONE.

TUNNELING MACHINE.

APPLICATION FILED JULY 12, 1911.

1,026,412.

Patented May 14, 1912.

7 SHEETS—SHEET 1.

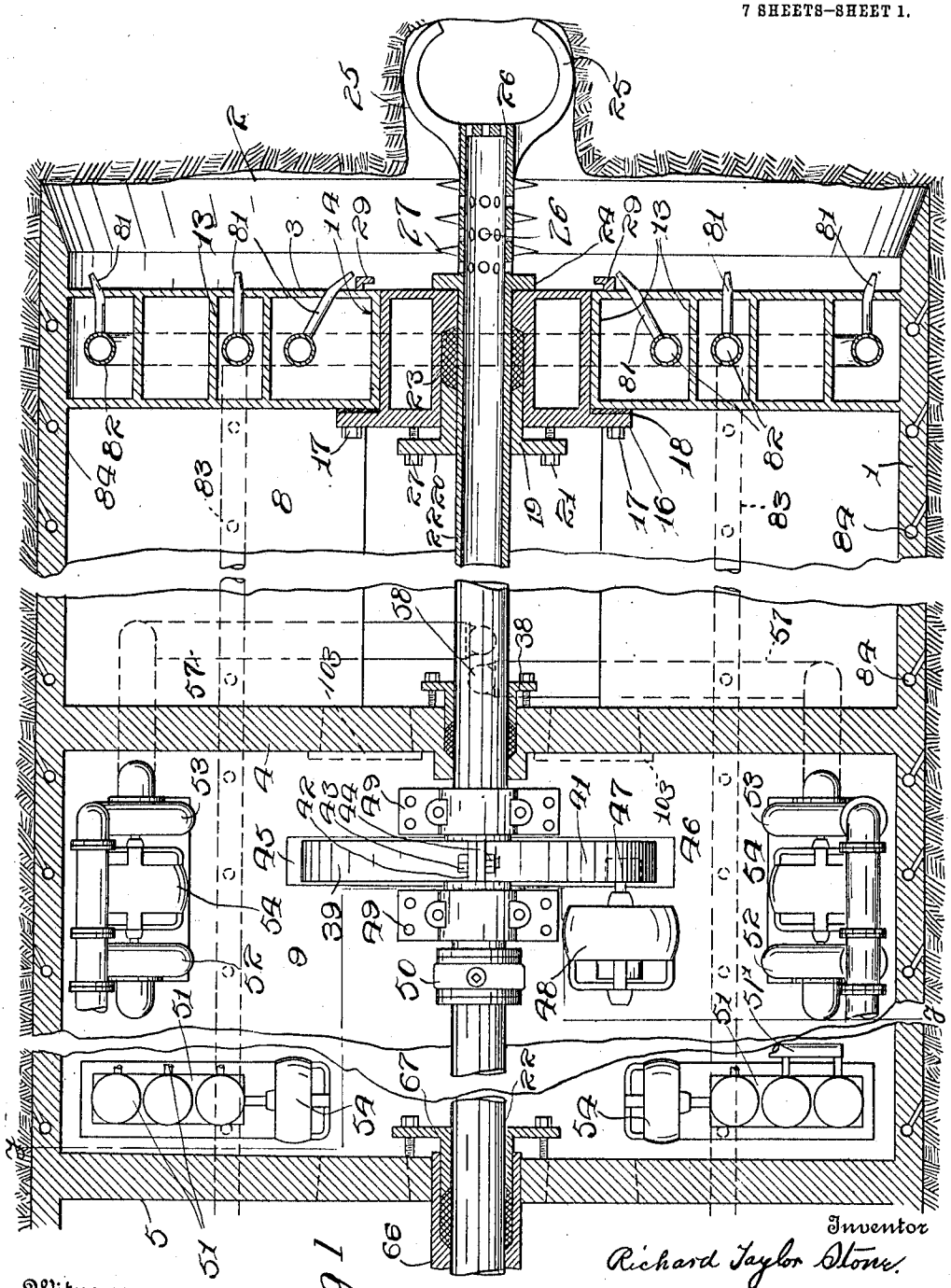

Fig 1

Witnesses

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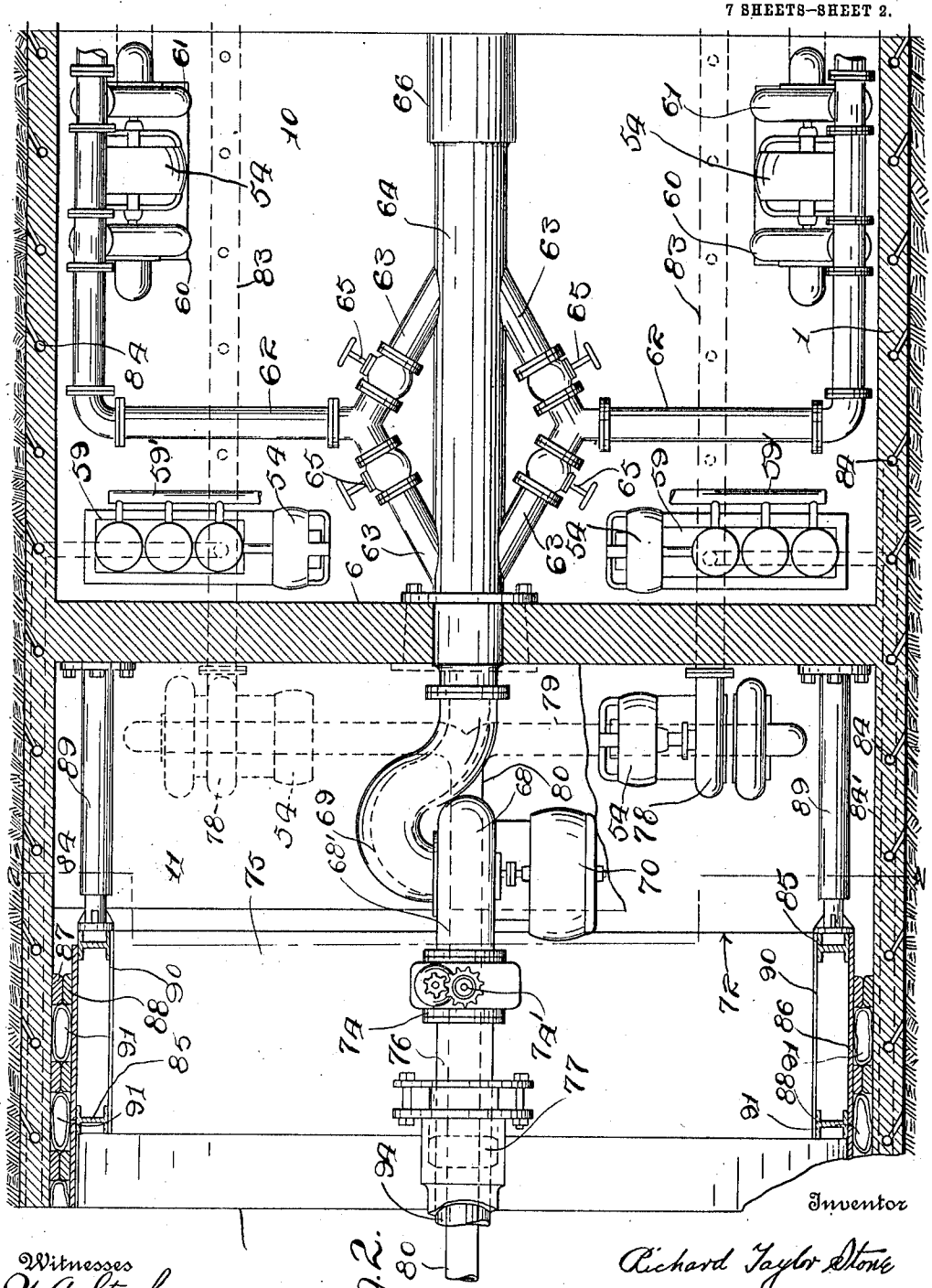

Fig. 2.

Witnesses

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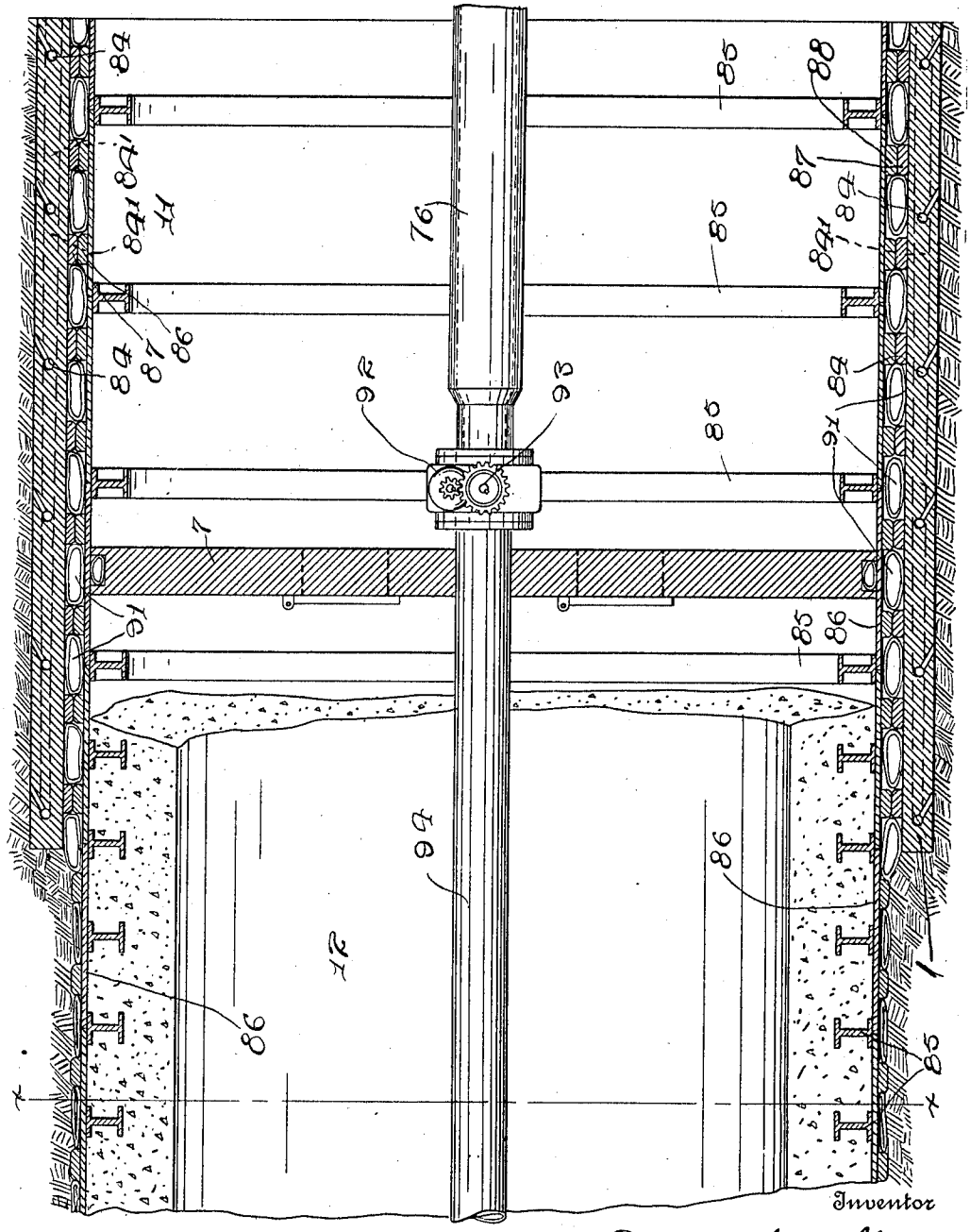

Fig. 3.

Witnesses

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7 SHEETS—SHEET 4.

Fig. 4.

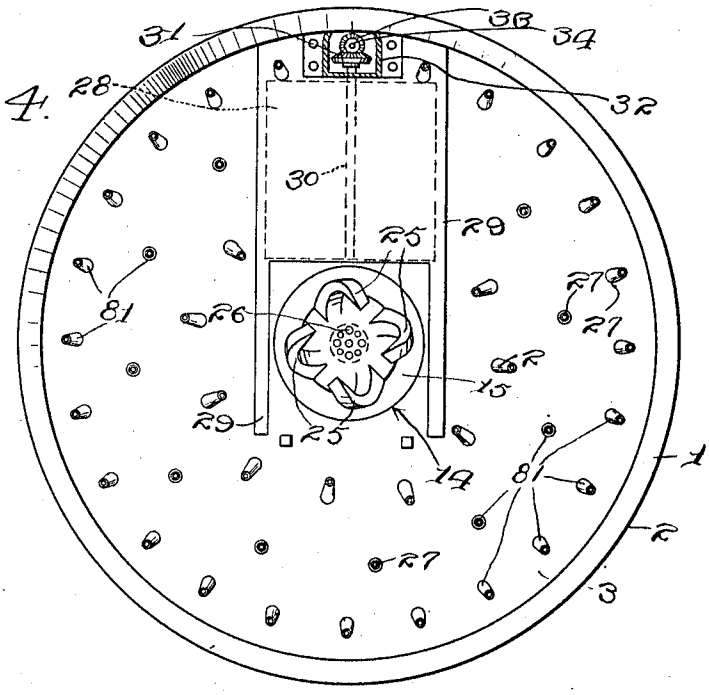
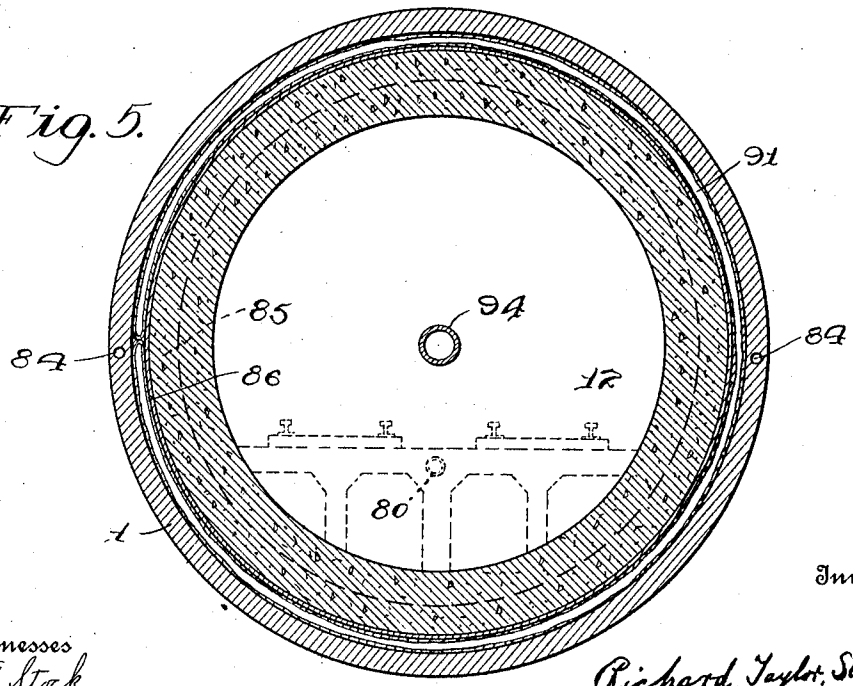


Fig. 5.



Witnesses

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7 SHEETS—SHEET 5.

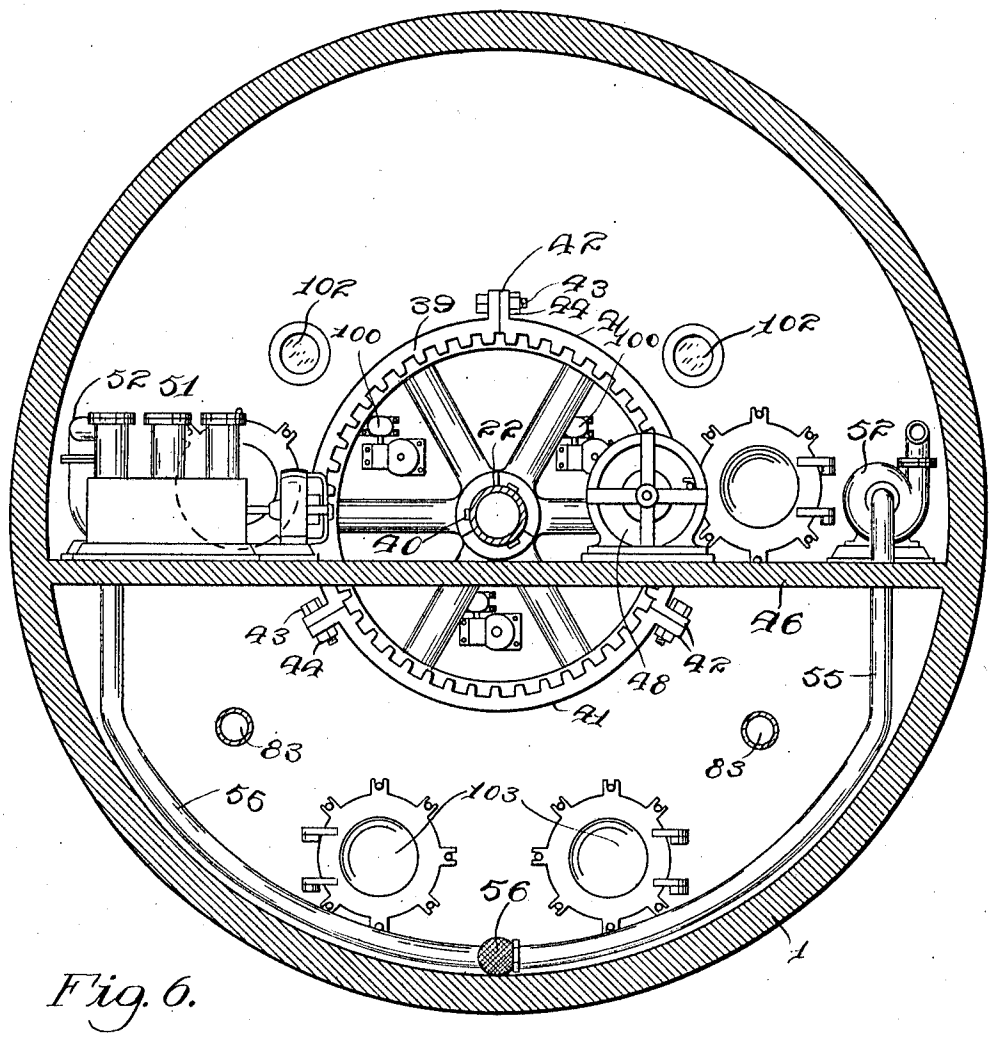

Fig. 6.

Witnesses
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7 SHEETS—SHEET 6.

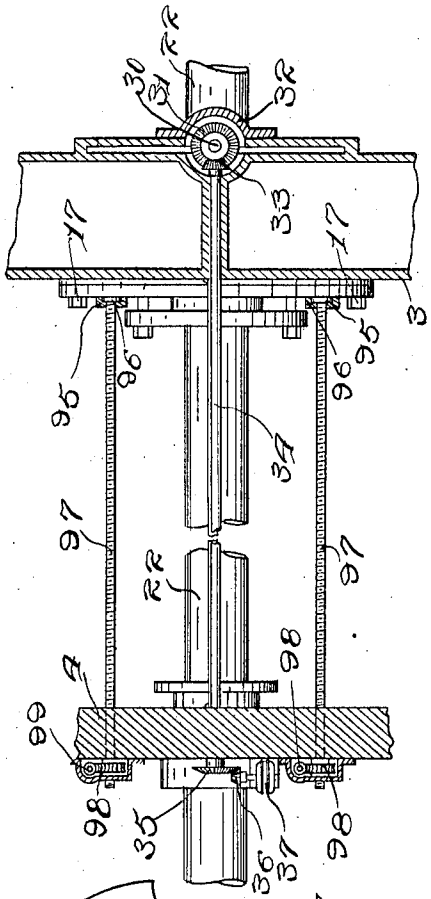

Fig. 7.

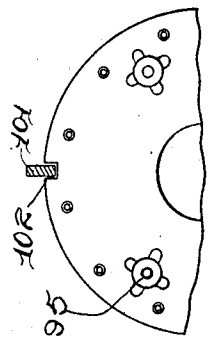

Fig. 9.

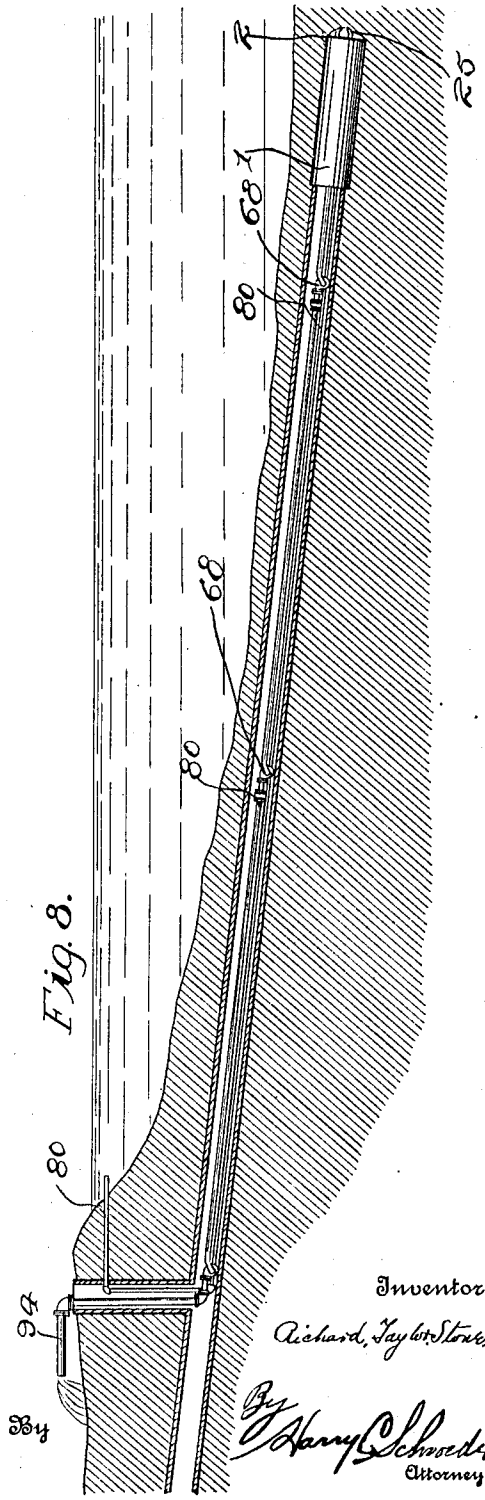

Fig. 8.

Witnesses

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7 SHEETS—SHEET 7.

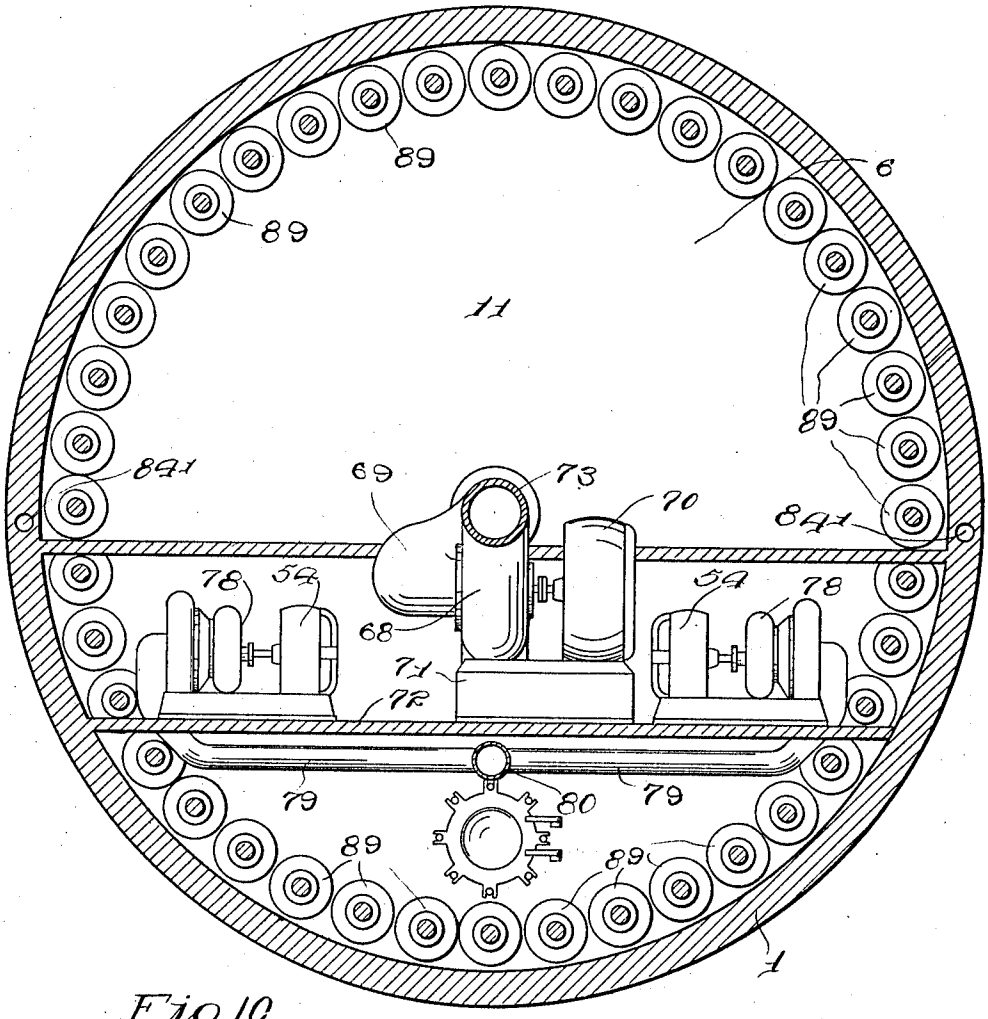

Fig. 10.

Inventor

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Witnesses

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UNITED STATES PATENT OFFICE.

RICHARD T. STONE, OF DEMING, NEW MEXICO.

TUNNELING-MACHINE.

1,026,412. Specification of Letters Patent. Patented May 14, 1912.

Application filed July 12, 1911. Serial No. 638,134.

To all whom it may concern:

Be it known that I, RICHARD T. STONE, a citizen of the United States, residing at Deming, in the county of Luna and State of New Mexico, have invented certain new and useful Improvements in Tunneling-Machines, of which the following is a specification.

This invention relates to excavating machines and has special reference to that class of excavating machines adapted for boring tunnels.

The invention has for its object to provide an improved apparatus for boring tunnels and has special reference to the boring of sub-aqueous tunnels, or tunnels which are built beneath a body of water.

The invention further has for its object to provide an improved apparatus of the kind described, which may be employed for the sinking of bridge piers, foundations, and mine shafts through yielding substance at great depths below the water level without the use of compressed air to equalize the pressure due to the head of water.

The danger and difficulty of working in high pressures required for a depth of 100 to 150 feet are well understood and beyond the depth of 150 feet the means heretofore employed are inadequate. By means of this invention tunnels may be driven to any depth as the atmosphere of all parts where men are required to work is at a low pressure sufficient to insure good ventilation, and, hence, they are able to work without inconvenience as there is no excessive pressure.

Referring to the accompanying drawings;—Figure 1 is a plan view in longitudinal section of a tunnel boring apparatus constructed in accordance with this invention. Fig. 2 is a plan view in longitudinal section of a continuation of the apparatus shown in Fig. 1, illustrating the central portion of the apparatus. Fig. 3 is a plan view in longitudinal section of a continuation of the apparatus shown in Fig. 2, and disclosing the rear portion of the apparatus and a portion of the completed tunnel. Fig. 4 is a front view of the apparatus. Fig. 5 is an end view in cross section on the line X—X, Fig. 3. Fig. 6 is an end view in cross section on the line Y—Y, Fig. 1. Fig. 7 is a detail plan view in horizontal section of a portion of the apparatus shown in Fig. 1. Fig. 8 is a view in longitudinal section of a portion of a river bed showing a tunnel thereunder as it is being constructed. Fig. 9 is a detail front view of the upper portion of a removable door in the front part of the apparatus. Fig. 10 is an end view in cross section on the line Z—Z, Fig. 2.

In carrying out the invention a cylindrical metallic shield 1 is employed of sufficient strength to resist the pressure at the greatest depth in the ground in which the tunnel is to be driven. The shield 1 is formed at its forward end with a tapering cutting edge 2 and with a number of partitions or bulk heads, a partition or bulk head 3 being located adjacent to the cutting edge 2 and at intervals apart from each other there being located partitions 4, 5, 6, and 7, dividing the cylindrical shield into a number of compartments 8, 9, 10, and 11. In Fig. 3 a section 12 of the completed tunnel is shown. The bulk head 3 is formed with a number of concentric annular partitions 13 forming a number of annular compartments and serving to strengthen the bulk head 3. The bulk head 3 is formed with a central circular opening 14 as shown in Figs. 1 and 4 in which is seated a circular door 15 provided on its inner end with an annular flange 16 secured to the bulk head 3 by means of bolts 17 and bearing against a gasket 18 located between the flange 16 and the bulk head 3. Mounted in a socket in the door 15 is a gland 19 having a flange 20 by means of which it is secured to the door 15. A hollow rotary shaft 22 extends through the gland 19 and the door 15 and a water tight joint is formed by the pressure of the gland 19 against the packing 23 in the door 15. The shaft 22 is formed with an annular flange 24 which bears against the outer end of the door 15 and serves with the gland 19 to clamp the door tight upon the shaft 22. The forward end of the rotary hollow shaft 22 projects from the bulk head 3 to a point a little way beyond the outer end of the cutting shield 1 and mounted upon the end of the shaft 22 is a cutting device consisting of a number of spirally shaped curved projections or fingers 25. In the closed end of the hollow shaft 22 and in the sides thereof adjacent to said end are a number of openings 26 for permitting mud, sand and debris mixed with water to flow into the hollow shaft 22. Mounted on the outer end of the shaft 22 adjacent to the lateral openings 26 are a number of taper-

ing projections 27 for breaking up matter too large to enter the holes 26. The distance across from the opposite spiral projections 25 from the outside of the same is less than the circular opening 14 so as to permit the cutter head to be drawn inside of the chamber 8 for repairs.

In order to close the compartments 8 when the door 15 has been drawn out of the opening 14 with the shaft 22 and the cutter head is within the compartment 8, a door 28 is provided as shown in Fig. 4, which is vertically movable in guide ways 29 and is operated by a screw shaft 30 on the upper end of which is a beveled gear wheel 31 located in a casing 32, meshing with a beveled gear wheel 33 on one end of a horizontal shaft 34 in the bulk head 3 and extending through the bulk head 4 and having on its other end a bevel gear wheel 35 meshing with a beveled gear wheel 36 on the shaft of a motor 37 mounted in the compartment 9.

The hollow shaft 22 extends through the bulk heads 4 and 5 through a gland 38 in the bulk head 4, forming a water tight joint therewith. Located in the compartment 9 is an internal gear wheel 39 keyed to the shaft 22 by means of keys 40 and formed in sections 41 having at their ends flanges 42 secured together by bolts 43 and nuts 44, this construction enabling the gear wheel 39 to be removed from the shaft 22 when necessary as hereinafter set forth. The toothed gear wheel 39 projects through an opening 45 in the floor 46 extending from side to side of the compartment 9 between its top and bottom. The gear wheel 39 meshes with a spur gear wheel 47 on the shaft of a motor 48 which thereby through said connection drives the gear wheel 39. The shaft 22 is mounted in bearings 49 secured to the floor 46 at the sides of the wheel 39. A valve 50 is located in the shaft 22 adjacent to bearing 49 through which the shaft 22 extends. Mounted on the floor 46 is a set of air compressors 51 and a double centrifugal pumps 52 and 53. These pumps are driven by motors 54 and each motor is water cased. The pumps 52 each takes its suction from the lowest point of the compartment 9 by means of the pipes 55 having their open ends covered with reticulated material 56 see Fig. 6. The pumps 53 are each provided with a pipe 57 which passes through the partition 4 and takes its suction from the lowest point of the compartment 8, as shown in dotted lines in Fig. 1 at the points 58. The air pumps 51 draw a fresh air supply from outside sources and discharge directly into the chamber 9 through the pipes 51′, the air pressure being kept in the compartment a few pounds higher than the atmospheric pressure and causing a constant flow of air from the working space to the outlet shaft.

The compartment 10 is duplicate of the compartment 9 in respect to the pump equipment, which is provided for emergency use in case the compartment 9 becomes flooded. The compartment 10 is provided with air compressors 59 having air discharge pipes 59′, and with pairs of centrifugal pumps 60 and 61. The centrifugal pumps 61 connect with compartment 9, while the centrifugal pumps 60 are connected by pipes 62 with the branch pipes 63 connecting with the main pipe 64, the branch pipes 63 being each provided with a valve 65. The pipe 64 is provided with an enlargement 66 and with a gland 67, the enlargement 66 being located in the partition 5. The rotary hollow shaft 22 passes through the stuffing box 67 and the enlargement 66 of the pipe 64. The inside diameter of the pipe 64 is large enough to permit the pipe 22 to telescope therein when the cutter head is withdrawn into the compartment 8 for repairs.

Within the compartment 11 is located a large centrifugal pump 68 connected by a curved pipe 69 with the pipe 64 and driven by means of a motor 70, the centrifugal pump 68 and motor 70 being mounted on a base 71 secured to the floor 72 extending across the compartment 11. The pump 68 provides the necessary suction to draw the water and debris from the cutting face of the tunnel. The centrifugal pump 68 is connected by a pipe 68′ with a casing 74 in which is located a valve operated by the gearing 74′. The pipe 76 connects the valve casing 74 with a slip joint 77 which serves to allow the shield and apparatus to advance without moving the rest of the discharge pipe. In the lower part of the compartment 11 are located duplicate sets of high pressure centrifugal pumps 78 which take their water supply from an external source through a pipe 80, as shown in Figs. 2, 8, and 10, the pumps 78 being connected with the pipe 80 by branch pipes 79. The water is pumped through the pipe 80 to the discharge nozzles 81, projecting from the bulk head 3, by means of annular pipes 82 located in the bulk head 3 to which the nozzles 81 are connected, and pipes 83 lead from the pumps 78 and are connected with the pipes 82. Water is also pumped to a number of outlets 84 arranged in the shield 1 and opening outward therefrom and connected by pipes 84′, shown in dotted lines in Fig. 2, with the pumps 78. By means of the outlets 84 the earth surrounding the shield 1 is softened by water discharged through said outlet 84 thereby enabling the shield to be worked forward.

Within the compartment 11 is located the sections which compose the permanent outer shell of the tunnel. These sections consist of segmental rings 85 preferably

formed of I-beams on the outside of which are bolted plates 86, also formed in segments. In order to keep the two cylinders concentric, rings 87 and 88 are provided, the former being attached to the shield 1 and the latter to the outside of plates 86.

A plurality of hydraulic jacks 89 are bolted to the partition 6 as shown in Figs. 2 and 10 and bear against the rings 85. To distribute the load along a great distance a number of ties 90 are provided. Inflated pneumatic bags 91 are employed and located between the shield 1 and the plates 86. The pipe 76 as shown in Fig. 3 is connected with a valve casing 92 operated by mechanism 93, said casing having connected thereto a fixed discharge pipe 94. As the tunnel advances the valve casing 92 is uncoupled from the pipe 94 and moved forward on the inner end of the pipe 94 and a new joint inserted between the valve and the pipe 94.

The bulk head 7 provides a safe guard against the flooding of the whole apparatus and serves as a place of retreat in case all of the other compartment become flooded. This bulk head 7 is of knock down form and is moved forward from time to time as the work advances. It is also packed with inflated pneumatic bags to make a tight joint between it and the shell.

If the tunnel bored is of great length several pumps 68 and valves 8, are located in the discharge line as shown in Fig. 8. To open and close the door 15 the inner face of the flange 16 is provided with a number of seats 95 in each of which is located the headed ends 96 of screw shafts 97 projecting through the partition 4, each of said shafts 97 having at its other end a worm wheel 98 meshing with a worm shaft 99 driven by a motor 100 as shown in Fig. 6 mounted on the partition 4.

The door 15 is prevented from rotation on the shaft 22 by means of a bar 101 which extends from the bulk head 3 to bulk head 4 and engages a notch 102 in the top of the door 15.

One of the main points of the invention is the utilization of the latent hydraulic forces, in the water above the working face, to accomplish a considerable portion of the work to be performed. This is done by introducing a large volume of water by means of the large pipe 80 running through the tunnel from the surface to the working face. At the working face this volume of water is introduced by a plurality of nozzles 81. The velocity of the water is to be supplemented by a double set of very high pressure centrifugal pumps 78 of the two step variety.

The apparatus is operated as follows: A sufficient amount of water will be introduced into the working face by the above means to supply the pumps 68 working on the main central line 94, which operates in connection with the cutting head having cutters 25 as shown in Fig. 1. This pipe line 94 is designed to carry away all materials from the working face, after being dislodged by the cutters and reduced by the action of the nozzles 81. The cutters are employed to remove a central core and the nozzles are intended to break down the surrounding face. The hydraulic action of the water, aided by the suction of the pumps will convey all materials to a common center, there to be drawn through holes 26 into the hollow shaft 22, and discharged by the main pump 68. The main pump 68 is supplemented by a series of pumps 68 placed at proper intervals along the main pipe line, to maintain a uniform velocity of the materials passing through said pipe. The mouth of the suction pipe is perforated with a series of coarse holes 26, about 4 inches in diameter, so arranged that through the sluicing action of the water the capacity of the pumps will not be overtaxed to handle the solids in suspension in the water.

The power to drive the rotary cutters is furnished by a water-cased motor 48 which engages with a large internal spur gear 39 keyed onto the rotating shaft 22 and readily detached from said shaft when it becomes necessary to telescope the rotating shaft 22 into the stationary pipe 64, located in chamber number 10 for the purpose of repairing the cutting head. When this becomes necessary the cutters are stopped, and the main pumps are operated until the water passing through the same is free from all solids. Then the pumps are stopped and gate valves 50 and 74 located in chambers 9 and 11 are closed.

After the circular gate 15 is securely clamped to the rotating shaft 22 the main pipe between the before mentioned gates 50 and 74 is charged with hydraulic pressure from the pump 60 sufficient to resist any pressure of water on the exterior of circular gate 15, while the operator is unfastening said gate from bulk head 3. This action is to be supplemented by the use of three very powerful screws 97 driven by motors 100 and worm gears operated in chamber 9. It is intended that either method will be sufficient in case of necessity. When said operator has fully released head gate 15, he will at once retreat into chamber 9, and seal the man hole located in the bulk head 4. When this has been fully attended to, the assistant engineer having previously removed the gear 39 will release the air valve thereby relieving the pressure in the main pipe, and allowing the rotatable shaft and cutters to be drawn fully into chamber number 8. On this being accomplished, the assistant operator will close the forward gate 28 on the face of the bulk head 3 by means

of motor 37 and the mechanism connected therewith. The assistant engineer starts one of the auxiliary bilge pumps 53 in the chamber 9. The suction pipe from both pumps leads to chamber 8, and is for the purpose of removing the water from the same. When this is accomplished which will be determined by observation made from time to time through one of the glass peepholes 102 located in bulk head number 4, the assistant operator will enter chamber 8 through one of the man holes in bulk head 4 covered by doors 103 and proceed with the proper assistance to make any repairs necessary to the cutters. When the same is completed, the operators will again retreat to chamber 9, sealing the man holes behind them. The assistant engineer will raise the gate 28 allowing the chamber 8 to fill with water. Then he will at once recharge the pipe 64 with compressed air or use screw rods 97, forcing rotating pipe 22 and the cutters forward into a working position and holding the same in position, while the assistant operator removes water from the chamber 8 by use of an auxiliary bilge pump 53. When the water in said chamber is completely under control of the operator, the assistant operator will again enter the chamber 8, and proceed to fasten the main head gate securely in position. When this is accomplished he will again retreat and seal the man hole as before. This completes the movement necessary to safely conduct the repairs that may be necessary from time to time.

The chamber 8 is especially constructed for the purpose of safely making repairs to the cutters and is used for no other purpose. The inventor's sole object in providing the above mentioned appliance is to safe guard human life, and to insure the successful operation of the entire invention thereby.

Chambers 9 and 10 are each provided with two sets of twin centrifugal motor driven pumps. There are also, two sets of duplicate high power, heavy duty, air compressors, making four complete installations of each. All water which may enter the working shield from any source will be immediately taken up by the auxiliary bilge pumps, and forced into the main pipe line, as shown in chamber 11.

The object in having in chamber 10 a duplicate set of apparatus as in chamber 9 is to provide an additional safeguard, if chamber 9 should become flooded.

The method by which the working shield is kept water tight is by means of circular rings 87 constructed and located on the inner side of the working shield, and which have a turned face, and which engage with a similar ring 88, fastened on the outer diameter of the tunnel shell. These rings are placed about 2 feet on centers, and are slightly rounded on the corners to prevent them from interlocking when the tube or shield is being thrust forward. In addition to these rings there is provided a very strong rubber tube 91 to go between each pair of the aforementioned rings, and to extend over the entire circumference of the working shield. It is intended that there shall be sixteen rings and fifteen rubber tubes, all within the rear end of the working shield. No less than nine of these rings and eight of these tubes are ever engaged at any time, thereby insuring a good working joint between the working shield and the tunnel which is advanced and constructed in the shield from time to time.

The method employed to push the shield forward is by means of a plurality of hydraulic or compressed air jacks 89 which are bolted onto the bulk head 6, which is built extremely heavy, to withstand the enormous strain imposed upon the shield necessary to insure the forward movement of the same. The plunger ends of said jacks are in contact with the steel shell of the tunnel, which is built sufficiently strong to withstand the thrust necessary to the forward movement of the shield. By means of these jacks the guiding of the apparatus is effected in the following manner:—Suppose it is desired to deflect the tunnel upward, in this case the jacks on the lower half of the shell are placed under greater pressure than the upper ones, this pressure to be greatest on the lowest jacks and being graduated to the top most one of which the least pressure is exerted. This action elevates the forward end and lowers the rear end, inasmuch as the jacks are working at the neutral axis of the shield. In order to lower the forward end this procedure is reversed using the greater pressure on the upper jacks and the least pressure on the lower jacks.

As the work progresses, the reinforced concrete is kept well within the working shield, to insure more complete stability at the point of contact between the tunnel and the working shield.

It will be noted in Figs. 2 and 3, that there is a stuffing box and an enlargement in the main pipe which contains 14 feet of telescoped pipe which is for the purpose of allowing the working shield to be moved forward 12 feet, equal to two complete forward movements of the aforementioned plurality of jacks. When this is accomplished, the cutters will be stopped. The main pumps will continue operating until all solids are removed from the main pipe line. When this is accomplished the pump will stop and the gate valves 74 and 92 on the main pipe line will be closed and the flanged joint nearest the stuffing box will be disconnected and the gland within the stuffing box will be telescoped, thereby admitting another section of pipe which will be fastened

into the main pipe line 94, thus allowing the operation of moving the shield to be repeated from time to time, as the work progresses. The aforementioned procedure applies at this point to the main water supply pipes, as well as to all other pipes, that may be found necessary to the successful use of this device.

This process is capable of being worked to a depth of 1000 feet below water, and is fully capable of resisting the resultant pressures. The amount of compressed air necessary for the successful ventilation of this process at the lowest depths will never exceed 8 pounds per square inch, and this will insure splendid ventilation. All motors and power lines leading into the working shield will be thoroughly water cased, as also are all switch boards.

What I claim is:—

1. In a tunneling apparatus of the kind described, an extended cylindrical shell formed with compartments accessible to one another, the forward end of said shell having a cylindrical cutting edge, means for compressing air in said compartments, a longitudinal rotary tube having its forward end projecting from the forward end of said shell and provided with a cutting head, and inlet apertures, mechanism for rotating said tube, and means for discharging water at the forward end of said shell.

2. In a tunneling apparatus of the kind described, a cylindrical shell formed with compartments and having a plurality of openings in its walls, a rotary tube extending longitudinally of said shell and having cutters at its forward end and water inlet apertures, a plurality of water discharge pipes at the forward end of said shell, means for discharging water through said pipes, means for drawing collected material into the forward end of said rotary tube, and means for compressing air in said compartments.

3. In a tunneling apparatus of the kind described, an extended cylindrical shell formed with a cylindrical cutting edge at its forward edge and with transverse partitions forming compartments, each of said partitions having a man hole, a rotary hollow shaft extending through said partitions and having cutters and water inlet apertures at its forward end, a cylindrical shell at the rear end of said cutting shell, rings and inflatable tubes located between said shell and said cutting shell, circular brace bars located within said inner shell and provided with cross bars, and a plurality of jacks located between said inner shell and brace bars and the rear partition of said cutting shell.

4. In a tunneling apparatus of the kind described, an extended cylindrical shell with a cutting edge at its forward end, said shell being formed in compartments, a revoluble hollow shaft extending lengthwise through said shell and having its forward end provided with a cutting head, water inlet apertures, and lateral cutting projections adjacent to said apertures, means for creating a suction in said shaft, and a discharge pipe at the end of said shaft.

5. In a tunneling apparatus of the kind described, an extended cylindrical shell having a cutting edge at its forward end, transverse partitions forming compartments in said shell, each of said partitions having man holes, and the partition at the forward end of the shell having an opening, a removable door in said opening, a revoluble hollow shaft having its bearings in said door and in said partitions and movable rearwardly, and having water inlet openings at its forward end, a cutter head on said forward end, and lateral cutting projections adjacent to said openings, and a discharge pipe in telescopic connection with the rear end of said revoluble shaft.

6. In a tunneling apparatus of the kind described, an extended cylindrical shell having a cutting edge at its forward end and formed with compartments, a revoluble hollow shaft extending lengthwise through said shell and having water inlet openings at its forward end with a cutter head and lateral cutting projections adjacent to said openings, a plurality of water discharge nozzles arranged circumferentially at the forward end of said shell, water pipes connected with said nozzles, centrifugal pumps connected with said pipes, air compressors located in said shell, a discharge pipe connected with the rear end of said revoluble shaft, and a centrifugal pump connected with said revoluble shaft for creating suction therein.

7. In a tunneling apparatus of the kind described, an extended cylindrical shell with a cylindrical cutting edge at its forward end, a revoluble shaft extending lengthwise through said shell and having a cutting head at its forward end, a cylindrical shell located within said first named cylindrical shell at the rear end thereof, cylindrical channel bars located within said second named cylindrical shell, cylindrical rings and inflated rings located between said shells, and means located between said structure and the rear portion of said first named shell for advancing the latter.

8. In a tunneling machine, a forward partition forming the face of a shield, a partition in spaced relation to the forward partition, a boring bar extending through said partitions and projecting inwardly of the forward partition, a door in said forward partition forming a journal for said boring bar, and means operable from the rear of the second partition to withdraw said door and bar from the first partition.

9. In a tunneling machine, a forward partition forming the face of a shield, a par-

tition in spaced relation to the forward partition, a boring bar extending through said partitions and projecting inwardly of the forward partition, a door in said forward partition forming a journal for said boring bar, means operable from the rear of the second partition to withdraw said door and bar from the first partition, and controlling means operable from the rear of the second partition to close the opening left by the withdrawal of the door from the first partition.

10. In a tunneling machine, a shield, a tunnel end, and a back between said shield and tunnel and comprising spaced pairs of rings, and flexible water proof tubes contained within the space between said rings.

11. In a tunneling machine, a forwardly movable cylindrical shell having a cylindrical cutting edge at its forward end and formed with compartments, a door in the forward bulk head rearwardly and longitudinally removable therefrom, a revoluble shaft extending through said door with cutters on its forward end, a vertically slidable door mounted on said bulk head and movable over the outer end of the opening in which said longitudinally movable door is seated, and mechanism connected with said sliding door for operating the same, and extending through the compartment next to said bulk head and to the compartment beyond the last named compartment, and a motor connected with said door operating mechanism, and mechanism connecting said longitudinally movable door with said motor.

12. In a tunneling machine, a longitudinally movable cylindrical shell having a cylindrical cutting edge at its forward end and formed with compartments, a revoluble hollow shaft extending through said shell longitudinally and having cutters and water inlet openings at its forward end, said shell having water outlet openings in its periphery, water distributing pipes in said shell connected with said tubular shaft and with said water outlet openings in the periphery of the shell, a water supply pipe connected with the pipes in said shell and leading to a source of supply, a water discharge pipe connected with said tubular shaft and leading to a distant point of discharge, and mechanism for drawing water into the water pipes in said shell and withdrawing it from said tubular shaft.

13. In a tunneling machine, an extended cylindrical shell with a cylindrical cutting edge at its forward end, and formed with compartments, a brace support located within said shell and consisting of annular angle iron bars spaced apart from each other, an extended cylindrical metallic shell mounted on said angle iron bars, and alternately arranged brace rings and collapsible inflated rings located between said shell and the first named extended shell.

14. In a tunneling machine, an extended cylindrical sheet metal cylinder, circumferential angle iron brace bars mounted within said cylinder at intervals apart, partitions located at intervals apart forming compartments in said cylinder, each of said partitions having a circumferential inflated ring extending about its circumference, a layer of alternately arranged brace rings and collapsible inflated rings located on the outside of said cylinder, and an excavating cylindrical shell extending about said brace rings and inflated rings and movable longitudinally thereon.

In testimony whereof I affix my signature in presence of two witnesses.

RICHARD T. STONE.

Witnesses:
ROSS WHITLOCK,
AMOS W. POLLARD.