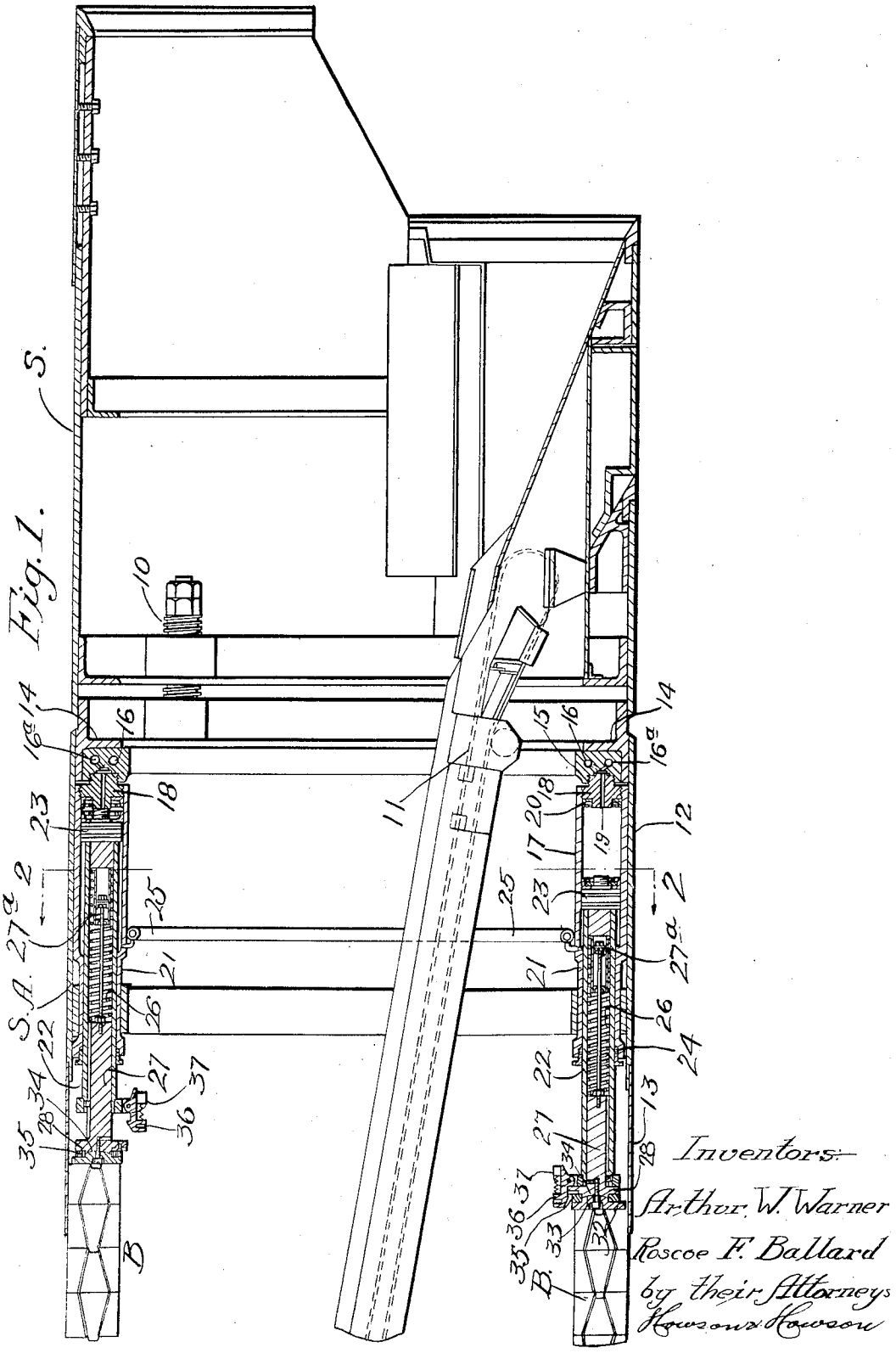
July 4, 1933. A. W. WARNER ET AL 1,917,170

METHOD OF AND APPARATUS FOR FORMING TUNNELS

Original Filed July 16, 1930 4 Sheets-Sheet 1



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METHOD OF AND APPARATUS FOR FORMING TUNNELS

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Fig. 2

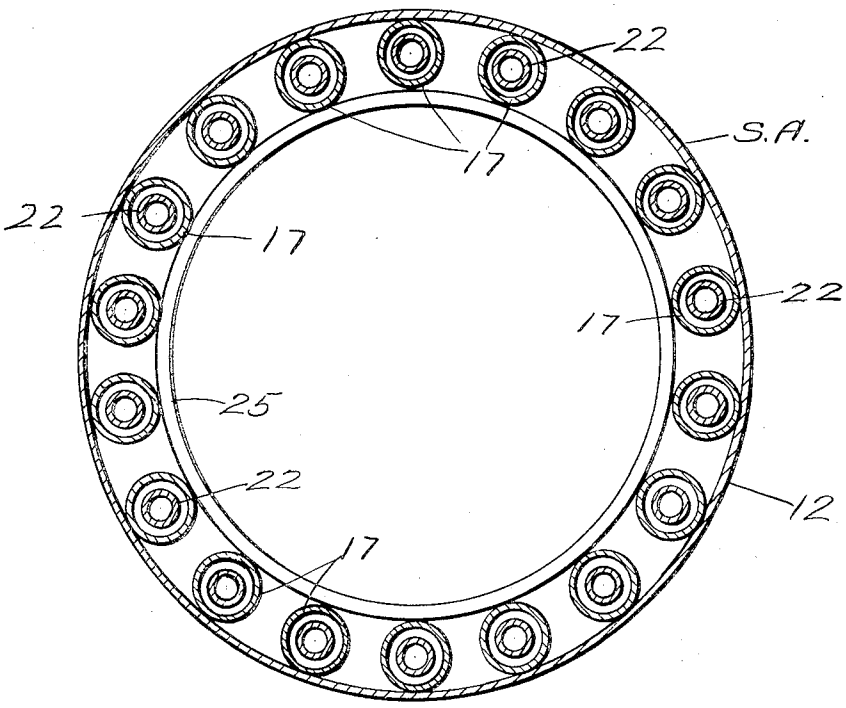


Fig. 3.

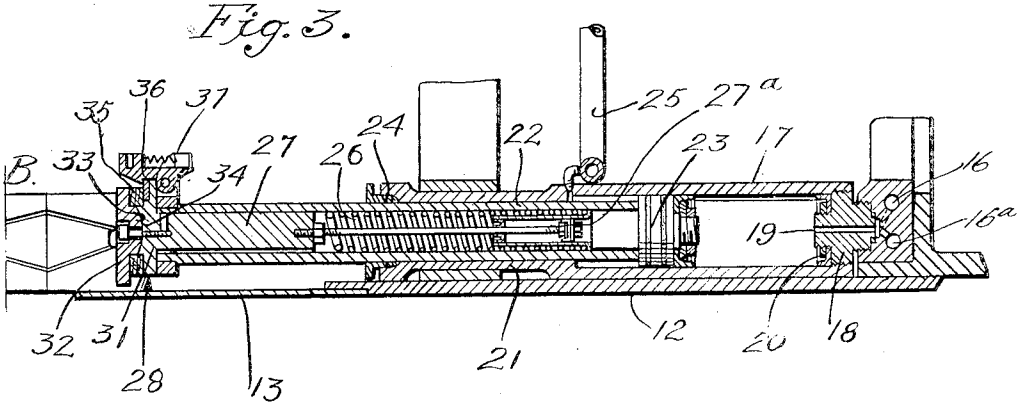
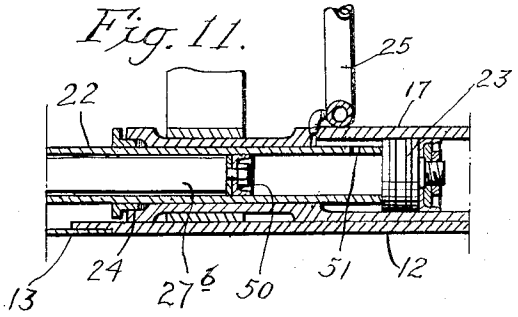


Fig. 11.



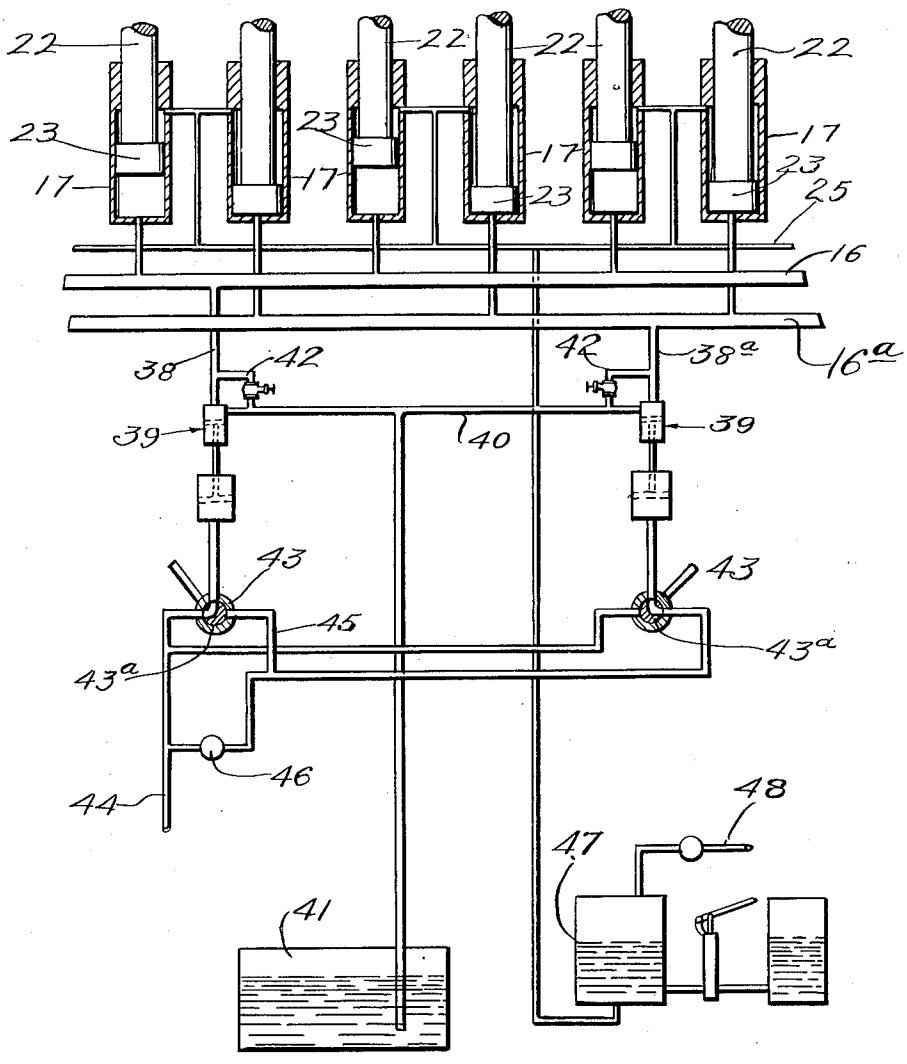
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METHOD OF AND APPARATUS FOR FORMING TUNNELS

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Fig. 4.



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Fig. 5. Fig. 6. Fig. 7. Fig. 8. Fig. 9.

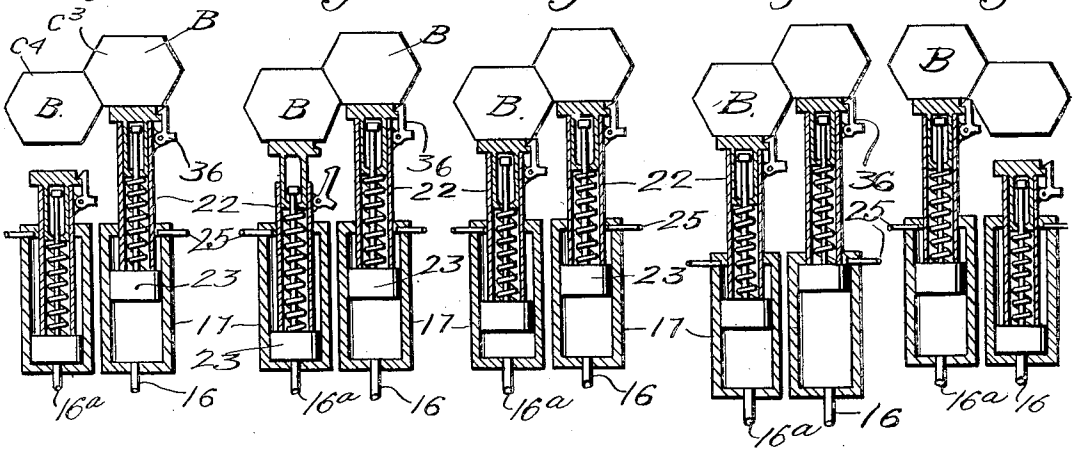
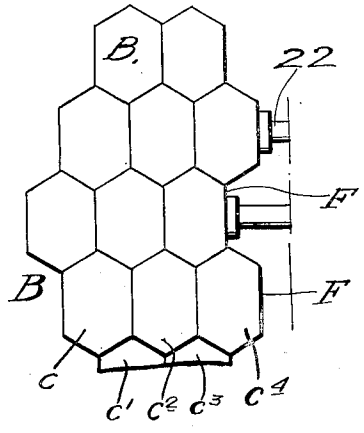


Fig. 10.



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UNITED STATES PATENT OFFICE

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METHOD OF AND APPARATUS FOR FORMING TUNNELS

Application filed July 16, 1930, Serial No. 468,338. Renewed April 27, 1933.

This invention relates to tunneling or mining machines, and more particularly to an apparatus of this character which employs a formed tunnel wall as a means for advancing a tunneling head or shield.

It has heretofore been considered necessary in constructing tunnels to either form the tunnel in a smaller size than the bore formed by the tunneling machine and fill the space thereabout, or to construct the tunnel of blocks of such character that pressure applied thereto would cause expansion of the tunnel wall after leaving the machine so that the tunnel wall finally fit tightly against the walls of the bore.

We have discovered that by employing a tunneling shield having a very thin skirt, a tunnel may be laid within the skirt tightly fitting the same and when expelled from the skirt without further expansion will provide a wall quite as smooth and uniform as the tunnel laid up by the latter process. This system has considerable advantages over such a process in that it permits ejection of the formed tunnel from the skirt of the shield without excessive friction such as must inevitably result when blocks calculated to produce expansion are laid up within a skirt and pressure applied thereto. When a tunnel of this character is forced into the bore from the skirt, there will be a slight clearance, the effects of which are negligible. In most soils, the earth will contract or settle to meet the blocks forming the tunnel wall and so maintain the tunnel in the condition in which it was originally laid up. If, as sometimes happens, the earth is self-sustaining and has no tendency to settle, the blocks forming the tunnel wall may fall away slightly and so come in contact with the earth wall. This will not, however, form excessive openings between adjacent blocks due to the fact that the difference in diameters is so slight, in practice about ¼", and the increase in circumference will be subdivided among the number of blocks distributed about this circumference so that the space between blocks is extremely small. This space may be readily taken care of by providing contacting faces of the blocks with tongue and groove joints and by applying to the faces of the blocks a thin coating of pitch which will act to provide a complete seal at the tongue and groove of any space which may be formed. It will, of course, be understood that the tongues will be of sufficient size to prevent any actual voids between adjacent blocks due to such falling away.

An important object of the present invention is the provision of a structure of such character that the previously laid tunnel wall may be very firmly held while a subsequent course of wall-forming elements is placed in position.

A further object of the invention is to provide a structure of this character wherein, during advancing movements of the shield, one course of wall elements is subjected to seating pressure while a second course thereof is subjected to just sufficient pressure to maintain the elements thereof in proper position to prevent the entry of dirt or other foreign matter between the faces of the wall elements and those of the preceding course.

A still further object of the invention is the provision of rams for advancing a shield so constructed that they may act first to apply a holding pressure to an installed wall element; second, to apply a low pressure thereto insuring holding of the wall element in a position preventing the entry of dirt; and third, to apply a shield-advancing pressure to this wall element.

A still further object of the invention is the production of apparatus of this character so arranged that control of the ram elements in their initial operation of holding an installed wall element in position may be readily effected.

A further object of the invention is to provide a novel and improved method of tunnel wall laying permitting two courses of tunnel wall-forming elements to be simultaneously held and subjected to pressures.

These and other objects we attain by the construction shown in the accompanying drawings wherein, for the purpose of illustration, we have shown a preferred embodiment of our invention and wherein:

Fig. 1 is a vertical sectional view through

tunneling mechanism constructed in accordance with our invention;

Fig. 2 is a section on line 2—2 of Fig. 1;

Fig. 3 is an enlarged sectional view through one of the jacks;

Fig. 4 is a diagrammatic view illustrating the fluid pressure operating connections to the jacks;

Figs. 5, 6, 7, 8 and 9 are diagrammatic views illustrating successive steps in operation of a pair of adjacent jacks;

Fig. 10 is a semi-diagrammatic view showing a section of tunnel lining and the action of the jacks; and

Fig. 11 is a sectional view showing a slightly modified form of jack cylinder.

Referring now to the drawings and more particularly to Fig. 10 thereof, a tunnel wall constructed in accordance with our invention comprises consecutive courses of blocks B, 5 courses being illustrated in the present instance, indicated at C, C—1, C—2, C—3 and C—4. The blocks B of each course interdigitate with the blocks of succeeding and following courses and the end faces F of the blocks B of any course are exposed after a succeeding course has been laid thereagainst so that the end faces of two courses at present indicated at C—3 and C—4 may be simultaneously engaged by holding or pressure devices. The method followed in erecting such a wall is that of installing the final course C—4 against the course C—3 and holding the same thereagainst by a suitable means, hereinafter described, while at the same time holding the course C—3 by means of similar holding means to which a greater pressure has been applied, a pressure insufficient to fully seat the block in its position, but sufficient to hold the block securely and prevent accidental intervention of foreign matter between adjacent faces of the blocks. The pressure on both holding means is then increased, that of the holding means of blocks C—3 to a final seating pressure which not only seats the blocks but, as hereinafter more fully set forth, advances a shield through which the tunnel bore is formed, and that of the holding means of course C—4 to that previously employed against the blocks of course C—3. The holding means of the blocks of course C—3 are then released and these holding means withdrawn so that the next course of blocks may be inserted. Each block, prior to its installation, is coated with pitch and the pressure employed in holding the blocks is insufficient to liquidate this pitch, while the pressure employed in finally seating the same is sufficient for this purpose so that during this final pressure and motion the pitch softens, permitting the block to find an accurate seat, and then as the pressure is released, to harden, holding the block in its position and sealing the interstices between it and adjacent blocks.

The tunneling apparatus employed includes a shield section S and a shield-advancing section SA, the shield being of any suitable construction and being at present illustrated as connected with the shield-advancing section SA by means of control screws 10, adjustment of which permits adjustment of the shield with relation to the shield-advancing section so that correction can be made in the direction of formation of the bore and accurate alignment maintained. The shield has associated therewith a conveyor 11 for the removal of excavated material which may be of any usual or desired construction.

The shield-advancing section comprises a main cylindrical portion 12 forming the front end thereof and a thin skirt 13 which forms the rear end thereof. At the forward end of the section 12 a pressure ring 14 is disposed against which is seated an annular manifold 15. In the manifold 15 a pair of annular passages 16 and 16*a* are formed, for a purpose presently to appear. The manifold at circumferentially spaced intervals is threaded, or otherwise adapted to receive the heads 18 of pressure cylinders 17, each head 18 having an intake passage 19 and being equipped with suitable pressure packing as at 20.

The rear ends of the cylinders are reduced in diameter as at 21 to slidably receive the hollow rods 22 of ram pistons 23 which operate in the cylinders, the extreme rear ends of these reduced portions being provided with packing glands as at 24 for sealing the space about the rods. At the junction of the main with the reduced bores the cylinders 21 are each in connection with a manifold 25. Each hollow ram houses a spring 26 which, at its rear end, abuts against the telescopically-inserted end of the stem 27 of a pressure head 28. The pressure head 28 is formed in two sections 31 and 32, the section 31 being rigidly attached to the stem 27 and the section 32 having pivotal engagement with the section 31 through a spherical hub 33 engaging in a spherical socket 34 formed in the section 31. About the hub 33 and between the sections 31 and 32 compressed material 35 is disposed, this material normally maintaining the sections 31 and 32 parallel but yielding when unevenly applied pressure resists to permit the section 32 to adapt itself to the surface against which the pressure is applied. Each ram 22 has pivoted thereto a latch 36, spring pressed to a normal position at which it is limited by a stop 37 and at which it is positioned to engage over the section 31 and hold the head 28 retracted against the action of spring 26. The nose of the latch and the co-acting face of the section 31 are beveled so that the latch may be thrown back against the action of its spring to permit passage of the head to the latching position. In order that dangerously rapid movement of the pres-

sure head may not take place when it is released to engage a block, a dash-pot 27*a* connects the stem 27 and the hollow ram. This dash-pot further serves as a means further preventing separation of the head and the ram.

The passages 16, 16*a* are in communication through conduits 38, 38*a* with a discharge of pumps 39. The intakes of these pumps are in communication through a conduit 40 with a sump 41 and the discharge lines 38, 38*a* are each connected with the intake conduit through a valved by-pass 42. The pressure ends of pumps 39 are each connected with one port of a three-way valve 43, each three-way valve 43 having a second port thereof connected with a source of high pressure 44 and a third port with a source of low pressure 45, the source of low pressure 45 being shown at present as produced by providing a branch of the source 44 including a reducing valve 46. The valve elements 43*a* are positioned to connect the pressure ends of pumps 39 with either source of pressure 44 or 45, or to disconnect the same from both sources of pressure.

It will be obvious that the pressure of the output of the pump may be regulated to provide either high or low pressure, or operation of the pump may be checked. When operation of the pump is checked by operating the valves of branches 42, the pressure in cylinders 17 may be released and the actuating liquid employed permitted to return to sump 41. Return of the rams is provided for by maintaining in manifold 25, which is in communication with the outer ends of cylinders 17, a constant low pressure. In the present instance this manifold is shown as in communication with a source of liquid supply 47 constantly submitted to pressure from a source 48.

It will be obvious that when operation of the pumps is cut off and the valve of the associated by-pass branch 42 opened up the pressure from liquid supply 47 will provide for withdrawal of the rams.

In operation, let it be assumed that the tunnel is partially formed and the wall thereof partially built, and that the parts are in the position illustrated in diagrammatic Fig. 5, ready for the insertion of a further course of blocks B. At this time the cylinders which are in communication with the passage 16 are under low pressure and the ram pistons thereof are forced rearwardly in contact with block B. The cylinders in communication with the passage 16*a* are in communication with the sump and therefore, due to the pressure to which the pistons are subjected through manifold 25, the rams are advanced to the greatest possible extent. The retraction of these rams provides spaces permitting the insertion of the blocks B of the new course which are placed in position and latches 36 released so that the parts assume the position in Fig. 6, and the blocks of the new course are held in position through the spring presure applied to the ram head. Low pressure is then introduced to the ram cylinders in communication with the passage 16*a* with the result that the pistons move rearwardly until the blocks B are subjected to low pressure and the latches 36 are engaged with the ram heads (see Fig. 7). At this time there will be no further movement of the blocks B beyond a slight settling thereof due to the fact that the low pressure is insufficient to cause either liquefaction of the pitch with which the blocks are faced, or to cause a shifting of the shield S. High pressure is introduced to the cylinders in communication with passage 16, this pressure shifting the rams rearwardly to the position shown in Fig. 8. The blocks of the newly laid course will follow the blocks of the previously laid course which are shifted by these pistons due to the fact that low pressure is still supplied through passage 16*a*. The pressure applied through the passage 16 and its rams to the previously laid course will cause liquefaction of the pitch placed between the blocks permitting this course to settle to its final position and will, furthermore, act to advance the shield S. The passage 16 is then placed in communication with the sump while the low pressure is held through passage 16*a* with the result that the pistons controlled through passage 16 will be retracted through the pressure supplied through manifold 25 so that the rams are now positioned for the insertion of a further course, as in Fig. 9. It will be noted that by use of this apparatus a step-by-step advance of the shield is provided and a progressive construction may be had in which the wall elements are at all times seated directly into position without being subjected to side strains. At the same time a structure is provided permitting ready insertion of the units and ready control of the holding apparatus for the units during the period of installation.

In Fig. 11 we have illustrated a modified structure for providing for extension of the ram head. In this structure the stem 27*b* of the ram head has a piston 50 packed to the walls of the hollow ram. The inner end of the hollow ram thus forms a cylinder which is in communication through a small port 51 with the rear end of the cylinder 17. The manifold 25 and its associated mechanism is the same in this structure as in the structure hereinbefore described. In a jack of the type just described, the back pressure employed for retracting the ram likewise serves to constantly urge the ram head to its extended position so that when the latches are released the ram heads will move slowly under the influence of this pressure

until they come into engagement with the blocks affording ample time for the workman to move his hands from the path of the head. When pressure is applied to the ram, the forward movement of the ram will compress the fluid contained in the bore of the ram causing the same to back up into the manifold 25 in the same manner that the fluid back of the ram does. With the exception of the head advancing means this jack is identical with the jack hereinbefore described.

As both the apparatus and method as hereinbefore set forth are capable of a certain range of modification, we do not wish to be understood as limiting ourselves to the particular structure hereinbefore set forth except as hereinafter claimed.

We claim:

1. In tunneling apparatus, a tunneling shield having a plurality of circumferentially-spaced longitudinally-extending hydraulic jacks therein and pressure supply means for said jacks comprising a pair of manifolds, each manifold communicating with alternate jacks.

2. In tunneling apparatus, a tunneling shield having a plurality of circumferentially-spaced longitudinally-extending hydraulic jacks therein, pressure supply means for said jacks comprising a pair of manifolds, each manifold communicating with alternate jacks and means for selectively connecting each manifold with a source of high or low pressure.

3. The method of tunneling consisting in employing a tunneling shield to form a bore, laying up a bore lining in annular courses in which the elements of the penultimate course are exposed between the elements of the final course and maintaining pressure between the shield and the exposed elements of the penultimate course while laying up the final course.

4. The method of tunneling consisting in employing a tunneling shield to form a bore, laying up a bore lining in annular courses in which the elements of the penultimate course are exposed between the elements of the final course and maintaining pressure between the shield and the exposed elements of the penultimate course while laying up the final course, and after laying up of the final course increasing the pressure to cause advance of the shield and seating of the elements of the penultimate course.

5. The method of tunneling consisting in employing a tunneling shield to form a bore, laying up a bore lining in annular courses in which the elements of the penultimate course are exposed between the elements of the final course and maintaining pressure between the shield and the exposed elements of the penultimate course while laying up the final course, and after laying up of the final course increasing the pressure to cause advance of the shield and seating of the elements of the penultimate course while applying pressure to the final course to maintain it in position against the penultimate course.

6. The method of constructing tunnels consisting in laying up the tunnel in annular courses of uniformly spaced blocks in a manner exposing the blocks of a previously laid course between adjacent blocks of a finely laid course and maintaining pressure in a direction longitudinal to the tunnel against each of the blocks of the previously laid course during laying up of the finally laid course then applying pressure to each of the blocks of the finally laid course and withdrawing pressure from said previously laid course.

7. The method of constructing tunnels consisting in employing a bore-forming means advanceable by pressure to form a bore, laying up a lining in the bore consisting of annular series of wall elements in which the elements of each series as laid are spaced from one another in a direction circumferential to the lining, have engagement with the elements of a previously laid series preventing displacement of the elements of the finally laid series in a direction circumferential to the lining, and have engagement with all adjacent elements of previously laid series which have faces exposed at the end face of the lining whereby strain may be applied therethrough to said elements of previously laid series in a direction longitudinal to the lining, employing uniform pressures between the bore-forming means and the lining at a series of uniformly circumferentially spaced points lying between the elements of the finally laid series to advance the bore-forming means while applying pressure between the bore-forming means and the elements of the finally laid series at a series of circumferentially spaced points aligning with the elements of the finally laid series to maintain the elements of the finally laid series in engagement with those of the previously laid series.

8. The method of constructing tunnels consisting in employing a bore-forming means advanceable by pressure to form a bore, laying up a lining in the bore consisting of annular series of wall elements in which the elements of each series as laid are spaced from one another in a direction circumferential to the lining, have engagement with the elements of a previously laid series preventing displacement of the elements of the finally laid series in a direction circumferential to the lining, and have engagement with all adjacent elements of previously laid series which have faces exposed at the end face of the lining whereby strain may be applied therethrough to said elements of previously laid series in a direction longitudinal to the lining, employing uniform pressures

between the bore-forming means and the lining at a series of uniformly circumferentially spaced points lying between the elements of the finally laid series to advance the bore-forming means while applying pressure between the bore-forming means and the elements of the finally laid series at a series of circumferentially spaced points aligning with the elements of the finally laid series to maintain the elements of the finally laid series in engagement with those of the previously laid series and then withdrawing the pressure at the first-named points of pressure application while maintaining it at the last-named points of application to thereby maintain the integrity of the lining and permit the installation of a further annular series of wall elements.

9. The method of constructing tunnels consisting in employing a bore-forming means advanceable by pressure to form a bore, laying up a lining in the bore consisting of annular series of wall elements in which the elements of each series as laid are spaced from one another in a direction circumferential to the lining, have engagement with the elements of a previously laid series preventing displacement of the elements of the finally laid series in a direction circumferential to the lining, and have engagement with all adjacent elements of previously laid series which have faces exposed at the end face of the lining whereby strain may be applied therethrough to said elements of previously laid series in a direction longitudinal to the lining, employing uniform pressures between the bore-forming means and the lining at a series of uniformly circumferentially spaced points lying between the elements of the finally laid series to advance the bore-forming means and then employing pressure between the bore-forming means and the finally laid series to maintain the integrity of the lining during the laying up of a further series of wall elements.

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