C. D. McARTHUR.

METHOD OF AND APPARATUS FOR TUNNEL WORK.

APPLICATION FILED AUG. 8, 1918.

1,380,400.

Patented June 7, 1921.

3 SHEETS—SHEET 1.

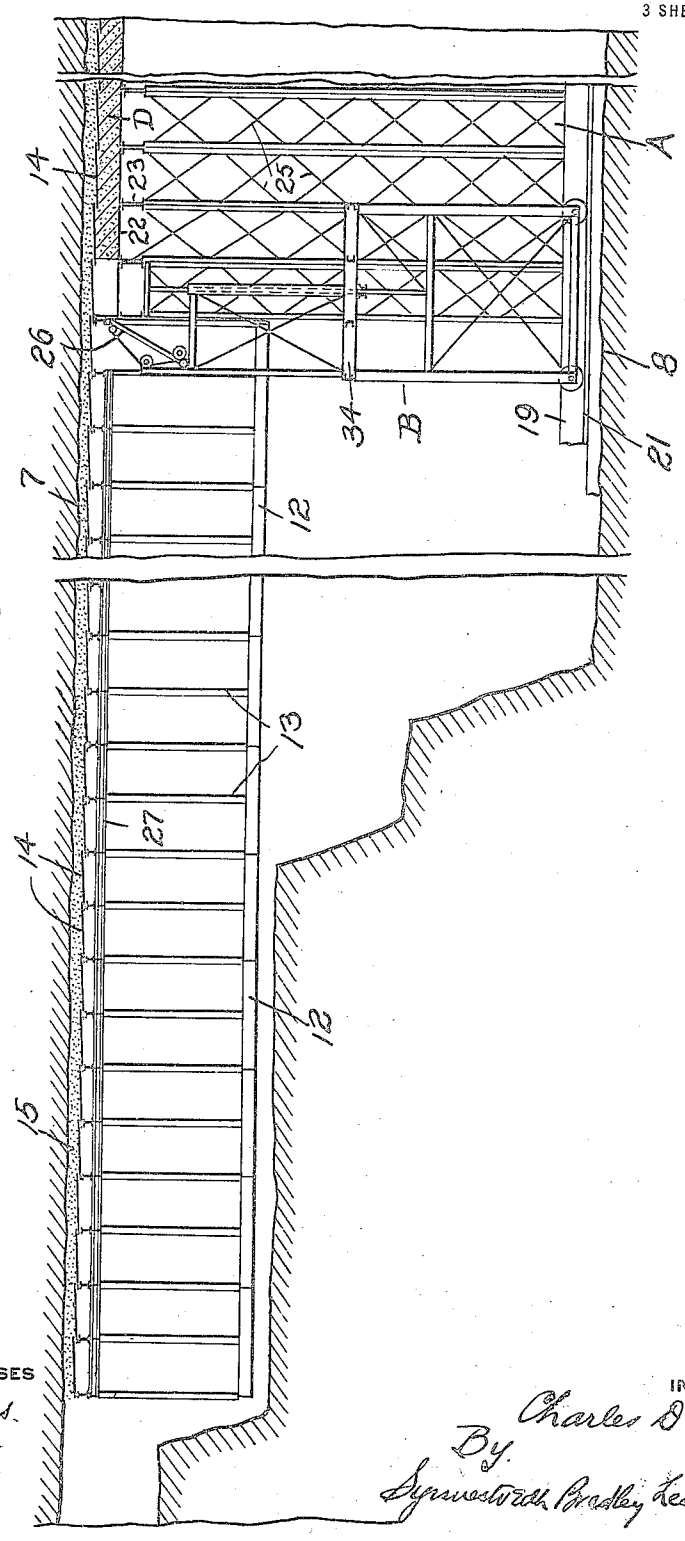



FIG. 1.

WITNESSES

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3 SHEETS—SHEET 2.

FIG. 2.

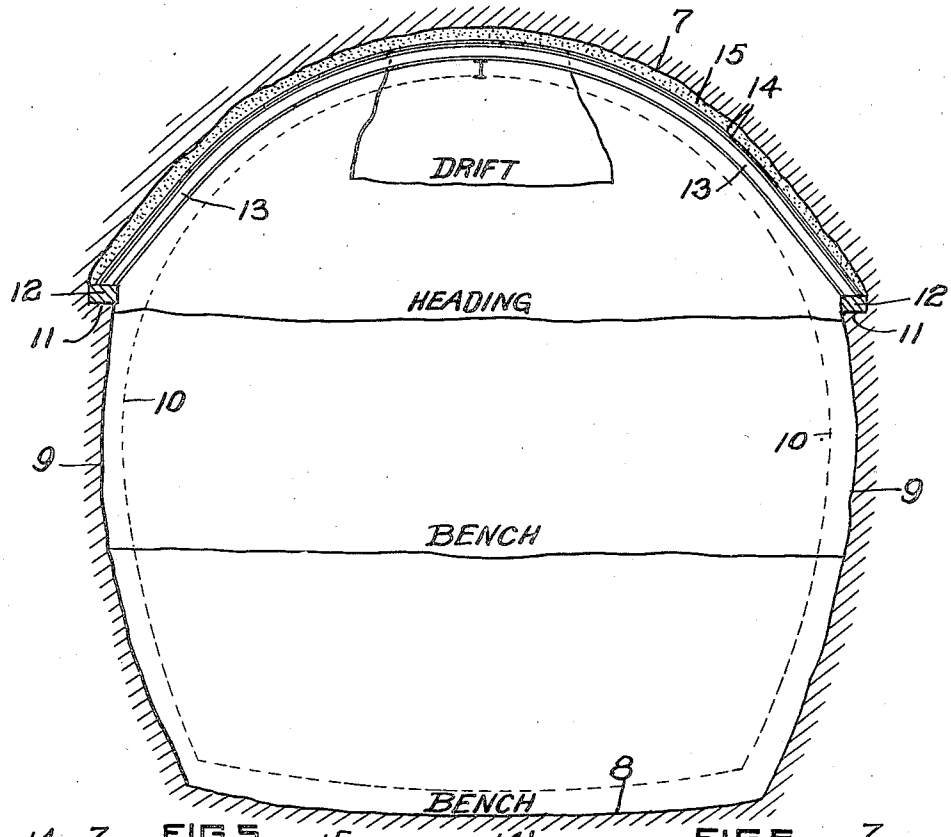



FIG. 5.

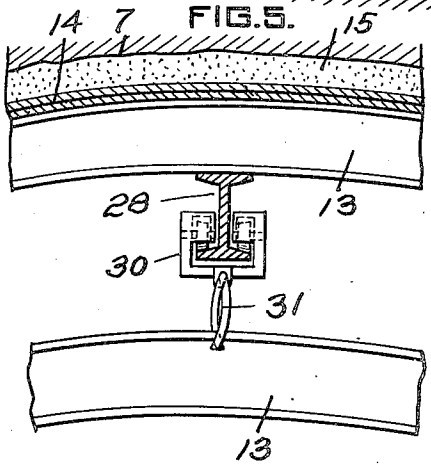
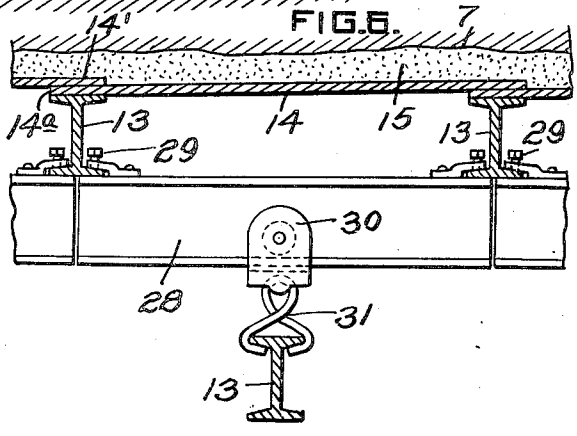



FIG. 6.




WITNESSES

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3 SHEETS—SHEET 3.

FIG. 3.

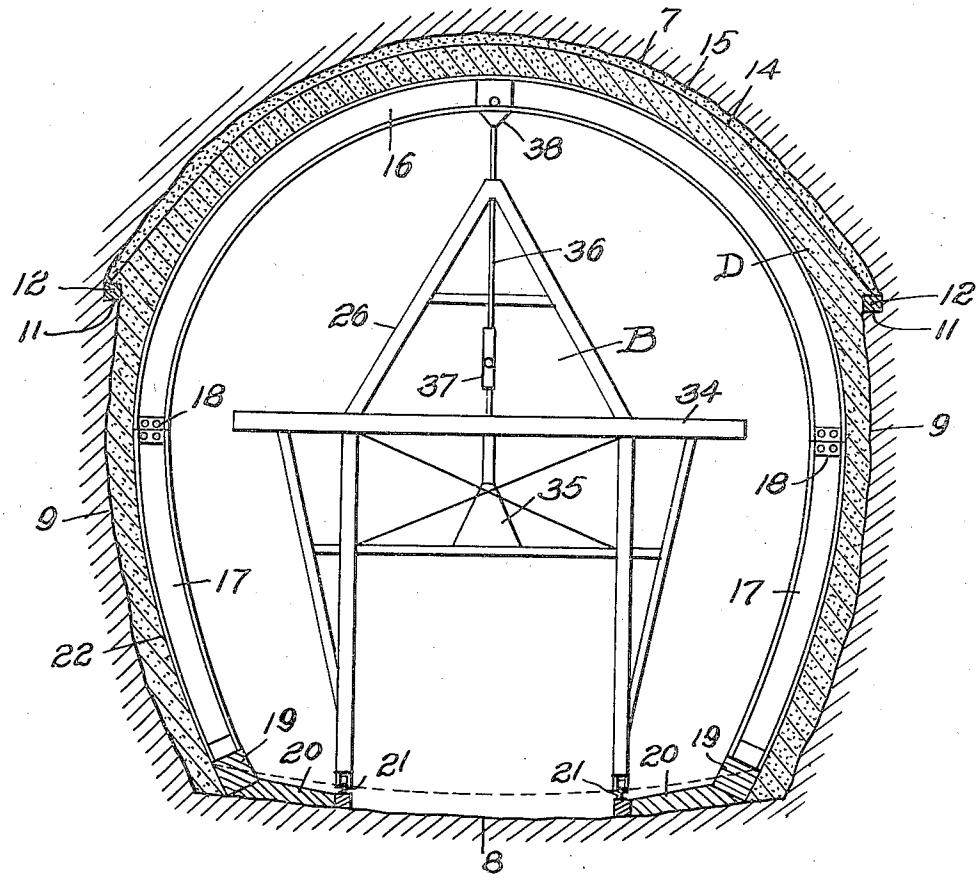
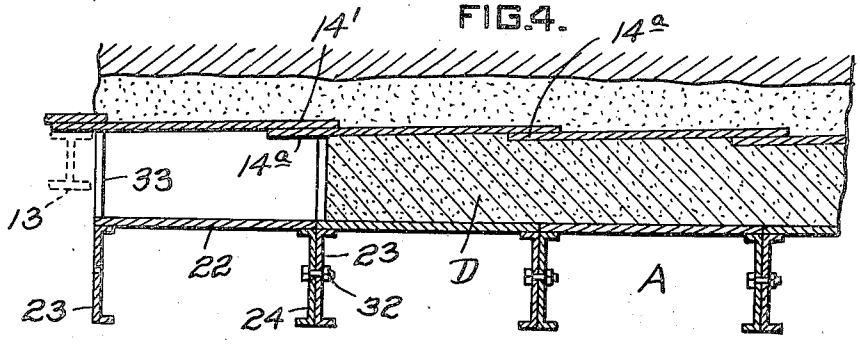



FIG. 4.




WITNESSES

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# UNITED STATES PATENT OFFICE.

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## METHOD OF AND APPARATUS FOR TUNNEL-WORK.

1,380,400. Specification of Letters Patent. Patented June 7, 1921.

Application filed August 8, 1918. Serial No. 248,839.

*To all whom it may concern:*

Be it known that I, CHARLES D. McARTHUR, a citizen of the United States, residing at Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Methods of and Apparatus for Tunnel-Work; and I do hereby declare the following to be a full and clear description of the invention, taken in connection with the accompanying drawings, such as will enable those skilled in the art to which it appertains to make and use the same.

The invention relates in general to tunneling work and the subsequent lining of the walls of the tunnels by concrete, and has for its principal objects to effect the supporting of the roof of the tunnel and the lining of the arch and walls thereof, first, with a maximum degree of rapidity and expedition, second, at a considerable reduction in relative cost, third, with the employment of fewer roof supporting and lining members than heretofore has been considered necessary on a given line of work, and fourth, in a very efficient manner in respect to each phase of the work as herein outlined.

The invention contemplates and provides for the progressive re-utilization of roof and lagging supporting members as the tunneling proceeds, and the collapsing and advancing of mold forms from the rear as the concrete sets to the front of the lined portion of the tunnel for erection there to replace, in a regular succession, those of the supporting members which have been advanced, and at the same time without withdrawing, during the advancing operation, the support necessary to the roof or lagging. In this way I eliminate the old wasteful practice of covering in by concrete the roof supporting members as the lining of the tunnel proceeded. The preferred embodiment of the invention is illustrated in the accompanying drawings, wherein—

Figure 1 represents a central vertical section taken through a tunnel in course of construction and wherein my invention is shown as applied, the illustration being in the main diagrammatic in character, with little attempt being made to disclose precise details of construction;

Figs. 2 and 3 are vertical cross-sectional views respectively along lines centrally and at the right of Fig. 1, and looking toward the left hand end of the drawing;

Fig. 4 represents an enlarged sectional view of the upper portion of the roof at the juncture of the lined and unlined portions thereof; and

Figs. 5 and 6 are enlarged sectional views illustrating in detail central portions of the roof support and track.

The tunneling excavation proper, as indicated in a general way in Figs. 1 and 2, comprises first the driving in of a drift near the top line of the projected tunnel, following which in order in a stepped relation are formed the heading which takes in the arch or head 7 of the tunnel, and one or more benches extending downwardly to the sub-grade 8 of the tunnel to form the side walls 9 thereof. The dotted line 10 in Fig. 2 indicates roughly the general outline of the tunnel when lined with concrete. It will be noted that the line 7 of the heading terminally extends outwardly beyond the side walls 9 to provide longitudinal shoulders 11 upon which are placed the sectional wall plates 12. As the drift is progressively widened and deepened to form the heading, sections of these plates 12 are successively laid down longitudinally in an abutting relation, as indicated in Fig. 1, before the benches are excavated.

Upon the plates 12 are positioned in spaced relation the arched roof supporting members 13, preferably of I-beam construction as shown, the upper flanges of which engage and support the lapped marginal portions of the arched lagging sections 14 as in the manner indicated in the drawings. A dry packing 15, which may be composed of dry earth or gravel, is placed between the lagging 14 and the roof 7 of the tunnel. It will be noted that the front marginal edge portion $14^a$ of a lagging section is interposed between its supporting member 13 and the rear marginal edge portion 14′ of the section just in advance of it, and this arrangement is carried out throughout as the roof supporting means are progressively advanced in the heading.

After the heading has been excavated a suitable distance, say fifty feet, the material is excavated down to sub-grade and thus provides sufficient room for the placing of the mold or collapsible sectional forms com-

prising in each section, as A, three parts, an arch portion 16 and a lower side portion 17 at each side of the mold to which the lower edges of the arched portion are detachably secured as by plates 18. In turn, the lower edges of the side portions rest upon the supporting plates or beams 19, and these may be maintained against inward displacement by providing braces or distance pieces 20 interposed laterally between the plates and the rails 21 of the track upon which latter the form traveler B is mounted for movement.

This traveler is designed to be employed as a convenient means for carrying forward the mold portions 16 and 17 of a rear section when collapsed subsequent upon the setting of that particular sector of concrete lining for which the section acted as a mold. When carried forward the parts are set up in advance of the other mold sections and opposite an unlined part of the tunnel. The mold portions 16 and 17 desirably comprise lining or lagging plates 22 mounted upon and supported by channel beams 23 and 24 which are cross-connected by diagonally disposed bracing rods 25.

In order that the rear roof-supporting members may be successively advanced in the heading to the front of the other members of the series, I provide the traveler B with a derrick 26 positioned to engage the rear roof-supporting member at its center, and further provide a sectional track 27 and whose sections 28 are detachably secured at their terminals by bolts 29 to the base flanges of the supports and which track extends longitudinally and centrally thereof to terminate at the front member of the series. Mounted upon this track for travel thereby is a trolley 30 carrying a gripping device 31 designed to grip the upper flange of the rear roof-supporting member when the latter has been lowered by the derrick 26 and advanced slightly in a forward direction by the traveler toward the trolley. When carried into the heading by the track and trolley the rear support is then set up in its advanced position.

The rear supporting member is not moved however until the rear mold section has been collapsed and carried forward by the traveler for replacement in advance of the lined portion D of the tunnel, in which position (see Fig. 4) the rear channel iron 24 is secured by bolts 32 to the front channel iron 23 of the adjacent mold section to form an I-beam at the line of juncture of the sections. A bulkhead 33 is then set up in position in close proximity to the rear roof support, which is then in readiness to be withdrawn and advanced since the replaced mold section constitutes a complete support for the lagging and the roof, in place of the withdrawn member, through the interposition of the bulkhead between the section and the lapped marginal portions of the lagging. Concrete is then introduced in any usual manner above the replaced section and the lining of the tunnel is again advanced to this extent. In this manner there are two cycles of operation, one conducted in phase with and dependent in a sense upon the other, the rear members of the two series being advanced successively so that the necessary support for the roof and lagging at the juncture of the series is never relaxed or in any way prejudiced. At the same time only a comparatively few roof supports are employed, and this is plainly in contradistinction to the customary and wasteful practice of utilizing a large number and covering them in as the lining operation proceeds. The saving effected by my method is noteworthy, and is so obvious as to require no amplification.

The form traveler B is further provided with a working platform 34 desirably employed to carry the lower side mold portions 17 when the latter are collapsed, and also centrally carries in its frame a jack adapted to lower the arch mold portions 16 after the side portions have been collapsed. This jack preferably embodies a base 35, a lifting rod 36, a turnbuckle 37, and a head 38 swiveled upon the upper end of the rod 36 and adapted to raise and lower an arch mold portion upon actuation of the turnbuckle. When the parts have been collapsed they are carried forward to the new advanced position to which reference has already been made, whereupon the side portions are set up and the mold section is completed in readiness for the introduction of concrete and the removal of the rear roof support upon the elevation of the arch portion and its association with the upper edges of these side portions and the bulkhead.

At the inception of the lining operation, the requisite number of mold sections are successively brought into action until all are in use and the rear lined portion has set. Then the rear section is carried forward and the cycle of replacement is continued until the tunnel is lined. Right from the start, however, of the lining operation, the roof supports are, in turn, advanced and replaced by the mold sections, as will be readily understood. The entire method and the apparatus therefore is simple, efficient, and effects a very material saving in cost of labor and material, and reduces the time necessary on a given piece of work as the entire operation is centralized to a restricted portion of the tunnel.

What I claim is:

1. In tunnel lining apparatus, the combination of a series of mold form sections and a series of roof-supports disposed in advance of said sections, lagging on said sup-

ports, said sections and supports disposed in succession longitudinally of the tunnel, and means for carrying forward rear sections and supports for positioning in advance of their respective series, the rear section designed to replace the removed rear support with reference to the lagging on said support, and bulkheads adapted to support the lagging from said mold form sections where they replace roof supports.

2. In apparatus of the character described, the combination of a series of roof-supports disposed longitudinally of the tunnel, lagging comprising sections carried upon said supports, means for removing the rear supports successively in a forward direction for positioning in advance of said series, and a plurality of mold forms designed to successively replace the removed supports and bulkheads adapted to support the lagging from said mold forms where they replace roof supports.

3. In tunneling apparatus, the combination of a series of spaced roof supporting members mounted longitudinally in the tunnel, upper and lower tracks in said tunnel, lagging sections having the marginal side edges lapped and resting on said members, a series of mold forms disposed rearwardly of the series of roof-supporting members and of the upper track, and means on said tracks for respectively advancing in succession the rear members of each series to the front of their respective series, the advanced rear form adapted to replace the rear roof-supporting member to be removed.

4. In apparatus of the character described, the combination of a series of roof-supporting members disposed in a spaced relation in the head of the tunnel, a track composed of sections detachably engaging members of said series, a trolley on said track for advancing rear members of the series, lagging on said members, and a forwardly movable mold form designed to be positioned adjacent the rear member and to take its place when advanced.

5. In a tunneling apparatus, the combination of a series of spaced roof supporting members, track sections supported from said members adapted to form a continuous track longitudinally of the tunnel, a trolley on said track adapted to carry a supporting member, and means for removing the rear roof supporting member and placing it on said trolley to be transferred forwardly to the front of the series.

6. In tunneling apparatus, the combination of a series of spaced roof supporting members, upper and lower tracks in the tunnel, a series of mold forms to the rear of the roof supporting members and of the upper track, and means on said tracks for advancing in succession the rear members of each series to the front of the respective series.

7. In tunneling apparatus, the combination of a series of spaced roof supporting members, upper and lower tracks in the tunnel, a series of mold forms to the rear of the roof supporting members and of the upper track, and means on said tracks for advancing in succession the rear members of each series to the front of the respective series, the advanced rear form adapted to replace the rear roof supporting member to be removed.

8. The herein described method of lining tunnels which consists in placing a series of arched roof supports in the forward portion of the excavation, in applying lagging over said supports, in placing a series of substantially U-shaped mold sections in the unlined portion of the excavation, in removing the rear roof supports in succession to the front of the excavation, in removing and transferring the rear mold sections to the front of the series, in supporting the lagging from the mold sections where the roof supports have been removed, and in filling the spaces over the mold sections with concrete.

9. The herein described method of lining tunnels which consists in excavating a heading, in placing a plurality of roof supports in the heading, in applying lagging strips over said supports, in further excavating the heading to form a bench, in placing a plurality of mold form sections in the bench, in removing the rear roof supports in succession to the front of the heading, in removing the rear mold form sections and replacing them beneath the lagging from which the roof supports have been taken, in placing bulkheads between the lagging and the mold form sections, and in filling the spaces over the forms with concrete.

10. The herein described method of lining tunnels which consists in placing a series of roof supports in the forward portion of the excavation, in applying lagging over said supports, in placing a series of mold sections in the unlined portion of the excavation, in removing the rear roof supports in succession to the front of the excavation, in removing and transferring the rear mold sections to the front of the series and using them to replace the roof supports, in placing bulkheads between the lagging and the mold sections, and in filling the spaces over the forms with concrete.

11. The herein described method of lining tunnels which consists in placing a series of roof supports in the forward portion of the excavation, in applying lagging strips over the said supports, in placing a series of mold sections in the unlined portion of the excavation, the longitudinal dimension

of which is no greater than the length of the lagging strips, in removing the rear roof supports in succession to the front of the excavation, in removing and transferring the rear mold sections to the front of the series, in supporting the lagging from the mold sections where the roof supports have been removed, and in filling the spaces over the forms with concrete.

12. The herein described method of lining tunnels which consists in placing a series of roof supports in the forward portion of the excavation, in applying lagging over said supports, in placing a series of mold sections in the unlined portion of the excavation, in removing the rear roof supports in succession to the front of the excavation, in removing and transferring the rear mold sections to the front of the series, in supporting the lagging from the mold sections where the roof supports have been removed, in filling the spaces over the forms with concrete, and in removing the lagging mold section supporting means.

CHARLES D. McARTHUR.