(No Model.)

H. R. KEITHLEY.

ELECTRIC TUNNELING MACHINE.

No. 563,491. Patented July 7, 1896.

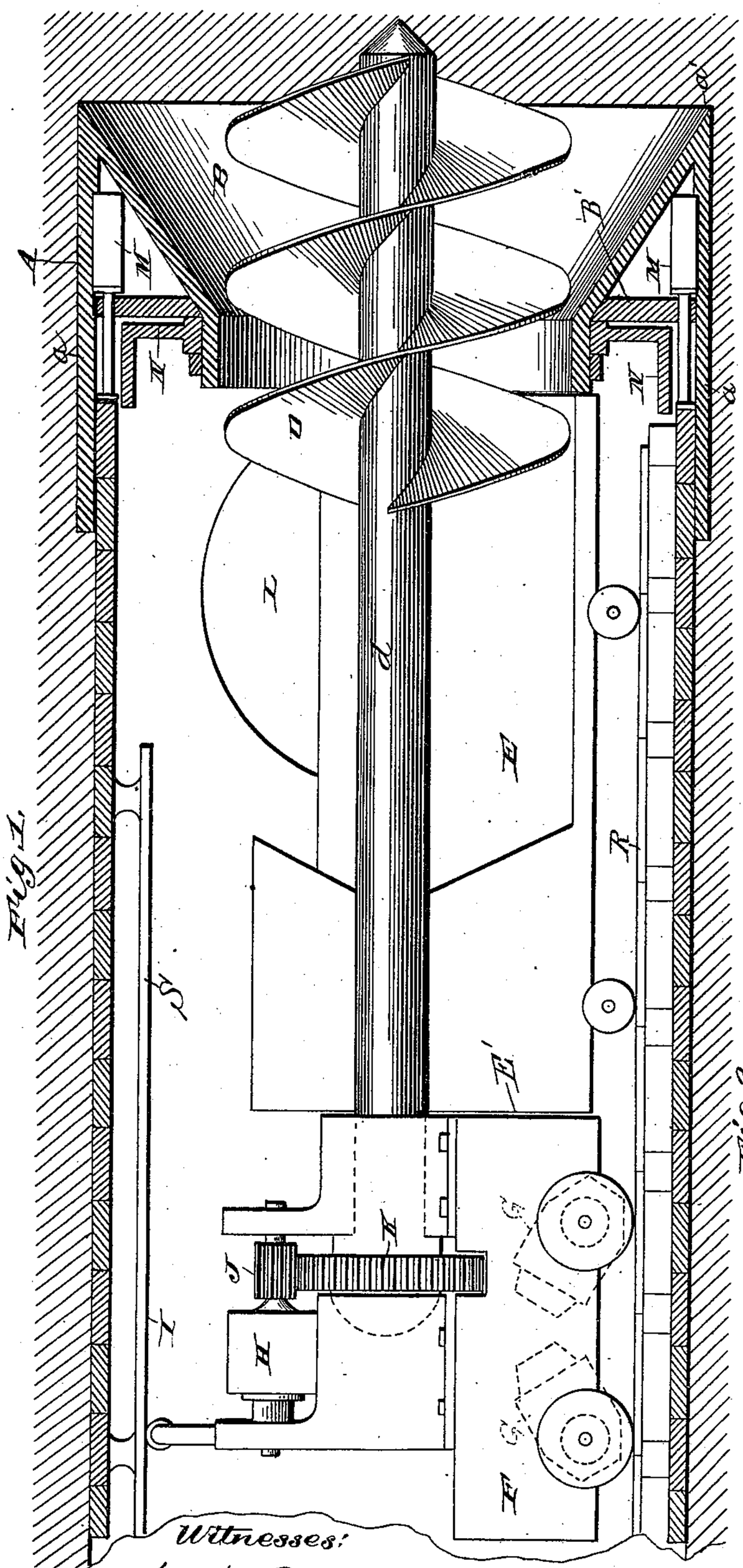

Fig. 1.

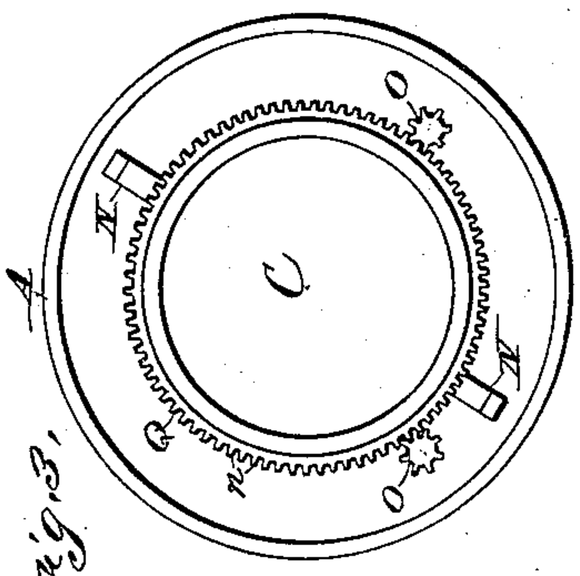

Fig. 3.

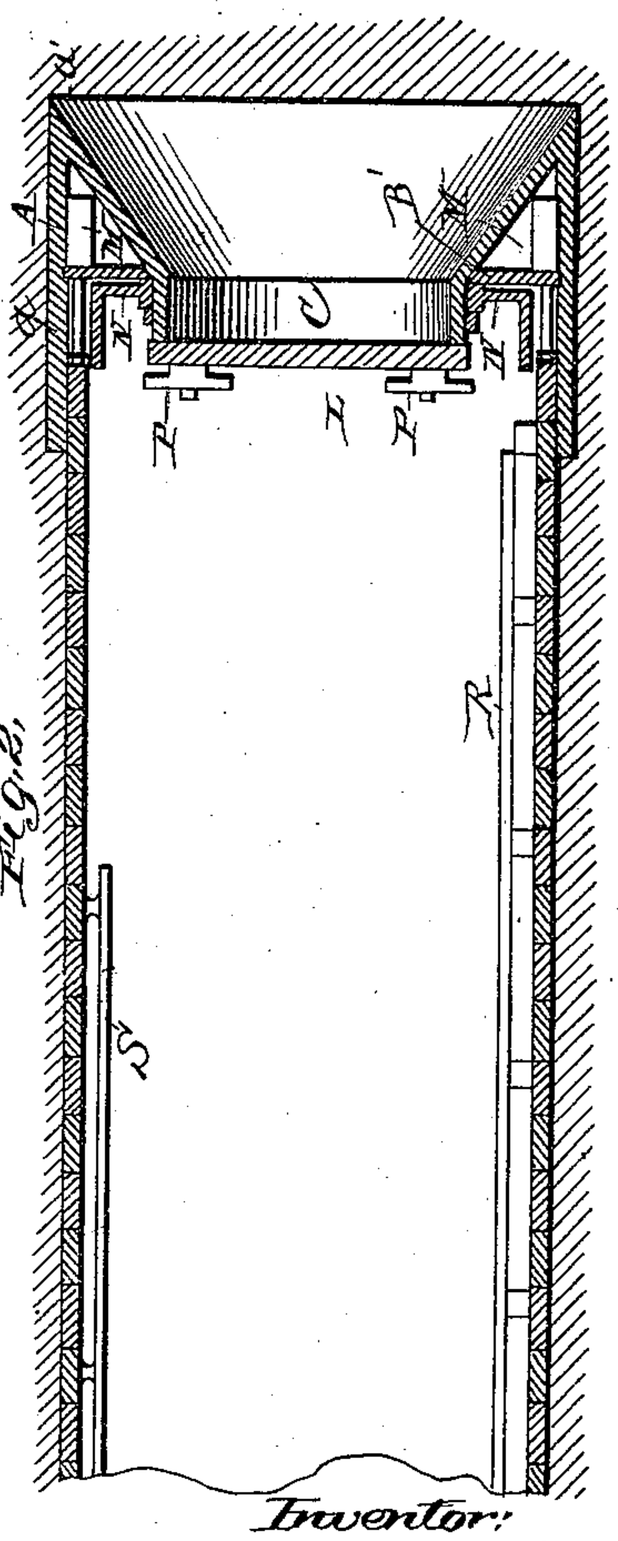

Fig. 2.

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HERBERT R. KEITHLEY, OF CHICAGO, ILLINOIS.

ELECTRIC TUNNELING-MACHINE.

SPECIFICATION forming part of Letters Patent No. 563,491, dated July 7, 1896.

Application filed May 21, 1892. Renewed August 6, 1894. Serial No. 519,607. (No model.)

To all whom it may concern:

Be it known that I, HERBERT R. KEITHLEY, a citizen of the United States, at present residing at Windsor Park, in the city of Chicago, county of Cook, and State of Illinois, have invented a new and useful Tunneling-Machine, of which the following is a specification.

This invention relates to improvements in machinery for use in excavating tunnels, subways, conduits, &c., the particular machine herein shown including also means for providing the tunnel with a permanent lining of metal segments, masonry, or wood placed in position, section by section, as the excavation proceeds.

The apparatus herein shown is of that general class in which a shield or open-ended cutting-tool of substantially the same shape that the finished subway is to have in cross-section is forced forward (usually by hydraulic power) into the tunnel-heading a distance equal to the length of one or more sections of the proposed tunnel-lining, the earth within the shield then excavated, a section of lining put in place, and the shield again driven forward.

The object of the present invention is to provide a tunneling-machine operated by electric motive power for excavating the material from the tunnel-heading, and for conveying it away as rapidly as it is excavated.

The invention consists in the matters hereinafter described, and more particularly pointed out in the appended claims.

The invention may be more readily understood by reference to the accompanying drawings, in which—

Figure 1 is a view in side elevation of my improved apparatus in operative position within a tunnel-heading, the tunnel being shown in vertical axial section. Fig. 2 is a view similar to that of Fig. 1, reduced, the excavator having been removed and the inner mouth of the shield closed preparatory to driving it forward. Fig. 3 is an inner face view of the shield.

The present machine is designed for excavating tunnels in any yielding earth, such as clay, sand, or silt, and whether the same be dry or combined with water, as when excavating beneath bodies of water.

As shown in said drawings, A designates, as a whole, a shield having straight cylindric sides *a* and an inner funnel-shaped lining portion B, which terminates at its rear or inner end in an open-ended cylindrical portion C. The forward or outer edge *a'* of the shield is provided with a sharp cutting edge. The inner end of the funnel-shaped lining is suitably supported and braced from the outer wall *a*, preferably by means of a diaphragm B'. The shield thus constructed is especially adapted for use in conjunction with a novel excavator now to be described, and said shield may be driven or forced forward into the earth by any desired means. As herein shown, however, said means comprises a series of hydraulic jacks M M, interposed between suitable bearings on said shield and the forward end of the tunnel-lining. These hydraulic jacks and their method of operation are well known, being similar to those used in the construction of the great railway-tunnels under the St. Clair river at Port Huron, Michigan, and under the Hudson river at New York city, and inasmuch as they constitute no essential part of the present invention need not be herein described.

In order to prevent the earth cut loose by the forcing forward of the shield from falling out through the latter, said shield is provided with a removable door L, which may be placed in position to close the opening and secured thereon while the operation of moving the shield is being performed.

Next describing the elevator, D designates, as a whole, a screw excavator or auger suitably mounted in position for insertion through the central opening C of the shield A and of a size substantially equal to the said opening. The said screw is herein shown as formed on the end of a shaft *d*, which is supported by being mounted at its rear end on the frame of a locomotive F, and as driven by an electric motor H, carried by said locomotive and geared directly to the shaft *d* of the auger by means of gears K and J. In addition to the motor H for rotating said auger, the locomotive is provided with suitable mechanism for driving it forward and backward within the tunnel. Such means as herein shown consists of a pair of powerful motors G G, connecting with and acting on the axles of the

locomotive in the usual manner. All three of said motors are provided with the usual connections and devices for operating, controlling, and reversing them.

E is a car arranged beneath the auger and between the locomotive and the tunnel-heading. Said car is provided with inclosing sides and a rear end E′, through which the shaft of the auger passes, but is open at its forward end for the passage of the spiral blade of the excavator. The shaft *d* passes freely through the rear end E′ of said car, and is of such length as to permit the auger to be advanced through or within the shield A far enough to excavate a quantity of earth sufficient to fill the car.

Track-rails R and an overhead guide-rail S are provided in the bottom and top, respectively, of the tunnel. Said rails serve to support the locomotive and car and to accurately direct the auger D through the shield.

The operation of the machine thus constructed is as follows: The shield having been placed in position it is driven forward until it is entirely filled with earth. The door L is then removed, the locomotive and car moved up to the shield, and the car is temporarily coupled to the shield by ordinary link couplings or otherwise. The spiral excavator is then operated to bore out the earth within the shield and force it backwardly into the car, the locomotive being advanced slowly as the auger loosens and conveys the earth to the car until the car is completely filled. When the car is filled, the motors are reversed and the screw turned back into the loose earth within the car and its actuating-motor H stopped. The car E is now uncoupled from the shield, and the locomotive draws the car to the outer end of the tunnel or a vertical shaft, where it is unloaded by setting the brakes on the wheels of the car and rotating the screw to force the load out at its forward end into a suitable receptable arranged beneath the track. This latter receptacle and the means for conveying it away may be of any desired construction, but as a convenient and durable arrangement said receptacle may be another car setting beneath the track on a transfer-table, from which latter it is lifted out of the tunnel through a vertical shaft by a hydraulic elevator.

While the locomotive F and car E are removed from the tunnel-heading it is clear of all obstructions, as shown in Fig. 2. The door L is then closed and the series of hydraulic jacks M M operated to drive the shield forward into the earth until its funnel-shaped front part is again filled.

In case the tunnel is to be provided with a lining, such as that herein shown, the iron plates or segments which form said lining are placed in position by means of a "segment-erector" attached to the shield A and operated by hand. Said segment-erector comprises a collar 2, revolubly mounted on the exterior of the cylindric portion C of the shield and provided with radially-extending L-shaped arms N N, the outer ends of which stand in planes parallel with and proximate to the lining of the tunnel, as clearly shown in the drawings. This segment-erector when revolved is adapted to lift and support the segments in position while they are bolted together. In order to thus revolve said segment-erector, it is provided with peripheral gear-teeth *n*, and a pair of small driving-pinions O O are mounted upon the shield and arranged to intermesh with and actuate said collar. These pinions will ordinarily be operated by removable cranks, but inasmuch as said segment-erector forms no essential part of the present invention it does not require more detailed illustration. As soon as the section of lining has been put in place all is ready for excavating another load, and the above-described cycle of operations is repeated.

By making the spiral-screw excavator of a diameter equal to five-eighths of the diameter of the inside of the tunnel proper and giving it a reach of six and one-half feet through the bulkhead, this tunneling-machine will excavate fifty feet of tunnel per day of twenty-four hours from a single heading at a rate of only one carload per hour. This would be more than four times as fast as any tunneling apparatus heretofore used.

While I have herein described the shield as circular, it may be obviously made of any desired shape at its cutting edge, as required by conformation desired in the finished tunnel, such as oval, rectangular, octagonal, or other form. The apparatus may also be readily adapted for use in excavating canals, ditches, or other open cuts.

It will also be obvious that various other modifications may be made, and that certain parts of the apparatus may be used independently either with or without equivalent devices for the parts omitted. For instance, the excavator screw and shield might be used but the car dispensed with and the earth removed by hand or otherwise. Moreover, while I consider the application of electricity to this use as a novel and highly-important part of the invention, yet, as far as certain other features of the invention are concerned, it is clear that steam, pneumatic, or other power might be employed for the purpose, the motors being, of course, changed to correspond.

It is also to be noted that the locomotive and car may be readily combined in one structure, or the screw excavator and its excavating-motor may be mounted on the earth-car while an independent locomotive is employed to move the car. The locomotive may also be entirely dispensed with and the car actuated from some stationary power-plant, as, for instance, by means of a driven cable or by means of a cable secured at the remote end and wound upon a windlass carried by the car, the actuation of the windlass being ac-

complished either by hand-power or by a suitable motor. The last-mentioned methods of moving the excavator and car will be especially desirable in the case of excavating tunnels on very heavy grades in which the coefficient of adhesion between the locomotive-wheels and track-rails would not be great enough to avoid slipping.

In the excavation of tunnels through wet sands or earths under water-courses or below the level of water which permeates the soil, the use of compressed air is required to prevent the infiltration or irruption of the water. If desired, the entire completed portion of the tunnel can be filled with compressed air and all air-locks placed in a large room or compressed-air reservoir at the top of the vertical shaft and communicating directly with it. By this arrangement no air-locks will be required in the tunnel proper, and all excavated material, lining material, and the like will be passed through said air-locks at the top of the shaft, thus giving the tunneling-machine a clear track to operate on in the tunnel and greatly facilitating the work of excavation. This, however, is only suggested as a desirable arrangement and does not constitute a part of the present invention.

I claim as my invention—

1. A machine for excavating earth, comprising an excavating device movable bodily toward and away from the heading to be excavated, an open-ended shield adapted to be forced into said heading and within which said excavating device is movable, means for actuating said shield and excavating device, and a car between the excavator and its actuating device and adjacent to the excavator, substantially as described.

2. A machine for excavating earth, comprising a shield adapted to be forced into the heading to be excavated, a removable closure for said shield, an excavating device working through said shield, means for actuating said excavator, and an earth-receptacle adjacent to said excavating device, between the latter and its actuating mechanism, substantially as described.

3. An excavating-machine, comprising an open-ended shield having a funnel-shaped interior terminating in a sharp edge at its forward larger end, an earth-auger working through said shield, an earth-receptacle at the rear of and adjacent to said shield, and means for actuating said auger, substantially as described.

4. An excavating-machine comprising an open-ended shield having straight parallel outer sides and a funnel-shaped interior terminating at its forward or larger end in a sharp cutting edge, a removable closure for the smaller end of said shield, a screw excavator working through said shield, an earth-receptacle at the rear of and adjacent to said shield, and means for actuating said excavator and shield located at the rear of the receptacle, substantially as described.

5. An excavating-machine, comprising an open-ended shield having straight parallel outer sides and a funnel-shaped interior, said shield terminating at its forward or larger end in a cutting edge, a removable closure for the rear end of said shield, a screw excavator working through said shield, a locomotive supporting said excavator and adapted to carry it bodily toward and away from the tunnel-heading, and a wheeled receptacle between the locomotive and the excavator, substantially as described.

6. An excavating-machine, comprising an open-ended shield having straight parallel outer sides and a funnel-shaped interior, an earth-auger working through said shield, an earth-receptacle at the rear of and adjacent to said shield, a locomotive supporting said augur and adapted to carry the same bodily toward and from the tunnel-heading, and driving devices on said locomotive for rotating said auger, substantially as described.

7. In a tunneling-machine, the combination, of a screw excavator, an earth-car adjacent to said excavator, a locomotive connected with said car, and an electric motor on said locomotive for actuating said excavator, substantially as described.

8. In a tunneling-machine, the combination, of an open-ended shield, an excavating device working through said shield, a car movable with said excavating device, and an electric locomotive supporting and actuating said excavating device, substantially as described.

9. In a tunneling-machine, the combination, of an excavating device, a receptacle adapted to receive the excavated material, said receptacle being movable bodily with said excavator, and a motor for actuating the excavator, said excavator being arranged to alternately transfer the material from the heading to the receptacle and to eject it from the latter, substantially as described.

10. In a tunneling-machine, the combination, of an excavator, a receptacle adapted to receive the excavated material directly from the excavator and movable bodily with the latter, a motor for actuating the excavator, and means for moving the excavator and receptacle together bodily toward and away from the tunnel-heading, said excavator being arranged to alternately load and unload the receptacle, substantially as described.

11. In a tunneling-machine, the combination, of an auger supported upon a car, a wheeled receptacle arranged adjacent to the excavator, and a motor adapted both to rotate the excavator and to move the latter and the receptacle bodily along the tunnel, said excavator being adapted to alternately load and unload the receptacle, substantially as described.

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