J. C. MEEM.

TUNNEL AND METHOD OF EXCAVATING.

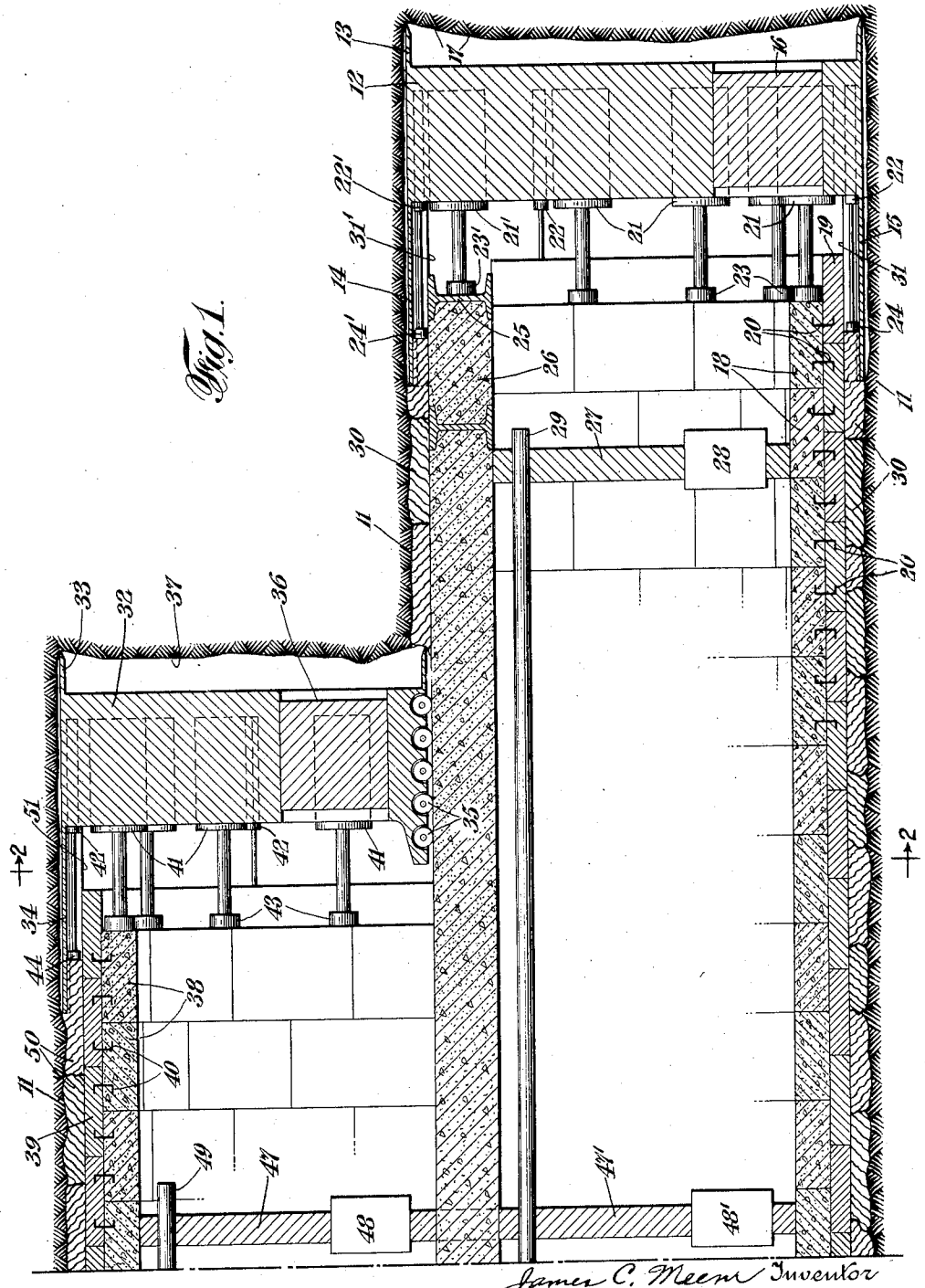
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1,338,030.

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2 SHEETS—SHEET 1.

Fig. 1.



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Fig. 2.

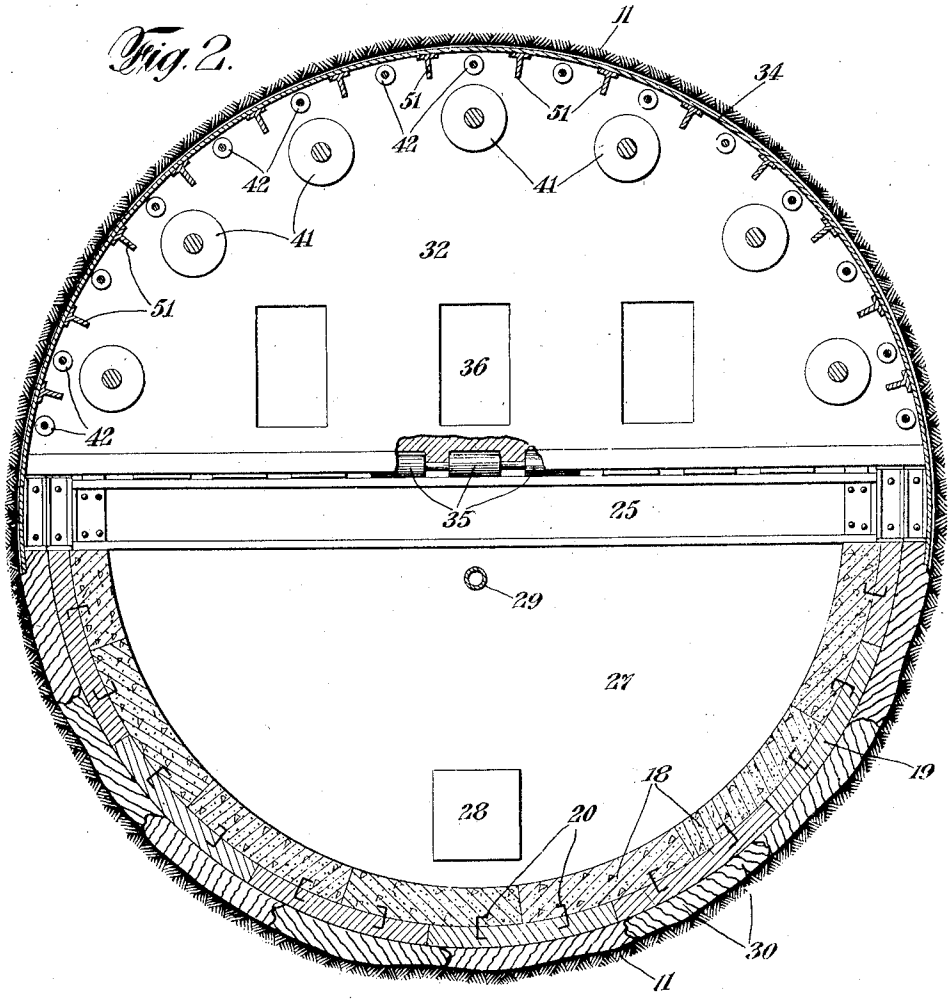
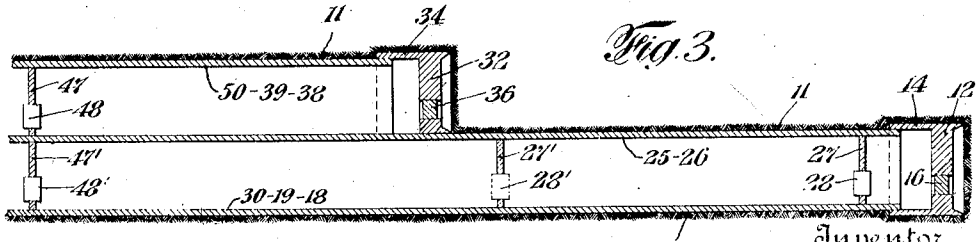


Fig. 3.



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TUNNEL AND METHOD OF EXCAVATING.

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To all whom it may concern:

Be it known that I, JAMES C. MEEM, a citizen of the United States, residing at Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Tunnels and Methods of Excavating, of which the following is a specification.

The principal object of my invention is to provide a new and improved method for the excavation of tunnels having a large vertical diameter. Other objects of my invention relate to the apparatus for excavating such a tunnel and for lining and bracing it after it is completed. Still another object of my invention relates to excavating a tunnel in more than one part, for example, an upper part and a lower part with a greater air pressure in the lower part than in the upper part. All these and other objects of my invention will be made apparent in the following specification and claims taken with the accompanying drawings, in which I have shown the apparatus diagrammatically. It will be understood that various modifications may be made within the scope of the invention.

In the drawings Figure 1 is a longitudinal section,

Fig. 2 is a cross section on the line 2—2 of Fig. 1, and

Fig. 3 is a longitudinal section on a reduced scale.

The unexcavated earth or rock is designated 11 and two shields are employed, one for the lower half of the tunnel, the other for the upper half, the lower shield 12 being advanced ahead of the upper shield 32. The shield 12 has the general shape of a hollow half cylinder with the closed end wall 12, the upper flat diametral wall 14, and the lower cylindrically curved wall 15. These walls 14 and 15 constitute the tail of the shield. The front part is extended at 13 to form an advance cutting hood. The main transverse wall 12 has the lower door opening 16 through which material excavated from the earth face 17 may be passed back.

The lining of the tunnel consists of an inner series of reinforced concrete blocks 18 and an outer series of fabricated steel blocks 19, the two series of blocks 18 and 19 being secured together by tie members 20. Around the periphery of the shield there in a series of powerful jacks 21 and 21′, those designated as 21 extending on a curve around the bottom and sides and those designated 21′ extending straight across the top. The heads 23 of the jacks 21 engage the lining blocks 18 and the reaction serves to advance the shield toward the earth face 17.

Outside the series of jacks 21 and 21′ is another series of smaller jacks 22 and 22′ with the heads 24 and 24′ respectively. The tail 14—15 of the shield has longitudinal ribs 31 and 31′ which serve to strengthen the tail and also to guide it on the tunnel lining. The shield 14—15 being outside the tunnel lining, there is necessarily a narrow space left between the tunnel lining and the earth face on the sides, bottom and top of the tunnel. Clay-balls 30 or other suitable material are introduced in front of the edge of the tunnel lining just within the tail 14—15 between the longitudinal ribs 31 and 31′ and packed back by the heads 24 and 24′ of the jacks 22 and 22′.

The flat horizontal roof lining for the lower advance part of the tunnel comprises the transverse I-beams or girders 25 with their ends resting on the lining blocks 18 and 19, and the suitable filling material 26 between the I-beams 25.

The air-tight bulk-head 27 is provided across the tunnel with an air lock 28, and a pipe 29 is provided by which compressed air of a certain degree of pressure can be supplied to the portion of the tunnel in advance of the bulk-head 27.

Behind the bulk-head 27 is the earth face 37 for the upper portion of the tunnel. The shield 32 is of generally semi-cylindrical shape with its diametrical margin below and carrying rollers 35 which rest on the partition 25—26. At its upper part the shield 32 carries a tail 34 with ribs 51 and it has a projecting hood 33 with a cutting edge. The shield 32 has door openings 36 through which excavated material from the earth face 37 may be thrown back into the tunnel above the floor 25—26.

The inside lining blocks 38 and 39 with the tie members 40 correspond respectively to the blocks 18 and 19 and tie members 20 for the lower part of the tunnel. Also the jacks 41 and 42 with the heads 43 and 44 correspond to the jacks 21 and 22 with the heads 23 and 24.

The bulkhead 47 is provided across the

tunnel having the air-lock 48 and the pipe 49 to supply compressed air of a lower degree of pressure than that supplied through the pipe 29. Below the bulk-head 47 is the bulkhead 47′ having the air lock 48′. The horizontal partition wall 25—26 is not air tight and therefore the space in front of bulkheads 47 and 47′ is at one pressure and those bulkheads may be regarded as essentially parts of a single bulk-head. The clay packing 50 for the upper part of the tunnel corresponds to the clay packing 30 for the lower part.

The operation of digging the tunnel involves excavating the material from the face 17 and passing it back into the tunnel through the door openings 16, and thence through the two air locks 28 and 48′. As sufficient room is provided in this way, the shield 12 is advanced by means of the jacks 21 and 21′. The iron lining members are placed in courses as room is provided by the shield moving forward, and then the concret blocks 18 are placed and anchored to the iron blocks 19 by means of the ties 20. The I-beams or other shapes 25 are placed successively with the filling material 26 between them. The clay masses 30 are placed in front of the edge of the lining between the guide ribs 31 and 31′ and packed back tightly around the outside of the tunnel lining behind the tail 14—15 by means of the jacks 22 and 22′.

The upper rear part of the tunnel is advanced in much the same way, the tunnel shield 32 being supported largely by the rollers 35 on the floor 25—26. From time to time the bulk-head 27 is advanced and it is always kept ahead of the face 37 for the upper part of the tunnel. The bulkhead 47—47′ will be advanced from time to time following the advance of the upper tunnel shield 32. Thus the part of the tunnel between the rear bulkhead 47—47′ and the shield 32 and the bulk-head 27 will all contain air of a certain degree of pressure and the part in front of the bulkhead 27 will contain air of higher pressure. In Fig. 3, the advance bulkhead has recently been moved forward from 27′ to 27, opening the airlock 28′. When the shield 32 has advanced beyond bulkhead 27′, then bulkhead 47—47′ will be advanced as far as 27′ and the latter will be made a part of the complete bulkhead just as 47′ is a part.

In a tunnel of large diameter, if it is attempted to excavate it at once, using the compressed air method, a difficulty arises. If an air pressure is employed of the proper degree for the upper part of the tunnel, then it will not be sufficient for the lower part, because the earth or rock is under a greater static head at the lower part and if the pressure is just enough to hold back the water and quick-sand at the upper part, it will not prevent their inflow at the lower part. On the other hand, if an air pressure is employed great enough to balance the static head at the lower part, this pressure will be excessive for the upper part and the air will be lost rapidly by percolating into the earth at the upper part and it will be very likely to blow out the roof of the tunnel. These difficulties have prevented the use of the compressed air method for tunnels of very large diameter and it is one of the objects of my invention to provide a method and apparatus by which the compressed air method can be used for tunnels of large vertical diameter.

It has been proposed to overcome the difficulties mentioned above by providing a single shield with horizontal partitions so that different air pressures of proper degree can be used at the different levels, but the difficulty with this plan is that the air tends quickly to percolate through the soil from the lower levels to the upper levels and equalize the air pressure in front of this divided shield. By my method the lower part of the tunnel is kept far enough ahead of the upper part to prevent such an equalization of the air pressure in the soil in front of the tunnel.

I claim:—

1. In the building of a tunnel underground by the use of shields and compressed air the method which consists in dividing the tunnel proper into parts at different depths, advancing a shield for the excavation for one part under an air pressure appropriate to the level of that part, building in advance the portion of the tunnel walls corresponding to this advanced part including a partition wall at the surface between the advanced part and the next adjacent part, then advancing an independent shield for the next adjacent part of the tunnel along said partition wall, under a different air pressure appropriate to the level of said next part, continuing the formation of the peripheral tunnel walls to inclose the portion of the tunnel corresponding to this second part, and maintaining a space between said shields to prevent leakage of the air pressure from one level of excavation to the other.

2. In the excavation of a tunnel by the use of shields and compressed air the method which consists in independently advancing the lower half of the excavation for the tunnel proper ahead of the upper half and at a higher pressure, lining the bottom and sides of the lower half with the corresponding peripheral tunnel wall, spanning the ends of said wall by a horizontally extending wall adapted to independently maintain the air pressure of that level, then excavating the upper half away from this horizontally extending structure and com-

pleting the peripheral walls of the tunnel from the ends of the lower portions thereof, and leaving said horizontally extending structure as a horizontal partition in the tunnel.

3. In the excavation of a tunnel by the use of shields and compressed air, the method which consists in advancing separate and independent shields in the upper and lower halves of the tunnel proper, with a rear bulkhead across the whole tunnel behind both shields and a forward bulkhead across the lower half of the tunnel between the shields, moving each bulkhead forward from time to time but keeping the forward bulkhead ahead of the rear shield, building independent tunnel sections behind each shield and maintaining different air pressures behind the respective shields.

JAMES C. MEEM.