No. 723,307. PATENTED MAR. 24, 1903.

J. W. RENO.

TUNNEL CONSTRUCTION.

APPLICATION FILED DEC. 24, 1902.

NO MODEL. 3 SHEETS—SHEET 1.

Fig 1

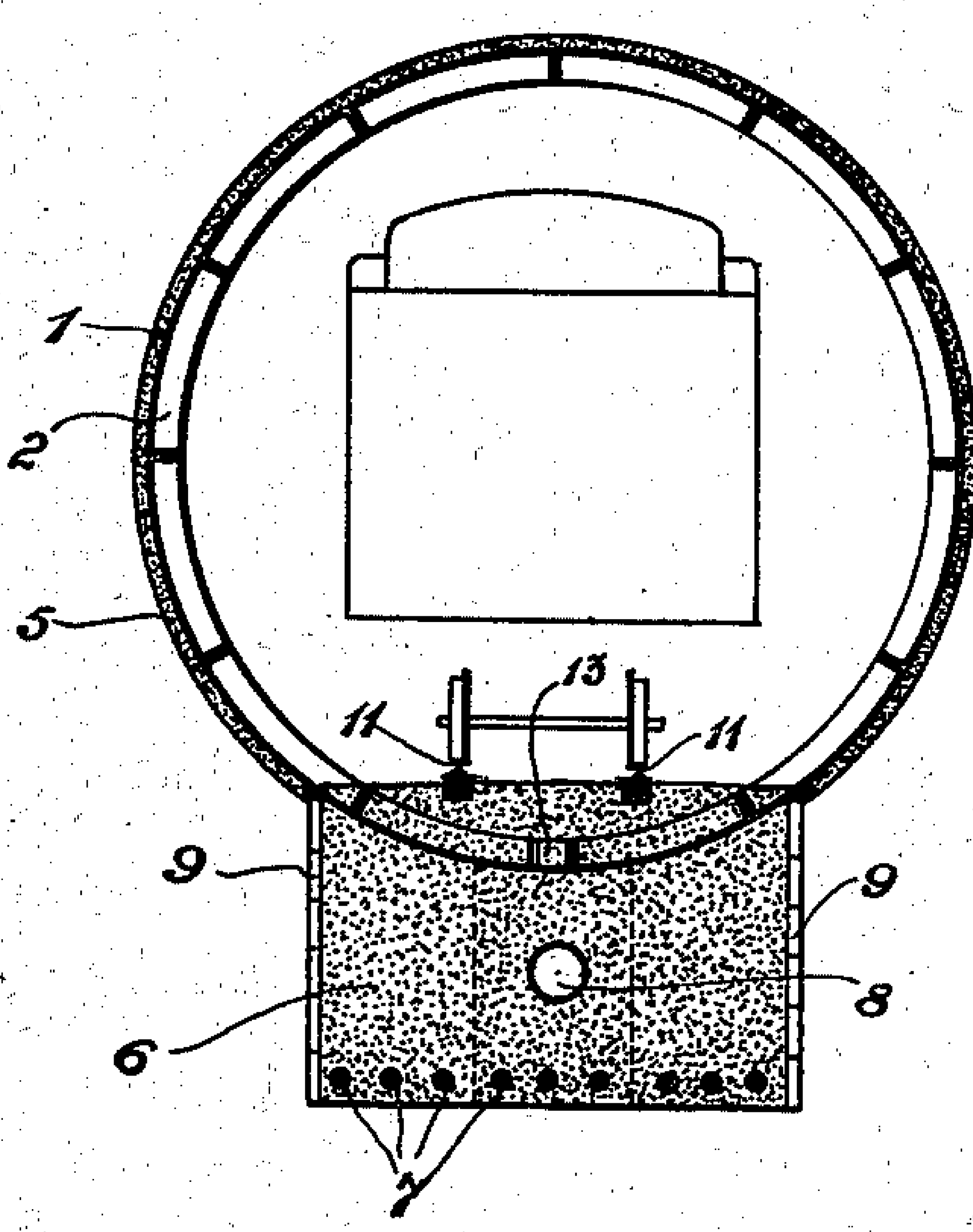
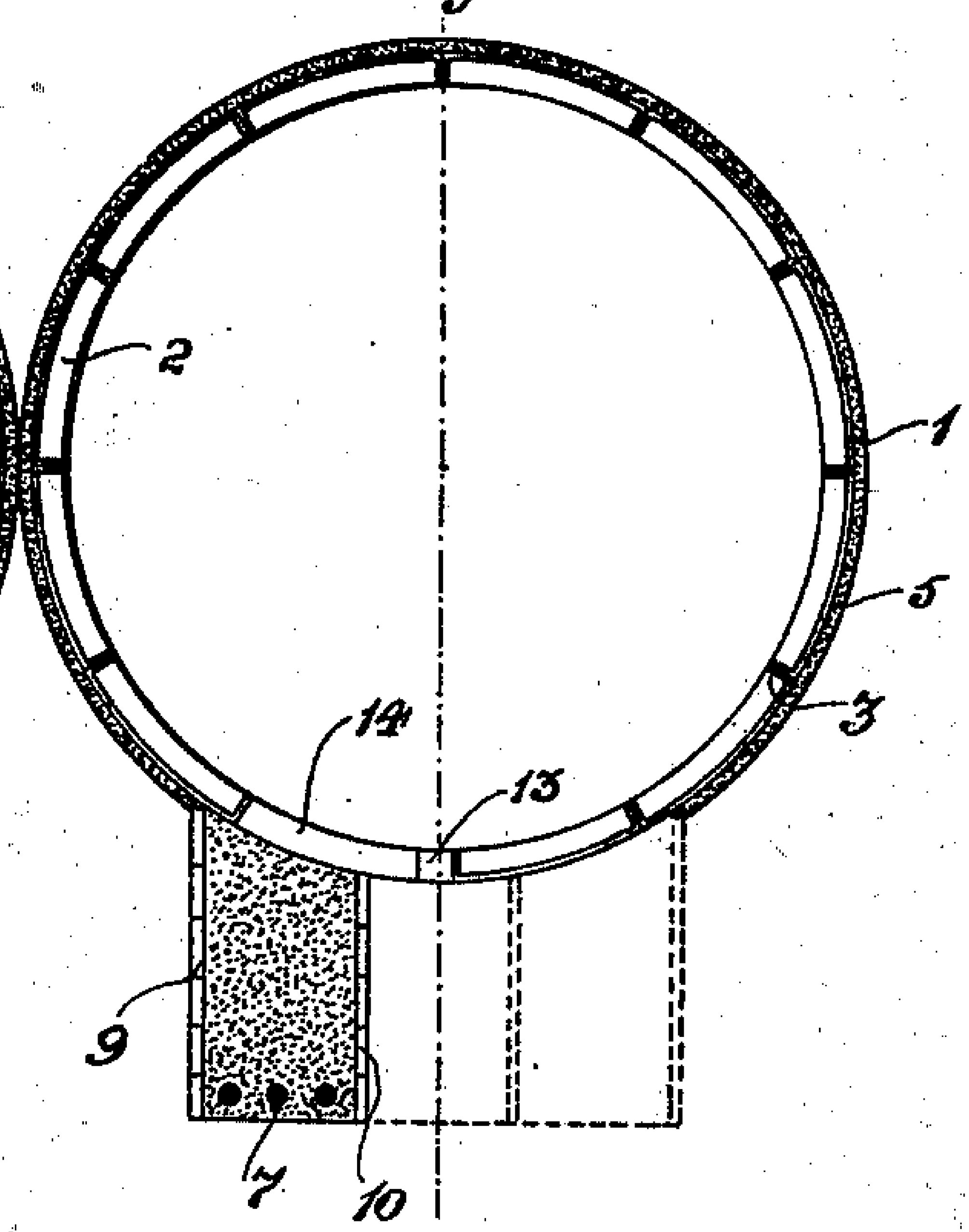


Fig 2.



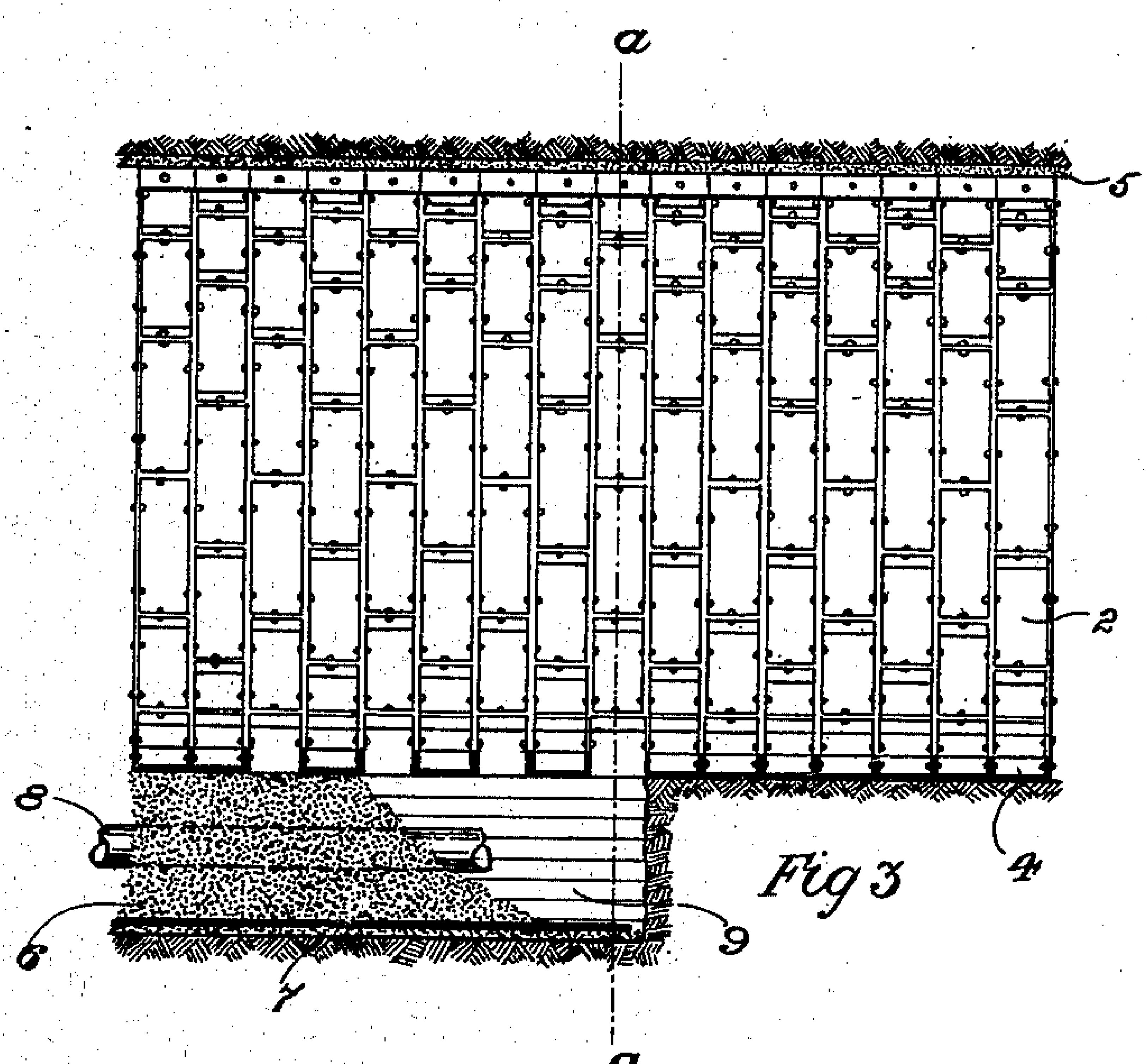


Fig 3

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NO MODEL. 3 SHEETS—SHEET 2.

Fig 4

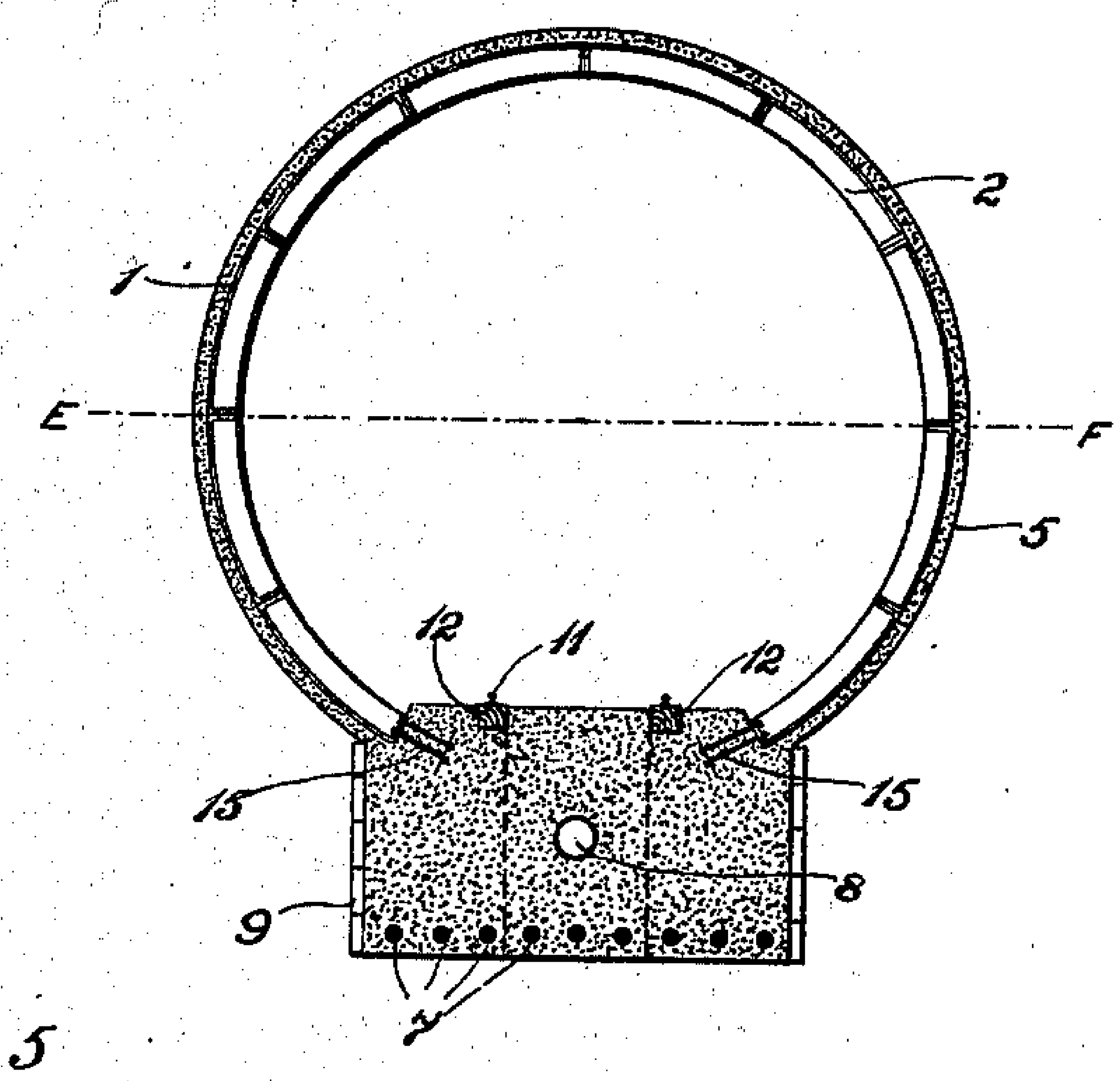
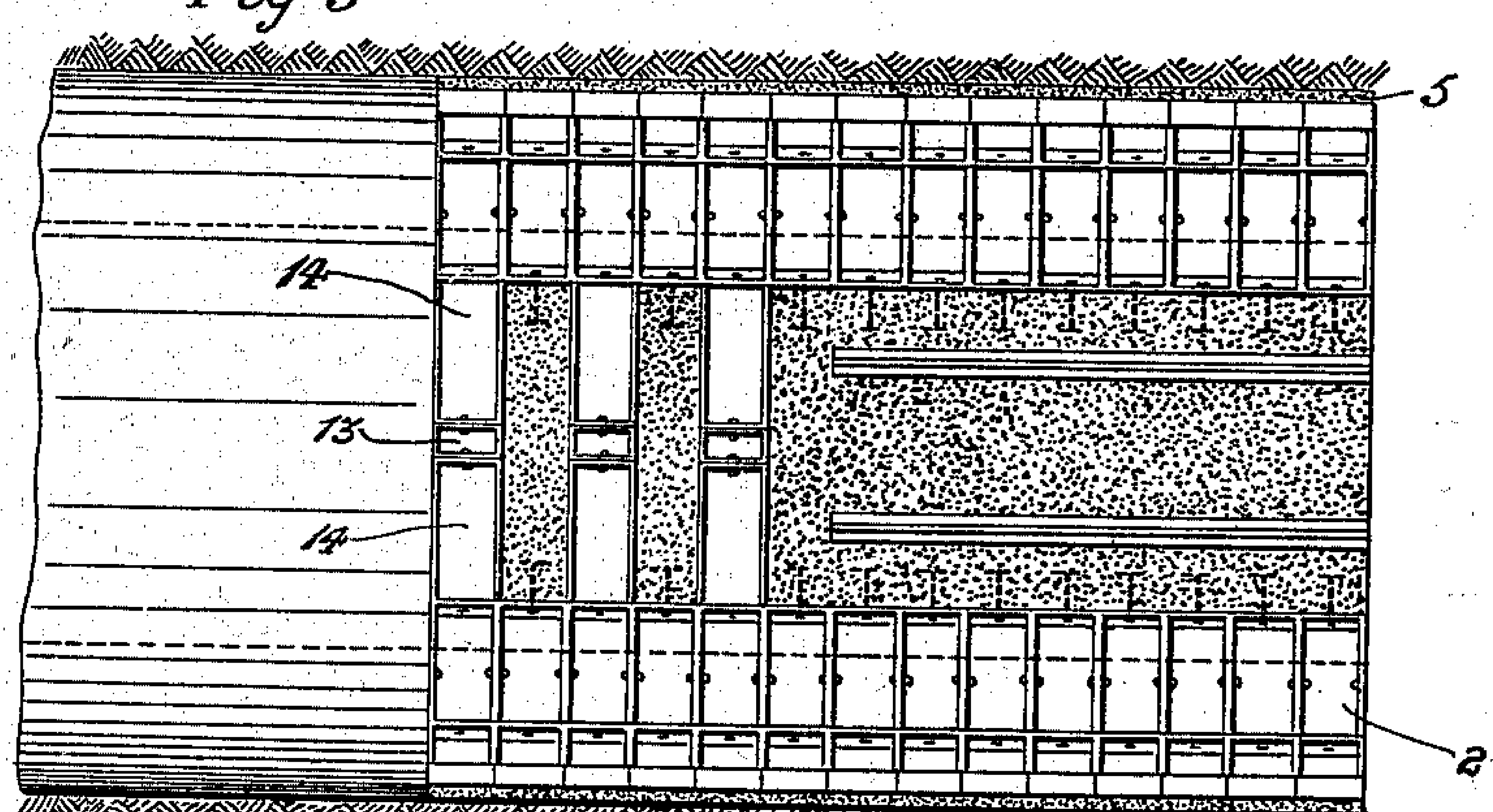


Fig 5



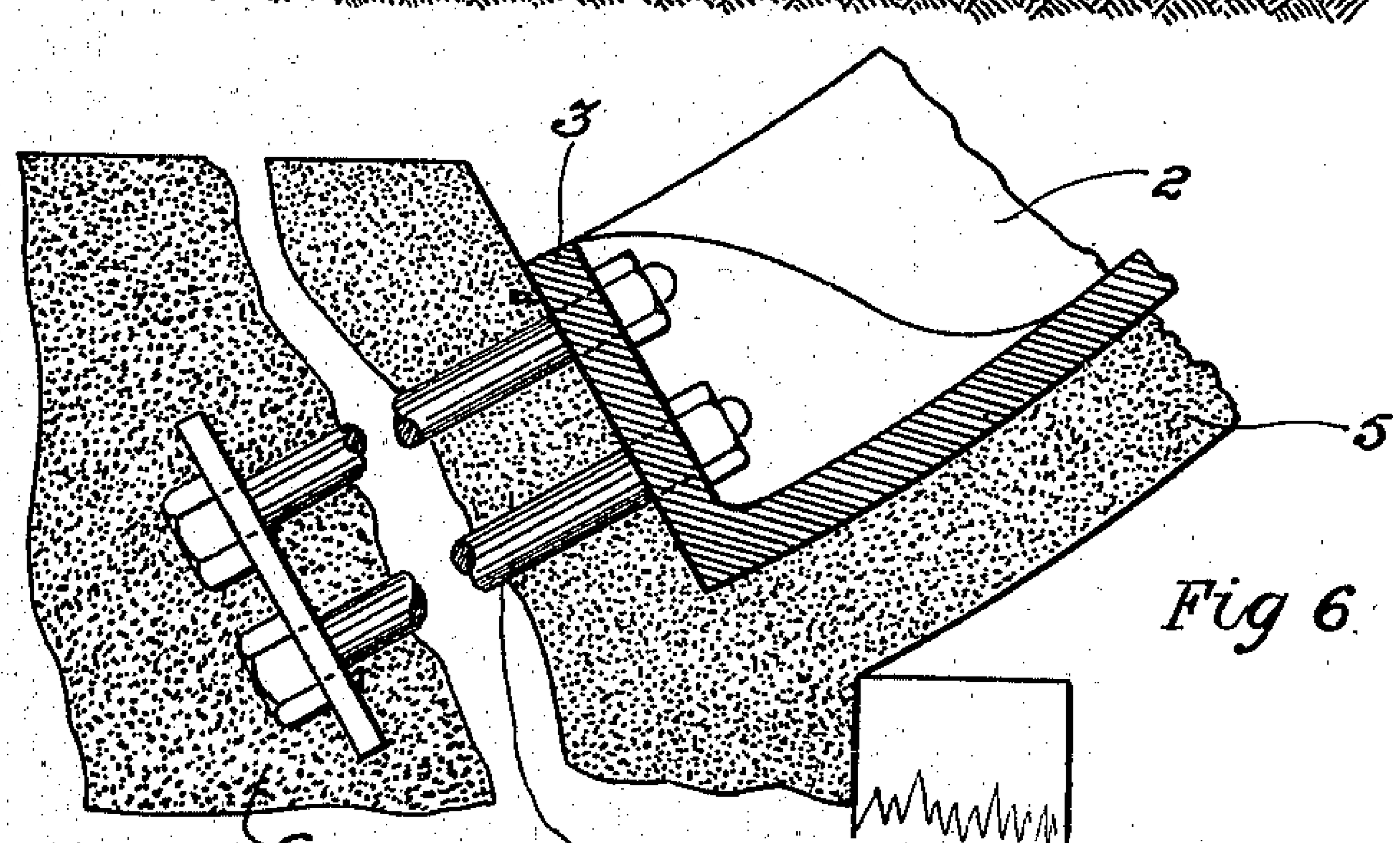


Fig 6

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NO MODEL. 3 SHEETS—SHEET 3.

Fig. 8.

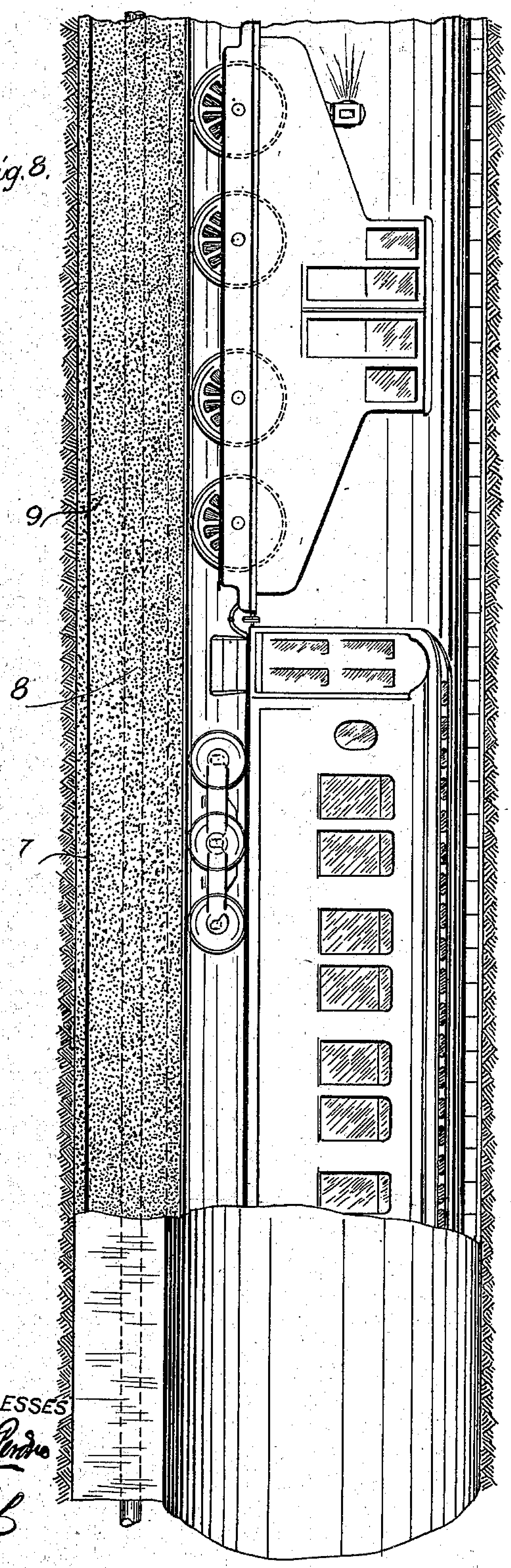
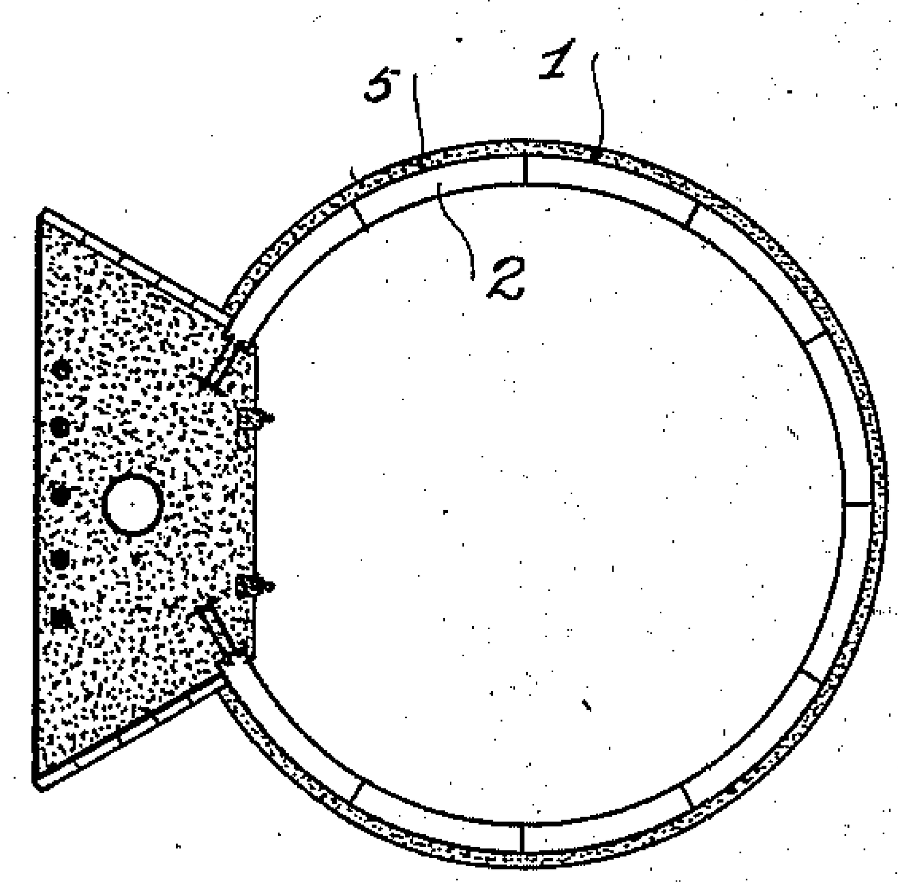


Fig. 7.



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JESSE W. RENO, OF NEW YORK, N. Y.

TUNNEL CONSTRUCTION.

SPECIFICATION forming part of Letters Patent No. 723,307, dated March 24, 1903.

Application filed December 24, 1902. Serial No. 136,454. (No model.)

To all whom it may concern:

Be it known that I, JESSE W. RENO, a citizen of the United States of America, and a resident of the city, county, and State of New York, have invented certain new and useful Improvements in Tunnel Construction, of which the following is a specification.

My invention relates to the construction of tunnels, and has for its object to provide a method and a construction for tunnels especially adapted for the easily-compressible earth—such as silt, wet sand, and the like—frequently found under the beds of rivers.

My invention consists in providing a tunnel-shell, preferably of the well-known type, in which segmental iron rings are bolted together to form the tunnel-wall and in firmly securing to the base of the tunnel a longitudinal girder, preferably made of concrete and bars of steel.

My invention consists, further, in providing a mechanical process or method by means of which my construction may be practically carried out.

The method of constructing a tunnel of segmental cast-iron rings is well known and consists, essentially, in driving a circular cutting-shield into the earth by hydraulic or other means, in excavating the material within the shield, and in placing circular segmental rings behind the shield as it is forced forward. A partition or bulkhead is placed in the completed tunnel a short distance behind the cutting-shield, and in the compartment thus formed air is maintained at a pressure sufficient to keep the water from entering this working compartment. Material is taken in and out of the working compartment through a suitable air-lock in a manner which is well understood. Tunnels of this description are well adapted for certain situations, especially when they are not of great size and where the ground is comparatively hard or compact and where the traffic through the tunnel is not heavy. My present construction, however, is designed for places where the earth through which the tunnel passes is comparatively soft and yielding, where the tunnels are large enough to take in the standard cars and locomotives of the steam-roads, and where the speed of trains will be very high. Under these conditions the thin shell of the ordinary tunnel construction is not rigid enough to withstand the enormous concentrated weights moving rapidly over it. Moreover, the vibrations caused by the rapidly-moving trains set up a motion in the particles of earth which immediately surround the walls of the tunnel, causing an unstable support for the walls and resulting in cracks and leaks in the tunnel.

In my invention I provide a concrete girder of sufficient mass to take up these vibrations before they reach the surrounding earth and of sufficient strength to distribute the load over a large area.

I will first describe the tunnel structure and afterward the method or process employed in its construction.

In the drawings accompanying and forming part of this specification, Figure 1 represents a cross-section on line *a a* of Fig. 3. Fig. 2 represents a similar section where one part of the concrete girder beneath the tunnel-shell has been built. Fig. 3 represents a vertical longitudinal section. Fig. 4 represents a transverse section of a tunnel in which the lower ends of the circular shell have been permanently removed and in which the end segments are anchored to the concrete girder. Fig. 5 represents a horizontal section on line E F of Fig. 4. Fig. 6 represents a section, on an enlarged scale, showing the manner in which the shell is anchored to the concrete girder. Fig. 7 represents a transverse section showing a modification of the shape of the concrete girder to give it a broader base. Fig. 8 represents a longitudinal section of the completed tunnel, showing therein an electric locomotive and car attached thereto.

The reference characters are used in the same sense in all of the drawings and the specification.

Numeral 1 represents the circular tunnel structure as it is ordinarily constructed.

2 represents the segments, which are bolted together by the flanges 3 to form the rings 4. These rings are in turn bolted together on their sides and form the main part of the shell of the tunnel.

5 represents the external layer of concrete or grout formed on the outside of the segmental rings.

6 represents the concrete girder joined to the base of the tunnel.

7 represents longitudinal rods which are embedded beam the base of the concrete girder 6.

8 represents a drain pipe or tube in the center of the concrete girder.

9 represents the sheeting on the outside walls of the girder.

10 represents the sheeting on the inside wall of the outer section of the girder.

11 represents track-rails.

12 represents stringers on which the track-rails rest.

13 represents narrow segments of the segmental rings located in the lower portion of the rings, the sides of which are parallel, so that they may be more conveniently withdrawn.

14 represents the segment adjacents to the narrow segments 13.

15 represents anchor-bolts which secure the end segments to the concrete girder.

It will be noted that by means of this structure a massive continuous bed is formed beneath the floor of the tunnel, which is adapted not only to absorb the short local vibrations incident to the rapid movement of heavy trains, but is also capable of distributing the load over a relatively large area. The concrete girder thus formed is abundantly able under ordinary circumstances to sustain the loads for which it is designed. It is, however, obvious that the concrete girder thus formed and anchored to the cast-iron shell above it will act with the shell as a single member or beam of relatively enormous moment of resistance, capable of distributing the load over a great length of the soft and easily-compressible earth in which it is located.

It is also to be pointed out that in the ordinary tunnel construction such as is herein described without the reinforcing concrete girder there is a decided buoyant effect or tendency for the tunnel to float. The weight of such tunnel without my reinforcing-girder would be about three hundred and fifty (350) tons for the length of about thirty (30) feet, while the weight of the material which the tunnel displaces for an equal length is about eight hundred and fifty (850) tons. It is therefore seen that in my construction this buoyant tendency is diminished to a great extent.

The method by which my invention is carried out is as follows: The segmental tunnel is driven, preferably, by means of a circular shield in the usual manner. A bulkhead is located a short distance back of the shield and advanced from time to time as the work progresses. The air in the space between the bulkhead and the shield is maintained at a pressure sufficient to prevent the entrance of water. When the shield has been advanced a sufficient distance from the bulkhead, about fifty (50) feet, one or two of the narrow segments 13 and the adjacent segments 14 are removed, as shown in Figs. 3 and 5, and the earth beneath the tunnel is removed to form a trench for the concrete girder. This trench is preferably excavated in three separate sections, as indicated in Fig. 2. First, the outer sections are formed by driving the wooden sheeting (indicated by numerals 9 and 10 in Figs. 1 and 2) forward for a length sufficient to allow the placing of a length of tension-rods 7. The two side trenches are then filled with concrete in the same manner, the drain-pipe 8 being formed by packing the concrete around suitable wooden molds, as is well understood. After the three sections of the trench have been filled with concrete up to the circular rings, forming the shell of the tunnel, the lower segments 13 and 14 are removed from the alternate rings, the anchor-bolts 15 are inserted in position, and the concrete is built up to the required level to support the track-stringers or cross-ties for the rails. After the concrete has set the remaining lower segments may be removed and the spaces which they occupied filled with concrete, as before.

By removing at one time only the alternate segments and allowing the concrete which replaces those segments to set before the remaining segments are removed all tendency of the shell to collapse by reason of their removal is avoided.

Having thus described my invention, what I claim is—

1. In a tunnel structure, the combination with a cylindrical shell, of an exterior reinforcing member rigidly attached thereto.

2. In a tunnel structure, the combination with a cylindrical shell, of an exterior reinforcing member rigidly attached to the lower side thereof.

3. In a tunnel structure, the combination with a hollow cylindrical shell, of a relatively massive vibration-absorbing member rigidly secured to the exterior of said shell and continuous longitudinally therewith.

4. In a tunnel structure, the combination with an arched tunnel-wall, of a concrete girder joined to its springers.

5. In a tunnel structure, the combination with a cylindrical shell having the shape of a horseshoe-arch in cross-section, of a continuous girder of concrete securely anchored to the springers of said arch.

6. In a tunnel structure, the combination with a cylindrical shell, of an exterior concrete reinforcement extending longitudinally beneath said shell and rigidly secured thereto, said concrete reinforcement having embedded within it longitudinal tension-rods.

7. A tunnel consisting of an arched shell joined at the base to a continuous longitudinal concrete girder.

8. The segmental tunnel-shell 1 joined by the anchor-rods 15 to the concrete girder 6,

the concrete girder having embedded near its base the longitudinal rods 7.

9. In a tunnel construction, the combination of iron segments bolted together in the form of a horseshoe-arch, a longitudinal concrete girder joining the end segments of said arch and anchor-bolts, securing said end segments to said concrete girder.

10. In a tunnel structure, the combination with a continuous segmental arch, of a concrete girder joined to its base, said concrete girder having a longitudinal drain-pipe formed within it.

11. The herein-described method of constructing a reinforced tunnel which consists in driving a segmental tunnel through silt, sand, or easily-compressible earth, removing one or more of the lower segments of said segmental tunnel, excavating a trench therebeneath and filling said trench with concrete.

12. The herein-described method of constructing a reinforced tunnel which consists in driving a segmental tunnel through earth, removing one or more of the lower segments, excavating therebeneath, forcing sheetings ahead and excavating between said sheetings and filling in the excavation thus formed with concrete.

13. The herein-described method of constructing tunnels in easily-compressible earth, consisting of first building a tunnel proper of segmental rings, then removing certain segments in the floor of said tunnel between the heading and the bulkhead, and then building under the floor a massive concrete girder.

14. The herein-described method of constructing tunnels consisting of first, building a tunnel of segmental rings, excavating beneath the lower segments of said segmental rings, forming a concrete girder in the excavation thus formed, removing the alternate segments and replacing them with concrete.

15. The herein-described process for constructing a reinforced tunnel consisting in forcing a cutting-shield in advance of a bulkhead, maintaining air under pressure between the cutting-shield and the bulkhead, excavating material cut by said shield, lining the cut made by the shield with segments adapted to resist the collapsing external pressure, excavating a trench beneath the working chamber and constructing therein a concrete girder.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

JESSE W. RENO.

Witnesses:

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JOSEPH FOLLAND PERDUE.