No. 629,133. Patented July 18, 1899.

W. H. KNIGHT & F. M. LANDÉ.

SUBAQUEOUS TUNNEL AND METHOD OF CONSTRUCTING SAME.

(Application filed Mar. 23, 1899.)

(No Model.) 5 Sheets—Sheet 1.

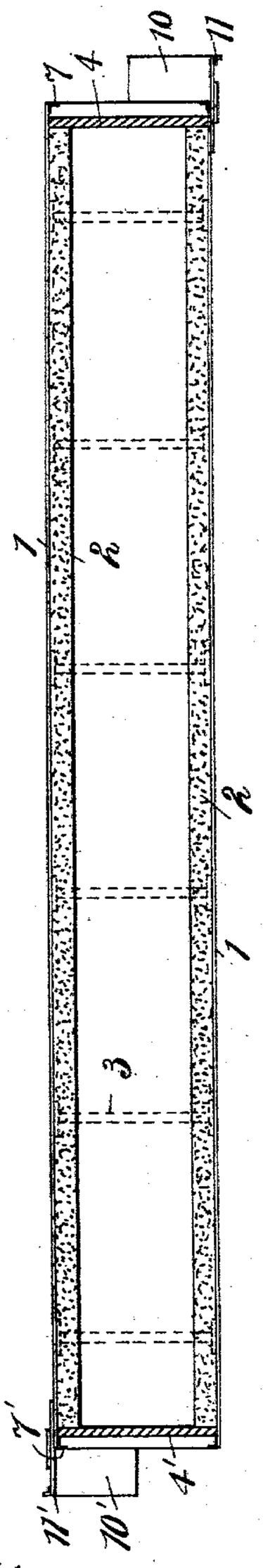

Fig. 1.

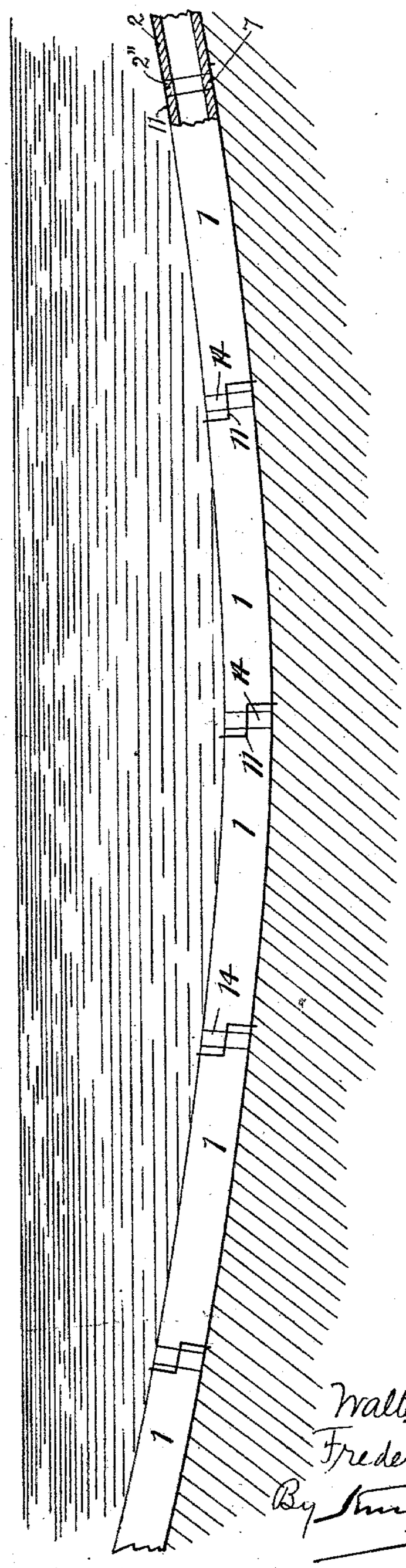

Fig. 2.

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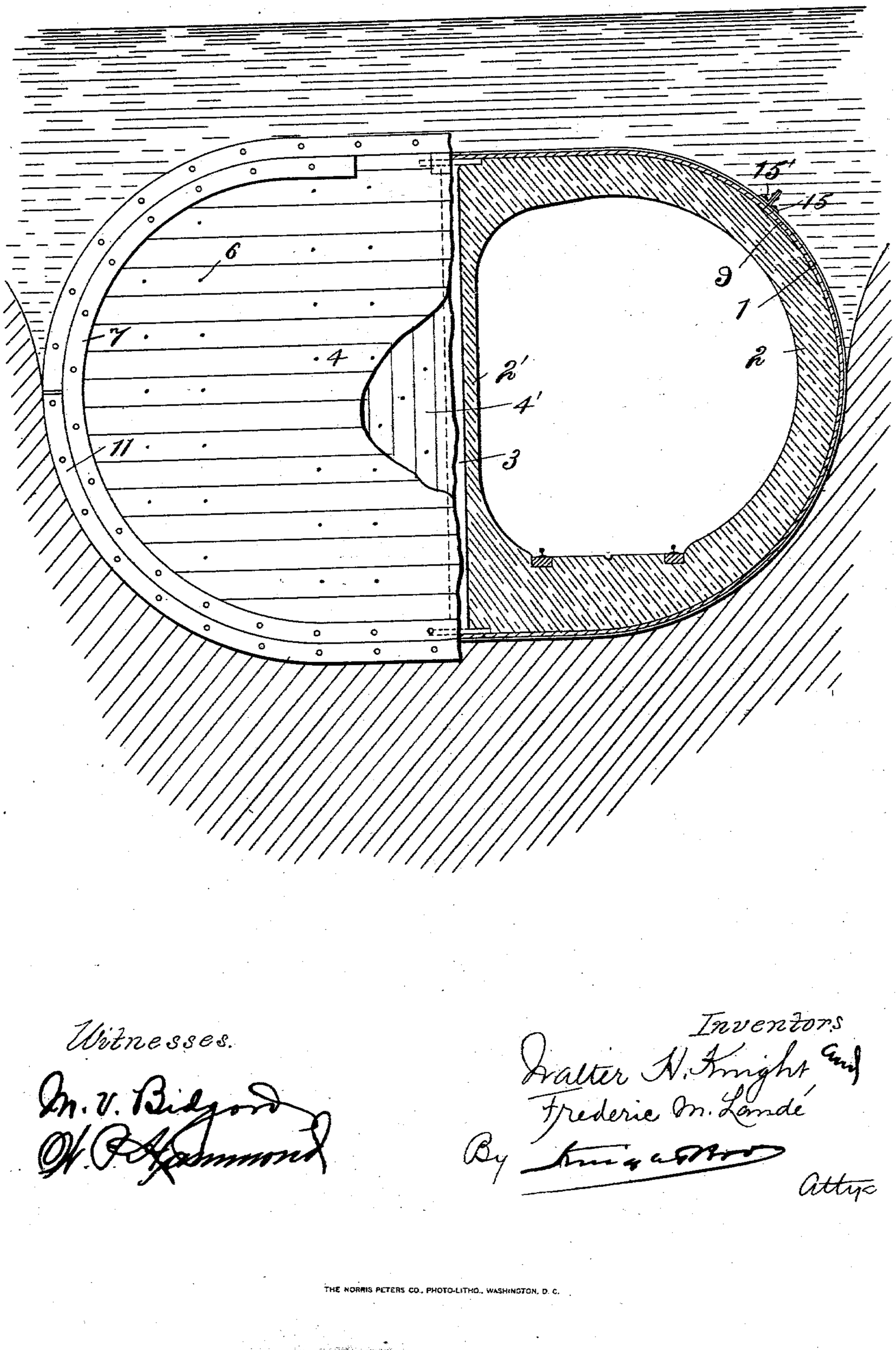
Fig. 3.



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(No Model.) 5 Sheets—Sheet 3.

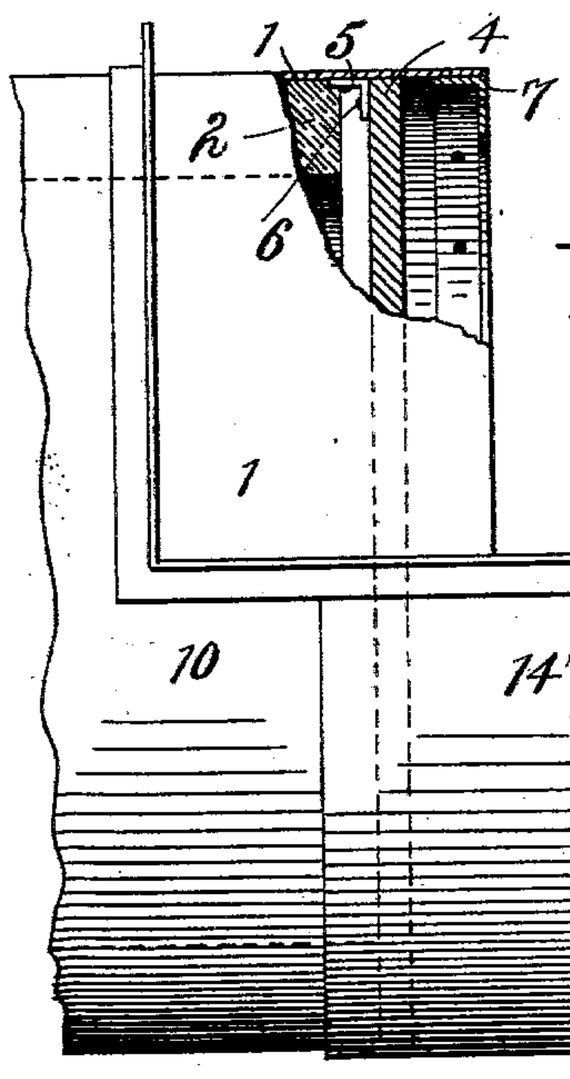

Fig. 4.

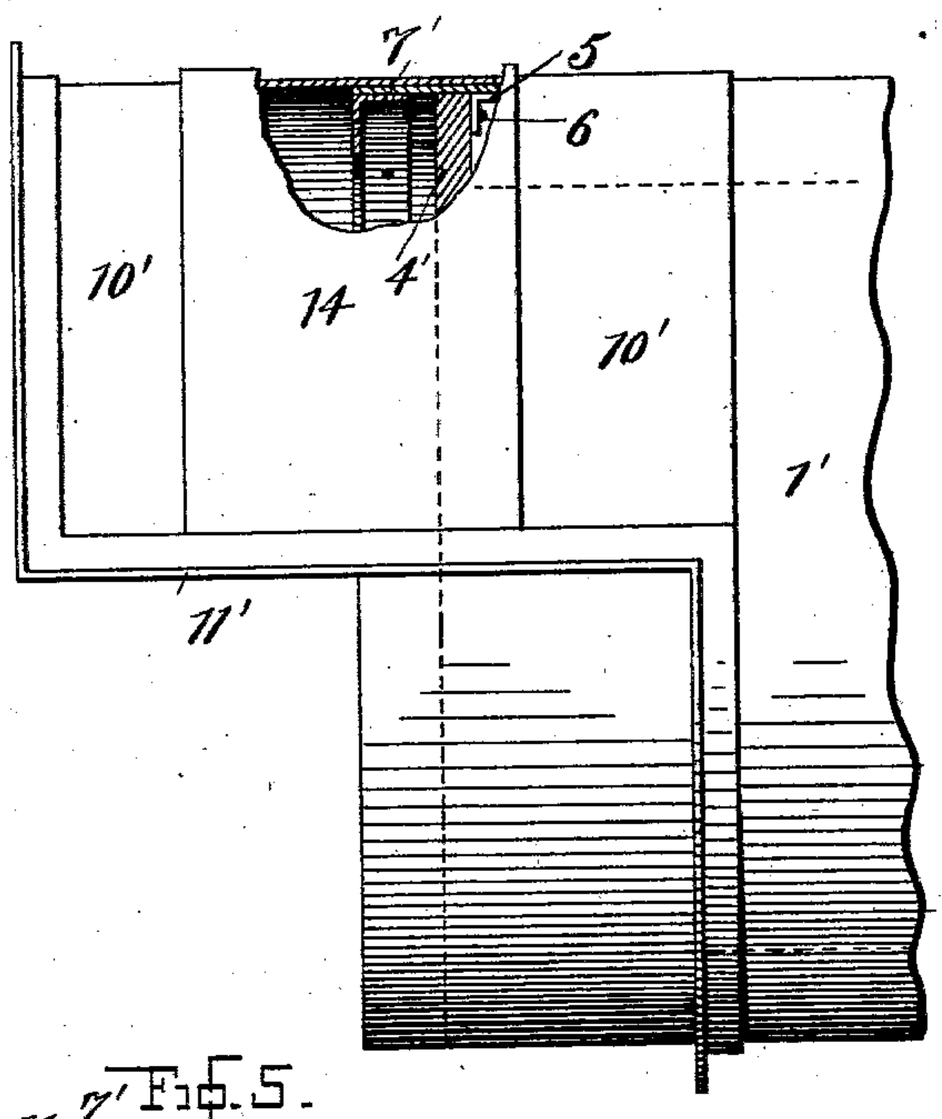

Fig. 5.

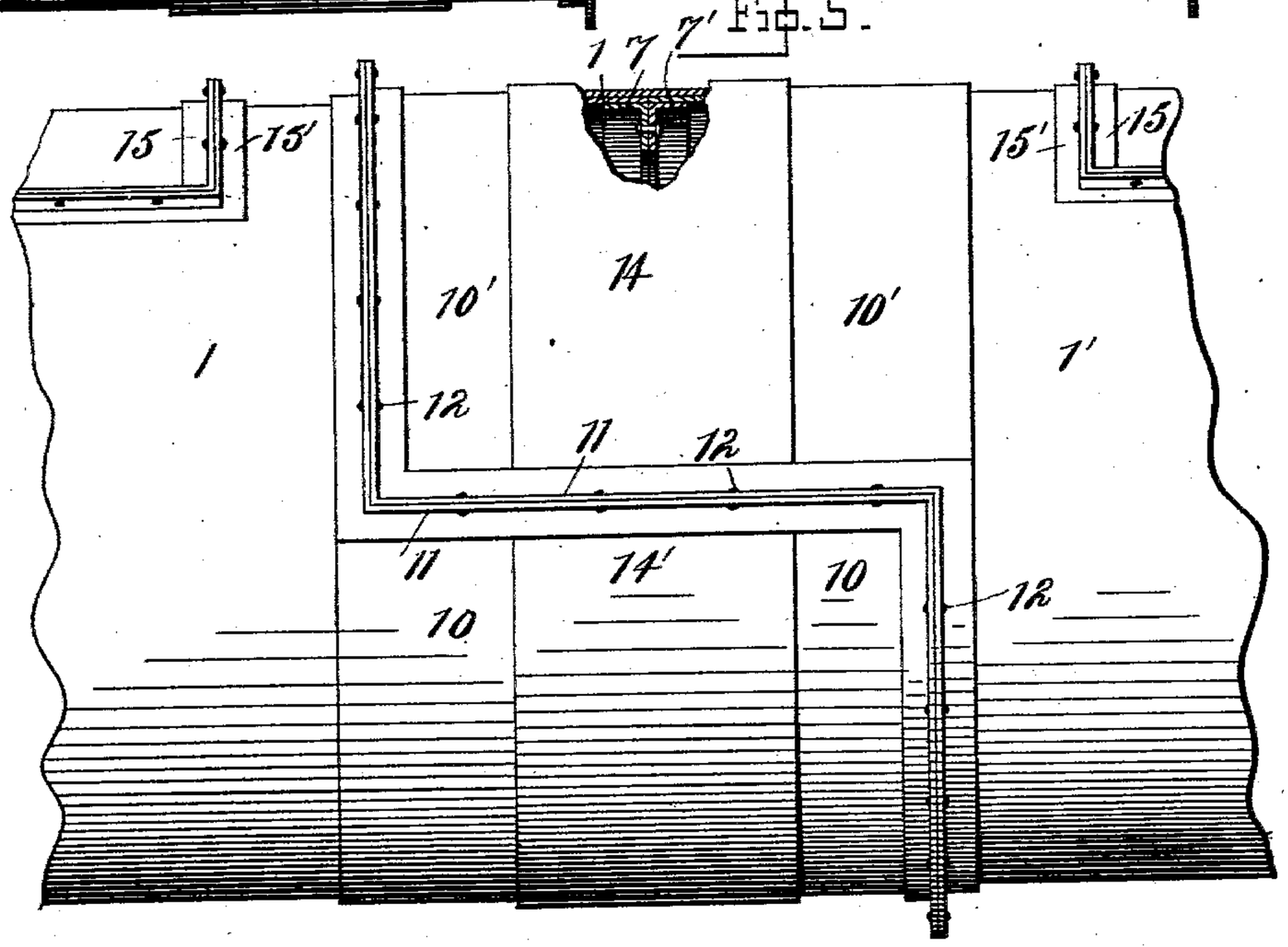

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FIG. 6.

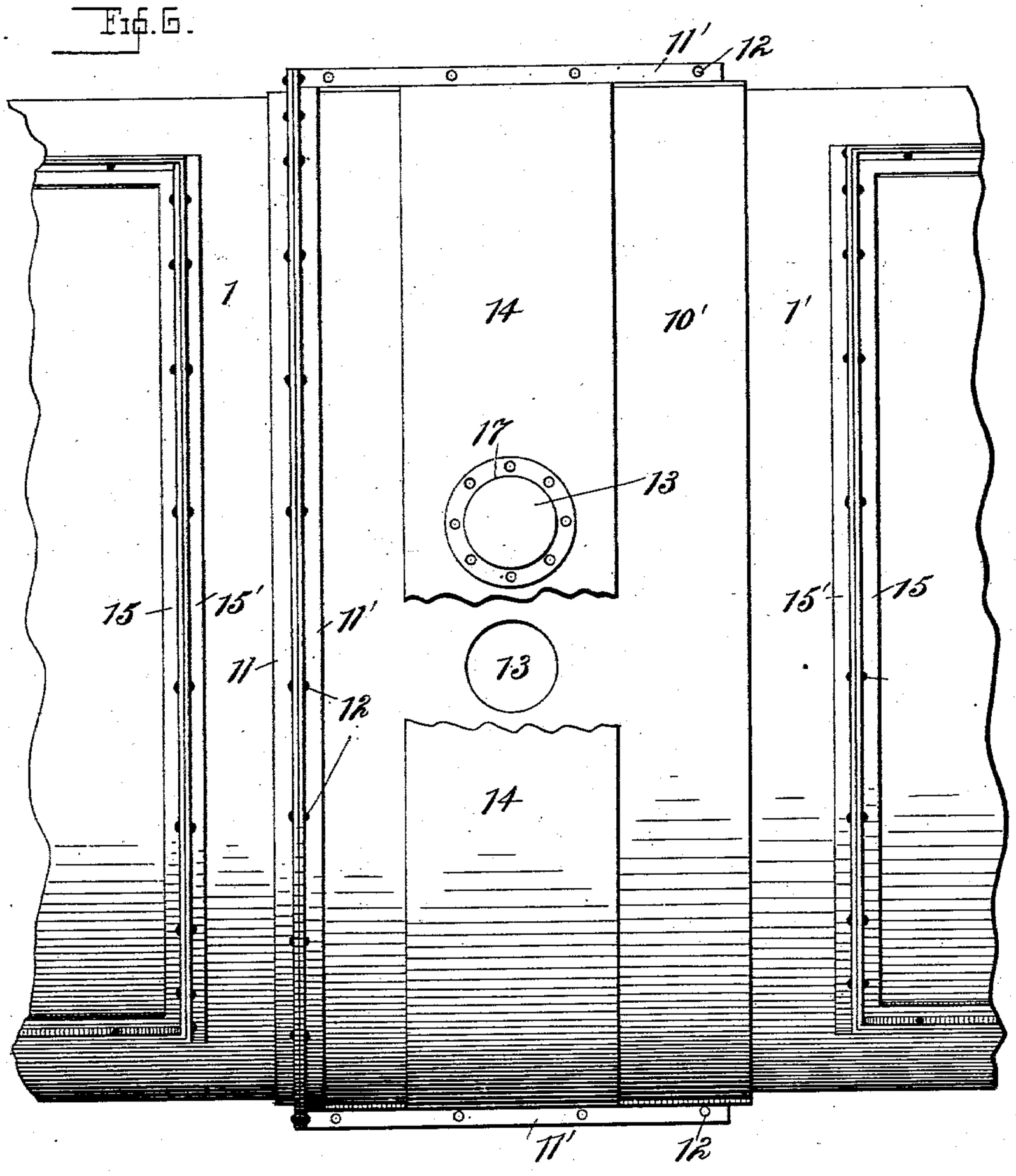

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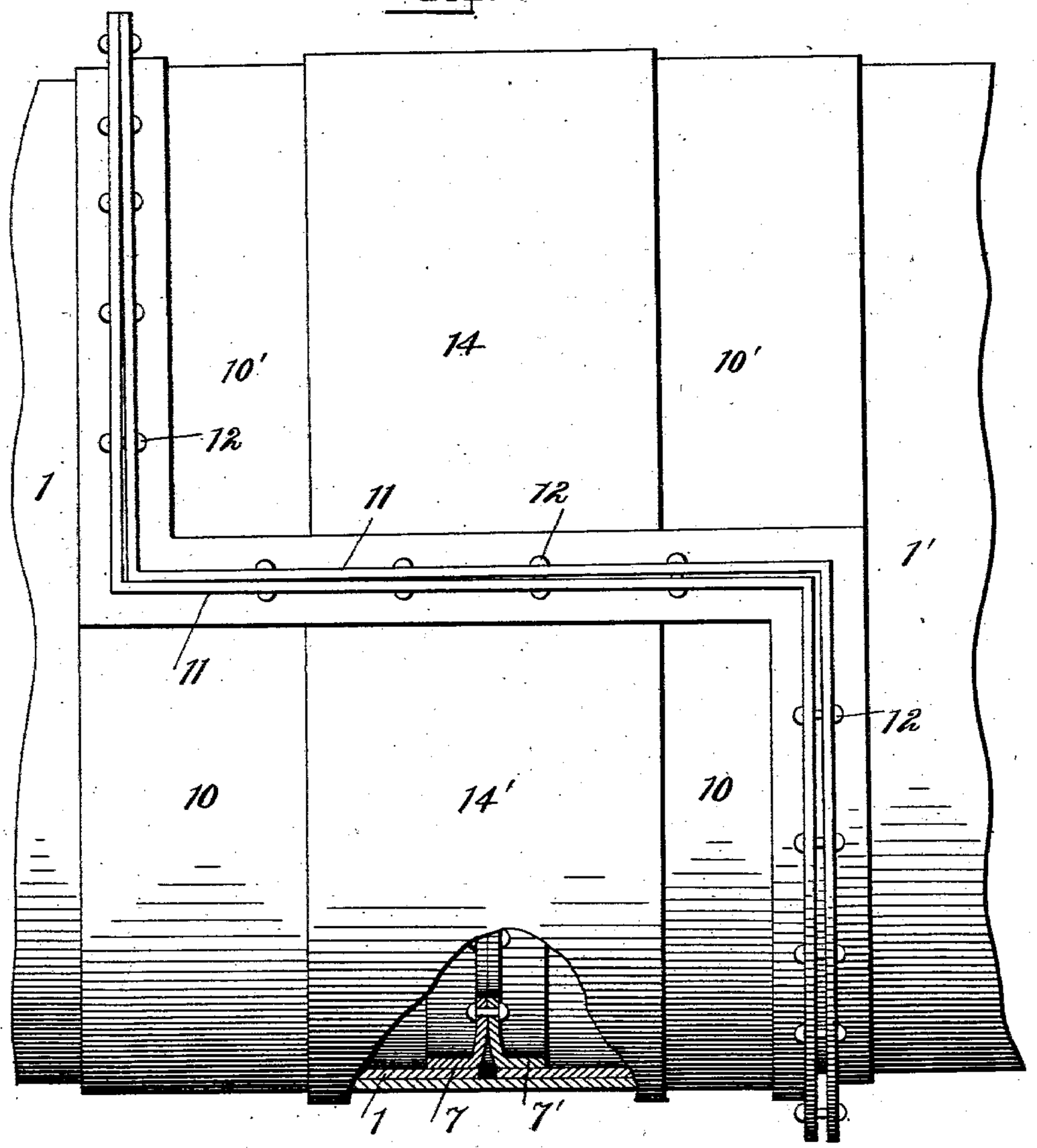
Fig. 7.



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UNITED STATES PATENT OFFICE.

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SUBAQUEOUS TUNNEL AND METHOD OF CONSTRUCTING SAME.

SPECIFICATION forming part of Letters Patent No. 629,133, dated July 18, 1899.

Application filed March 23, 1899. Serial No. 710,185. (No model.)

To all whom it may concern:

Be it known that we, WALTER H. KNIGHT, residing at New York, (New Brighton,) Richmond county, and FREDERIC M. LANDÉ, residing at New York, in the county of New York, State of New York, citizens of the United States, have invented certain new and useful Improvements in Subaqueous Tunnels and Methods of Constructing Same, of which the following is a specification.

This invention relates to subaqueous tunnels; and its object is to facilitate the construction of such tunnels and to provide a structure that, while of comparatively low cost, is of stable and enduring character.

It has been proposed to form subaqueous tunnels by joining tubular sections and sinking the structure so formed into the bed of the waterway. The constructions so proposed have not, however, been adapted either to a large diameter of tunnel or to any great depth of waterway on account of their lack of stability, strength, stiffness, and weight and on account of the deficiencies of the joint-closing means.

Our invention relates particularly to improvements in the joint-closing instrumentalities and to means for rendering the structure waterproof throughout.

In the present case the tunnel-sections consist of a shell of metal, such as iron or steel, with a lining of cement or cemented material. The metal shell or casing gives the form to the whole and gives the necessary longitudinal strength, while the cement lining gives stiffness and strength to resist the compressive strains due to the external water-pressure and also gives the weight required to hold the tunnel in place. The cement further serves to seal to some extent the numerous joints of the metal structure, the latter being composed of a great number of plates riveted together; but to render this structure still more waterproof we provide a special layer or lining of waterproof material. The tubular tunnel-sections formed in this manner of any suitable length are provided with removable bulkheads near each end, so that when placed in the water they will substantially exclude the water and will float. They are, however, of such weight that they will float substantially awash, so that by slightly loading them by the admission of water or otherwise they can be sunk to the bed of the waterway, or they may be sufficiently heavy to sink by their own weight. They are also provided with means for joining them end to end when so sunk and for rendering their junctions water-tight, as hereinafter set forth.

In laying the tunnel a channel is first dredged across the bed of the waterway along the desired course of the tunnel and the sections are then laid end to end therein and joined together. On then pumping out such water as may be in the tunnel-sections, removing the bulkheads, and "lining up" with cement a tunnel is obtained which is of sufficient weight, stiffness, and strength to be absolutely stable and is sufficiently waterproof. The tunnel may be thus laid partly or wholly below the bed of the waterway.

In the accompanying drawings, which form a part of this specification, Figure 1 is a longitudinal sectional view of one section of this improved tunnel construction. Fig. 2 is a diagrammatic transverse section of a waterway, showing a portion of the tunnel laid in place. Fig. 3 is a cross-section of the tunnel, the section being taken on one side in front of a bulkhead and on the other side behind the bulkhead. Figs. 4 and 5 show in partly sectional side elevation the adjacent ends of two adjacent sections respectively before and after they are joined together. Fig. 6 is a plan view, partly broken away, of the junction of two adjacent sections. Fig. 7 is a partly-broken side elevation of the junction of the sections, showing the flexibility of the inner joint.

This tunnel structure comprises a series of sections which are constructed separately and each of which is of the general form shown in Figs. 1 and 3. Each tunnel-section comprises an outer shell or tubular casing 1 of iron or steel and an interior lining 2 of cement or cemented material. In case the tunnel is of a double construction, as shown, a cross-wall 2′ of cemented material is built between the two portions thereof to brace and support the structure, and thrust-posts 3 are also provided for the same purpose.

At each end of the tunnel-section we provide a removable bulkhead, consisting, for example, of wooden boards or stanchions 4 4′,

arranged in transverse directions and bolted to one another and to brackets 5 on the shell 1 by bolts 6. The shell 1 extends somewhat beyond the bulkheads and has at its extreme ends internal flanges 7 7′, adapted to engage with corresponding flanges on the adjacent sections.

In constructing each tubular section a layer 9 of waterproof material, such as felt impregnated with asphaltum, is placed directly against the inside of the iron shell, and the cement lining is applied against this waterproof layer. All joints are calked in any suitable manner, so as to render the hollow tubular body or tunnel-section practically impervious to water.

The junction-flanges of the sections are shown in Figs. 4 to 6, where 1 and 1′ represent adjacent end portions of adjacent tunnel-sections. When the sections are thus placed end to end, their internal terminal flanges 7 7′ come together and are adapted to be bolted tightly together to form a watertight joint. Such joint is not, however, intended to take any of the strain of support or alinement of the sections, separate means being provided for this purpose, as follows: From the end of section 1 extends a bottom projection or ledge 10, which is of the same shape as the lower half of the tunnel-shell, but is a little larger, so as to receive and embrace the under half of the section 1′. The latter section has a top projection or bracket 10′ of a shape to conform to and fit over the top of section 1. Thus supposing section 1 to have been lowered into place the section 1′ is lowered, so that its end falls into the semitubular guide and support formed by the projection or ledge 10, while its semitubular projection 10′ comes over and embraces the top of section 1. The two sections are thus mutually interlocked, and as the end of section 1 can descend no farther than the ledge 10 it is stopped thereby in exact vertical alinement, and horizontal alinement is insured by the upwardly-extending sides of the projecting ledge 10 and the downwardly-extending sides of the projection 10′ engaging with the respective sections 1′ and 1. Flanges 11 11′ extend around each of the tube-sections 1 1′ and their projections 10 10′ along the extreme line of overlap of such sections and projections, so that when the sections are brought together, as indicated in Fig. 5, they will be substantially in contact or at least sufficiently close together to enable them to be bolted together, as indicated at 12. The lower parts of the tubes being more or less submerged in the river-bed when the sections are sunk into place, it may not in general be practicable to apply bolts to such portions; but enough bolts may be applied to the accessible portions of the joint to firmly hold the sections together, it being understood that this joint is strictly for mechanical support and alinement and is not depended on for waterproofing, that function devolving on the interior flange-joint. The extensions 10 or 10′ are of sufficient length to extend beyond the bulkhead of the adjacent section when the sections are placed end to end.

The bulkheads 4 4′ are arranged at such a distance from the section ends that when the latter are brought together sufficient space will be left between such bulkheads for one or more men to work, and in the top of the shells 1 and 1′ and the projection 10 are formed manholes 13, through which divers may gain access to this space after the sections are sunk into place. The cement lining 2 extends around and lines the whole interior of each tunnel-section between the bulkheads; but the space outside of these bulkheads is not thus lined up, as it is necessary to leave the internal flanges 7 7′ uncovered and accessible. This results in a temporary weakness at this point, which is overcome by placing a reinforcing-band made in upper and lower halves 14 14′ over this portion of the tube-sections.

In order to facilitate the application of the waterproof lining 9, we may leave the top central portion of the tubular section open until the said lining and the cement lining are finished, when the top part is put on and fastened to the other part by flanges 15 15′.

Each section may be finished before it is placed in the water; but it is more convenient to place the shell in the water before the lining has been applied. The bulkheads having previously been put in place and calked, the structure will float on the water, and then as the cement lining is built up the tubular body will sink in proportion to the weight thus brought upon it. This results in an even distribution of strains on the tube and allows a tube of very large dimensions to be built as a single section without liability to excessive strains or necessity of transportation to the water of anything but the comparatively light shell. When the section is completed and covered over, the weight of the whole is such that when it is substantially free of water inside it will float almost awash, so that by suitably loading it, either by admitting a little water or otherwise, it may be sunk to position.

Preliminary to sinking the sections a channel is dredged across the waterway in the line of the proposed tunnel, this channel being of sufficient dimensions to receive the tunnel and preferably to allow it to sink completely below the bed of the waterway. The channel is also dredged in the banks of the waterway for some distance to connect with an open cut, so that no tunnel-driving, strictly speaking, is required. The first section of tunnel is sunk at one end of this channel, and the sections are then laid down successively, the end of each section dropping on and engaging with the projection or ledge 10 of the preceding section and the adjacent sections being bolted together at the joints by means of flanges 11 11′. Just before a section is laid down the channel is cleared to receive

same, and, if necessary, a blanket or bedding of fabric or matting may be laid at the points where the section end descends. Foundation-piling and sheet-piling for lateral support may also be driven where necessary to form a proper support for the tunnel. When the sections have been joined in this manner, divers enter the manholes 13, fasten together the flanges 7 7′, and calk same with lead or otherwise, so as to render same water-tight. The manholes being subsequently closed by covers 17, the tunnel is completely closed and substantially water-tight. Connections are made at each end of the tunnel with an open cut or other viaduct, and finally the bulkheads are removed one by one and the interior of the tunnel lined up with cement, masonry, &c., in any suitable manner at the joint, as indicated at 2″ in Fig. 2. Filling material is deposited over the tunnel structure, especially at the joints, to weight and seal the same, and the water in the spaces between adjacent bulkheads is pumped out at any suitable time before the removal of the said bulkheads.

By the above means a tunnel is provided which is substantially water-tight and free of water and is of sufficient weight and stiffness to hold itself in place and maintain its form against the flotative and compressive influences of the water.

The original tunnel-sections may, if desired, be made of sufficient weight to slightly overbalance the flotative effect, so that they will tend to sink, in which case temporary means, such as pontoons, must be provided for supporting them on the surface of the water until the proper time for sinking them. They are then lowered into place by their own weight, being guided by guy-cables or otherwise from the pontoons.

The tunnel-lining may be of any suitable cemented material—such as concrete, masonry, &c.

It will be observed that the interior flanges 7 7′ for making the joint between the sections water-tight are protected from injury, being inside the tunnel, and these flanges may therefore be made of thin and flexible material, thus greatly facilitating their clamping together, particularly where the angular deviation of the adjacent tunnel-sections is appreciable. By this means a water-tight joint may be insured at this point; but to obtain this effect without danger of injury to these flexible flanges it is necessary that the two adjacent section ends should be otherwise supported against relative lateral displacement—as, for example, by the projections and external flanges above described. This coöperation of the internal flexible flanges and the external supporting-flanges is illustrated in Fig. 7, wherein the adjacent sections are shown as laid at such an angle that the external flanges 11 11′ cannot meet at the bottom, but are sufficiently held by bolts at the upper part and the sides, while the joint is sealed by the internal flexible flanges 7 7′. Other features of importance of the construction shown are that the external flanges are located in different planes on both sides of the internal joint, which is in one plane, so that the distortion or separation due to a given deflection of the tunnel-sections will be greater in these external joints than in the internal joint, so that the external-joint fastening devices are enabled to exert their supporting effect in an advantageous manner, while the internal joint is not subjected to undue strain. The fact that the internal and external flanges break-joint, as shown, also contributes to the same end, as does the fact that the external flange has a portion—namely, the horizontal portion—crossing the internal flange. It is also of importance that the extensions 10 10′ extend beyond the bulkheads, as shown, so as to reinforce this part of the structure.

Having thus described our invention, what we claim as new therein, and desire to secure by Letters Patent, is—

1. A subaqueous tunnel structure comprising a tubular metallic shell, a waterproof lining within said shell, and an interior lining of cemented material.

2. In a subaqueous tunnel, the combination of two adjacent sections, provided at their junction with external flanges, and means for fastening such flanges together, and also provided with internal flanges and means for fastening same together, the said internal flanges breaking joint with the external flanges.

3. In a subaqueous tunnel, the combination of two adjacent sections one of which has an extension overlapping and partly surrounding the end of the other section and said sections being provided at their junction with external fastening means following the junction-line of the section end to the said extension for holding the tunnel-sections in contact and alinement and an internal joint and means for fastening said internal joint and rendering same water-tight.

4. In a construction for a subaqueous tunnel, the combination of two adjacent sections having interior bulkheads near their ends but with a free space between them and the junction of the sections, such sections being provided with manholes communicating with such space, means on the ends outside of the adjacent sections for fastening such sections together, and an internal joint at the junction of such sections and means for fastening and closing same in a water-tight manner.

5. In a subaqueous tunnel, the combination of two adjacent sections provided at their junction with a flexible internal flange-joint and with an external flange-joint for mechanical support.

6. In a subaqueous tunnel, the combination of two adjacent sections, one of which has a projection overlapping and partly surround-

ing the end of the other section, flanges on said section and projection at the edges thereof and means for fastening same together.

7. In a subaqueous tunnel, the combination of two adjacent sections, each of which has a projection overlapping the end of the other section, of flanges on the respective sections and projections and means for fastening same together.

8. In a subaqueous tunnel, the combination of two adjacent sections, having means for rigidly supporting their ends against relative lateral displacement, and a flexible flange-joint connecting their ends.

9. In a subaqueous tunnel, the combination of two adjacent tunnel-sections having interior linings of cemented material, extending to near their ends, fastening devices at their adjacent ends, fastened from inside the tunnel, and a lining of cemented material over such fastening devices and continuous with the aforesaid interior linings of the sections.

10. In a subaqueous tunnel, the combination of two adjacent tunnel-sections placed end to end, internal flanges attached at the ends of said sections and fastened together, an external projection on one of the sections extending over and partly surrounding the end of the other section, an external flange extending around the edge of such projection and means for fastening same to the other section.

11. In a subaqueous tunnel, the combination of two adjacent tunnel-sections having interior flanges forming a joint in one plane, of external flange-joints on said sections arranged on both sides of such internal joint.

12. In a subaqueous tunnel, the combination of two adjacent tunnel-sections having interior flanges forming a joint in one plane, of external flange-joints on said sections arranged on both sides of such internal joint and extending across same.

13. A construction for subaqueous tunnels, comprising two adjacent tunnel-sections each having an interior bulkhead near its end, of extensions from each section overlapping and partly surrounding the adjacent section and extending beyond the bulkhead therein, flanges on the said sections and extensions and means for fastening same together.

14. A construction for subaqueous tunnels, comprising two adjacent tunnel-sections each having an interior bulkhead near its end, of an extension from one section overlapping and partly surrounding the adjacent section and extending beyond the bulkhead therein, flanges on said sections and extension and means for fastening same together.

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