Feb. 9, 1926. 1,572,741

J. C. MEEM

TUNNEL AND METHOD OF BUILDING AND SUBMERGING

Filed July 2, 1925 3 Sheets-Sheet 1

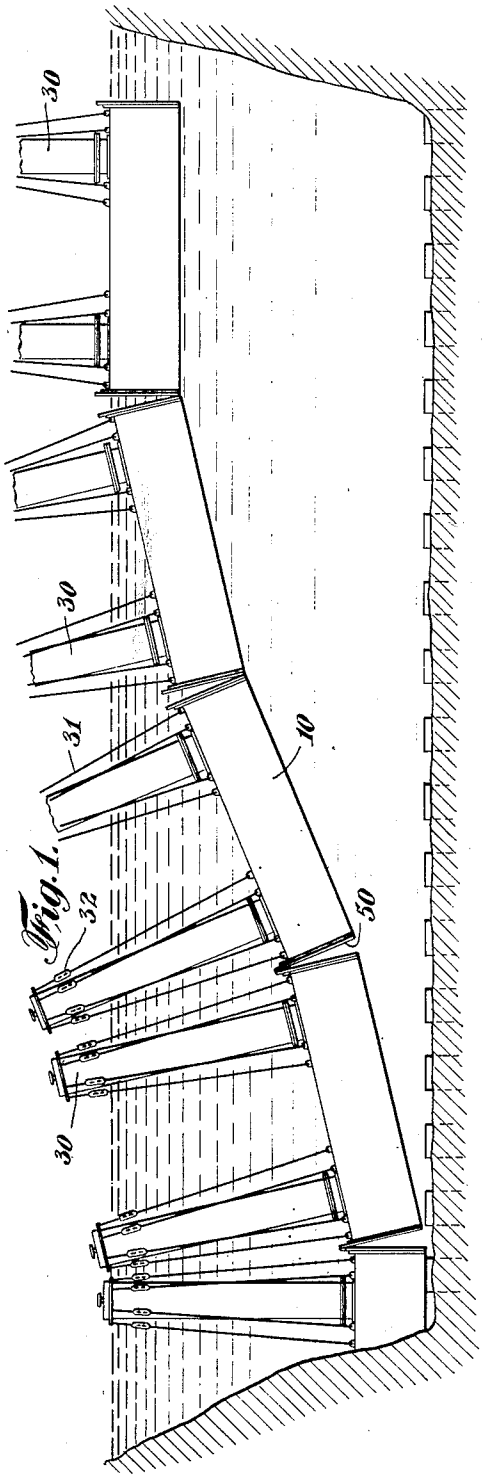


Fig. 1.

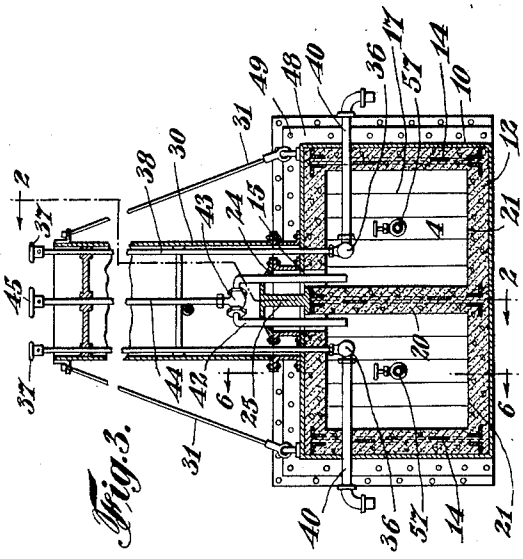


Fig. 3.

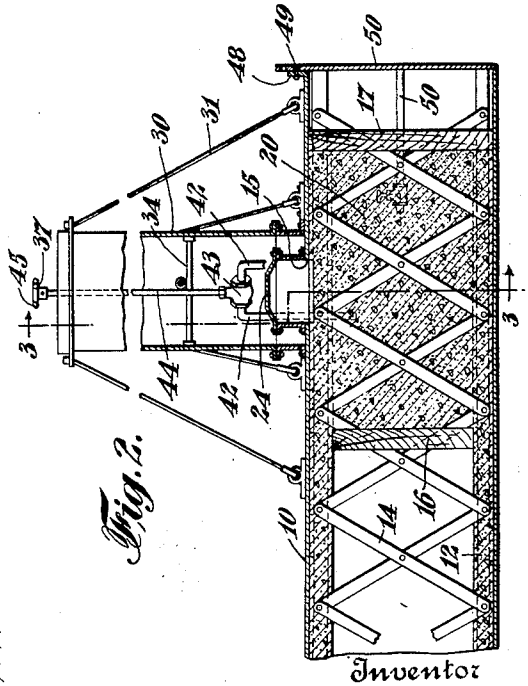


Fig. 2.

Inventor

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By his Attorneys

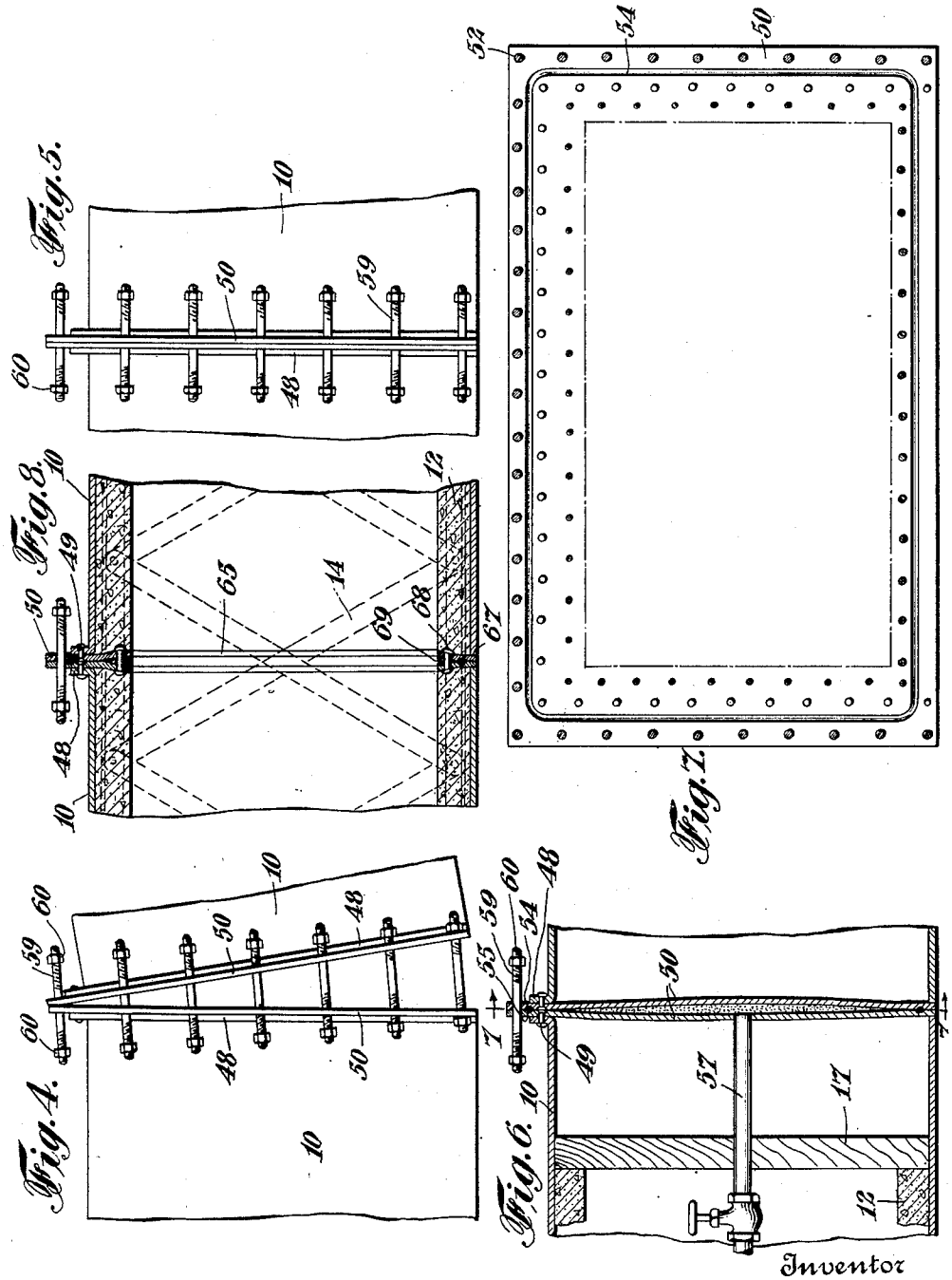
Edwards, Sager & Bower

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TUNNEL AND METHOD OF BUILDING AND SUBMERGING

Filed July 2, 1925 3 Sheets-Sheet 2



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TUNNEL AND METHOD OF BUILDING AND SUBMERGING

Filed July 2, 1925 3 Sheets-Sheet 3

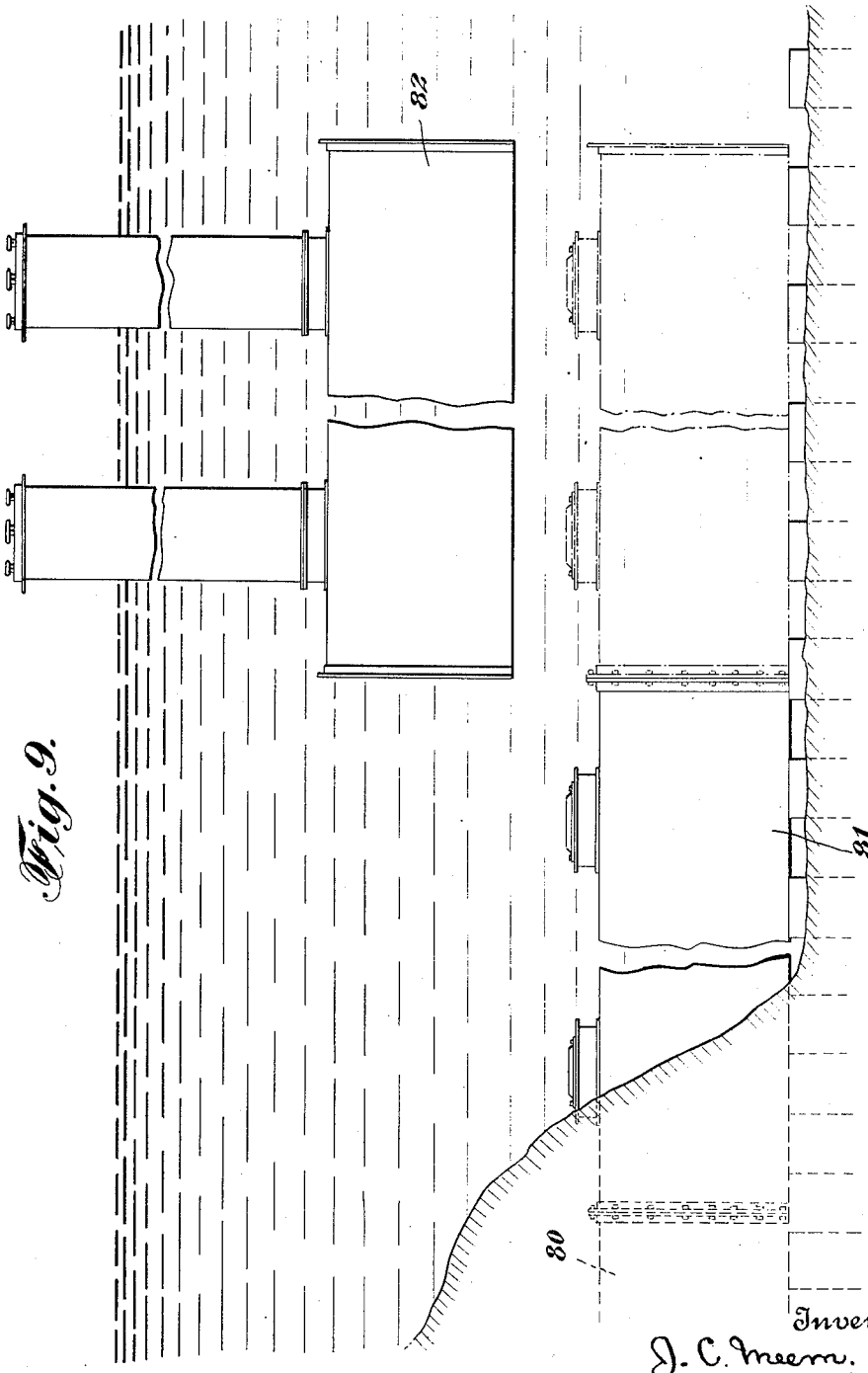


Fig. 9.

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Patented Feb. 9, 1926. 1,572,741

UNITED STATES PATENT OFFICE.

JAMES C. MEEM, OF BROOKLYN, NEW YORK, ASSIGNOR OF ONE-HALF TO FREDERICK L. CRANFORD, OF BROOKLYN, NEW YORK.

TUNNEL AND METHOD OF BUILDING AND SUBMERGING.

Application filed July 2, 1925. Serial No. 40,987.

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 Building and Submerging, of which the following is a specification.

This invention relates to an improved method and construction of sub-aqueous tunnels.

It has heretofore been a practice in constructing sub-aqueous tunnels to build sections of the tunnel above water, bulkhead the sections and sink them successively as by flooding them with water, each section being permanently joined under water to the portion of the tunnel previously laid. The joining is usually accomplished by workmen who enter the previously laid portion of the tunnel which has been dewatered, remove the bulkhead at the end of the portion and bolt, rivet or otherwise permanently secure the added section to the previously laid portion. This operation is accompanied by considerable danger to the workmen. The added section of the tunnel may not have been moved into contact or into sufficiently good contact with the end of the previously laid portion of the tunnel to form a watertight joint and when the bulkhead at the end of the previously laid portion is removed the entire tunnel may become flooded.

One of the major objects of my invention is to provide an improved method and means whereby the added section of the tunnel may be easily and permanently joined to the previously laid portion without danger to the workmen engaged in the joining operation. For this purpose I close the several tunnel sections before sinking them by diaphragms which lie substantially flush with the ends of the section. When a section is sunk and moved into alignment and contact with the end of the portion already laid, the outer face of the diaphragm which closes the end of this portion and the outer face of one of the diaphragms which close the added section will be in substantial contact. Whatever space may then remain between these faces may be filled with grouting introduced, for example, from the previously laid portion of the tunnel through an opening in the diaphragm at its end. When this grouting has set, a central opening is cut through the adjacent diaphragms and any grouting between the same and the remaining parts of the diaphragms are riveted together inside the tunnel and, if desired, suitably caulked.

If desired, the diaphragms may be provided with external peripheral gaskets so that when each section is sunk into position in contact with the end of the tunnel previously laid, any space between the two adjacent diaphragms may be closed. These gaskets form an additional element of safety and may be used in addition to the grouting to prevent the flow of water into the tunnel when the central openings are cut in the diaphragms.

The methods heretofore used in sinking the several tunnel sections and moving them into proper position relative to the previously laid portion have been laborious, costly and uncertain. In one embodiment of my invention I provide an improved means and method whereby the uncertainty and much of the cost and labor are eliminated. In accordance with such embodiment, I build and sink a long tunnel structure composed of sections which have been hinged or pivotally or flexibly joined to one another above the water; the sinking being accomplished by gradually and progressively submerging the successive sections. The flexible connections between the sections are such that as each section finally reaches the bottom of the waterway it will be in proper position to be permanently joined to the end of the previously laid portion of the tunnel, as in the manner above described. In practice, I preferably form the flexible connections by extending the diaphragms at the ends of the sections beyond the top and sides of the sections and loosely couple successive sections together by bolts which pass through the extended portions of adjacent diaphragms. The bolts permit successive sections to assume varying angular positions relative to one another and thus permit one portion of the tunnel to have assumed its final position on the bed of the waterway while other sections connected therewith are being sunk.

Numerous other objects and advantages of my invention will appear from the fol-

lowing description, taken in connection with the accompanying drawing, wherein—

Fig. 1 is designed to illustrate one method of submerging the tunnel sections and shows diagrammatically a series of inter-connected sections one of which is in its final position on the bottom of the waterway, and other of the sections at varying stages of submersion.

Fig. 2 is a sectional view of one end of a tunnel section taken on the line 2—2 of Fig. 3 and showing the diaphragm closing the end of the section, bulkheaded spaces near the end of the section, and a buoyant shaft connecting with the bulkheaded spaces, which shaft I utilize to control the sinking operation.

Fig. 3 is a section taken on the line 3—3 of Fig. 2.

Fig. 4 is an enlarged detail elevation showing a portion of two tunnel sections which are inclined to one another and showing the means for flexibly connecting the sections together.

Fig. 5 is a view similar to Fig. 4 but showing opening between the section ends closed and the sections lightly bolted to one another.

Fig. 6 is an enlarged sectional view taken on the line 6—6 of Fig. 3 and showing adjoining ends of two sections at the time grouting is introduced between the diaphragms.

Fig. 7 is an enlarged view taken on the line 7—7 of Fig. 6.

Fig. 8 is a view similar to Fig. 6 but showing the completed tunnel joint construction.

Fig. 9 is a diagrammatic view designed to illustrate a modified method of sinking the tunnel sections wherein such sections are sunk as separate units.

The sections are preferably built on suitable ways and as each section is completed and bulkheaded it may be launched and subsequently connected to the next section built. In certain cases these sections may be built on rafts and launched from the raft, or the raft may be wrecked, leaving the section floating.

The tunnel structure and the method of building the same may vary considerably. In the form shown in Figs. 1 to 3, the section comprises an outer metal shell 10 lined inside with concrete 12 and re-enforced by a central and two side longitudinal girders 14. Near each end of the section the shell 10 is provided with an opening 15. Bulkheads 16 and 17 are provided adjacent to and on opposite sides of each opening 15, and joining the two bulkheads adjacent each opening is a central partition 20 which divides the bulkheads into two chambers 21. The partition 20 may, if desired, be made of concrete and formed as a continuation of the concrete lining 12. Suitable hatchway or manhole covers 24 are provided for the openings 15 and these covers are provided with depending ribs 25 which extend across the openings and engage the upper edges of the partitions 20 at the openings 15 so as to effectively seal from one another the chambers 21 at opposite sides of the partition 20.

There is then erected around each of the openings 15 a buoyant shaft 30 which is of sufficient height to extend above the water when the section has been sunk to its final position. These shafts are secured to the tunnel by bolt and flange connections which form a water-tight joint, and the shafts are guyed to the tunnel by cables 31 provided with adjusting turn-buckles 32. While of considerable volume, the shafts 30 are of very light construction and depend for their stability and strength on light internal bracing 34 and the guys 31.

Valves 36 are provided in each of the chambers 21 and these valves are operated from the top of the shaft 30 by handles 37 which are connected to the valves 36 by rods 38 which extend through the section casing and through the shaft 30. The valves 36 are designed to permit water to enter the chambers 21 from outside the section through pipes 40. The chambers 21 communicate with the interior of the shafts 30 through pipes 42 located at opposite sides of the partition 20 and rib 25 and extending through the manhole cover 24. Flow through these pipes is controlled by means of a valve 43 located in the shaft 30 and operated from the top of the shaft by means of a rod 44 and handle 45. The central and side longitudinal girders 14 extend through the bulkhead 37 and terminate somewhat short of the end of the section, and the concrete lining 12 terminates at the end bulkhead 17 as shown in Fig. 2 of the drawings. The metal shell 10 at each end of the section is formed as a peripheral flange 48 which extends beyond the top and sides of the section, but in the preferred construction this flange is interrupted at the bottom of the section. Tightly secured to the flange 48 by rivets 49 is a metal diaphragm 50 which closes the open end of the section. This diaphragm extends beyond the flange 48 at the top and sides of the shell 10 and terminates flush with the bottom of the shell. Along the top and sides the diaphragm is formed with a peripheral series of bolt-receiving openings 52. The diaphragms 50 are preferably formed with a peripheral groove 54 extending entirely around the diaphragm and a gasket 55 is held in the groove 54 by any suitable means. Extending from the chambers 21 at opposite sides of the partition 20 through the end bulkhead 17 and the diaphragm 50 are pipes 57 which are adapted to supply grouting to the space between adjacent diaphragms, should any such space

exist, when a section has been sunk into alignment and contact with the end of a previously laid section.

Prior to submerging each section, each section is loosely joined to the end of the next section by a series of bolts 59 which extend through the openings 52 in the diaphragms 50. The bolts are provided with nuts 60 which during the operation of submerging are unscrewed sufficiently to permit two successive sections to assume different angular positions relative to one another.

Before sinking any of the sections the bed of the waterway is suitably prepared for the reception of the tunnel, as by dredging to the proper depth and grade and driving a series of supporting piles 62. The tunnel sections are then gradually and progressively sunk in the manner indicated in Fig. 1 of the drawings by permitting water to flow into the chambers 21 through valves 36 and thence through pipes 42 into the buoyant shafts 30. The structure shown permits an accurate control of the sinking operation. As the section sinks, more of the buoyant shafts 30 become submerged and this acts to check the sinking, requiring an additional quantity of water in the shaft to continue the sinking. The valves permit a perfect control of the flow of water as desired into either or both of the chambers 21 and shaft 30. The partitions 20 prevent the water in the section from flowing all to one side of the section and so turning the section on its axis, and the bulkheads prevent the water in the section from flowing all to one end of the section and causing the section to tilt on end.

Should it be desired to lift the tunnel or a section thereof after its submergence, this may be done by pumping down the water in the shafts 30.

When a section of the tunnel has reached its final position on the supporting piles 62, grouting is introduced through the pipes 57 to any space which may remain between the adjoining diaphragms 50. After the grouting has set, the end bulkhead 17 of the previously laid portion of the tunnel which has been de-watered, is removed and a central opening 45, as shown in Fig. 8, cut through the adjacent diaphragms 50, thereby extending the tunnel passage into the section just laid, the portions of the diaphragms 67 which remain attached to the sections are riveted together at 68 inside the tunnel and any space between these diaphragms is caulked as at 69. The tunnel is completed at the joint by joining the girders 14 of the previously laid portion with the girders of the section just laid in the manner shown in Fig. 8, and the concrete lining 17 at the joint is completed. If preferred, the sections instead of being submerged gradually as shown, may be submerged and joined in successive units, that is, each floating section may be sunk and joined to the section in place, by having divers place and tighten a sufficient number of bolts to insure facial contact in the diaphragms while the tunnel is being back-filled, unwatered and completed as described.

Fig. 9 illustrates the manner in which the sections may be sunk as separate units. In this figure 80 and 81 represent sections of the tunnel which have been previously sunk and joined, and the trench in which they are laid partly filled in as by sinking a pile of cement bags around the sections. 82 represents a section which is being lowered into position in contact and in alignment with the section 81, the position of the section 82 when it has finally reached the bed being indicated in dotted lines.

I claim:

1. The method of adding a tunnel section to an end of a previously laid portion of a sub-aqueous tunnel, said section being closed by diaphragms positioned substantially flush with its ends and the end of said previously laid portion being closed by a similarly located diaphragm, which method consists in sinking said section to a position such that one of its diaphragms is in substantially facial contact with the diaphragm at the end of the previously laid section, sealing any remaining space between said contacting diaphragms by introducing grout therebetween from the interior of said previously laid portion, cutting central openings in said contacting diaphragms and riveting the remaining portions of said diaphragms to one another.

2. The method of adding a tunnel section to an end of a previously laid portion of a sub-aqueous tunnel, said section being closed by diaphragms positioned substantially flush with its ends and the end of said previously laid portion being closed by a similarly located diaphragm, said diaphragms being provided with peripheral gaskets on their outer faces, which method consists in sinking said section to a position such that one of its diaphragms is in substantially facial contact with the diaphragm at the end of the previously laid section, sealing any remaining space between said contacting diaphragms by introducing grout therebetween from the interior of said previously laid portion, cutting central openings in said contacting diaphragms and permanently securing the remaining portions of said diaphragms to one another.

3. The method of adding a tunnel section to an end of a previously laid portion of a sub-aqueous tunnel, said section being closed by diaphragms positioned substantially flush with its ends and the end of said previously laid portion being closed by a similarly located diaphragm, which method consists in sinking said section to a position

such that one of its diaphragms is in substantially facial contact with the diaphragm at the end of the previously laid section, cutting central openings in said contacting diaphragms, permanently securing the remaining portions of said diaphragms to one another, and caulking any space between the same.

4. The method of adding a tunnel section to an end of a previously laid portion of a sub-aqueous tunnel, said section being closed by diaphragms positioned substantially flush with its ends and the end of said previously laid portion being closed by a similarly located diaphragm, which method consists in sinking said section to a position such that one of its diaphragms is in substantially facial contact with the diaphragm at the end of the previously laid section, sealing any remaining space between said contacting diaphragms by introducing grout therebetween from the interior of said previously laid portion, cutting central openings in said contacting diaphragms, permanently securing the remaining portions of said diaphragms to one another, and caulking any space between the same.

5. The method of constructing a sub-aqueous tunnel from a plurality of tunnel sections having bulkheaded spaces therein and buoyant shafts in communication with said spaces, said sections being connected together by means which will permit angular movement between successive sections, and each section being closed by diaphragms extending across the ends of the sections, which method consists in gradually sinking said sections by admitting water to said bulkheaded spaces and shafts, the sinking being effected in such a manner that successive sections progressively reach their final position on the bed of the waterway, progressively sealing spaces between the pairs of adjacent diaphragms by introducing grout into such spaces and progressively extending the passage through the tunnel by cutting openings in said pairs of diaphragms and permanently joining said sections by riveting together the remaining portions of said pairs of diaphragms.

6. The method of adding a tunnel section to an end of a previously laid portion of a sub-aqueous tunnel, said section being closed by diaphragms positioned substantially flush with its ends and the end of said previously laid portion being closed by a similarly located diaphragm, which method consists in sinking said section to a position such that one of its diaphragms is in substantial facial contact with the diaphragm at the end of the previously laid section, cutting central openings in said contacting diaphragms, permanently securing the remaining portions of said diaphragms to one another and joining the inner edges of said remaining portions in such a manner as to seal any space between said portions from the space inside the tunnel.

JAMES C. MEEM.