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Fouillade

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[54] **CONSTRUCTION OF IMMERSED STRUCTURES**

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[51] **Int. Cl.²** **E21D 9/24**

[58] **Field of Search** ..... 61/84, 85, 43, 36 A, 45

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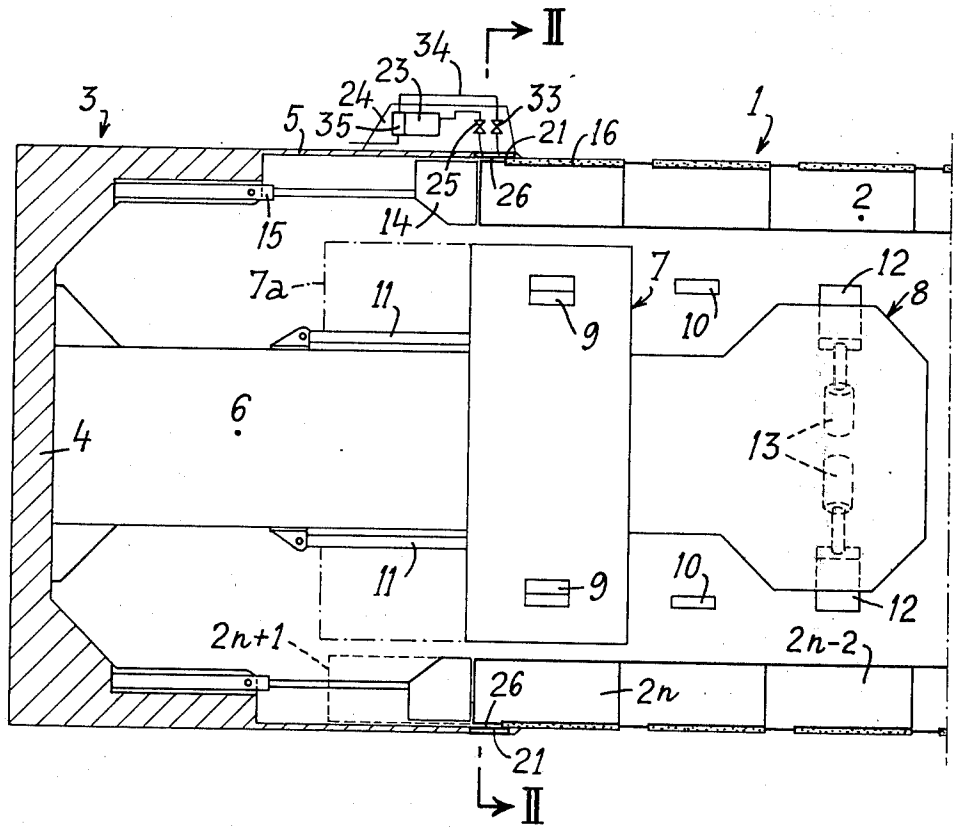
[57] **ABSTRACT**

Process and apparatus for producing a seal between a caisson shield and the end portion of a linear immersed structure which is being constructed in which the caisson has a hollow, tubular skirt which surrounds and is slightly spaced from the previously formed portion of the structure to provide an annular space between the skirt and said portion. At its free end, the skirt carries an elastic seal which contacts the structure and seals one end of said space against the ingress of fluid, and a ring within the skirt and adjacent the end of said portion of the structure and provided with elastic seals engaging respectively the end of the structure and the interior of the skirt seals the opposite end of said space. Refrigerated water is supplied to said space from the skirt and the hollow portion of the skirt has at least one cooling coil through which a refrigerating fluid is passed to freeze the water in said space and thereby form a sealing plug of ice between the skirt and said portion of the structure.

7 Claims, 4 Drawing Figures



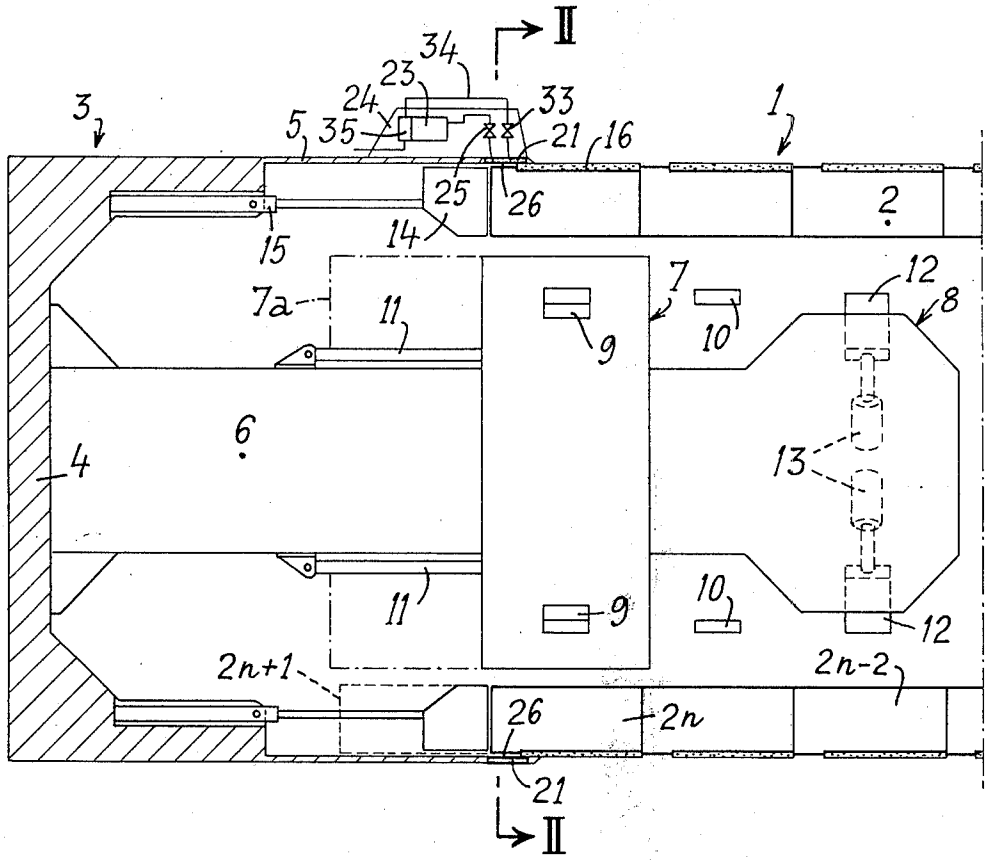

II
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Fig. 1

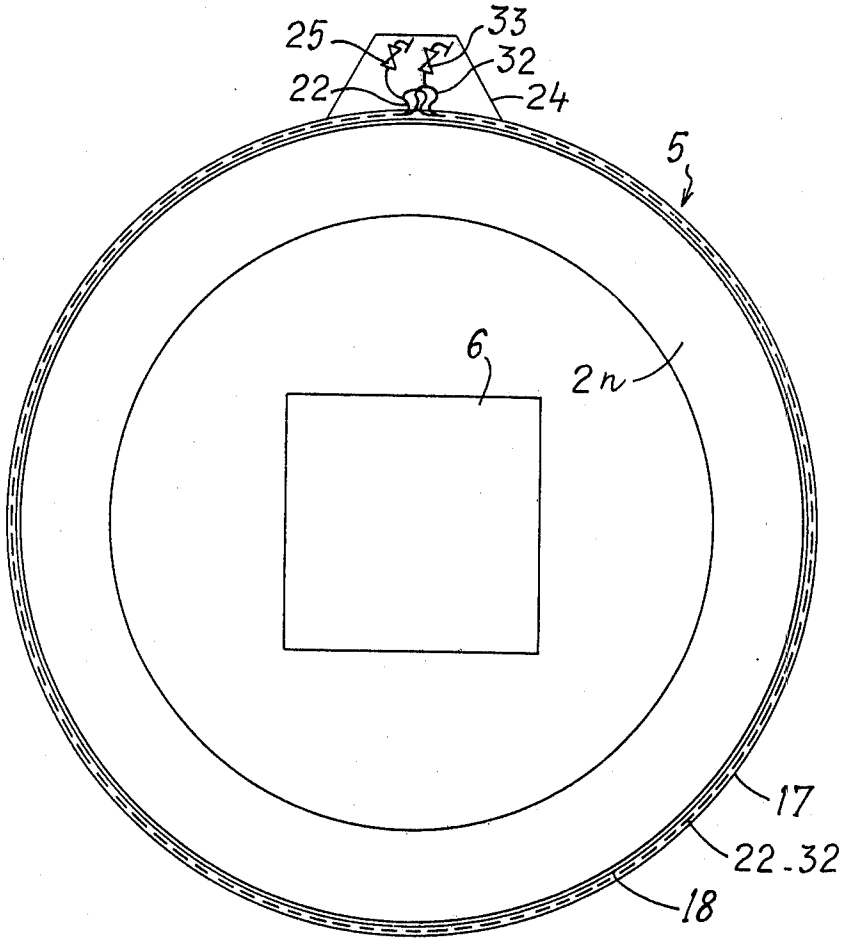

Fig-2

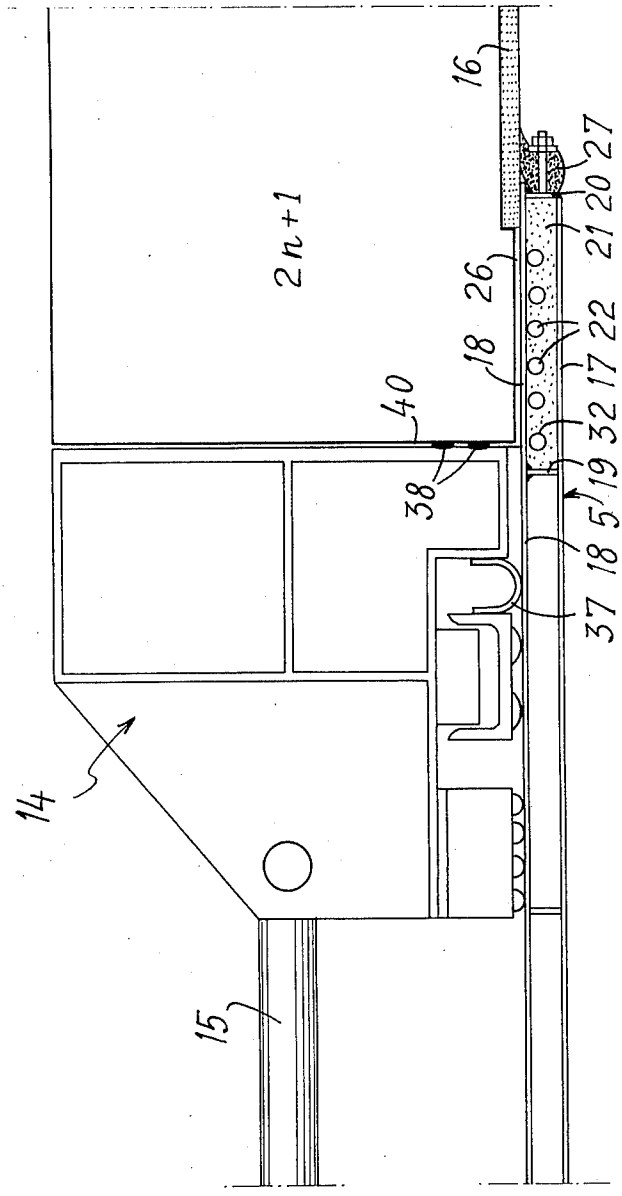

FIG-3

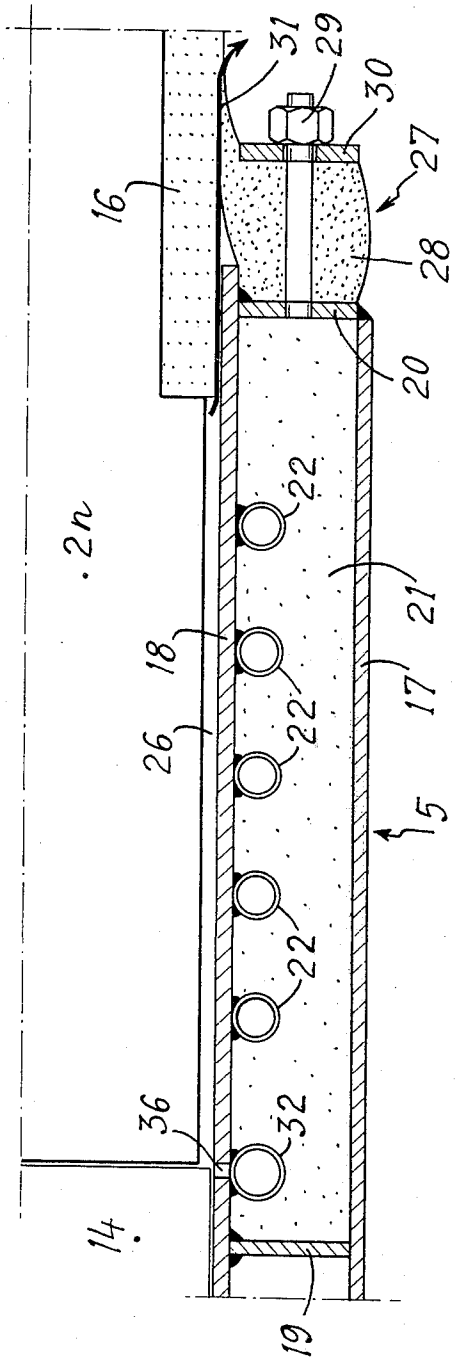

Fig-4

CONSTRUCTION OF IMMERSED STRUCTURES

The present invention applies to the submarine construction in successive sections of tunnels for the passage of pedestrians, road or rail vehicles, various materials, etc. and pipes carrying various liquids such as drinking water, waste water, etc.

BACKGROUND OF THE INVENTION

The present invention relates to a process and apparatus for producing, when constructing a linear immersed structure in a substantially normal atmosphere, the sealing between the final member of the structure constructed and the terminal portion of a caisson shield which covers the said member in order to define a working enclosure in which a new member can be constructed.

The object of the invention is to obtain rapidly and with maximum efficiency the sealing of this joint up to a relatively large immersion depth, both when the caisson shield is locked on the final members constructed so as to permit the construction of a new member and when the shield is moved towards the front in order to free a new atmospheric space in the immersed zone for the construction of a member.

A further object of the invention is to make the sealing automatic and completely resistant to the hydrostatic pressure of the atmosphere.

SUMMARY OF THE INVENTION

According to the invention the process consists of causing a liquid penetrate between the last member constructed and the terminal portion of the caisson shield and then cooling this liquid to form a solid sealing plug preventing the passage of the ambient liquid.

According to a particularly preferred embodiment of the invention between the final member constructed and the terminal portion of the caisson shield is circulated water cooled to a temperature close to freezing point in order to both expel the ambient water which has entered this space together with the impurities such as sand, mud, etc. contained therein and lower the temperature of the walls delimiting this space, the circulation of the water is interrupted when the temperature of these walls is sufficiently low and this water is further cooled through the outer wall formed by the terminal portion of the caisson shield until ice is formed, becomes completely firm and remains extant while work is being carried out.

Moreover, according to another important characteristic of the process as the ice plug no longer or only poorly ensures the sealing while the caisson shield is moved forwards for the construction of a new member, this sealing remains extant by means of elastomer joints which take the place of the said plug and to this end are applied against the wall of the caisson shield and against the free front surface of the final member constructed.

The invention also extends to an apparatus for performing this process. The apparatus is applied to a caisson shield whose lateral, cylindrical or parallel facetted jacket covers the final member constructed and whereof the base is coupled to a feed and stopping device which is supported on at least one of the existing members.

According to the invention in the said apparatus a tubular cavity is provided between the outer surface of the final member constructed and an inner wall of the terminal portion of the caisson shield, whereby the said cavity issues to the outside into the ambient liquid. At least one coil surrounding on the outside the above-indicated inner wall is applied against this wall in such a way as to provide good frigorific transfer conditions through the said wall. A cold source supplies a refrigerating fluid to the coil and causes it to circulate therein. The cold source can comprise liquid nitrogen cylinders or a refrigerating unit.

Other and further objects of the present invention will be apparent from the following description and claims, and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what are now considered to be the best modes contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the scope of the appended claims.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** is a vertical axial section of the caisson shield and its sealing apparatus according to the invention;

FIG. **2** is a cross-section along the line II—II of FIG. **1**;

FIG. **3** is a view identical to that of FIG. **1** showing on a larger scale the complete sealing apparatus;

FIG. **4** is a view identical to that of FIG. **3** illustrating on a still larger scale the part of the apparatus permitting the formation of a solid plug by freezing a liquid.

The process and apparatus described hereinafter permit the submarine construction of large linear structures, preferably of reinforced concrete which is cast in situ but they can also comprise any other appropriate material such as steel welded in situ.

In the represented example is shown a reinforced concrete pipe **1**, whereof tubular portions **2** are constructed successively and end to end. This pipe forms a route for the passage of vehicles, pedestrians and various materials. In particular, it can form a submarine or subfluvial passage or tunnel for pedestrians, road vehicles, trains, subways, etc. and can also form a pipe system for sewers or for discharging waste water out to sea.

The apparatus comprises a caisson shield **3** with a base **4** and a lateral tubular skirt **5** whose cross-section is such that it covers, with an adequate clearance, by means of its free end the already constructed portion of the pipe **1**.

This caisson shield **3** must be solidly anchored to this portion of the pipe to resist the hydrostatic pressure of the ambient water on the base **4** while a new tubular section **2** $n + 1$ is being constructed. It must also be movable forwards by the length of one section **2** when, with section **2** $n + 1$ completed, a new atmospheric space is to be isolated from the liquid medium for the construction of the next section.

To this end the base **4** of the caisson shield is integral with a shaft **6** extending coaxially with the jacket **3** and supporting both an expansible formwork **7** and an anchoring head **8**. The outer retractable wall of formwork **7** is equipped with projecting cores **9** which serve to form in sections **2** gripping slots **10** distributed in equiangular manner. Moreover, in the retracted position,

the formwork 7 can be moved along the shaft 6 by means of jacks 11 supported in both directions on the said shaft. The anchoring head 8, which is integral with the latter, is equipped with radially movable cramp-irons 12 and operated by jacks 13 which make them project sufficiently to permit them to enter the slots 10 of a section 2 and grip therein or cause them to retract so that this section cannot oppose the axial displacement of head 8, shaft 6 and caisson shield 3. Moreover, a ring 14 is arranged within the lateral tubular jacket of the caisson shield. It is connected to jacks 15 supported on the latter for its movement in axial translation following a course identical to that of form 7 and therefore to the length of sections 2.

Therefore, when section 2 *n* is completed, the jacks 15 are actuated in order to move ring 14 forwards, thereby freeing the space wherein a new section 2 *n* + *1* must be constructed. The reinforcements thereof are then fitted and bound to the projecting portion of those of section 2 *n*. A plastic foam packing 16 can also be applied to the jacket 5 permitting the subsequent easy displacement thereof without danger of jamming or seizing.

The formwork 7 is then retracted in order to remove section 2 *n* from the mold and completely extract cores 9 from the slots 10 in the latter.

As the cramp-irons 12 of head 8 are firmly gripped in the slots 10 of section 2 *n* − 2 the jacks 11 are actuated to bring about the forward displacement of formwork 7 along shaft 6 until it is located at the correct point 7*a* for the construction of the new section 2 n + 1. The formwork is then expanded and is supported by its ends on section 2 *n* and ring 14. The concrete is then cast.

When the concrete of section 2 n + 1 has become sufficiently firm the cramp-irons 12 of head 8 are retracted by means of jacks 13. As formwork 7 is firmly anchored in the concrete of section 2 n + 1 caisson shield 3 adequately resists the hydrostatic pressure of the atmosphere and can be moved forwards by a distance equal to the length of one section by means of the jacks 11 supported on the said formwork.

It is relatively unimportant which particular means are used for moving the formwork by one step relative to the caisson shield and the latter relative to the already constructed sections of the structure, because the invention concerns the sealing between the jacket 5 and the last section 2 constructed.

The following description relates to this sealing with reference to FIGS. 2 to 4.

The free end of skirt or jacket 5 has an outer wall 17 and an inner wall 18 interconnected by means of annular bulkheads 19,20 in such a way as to define a tubular refrigerating chamber 21. One or more coils located in chamber 21 are thermally connected e.g. by welding to inner wall 18. The said chamber 21 is filled with an insulating material, such as injected polyurethane foam. The coil or coils 22 are connected to a refrigerating source 23 supplying a refrigerating fluid. The refrigerating source can comprise liquid nitrogen cylinders or a refrigerating unit in a sealed case 24 integral with outer wall 17 and located above the same. Obviously, the circulation of the refrigerating fluid and its interruption are controlled by any appropriate means and more particularly by a valve 25.

The inner wall 18 delimits with the outer surface of a section 2 a tubular cavity 26 blocked at its ends by a ring 14 and an elastic joint 27 respectively. This joint comprises a thick ring 28 fixed by means of studs 29 and a counter-flange 30 between bulkhead 20 and extended by a lip 31 which is applied against the packing 16 of the cooperating section.

Thus, cavity 26 is filled with the ambient water and is frozen by the refrigerating wall 18. Therefore, an ice plug is formed which ensures the sealing between the jacket 5 of the caisson shield and the last section constructed 2 *n*. Thus, no leak can enter the working area within the caisson shield and the construction of a new section 2 *n* + 1 can be started.

Obviously the ambient water entering cavity 26 can contain corrosive particles or particles which can destroy the sealing e.g. mud, sand, algae, etc. In addition, the temperature of this water is relatively higher than the freezing temperature, particularly since on coming into contact with the concrete of section 2 *n* which evolves heat during curing the water in cavity 26 tends to heat up. Therefore the freezing period of the ice plug may become too long for the construction programme of the structure.

it is then advantageous to fix against the inner wall 18 of the jacket and in chamber 21 a toroidal tubular ring 32 for distributing the refrigerating water. This ring is connected via a valve 33 to a pure water pipe 34 which traverses a refrigerating source 35, e.g. a refrigerating unit (FIG. 1). Ring 32 and wall 18 define apertures 36 issuing into cavity 26 close to ring 14. Thus, the pure cold water expels the ambient water in this cavity, together with the impurities by raising lip 31 of joint 27. Moreover, its circulation cools section 2 *n* of jacket 5. When the temperature of the latter members is reduced by 3° to 4°C, which can take 5 to 10 minutes, the cold water is kept under pressure by progressively decreasing the flow rate until it is eliminated by means of valve 33. The coil or coils 22 is then connected by means of the other valve 25 to the refrigerating source 23 which supplies a refrigerating fluid which can be e.g. between −20° and −30°C, in such a way that the solidification of the ice plug is very rapid.

During the movement of the caisson shield 3 from section 2 *n* to section 2 *n* + 1 there is a danger of the ice plug being at least partly destroyed, whereby leaks can occur. In order to obviate this disadvantage and as can be gathered particularly clearly from FIG. 3 ring 14 is provided with both a U-shaped peripheral annular elastic joint 37 ensuring the sealing between the said ring and the inner wall 18 of jacket 5 and at least one toroidal elastic joint 38 ensuring the sealing between the said ring and the front surface 40 of the last section constructed 2 *n* + 1.

It is therefore when a new ice plug is formed, as indicated hereinbefore, between jacket 5 and section 2 *n* + 1 that ring 14 can be moved away from the latter by means of jacks 15 to provide a new concrete casting space in the caisson shield.

The invention can be used in all cases where, in order to construct a linear immersed structure by means of juxtaposed and aligned members, it is necessary to ensure the sealing between the last member constructed and a caisson shield covering the same in order to delimit a space isolated from the ambient liquid and wherein the air is renewed at atmospheric pressure.

The apparatus forming the object of the invention is applicable to the submarine construction of tunnels for the passage of pedestrians, road or rail vehicles, various

materials etc. and to pipes carrying various liquids such as drinking water, waste water, etc.

While there has been described and illustrated the preferred embodiments of the invention, it is to be understood that these are capable of variation and modification, and it is not therefore desired to be limited to the precise details set forth, but to include such modifications and alterations as fall within the scope of the appended claims.

What is claimed is:

1. In a method of constructing in a substantially normal atmosphere a linear structure immersed in a fluid in which method a portion of the structure to be added to previously formed such structure is constructed within a tubular caisson shield having a portion surrounding and spaced from said previously formed structure to provide a space between said shield and said lastmentioned structure and extending around the latter, the step of sealing said shield to said lastmentioned structure by introducing into said space a liquid which can be made solid by cooling and by cooling said liquid until it is solid.

2. The method as set forth in claim **1** in which said liquid is water and in which prior to cooling the water until it forms ice, said water, at a temperature close to its freezing temperature, is caused to flow through said space to expel ambient water and impurities and to lower the temperature of the portion of said previously formed structure and the portion of said shield defining said space, the flow of said water is then interrupted with said space substantially filled with water and then the water in said space is cooled to its freezing temperature to form a plug of ice by cooling said water in said space through said portion of said shield.

3. The method as set forth in claim **2** further comprising moving said shield with respect to said plug of ice subsequent to the formation of the latter while maintaining a fluid seal between said shield and said previously formed structure with at least one elastomeric sealing member contacting the interior of said shield and intermediate said shield and said previously formed structure.

4. Means for constructing a linear structure immersed in a fluid, said means comprising a tubular caisson shield having an open end with a skirt portion extending therearound, a feeding and stepping device coupled to said shield for stepwise advancement of the latter and extending outwardly of said open end, said device having means engageable with a previously formed portion of said structure for supporting said device during said stepwise advancement of said shield, said skirt portion having an inner wall adapted to extend around said structure in spaced relation thereto to define an annular cavity between said wall and said structure, at least one tube coil on said skirt portion in good thermal connection with said wall, and means for passing a refrigerating fluid through said coil for freezing water within said cavity and thereby provide a seal between said shield and said structure.

5. Constructing means as set forth in claim **4** further comprising a ring slidably mounted in said shield for movement away from said cavity and further comprising an activator extending between said shield and said ring for moving said ring with respect to said shield, an elastomeric seal on the periphery of said ring and engaging the inner wall of said shield and at least one further elastomeric seal on the surface of said ring facing toward said cavity for engaging and providing a seal with said structure.

6. Constructing means as set forth in claim **4** wherein said skirt portion has a free end and further comprising an elastomeric seal carried by said skirt portion at said free end, said seal having a lip engageable with said structure to close one end of said cavity, a bulkhead within said shield and spaced from said free end for closing the opposite end of said cavity, a tubular ring on said skirt portion intermediate said free end and said bulkhead and having apertures therein extending to the interior of said skirt portion for supplying refrigerated water to said cavity, and means for delivering refrigerated water to said ring, including a pump, a filter, and a refrigerating unit.

7. Constructing means as set forth in claim **6** wherein said bulkhead is a ring slidably mounted in said shield for movement away from said cavity and further comprising an activator extending between said shield and said ring for moving said ring with respect to said shield, an elastomeric seal on the periphery of said ring and engaging the inner wall of said shield and at least one further elastomeric seal on the surface of said ring facing toward said cavity for engaging and providing a seal with said structure.

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