Sept. 20, 1966 J. DELARUELLE ET AL 3,273,346

POSITIONING OF SUBMARINE TUBES

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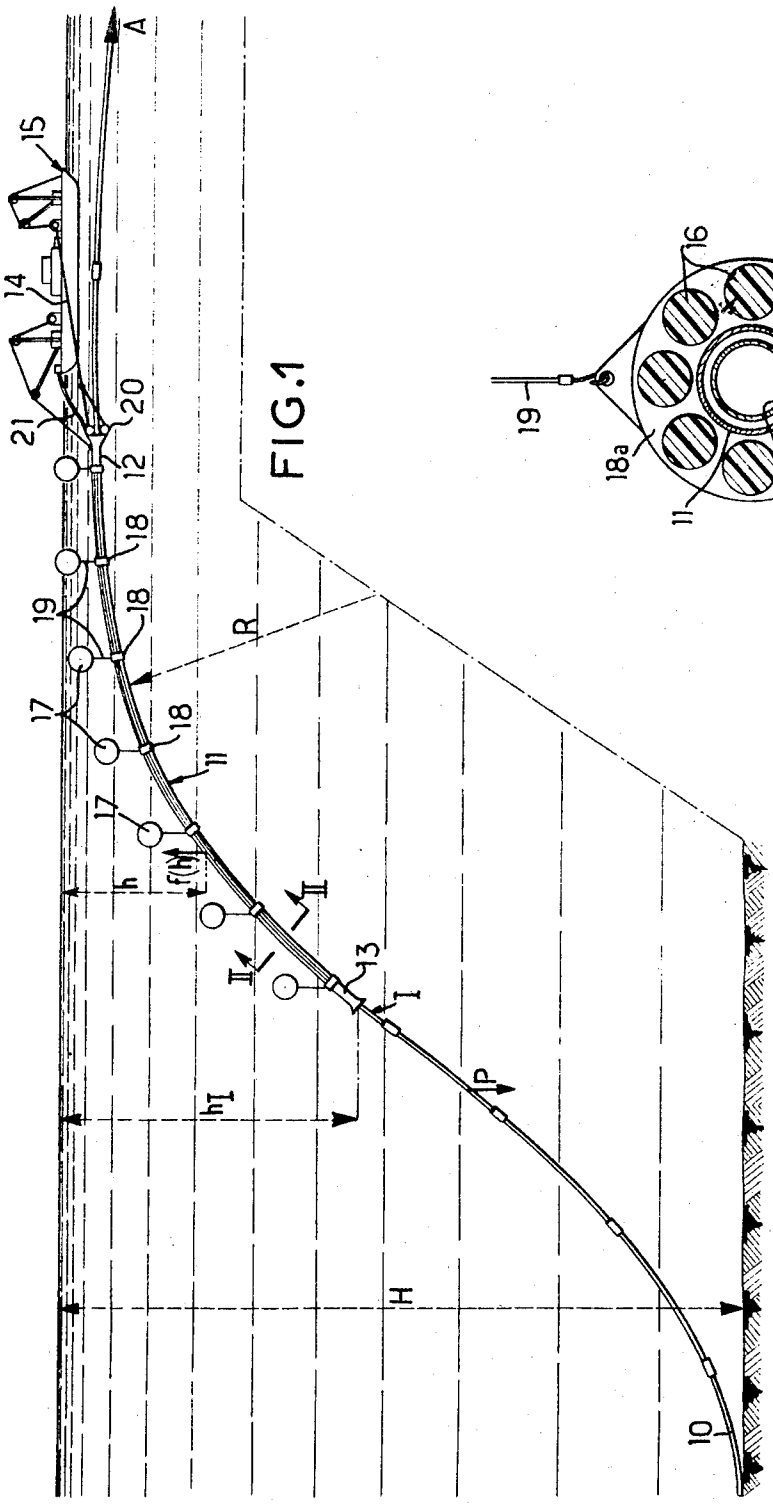


FIG.1

FIG.2

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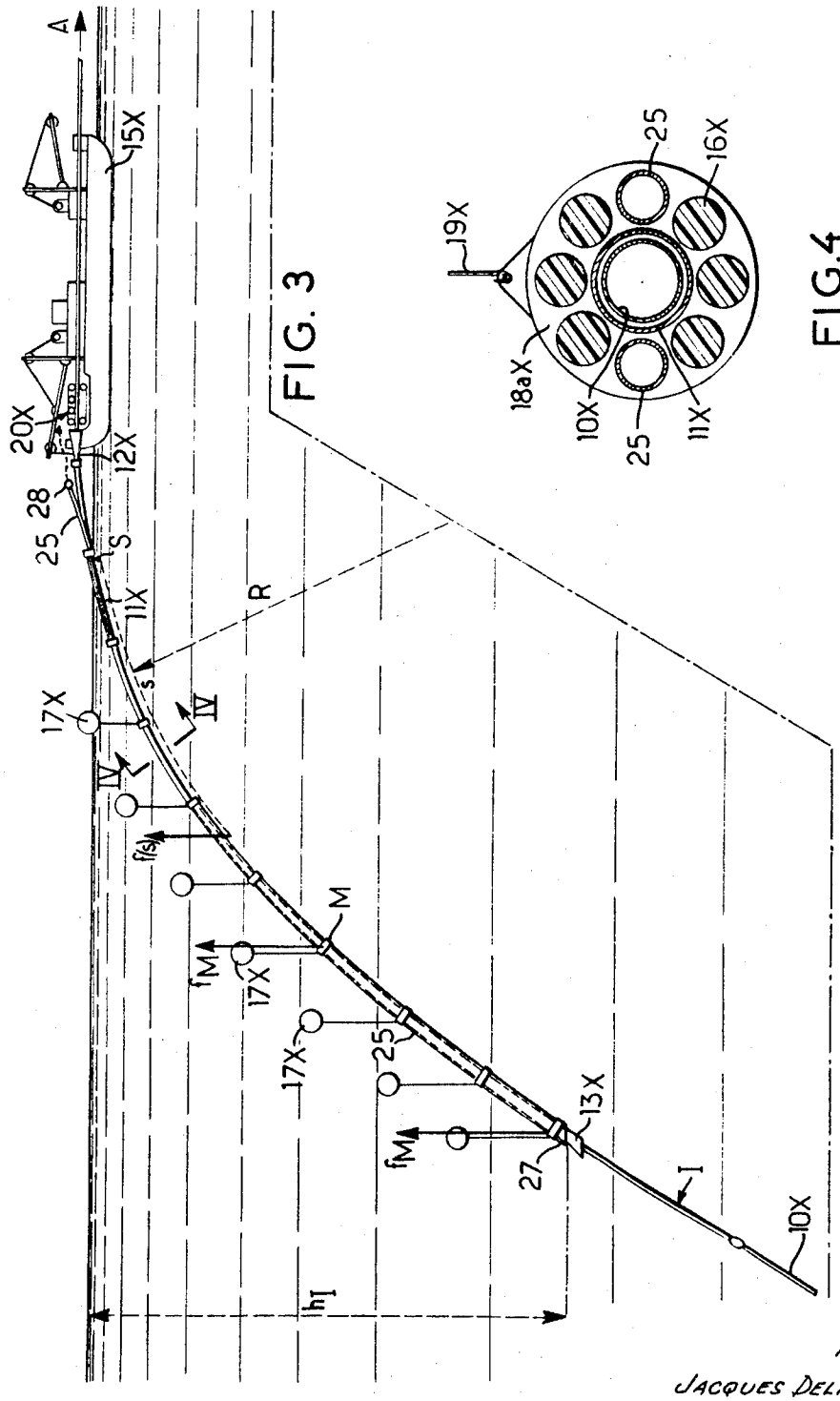


FIG. 3

FIG. 4

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3,273,346

POSITIONING OF SUBMARINE TUBES

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1 Claim. (Cl. 61—72.3)

This invention relates to the positioning of submarine tubes or pipelines and particularly to positioning such tubes at great depths employing the technique of attaching additional horizontal sections of pipeline to a section of the already laid cable or pipeline.

In the specification of co-pending patent application Ser. No. 99,148, now abandoned, a method of positioning a submarine tube so as to enable fresh sections of the tube to be attached to a previously laid section of the tube is described and claimed. That method comprises the steps of applying to the end of the section of the tube already laid horizontal and vertical forces by means of immersed floats so as to cause the tube to assume a substantially S-shape curvature with the upper end thereof substantially horizontal and defining a downwardly-directed concavity, successively releasing the vertical forces from the tube in a region of predetermined depth where the curvature of the tube passes through a point of inflection, and successively applying vertical forces to the tube in the region where the curvature of the tube is substantially horizontal.

In this method, the curvature of the section of tube already laid is produced by the combined action of a horizontal traction applied to the end of the tube already positioned and of a number of vertical forces appropriately distributed along the upper portion of the said tube and produced by means of a series of lightening floats.

The performance of this method necessitates either the unhooking of at least some of the lightening floats as positioning progresses beyond a region of predetermined depth, and the rehooking of the same onto the freshly added sections, or the use of floats constructed progressively to lose their buoyancy which diminishes and loses its lifting effect at a certain depth.

The present invention is concerned with an improvement of the aforesaid methods and makes it possible to avoid, in the former case, the periodic hooking and unhooking of the floats and consequently to economize the fleet of boats necessary for laying the tube, and, in the latter case, the loss of the variable-buoyancy floats or the difficult problem of their recovery.

According to one aspect of the present invention there is provided a method of positioning a submarine tube so as to enable fresh sections of the tube to be attached to a section of the tube already laid, wherein there are applied to the end of the section of the tube already laid horizontal and vertical forces to cause the tube to assume a substantially S-shaped curvature with the upper end thereof substantially horizontal and defining a downwardly-directed concavity, and wherein the vertical forces are applied to the tube through the intermediary of a flexible guide connected to a rigging craft, positioning being effected by imparting a horizontal translational movement to the guide and by sliding the tube relative to the guide. In other words, the upper portion of the tube is carried by the aid of a guide which is itself carried by floats or other lightening means distributed appropriately along its length so as to impart the desired curvature to it.

By virtue of this arrangement, positioning may be performed by simply sliding the tube through the guide at a

speed equal to the speed of horizontal translation of the guide and of the tube between the bottom and the surface. In this manner at least a part of the lightening force required for positioning the tube the attainment of which force generally represents a large proportion of the cost of the tube, is not exerted directly on the latter but on the guide. Each new tube element to be positioned is butt-jointed to the extremity of the previous element which has arrived close to the entrance of the guide, and is in turn introduced into the latter. The said elements may be sections of great length brought up either in the holds of ships or by flotation. They may likewise be comparatively short sections assembled by screwing or welding on board a factory ship which performs the positioning and carries the entrance of the guide.

This invention also relates to a device for performing the above method, such device including the aforesaid guide.

This guide is intended to guide and carry the submarine tube between its upper extremity or extremity of entry located close to the surface of the sea where the tube is horizontal, and its lower extremity or extremity of exit which is close to the point of inflection of the tube, and the guide will necessarily have a comparatively great length; since submarine tubes do not usually permit radii of curvature less than some tens of metres, the length of the guide will be from some tens to some hundreds of metres.

This comparatively great length makes it necessary that the guide should be deformable so as to be able to resist the constraints to which it is subjected on the part of the tube, of its lightening means, and of marine currents. Thus it is necessary for the guide to have an articulated or flexible structure, not merely in the vertical plane in which the desired curvature is in principle located, but also in the horizontal plane. Indeed, whereas in the case of positioning in the absence of transverse currents the S-shaped curve of the tube is contained in a vertical plane, in the general case where marine currents are present and have a component of motion perpendicular to the alignment of the tube, the upper portion of the tube will describe a skew curve in the region of action of the currents.

The guide must be as light as possible, so that its own lightening means intended to support it in the water shall not be excessively voluminous, as this would render it expensive and would likewise confer the disadvantage of presenting too great a grip or purchase for marine currents.

As the tube is acted upon by its own weight, which may be considerable, it is necessary to provide a braking system capable of resisting the relative movement of the tube with respect to the guide with a force at least equal to the said action.

Accordingly, another aspect of the present invention provides a device for positioning a submarine tube so as to enable fresh sections of the tube to be attached to a section of the tube already laid, wherein the device comprises an elongated guide which is flexible both in its longitudinal direction and transverse thereto, the guide being capable of supporting the tube to be positioned between an upper extremity of entry adapted to be connected to a rigging ship, and a lower extremity of exit, and wherein means is provided for exerting a vertical force on the guide, when immersed, to impart thereto a curvature defining a downward concavity between the two said extremities, the upper of which lies substantially horizontal, there also being provided a braking device adapted to oppose the relative movements of the tube by a force adjustable at will.

The braking device is desirably arranged at the entrance of the guide, and this arrangement provides the advantage in practice, that, because—as will be seen here-

inafter—it is by adjusting the braking action that the speed of positioning is regulated and, more particularly, that stoppage of the said positioning is obtained.

The guide may take various forms, such as for example, a chain of roller type cradles, which would be capable of supporting and guiding the tube and of presenting the required double flexibility by virtue of a series of appropriate articulations, to which the lightening or additional lightening floats of the guide might be hooked. However, the guide is preferably a cylindrical guide tube extending with a substantially uniform internal cross-section adapted to permit sliding of the tube with sufficient play between two flared end nozzles.

Such a tubular structure presents surprising advantages, since the assembly of the tubular structure with the submarine tube in its interior behaves—from the mechanical standpoint—like a flexible rope stretched in a flexible sheath, and the longitudinal compression of the sheath at each point does not lead to buckling thereof, by reason of the corresponding tension of the tube at that point. The guide sheath may advantageously be made of steel having a thickness of only a few millimetres in order to resist simple compression. Since its internal diameter is close to the external diameter of the tube, it is protected by the tube itself against any tendency to undulate. The construction becomes especially simple and economical in the case where the sheath is constructed of sections of 10–15 metres in length as it is then possible to hook floats onto sleeves connecting the said sections. It is easy to provide a primary lightening means in the form of bundles attached to the periphery of each section so as to provide the guide itself immediately with a low weight in water and thus to reduce the buoyant capacity required for the floats. The flexibility imparted to the tube by its slight thickness is amply sufficient to provide the guide with the double flexibility which is required simultaneously in the vertical plane and in the transverse direction. The flared end nozzles facilitate the entry and the exit of the tube and avoid the risk of damage to the anti-corrosive cladding with which the latter is generally fitted.

Such a tubular guide is readily transported between two positioning operations by towing it between different locations in the same manner as a section of the tube. For this purpose, it is sufficient for the primary lightening means secured directly to the external face of the guide to provide the latter with a low weight in water—for example, 2 kg./m.—the balance of the lightening means being constituted by floats attached to the guide by means of guy-ropes of sufficient length to lower the guide to a position where it is unaffected by any surface swell.

In order to enable the invention to be more readily understood, reference will now be made to the accompanying drawings, which illustrate diagrammatically and by way of example some embodiments thereof, and in which:

FIGURE 1 is a diagrammatic elevation of a method of laying and positioning a submarine tube using a guide having lightening means distributed uniformly along it,

FIGURE 2 is an enlarged cross-section taken along the line II—II in FIGURE 1,

FIGURE 3 is a view similar to FIGURE 1 showing another method of laying and positioning a submarine tube, employing variable lightening means along the guide, and

FIGURE 4 is an enlarged cross-section taken along the line IV—IV in FIGURE 3.

Referring now to FIGURES 1 and 2, there is shown the positioning of a submarine tube **10** which is being laid at a depth H. That portion of the tube **10** which is not yet in contact with the bottom has its extremity subjected to a horizontal tractive force in the direction of the arrow A and produced by one or a plurality of tugboats, not shown in the drawings. A tubular guide **11** extends from a flared nozzle **12** forming its upper extremity or extremity of entry to a flared nozzle **13** forming its lower extremity or extremity of exit, the extremity **12** being immersed in this case to a depth of a few metres and attached by means of cables **14** to a positioning ship **15**. Instead of attaching the guide to the ship, it is also possible effectively to render the guide integral with the ship by anchoring it in the ship, as will hereinafter be described with reference to FIGURE 3. The tubular body **11** of the guide is composed of sections of a steel pipe having an internal diameter slightly greater than the external diameter of the tube (or more precisely, of connecting sleeves of the latter) in such a manner that the tube is able to slide through the body **11** of the guide. As shown in FIGURE 2, each section of the tubular body **11** is covered externally with a bundle of rods **16** of cellular material such as expanded polystyrene, constituting a primary lightening means, and a series of floats **17** are hooked through the intermediary of brackets **18***a* to the connecting sleeves **18** of adjacent sections of the guide by means of guy-ropes **19**, which are, for example, some 15 metres in length. The connecting sleeves **18** will advantageously be of the screw-threaded type, which enables the guide to be shortened or lengthened more readily whenever necessary.

A device for braking the tube is constituted by a toroidal hollow body **20** of flexible material disposed round the tube adjacent the entry nozzle **12**, and connected by a flexible pipe **21** to a source of pressurized fluid (not shown in detail) arranged on board the ship **15**, means being provided for regulating the pressure of the said fluid as required between certain limits. Such braking devices are disclosed in greater detail in U.S. Patent No. 2,775,869, Jan. 21, 1957, and also in French Patent No. 1,081,361, Dec. 20, 1954, and its Addition No. 66,721, Aug. 19, 1957, and in French Patent No. 1,132,160, Mar. 6, 1957. Reference is made to these prior patents so as to avoid the inclusion of unnecessary disclosure of known structure in the present application.

As may be seen in FIGURE 1, the guide **11** supports the tube **10** and guides the same, between the entry nozzle **12** located close to the surface and the exist nozzle **13** located at a certain depth h_1, along a curve of downward concavity between a substantially horizontal point of departure at the entry **12** and a point of inflection I located in the vicinity of the exit **13**.

The immersion to a depth of some metres of the upper extremity of the guide, as illustrated in FIGURE 1, presents the advantage of sheltering the guide from the effects of any surface swell.

The first element of the tube to be positioned with the guide is placed in the tubular guide structure at the shore workshop where the elements are prepared, and the whole is launched and towed to the point of commencement of positioning or of connection of the said element to a portion of tube already positioned—possibly by other methods. The first operation therefore will be to butt-joint the rear extremity of the first element carried by the guide—still at the surface—to the terminal portion of the tube already positioned. The said terminal portion may be maintained provisionally in the S-shaped position required to that end by means—for example—of appropriate floats according to any one of the techniques we have described elsewhere. The S-shaped configuration of the tube and guide will be established as the terminal portion of the tube already positioned is allowed to descend towards the bottom, involving in the said movement the first element carried by the guide. The chosen configuration having been effected, regulation of the speed of positioning is obtained from then onwards by means of the pneumatic or hydraulic brake **20**, in proportion to the depth and desired speed of positioning. The new tube elements are brought up to the site from the shore workshop by towing, for example, and are equipped for that purpose with appropriate lightening means, the elements being freed from the said lightening means shortly prior to their arrival at the entrance to the guide.

The shape of the guide may be the subject of a continuous check, both during positioning and during stoppage, and to this end a certain number of—for example, manometric—appliances giving the depth at the corresponding points, and inclination indicators, if desired, may be distributed along the guide. The indications of the said appliances can readily be transmitted to the surface by means of suitably protected signalling cables attached along the guide. Since the said arrangements involve only well-known and tried techniques, it is not deemed necessary to show them in detail in the accompanying drawings.

The guide such as described presents to the currents a grip or purchase little greater than that of the tube itself, so that its presence does not substantially increase the difficulties of positioning across the current. Its flexibility also enables it to assume easily the form of a skew curve in the region of action of a current which is oblique with reference to the positioning direction.

If bad weather should make it impossible to continue positioning operations, the assembly of tube and guide is completely immersed and laid on the sea bed, so that it is sheltered from marine currents and from the swell. In order to facilitate the immersion, it is advantageous to effect a part of the lightening of the guide by means of floats which are adapted to lose their bouyancy progressively with increasing depth—for example, of compressible floats or of floats adapted to allow water to penetrate when the external pressure exceeds a certain value. Such floats are described and claimed in the earlier-filed application of one of the present inventors, which matured to U.S. Patent No. 3,114,920, Dec. 24, 1963. Reference is made to this patent in order to avoid the unnecessary disclosure of known structure in the present application.

To effect immersion of the assembly to the sea bed, it is sufficient to seal the tube element which is being positioned and to secure its extremity to the extremity of the guide, to release the latter from the positioning boat **15** whilst disconnecting the pipe **21**, to ballast it with a deadweight, and to exert on the assembly a fairly strong tractive force (for example, of the order of twice the normal positioning traction force A) by the aid of the cable or rope **14**, for example. The effect of this tractive force is first to straighten slightly the S-shaped curve of the still unpositioned portion of the assembly of the tube and guide. The steel cable or rope **14** is then unwound, enabling the deadweight to drag the extremity **12** towards the bottom, and when the guide **11** has arrived on the bottom, the steel rope is made fast to a buoy.

The buoy enables the tube to be marked, and to be returned to the surface when weather permits positioning operations to be resumed.

In order to return the assembly to the surface it is merely necessary to raise the rope **14** in order to bring the extremity **12** of the guide up to the surface. The use of the compressible floats referred to hereinabove, which regain their buoyancy above a certain depth, facilitates the re-establishment of the S-shaped curve and the continuation of the positioning operation.

When determining the lightening means to be disposed on the guide, the conditions of equilibrium when positioning is stopped must be taken into account. During laying, the horizontal translation of the S-shaped curve formed by the tube and the guide generates hydrodynamic forces, the horizontal components of which oppose the movement, but the vertical components of which are directed upwards and are added to the lifting force of the floats on the guide.

It can be shown that the general condition of equilibrium at rest of the tube and guide assembly between the bottom and the surface is expressed by:

$$pH=\int_0^{h_I} f(h)\,dh \qquad (1)$$

where

p is the apparent weight of the tube in kilograms/meter,
H, the positioning depth in meters,
$f(h)$, the lifting force in kilograms per metre at a point of depth h (in meters) of the guide, and
h_I, the depth in meters of the lowest point of the guide located in the vicinity of the point of inflection I of the S-shaped curve.

The lightening means of the guide must therefore be constructed in such manner that the said relation is satisfied. It is also necessary for the radius of curvature in the vicinity of the surface in the least favourable case—i.e. during stoppage—to be greater than the minimum value dictated by the mechanical strength of the tube and of the guide.

Where A designates the horizontal traction force in kilograms exerted at the surface on the tube and guide assembly, and $f(o)$ the buoyancy in kilograms/meter of the guide at the surface, it can be shown that the radius of curavture R, in meters, of the upper portion of the S-shaped curve is given, if the rigidity of the tube and of the guide are neglected, by the formula:

$$R=\frac{A}{f(o)-p} \qquad (2)$$

It should also be noted that the rigidity always has a favourable effect upon the behaviour of the tube, but that its effect upon the shape of the S-shaped curve is generally negligible.

Taking these fundamental observations into account, various manners of lightening the guide are contemplated according to the present invention.

In the construction illustrated in FIGURE 1, the lightening means have been considered as uniformly distributed along the guide, and this is the simplest arrangement.

It is easy to demonstrate that the guide in this case assumes substantially the form of a catenary (except for the rigidity). If the adopted uniform value of the lightening provided is designated by f (corresponding to fo of Equation 2), the condition of equilibrium 1 gives as the depth of the lowest point of the guide:

$$h_I=\frac{p}{f}H \qquad (3)$$

Taking $f=2p$, the point of inflection I is seen to be located at one half the depth, and the S-shaped curve is in that case constituted by two identical catenaries which have vertical axes, and which are tangential respectively to the bottom and to the surface, the catenaries being connected together at the point of inflection.

The said arrangement—the simplest—presents the drawback that it necessitates a relatively great length for the guide, which increases its cost and the cost of the lightening means. It is advisable to bring the point of inflection I as close as possible to the surface by increasing the buoyancy f, involving the necessity of simultaneously increasing the horizontal tractive force A so as not to go below the dictated minimum radius of curvature.

A practical example of the application of this manner of uniform lightening will be given hereinafter:

Apparent weight of the tube p _____ 10 kg. per metre.
Positioning depth H _____ 2500 metres.
Permissible radius of curvature R ____ 100 metres.
Permissible tractive force A _____ 4000 kg.

Under the above conditions, the depth h_I of the point of inflection is located at 500 m., and the length of the guide is approximately 600 m.

The buoyancy f of the guide will have to be 50 kg. per metre (i.e., five times the apparent weight of the tube) and the lightening means to be provided in the guide will be equal to this value plus the apparent weight in water of the guide itself.

Since the tube when fitted with its covering has an external diameter—in the particular case under consider-

ation—of 270 mm., the guide will be constituted by a steel-pipe of 300 mm. internal diameter and of a quality which will enable it to tolerate the radius of curvature of 100 m. under a longitudinal compressive force equal to the maximum braking force—i.e., pH=25 tons.

Under these conditions, the guide should be 5 mm. thick, as the maximum fatigue rate of the metal under these conditions is 40 kg./mm.^{2} in the compressed state.

Since the weight in water of the guide thus constituted is 32 kg./m., the total lightening to be provided will therefore be 82 kg./m.

The primary lightening produced by the bundle **16** of rods of expanded polystyrene (density 0.6) is 30 kg./m. and the secondary lightening of 52 kg./m. is constituted by floats **17** having a buoyancy of 1600 kg. hooked at every 30 metres by guy-ropes 15 metres in length.

The length of the guide is of course provided for the maximum positioning depth to be contemplated. Where the depth is less than this maximum, only one portion of the guide is immersed at depth, the other remaining in the vicinity of the surface, so that the buoyancy of the guide shall correspond to the weight of tube in course of being positioned; this variation of the immersed length of the guide, and therefore in the depth h_I of the point of inflection, is rendered possible by the combined action of the horizontal traction force A and of the operation of the brake. Of course, this adjustment of the brake becomes impossible above a certain limiting depth, and it is then necessary either to exert the traction force A on the guide itself, or else to shorten the guide, for example when butt-jointing a new section.

Instead of the uniform lightening considered hereinabove, it is likewise possible to contemplate a variable system of lightening (FIGURE 3), and preferably a form of lightening which increases with depth. It can be shown that if an increasing lightening $f(s)$ kilograms/meter, is disposed along the guide and has the value:

$$f(s)=p+\frac{A}{R\cos^2\frac{s}{R}} \qquad (4)$$

where R is constant and s the distance in meters of the point in question from the origin S of the guide at the surface, the curve formed by the guide will be a circular arc of radius R, tangential to the surface at S.

It is not usually possible to retain this law of distribution as far as the point of inflection I, because the lightening $f(s)$ would then have to attain excessively high values, which are difficult to realise in practice.

As from a specific point M, it is thus necessary, for example, to retain a lightening of constant value f_M kilograms/meter, and the curve is then continued beyond the said point M by a catenary arc.

It is possible to show by calculation that this manner of lightening results in a much smaller length and depth for the guide than in the case of a uniformly distributed lightening, whilst simultaneously the tractive force A to be exerted at the surface may be relatively slight, and now limited only by the curvature at the bottom.

Taking once again the conditions considered in the previous example, of a tube weighing 10 kg./m. in water and positioned at a depth of 2500 m. with a permissible radius of curvature of 100 m., the tractive force A to be exerted will be 1000 kg. the length of the guide will be reduced to 215 m. and its depth h_I to approximately 160 m., with variable lightening ranging between $f(o)$=10 kg./m. at the surface and a maximum f_M=250 kg./m. over a length of approximately 80 m. in the lower portion.

To this variable lightening there will of course be added a uniform lightening of 42 kg./m. corresponding to the weight in water of the guide and of the tube, also a lightening element to compensate for the weight of the floats themselves.

Referring now to FIGURES 3 and 4, which illustrate an example of such a construction, the reference symbols already used in FIGURES 1 and 2 are repeated, accompanied by the index X to designate corresponding or equivalent elements.

It will be seen that the floats **17X** are again attached to the guide **11X** through the intermediary of guy-ropes **19X** and of brackets **18***a*X fastened to the connecting sleeves. The above variable supplementary lightening is composed of pipes **25** of increasing cross-section extending from the upper extremity of the guide, the pipes **25** being fastened end to end along the guide and communicating with one another. The pipes **25** are open at their lower extremity **27**, and hence communicate with the sea, whereas at their upper extremity **28** they are placed in communication by a flexible pipe with a source of compressed air (not shown) carried by the ship **15X**.

In this manner, supplementary adjustment of the additional lightening is effected in proportion to the positioning depth. This supplementary adjustment is necessary here, because it is no longer possible to cause a variable initial portion of the guide to rise to the surface when the positioning depth becomes smaller; the result of this would be to diminish the radii of curvature at all points.

The device described enables the length of lightening of the guide near its lower extremity towards the point of inflection I—and hence the depth of that point—to be regulated. It will be seen, in fact, that the supplementary lightening produced by the pipes **25** exists only above the level at which the water rises in their interior. Now, this level is determined by the air pressure of the compressed air source from the ship. If the guide has a tendency to rise to the surface, the pressure is reduced so as to make its lower portion heavier, but if on the contrary it tends to sink, the pressure of the compressed air source is increased until equilibrium is achieved.

In the case of the example considered, the said variable lightening is constituted by the two pipes **25** which are arranged on each side of the guide, and the diameters will vary between 80 mm. at the upper extremity and 400 mm. towards the lower extremity.

The conditions of braking and of longitudinal compression of the guide remain unchanged.

In the case of the construction illustrated in FIGURE 3, the upper extremity **12X** of the guide is taken on board the ship **15X**, where the butt-jointing of the successive tube elements may be effected. In this case, the extremity of the guide is anchored and made integral with the craft, and braking of the tube may be effected by any known system—for example, the ship's brake or a "caterpillar" of the type indicated at **20X**—which is arranged on the deck of the ship and in which the tube is engaged.

In the event of bad weather, in this case as with the previous example, steps will be taken to immerse the tube and guide assembly and lay it on the sea bed after disengaging the extremity **12X** from the ship **15X**. This operation is facilitated in the present case by the variable lightening constituted by the pipes **25**. It is in fact sufficient to bleed the air completely from the pipes in order to immerse the assembly. Upon subsequent raising, the pipes are repressurised when the extremity reaches the surface.

It should also be noted that during the course of operation the sliding movement of the tube in the guide naturally depends upon the friction. However, the total effect of friction on the tube in the guide is usually very much lower than the braking force requiring to be exerted between the tube and the guide. There is therefore a favourable diminution of the braking required. In the course of the studies on construction shown in FIGURES 1 and 2, it was possible to estimate the magnitude of the braking force by distinguishing between the following three terms:

(1) Friction on that portion of the guide located between the point of inflection I and the surface;

(2) Friction on that portion of the guide which possibly remains in the vicinity of the surface (in the case of uniform lightening with reduced positioning depth);

(3) Friction resulting from undulations produced by the localised forces of the floats.

In the example considered above, the calculations performed yield a total friction force of approximately seven to eight tons, taking a co-efficient of friction at rest of 0.2 and a distance of 30 metres between localised floats. The braking force exerted at rest is therefore reduced, by virtue of the friction, to only 17–18 tons for a depth of 2500 metres.

During positioning, the reduction in the frictional resistance of the tube against the guide due to the lowering of the coefficient of friction is more or less compensated, as regards the braking force to be exerted, by the hydrodynamic forces which—as stated hereinabove—produce an additional lightening of the tube, which is subtracted from the total weight *p*H to be compensated.

By means of the present method it is possible to position an unlightened, or at least comparatively unlightened, submarine tube, with a resulting economy of positioning costs. Furthermore, the length of the successive tube elements to be positioned is irrelevant, and the method enables the tube to be constructed on board the positioning craft with the help of short screwed or welded sections. Since the guide is provided for a given maximum positioning depth, positioning may be performed at any intermediate depth without major modification using a guide of simple and inexpensive construction, and the method thus has great flexibility of utilisation.

In addition the positioning speed may easily be adjusted or stopped by means of the brake without the use of auxiliary stoppage floats, and the tube need not be subjected to substantial traction forces at the surface, thus enabling tugs of comparatively low power to be employed.

The rigidity of the guide is added to that of the tube in the upper portion of the S-shaped curve, where the flexural constraints are greatest when positioning is stopped, and devices may be installed to check the shape and location of the upper portion of the S-shaped curve. The guide and tube assembly offers little grip or purchase to marine currents, and—in the case of positioning across the current—readily assumes the form of a skew curve, while in the event of bad weather, it can be immersed and laid on the sea bed so that it is sheltered from marine currents and from the surface swell.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent, is:

In a method for laying a hollow steel pipe to be used as a pipeline on an immersed bottom from one shore to another shore by imparting to said pipe a resilient deformation in an immersed section thereof that joins a pipe portion already laid to a pipe portion awaiting to be laid with the latter portion adjacent the vicinity of but below the surface of the water and in a position substantially parallel to the surface of the water, said deformation

being such that said pipe section has a lower branch tangential to the bottom and an upper branch having a horizontal terminus and an S-curve between the bottom and said horizontal terminus, the S-curve having an inflection point between said branches, said section progressively sinking to the bottom during laying of the pipe so that the S-curve advances toward said another shore with said horizontal terminus moving above and in advance of said inflection point and said inflection point moving above and in advance of the point at which said lower branch is tangential to the bottom, with said horizontal terminus and said inflection point and said tangential point all advancing in that order lengthwise along the pipe, said pipe further having by itself when immersed a negative buoyancy; the improvement comprising imparting to said upper branch a positive buoyancy by supporting said upper branch on and for sliding movement relative to an elongated guide which extends from adjacent said inflection point to adjacent said horizontal terminus and which is flexible in all transverse directions while applying upward buoyant forces to said guide simultaneously at a plurality of points distributed lengthwise of the guide, the sum of said buoyant forces being greater than the sum of the submerged weights of said guide and said upper branch, moving said guide relative to said pipe while maintaining the positions of said forces fixed relative to each other along the length of the guide, in the direction of said another shore, at a speed equal to the speed of laying said pipe, while exerting on said pipe adjacent the surface of the water a horizontal traction in the direction of said another shore.

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