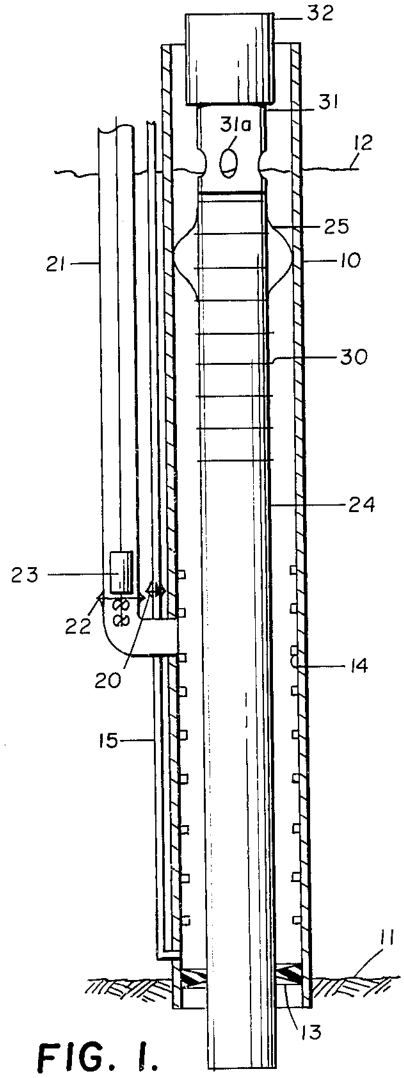

FIG. 1.

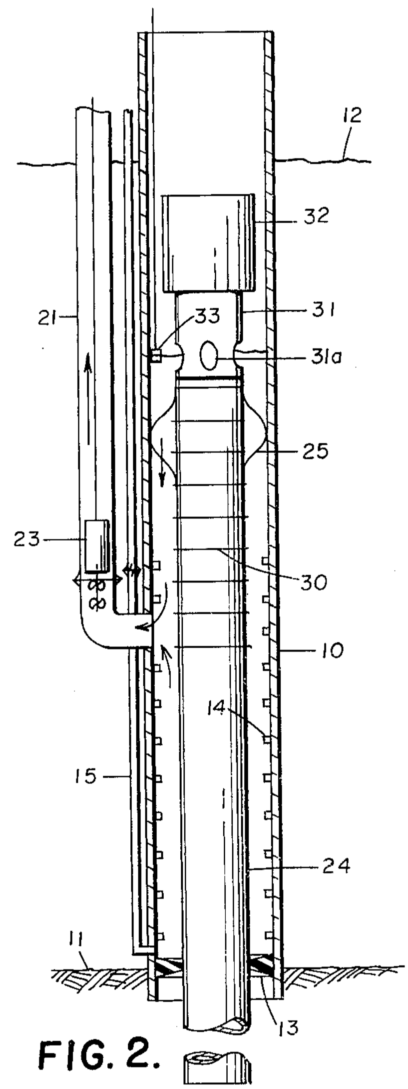

FIG. 2.

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Oct. 26, 1965 W. F. MANNING 3,213,629

APPARATUS AND METHOD FOR INSTALLATION OF A PILE-JACKET ASSEMBLY IN A MARINE BOTTOM

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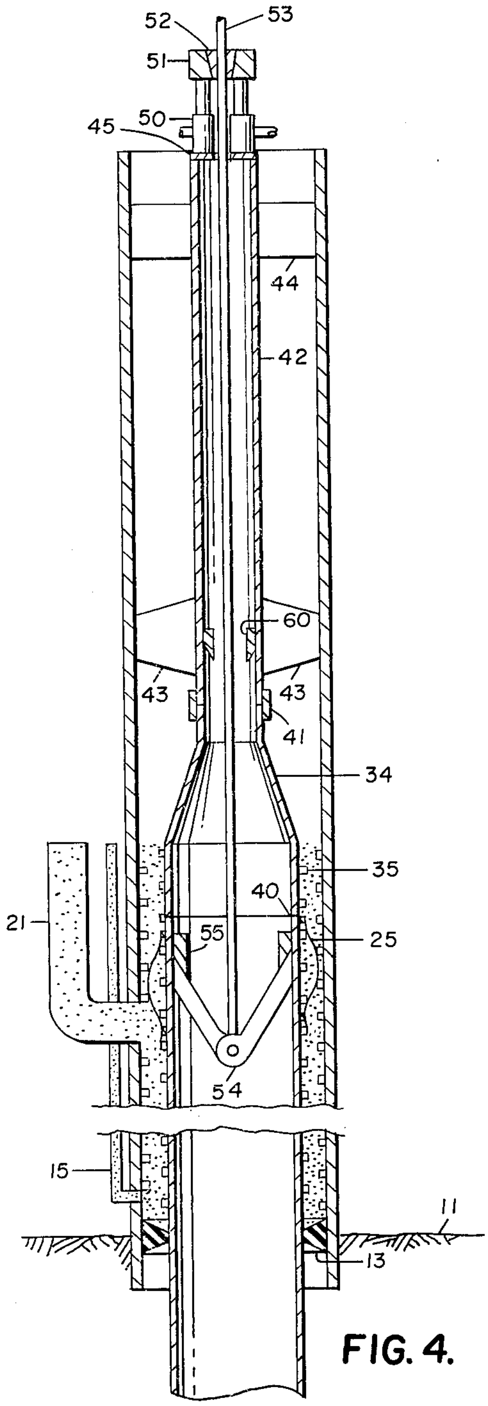

FIG. 4.

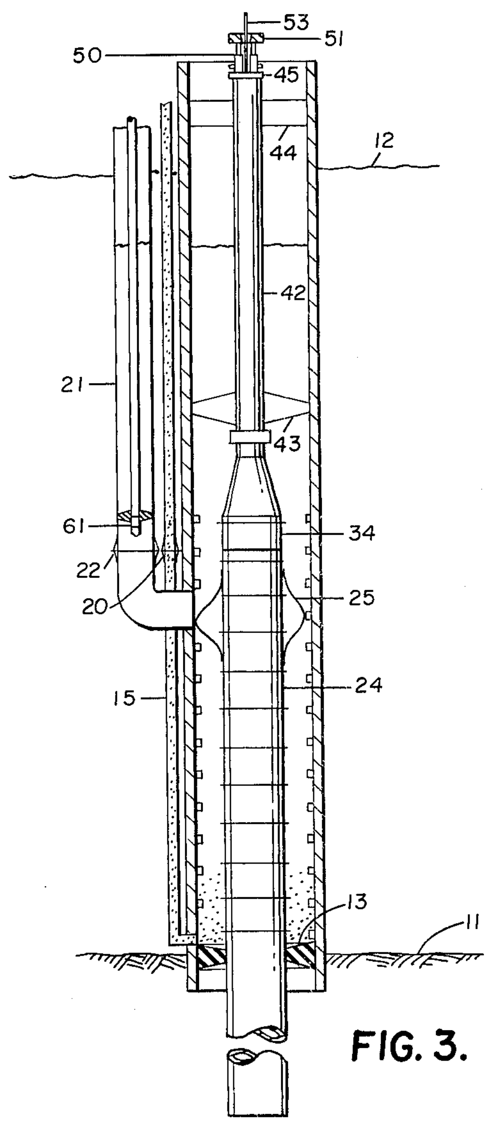

FIG. 3.

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APPARATUS AND METHOD FOR INSTALLATION OF A PILE-JACKET ASSEMBLY IN A MARINE BOTTOM

Filed March 20, 1963 3 Sheets-Sheet 3

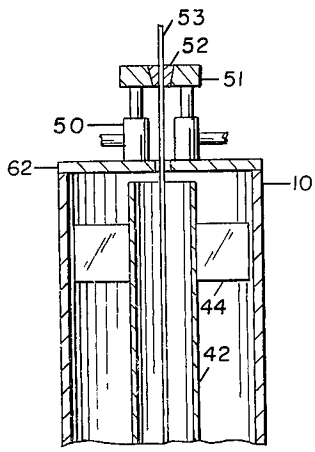

FIG. 5.

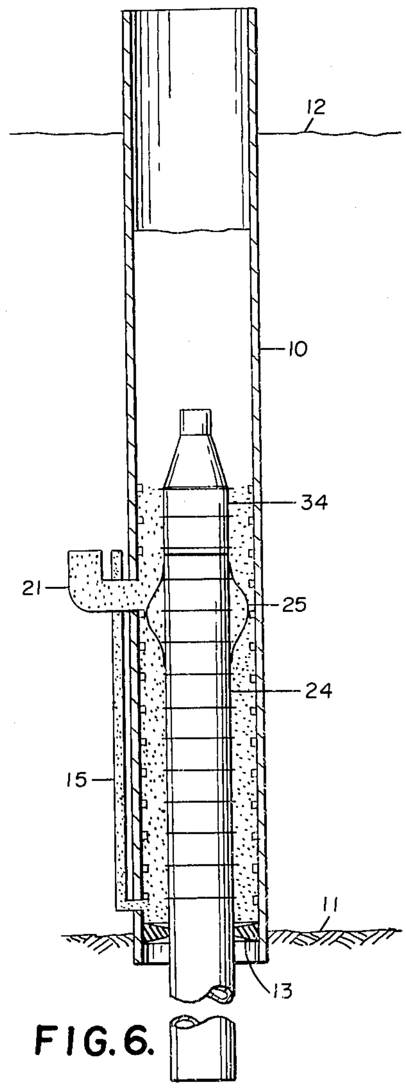

FIG. 6.

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United States Patent Office

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Patented Oct. 26, 1965

3,213,629

APPARATUS AND METHOD FOR INSTALLATION OF A PILE-JACKET ASSEMBLY IN A MARINE BOTTOM

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Filed Mar. 20, 1963, Ser. No. 266,734
13 Claims. (Cl. 61—53.52)

This invention relates to apparatus and a method of installing a pile and jacket assembly in an ocean bed. More particularly, this invention relates to the driving of a pile through a jacket into an ocean bed, securing the pile to the jacket by grouting, and subsequently testing the bond obtained between the pile and the jacket.

The securing of piling into earth structures underlying ocean beds is an art which has been practiced over a period of many centuries. In recent years, an important application of piling installations has been in connection with offshore structures in the drilling of oil wells and the subsequent producing of oil from such wells. Various problems are encountered in connection with such applications due to the extreme water depths often involved.

In the most common form of pile installation in water, each pile is driven with the driving force being applied at locations above the structure through which the pile is being driven and generally above the level of the water. In some instances, a pile has been driven through a structure such as a caisson with the driving hammer following the upper end of the pile downwardly through the caisson, the caisson being watertight and thus dry throughout its length. The keeping of such caisson dry can present serious and expensive problems.

For various reasons it is preferred, where a pile is installed in an ocean bed through the leg of a structure or some other form of jacket extending to the ocean bed, that a pile of minimum length be used. Elimination of excess length of pile which must be cut off above the jacket reduces the cost of an installation. In addition, increased driving efficiency by improving the effectiveness of the hammer blows is obtained by minimizing the distance between the point at which the hammer blows are applied to the pile and the ocean bed into which the pile is being driven. Such advantages may be obtained by providing methods and apparatus wherein the driving hammer may follow the pile into the jacket through which the pile is being driven. Also, with the hammer following the pile into the jacket, the jacket may be positioned at angles other than vertical, with the hammer being adequately supported within the jacket itself.

It is an object of the present invention to provide pile and jacket apparatus and a method for installing same wherein there is a reduction in excess pile length and an improvement in efficiency of energy utilization in driving the pile. It is another object of the present invention to provide pile and jacket apparatus and a method for installing same wherein a pile hammer may follow the pile through the jacket until maximum penetration of the pile into an ocean bed has been obtained. It is a still further object of the invention to test the bond obtained between a pile and a jacket when the pile has been grouted to the jacket.

In accordance with one aspect of the invention, there is provided a method of installing a pile and jacket combination on an ocean bed which includes the steps of positioning a jacket in a body of water with its lower end at or adjacent to the bottom; placing a pile through the jacket with the lower end of the pile being allowed to come to rest in the bottom; driving the pile downwardly through the jacket by means of a pile hammer, the pile hammer following the pile through the jacket until maximum desired pile penetration is obtained while simultaneously reducing the water level within the pile and jacket to maintain such water level below the point of impact by the pile hammer; and, when maximum desired penetration of the pile into the bottom is obtained, grouting the pile to the jacket. In accordance with another aspect of the invention, there is provided a pile and jacket combination which includes a hollow jacket open at opposite ends, having in its lower internal region a quantity of grout lugs and at its lower end an annular seal adapted to cooperate with a pile to form a substantially watertight barrier at the lower end of the jacket; means connected into the jacket for progressively lowering the water level within the jacket and pile to a point below the lowest position at which it will be necessary to apply energy by means of a pile hammer to the upper end of a pile within the jacket; means connected into the jacket for pumping grout into the lower portion of the jacket; and a pile adapted to be positioned through the jacket, the pile having a plurality of grout lugs surrounding its upper region. In accordance with a further aspect of the invention, there is provided a method of testing the bond achieved between a pile and a jacket which have been grouted together including the steps of positioning a pile test section on the upper end of the pile within the jacket; pumping grout into the annular space between the test section and the jacket; allowing the grout to set; and applying a predetermined force to the test section, tending to break the bond between the test section and the jacket. In accordance with a still further aspect of the invention, apparatus is provided for holding a pile and jacket together during grouting and for testing the bond obtained between the pile and jacket where the pile has been grouted to the interior of the jacket, such apparatus including a pile test section positionable upon the upper end of the pile; means for exerting a force between the test section and the upper end of the pile, tending to urge the test section into contact with the pile; and means for exerting a force between the test section and the jacket, tending to break the grout connection between the test section and the jacket.

In the drawings:

FIGURE 1 is a view in cross section illustrating the apparatus of the invention with a pile in position ready to be driven into an ocean bed;

FIGURE 2 is a view similar to FIGURE 1 illustrating an intermediate step in the driving of the pile into the ocean bed;

FIGURE 3 is a view similar to FIGURE 1 showing the pile driven to maximum penetration and apparatus for holding the pile and jacket together during grouting and for testing the effectiveness of the grouting;

FIGURE 4 is an enlarged view in cross section illustrating the positioning of the pile holding and test apparatus at a stage in the method of the invention when the grouting of the pile to the jacket has been completed;

FIGURE 5 is a partial view in cross section illustrating the arrangement of the pile holding and test apparatus at a stage in the method of the invention when the apparatus is positioned to apply a test force on the test section of the pile; and

FIGURE 6 is a view in cross section illustrating the pile grouted to the jacket with the pile holding and test apparatus, the water exhaust conduit, and the grout line removed.

Referring to FIGURE 1, a jacket **10** is placed in a desired position with the lower end of the jacket resting on or extending into the ocean bottom **11** and the upper end of the jacket extending above the water surface **12**. Jacket **10** may be intended to serve any one of a multiplicity of purposes for which pile-jacket combinations are installed in ocean locations. For example, jacket **10** may be one of the several legs of a prefabricated platform which is to be placed upon and anchored to the ocean bottom. Jacket **10** may also be one of the legs of a platform or other form of structure being assembled at and erected on an ocean site. Jacket **10** may also comprise an element of other forms of piling arrangements which may be desired at an ocean site. Jacket **10** may be placed in a vertical position with respect to the ocean bottom or at an angle with such bottom as required by the particular situation. If jacket **10** is a leg of a prefabricated type of platform, the jacket will be held in place by the structure of the platform to which the jacket is connected. If, on the other hand, jacket **10** comprises one of the several legs of a structure being assembled on an ocean site, it may be placed in position and held there until anchored by its associated piling with a derrick boom supported on a floating barge or ship. While jacket **10** normally will be a cylindrical form of structure, such as a section of pipe of the desired size, it is not intended that the invention be restricted to a jacket of any particular configuration in cross section. Secured within and near the lower end of the jacket is an annular seal **13** which is adapted to cooperate with a pile to form a substantially watertight barrier across the lower end of the jacket. Seal **13** may be formed of rubber or any other material satisfactory to fulfill the stated objective. Secured along the inner surface of the lower portion of the jacket are a plurality of grout lugs **14** which function to improve the bond between the grout which is deposited within the jacket to establish a connection between the jacket and the pile. Lugs **14** are placed within the jacket only as high above the bottom of the jacket as it is expected the upper portion of a pile will extend when it has been driven to its maximum penetration into the bottom. Connected into jacket **10** at any desired level, preferably at a location which will be near the bottom of the jacket when the jacket is in contact with the bottom, is a grout pipe **15** which is strapped or otherwise securely connected to the jacket and extends above the water surface **12**. Grout pipe **15** serves to allow grout to be pumped into the interior of the jacket. At a point along the length of the grout pipe, a quick-break joint **20**, any form of pipe connection which may be quickly disconnected, is provided in grout pipe **15** to allow the major portion of the length of the pipe to be removed when it has fulfilled its purpose. Water exhaust conduit **21** extending from the surface is connected into jacket **10** at a level which preferably is below the upper end of the pile when the pile has been driven to maximum penetration in the bottom. Conduit **21** runs along the length of jacket **10** and may be supported from the jacket by any desired means. Conduit **21**, like grout pipe **15**, is provided with a quick-break joint **22** to permit removal of the major portion of the conduit when it has completed serving its function. A submersible pump **23** may be suspended from the surface within conduit **21** for the purpose of removing water from the jacket, as will be explained hereinafter. Pump **23**, since it is used only during a portion of the method of the invention, is supported within the conduit in any satisfactory manner which will permit its ready insertion into the conduit and removal from the conduit when desired.

In FIGURE 1, a pile **24** is illustrated in position within jacket **10** resting with its lower end in bottom **11** ready to be driven to the desired depth into the bottom. Generally, pile **24** is positioned within the jacket by lowering the pile through the upper end of the jacket and allowing it to come to rest with its lower end penetrating the bottom to some extent, depending upon the weight of the pile and the nature of the soil comprising the bottom. As previously indicated, seal **13** fits around pile **24** to provide a substantially watertight barrier at the lower end of the jacket. Seal **13** may also function as a lower guide for the pile or sturdier means, of similar configuration, may be provided. Secured near the upper end of the pile and at such other locations as required by the length of

the pile and jacket are pile guides **25** which serve to maintain the pile in a generally centered position with respect to the jacket during its travel through the jacket. Guides **25** may be constructed of any material and in any form which will permit them to maintain the desired centering of the pile without conflicting with the grout lugs **14**. Thus, guides **25** may be formed of spring steel which will easily slide over the grout lugs. Secured around the upper portion of pile **24** are a plurality of grout lugs **30** which, as do grout lugs **14**, function to improve the bond between the external surface of the pile and the grout which will surround the upper portion of the pile when it has been driven to its maximum extent into the bottom. Grout lugs **30** are positioned along only that portion of pile **24** which will remain exposed above the bottom after the pile has been driven its maximum extent into the bottom. Positioning grout lugs at any lower level on the pile will rupture seal **13**.

While the pile has been described as being lowered into position within the jacket after the jacket is on location, it will be recognized that in some instances it may be desirable to place the pile within the jacket on shore and transport it within the jacket to the marine site. In such instance, the pile should be firmly but temporarily fixed in position within the jacket, such as by spot welding to support members between the pile and the jacket. The support members should be formed so that they can be easily broken out at the time of driving the pile into the bottom.

When pile **24** has been positioned within jacket **10** and allowed to come to rest with its lower end at or slightly penetrating bottom **11**, as illustrated in FIGURE 1, an anvil **31** is placed in contact with the upper end of the pile. Anvil **31** is hollow and is provided with ports ***31a*** to permit water within the pile to be exhausted as the pile is driven downwardly. Inasmuch as anvil **31** functions only as long as the pile is being actually driven downwardly, it is necessary to secure the anvil to the upper end of the pile in only a temporary fashion which will permit its ready removal once it has served its purpose. For example, the anvil may have on its lower end a portion of reduced diameter which will fit within the upper end of the pile. If the pile were solid in construction, the anvil may have a circumferential skirt which will fit over the upper end of the pile. With the pile and anvil in position as illustrated, the driving of the pile into the bottom is commenced by repeatedly contacting the upper end of the anvil with hammer **32** which is repeatedly raised and lowered into contact with the anvil by means of any conventional form of pile driver.

At the beginning of the driving of the pile, the water level within the jacket and pile will generally be the same as the water level surrounding the jacket. The upper end of anvil **31** should be above the water surface **12** to eliminate a dampening effect by the water upon the energy being delivered by the hammer. Prior to actually starting the driving of the pile, submersible pump **23** will have been placed within the conduit **21** to allow water to be pumped through the conduit from the interior of the jacket and pile. The water trapped within the pile may flow from the pile through the anvil and from the anvil through ports ***31a*** into the jacket. Allowing the jacket and pile to be initially filled with water permits minimizing the time during which a condition of hydrostatic pressure unbalance will exist between the interior of the jacket and/or pile and the surrounding water. In other words, by not requiring that the jacket be dry through its entire length during the complete procedure of driving the pile, the expense of providing necessary apparatus to maintain complete watertight integrity of the jacket is substantially eliminated. Simultaneously with the beginning of the driving of the pile by means of hammer **32**, pump **23** is started and operated at a rate which will effect lowering of the water level within jacket **10** and pile **24** in accordance with the rate at which the pile is driven downwardly.

Water is pumped from the interior of the jacket and pile by pump **23** and exhausted to the surrounding water through conduit **21**. The surface of the water within the jacket is maintained at a level approximately at the upper end of the pile and below the point of contact between the anvil and the hammer. Preferably, the water level within the jacket is lowered such that it will at all times remain below the point at which the energy of the hammer is delivered to the pile until the pile has been driven to its point of maximum penetration into bottom **11**. The level of the water surface within the jacket is determined by means of a float indicator **33**, as illustrated in FIGURE 2, which is placed in contact with the level of the water within the jacket. Any form of float indicator is satisfactory which will provide at the upper end of the jacket an indication of the level of the water within the jacket. By observing the float indicator and knowing the extent of penetration of the hammer within the jacket, along with the length of the anvil, the rate of pumping by pump **23** is readily adjusted to maintain the water level within the jacket at the desired rate of descent. As indicated in FIGURE 2, the hammer follows the upper end of the pile into the jacket and continues through the jacket until the pile has been driven to the desired depth of penetration into the bottom. By allowing the hammer to follow the pile into the jacket, the length of pile necessary is minimized and the jacket may be placed at positions other than the vertical, with the inside of the jacket serving as a guide for the hammer. Some form of guides, in addition to springs **25** on the pile, will be required in association with the hammer to maintain the hammer in a centered position within the jacket. Any form of contact member secured on the hammer and extending to the interior walls of the jacket will satisfactorily fulfill this purpose. Driving of the pile downwardly and the simultaneous pumping of water out of the jacket and pile are continued until the pile has penetrated to the desired extent into bottom **11**, at which time the grout lugs **30** on the pile will be substantially adjacent to the grout lugs **14** within the jacket. FIGURE 3 represents a condition of maximum penetration of the pile into the bottom, at which time the hammer and anvil are removed from the pile and jacket.

Subsequent to removal of the hammer and anvil, apparatus, as illustrated in FIGURES 3 and 4, is installed within the jacket at the upper end of the pile. The apparatus, which is employed for both holding the pile and jacket during grouting and testing the effectiveness of the grouting, may best be understood by reference to FIGURE 4. Test section **34** is, in its lower portion, constructed identical to the upper end of pile **24** to present the effect of an upward extension of the pile. The lower portion of the test section is provided with grout lugs **35** to improve the bond between the test section and the grout. A gasket **40** may be provided on the lower end of the test section so that a seal will be achieved between the lower end of the test section and the upper end of the pile to preclude grout leaking to the interior of the pile. The upper portion of the test section is tapered inwardly to threaded coupling **41** which functions to connect the upper end of the test section to compression struct **42**. Around the lower portion of the compression strut are positioned a plurality of guide members **43**, which may be three in number located at spacings of 120° around the strut, to guide the strut downwardly through the jacket. A plurality of temporary shear plates **44** are secured around the upper portion of the compression strut **42**. Resting on the upper end of the compression strut **42** is reaction base **45** which provides a support for hydraulic jacks **50**. Resting on hydraulic jacks **50** is a loading yoke **51** which supports slips **52** on an internal tapered seat. Extending through slips **52** is a rod **53** which has secured to its lower end a grappling hook **54** comprising hinged members, as illustrated, to permit ready entry into and removal from the test section and compression strut. Secured to the upper end of pile **24** are a plurality of lower reaction lugs

55 which may be three in number spaced apart 120° around the internal wall of the upper end of the pile. Secured within the lower portion of compression strut **42** are upper reaction lugs **60** which also may be three in number spaced apart 120° around the internal wall of the compression strut. Reaction lugs **55** and **60** cooperate with grapping hook **54** for purposes which will be explained hereinafter.

With the above-described test section **34** and its associated apparatus assembled in the fashion illustrated in FIGURE 4, the test section and related apparatus are lowered through the jacket until the lower end of the test section, with gasket **40**, rests on the upper end of pile **24**. Rod **53** is manipulated until grappling hook **54** is in engagement with reaction lugs **55**. Reaction base **45**, hydraulic jacks **50**, and loading yoke **51** are placed on the upper end of the compression strut **42**; and rod **53** is placed in tension by exerting an upward force on the loading yoke with the hydraulic jacks. Placing rod **53** in tension with the grappling hook engaged with lugs **55** serves to securely hold test section **34** in place on the upper end of pile **24**. With the proper tension being exerted on rod **53**, the outward ends of temporary shear plates **44** are welded to the interior of jacket **10**. It will be recognized that by welding the temporary shear plates to the interior of the jacket, the test section will be held in place as long as desired. The inward ends of the shear plates hold the compression strut with the lower end of the compression strut pressing on the upper end of test section **34** to maintain the test section in position on the upper end of the pile. Also, the tension in rod **53** in cooperation with the welded connection between the shear plates and jacket preclude relative movement between the pile and jacket during grouting and until the grout is set. The engagement of the grappling hook and the tension on the rod are maintained until the grouting step has been completed and the grout has set.

With the test section **34** and its related apparatus securely held in position, as illustrated in FIGURES 3 and 4, the step of grouting the pile to the jacket may be started. Submersible pump **23** is removed from conduit **21** and replaced with a grout level indicator **61** which may be any satisfactory form of apparatus which will provide an indication at the surface of the level of grout within the conduit **21**. In other words, level indicator **61** may be any apparatus which is responsive to the level of grout within the conduit. For example, it may comprise a rod, to the lower end of which is secured a float which will rise as the grout level rises within the conduit. Since there probably will have been some water leakage around seal **13** into the jacket, the water level within the jacket may have risen to some extent as shown in FIGURE 3. This water level may be allowed to adjust itself or, on the other hand if found desirable, pump **23** may be placed at an elevation somewhat above the grout level indicator **61** to assist in controlling the level of the water within the jacket. Entry of grout into the pump may readily be prevented by providing the pump with a specific gravity valve which will allow water to flow through the pump but which will close upon entry of grout into the pump inlet. Grout is pumped into the interior of jacket **10** through grout pipe **15** until the level of the grout is determined to be at the upper end of test section **34**. Prior to actual introduction of the grout into the annulus between the pile and jacket, it may be preferred that the annulus be flushed with water delivered through the grout pipe so that the mud on the pile, the interior of the jacket, and the lugs will be washed off of the elements to permit a better bond with the grout. The mud is suspended within and on the surface of the water which will in turn be displaced by entry of the grout into the jacket. With the annulus in the jacket filled with grout, the grout is permitted to set for whatever period of time is required for its hardening under the particular conditions depending upon the type of cement which comprises the grout. FIGURE 4 best illustrates the elevation to which the grout is pumped in the annulus between the pile test section and the interior of the jacket.

When the grout has set the required period of time, temporary shear plates **44** are cut loose from the jacket and the tension on rod **53** is relieved to allow relocation of the grappling hook **54**. Rod **53** is rotated until it is determined that the grappling hook **54** is disengaged from the reaction lugs **55**. Rod **53** is then lifted and raised to place the grappling hook in the vicinity of upper reaction lugs **60**. Reaction base **45** is replaced with reaction base **62**, as illustrated in FIGURE 5. Reaction base **62** is of sufficient size that it will rest on the upper end of jacket **10** rather than the upper end of the compression strut as did reaction base **45**. Other than being of sufficient size to rest on the upper end of jacket **10**, there is no difference between the structure and function of the two reaction bases. Depending upon the form of the reaction bases, it may be necessary to remove the hydraulic jacks and loading yoke during the change of reaction bases. The reason for change of the reaction bases is that with reaction base **45**, loading is effected on the upper end of the compression strut, while with reaction base **62** loading is effected on the upper end of jacket **10**. With reaction base **62** in position and jacks **50** and loading yoke **51** located as shown in FIGURE 5, grappling hook **54** is manipulated by means of rod **53** to engage the grappling hook with upper reaction lugs **60** within the compression strut. After the grappling hook has been engaged with the upper reaction lugs, rod **53** is again placed in tension by urging slips **52** and loading yoke **51** upwardly by means of the hydraulic jacks **50**. It will be recognized by examination of FIGURE 5 that the hydraulic jacks resting on reaction base **62** are exerting a downward force on the upper end of jacket **10**, while the upward force from the hydraulic jacks placing rod **53** in tension causes an upward force to be exerted on the compression strut through the connection between grappling hook **54** and upper reaction lugs **60**. Such application of forces as just described causes an upward force to be exerted upon test section **34** relative to jacket **10**. With the test apparatus thus realigned, as illustrated in FIGURE 5, hydraulic jacks **50** are employed to exert a predetermined force on test section **34** through rod **53** to determine if a secure bond has been obtained between the test section and the jacket through the mechanism of the grout. Assuming the bond meets the desired test requirements, the test apparatus, including reaction base **62**, the hydraulic jacks, rod **53**, and the grappling hook, are removed from the jacket; and the compression rod is rotated to break the screwed coupling **41** to allow removal of the compression strut. The water exhaust conduit **21** and grout pipe **15** are then removed by breaking their respective quick-break joint, with the final condition of the pile-jacket assembly appearing as is illustrated in FIGURE 6. The level of the water within jacket **10** may be left at such elevation as is desired, depending upon factors including the buoyancy required and the collapse strength of the jacket. Should the bond between the pile and the grout prove to be inadequate, steps may be taken to go into the jacket and weld the upper end of the pile to the internal surface of the jacket. It will be observed that upon completion of the above-described procedure, there exists no excess pile which must be cut off above the upper end of the jacket.

Having thus described the invention, it will be understood that such invention is limited only within the scope of the appended claims.

What is claimed is:

1. In a method of installing a pile within a jacket having a quantity of water therein and supported on the bed of a body of water and having its upper end extending above the surface of said body of water, the steps which comprise:

(a) positioning said pile within said jacket;

(b) driving said pile downwardly into said bed by means of a hammer until said pile is at maximum desired penetration depth within said bed at which the upper end of said pile is below the top of said jacket and the surface of said body of water, said hammer following said pile downwardly within said jacket;

(c) simultaneously with the driving of said pile, lowering the water level within said jacket and pile at a rate which will maintain said level below the lower face of said hammer; and

(d) grouting at least a portion of said pile remaining within said jacket to the internal surface of said jacket after said penetration depth has been obtained.

2. A method as defined in claim **1** including the additional steps of:

(a) positioning a pile test section on the upper end of said pile when said pile is at maximum penetration depth and before said pile is grouted to said jacket;

(b) grouting said pile test section to said jacket at the time of grouting said pile to said jacket; and

(c) when said grout has set, imposing a predetermined force upon said test section tending to pull said test section away from said pile and break the bond between said test section and said jacket to provide a measure of the effectiveness of the bond obtained by said grout with said pile and jacket.

3. In a method of installing a pile within a jacket having a quantity of water therein and supported on the bed of a body of water and having its upper end extending above the surface of said body of water, the steps which comprise:

(a) positioning said pile within said jacket;

(b) permitting said pile to attain a condition of rest in accordance with its weight and the character of the soil comprising said bed;

(c) positioning a hammer above said pile;

(d) driving said pile downwardly through said jacket into said bed to a depth at which the upper end of said pile is below the top of said jacket and the surface of said body of water, said hammer following said pile within said jacket;

(e) simultaneously, while carrying out step (d), lowering the water level within said jacket and pile at a rate which will maintain said water level below the face of said hammer;

(f) terminating steps (d) and (e) when said pile is at maximum desired penetration depth into said bed; and

(g) grouting at least a portion of said pile remaining within said jacket to said jacket.

4. A method as defined in claim **3** including the additional steps of:

(a) positioning a pile test section on the upper end of said pile when said pile has reached said maximum penetration depth and before said pile is grouted to said jacket, said test section having substantially the same cross-sectional configuration and dimensions as the upper end of said pile;

(b) grouting said pile test section to said jacket at the time of grouting said pile to said jacket; and

(c) imposing a predetermined force on said pile test section tending to pull said pile test section away from said pile to provide a measure of the effectiveness of the bond obtained between said grout and said pile and said jacket.

5. In a method of installing a pile within a jacket having a quantity of water therein and supported on the bed of a body of water and having its upper end extending above the surface of said body of water, the steps which comprise:

(a) introducing said pile into said jacket until the lower end of said pile is adjacent the lower end of said jacket;

(b) releasing said pile to permit said pile to come to rest in accordance with its weight and the character of the soil comprising said bed;
(c) positioning an anvil on the upper end of said pile;
(d) striking said anvil with repeated blows from said hammer to drive said pile into said bed to a depth at which the upper end of said anvil is below the top of said jacket and the surface of said body of water, said hammer following said pile and said anvil through said jacket;
(e) pumping water from said jacket at a sufficient rate to maintain the level of said water within said jacket and pile below the upper end of said anvil until said pile is driven to maximum penetration in said bed;
(f) when said pile has reached maximum penetration, terminating the driving of said pile and pumping of said water from said jacket;
(g) removing said hammer and said anvil from said jacket; and
(h) pumping grout into the annulus between said jacket and the portion of said pile within said jacket until said annulus is filled with said grout to the level of the upper end of said pile.

6. A method as defined in claim **5** including the additional steps of:
(a) prior to the pumping of grout into the annulus between the jacket and the pile, positioning a pile test section on the upper end of said pile, said test section having a cross-sectional configuration and dimensions substantially identical to those of the upper end of said pile;
(b) pumping grout into the annulus between said pile test section and said jacket until said grout has filled said annulus to the level of the upper end of said pile test section;
(c) allowing said grout to set; and
(d) applying a force to said test section tending to pull said test section away from said pile to provide a measure of the effectiveness of the bond between said grout and said pile and said jacket.

7. In a method of installing a pile within a jacket having a quantity of water therein and supported on the bed of a body of water and having its upper end extending above the surface of said body of water, the steps which comprise:
(a) positioning said pile within said jacket with the lower end of said pile being located at the surface of said bed;
(b) releasing said pile to permit said pile to come to a condition of rest in accordance with its weight and the character of the soil comprising said bed;
(c) placing an anvil on the upper end of said pile;
(d) positioning a hammer above said anvil;
(e) repeatedly contacting said anvil with said hammer to drive said pile downwardly into said bed to a desired maximum penetration depth at which the point of contact of said anvil and said hammer is below the top of said jacket and the surafce of said body of water, said hammer following said pile and anvil within said jacket;
(f) simultaneously with step (e), pumping water from said jacket through a conduit connected into said jacket at a location below the lowest point of travel of said hammer when said pile is driven to maximum penetration in said bed, the level of the surface of said water being maintained below the point of contact of said hammer with said anvil;
(g) when said pile has been driven to maximum penetration within said bed, terminating the pumping of said water from said jacket and removing said hammer and said anvil from said jacket; and
(h) pumping grout through a pipe connected into said jacket into the annulus between said jacket and the portion of said pile remaining within said jacket until said annulus is filled to the level of the upper end of said pile.

8. A method as defined in claim **7** including the additional steps of:
(a) prior to pumping grout into said jacket, positioning a pile test section on the upper end of said pile, said pile test section having a cross section of substantially the same configuration and dimensions as the upper end of said pile;
(b) effecting a temporary connection between said pile and said jacket and exerting a force on said connection to maintain said pile in position within said jacket;
(c) pumping said grout into said annulus until the level of said grout is substantially even with the upper end of said test section;
(d) allowing said grout to set;
(e) breaking said temporary connection between said jacket and said pile;
(f) effecting a temporary connection between said pile test section and the upper end of said jacket;
(g) applying a force to said test section tending to pull said test section away from said pile to provide a measure of the effectiveness of the bond between said grout and said pile and jacket; and
(h) removing said temporary connection between said jacket and said pile test section.

9. In a pile-jacket assembly for installation through a body of water into the bottom hereof the combination which comprises:
(a) a hollow jacket of a length to extend from above the surface of said water into said bottom;
(b) a pile positioned within said jacket and adapted to be given through said jacket into said bottom;
(c) means within the lower end of said jacket for effecting a substantially watertight seal with said pile;
(d) means within the lower portion of said jacket for establishing an effective bond between said jacket and grout introduced thereinto;
(e) means forming a first fluid passage extending from the interior of said jacket to the exterior thereof for introducing grout into said jacket;
(f) means forming a second fluid passage extending from the interior of said jacket to the exterior thereof for removing water from said jacket to a level below the upper end of said pile driven through said jacket to maximum desired penetration in said bottom; and
(g) means around the upper portion of said pile for establishing an effective bond between said pile and grout introduced into said jacket.

10. In a pile-jacket assembly for installation through a body of water into the bottom thereof the combination which comprises:
(a) a hollow jacket of a length to extend from above the surface of said water into said bottom;
(b) a pile positioned within said jacket and adapted to be driven through said jacket into said bottom;
(c) means within the lower end of said jacket for effecting a substantially watertight seal with said pile;
(d) means within the lower portion of said jacket for establishing an effective bond between said jacket and grout introduced thereinto;
(e) means forming a first fluid passage extending from the interior of said jacket to the exterior thereof for introducing grout into said jacket;
(f) means forming a second fluid passage extending from the interior of said jacket to the exterior thereof for removing water from said jacket to a level below the upper end of said pile driven through said jacket to maximum desired penetration in said bottom;
(g) means around the upper portion of said pile means for establishing an effective bond between said pile and grout introduced into said jacket means; and
(h) means interconnecting said pile and said jacket

for temporarily restraining said pile and said jacket from movement relative to each other when said pile has been driven into said bottom and for providing a measure of the effectiveness of the bond between said jacket and pile and grout introduced into said jacket.

11. In a pile-jacket assembly for installation through a body of water into the bottom thereof the combination which comprises:

(a) a hollow jacket of a length sufficient to extend from said bottom to above the surface of said water;

(b) a pile positioned within said jacket and adapted to be driven into said bottom through said jacket;

(c) a seal within the lower end of said jacket to co-operate with said pile to maintain the lower end of said jacket substantially watertight;

(d) grout lugs around the interior of said jacket and extending upwardly a predetermined distance;

(e) a grout pipe connected into said jacket near the lower end thereof and extending upwardly along said jacket to above the surface of said water;

(f) a water conduit extending from above the surface of said water and connected into said jacket at a location below the upper end of said pile when said pile is at maximum penetration depth in said bottom;

(g) grout lugs around the outer surface of said pile extending from the upper end of said pile downwardly over at least a portion of said pile remaining within said jacket when said pile has been driven to maximum penetration depth in said bottom;

(h) a pile test section on the upper end of said pile, said pile test section having a cross section along at least a portion of its length substantially identical to the upper end of said pile;

(i) grout lugs around the outer surface of at least a portion of said pile test section;

(j) a compression member secured to the upper end of said pile test section and extending to the upper end of said jacket; and

(k) means carried by said compression member for effecting a temporary connection between the upper end of said compression member and the upper end of said pile to hold said pile test section in position on the upper end of said pile.

12. In an apparatus for testing the bond effected between grout and a pile and jacket where said pile is driven through said jacket into an ocean bed and said grout is introduced into the annulus between said pile and said jacket the combination which comprises:

(a) a pile test section securable on the upper end of said pile, said pile test section having a cross section along at least a portion of its length substantially identical to the upper end of said pile;

(b) grout lugs around the outer surface of at least a portion of said pile test section;

(c) a compression member secured to the upper end of said pile test section and extending to the upper end of said jacket; and

(d) means connected to said compression member for effecting a temporary connection between said compression member and the upper end of said jacket for exerting a force between said jacket and said compression member tending to pull said pile test section away from the upper end of said pile.

13. In a pile-jacket assembly installed on the bed of a body of water, the combination which comprises:

(a) a hollow jacket supported on said bed and extending to a point above the surface of said water;

(b) a pile penetrating said bed and extending upwardly into said pile to a point below the level of said water;

(c) means within the lower end of said hollow jacket for effecting a substantially watertight seal in said pile;

(d) grout in at least a portion of the annular space between said jacket and said pile;

(e) means on the exterior surface of said pile coextensive with at least a portion of said grout for establishing an effective bond between said pile and said grout; and

(f) means on the interior surface of said jacket coextensive with at least a portion of said grout for establishing an effective bond between said jacket and said grout.

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