

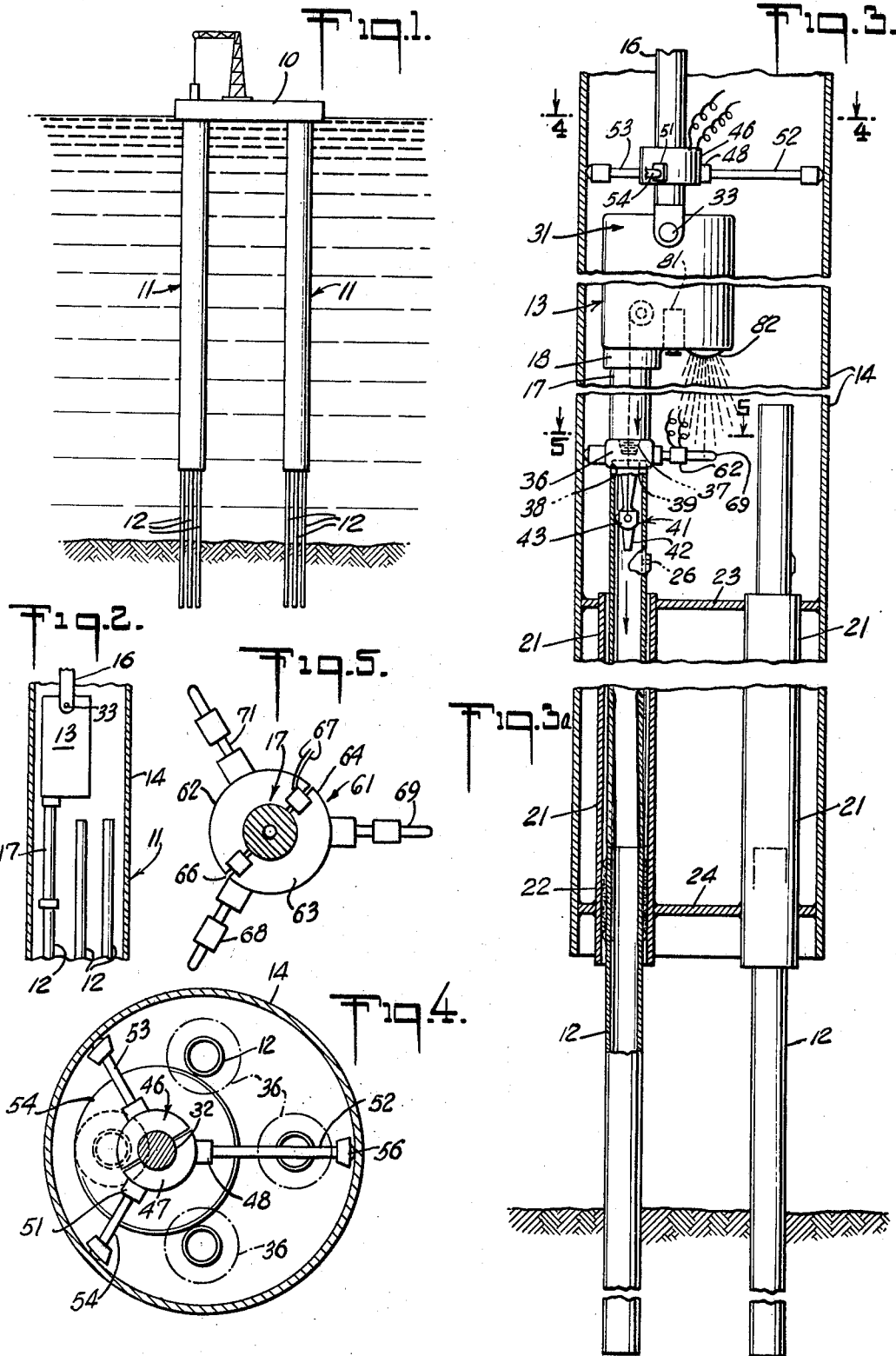
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PILE DRIVING APPARATUS FOR SUBMERGED STRUCTURES

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PILE DRIVING APPARATUS FOR SUBMERGED STRUCTURES

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ABSTRACT OF THE DISCLOSURE

The invention relates to a novel method and apparatus therefor, adapted to driving piles into the ocean bottom for anchoring an offshore, deep water marine platform. The apparatus contemplates use on a platform supported on one or more canted legs, each of which includes at least one, and usually a plurality of pre-positioned piles. A mobile pile driving mechanism is adjustably and guidably suspended in a casing surrounding the piles. The driving mechanism is then sequentially rotated to drive the respective piles through relatively short increments of length. Positioning means carried on the pile driving apparatus includes outwardly radiating arms which are remotely controlled from the water's surface. The arms, when in contact with the wall of a platform leg, are actuatable to position the pile driving mechanism with respect to said wall.

BACKGROUND OF THE INVENTION

The technology related to offshore type well drilling platforms is generally geared to relatively shallow depths of water up to about 300 feet. It is known and contemplated however, that future restrictions to such water depths will not be feasible in view of the vast oil resources to be found in deeper water such as mid-ocean and the like. The equipment required for raising such deeply buried crude oil is similar in many respects to equipment presently utilized in immediate offshore installations. However, it will be appreciated that the added depth does introduce new and diverse problems which must be overcome to alter and adapt existing equipment and methods, and also to implement new equipment to deep water environment.

In the instance of many marine drilling platforms, anchoring is normally directly to the ocean floor with the platform supported above the surface. This is achieved through the use of either cable mounted anchors which limit movement of the platform to a restricted area, or to leg mounted platforms which are fixedly positioned. The latter of course suggest a more efficient operation both in drilling and producing since the platform remains virtually stationary after it has been set, and is affected only by severe water movements.

In the instance of leg positioned platforms, it is the practice to support the platform slightly above the water surface on three, preferably four, and even more hollow legs. These legs will of course be of a size commensurate with the water depth and with the load carried by the platform.

The respective legs are normally positioned by tubular metallic piles driven into the ocean floor for a sufficient depth to assure that the lower end of the leg is stationary. While as above noted, a number of legs are employed, it may suffice to utilize merely a single pile in each leg to satisfactorily anchor the platform. In the instance of larger diameter legs, or casings as they are referred to, it has been found feasible and indeed desirable to implement the anchoring with a number of piles, which members can also function as structural components in the leg assembly.

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The usual method for anchoring a plurality of such piles is to pre-position the same within the platform support leg and individually imbed them into the ocean floor. This of course necessitates elongating the pile with additional lengths of tubing as the lower end penetrates the anchoring media. Thus the pile progressively grows in length by the expedient of welding or otherwise fastening the additional lengths to the upper end normally in 25 to 30 foot increments.

For use in relatively shallow water, the pile itself will ordinarily extend to a reasonable length of 200 or 300 feet and can be readily inserted into the ocean floor by driving or hammering with the aid of a barge mounted pile driver.

In an instance where it is known beforehand the approximate depth to which the pile may or must enter the anchoring media, the final length of the pile is readily determined. Thereafter as the pile is imbedded, a follower pipe is normally used as an intermediary between the top of the pile and the pile driver. Where of course the composition of the anchoring strata is unknown, the pile will be driven to an indeterminate depth until a firm anchor is established.

For deep water installations, where a number of piles are used through each leg, it becomes uneconomical, and practically inadvisable to follow the above noted piling procedures. For one thing, the greater the pile is in length the greater will be its ability to absorb the hammer impact. Thus a point will be reached where an inefficient operation results since most of the hammer's impact is absorbed due to the pipe's elastic characteristics. Where a follower type pipe is used at the upper end of the pile, somewhat the same problem is encountered. Notably, there is a reduction in hammering efficiency as the result of the deflection of both the follower and the pile, due to the hammering impact at the upper end.

Another problem ancillary to the setting of the piles is the method by which they are driven. This usually constitutes the use of a barge mounted derrick floated adjacent to the platform which supports the drilling equipment. The use of floating derricks and such equipment for an extensive period of time is relatively expensive and consequently increases the overall cost of the installation. Further, the use of barge mounted derricks introduces the problem of the driving operation being subject to weather and wave conditions which rock the derrick barge. On the whole, the driving operation for relatively long piles has up to now been considered undesirable, and when used, relatively uneconomical.

Since the composite type of platform leg is found to be a practical support member, that is, incorporating both a relatively heavy casing and a plurality of relatively light piles extending from the lower end into the anchoring media, such composite construction is desirable. However, methods for individually driving the plurality of piles from the surface of the water, for the aforementioned reasons is impractical.

It is therefore an objective of the invention to provide a novel method for anchoring a leg supported marine platform in the ocean bottom. A further object is to provide a method for the simultaneous anchoring of a plurality of piles contained within a single marine platform leg structure. Another object is to provide for the effective use of pre-positioned, relatively short piles in a deep water marine platform installation. Still another object is to provide an apparatus to accurately and simultaneously inserting a plurality of piles confined within a closed casing.

The invention in brief contemplates an apparatus for achieving the described method, which apparatus utilizes a mobile pile driving unit that is supportably guided through a marine platform leg. The latter embodies a plu-

ality of pre-positioned and downwardly extending piles which are inserted by the mobile drive mechanism into the ocean bottom. A gripping device such as an expandable collar is controllably regulated to govern the position of the pile with respect to the drive mechanism during the hammering period. One or more pile guides extend for a portion of the casing length to afford the respective piles lateral support during both the driving period and for the transmission of bending movement from the piles to the casing. The mobile driving unit is so operably positioned within the casing as to be readily manipulated and controlled from the drill platform to sequentially drive the respective piles through short incremental units of depth of 20 or 30 feet at a time.

Referring to the drawings:

FIGURE 1 is a diagrammatic view of drilling platform in a marine location.

FIGURE 2 is a view partly in section of a mobile pile driving unit located in a support leg for the platform.

FIGURE 3 is an enlarged, partly sectional view of the upper portion of the support leg and mobile pile driving unit showing greater detail.

FIGURE 3a is a partly sectional view showing the lower portion of the support leg.

FIGURE 4 is a transverse sectional view taken at 4—4 of FIGURE 3.

FIGURE 5 is a transverse sectional view taken at 5—5 of FIGURE 3.

Referring to FIGURE 1, the marine drilling platform 10 is shown supported on a plurality of composite legs 11 which as mentioned, are adequate in number to anchor the platform firmly regardless of the depth of the water. Legs 11 extend downwardly from platform 10 and terminate in a plurality of piles 12 which depend from the lower end and penetrate the ocean floor for a predetermined depth.

In accordance with known factors, platform 10 accommodates the normal equipment ancillary to a drilling or producing operation including derricks, turntable, draw works, etc. The respective legs 11 may be permanently fixed to the platform 10. However, they are preferably of the jack-up type and thus connected to the platform in a manner that the legs might be raised and lowered as needed in accordance with the depth of water in which the platform is to operate.

It is understood that the present apparatus and method are readily adapted to be used on equipment in relatively shallow water. However, the severe conditions imposed by deep water operations prompted development of both the apparatus and the method disclosed herein which is effective in deep waters on the order of magnitude of 500 to 1,000 feet.

While the terminology herein used relates to an ocean floor it is understandable that both the method and the apparatus are applicable for a pile structure in any form of strata, and under conditions other than those related to deep water.

Referring to FIGURES 2 and 3, mobile pile driving unit 13 is shown suspended in leg casing 14 by an overhead support mechanism such as pipe string 16, cable, or other means connected to the platform positioned derrick. Drive unit 13 includes an internally powered mechanism (shown in phantom) similar to that embodied in the normal surface type pile driving unit and operates mechanically in substantially the same way as the latter. For example, the present unit might be actuated and controlled by steam, compressed air, electric power, or otherwise to regulate the repetitive actuation of the hammering mechanism at a desired frequency. The drive unit is provided with an anvil 17 slidably and sealably mounted in a guide bushing 18 depending from the drive unit underside. The lower end of anvil 17 is adapted to engage and attach to the upper end of the respective piles 12 and hold the same during the driving operation.

Referring to FIGURE 3, the respective composite platform support legs comprise basically an elongated cylindrical casing 14 formed of a series of short, end welded casing lengths which are assembled into the required predetermined length. The upper end of casing 14 terminates at platform 10, the lower end terminates a short distance above the ocean floor. Casing 14, being of welded construction, might be watertight although such a requirement is not essential. However, where the casing is to function as an oil storage facility as well as a support member it might be fabricated as to be liquid tight. The lower part of casing 14 is provided with a plurality of longitudinal pile guides 21 which extend from the lower end upwardly toward the water surface. The primary function of these members is to slidably receive a pile to guide the latter to its anchoring point. The pile guides 21 serve the further function of engaging the pile in a rigid cemented joint 22 adjacent to the lower end. These guides, with respect to the pile, also provide a degree of rigidity between the pile and the casing as to reinforce the entire leg member.

Pile guides 21 are so arranged within casing 14 in a manner to structurally reinforce the latter by means of longitudinally spaced brackets 23 and 24 which mutually engage pile guide 21 and the casing 14 inner wall. Said brackets are spaced along the length of the casing as needed to properly reinforce and brace the latter, particularly against undue flexure.

The type of pile 12 carried in the respective pile guides 21, is of a familiar structure in the art and comprises essentially an elongated rigid, metallic tubular member. The tubing may be open at the lower end to facilitate penetration of an ocean floor, or it may be adapted to more readily penetrate a particular composition of the ocean floor. The respective piles are preferably pre-positioned within casing 14 in a manner to extend there-through, having the lower end of the pile disposed adjacent to the casing lower end. In such a condition casing 14 is manipulated to its desired upright position in a body of water, after which the piles are individually driven into the ocean floor.

Because the piles are of a predetermined length in accordance with the condition of the ocean floor, the pile upper end is the only portion that will be subject to direct hammering action. This upper end may therefore be provided with a cap, outer circular ring, or other reinforcing member fitted to the pile temporarily to avoid deforming the upper face, a factor which might otherwise hamper the driving operation. Since initially the entire leg section will be submerged in water, and since the casing need not be essentially watertight, the pile is adapted to avoid entrapment of water which would counteract and lessen the force of the driving hammer. Further, since anvil 17 tightly holds the pile upper end during the hammering, entrapped water would have no opportunity to escape. The pile is therefore vented at opening 26, which opening may be provided with a check valve to permit unidirectional discharge of water from the pile interior as the latter is driven.

The novel mobile pile driving apparatus comprises basically a body or driving head 31 which includes an outer casing or cover constructed as to enclose a watertight interior. The body upper end is provided with a pivotal support bracket 32 which is operably engaged by a connection 33 hinged at opposed sides of the body. Support member 16 as mentioned might be a pipe string which threadably or otherwise fastens into support bracket 32. Support of the body might also be affected as mentioned through a single suspension cable fastened to bracket 32.

In that the hammering and hammer actuating mechanism comprise arrangements familiar in the art, no further description is here required except to note that the reciprocally slidable hammering mechanism is disposed in substantially vertical alignment with anvil 17.

The lower end of body 31 is provided with protruding guide sleeve 18 having a central passage registering the upper end of anvil 17 to slidably guide the latter. Sleeve 18 simultaneously provides a liquid tight annular seal to avoid entry of water into the body through the sliding fit between said anvil and said sleeve.

Anvil 17 may comprise a relatively short metallic member, either tubular or solid construction, for transmitting the hammer blow to the pile end. In the instance of hammering a singular pile within a casing, the length of anvil 17 might be minimized. However, as presently contemplated the driving mechanism will be utilized to sequentially imbed a plurality of adjacently spaced and grouped piles in a casing. Anvil 17 is therefore preferably generally elongated to approximately the length of a pile section, that is 25 to 30 feet. Said member is further formed in a hollow or tubular disposition with a center passage to accommodate lubricant and fluid control lines.

Anvil 17 is provided with an adapter cap 36 removably carried on the anvil lower end by a threaded or similar connection to permit replacement of the cap and adapt the same for a particular pile diameter. Thus cap 36 is provided with a threaded opening 37 into which a mating nipple on the anvil might be engaged and locked. The lower face of adapter 36 includes a tapered recess 38 contoured to engage the end of a particular pile being driven. Preferably this recess fits closely about the outer end of the pile to avoid spoiling or deforming the latter as a result of the hammering action.

Cap adapter 36 further includes an elongated internal probe 39 adapted to be inserted into the pile end and to support the upper inner wall thereof. An expander 41 carried on probe 39 includes a tapered nose 42 which connects to a radially expandable section 43. The latter comprises a plurality of movable segments adapted to be urged outwardly by hydraulic pressure to tightly engage the inner wall of the pile thereby fixing it in relation to anvil 17 so that the pile and anvil will move as a unit. Use of expander 43 permits retention of the pile should it be struck with sufficient force as to imbed the same too deeply in the ocean floor due to a void or a soft spot in the floor composition.

In accordance with usual pile driving construction, the pile itself is normally heavy enough to be at least partially driven under the force of gravity. However, for controlled hammering the anvil may be spring biased or mechanically arranged to oscillate.

To function in accordance with the method here described, drive unit 13 is suspended to assume a position over each of the plurality of circularly placed piles in rotating sequence. The unit thus embodies means for rotatably controlling its position to align anvil 17 over a particular pile. Such positioning mechanism might include the supporting pipe string 16 which can be controllably rotated at the well head a predetermined distance to align with a particular pile. However, because of the great length of the piles, it is improbable that the latter would assume a regular peripheral spacing when disposed in the casing particularly at the upper unsupported end.

Referring to FIGURE 4, to more accurately position drive unit 13 then, the latter is provided with a rotary positioner 46 adapted to removably engage either bracket 32 or a mounting head protruding from body 31.

A remotely controlled rotary positioner 46 may be integral with the head or separable therefrom, the latter embodiment including essentially collar 47 having a central opening adapted to connect to support bracket 32. Collar 47 includes a plurality of peripherally spaced hubs 48, 49 and 51, each being formed to receive a radially extending, retractable arm 52, 53 and 54. The respective arms need not be uniform in length since the rotary positioner must be adapted to accommodate a number of different size casings. Positioner 46 includes the further

feature of accommodating different lengths of arms in each of the respective hubs 48, 49 and 51 to increase its versatility and be usable in various sized casings.

The respective guide tubes 21 are positioned in the present arrangement, equidistant from the center of casing 14 in a generally circular configuration. Thus, to be accurately positioned in sequence over each of the guide tube ends, drive unit 13 is rotatably adjusted. Arms 52 and 53 are therefore in the present arrangement, equal in length to support the drive unit essentially from one side of casing 14, while extended arm 54 supports it from the opposite side. Each of the legs is provided at its outer end with a propelling vehicle 56 such as a cog wheel axially mounted to be rotatably and controllably driven by a motor or transmission not presently shown. This propelling or drive member may include mechanical means, or hydraulically powered motors so controlled as to permit the driving of one or more of the respective vehicles 56 to propel the drive unit 13 about the casing interior. Each drive vehicle is spring biased toward the casing wall when in the extended position to assure a sufficient friction contact therebetween to provide the necessary driving traction.

The respective outwardly extending arms are further adapted to be rotated about their own axes. Thus said arm may be rotated 90° to position the propelling vehicle in an upright position whereby the entire head might be vertically controlled.

Under normal conditions, unit 13 would be rotated for at least 180° in one direction to sequentially drive half of the piles, after which it is rotated in the opposite direction to accommodate and drive the oppositely positioned piles.

It is understood that the presently described rotary drive mechanism illustrates one embodiment of the means by which the position of driving unit 13 might be accurately controlled. Further, it is understood that for a different diameter casing and a different arrangement of the circularly arranged piles, the rotary positioner might be varied to sequentially be aligned with each of the piles.

A second or lateral positioner 61 is carried at the lower end of anvil 17 and includes means for horizontally adjusting the position of elongated anvil 17 into alignment with a pile, after rotary positioner 46 has guided the drive unit to its next approximate operating position.

Lateral positioner 61 includes essentially a split collar, which further includes clamping means to be expandable, and either clamp to the outside of anvil 17 or to open, thereby becoming disengaged from the anvil. Lateral positioner 61 is made up of collar segments 62 and 63 formed of mating halves connected at oppositely positioned expansion joints 64 and 66. The respective joints are provided with a hydraulic actuator or the like having control conduits 67 extending from the actuator to the well platform 10, to remotely adjust the collar between open and closed positions. Collar 62-63 is actuatable by the two expansion joints to a closed position wherein the collar inner surface engages the anvil outer surface. In open position the collar is expanded, spaced radially from the anvil, and thus exerts no control over the latter. The inner surface of the respective collar halves might be provided with a suitable slide surface or bearing means to permit free reciprocation of anvil 17 during the driving operation without affecting the position of the lateral guide 61.

A plurality of telescoping arms 68, 69 and 71 extend radially from the respective collar segments and toward the wall of casing 14. As shown, the three arms might be equidistantly spaced from the center of the anvil or conveniently spaced to provide the desired degree of movement for laterally positioning the anvil. Arms 68, 69 and 71 therefore are of a suitable length to facilitate the adaptation of a particular driving unit 13 with a particular diameter casing. Thus, said arms, as in the

instance of the rotary positioner 46, are adjustable to reach the remote wall of the casing 14.

Functionally, anvil positioner 61 acts as a vernier adjustment for anvil 17 after drive unit 13 has been circumferentially positioned and aligned by the rotary positioner 46.

Each telescoping arm 68, 69 and 71 is provided with a motor for adjusting the arm outer ends with respect to the inner ends. Each adjusting motor 76 through 78 inclusive is individually and remotely controlled by hydraulic lines extending from the respective motors to the drill platform. Thus when driving unit 13 has been roughly positioned above, and in the area of a pile to be driven, the finer adjustment is actuated by altering the length of the respective telescoping arms so as to accurately displace the anvil and to engage a pile upper surface.

The preferred method for simultaneously inserting a plurality of piles by use of the presently described mobile pile unit is best described with reference to FIGURES 2 and 3.

As previously mentioned the respective piles 12 are fabricated to a predetermined length and pre-positioned within a casing leg for temporarily holding them in place prior to being driven. When leg 11 is adjusted to an upright position, in the instance of a relatively elongated casing, the upper end of the respective piles might fall anywhere along the casing length.

The drive unit 13 is suspended by derrick or a suitable connecting means above the casing and lowered therinto. The exact position of drive unit 13 with respect to the piles might be determined by a number of methods. However, it is found that a closed television circuit including lighting means 82 carried within pile head 31 provides means for quickly and accurately making the necessary alignment. To this end, a camera aperture 81 is provided at the lower end of the drive unit, together with a lighting means so positioned to provide a maximum scanning of the area in which the pile unit works. This feature becomes essential in deeper units or where the water would become sufficiently murky to otherwise obviate positioning of the unit over a pile.

With the upper ends of the respective piles at approximately the same level drive unit 13 is aligned with the first pile to be driven by actuation of rotary positioner 46 and lateral positioner 61. For the present description anvil 17 will be presumed to be about 30 feet long. Thus, each pile 12 can be driven to a depth of approximately 30 feet before the unit 13 is raised and rotated to the next pile, to drive it an equal depth. With anvil 17 in alignment with a pile end, the unit is lowered to insert guide nose 42 into the pile and bring the upper end of the latter into engagement with the lower face of cap 36.

At the start, the piles might be given an initial impact to jar them loose from their retaining means within casing 14. Thus the weight of the respective piles will ordinarily be sufficient to cause them to enter and penetrate the ocean floor for a depth depending upon the pile length and the composition of the floor. With the piles at a lower position pile drive unit 13 is rotatably adjusted to bring anvil 17 into alignment with the uppermost pile end. After the above noted clamping operation at which expander 43 is opened to engage the inner wall of the pile and hold it in engagement with cap 36, the pile mechanism is actuated whereby the pile is imbedded and followed by the drive unit 13 until the latter approaches the upper surface of the next pile.

The same procedure is followed sequentially on each of the piles whereby they are incrementally driven into the anchoring strata until a predetermined depth is reached. Thereafter the respective piles are fastened to the pile guides 21 at a peripheral collar such as a cement or grouted collar 79 formed at the annulus defined by the adjacent pile and pile guide walls. After the cement

has hardened the respective piles will be rigidly positioned thereby rigidly positioning casing 14. Pile unit 13 is then withdrawn from the casing and moved to another leg whereby the same procedure is followed to again drive the piles in the second, third or remaining legs in order.

I claim:

1. In a mobile pile driving apparatus for guided movement in a casing holding a plurality of discretely placed piles positioned longitudinally of said casing to be drivingly imbedded into an anchoring medium, which apparatus comprises:

(a) a driving head including;

(1) an anvil having inner and outer ends, said inner end being reciprocally retained in said head for movement between an extended power stroke and a retracted position,

(2) means for reciprocally actuating said anvil between said extended position on the power stroke, and said retracted position in a return stroke,

(3) pile engaging means carried on said anvil outer end, being adapted to engage the upper end of at least one of said plurality of piles for maintaining said anvil in corrected alignment with said at least one pile upper end during the driving of the latter, and

(4) a rotary positioner connected to said driving head, the latter being remotely controlled to sequentially position said anvil in alignment with the upper end of each of said plurality of piles, said rotary positioner including driving means extended radially from said driving head to engage the inner wall of said casing at the respective pile upper ends, whereby to be remotely actuated for controlling the position of said driving head with respect to said pile ends.

2. In an apparatus as defined in claim 1 wherein said rotary positioner is connected integral with said head and includes;

(a) a plurality of peripherally spaced arms being outwardly extendable from said head,

(b) a drive member at the extremity of at least one of said arms for engaging said casing inner wall, and

(c) motor means connected to said drive member for selectively actuating the same to rotate said driving head about said casing.

3. In an apparatus as defined in claim 1 wherein said pile engaging means includes a guide member for aligning said anvil with said pile.

4. In an apparatus as defined in claim 1 wherein said pile engaging means includes an elongated sleeve adapted to slidably engage the outer walls of said pile during reciprocal movement of said anvil.

5. In an apparatus as defined in claim 1 wherein said rotary positioner includes;

(a) a plurality of peripherally spaced, outwardly extendable arms,

(b) a propelling vehicle disposed at the extremity of at least one of said extendable arms in contact with the inner wall of said casing,

(c) motor means connected to said propelling vehicle for selectively actuating the same to rotate said driving head in a desired direction.

6. In an apparatus as defined in claim 5 wherein each of said extendable arms includes; a mounting end disposed oppositely from a driving end, said respective mounting ends being pivotally connected in said head, and means for separately urging said respective arms into engagement with a laterally positioned casing wall.

7. In an apparatus as defined in claim 5 wherein at least one of said plurality of peripherally spaced arms is adapted to be rotatably positioned with respect to said driving means to provide both horizontal and vertical controlled movement thereto.

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8. In an apparatus as defined in claim 10 including; means for individually adjusting the length of said respective arms when the latter are in contact with the casing walls.

9. In an apparatus as defined in claim 7 wherein at least one of said arms is extendable.

10. In an apparatus as defined in claim 1 including; a lateral positioner carried on said anvil, being spaced longitudinally from said rotary positioner and adapted to horizontally adjust the relative position of said anvil with respect to the walls of said casing for aligning said anvil with said pile ends.

11. In an apparatus as defined in claim 10 including a collar slidably carried on said anvil, and clamping means carried on said collar being operable to clamp against said anvil to fixedly position the collar thereto, and being further operable to disengage said collar from the anvil thereby permitting reciprocal movement of said anvil independently of said lateral positioner.

12. In an apparatus as defined in claim 10 wherein said lateral positioner includes a collar slidably carried on said anvil, and including a plurality of arms extending

outwardly therefrom and adapted to engage the casing wall.

13. In an apparatus as defined in claim 12 including; bearing means at the inner side of said collar for engaging said anvil to permit independent movement of the latter when said collar is disengaged therefrom.

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ERNEST R. PURSER, Primary Examiner

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