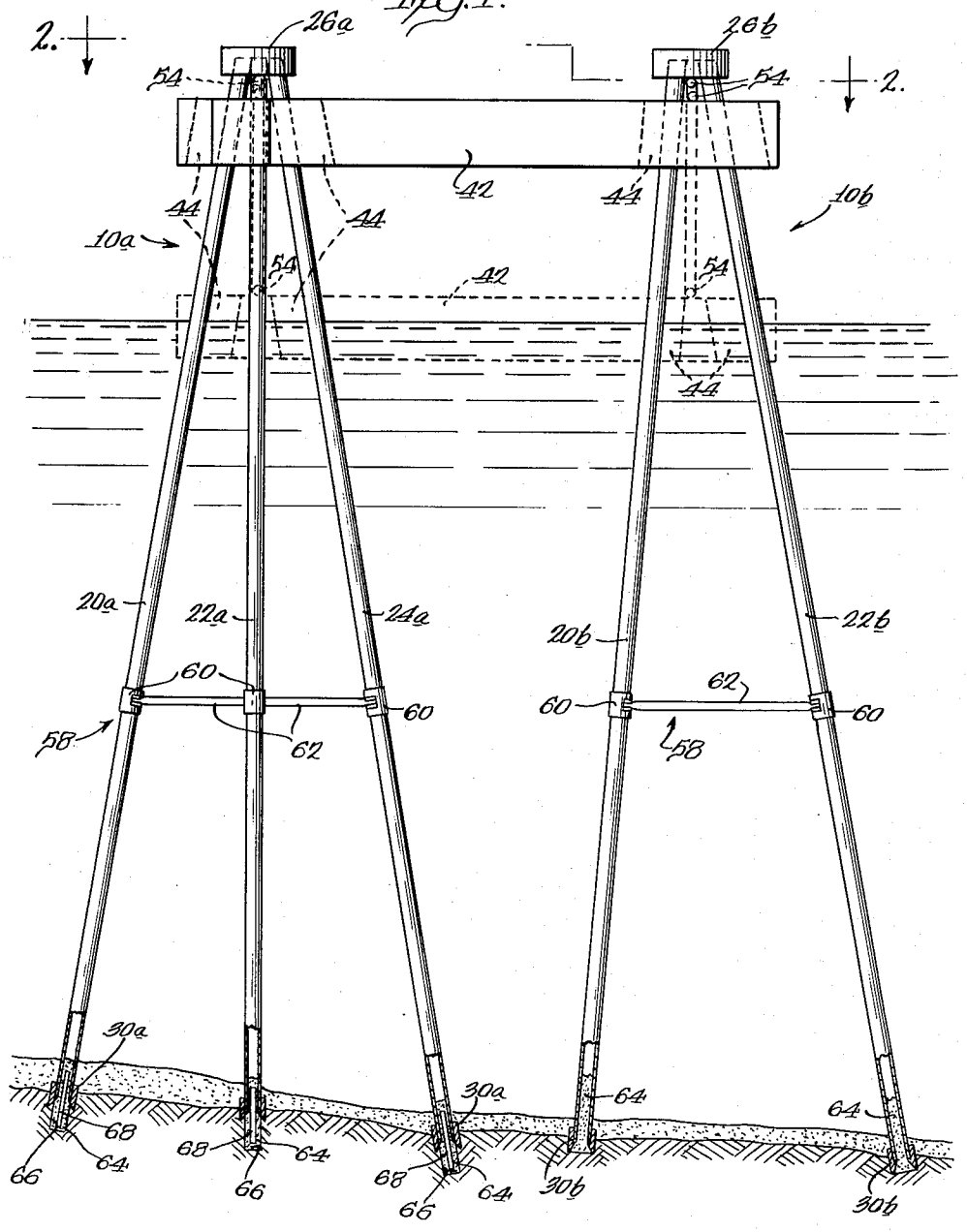
Dec. 24, 1963 J. H. THORNLEY 3,115,013

ARTIFICIAL ISLAND AND METHOD OF CONSTRUCTING THE SAME

Original Filed Sept. 5, 1956 3 Sheets-Sheet 1

Fig. 1.



INVENTOR.
Joseph H. Thornley
BY
Brown, Jackson, Boettcher & Dienner
Attys.

Dec. 24, 1963 J. H. THORNLEY 3,115,013

ARTIFICIAL ISLAND AND METHOD OF CONSTRUCTING THE SAME

Original Filed Sept. 5, 1956 3 Sheets-Sheet 2

Fig. 2.

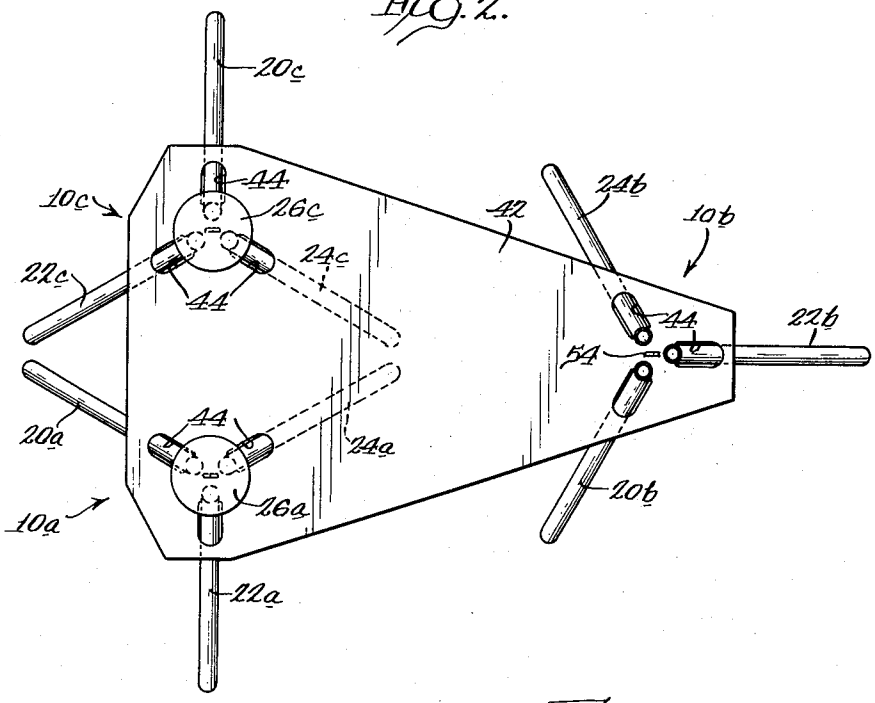
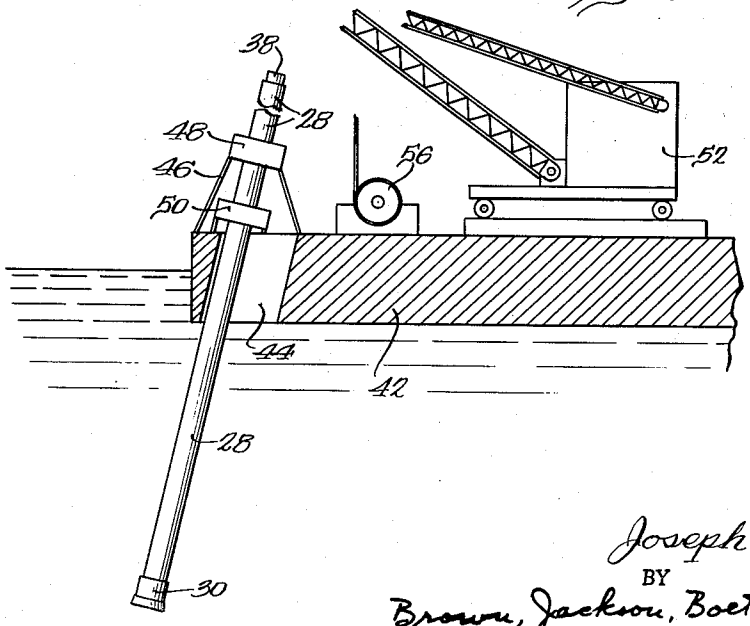


Fig. 3.



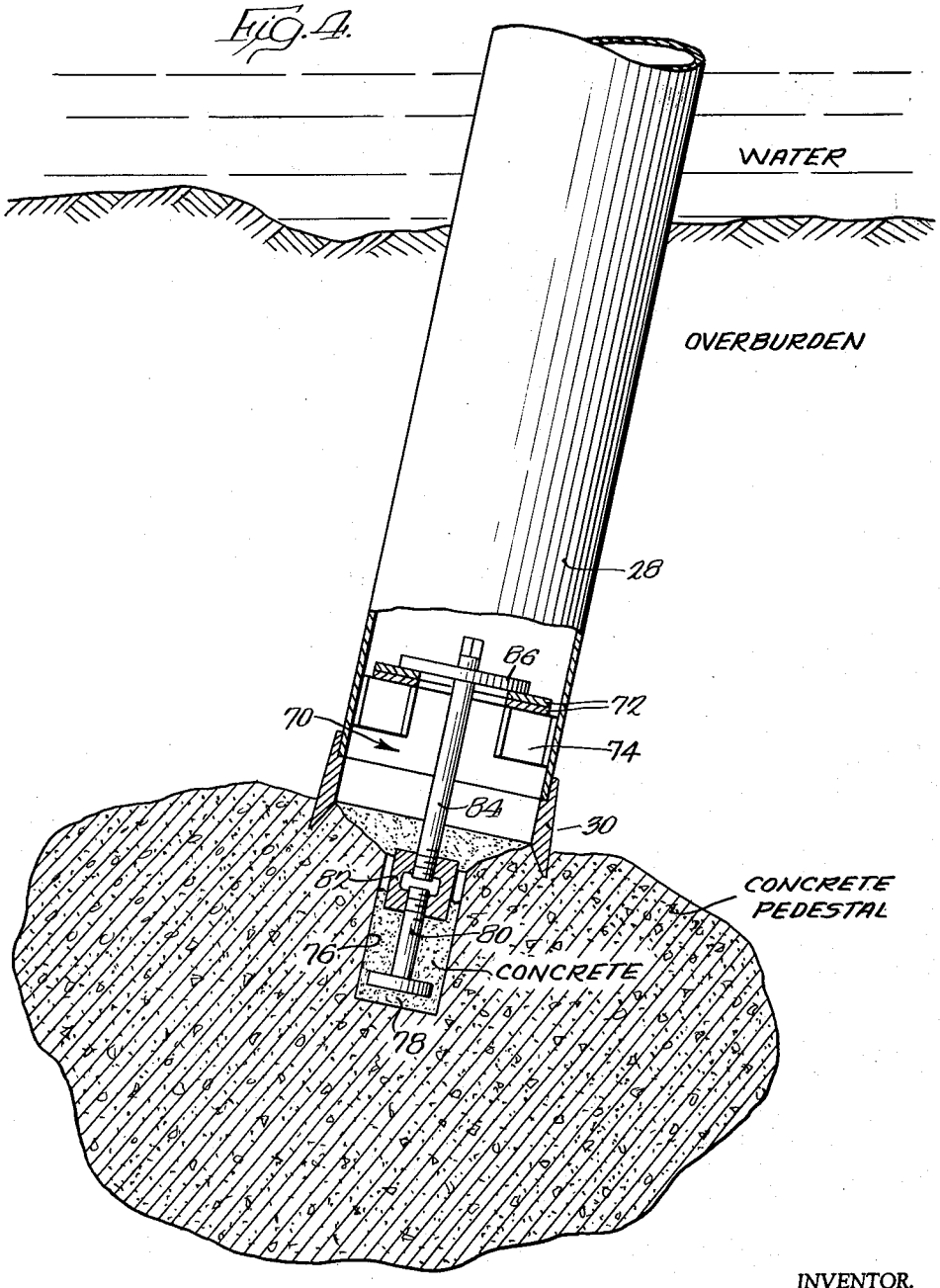
INVENTOR.
Joseph H. Thornley
BY
Brown, Jackson, Boettcher & Dienner
Attys.

Dec. 24, 1963 J. H. THORNLEY 3,115,013

ARTIFICIAL ISLAND AND METHOD OF CONSTRUCTING THE SAME

Original Filed Sept. 5, 1956 3 Sheets-Sheet 3

FIG. 4.



INVENTOR.
Joseph H. Thornley
BY
Brown, Jackson, Boettcher & Dienner

Attys.

United States Patent Office 3,115,013 Patented Dec. 24, 1963

3,115,013

ARTIFICIAL ISLAND AND METHOD OF CONSTRUCTING THE SAME

Joseph H. Thornley, 2503 West Drive, Douglaston, N.Y.

Original application Sept. 5, 1956, Ser. No. 608,079. Divided and this application May 2, 1958, Ser. No. 732,609

5 Claims. (Cl. 61—46.5)

The present invention relates to artificial islands, and to improved methods of and improved apparatus for erecting such islands. The application is a division of my co-pending application Serial No. 608,079, filed September 5, 1956, and now abandoned.

Recent developments in our national defense and in the oil industry have given rise to demand for artificial islands along the coastal areas of the country for radar installations and off-shore drilling rigs. In both cases, the islands may be only temporary and, therefore, must be economical, relatively easy to erect, and capable of being easily dismantled so as to cause no permanent obstruction to navigation. Yet, in use, the islands must be completely stable and therefore require a fixed foundation. When installed, such islands are subject to little vertical load, but live horizontal loading is large and of variable direction and magnitude as caused by shifting winds, currents, tides and waves. The demands thus imposed upon the structure obviously do not admit of a conventional solid masonry foundation, nor is the conventional pile form of support adequate. Specifically, horizontal load is delivered to a pile by cantilever beam reaction set up when the force tends to cause lateral movement at the upper end of the pile. Therefore, the optimum load sustaining characteristic of the pile, i.e., in compression, is not utilized in cases of dominant horizontal load. Moreover, the pile foundation suffers the disadvantage of requiring firm overburden at a limited depth, a situation not always encountered in off-shore areas, since resistance of the pile to horizontal loading is in inverse proportion to depth, i.e., stability is lost in direct proportion to increase in depth. Thus, masonry and pile foundations are not the answer to the problem.

It is one object of the present invention to provide an improved artificial island meeting and fully satisfying all of the demands of the art, and in particular, to provide an island that is economical, easy to erect, completely stable under the most severe conditions of horizontal loading without any required vertical load, and capable of being readily and completely dismantled.

Another object of the invention is the provision of an improved artificial island comprising at least three bottom anchored top joined conical skeletal foundation units disposed preferably in spaced geometric relation as viewed in plan, each unit comprising at least three downwardly divergent rigid elongate supports connected together at their upper ends and firmly anchored at their lower ends to sustain load in compression or tension longitudinally thereof, the supports of each unit extending above peak water level, and a barge slidably mounted on the upper end portions of the supports of each unit.

It is also an object of the present invention to provide an improved method of and improved apparatus for erecting artificial islands, especially my said improved island.

An additional object is to provide an improved method of and apparatus for erecting foundations in water courses, at sea, and in tidal areas, either as a temporary or permanent foundation.

Yet another object of the invention is to provide an improved method of and apparatus for erecting my said island, wherein a single barge is employed, first, to caryy the materials of construction to the site, second, to serve as the erection plateform, third, to guide the caissons during erection, fourth, to constitute the means connecting the upper ends of the foundation units, and fifth, to comprise the island per se in the complete construction.

A further object of the invention is the provision of improved apparatus for erecting and comprising an off-shore island, including a buoyant barge having at spaced points thereon at least three groups of guide means, each group including at least three guide means disposed on a batter the axes of which define a downwardly divergent conical skeleton, a plurality of rigid elongate supports, crane means on said barge for lifting and placing one of said supports in each of said guide means and for driving each support at a batter under the guidance of the respective means downwardly relative to said barge to rigid anchorage to define a stable conical skeletal foundation unit at each of said points, and hoist means on said barge for lifting the same upwardly on the upper extensions of said supports to dispose the barge above peak water level, whereby said barge comprises the vessel for carrying the apparatus to the island site, the plateform for erecting said foundation units and the island per se.

A still further object of the invention is the provision of an improved method of foundation erection as above defined including the steps of floating the barge to the site, utilizing the same as a work platform to drive the caissons, with portions of the caissons projecting above the platform, and subsequently elevating the barge on the caissons to dispose the same above peak water level to avoid as far as practicable the adverse effects of tidal and wave action.

Other objects and advantages of the invention will become apparent in the following detailed description.

Now, in order to acquaint those skilled in the art with my improved artificial island and my method of and apparatus for erecting the same, I shall describe, in connection with the accompanying drawings, a preferred embodiment of my island, the preferred apparatus used in erection of the island, and the preferred method of erecting and using the island.

In the drawings, wherein like reference numerals indicate like parts:

FIGURE 1 is a side view of my improved artificial island, the view showing the caissons of the tripod unit to the left of the view permanently set and the caissons of the tripod unit to the right of the view temporarily set, the barge, platform, or island being shown in dotted lines in its initial position and in solid lines in its final position;

FIGURE 2 is a top view of the island of FIGURE 1, the view being taken substantially on line 2—2 of FIGURE 1;

FIGURE 3 is a somewhat schematic fragmentary representation of the barge and equipment employed in erection of the island; and

FIGURE 4 is a fragmentary vertical section of a caisson and anchoring means therefor showing, first, an improved manner of anchoring a caisson other than by imbedding the same in bed rock, and second, an improved device for attaching the caisson to its anchor, whether that be bed rock or other means.

Referring now to FIGURES 1 and 2, I have shown an improved foundation for use as an artificial island that is stable under all loading conditions and is particularly adapted to support live horizontal loads applied in any direction. The foundation construction is comprised of a plurality of the anchored tripod or conical units 10 of my said co-pending parent application, preferably at least three in number, and disposed in spaced triangular or other geometric relation, as indicated respectively at 10*a*, 10*b* and 10*c*, and a member 42 supported on the upper end portions of the tripod units. Each conical tripod

unit 10 comprises at least three mutually downwardly divergent supports or caissons 20, 22 and 24. The caissons are immovably anchored at their lower ends and extend upwardly above the surface of the water. The axes of the caissons of each unit have a common point of intersection substantially above the surface, the caissons terminating somewhat below that point but above surface level, i.e., above the surface of the water in which the structure is erected, and being rigidly but detachably connected at their upper ends by a cap 26*a*, 26*b*, and 26*c*, respectively. The cap members, or the points of intersection defined by the several tripod or conical units, are disposed in geometric relation, a triangle in the case of three units as is shown in FIGURE 2, whereby spaced stable points or areas of support are provided.

Each unit individually is a highly stable instrumentality, the legs or caissons thereof being especially adapted for loading in both compression and tension. However, each unit individually suffers the one disadvantage that the caissons or supports thereof have a common axis of rotation and therefore cannot be stressed in the direction of the longitudinal axis upon application of a torque couple in the horizontal plane. For resolution of straight line forces, optimum design dictates a common point of caisson intersection, but the stated disadvantage then results. When three or more units have their apexes disposed in substantially a common horizontal plane and said apexes are rigidly interconnected as by a frame or platform, then they are capable of sustaining horizontal or vertical or twisting loads upon said frame or platform. Resistance to all overturning forces applied to the apex of a unit will be developed as tension or compression longitudinally of the individual caissons. The caissons are of ample strength to sustain the load in shear which results from horizontally acting forces or force components.

The preferred embodiment of the foundation unit of my invention is the symmetrical arrangement of the caissons on an equal predetermined batter having their lower ends connected to firm earth strata with an anchorage which is able to develop the full strength of the caisson in either tension or compression, and having the upper ends of the caissons converging to substantially a common intersection or apex and having said upper ends joined together in a cap with a connection to each other which is able to develop the full strength of the caissons in either tension or compression. This structure has remarkable properties, some of which are as follows:

(1) The unit develops resistance to horizontal forces applied at the cap and tending to overturn the unit, by developing tension and compression in the caissons. The strength of the structure to resist such load in any compass direction is substantially uniform. No vertical load is required to develop this property.

(2) The height to which the cap is carried above the base anchorage does not (within wide limits, and theoretically with no limits) affect the strength of the structure, for a given cross sectional size of caisson, to resist such overturning forces.

(3) The height of the unit or the direction of the horizontal force has no effect upon shear stresses which are the same for all heights and for all compass directions of the design load.

(4) For a given cross sectional size of caisson, the vertical load bearing value and stability of the unit is independent of the height of the structure.

(5) For developing resistance to a horizontal force at any reasonable distance above firm earth strata and from any compass direction, such, for example, as providing support for an off-shore drilling platform for any reasonable depth of water, the aforesaid unit requires a minimum of material and installation cost. No other known structure of equal strength and stability approaches it in economy and ease of construction.

(6) For a given foundation value, after being put into service, it requires a minimum of difficulty for its removal.

The member 42, being mounted on and connecting the upper end portions of the supports or caissons of all of the tripod units, thus is supported by the units against all forces that could be applied to the foundation. Moreover, the several units support the member 42 over an exceedingly large area of bed rock or rigid anchorage. Due to the downwardly divergent batter to the caissons in each unit and the fixed anchorage thereof, the area of anchorage encompassed by the nine or more caissons is large and is incorporated directly in the foundation construction as an integral part thereof. The caissons effectively raise that area of anchorage to the surface, so that the member 42, which is of relatively small area, is effectively bonded in and supported by a much larger volume of rigid anchorage. The member 42 thus is completely stable under all loading conditions irrespective of the forces and the direction of the resultant of the forces applied thereto. In particular, the foundation is especially adapted to installations wherein vertical loading is slight and horizontal forces are large, and of variable magnitude and direction.

By way of example, considerable interest has arisen recently in off-shore oil fields in the Gulf of Mexico and in the Pacific Ocean off the California coast. For operating a producing well in these fields, a fixed, semi-permanent artificial island is required. The island should be disposed above peak water level and must resist all forces applied thereto and support the oil pumping and storing equipment. For such islands, the loading problem is severe, residing primarily in the horizontally applied forces consequent upon wind and wave action. The principal load thus is a lateral force exerted at any point 360 degrees around the island, and its intensity may vary from zero during a dead calm to the extreme upper limits imposed by a hurricane. Foundation designs previously known to the art are not well suited for resistance to such loading. However, my improved foundation structure as shown in FIGURES 1 and 2 is ideally suited for this specific purpose, being stable under all load conditions. Thus, the invention affords an optimum solution to a specific current problem.

However, this problem is not the only one presently encountered in the off-shore oil fields, and it is an object of the invention to afford a complete solution of the problems concerning the instrumentalities from which drilling and production must be carried out. Specifically, to reach the oil in the off-shore fields, exploratory wells must first be drilled. To carry out the drilling operations, a drilling platform in the nature of a fixed island is required. If the drilling brings in a producing well, a permanent island is necessary, but if a producing well is not brought in, all of the equipment must be removed, at least at the mud line, so as to leave no obstruction to navigation.

With the equipment presently known to the art, feasible drilling platform designs are frequently limited to use in water depths up to about 50 feet, and up to 100 feet as a maximum, and then only in areas where the soil overburden is suitable to carry concentrated loads at a reasonable depth. Many of the rigs available to the art are usable only during periods of relatively calm whether and are not capable of use as drilling platforms in violent sea, or during the hurricane season in the Gulf of Mexico or the stormy season in the Pacific. Moreover, in the Pacific, depths frequently will be in excess of that feasible for known designs, and the soil overburden is too shallow and the rock profile too irregular reasonably to permit of use of conventional apparatus. Currents and wave action also tend to undermine known apparatus and seriously mitigate against maintaining the drilling platform stationary. If drilling brings in a producing well, then the permanent island for well operation must be erected separately of the drilling platform.

To overcome the disadvantages of known apparatus and methods, and to increase appreciably the areas of exploration and operation in off-shore oil fields, the present inven-

tion provides improved foundation means, and an improved method of and apparatus for constructing and using the same, that are suited for off-shore oil exploration and production. According to the invention, the practical depths of operation are increased to upward of 300 feet, soil overburden or lack thereof is not a factor controlling use of the equipment, cost is decreased, stability is increased, and the drilling platform is retained stationary despite the action of the sea. If a well is not brought in, the equipment is readily moved for use at another site, and if a producing well is brought in, part of the equipment used for the exploratory drilling becomes the permanent island foundation structure of FIGURES 1 and 2, and the remainder of the equipment may be removed for use elsewhere.

In bringing the foregoing advantages to practical fruition, the basic equipment employed by me, in its simplest form, is the foundation structure of FIGURES 1 and 2 embodied in the manner schematically shown in FIGURE 3. As shown in FIGURES 1 to 3, the member 42 comprises a buoyant barge generally of triangular configuration having at each of the three corners thereof three batter slots 44 disposed in star relation. Also at each corner, I provide a tower 46 extending upwardly from the barge deck and carrying guide collar means 48 at the upper end thereof. Each tower structure also includes locking means 50 adjacent the barge deck for a purpose to be described. Preferably, three guide collars and three locking rings are provided at each corner aligned respectively with the outer batter surface of the three slots as shown in FIGURE 3.

As to size, I contemplate that maximum loading conditions and space requirements should result in a design wherein, for purposes of example only, the barge may be approximately 160 feet long, 80 feet wide and 18 feet deep, having a draft under maximum load of 10 feet. The shells of the caissons may be from about 2½ to about 4 feet or more in diameter, as occasion requires, and wall thickness may be of the order of 1 to 1½ inches more or less, depending upon circumstances and the composition of the pipe, the slots 44, guides 48 and rings 50 being of a size to accommodate and guide the shells. Major deck equipment, in addition to the guides 48 and rings 50, includes means for anchoring the barge during erection of the foundation units, means for placing the caissons in the guides, for driving the caissons to rigid anchorage and for subsequently raising the barge on the caissons, and the necessary auxiliary gear. The lifting means may, for example, comprise a fifty-ton capacity crane 52 with controlled travel of eighty feet along the major axis of the barge, or two fifty-ton capacity stiff leg derricks, or suitable jacks. The caisson driving means suitably comprises a 24,000 ft.-lb. impact, differential or single acting steam hammer with the necessary boiler, leads, etc. If jacks are not provided between the barge and the caissons, I contemplate the use of three sets of blocks and tackle 54 for raising the barge on the caissons, each set to develop approximately 1200 tons and be operated by single or double hoists 56 developing a whipline pull of approximately sixty tons. The anchoring means preferably comprises three or more 2000 or 3000 lb. Danforth anchors with cable to give sufficient rode to hold the barge in approximate position in the maximum wind anticipated during erection.

Prior to the start of the drilling operation, a careful sounding and core boring operation will be carried out to determine rock contours and the nature of overburden and of bed rock.

To commence operations, the barge 42 is floated on the body of water in which exploratory drilling is to be carried out and the equipment, including the caisson components, is loaded on the barge. The barge is then towed to the drilling site. Upon nearing the well location, nine caisson pipes 28, each perhaps 160 feet long, will have been threaded by means of the crane 52 through the guide collars 48, locking rings 50 and batter slots 44, the pipes in their initial position, dependent upon the depth of the water, extending 30 or 40 feet below the bottom of the barge as shown in FIGURE 3 and being guided by the collars 48 above the deck. The degree of batter, about 1:8, is calculated for the maximum initial thrust of wind and wave action and for the maximum final lateral load under the worst possible conditions, the batter, anchorage and thickness being adjusted accordingly. Each pipe passes through a locking ring 50 at deck level so that it may be restrained from descending under its own weight. When the time comes to lower a pipe, it will be raised slightly by the derrick or crane to free the locking ring wedges and then lowered to the required position. At its lower end, each of the nine pipes or shells 28 carries a tool steel tempered cutting or drive ring 30 and at its upper end an internal or external splice ring 38.

When the barge reaches the drilling site, three or more anchors are placed to retain the barge in position. Assuming water depth at the drill site to be 200 feet at mean high tide, and the overburden to comprise 15 feet of silt and sand overlying medium hard bed rock having an irregular surface, the foundation is set as follows: The first section of the shell of each caisson is lowered by the crane 52, after release of the lock 50 in the manner described, to the top of the deck tower. The second sections of the caissons, which may each be 100 feet or more or less long, are then set over the splice sleeves 38 at the top of the first sections and a team of two or three welders to each three caisson group welds the second sections to the lower sections. The locking rings are again released and all pipes lowered until they contact the rock. Each of the nine caisson pipes is then driven to refusal on or in the rock, using the heavy duty hammer. Thereafter, a removable head cap (26*a*, 26*b* or 26*c*) is mounted and clamped on each of the tripod caisson groups or conical foundation units.

In the above situation, wherein bed rock is not particularly deep and soil overburden is shallow, the caisson shells are driven to bed rock as described. However, if bed rock were considerably deeper, and firm soil overburden were of substantial depth, concrete pedestals could be driven out in the overburden as illustrated in FIGURE 4. Specifically, as shown, a substitute for bed rock may be employed in instances wherein the substitute can be provided at greater economy and with greater practicality than driving the caissons to bed rock. In certain areas, it will be found that the strata of the earth are such that bed rock is exceedingly deep and there is a great depth of firm soil overlying bed rock. Under these conditions, it is practical, both commercially and from the standpoint of structural rigidity, to substitute for bed rock huge pedestals formed by the driving out of large bodies of concrete into the overburden, the depth in the overburden at which the pedestals are formed, together with the volume of concrete used, governing the load capacity of the fabricated anchor either in tension or compression. In such case, the caissons would be driven to a firm seat on the pedestals, preferably to refusal after the concrete had set so that the caissons could readily be removed for the purpose and under the circumstances to be described hereinafter.

After the caisson shells have been driven to refusal, spiders or sway bracings 58 are installed on each conical unit, the spiders being mounted on and rigidifying the caissons of each unit intermediate bed rock and the platform 42. Each spider may suitably comprise three collars 60 slidably mounted respectively on the caisson shells, and three horizontal ties 62, for example 12 inch diameter pipes, extending between and detachably connected to the collars. Due to the downwardly divergent relationship of the caissons, the spider by its own weight will slide down into locking engagement on the pipes.

Dependent upon expected weather and/or sea conditions during exploratory drilling, the caisson shells of each

of the conical units may be bonded to their anchors, i.e., bed rock or a suitable pedestal, in any one of several manners. For temporarily bonding each caisson to its anchor, the simplest procedure is to deposit concrete within the lower end of each caisson shell to extend a short distance into the shell, as indicated by the concrete plug 64 in the caissons of the unit 10*b* at the right side of FIGURE 1. For purposes of rigid bonding, a socket 66 is drilled prior to setting the concrete plug 64, and a short axial re-enforcing stub 68 of a length to extend upwardly from the socket a short distance into the pipe is employed, as shown at the left side of FIGURE 1. Alternatively, for either permanent or temporary anchorage, an anchoring device of the character disclosed in FIGURE 4 may be employed.

In FIGURE 4, the anchoring device, indicated at 70, is shown as being bonded in a concrete pedestal. It is to be appreciated, however, that the anchoring device may be applied with equal facility in bed rock. As shown, the device comprises one or more annular bearing plates 72 supported in the interior of the caisson shell adjacent the lower end thereof by brackets 74 welded to the wall of the shell. The central opening in the bearing plates may, for example, be about 20 inches in diameter to accommodate passage therethrough of a drill after the shell has been driven to refusal on bed rock or a pedestal. The drill is operated in the manner previously described to produce a socket 76 below the cutting shoe of the shell, which socket may, by way of example, extend approximately 6 feet below the shoe. When the socket is completed, the drill is removed and grout, indicated at 78, is placed in the socket to a depth of five feet or so in the example given. Before the grout sets, an anchor member 80 is set axially in the socket 76 and imbedded in the grout therein, the member suitably comprising a piece of shafting of the necessary diameter to take the calculated uplift and a heavy base plate of approximately the maximum diameter that can be accommodated in the socket. At its upper end, the shaft of the member 80 is threaded for the reception of a sleeve coupling 82. The member 80 and coupling 82 are preferably assembled and lowered as a unit into the grout, and are located in the socket with the upper portions of the coupling protruding above the surface of the grout. When the grout is set, the members 80 and 82 are rigidly bonded in bed rock or in a pedestal effectively to constitute a unitary part thereof and to provide a "handle" on bed rock or the pedestal for attachment thereto of the caisson shell. In the embodiment disclosed, attachment of the caisson shell is effected by means of a second or top anchoring member 84 comprising a piece of shafting of the same diameter as the bottom member 80 and a bearing flange 86 of a diameter greater than the inner diameter of the bearing plates 72, the flange 86 being welded to the shaft adjacent, but in spaced relation to, the upper end thereof. The shaft of the top member 84 is threaded at its lower end for attachment to the coupling sleeve 82 and is squared at its upper end to accommodate a wrench by means of which the top member may be threaded into the sleeve to force the flange 86 into secure engagement with the upper bearing plate 72 whereupon the caisson shell is bottom anchored to accommodate tension loading thereof. Points or areas of moving contact in the anchoring device are preferably graphite packed, and the ungrouted section of the socket and the bottom three to four feet of the shell may be filled with mastic or grease to prevent rusting.

When the caisson shells of the various foundation units shown in FIGURES 1 and 2 have been engaged on or set in rigid anchorage, i.e. bed rock or a pedestal, in any of the manners above described, and the sway bracings have been installed, the guide collars 48 and locking rings 50 may be removed from the caisson shells. The lifting tackle sets 54 are then attached to the bottoms of the caps 26, and the hoists 56 are operated to raise the barge 42 on the upper extensions of the caissons. Lifting is simultaneously carried out at the three locations to insure uniform raising of the barge, and also to accommodate such trimming of the barge as may be necessary. The barge is raised on the tripod units to the required height in relation to peak water level, whereupon the barge comprises a stationary drilling platform, the slots 44 in the barge being of a length to accommodate such raising of the barge, as is clearly shown in FIGURE 4.

With the caisson shells set, the sway bracing spides in place, and the barge elevated, a highly stable, stationary drilling platform is afforded and exploratory drilling may be commenced immediately.

If the exploratory drilling is non-productive and the site is to be abandoned, the drilling equipment is retracted to the barge or platform 42, the barge is lowered on the caissons to a floating position on the body of water, and the guides 48 and locking rings 50 are again disposed about the caissons on the towers 46. If the caisson shells were anchored by means of concrete plugs 64, the plugs are drilled out. If stub cores were employed, the same are removed, if convenient, after drilling out the plugs 64. If the anchoring device shown in FIGURE 4 were employed, the top member 84 thereof is threaded out of the sleeve 82 and removed. In any event, the caissons are first released from their bottom anchorage. The spiders 53 are then removed by lifting each spider by means of the crane 52 to slack off the connections of the ties 62, whereupon the ties may each be detached from one collar and the three collars and ties raised to the barge. The crane 52 and locking rings 50 are thereafter employed to retract the caissons from bed rock to substantially the position shown in FIGURE 3. As the upper pipe section of each caisson is raised above the respective tower 46, it may be removed from the lower section, thus to restore the apparatus substantially to its original condition, whereupon the anchors may be weighed and the barge towed to a new drilling location.

As one drilling site is abandoned, the entirety of the apparatus employed for the temporary island is removed, with the exception of the pedestals and/or the stub cores, bottom members and sleeves of the anchoring device, if employed, so that there is little if any material waste and no remaining obstruction to navigation.

If at the first or subsequent drilling site a producing well is brought in, or if added stability is desired, the island may be rendered permanent with particular facility. Specifically, if the caisson shells were merely driven to refusal in bed rock or a pedestal in the first instance, or if the same were temporarily anchored by means solely of the concrete plugs 64, the shells are first rigidly anchored at their bottoms by drilling out the concrete plugs and drilling a socket in bed rock or the pedestal in axial alignment with each caisson shell. Each socket is cleared and a charge of grout deposited therein. Re-enforcing stub cores 68 or the bottom members 80 of the anchoring devices 70 are then inserted in the sockets and the grout is permitted to set. If stub cores are employed, as shown in the unit at the left in FIGURE 1, the shell is filled at its lower end with concrete to bond the shell or pipe to the core and thus to bed rock or the pedestal. According to the present invention, I prefer to employ the anchoring devices shown in FIGURE 4, which devices are installed in the manner previously described.

If in the original installation of the caisson shells, the shells were bottom anchored by driving the shells into pedestals prior to setting thereof, or by bonding stub cores in sockets in bed rock or the pedestals and in the lower ends of the shells, or by use of the anchoring device of FIGURE 4, the caissons would already have been bottom anchored to the extent necessary for a per-

manent island installation and further bottom anchorage would not be required.

In those instances where contemplated use of the foundation is as a temporary or semi-permanent island or foundation construction, the caisson shells or pipes are designed to carry the calculated load without necessity for the extra stiffening and bearing value that would be afforded by use of a complete concrete fill and a full length core in a permanent installation. By virtue of this design, the caisson shells even when rigidly anchored at their bottoms are hollow throughout substantially the full length thereof. This affords the distinct advantages, as will be pointed out hereinafter, of facilitating complete removal of any possible obstructions, and of accommodating recovery to the greatest extent possible of reusable components of the foundation when the temporary or semi-permanent island or other installation is abandoned. Nevertheless, with this design, the shells afford a permanently usable foundation even in those cases where the contemplated temporary nature of the structure proves to be erroneous.

When the caissons of the several foundation units have been rigidly anchored at their bottoms in any of the manners described, the caps **26** of each tripod or conical unit are permanently set. The foundation is then complete and rigid and the barge **42** comprises a permanent fixed island from which the operations necessary to oil production or the like may be carried out. The barge may be locked semi-permanently to the upper end portions of the caissons or the caps **26**, whereafter the sets of tackle **54** may be removed. All unnecessary equipment including the towers **46**, guides **48**, locks **50**, crane **52**, tackle sets **54** and hoists **56** may then be removed from the barge for use on another rig at a different location.

In all cases, there is little or no waste of equipment. The island, whether temporary, semi-permanent, or permanent, is comprised solely of its essential components and all additional material may be re-used. The conversion of the drilling platform to a permanent foundation is readily effected at substantial economy, particularly as compared to the prior practices of the art. Yet, the resultant foundation is completely and optimumly stable under all loading conditions, and provides an optimum, fixed area for carrying out the functions of oil production or the like.

While the resultant island construction is permanently fixed against the elements to which it may be subjected, the same still affords the distinct advantage of semi-permanency as concerns its users. Specifically, if the well should run dry, the island may be dismantled by reinstalling thereon the equipment previously described. The barge is first released from the caissons and lowered to water level, and the rigid cap on each conical unit is removed. The bottom anchorage is then eliminated by release of the anchoring device or by drilling as may be appropriate according to the anchoring means employed. After each caisson has been released from its anchor, the caisson shell may, due to the fact that it is hollow and of relatively light weight, be raised to the barge deck, whereby all equipment above bed rock or the pedestals, and thus above the mud line, is removed from the site, so that there is no remaining obstruction to navigation. Moreover, the barge is then restored substantially to its originally equipped condition for use at other drilling sites.

While the foundation of FIGURES 1 and 2, and the artificial island described in conjunction therewith, have been shown and described as embodying three of the conical units of my said parent application, it is to be appreciated that any number of the units, each comprised of three or more legs, may be employed in any desired pattern to afford a rigid foundation adapted to a wide variety of uses. Each of the bottom anchored conical skeletal units affords a point of rigid support, a strong point, which inhibits lateral movement of the barge or other structure supported thereby irrespective of the interaction it has with other strong points. Thus, the strong points afford wide latitude as to number and the pattern of placement.

From the foregoing, it is to be appreciated that the present invention provides an improved foundation adapted especially for use as a temporary, permanent, or semi-permanent artificial island, and an improved method of and apparatus for erecting such foundation, that are ideally and optimumly suited for use in the manner described in off-shore oil fields and for other off-shore uses. Thus, all of the objects and advantages of the invention have been shown to be attained in an economical, convenient and practical manner.

While I have shown and described what I regard to be the preferred embodiments of my artificial island and of my method of and apparatus for erecting the same, it will be apreciated that various changes, rearrangements, and modifications may be made therein without departing from the scope of the invention, as defined by the appended claims.

I claim:

1. Method of erecting an artificial island in a body of water which comprises floating a barge on said body of water whereby it initially gains vertical support, anchoring said barge to the ground for lateral support at the location where said island is to be located, lowering from said barge three downwardly divergent tubular casings guided endwise into engagement with a rigid stratum below the barge, driving each casing into tight engagement with the rigid stratum, cutting a socket into the rigid stratum as an axial extension of the bore of said casing, disposing a metallic anchoring member partly in the socket and partly in the bore of the casing, filling each socket with cement to bond the anchoring member to the walls of the socket, connecting said anchoring member to the inside wall of the casing, connecting the upper ends of the convergent casings together at a point above the barge in a common cap by which the upper ends of the casings are rigidly secured together against relative endwise movement with respect to each other to form a stable bottom anchored tripod capable of resisting large forces applied to the cap member from any direction, erecting on the bottom below said barge at least two additional stable tripods as aforesaid to form a polygonal figure, transferring the lateral anchorage of the barge from said ground anchorage to said stable tripods, raising the barge from the supporting water by transferring the weight of the barge to said stable tripods and holding the same by connection with said caps against horizontal and vertical forces whereby said barge forms a platform supported against overturning by the full strength of the rock socketed casings in tension and compression longitudinally thereof without any substantial bending forces and resisting overturning independently of vertical loading.

2. Method of erecting an artificial island in a body of water which comprises floating a barge on said body of water whereby it gains vertical support, anchoring said barge to the ground for lateral support at the location where said island is to be located, emplacing from said barge a series of at least three groups of caissons, said groups being disposed in a closed pattern, each group consisting of three downwardly divergent upwardly convergent caissons bonded at their lower ends into sockets in underlying firm earth strata for supporting tension or compression axially of the caissons, and bonding their upper ends together rigidly against longitudinal or lateral movement with respect to each other by a cap, transferring the lateral support of said barge to said groups of caissons and transferring the weight of said barge to the caps of said groups and raising the barge above the level of the water, whereby said barge constitutes a platform supported by said groups of caissons against overturning independently of vertical loading, and capable of resisting lateral

and vertical loads without imposing bending stresses upon the caissons.

3. The method of claim 2 applied at a location where the bottom of the body of water comprises rock with overburden ineffective to support driven piles, and wherein the lower ends of the caissons are projected into and bonded into sockets in the rock for supporting tension or compression along the longitudinal axes of the caissons to substantially their full strength and without substantial bending stress being produced in said caissons by horizontal forces acting upon said platform.

4. Method of erecting an artificial island in a body of water which comprises floating a barge upon said body of water, anchoring said barge to the ground for lateral support at the location where said island is to be erected, emplacing from said barge a series of at least three bottom anchored top bonded tripods by projecting down from the barge and anchoring into rigid strata downwardly divergent caissons in sets of three to form tripods, said three caissons of each set converging at their upper ends, bonding said convergent caissons of each set of three together at their upper ends against relative movement longitudinally and laterally, whereby forces from any direction applied to said bonded ends are resisted without incurring bending stresses in said caissons, transferring the lateral support of the barge to said bonded together upper ends of said tripods, transferring the weight of said barge to said bonded together upper ends of said tripods and raising the barge above the level of the water whereby said barge constitutes a platform capable of resisting lateral and vertical loads without imposing bending stresses upon the caissons.

5. A structure of the class described for providing an artificial island in a body of water comprising a buoyant barge having releasable means for anchoring the same on the water at the intended location of the island, a series of at least three tripods arranged at the corners of a polygon consisting of three downwardly divergent caissons bonded in rigid sockets in firm strata at their lower ends whereby they are capable of rigidly sustaining loads in tension and compression in the direction of their longitudinal axes, said caissons converging at their upper ends, caps in which said upper convergent ends are bonded together against movement relative to each other for each tripod, said barge having means employed while the barge is floating in the water to guide the caissons and emplace them, and means on said barge for connecting it with the caps of said tripods to carry the weight of the barge upon said caissons when the barge is raised out of the water, said barge when raised out of the water and supported upon said caps being capable of resisting horizontal forces from any compass direction by tension and compression in said caissons in the direction of their longitudinal axes without substantial bending stresses and being stable against overturning independently of vertical loading.

References Cited in the file of this patent

UNITED STATES PATENTS

1,164,085	Goldsborough	Dec. 14, 1915
1,365,197	Scott	Jan. 11, 1921
1,449,236	Malone	Mar. 20, 1923
2,472,869	Travers	June 14, 1949
2,475,933	Woolslayer	July 12, 1949
2,531,983	McCoy	Nov. 28, 1950
2,589,146	Samuelson	Mar. 11, 1952
2,600,761	Halliburton	June 17, 1952
2,608,830	Burrell	Sept. 2, 1952
2,653,451	McCullough	Sept. 29, 1953
2,699,042	Hayward	Jan. 11, 1955
2,740,261	Stark	Apr. 3, 1956
2,774,218	Hazak	Dec. 18, 1956
2,775,095	Harris	Dec. 25, 1956
2,927,435	Upson	Mar. 8, 1960