United States Patent

Olsen et al.

[15] **3,645,345**

[45] **Feb. 29, 1972**

[54] DYNAMIC PILE-DRIVING SHOES

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[22] Filed: **July 14, 1970**

[21] Appl. No.: **54,774**

[52] **U.S. Cl.** **175/56**, 61/53.5, 175/19, 175/56, 175/103, 175/171

[51] **Int. Cl.** **E21b 1/06**

[58] **Field of Search** 175/19–23, 94, 175/92, 171, 402, 56, 103; 61/53.5

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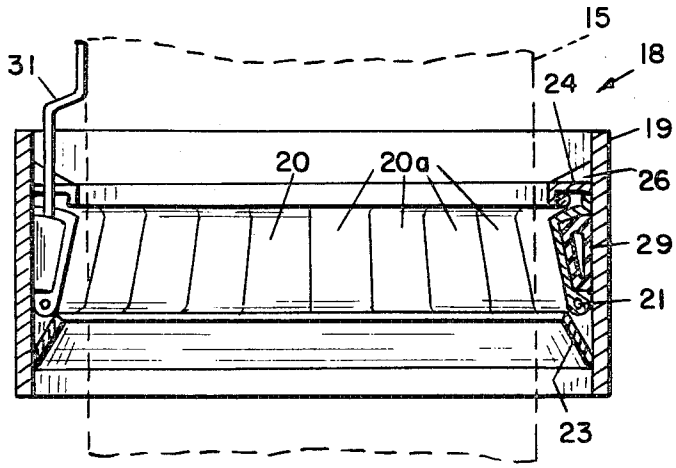
[57] **ABSTRACT**

An annulus encircles the lower end portion of a pile which is impacted at its upper end. The annulus contains a radially contractable and expansible collar consisting of a plurality of individual segments, and an expansible and contractable hollow ring is interposed between the annulus and the collar. The collar is actuated by hydraulic fluid under pulsating pressure, so that the collar segments impart vibration to the pile while it is being driven into the earth. The hollow ring has at least two segmental sections each spanning only a portion of the total number of collar segments, and the hydraulic fluid supply is controllable by valves so that the ring segments may be actuated in unison or in alternating succession.

8 Claims, 6 Drawing Figures



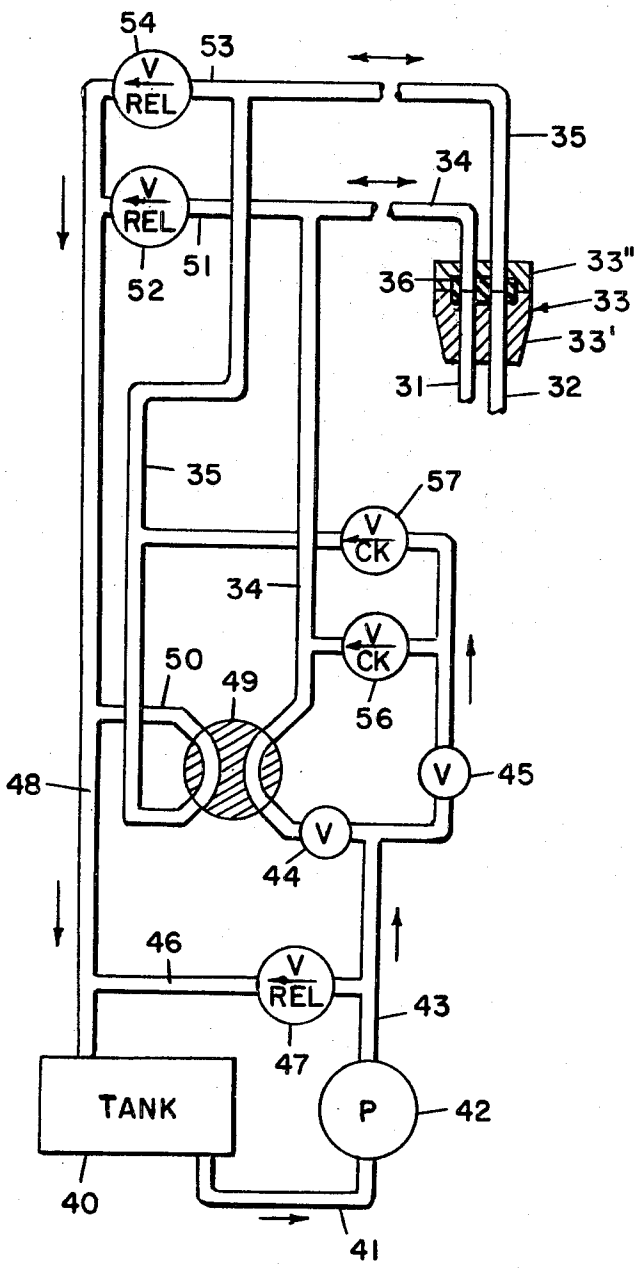


FIG. 2.

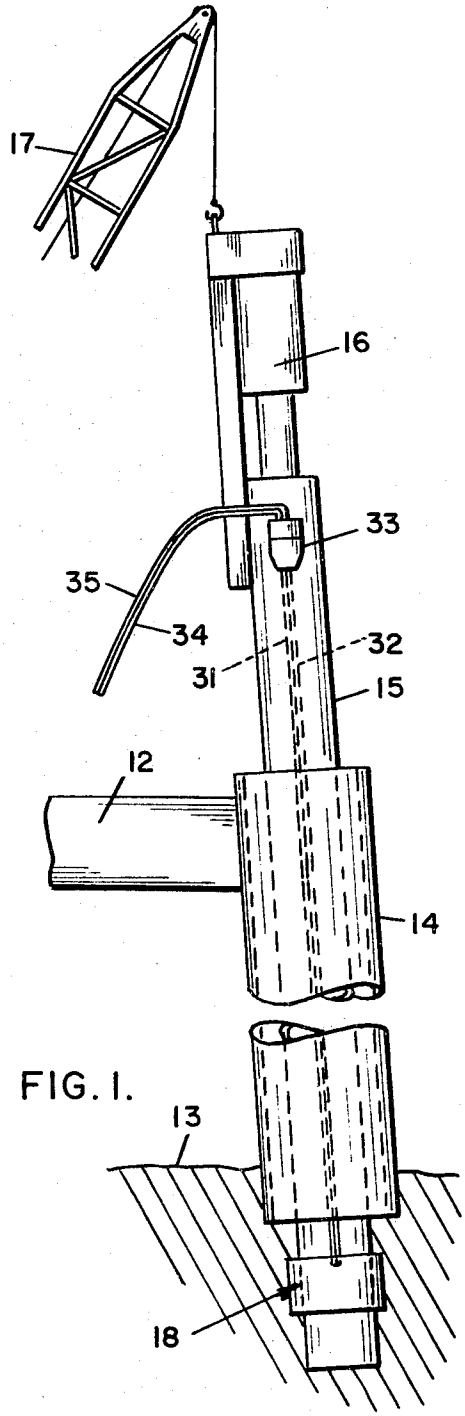


FIG. 1.

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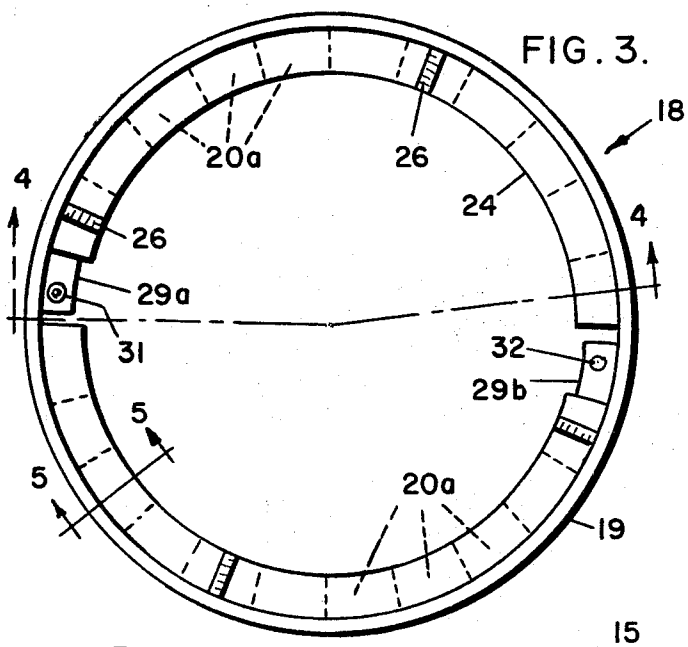
FIG. 3.



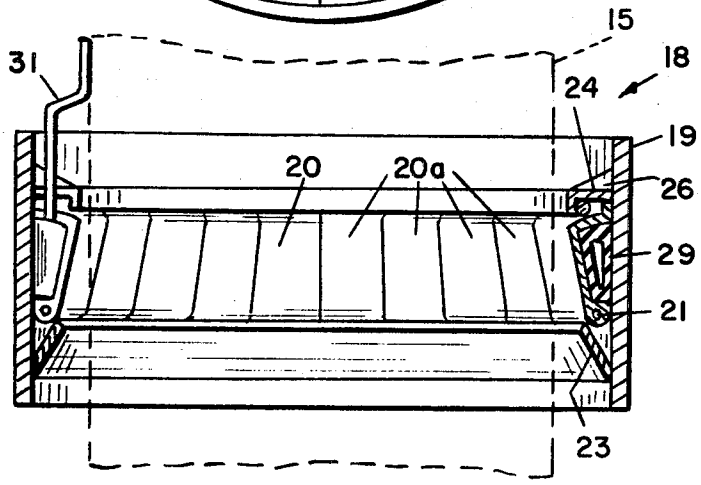


FIG. 4.

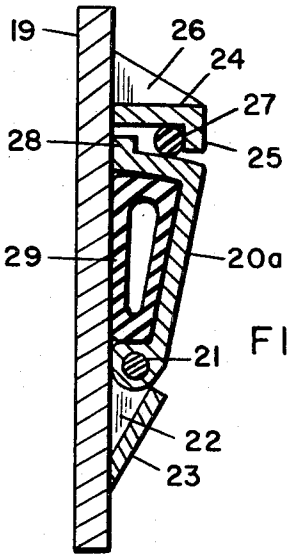


FIG. 5.

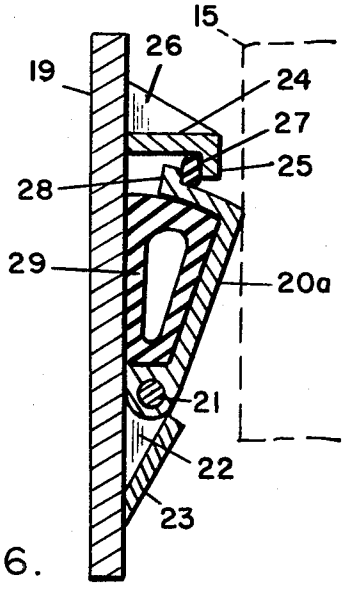


FIG. 6.

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DYNAMIC PILE-DRIVING SHOES

This invention relates to new and useful improvements in the art of pile driving, and while it is applicable generally to driving of piles into the earth, it is particularly concerned with pile driving into the bottom of oceans, lakes and other bodies of water, for the purpose of anchoring offshore oil-drilling equipment, marine platforms, dock facilities, dam installations, and the like.

The piles commonly used in this environment are open-ended and their driving into the sea bed is resisted by skin friction both outside and inside the pile. As driving continues, at some depth the inside skin friction or plug resistance increases to a value which exceeds the force required to produce a bearing failure below the pile tip and, as a result, the pile ceases to core the earth and becomes plugged, thus making it difficult, if not impossible, to drive the pile to a greater depth.

Some efforts have been made to eliminate this difficulty by placing a so-called shoe on the lower end portion of the pile which is driven into the earth, such efforts being based on the theory that skin friction would be reduced by the increased area of displacement which the shoe affords. However, such conventional shoes, rigidly secured to the pile, have not been very successful in their intended purpose and, under some conditions of soil, have not been successful at all.

It is, therefore, the principal object of the invention to provide an improved pile-driving shoe which, rather than being static or rigidly fixed to the pile, is of a dynamic nature and capable of imparting vibrations to the lower end portion of the pile so as to substantially minimize internal soil resistance and skin friction and thereby materially facilitate penetration of the pile into the earth.

As such, the dynamic shoe of the invention consists of a pile-encircling annulus which contains a radially contractable and expansible collar composed of a plurality of individual segments. An expansible and contractable hollow ring is interposed between the annulus and the collar and is actuated by hydraulic fluid under pulsating pressure so that the collar segments impart vibrations to the lower end portion of the pile on which the shoe is positioned, to substantially minimize internal soil resistance and skin friction as the pile is driven into the earth. The arrangement is such that the collar segments may be actuated either in unison or in alternate succession, as may be desirable under different soil conditions.

With the foregoing more important object and features in view and such other objects and features which may become apparent as this specification proceeds, the invention will be understood from the following description taken in conjunction with the accompanying drawings, in which like characters of reference are used to designate like parts, and in which:

FIG. 1 is a fragmentary view, partly in elevation and partly in vertical section, showing the shoe of the invention applied to a pile which is being driven into the sea bed to anchor an offshore platform;

FIG. 2 is a diagrammatic view of the hydraulic system used for actuating the shoe;

FIG. 3 is an enlarged plan view of the shoe per se;

FIG. 4 is a vertical sectional view of the shoe, taken substantially in the plane of the line 4—4 in FIG. 3;

FIG. 5 is an enlarged sectional view, taken substantially in the plane of the line 5—5 in FIG. 3 and showing one of the collar segments in its outwardly moved or expanded position;

FIG. 6 is a view similar to that in FIG. 5, but showing the collar segment in its inwardly moved or contracted position.

Referring now to the accompanying drawings in detail, more particularly to FIG. 1, the same illustrates a portion of an offshore platform 12 supported on the sea bed 13 by a plurality of legs, only one of which is shown as consisting of a tubular jacket 14 through which an anchoring pile 15 is driven into the sea bed. The driving of the pile is effected in the conventional manner by delivering impacts to its upper end, as by a power hammer or pile driver 16 suspended from a crane 17. The dynamic shoe of the invention, designated generally by the reference numeral 18, is applied to the lower end portion of the pile 15, it being understood that some clearance usually

exists between the outside diameter of the pile and the inside diameter of the jacket 14 so that the pile with the shoe thereon may be passed downwardly through the jacket and driven into the sea bed, the shoe remaining on the pile when the driving operation has been completed.

Reference is now drawn to FIGS. 3–6 which show the shoe 18 in detail. The same comprises an annulus 19 which is of sufficient diameter to freely encircle the pile 15 and is provided on the inside thereof with a radially contractable and expandible collar 20 consisting of a plurality of individual collar segments 20*a*. These collar segments, made of metal, are mounted by individual pivot pins 21 in bearing blocks 22 which are secured at circumferentially spaced points to the inside of the annulus 19. The collar is radially contracted when the collar segments 20 are swung radially inwardly about the pins 21 to the position shown in FIG. 6. Conversely, the collar is expanded when the segments 20*a* are swung radially outwardly in the direction of the annulus to the position shown in FIG. 5. An inclined annular shield 23 is secured to the inside of the annulus 19 below the collar 20 and overlaps the bearings 22 and the pivoted lower portions of the collar segments 20*a*, whereby to prevent soil from gaining access to or plugging up the pivotal mountings of the segments when the shoe with the pile is being driven into the earth.

An annular member 24 with a downturned marginal lip 25 is secured to the inside of the annulus 19 above the collar 20, and a bumper ring 27 of elastic material is positioned below the member 24 at the inside of the lip 25. The collar segments 20*a* are provided at their upper end with detents 28 and when the segments are moved radially inwardly to the position shown in FIG. 6, the detents 28 come into engagement with the bumper ring 27 and thus stop means are provided for limiting the extent of inward movement of the collar segments. As this occurs, the elastic bumper ring 27 is compressed against the lip 25 and when the force which moved the collar segments inwardly ceases, expansion of the elastic ring 27 biases the collar segments outwardly in the direction of the annulus 19.

The contractable and expansible collar 20 is actuated by an expansible and contractable ring 29 of elastomeric material, which ring is interposed between the annulus 19 and the collar sections or segments 20*a*, so that when the ring 29 is expanded by hydraulic fluid under pressure, the collar 20 is contracted and, conversely, when the ring 29 is contracted, the collar 20 is expanded by movement of the collar segments 20*a* outwardly under the bias of the bumper ring 27. In the contracted position of the collar 20, the segments 20*a* come into positive engagement with the pile 15, while in the expanded position of the collar the positive engagement of the segments with the pile is substantially relaxed, if not fully separated. Thus, by alternately contracting and expanding the collar 20, a series of vibrations may be imparted to the lateral surface of the pile 15. These vibrations may have a fairly high frequency and may be produced by very small pivotal movement of the collar segments 20*a*, not necessarily as large as may seem from a comparison of FIGS. 5 and 6 where the extent of movement has been exaggerated for illustrative purposes.

Under some soil conditions it may be desirable to vibrate the pile by alternately contracting and expanding all of the collar segments 20*a* is unison. Under other soil conditions it may be preferred to actuate the collar segments sequentially, as for example, by contracting the collar segments on one side of the pile and expanding those on the opposite side of the pile. To afford such sequential actuation, the actuating ring 29 is divided into a plurality of segmental sections which are isolated from each other and each of which has a circumferential span extending over only a portion of the total number of the collar segments 20*a*. Possibly, a separate actuating ring section may be provided for each collar segment, but satisfactory results can be obtained if the actuating ring is composed of only two substantially semicircular sections, as shown at 29*a* and 29*b* in FIG. 3, where each of the ring sections spans one-half of the total number of collar segments 20*a*.

Hydraulic fluid under pulsating pressure is delivered to the two ring sections 29*a*, 29*b* by separate conduits 31, 32, respectively, which extend upwardly from the annulus 19, either along the outside or the inside of the pile 15 to a junction block 33 which is provided on the outside of the pile adjacent its upper end, as will be apparent from FIG. 1. Inside the annulus 19, the aforementioned annular member 24 may be interrupted or recessed as shown in FIG. 3 to afford clearance for the conduits 31, 32.

The junction block 33 near the upper end of the pile 15 consists of two separable members 33′ and 33″, the member 33′ being secured to the pile and having the conduits 31, 32 connected thereto. The member 33″ is removable from the member 33′ and has connected thereto conduits 34, 35 which communicate with the respective conduits 31, 32 when the members 33′, 33″ are coupled together. Suitable sealing means 36 are provided to prevent leakage at the points of connection of the conduits 31, 32 with the conduits 34, 35. The conduits 34, 35, which for most part may consist of flexible hoses, extend from the junction block 33 to a hydraulic system on the platform 12, the details of the hydraulic system being hereinafter described. In the meantime it may be noted that when the pile is composed of a number of sections which are driven in succession and are welded in series as the driving continues, each pile section is provided with the conduits 31, 32 having a junction block member 33′ at their upper end and a junction block member 33″ at their lower end, so that as each pile section is added, the conduits 31, 32 are correspondingly extended by connecting the block member 33″ at the lower end of the added pile section to the block member 33′ at the upper end of the preceding pile section, while the block member 33′ at the upper end of the added section is connected to the member 33″ on the conduits 34, 35.

The hydraulic system shown diagrammatically in FIG. 2 includes a fluid reservoir or tank 40 supplying fluid through a line 41 to a motor-driven pup 42, the pump having a discharge line 43 extending to a pair of manually operable shutoff valves 44, 45. A bypass line 46, equipped with an excess pressure relief valve 47, extends from the discharge line 43 to a fluid return line 48 for the tank 40.

The valve 44 communicates with one port of a four-way valve 49, another port of which communicates with the aforementioned conduit 34 and hence with the conduit 31 leading to the ring section 29*a* in the shoe 18. A third port of the valve 49 communicates with the conduit 35 and hence with the conduit 32 leading to the ring section 29*b*. The fourth port of the valve 49 is connected as at 50 to the fluid return line 48. The conduit 34 has a branch 51 provided with a release valve 52 and similarly the conduit 35 has a branch 53 provided with a release valve 54, both the valves 52 and 54 discharging into the return line 48.

The valve 45 communicates by a branched line 55 with a pair of check valves 56, 57, the valve 56 being connected to the conduit 34 and the valve 57 being connected to the conduit 35, as will be readily apparent.

In operation, assuming that the pump 42 is energized, the valve 44 is open, the valve 45 is closed and the four-way valve 49 is in the position shown in FIG. 2, fluid flows from the pump through the open valve 44 and through the valve 49 into the conduits 34, 31 and into the ring section 29*a*, thus expanding the latter and causing the collar segments 20*a* spanned by the ring section 29*a* to contract or move inwardly into positive engagement with the adjacent side portion of the pile 15. Simultaneously, the valve 49 permits backflow or drainage of fluid from the ring section 29*b* through the conduits 32, 35 and 48 to the tank 40, so that the collar segments 20*a* which are spanned by the ring section 29*b* are relaxed from their positive engagement with the opposite side portion of the pile 15.

When fluid pressure in the ring section 29*a* builds up to a predetermined value, the release valve 51 opens for a brief discharge of fluid into the return line 48 and the resultant drop in pressure instantly closes the release valve 52, thus allowing the pressure to build up again. Thus, fluid under pulsating pressure is delivered to the ring section 29*a* to produce vibrations on only one side of the pile, while the ring section 29*b* on the opposite side is inactive. Similarly, when the four-way valve 49 is turned by 90° from the illustrated position, the valve 44 delivers fluid into the conduit 35 and the conduit 34 is communicated with the return line 48 through the connection 50. In such instance the release valve 54 creates pulsating pressure in the conduits 35, 32 and in the ring section 29*b* to actuate the latter, while the ring section 29*a* in inactive.

In another mode of operation the valve 44 is closed, the valve 45 is opened, and the valve 49 is turned through 45° from the illustrated position so that all four ports of the valve 49 are closed. Fluid then flows from the pump through the open valve 45 and through both check valves 56, 57 to both conduits 34, 35, and hence through the conduits 31, 32 to both ring sections 29*a*, 29*b*, the release valves 52, 54 again serving to produce pulsating pressure in the conduits and ring sections, but this time in both ring sections in unison. Thus, all the collar segments 20*a* are alternately contracted and expanded in unison around the entire circumference of the pile, as distinguished from impacting first one side and than the other side of the pile, as in the mode of operation first described.

Obviously, the four-way valve 49 may be either a sliding valve or a rotary valve. Also, the two valves 44, 45 may be substituted by a single two-way valve, capable of delivering the pumped fluid either to the valve 49 or to the valves 56, 57.

While in the foregoing there has been described and shown the preferred embodiment of the invention, various modifications may be resorted to, falling within the spirit and scope of the claims.

What is claimed as new is:

1. A dynamic driving shoe for placement on the lower end portion of a pile which is driven into the earth by impacts delivered to its upper end; said shoe comprising a pile-encircling annulus, a radially contractable and expansible collar mounted on the inside of said annulus for engagement with a pile, and hydraulically actuated means for alternately contracting and expanding said collar whereby to impart vibrations to the pile.

2. The device as defined in claim 1 wherein said hydraulically actuated means include an expansible and contractable hollow ring interposed between said annulus and said collar, and means for delivering hydraulic fluid under pulsating pressure into said ring.

3. The device as defined in claim 2 wherein said collar includes a plurality of individual collar segments engaged by said ring.

4. The device as defined in claim 2 wherein said collar includes a plurality of individual collar segments engaged by said ring, said ring consisting of at least two segmental ring sections which are isolated from each other and are connected independently to said fluid-delivering means, each of said ring sections spanning only a portion of the total number of collar segments.

5. The device as defined in claim 4 wherein said fluid-delivering means include at least two conduits connected to the respective ring sections, a hydraulic pump, and valve means operable to deliver hydraulic fluid from said pump under pulsating pressure to said conduits selectively in unison or in alternating succession.

6. The device as defined in claim 1 wherein sad collar comprises a plurality of individual collar segments movable radially inwardly from said annulus when the collar is contracted, and stop means provided on the inside of the annulus for engagement by said collar segments to limit their inward movement.

7. The device as defined in claim 6 together with resilient bumper means interposed between said collar segments and said stop means, said bumper means being resiliently compressed when the collar segments are moved inwardly and serving to bias the segments in the outward direction.

8. The device as defined in claim 6 which is further characterized in that said collar segments are pivotally mounted in said annulus.

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