US006386295B1

(12) **United States Patent**
Suver

(10) **Patent No.: US 6,386,295 B1**
(45) **Date of Patent: May 14, 2002**

(54) **VIBRATORY DRIVER FOR PIPE PILING**

(76) Inventor: **Paul W. Suver**, 11025 14th Ave., S. Seattle, WA (US) 98168

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/525,631**

(22) Filed: **Mar. 10, 2000**

(51) **Int. Cl.**[7] **E02D 7/18**
(52) **U.S. Cl.** **173/1**; 173/49; 175/55; 405/232
(58) **Field of Search** 173/1, 49, 132; 405/231, 232; 175/55

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,917,426	A	11/1975	Wohlwend et al.	404/133
5,117,925	A	6/1992	White	173/162.1
5,263,544	A	11/1993	White	173/162.1
5,544,979	A	8/1996	White	405/232
5,568,997	A	10/1996	Raunisto	405/232
5,609,380	A	3/1997	White	294/104
5,653,556	A	8/1997	White	405/249
5,794,716	A *	8/1998	White	173/49
5,988,297	A *	11/1999	Zimmerman et al.	173/1
6,073,704	A *	6/2000	Yasuoka et al.	175/55
6,129,159	A *	10/2000	Scott et al.	173/49
6,302,222	B1 *	10/2001	Vessat	405/232

FOREIGN PATENT DOCUMENTS

EP	0 496 167 A1	12/1991	E02D/11/00

* cited by examiner

Primary Examiner—Scott A. Smith
(74) *Attorney, Agent, or Firm*—Delbert J. Barnard

(57) **ABSTRACT**

A coupler assembly (**46, 48**) is suspended from a forward section (**12**) of a boom (**14**) that projects from a mobile base (**18**). An upper end portion (**160**) of a pipe piling (P) is gripped by a pair of clamp jaws (**148, 150**). The clamp jaws (**148, 150**) are movable together and apart and they are mounted for rotation around a common axis. This allows an end portion (**160**) of a pipe piling (P) to be gripped by the clamp jaws (**148, 150**) while the pipe piling (P) is in a substantially horizontal or some other non vertical position. Then, the coupler assembly (**46, 48**) can be lifted to lift the gripped end portion (**160**) of the pipe piling (P) upwardly. As end portion (**160**) moves upwardly, the clamp jaws (**148, 150**) will rotate in position so as to enable the pipe piling (P) to swing upwardly while its lower end is on a support surface. The rotation of the clamp jaws (**148, 150**) will continue until the pipe piling (P) is suspended from the lifting boom section (**12**) and is in a substantially vertical orientation.

40 Claims, 6 Drawing Sheets

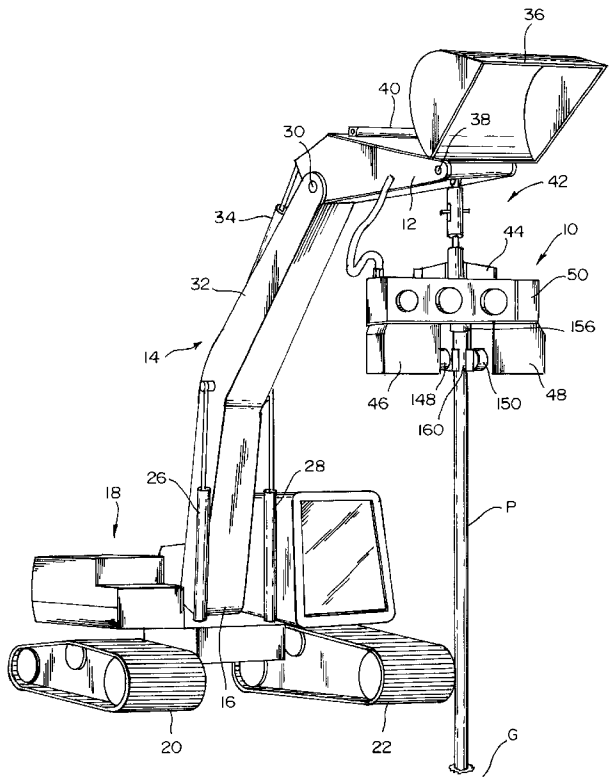
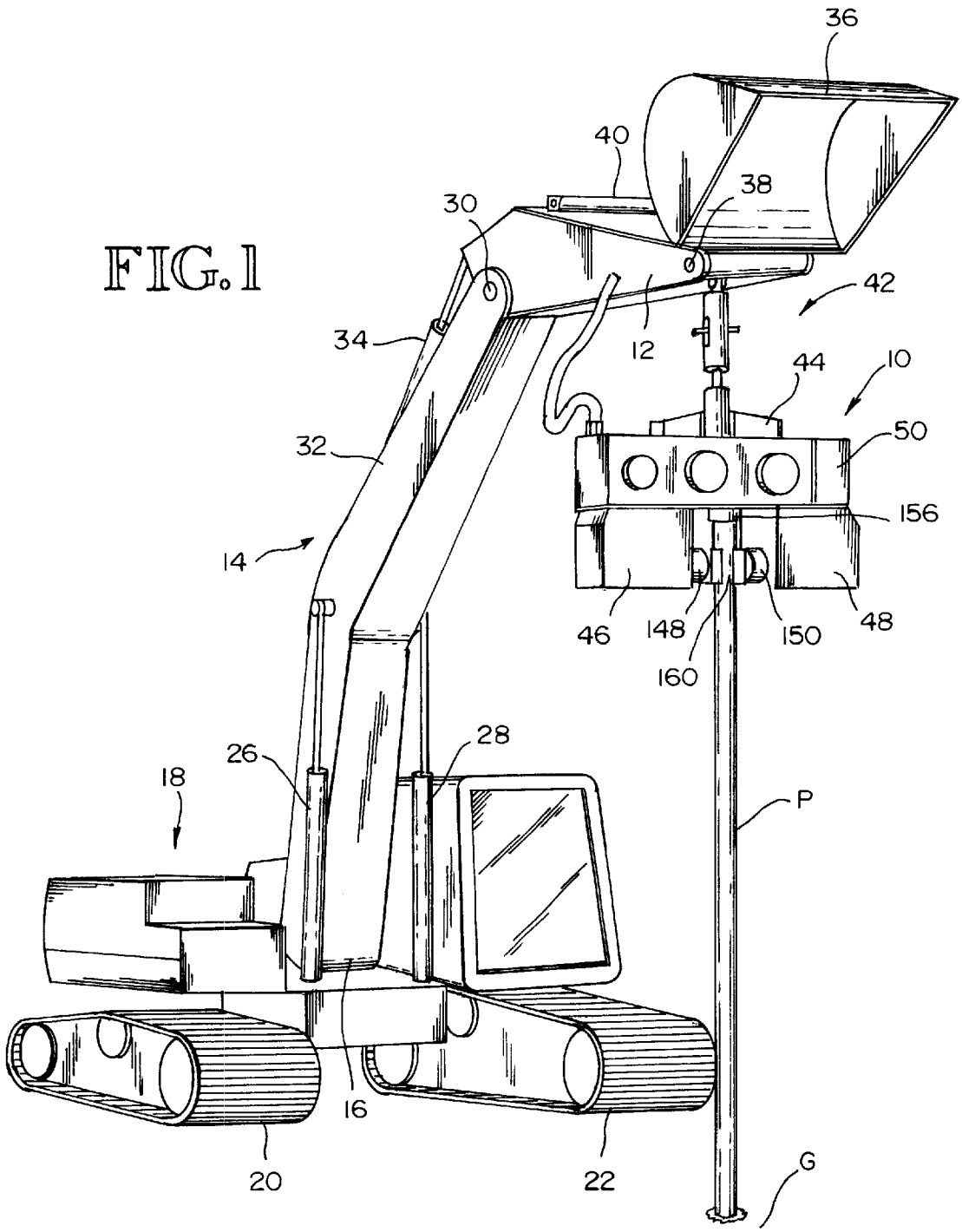


FIG. 1


36
40
38
30
42
34
12
44
10
32
50
156
14
46
148
150
48
160
26
28
18
P
16
20
22
G

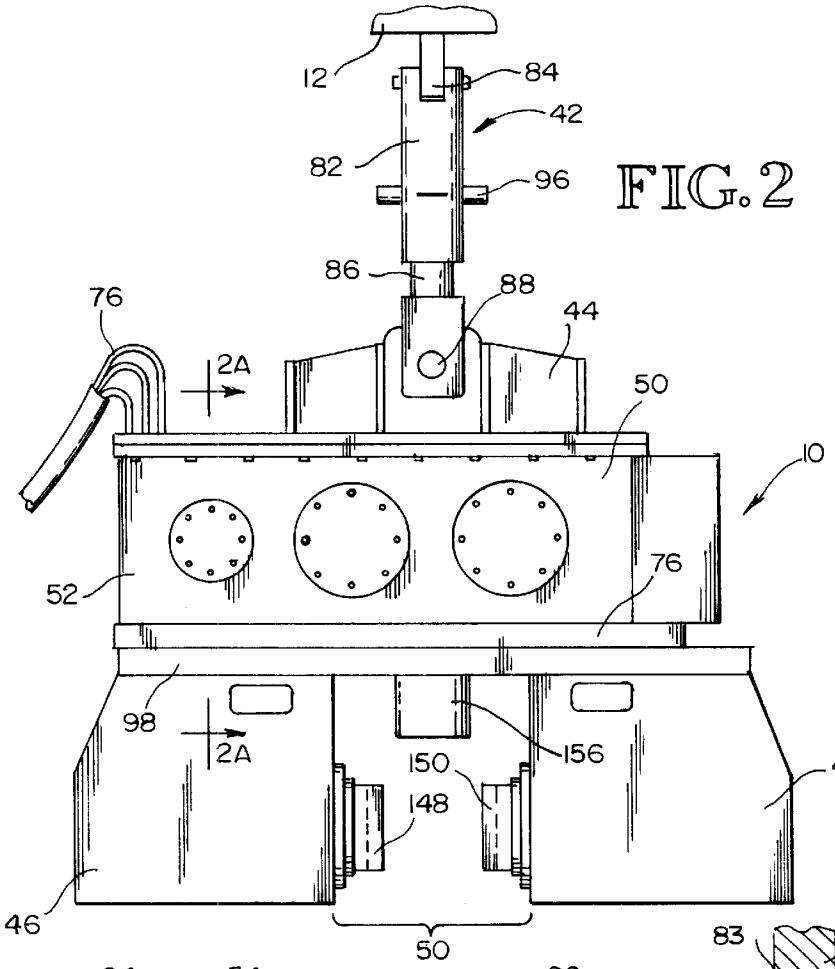


FIG. 2

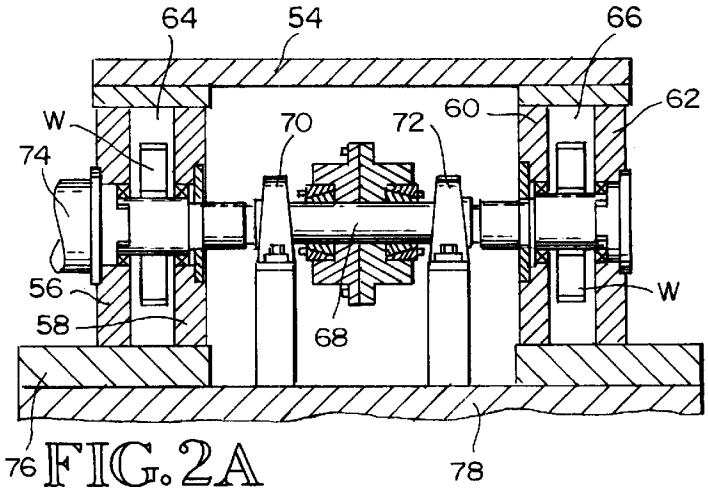


FIG. 2A

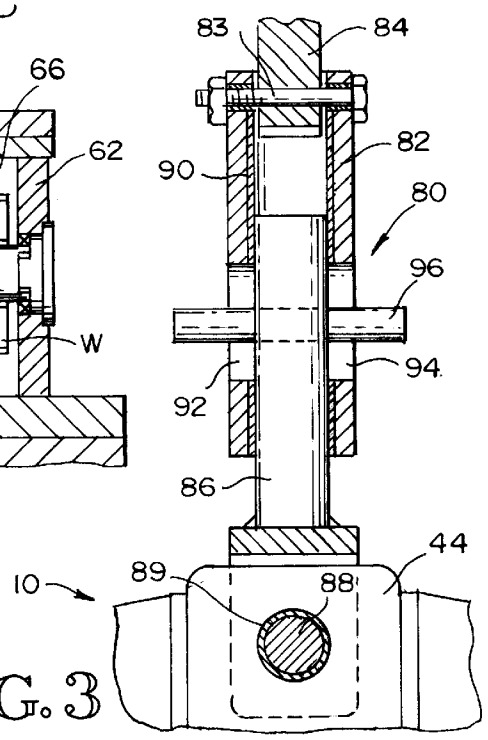


FIG. 3

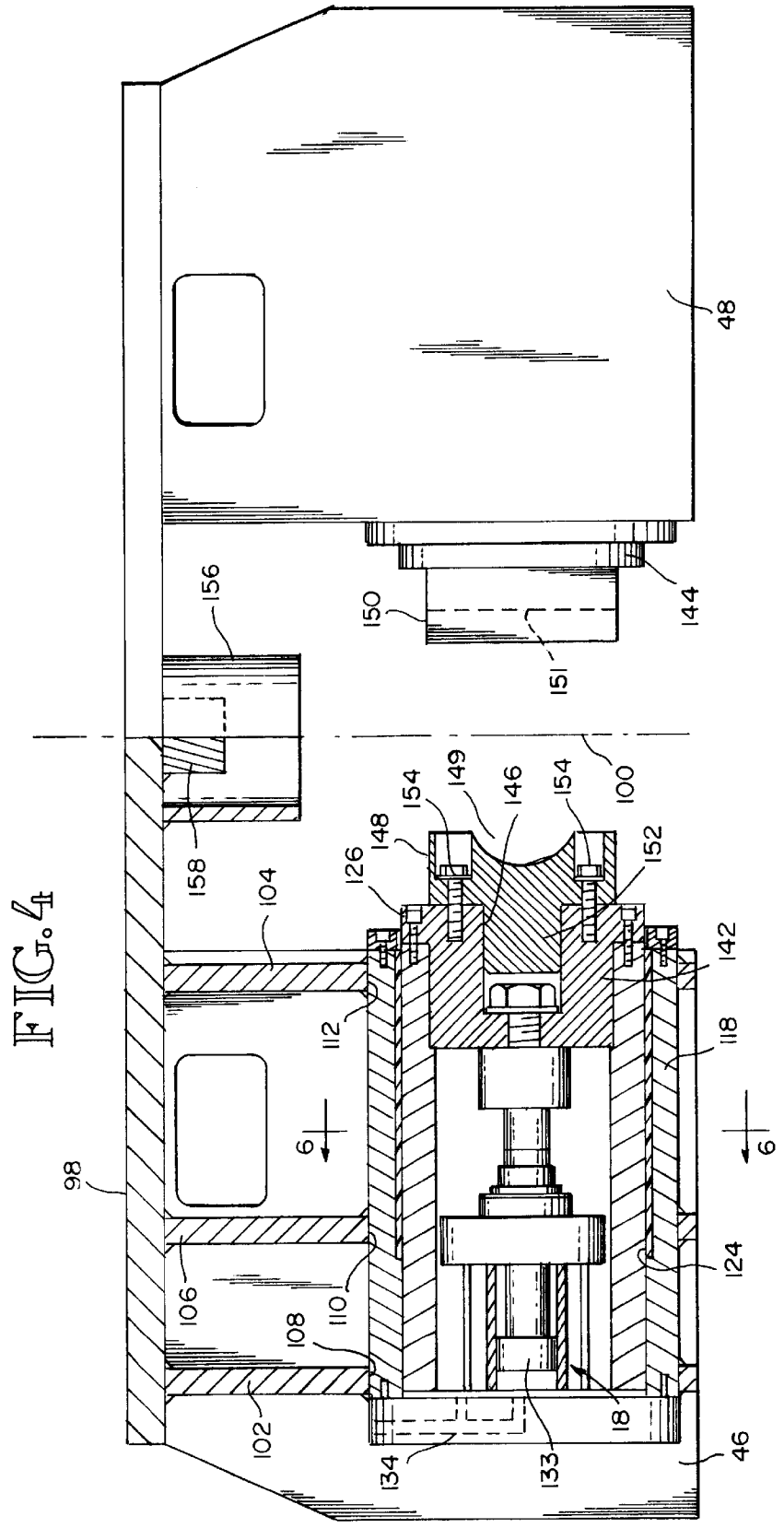

48
156
150
144
151
158
104
154
149
146
154
148
126
152
100
142
112
118
6
6
98
106
110
108
124
102
18
134
133
46

FIG. 4

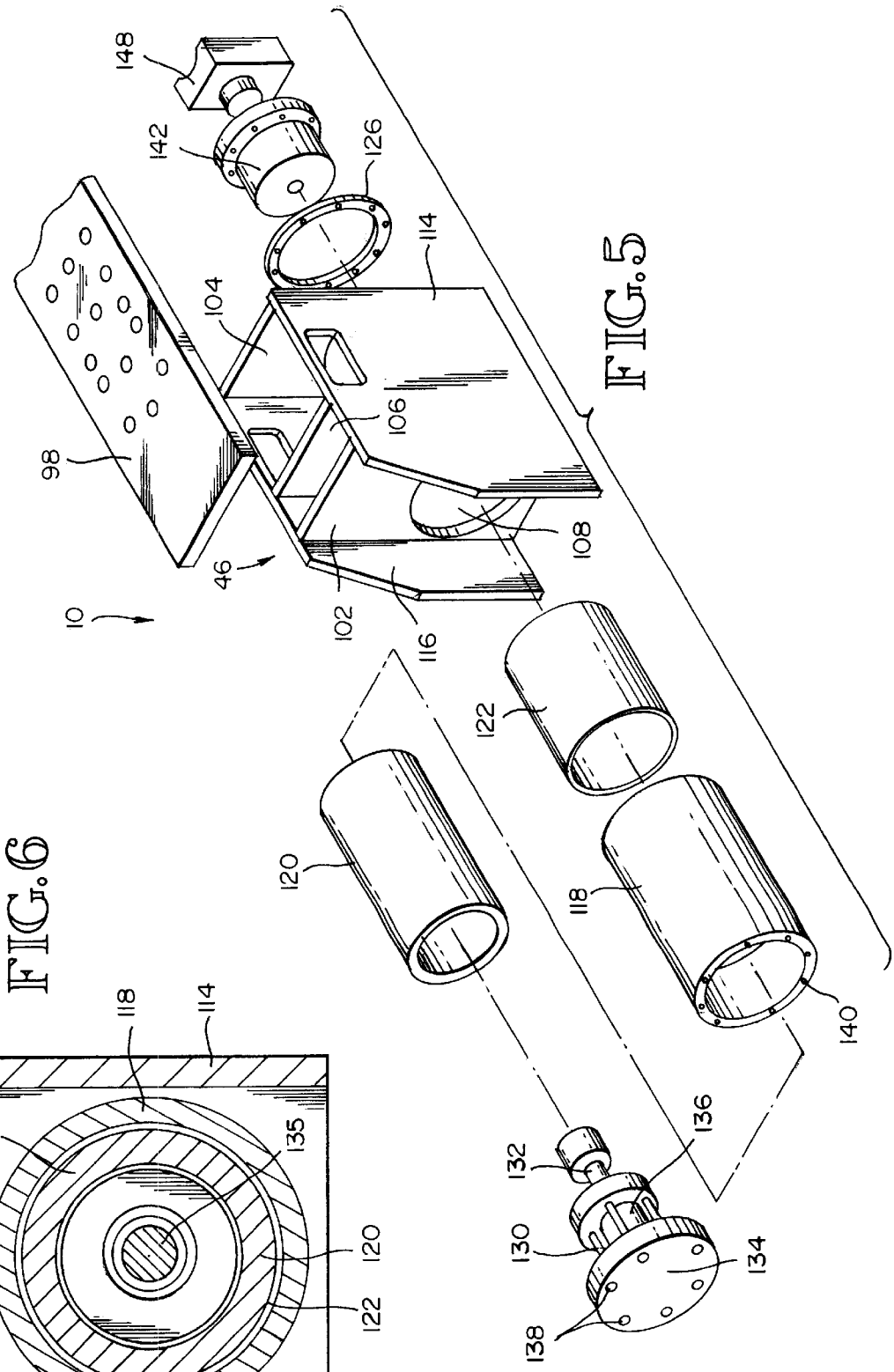

148
142
126
114
104
106
98
108
46
10
102
116
122
120
118
140
132
136
130
134
138

FIG. 5

118
114
136
135
120
122
116

FIG. 6

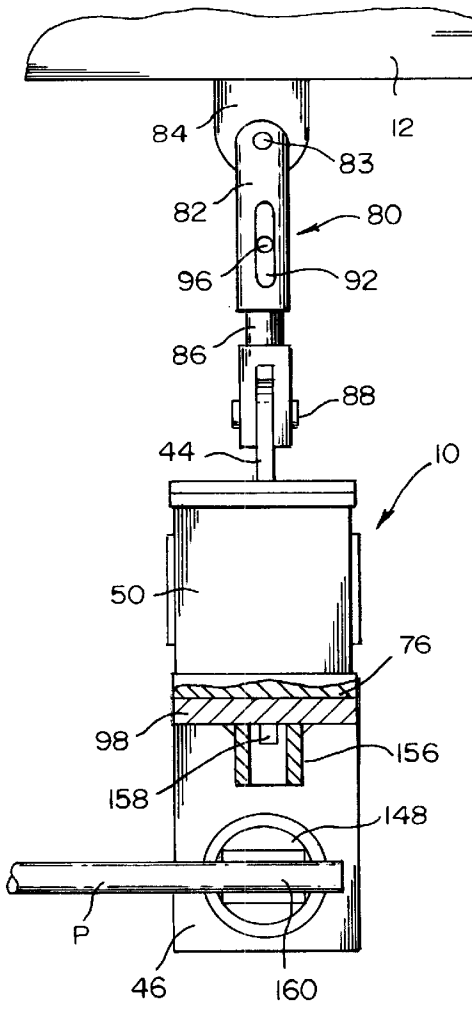

12
84
83
82
80
96
92
86
88
44
10
50
76
98
156
158
148
P
46
160

FIG. 7

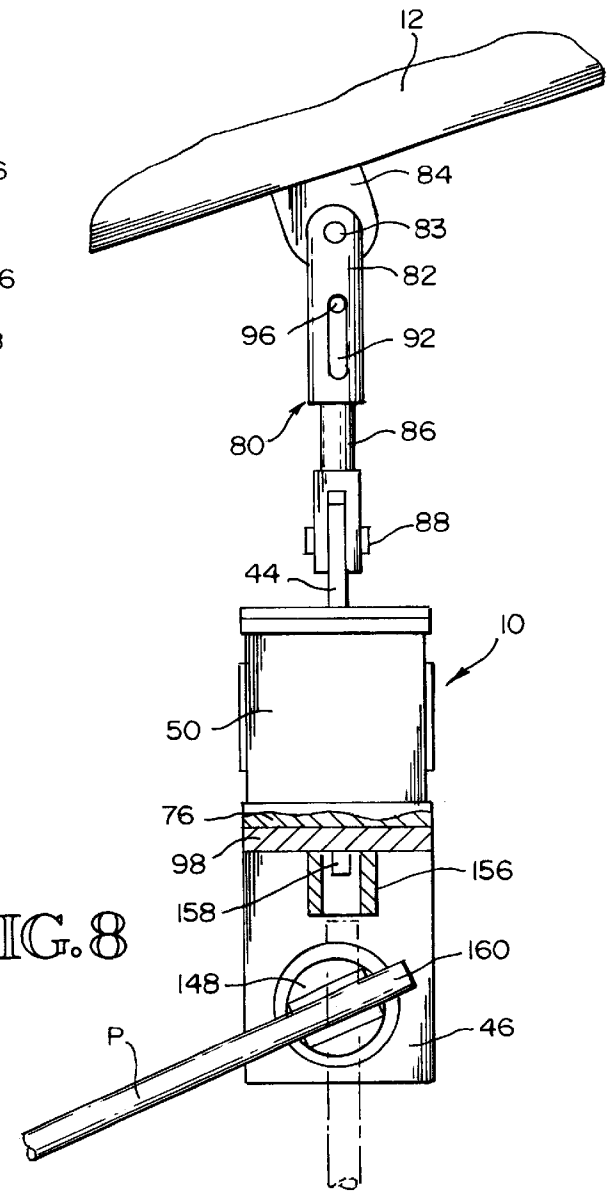

12
84
83
82
96
92
80
86
88
44
10
50
76
98
156
158
160
148
46
P

FIG. 8

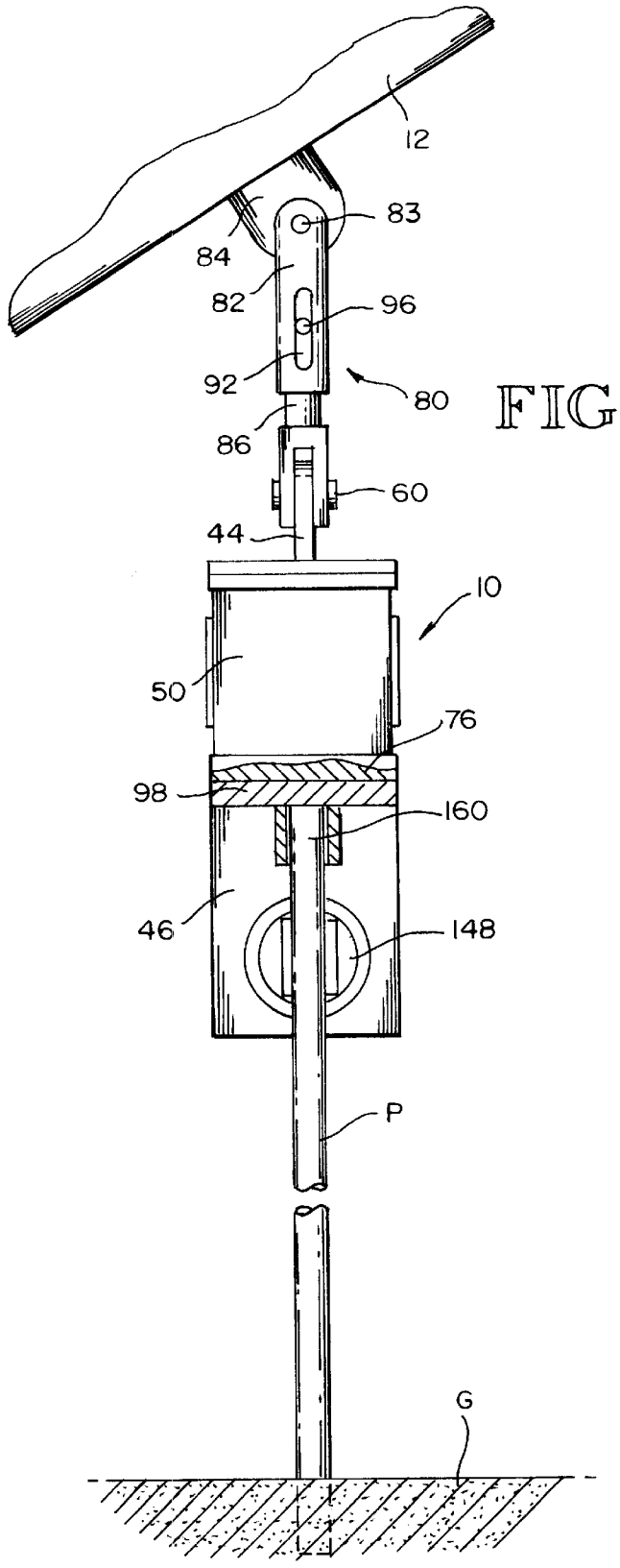


FIG. 9

VIBRATORY DRIVER FOR PIPE PILING

TECHNICAL FIELD

The present invention relates to a vibratory pile driver. More particularly, it relates to the provision of (1) a pile driver that is adapted to be suspended from the boom of an excavator, or some other overhead supporting device, (2) a pile driving machine that includes a mobile base, a boom connected to and extending from the mobile base, (3) a vibrator assembly that is suspended from the boom, and (4) a pile driving method.

BACKGROUND OF THE INVENTION

Known boom supported devices for driving pipe piling and/or other piling are disclosed by: U.S. Pat. No. 5,117,925, granted Jun. 2, 1992, to John L. White; by U.S. Pat. No. 5,263,544, granted Nov. 23, 1993, to John L. White; by U.S. Pat. No. 5,544,979, granted Aug. 13, 1996 to John L. White; by U.S. Pat. No. 5,568,997, granted Oct. 29, 1996, to Yrjö Raunisto; by U.S. Pat. No. 5,609,380, granted Mar. 11, 1997, to John L. White; by U.S. Pat. No. 5,653,556, granted Aug. 5, 1997 to John L. White and by European Patent Publication No. 0 496 167 A1, published Jul. 29, 1992, filed by Kencho Kobe Co., Ltd., the applicant.

There is a need for an improved vibratory pile driver that is relatively simple and easy to operate but yet is effective to drive pipe pilings. There is also a need for a boom supported pile driver that is adapted to easily and quickly pick up a pipe piling, e.g. from a stack on the ground, by a simple lifting of a boom to raise the pipe piling up into a substantially vertical position so that it can be driven into the ground. There is a further need for a pipe piling driving method that provides for quick, easy and simple handling of the pipe piling both before and during the driving operation. It is an object of the present invention to fulfill these needs. It is a further object of the present invention to provide a quick and easy way of coupling the pile driving mechanism to a pipe piling, and then decoupling the mechanism from the pipe piling after the pipe piling has been driven into the ground. Still yet another object of the invention is to provide an improved way of transmitting energy from a vibrator to pipe piling through coupler components that couple the pipe piling to a housing portion of the vibrator.

BRIEF DESCRIPTION OF THE INVENTION

A vibratory pile driver of the present is characterized by a vibrator having an upper portion that is adapted to be connected to a supporting structure that is above the vibrator, and a lower portion. The lower portion of the vibrator includes a chuck assembly that is adapted to be connected to the pipe piling. The chuck assembly includes a coupler or pair of horizontally disposed linear hydraulic actuator. Each actuator comprises a fixed outer end portion and a retractable/extendable/rotatable inner end portion. The chuck assembly also includes pile-engaging clamps at the inner ends of the actuators. The clamps confront each other and are adapted to receive a piling between them. The actuators are adapted to the retracted to move the clamps apart and provide between them a piling receiving space. The actuators can be extended to move the clamps towards each other and into clamping engagement with a piling that has been placed in the space, between the clamps.

According to another aspect of the invention, the vibrator includes a vibrator frame and an elongated first coupler member that has a lower end that is secured to an upper central portion of the vibrator frame. The first coupler member extends upwardly from its connection to the vibrator frame. An elongated second coupler member has an upper end that is adapted to be connected to a supporting structure that is above the vibrator. One of the coupler members is tubular and the other extends inside of it, in telescopic fashion. The tubular coupler member includes a sidewall and at least one longitudinal slot in the sidewall that is closed at both ends. A pin extends laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

According to a further aspect of the invention, the chuck assembly or coupler includes chuck frame structure and a pair of horizontal, co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis. The actuators are inside of the tubular trunnions. The fixed outer end portions of the actuators are connected to the frame structure. The inner end portions of the actuators are connected to the tubular trunnions. In preferred form, the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a tubular bearing positioned radially between each trunnion and its housing.

According to a further aspect of the invention, the frame structure may include a downwardly opening cup that is above and between the two piling-engaging clamps. The cup is adapted to receive an upper end portion of a piling that is positioned between the two clamps.

According to yet another aspect of the invention, a pile driving machine is provided that includes a mobile base. A boom is provided that has a first end that is connected to the mobile base and a second end that is spaced from the mobile base. The boom is movable relative to the base and the second end of the boom is movable up and down. The pile driving machine further comprises a vibratory pile driver having a vibrator that includes an upper end that is connected to the boom at the second end of the boom, and further has a lower portion that includes a chuck assembly is connected to the lower portion of the vibrator. The chuck assembly includes a pair of horizontally disposed linear hydraulic actuators. Each actuator comprises a fixed outer end portion and a retractable/extendable/rotatable inner end. A pair of piling engaging clamps are connected to the inner end portions of the actuators. The clamps confront each other and are adapted to receive a piling between them. The actuators are retractable to move the clamps apart and provide between them a piling receiving space. They are extendable to move the clamps towards each other and into clamping engagement with a piling that has been placed in the space between the clamps.

According to a further aspect of the invention, the vibrating pile driving attachment is suspended from an outer end portion of a boom but at a location that is inwardly of a bucket or other material handler that is at the extreme end of the boom. This enables the boom to be manipulated for the purpose of positioning the pipe driving attachment and a piling connected thereto, and then be used during the pile driving operation, without a need to remove the bucket or other device from the boom. The bucket is present so that it can be used during the pile driving operation, either for moving material or for supporting the end of the boom during a repositioning of the mobile base on which the boom is supported.

According to still a further aspect of the invention, a pile driving method is provided that includes the step of provid-

ing an elongated piling having first and second ends. A pile driver is provided that has a vibrator and laterally spaced apart clamp jaws below the vibrator. The clamp jaws are positioned as to define between them a space for receiving the first end of the piling. The vibrator is then moved to place the first end of the piling between the clamp jaws. Next, the clamp jaws are moved together into a clamping engagement with the first end of the piling. Then, the vibrator and clamp jaws are lifted so as to lift the piling up into a substantially vertical position. The second end of the piling placed on the ground. The vibrator and the clamp jaws are held in a position that maintains the piling in a substantially vertical position. Then, the vibrator is operated to apply a vibration force on the upper end of the piling so as to drive the piling downwardly into the ground. The vibrator and the clamp jaws are lowered as the piling moves downwardly into the ground. The clamp jaws are moved together into a clamping engagement with the first end of the piling when the piling is in a position other than a vertical position, e.g. a horizontal position. The clamp jaws are rotated as the vibrator and the clamp jaws are lifted. The weight of the piling causes the clamp jaws to rotate and follow movement of the piling from its initial position up into a substantially vertical position.

In preferred form, the clamps are provided with a pair of horizontal hydraulic actuators. Each hydraulic actuator has a fixed component and a movable component. The clamp jaws are secured to the movable components. The movable components of the actuators are retracted to move the clamp jaws apart and provide space between them for receiving the first end of the piling. Then, the movable components of the actuators are extended to move the clamp jaws towards each other and into clamping engagement with the piling. In preferred form, the actuators are supported for rotation in response to a force being applied to the clamp jaws that would prompt them to rotate.

According to a further aspect of the invention, the weight of a piling is used to apply a force on the clamping jaws that causes the clamping jaws to rotate in position. The clamping jaws are clamped onto a first end of a piling when the piling is in a position other than a vertical position. For example, it may be lying substantially flat on the ground. The clamping jaws are lifted. In response to their upward movement, and further in response to a force being applied on them by the piling, the clamp jaws will rotate as the piling moves from its initial position into a substantially vertical position.

Other objects, advantages and features of the invention will become apparent from the description of the best mode set forth below, from the drawings, from the claims and from the principles that are embodied in the specific structures that are illustrated and described.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

In the drawings, like reference numerals and letters refer to like parts throughout the several views and:

FIG. **1** is a pictorial view of an excavator and a pile driving attachment suspended from the boom of an excavator, such view showing the pile driving attachment in the process of driving a pipe piling into the ground;

FIG. **2** is an enlarged scale side elevational view of the pile driving attachment, such view showing a coupler above the attachment and a chuck assembly including a cup and a pair of gripping jaws adapted for receiving an upper end portion of a pipe piling;

FIG. **2A** is an enlarged scale fragmentary view of a central portion of FIG. **2**, such view showing a typical use of orbiting weights for providing the vibratory energy;

FIG. **3** is an enlarged scale view of the coupler shown in FIG. **2**, showing some parts in longitudinal section and some parts in side elevation;

FIG. **4** is an enlarged scale view of the chuck assembly showing some parts in section and other parts in elevation;

FIG. **5** is an exploded pictorial view of the gripping jaw assembly that is pictured on the left in FIG. **4**;

FIG. **6** is a cross sectional view taken substantially along line **6**—**6** of FIG. **4**;

FIG. **7** is a diagrammatic view of the pile driving attachment showing the clamping jaws of the chuck assembly coupled to a pipe piling that is in a horizontal position;

FIG. **8** is a view like FIG. **7** but showing the boom of the excavator and the coupler moved upwardly and further showing the pipe piling in a sloping position and the clamping jaws rotated to permit the position change of the pipe piling; and

FIG. **9** is a view like FIGS. **7** and **8**, but showing the excavator boom in a higher position and showing the pipe piling in a vertical position and moved upwardly to where its upper end is within the cup, and further showing the clamping jaws rotated further to permit the pipe piling to extend vertically.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. **1**, a vibratory pile driver **10** is shown suspended from a forward section **12** of an articulated boom **14**. Boom **14** includes a lower end portion **16** that is pivotally connected in conventional fashion to a mobile base **18**. Base **18** may include a pair of laterally spaced apart tracks **20**, **22**. As is known per se, the tracks **20**, **22** may be operated together to move the base **18** forwardly and rearwardly. Or, one track **20**, **22** can be rotated in a first direction and the other track **20**, **22** can be rotated in the opposite-direction, for turning the base **18**. A pair of hydraulic cylinders **26**, **28** are interconnected between the base **18** and the boom **14**. Extension of the cylinders **26**, **28** acts to lift the boom **14**. Retraction of the cylinders **26**, **28** acts to lower the boom **14**. Herein, "lift the boom **14**" means swinging it upwardly about its pivotal connection to the base **18**. Herein, "lower the boom **14**" means swinging the boom downwardly about its pivotal connection to the base **18**. Forward section **12** of boom **14** is pivotally connected at **30** to the main portion **32** of the boom **14**. A hydraulic cylinder **34** is interconnected between boom forward portion **12** and boom main portion **32**. Extension of cylinder **34** causes the forward section **12** to swing downwardly relative to boom section **32**. A retraction of cylinder **34** causes the forward section **12** to swing upwardly relative to the boom section **32**. Preferably, a bucket **36** or some other material handler is pivotally connected to the forward boom section **12** by a pivot pin **38**. A hydraulic cylinder **40** is interconnected between the bucket or other member **36**. Extension of cylinder **40** causes the member **36** to swing forwardly. Retraction of cylinder **40** causes the member **36** to swing rearwardly.

According to an aspect of the present invention, the pile driver **10** is suspended from the forward boom section **12**. It is connected to the forward boom section **12** by a coupler **42**. The upper end of the coupler **42** is attached to the boom section **12** at a location inwardly of the pivot pin **38**. The lower end of the coupler **42** is connected to an upper frame portion **44** of the vibrator **10**.

As best shown by FIG. **2**, the vibrator **10** has a two part lower portion **46**, **48** which houses a chuck assembly **50**. An

intermediate section **50** is positioned between the upper frame part **44** and the lower portion **46, 48**. Intermediate portion **50** includes a frame or housing portion **52** in which forwarding weights W are located. Housing **52** includes a top wall **54** to which the frame portion **44** is connected. It further includes vertical walls **56, 58, 60, 62**. A first weight chamber **64** is defined by and between vertical walls **56, 58**. A second weight chamber **66** is defined by and between vertical walls **60, 62**. A shaft **68** may extend horizontally through the housing **52** and include the weights W. One weight W is within chamber **64**. The other weight W is within chamber **62**. The vertical walls **56, 58, 60, 62** include openings in bearings that surround the openings. The bearings support the shaft **68** for rotation. Shaft **68** may also be supported by pillow blocks **70, 72**. The weights W may be eccentric weights such as disclosed in U.S. Pat. No. 3,917,426, granted Nov. 4, 1975 to Donald M. Wohlwend and Maurice Wohlwend. In that patent, the eccentric weight is designated (**76**). Here, one end of shaft **68** is connected to a rotary drive motor **74**. In the illustrated embodiment, drive motor **74** is a hydraulic motor. Hoses **76** are shown in FIG. **2** for delivering hydraulic fluid to and from the motor **74**. As is well known in the art, rotation of the eccentric weights W will cause the housing **54, 56, 68, 60, 62** to vibrate. This vibration is transmitted by the lower frame portion **76** to the top wall **78** of the assembly **46, 48**.

Referring to FIG. **3**, in preferred form, the pile driver **10** is connected to the boom section **12** by a two part coupler **80**. A first end portion **82** of the coupler **80** may be pivotally connected by a pin **83** to an ear **84** that is provided on a lower portion of the boom section **12**. Coupler section **86** is connected at its lower end to the housing portion **44**, by a pivot pin **88** that is surrounded by a sleeve bearing **89**. Sleeve bearings may surround the pin **83**. One of members **82** is tubular. The other is received inside of it, in a telescopic fashion. In the illustrated embodiment, the upper end member **82** is tubular. It is lined by a sleeve **90** of bearing material. The coupler member **86** is in the nature of a rod that is slidably received within the bearing **90**. Tubular portion **82** includes a pair of diametrically opposed slots **92, 94**. Slots **92, 94** extend longitudinally of the coupler **80**. A cross pin **96** extends through both slots **92, 94** and also extends laterally through coupler member **86**. The slots **92, 94** are of a width to accommodate the pin **96**. Member **86** can move into and out from member **82** within a limit provided by the cross pin **96** and the ends of the slots **92, 94**. In FIG. **3**, if the boom is raised, the coupler member **82** will move upwardly with it. Member **82** will move relative to member **86** until the lower ends of the slots **92, 94** contact the cross pin **96**. Thereafter, any further upward movement of the boom will cause the cross pin **96**, the member **86**, the pin **88**, the frame member **44** and everything below it to move upwardly with the boom. The cross pin **96** will engage the lower ends of the slots **92, 96** and keep the members **82, 86** together and will arrest any further upward movement of **82** relative to member **86**. When the boom is lowered, the entire coupler **80**, the pin **88** and the frame member **44**, and the structure below frame member **44**, will move downwardly together with the boom until the lower portions **46, 48** of the pile driver **10** are in some manner stopped, either by contacting the ground or some other support surface, or by a piling P that is coupled to the vibrator **10** having its downward movement arrested by contact with a surface below it that is solid enough to arrest movement of piling P. When downward movement of piling P stops, the further downward movement of coupler member **86** will also stop. Coupler member **82** will continue to move downwardly, however, until the cross pin **96** contacts the upper ends of the slots **92, 94**. When this happens, the coupler portion **82** will not move downwardly unless it is able to move downwardly with coupler portion **86**, cross pin **96**, pin **88**, vibrator frame **44**, etc. This is because there is contact between the ends of the cross pin **96** and the upper ends of the slots **92, 94**. As will be appreciated, a forceful downward movement of the boom can cause the coupler portion **82** to exert a downward force on the cross pin **96** that is sufficient to move the coupler portion **86** and the pin **88** and the vibrator frame **44**, and the piling P downwardly, with the piling P moving into the ground.

A feature of the coupler is that it isolates the excavator from the vibration forces.

Referring to FIG. **4**, a top plate **98** extends horizontally across the upper end of the housing portions **46, 48**. Top plate **98** may be secured to the aforementioned plate **76** (FIG. **2A**). FIG. **5** is a view of the components of coupler portion **46**. It is also a showing of the components of coupler portion **48** as the coupler portions **46, 48** are substantially identical. Each is a mirror image of the other, positioned on an opposite side of a centerline **100**. Referring to FIG. **5**, coupler portion **46** includes spaced apart end walls **102, 104**, and a center wall **106** between them, each of which includes a tube receiving opening, one of which is designated **108** in FIG. **5**. Opening **108** is in end wall **102**. Like openings **110, 112** (FIG. **4**) are provided in end wall **104** and center wall **106**. The openings **108, 110, 112** are in coaxial alignment, as shown by FIG. **4**. The walls **102, 104, 106** are connected together by sidewalls **114, 116**. The openings **108, 110, 112** are sized to receive a tubular housing **118**. Once inside the openings **108, 110, 112**, the tubular housing **118** is welded to the walls **102, 104, 106**, as is shown in FIG. **4**. A smaller tubular member **120** fits inside of tubular housing **118**. A tubular bearing **122** fits inside of tubular member **118**, between it and tubular member **120**. As shown in FIG. **4**, a substantial portion of the tubular housing **118** may be machined to give it an inner diameter that is larger than the inner diameter of the remaining portion of member **118** and is larger than the outside diameter of tubular member **120**. This forms an annular space in which the bearing sleeve **122** is received (FIG. **4**). A radial surface or shoulder **124** is formed between the smaller inner diameter portion of tubular member **118**, shown on the left in FIG. **4**, and the larger inside diameter portion, shown on the right in FIG. **4**. The inner end of the tubular bearing **122** abuts this shoulder. A retaining ring **126** abuts the opposite end of the bearing sleeve **122**.

A linear hydraulic motor **128** is housed within the tubular housing **120**. The hydraulic motor **128** includes an outer end portion **130** and an inner end portion **132**. In the illustrated embodiment, the outer end portion **130** is a cylinder. The inner end portion **132** is a piston. Piston **132** includes a piston head **133** within the cylinder **130** and a piston rod **135** that projects from the piston head outwardly from the cylinder. The piston is extendable and retractable relative to the cylinder **130**.

As shown by FIGS. **4** and **5**, the cylinder includes a radial end wall **134** and a tubular sidewall **136**. The end wall **134** is of a diameter substantially equal to the diameter of tubular member **118**. It is removably secured to end of tubular member **118** by screw fasteners. The screws extend through screw openings **138** and end wall **134** and screw into threaded openings **140** in the near end of tubular housing **118**. The screws secure the end wall **134** to the tubular housing **118**, thus fixing the outer end portion **128** of the linear hydraulic motor to a fixed portion of the frame. The

inner end portion **132** of the linear hydraulic motor is connected to a head member **142** that in turn is connected to inner end tubular member **120**. As a result of this connection, the tubular inner member **120** will extend and retract together with the piston **132** and the member **142**. In FIG. **4**, the linear hydraulic motor is shown in its fully retracted position. When hydraulic fluid is entered into the base end of the linear hydraulic motor, and removed from the piston rod end, the piston and piston rod will extend. They will move outwardly from the position shown in FIG. **4**. The inner tubular housing **120** will move with them because the end member **142** is connected to both the piston rod and the tubular housing **120**. As it moves in and out, the tubular housing **120** slides on the bearing sleeve **122**. The head member **142** and the tubular inner housing **120** can also rotate in position together with the piston head **133** and the piston rod **135**. The piston rod **135** extends out through a seal at the rod end of the cylinder barrel. There is nothing that restrains the piston head **133** and the piston rod **135** from rotating within the cylinder barrel when and if a force is applied on them that would tend to make them rotate.

The above description of coupler end portion **46** applies equally as well to coupler end portion **48**. This is because of the fact that the two coupler end portions **46**, **48** are identical, as previously described. The coupler portion **48** includes an end member **144** that is like end member **142**. The end members **142**, **144** include co-axial sockets. The socket in end member **142** is designated **146**. The sockets receive pins that are at the inner ends of grip jaws **148**, **150**. The pin for grip jaw **148** is designated **152** in FIG. **4**. The grip jaw pins are inserted into the sockets and then the grip jaws are connected to the heads **142**, **144**, by means of a series of bolts **154**.

As shown by FIGS. **2** and **4**, a tubular cup **156** is connected to the plate **98** at a location that is above and between the two jaws **148**, **150**. A pin **158** is connected to plate **98** inside of the cup **156**. Cup **156** extends concentric to the axis **100**. Pin **158** also extends from plate **98** concentric with axis **100**. The cup **156** receives a first end portion **160** of a pipe piling P. The outside diameter of the pipe piling P fits rather snugly into the inside diameter of the cup **156**. The pin **158** fits rather snugly into a center opening that extends through the pipe piling P. Pipe piling P is tubular and includes a sidewall forming and surrounding a center opening that extends axially through the pipe piling P.

Referring now to FIGS. **7–9**, FIG. **7** shows a pipe piling P in a substantially horizontal position. It also shows an upper end portion **160** of the pipe piling P engaged by clamp jaw **148**. It is also engaged by clamp jaw **150** that is not shown in FIGS. **7–9**.

It is necessary that end portion **160** of pipe piling P be elevated in some manner. Pipe piling P might be on top of a stack of pipe pilings P. In that case, it may be moved endwise until the end portion **160** is overhanging the rest of the pile or stack. Then, the coupler assembly **46**, **48** is lowered until end portion **160** of pipe piling P is between the two jaws **148**, **150**. Of course, at this time, the hydraulic linear motors are retracted and the jaws **148**, **150** are spaced apart so as to define between them a space for receiving the end portion **160** of pipe piling P. Also, the jaws **148**, **150** are rotated such that their pipe engaging recesses **149**, **151** are parallel to each other and to the pipe piling P. In FIG. **4**, jaw **148** and its recess **149** is oriented to engage a pipe piling P that is substantially horizontally oriented. In FIG. **4**, the jaw **150** and its recess **151** are oriented to engage the pipe piling P that is substantially vertically oriented. As described above, the jaws **148**, **150** are rotatable with the head members **142**, **144** and the piston components to which the head members **142**, **144** are connected.

The coupler assembly **46**, **48** is moved to position the pipe piling end portion **160** in line with the two recesses **149**, **151**. Then, the linear hydraulic motors **128** are extended to move the jaws **148**, **150** together. This moves the recesses **149**, **151** into clamping engagement with the pipe piling end portion **160**. This is the orientation and relationship that is shown in FIG. **7**. Next, the operator lifts the boom section **12** to in turn lift the coupler assembly **46**, **48**. As the coupler assembly **46**, **48** moves upwardly, it moves with it the gripped end portion **160** of the pipe piling P. This lifting of end portion **160** while the opposite end of the pipe piling P remains supported, causes the pipe piling P to move from a substantially horizontal orientation to a sloping orientation. An early stage of the sloping orientation is shown by FIG. **8**. Because the clamp jaws **148**, **150** are able to rotate, they will rotate as the pipe piling P moves upwardly.

The weight of the pipe piling P will act to hold its second end downwardly while the end portion **160** moves upwardly. The boom **14**, and in particular the boom section **12**, are moved upwardly until the pipe piling P is in a substantially vertical orientation and is suspended from the clamp jaws **148**, **150**. Then, the assembly is lowered until the lower end of the pipe piling P is resting on and is supported by the ground. Then, the clamp jaws **148**, **150** are retracted slightly so as to allow the piling end portion **160** to move relatively endwise while still within the confines of the clamp jaw recesses **149**, **151**. Then, the coupler assembly **46**, **48** is lowered to allow the piling end portion **160** to enter into positioning cup **156**, and allow pin **158** to enter into the open upper end of piling end portion **160**. The coupler assembly **46**, **48** is moved downwardly until the upper end surface of the pipe piling P is against the plate **98**. Then, the linear hydraulic motors are extend to move the clamp jaws **148**, **150** back into a gripping engagement with the pipe piling end portion **160**. At times it may be desired to loosen the jaws and rotate the pipe P while it is still constrained but not gripped by the jaws.

A particular desirable feature of the coupler **80** is that it holds the assembly in a substantially vertical orientation when the lower end of the pipe piling P is set on the ground and the boom section **12** is moved further downwardly. If a cable or a hook connection were to be used in place of the coupler **80**, the structure below frame member **44** would lean sideways in response to the additional lowering of the boom section **12**. Instead, when the coupler **80** is used, the lower end of the pipe piling P can be set on the ground and the boom section **12** can be lowered without the coupler assembly **46**, **48** and the pipe piling P leaning from vertical any substantial amount. As boom section **12** moves downwardly, the coupler member **86** moves into the coupler member **82**. The snug fit of coupler member **86** within the sleeve bearing **90** keeps the two parts **82**, **86** of the coupler **80** in alignment. The pivot pins **83**, **88** are perpendicular to each other. This acts to prevent pivotal movement at either pivot pin **83**, **88**. Instead, the entire assembly retains its substantially vertical orientation and the coupler member **86** moves relatively upwardly within the coupler member **82** until the cross pin **96** contacts the upper ends of the guide slots **92**, **94**. This engagement of the cross pin **96** by the sides of the guide slots **92**, **94** also helps to maintain the desired vertical alignment of the structure.

When the structure is in the position shown by FIG. **9**, the pile driving operation can begin. Initially, the boom can be swung downwardly to apply a downward endwise force on the coupler assembly **46**, **48** and the pipe piling P. If the

ground material G is soft, the pipe piling P will move downwardly rather easily and quickly in response to the downward movement of the boom section **12**. Because the pivot pin **83** would tend to travel an arcuate path in response to a downward swinging movement of boom section **12**, the operator will usually drive the tracks **20**, **22** to move the support base **18** rearwardly an amount sufficient to maintain the vertical orientation of the pipe piling P.

When the pipe piling P is moved into the ground G as far as it will go by movement of the boom section **12** alone, the vibrator will be turned on to impose vibratory energy on the upper end portion **160** of the pipe piling P. It is imposed where contact is made between plate **98** and the upper end of the pipe piling P. It is also imposed where the pipe piling end portion **160** is gripped by the clamp jaws **148**, **150**. The addition of the vibratory energy causes the pipe piling P to resume its downward movement in the ground G. It will be moved until either it stops moving because its lower end contacts solid rock that will not permit it to move any further, or until its upper end portion **160** is near the ground G. Whenever the first situation happens, the linear hydraulic motors are retracted so as to release the grip of the clamp jaws **148**, **150** on the piling end portion **160**. Then, the pile driver is moved away from the pipe piling P. Then, the pipe piling P is cut off at a desired distance above the ground G. Whenever the second situation happens, the coupler assembly **46**, **48** is decoupled from the pipe piling end portion **160** and is moved away from it so that another length of pipe piling P can be added to the pipe piling P that has been sent into the ground G. The pile driver or some other suitable tool can be used to lift up another section P, orient it into a substantially vertical position, and set its lower end on top of the upper end of the buried pipe section P. Then, the two ends of the two pipe sections P can be welded together. Or, a threaded connection can be provided where the two pipe sections P are to be joined and used in lieu of welding. After the new pipe section P has been added, the jaw assembly **46**, **48** is moved upwardly and is attached to the upper end of the new pipe piling section P, in the manner described above. Then, the pile driving operation is repeated. This is continued until the assembly of pipe piling sections P has contacted rock and will move no further.

As explained above, some of the vibratory energy is transmitted by the plate **98** to the upper end of the pipe piling P. The downward forces that are imposed on the clamp jaws **148**, **150** are transmitted through the tubular members **118**, **122**, **120**. The use of the nesting tubular members **118**, **120**, **122** also contributes to an effective transmission of the vibratory energy from the frame structure **98**, **102**, **104**, **106**, **118**, **122**, **120**, to the head structures **142**, **144** and the clamp jaws **148**, **150**.

The illustrated embodiments are only examples of the present invention and, therefore, are non-limitive. It is to be understood that many changes in the particular structure, materials and features of the invention may be made without departing from the spirit and scope of the invention. Therefore, it is my intention that my patent rights not be limited by the particular embodiments illustrated and described herein, but rather determined by the following claims, interpreted according to accepted doctrines of claim interpretation, including use of the doctrine of equivalents and reversal of parts.

What is claimed is:

1. A vibratory pile driver, comprising:

a vibrator having an upper portion that is adapted to be connected to a supporting structure that is above the vibrator, and a lower portion; and

a chuck assembly connected to the lower portion of the vibrator, said chuck assembly including:

a pair of horizontally disposed linear hydraulic actuators, each said actuator comprising a fixed outer end portion and a retractable/extendable/rotatable inner end portion, and

a pair of pile-engaging clamps connected to the inner end portions of the actuators, said clamps confronting each other and being adapted to receive a piling between them,

whereby the actuators can be retracted to move the clamps apart and provide between them a piling receiving space, and the actuators can be extended to move the clamps towards each other and into clamping engagement with a piling that has been placed in said space between the clamps.

2. The vibratory pile driver of claim **1**, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is adapted to be connected to a supporting structure that is above the vibrator, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

3. The vibratory pile driver of claim **1**, wherein the chuck assembly includes chuck frame structure and a pair of horizontal co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

4. The vibratory pile driver of claim **3**, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between each trunnion and its housing.

5. The vibratory pile driver of claim **3**, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame and an elongated second coupler member having an upper end that is adapted to be pin connected to a supporting structure that is above the vibrator, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end connected to the other coupler member.

6. The vibratory pile driver of claim **5**, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between each trunnion and its housing.

7. The vibratory pile driver of claim 1, comprising frame structure including a downwardly opening cup above and between the two piling-engaging clamps, said cup being adapted to receive an upper end portion of a piling that is positioned between the two clamps.

8. The vibratory pile driver of claim 7, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is adapted to be connected to a supporting structure that is above the vibrator, wherein one of the coupler members is tubular and the other coupler member sits inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular member, and having an inner end that is connected to the other coupler member.

9. The vibratory pile driver of claim 8, wherein said chuck assembly includes chuck frame structure and a pair of horizontal co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

10. The vibratory pile driver of claim 9, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between said trunnion and the housing.

11. The vibratory pile driver of claim 1, wherein the inner end portion of each said actuator includes an inwardly opening blind socket, and each said clamp includes a pin that is snugly received within the blind socket and a clamp jaw that is connected to said pin and is positioned to confront the clamp jaw for the other actuator of the pair, and wherein each clamp jaw includes a recess for receiving a peripheral portion of a said piling that is positioned between the clamp jaws.

12. The vibratory pile driver of claim 11, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame and an elongated second coupler member having an upper end that is adapted to be connected to a supporting structure that is above the vibrator, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

13. The vibratory pile driver of claim 11, wherein the chuck assembly includes chuck frame structure and a pair of horizontal, co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

14. The vibratory pile driver of claim 13, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between each trunnion and its housing.

15. The vibratory pile driver of claim 11, comprising frame structure including a downwardly opening cup above and between the two pile-engaging clamps, said cup being adapted to receive an upper end portion of a pile that is positioned between the two clamps.

16. The vibratory pile driver of claim 15, wherein said frame structure is in contact with said vibrator, and wherein said frame structure and said cup are directly vibrated by the vibrator and in turn transmit vibration energy to the upper end of a pile that is within said cup.

17. A pile driving machine, comprising:

a mobile base;

a boom having a first end connected to the mobile base, and a second end spaced from the mobile base, said boom being movable relative to said base and said second end of the boom being movable up and down; and

a vibratory pile driver, comprising:

a vibrator having an upper portion that is connected to the boom at said second end of the boom, and further having a lower portion; and

a chuck assembly connected to the lower portion of the vibratory, said chuck assembly including:

a pair of horizontally disposed linear hydraulic actuators, each said actuator comprising a fixed outer end portion and a retractable/extendable/rotatable inner end portion, and

a pair of piling-engaging clamps connected to the inner end portions of the actuators, said clamps confronting each other and being adapted to receive a piling between them,

whereby the actuators can be retracted to move the clamps apart and provide between them a pile receiving space, and the actuators can be extended to move the clamps towards each other and into clamping engagement with a piling that has been placed in said space between the clamps.

18. The driving machine of claim 17, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is pin connected to the boom, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, and wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

19. The pile driving machine of claim 17, wherein the chuck assembly includes chuck frame structure and a pair of horizontal co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

20. The pile driving machine of claim 19, wherein the chuck frame structure includes a pair of tubular housings in

which the tubular trunnions are received, and further includes a bearing positioned radially between each trunnion and its housing.

21. The pile driving machine of claim **17**, comprising frame structure including a downwardly opening cup above and between the two pile-engaging clamps, said cup being adapted to receive an upper end portion of a pile that is positioned between the two clamps.

22. The pile driving machine of claim **21**, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is pin connected to the boom, wherein one of the coupler members is tubular and the other coupler member fits inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular member, and having an inner end that is connected to the other coupler member.

23. The pile driving machine of claim **22**, wherein said chuck assembly includes chuck frame structure and a pair of horizontal co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

24. The pile driving machine of claim **23**, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between said trunnion and the housing.

25. The pile driving machine of claim **17**, wherein the inner end portion of each said actuator includes an inwardly opening blind socket, and each said clamp includes a pin that is snugly received within the blind socket and a clamp jaw that is connected to said pin and is positioned to confront the clamp jaw for the other actuator of the pair, and wherein each clamp jaw includes a recess for receiving a peripheral portion of a said pile that is positioned between the clamp jaws.

26. The pile driving machine of claim **25**, wherein the vibrator includes a vibrator frame, an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is pin connected to the second end of the boom wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

27. The pile driving machine of claim **17**, wherein the chuck assembly includes chuck frame structure and a pair of horizontal, co-axial, tubular trunnions mounted on the chuck frame structure below the vibrator, for rotation about a horizontal axis, wherein the actuators are inside the tubular trunnions, wherein the fixed outer end portion of each actuator is connected to the chuck frame structure, and wherein the inner end portion of each actuator is connected to its tubular trunnion.

28. The pile driving machine of claim **27**, wherein the chuck frame structure includes a pair of tubular housings in which the tubular trunnions are received, and further includes a bearing positioned radially between each trunnion and its housing.

29. The pile driving machine of claim **17**, comprising frame structure including a downwardly opening cup above and between the two piling-engaging clamps, said cup being adapted to receive an upper end portion of a piling that is positioned between the two clamps.

30. The pile driving machine of claim **29**, wherein said frame structure is in contact with said vibrator, and wherein said frame structure and said cup are vibrated by the vibrator and in turn transmit vibration energy to the upper end of a piling that is within said cup.

31. The pile driving machine of claim **17**, wherein each clamp includes a clamp jaw that confronts the other clamp jaw, and each clamp jaw includes a recess for receiving a peripheral portion of a said piling that is positioned between the clamp jaws, and wherein the clamp jaws are rotatable between a position in which the recesses are substantially horizontal when the vibrator is substantially vertical, and a position in which the recesses are substantially vertical when the vibrator is substantially vertical.

32. The pile driving machine of claim **31**, wherein the clamp jaws are secured to the inner end portions of the hydraulic actuators, and wherein the inner end portions of the hydraulic actuators and the jaws rotate together relative to the fixed outer end portions of the hydraulic actuators.

33. The pile driving machine of claim **32**, wherein the vibrator includes a vibrator frame, and the pile driving machine includes an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is pin connected to the boom, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, and wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

34. The pile driving machine of claim **31**, wherein the vibrator includes a vibrator frame, and the pile driving machine includes an elongated first coupler member having a lower end that is secured to an upper central portion of the vibrator frame, said first coupler member extending upwardly from its connection to the vibrator frame, and an elongated second coupler member having an upper end that is pin connected to the boom, wherein one of the coupler members is tubular and the other coupler member extends inside of it, in telescopic fashion, and wherein said tubular coupler member includes a sidewall and a longitudinal slot in said sidewall that is closed at both ends, and a pin extending laterally of the two coupler members, through the slot in the sidewall of the tubular coupler member, and having an inner end that is connected to the other coupler member.

35. A pile driving method, comprising:

providing an elongated piling having first and second ends;

providing a pile driver having a vibrator and laterally spaced apart clamp jaws below the vibrator;

positioning the clamp jaws so as to define between them a space for receiving the first end of the piling;

moving the vibrator to place the first end of the piling between the clamp jaws;

moving the clamp jaws together into a clamping engagement with the first end of the piling;

lifting the vibrator and the clamp jaws so as to lift up the piling, and continuing the lifting until the piling is substantially vertically oriented;

placing the second end of the piling on the ground and holding the vibrator and the clamp jaws in a position that maintains the piling in a substantially vertical position;

providing contact between the vibrator and the first end of the piling, above the clamp jaws; and

operating the vibrator to apply a vibration force on the upper end of the piling, so as to drive the piling downwardly into the ground;

lowering the vibrator and the clamp jaws as the piling moves downwardly into the ground;

said method including the clamp jaws together into a clamping engagement with the first end of the piling when the piling is in a position other than a substantially vertical position, and rotating the clamp jaws as the vibrator and the clamp jaws are lifted, and using the weight of the piling to cause the clamp jaws to rotate and follow the movement of the piling from its initial position up into a substantially vertical position.

36. The method of claim **35**, comprising providing a pair of horizontal hydraulic actuators, each with a fixed component and a movable component, securing the clamp jaws to the movable component, retracting the movable components of the actuators and the clamp jaws to provide a space between the clamp jaws for receiving the first end of the piling, and extending the movable portions of the actuators to move the clamp jaws into clamping engagement with the piling.

37. The method of claim **36**, comprising operating the clamps to clamp onto a first end portion of a piling when the piling is laying on the ground, and then lifting up on the clamp jaws and the piling to lift the first end portion of the piling upwardly and move the piling into a substantially vertical position, attended by rotation of the clamp jaws.

38. The method of claim **35**, comprising operating the clamps to clamp onto a first end portion of a piling when the piling is laying on the ground, and then lifting up on the clamp jaws and the piling to lift the first end portion of the piling upwardly and move the piling into a substantially vertical position, attended by rotation of the clamp jaws.

39. The method of claim **35**, comprising providing a vehicle that includes a mobile base and a boom pivotally attached at one end to the mobile base and extending from the mobile base to an opposite second end, and connecting the pile driver to the second end of the boom and using the boom to lift and position the pile driver and any piling connected to it.

40. The pile driving method of claim **39**, comprising providing the outer end of the boom with an attachment for handling material, and coupling the pile driver to the boom at a location near the outer end of the boom spaced inwardly from such attachment, and raising the attachment into a position above the vibrator such that it remains on the boom but is in a position where it will not interfere with the operation of the vibrator.

* * * * *